



Namibia University of Science and Technology
Faculty of Computing and Informatics

Information Systems and Emerging Technologies & Data Science, Machine Learning and Artificial Intelligence (PROCEEDINGS OF ICISSET'22 & DSMLAI'22)

Editors

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DATA SCIENCE, MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE
(PROCEEDINGS OF ICISSET'22 & DSMLAI'22)**

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Windhoek, Namibia

Editors

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ICISSET'22 & DSMLAI'22
Namibia University of Science and Technology

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Welcoming Remarks



Dr Eroid Naomab
NUST Vice-Chancellor
Namibia University of Science and Technology

Ladies and Gentlemen,

Good morning,

It is my profound honour to welcome you here this morning at the opening of the two conferences: The International Conferences on Information Systems and Emerging Technologies (ICISSET) and the Second International Conference on Data Science, Machine Learning and Artificial Intelligence (DSMLAI).

The themes of conferences are timely and relevant as it speaks to national imperatives to address socio-economic challenges using technology. Further, the Conferences will contribute to accelerating the Namibian society's development and one or more of UNESCO's priorities as outlined in the Medium-Term Strategy (2022-2029) and the Approved Programme (2022-2025). This is a truly unique platform for us to come together and shape the future of sustainable development.

These conferences are organised by the Namibia University of Science and Technology's, Faculty of Computing and Informatics in association with the Association of Computing Machinery (ACM) Windhoek.

On behalf of the University, I would like to take this opportunity to wholeheartedly welcome His Excellency Dr Terhemmen Tarzoor, High Commissioner of Nigeria to

Namibia, who will deliver the inaugural speech and officially open this Conference. We appreciate your support for the Conference.

Let me also express my sincere appreciation to the Secretary-General: of Namibia National Commission for UNESCO, Mr Roderick April, who supported the recently established UNESCO Chair on Secure High-performance Computing for Higher Education and Research. The UNESCO Chair aims to contribute and accelerate the development of Namibian society, building the foundations for technology by creating a critical mass of high-level expertise in the field of High-performance Computing and Emerging Technologies. This will be achieved by strengthening the focused area in the Smart and Secure Environment to build institutional and national capacity for quality teaching programmes, applied research, and the promotion of information sharing in communication, big data, and cyber security. The DSMLAI is testimony to this.

We would like to welcome Prof Fransisca O Oladipo, Vice Chancellor, Thomas Adewumi University, Oko, Nigeria as the inaugural keynote speaker of the Conference, which aims to debate a broad spectrum of emerging technologies about applications revolving around the fields of information systems, artificial intelligence, high-performance computing and data science.

This is an international forum for researchers and practitioners to present and discuss recent innovations, trends, results, experiences and concerns in the several aspects of Information Systems, Emerging technologies, Data Science and Artificial Intelligence.

In particular, the Conference will focus on:

- Proposing new technologies, sharing experiences and discussing future solutions for the design of Information Systems, Intensive Data Applications, Intelligent Systems and Interaction, Learning and Adaptation, Machine Learning and Artificial Intelligence for emerging applications.
- To provide a platform for researchers and practitioners from academia and industry to meet and share cutting-edge development and achievements in the field.
- Enriching technocrats and academics by presenting their innovative and constructive ideas
- And discussing innovative issues internationally by bringing together a cream of participants, including experts from different countries.

Distinguished Guests, Ladies and Gentlemen

The Conference provides a unique opportunity for all of us because of its scope; it has attracted delegates from all over the world, people with wide-ranging knowledge on the issue of Information systems, Big data Analytics, Cyber Security and Artificial Intelligence. We will listen to the keynote addresses on various aspects of Information systems, Data Science and Artificial Intelligence by our guest speakers.

I believe this Conference could result in new regional cooperation, practical measures, and a forward action plan to deal with computing and emerging information technologies.

I would also like to take this opportunity to thank the organising team for their tireless commitment and involvement in ensuring the success of these conferences. A conference of this magnitude would not have been possible without the dedication, support and concerted efforts of committee members, industry, sponsors, academic institutions, and all supporting organisations.

With these few remarks, I thank you and wish you fruitful deliberations.

Windhoek, 23 NOVEMBER 2022

Dr Eroid Naomab

**Message from Conference
Technical Programme Committee Chair**



Prof Dharm Singh Jat
Professor of Computer Science and UNESCO Chairholder
Secure High-performance Computing for Higher Educ and Res
Faculty of Computing and Informatics
Namibia University of Science and Technology

Good morning,

On behalf of the program committee, it is our great pleasure to present to you an excellent technical program of the first International Conference on Information Systems and Emerging Technologies (ICISSET) and Second International Conference on Data Science, Machine Learning and Artificial Intelligence (DSMLAI).

The technical program covering a wide range of topics focused on the Design and Analysis of Information and Artificial Intelligence-Based Computing Systems. Conferences feature a high-quality technical program across a wide range of research areas in Information Systems, Data Science, HPC, Machine Learning and Artificial Intelligence. It is an excellent opportunity for all the faculty members, research scholars and students to exhibit their aptitude for research. Conference also encourages and promotes communication and collaboration between researchers at the university, national and international levels.

Over 200 participants and experts from four continents and 11 countries: Namibia, South Africa, Nigeria, United Arab Emirates, Zimbabwe, United Kingdom, Uganda, India, Botswana, United States, and Egypt will participate in this conference.

ICISSET has been fortunate to receive 92 papers, of which 58 were accepted and DSMLAI has been fortunate to receive 23 papers, of which 9 were accepted to the main technical program after a thorough, rigorous international peer-review process. Eighteen (18) invited Speakers and Session

Chairs from four (4) continents Africa, Asia, America , And Europe, will present ground-breaking work on trends in Information Systems, Data Science, HPC, Machine Learning and Artificial Intelligence.

All accepted and presented papers will be hosted an open-access online Elsevier SSRN. Proceedings of the conference will be permanently showcased on the public, freely accessible to SSRN users and the public.

We warmly thank the keynote speakers, the reviewers, the session chairs and all the researchers and scientists who contributed in the organisation of the ICISSET and DSMLAI conferences with their time and efforts.

But above all, we thank the authors and presenters for making both conferences a great success!

I wish to acknowledge, with appreciation, the role played by members of the technical programme committee and the publication approval committee of the Elsevier SSRN for approving the publication.

Prof Dharm Singh Jat

Acknowledgement



Professor Jude Osakwe
Local Chair ICISSET'22

On behalf of the conference organising committee, I humbly wish to acknowledge the assistance and encouragement that we received from the University management, management of Faculty of Computing and Informatics (FCI) and many other individuals who helped to organise this event. The success of this conference was, first of all, as a result of the quality and the motivation of its participants. So I would like to thank all participants for their presence and for their contribution to a friendly atmosphere during this event. Our thanks are also go to all the session chairmen and women, who directed the programme. We are also very grateful to the reviewers, whose very consistent reviewing of manuscripts was of great help to improving the quality of many papers.

I am particularly thankful to the staff of FCI and members of the Programme and Organising Committee for their hard work and diligence.

Prof. Jude Osakwe

A Process Mining Framework for Analysing Students' Behaviours Using Digital Twin

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Abstract

Electronic data mining techniques such as classification, clustering, regression, association rule mining and sequence mining are not process-centric. They do not aim at discovering, analysing or providing a visual representation of the complete educational process that would help to understand students' behaviour during online learning. This paper presents a framework that uses process mining approach to analyse event log data generated within educational information systems, and discover meaningful knowledge about students' behaviours. Digital twin concept was employed to present a virtual representation of the students' activities on the Learning Management System. The framework was evaluated for conformance with the activities observed in the log. The analysis conducted during this study showed the disparity between the behaviours of students that passed a particular course and students that failed the course. Findings also showed that using the inductive and the fuzzy miner algorithms produced better fitness levels for the process model when compared with other previously used algorithms such as the heuristic miner and alpha miner algorithms. This paper concluded by recommending that the development of educational process mining specific tools can help domain experts better understand students' learning patterns.

Keywords: Data Mining, Digital Twin, Educational Process Mining, EDM, E-Learning, Learning Management System and LMS.

1. Introduction

Several classical data mining methods have been applied to find patterns, produce descriptive and predictive models from huge volumes of data accumulated during the use of different educational information systems. However, most of the traditional data mining techniques do not focus on the process as a whole. Educational Data Mining (EDM) techniques such as classification, clustering, regression, association rule mining (ASR) and sequence mining are of little use for control-flow discovery and are not process-centric. They do not aim at discovering, analyzing, or providing a visual representation of the complete educational process (Romero, Cerezo, Bogarín & Sánchez-santillán, (2016). Thus, higher institutions cannot evaluate the effect of its virtual educational processes and the interaction of its students and lecturers with the educational information system in use. A new technique to solve this kind of shortcoming has been proposed in this study.

The proposed technique uses process model to achieve a result in educational domain. This technique is called Educational Process Mining (EPM). EPM can help generate educational models that predicts which student is likely to pass or fail a particular course, understand students' learning behaviours and reflect on their teaching. EPM can also support learners'

reflection and provide proactive feedback to learners, and also determine how best to remove bottlenecks on the student's interaction with educational information systems (EIS). Educational process mining techniques and tools are particularly aimed at extracting process-related knowledge from event logs recorded by information systems (Třčka, and Pechenizkiy, (2009).

In addition, there exists large amount of educational data about students, alumni, courses, academic staff, etc. that is "hidden" in various databases and files of higher institutions. These data can serve as strategic resources for institutions in order to enhance the quality of their educational processes (Chalaris, Gritzalis, Maragoudakis, Sgouropoulou, Tsolakidis (2014). This can be achieved by extracting useful knowledge that will support the administration of each institution in making the appropriate decision for improving the quality of the educational processes. There is thus a need to develop a system that allows higher education institutions mine the data hidden in its educational information system. For administrators to be able to build complete virtual representations of its educational processes, the system should be able to: (i) detect learning difficulties early, (ii) give feedbacks teachers and researchers alike, (iii) able to produce better advice and recommendations to students, and (iv) aid detect that have special learning needs, or learning difficulties.

The use of electronic learning platforms in institutions of higher learning has increased rapidly in most recent years. This rapid adoption is sponsored by the flexibility of the system, allowing users, students, teachers and administrators to perform educational activities from any location. This form of electronic based education is independent of a specific hardware platform (Romero, Pedro, Zafra, Romero, and Ventura, 2013)]. These systems are expensive to setup and maintain, thus it has become important for school administrators to measure its impacts by striving to understand students use and behaviour on these systems, this will help them determine the efficiency of these systems and determine if they are meeting their objectives or not (Lorenzen and Alstrup, 2018). Analyzing the event logs data generated and stored in the database by these systems can help to understand educational information system and ultimately understand the activities and behaviours of students using them. The results of such analysis can be used to optimize learning experiences for students and lecturers as well and also improve the quality and academic performance of students.

Most of the literatures in this study have used factors such as students' previous results, level of participation in forums, academic qualifications, race and even age to classify and predict students' retention rates, admission qualification, students' drop out risk and students' final semester grades. The need to improve the mode of course delivery on these educational information systems calls for a direct assessment of processes and activities carried out on these systems.

Process mining techniques brings a different form of analysis that's based on the actual behaviour exhibited by these students' as they learn and interact with the educational information systems (Mukala, Buijs, Aalst, 2015). As institutions face market and competitive pressures, they are forced to find new methods to reach maximum efficiency while still increasing customer satisfaction. Many companies are exploring the idea of creating a "digital twin" to help them

drive improvements (Mellon, 2018). Many organizations today have invested heavily on long-term interests in the predictions of their organization's development. In a fast-paced world as we have now, and to ensure recurring success, organizations must be able to adapt to changes as quick as possible (Kathuria, 2018). Consider the possibility where the activities and processes in an organization are represented digitally, this would allow seamless monitoring and analysis of the factors affecting the performance of the organization. In digital twin, the researchers consider the concept of representing the entire organizational processes visually.

Digital Twin was conceptualized in 2003 by Dr Michael Grieves, during his presentation on Product Lifestyle Management (PLM) (Grieves, 2014). The scope of digital twin at that time was largely limited owing to limited technological advancements. The academic and industrial domains have formulated different explanations for the digital twin phenomenon. DT is largely regarded as the simulation of systems and products which uses historical data and real time data to mirror the life and behaviour of a corresponding twin (Glaessgen and Stargel, 2012). Dazhong, Lane, David and Dirk (2015) defined DT as a model that easily combines the behaviours of autonomous systems and their physical world environments. Digital twin can also be defined as mapping of all components in the product life cycle using physical data, virtual data and interaction data between them (Fei, Fangyuan, Ang, Qinglin, Meng, Boyang, Zirong, Stephen, Lu & Nee, 2018). Digital twin framework helps us to build the virtual representation of the educational process engaged by students. This helps to scrutinize the model that was represented, allowing the detection of anomalies, and bottlenecks, as well as find out ways to improve the actual process.

This study aimed at providing a digital twin model for analysing students' electronic learning behaviours using educational process mining techniques in order to ultimately improve the experience of online students. The use of a digital twin to analyse students behaviour in online learning or Open and Distance Education (ODE) is quite novel and serves as the main contribution of the study. To achieve the goal of this study, the following activities were carried out: (Activity-I) extraction of event logs from the Moodle (Learning Management System) LMS and pre-processing the logs acquired, (Activity-II) application of the Inductive and Fuzzy Miner algorithms on the ProM Framework to produce a process model from the recorded event logs, (Activity-III) development of the digital twin model and performing comparison evaluation of the produced process model for deviations and conformity with observed activities in acquired event logs; and (Activity-IV) evaluation of the produced model and provision of process improvement recommendations.

This paper is structured as follows: section two contains literature review. Section three describes research methodology. System design, and Data description/implementation are presented in section four and five respectively. Section six highlights results and discussion, while section seven concludes the paper.

2. Literature Review

2.1 Electronic Learning Processes

The explosion of the knowledge age has changed the context of what is learnt and how it is learnt – the concept of electronic learning processes is a manifestation of this knowledge revolution. Electronic educational processes refer to instruction in a learning environment where teachers and students are separated by time or space, or both, and the teacher provides course content through course management applications, multimedia resources, the Internet and video conferencing (Cole, and Foster, 2008), Rice, 2006). Students receive the content and communicate with the teacher via the same technologies. Whether you have been looking to guide your own professional development or your organizations, you will undoubtedly have noticed the trend away from the traditional classroom learning experience. Tradition is being replaced by a wide range of technology-enabled learning modalities, from podcasts and webinars to formal, one-on-one coaching and a range of e-learning platforms. A key reason individuals and organizations are embracing technology-driven learning modalities today is as a result of the efforts of learning providers to ensure the new format delivers strong results.

Continuous learning and constant training have become vital for job holders and organizations alike to remain relevant and competitive in the global job market. 65% of higher education have been said to have identified electronic/online learning as a vital component of their long term plan for continued sustenance and relevance in providing quality education (Elaine, 2011). This wave of interest has led to massive introduction and extensive use of online learning management systems in various higher educational institutions. By the year 2012, the percentage of higher educational institutions in the US using some form of LMS had risen to a staggering 93% rising exponentially from the meagre 15% in 2000 (Green, 2013). A new and improved form of learning management systems is emerging in the market. These systems have superior functionalities over the previously used traditional LMS. These new LMS have embedded in them current forms of sharing information over social media, allowing more people to be reached and wider spread of information and course contents, a possibility which was limited in the old forms of LMS. These upgraded systems have extensive impact on traditional methods of running educational institutions and very much support current learning environments (Watson and Watson, 2007). Non-traditional educational settings such as the military and corporate organizations have taken advantage of LMSs in order to train their members. Despite the different educational requirements spread across various industries and organizations, there seems to be a common ground regarding the expected outcomes from the use of learning management systems. LMSs have capabilities to integrate with other platforms or applications. These partnerships can be employed to meet certain business or organizational goals or objectives (Ellis, 2009).

The first iterations of learning management systems were the PLATO learning system which was developed at the University of Illinois during the 1960s, and the TICCIT System developed by the MITRE Corporation. As the earlier developed LMS moved from managing single lessons to a wider collection of lessons, it became paramount to introduce a system to help properly manage these additional lessons. This need brought about the development of Integrated Learning Systems (ILS) and Course Management Systems (CMS). These new systems advertised new features such

as reporting dashboards, pre-test and post-test techniques and students tracking as features that could improve learning experiences. Some platforms had risen to market leader's status at the end of 2011. These platforms include Moodle, Pearson, Desire2Learn, Sakai and Blackboard (Hill, 2014).

Moodle

Moodle, a very popular course management learning system helps educational institutions easily create, administer and manage electronic learning communities. Moodle is distributed free under open source licensing and has gathered countless university installations and use all around the world (Manolis, Stefanos, Manolis, Cleo and Anastasios, 2014). The Moodle application logs tracks events and every activity performed on the system by students, instructors and all users of the system. Moodle has log viewing dashboard built into it allowing approved users view, manage and perform other actions. The collected log data was also anonymized by removing all tables or identities that uniquely identifies users of the system. And then provide a random unique identifier for each row, which serves to represent the performers of the actions recorded on the event log.

2.2 Educational Data Mining

One of the ways to enhance the quality of educational learning processes is the provision of useful knowledge previously hidden to the administrators of higher institutes of education. The use of interactive learning environments has resulted in the collection of huge volumes of data, as these environments log all user actions during the use of the system for learning (Watson and Watson, 2007). This knowledge is useful to improve the quality of decision-making processes. This "knowledge" can be discovered from the enormous amount of data residing in the databases of these organizations and can be extracted for analysis purposes by applying data mining techniques.

Data Mining (DM) techniques have been widely used to discover knowledge from huge datasets. Data mining is defined as a process that performs the extraction, classification and analysis of information from huge databases using statistical, mathematical and machine learning techniques (Batware, 2007). DM helps to discover students' learning patterns (Baker, 2008). Data mining is also known as a process of discovering or extracting useful knowledge from huge amounts of data stored in multiple data sources (Job, 2018). Luan, (2002) defined DM as a process of discovering "tacit" knowledge and patterns within large amounts of data in order to make predictions of a possible future occurrence or outcome. The use of data mining methods in the educational domain has been termed Educational Data Mining (EDM).

EDM is a new body of research in the field of data mining and Knowledge Discovery in Databases (KDD) which is concerned with the mining relevant patterns and knowledge from educational information systems such as course management systems, registration and admission systems (Abu, 2016). Educational data mining is defined as a growing body of study that is concerned with the development and execution of methods for exploring the unique data types that emerge from educational settings, and the use of this data to better understands student behaviours and the settings in which they learn the best (Ihantola, 2015; Romero, and Ventura, 2010; Bogarín,

Cerezo and Romero, 2018). EDM researchers focus on extracting valuable knowledge for use to help educational institutes manage students activities better, and to help improve the performance of its students (Abu, 2016). The EDM process transforms raw data gotten from educational databases into useful information that could potentially have huge impact on educational processes and practices. This process follows the same steps as the general Data Mining (DM) process; pre-processing and post processing. Traditional EDM techniques include classification, clustering, association-rule mining, sequential mining, text mining, etc (Romero and Ventura, 2010). Classification is the most commonly used and also adjudged the most effective educational data mining technique; it is useful for the classification and prediction of values. Classification data mining technique was used in (Abu, 2016) for the analysis of students information collected through surveys, the goal was to provide classifications based on the collected data to predict students' performance in the upcoming semester.

Despite the many successes, the use of classical EDM techniques recorded in the educational domain, it however does not come without its shortcomings. A major one of such is that classical EDM techniques do not consider process flows and cannot be used for the discovery of workflows. There exist factors that limit the value of a data-driven approach if there is no theory that guides such process. Some authors, Cairns, (2014) and Khodabandelou, (2013) considers recommendation as a major salient type of Process mining. Some authors however choose to see Recommendation as an extended form of enhancement.

3. Methodology

Recall the four Activities presented in section one of this paper, including Activity-I, Activity-II, Activity-III and Activity-IV.

First Activity: In order to achieve the first Activity for this research work, the extraction of event logs from educational information systems was carried out on the Moodle platform. The administrator logs into the system, navigate to the administration tab, then the course administration, and click on reports and then logs. The administrator is provided with course title, participants' type, length of days, activity types, action types and event type's options. After making preferred choices, the administrator proceeds to display logs by clicking on the "Get these logs" button. Once the logs have been displayed, the administrator selects his/her preferred download output, then clicks to download. The output can be formatted into different extensions (e.g. CSV, ODS, TXT). The collected log data was also anonymized by removing all tables or identities that uniquely identifies users of the system. And then provide a random unique identifier for each row, which serves to represent the performers of the actions recorded on the event log. The ProM framework cannot directly utilize the generated output from the Moodle platform. The output from Moodle usually comes in CSV. Process mining software has a preferred file formats in CSV file and must be into the MXML (Mining eXtensibleMarkup Language) or XES (eXtensible Event Stream). For this research, the preferred format type is XES, because it is the most updated and comprehensible of the two available log types for process mining. This conversion is performed by first importing the log files into the ProM Framework tool. Clicking the import option available at the far-right side of the application interface opens a dialog that allows selecting the intended log file from the computer storage. After a successful import, the

ProM Framework then invokes the “Convert CSV to XES” plugin, which then converts the log file to XES, making it ready for further process mining analysis.

Second Activity: Achieving the second Activity involves the application of the Plugins for the two selected algorithms (inductive and fuzzy miner algorithms). This would serve as a form of comparison between the two selected algorithms and the two widely used algorithms for process discovery, the heuristics miner algorithm and the alpha miner algorithm.

Third Activity: For the third Activity, the conformance checking analysis of process mining will be performed on the process model gotten from achieving objective two to determine the conformity of the process model to the predefined curriculum and observed activities in the event logs. This action helps to detect bottlenecks and deviating instances in the use of the information system. ProM was the tool engaged.

Four Activity: In achieving the final Activity, the model obtained were exported, interpreted and used to proffer recommendations. The administrators use the acquired information to produce recommendations tailored towards improving the students’ learning experience.

4. System Design

Figure 1 depicts the workflow of the overall system. It comprises of two approaches, the existing approach, and the improved approach. The traditional approach involves collecting event log data from the Moodle LMS system. This activity was done by having a user with admin level access log into the Moodle platform and navigate to extract the needed event logs captured by the system during interaction with users. The Alpha Miner, Heuristic Miner, Fuzzy Miner and Inductive Miner Algorithms on the ProM Framework were used to produce process models from the acquired event logs. Once this was achieved, the plugins for the conformance checking on the ProM Framework would be called to perform conformance analysis on the produced process model displaying the level of compliance of the produced process model with the extracted event logs.

The proposed framework in Figure 1 was adapted from Aguirre and Parra, (2011), it begins with the extraction of event logs from the Moodle platform. The application of process discovery algorithms Fuzzy and Inductive miner algorithms was followed. Afterwards, the digital twin model was developed by performing comparison evaluation of the produced process model for conformity and deviations with the expected activities. Once this is achieved, the results of the analysis would be used to generate recommendation based on the data processed. The following subsection further describes the methodology.

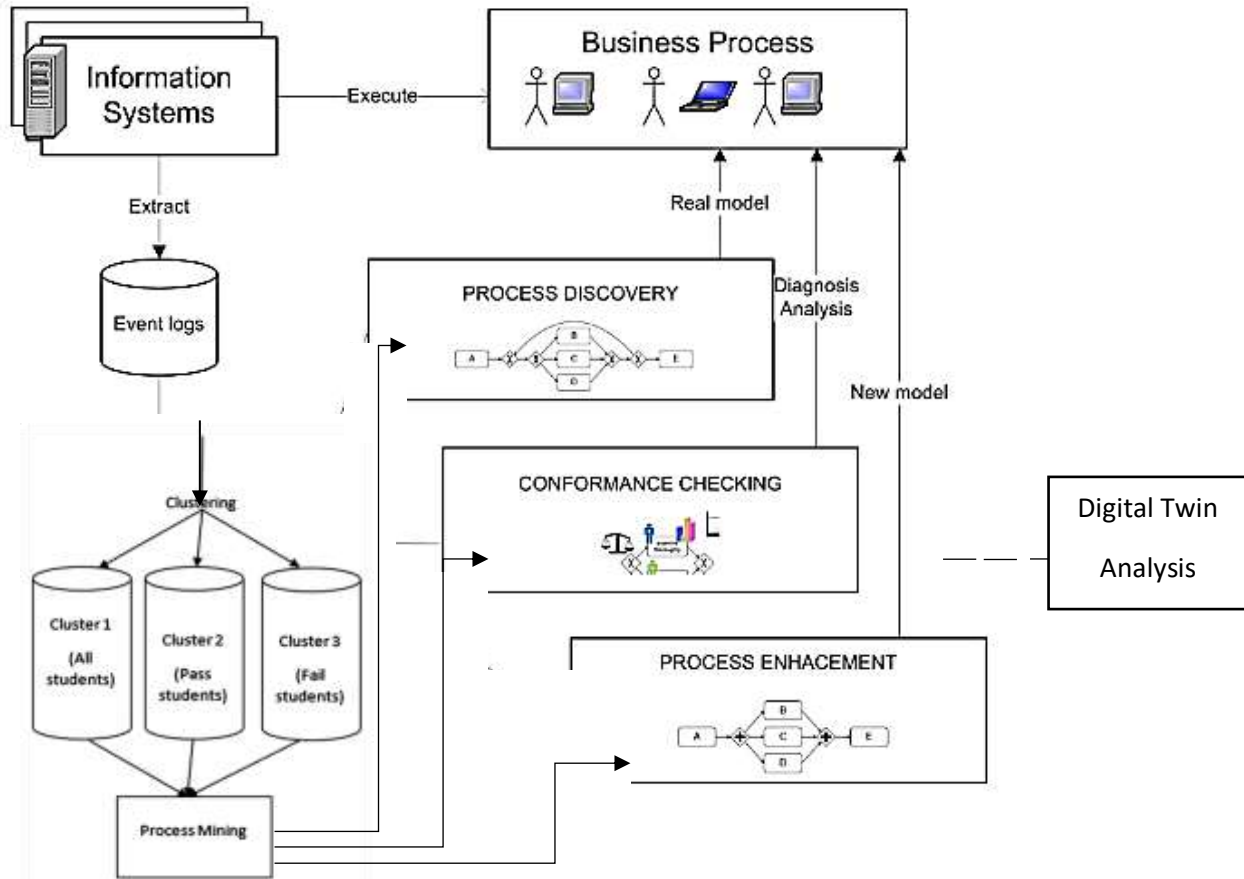


Figure 1: The proposed process mining framework

Event Logs

This study used data from 115 undergraduate e-learning enthusiastic students, who completed an online course using the corporate LMS Moodle. The students participated in a trial course and test program with the aim of capturing the student's interactions with the system for analysis use. After data extraction from the Moodle LMS, and upon pre-processing which included identification of the students' records to ensure anonymity, a total of 19,275 were gathered from the interactions of the 115 students with the system. The derived dataset were used as input for the process discovery stages of process mining. The process models derived were compared following the application of three process discovery algorithms to determine their fitness.

Process Mining

Process mining allows educators, instructors and administrators to discover new forms of data analysis using educational datasets. Traditional methods of analysis which provides limited insights, process mining can help trace the students' activities on the LMS, thus providing a more granular insight into the students learning behaviours.

Process Discovery

This study compared the results of the four algorithms used for process discovery/process mining analysis: these algorithms are the Alpha Miner, Heuristic Miner, Fuzzy Miner and the Inductive Miner algorithm.

- **Alpha Miner (AM):** was the first recognized process discovery algorithm. Its deficiencies and shortcomings help informed the development of later and better performing algorithms. Its main recorded shortcoming was its inability to use frequencies, thus it's unable to guarantee "sound" process models. Sound in this case implies that a process model should be able to reach the end state from its start state without bugs. The AM is also most suitable for noiseless event logs.
- **Heuristic Miner (HM):** The HM which was introduced by (Bogarín Romero, Cerezo and Sanchez-Santillan, 2014) recorded slightly better results than the Alpha Miner algorithm. The HM has three major advancements over the AM. It is able to filter out noisy and infrequent behaviors from event logs with its ability to use frequencies.
- **Fuzzy miner (FM):** this is one of the newer process discovery algorithms. It is the first algorithm to directly address the problems of large numbers of activities and highly unstructured behaviour (Bogarín, Cerezo and Romero, 2018).
- **Inductive Miner (IM):** The IM is clearly an improvement over the AM and HM algorithms, as it guarantees "sound" process models. It does this by first finding the most prominent split in an event log, then detects the relationship between the splits and then continues on both the split logs.

All of the above actions were performed on the process mining tool ProM Framework, which is adjudged the most suitable for process mining projects in educational domains (Cairns, 2014).

Conformance Checking

The conformance checking activity describes the activity of checking if the behaviour in the produced process models matches with the behaviour observed in the event logs. Conformance analysis is useful to detect students' learning behaviour anomalies and possible bottlenecks encountered by students and other users during use of the learning management system. Results of the conformance analysis stage can help determine where exactly these bottlenecks are and their severity if any. After the process discovery stage, this study proceeded to first use the *Linear Temporal Logic Analysis* feature of the ProM Framework. This activity is performed by calling the *LTL Checker plugin* that checks if the event log used satisfies a predefined set of properties expressed in LTL Logic. There exists a set of formula already predefined in the LTL Checker plugin. However, these formulas can be customized to fit user requirements as the need arises. To perform a check to determine if students are required to perform the task "Quiz review" before the task "Quiz review summary", the formula will be defined as:

```

formulaquiz_review_is_a_prerequisite_of_quiz_review_summary
c1: ate.WorkflowModelElement,
c2: ate.WorkflowModelElement) :=
{<h2> Is the activity Quiz review a prerequisite for the activity Quiz Review Summary?
</h2>}
(<>(activity==c2)/\ (activity!=c2 _U
activity==c1));

```

Equation 1: LTL Logic for conformance checking

The second activity in the conformance checking stage is the application of the *Conformance Checker* Plugin. This plug-in allowed us to analyze the produced model precision, fitness and structure via log replay (which is the replay of the produced model on the original log), and state space analysis and structural analysis. To perform this action, the *Conformance Checker* Plugin on the produced model was applied from the inductive miner process discovery stage taking the event dataset as input. The results of this stage were two traces which represented conforming and non-conforming traces.

5. Data Description and Implementation

This study used data from 115 undergraduate e-learning enthusiastic students, who completed an online course using the corporate LMS Moodle. The students participated in a trial course and test program with the aim of capturing the student's interactions with the system. After data extraction from the Moodle LMS, and upon preprocessing which included the identification of the students' records to ensure anonymity, a total of 19,275 were gathered from the interactions of the 115 students with the system. The event log file extracted from Moodle serves as the starting point into the analysis process in this study. It is vital to preprocess the log files by filtering it as a real event log that often contains noisy data (Romero and Ventura, 2010)

The students' private data such as names and IDs were deleted and each student was assigned a random id number so as to ensure anonymity and data privacy. Some attributes from the log file were deleted leaving only four (Full name, Action, Information and Timestamp). Some students' actions gathered on the log were also not considered for this analysis. Only actions that were relevant to the learning process and academic performance were considered. Next the Excel CSV log file was transformed using the "Convert CSV to XES" plugin on the ProM Framework into the XES (eXtensible Event Stream) format which is required by the ProM Framework for process mining. Table 1 and 2 contains the attributes of a Moodle event log and action attributes respectively.

Table 1: Attributes of a Moodle event log

Attributes of a Moodle event log file	
Attribute	Description
Course	The name of the course
IP Address	The IP of the device used to access Moodle
Time	The date Moodle was accessed
Full Name	The name of the student
Action	The action that student performed
Information	More information about the action

For thorough analysis of students' behaviour, this study used students' test grades to group these students into two categories. The test scores ranging from 0 to 100 was divided into two using the range, 0 to 49.9 classified as "Fail" and 50 to 100 classified as "Pass". Clustering by grades is useful for comparing the performance of different algorithms and for producing slimmer process models that's more likely to be accurate in replicating the observed events from the event logs (Bogarín, Cerezo and Romero, 2018). At the end of this preprocessing step, the data was divided into three subsets; All (containing events for all the 115 students that took the Moodle course), Pass (containing events of 64 students considered to have passed the course) and then Fail (containing event actions of 51 students that failed the course).

Table 2: Moodle Actions Attributes

Moodle Attribute Actions	
Low level Moodle Action	High Level Codification
assign submit	EXECUTING
assign view	PLANNING
forum add discussion	FORUM PEER LEARNING
forum add post	FORUM PEER LEARNING
forum update post	FORUM PEER LEARNING
forum view discussion	FORUM PEER LEARNING
forum view forum	FORUM PEER LEARNING
page view	LEARNING
quiz attempt	EXECUTING
quiz close attempt	EXECUTING
quiz continue attempt	EXECUTING
quiz review	REVIEW
quiz view	PLANNING
quiz view summary	PLANNING
resource view	LEARNING
URL view	PLANNING

At the end of this process the study then went ahead to perform the conformance checking analysis on the optimized process model and also evaluate the framework and the outcomes of the various algorithms used.

5.1 Implementation Interfaces

The different interfaces engaged in the analysis process have been displayed as follows: Figure 2 shows the event log dataset used for this analysis in CSV format. Figure 3 shows the process of converting CSV file to the expected file format XES for PRoM.

	activity_name	course_id	module	idnumber	added	score	visible	visibleold
1	assign submit	10464	9	user186977097674129409	1372670270	94.5	1	1
2	resource view	10464	19	user4786049973974204417	1378189004	44	1	1
3	forum view forum	10464	7	user7133053338412646401	1372678410	85	1	1
4	assign submit	10464	9	user3543713697010548737	1372677682	30	1	1
5	quiz view	10464	16	user1626801571545219073	1372678281	38.5	1	1
6	quiz view	10464	16	user4549114572627247105	1372679905	82	1	1
7	forum view forum	10464	7	user6741987709889282049	1372678410	52.5	1	1
8	forum add discussion	10464	3	user1752183332046635009	1372677766	8.5	1	1
9	forum add discussion	10464	3	user8345756041840951297	1372678056	18.5	1	1
10	forum update post	10464	5	user2125677738260955137	1372678792	59	1	1
11	quiz review	10464	15	user3180865810348376065	1377792996	60	1	1
12	quiz review	10464	15	user3098829117496229889	1435737732	40.5	1	1
13	quiz review	10464	15	user1639510899465125889	1377683443	90	1	1
14	quiz close attempt	10464	12	user7739766835326746625	1449566049	64	1	1
15	forum add discussion	10464	3	user8627213778552881153	1372744095	67.5	1	1
16	quiz attempt	10464	10	user2420451385418973185	1377242031	67	1	1
17	quiz close attempt	10464	12	user2896319635668336641	1449570716	97	1	1
18	assign submit	10464	9	user2216540094985142273	1377095848	62	1	1
19	quiz view	10464	16	user8371538219417731073	1372679905	50	1	1
20	quiz continue attempt	10464	13	user2986645744250781697	1372680029	58.5	1	1
21	forum view discussion	10464	6	user1395770998610984961	1377243045	97.5	1	1
22								

Figure 2: Event log used for analysis



Figure 3: Process of converting CSV Log file to XES format

6.1 Process Analysis Evaluation

It's worthy to note that although Fuzzy miner produces very good and understandable process models, it does not provide enough information useful for evaluation and as such was not considered for evaluation. Table 3 shows the evaluation table.

Table 3: Evaluation table

Algorithm	Cluster	Trace Fitness
Alpha Miner	All	0.789
Heuristic Miner	All	0.567
Inductive Miner	All	0.867
Alpha Miner	Pass	0.651
Heuristic Miner	Pass	0.599
Inductive Miner	Pass	0.935
Alpha Miner	Fail	0.774
Heuristic Miner	Fail	0.632
Inductive Miner	Fail	0.927

The process analysis was conducted using the Dotted Chart Analysis Technique in the ProM Framework. The x axis of the chart indicates the timestamp of the event (the period an event was executed) while the y axis indicates the performers of the event (in this case, the students). The blue dots signify the first time a lecture video was watched, while the white dot signifies the time a quiz was submitted on first attempt. Events reoccurrence such as students watching a video again and students submitting quizzes in subsequent attempts is indicated using Yellow and Red respectively. The black line across the face of the chart indicates the specified soft deadline, while the white line indicates the hard deadline which is the final day of submission for quizzes after the initial period of grace.

The outcome of this study shows that the cluster of students that passed the course tends to watch course videos first and then attempt the corresponding quiz before the hard deadline elapses. The study also found that after the deadline, some students in this cluster went ahead to watch those videos again for better understanding of what the video teaches. On the other hand, students of the fail cluster failed to keep to the set deadline. The dotted chart analysis also shows that their behavior could largely be unpredictable as some even watch videos after the related quiz has closed. Finally, the analysis further shows the behavior of students while submitting quizzes amongst the cluster that passed the course. This analysis reveals a fine pattern of students who strive to submit quizzes before the hard deadline. While noticing the trend from the analysis of students that failed, the course shows that a lot of these students fail to meet the soft deadline and a few of them still struggle to meet the hard deadline.

7. Conclusion

This research is focused on providing higher educational institutions with the ability to see through its data opportunities to effectively improve its educational processes, thus impacting

on the quality of students it turns out as graduates. Expected at the end is an optimized process model useful for recommendation and improving the student, and instructor interaction with educational information systems. The results in this current research are useful for studies in Open and Distance Learning (Ayo, Odukoya and Azeta, 2014; Azeta, 2008; Azeta, Inam and Daramola, 2018). This study has been able to address the problem of over dependence on data in analyzing student's behavior in online learning. The result of such analysis may be biased due to over fitting, whereas students' behavioral analysis using process mining would showcase student's actual behavior through visualization. The use of a digital twin to analyze student's behavior in online learning or Open and Distance Education (ODE) is quit novel and serves as the main contribution of this study. As part of recommendation and future works, it is essential to enhance the diagnosis of students' behavior through the development of more specific EPM tools in order to help domain experts (such as, educational specialists and researchers) to properly analyze educational processes.

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Machine Learning Techniques for Automatic Long Text Examination in Open and Distance Learning

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Abstract

Assessment and examination are the most critical and important activities in any Open and Distance Learning (ODL) platform. The main concern for assessment in the ODL system is its ability in assessing the student's understanding, skillset and knowledge. Multiple-choice questions, Single-choice questions, and subjective and true/false questions are the most common assessment pattern used in existing open distance learning platforms. ODL platforms support long text answers and essay-type questions. However, long text and essay-type questions are graded manually which takes a lot of time to evaluate and give feedback. Therefore, this research addresses the aforementioned challenges by demonstrating a new model for automatic long-text examination in ODL using seven machine-learning techniques. This study implemented seven machine learning techniques for grading easy-type examinations and carried out a comparative study based on their performance. A two-top monolingual aligner for text-matching tasks such as long-text, recognition of textual entailment and paraphrase detection was also developed. The result shows that the Support Vector Machine performed best in terms of performance accuracy followed by Artificial Neural Networks, Decision Tree, Logistic Regression, K-Nearest Neighbour and Random Forest, while the Naïve Bayes classifier performed worst. We also compare four similarity matching techniques, our experimental result shows that the cosine similarity matching technique outperformed Levenshtein, Longest Common Distance and Jaccard similarity matching techniques. The system was tested and evaluated and the result shows that the system performs 0.833% accuracy prediction when compared with human-graded answers.

Keywords: Examination, Long Text Similarity Matching, Machine Learning, Open Distance Learning, Semantic Similarity.

1 Introduction

Open and distance learning (ODL) is a type of education that uses technology to connect students, lecturers and educational materials in different locations. ODL is a teaching style that is being more widely adopted every day than previous traditional teaching methods (Karaduman & Mencet, 2013). ODL is a learner-centred environment, ODL learning pattern differs from those of the conventional and traditional university system where both course materials and instructional activities are lecturer-centred. Hence, academic activities in an ODL institution seek to satisfy the needs of students and learners (Onwe, 2013). The major task of ODL providers is to develop an educational experience that encourages learning. ODL providers and institutions need too many factors to implement ODL efficiently and effectively to overcome different barriers. The important factors that affect learners' success in ODL include interactivity, collaboration, communication, assessment and feedback made available to the students (Dzakiria et al., 2013). ODL provides education and learning for all, encourages lifelong learning, and creates a great impact on the economies of scale in the education system (Onwe, 2013). Due to the increasing

awareness and recognition of ODL as a platform for expanding access to education, it has become critical to develop and maintain quality processes such as quality examinations and student assessments if ODL is to be adopted as a complement to traditional institutions of higher learning (Pitsoe & Maila, 2014).

With the increasing growth of modern education, the idea of open and distance learning systems has been implemented to enhance the quality delivery of online courses, allowing teachers to offer electronic examinations through online open and distance learning platforms. Examinations are an essential activity for accessing the abilities, knowledge and level of understanding of open and distance learning students (Alrehily et al., 2018). Hence, it is very essential to implement a quality assessment and examination platform for open and distance learning courses to evaluate the student's level of understanding. Thus, there are existing electronics assessments and examination modules for massive open online courses (MOOCs) but these systems are limited to examinations with multiple-choice questions (MCQs), single-choice questions (SCQs) and subjective questions with short-text answers (Parekh et al., 2015). Assessment and examination is the most critical and important activity in any educational system. MOOCs based educational resources are providing one of the most effective ways to offer access to quality open distance learning education, especially for learners residing in disadvantaged or remote areas (Daradounis et al., 2013). By offering ODL courses it becomes very important to provide evaluation and grading services. Recently there are more advanced question types such as inputting mathematical equations, circuits and question types with a textual summary but are limited to short-text question types (Mitros *et al.*, 2013).

The existing ODL E-examination and assessment systems evaluate its long text and essay-type questions manually. This takes a lot of time and manual labour to evaluate the entire student's answers and give feedback. Hence, long-text answer question type will always make the students reduce the stress of manual evaluation and create efficient, fast and reliable grading and feedback (Kumaran & Sankar, 2014). Moodle is also an open-source distance learning platform. It helps educators to create open distance learning courses and it is used in many development and training setups. Moodle assessment methods include electronic audio recording questions, MCQs, essay format, random short answer, interactive audio and video recording, short answer questions, Pdf and MS-WORD upload option, and Numerical and Short answer questions. However, the long answers and essay answers are graded manually (NT et al., 2015). Sakai is also an open and distance learning platform that is mainly used in educational institutions for collaboration, teaching and research. It is also used by the military, corporate and government to carry out open and distance learning activities. The assessment methods are timed assessments, matching questions, essay-type questions, short-text answers, matching questions and open-ended questions. However, descriptive answers and essay-type questions are manually evaluated by teachers. Hence, it is nearly impossible for a teacher to typically go through each student's answer to evaluate their answer (NT *et al.*, 2015). E-examination and assessment models for open distance learning courses with new technologies are on the rise daily and have

improved the capabilities and users' experience of open and distance learning course platforms in conducting MCQs, SCQs and short-text similarity matching examinations and assessments.

A language is an important form of communication between humans, Natural Language Processing (NLP) serves as an interaction between human and computer languages. NLP platforms operate jointly on the semantic analysis (conceptual level) and morphological analysis (word level) and are mostly automatic encoding tools. The NLP platform is aimed at representing knowledge expressed by sentences and words of the document (Meystres & Haug, 2005). One of the major objectives of NLP is the capacity for information retrieval through a means of a user-defined query. Natural language processing (NLP) is a subfield of computer science and artificial intelligence that utilises linguistic analysis to obtain knowledge from an unstructured free text (Doan et al., 2016). NLP algorithms and their techniques such as information extraction are widely used within the semantic analysis of short-text and long-text to process large quantities of unstructured datasets such as plaintext and return structured information. Short-text similarity matching is an important aspect of NLP applications in academic assessment and examination, for example, student responses to the subjective-answer question (short-text answer questions) can be automatically graded based on their semantic similarity with the trained dataset (experts in the subject domain provided correct answers to those questions). NLP is also applicable in automatic question answering, where short-text matching with the required question is used to evaluate student answers. However, there has been little application of NLP techniques in the automatic assessment of long-text examination in open-distance learning systems (Agirre et al., 2015).

In this study, we introduced a Support Vector Machine (SVM) technique to improve the quality of assessment and examination of existing open-source open distance learning systems. SVM Automatic grading systems could improve in maintaining consistency in evaluating and grading students' answers if trained well, these models can evaluate as accurately as human examiners with a very high correlation between machine and human graders. SVM algorithms are varied and include pattern recognition and machine learning algorithms. There are two types of machine learning models: generative and discriminative. The generative approach would apply the use of many features and it is more intractable when a lot of features are applied. Discriminative methods on the other hand rely on a less knowledge-intensive approach to find the closest match. SVM is a discriminative learning approach that classifies input based on feature sets (Nadkarni et al., 2011). This input could be mathematically transformed to ensure linear separation of data points from distinct categories using a (kernel) function. SVM is based on statistical learning theory and has several distinct advantages when it comes to handling non-linear, small data points and high-dimensional pattern recognition issues, overcoming greatly the problem of overlearning and the cause of dimensionality among other issues. It has a straightforward mathematical model (Weng et al., 2016). Among applications where SMV can be applied includes facial recognition, handwritten character recognition, time series prediction, genetic classification and short-text similarity matching and long-text similarity matching tasks. Hence, this study introduced machine learning for the automatic long-text assessment grading

model in open-distance learning. This study aims to analyse and implement an automatic assessment of long-text examination in open and distance learning using machine learning techniques and text-based similarity matching techniques.

2. Related Works

A mobile-based learning platform featuring an examination module was developed by Parekh et al. (2015). According to the authors, the current system consists primarily of Single Choice and Multiple-Choice Questions, and it can only test and summarise knowledge in a single topic domain. As a result, a short-text examination module was proposed for an in-depth understanding of the subject domain. However, the approach was designed to make learning and assessment more convenient, but it could not handle semantic heterogeneity that could occur from the presence of synonyms in natural language. As a result, if the system is operational, it may encounter the challenge of semantic heterogeneity. Blackboard learn offers learner-centred open and distance learning courses that enhance long-life learning and basic teaching tasks. It provides customized course delivery and management and also offers a free evaluation model which includes file upload of questions, essay-type questions fill in blanks, True/False questions, matching questions MCQs, short answer questions, form question pool and random pool questions. However, descriptive answers and long-text question types are graded manually. Wu & Shih (2018) presented a short answer grading system in Chinese using the Support Vector Machine (SVM) approach. The experimental result was tested with translated corpus from two commercial corpora in English. The result shows that the outcome of the two different corpus is promising for an automatic short answer grading system. However, the experiment is limited to subjective questions. Sultan *et al.*, (2016) developed a short-text answer grading system for short-text answers in English. The system automatically measures the correctness of a student's answer by calculating the similarity with the correct answers based on a given question and its reference answers. Sheeba (2014) introduced an approach for automatically evaluating single descriptive sentence answers. By examining learners' subjective answer sheets, the author proposes a method for determining students' level of learning. Subjective answers are expressed as graphs and compared to the required marking scheme (standard answer). Only a theoretical foundation for archiving a semantic-based subjective electronics assessment is presented in this study. Nonetheless, the system was not implemented to test the framework's viability.

Shinde & Chokhadres (2013), presented a novel approach the e-assessment system that supports both short-text and objective questions. The platform is an improvement on the e-assessment platform for multi-choice and objectives examination. The system, however, is syntax sensitive. The learner must enter the actual phrase or keyword, without considering synonyms. A fundamental weakness in this approach is semantic heterogeneity. This setback will be addressed in this work using the NLP algorithm for long-text similarity matching. Kumaran & Sankar (2013), developed an automatic assessment system using a concept map and ontology for evaluating student knowledge. The concept mapping technique is created for the student's answer and ontology is developed for the concept map. The ontology is matched with the reference answer ontology by using the ontology mapping technique to evaluate the student's knowledge. The

limitation of the system is that only one key answer is used to evaluate the answer. While several automatic assessment systems are publicly available, such as clustering-based scoring Zesch et al. (2015), an essay evaluation system for Swedish (Östling et al., 2013), or Neural Essay Assessor (Taghipour & Ng, 2016), these systems are cumbersome when it comes to applying or extending the new dataset and they are typically centred around specific method and dataset.

3. Methodology

This section introduces the methodology of the current research. It also presents the overview of the system, requirements specification, analysis and design of the system. The proposed framework and the implemented techniques are also discussed. Also, reflected in the proposed model is the use of machine learning techniques and text-based similarity-matching techniques to execute long-text similarity-matching tasks, and two-top monolingual aligners for text-matching tasks such as recognition of textual entailment and paraphrase detection.

3.1 Design Framework

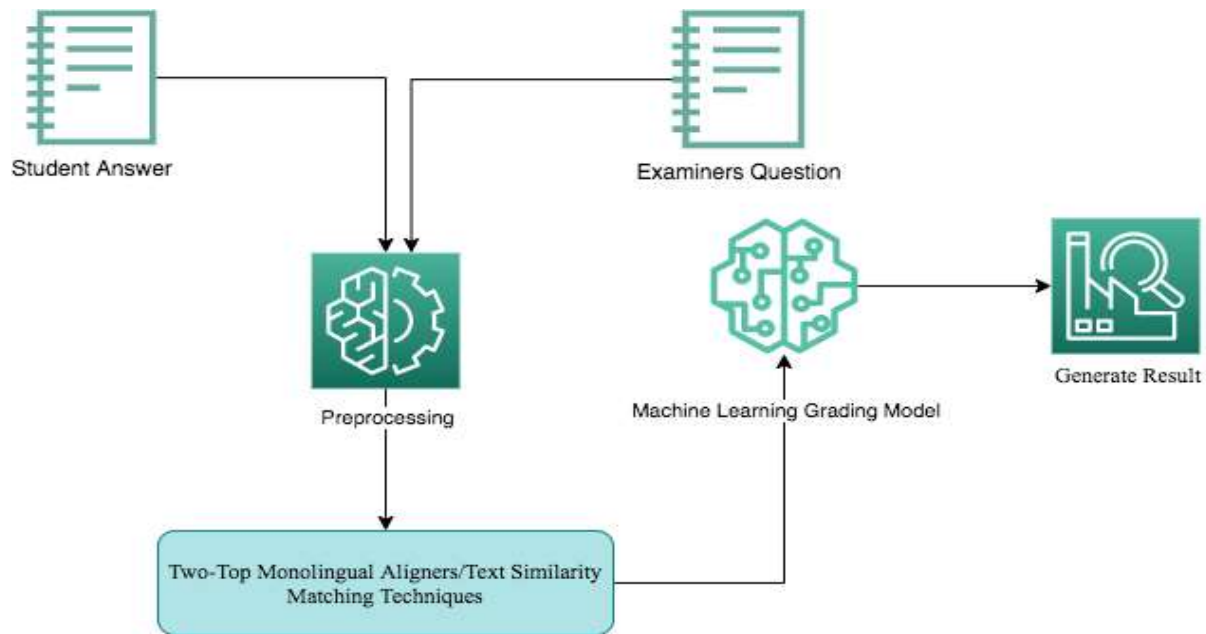


Figure 1. Long-Text Examination Grading Framework

3.2 Pre-Processing of Text-Based Document

For the sentences to be suitable for computation and evaluation, they have to be pre-processed as illustrated in Figure 1. The pre-processing stage is essential in designing our automatic long-text examination grader. In our model, both the examiner's reference answer and the student's answer are passed through the pre-processing stage. The pre-processing stage plays a vital role in our automatic long-text examination grader for many reasons. It helps in the significant reduction of processing time and the space of words. It also helps in removing stop words and noisy words which frequently occur in the dataset. The various steps employed before executing tagging as a part of pre-processing of the examiner's answers (marking scheme) and the student's

answers include: (i) Tokenization of document sentences, (ii) removal of noise and stop words, and (iii) part of speech tagging.

Noise removal converts the original textual data into the document which consists of content linked to the subjects of the document. Stop words are phrases that do not include vital information or are significant enough to be employed in search queries but do not contain valuable information. These words are usually taken out of search queries because they return a great volume of irrelevant data. Tokenization involves breaking a stream of sentences into phrases, words, or other meaningful elements called tokens. The list of tokens, words or phrases becomes the input for further processing such as text mining or parsing. Tokenization is the process of breaking down a string of characters into lexical components such as punctuations or words. The answer question may contain multiple paragraphs and each paragraph contains multiple sentences. For efficient answers evaluation words must be split from sentences and sentences must be split from paragraphs. This type of splitting mechanism among paragraphs or sentences is called token separation. The technique of breaking words and punctuation into individual sentences is known as sentence splitting. Part of Speech (POS) Tagging, also known as grammatical tagging, is the technique of identifying a word in a phrase as belonging to a specific part of speech (adverbs, adjectives, verbs, nouns, etc.). Part of speech tagging is a type of word meaning disambiguation that seeks to assign each word in a document to one of a set of POS such as noun, verb, adjective, or adverb. Since many words have multiple possible tags, we used POS to decipher them.

As a result, the primary function of POS is to identify the precise tagging for each word in the corpus. The process is achieved based on word definition, as well as its context, i.e. related words in a sentence and their relationship with adjacent. The important sentences for the corresponding answer are to be retrieved from the knowledge base and assigned to the suitable parts of the speech tag. To bring forth quality information for a certain document, the POS tags useful material from knowledge sources. In the proposed model, course codes were used to separate each examination type. POS is also an important syntactic feature. It means that if the student's answer and the examiner's reference answer share the same POS tags, that means they both have similar syntactic structures and are more likely to have the same meaning. The block diagram of the pre-processing phase is shown in Figure 2.

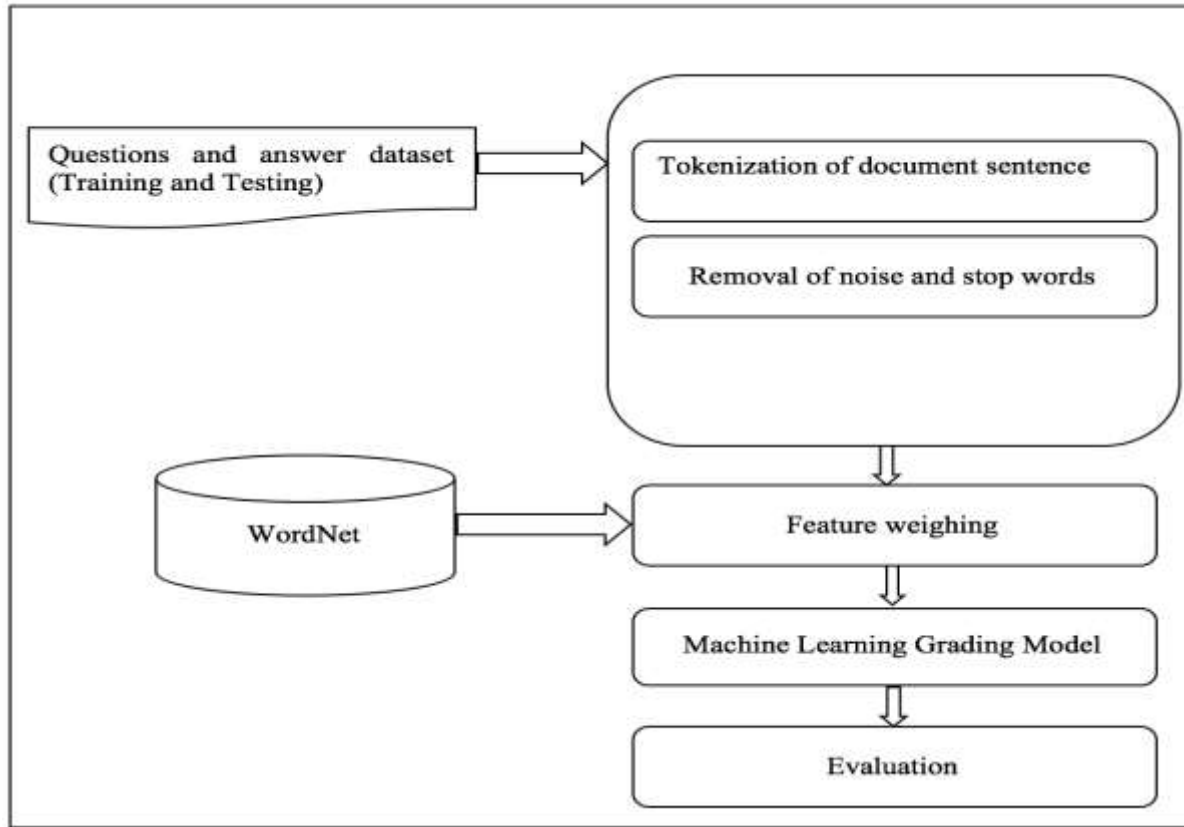


Figure 2: Block Diagram of the Pre-processing Phase

3.3 Design of the Semantic Similarity Matching

Semantic similarity is a technique defined over a set of terms or text documents. The distance between the set of terms or text documents is based on the likeness of their semantic content or meaning rather than their syntactical representation or their string format. This method executes the similarity between two texts by computing the cosine. Cosine similarity matching is a mathematical technique that is used to derive semantic similarity matching based on analysing word-to-word co-occurrence in a collection of sentences. Using the cosine similarity technique makes it possible to compute similarity measures for adverbs and adjectives too, not only for verbs and nouns. The cosine between two vectors or two text documents on the vector space is a measure that evaluates the cosine of the angle between them. It generates a metric that says how identical are two text documents by measurement of orientation and not the magnitude as shown in Equations 1.1, 1.2 and 1.3.

$$\text{Cosine Similarity} = \vec{a} \cdot \vec{b} = \|\vec{a}\| \|\vec{b}\| \cos\theta \quad \text{Cosine Similarity} = \vec{a} \cdot \vec{b} = \|\vec{a}\| \|\vec{b}\| \cos\theta \quad (1.1)$$

$$\text{Cosine Similarity} = \cos\theta = \frac{\vec{a} \cdot \vec{b}}{\|\vec{a}\| \|\vec{b}\|} \quad \text{Cosine Similarity} = \cos\theta = \frac{\vec{a} \cdot \vec{b}}{\|\vec{a}\| \|\vec{b}\|} \quad (1.2)$$

$$\text{Cosine Similarity} = \cos\theta = \frac{\vec{a} \cdot \vec{b}}{\|\vec{a}\| \|\vec{b}\|} = \frac{\sum_{i=1}^n A_i * B_i}{\sqrt{\sum_{i=1}^n (A_i)^2} * \sqrt{\sum_{i=1}^n (B_i)^2}} \quad (1.3)$$

The cosine similarity matching vector space model is shown in Figure 3.

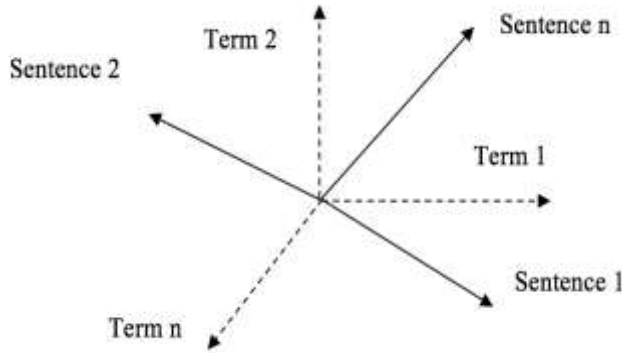


Figure 3. Cosine Similarity Matching Vector Space Model

The cosine similarity matching formula can be demonstrated through the following example:

Sentence 1: Blessing eats more food than Emmanuel does, and

Sentence 2: Emmanuel eats less food than Blessing.

It can deduce how identical or similar these sentences are in terms of word count. Lists of the words from both sentences are constructed without redundancy, which is denoted as “Blessing eats more food than Emmanuel does less”. The number of times each of the words in the constructed list appears in each sentence is counted. This word count is summarized in Table 1.

Table 1: Word Count Based on SVM Cosine Similarity Matching Formula

	Blessing	eats	More	Food	Than	Emmanuel	Does	Less
Sentence 1	1	1	1	1	1	1	1	0
Sentence 2	1	1	0	1	1	1	0	1

In this scenario, the interest is only in the two vertical vectors of counts. When the formula in Equation 1.4 is applied, Equation 1.4 would be derived:

$$\cos\theta = \frac{1*1+1*1+1*0+1*1+1*1+1*1+1*0+0*1}{\sqrt{1^2+1^2+1^2+1^2+1^2+1^2+1^2+0^2} \cdot \sqrt{1^2+1^2+0^2+1^2+1^2+1^2+0^2+1^2}} \quad 1.4$$

$$\cos\theta = \frac{5}{\sqrt{7} \cdot \sqrt{6}}$$

$$\cos\theta = \frac{5}{6.5}$$

$$\cos\theta = 0.76$$

The result of the above calculation will always be a value between 1 and 0, where 1 means 100% similar and 0 means 0% similar. The cosine similarity matching formula will generate a metric that says how identical or related are two text documents by looking at the angle rather than the magnitude, like in the example in Figure 4.

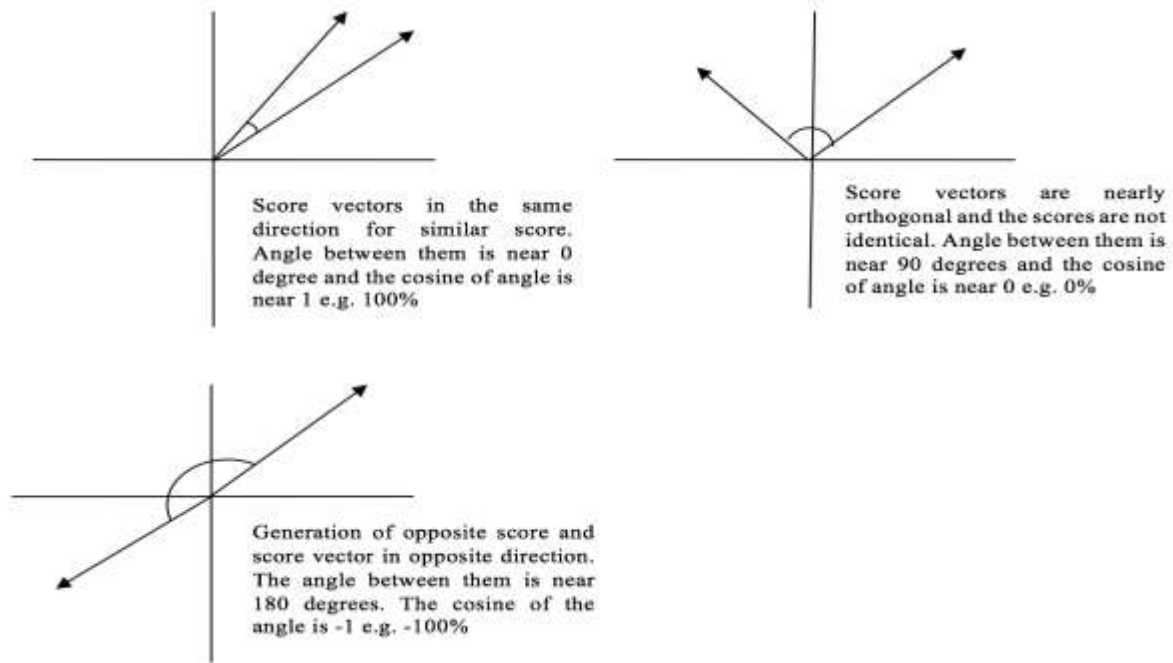


Figure 4: Cosine Similarity Matching Formula

3.3.1 Cosine Similarity Matching Algorithm

In this section, the cosine similarity algorithms were designed to illustrate sentence similarity measurement for long text similarity ranking tasks.

Algorithm:

```

define cosine_simiary (vector1, vector2):
    common = set (vector1.keys()) and set(vector2.keys())
    numerator = summation([vector1[x] * vector2[x] for x in common])
    summation1 = sum([vector1[x]**2 for x in vector1.keys()])
    summation2 = sum([vector2[x]**2 for x in vector2.keys()])
    denominator = sqrt(summation1) *sqrt(summation2)
    if not denominator:
        return 0.0
    else:
        return float(numerator) / denominator

define text_to_vector(text):
    sentence = text.split()
    return counter(sentence)

examiner_reference_answer = "A tree is a hierarchical data structure that naturally stores
information in a hierarchy fashion."

student_reference_answer= "Tree is a data structure which stores information naturally in
hierarchical pattern."

vector1 = text_to_vector(examiner_reference_answer)
vector2 = text_to_vector(student_reference_answer)
cosine_similarity_matching = cosine_simiary (vector1, vector2)
print(cosine_similarity_matching.

```

3.3.2 Block Diagram of the Cosine Similarity Matching

Figure 5 describes the steps for similarity matching between the examiner reference answer and the student answer.

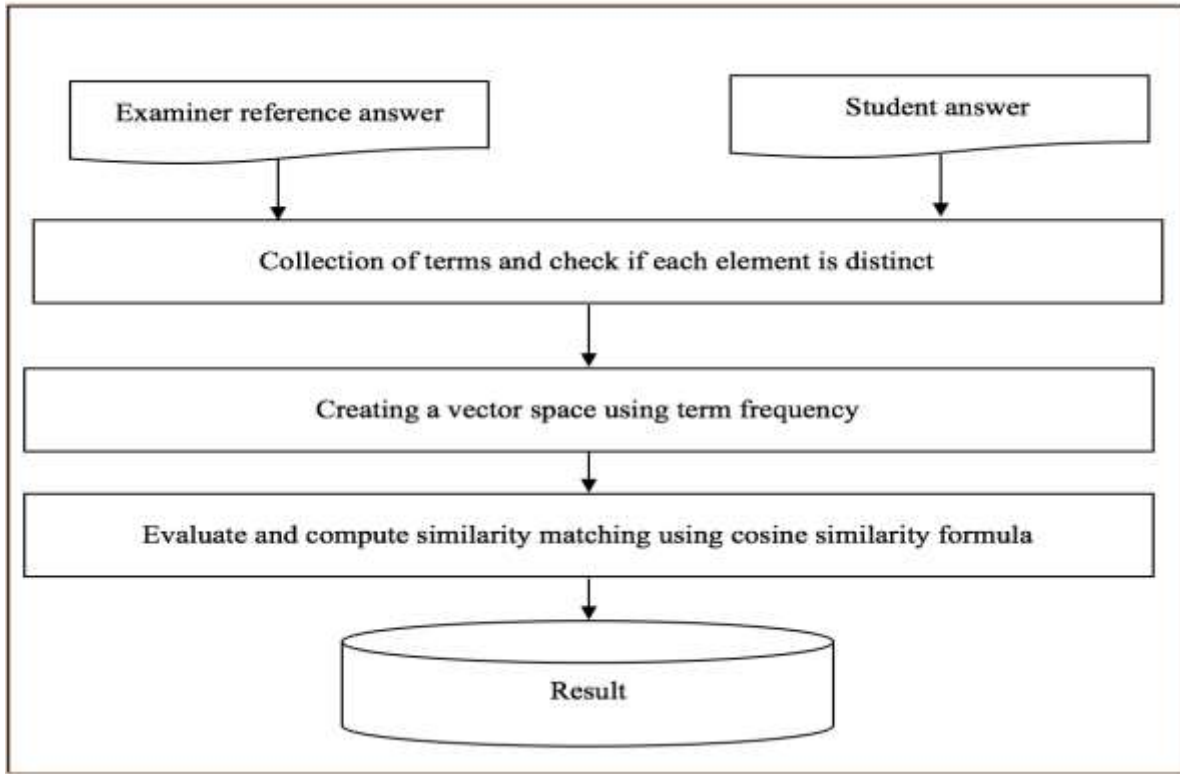


Figure 5: Cosine Similarity Matching Block Diagram

3.4 Design of the Paraphrase Detection

The objective of paraphrase detection is to determine if two sentences have identical meanings. Here, the two-top monolingual aligners for paraphrase detection task and the aligners for sentence and word alignment were employed and designed respectively. The aligners operationalize the simple hypothesis that related words in two sentences snippets can be identified using similarities in their own meaning and the context in which they have been used in the sentence snippets.

For example, Given a long text pair $L^{(1)} = (w_1^{(1)}, \dots, w_n^{(1)})$ and $L^{(2)} = (w_1^{(2)}, \dots, w_m^{(2)})$, $L^{(1)} = (w_1^{(1)}, \dots, w_n^{(1)})$ and $L^{(2)} = (w_1^{(2)}, \dots, w_m^{(2)})$, where each w is word, the goal of the alignment is to generate a set of token index pairs $\{(n, m)\}$ such that $w_n^{(1)}$ is aligned to $w_m^{(2)}$. An example is shown in Figure 6. The word pair (2,2), for example, indicates soldiers in $L^{(1)}$ is aligned to troops in $L^{(2)}$. The phrasal alignments are represented as sets of index word pairs where each word token in the $L^{(1)}$ phrase is aligned to each word token in the $L^{(2)}$ phrase. For example, (4,4), and (5,4) together encode the alignment between jail and prison in Figure 6.

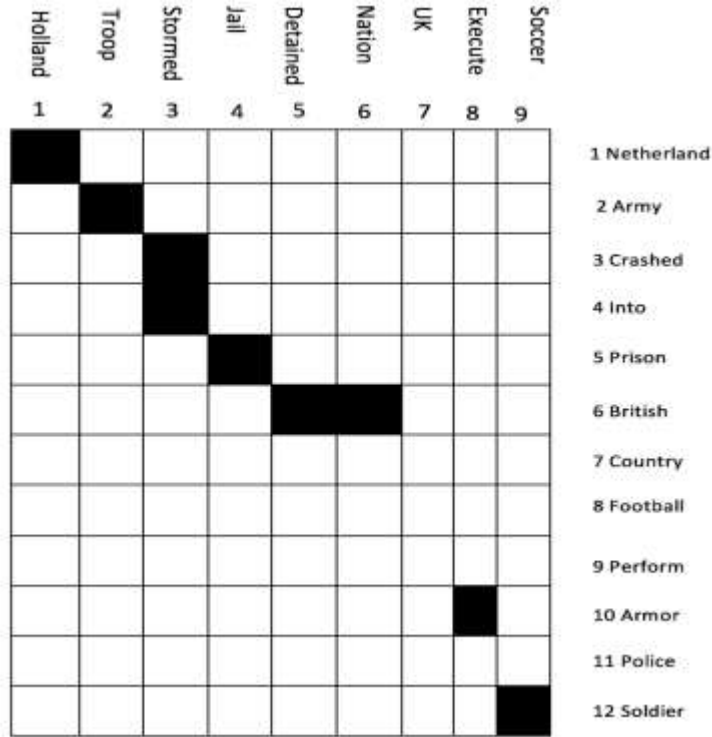


Figure 6: Human Alignment Sentence Pair (MSR Alignment Corpus)

The shaded areas or cells in Figure 6 depict the alignments of word pairs, which can be represented as the set of word tokens pairs $\{(1,1), (2,2), (3,3), (4,4), (5,4), (6,7), (7,8), (8,9), (9,8), (10,2), (11,5), (12,2)\}$. The phrasal alignments are stored as multiple word alignments: For example, (3, 3) and (4, 4) together represent crashed into stormed. The goal of the aligner is to execute and output this set of pairs. In Figure 6, Soldier (12) is not aligned to Troop (2) despite that both words form semantic equivalence in isolation, due to the presence of a competing word pair (Army (2), Troop (2)), which is a better fit in the context.

3.5 Dataset Description

The Automated Assessment Prize (ASAP) dataset from the Hewlett Foundation was used in this study. The dataset was partitioned into eight (8) sets, each with its domain. This allows for domain diversity in the dataset. Each set contains tagged question, answer, and grade data for testing and training. All questions were manually graded by two (2) to three (3) teachers and based on the instructors' combined scores. Each set of questions has a different grading scale, ranging from 1 to 10. (Set 1: 2-12, Set 2: 1-6, Set 3: 0-3, Set 4: 0-4, Set 5: 0-4, Set 6: 0-5, Set 7: 0-30, Set 8: 0-60). Four (4) question sets (Sets 2, Set 3, Set 4, and Set 6) were used out of the eight available. 70% of the dataset was used for training the model, while 30% was used for testing. Table 2 shows a summary of the dataset.

Table 2: Experimental Dataset

Question Set	Answer Score	Training Set	Testing Set	Average Word Count
Set 2	1-6	70%	30%	500
Set 3	0-3	70%	30%	350
Set 4	0-4	70%	30%	400
Set 6	0-5	70%	30%	500

4. Results and Discussion

This section focuses on evaluating the result by applying Accuracy, Precision, Recall and F1-Score to evaluate how well our automatic long-text examination model performed. For recall, precision, and F1-Score. Since the proposed model must determine when a student's answer is erroneous, the incorrect answers were assigned to the positive class.

4.1 Results of the Different Similarity Matching Techniques

In this section, the performance of four similarity matching techniques (Cosine Similarity Matching, Jaccard Similarity Matching and Levenshtein Similarity Matching) was compared. The aforementioned techniques were evaluated based on performance accuracy which is simply the ratio of correctly similarity-matching outcomes or observations to the number of actuals. Table 3 presents the performance of the four similarity-matching techniques while Figure 6 illustrates the significance test of the four similarity-matching techniques

Table 3: Performance of the Four Similarity Matching Models

Similarity Matching Model	Performance Accuracy
Cosine Similarity Matching	0.84*
Jaccard Similarity Matching	0.29
Longest Common Subsequence	0.76
Levenshtein Similarity Matching	0.80

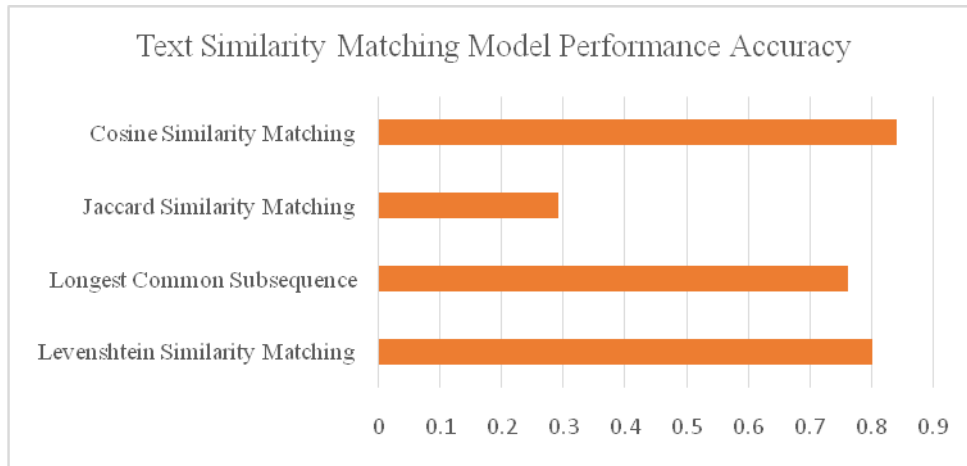


Figure 6: Performance accuracy of the four similarity-matching models

The experimental result shows that the cosine similarity matching technique outperformed Levenshtein, Longest Common Distance and Jaccard similarity matching techniques as illustrated in Table 3 and Figure 6.

4.2 Results of the Different Machine Learning Techniques

Seven machine learning algorithms (Decision Tree, Nave Bayes, Logistic Regression, Support Vector Machine, Random Forest, and K-Nearest Neighbour) were compared in this subsection. In these experiments, performance accuracy was utilised as the evaluation metric. Therefore, the accuracy used is simply the ratio of correctly predicted outcomes or observations to the number of actual ones. The performance of the seven machine learning classifiers is shown in Table 4. The performance accuracy of the seven machine learning classifiers is shown in Figure 7.

Table 4: Performance of the Machine Learning Classifiers

Machine Learning Classifier	Performance Accuracy
Artificial Neural Networks	0.83
Decision Tree	0.82
Naïve Bayes	0.68
Logistic Regression	0.81
Support Vector Machine	0.85*
Random Forest	0.76
K-Nearest Neighbour	0.78

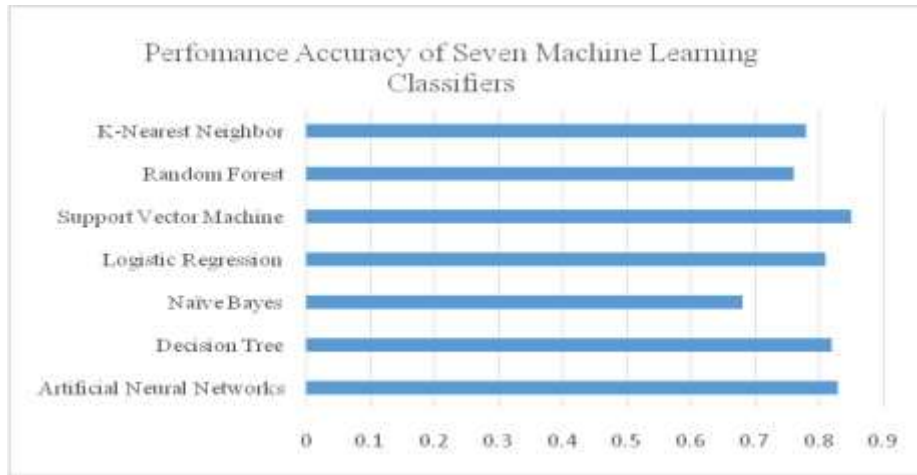


Figure 7: Performance Accuracy of the Seven Machine Learning Classifiers

After combining SVM, cosine similarity matching techniques, and two-top monolingual aligners, the accuracy was measured. The result shows that the automatic long-text examination grader has good performance accuracy but still needs improvement. With these results, it can be concluded that Machine Learning and similarity matching techniques can improve the quality of automatic long-text examination grading tasks when combined with selected features like aligners, textual entailment, WordNet, POS tags and cosine similarity matching techniques. The result shows that SVM performed best in terms of performance accuracy followed by Artificial Neural Network, Decision Tree, Logistic Regression, K-NN and Random Forest, while the Naïve Bayes classifier performed worst.

5 Conclusion

This study has presented a design and implementation of an automatic long-text examination grading model for open and distance learning using machine learning techniques and text similarity matching techniques. The outcome of this study was to improve the existing ODL examination approach for long-text examination. The proposed model consists of three phases: (i) The cosine similarity matching phase, (ii) textual entailment and (iii) two top monolingual aligners. This approach, compare the student answers to a human-graded answer and performs an evaluation based on word count similarity matching and paraphrase detection. The system uses NLTK and WordNet for matching students' answers and human-graded reference answers and measures the strength of their relationship by matching both word count and sentences. Testing and evaluation were performed on a dataset that contains a set of human-graded questions along with the student's answers. The accuracy was measured and the result shows that the performance accuracy of the implemented model is 0.833% which is a good prediction accuracy but still needs improvement. With the implemented system, a solution to improve the examination method of ODL institutions was created. This means that we have eliminated to the barest minimum the problem of evaluating long-text and essay-type examinations in ODL platforms. In the future and as part of further studies, this research can be extended to include some features of voice technologies in ODL (Ayo and Azeta, 2009; Azeta et al., 2009).

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Tech4Good: Artificial Intelligence Powered Chatbots with Child Online Protection in Mind

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Abstract.

This review paper explores literature focused on technology for good also known as “tech4good”, that outlines topics of chatbots and Artificial Intelligence (AI) for Child Online Protection (COP). Texts dated from 2017 – 2022 have been surveyed that covers subject of “chatbots”, “artificial intelligence solutions”, “ethical guidelines” and “child online protection”. This paper defines the themes discussed in literature that places an emphasis on technology for good such as the importance of ethical guidelines when designing AI based solutions. Technology for good’s vision, is applying these technologies for a beneficial goal within the technological ecosystem, to make a difference to society and ensure safety of all its users online. With further advancement in technology, a wide range of users such as children are also tapping into technological space, either for educational purposes, gaming and other online entertainment. However, do technologists, entrepreneurs, key-industry players, and other stakeholders keep children’s safety and wellbeing in mind in the online world? As many companies invests in AI powered solutions, how many of these solutions are there to empower, educate, raise awareness and are community focused? In addition, this paper will showcase Chatbots, and AI based solutions that contributes to the safety of children navigating online.

Keywords: Chatbots, artificial intelligence solutions, child online protection, online safety, guidelines

1. Introduction

The era of the 4th industrial revolution has increasingly pushed the online world to evolve rapidly. Access to global education via online classes, utilising video conferencing tools and advancements in healthcare (such as telehealth) has made sharing of information easy and readily accessible in the online world. With a combination of technological advancements and processes, the power of AI, blockchain, high performing computers and other exponential technologies, has forced many industries to do business differently in an emerging technological world.

The main objective of this paper is to explore various AI powered chatbots for online safety, available in existing literature, with a theme focusing on online safety education in chatbot conversations for Child Online Protection. The focus of this paper narrates that although development in technology has many pros, it has also made protecting children online a daunting and difficult task for different stakeholders. The paper also poses a question on what AI solutions are being used for online safety education in chatbot conversations? What ethical guidelines are stipulated for AI solutions in Child Online Protection? It also identifies commonalities and possible gaps in existing published work. This paper explored AI Solutions chatbots; Sweetie 2.0 chatbot, AiBA (Author input Behavioural Analysis), PrevBOT and Seri (Stop cybERgroomIng), which are AI solutions with Child Online Protection in mind.

1.1 Tech4good and its Ecosystem

Technology for the greater good are people focused, has no division and focuses on having a positive impact in society (Open Tech4Good, n.d.). This is some of the goals of Tech4good (Open Tech4Good, n.d.). Many businesses are now turning to academia and start-ups when developing technologies, as synergistic innovation ecosystem is an essential element before developing technology in a larger scale for industry (Podder et al., 2018). The player in this ecosystem consists of Government, Businesses, Academia and Civil Society. It is of the essence to turn to academia and research institution to vet different frameworks, prototype, and other design for an innovative solution (Podder et al., 2018).

However, technology advancements do not always have a positive connotation. Such as people's privacy are at risk and the rise of mental health problems due to social media consumption. Tech4good's aim is to solve these so called "wicked problems" that are deemed difficult to solve in a short span of time (Krieshok, 2020). The framework of Tech4good consists of points that builds a stable foundation of digital ethics, engineering solutions, embedding social good within the Tech4good framework, enabling, and educating to have a huge impact in society and furthering technological advancement (Podder et al., 2018).

Embedding social good within the Tech4good framework poses questions such as, are designers focusing on points such as accessibility, audited algorithms that presents unethical practices and other biases (Podder et al., 2018). Bourban and Rochel (2021) expressed the importance of Innovation Ethics (IE) and Responsible Innovation (RI). It assesses the criteria within the process of technologically innovative designs placed on researchers and policy makers. With an emphasis on the need for ethical guidelines, Bourban and Rochel (2021), further stresses on the matter of responsible research and design. Therefore, technological advancements will be done within the scope of Tech4good framework. The next section discusses more on technology for greater good in Child Online Protection.

1.2 Child Online Protection

An interconnected world where virtual meets reality is how many children live, before, during and the aftermath of the COVID-19 pandemic. Erokhina and Letuta (2020) stated that numerous countries are updating their policies on Child Online Protection as it is an emerging area of research in academia and in industry. Cyber protection for children also known as minors, is a difficult and yet important issue to solve. Furthermore, the issue relating to Child Online Protection needs to be solved within a cross-disciplinary field and all areas of research. Child Online Protection serves to safeguard children going online, prevent them from cyberthreats, protection of privacy and personal data, supervision, raising awareness, as well as education about online safety (Erokhina & Letuta, 2020).

To date AI chatbots have been used in education for Content and Language Integrated Learning (CLIL) using AsasaraBot (Mageira et al., 2022). Krueger, 2022 presents a report on how eighth graders developed an AI driven chatbot to teach on local produce. Chatbots are no doubt proven

to provide personalised lasting learning experiences through interactive engagement with the end users in a safe space. JUJI offers a platform for personalised learning. Thus, chatbots can be adopted for child online protection. It has been established also that AI can bring in biases if not designed ethically, thus the next section looks at digital ethics guidelines.

1.3 Digital Ethics guideline

The need to develop digital ethics guidelines in AI solutions seems to grow in recent years due to rapid innovative development and design in technology (Saito, 2021). As AI changes the world of video games, toys, chatbots and more, the world is also faced with privacy issue, information safety, as well as cyber security. AI algorithms recommends to children what to watch next, who to be friends with and even the kind of music they can listen to next. Another aspect of AI is used for development of programs, digital connectivity at school and predicting diseases in developing countries (UNICEF, 2021). An issue invoked by experts concerned with children safety is AI algorithm biasness and if ethics guidelines has been adhered to (Saito, 2021). In addition to being ethically grounded, AI innovative solutions should be in-line and support Sustainable Development Goals (SDG) (World Economic Forum, 2022).

Various stakeholder such as government, organisations and academia are key players and should aim to work within the AI guidelines. This ensures that innovative AI solutions are designed and developed with all user's well-being, safety and protection in mind that is of outmost benefit for all its users. The Institute of Electrical and Electronics Engineers (IEEE, 2017) advocates "Ethically Aligned Design". "Principles on AI" was formulated by the Organization for Economic Cooperation and Development (OECD, 2019). UNICEF (2020) designed a guideline called "Policy Guidance on AI for Children," that stipulates the directions to go forth, with child online protection in mind. Furthermore, "Ethical Guideline" was established by the Japanese Society for Artificial Intelligence, focusing on human rights in AI community (JSAI, 2017).

AI policies and guidelines need to be in accordance with children's developmental stages because their perception of real vs virtual is still blurred (Saito, 2021). Furthermore, AI for children should be beneficial for children, not causing further harm, as they are not able to make the right decisions for themselves yet (Saito, 2021).

The employment of ethical thinking keeps all internal and external stakeholder in mind. Therefore, when designing AI centred technology solutions, it is of utmost importance that children's wellbeing is top priority as well as design elements that is fair, inclusive, responsible, safe, and transparent (World Economic Forum, 2022). A checklist that describes goals, potential harm, and ways to reduce risks is there to achieve harmony and ensure product developments are built ethically (World Economic Forum, 2022).

The IEEE's ethical framework foundations are based on three (3) principles which are Universal Human Values (1) that is Autonomous and Intelligent Systems (A/IS) is designed for the good of society and respects all rights of human beings, Political Self-Determination and Data Agency (2)

to improve efficiency within the government, data is always protected and Technical Dependability (3) that is focused on a trustworthy technology (IEEE, 2019).

UNESCO (2021), recommends a universal framework that includes international law that embeds ethics for developing AI systems. Its values includes, do no harm, eliminate biasness and enhancement of life and not create division (UNESCO, 2021).

2. Methodology

This paper is based on secondary sources of published reports, thus, data collection was focused on what already exist (The Wallace Foundation, 2009). The protocol implemented involves first identifying the sources of information. In this case the criteria were up to date journals, reports and further literature dated between 2017-2022, on chatbots pertaining to child online protection that used AI solutions. Search keywords were identified as chatbots, AI solutions, Child Online Protection and ethical guidelines. To ensure accuracy, parenthesis quotes and filters according to years were applied. Papers were collected based on secondary data collection in multiple databases, gathering these existing sources using search strings and keywords. Duplicates were removed by using referencing tools, in this case Mendely has a built-in duplication system. Then to normalise the data, by comparing, this is done through a synthesis matrix, lastly to analyse the data and find a gap from data gathered (The Wallace Foundation, 2009).

The approach of reviewing literature by matrix method is a way to eliminate subjectivity of literature, or naïve assumption upon a subject due to lack of knowledge (Klopper et al., 2007). A matrix analysis is described as structure to form competency and functionality on a specific topic, formed in a grid format to draw conclusions (Klopper et al., 2007). Reorganisation of information on a matrix may include publication source and the date, consolidated data, themes, outcomes of variables and possible relationships that draws attention to a particular problem. Ramdhani et al., (2014) states that with the reorganisation of data, it is essential to include a summary and synthesis of sources, this is to say how it relates to each other. Rashid (n.d.) recommended six to twelve sources, as a far too long literature may prove to not have an in-depth information and may become repetitive.

The strategy used is the synthesis matrix as it re-evaluates various existing literature. Murniarti et al. (2018) states that a suitable approach is still open to debate when assessing literature review. Furthermore, it is proposed that procedure in writing literature review paper can follow input while writing (collecting of information), process (synthesises through a matrix) and produce an output (a review) (Murniarti et al., 2018).

The desired results illustrated in the next section shows a comparison of AI Solutions chatbots; Sweetie 2.0 chatbot, AiBA (Author input Behavioural Analysis), PrevBOT and Seri (Stop cybERgroomIng), which are AI solutions with Child Online Protection in mind. It also lists the themes that this paper looks at which are: Sources Industry, Main Goal of the Technology, Where it is used, AI Model, Goal of AI Solution, Ethical Guidelines, Targeted Users and Gaps / Challenges

to be solved. The author scrutinised publications to sought out related data, reorganise the data and how it relates to one another.

3. Industry Driven AI Solutions

Protecting children online cannot lie solely in the hands of parents as too much information and technological advancements grows at a rapid pace. Technology advancements can be used as one of the tools to complement parents in responsibly guiding children behaviour online. AI can be an amazing tool as it imitates behaviours and patterns intellectually (Erokhina & Letuta, 2020). The different but not limited AI technology landscape can vary from Cognitive Computing, Computer Vision, Machine Learning, Neural Network, Deep Learning and not limited to Natural Language Processing.

This section highlights chatbots that are focused on Child Online Protection and highlights goals and challenges of each chatbot. Child Online Protection AI Solution chatbots analysed are; Sweetie 2.0 chatbot, AiBA (Author input Behavioural Analysis), PrevBOT and Seri (Stop cybERgroomIng). These were specifically selected as they address current online issues in chatrooms and social media, has an implemented and tested AI model.

The summary outlined in Table1 is presented in themes in a synthesised matrix. It compares how each chatbot contributes its unique AI solution-based aspect as well as the model used. It also highlights its goals, gaps and challenges. As previously discussed in the methodology section, a matrix rearranges data from source and compares the data. In the case on the comparison of the AI Solution chatbots, themes were selected to demonstrate that although AI Chatbots were utilised in different industries, it implemented AI models, some ethical guidelines are present in some chatbots framework and missing in other. It reiterates that digital ethical guideline is an important component in an artificial intelligent powered chatbot that deals with child online protection.

Table 1 Comparative verification of AI powered Chatbots

Themes	Sweetie 2.0 chatbot	AiBA (Author input Behavioural Analysis)	PrevBOT ('crime preventive robot')	Seri (Stop cybERgrooming)
Sources	Schermer, B., Georgieva, I., van der Hof, S., & Koops, B.-J. (2019). Legal Aspects of Sweetie 2.0. 1–94. https://doi.org/10.1007/978-94-6265-288-0_1 Stănilă, L. (2020). Memories of the Future - Sweetie and the Impact of the New Technologies on the Criminal Justice System. EU 2020 – Lessons from the Past and Solutions for the Future, 4, 557–575. https://doi.org/10.25234/eclic/11916 Buwalda, N. (2017). Open source systems for dialogue systems. In Journal of Computational and Applied Mathematics. https://doi.org/10.1016/s0377-0427(91)90073-s	AIBA Ai. (2022). Safe digital lives. https://aiba.ai	Sunde, N., & Sunde, I. M. (2021). Conceptualizing an ai-based police robot for preventing online child sexual exploitation and abuse: Part i - The theoretical and technical foundations for prevBOT. Nordic Journal of Studies in Policing, 8(2). https://doi.org/10.18261/ISSN.2703-7045-2021-02-01	Wang, P., Lu, C., & Wang, P. (2021). Generative Chatbot Framework for Cybergrooming Prevention Generative Chatbot Framework for Cybergrooming Prevention.

Industry	Non-profit Organisation and Academia	Industry	Law Enforcement	Academia
Main Goal of the Technology	Fight against webcam child sex tourism and present child online sexual abuse imagery to be distributed online	Detecting if the person the child is talking to is an adult grooming the child for sexual abuse	A tool that is automated to assist law enforcements in preventing child online sexual abuse to happen online	Its aim is to accommodate safe environment and mimic authentic chat conversations between perpetrators and its victims raise awareness about cybergrooming
Where it is used	Online	Chatrooms	Online Chatrooms	Social Media Platform
AI Model	Three-dimensional imagery, chatbot facilities, software framework, Superscript	Linguistic, behavioural patterns	Machine Learning, forensics linguistics	Natural Language generation model, Metrics, Models, Deep Reinforcement Learning (DRL)
Goal of AI Solution	Use AI solutions to automate conversations on chatbots as previous versions made use of human resources	Real time detection of grooming online	Predicts conversations on whether it will flow into child sexual exploitation and to prevent it, if detected then police will intervene	Design a generative chatbot framework, learn authentic and strategic conversation used about online grooming
Ethical Guidelines	The chatbot focused on comparative legal analysis in different countries and its legal system	None presented	This chatbot includes knowledge about online automatic policing, forensics linguistics, criminology	Mentioned, but more focused on the text conversations and degree of accuracy

				not so much on the human aspect
Targeted Users	Perpetrators of child sex tourism, assist law enforcements to catch these perpetrators	All online users	Perpetrators in chatrooms and assist law enforcements	Perpetrators in social media chatrooms
Gaps / Challenges to be solved	International law, posed question: Will interacting with Sweetie 2.0 be deemed as a criminal act? More legality issues to be ironed out as perpetrators hides behind webcams	Not enough information	No identity of the perpetrators	Not enough data, non-human-like conversations, does not detect slangs

The findings show that insufficient datasets, use of emojis in text proves to be a challenge as it replaces human-like languages (Wang et al., 2021). Although, the chatbots reviewed in Table 1 contribute to making the online world safer for children. Its main goal is against perpetrators who want to exploit and extort children online. No AI driven solutions were found on awareness or educational purposes that highlight information giving towards children or parents. Thus, it is evident that there are AI solutions on mitigating dangerous experiences for children.

Sunde and Sunde (2021) described a tool made for law enforcements that has the law and digital forensics in mind, it predicts conversations through machine learning to assist in preventing online grooming. Schermer et al., (2019), posed the question of a perpetrator being executed when the crime was towards a bot and not a child. Stănilă (2020), AI chatbots is controversial and could lead to more legality issues.

Perpetrators hide behind fake identities such as a fake profile, it all starts off with curiosity for child online sexual abuse content that later escalates to abuse of children (Buwalda, 2017). Prediction of conversations going wrong, regulating conversations within chatrooms or on social media that could lead to online danger is also a reason to turn to AI solutions (Schermer et al., 2019). It is difficult to cover wide areas online using human resource alone and the need for real-time responses is also a reason to turn to AI solutions as it is so fast paced (Schermer et al., 2019).

4. Conclusion

To reiterate on whether technologists, entrepreneurs, key-industry players, and other stakeholders keep children's safety and wellbeing in mind in the online world? There is technology designed and developed that aids in online safety for children. More and more of these emerging technologies are incorporating AI based solutions. The commonalities found in the research is that the chatbots are designed to detect online conversations that could lead to sexual abuse and exploitation by perpetrators towards children.

The gaps found in this review paper are that although there are AI solutions focused on Tech4good, there is still much to do after the design and implementation of such technology. If various stakeholders have children's wellbeing in mind when designing any applications or any tools, the problems deemed to be "wicked problems" would be minimised. These various chatbots still has many challenges that needs to be solved. These challenges vary from language detections issues as chats are using emojis within the chatrooms and social media platforms, litigation issues in several countries as different countries have different laws in which it operates as well as lack of datasets. The AI powered chatbots' focus is on online grooming and preventing harm to children. The issue of insufficient or not coming to an agreement still hangs in the air and remains unsolved.

Another gap found is that Chatbots focused on raising awareness, so children are not victimised online. Technology focused on awareness campaign for parents are not yet available. If the aim is to prevent and mitigate children online abuse, education and awareness for parents, guardians and caregivers is still a topic to be addressed in Tech4good, using AI powered solutions and chatbot technology.

This review established that ethical guidelines are stipulated in industry, with an aim to eliminate biasness, protect data and privacy of data. Ethical thinking in Tech4good should be the main aim of all designers involved with AI solutions. Future work will focus on designing an AI powered chatbot that aims to educate parents guardians and caregivers. As part of a contribution to Tech4good done in accordance with the ethical guideline stipulated.

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Structural Vetting of Research Proposals: Problematisation and Solving With Artificial Intelligence

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Abstract.

The structure of content in academic writing is formal and research proposals with poor structure is a concern during supervision. In supervision pedagogy, proofreading of research proposals is an important routine task involving various tools and time commitment. In this paper, we have motivated the need for an Artificial Intelligent (AI) tool that can assist a human expert in the process of vetting the structure of research proposals. The research method involves interviewing experts with vast experiences in postgraduate supervision about the concept of structural vetting, and the time it takes when there are many students. We identified some of the issues facing postgraduate supervisors for which an implementation of an AI tool would be beneficial. The survey was done using an interactive AI chatbot, available at <https://bit.ly/3bFK3gV>, which allowed for capturing feedback survey from academics in an engaging and interactive manner. All respondents identified poor structure as an issue in submitted research proposals and only 34% of the respondents' supervisors would consider research proposals with poor structure for acceptance into further postgraduate studies.

Keywords: Postgraduate Supervision, Document Vetting, AI Tool, Structural Editor, Supervision Pedagogy

1. Introduction

Artificial Intelligence (AI) is arguably the driving force for the future of education, offering effective support for learning and teaching (Popenici and Kerr, 2017). Presently, higher education is laced with responsibilities and functions that needs to be continuously improved and impacted by technology. Supervisors have multifaceted roles in the discharge of their duties which may be impacted by technology to deliver more output (Jan Botha, 2019). Some of the issues faced in postgraduate supervision may be sacrosanct such as supervision versus supervisee ratio imbalance. However, AI tool can be deployed as a complementary approach for improving supervision pedagogy thereby alleviating work load challenges (Rakhmatov and Arzikulov, 2021). The postgraduate research supervision pedagogy is fundamental to the quality of research outputs in higher education hence technology support cannot be overemphasized.

Since the aftermath of COVID, academics have been faced with new realities of radical transformation in teaching into digital or hybrid methods which has caused a new kind of more stressful workload (Dwivedi et al., 2020). COVID 19 inadvertently brought about unprecedented changes in educational practices and some embrace of innovative tools and many more are expected to emerge in Education 4.0 era (Kang, 2021). This level of digital transformation in education may not be sustained by infrastructure and platforms only, but by some overhaul that can sustain the entire workload of professors and supervisors. Students' enrolment into higher education is growing steadily and work balance for supervision may be

at risk. There is need to digitally transform education and improve quality research outputs. This undoubtedly requires emerging software to continuously improve the efficiency of postgraduate supervisors. This is corroborated in a study by Hey-Cunningham et al. (2021), in which supervisors expressed the need for more technology aid. Interestingly, there have been lots of encouragement to students for active participation and quality research output in postgraduate schools but little attention to supervisors or supervision needs. Same measure of support is required for supervision of postgraduates for better productivity. Studies show arguably that senior academics may be reluctant to digital transformation in carrying out their duties but many academics experienced a major shift during COVID era (Netshitangani and Machaisa, 2021). Academia and its academics embrace various tools in order to meet the needs of their students. Academics yet face many challenges in meeting the work schedule timelines of proofreading many students' proposals. In this study, we interacted with post graduate supervisors from various regions and institutions and sought to know some gaps faced, which present tools have not addressed, for which AI solution may be applied in assisting postgraduate supervision.

Right innovative solutions can reduce significantly the stress and time for associated work load on postgraduate supervisors. The fourth industrial revolution (4IR) premised on the ongoing digital age is transforming the way we live, relate, work, study and many things. The term "education 4.0" is largely associated with technologies that is influencing the education sector. Technology eventually improves efficiency and productivity and 4IR would transform global education (Suganya, 2017; Miranda et al., 2021). More adaptive tools need to emerge to make the workload lighter for Academics. Emergence of new technologies embraces pedagogy procedures that provide the right innovative solutions in line with education 4.0. (Miranda et al., 2021). The advancement of education 4.0 for innovative solutions would consider not only students but also all activities around academics and collaborators within the learning environment (Miranda et al., 2021). Addition of new senior academics for postgraduate supervision may not be feasible in quick successions of the academic year even as enrolments go on the rise, however more efficient work systems across board and human assistance AI tools can arguably reduce time spent on supervision tasks.

A variety of digital platforms are available in higher education institutions (HEI) – digital educational apps like Blackboard and Google Classroom for online teaching, virtual meeting rooms (e.g. Zoom, Skype, Microsoft teams) for supervisory conversations, document sharing tools (e.g. Google drive) and instant messaging tools are available to academics. Grajek (2021) expressed that HEIs will keep evolving and embrace more technology and AI-enabled tools that develop supervisors into digital faculties for innovative students. It is now common to find postgraduate supervisors make use of platform tools such as Turnitin for spotting plagiarism, Grammarly for automatic spell-check errors, Microsoft word review tool for online document revision or feedback to their students and other collaborative tools, instead of the old fashioned way.

AI can be applied to solve numerous tasks and improve efficiency in expert tasks that may have become monotonous or repetitive to humans. The creation of AI tools for domain expert task requires a data science research methodology approach of which problematisation in the research area is the first step. The objectives of this paper at this stage of our research are to 1) explore the tasks and perceived efficiency of supervisors hence determine the need and area for an AI tool for supervisors, 2) establish the knowledge area for the development of IT artefact focused to assist in vetting of proposal, and 3) establish the unique product offering of a proposed IT artefact.

2. Background

There is a large gap between student enrolment numbers and available supervisors partially due to recognition of the sector as being vital to development and government's plans to increase There is a large gap between student enrolment numbers and available supervisors partially due to government's continued plans to increase university enrolment in recognition of the sector as being vital to national development (Tjonneland, 2017; Swanzy, 2018; DHET, 2022). The supervisor-student ratio will continue to stretch as plans to increase students' enrolment gains success. According to a survey by Cekiso et al. (2019), some supervisors were supervising as much as eighteen (18) postgraduate students. Postgraduate study is a bumpy ride for students with records of high attrition, complaints of feedback and supervisory practices e.t.c. So also, it is a bumpy period for supervisors who have to cope with many students' submission amidst other work activities in a fast-paced world. The application of AI in education ranges from personalised computer-aided instructional platforms, educational game-based environments, research support chatbots, AI-driven software and teaching platforms that support teaching and learning needs (Okonkwo and Ade-Ibijola, 2020; Hamal et al., 2022), immersive learning using virtual reality platform (Ip and Li, 2015), games (Villagrasa et al., 2014) and many others (Holmes et al., 2019; Xuesong Zhai, 2021). Supervision as a core integral of higher education has its fair share of AI tools, many of which are generic. In this section, we reviewed some existing AI tools presently used by supervisors in performing a key task of revising students' manuscripts.

a. AI Tools for Education 4.0

There are lots of opportunities and applications of AI in the digital era for improving student life, teaching and supervision methods in higher education. These practices and methods are summarized in literature studies of Education 4.0. There are AI tools at the institutional and administrative level - for admission, counselling, library services, as well as at the academic support level - for teaching and learning e.g., assessment, feedback, tutoring (Zawacki-Richter et al., 2019a; Siau and Ma, 2018). Some literature summarizes the existing AI applications in higher education into the following categories (Romanov et al., 2020; Celik et al., 2022; Pedr'o, 2020; Luckin and Holmes, 2016):

1. Personalized AI tools – platforms that provide personalised learning approach to student and allows faculties to discover students' unique ability or personalized learning needs. Examples include systems for automated distribution and scheduling of training load (Zawacki-Richter et al., 2019b), chatbots for personalised help and guidance (Chinedu and Ade-Ibijola, 2021 a,b), serious games (Ade-Ibijola et al., 2022; Dele-Ajayi et al., 2016), intelligent tutoring systems (Zawacki-Richter et al., 2019b), enrolment student portal and other forms of personalised content for students' experience.
2. Virtual reality (VR) tools – Virtual and augmented reality for simulations of various kinds for immersive classroom experience. Pratical experience of taught lessons can be done through virtual environments, providing experience of how things work. Examples include VR systems created in medical field about the function and anatomy of the human body (Fayaz Ahmad et al., 2021), virtual and augmented reality for engineering lab designs simulations (Pedr'o, 2020)
3. Collaborative tools – AI tools exists for participatory learning and supervision feedback (Maor and Herrington, 2011). Collaborative tools can be explored from these four dimensions – class management, teaching observation, learning assistance and administrative sharing (Wang W, 2021). Now classrooms are on students' phones, team conversations are on WhatsApp, team assignments are on various online collaborative tools (Editorial team, 2020). Collaborative

tools for meetings and feedback review have also been useful in Supervision and teaching practices. Collaborative tools facilitate ease of communication and feedback amongst students and faculties. AI tools for virtual meetings and document review/proofreading of academic papers have particularly been useful and popular amongst academics. The application of AI in proofreading of academic papers has been mainly in the area of using collaborative tools for plagiarism, grammar and spell check checks.

b. Some AI Tools for Proofreading

Content and structure editing for preparing a quality manuscript is an important task in supervision. Proofreading of content checks on the grammar, spellings, writing; while structural editing focuses on the arrangement and connectedness of the content. We observed the features of some proofreading tools of which syntax and context check feature is missing – Table 1 shows the comparison of some existing proofreading tools commonly used by postgraduate supervisors. The syntax and structure review of a document is a time-consuming task in proofreading of academic writings. The content is checked for formal writing style, arrangements of the various contents and completeness of the content. Faculty administration sometimes have pre-defined guide documents that specifies the expected structure of the academic writing which is as a useful guide for supervisors in manual vetting of proposals.

Authors have proposed tools based on various approaches, including rule-based methods (Alamoudi et al., 2021; Ade-Ibijola, 2016), improved deep learning models (Harer et al., 2019; Liu and Lapata, 2018) and or combinations (Harer et al., 2019) to advance the solution to the gap of syntax or context automated review of text writings. Models and tools have been developed for documents such as – software requirements specification documents (Sabriye and Zainon, 2018; Verma et al., 2014), business documents (Rasmus, 2019; Ade-Ibijola, 2016), clinical notes (Abbott and Ade-Ibijola, 2019) and essay writings (Crossley et al., 2019). A common factor is that these documents follow a natural tree structured representation which can be generated by fitting a sequence to a grammar (Harer et al., 2019). In the case of academic writings of research proposals, we consider this knowledge representation as an abstraction of the knowledge in a research writing guide template. We propose a tool that abstracts this knowledge into a tool for academic documents (research proposals) – such documents that follow a strictly predefined template.

Table 1: Top Free Online Proofreading Tool

S/N	Proofreading Tool	Main Features	Usability and Reliability
1.	ProWritingAid	Grammar checks, spelling errors correction, real-time editing, etc.	Powerful, easy to use and powerful writing reports with the free version.
2.	Paperrater	Grammar check, plagiarism detection, reporting statistics, spell check, text editor.	Easy-to-use and basics features on free version. Premium version offers more features.
3.	Typely	Punctuation check, spell check, style check, editor check, easy-to-use reporting and statistics	Crucial features such as plagiarism check left out of free version.
4.	Grammarly	Grammar check, plagiarism detection, reporting statistics, text editor, spell check, style check and punctuation check.	Excellent on all levels.
5.	Proofreading Tool	Grammar check, punctuation check, spell check, text editor	A great tool to use. Free 7-day trial of premium features.
6.	Wordy	Grammar check, punctuation check, plagiarism check, text editor and human editing online proofreading service.	Easy-to-use and has a waiting period.

source <https://www.softwaretestinghelp.com/free-online-proofreading-tools/>

c. The Gap – Need for An AI Tool

These tools available to supervisors for proposal review and vetting clearly defines narrow task for which these have become very valuable, refer to Table 1. Their use will improve efficiency by reducing the turnaround time for reviews compared to a manual review process. There are many tasks performed by the supervisors in reviewing a proposal, for which feedback can be provided to the student. A missing salient feature in all the tools we have observed and of research interest is in checking the syntactic structure of the writing components – includes structure of document sections and statements. Grammarly as one of the most developed automated review writing tools has not fulfilled users' satisfaction in checking context of writing Nova (2018).

Digital transformation is evolving and its processes will bring about new software solutions for HEIs and or improve existing software. There is need to seek to understand salient specific issues faced by postgraduate supervisors before proposing a tool. The study is to further the research work done in postgraduate research supervision towards ultimately improving the research

3. Methodology

The study relied on a purposive sample of senior academics who perform the duties of postgraduate supervision. Participants responded to an online survey chat-bot designed for this study as an intelligent tool for a semi-structured survey, named as "Interview Assistant". Some of the respondents who obliged to provide further insights for the research study were interviewed which gave us rich insights into issues faced in postgraduate supervision. The details of our approach, participants, guides and findings are further explained.

d. Approach

The study is based on design science research approach, an increasingly popular process for development of design projects. Investigations are carried out at the initial stage to determine where lies the problems and opportunities from potential users - known as problematisation stage. The interest at this stage is the discovery of underlying challenges faced by supervisors in proofreading proposals, that are yet unresolved and could be implemented as an AI tool. The mixed methods of quantitative and qualitative analysis were used to uncover facts about the issues faced by postgraduate supervisors on structural vetting of research proposals. The use of mixed methods in active research is more effective way (Masadeh, 2012; Eliot and Associates, 2017). A set of structured and open-ended questions were answered in the survey. This quantitative phase allowed the researcher to identify the issues in supervision without interrupting the schedule of senior academia. An interview was conducted afterwards with some respondents to have an in-depth understanding of the issues faced.

e. Participants and Data Collection

Forty-two (42) target sample of senior academia were purposely selected from various university's postgraduate education across five (5) different countries - South Africa, Nigeria, Malaysia, Ghana and India. The request to engage in a conversation and survey was sent via email. Twenty-one (21) consented to participating in the research, and responded to all the questions. These are experienced academia who are actively involved in post graduate supervision. They had two or more academic portfolios which ranges from teaching, supervision of masters/doctoral students, consultation, school administration, research and publishing. They were all very busy individuals which is quite typical of many postgraduate supervisors. A "smart" survey approach, different from the usual method, was used to engage respondents in closed and open-ended questions from general to more specific enquiry. This was designed as a chatbot tool which is interactive and allowed respondents to interact at their convenient time. The survey was presented as a conversational AI tool - <https://bit.ly/3bFK3gV>, i.e., chatbot, containing both multi-choice and free-text questions to extract more details. It allowed for dynamic branching of questions based on the answers given by the respondents, making the survey process interactive. The chatbot contained twenty-eight questions starting off with consent and general questions to more specific details which allowed for feedback in large free text style.

4. Results and Discussions

The surveys and the interviews probed for an understanding of the extent of work effort on the supervision of research proposals. What are the common issues seen in submitted proposals while reviewing or proofreading them? Students still commit these mistakes, despite having the "proposal guide

document”, a document on instructions of academic writing and styling, usually provided by the faculty or department of many Universities to incoming students.

f. Results

The study identified key issues present in submitted proposals. The findings show many supervisors’ views of acceptance or rejection of proposals with poor writing style and arrangement. The summary of the findings is expressed Figure 1 and Figure 2.

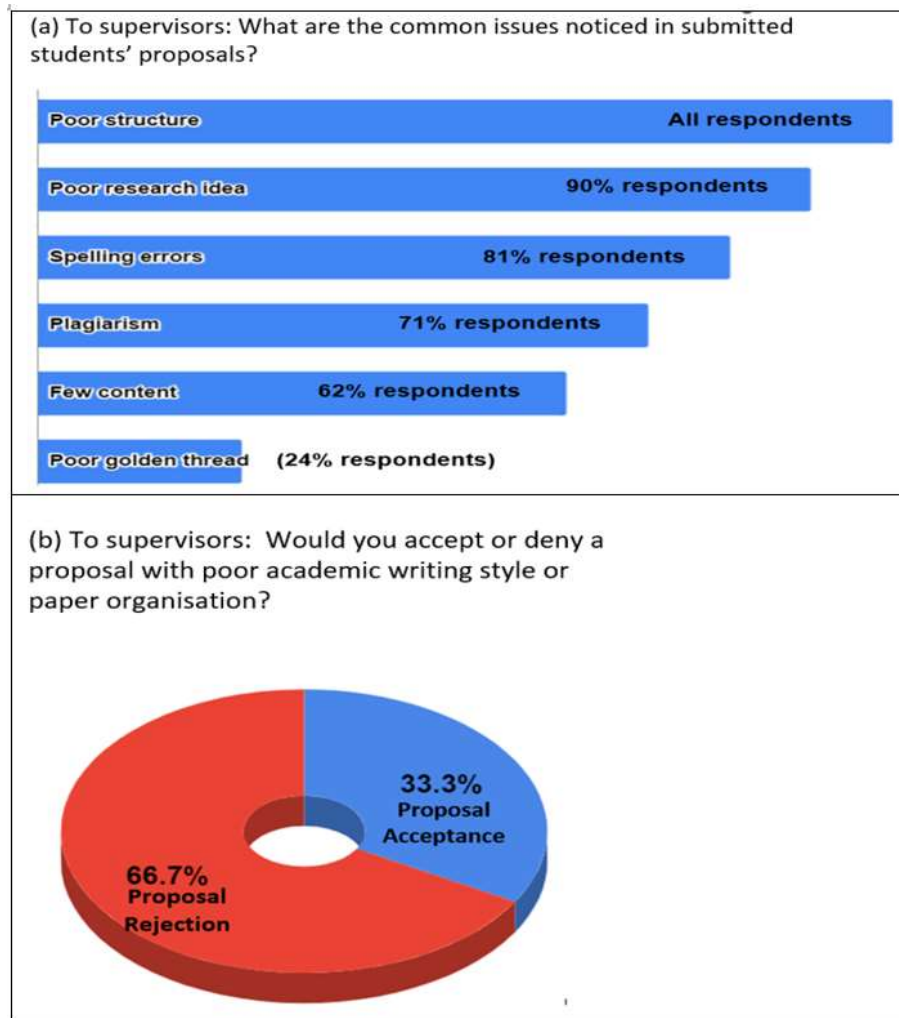


Figure 1: Supervisors are 67% likely to reject proposals with poor structure. All respondents mentioned that poor structure of academic writing style is a common issue in submitted proposals

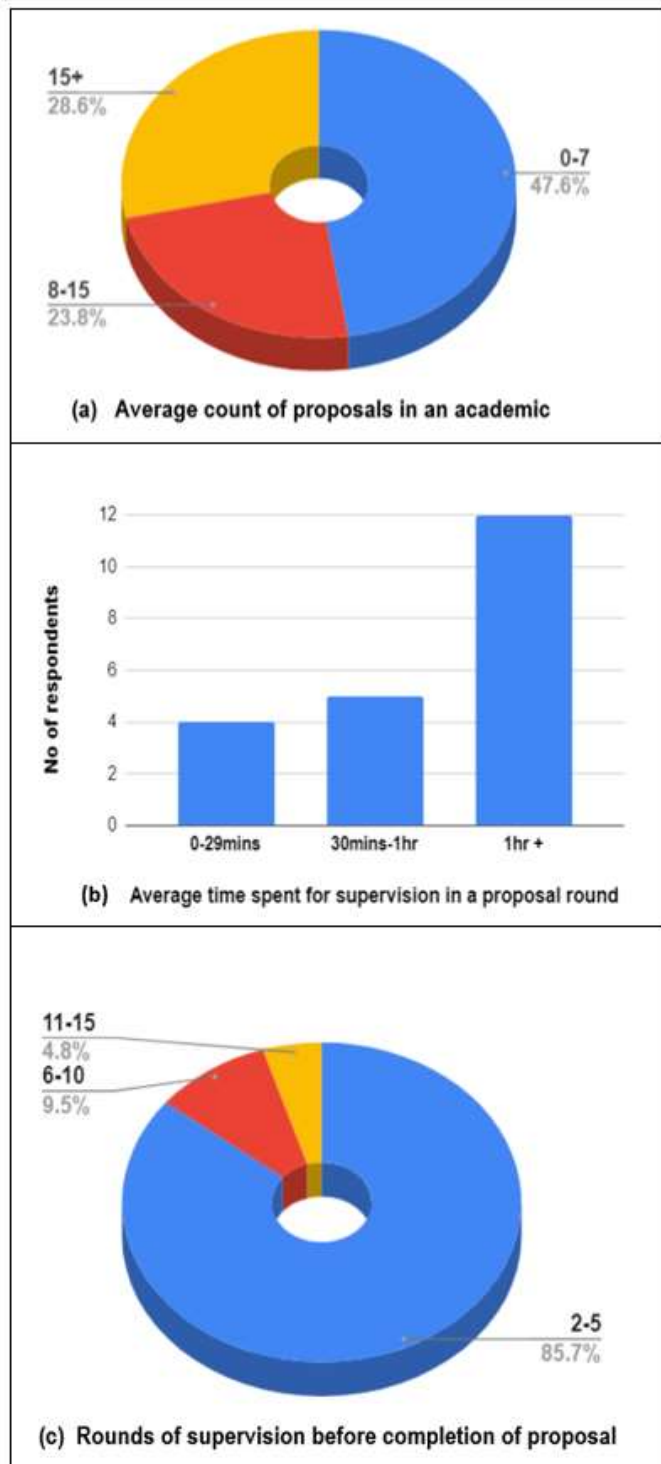


Figure 2: Supervisors spend a lot of time in performing the duties of proposal supervision given that: (a) shows that 23.8% of respondents have 8-15 proposals and 28.6% respondents have 15 proposals in an academic year, (b) shows that 57% of respondents spend averagely over an hour on supervision and (c) shows that some supervisors can have as much as six or more supervision rounds.

More insights on the pain points of the academics in performing the task of structural vetting of research proposals was captured as free text. The respondents also described the features expected of an AI tool for performing this function. The extracts from the survey feedback supporting this claim is given in Table 2.

Table 2: Excerpts from survey: Reasons given by some respondents for need of an AI tool

S/N	Comments by respondents
1.	I have need of the tool so as to minimise eye contact on the screens.
2.	Structure and style are important in academic writing: lack of structure disconnects the research idea.
3.	A high percentage of students' proposals have lack of structure at the initial stage.
4.	Tools like this will alleviate some stress of the work load.
5.	I have need of a tool that analyses sections of a proposal, such as extraction of the research gaps of many proposals submission to analyse the trend in them.
6.	There is yet need for a tool that checks structure and coherence of a proposal document.

g. Findings and Discussions on Solving with AI Tool

The feedback from senior academics shows that there are re-occurring issues of poor structures in submitted proposals which are revised manually until the manuscripts is ready for submission, refer to Figure 2. There are existing tools used to perform supervision tasks but we have found none for the structural vetting of research proposals. The comments from the respondents expresses the need for a tool that can perform this task in addition to the features derived from other automated review tools, refer to Table 2. We therefore propose an AI tool which can vet the structure of many academic proposals and assist supervisors in automatic proofreading of submitted proposals and feedback to many students. The concept describing the need of the AI tool is expressed in Figure 3.

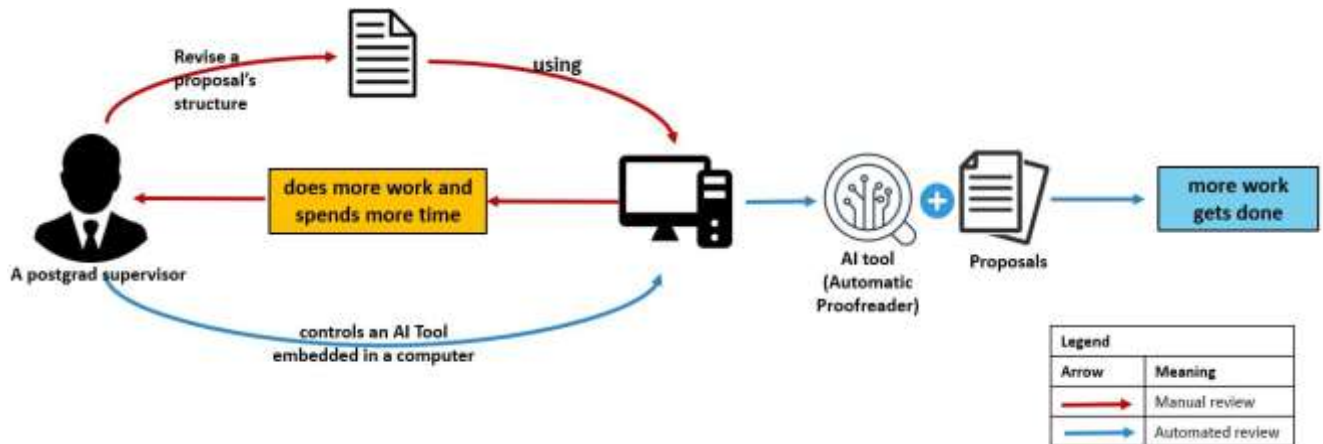


Figure 3: Solving with AI Tool

5. Conclusions and Recommendations

This study gathered insights describing challenges that may be faced by supervision practices in proofreading of higher education academic proposals. In the survey, a number of existing tools commonly used and mentioned by the participating senior academics, had less benefits on proofreading documents for structure – organisation of contents. Tools mentioned notable for resolving common issues such as spelling errors, semantics and plagiarism noticed in students' proposal. However, a main requirement for submitted academic proposal, i.e., academic writing structure, was not part of the features of any of these tools.

The paper is a survey approach which identified specific needs of proofreading of research proposals with underlining structure or content organisation. *What were the problems facing postgraduate supervisors for which a tool is important and proposed?* The study shows that the implementation and use of the AI tool can improve the turn-around time of postgraduate supervision feedback on research proposals and of benefit to work efficiency. According to the survey, the mean average time spent in a round for reviewing a research proposal is greater than an hour. This which can be reduced by the automation of the review of poor structure, a main issue noticed by all participants. The problematisation is the initial stage of the research approach for the design of the AI tool, which we will progress by scoping the features for the proposed tool, design, test and deploy. The insights from the study will form the basis of the features for the AI tool design - a solution to the challenges faced in the structural vetting of academic proposals.

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Unmanned Aerial Systems for Simultaneous Medical Logistics and Computer Vision Derivatives

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Abstract.

With rapid advances in emerging technologies, unmanned Aerial Vehicles (UAVs) have increased mobility over challenging and remote geographical barriers. These advanced systems bring together computing, robotics, aviation and numerous application fields. They have in turn, shown great potential to disrupt the global logistics and transportation supply chains which makes a more relevant context of emerging technologies especially in Africa where technology uptake is usually much slower than the developed world. However, most of the UAV platforms currently used in African medical logistics are imported or not designed and made on the African soil. Their intricate specifications remain unknown to the beneficiaries and this creates a huge capacity gap on the continent, remaining reliant on external technology and skills hence remaining on the back foot to independently drive sustainable changes. The aim of this paper is to highlight the current status of medical and drone logistics by presenting a brief literature of drone uptake in medical logistics within and the African context. The paper also aims to present a proudly African proof of concept UAV system and with a computer vision based drop off mechanism design and manufacture for mapping and mission execution. The system is presented as evidence of home grown solutions that address Sustainable Development Goals on Health and Access. The findings of the review and study are that much can still be done to amass capacity in Africa for adopting emerging technologies such as drones within logistics. It is recommended that at scale, fixed wing and vertical take-off and landing (VTOL) UAVs offer durability in drop off logistics as compared to the tested hexa-copter model.

Keywords: Emerging technology, Health logistics, Computer vision

1. Introduction

Sub-Saharan Africa is perceived to be one of the world's most deprived regions with a history of civil challenges, poor governance systems that often result in lower educational enrolment levels, gender inequalities, weak healthcare delivery, a wide digital divide, as well as undeveloped infrastructure that inadequately meets present day global socio-economic demands. (Haula, K. and Agbozo, E., 2020). The recent pandemic and its global impact have raised an important discussion around the importance of wellness and medical logistics based on the need to reach out and capacitate entire populations for a timely and efficient health response. In particular, Sustainable Development Goal 3ⁱ on Health and well-being further supports this discussion as it highlights that health has a central position in the current global agenda, and that it is closely linked to over a dozen targets in other goals related to reproductive health, equal access to treatments, and non-communicable diseases, among others. This entire context that ties health to maternal,

reproductive matters, logistics as well as access indicators, makes the African context an interesting laboratory for experiments and discussion on the role that emerging technologies can play in remote areas.

In Africa, remote areas often have a high dependence on traditional (land or water-based transportation including animal driven carts, human mobility, boats, motor bikes and trucks) with minimal use of air-based transportation except in emergencies. Indigenous transport systems are greatly supported as pro-green climate regimes, although they face several obstacles in areas where infrastructure is not fully mature. The setbacks may include but are not limited to a lack of access to up to date maps for specific delivery location information, poor transportation support or infrastructure, scarcity of human and facility resources as well as governance or development related needs. Amidst these setbacks, the ongoing global health crisis has also been instrumental in further highlighting social and equity challenges as well as emphasizing a need for rapid technological adaptation and improved supply chain to execute missions on mobilizing essentials to receiving communities within the shortest possible logistical times. The pandemic specifically presented the developing world with a unique set of circumstances that pointed to a need to pay greater emphasis on functional health and efficient logistics that are supported by infrastructure and mapping and geospatial technologies plays in planning systems within global economies through their ability to enable the establishment of base data tools for managing infrastructure and resources (Berry et al, 2008; Scott & Scott, 2018). The successful execution of most logistical missions will depend on the efficiency of transportation systems, legislative aspects and the quality of mission planning. It cannot be emphasized further that quality mission planning in remote and low access areas of developing areas, will link back to effective transport systems and essential tools of planning efforts in communities across the world. (Arab-Mazar et al, 2020).

2. Related literature: Health-UAV logistics and computer vision

For context, unmanned aerial vehicles (UAV's) are defined as non-crewed emerging technologies that are also known as drones, unmanned aerial systems (UAS) or remotely operated aircrafts (RPA) (Zhang and Kovacs, 2012). As already highlighted recent advances have focused more on their application in civilian applications presenting them as low cost mobile platforms with increasing use in logistics, mapping, mining, construction, urban, environmental and agricultural services (Freeman and Freeland, 2015). There is still a great need for researchers to educate governors on the merits of this technology and prescribe optimum use cases to improve the use of this technology to its full potential through literature and experimentation. This paper presents a literature review on UAV adoption in Africa as well as the emergence of medical, computer vision derived mapping and logistical approaches. The technologies discussed in this paper are strongly connected to UAV design and computer vision riding on the drone's potential to leapfrog traditional transportation infrastructure as a reference focus (Scott J., 2019).

Although at different stages of testing and implementation health related drone delivery applications have been conducted by entities such as Amazon, Google, Jonson, and Jonson as well as Zipline amongst a few others had already conducted advanced tests on parcel piloting prior to the pandemic (Kimchi et al, 2020). Examples of specific medically incline drone delivery have been incorporated in Rwanda and Ghana, Malawi, United States, Canada, Caribbean, Netherlands, and Nepal in delivering medical supplies (Ackerman and Stickland (2018), Ayamga M., et al

(2021), Glaucer W (2018)). In Africa major examples include the Zipline project which is now well known and functionally accounting for over 75% of blood delivery in Rwanda¹.

Of recent UAVs have also emerged as rapid, efficient, low-cost and flexible acquisition systems for collecting remotely sensing image data for photography and mapping bringing in the notion of computer vision skills (Colomina & Molina, 2014). In the context of computer vision based mapping which speaks to the simultaneous collection of footage as the drone is in flight, derived image datasets provide opportunity for various processing algorithms resulting in the automated creation of terrain maps and digital surface models (Siebert and Teizer, 2014). To optimize the image views, the datasets can be captured through multiple sensors, scans, orbits, resolutions and from various viewing angles (including vertical, tilted, oblique panoramic), depending of course on the camera/sensor/scanner type and intended use (Antrop and Van Eetvelde, 2000). UAV based sensors tap energy from scenes below that produces image abstractions of the real world in different formats and in a variety of electromagnetic energy bands including the visible spectrum (RGB), laser, infra-red and, microwaves. Images are made up of configurations of pixels which can be described as either expressing the world domain, the scene domain, or the image domain. The characteristics of the individual pixels and their configuration can be interpreted to reconstruct the world domain in two or three dimensions (Haala and Kada, 2010). This positions UAV captured images can therefore assume various forms including grey-scale, color, multispectral, hyperspectral, radar and laser as used in man-made object extraction (Paine and Kiser, 2003) These then create two and three dimensional models of the earth that can encapsulate additional cues such as heights, ground intensity and multiple orientation (Chikomo et al., 2007). UAV based data collection strategically to offer low-cost imaging technologies at high resolution for application in a variety of fields (Remondino et al., 2011, Meng et al., 2009a). Although UAV systems for image capture have matured over recent years in their applications and use, there are still limited examples of their applications in remote and less developed areas. This indicated some exclusion of these areas as preferred sites for data capture due to a variety of reasons including developmental and interest related causes. Literature posits very few cases where remote area footage has been collected for agriculture and planning purposes (e.g., used drones for land registration in remote areas in. A greater focus is evident in literature that UAV based applications are in developed areas where planning and growth is more imminent. The current study addresses this gap by creating opportunity to collect redundant footage using the delivery drone mission as it navigates what would otherwise have been a logistics-based flight.

3. Materials and methods

This section describes the theory review strategy, material specifications and method details of the study that were used in the design and manufacture of the UAV prototype. The initial step in the research was to systematically review related literature in the area of UAV for medical logistics and computer vision aspects that are incorporated into the drop off. This step informed the researchers of best practices and gaps in knowledge. Thereafter a prototype hexacopter UAV was designed and manufactured. Table 1 below starts off with a materials summary of the study materials utilised for. As per drone design components earlier listed in Table 1, a hexacopter was assembled with an appropriate package carrying compartment unit to carry a sanitary pad payload

and beside it was an RGB sensor to simultaneously capture aerial image footage directly below. The UAV as described initiates an automated drop off on the trigger of the servo mechanism. The entire concept was designed and physically implemented into a successful prototype. A use and needs analysis were established to detail out the needs for the pad delivery execution. The following were noted as user needs requirements: -*User needs established: - UAV system must be durable and be able to fly at least 40km from base when implemented at scale, must have automated drop off mechanism to preserve drone integrity at the drop off point, must be location aware and have Global navigation system on board so that it can fly to a given coordinate location, must have a secondary way to verify that this is the desired drop of point, to collect image footage of ground below it while in flight.* Based on these user needs the design was initiated to address each need. The aircraft for delivery was designed using common airframe pieces based on a simple S550 Hexacopter frame. Although the fixed wing drone would be most ideal for the medical delivery needs case it was decided that the prototype was built based on a hexacopter frame to minimise costs. The drone design was done within AUTO-CAD and some minimal three-dimensional printing of a few composites to reinforce the existing parts was incorporated via a 3D printer. The components listed in Table 1 in section 3 were then assembled into a hexacopter UAV and both the box and sensor were attached and fastened to the aircraft. Since the drop off coordinate is known prior and even in the case of test flights, it was accurately identified on ground and established to lie within the Helipad area to avoid complicating the delivery decision process.

Table 1 Table summarising main project materials

Design Component	Specifications
Eco friendly sanitary pad creation	Reusable sanitary pad pattern design, Reusable pad suitable fabric layers, Press studs and ric-rac embellishments, Packaging, Sewing machine and respective laundry system
Sanitary request system design	Online portal pad alert system which receives specific detail of station requesting pads and matches it with existing database coordinates
UAV system design and manufacture	RGB sensor attachment, Hexacopter frame S550, Landing gear, T-motor and propeller set, Speed controllers, Pixhawk with GPS, Radio telemetry, LiPo battery, Servo release mechanism, FrSky Taranis and Receiver, I-Charger with leads and balance board, Cardboard box for payload packaging, Pack of pads for test delivery, Ground control station.
UAV drop off and integrity system	2 Circular artificial Helipads, Human recipient to collect package

In order to illustrate some of the materials pictorially, Figure 1 below illustrates a Pixhawk controller and ground control station respectively.



Figure 1 Ground control station and Pixhawk controller, Source²:Pixhawk Controller

For further clarity, the overall design of the medical UAV delivery system is summarised by a schematic diagram in Figure 2. below.

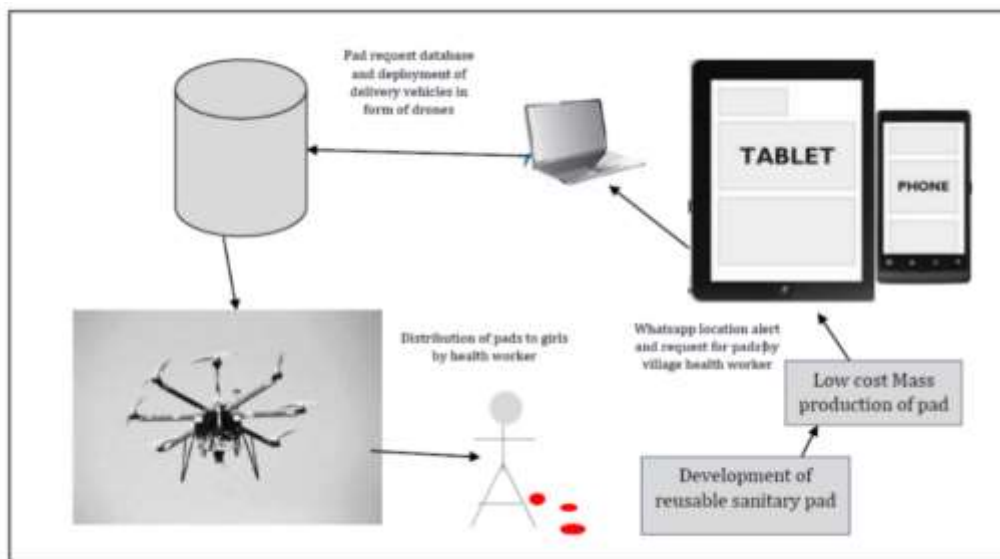


Figure 2. Illustration of drone and sanitary pad delivery system architecture. Source: Own compilation /

The depicted work flow architecture covers the entire system from a maternal sanitary pad request to UAV deployment. Candidate X, who is located in a designated rural school, initiates the process by logging a request either by WhatsApp (or a form on a portal online). It is known that mobile phones and internet access are increasingly available to rural folk hence this will not limit the success of the system. X raises the alert on their mobile phone advising the pad deliverers of her crisis and location. The entry alert is populated on a spreadsheet and this is a cue for deploying the pad delivery team who are at a fixed base. The pad delivery team are appraised on the girls

coordinates as provided in the alert and immediately pack a maternal towel package into the prototype drone cargo section. The drone is deployed to fly on coordinate way points towards the specified drop off coordinate where it will execute a drop off, turn and return to base to land and abort mission autonomously. While on mission a fitted sensor or camera simultaneously captures automated footage for storage and future mapping purposes. The camera is also useful in reconciling the drop off point coordinate with the presence of a helipad to confirm a positive drop off using computer vision techniques. To positively identify the helipad from the image below, computer vision-based object models are important and were utilised as they encode information on physical properties of a specific class of objects in scenes in two or three dimensions e.g., buildings. Scene models in addition aimed at the separation of other scene elements such as trees, shadow, and vegetation. The specific extraction framework adopted to identify the helipad can further be classified as model driven. Model driven concepts are top-down approaches often used in cases where the resulting objects have an expected shape as is often seen in medical image processing and x-rays. This differs from data driven concepts which are bottom-up techniques which group small image components to form the model. The UAV delivers the package by means of an automatic unlatch and drop before returning to home for landing and reassignment. An aviation-regulation model aircraft free testing site for the concept was used in model aircraft free flying spaces hence compliance to regulations was upheld. The helipad is automatically detected from the image as a drop off target.

4. Results and analysis

In most of Southern Africa where the specific project is based, the uptake of introducing clear drone regulations is still very much in its infancy (See Figure 3 below). Where regulations exist, there may be insufficient infrastructure and capacity to fully implement them. Many countries in the region still depend on the more mature framework in South Africa for training. In order to register as a remote pilot license holder in South Africa one has to complete theory and practical based assessment in key aviation areas towards preparing to sign out at a skills test held by the Civil Aviation Examiners. Thereafter the pilot is not totally open to fly at will but must operate under a Remotely Piloted Aircraft System Operating Certificate (ROC) to legally utilize drones for corporate or commercial work such as mapping. An ROC is very expensive and presents a barrier to entry. This creates pros and cons in terms of research flexibility although it is appreciated that the main to make it challenging to break in has been to ensure safety and liability capacity or compliance. The transportation of medical/wellness products as defined above, refers to the movement various supplies including maternal medicines, blood samples, blood products, health related equipment, vaccines, test kits, aid between supplier and recipient. Health packages are typically lightweight in nature, yet extremely valuable in terms of their impact on the health of global populations, thus making these items a potential focus for the development of drone-based delivery solutions. Loading medical parcels onto UAV platforms has also been seen as an opportunity to narrow the access to health divide by delivering required supplies to more remote areas. The drone industry discourages drop off from drones and is still highly regulated in the activities around UAV applications.

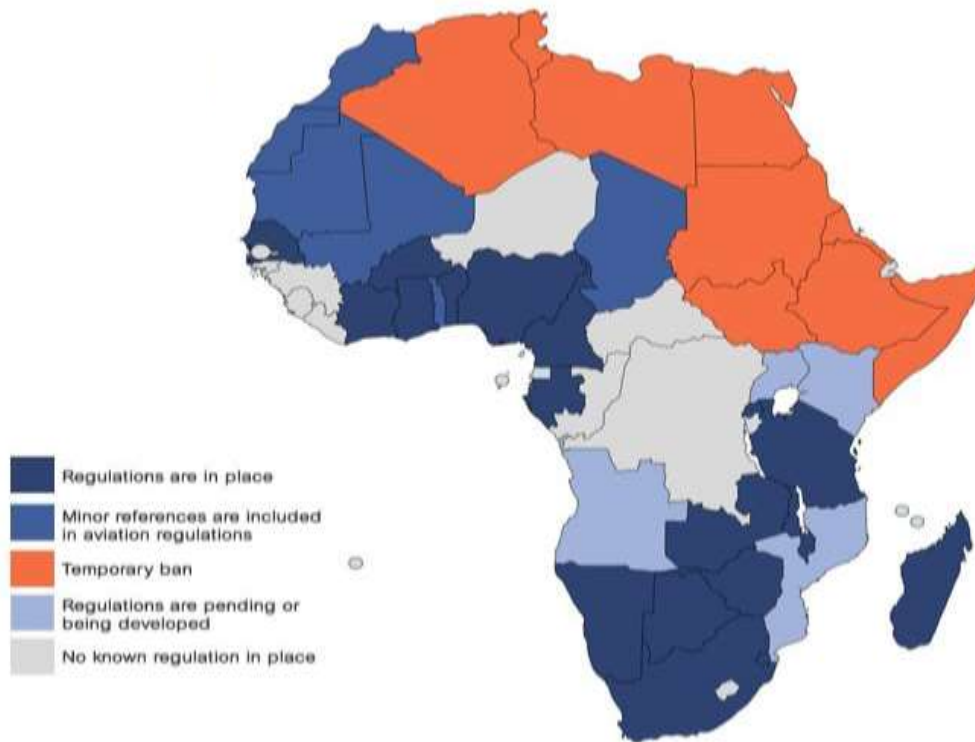


Figure 3. Drone regulations in Africa (Source: Africa goes Digital³)

On the UAV design and testing, the challenging aspects were in calibrating the aircraft in the field to ensure it can take off, execute mission on way points and land autonomously. This took a lot of the project time to complete, iterate and retry. As required, an additional payload in form of a cardboard shaped and coloured to carry the pads was reinforced below the craft for automated drop off release and a detachable RGB camera was employed. Figure 4 below shows the hexacopter components in assembly and on testing.

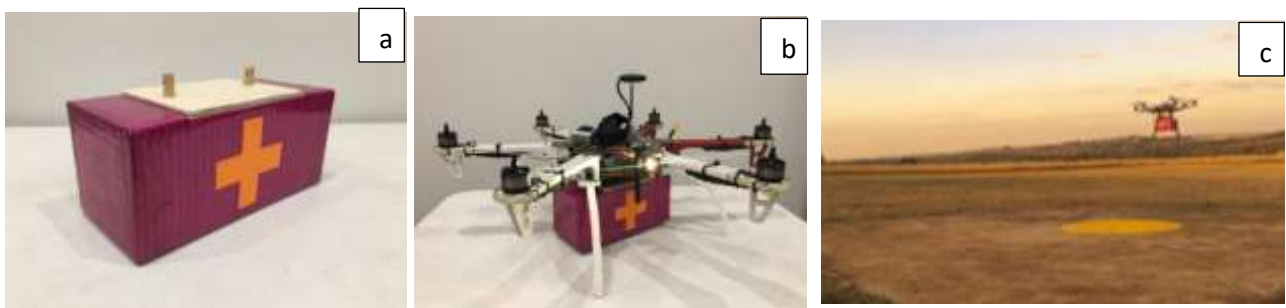


Figure 4. a) Pad loaded box b) Pad payload attached to hexa-copter c) Hexa-copter in flight Source: (Photographed in production by Mr Michael Gerhard Karl)

Once in the testing flight the hexa-copter with an RGB sensor on board was able to capture aerial photographs along its delivery flight path. In order to uphold the integrity of the drone the study considered whether the hexa-copter must land and drop off the package or drop off in flight and deploy for return. For safety it was decided that landing may not guarantee the integrity of the drone as there may be damage or in extreme cases damage by ground agents, hence a near land and re-route to home point approach was adopted. In order to positively identify drop off locations it was designed that although a Heli-pad of circular nature similar to the type purchased from commercial drone companies was an ideal identifier for a set drop off point per school. In practice this could be a set point in open field with no occlusion of buildings and vegetation. An automated identification of the drop off point was tested using the ISO unsupervised classification, The Sobel edge detector, and the Laplacian filter. Figure 5 below shows some basic outputs from one scene of the tests. As highlighted before, a model driven approach is selected as the best extraction approach for Helipad identification. All three methods tested above proved successful as the circular shape and spectral property of the helipad make its identification simpler to process. The best choice for identifying the helipad appeared to be the ISO classification as it converges quickly and upholds the H in the middle. The H makes it more certain that no misclassification exists except with another helipad. However, it runs optimally when the background is non heterogeneous, and the classes selected are between 3 and no more than 5. The Sobel performs slightly less optimally as a lot of context is lost to background in the binary output. The drop off performed as expected in the prototype. The field test then implemented the ISO classification to identify the helipad below it at drop off.

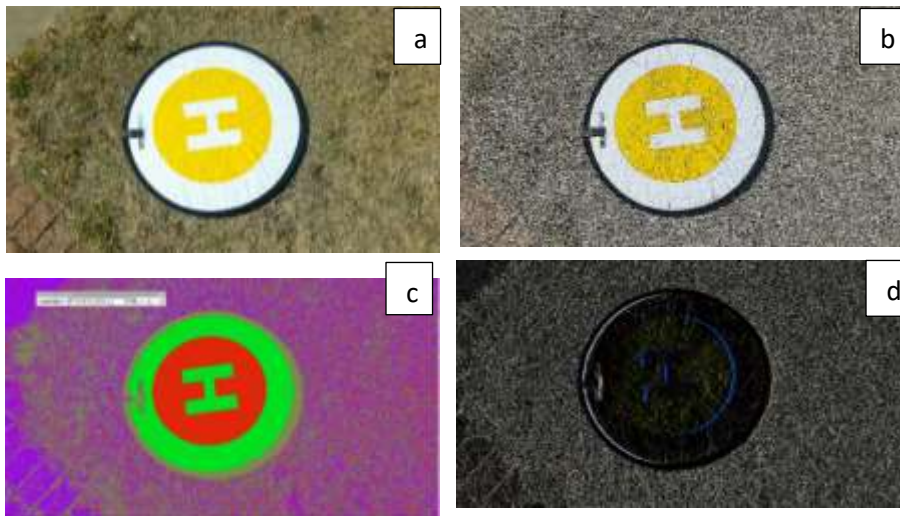


Figure 5 a) Drone-shot overhead drop off Helipad b) Original overhead shot verified by applying 5x5 Laplacian kernel c) Original overhead shot verified by applying iso-unsupervised classifier with 4 classes d) Original overhead shot verified by applying a vertical Sobel edge filter. Source: (Own Compilation)

5. Discussions and further works

The limitation of the prototype system was that it was tested at small scale, to apply it at large scale a fixed wing drone is recommended as it gives greater flying ranges and durability. Ethical considerations surrounding the regulatory framework of the study the prototype had to only been tested with an allowable model aircraft flying area. The researchers are valid holders of a Remote Pilot License and all necessary flight planning and risk assessments within the model aircraft area were done. The field team also included a trained observer and a fire marshal to assist in the unlikely event of any emergency. In summary, the restricting aviation laws remain a key challenge in full project dissemination as there is several layers of deterrents to minimize drone use without special permissions from the civil aviation. Moreover, dropping objects from drones even for research

remains a no-go area with prohibitions. Further work will involve engaging in drone regulation policy improvements for health logistics related work as well as scaling up the prototype. There is need for aviation to award a special class of license for research initiatives. Currently this is on a case-by-case basis if at all, hence is not regulated. No human subject was used to initiate a maternal pad health request as the flight was only simulated within the model airfield hence the researchers simulated a self-request and tested drop off based on that. The test was successful. With more capacity the project has ability to take off at full scale.

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Link: <https://www.linkedin.com/feed/update/urn:li:activity:6600637955688185856/>

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Explainable Artificial Intelligence, the Fourth Pillar of Zero Trust Security

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Abstract

The adoption of zero trust security in today's borderless networks is gaining ground to combat lateral movement. With a full-scale zero trust security system, malicious actors are unlikely to spread over the network from a compromised or vulnerable endpoint. However, a previously verified session from a compromised or exploited endpoint, on the other hand, can be utilised to execute limited but nefarious operations, rendering zero trust security exposed. This research provided an XAI conceptual framework for effectively detecting intrusions based on anomalies induced by malicious or compromised endpoints while ensuring explainability. A search query was executed on scientific databases such as Springer, Scopus, Wiley, IEEE, arXiv, ACM, and other databases to identify relevant articles. A total of 30 articles were considered for this study from the 2800 articles retrieved from the search result. The results show that parameter-based security infrastructures are no longer sufficient to keep modern operational technology and IT infrastructures safe. The study reveals that malicious actors can attack zero trust security defence infrastructure by compromising users' devices or endpoints based on the previously verified session. Hence, deploying XAI models as the fourth pillar of zero trust security architecture will efficiently detect patterns and extract large sets of data in which humans and the existing zero trust security architecture have been rendered ineffective.

Keywords: Zero trust security, XAI, Machine learning, Deep Learning, Fourth Pillar

1. Introduction

Most organisations' resources and data are no longer held on-site due to the recent transformation in cloud computing. Furthermore, the current COVID-19 pandemic has shifted work patterns dramatically, requiring most organisations and employees to work remotely. Working remotely presents organisations with new and serious security concerns since many "untrained" employees access organisation resources with their devices. Organisations must adapt to current trends and widen their cybersecurity perimeter, as seen by remote working and cloud computing (Alevizos *et al.*, 2021). The assets and resources of an organisation are presumed to be trustworthy and legitimate in traditional perimeter-based security architecture. To protect organisation security parameters from sophisticated attacks, cybersecurity methods such as intrusion detection systems or firewalls are normally employed. As proven by recent cyberattacks targeting remote employees, this paradigm looks to be ineffective in recent times. The underlying premise of perimeter-based security is that there is a mechanism to classify traffic, devices, users, and transactions as untrusted or trusted. Unfortunately, it has been difficult to overturn this assumption. Compromised credentials, insider threats, phishing, compromised devices, and denial of service attempts have produced a precipitous surge in breaches, disproving the concept of a protective perimeter. As estimated by projections, cybercrime losses will quadruple from 3 trillion USD in 2015 to 6 trillion USD in 2021, indicating that an inquisitive insider, malicious employees, or competitive adversary inside the perimeter may compromise an organisation's IT Infrastructure (Campbell, 2020).

Antivirus, intrusion detection systems, firewalls and web application firewalls are no longer sufficient to keep modern operational technology and IT environments safe and secured. Many organisations employed perimeter-based security as their principal security paradigm, especially when their data was stored in on-premises data centres. Conventional defensive infrastructure based on external and internal disparity is already becoming outdated, as the threat landscape changes dramatically, ultimately leading to the extinction of perimeter-based security infrastructure (Teixeira et al., 2018; Rose, Borchert, Mitchell & Connelly, 2020). A new security architecture is required to deal with today's complicated network infrastructures, as well as the continuously evolving threat spectrum. Zero trust security has surfaced by instituting a borderless automated identity-based perimeter in which data is at the heart of the cybersecurity infrastructure and the infringement ideology continues to dominate the threat surface, contributing significantly to the operations, access control landscape, and hosting environments, interconnecting infrastructures, and endpoints. The term "zero trust" refers to a new set of cybersecurity approaches that shift defences and counterattacks away from static perimeters, network-based and toward assets, resources and users

Zero trust in the context of the fourth main pillar involves verifying the users, validating their devices, limiting access and privilege, and learning to adapt. Every access request is subjected to a trust and risk evaluation to differentiate the users. The evaluation is done constantly (in the access phase) and automatically (based on situational conditions). Verified devices are one of the core pillars of the zero trust security framework. Since unsupervised devices provide a convenient point of entry for malicious actors, it is critical to ensure that only healthy devices have access to organisation data and applications to preserve optimum security and explicit trust (Columbus, 2018). To keep privileges and access to a minimum, every access should be offered with the least privileges. The permission or access is only allowed for one resource (depending on the resource's sensitivity) and is not transferable to another resource. The learn and adapt pillar, involves discovering risky user behaviour, and monitoring the security posture of all network assets and requested subjects continuously. This also involves the evaluation of behavioural patterns of users and network assets, and the security posture of devices in terms of adherence to security policy requirements (Columbus, 2018).

The fourth pillar of zero trust security can rely on explainable AI (XAI) to identify malicious users' behavioural patterns and integrate conditional access resources while justifying important features that impact the model decision logic without affecting user experiences. Even though zero trust security assumes the presence of malicious and untrustworthy actors both outside and inside the network, XAI offers the ability to access data about users, their devices, and their behavioural patterns in grant access, restricting, or imposing authorisation while ensuring the model's interpretability. With XAI, user policies can be updated in real-time and automatically with the hope of providing domain experts with the reason for each decision.

This study aims to investigate the impact of the XAI framework as the fourth pillar of zero trust security. The remainder of this work is organised in the following manner. In Section 2, we discuss the methodology adopted for this paper, the research questions, the justification behind each of the questions, and present the eligibility criteria for selecting the required papers. Section 3 provided answers to the research questions and provided solutions to the existing open problems and challenges of zero trust security architecture. Section 4 presents and discusses processes and factors needed to be considered to successfully migrate to zero trust security architecture. Finally, Section 5 brings this paper to a conclusion.

2 Research Methodology

This research presents a cutting-edge review approach based on the Prisma International Standards (Moher, Liberati, Tetzlaff & Altman, 2010). The goal of this study is to uncover a set of studies that were useful on the issue of XAI as the fourth pillar of zero trust security architecture. To do so, the authors outlined the research questions in this study and explained why each question was asked. The method of obtaining relevant articles and the selection criteria of the articles utilised in this study were also discussed. The proposed conceptual framework is designed to discover malicious threats by using deep neural networks (DNNs) to execute continuous monitoring of patterns to improve the learn and adapt phase of the traditional zero trust security architecture. The proposed framework involves the automatic discovery of risky user behaviour, and continuous monitoring of the security state of all network assets and requesting subjects. The model-agnostic technique for post-hoc explainability is adopted to illustrate relevant features that may influence the decision logic of deep learning models as the fourth pillar of zero trust security architecture.

2.1 Research Questions

The research questions, as well as the justification, are depicted in Table 1, which also serves as a foundation for selecting the studies and generating search criteria.

Table 1: Research Question

Research questions	Justification
RQ1: What are the open problems and challenges in zero trust security architecture?	To identify the open problems and challenges in zero trust security based on findings from existing literature.
RQ2: What are the potential solutions of the open problems?	To identify XAI techniques that provide solutions to open problems and challenges.
RQ3: How can XAI be integrated as the fourth pillar of zero trust security architecture?	To identify the XAI techniques to improve the existing gaps of zero trust security architecture and suggest interpretable machine learning and deep learning techniques that are capable of eliminating the existing gaps.

3.2 Search Criteria

The following is the outcome of the search string that were used to identify relevant literature: ("Open problems of zero trust security" OR "Challenges of Zero Trust Security" OR "Challenges of ZTA") AND ("Pillars of Zero Trust Security Architecture" OR "Machine learning in Zero Trust Architecture" OR "eXplainable AI in Zero Trust Security Architecture" OR "Deep learning in cyberattack detection") AND ("XAI in Zero Trust Security Architecture" OR "Integration of AI in Zero Trust Security Architecture"). The eligibility criteria were applied based on three factors: inclusion, exclusion, and quality criteria. The selected articles were extracted from the search results using these parameters.

2.3 Exclusion Criteria

The retrieved literature was evaluated using the following exclusive criteria:

1. The research questions are not discussed in the literature.

2. Articles with the same title as one another.
3. Identical articles from several databases
4. Articles that do not cover zero trust security architecture, AI in zero trust security architecture, integrating deep learning and machine learning to zero trust security architecture, or XAI in zero trust security architecture.

2.4 Inclusion Criteria

The retrieved literature was assessed using the following criteria:

1. Relevant literature on zero trust security architecture.
2. Conceptual framework, techniques, theoretical frameworks, conference proceedings, journals, whitepapers, scholarly work, and symposiums addressing zero trust security architecture.
3. Literature addressing AI, XAI, machine learning and deep learning methodologies including improving the existing zero trust security architecture.

2.5 Quality Criteria

The following criteria were used to assess the quality of the articles:

1. Are most of the research questions answered in the literature?
2. Is it possible to explain the XAI techniques that are utilised to improve the existing zero trust security framework?
3. Is there any information in the article that answers any of the research questions?
4. Is the research methodology appropriately disclosed in the literature?

2.6 Selection Criteria and Source of Selected Articles

Springer, Scopus, Wiley, IEEE, arXiv, ACM, and other databases were used as the primary search criteria for this study. The procedure of identifying relevant publications for this study is illustrated in the PRISMA flow diagram in Figure 1. The following are the steps in identifying relevant articles:

1. Stage 1 (Articles Identification): This involves extracted data from the downloaded articles in excel format. A robust search was performed on nine electronic databases as previously mentioned, producing a total of 2800 articles, which served as a range of possible articles for eventual selection (see Table 2).
2. Stage 2 (Screening of Identified Articles): Based on the results from Table 2, a total of 2800 possible articles were extracted. Among the 2800 articles captured, there were 1600 duplicates. This is because the articles were in multiple databases. The filtering process was then carried out based on the insignificance of the article titles, with 518 articles ruled inadequate for this study.
3. Stage 3 (Eligibility Criteria): The validity and quality of an article are not exclusively assessed by its title and abstract alone. As a result, complete text-based selection criteria were employed to retrieve relevant articles for the study. A total of 682 articles were assessed for eligibility, with 652 being rejected due to ambiguous or imprecise methodologies.
4. Stage 4 (Inclusion): For the remaining articles, a quality review based on the outlined research questions in Table 1 was executed. Following the resolution of article selection constraints, a total of 30 articles were investigated in this study, as illustrated in Figure 2.

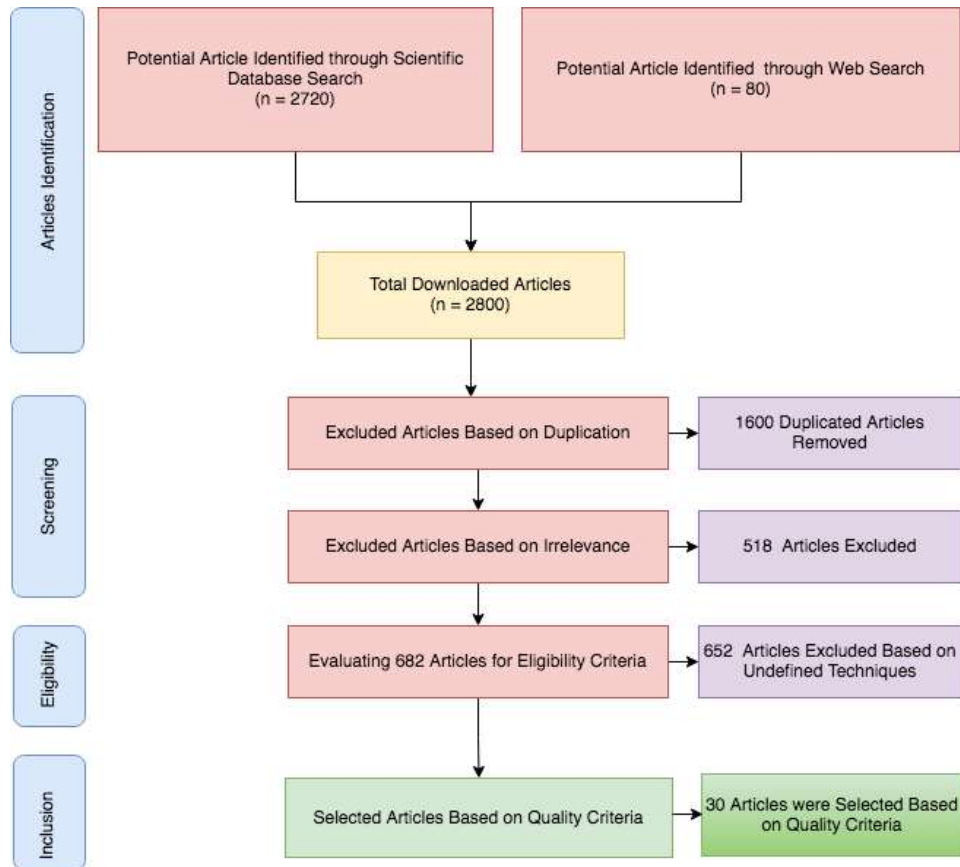


Figure 1: PRISMA flow diagram for eligibility criteria and selection of relevant articles

The articles in this study were retrieved from eight (8) digital databases. A search query was also conducted on various web sources. ACM, arXiv, IEEE, MDPI, Scopus, Springer, Tech Science and Wiley are among the digital databases utilised in this study. Figure 2 depicts the sources of the selected articles. The search strings in Section 3.2 were utilised to execute the search query in the selected databases. The result in Figure 3 shows that IEEE had the most relevant articles with eight (8), followed by search queries from web sources (7), Scopus had five (5) publications, ACM had four (4) publications, and arXiv had two (2) publications. In contrast, MDPI, Springer, Tech Science, and Wiley have one (1) publication, respectively. Figure 3 shows that the 30 selected articles were published as follows: fourteen papers from journals, seven papers from conferences, four articles from scholarly work, two articles from workshops and whitepapers, respectively, and one article from the symposium.

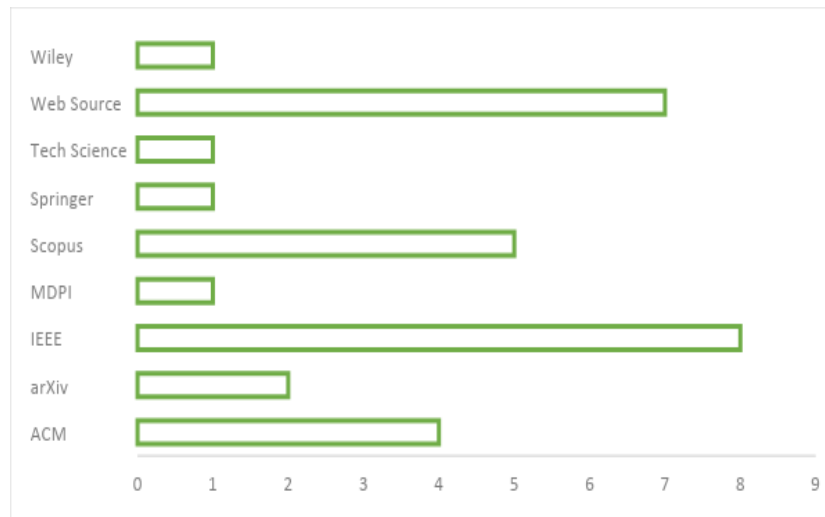


Figure. 2: Source of Selected Articles

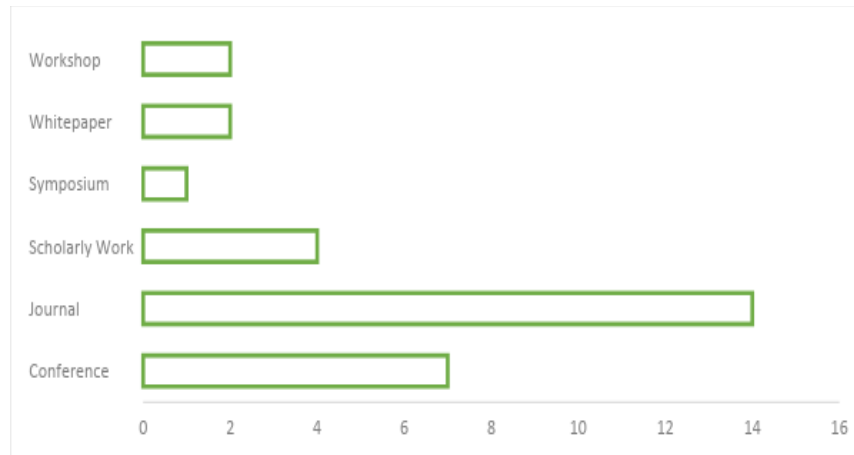


Figure. 3: Number of Selected Articles

Figure 4 demonstrates that 2021 had the most relevant papers (9), followed by 2018 (5) publications, and 2020 (4) publications. Whereas 2015, 2012, 2010, 2006, and 2002 have the least number of publications (1), respectively. This shows that researchers are currently interested in improving zero trust security architecture to combat sophisticated attacks, and XAI is a recent technique to improve zero trust security architecture.

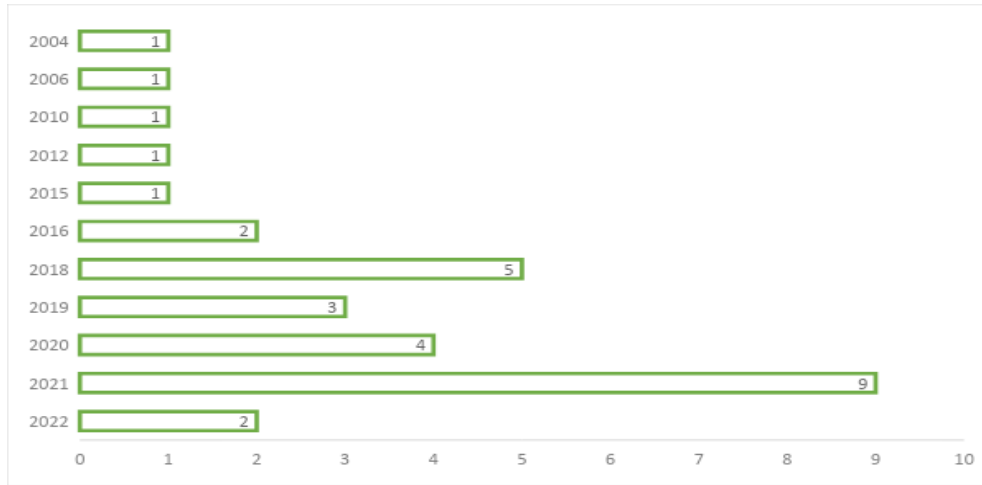


Figure. 4: Selected Articles Publication Year

2.7 Related Works

Chen et al., 2021, in a zero trust secured awareness and protection system for 5G intelligent healthcare. The authors presented a behaviour-based anomaly detection approach integrating endpoints and user identification, terminal security status, system behaviour, and user behavioural patterns to perform the trust evaluation process. The proposed method employed hierarchical trust level-based access control, in which resource access is only authorised when a subject's trust level exceeds a specified threshold. However, it may have trouble analysing traffic due to high bandwidth and low latency rates.

Mahbooba et al. (2021) proposed an XAI model to improve trust management in an intrusion detection model using a decision tree algorithm. The authors demonstrated how to identify malicious from legitimate network data using a collection of features. When cybersecurity domain professionals and network security administrators understand the decision logic, it improves trustworthiness by acting in the event of adversarial traffic authentication. The decision tree approach outperformed other state-of-the-art algorithms regarding precision, recall, accuracy, and F-1 scores. The decision tree was easier to understand and computationally less expensive than other state-of-the-art methods. However, when the algorithm encounters noise in the dataset, there is a possibility of overfitting.

Mandal, Khan & Jain (2021) developed a cloud-based zero trust access control scheme. The authors presented a multiplicative increment and additive reduction technique in the software-defined network architecture of cloud computing to limit incoming traffic and verify MAC spoofing threats directly. On the other hand, monitoring traffic and discovering malicious users takes time.

Yao et al. (2020) presented a zero trust security model based on dynamic access control and authorisation system. The authors implemented a trust-based access control system to calculate the user's behaviour trust score and grant authorisation if the behaviour trust score exceeds the minimum trust score necessary to access the resource. The login, network, and operational behavioural patterns impacted the behavioural trust score computation. However, the proposed technique finds it challenging to analyse high traffic rates.

3 Research Question 1: Open Problems of Zero Trust Security Architecture

As previously stated, the major purpose of a correctly implemented zero trust security architecture is to execute fine-grained identity-based access control, specifically to prevent the increasingly serious risk of lateral movement. Access controls come in a variety of forms, including role-based and attribute-based. In contrast, zero trust security architecture controls access based on the user's identification (i.e., identity-based). Furthermore, zero trust security policy focuses on securing user accounts, services, network assets and traffic instead of network segments. Within the framework of zero trust security architecture and its link to the general security posture of the resource, the network location (e.g., work, public place or home) is deemed unimportant. The preceding reasoning, however, is based on the assumption that the main components of a zero trust security architecture ought to be able to analyse users' access requests before granting permissions to access privileged resources. Several factors (i.e., time of the request, location, operating system version, software patch levels, and IP address) must be met before a user is granted access to privileged resources. Of course, such information is subject to each company's policies as well as the circumstances. This strategy can be successfully adopted if researchers, cybersecurity experts and designers assume highly restricted or fully regulated devices, such as in BeyondCorp, where only corporate Google Chromebook laptops are allowed access and no BYOD is allowed (Alevizos *et al.*, 2021). However, most organisations still use Windows as their primary operating system and may use a variety of legacy, out-of-date apps and/or middleware, which increases security vulnerabilities. Dedicated criminals have consistently demonstrated how typical perimeter-based cybersecurity security mechanisms can be circumvented or compromised, for example, through phishing and malware attacks, to gain access to an organisation's networks.

Since possible malware in the operating system kernel can interfere with the zero trust security health checks that are part of the context provided by zero trust security architecture, once a device has been infiltrated, the operating system (and the device that executes it) can no longer be trusted. As a result, the fundamental control implemented in a zero trust security architecture is eventually bypassed. As a result, organisations that use one of the current zero trust security frameworks may mistrust user endpoints or devices, because intruders can still jeopardise those devices and start riding the already verified user's session to explore a range of users and device-centric malicious purposes other than lateral movement. The MITRE ATT&CK vector attack method, which comprises malware payload execution, privilege escalation, and defence evasion to infiltrate user devices, is an excellent example. The repercussions of an infected device belonging to an administrator are serious (Alevizos *et al.*, 2021). Considering the aforementioned problem, one might argue that the zero trust security model generates a false sense of safety, especially when it comes to endpoints, even though organisations that adopt zero trust security architecture are motivated to allow access to organisation resources either through BYOD, uncontrolled, or even personal devices, reliant on a combined effect of health and security inspections and context that can be forged once an endpoint is impacted (Alevizos *et al.*, 2021).

3.1 AI in Zero Trust Security Architecture

According to a new research report from cloud security firm Trend Micro, as AI grows more prevalent, technology will certainly replace humans in the cybersecurity profession shortly. Because cybercriminals are always improving their sophisticated tools, AI will be the most effective way to address the cybersecurity skills gap. According to the survey, 41% of IT executives predict that AI would replace humans by 2030. However, 32% of IT directors, managers, CIOs, and CTOs predict that, in the future, this technology would entirely automate all cybersecurity-related functions with little or no human

participation (Greycamp, 2021). Threat intelligence is becoming increasingly vital for correlating signals across pillars and prioritising incidents as cyberattacks become more complex and pervasive. End-to-end transparency and automatic response to protect assets, mitigate threats, and aid investigations will require intelligent and integrated extended detection and response across pillars. This approach will also give security personnel the time and expertise they need to deter, detect, and eliminate the most dangerous external and internal attack patterns (Microsoft, 2021). With greater AI implementation, risk-based authentication will continue to improve. The accuracy and scope of the AI-based authentication framework will be improved by using cross-referencing various machine learning algorithms, AI-based pattern recognition, and time-series-based prediction algorithms. As a result, businesses can incorporate AI concepts into authentication processes to improve explicit verification and validation of users as well as other aspects of cybersecurity, such as botnet identification and network penetration (Greycamp, 2021). Every security use case has been invaded by artificial intelligence (AI), and zero trust security frameworks are the next target. AI will play a bigger role in calculating the dynamic risk of access as identity verification becomes more relevant. This will need a level of computational complexity unavailable from a rules-based approach. Deep learning supervised and unsupervised, reinforcement learning, and genetic algorithms will enable security solutions to adapt to changing enterprise behavioural patterns and learn from other enterprises as they encounter and defeat threats, in addition to applying lab-trained inference models. (Campbell, 2020; Guembe *et al.*, 2022).

Machine learning models trained on user interaction offer a means of determining which data to focus on and comprehending the local context; models trained to detect anomalous activities are more likely to increase zero trust security detection efficiency. AI techniques such as deep learning and machine learning will not only save money but also enables a speedier response in the most essential situations (Pupillo, Fantin, Ferreira & Polito, 2021; Guembe *et al.*, 2021). AI can help detect new anomalies by learning robust patterns from the data it is fed. AI is especially good at recognising patterns and extracting procedures from massive sets of data where humans are ineffectual (Pupillo, Fantin, Ferreira & Polito, 2021). Asynchronous user profiling, assessing deviation from common behaviours, and going back to much bigger data volumes to understand behaviour all require machine learning. Long-term and broad-reaching attacker detection can be aided by an AI model trained on immutable attacker 'Tactics, Techniques, and Procedures (TTP) behaviours (as specified in the Mire Attack framework).

3.3 Research Question 2: Potential Solution of Open Problems

Based on the observation from the previous section, improving the effectiveness of zero trust security architecture requires addressing endpoint integrity and detecting compromised endpoints. This section reviews potential approaches and XAI techniques to solve the challenges of zero trust security architecture endpoints. The potential solutions are discussed in the next sections:

A well-known strategy is to utilise Intrusion Detection Systems (IDSs) to identify intrusions based on anomalies created by adversarial or hacked devices. As a result, it is among the most effective alternatives to the issue described in Section 2. In the case of large organisations, however, establishing a standalone IDS is insufficient because of the huge number of misclassification rates (Meng *et al.*, 2015; Fung *et al.*, 2010; Duma *et al.*, 2006). As a result, Alevizos *et al.* (2021) recommended using DCIDSs to enhance the effectiveness and availability of standalone IDSs. Collaborative intrusion detection systems (CIDSs) or collaborative intrusion detection networks (CIDNs) were used to overcome the limitations of standalone IDSs (IDSs). CIDSs is made up of cooperative IDSs that work together to produce higher intrusion detection

accuracy through collective knowledge. DCIDSs also deal with a wide range of IDS weaknesses, such as Distributed Denial of Service (DDoS) attacks (Alevizos et al., 2021). When compared to a single IDS arrangement, CIDSs can reduce the misclassification rate (to one out of every seven cases) and completely eradicate the misclassification rate in their test system (Wu et al., 2004).

Machine learning, on the other hand, excels at detecting patterns and extracting procedures from big datasets where humans are rendered ineffective (Pupillo, Fantin, Ferreira & Polito, 2021). Incorporating machine learning into zero trust architecture improves network context and assurance. Machine learning can also detect intrusions based on abnormalities created by malicious or hacked devices, as well as unknown threats, quickly, accurately, and with a low false-positive rate (Awadallah, 2021; Pupillo, Fantin, Ferreira & Polito, 2021; Navya et al., 2021).

3.4 Research Question 3: XAI as the Fourth Pillar of Zero Trust Security

When including XAI as the fourth pillar of zero trust cybersecurity, incorporating interpretability as a design catalyst would enhance the model implementation and enforce impartiality in the model outcome. For example, detect anomalies and immediately correct bias in the training sample, and deliver resiliency by highlighting potential anomalies and threat actors that could alter the prediction and decision logic. It also ensures that meaningful features can deduce the outcome and underlying truthful causality must exist in the reasoning and decision-making process of the model (Zhu et al., 2018; Dosilovic, Brcic & Hlupic, 2018). When compared to black-box AI models, XAI can provide both decision-making and model explanations. XAI facilitates the development and deployment of ethical and philosophical AI models based on the interpretability of the model decision logic (Keeling, 2019). Hence, the embedding of XAI as the fourth pillar in zero trust cybersecurity, and XAI methods in collaboration with the human in the loop can improve the security and trust in the decision-making process, and it is also capable of eliminating the bias attached to traditional AI black-box models. Explainable machine learning and deep learning can enable IT and security teams to surface threat indicators that would otherwise be lost in a sea of data. It is capable of providing cybersecurity teams and domain experts a better understanding of the activity occurring within an account, as well as the documents contained within, and can pair the data with typical user access patterns that the model has been trained against to determine if an account is acting suspiciously. As a result, explainable machine learning and deep learning can efficiently assist organisations in strengthening their defences against both internal and external threats, as well as in implementing a more robust zero trust security model.

3.5 XAI Conceptual Framework as the Fourth Pillar of Zero Trust Security

The methodology of the proposed model architecture is described in this section. The conceptual workflow of the framework is presented, followed by a brief description of the architecture (DNN and Model-agnostic technique) that inspired the fourth pillar of the zero trust security conceptual framework. The proposed framework is designed to identify malicious threats using deep neural networks (DNNs) to execute continuous monitoring of patterns and enhance the security posture of the traditional zero trust security architecture. The proposed framework involves the automatic discovery of risky user behaviour, and continuous monitoring of the security state of all network assets and requesting subjects. This also involves the evaluation of behavioural patterns of users and network assets and the security posture of devices in terms of compliance with security policy rules. DNNs are one of the most widely used deep learning techniques. By combining more layers and more units per layer into a neural network, they can reverse increasingly complex functions. A DNN can be used to implement the fourth pillar of zero

trust security architecture, which is responsible for learning and adapting while detecting malicious behavioural patterns in large amounts of real-time data sources or structured data. DNNs are an effective technique for conducting supervised learning for detecting malicious network patterns and user behaviour, particularly in the context of zero trust security architecture's never trust and always verify nature (Sohi, 2021).

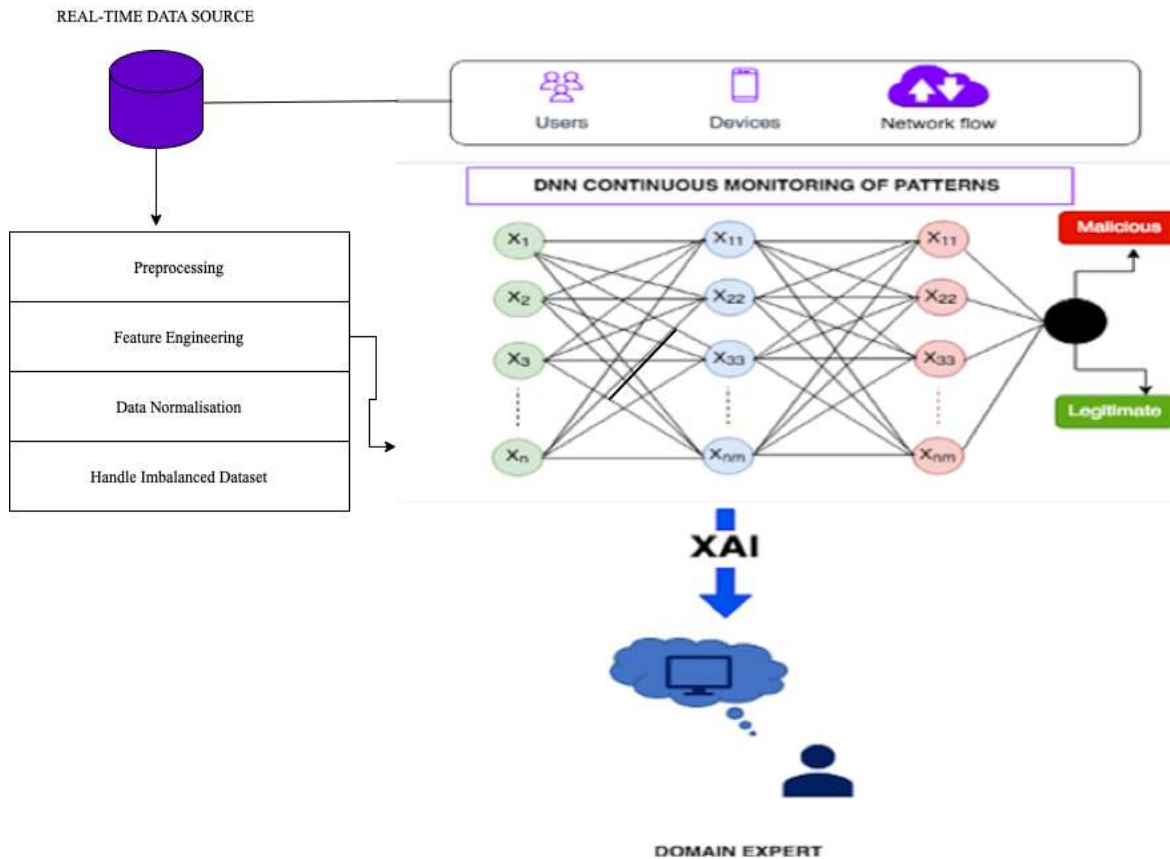


Figure 5: Fourth Pillar of Zero Trust Security Conceptual Framework

The feature extraction module is used to transform the raw data into feature vectors. The captured set of raw data is reduced to more manageable groups for processing because features that are improperly selected will hurt the performance of our model. Data processing is an essential component of the entire model training pipeline. It is triggered and controlled regularly during the feature engineering phase. Although the DNN technique has strong learning ability, DNN models cannot learn domain knowledge directly from all types of real-time data sources. The primary reason for pre-processing is that the data is in various formats and is collected from various locations; it also ensures the reliability, effectiveness and accuracy of the model being trained on this data. The DNN model can be employed for continuous monitoring of patterns, detection of malicious patterns, and behavioural analysis. The DNN's continuous monitoring of patterns can analyse patterns and learn how to prevent malicious and changing behaviours. This will help the cybersecurity team to be more proactive and able to detect sophisticated attacks in real-time as shown in Figure 1. The model is designed to classify malicious behaviour from legitimate behaviour in real-time which is the core principle of the fourth pillar of zero rust security (learn and adapt). The XAI technique is used to make better use of the output the DNN model gives, making them have even more impact on the decision-making. It also enables the human expert to react to the decision and execute an

audit for the training set. Interpretability is especially important in sensitive domains like medicine and cybersecurity systems, where the patterns revealed by a model are frequently more important than the model's prediction performance. Hence, trust is essential for effective interpretation and human interaction with the DNN cybersecurity detection models and explaining individual predictions with a model-agnostic technique is a good way to assess trust and interpretability. A model-agnostic technique for post-hoc explainability is adopted to illustrate relevant features that may influence the decision logic of deep learning models as the fourth pillar of zero trust security architecture. Model-agnostic post-hoc explainability techniques are intended to be plugged into any black-box model to extract some information from its prediction procedure. The feature relevance technique is also used to describe how an opaque model works by rating or evaluating the influence, relevance, or importance of each feature in the model's prediction output. The Shapley Additive exPlanations (SHAP) method is also used to demonstrate how to calculate an additive feature importance score for each prediction that has a set of desirable attributes that its predecessors lacked, such as local accuracy, missingness, and consistency.

The model-agnostic technique for post-hoc explainability is utilised to create a transparent and trustworthy DNN detection model. This technique enables the interpretation of the DNN detection model and its predictions, yielding feature importance values for individual predictions from the model. The DNN's network structure consists of three layers: an input layer which brings the real-time data source into the system for processing by the artificial neurons by subsequent layers, a hidden layer which transforms the input layer to what the output layer can detect as a malicious or legitimate source, and an output layer which transforms the hidden layer activation to malicious or benign, each of which is fully connected. Each neuron has no connections between layers and is connected to all neurons in the subsequent layer. An activation function acts on the output after each layer of the network, enhancing the effect of network learning. As a result, DNN can be viewed as a huge perceptron made up of numerous perceptrons. The formula for the i th layer forward propagation computation is as follows:

$$x_i + 1 = \sigma (\sum w_i x_i + b) \quad (1.0)$$

The real-time data source (input value) is represented by x , the weight coefficient matrices are represented by w , and the bias vector is represented by b .

The interpretability aids in the provision of impartiality in decision-making, i.e., detecting, and correcting bias in the training dataset, facilitating the provision of robustness by highlighting potential adversarial perturbations that could alter the prediction, and acting as insurance that only relevant variables infer the output, i.e., guaranteeing that the model reasoning is based on truthful causality. Figure 1 illustrates the fourth pillar of the zero trust conceptual framework. The post-doc explainable technique employs a game theory approach (Shapley Values) integrated into a black-box model such as DNN to fairly distribute contributions to the model features for the desired output. The fundamental process of obtaining the Shapley values for a specific feature x from the set X can be classified as follows:

- i. Obtain the power set of, X which has feature combinations.
- ii. Execute the model for all possible permutations, treating features outside the subset as missing.
- iii. Keep records of minimal contributions to the model output for x
- iv. To obtain the Shapley value of feature x for a given output, calculate the weighted sum of x minimal contributions.

4. Result and Discussion

This study employs the eligibility criteria (exclusion, inclusion, and quality criteria) to select 30 articles out of the 2800 articles extracted from scientific databases and web sources. From the selected articles, the result shows that 2021 had the most relevant papers (9), followed by 2018 (5) publications, and 2020 (4) publications. Whereas 2015, 2012, 2010, 2006, and 2002 had the least number of publications (1), respectively. This indicates that there is an upward trend in this research domain, and cybersecurity experts and researchers are willing to adopt XAI techniques to combat sophisticated attacks and improve their cybersecurity defence infrastructures (Barredo et al., 2020). As discussed in this study, the fourth pillar of zero trust security is the learn and adapt phase, which involves the discovery of risky user behaviour, and continuous monitoring of the security state of all network assets and requesting subjects. However, the control fundamental control implemented by zero trust security architecture can be bypassed by unhealthy validated devices. Hence, it is necessary to deploy XAI techniques to execute continuous monitoring of devices, user's behavioural patterns and network flows while explaining essential features that influence the model decision logic. The result shows that if the proposed conceptual framework is correctly implemented, the fundamental control implemented in zero trust security will not be bypassed by unhealthy devices due to the continuous monitoring of devices and behavioural patterns of the proposed conceptual framework. This framework can also be used to extend the works of Azeta et al., (2016) and Azeta et al., (2017) in the future.

5. Conclusion

This study presented a state-of-the-art review on zero trust security architecture and XAI as the fourth pillar of zero trust security architecture, both of which are relevant and emerging research and development areas in the cybersecurity domain. Several aspects of zero trust security techniques were examined using 30 articles from XAI, deep learning, machine learning, and zero trust security architecture. The pillars of zero trust security architecture were discussed. Furthermore, the core tenants and core capabilities of XAI as the fourth pillar of zero trust security architecture were presented. Then, using case studies and examples, the security challenges and open problems with the existing zero trust security architecture were discussed, and interpretable machine learning and deep approaches were outlined as promising approaches to address those problems. One of the approaches investigated in this study is the possibility of adopting a DNNs model with a model-agnostic technique for post-hoc explainability for the asynchronous device, network, and user profiling, measuring deviation from common behavioural patterns and returning to continuous pattern monitoring while ensuring transparency and interpretability to the model decision logic. Based on the current state of the art in this research domain, the study concluded that XAI can play an important role in augmenting one of the core tenets of zero trust architectures, namely, the assumed breach mindset and the learn and adapt phase (fourth pillar of zero trust security). The best method to harden cybersecurity zero trust security infrastructures is to deploy interpretable machine learning and deep learning techniques for continuous monitoring of patterns and detection of known and unknown attacks in real-time while explaining essential features that influence the model decision. Finally, this study recommends that XAI techniques be used to detect intrusions based on anomalies generated by compromised or malicious devices, as well as known and unknown attacks while increasing the speed and accuracy of detection.

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An Improved Deep Sparse Autoencoder Driven Network Intrusion Detection System (IDSAE-NIDS)

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Abstract.

Computer network users experience persistent attack due to vulnerabilities in the systems and applications. Intrusion detection systems (IDS) examines the flow of data in the network and detect abnormal traffic. The IDS also alerts security administrator of the presence of unwanted traffic or abnormal activity on the network. An IDS may fail sometimes, hence it does not guarantee absolute security. The system may also run into error in a bid to detect unauthorized access or malicious traffic. Hence the need to develop a system that can detect intrusions in a network with minimal error. This paper proposes an improved deep sparse autoencoder driven network intrusion detection system (IDSAE NIDS) which addresses the issue of interpretability of L2 regularization technique employed in other works. The proposed IDSAE NIDS model was trained using a mini-batch gradient descent algorithm, L1 regularization technique and ReLU activation function to achieve better performance. The results of experiments based on NSL-KDD dataset produced a performance accuracy of 98.33% with a low loss value of 0.0484. The learning is sufficient enough to enable the model understand patterns in the training set within an error margin of 0.0484. This shows that the proposed approach has significant performance than other deep sparse autoencoder NIDSs.

Keywords: Activation function, Autoencoder, Regularization, Softmax and Sparse Autoencoder.

1. Introduction

An intrusion detection system tracks and analyzes the flow of traffic on networks and alerts security administrators (or reports to security information and event management system) whenever it discovers unauthorized activities. It examines a network or system for suspicious activities which violate security policy. Although IDSs are effective for detecting malicious activities, they are susceptible to false positives or false negatives. It is imperative to configure and optimize an IDS product after installation to ensure that it is effective at distinguishing legitimate traffic from unauthorized events (Gross, 2019). An anomaly-based IDS, also called behavioral-based intrusion detection system tracks specific activities in order to detect malicious behaviour. This

is challenging because it can lead to false positives. For instance, a legitimate outbound Uniform Resource Locator or domain may be blocked in error (Jyothsna et al, 2011). On the other hand, a signature (or knowledge) based IDSs look for specific patterns of information that indicate attacks. The tools have low false positive rates because they use highly specific search criteria based on signatures in the search database. Hence previously unknown attacks can bypass the IDS and penetrate the network. This technique cannot detect previously unknown attacks because they are based on regular expressions and strings (Gross, 2019). Other categories of IDSs are the host-based, application-based, and the network-based IDSs (Gross, 2019).

2. Related work

NIBUSINESS (2021) proposed an autoencoder which used hybrid deep learning for dimensionality reduction and extraction of salient and most discriminant features from data. A related study applied Deep Belief Network (DBN) on KDDCUP'99 dataset to model an IDS. ADBN integrates multiple layers of Restricted Boltzmann Machines (RBM). Such multi-layer was used for anomaly detection on real time traffic obtained from workstations over a period of forty-two hours (Taher et al, 2019). KDD-CUP'99 dataset. The model achieved approximately 85% accuracy based on 10% of KDDCUP99 dataset. An unsupervised greedy learning algorithm has also been used to identify similar patterns in large datasets (Wang et al, 2018). An evaluation of the approach shows that an RBM with four hidden layers has better performance than support vector machine and artificial neural network. On the other hand, long short-term memory (LSTM), which is a variant of generative models has better performance accuracy than other classifiers such as kernel neural network and support vector machine (Fahimeh and Heikkonen, 2018). Such models have high expressive power and good detection accuracy. Accelerated Deep network neural architecture was used to detect malicious network traffic at an enhanced training speed (Majjed et al, 2018). This was achieved by using a multicore CPU to support parallel processing. A deep neural network (DNN) trained with only normal traffic data is able to evolve and learn malicious behaviour in a dynamic way (Zhang et al, 2018). Recent approaches for anomaly detection include nonsymmetric deep autoencoder (Versloot, 2020) and self-organization map (SOM) neural network (Sadaf and Sultana, 2020). The detection rates for SOM are 92.37% and 75.49% for KDDCUP'99 and NSL-KDD datasets respectively. An enhanced approach used a greedy deep autoencoder to achieve high accuracy and prevent overfitting (Jordan, 2020). A major limitation of the approach is its high computational cost.

The study by (Majjed et al, 2018) introduced sparsity using KL divergence regularization technique while (Zhang et al, 2018) achieved sparsity by integrating KL divergence and L2 regularization techniques. However, both Majjed et al (2018) and Zhang et al (2018) used sigmoid as activation function. Although the L2 regularization technique is suitable for high-dimensional data with high feature correlation, the L2 regularization technique employed by Zhang et al (2018) has interpretative issues and does not promote sparsity (Versloot, 2020). This implies that the approach does not deactivate hidden-layer neurons in order to minimize complexity and improve accuracy. Low dimensional dataset may make L2 regularization produce an uninterpretable model. The most appropriate technique for variational autoencoders is KL divergence regularization (Sadaf and Sultana, 2020) because it computes

the difference between two probability distributions which is suitable for autoencoders which provide probabilistic measure of observations (Jordan, 2018). Hence, the motivation to propose an improved solution with better accuracy than the previous studies such as Sadaf and Sultana (2020), Zhang et al (2018) and Majjed et al (2018).

3. Methodology

Figure 1. is the research process flow for implementing the proposed improved deep sparse autoencoder driven intrusion detection system (IDSAE-NIDS).

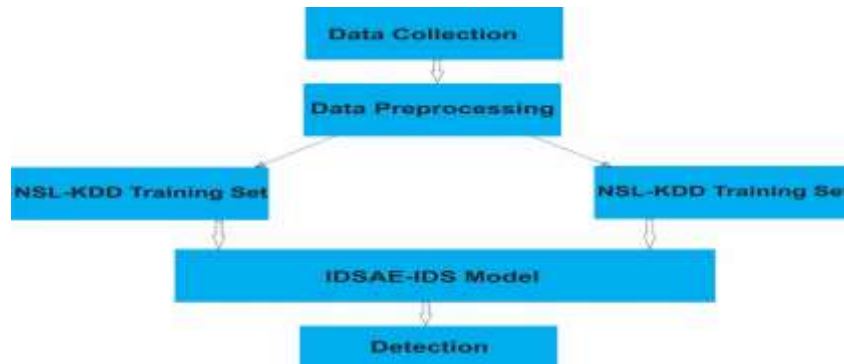


Figure:1. Experimental process flow

3.1 Data Collection

The proposed deep sparse autoencoder IDS was implemented using python programming language. The experimental data is captured from the NSL-KDD dataset. This dataset is an improved version of KDDCUP'99 (Edureka et al, 2019). It consists selected records of KDDCUP'99 data set. Classifiers which use NSL-KDD dataset have unbiased results because the training set of the dataset does not have redundant records. NSL-KDD test set does not contain duplicate records, which results in better reduction rates.

Table: 1. Mapping of attack class with attack type (Fahimeh and Heikkonen, 2018)

1	DoS	Back, Land, Neptune, Pod, Smurf, Teardrop, Apache2, Udpstorm, Processtable, Worm (10)
2	Probe	Satan, Ipsweep, Nmap, Portsweep, Mscan, Saint (6)
3	R2L	Guess_Password, Ftp_write, Imap, Phf, Multihop, Warezmaster, Warezclient, Spy, Xlock, Xsnoop, Snmpguess, Snmpgetattack, Httpptunnel, Sendmail, Named (16)
4	U2R	Buffer_overflow, Loadmodule, Rootkit, Perl, Sqlattack, Xterm, Ps (7)

A. Preprocessing

This phase transforms the data before loading it to the model (Syoya, 2018). This involves checking for redundant rows in the dataset and removing them. It is worthy of note that NSL-

KDD dataset does not come with column names. Hence, the need to add column names to each feature of the dataset.

B. Training

The research used mini-batch gradient descent for training the proposed model. Gradient descent finds optimal parameter values (or weights) that produce the least possible cost function. Gradient measures change in error with a corresponding change in all weights (Yuancheng et al, 2015). A high gradient shows that the model can learn at a fast rate. A zero gradient indicates that the model cannot learn beyond that point. Gradient descent equation is presented in (1) and (2) as follows:

$$W_{ij}^{(l)} := W_{ij}^{(l)} - \alpha \frac{\partial}{\partial W_{ij}^{(l)}} J(W, b) \quad (1)$$

$$b_i^{(l)} := b_i^{(l)} - \alpha \frac{\partial}{\partial b_i^{(l)}} J(W, b) \quad (2)$$

where α is the learning rate (lr), with value 0.001. It is the optimized rate at which a network minimizes the loss function. The key step is computing the partial derivatives above. The study used backpropagation to compute the partial derivative above. $J(W, b)$ is the cost function while b is the bias term. Training neural network basically reduces the loss function. The loss function measures how far from perfect the accuracy of the model on the dataset is (Fiore et al, 2013). Moreover, the trained model uses the sampled data to learn optimized values of weights and bias.

D. Modeling IDSEA-NIDS

Figure 2 presents the architecture of the proposed model. The model uses the same number of hidden layer nodes to introduce information bottleneck. It also imposes regularization by activating few neurons (Gao et al, 2014).

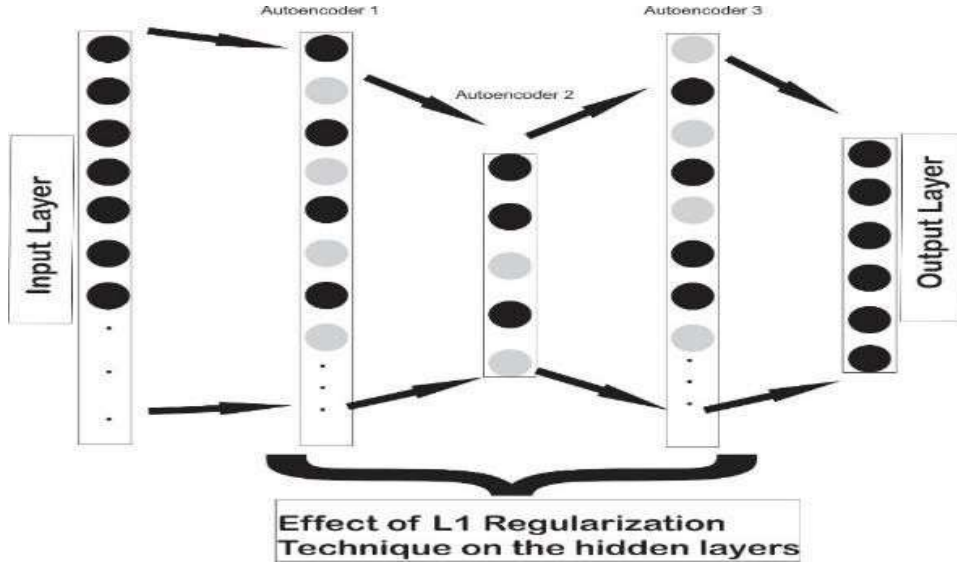


Figure: 2. IDSAE-NIDS Architecture

Sparsity was applied to the model by using L1 regularization technique to set weights to zero so as to achieve a reduction in loss value. Note that more zeros weights produce a sparse model. The study also used ReLu activation function that can actually allow the neurons to output a zero value that is, it penalizes the neurons as expected. Sparse autoencoders are autoencoders whose training procedure involves sparsity constraints. The implementation of sparsity involves the uses of regularization techniques that impose penalty to the neurons in the model. L1 regularization technique dropout and rectified linear activation function (ReLU) were used to achieve desirable sparse representation. Here, the study penalized the absolute value of the weights and as such the weight can be reduced to zero. A good model must minimize the outcome of their loss function.

$$\text{Loss Function} = \text{Loss} + \lambda/2m * \sum ||\mathbf{W}'|| \quad (3)$$

The loss function used is the 'sparse categorical crossentropy'. Lambda (λ), m and W are regularization parameter, sample size and weight of input data respectively (Jihyun et al, 2016).

Consider the equation:

$$\mathbf{y} = \mathbf{W}\mathbf{x} + \mathbf{b} \quad (4)$$

where $\mathbf{x}$ is the input, $\mathbf{y}$ the output, $\mathbf{w}$ is the weight, and $\mathbf{b}$ is the bias.

There are three (3) ways of applying regularizers as a neural network layer's parameter: Kernel regularizer, Bias regularizer and Activity regularizer (Potluri and Diedrich, 2016). L1 regularization is either applied to the weight to reduce the layer's weights $\mathbf{w}$ with 'Kernel regularizer' or a 'Bias regularizer' applied on the bias to reduce the bias $\mathbf{b}$. 'Activity regularizer' is used to achieve a reduction in the output $\mathbf{y}$. This reduced the weight and adjust the bias so

that $\mathbf{Wx+b}$ is smallest. The goal is to ensure that the output of some nodes in a particular layer is low or closer to 0 (or even 0) for the node to be deactivated completely. The research employed L1 regularization which made the weight matrix of the layer's output $\mathbf{y}$ to return 0, in other words to impose sparsity in the neural network (Jin et al, 2017) there by helping to overcome model overfitting.

Activation function is used to get the output of a neuron. Also responsible for modifying and transferring the content (the input data) of the neuron from the current neuron to the next neuron (Nathan et al, 2018).

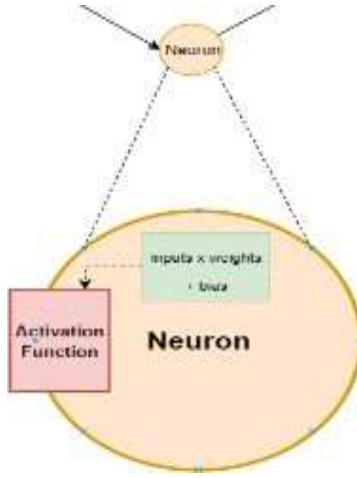


Figure: 3. A typical neuron and an activation function (Laheeb et al, 2013).

At first, the weighted sum of the inputs of the neuron were calculated as

$$Y = \sum(\text{weight} * \text{input}) + \text{bias} \quad (5)$$

For example, if the inputs are: $x_1, x_2, \dots, x_m$ and the weights are: $w_1, w_2, \dots, w_m$. After which the weighted sum (the weighted sum is the product of the inputs and the weights) is computed resulting to: $x_1 w_1 + x_2 w_2 \dots + x_m w_m$. Subsequently, a bias is added to the weighted sum: $x_1 w_1 + x_2 w_2 \dots + x_m w_m + \text{bias}$. Lastly, the value computed is passed to the activation function, which then prepares an output.

$$\text{Activation function } (x_1 w_1 + x_2 w_2 \dots + x_m w_m + \text{bias}) \quad (6)$$

4. Results and discussion

Figure 4 is the extract of results of the last eight epochs (63 to 70) of the experiment. The figure shows that increase in accuracy leads to decrease in loss. This implies that accuracy is inversely proportional to loss. The relationship is captured in the equation:

$$\text{Accuracy} \propto 1/\text{Loss} \quad (7)$$

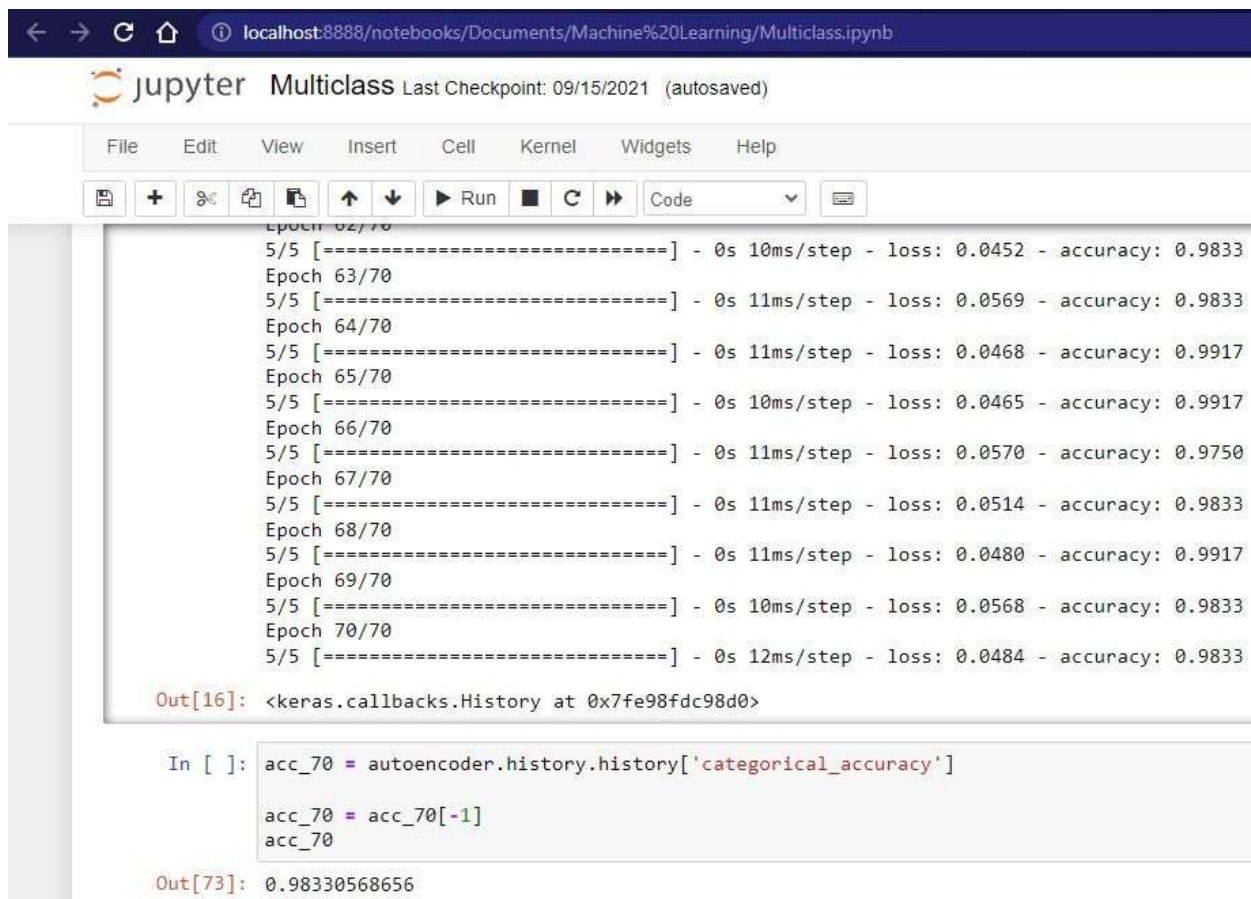


Figure: 4. Multiclass Classification Result

The model hyperparamters are:

Regularization Technique: L1 regularization Output

layer's Activation Function: ReLU Epochs: 20, 30, 40, 50, 60 and 70.

Batch size: 64; Drop out percentage:10% Numbers of hidden layers:

Table 2 shows that 20 epochs produced 58.23% accuracy.

Table: 2. Number of Epochs Vs Accuracy

S/No.	Number of Epochs	Accuracy	Loss
1.	20	58.23%	34.4202
2.	30	58.14%	0.2427
3.	40	60.00%	0.0890
4.	50	97.50%	0.0573
5.	60	97.50%	0.0672
6.	70	98.33%	0.0484

An increase in the number of epochs to 30 and the accuracy turn out to be 58.14% which is a decrease in the accuracy. The model has good performance due to reduction in loss (the model's error value) from 34.4202 to 0.2427. The loss value measures how poor the prediction rate is at a given number of epochs. More so, at this point the model has not yet learnt sufficient features of data so as to have higher accuracy. The accuracy also increased to 60.00% when the epoch increased to 40. The performance of the model improved at this point because higher accuracy corresponds to lower loss value of 0.0890. The accuracy at epoch 50 was 97.50%, while epoch 60 produced 97.50% accuracy. The respective error values for epoch 50 and epoch 60 are 0.0573 and 0.0672 respectively. It is suggested that the experiment should be terminated once there is continuous increase in loss value. This is because of continual depreciation in accuracy at this point. Updating the weights reduces the loss or error in the next epochs. Excessive training results in overfitting, hence early stopping is used to determine the maximum number of epochs a model can execute before it becomes susceptible to overfitting. Model training is usually stopped when the generalization error (the loss value) starts to increase. The last epoch (epoch 70) was added. This results in accuracy of 98.33% with a low loss value of 0.0484. The learning is sufficient enough to enable the model understand patterns in the training set within an error margin of 0.0484. It also the point where the model can be said to have converged.

Figure 5 shows that y axis represents the accuracy from 0 to 1 (represented in percentage).

Graphical representation of result



Figure:5. Accuracy vs Epochs

The x axis is the epochs' axis, that has numbers from 20 to 70 epochs in all. The curve above shows the expected increase in accuracy at the y axis as the epochs at the x axis increases. Very few epochs lead to underfitting. An increase in the number of epochs requires adjustment in the weights of the network. Increasing the epochs is not necessarily a bad idea since it can help make the proposed model more accurate. However, an ever-increasing epoch may lead to over-fitting of the neural network (Chao et al, 2019). The curve moves down a bit then up after which it reaches a plateau. Increasing the epoch at this does not produce any increase in accuracy. Hence at epochs 70 it converges, giving us an optimal model performance of 98.33%.

5. Conclusion and future work

This study proposed an improved deep sparse autoencoder intrusion detection system. The proposed approach has an accuracy of 98.33% which is higher than what was obtained in previous solutions by Quamar et al (2016) and Chuanlong et al (2019). The performance of the model is also better than what was obtained by (Sadaf et al, 2020) and (Zhang, 2018), with accuracies of 95.40% and 88.40% respectively. This is because of the application of representational sparsity in the form of rectified linear activation function (ReLU) and L1 regularization technique in the experiments. The use of ReLU, L1 regularization technique and a suitable learning rate of 0.001 results in increased detection rate of the model. A future study will implement the proposed model on more recent network intrusion dataset of higher-dimensionality since L2 regularization technique is suitable for datasets with high dimension.

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Computation of Radio Refractivity using Machine Learning Techniques

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Abstract.

In this paper, different programming languages such as R, MATLAB and Python; framework such as Sci-kit learn; and algorithms such as Regression and Artificial Neural Network (ANN) were used to compute radio refractivity in Abuja, Northcentral Nigeria. The upper air data of atmospheric parameters were collected from the Nigerian Meteorological Agency (NiMet), Abuja, Nigeria with a radiosonde. The data collected are pressure, temperature and relative humidity. The algorithm with the best results for radio refractivity computation was selected, though it was observed that all the algorithms utilised for the computation performed well. However, the ANN performed best as predicted and actual values of radio refractivity were closely related and relative errors were lower compared to other programming languages and algorithms. Hence, it was concluded that using ANN along with MATLAB would be the best algorithm and programming language for computing radio refractivity successfully.

Keywords: Atmospheric parameters, machine learning, refractivity

1. Introduction

Radio wave propagation is motivated by the traits of the atmosphere and may be scattered, absorbed, reflected or refracted because of diverse atmospheric behaviours (Adeniji et al., 2021). The troposphere is part of the atmosphere that is closest to human life and starts from the earth's surface to a height of approximately 10 km at the poles and 17 km at the equator (Hall, 1979). Radio links in the troposphere are usually affected by pressure, temperature and relative humidity (Adeniji et al., 2021). These parameters disturb the frequency and power of the radio signal (Afolabi, et al., 2019). Radio waves have significant applications in radio communications, disaster forecasting, aerospace, and environmental monitoring or impact assessments. The application of radio waves is not only restricted to the foregoing as it is also being used in medical fields (Wallnöfer et al., 2020). Also, poor propagation lessens the proper functioning of a communication link, thereby resulting in signal decline at the receiver end. The refractivity changes in the troposphere depend on different factors and consequently on radio waves effects such as refraction and interference from radio stations. Radio refractivity, n is described as the ratio of radio wave propagation velocity in free space to its velocity in an exact medium. It is mathematically written as:

$$n = \frac{vf}{vm} \quad (1)$$

Here, the velocity in a loose space is denoted by vf , while vm describes its velocity with respect to a specified medium. In the troposphere, radio wave propagation is evaluated primarily based on variations in air refractivity. The use of radiosonde by the Nigerian meteorological agency to record meteorological data is expensive and tedious (Afolabi, et al., 2019). This was why radiosonde accents were discontinued for over two decades in most places in Nigeria. Hence, some research efforts in the past such as Igwe and Adimula (2009) and Igwe (2010), at the time, could not get current upper air data for their analyses. Unfortunately, also, predicted or computed values from models used for forecasting radio refractivity are most times far from the measured values, thereby giving higher error margins. Thankfully, in recent times, the introduction of soft computing methods which can handle larger number of atmospheric data (Igwe

et al., 2017; Igwe et al., 2021) has been able to reduce this error in the prediction of radio refractivity, thus giving more accurate results.

This paper, therefore, aims at computing radio refractivity by employing different machine learning languages and atmospheric data of temperature, pressure and relative humidity, thereby determining the best algorithm from the computational results.

2. Methodology

Atmospheric parameters within a three-year time frame were used to compute radio refractivity using different machine learning programming languages. Then the best algorithm with the best results for computing radio refractivity was selected. The data collected include pressure, temperature and relative humidity. A radiosonde device was used for the data measurement and collection.

The atmospheric radio refractive index, n , was computed using:

$$n = 1 + N \times 10^{-6} \quad (2)$$

N is the radio refractivity, and it is given as:

$$N = 77.6 \frac{P_d}{T} + 72 \frac{e}{T} + 3.75 \times 10^5 \frac{e}{T^2} \quad (\text{N-units}) \quad (3) \quad \text{where:}$$

P_d : dry atmospheric pressure (hPa)

e : water vapour pressure (hPa)

T : absolute temperature (K)

C. Machine learning and predictive modeling methods

- **Regression model**

As an introduction, notation for regression models are presented. Let Y denote the response (dependent) variable, and let $X = X_1, X_2, \dots, X_p$ denote a list or vector of predictor variables (also called covariables or independent descriptors or concomitant variables). These predictive variables are assumed to be constant for a given individual or subject of the population of interest. Let $\beta = \beta_0, \beta_1, \dots, \beta_p$ denote the list of regression coefficients (parameters). β_0 is an optional intercept parameter and $\beta_1, \dots, \beta_p$ are weights or regression coefficients corresponding to $X_1, \dots, X_p$. A matrix or vector notation is used to describe a weighted sum of the X s: $X\beta = \beta_0 + \beta_1 X_1 + \dots + \beta_p X_p$, where there is an implicit $X_0 = 1$. A regression model is hence, stated in terms of a connection between the predictors X and the response Y . Let $C(YX)$ denote a property of the distribution of Y given X (as a function of X). For example, $C(YX)$ could be $E(YX)$. The regression model was used to compute atmospheric parameters and radio refractivity

- **Scikit-learn framework**

The Scikit-learn model is an open-source python machine learning library designed to work alongside NumPy. It features various machine learning algorithms for classification, clustering, and regression. The Scikit-learn model was also used to compute atmospheric parameters and radio refractivity.

- **Artificial neural network model**

Artificial neural network (ANN) with MATLAB as its machine learning algorithm was likewise used to compute atmospheric parameters and radio refractivity. The machine learning process involves: i. Data Preparation ii. Feature Selection iii. Forecast Module. The data preparation involves cleaning and organising the data to make it suitable for building and training the model. The feature selection stage helps select the appropriate features for the model. The last stage (i.e. Forecast Module) involves using the ANN to compute the radio refractivity from the selected features. The ANN was employed to make the computation via model training. The ANN architecture was used to train the data (temperature, pressure, and humidity) and make refractivity computation.

2. Results and discussion

The data was prepared, analysed and computations were made based on the selected algorithms. The results from these analyses are hereby presented.

D. Computation using regression analysis

The computations of atmospheric parameters were carried out first before the computation of radio refractivity was done using regression. The results revealed that pressure decreases as altitude increases (as shown in Figure 1). At a height of 110 m, it was observed that pressure was 1000 hPa. At 800 m, it was observed that atmospheric pressure had reduced to 922 hPa. Relative humidity was directly proportionally to height (as shown in Figure 2). At a height of 100 m, relative humidity was 50%. However, at a height of 805 m, relative humidity rose to 79%.

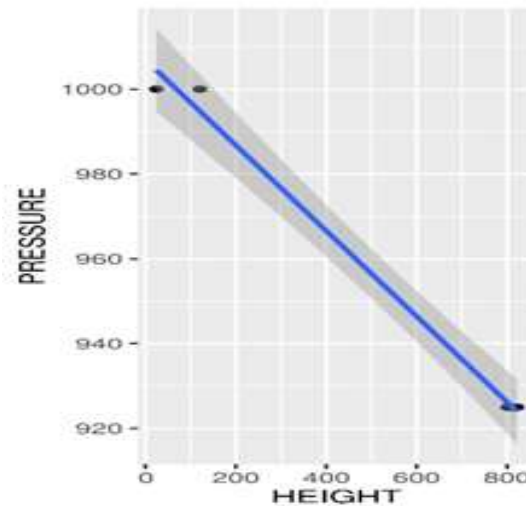


Figure 1: Relationship between Pressure and Height

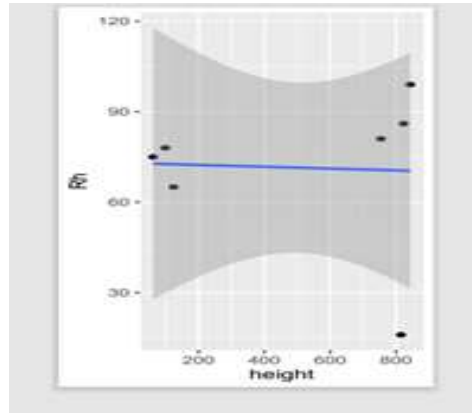


Figure 2: Relationship between Relative Humidity and Height

The predicted and actual values of the atmospheric parameters and relative errors (RE) are presented in Table 1. It was observed that the relative errors were less than 0.5%. This suggests that the regression model used for this study has a high accuracy.

Table 1: Actual and predicted values of atmospheric parameters using Regression

Mnth	Hght	Act Pres	Pred Pres	RE	Act Tem	Pred Tem	RE	Act RH	Pred RH	RE
Jan	1569	850	850	0.001	20.3	25.1	0.002	88	90.1	0.001
Feb	1711	835	849	0.002	20.3	20.7	0.003	31	34.4	0.003
Mar	495	958	957	0.002	31.9	31.9	0.000	54	54.0	0.000
Apr	1460	859	870	0.008	19.1	19.7	0.001	56.7	59.0	0.002
May	827	925	970	0.003	21.9	22.2	0.001	55	55.2	0.001
Jun	789	928	930	0.002	23.5	23.7	0.000	86	87.3	0.001
Jul	1518	855	860	0.004	20.8	20.7	0.001	86	86.0	0.000
Aug	1109	896	896	0.001	24.3	24.7	0.001	81	83.4	0.002
Sep	380	880	900	0.007	21.3	21.5	0.001	50	50.1	0.001
Oct	1897	816	821	0.004	18.7	19.2	0.003	84	87	0.003
Nov	392	970	971	0.003	32.8	33.7	0.001	42	42.2	0.002
Dec	399	972	974	0.002	30.0	30.3	0.000	57	58.1	0.001

E. Prediction using scikit-learn framework

Scikit-learn framework (A python machine learning library) was also used for the atmospheric data prediction in this work. The comparison between the predicted and actual values of pressure is shown in Figure 3. The predicted and actual values of pressure agree well with each other till day 100. However, as shown in Figure 4, the predicted and actual relative humidity values are far from each other. The comparison between the predicted and actual values of temperature is given in Figure 5. The error is again less than 0.5%, which guarantees the accuracy of the suggested scikit-learn framework.

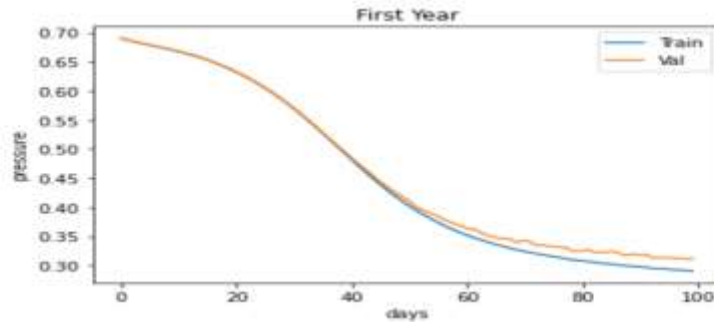


Figure 3: Comparison between predicted and actual values of pressure in relation to days

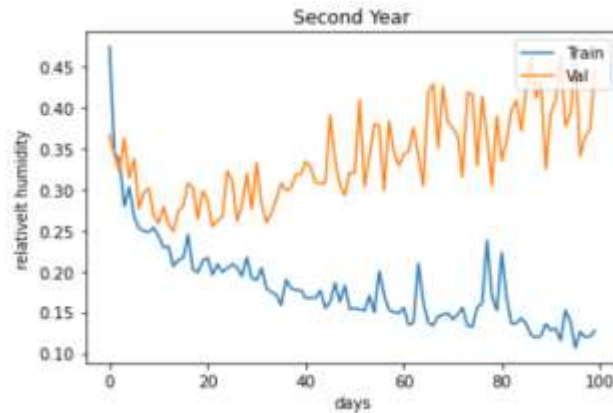


Figure 4: Comparison between predicted and actual values of relative humidity in relation to days

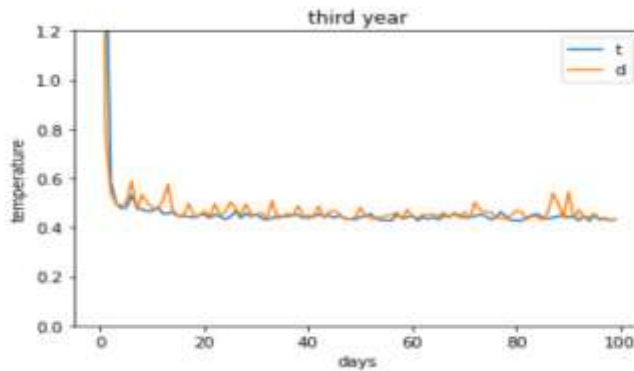


Figure 5: Comparison between predicted and actual values of temperature in relation to days

Also, the predicted and actual values of temperature, pressure, and humidity with the various computed relative errors were compared as shown in Table 2. The study reveals that the error margins between

the predicted and actual values were a bit high. For instance, the relative error for atmospheric pressure in June was 0.08 %.

Table 2: Actual and predicted values of atmospheric parameters using Scikit-learn Framework

Mnth	Hght	Act Pres	Pred Pres	RE	Act Tem	Pred Tem	RE	Act RH	Pred RH	RE
Jan	1570	925.0	925.1	0.01	18.0	18.1	0.01	81	81.5	0.04
Feb	1570	925.0	925.6	0.06	18.0	18.3	0.03	94	94.2	0.02
Mar	831	925.0	925.5	0.05	18.5	18.4	0.01	69	69.2	0.02
Apr	1565	925.0	925.3	0.03	19.0	19.3	0.03	54	54.4	0.01
May	1561	925.0	925.5	0.05	18.7	18.5	0.02	82	82.4	0.02
Jun	1550	925.0	925.8	0.08	17.8	17.4	0.04	94	94.5	0.01
Jul	827	925.0	925.1	0.01	19.1	19.4	0.03	86	86.0	0.00
Aug	1546	925.0	925.4	0.04	18.8	18.4	0.04	87	87.2	0.02
Sep	1570	925.0	925.8	0.08	19.7	19.5	0.02	67	67.5	0.05
Oct	1549	925.0	925.5	0.05	20.2	20.3	0.01	76	76.6	0.05
Nov	1570	925.0	925.7	0.07	19.1	19.4	0.03	80	80.5	0.03
Dec	1570	925	925.2	0.02	25	25.2	0.02	84	84.2	0.01

2.1 Prediction using artificial neural network

For artificial neural network prediction, information for evaluating the quality of the trained network is available from the error histogram shown in Figure 6. This gives the distribution of the residuals between targets and network outputs. The histogram is also able to indicate outliers. It was observed that most errors lie between - 1.036 and - 1.955. Although the outputs were slightly larger than the targets, the error for the best performance stood at -1.036. This indicates very low error values.

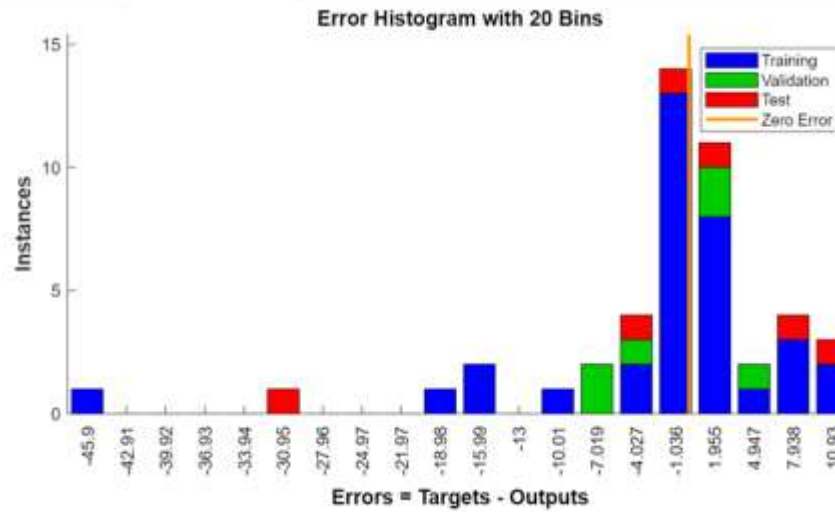


Figure 6: Error histogram of target and artificial neural network

The scatter plot shown in Figure 7 reveal that the predicted values are closer to the actual values. The correlation coefficient between the ANN output and the target values were high. The r-squared values for training, validation and test are 0.94, 0.99 and 0.91 respectively.

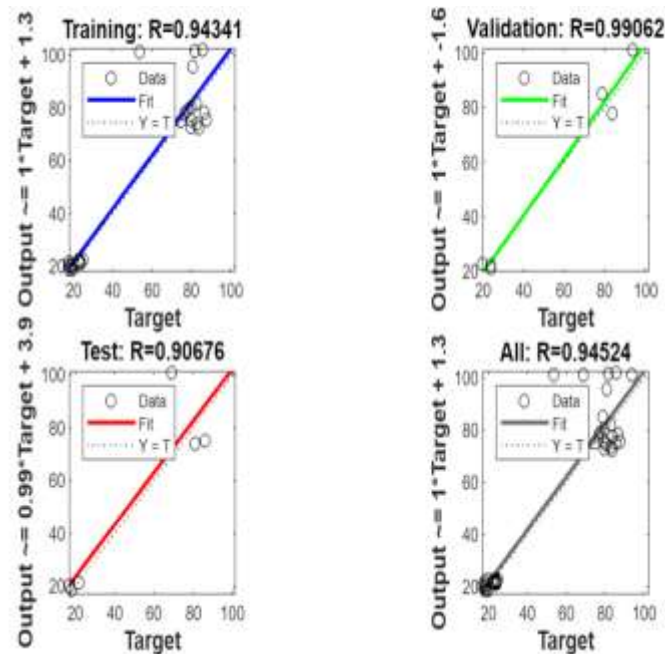


Figure 7: Scatter Plots showing Training, Validation and Test results for the ANN model

The actual and predicted values of atmospheric parameters using artificial neural network is shown in Table 3. It was observed that the relative errors were lower than 0.5% for each parameter. The relative errors for pressure, relative humidity and temperature were between 0.001 and 0.003 in most instances.

Table 3: Actual and predicted values of atmospheric parameters using artificial neural network

Mnth	Hght	Act Pres	Pred Pres	RE	Act Tem	Pred Tem	RE	Act RH	Pred RH	RE
Jan	1370	872	872.6	0.001	22.0	28.1	0.007	77	77.8	0.002
Feb	818	925	925.3	0.001	21.2	29.3	0.002	15	15.3	0.001
Mar	1544	925	925.5	0.001	22.5	28.7	0.003	52	57.9	0.003
Apr	1546	925	925.3	0.001	21.3	21.5	0.002	62	62.4	0.001
May	1560	925	925.4	0.001	19.1	21.4	0.002	95	95.3	0.001
Jun	1552	925	925.3	0.001	20.4	20.6	0.001	66	78.9	0.007
Jul	1568	925	925.2	0.001	21.4	23.1	0.003	52	52.3	0.001
Aug	1588	924	924.5	0.001	16.2	18.9	0.002	99	99.3	0.001
Sep	1581	925	925.0	0.001	19.0	19.9	0.001	77	77.4	0.001
Oct	1570	925	925.42	0.001	18.2	30.2	0.008	86	89.0	0.002
Nov	1567	925	925.4	0.001	20.0	21.3	0.001	63	63.8	0.001
Dec	832	1000	1000.32	0.001	23.0	23.4	0.001	68	69.7	0.002

The actual and predicted values of refractivity, N_s using the three algorithms (Regression, Scikit learn and ANN) are shown in Tables 4 - 6.

Table 4: Actual and predicted values of Refractivity, N_s using Regression

Month	1st Year			2nd Year			3rd Year		
	Act	Pred	RE	Act	Pred	RE	Act	Pred	RE
	N_s	N_s		N_s	N_s		N_s	N_s	
Jan	235.57	268.23	0.24	303.97	297.03	0.23	372.37	325.83	0.17
Feb	241.27	270.63	0.22	309.67	299.43	0.21	378.07	328.23	0.23
Mar	246.97	273.03	0.24	315.37	301.83	0.21	383.77	330.63	0.31
Apr	252.67	275.43	0.24	321.07	304.23	0.25	389.47	333.03	0.27
May	258.37	277.83	0.27	326.77	306.63	0.26	395.17	335.43	0.25
Jun	264.07	280.23	0.23	332.47	309.03	0.23	400.87	337.83	0.35
Jul	269.77	282.63	0.24	338.17	311.43	0.13	406.57	340.23	0.34
Aug	275.47	285.03	0.27	343.87	313.83	0.14	412.27	342.63	0.37
Sep	281.17	287.43	0.24	349.57	316.23	0.17	417.97	345.03	0.32

Oct	286.87	289.83	0.26	355.27	318.63	0.12	423.67	347.43	0.31
Nov	292.57	292.23	0.24	360.97	321.03	0.18	429.37	349.83	0.38
Dec	298.27	294.63	0.23	366.67	323.43	0.10	435.07	352.23	0.34

Table 5: Actual and predicted values of Refractivity, N_s using Scikit-learn

Mnth	1st Year			2nd Year			3rd Year		
	Act	Pred	RE	Act	Pred	RE	Act	Pred	RE
	N_s	N_s		N_s	N_s		N_s	N_s	
Jan	358.60	341.32	0.12	363.59	353.32	0.21	363.59	358.60	0.23
Feb	360.12	342.32	0.18	363.59	354.32	0.21	363.59	358.60	0.21
Mar	361.13	343.32	0.21	363.59	355.32	0.25	363.59	358.60	0.24
Apr	363.59	344.32	0.22	363.59	358.60	0.23	363.59	358.60	0.22
May	363.59	345.32	0.23	363.59	358.60	0.24	363.59	358.60	0.24
Jun	363.59	346.32	0.20	363.59	358.60	0.23	363.59	358.60	0.24
Jul	363.59	347.32	0.16	363.59	358.60	0.21	363.59	358.60	0.24
Aug	363.59	348.32	0.22	363.59	358.60	0.23	363.59	358.60	0.24
Sep	363.59	349.32	0.23	363.59	358.60	0.23	363.59	358.60	0.24
Oct	363.59	350.32	0.24	363.59	358.60	0.21	363.59	358.60	0.24
Nov	363.59	351.32	0.22	363.59	358.60	0.24	363.59	358.60	0.24
Dec	363.59	352.32	0.22	363.59	358.60	0.23	363.59	358.60	0.24

Table 6: Actual and predicted values of Refractivity, N_s using ANN

Mnth	1st Year			2nd Year			3rd Year		
	Act	Pred	RE	Act	Pred	RE	Act	Pred	RE
	N_s	N_s		N_s	N_s		N_s	N_s	
Jan	358.60	357.30	0.21	363.59	352.49	0.22	363.59	356.14	0.20
Feb	360.12	359.01	0.20	363.59	353.56	0.21	363.59	355.87	0.23
Mar	361.13	360.10	0.23	363.59	352.53	0.23	363.59	352.82	0.21
Apr	363.59	362.60	0.21	363.59	356.76	0.20	363.59	350.80	0.22
May	363.59	357.95	0.21	363.59	356.40	0.21	363.59	353.13	0.21
Jun	363.59	359.24	0.20	363.59	355.34	0.22	363.59	353.91	0.22

Jul	363.59	360.94	0.21	363.59	358.00	0.25	363.59	354.85	0.22
Aug	363.59	358.38	0.22	363.59	357.30	0.23	363.59	346.59	0.23
Sep	363.59	359.57	0.21	363.59	357.19	0.21	363.59	353.59	0.20
Oct	363.59	356.39	0.21	363.59	353.49	0.25	363.59	353.59	0.24
Nov	363.59	355.19	0.24	363.59	357.65	0.21	363.59	353.59	0.21
Dec	362.59	354.22	0.22	363.59	357.31	0.21	363.59	353.59	0.22

From Tables 4-6, it is observed that refractivity values are lower for the first year, whereas higher values were observed for the remaining 2 years. It is also noticed that predicted refractivity values were closer to actual values with the relative error values less than 0.5% in all the years. However, radio refractivity computation using artificial neural network gave better results. This agrees with the conclusions of Javeed et al. (2018) and Ayantunji et al. (2019). They concluded that neural networks can be used for successful estimations of atmospheric parameters of humidity, pressure, and refractivity.

3. Conclusion

Radio refractivity has been computed using different algorithms and frameworks in this paper. The best algorithm was selected as the most appropriate. Regression analysis with R programming language, scikit-learn framework with Python programming language and artificial neural network with MATLAB were employed to compute selected atmospheric parameters (pressure, temperature, relative humidity) and radio refractivity. The results revealed that the computed relative errors for the atmospheric parameters and radio refractivity were relatively low. In all, the computed values of all the atmospheric parameters and refractivity were close to their respective actual values, with less than 0.5% relative errors. Also, refractivity values were lower for the first 1 year, whereas higher values were observed for the remaining 2 years. However, computation of radio refractivity using artificial neural network was better in comparison to other algorithms.

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Prediction of Lightning Occurrence in South Africa Using Neural Network and Meteorological Data

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Abstract.

Many advances are being made in the prediction of lightning across the world. Researchers have investigated many different ways to predict lightning, from statistical techniques to the traditional machine learning techniques and most recently the use of deep learning techniques. The data used for these predictions range from the use of numerical weather prediction (NWP) models and parameterization schemes to using satellite images or the commonly available meteorological features which are easier to obtain and make for computationally less expensive models. South Africa is one of the leading African countries in lightning research and lightning detection, but very few papers have focused on using the available lightning detection networks to develop lightning prediction models to manage the risk of lightning in the country especially in rural areas which are prone to such incidents due to the lack of protection and efficient warning systems. In this paper, we use deep neural networks and meteorological data from the SAWS to predict the occurrence of lightning.

Keywords: Music genre classification, Q-learning, recommendation, Content-based Features, Machine Learning

1. Introduction

Wildfires, human loss, rocket crashes, and electrical outages. A large portion of these unfortunate events can be accredited to lightning storms, and due to climate change, they are only getting worse Mahomed et al. (2021). These disasters cause a lot of distress to our livelihoods as they affect the economy at large. We thus see the need to accurately predict the occurrence of this phenomenon in order to avoid or limit its effect. Researchers have come up with different methods and approaches for the accurate prediction of lightning. From using numerical weather methods with parameterization schemes, to the use of historical data for either statistical, Machine learning, or most recently the use of deep learning models to accurately predict lightning occurrences. Each one of these methods produced varying results in accuracy levels, but the use of these deep learning techniques has shown significant improvement in their predictions with the downside being that a lot of the models are either computationally expensive or require satellite data and radar systems which are too expensive and difficult to maintain for developing countries. This is a problem because developing countries in Africa and South America experience some of the highest number of lightning strikes in the world and these countries are mostly rural and lightning mortality is significantly more of a problem in the rural areas. According to Blumenthal et al. (2012) rural areas in South Africa have an 8.8 people-per-million mortality rate compared to a 1.1 people-per-million in urban areas.

Evidently, we need to develop cheaper lightning prediction models that are not too difficult to maintain in order to protect some of the most vulnerable people in the world, the people in the rural areas of developing countries. South Africa has made great investments in lightning detection with their acquiring

of a vaisala-sensors lightning detection network which made them only the third country in the southern hemisphere after Australia and Brazil to own such a network Mahomed et al. (2021). There have been many attempts and contributions to the field of lightning research from multiple institutions in the country, while the forecasting of lightning threat has been documented by the SAWS mostly Mahomed et al. (2021). Although many strides have been made and South Africa is one of the leading African countries in lightning research, there have been very few approaches using deep learning and machine learning techniques which have provided some of the highest accuracy in predictions in other countries. In this paper we try and use commonly available meteorological parameters along with the lightning data from SALDN to train a deep neural network using Keras to predict the occurrence of lightning.

2. Related Work

Lightning is defined as a very long electrical spark generated in thunderstorms and measures an average length of 5 km to 10 km with extremes of about 100 km Dwyer & Uman (2014). Lightning is formed due to charge transfers in thunderstorms, and these charge transfers occur when soft hail particles that are heavy enough to fall or remain stationary in the updrafts of thunderstorms and tiny ice crystals that are light enough to be carried upwards in those drafts collide in very cold altitudes. These particle collisions need to happen at very high altitudes where the temperature is considerably colder than freezing, generally -10 degrees to -20 degrees Celcius" Dwyer & Uman (2014). Lightning occurs more often than any other phenomena and despite lightning being the subject of many research papers, it is still the subject of many debates within the field of physics, with different researchers providing different explanations about its formation. According to Blumenthal et al. (2012) about 2 000 thunderstorms occur worldwide, producing about 100 lightning strikes each second or 8 million strikes each day and excluding incidental catastrophes and disasters, lightning causes more deaths than any other natural event or phenomenon claiming about 24 000 lives each year. It is also estimated that some 240 000 people a year will survive a lightning strike. Mahomed et al. (2021) suggests that South Africa has some of the highest lightning mortality rates in the world which might also be understated due to the tendency of people in rural areas not to report such incidents. Due to climate change continuing to raise the general temperatures in Africa, lightning will continue to be a problem that affects the development of the continent because of the nature and extent of the damage it brings to the land.

2.1 Formation of Lightning Clouds

Electrostatic discharge occurs when there is a build up of static charge which occurs due to the electrification and electrostatic induction Akinyemi et al. (2014). The flow of electrical charge can result in an electrical spark being created, and this spark carries a cracking sound. Lightning and thunder are large scale occurrences of this electrostatic discharge that occur in the atmosphere. As the air pushes upwards in the clouds, ice particles moving in opposite directions rub against each other and this creates a polarization process where different particles acquire different charges of electricity. Positive charges that are generated in the process drift upwards in the cloud and the negatively charged particles drift downwards. As the cloud size increases, there is an increase in electric potential difference between the upper positive and lower negative parts, which in turn lead to electrostatic discharge between the two oppositely charged areas in the clouds Akinyemi et al. (2014).

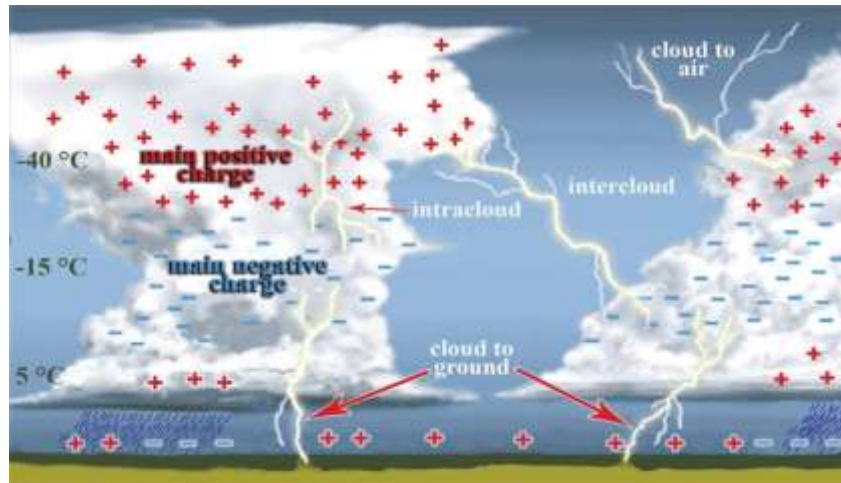


Figure 1: Separation of charge in a cloud (Dwyer & Uman, 2014)

2.2 Categories of Lightning

Lightning discharges fall into two categories: Cloud lightning and Cloud-to-ground lightning. Cloud lightning is then further divided into two categories, namely: Intra-cloud lightning and Inter-cloud lightning. Intra-cloud lightning occurs between particles within the same cloud and is thought to be the most common type of lightning Dwyer & Uman (2014). Inter-cloud lightning occurs between charged particles in different clouds.

Lightning is not only a threat to the human population, but it affects animals and the ecological system since it is one of the sources of forest fires. Blumenthal et al. (2012) estimates that each year the death rate because of lightning is between 1.5 and 8.8 people per million in urban areas and rural areas respectively. It becomes necessary to predict lightning in order to avoid hazards and protect people and the environment.

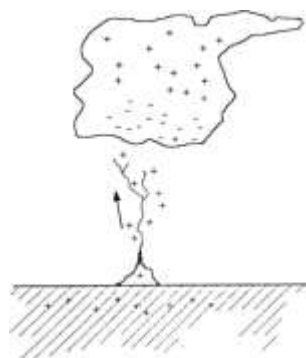


Figure 2: upward positive lightning. adapted from (Akinyemi et al., 2014)

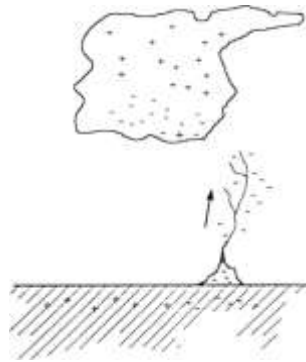


Figure 3: upward negative lightning. adapted from(Akinyemi et al., 2014)

The outstanding issue is that it is hard to predict thunderstorms because they occur in a very small area of the world at a particular time, and they only occur for a relatively short time period in most areas of the world. Due to this uncertainty in the development of these thunderstorms, and researchers having different ideas about how we come to experience this phenomenon, it becomes difficult to make these forecasts Akinyemi et al. (2014). There have been many approaches to predict lightning, with different researchers using different approaches that range from the NWP models which given initial conditions simulate atmospheric evolution in order to make predictions about the future Geng et al. (2019). Statistical techniques have also been used for the prediction of lightning, these techniques usually depend on the relationship between lightning occurrence and the parameters of the environment before the storm Gijben et al. (2017), Deep learning techniques have been some of the recent and most accurate models in the prediction of lightning.

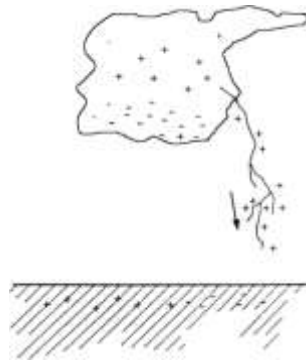


Figure 4: downward positive lightning. adapted from (Akinyemi et al., 2014)



Figure 5: downward negative lightning. adapted from (Akinyemi et al., 2014)

2.3 Data and Features

Different authors have provided different implementations from a range of data. Lightning prediction methods often use numerical weather prediction models and parameterization schemes. Gijben et al. (2017) uses NWP data to forecast the probability of CG lightning for austral summer months. Essa et al. (2020) used the past lightning events data from the South African Lightning Detection Network to predict lightning flash-densities in two areas. One area represented a high flash-density area and the other one represented a moderate flash-density area for short periods using four years of training data for the corresponding periods of prediction. Mostajabi et al. (2019) also used commonly available meteorological data from the air pressure to the temperature and wind speed. They took this data from 12 weather stations widely distributed across different ranges of altitudes and topographies in Switzerland. The idea of combining two lighting prediction approaches strongly relates to Geng et al. (2019)'s proposal of a dual-encoder that uses recent lightning observations along with the observations it gets from the Weather Research and Forecasting model, which is a numerical weather prediction system that provides the simulation data to calibrate the simulations and assist with the prediction. Schöon & Dittrich (2019) uses satellite images and past lightning observations to predict whether or not lightning will occur whereas Omar et al. (2013) also used the meteorology parameters obtained from the local Malaysian weather service. These features ranged from the minimum and maximum humidity, the minimum and maximum temperature, the rainfall alongside the month and specific week. Omar et al. (2013) used these inputs and classified them according to their severity. Speranza III (2019) used data from the Electric Mill Fields (which are not present in all countries) and combined it with surface observations from the 50 nearby weather stations which were processed to identify suitable regressors.

2.4 Models and Accuracy

Several lightning prediction models have proposed several different techniques. Geng et al. (2019) developed a dual-encoder that uses both Numerical Weather Prediction models and recent weather observations. Their method starts by extracting features concerning space and time in the data from the WRF model and the historical data observations, they do this via the dual encoders. The extracted features are then brought together by a fusion module and, then they serve as input into a spatiotemporal decoder to make predictions. They used a Convolutional LSTM instead of using a fully connected LSTM for its ability to better handle spatial-temporal data. This paper also introduces two versions of this dual encoder,

Lightnet-O, and Lightnet-W which respectively represent the Lightnet algorithm but with the Observation Encoder removed, and another that does not have the NWP model data encoder.

In comparison with seven other prior models and conventional methods used in meteorology, including the commonly used PR92. The performance evaluation is done using the False Alarm Ratio, the Probability of Detection (POD), and the Equitable Threat Score. The model results show that for an hour's prediction their LightnetO version achieves the highest POD values, and for the first 3-hour prediction, their Lightnet and Lightnet-O have pretty much the same POD values and have an obvious advantage over other models that they are being compared to. For the 6-hour prediction, Lightnet achieves the highest performance tally on the POD test. The proposed dual-encoder performs significantly better than other models when it comes to prediction and serves as a new comparative baseline for improvements albeit being computationally expensive. The Lightnet dualencoder was extended from Shi et al. (2015) who first proposed the use of a Convolutional-LSTM over a Fully-connected LSTM for nowcasting precipitation.

The two methods proposed are the Gradient Descent with Momentum Backpropagation and the Scaled Conjugated Gradient Backpropagation provided satisfying results in classifying the severity of daily lightning using the seven meteorology parameters used as input. In this paper, we are interested in Omar et al. (2013) because of the use of the meteorological features which we will consider using for our research as we aim to improve upon the work done by Essa et al. (2020). Essa et al. (2020) who was the first publication to use deep learning for lightning research in the country, Essa et al. (2020) used the LSTM Recurrent Neural Network for predicting lightning flash-densities and performance tested the hypothesis using POD and FAR. They found that the LSTM model was able to predict just over a third of the major lightning events. In the high flash-density area, about half of the predicted outcomes came true while only 20% of the predictions turned out to be true in the area of moderate flash-density. These results serve as motivation for expanding and improving upon the prediction of lightning flash-densities, which is the purpose of this paper.

In this paper we aim to develop a deep neural network using meteorological parameters from the SAWS in order to predict the occurrence of lightning in 9 different weather stations located in each province as to provide different topographies and characteristics. We develop our model using data we received from the SALDN and make the prediction of whether lightning will occur or not. Our study contributes to the current literature in a way that: It is the first use of deep learning techniques to predict lightning occurrence in South Africa; and it uses cheaper more accessible information like the meteorological parameters in order to make these predictions.

The aim of the research is to develop a lightning prediction model that uses commonly available meteorological parameters and lightning data from the SAWS to predict the occurrence of lightning in an area. Lightning prediction models are much needed in our society and an accurate lightning prediction model would save lives and the economy. We develop a DNN using commonly available meteorological parameters from SAWS in 9 weather stations located in each province of the country. We make predictions for different intervals of time to test the accuracy of our model.

3. Methodology

In this research we use a deep neural network in Jupyter Notebook using Keras to predict the occurrence of lightning. We train our data using meteorological parameters such as the temperature, air pressure and lightning data that we got from the SAWS, and we use the SALDN data to indicate whether or no lightning has occurred.

3.1 Data

We use two datasets from the SAWS and SALDN. One dataset contains the hourly recording of the temperature, pressure, wind speed, wind direction, humidity and rain at 28 weather stations distributed in all provinces of the country. The data starts from January 2007 up until December 2020 and is split into 3 excel files containing data for 3 provinces each.

3.2 Methods

We start by constructing a deep neural network in python using Keras, our variables are the meteorological parameters provided by the weather stations dataset. Using the SALDN data we introduce a class that describes the occurrence of lightning. If there was a record of lightning in a particular hour the value of that column is stored as 1 which means yes and if not we store it as 0 - meaning false. We then create a sequential model where we find optimal number of layers for our model and use a fully-connected model to predict the occurrence of lightning. *Inputs:* The input layer takes in the 6 meteorological features that we have - Temperature, Windspeed, Humidity, Wind Direction, Pressure and Rain. We re-scale our input to be in the range 0-1 so to assist in learning and to avoid unseen weighting of features.

Models We used a standard Neural Network constructed using the sequential() model in keras, it has 2 layers that uses the tanh function along with the sigmoid function for classification. This model was developed in Jupyter notebook using Keras. We ran the model with varying epoch values - but stuck with 29 epochs and a batch size of size - based on trial and error. We used Adam optimizer along with the Binary-cross entropy metrics for learning - we reduce data overfitting by initiating L1 and L2 regularization term when training the data. We compared the learn rate of our standard Neural Network with Radial Basis Function Networks - of which we created a layer that takes in 4 units and gamma as 0.5. We define 2 dense layers with an RBF layer in-between still using Adam optimizer and Binary-cross entropy metrics for learning. *Outputs:* Binary classification with output 0 or 1 which indicates whether or not lightning occurred.

4. Analysis

Evaluation of Neural Network Predictive Ability

We assess the performance of all our models by using the binary Cross-Entropy function

$$LogLoss = \frac{1}{N} \sum_{i=1}^N - (y_i * \log(p_i) + (1 - y_i) * \log(1 - p_i))$$

Since we map our class output to either 0 or 1. Here p_i is the probability of class 1 and $(1 - p_i)$ is the probability of class 0. N is the number of entries/rows. We cross-validated the data using 5-fold cross validation to test the model's predictive ability. We also evaluated the predictive ability among the test set.

4. Results

4.1 Accuracy Comparison Between Standard Neural Networks and Radial Basis Function Network

Table 1: Train vs Test Accuracy of Standard NN and the RBFNN on combined dataset

	<i>Train</i>	<i>Test</i>
<i>StandardNeuralNetwork</i>	79.43%	78.97%
Radial Basis Function Net	80.08%	80.32%

Table 2: Avg. Train vs Test Accuracy of High-Lightning density areas Standard NN and the RBFNN in

	<i>Train</i>	<i>Test</i>
<i>StandardNeuralNetwork</i>	78.47%	78.91%
Radial Basis Function Net	78.12%	80.00%

Table 3: Train vs Test Accuracy of Standard NN and the RBFNN in Low Lightning density areas

	<i>Train</i>	<i>Test</i>
<i>Standard Neural Network</i>	80.39%	79.37%
Radial Basis Function Net	79.79%	81.17

Tables 1, 2, and 3 represent the predictive ability of each Neural Network using different training sets. In the first method, we combine all the weather stations into one and then we train the neural networks based on those results. Secondly we train our model on the high-lightning density areas and the low density areas. These tables also provides a competitive comparison between our models and their accuracy in prediction.

4.2 Loss Comparison between Standard Neural Networks and Radial Basis Function Network

Figure 6 and 7 have the validation error being below the loss error which means that the error e get from the training data is higher than the error we get from the validation data. We can accredit this behaviour to the regularization terms we use during training and it's absence during validation.

Comparing figures 6 and 7 with figure 8 and 9, we can clearly see that the RBFN converges quicker and learns the parameter quicker than the Standard Neural Network Models which is expected by (Jeatrakul & Wong, 2009)'s comparison.

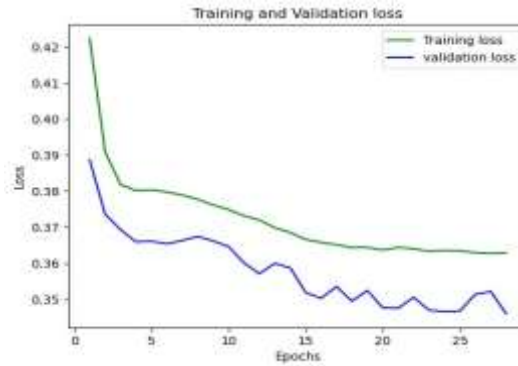


Figure 6: Training Loss vs Validation Loss for Std. Neural Network using combined SAWS data

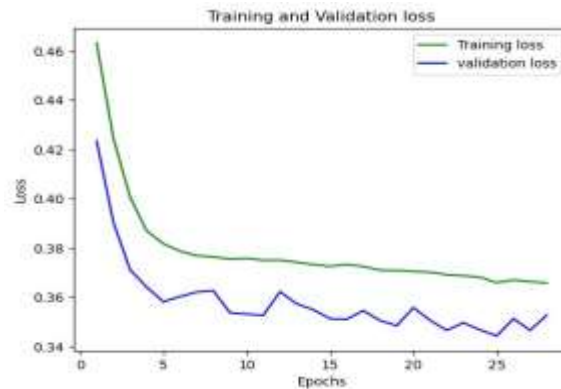


Figure 7: Training Loss vs Validation Loss for Std. Neural Network using Highdensity lightning areas

The low-lightning density areas the accuracy for both models was higher than when we were predicting the occurrence of lightning in high-lightning density areas, this may be accredited to rarity of the events and the clear distinction that we have in these areas when there are thunderstorms and when there aren't any.

4.3 Prediction

We found that the commonly available weather parameters are good enough in simple lightning occurrence predictions. We also observe that RBFNs - which are as accurate in prediction can improve upon the standard Neural Networks by using a simple architecture that learns a lot faster than the standard Neural Network.

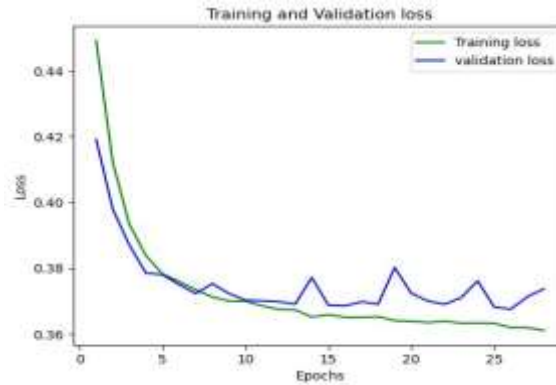


Figure 8: Training Loss vs Validation Loss for Std. Neural Network using Lowdensity lightning areas

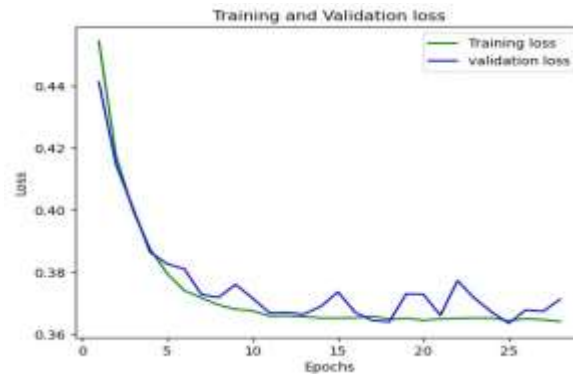


Figure 9: Training Loss vs Validation Loss for RBFNN using using combined SAWS data

When we plot the accuracy matrix we did not see any False Classifications which was concerning and means that we did not have enough training data for our models as they both classified the same way but the accuracy results do not point us towards overfitting.

5. Conclusion

A lot of work has gone into lightning research both in South Africa and Africa at large, so as to address one of the deadliest natural events in the continent Blumenthal et al. (2012). Very few literature has focused on the prediction of this phenomenon with Gijben et al. (2017) being the first to use an NWP model to forecast lightning events and Essa et al. (2020)'s work being the first one to use deep learning for lightning research in the country even though deep learning approaches have been some of the most accurate models in lightning predictions.

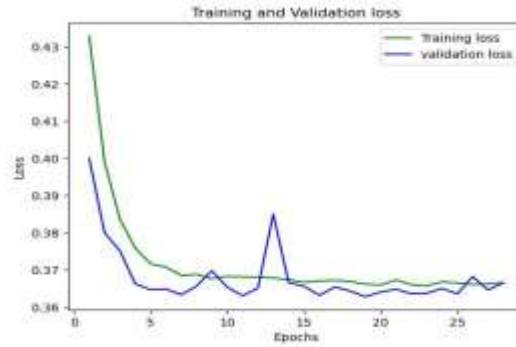


Figure 10: Training Loss vs Validation Loss for RBFNN using High-density lightning areas

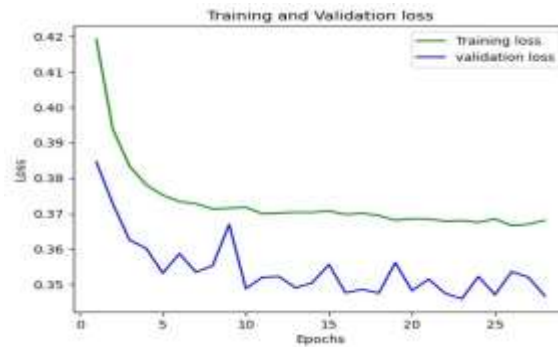


Figure 11: Training Loss vs Validation Loss for RBFNN using Low-density lightning areas

Understandably, developing some of these models is expensive and impractical for most African countries so the focus should be to use more accessible information to make these predictions.

We have managed to show that Deep Learning Approaches provide good predictions in the prediction of lightning as we are able to identify relationships between them and the occurrence of lightning from 2 distinct datasets. We could improve upon this model by introducing more data for training and using time series data to identify more complicated relationships in terms of predicting lightning.

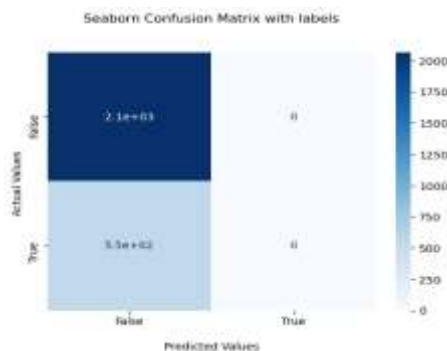


Figure 12: Confusion Matrix for both Neural Network models

We can successfully predict the occurrence of lightning, we can build upon this and utilise time series data in an attempt to determine the exact hour lightning is gonna occur. We could utilise these commonly available weather parameters to build more complicated systems such as time series data using Convolutional Neural Networks following in the work done by Essa et al. (2020) by identifying spatial features in the SALDN dataset. The amount of data we used for training provided a bias in our network as we used a sample of the data we had in order to construct the network. In this way we can improve our predictive model.

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Stock Trading Optimization in Emerging Market of Nigeria Using Deep Reinforcement Machine Learning and Equity Market Neutral Strategy

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Abstract

Investment managers are continuously looking for new technologies and better ideas to enhance their results of higher returns on investments in stock trading, and with the successes machine learning methods have been recording in other fields, it has been attracting the full attention of industry players. However, in traditional and generic portfolio strategies, forecasting of future stock prices as model inputs is a requirement, but it is not a trivial task since those values are not easy to obtain in the real-world applications. In an attempt to overcome this shortcoming, Mu-En Wu et al., (2021) developed an equity market neutral (EMN)-based portfolio management system (PMS), using reinforcement machine learning (RML), in which deep deterministic policy gradient (DDPG) and vanilla policy gradient (VPG) algorithms were used to train two neural networks; convolutional neural network (CNN) and recurrent neural network (RNN), and novel reward functions involving average returns (Aret) and Sharp ratio (Shar) were used to evaluate the performance of the developed model. Experimental results of this strategy show that the sharp ratio reward function (PMS_CNN_Shar and PMS_RNN_Shar) outperformed the returns reward function (PMS_CNN_Aret and PMS_RNN_Aret) in terms of profitability and risk. Sharp ratio reward function achieved 11.152% higher profits than those obtained using the return reward function. This study aims to improve on the study done by Mu- En Wu et al., by optimizing features selection process using ant colony optimization (ACO), the results of which show marginal improvement on the ones obtained in literature. The study also show that there is no difference whatsoever between results obtained using data from the emerging market of Nigeria and that obtained from advanced economy used in literature.

Keywords: Stock Optimization, Emerging Market, Reinforcement Machine Learning, Equity Market Neutral

1. Introduction

Investment in stocks is one of the legal means by which wealth is being created worldwide. Financial market applications routinely make use of engineering methods and systems, such as signal processing, control theory, and advanced statistical methods Kanwar (2018). Investment funds managers are continuously looking for new technologies and ideas to enhance their results of better returns on investments, and lately, with the success observed in other fields, wealth managers are taking a very kin interest in machine learning methods Huertas (2020). An increasing number of funds are beginning to include machine learning techniques as part of their tools for wealth management Huertas (2020). Due to its versatility across a wide range of fields, reinforcement machine learning (RML) is a important area of study in this field. Neural network

(NN) models are utilized as policy agents within the RML architecture and are employed to support decision-making through extensive trial-and-test procedures.

NNs comprise of a number of highly-interconnected elements, processing information at multiple levels via dynamic response to external information, Mu-En Wu et al. (2021). Deep learning refers to a number of codified layers of NN that have been developed as a result of the quick development of computing power and parallel computing. Recurrent neural networks (RNN) and convolutional neural networks (CNN) are typical deep-learning architectures (CNN).

Stock financial data comprises time-series information related to prices, such as, opening, highest, lowest, and closing prices (abbreviated as OHLC prices), Mu-En Wu et al., (2021). Time-series can be thought of as sequential data that works well for RNN-based prediction applications.

According to Syu JH et al (2019), the learning mechanism of RML is similar to human investment activities. Investors can get information for future investments through trial-and-error of actions (investment decisions) and rewards (investment returns), through the interaction between investment managers (learning agent) and the stock market (environment). The aim of this study is to develop a reinforcement machine learning (RML) model for generating profitable stock trading strategy, in emerging market of Nigeria, using equity market neutral (EMN) technique. The objectives to realizing this set goal are to:

- i. build dataset for daily stock prices, ranging from January 1, 2000 to December 31, 2003.
- ii. transform the dataset into input tensors (stock trading environment) for the neural network (NN)-based RML training, and decompose the tensors into long and short independent RML models.
- iii. train Recurrent Neural Network (RNN) and Convolutional Neural Network (CNN) using five (3) different algorithms for the two independent RML models and summing the output weights to construct the final portfolio.
- iv. evaluate the performance of the developed model in terms of the various reward functions (returns, Sortino, Sharpe ratio, MDD, and PF), and in terms of scalability of the proposed PMM.

The PMS presented in this study comprises of three major modules thus: (1) data curation and pre-processing; (2) NN-based RML portfolio; and (3) EMN strategy. The data curation and pre-processing phase arranges price data from different sources and periods and transforms them into input tensors for the NN-based RML portfolio module, which in turn learns trading information from the data in order to generate long- and short-term portfolios. The final states for portfolio management are obtained by combining long and short positions in the EMN strategy module. In order to improve the portfolio strategy, spatial and temporal information was also handled by the two NN-based RML models (CNN and RNN). This made it possible for the PMS_CNN and PMS_RNN models to provide stocks the proper weights to help with resource allocation for each training day.

For evaluating the PMS's performance, several indicators were used. Total return gauges how profitable a particular technique is. The maximum drawdown (MDD) shows the largest losses that can be sustained while trading, while the Sharp ratio shows the amount of profit that can be

made for a given unit of risk (volatility). These are the phrases that are most frequently used to describe the effectiveness and efficiency of trading strategies.

2. Literature Review

2.1 Equity Market Neutral (EMN)

A hedging technique named EMN is based on holding onto relatively strong commodities while shorting comparatively weak ones in order to profit from the difference in value between the two holdings. While the corresponding long and short positions are utilized to lower systemic risk in the market, all of the money from short positions is invested back into the market and covers all of the long holdings. The net investment money is zero, and theoretically, EMN does not impose any investment capital. In reality, short selling needs a certain margin to keep EMN's balance, and in actuality, EMN still needs some investment funds.

Many variants of the EMN model have been developed in recent decades. Alexander and Dimitriu (2002) proposed the EMN strategies with enhanced index tracking, wherein portfolios are optimized through co-integration rather than correlation, resulting in 2% annual volatility in the DJIA. Vijayalakshmi and Michel(2019) solved complex constrained EMN portfolios using differential evolution for optimization.

The aforementioned studies show how effective and profitable EMN-based portfolio management strategies are, however it should be emphasized that assessing and categorizing companies based on their characteristics (strongness and weakness) is not an easy operation. Investors typically use the stock's previous performance to estimate the stock's future performance and to determine how strong the stock is. However, it necessitates a significant assumption - one that cannot be proved and is frequently mistaken in the financial markets - that the attribute is stationary.

Attributes can also be evaluated according to their features, such as the multi-factor model Mu-En Wu et al. (2021); however, feature gathering is costly, and over-fitting is a constant issue. Therefore, to assess stock features, choose portfolio weights, and create an EMN portfolio strategy, state-of-the-art RML technique is being applied.

2.2 Reinforcement Machine Learning (RML)

The neural network learning technique known as reinforcement machine learning (RML) is centered on how a software agent behaves in a given environment. It refers to learning how to control a system (environment), so as to maximize some numerical value, which represents a long-term objective (discounted cumulative reward signal), Fellowet.al (2016). The agent learns behaviors in order to accomplish its objective using reinforcement learning techniques. As a sub-field of machine learning, it can be applied to a gamut of domains including Robotics, Medicine and Finance, Huertas (2020). The aforementioned domains have seen numerous RML applications that have been effective. This study is developing an agent that will be intelligent enough to comprehend the dynamics of the stock market and assist traders in maximizing their earnings with the least amount of supervision and input. When interacting with the stock market environment, the developed portfolio management agent will act when it is presented with new states. Additionally, the environment will inform the agent of any gains or losses in wealth when each action is completed.

A reinforcement learning system has four basic sub-elements, in addition to the agent and the environment: a policy, a reward signal, a value function, and, if present, a model of the environment. (Source: *Reinforcement Learning: An Introduction; second edition; Richard S. Sutton and Andrew G. Barto*).

2.3 Convolutional and Recurrent Neural Networks (CNN & RNN)

Deep neural network topologies used in a number of applications include convolutional neural networks (CNNs) and recurrent neural networks (RNNs). A subclass of the discriminative deep architecture, CNN has shown success in the processing of multi-dimensional data (images and videos). Using convolution and pooling techniques, it also lowers the complexity of the learning process. In addition to being utilized for financial data analysis, CNN has been employed for jobs involving recognition and classification in multimedia. Tsantekidis et al. (2017) proposed a deep CNN scheme for the prediction of price movements using a large dataset of high-frequency transactions records. Their scheme outperformed simple DNN and SVM in terms of recall as well as precision. Chen et al. (2020) formulated a deep CNN model using planar feature representation for the analysis and prediction of stock prices. Their scheme achieved accuracy of 57.88% in three-category prediction.

In contrast to feed forward networks, RNNs use a feedback loop to keep track of prior choices and permit iterative development. Their memory architecture was modeled after how humans learn and remember things, where information and choices from the past can influence actions taken in the present. In both financial and natural language processing, RNN has demonstrated exceptional effectiveness. Rastegar&Dastpak, (2018) predicted stock closing prices by RNN model with principal component analysis (PCA) dimension reduction. Price forecasting is the main focus of the majority of recent research on CNN and RNN use in the financial sector. This research, on the other hand, concentrates on creating precise trading strategies and techniques for managing a portfolio.

3. Methodology

The premise of this work is the optimization of asset allocation and portfolio management using reinforcement machine learning (RML) techniques. Deep Learning networks were used as the portfolio management agents that experimented in the stock market environment, thus learning in the process the dynamics, and invested in the best stocks, thereby increasing the overall portfolio wealth. Deep Learning networks are well known for their abilities as systems for approximating function to learn highly complex features in a high dimensional space.

The approach used in this study covers four (4) distinct topics. In the first, problems with data curation and pre-processing are discussed, and in the second, techniques for reinforcement machine learning (RML) are discussed. Understanding the inner workings of the RML agents depends heavily on this. Reinforcement machine learning (RML) portfolio is covered in the third section, and EMN approach is covered in the fourth section to close out the chapter.

3.1 Stock Data from Nigerian Stock Exchange (NSE)

The dataset for daily stock prices covering the period from January 1, 2000 to December 31, 2003 was created using the stock prices from a chosen thirty (30) companies listed on the NSE. The

financial, manufacturing, and general services sectors of the economy are represented by the 30 companies that were chosen. These businesses come from:

From the financial sector, sixteen (16) businesses were chosen, including eight (8) from the banking industry and eight (8) from the insurance industry. Three (3) businesses were chosen from the general services sector, and eleven (11) were chosen from the manufacturing sector. The NSE permits daily data requests for a range of stocks. Data collection times for training, testing, and evaluation were separated. The testing period for the training data was from January 1, 2002 to April 30, 2003, the evaluation period was from May 1, 2003 to December 31, 2003, and the training period for the training data was from January 1, 2000 to December 31, 2001 (50%), respectively. For each stock, the data includes the standard open, high, low, close, and volume values for each day. The daily price information for 30 companies is included in the entire dataset.

Following the acquisition of the raw data, a representation of the data that can be used to train a neural network was created. A reward function was then developed to describe performance for each daily time step, as well as the reasoning behind updating the environment after each step.

3.2 Data Cleaning and Pre-processing

The pre-processing carried out on the data obtained is discussed here. The processing commences with data curation, which is the organization and integration of the data collected from various sources, for the different companies used in the study. Following that, the values of the features (prices) were normalized because the scale of the time-series features varies (different price scales for each stock). The normalization method is shown in equation (3.1).

$$\begin{aligned}
 T_t &= [P_t^1, P_t^2, \dots, P_t^{M-1}, P_t^M] \\
 Open_t^i &= \left[\frac{open_{t-n+1}^i}{close_t^i}, \frac{open_{t-n+2}^i}{close_t^i}, \dots, \frac{open_{t-1}^i}{close_t^i}, \frac{open_t^i}{close_t^i} \right] \\
 High_t^i &= \left[\frac{high_{t-n+1}^i}{close_t^i}, \frac{high_{t-n+2}^i}{close_t^i}, \dots, \frac{high_{t-1}^i}{close_t^i}, \frac{high_t^i}{close_t^i} \right] \\
 Low_t^i &= \left[\frac{low_{t-n+1}^i}{close_t^i}, \frac{low_{t-n+2}^i}{close_t^i}, \dots, \frac{low_{t-1}^i}{close_t^i}, \frac{low_t^i}{close_t^i} \right] \\
 Close_t^i &= \left[\frac{close_{t-n+1}^i}{close_t^i}, \frac{close_{t-n+2}^i}{close_t^i}, \dots, \frac{close_{t-1}^i}{close_t^i}, \frac{close_t^i}{close_t^i} \right] \\
 Volume_t^i &= \left[\frac{volume_{t-n+1}^i}{volume_t^i}, \frac{volume_{t-n+2}^i}{volume_t^i}, \dots, \frac{volume_{t-1}^i}{volume_t^i}, \frac{volume_t^i}{volume_t^i} \right]
 \end{aligned} \tag{3.1}$$

3.3 RML Environment

The data was collected between January 1, 2000, and December 31, 2003. This indicates that each stock will have a total of 1,460 days' worth of data. The data includes Date, Open Price, High

Price, Low Price, Close Price, Volume, and Stock Ticker. All prices are in Naira, and the volume is defined as the total number of shares traded for that ticker on that particular day. The following categories were used to separate the data:

Total Days = 1,460 days (100%)

Train Days = 730 days (50%)

Test Days = 521 days (35%)

Validate Days = 209 days (15%)

The assets that were chosen have historical data that could be analyzed. When stock data wasn't accessible, the time series were kept up to date by filling in the empty price data with the previous day's close price and setting the volume to 0 to signify that the market was closed that day. The price data were standardized in order to create a general agent that is resilient with different stocks. To achieve this, the highest closing price of the entire period was multiplied by the opening price, closing price, highest price, and lowest price. Since the policy is a neural network, normalization is frequently advised to improve training stability. The network used an input tensor with the following dimensions: $[M, T, 4]$, where M is the total number of stocks that can be traded, T is the length of look-back window and 4 represent the number of features.

The elements of RML are described in this section, along with how the study was carried out using multiple RML environment state spaces. Constructing an environment that can accurately reflect the market and its eco system at hand is difficult when building an RML system, as was previously said. The stock portfolio account varies with each action the agent does, and the environment is made up of stock analysis technical indicators. Despite the fact that the action is created outside of the environment, the design of the action area is linked to how the environment functions as a whole. The following Sections 3.3.1, 3.3.2, 3.3.3, and 3.3.4, respectively, show how the environment action space, state space, reward function, and policy agent were designed.

3.3.1 Reinforcement Machine Learning (RML) Environment Components

The RML system is made up of various parts, which are shown in Figure 3.1. The portfolio account, which consists of equities and investment funds, is the first part. The second aspect is the situation of the market, which has an impact on the account's net value and fluctuates with each passing second. The third element is an intelligent agent that will monitor the situation of the market at any given time and take appropriate action to optimize the portfolio account. The state of the market that needs to be created is represented by a stochastic model.

The stochastic modeling approach of Markov Decision Process (MDP) is adopted to represent the market. The Markov model presupposes that the market's current state is a good predictor of its future state, assuming that the current state has enough statistics to reflect the environment's history. Various technical indicators of the stocks are incorporated into the state in order to construct a state that satisfies this condition. These technical indicators, such as the relative strength index (RSI), provide a good depiction of the stock over the look-back period and are being calculated throughout that time frame. The agent's judgment should be based on the situation of the portfolio account and the state of the market. The agents are two neural network models, CNN and RNN.

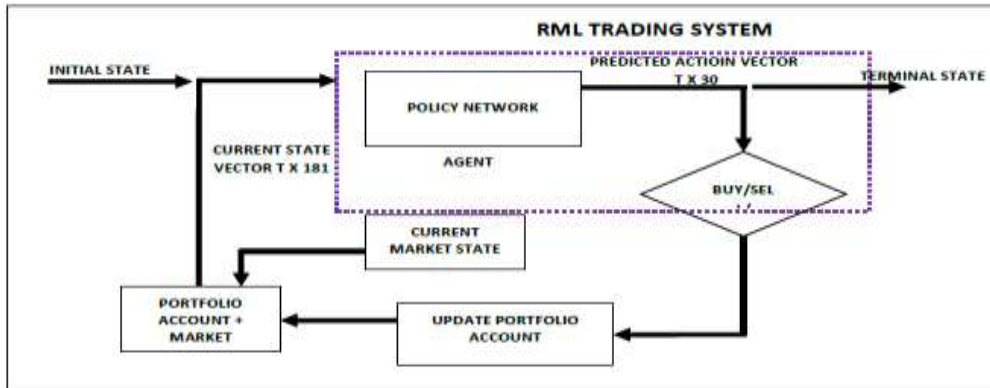


Figure 3.1: Block diagram of Reinforcement Learning System

3.4.3 NN-based Policy Network for RML Agent

The reinforcing method for managing portfolio accounts is shown in Figure 3.1. The "policy network" and module that carry out the projected action make up the Agent. The current market and portfolio account conditions are combined as the input to the policy network. The policy network will forecast an action vector based on this input. The account's net value will be changed through the use of these techniques.

The suggested system's flowchart for the generic RML framework as applied to stock portfolio optimization is shown in Figure 3.2. The RML issue is primarily about defining a training environment. This study is limiting itself to a few limitations and presumptions. The first is the assumption that the behavior of the market is unaffected by agent activity, and the second is that there is no lag between placing an order and having it executed. These restrictions are required since a model that is intended to be used in the real market cannot readily ignore those aspects.

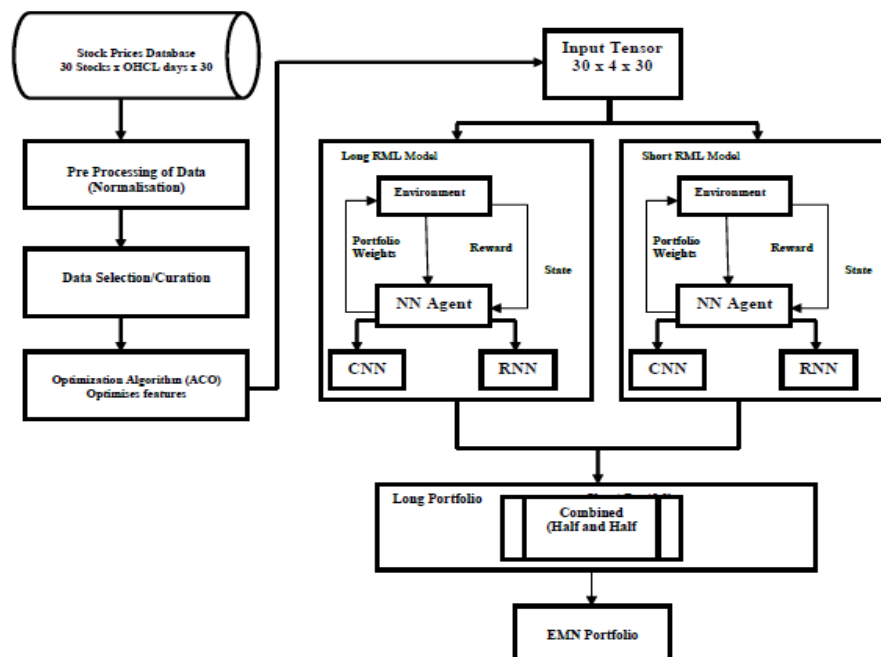


Figure 3.2: The PMS Framework

RML is employed in this study to manage the portfolio. The price tensor (T , $M \times 4 \times N$ tensor) is used as an input by the proposed policy network, which then predicts the weight of the portfolio (W) as an output. The portfolio weight of M assets is represented by W , an M -dimension vector with a total of 1 (by the softmax layer). Every time an action is taken, the environment transfers a reward, instructing the agent to update the policy network. The NN agent will acquire improved portfolio management patterns with each update epoch, allowing for the creation of an appropriate portfolio strategy.

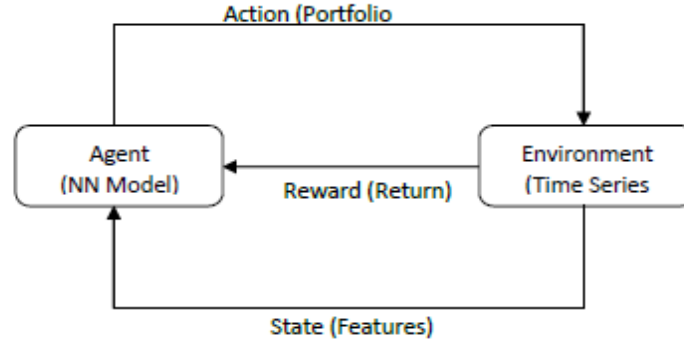


Figure 3.3: A Simple Architecture of Reinforcement Learning

To collect the temporal and spatial information, the study uses two different types of neural networks in the PMS that was built. The networks are displayed in Tables 4 and 5 for the PMS with CNN and RNN, which are designated as PMS CNN and PMS RNN, respectively. The CNN agent's constructed network, shown in Table 1, uses convolution to assess the spatial coherence of features. The stride of convolution is applied to the direction of the time series in the Conv 2D layers in order to find the patterns of the time series using the network. Additionally, the third dimension's size can be compressed as one of the output tensors by the second layer of Conv 2D's kernel, which is (1, 3rd-dim previous output).

A dense layer with M neurons and a softmax activation function to the end of the network as the portfolio weights after feature extraction by convolution layers is added. When compared to a simple neural network, the design system's used RNN and CNN may extract spatial information from various linear transformations using learnt kernels, which can address some of the limitations of basic neural networks, respectively. In this method, portfolio management can find and achieve a better balance between profit and risk. It should be noted that the stride is set to 1 in all of the CNN network's convolutional layers and that no padding is applied.

The developed RNN agent's network, shown in Table 2, is excellent at spotting coherence in time series of features utilizing memory states. A single-layer LSTM with a dropout layer is used in the planned RNN, and it ends at an M -neuron dense layer with softmax to produce an M -dimensional output that is used as the portfolio's weight.

Table 1 The designed network of the CNN agent

Layer	#Filter	Filter size	Activation
Input		M x 4 x N Vector	
Conv_2D	2	(1,2)	relu
Conv_2D	48	(1,3 rd -dim previous output)	relu
Conv_2D	1	(1,3 rd -dim previous output)	relu
Flatten	-	-	-
Dense	M	-	softmax
Output		M-dimensional Vector	

Table 2 The designed network of the RNN agent

Layer	Detail
Input	M x 4 x N Vector
LSTM	Neurons = 51
Dropout	0.2
Flatten	-
Dense	Neurons = M, softmax
Output	M-dimensional Vector

3.5 Training Methods

The model-free RML algorithms used in this study are used to carry out the various experiments. The key benefit is the ability to train without specialist equipment like CPUs while yet achieving comparable performance to more expensive and time-consuming techniques of computation. Additionally, it will serve as the foundation for comparing the final results with those found in the literature. The training data, as previously mentioned, comprises of daily stock values from January 1, 2000 to December 31, 2001. (2 years). The validation period runs from May 1, 2002 to December 31, 2003 (3/4 year), whereas the testing period runs from January 1, 2002 to April 30, 2002 (11/3 years, 6 years).

The model parameters are generated using the Adam optimizer. The learning rate, which is set at $1e-5$, and the discount factor $\gamma=1$, are the only parameters in the model. Normally, the factor is configured to reduce the cumulative rewards as the simulation progresses, however in the case of profit or monetary incentives; a Naira earned today is equivalent to a Naira earned a week ago because the models do not account for currency depreciation. Cash, a risk-free asset with constant returns of zero, is also included in the model.

3.6 EMN Strategy

A potent hedging portfolio approach known as EMN involves shorting (selling) relatively weak commodities and buying relatively strong ones. The trading mechanism of the RML-based portfolio management system is the EMN strategy. The size of long and short positions should be equal based on the EMN strategy concept. The PMS is intended to be divided into independent long and short RML models, with the output weights (of each stock) from both models being added equally to create the final portfolio weight.

To determine the patterns associated with taking long and short positions and to recommend optimal portfolio weights for each asset, two separate models were used. Equation (3.11) demonstrates that the total of long weight (WL) and short weight (WS), where M is the number of assets, is equal to 1 in both cases. The final portfolio weight, WC, along with the long-weight and short-weight, WL and WS, are combined to prevent scenarios when a specific asset is purchased and sold at the same time. Equation (3.12) demonstrates that the total weights are equal to zero. The absence of an EMN-based PMS and the zero WC show that the size of the long position is equal to the short position and that all of the money from the short position was reinvested in the market. The long and short RML models are respectively referred to as -Long and -Short in the designed system.

$$w_L = (w_{L1}, w_{L2}, \dots, w_{LM}), \quad w_{Li} \in [0,1], \quad \sum_{i=1}^M w_{Li} = 1$$

$$w_S = (w_{S1}, w_{S2}, \dots, w_{SM}), \quad w_{Si} \in [0,1], \quad \sum_{i=1}^M w_{Si} = 1 \quad . \quad . \quad . \quad 3.11$$

$$w_c = (w_{L1} - w_{S1}, w_{L2} - w_{S2}, \dots, w_{LM} - w_{SM})$$

$$\sum_{i=1}^M w_{ci} = \sum_{i=1}^M w_{Li} - w_{Si}$$

$$= \sum_{i=1}^M w_{Li} - \sum_{i=1}^M w_{Si} = 1 - 1 = 0 \quad . \quad . \quad . \quad 3.12$$

4 Experimental Results

This section outlines the experimental design, experimental procedures, evaluation and discussion of the findings, as well as any recognized limitations of the suggested course of action. The 30 premium equities from the Nigerian Stock Exchange (NSE), Lagos, are the study's trading target (stock pool). The daily OHLC data as well as the stock price information were gathered from NSE. Maximum drawdown (MDD), Sortino ratio, Sharpe ratio, profit factor (PF), and total return were all utilized as performance indicators to confirm the effectiveness of the PMS. Total return is calculated by dividing the net earnings made during the full trading period by the initial assets. A risk adjustment metric known as the Sortino ratio is used to calculate the added return for each unit of down risk. The Sharpe ratio is the total return divided by the standard deviation of the daily profit. MDD is the largest observed loss from a peak to a trough before a new high is attained. In essence, it shows the highest rate of loss over the trading period, with a lower figure signifying greater performance. PF stands for net profit divided by net loss as a whole.

4.1 Comparison of Different Reward Functions

When trading on a real market, RML agents are helped to learn via the reward mechanism in PMS. When learning and developing the system, Sharpe ratio is utilized as a novel reward function as opposed to the traditional reward function of trading returns to take into account investment risk. When learning and developing a system, the Sortino ratio, an improved version of the Sharpe ratio, is utilized to also account for investment risk. Table 3 compares the

performances of the proposed PMS_CNN and PMS_RNN for the reward functions of average return (Ret), Sortino (Sor), and Sharpe ratio (Sha).

The Sortino ratio reward function (PMS_CNN-Sor and PMS_RNN-Sor) outperformed the return reward function (PMS_CNN-Ret and PMS_RNN-Ret) respectively in terms of profitability and risk, indicating that the choice of reward function had a significant impact on the outcomes. In general, as shown in the table, PMS CNN performs much better than PMS RNN. The reward function that used in the following experiments is determined by the overall performance.

Table 3: Performance indicators of PMS with different reward functions on NSE, Lagos

Developed systems	Return	Sortino	Sharp	MDD	PF
PMS_CNN-Ret	28.326%	0.2697	0.21592	0.16019	0.89620
PMS_RNN-Ret	16.485%	0.3121	0.29372	0.21676	1.00719
PMS_CNN-Sha	112.591%	0.7031	0.59157	0.13354	1.37631
PMS_RNN-Sha	20.063%	0.5001	0.46146	0.05823	1.18142

The Sortino ratio reward function achieved 32.57% higher profits than those obtained using reward function when facing a unit of volatility and 38.766% higher profits when facing a unit of loss, according to an average of PMS_CNN-Sor and PMS_RNN-Sor, which are higher at 43.82% return, 0.3257 Sortino ratio, 0.266670 Sharpe ratio, and 0.38766 profit factor (PF). When faced with a unit of volatility and a unit of loss, the Sharpe ratio reward function generated profits that were 26.67% and 38.766% larger, respectively, than those generated by the reward function. The average MDD value was also decreased by using the Sortino ratio reward function, going from 18.005% to 7.364%.

While PMS_RNN-Sha was the most stable, PMS_CNN-Sor had the biggest profits (i.e., extremely small drawdown). Despite having profits that were on par with PMS_RNN-Ret, PMS CNN-Ret and PMS_RNN-Ret showed greater volatility. Overall, the return reward function and Sharp ration both underperformed the Sortino ratio reward function.

4.2 Performance of long and short models in the PMS

Two neural networks, designated PMS_CNN and PMS_RNN, were built for the RML agents in the designed PMS. A long model was trained to generate buying patterns, and a short model was likewise trained to derive selling patterns from real markets, as explained in Section 3.4. The trading performance of using long and short models while utilizing the PMS are compared in the ensuing tests, as illustrated in Table 4.

Portfolio management system in equity market neutral

Table 4: Performance indicators of the long, short, and combined models of the PMS

Developed systems	Return	Sortino	Sharp	MDD	PF
PMS_CNN-Long	48.41%	0.72003	0.62841	0.05661	1.20063
PMS_CNN-Short	64.274%	0.75821	0.63211	0.16100	1.17690
PMS_CNN-Combined	112.591%	0.70310	0.59157	0.13354	1.37631
PMS_RNN-Long	14.747%	0.71175	0.58701	0.03981	1.21009
PMS_RNN-Short	6.31%	0.57473	0.46713	0.14648	1.00472
PMS_RNN-Combined	20.063%	0.50010	0.46146	0.05823	1.18142

In this study, two neural networks known as PMS_CNN and PMS_RNN were developed for RML agents. Short model was trained and tested to extract selling pattern from actual markets, while long model was trained and tested to derive purchasing pattern. As shown in table 4, the proposed experiment looked into the trading performance of employing long and short models when using the PMS. The table demonstrates that PMS_CNN-Long and PMS_CNN-short have comparable total returns, Sortino ratios, and Sharpe ratios. Additionally, it demonstrates that a short position is more vulnerable to risks, losses, and lesser PF. This is in line with the widespread perception in stock trading that short selling is profitable but highly dangerous.

Regardless of the indicator, PMS RNN-Long outperformed PMS RNN-Short, demonstrating that the portfolio may increase profits while lowering risk. Comparing the Sortino ratio, Sharpe ratio, and PF of the PMS RNN-Long model, they are better than the PMS_RNN-Short model (57.473%, 46.713%, and 1.00472). The long model's MDD was 27% lower in terms of risk than the short model's. Since drawdown reflects the magnitude of asset loss, a higher drawdown denotes a greater asset loss over the course of a certain trading period. The short models in the PMS_CNN and PMS_RNN systems invariably led to higher risk and MDD. These findings are consistent with empirical experience, which shows that taking a short position always carries more risk. The experiment's findings show that in terms of total return, Sortino ratio, Sharpe ratio, and PF, PMS_CNN combination fared better than all of the other systems. These results have the conclusion that the system an investor will select will rely on the investor's level of risk tolerance.

5 Conclusions and discussion

EMN, a hedging strategy, has emerged as one of the most successful methods for risk management among the numerous portfolio management techniques since it balances long and short holdings. In this study, an artificial intelligence (AI)-based Portfolio Management System (PMS) was created to assist with human decision-making and resource allocation in real-world trading scenarios. Based on RML and NN, the system learns how to trade and maintain a portfolio by interacting with the market. To enable the extraction of spatial and temporal information and to create two reward functions to maximize profitability while taking risk into account, two NN models were connected with the proposed RML system. The suggested PMS with Sortino ratio reward function beat the Sharpe ratio and traditional return-based reward functions in trials, resulting in 43.82% larger profits and 7.364% less drawdown. In terms of returns, Sharpe ratio, and Sortino ratio, the PMS CNN beat the PMS RNN; nevertheless, the risk of drawdown was higher.

Using data from the Nigerian Stock Exchange (NSE), the proposed PMS outperformed the industry benchmark methods on all metrics, proving its profitability and effectiveness while lowering investment risk. It was also demonstrated that the unique reward function improved investment performance.

As a conclusion, the resource allocation in empirical stock trading in emerging markets can be supported by the PMS. Additionally, EMN is a hedging technique that has been successful in managing risk by balancing long and short positions, making it one of the alternative portfolio methods. In this study, a novel Portfolio Management knowledge-based System (PMS) is created to aid in resource allocation and human decision-making in real-world trading scenarios.

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Feature Selection for Evaluating Deep Reinforcement Learning DDoS attack Detection Mechanisms using the CICIDS2017 Dataset

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Abstract

Selecting relevant features from a dataset remains a critical element in the evaluation of an intrusion detection mechanism's performance. Features used in evaluating an intrusion detection mechanism have a direct correlation with the performance of the detection mechanism. Therefore, to improve the performance of intrusion detection mechanisms, attention must also be given to the process of feature selection. The feature selection methods in use to date, have different techniques that have been used individually to select features, however, recent studies use a combination of heterogeneous methods creating a hybrid approach, and others a combination of different techniques from the same method introducing an ensemble approach. These approaches have gained popularity as they have produced state-of-the-art results. Thus, this paper reports on the application of an ensemble approach of combining more than one technique under the filter method called the EMFFS to the CICIDS2017 dataset to select features that were used to evaluate a Hybrid Deep Reinforcement Learning Mechanism for DDoS attack Detection. Our results show that the selected features achieved a 96.44% accuracy, a false positive rate of 0.02, a Specificity of 94.90%, and a sensitivity of 97.44%.

Keywords: *Feature selection, CICIDS2017 dataset, Distributed Denial of Service attack, Intrusion Detection System, Deep Reinforcement Learning*

1 Introduction

Since the Introduction of Intrusion Detection Systems (IDS), different approaches have been used in designing IDS but one of the critical steps in the process of designing an IDS is the need for a performance evaluation of the detection mechanisms (Ulvila & Gaffney, 2003). In an ideal situation, an evaluation is supposed to be done in the environment where the detection mechanism will operate. However, due to security concerns on user privacy and network security, datasets that are generated from different types of network configurations are used to evaluate the IDS. The KDD CUP, NSL KDD, CAIDA, and the CICIDS2017 are some of the common datasets that have been used to evaluate the different proposed detection mechanisms (Sharafaldin et al., 2017). Datasets are not often used in their original state as they contain other elements that are not relevant to the evaluation of an IDS. This is why the process of selecting features that are relevant to the evaluation of an IDS is necessary and that features have a direct correlation to the performance of a detection mechanism (Gu et al., 2019). We, therefore, carried out a study aimed at determining the best features from the CICIDS2017 dataset, produced by the Canadian Institute for Cybersecurity, to evaluate a Hybrid Deep Reinforcement Learning Mechanism (HDRMLM) that is designed for the detection of DDoS attacks.

The primary objective is to identify the best features from the CICIDS2017 dataset for evaluating a DDoS attack detection mechanism built using Deep Reinforcement Learning. The other

objective is to evaluate feature subsets from the CICIDS2017 datasets selected using different feature selection methods and techniques to detect DDoS attacks when used on the HDRLM.

The remaining portion of the paper is structured as follows; The related works are presented in Section 2. Section 3 provides a presentation of the methodology which also describes the dataset used, the feature selection process, the Hybrid Deep Reinforcement Learning Mechanism along with the evaluation parameters and the validation. Section 4 presents the experimentation, results, and discussion. The conclusion and future works are presented in section 5.

2 Related Works

Singh, Raiwani, & Singh, (2019) defines feature selection as a method of selecting a small subset of attributes that are deemed relevant from many attributes of a specific dataset, which is accomplished by using special evaluation criteria to enhancing a classifier's performance while minimizing the data's dimensionality. This approach has been employed in different research disciplines for classification such as image recognition (Ewees & Eleraky, 2019) medical imaging (Han & Jiao, 2017), Fraud detection (Lima & Pereira, 2016), and DDoS attack detection (Gu et al., 2019).

Features have affected the efficacy and efficiency of an intrusion detection mechanism as Sahu, Sarangi, & Jena (2014) suggested that feature selection has demonstrated abilities to decrease computational requirements, overfitting, model size, and boost accuracy. Feature selection is applied using methods categorized into three: filter method, wrapper method, and embedded method (Khalid et al., 2014). There are many techniques within each of these methods. In the filter method, features are selected based on their inherent characteristics or their intrinsic value independent of a classifying algorithm, they can also be selected based on their relationship with other features (Osanaie et al., 2016). With the embedded method, features are selected through direct interaction with the classifier based on its performance by the classifier measuring the quality of each feature. The wrapper method has the classifier as part of the feature selection similar to the embedded method, however, the classifier is without specific knowledge of the target in the classification thus using black box analysis.

A hybrid approach through combining techniques from two different methods is known to produce better accuracy. Thus, by combining a technique from the filter and embedded methods. Gu, Li, Guo, & Wang (2019) propose a hybrid approach that first identifies candidate features through a literature review and subjects the candidate features to a filter method and obtains a feature subset which is further input to a classification algorithm to obtain the best features. This approach produces the best features that give a high accuracy but has a pitfall of taking more time and using more computational resources. To increase efficiency and high accuracy, the use of knowledge of the DDoS attack characteristics is proposed, through which specific features are identified and a subset of them are used for detection (Yusof et al., 2018). Using this technique DDoS characteristic features (DCF) in DDoS characteristic-based features (DCF) the six features identified were DestIP, DestPort, SrcIP, SrcPort, packet length, and ACK (Yusof et al., 2018). The authors combined the DCF with consistency subset evaluation (CSE) to obtain better accuracy and testing time when compared with customary chi-square, information gain, gain ratio, and correlation feature selection. In their work, Abdulrahman & Ibrahim (2018) applied the

Information gain techniques, they find the entropy of each feature and by ranking obtained the best 10 feature Fwd.IAT.Total, Flow.IAT.Total, Active.Max, Active. Min, Fwd.IAT.Max, Active.Mean, Idle.Min, Flow.IAT.Std, Flow.IAT.Mean. Osanaiye et al., (2016) propose an ensemble approach called Ensemble Multi-Filter Features Selection (EMFFS) It employs the filter method by using the four techniques Information Gain, Gain Ratio, Chi-Square, and ReliefF. EMFFS has been applied to KDD-NSL (Osanaiye et al., 2016) and has yielded state-of-the-art results. We, therefore, apply this method to the CICIDS2017 dataset with a focus on DDoS attacks which has not been done before.

3 Methodology

In designing a DDoS attack detection mechanism the use of a dataset, in place of live network traffic to evaluate the mechanism is a more adopted approach (Sharafaldin et al., 2017). Identifying the most appropriate dataset is important and most of all is the identification of the features that are relevant from the chosen Dataset for specific types of attacks and detection mechanisms.

To achieve the objective of identifying the best features from the CICIDS2017 dataset for evaluating a DDoS attack detection mechanism built using Deep Reinforcement Learning. we employed a sequential triangulation of the qualitative-quantitative method, by combining a literature survey and an experiment was used (Clarke, 2005). The literature survey was predominantly used in identifying the dataset for evaluating DDoS attack detection mechanisms, best feature selection technique, and features subsets. The experimental approach was employed to obtain to evaluate the performance of the identified feature technique and feature subset. The results from the literature survey were used to validate the results of the experiment.

3.1 The CICIDS2017 Dataset

Based on a framework proposed by Gharib et al., (2017), the CICIDS2017 dataset emerged as the more appropriate dataset for the evaluation of a DDoS attack IDS by having a DDoS attack and benign traffic isolated from the other types of traffic. The CICIDS2017 dataset has a range of attacks from traffic captured in five days, Monday to Friday, and the Friday afternoon contains the DDoS attacks and normal traffic only (<https://www.unb.ca/cic/datasets/ids-2017.html>). Since DDoS attack detection was the focus of this study, only the Friday afternoon traffic with a DDoS attack was used. The CICIDS2017 dataset, its features, how it was prepared, and how the feature selection was performed are presented in the subsequent sections.

In its original format, the dataset contains more than 80 features including nominal and statistical features. For evaluating a mechanism, only statistical or numerical features are used. There are a total of 225745 instances captured and available in the dataset. The instances are labelled as either Benign or DDoS with a total of 97718 instances as benign which represents 43% and 128027 instances labelled as DDoS attacks representing 57% (Abdulraheem & Ibraheem, 2019). This is a fair distribution of the two classes that overcomes class imbalance that eventually reduces bias in the classification algorithm.

Like most datasets, the CICIDS2017 cannot be to be used in its raw state to evaluate a DDoS attack detection mechanism. The dataset requires to be cleaned and preprocessed to remove unwanted features or features that are not relevant that do not impact the performance of a mechanism.

3.2 Dataset Pre-processing

The CICIDS2017 dataset was pre-processed using the WEKA tool (Srivastava, 2014). The dataset was first cleaned by undertaking the following steps. First step check for redundancies for both features and instances. The feature named "Fwd_Header_Length" was discovered to be in duplicate and was therefore removed. Additionally, 109 redundant instances were subsequently removed. The Second step involved checking all missing values. Missing values are values that might have been omitted or captured erroneously (Panigrahi & Borah, 2018). During this process, all the missing were removed. In the third step, all the nominal features were removed. The nominal features are attributes that contain non-numeric values and are included in the dataset for information purposes. The dataset contains five nominal features which are *FlowID*, *SourceIP*, *DestinationIP*, *External IP*, and *Timestamp*, these were manually removed. The fourth and final step was to identify instances that contained infinity values that were replaced by the mean of the feature value. At the end of these cleaning exercises, 79 features remained on the dataset.

The data was then standardised by transforming the values into a standardized representation using the Z-score Normalization decimal scaling normalisation score and the values for the attributes were represented by the standard deviation using the Z-score Equation (2) (Abdulrahman & Ibrahim, 2019)

$$Z = \frac{X - \mu}{\sigma} \quad (2)$$

Where **Z** represents the standard score, and **X** is the observed value, μ is the mean of all values, and σ is the standard deviation of all values. At the end of this process, the dataset was clean for feature selection to be performed.

3.3 Feature Selection

The EMFFS was applied by combining four techniques namely; Information Gain, Chi-Square, Gain Ratio, and ReliefF (Osanaiye et al., 2016). This approach was employed, in contrast to using a single technique, to gain the most from the techniques by combining them so they collectively compensate for the shortfall of each other if used individually. Figure 1 shows how the EMFFS was applied to the CICIDS in which each of the four techniques was first applied to the CICIDS2017 dataset individually and the results for all the individual techniques were put together and subjected to a majority vote. The features that did not meet the criteria that were set at *T* were dropped and only features that were more than *T* were considered to form the feature subset.

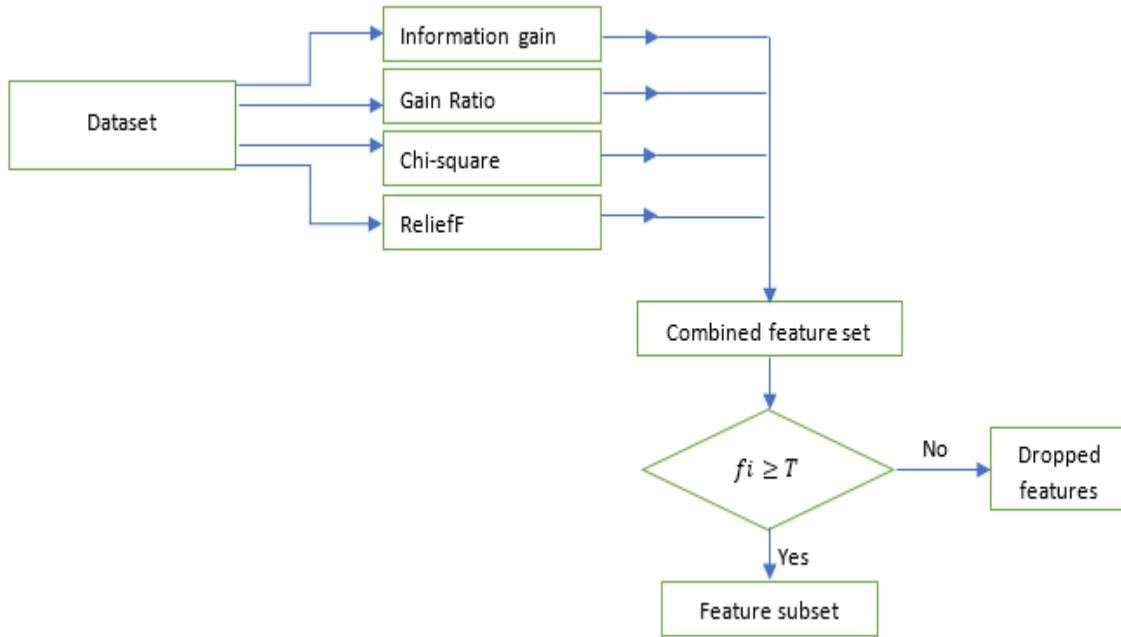


Figure 1: The EMFFS workflow. Source (Osanaiye et al., 2016)

The candidate features obtained for each of the techniques Information Gain, Chi-Square, Gain Ratio, and ReliefF are set represented in Table 2.

Table 2: EMFFS candidate features for each Technique

Feature selection Top fifteen Ranked Features
Technique

Information Gain	Total Length of Fwd, Subflow Fwd Packets, Average Packet Size, Total Length of Bwd, Subflow Bwd Packets, Avg Bwd Segment Size, Bwd Packet Length Mean, Fwd Header Length1, Destination Port, Bwd Packet Length Max, Subflow Bwd Bytes, Avg Fwd Segment Size, Fwd Packet Length Mean, Fwd Packet Length Max
Gain ratio	Destination Port, Fwd Packet Length Max, Subflow Bwd Packets, Total Length of Bwd, Bwd Packet Length Min, Avg Fwd Segment Size, Fwd Packet Length Mean, URG Flag Count, Avg Bwd Segment Size, Bwd Packet Length Mean, Init_Win_bytes_forward, Subflow Bwd Bytes, Subflow Fwd Packets, Total Length of Fwd
Chi-squared	Subflow Fwd Packets, Total Length of Fwd, Average Packet Size, Destination Port, Fwd Header Length1, Subflow Bwd Packets, Total Length of Bwd, Avg Bwd Segment Size, Bwd Packet Length Mean, Bwd Packet Length Max, Subflow Bwd Bytes, Bwd Header Length, Fwd Packet Length Mean, Avg Fwd Segment Size
ReliefF	Total Length of Fwd, Subflow Bwd Packets, Total Length of Bwd, Avg Bwd Segment Size, Bwd Packet Length Max, Bwd Packet Length Mean, Subflow Fwd

Packets, Fwd IAT Mean, Fwd Packet Length Min, Avg Fwd Segment Size, Bwd Packet Length Std, Fwd PSH Flags, Fwd URG Flags, ACK Flag Count

The candidate futures were subjected to the simple majority vote by use of frequency and ranking, from which the best six features were obtained. The features presented in Table 3 emerged to be the best from the experiment using the EMFFS approach.

Table 3: Feature subset from EMFFS

Feature

Total Length of Fwd Packets, Total Length of Bwd Packets, Bwd Packets Length Mean, Avg Bwd Segment Size, Subflow Fwd Packets, Subflow Bwd Packets

The feature subset was evaluated on a Hybrid Deep Reinforcement Learning Mechanism to establish its effectiveness.

3.4 The Hybrid Deep Reinforcement Learning Mechanism

The classification mechanism was built using the Deep Reinforcement Learning algorithm with a Deep Q Network (DQN) algorithm and combined two heterogeneous neural networks of Convolution Neural Network and Deep Neural Network. The DQN algorithm is made up of a Q-learning algorithm a traditional Reinforcement Learning algorithm and Neural Network for value approximation.

3.4.1 Deep Q Network Algorithm

The DQN is built on the Q-learning algorithm, a reinforcement learning algorithm that uses Q-values from the Q-table (Arunraj & Umarani, 2017). The Q-table in a Q-learning Algorithm is a matrix of actions and states as columns and rows respectively. It is used to determine the best action an agent must take in a given state. The DQN uses a Deep Learning algorithm instead of a Q-table to approximate the Q-values. Combining the CNN and the DNN on the DQN algorithm for value approximation we created a hybrid Deep Reinforcement Learning classification mechanism.

3.4.2 Convolution Neural Network

A convolution Neural Network (CNN) is a type of artificial neural network that is largely used in image analysis such as face recognition (Chilimbi et al., 2014) but has also been used for other data analysis and classification problems including DDoS attack detection and produced tremendous results (Haider, Akhunzada, Ahmed, & Raza, 2019). Hidden layers with the specialized capacity to recognize patterns and interpret them, known as convolution layers, form the foundation of a CNN. This pattern detection ability made CNN useful for this mechanism to detect DDoS attacks.

3.4.3 Deep Neural Network

A Deep Neural Network (DNN) is an algorithm that emerged from the neural network as an advancement of the Neural Network from having a single hidden layer to having more than hidden layers that are hierarchically cascaded between its input and output (Potluri & Diedrich,

2016). Recent research has shown the improved performance of DNN in various fields of applications such as medicine, image classification, and intrusion detection (Potluri & Diedrich, 2016). DNN has shown capability in classification problems that involve complex and huge data. This capability has made DNN applicable in the classification of a huge amount of network traffic (Kim et al., 2017).

3.5 Evaluation Parameters

The feature subset was evaluated to establish their performance by the following parameters: Accuracy and False Positive Rate (FPR), and Specificity were used to evaluate the performance of features subset on the HDRLM.

The formulae used to compute the accuracy is presented in Equation (3), false positive rate is presented in Equation (4), sensitivity is presented in Equation (5), and specificity is presented in Equation (6).

$$\text{Accuracy} = \frac{\text{True Positive} + \text{True Negative}}{\text{True Positive} + \text{True Negative} + \text{False Negative} + \text{False Positive}} \quad (3)$$

$$\text{False Positive Rate} = \frac{\text{False Positive}}{\text{True Negative} + \text{False Positive}} \quad (4)$$

$$\text{Sensitivity} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}} \quad (5)$$

$$\text{Specificity} = \frac{\text{True Negative}}{\text{True Negative} + \text{False Positive}} \quad (6)$$

3.6 Validation

To validate the selected feature, we considered two other features from literature selected from the CICIDS2017 Dataset that were used for DDoS attack detection. The two features are among those that obtained the state of the art results of 95% and 99% when used on machine-learning Random Forest algorithm multilayer perceptron (MLP) algorithms (Abdulrahman & Ibrahim, 2019) and REPTree classification algorithm (Singh et al., 2019). All three features are presented in Table 4.

Table 4: Feature subsets for validation

Feature subset	Method and technique	Features
Proposed	EMFFS	Total Length of Fwd Packets, Total Length of Bwd Packets, Bwd Packet Length Mean,

		Avg Bwd Segment Size, Subflow Fwd Packets, Subflow Bwd Packets
(Abdulrahman & Ibrahim, 2019)	Filter (Information Gain)	Fwd.IAT.Total, Flow.IAT.Max, Active.Max, Active.Min, Fwd.IAT.Max, Active.Mean, Idle.Min, Idle.Max, Flow.IAT.Std, Fwd.IAT.Mean
(Singh et al., 2019)	Embedded (J48)	Destination Port, Total Length of Fwd Packets, Total Length of Bwd Packets, Fwd packets Length Min, ACK flag Count, Init_Win_bytes_forward, Init_Win_bytes_backward, Idle Min

4 Experimentation

The features were subjected to experimentation with the HDRLM as the algorithm for the detection of DDoS attacks. The experiment was performed on an 8th-generation computer running Windows 10 operating system. The processor was a Core i7-8550U CPU @ 1.80GHz, 1.99GHz, and 8Gigabytes of Random Access Memory.

4.1 Results

The results obtained from the experiment were recorded on a graph and a confusion matrix and are presented based on each of the evaluation parameters (accuracy, false positive rate, sensitivity and specificity) in the subsequent sections.

4.1.1 Accuracy

Figure 2 is the accuracy obtained by the feature subsets based on the evaluation of the HDRLM in which the proposed feature subset obtained from the EMFFS achieved an accuracy of 96.48.9%, feature subset 2 from Abdulrahman & Ibrahim (2019) achieved an accuracy of 90.54% and feature subset 3 from Singh et al., (2019) obtained an accuracy of 94.29%. From the results obtained the proposed from the EMFFS shows a more improved accuracy as compared to the other feature subsets with feature subset 2 achieving the least accuracy of 90.54%.

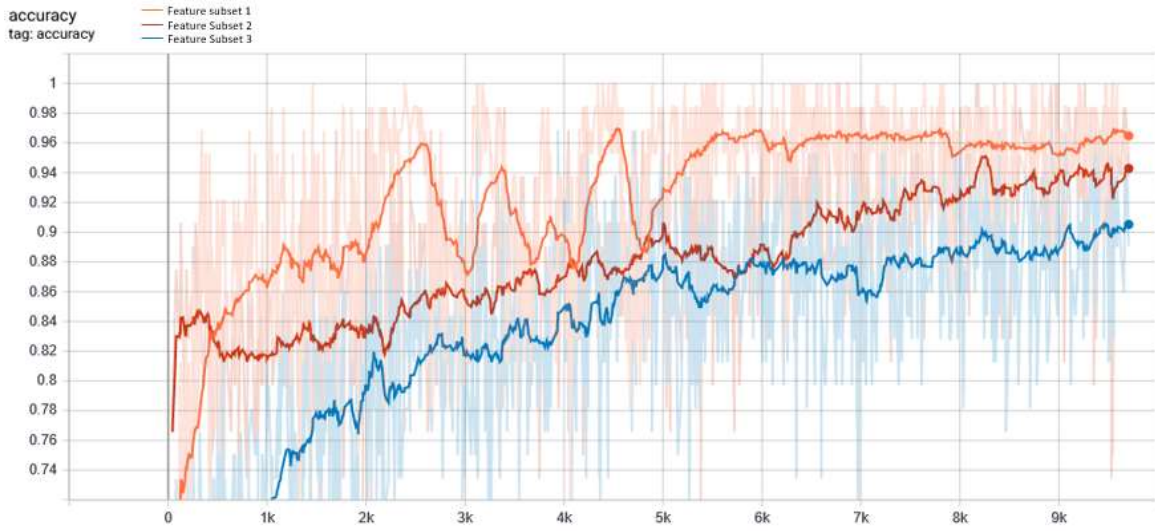


Figure 2:Accuracy results of the three feature subsets

4.1.2 False Positive rate, Sensitivity, and Specificity

The false positive rate (FPR), Sensitivity, and Specificity for each of the feature subsets were also obtained from the Confusion Matrix recorded from the experiment.

Figure 3 presents a confusion matrix for feature subset 1.

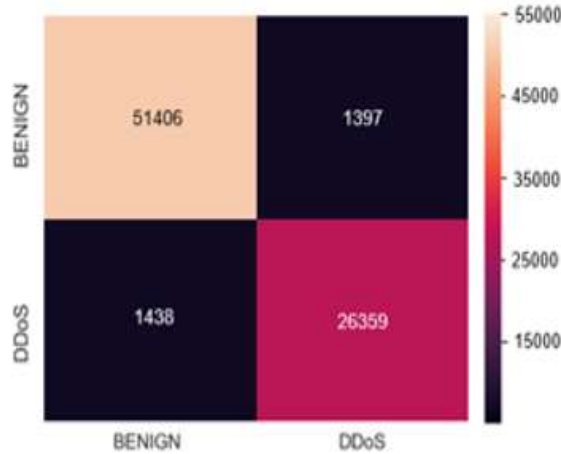


Figure 3:Confusion matrix for feature subset 1

For feature subset 1(EMFFS), the calculated false positive is represented in Equation (7), Sensitivity positive is represented in Equation (8), and Specificity positive is represented in Equation (9).

$$\text{False Positive Rate} = \frac{1397}{26359 + 1397} \quad (7)$$

$$=0.05$$

$$\text{Sensitivity} = \frac{51406}{51406 + 1397} \quad (8)$$

$$=0.97$$

$$\text{Specificity} = \frac{26359}{26359 + 1397} \quad (9)$$

$$=0.95$$

Figure 4 presents a confusion matrix for feature subset 2.

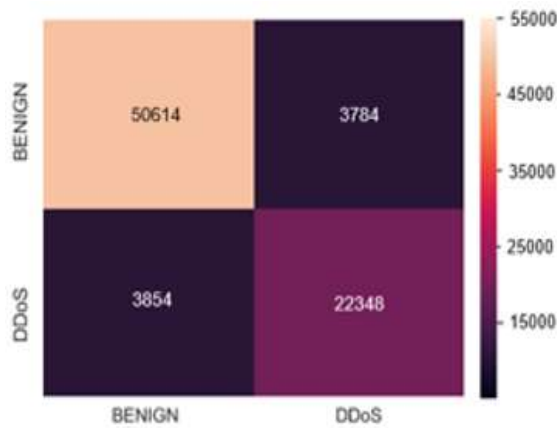


Figure 4: Confusion matrix for feature subset 2

For feature subset 2 (Abdulraheem & Ibraheem, 2019), the calculated false positive rate is represented in Equation (10), Sensitivity is represented in Equation (11), and Specificity is represented in Equation (12);

$$\text{False Positive Rate} = \frac{3784}{22348 + 3784} \quad (10)$$

$$=0.14$$

$$\text{Sensitivity} = \frac{50614}{50614 + 3784} \quad (11)$$

$$=0.95$$

$$\text{Specificity} = \frac{22348}{22348 + 3784} \quad (12)$$

$$=0.86$$

presents a confusion matrix for feature subset 3.



Figure 5: Confusion matrix for feature subset 3

For feature subset 3 (Singh et al., 2019), the calculated false positive rate is represented in Equation (13), Sensitivity is represented in Equation (14), and Specificity is represented in Equation (15)

$$\text{False Positive Rate} = \frac{1847}{25859 + 1847} \quad (13)$$

$$= 0.07$$

$$\text{Sensitivity} = \frac{50135}{50135 + 1847} \quad (14)$$

$$= 0.96$$

$$\text{Specificity} = \frac{25859}{25859 + 1847} \quad (15)$$

$$= 0.93$$

4.2 Discussion

Based on the results of the three feature subsets in terms of the four evaluation parameters of accuracy, False positive rate, sensitivity, and specificity are presented in Table 5 shows that the proposed feature subset from the EMFFS approach outperformed the other two feature subsets based. Based on the accuracy obtained by using the proposed feature subset the HDRLM correctly detected instances to be either DDoS attacks or benign at 96.48%. When feature subset 2 was used the detection accuracy was at 90.54% which was the lowest among the three feature subsets.

Table 5: Summarised feature subsets results

	Feature Subset 1	Feature subset 2	Feature Subset 3
Accuracy	96.48	90.54	94.29

False Positive Rate	0.05	0.14	0.07
Sensitivity	97.44	96.50	96.0
Specificity	94.90	86.0	93.4

The False Positive Rate obtained by the proposed feature subset at 0.05 was the best compared to the 0.07 from feature subset 3 and 0.14 from feature subset 2. When it came to sensitivity, again the Proposed feature subset obtained the highest rate of 97.44% followed by feature subset 2 with 96.5% and the lowest was feature subset 3 with 96.0%. Finally, the Specificity for the three feature subsets shows that the proposed feature subset obtained the best specificity at 94.90% followed by 93.4% and the least was 86.0 for feature subset 2.

5 Conclusion and Future works

The approach of combining the methods has empirically shown improved results. the Ensemble-based Multi Filter Feature selection approach was applied to the CICIDS2017 dataset to obtain features for the evaluation of detection mechanisms designed for DDoS attack detection. Subjecting the features from the EMFFS on the HDRLM in comparison to features from the literature, our results have shown that the proposed feature subset from the EMFFS produced the best performance of 96.44% accuracy, a false positive rate of 0.02, Specificity of 94.90% and sensitivity of 97.44%.

For future research, the proposed features will be subjected to other algorithms that are designed based on Ensemble and hybrid approaches.

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A Critical Assessment of the Factors Impacting the Full Utilization Of IS/IT in Organisations

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Abstract.

Organisations develop and implement information systems and technologies to support and enable business processes efficiency and effectiveness. However, the implemented systems are not always fully utilised by employees. Organisational employees tend to only use some modules integrated within a system and neglect other modules. Employees do not fully utilise implemented IS/IT modules due to various factors such as a lack of skills in the functionality of the module. Therefore, employees resort to executing some of the organisation processes manually even if they are supported by the deployed IS/IT. When deployed IS/IT is not fully utilised, it negatively impacts the organisation competitive advantages and returns on investment of IT resources as both manual and automated processes are run in parallel. Process parallelism leads to data inconsistencies and duplication of efforts. The study employed a qualitative case approach to understanding why implemented information Systems are always not fully utilised. Semi-structured interviews were used as a data collection technique. Data was analysed interpretively and from analysis six factors were found to be critical for implemented systems' full utilisation. Based on the findings, a full IS/T utilisation model was developed. The model aims to guide organisations towards the improved use of IS/IT.

Keywords: Information System, Information technology, full utilization, organisations

1. Introduction

In recent years as the global economy grows, more organizations in Namibia have been investing in information systems/information technology (IS/IT) (Uaandja, 2016). IS/IT are computer systems that support an organisation's goals and objectives using hardware and software as well as networks (Reynolds & Stair, 2021) . IS/IT mainly focuses on information processing and automation of business processes that bring economic value to an enterprise (Swanson, 2020). Organisations implement IS/IT to digitise their business process.

However, in most organisations, IS/T is underutilised as their modules' functionality is partially used or not used at all (Norizan & Mohamad, 2014). Employees use quite narrow feature breadths as they only use a few features of IS/IT, and sometimes they rarely initiate technology or task-related extensions of the available features (Varajão, et al., 2022). When employees are not fully utilizing the implemented IS/IT, it can be costly for an organisation, as it will not attain its intended benefits from the implemented system. Khaled and Bach (Khaled & Bach, 2014) argue that the success of IS/IT in an organisation does not only depend on how it was implemented but that it is also depends on how it is being utilized by its employees. Full utilisation of IS/IT is when the implemented IS/IT modules are all used to carry out the business processes that they are mapped to (Swanson, 2020). This is done by using all the modules'

features to carry out a business process without resorting to any other form of method to complete the process, that does not involve using the IS/IT that an organisation has implemented (Khaled & Bach, 2014, A).

The full utilisation of IS/IT presents many benefits to organisations such as giving value to business processes because they are carried out more reliably and conveniently (Luftman et al., 2017). However, in some of the Namibian organisations, the implemented IS/IT is not being fully utilised. This negatively impacts the IS/IT business value. Thus, this study aims to investigate and understand the factors that impact the full utilisation of IS/IT in organisations.

2. Literature Review

Full utilisation of IS/IT is the execution of the organisation's activities using the implemented IS/IT to its fullest capacity, in an effective way (Labat, 2013). Khaled and Bach, (2014, B) however, view full utilisation of IS/IT as the measure of its successful implementation. Organisations need to fully utilise the implemented IS/IT to increase processes' effectiveness and efficiency (Vannoy, 2015). Full utilisation of the implemented systems is required in an organisation for it to be able to reap financial benefits and to account for all its processes (Reynolds & Stair, 2021) .

Utilising IS/IT fully has been a major problem in most organisations (Labat, 2013). Varajao et al. (2022) argued that most organisations face challenges such as inadequate system knowledge, long system adoption time by employees and low investment by management in training IS/IT users. Harlie et al. (2020) stated that the challenges faced by organisations with their implemented system manifest from individual behaviours and their attitude toward change. Aghajani et al. (2020) argued that most IS/IT are not fully utilised because they are very difficult to use and it's never the user to blame. Dwivedi et al. (2017) supports that full utilisation does not only become a problem when the system is implemented, but it draws back to the communication between employees and management when the IS/IT was getting implemented.

In addition, the lack of systems knowledge makes it difficult for employees to fully utilize IS/IT (Varajao et al., 2022) Thus, the need for organisations' management to invest more in training users about the newly implemented IS/IT.

3. Methods

This study was based on the qualitative strategy. Qualitative research helps researchers study participants' thoughts and feelings, enabling a better understanding of the people's experiences in the given context (Sutton & Austin, 2015). Qualitative data was collected using semi-structured interviews. Semi-structured interview technique was employed in this study as it allows respondents to give their own opinions about the phenomenon being studied.

In this study, Lexis Insurance was used as a case. Lexis Insurance organisation has implemented several information systems that are used to carry out its business processes and activities. The different departments of the organisation complete different organisational processes, so every department uses a unique information system. However, the IT department oversees all the organisation's implemented information systems.

Data was collected from different departments of the organization. These departments were Human Resources, Information Technology, Pension, Insurance, and Finance department. The respondents from these departments included managers and employees that have been in their position for more than a year. In total, ten (10) employees were interviewed.

During the interview process, the researcher used interview questions as a guide. The interview questions were generated from the research questions, which are: (1) How are the information systems and information technologies utilised towards their intended purpose in organisations? (2) What are the factors that impact the full utilisation of IS/IT towards their intended purpose in organisations? During the interview process, the researcher was able to ask follow-up questions that varied depending on the response given by the respondents.

4. Data Analysis

The data collected was interpretively analysed. The interpretive analysis allows the researcher to derive in-depth meaning about the phenomenon of interest by analysing people's experiences (Melendez-Torres, et al., 2017). The analysis is presented per data collection questions as follows:

1. How many Information systems do you use in your organisation to support your business processes?

As one of the insurance organisations in Namibia, Lexis Insurance is dependent on Information systems to carry out its business processes and activities. Due to the organisation dependency on Information Systems, an IT department was established. The IT department manages the implemented Information Systems. One of the participants who is a manager stated that *"we have a lot of Information Systems which includes Sapiens Reinsurance, Sapiens IDIT, and Decision Support system, HR Systems, Alex one"* P1, pg1:11-13.

2. Briefly explain to me what do you use these systems for? Or what business processes are executed/supported by these information systems?

At Lexis Insurance, Information Systems are implemented to automate business processes and to enable the achievement of organisational goals. The implemented systems help the various business units carry out their business process which includes, processing of pension and insurance policies for organisations and individual clients. The participants described the systems that they use as follows:

"4gen is used in the finance department to make all the financial processes like calculating pay-outs" P1, p1:16-17.

"EES and ESS are HR systems, so they are used for HR processes, but EES is the new system and ESS is the one we had first, but we still use some of its functionalities" P09, pg22:553-554.

"Alex is for pension, Sapience is for insurance and 4Gen is for Finance" P09, pg22:554-555.

3. What are some of the challenges you encounter as you use this information system?

When using the implemented information systems to carry out various processes, employees encounter several challenges. Employees from different departments face different challenges since each department has its systems. Some of the challenges encountered by employees are

difficulties with navigating around the system, difficult user interface as well as not getting enough training which makes it hard for them to complete tasks on the systems. One of the participants stated that *"I mostly use the Alex system, but it is really difficult to navigate around so I think that is my greatest challenge"* P02, pg4:93-95.

Another participant stated that *"The system I use most is the Alex one and honestly it has a challenging interface. I also have to draw reports from 4Gen sometimes and that system I find complicated"* P1, pg1:24-26.

4. Information Systems contain modules. Are all modules or features that are part of the IS used in your organization?

Information systems are packaged with different modules, which are the features that enable different tasks to be completed. Each information system module caters to a different task. However, employees do not use all the modules incorporated in the information systems as they tend to only use some modules and leave some unused when completing their tasks. One of the participants said *"with the system we have in our department we do not use all the modules"* P03, pg7:176 when asked whether all the modules part of the organizations information systems are used.

5. Why do you think it's important to use all modules of an information system to carry out business activities?

Employees must use all the modules of the organisations implemented information systems. Using all modules to complete daily tasks allows employees to carry out their tasks more efficiently and reliably which can be accounted for on the systems. It also allows organisations to achieve their goals and to benefit from their investment. One of the participants stated that *"the reason the organisation implemented these systems is for us to use them when completing our tasks, these systems make it easier to carry out processes and they are more efficient to use"* P06, pg17:417-419.

Another participant stated that *"the systems keep a record of what was completed making everyone accountable when they complete tasks and good results can only be achieved when everything is done and used the right way, so we must use all the modules"* P09, pg24:592-594.

6. Why do you think some of the employees do not utilize all the modules of the implemented Information System?

There are various reasons why employees do not use all the information system modules. The reasons differ from one department to another since Lexis insurance organisation is reliant on about 7 different active information systems to carry out its business processes. Every information system contains different modules that are responsible for carrying out different tasks within the organization. The organisations employees however do not utilize all the modules in their information systems due to various reasons such as having so many systems that can do the same tasks causing a repetition of modules within different systems, lack of knowledge on the systems functionalities, and personal preference when completing tasks. One of the participants stated that *"we have a lot of systems and most of them can carry out the same*

tasks, so some modules appear in more than one system so there is no need to use them on every system" P07, pg19:486-487.

Another participant stated that *"I believe that most employees don't use all modules because they receive very basic training causing them to not know how to use all the modules of a system, but some may simply just choose to complete their tasks differently not using all modules required"* P02, pg5:118-122.

7. How does not using (utilizing) all modules impact organisation goals achievement and investment in IT?

When all the modules are not used when executing business processes, the organisations goals achievement and IT investment can be affected negatively. Not using all modules can lead to failure of completing tasks on time or correctly and it also results in a waste of IT investment for the unused system modules. One of the participants stated that *"with achieving the organisation's goals I can say that if the systems were used to their fullest capacity the organisation could be doing greater than it currently is, but we are still doing well. With IT investment we are losing money for what we do not use"* P03, pg8-9:205-209.

Another participant stated that *"with achieving organisational goals we do experience underperformance here and there, but the main goals are still achieved, and with IT investment one can say that money sometimes goes to waste"* P10, pg27:661-663.

8. What do you think should be done to ensure that employees use all modules of Information systems to carry out their business activities?

Not utilizing information system modules fully, have a negative effect on the organisations performance, something must be done to ensure that employees utilize all the modules when carrying out business activities. Most participants suggested that employees need to get more training on using the systems. Training employees gives them a better understanding of the different system functionalities. Employees should also get extended time to learn how to complete different tasks using different system modules. Some of the employees suggested that employees should be provided with user guides of different systems to do self-learning. They also suggested that more awareness should be raised within the organization on the importance of utilizing information system modules. The participants gave different suggestions as to what can be done to ensure that employees utilize all the information systems modules as follows: *"Although they provide us with training, I think it is not enough and new employees should be provided with more training and they should be given enough time to learn how to use the systems"* P02, pg6:141-142.

"I think training the new employees more can bring a change in how they use the information systems or even just providing them with the user guide for them to do self-study on the functionalities of the system" P05, pg15:366-368.

"More awareness should be raised every once in a while, by briefing employees on the importance of using different system modules and how it is important to the organization" P07, pg20:493-495.

5. Results and Discussion

From the data analysis that was carried out, five (5) findings were identified. The findings represent the factors that critically affect the full utilization of IS/T in organisations. The five (5) findings are discussed below:

i. Modules similarities

Similar information systems modules were across the implemented systems. This means that there is more than one information system that a specific business process was mapped to. This then leads to a process being completed using a module of more than one information system.

Having similar modules across different systems makes it impossible for all information system modules to be utilized by the employees. This is because the same task can be completed using different information systems. Employees then end up using different modules depending on the one that they are more familiar with. This causes records of tasks to be mixed up due to the use of different systems. Having mixed-up records can affect processes transparency and accountability across the organisation. (Reynolds & Stair, 2021) suggest that the only way to create functional modules is to acquire proper data before designing any system, this way an organisation can avoid having repeated modules in different systems that carry out the same processes.

ii. Insufficient user training periods

A training period is a duration allocated to training employees on how to use the implemented IS/IT. Employees at Lexis insurance organisation often received systems training for a period of seven (7) days when new systems are implemented. This training duration was considered insufficient by many of the employees to equate themselves with the systems. The insufficient periods make it very difficult for employees in the organisation to understand and acquire the necessary knowledge on how all the systems modules work, as they are rushed to start using the system.

As a result, some of the employees only use some modules and leave out others due to a lack of knowledge of how they function. When users receive sufficient training, they gain knowledge on how to use the information systems, and they will be able to use more of the system's features. This can help increase the utilization of all the systems modules since employees will be familiar with and acquitted. Users should be trained before the deployment of a new system and may need further training after implementation as well as when any upgrades are made to the system (Scherzinger, 2021).

iii. Unfriendly users' systems interfaces

A systems user interface is the point of interaction between the user and the information system functionalities that allows the user to navigate around the system. Most of the employees struggled to navigate around the information systems due to difficult user interfaces. Employees have difficulties locating different system features when completing their tasks and this often slows down their work. This result in employees only using modules that have easily locatable features. The difficult interfaces lead to some of the employees finding alternative ways of

completing tasks and not using the implemented information systems. In agreement to that Lukin, Dzyubenko and Chechikov (2020) stated that modern interfaces have so many problems and suggested that the user interface design approach needs to change, otherwise more systems that users aren't able to interact with will continue getting implemented.

iv. Lack of systems user documentation

System user documentation is a user manual that explains the different system features and how to use them. System documentation is provided by the information system developers. Lexis insurance organisations employees are however not provided with the user documentation of the information systems that they use. This causes them not to fully utilize the information systems as they have no user manuals, they could refer to for further details on system functionality.

Systems user documentation is important as it is used as a guide by the users to learn how the system function. Providing systems user documentation can enhance self-learning of the information systems because users will have access to documentation all the time. User documentation can also be the first source of reference when a user is struggling to locate system features. Providing employees with systems documentation enables systems full utilisation because information on systems functionality and how to use all the systems modules is accessible to the employees. Documentation is affected by numerous factors such as insufficient or inadequate content and obsolete, ambiguous information which leads to there being no clear documentation for the users to use (Aghajani, et al., 2020)

v. Lack of management support

Management support is critical for the full utilisation of information systems. Management support enables the full utilisation of IS/IT by allocating resources such as time and funds required by employees to be trained on how to use information systems. In addition, management can advocate for systems user documentation for all the developed and implemented systems to always be documented. Systems user documentation acts as a living document that can be provided to newly appointed employees to familiarise themselves with the features of the system.

Management however fails to show this support to employees. This results in a lack of effort from employees in using information systems, as they do not understand their importance to the organisation. Employees then turn to other alternatives when completing tasks causing them to abandon implemented IS/IT (Scherzinger, 2021).

6. Information Systems full utilisation model

The full utilisation model guide is developed based on the findings as presented above in section (5). The model as illustrated below in figure 1 consists of five factors namely: IS/IT modules selection, systems user documentation, management support, systems interface ease of use, and system user training. The arrow illustrates the interdependence between the factors. These factors are discussed below as follows:

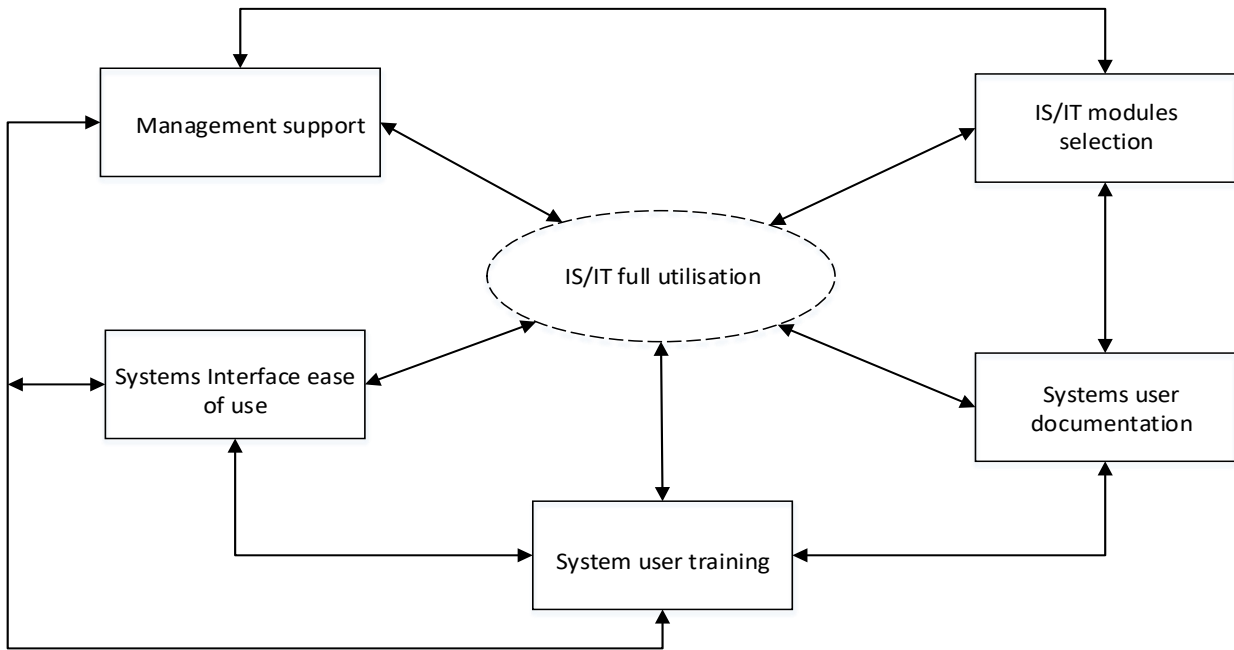


Figure 1: IS/T full utilisation model (authors' design)

i. IS/IT modules selection

When an organisation recognises a need for IS/IT, it selects the modules that should be part of it. Every IS/IT module is unique as it is mapped to its business process. During the module selection process, all the business processes are evaluated. This is done to see how they are currently carried out and if they are carried out effectively towards achieving the organisation's goals.

The process of selecting modules should include the input of employees since they are the ones responsible for carrying out daily business activities. Employees must be allowed to give opinions on how business processes can be efficiently carried out for the right modules to be selected. If employees are not involved in the selection of IS/IT modules, the organisation risks implementing modules that are not aligned with the business processes.

ii. Management support

Management support can help promote the full utilization of all the IS/IT modules as employees are provided with the various resources that they need in using the implemented systems. Examples of these resources are training, funds, and systems user documentation. Lack of management support leads to demotivated employees that will not see the need in using information systems. Employees then turn to other alternatives such as manual methods when completing tasks causing them not to fully utilize the implemented IS/IT.

iii. System user training

During systems user training the organisation must offer sufficient training for users to gain knowledge on the implemented IS/IT. Sufficient user training periods enable users to use more of the system's features based on the knowledge acquired from the training. The system's users

also get the time to individually explore the different system modules and how they operate during their training periods.

Systems user training should be carried out by the people who implement the IS/IT as they are likely to have extensive knowledge of the systems. This is because they are the ones who developed systems and they know how it operates.

iv. Systems user's documentation

User documentation is a manual that explains the different system features and how to use them. The system implementers must develop system users' documentation. The documentation should include all system modules, how to locate and operate them as well as all the functionalities of the system.

Systems user documentation is important as it enhances self-learning among the employees, as they will have access to it all the time. The systems documentation manuals act also as the first point of reference when employees are struggling to locate features on the system. This can help assure that modules will be fully utilized because users have the information on how to use all the systems modules at hand.

v. Systems interfaces ease of use

Systems interface ease of use refers to the use of interfaces without difficulties. With systems interface ease of use, employees will navigate around IS/IT functionalities without challenges enabling them to execute their tasks effectively. Therefore, the systems interface should be designed in such a way that it is user-friendly to enable ease of interaction with the user. This can be done by using the correct colours, the right font, and an understandable design of the system. Employees are more prone to using a system if its interface is designed to enable them to locate different features of the modules. If employees find the IS/IT user interface friendly, they will be able to fully utilise it.

7. Conclusion

Based on the analysis of the collected data, it was clear that information systems and information technologies are not fully utilised towards their intended purpose in organisations. This is caused by factors such as information systems module similarities, insufficient user training periods, unfriendly systems user Interfaces, lack of systems user documentation, and lack of management support. These factors have effects that are mostly underestimated in organisations.

For organisations to combat partial utilisation of IS/IT, it is recommended that organisations change their approach to implementing IS/IT. The systems requirements should clearly be defined from the beginning and both the employees and those in management should participate in this process. During this process, different problems that might be faced by employees when utilising the IS/IT after its implementation should also be highlighted for solutions to be created from the beginning. Organisations should also start implementing IS/IT in consideration of how technology keeps advancing, to avoid having to implement new systems often. By doing this, employees will also become more familiar with the IS/IT implemented, which means most of them will be able to make use of it. This can be attained by carrying out proper research and doing correct module mapping to make sure that each business process is catered for by the

IS/IT. Organisations can also improve their approach to systems module selection, this should be done to counter the issue of having a repetition of modules that end up not being used. This can help minimise the factors that impact the full utilisation of IS/IT in organisations after they are implemented.

The developed model was not tested and therefore remains a theoretical concept, therefore future studies may look into testing the model. Testing the model is critical to ensure its practicality among organisations. Otherwise, the increase is practical rather than leaving it theoretical.

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Mobile Phone-Based Money as a Tool for Financial Inclusion in Developing Countries: A Review

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Abstract.

As new technologies and business models evolve, they have a growing impact on economies and societies worldwide. Digital transformation has enabled countries to foster inclusive and sustainable development, particularly in traditionally disadvantaged areas. The digital age has advanced mobile technology that has improved global communication accuracy, economic activity, social inclusion, and productivity in industries such as agriculture, health, education, and finance. However, although telephone penetration is increasing in developing countries, their use for financial services provision is still at an early stage and mostly associated with traditional banking. Due to this, bridging the financial inclusion gap between urban and rural poor has remained a challenge. While there are some developing countries that have embraced mobile phone-based money also known as 'Mobile Money' to serve low-income, unbanked populations, it is still unclear what characteristics, preferences, and needs could motivate its ignition other developing countries. Through an in-depth review of literature on financial inclusion and technology usage, this paper is primarily focused on bringing mobile money (MM) best practices that can be used to enhance financial inclusion in developing countries. Results indicate that individual's perception of technology including perceived usefulness, perceived ease of use, trust and perceived risks, followed by social and organizational factors are core for the use of MM to enhance financial inclusion.

Keywords: Mobile Money; Financial inclusion; Economic growth; Financial digital services; Technological innovations

1. Introduction

The use of smartphones, tablets, and dongles to access mobile data services has significantly impacted on economic developments through the provision of high value 3G and 4G data services. The increasing pervasiveness of mobile technology has become an essential part of how economies work and function, the mobile telecommunications sector continues to offer unprecedented opportunities for economic growth both in developed and developing markets (Dwivedi et al., 2021). In developing markets, mobile telephony has revolutionized the way consumers and organizations conduct business as they have become the universal provider of communications services through the wireless products that has improved the way in which people connect and work and has positively impacted on economic development (Isukul & Tantua, 2021). Mobile services by using mobile data has become the new wave of advancement for businesses that are looking for ways to enhance agility, speed, and data-driven decision-making and poses a big contribution towards the enhancement of economic growth through increasing financial inclusion (Lashitew et al., 2019).

Faye and Triki (2013) indicated that the increasing use of technology has seen the development of technology-based financial services using different business models in many developing countries in Africa. They indicated that these models are basically of three categories namely; bank-focused models such as the automated teller machines (ATMs), internet banking as well as mobile phone banking. This bank-focused model could be looked as a modest extension of conventional branch-based banking hence it has limited effects on financial inclusion (Faye & Triki, 2013; Murendo et al.,

2017). Another model is the bank-led models that uses agents such as lottery outlets, supermarkets, post offices, petrol stations, and grocery stores to provide financial services to customers. This model has a significant inclusive impact as it can contribute to reaching those excluded from financial systems (Andrianaivo, & Kpodar, 2011; Faye & Triki, 2013). Lastly, is the nonbank-led models which operate with limited involvement of the bank in the day-to-day account management and mostly operated by Telecommunications operating companies such as MTN, Airtel, Orange and Vodacom (Murendo et al., 2017; IFC, 2018).

The nonbank-led model has given to various forms of digital revolution of financial services that have led to significant improvements in connectivity of systems using computing power and have hence increased financial inclusion (Chopra et al., 2015). As a result of these improvements, transaction costs have decreased and new business models and entrants have emerged through the use of mobile telephony. With the advent of these mobile telephone technological transactions, many developing countries in the Sub-Saharan Africa like Kenya, Uganda, Zimbabwe and Rwanda have seen steady improvement in financial inclusion by using mobile-based money. Mobile-based money commonly known as mobile money which is a service in which the mobile phone is used to access financial services including payments and receiving money (Kanobe et al., 2017; Dwivedi et al., 2021). Mobile money transfer leverages mobile phone to create mobile wallet and accrues to a mobile wallet, and/or is initiated using a mobile phone (Evans & Pirchio, 2015).

This mobile-based money model has tremendously enhanced financial inclusion since it has the potential of reaching those unbanked customers that have been excluded from conventional financial systems (Isukul & Tantua, 2021). Various researchers have defined financial inclusion with varying definitions depending on context and geographical region. However, the Banking Association South Africa (2018) gave a working definition of financial inclusion to include; the access and usage of a broad range of affordable, quality financial services and products, in a manner convenient to the financially excluded, unbanked and under-banked; in an appropriate but simple and dignified manner with the requisite consideration to client protection. This definition was adapted for this study.

With the increasing globalisation and competitive markets, developing countries can no longer solve their financial inclusion problems by using traditional banking methods as it has become apparent that many banks are hesitant to open up branch offices due to financial viability (Murendo et al., 2017; IFC, 2018). To operate efficiently, banks need an enormous amount of staff, equipment, and resources that requires huge capital investments and such might take them long to realize their return on investments (Dwivedi et al., 2021). This implies that the use of banking business offices to address the challenge of financial inclusion lacks feasibility in most developing countries where low income is the norm rather than the exception (Chopra et al., 2015). Amidst these challenges, governments as well as financial institutions need to leverage technological innovations like mobile phone-based money (Mobile Money) as a tool for financial services and products provision.

Developing countries such as those in the Sub-Saharan region, have seen their growth rates rise over the past decade as some have undertaken structural changes, but the progress hasn't resulted in significantly reduced poverty (Lashitew et al., 2019). Several countries in both developed and developing regions have implemented financial reforms in order to bring meaningful change to their citizens by contributing to poverty alleviation through enhancing their income (Sarpong & Nketiah-Amponsah, 2022). Additionally, financial services are expanding rapidly in developing countries, where millions of unbanked people are expected to benefit from technological innovations like mobile money (MM). However, adoption rates vary considerably across countries, and innovations have also experienced different degrees of success within countries (Evans & Pirchio, 2015; Kanobe et al., 2017). In order to understand the factors that influence the diffusion of mobile money services,

this study used textual analysis approach of in-depth literature search to identify these factors needed for successful MM innovations.

The remaining part of this paper is structured as follows, first the paper discusses the role of technological innovations in the financial sector. This section includes the identification of factors that are essential for the adoption and use of mobile money. This is discussion of the relevant literature is followed by the methodology, presentation of results, discussion and conclusion.

2. Technological Innovation in the Financial Sector

There would have been greater incentive for banks and other financial institutions to open branches in small towns and rural communities if they had been more profitable (Dwivedi et al., 2022). By having such a network of branches, services could be provided more efficiently and financial inclusion can be enhanced. In these areas, however, the costs are high and profitability is low, making the opportunity unattractive. It therefore remains prudent for banks and financial institutions to leverage low-cost technology and innovate low-cost business models in order to overcome the vast distances, costs of travel, and other overheads (Murendo et al., 2017; IFC, 2018). Utilizing technological innovation, such as MM offers viable solutions since there implementation enables financial institutions to cope with divergent needs, long-term demands, low financial engagement, and the need for public policy (Kanobe et al., 2017).

As customers become more informed, their needs for change becomes paramount, hence financial institutions need to adapt innovative means and techniques to satisfy and serve their clients. These increasing needs have increased financial innovations that have seen the advent of more banking channels such as the ATMs, video teller machine (VTM), internet banking, SIM application-toolkit, secure short messaging service (SSMS), contactless payments using near field technology (NFC), unstructured supplementary service data (USSD), radio frequency identification (RFID) technology, and mobile banking (Andrianaivo, Kpodar, 2011; Faye & Triki, 2013). The mobile banking (mBanking) developments particularly MM has successfully been used in various countries to improve financial inclusion as its operations rest entirely on mobile phone telecommunication networks (Evans Pirchio, 2015; Murendo et al., 2017; IFC, 2018). One feature that has made MM to ignite in some developing countries is the fact that customers are capable of carrying out financial transactions like transferring funds to beneficiaries, paying non-bank customers via cell phones, buying airtime and data from telecommunication houses as well as a medium for saving their income without having to going through the stringent procedures of opening up bank accounts.

In spite of a dramatic improvement in financial inclusion in Sub-Saharan Africa, the growth of traditional financial institutions has stagnated (IFC, 2018). This has been mainly due to the stringent measures of opening and operating a bank account which measures are prohibitive to many rural population of people without monthly salary earnings (Mondego, 2018; Talwar et al., 2020). More so, like many profit-making organizations, banks first conduct internal cost-benefit analyses before investing in a costly venture. This implies that before engaging in financial inclusion projects, the benefits will be weighed against the costs and if a negative cost-benefit analysis is obtained, the financial institution will be hesitant to participate in such projects (Ozili, 2020). These limitations have been major influencing factors that have enabled other banking channels like MM to have a wide spread. In Sub-Saharan Africa, East Africa, specifically Kenya, has had the fastest growth in MM and agent banking. During 2007, Safari.com launched the M-Pesa mobile money service in Kenya that provided people with cash-in and cash-out services via their cell phones, this marked the beginning of the digital financial services (DFS) revolution in the region. Initially, MM was used for person-to-person transfers, airtime topping-up, and cash-in and cash-out services, it has however of late

expanded to include, paying from phone to bank accounts and vice-versa as well a mode of payment for services and commodities (Evans & Pirchio, 2015; Kanobe et al., 2017).

The use of mobile money services has spread all over Sub-Sharan Africa and is recognised for its role in improving financial inclusion in many countries with less strict financial regulations (Evans & Pirchio, 2015; IFC, 2018). Mobile banking not only has the potential to impact financial inclusion, but also to uplift the poor and rural-based customers by providing micro-loans and micro savings, as well as international remittances (Evans & Pirchio, 2015). Developing a financial system that is all-inclusive requires taking the needs of the different users into account so that financial products can be appreciated by everyone. It is crucial to determine the factors that are driving financial inclusion in order to increase the uptake of financial products. Different countries have different levels of financial inclusion, and the reasons may be macro or micro. Abel et al. (2018) argue that individuals decide whether to be included or not based on a number of factors that determine their reaction threshold. Those beyond the critical threshold level will not seek inclusion in the formal financial markets, but those at the critical threshold level are motivated to join the formal financial markets. Although people worldwide have been fast to adopt technology for social interaction, such as WhatsApp and Facebook, the adoption of mBanking especially mobile money has been slow. It is imperative that the factors influencing mobile money adoption and usage be well researched and documented.

3. Methodology

To extend the knowledge of mobile money adoption and usage factors, a content search of databases, journal articles, conference articles, and direct search engines was carried out for the terms “mobile banking adoption”, “mobile banking usage”, “mobile money”, “mobile banking + mobile money usage”, “mobile money in developing countries” as well as “technological innovations + mobile money”. The study reviewed thirty scholarly articles that included journals, conference proceedings, web articles, and internet magazines. Different databases and search engines were searched including IEEE Xplore, Google Scholar, Elsevier Science Direct, Emerald and ProQuest. This search revealed several factors from different publications ranging from 2013 to 2021 in the fields of information systems, finance and marketing, social psychological, and business administration.

The range from 2013 was considered because of two main reasons, first much mobile banking is not new in the financial sector, the concept of mobile money is new and actually in Sub Saharan Africa the known pioneers is Kenya 2007, Uganda, Zambia and Ghana in 2009 where as others followed like Nigeria 2011 and Zimbabwe and Nigeria in 2011 and 2019 respectively (Kanobe et al., 2017). Another reason is that there are many other countries in Sub Saharan Africa where mobile money has not ignited and in others like South Africa where even though mobile money started in 2010 the most part of its transactions needs one customer to have a bank account (Evans & Pirchio, 2015). The search indicated that many of the factors had been extracted from various theoretical frameworks and models of technology adoption, utilization as well as acceptance and usage.

4. Results

The identified factors from the content search are summarized in Table1, along with the cumulative frequencies of their appearance in the searched literature. The legend to the interpretation of the theories are as follows:

BCF	Burton, Cabrera, and Frank model of crystal growth of facets
DOI	Diffusion Of Innovation Theory, or Innovations Diffusion Theory (IDT)
ELM	Elaboration Likelihood Model of Persuasion (change of attitudes)

ISSM Information Systems Success Model

RMM Response Modelling Methodology

SDM Strategic Decision-Making Theory

SST Socioemotional Selectivity Theory

TAM Technology Acceptance Model

TPB Theory of Planned Behaviour

TTF Task Technology Fit

UTAUT Unified Theory of Acceptance and Use of Technology

Table 1: Common factors influencing mobile banking adoption and usage

Factor	Abbreviation	Frequency	Theory
Perceived ease of use	PEOU	27	TAM, DOI, SDM
Perceived usefulness	PU	23	TAM, SST A/I UM
Trust	TRU	16	BCF, DOI, ISSM, SDM, UTAUT
Social influence / Subjective Norm	SI	15	TAM, SDM, TPB, UTAUT
Perceived risk	RIS	14	TAM, DOI, SDM, UTAUT
Self-efficacy	SE	11	BCF, ELM, DOI, SDM, TAM, UTAUT
Compatibility	COM	10	DOI, SDM, TAM
Facilitation conditions	FC	9	SDM, TAM, TTF, UTAUT
Cost	COS	8	RMM, TAM, UTAUT
Credibility	CRE	8	DOI, TAM, UTAUT
Culture	CUL	8	SDM, UTAUT
Demographic factors	DEM	8	DOI, SDM, TAM, UTAUT
Structural assurance	SA	8	ELM, SDM, TAM, UTAUT
Relative advantage	RA	6	DOI, SDM, TAM
Attitude toward use/m-banking	ATT	5	SDM, TAM, TPB
System quality	SYSQ	5	ELM, ISSM, TAM, SDM
Trialability	TRI	5	DOI, SDM, TAM, UTAUT
Effort expectancy	EE	4	UTAUT
Information quality	IQ	4	ELM, ISSM, SDM
Security	SEC	4	BCF, SDM, TAM
Accessibility	ACC	3	DOI, SDM, UTAUT
Complexity	CPX	3	DOI, SDM
Convenience	CONV	3	BCF, DOI, UTAUT
Need for interaction	NI	3	SST, TAM
Perceived benefit	PB	3	DOI, SDM, TAM
Perceived behavioural control	PBC	3	BCF, SDM, TPB
Personal innovativeness	PERI	3	DOI, SDM
Performance expectancy	PE	3	UTAUT
Satisfaction	SAT	3	ISSM, UTAUT

Speed	SPE	3	SDM, RMM, TAM
Uncertainty avoidance	UA	3	SDM, UTAUT
Consumer awareness	CA	2	TAM
Image	IMA	2	SDM
Privacy	PRI	2	DOI, SDM
Perceived innovativeness	PEIN	2	SDM, TAM
Perceived enjoyment	ENJ	2	SDM, TAM
Service quality	SQ	2	ELM, ISSM
Ubiquity	UBI	2	SDM
Affordability	AFF	1	SDM
Alertness	ALE	1	UTAUT
Banking needs	BAN	1	DOI
Behavioural introspection	BEI	1	BCF
Benevolence	BEN	1	DOI
Conventional interface	COIN	1	SDM
Device type/features	DEV	1	SDM
Economic factor	ECOF	1	SDM
Expectations	EXPEC	1	SDM
Experience	EXP	1	SDM
Expertise	EXPER	1	BCF
External influence	EXTI	1	SDM
Firm reputation	FREP	1	DOI,
Flow (experience)	FLOW	1	SDM
Frequency of usage	FU	1	SDM
Functional factor	FF	1	SDM
Information presentation	IP	1	ISSM
Integrity	INTEG	1	DOI,
Mobile phone efficacy	MPE	1	UTAUT
Organisational factor	OF	1	SDM
Perceived competence	PCOMP	1	DOI,
Perceived elitism	PELIT	1	TAM
Perception of latest banking Channels	PBLC	1	SDM
Personal involvement	PINV	1	ELM
Personalisation	PERS	1	UTAUT
Reputation	REPU	1	SDM

Results demonstrability	RD	1	SDM
Situational normality	SITNO	1	TAM
Service compatibility	SC	1	UTAUT
Services adopted	SADO	1	SDM
Strategic factor	SF	1	SDM
Tag-based interface	TBI	1	SDM
Task characteristics	TCHA	1	UTAUT
Technological factor	TF	1	SDM
Technology anxiety	TA	1	BCF
Technology characteristics	TECHA	1	UTAUT
Technology readiness	TR	1	ELM
Individual mobility	IM	1	TAM
Utility expectancy	UE	1	UTAUT
Visibility	VIS	1	SDM
Innovation resistance	IR	1	TAM
Power distance	PD	1	UTAUT
Task Technology Fit	TTF	1	TTF
Individualism	IND	1	SDM
Long-term orientation	LTO	1	SDM
Masculinity	MAS	1	SDM

After the content search, a close examination of the factors illustrated in Table 3.1 was carried out and indicated that some factors were just named differently by different researchers when they actually mean the same. These factors were reviewed one by one and similar ones were combined.

Mobile money is a technological innovation that uses wireless technologies to provide customers with real-time services, such technologies like General Package Radio Services (GPRS) and Code Division Multiple Access (CDMA). Thus, information system theories and models developed in this context inform its adoption, use, and success. As illustrated in Table 1, the most commonly used factors to explain the adoption and use of mobile money are either directly taken from information systems theories and models of technology adoption or modified from them.

5. Discussion

In order to reduce poverty and increase economic growth, affordable financial services are essential. A country with a deeper and more developed financial system experiences higher economic growth, lower poverty levels and greater income levels inequality (Dwivedi et al., 2021). People with poor incomes can become more resilient by accessing and using basic financial services and improve their lives hence the need to improve financial inclusion by leveraging the prevalent mobile technology applications such as mobile money (Lashitew et al., 2019).

Technology-based financial innovations involve a variety of stakeholders and steps, including individuals, government regulation, liberalization, tax policies, privatisation, globalization, and integration with international financial markets and taking on risks (Kanobe et al., 2017; Lashitew et al., 2019). As illustrated in Table 1, it is evident that individuals' perception of technology such as its ease of use that leads to self-efficacy, its usefulness in relation to the expected benefit obtained by using it, the trust they have in it as well as risks they expect from it, plays critical role in the success of mobile money. It is also evident that technology characteristics such as its compatibility, privacy, reliability and availability influences users intention to use it. Additionally, some organizational factors as well as individual traits are also salient. Based on the frequencies of the factors demonstrated in Table 1, it could be deduced that the factors of influencing mobile money can be categorized as technological factors, organizational factors, environmental factors, individual factors, contingency factors and behavior factors.

By regrouping and renaming similar factors and considering their frequencies in the search, seventeen (17) factors were deduced as the most influencing factors for mobile money success in improving financial inclusion. These factors are; Relative advantage, Complexity, Compatibility, Support, Perceived financial costs, Subjective norm, Culture, Environment factors, Individual characteristics, Attitude, Trust, Self-efficacy, Banking needs, Cell phone experience, Perceived Risks, Security and Behaviour Intention.

The peak of Covid-19 pandemic saw lock down in almost all parts of the world. The pandemic saw the amplification of the benefits of digital financial services, as fewer physical interactions were needed in retail and financial transactions (Kalema, 2022). The post Covid-19 along with the increasing digitalization due to fourth industrial revolution(4IR) continue to provide insights of the need to leverage technology for financial services especially the mobile money that permit remote payments and transactions, enabling the social distancing recommended to reduce contagion. Through electronic payments, consumers can transfer funds, pay bills and pay for goods and services from their home, or in a market or store setting, with limited physical contact. Further more it is important to note that unlike the tradition mobile banking that requires one customer to have a formal bank account, the use of mobile money is paramount for continued provision of financial services in situations of unpreparedness and pandemic.

6. Limitations, Recommendations and Conclusion

This section highlights the areas that this study could have covered but because of some constraints it couldn't cover all of them. These areas are presented as limitations and thereafter suggestions for future research are give. The last section concludes the study and give insights on future trends of financial inclusion in developing countries.

6.1 Limitations and Recommendations

This study only used secondary data were analysed data was based on the literature conducted in the past nine years. Much as the results of the study are explorative enough, they can be limited in generalization to all developing countries as the search of the literature was general. More so, many of the published articles based on their findings on those countries where mobile money has ignited leaving uncertainties for the many factors

that are challenging those that have not fully embraced mobile money. This study therefore recommends that, future research should make the use of both primary and secondary data so as to get a contextualized approach to the use of mobile money for financial inclusion.

Another crucial point to consider is the fact users' perceptions change with time hence, it is essential that their demographics or situation variables are analysed to determine their interacting effects on the adoption and use of technology. Since this study only used related literature for analysis, there was no chance of analyzing users demographics and situational variables that could play a role as moderating factors. This study recommends that future studies should examine the interacting or moderating effects of the users' demographics and situational variables.

6.2 Conclusion

This study sought to find factors that influence the use of mobile phone-based money (mobile money) as a tool for financial inclusion. However, to achieve this goal, it was essential to first establish those factors that influence mobile money usage so as it is applied as a tool for financial inclusion. The use of mobile money automatically leads to financial inclusion as unbanked customers become involved in the use financial services and products regardless of their geographical, political and social barriers. As Ozili (2020) observed, financial inclusion is attained when citizens access and use financial services and products. This study also supports the argument of many previous researchers such as (Kanobe et al., 2017; Lashitew et al., 2019; Talwar et al., 2020; Isukul & Tantua, 2021; Sarpong & Nketiah-Amponsah 2022) who argued that mobile money being based on mobile technology that is prevalent in many developing countries, it is an appropriate tool for improving financial inclusion.

Like wise, literature indicates that there are many people in developing countries rural settings that use their bank accounts as a conduits to receive their salaries and wages but they hardly use their debit cards due to the long distances from banking facilities, including ATMs (IFC, 2018; Isukul & Tantua, 2021). Such customers withdraw their earning soon as it is deposited into the accounts. These customers are challenged to have proper financial planning, which defeats the essence of financial inclusion. Hence, mobile money remains a better option for such individuals as they can withdraw at the same time make savings of their earnings.

There is still a lack of digital literacy in many developing countries, making digital transactions with established banks difficult due to customers' fear however, the high rate of telephony penetration could imply that citizens, even those in rural settings, have efficacy with mobile technology (Mondego, 2018; Talwar et al., 2020). Therefore, leveraging mobile money for financial inclusion not only help poor households to access banking services and products but also assist those many customers who perceive digital financial transactions as complex. Additionally, mobile money uses the already available infrastructure of telecommunication service providers and have extended to cover wider geographical settings. Hence, supporting the use of mobile money by both policer makers and financial institutions is a better way to achieve full and universal financial inclusion. This study therefore recommends development of empirically validated models and frameworks to inform mobile money usage.

Due to the high penetration of mobile technology in less advantaged rural communities, mobile phone money can be used to improve financial inclusion at much lower costs. It can also provide cost-effective financial services and products to the poor, if governments put favourable policies and regulations in place, which can allow non-banking institutions to participate in the financial services provision. It is also important for governments to put in place favourable policy reforms that will increase household income rates and reduce illiteracy, as well as boost or subsidize investments in ICT. Additionally, forming or expanding partnerships between financial institutions, such as banks and other non-banking institution, microfinance institutions, and mobile money service providers like telecommunications networks is urgently needed. Lastly, it is important to note that cell phones are increasingly prevalent among unbanked communities in developing countries, especially in Sub-Saharan Africa, and could serve as an effective and economically viable means of bringing financial services to rural populations which are financially excluded.

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The Effects of Blended Learning Approaches on Class Attendance Scores in Two Final-Year Undergraduate Financial Accounting Courses

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Abstract

At the convergence of declining class attendance and the desire to maintain satisfactory academic progress lies ample research proof that engaging students through blended learning approaches, that is, combining traditional face-to-face and technology-mediated instruction, is a strategy worth pursuing. However, much less is known about the link between blended learning approaches and student class attendance scores. This paper reports on the results of a survey-based investigation into the respective effects that a restricted and an extended blended learning approach had on class attendance scores in two final-year undergraduate financial accounting courses. For the restricted blended learning approach, significant positive effects were reported for the following combination of constructs: student–instructor interaction using ICT, classroom and course experience using ICT, and student–course engagement. For the extended blended learning approach, the same constructs, as well as personal blended learning experience, returned significant positive effects. A collaboration and social experience using ICT construct was excluded as a predictor of class attendance in both approaches. In addition, a larger significant effect for class attendance scores was reported when an extended blended learning approach was followed, with the impact greater for female students.

Keywords: Blended Learning Approaches; Class Attendance Scores; Information and Communication Technologies; Financial Accounting Course; Absenteeism

1. Introduction

Student absenteeism in face-to-face (FTF) higher education institutions (HEIs) is not a new phenomenon. More than a decade ago, declining class attendance was reported a growing trend (Massingham and Herrington, 2006). Some reasons provided by students include, inter alia, the methods of teaching (Alija, 2013), a lack of motivation, boring, worthless lectures and incompatible learning styles of students and instructors (Kottasz, 2005), as well as extracurricular, academic or personal conflicts (Clay and Brelow, 2006). There against, the research literature provides substantial evidence of a largely positive correlation between class attendance and academic performance (Alija, 2013; Guleker and Keci, 2014; Park and, Kerr, 1990; Romer, 1993). Accordingly, it has been concluded in a meta-analysis of previous research that class attendance is the most accurate known predictor of academic achievement (Credé et al., 2010). Similarly, class attendance has been ranked 6th among 105 variables that are related to achievement in higher education (Schneider and Preckel, 2017).

At the convergence of declining class attendance and the desire to maintain satisfactory academic progress and student performance lies further research proof that engaging residential students through blended learning (BL) approaches (BLAs), that is, combining traditional FTF and technology-mediated instruction, is a strategy worth pursuing (Lan, 2011; Galy et al., 2011; McKenzie, 2013; McLaughlin et al., 2015). The exact relationship between BLAs and class attendance scores, however, has not been rigorously assessed. There is a need for such research. Physical class attendance, especially in more demanding academic subjects, facilitates learning in a variety of ways, and there is concern among academics that providing

students with an element of control over time, place or space as afforded by BLA may be counterproductive i.e. result in lower class attendance rates.

In this paper we report on the results of an investigation into the respective effects that a restricted and an extended BLA had on class attendance scores in two final-year undergraduate financial accounting (FA) courses. Specifically, we compare the effects that a restricted BLA followed in a 1st semester FA course (FA I) had on class attendance scores, repeated for a follow-up 2nd semester FA course (FA II), where a more comprehensive BLA was followed. FA is a difficult academic subject demanding systematic work (Burgess, 2008), regular class attendance and the use of supplementary and innovative teaching and learning approaches. As a mathematical, precise and bounded subject, it also lends itself to the imaginative use of information technology (Bawaneh, 2011). In the HEI under study, a continuing problem of non-attendance and student dropout led management to actively drive the adoption of BLAs. For these reasons, a suitable research setting to investigate the effect of BLA on class attendance scores was made available. In reporting our results, the goal of this study is to fill the research gap on the relationship between BLAs and class attendance scores.

2 Background and hypothesis development

As noted in the introduction, prior research in the area of BL effects has generally focused on student academic performance, with largely positive effects reported (Bawaneh, 2011; Delane, 2010; Yapici and Akbayin, 2012). To the best of our knowledge, only one study (Collins and Daly, 2014) has specifically investigated the link between BLAs and class attendance scores. In engaging undergraduate nursing students in a BLA, class attendance increased to almost 100%. One other study, in observing student perceptions of BL and final marks, noted an indirect correlation between BL variables and class attendance, suggesting that a BLA may lead to greater student commitment and perseverance (López-Perez et al., 2011).

Given the dearth of research on BLAs and class attendance scores, the broader and mostly consistent literature on BL effects on student performance was reviewed with the purpose to gain an overview of the context within which results were reported. Table 1, which lists most studies referenced in this paper, presents a frequency table summary of our review. Specifically, the table reflects the subject area, the level of study, as well as whether any BL effects on student performance was observed.

From our review, 23 studies reported positive BL effects on student performance, while only one did not. Notably, only one study (at third-year level) was conducted in the subject area of Accounting. For these reasons, ample scope existed for using the BL-performance literature to extract guidelines in construction of suitable research hypotheses to fit the current study's focus areas.

Table 1: Review of research studies on BLAs and student performance outcomes: frequency counts for BL effects for different levels of study and subject area.

Year of study		1st	2 nd	3 ^r	4 th	5 ^t	Total
BL effects	Yes	3	5	7	2	5	22
	No		1				1
Subject areas	Accounting			1			1
	Business		1			3	4
	Commerce			1			1
	Economics	1	1				2
	Marketing			1			1
	Sociology				1	1	2
	Statistics		1	1			2
	Sports	1	1				2
	Mathematics		1	1			2
	Statistics		1	1			2
	Engineering	1		1	1		3
	Medical sciences					1	1

As basis, we selected a model (Rugutt and Chemosit, 2005) which investigated the influence of student active learning strategies, student-faculty interaction, quality of instruction and overall college experience, and internet and campus technology on student academic achievement. To this, and starting our review, we add a research-acknowledged gender effect.

A recent study (Kwak, 2014) reported student performance not to be affected by the introduction of BLAs, irrespective of characteristics such as age, nationality and achievement level. It did, however, report a negative BL effect for male students and a positive effect for female students. Female students have also been found to be more successful in both an FTF and BL environment (Kazu and Demirkol, 2014), but also more influenced by personal factors, instructors and institutional support, which in turn may affect their perceived accomplishment, enjoyment and learning satisfaction (Dang et al., 2016). This differential impact of BL was tested with hypothesis H1 but limited to the more comprehensive FA II BLA. **Hypothesis H1:** There is a gender difference in terms of the effect an extended blended learning experience has on students' class attendance in the FA II course.

It is imperative that students engage actively in BLAs in order to advance their academic status, including self-directed learning, participation in group discussions and unassigned academic work (Arnett, 2016). Although gender, as already highlighted, may play an influencing role, BL is known to have a perceived positive effect through a high degree of utility, motivation and satisfaction, which could lead students to have a positive attitude towards learning; this, in turn, may have a favourable influence on their independent work ethic, and an indirect correlation between BL activities and class attendance (López-Perez et al., 2011). This notion was hypothesised as follows: **Hypotheses H2a and H2b:** Personal blended learning experience has a positive influence on students' class attendance in the FA I (H2a) or FA II (H2b) course.

While discussions around BLAs often focus on software, hardware and classroom layouts, some of the most powerful benefits of BLAs are the ways in which it allows teachers and students to have more meaningful interactions during the learning process (Arnett, 2016). In order to create a positive learning environment, teachers using a BLA should actively encourage student participation (Guzer and Caner, 2014). The following hypotheses were tested: **Hypotheses H3a and H3b:** Student–instructor interaction using ICT has a positive influence on students’ class attendance in the FA I (H3a) or FA II (H3b) course. A range of literature on student engagement is cited in the classroom. In a BL environment, teachers should not only consider an engagement scheme to support student performance in an FTF context, but also how they need to manage the online learning environment (Radloff and Coates, 2011; Hung and Chou, 2015). Based on this view, the following hypotheses were formulated. **Hypotheses H4a and H4b:** Classroom and course experience using ICT have a positive influence on students’ class attendance in the FA I (H4a) or FA II (H4b) course.

Whereas BL is perceived as useful, enjoyable, supportive, flexible and a motivator for learners, these factors alone are not enough to create an atmosphere for successful learning (Arnett, 2016). Instructors may nurture collaboration by finding ways of creating opportunities for social interaction. The result is a positive association between, for example, online discussion forum participation by learners and their academic attainment (Delaney et al., 2010). Collaboration and social experience using ICT were tested with hypotheses H5a and H5b. **Hypotheses H5a and H5b:** Collaboration and social experience using ICT have a positive influence on students’ class attendance in the FA I (H5a) or FA II (H5b) course. Finally, a positive outcome associated with student attentiveness and engagement in a BLA has been reported (McLaughlin et al., 2015), while student attendance does not appear to decrease when online lectures are provided (Kinash, 2012). Consequently, two final hypotheses were formulated: **Hypotheses H6a and H6b:** Student–course engagement has a positive influence on students’ class attendance in the FA I (H6a) or FA II (H6b) course.

3. Research setting and methodology

3.1 Research setting

The HEI where the study was conducted is a private residential HEI in a developing country in Africa. The two FA courses are core offerings attended by final-year undergraduate students, split into a first semester (FA I) and a second semester (FA II). The FA I (semester 1) curriculum was complemented with the introduction of the online learning platform Moodle (the restricted BLA). A few instructors uploaded extended learning resources (LRs) to Moodle, preferring to provide students with soft copies of standard LRs i.e. employing Moodle as a file repository. In the extended BLA (2nd semester FA classes), instructors uploaded LRs inclusive of study guides, continuous assessment marks, assignments, projects, tutorial questions and lecture notes, and encouraged students to make use of collaborative tools such as email and a discussion forum. This increased use was facilitated by management who implemented a policy aimed at ensuring the effective utilisation of Moodle e.g. instructors were required to report on reasons for non-use.

3.2 Method

The research design employed the survey method (printed questionnaire) for data collection. Ethical clearance was obtained from the relevant authorities, with participation voluntary and

strictly confidential, that is, the instructor linked and anonymised the returned surveys and attendance scores awarded. The questionnaire was constructed using questions from a study of factors that influence student participation in programs and activities provided by institutions (Rugutt and Chemosit, 2005) and which we adapted to include ICT engagement in an BL environment. The final questionnaire was subdivided into two sections: SECTION A: demographic and background data (age, gender, extent of ICT use); and SECTION B: BL experience, comprising 22 questions. Participants were requested to rate five constructs: Construct B: BL experience (4 indicators: independent study using ICT; course content discussions using ICT; unassigned work using ICT; studied with other students using ICT); Construct C: Instructor (3 indicators: academic support via ICT; role of ICT in creating a respectful learning environment; emotional support and encouragement via ICT); Construct D: Course experience (4 indicators: ICT made course relevant; ICT increased the quality of course; faculty contact using ICT; overall class experience using ICT); Construct E: Collaboration (5 indicators: email communication with faculty / fellow students / peers; participation in class discussion using email and Internet; and use of the Internet) and Construct F: Engagement (6 indicators: listening to instructors; active participation; concentration; additional effort; class discussions). Rating was done using a five-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = indifferent, 4 = agree and 5 = strongly agree. The survey took place at the end of a 2nd semester lecture week when discussions/tutorials of the forthcoming examination were presented and when maximum attendance was ensured. The data collected from 48 students were analysed using data analysis methods.

4 Data analysis and results

4.1 Reliability

Cronbach reliability coefficients returned for the independent variables were Construct B: BL experience (0.856); Construct C: Instructor (0.885); Construct D: Course experience (0.85900); Construct E: Collaboration (0.874); and Construct F: Engagement (0.879). All the values were greater than 0.8, which is indicative of a “good” α coefficient (Hung and Chou, 2015) and reliable questionnaire scores.

4.2 Demographic and background data (age, gender and extent of use of ICT for purposes of teaching)

Fifty-four percent of the 48 respondents who completed the questionnaire were female. Most students (62.5%) were aged 22 or younger, but as final-year students, closer to 21. Multiple regression analysis was conducted to analyse the relationship between the extent ICT was used in the teaching of the FA II course and the class attendance score. The relationship reported was significant ($t = 2.261$, $p < 0.05$), with the regression model explaining 10% of the total variation.

4.3 Gender differences

For the FA II course, the correlation between class attendance score and gender was positive for both males and females ($r = .92$ and $r = .97$, $p < .001$, respectively). The effect was less pronounced for the male group ($R^2 = .86$, 86.3%) than for the female group ($R^2 = .957$, 95.7%). That is, the extended BLA had a slightly larger positive impact on female student attendance.

4.4 Construct analysis

Multiple regression analysis techniques were applied in the prediction of regression model 1 (FA I) and regression model 2 (FA II). The results are presented in Table 2.

Table 2. Summary of multiple regression analysis (n = 48)

Constructs	Model 1 (FA I) Unstd B / Std β	Model 2 (FA II) Unstd B / Std β
Construct B: BL experience	-3.218(.203)	3.791(.219) **
Construct C: Instructor	7.311(.453)*	7.428(.423)*
Construct D: Course experience	8.371(.509)*	4.010(.224)**
Construct E: Collaboration	-1.173(-.068)	-.171(-.009)
Construct F: Engagement	5.063(.303)**	4.840(.266)*
R ²	0.766	0.917
R ² Adjusted	0.738	0.907

* significant at $p < 0.01$, **significant at $p < 0.05$

For model 1, three predictors, namely Construct C: Interaction, Construct D: Course experience and Construct F: Engagement were statistically significant. Construct B: BL experience and Construct E: Collaboration was not statistically significant. $R = 0.875$ represents a good level of prediction of the attendance score, while $R^2 = 0.766$ indicates that 76.6% of the variance in students' class attendance scores can be predicted from Construct B: BL experience, Construct C: interaction, Construct D: course experience, Construct E: collaboration and Construct F: engagement. For model 2, four predictors, namely Construct B: BL experience, Construct C: Instructor, Construct D: Course experience and Construct F: Engagement were statistically significant. Here only Construct E: Collaboration was not statistically significant. The R^2 value of 0.917 shows 91.7% of the variance in students' class attendance scores can be predicted from the same constructs as in model 1.

Notably, the effects of the extended BLA on class attendance scores in model 2 was higher than the effects for model 1. Finally, a comparative analysis of FA I and FA II attendance scores was conducted. Results reflect an improvement in attendance for FA II (43-100%) compared to FA I (29-93%). In order to confirm the effect, a paired sampled t-test was conducted. The results revealed FA I and FA II to have had mean scores of 64.10% and 69.88% respectively, the difference being significant ($t(47) = 2.817$, $p < 0.05$). The paired difference between the semesters was 5.78%.

4.5 Confirmation of hypotheses

A summary of the hypothesis testing is provided in Table 3.

Table 3. Hypothesis testing summary

Hypothesis, Variables	Constructs	FA (Restricted BLA)	FA (Extended BLA)
H1 Gender		-	Supported
H2 <u>Construct B</u> : BL Experience		Not supported	Supported**
H3 <u>Construct C</u> : Instructor		Supported*	Supported*
H4 <u>Construct D</u> : Course Experience		Supported*	Supported**
H5 <u>Construct E</u> : Collaboration		Not supported	Not supported
H6 <u>Construct F</u> : Engagement		Supported**	Supported*

*significant at $p < 0.01$, **significant at $p < 0.05$

Hypothesis H1: There is a gender difference in terms of the effect of an extended blended learning experience on students' class attendance in the FA II course is supported. With an equal split between male and female students (54% of students were female), the extended

BLA had a slightly larger positive impact on female attendance. The small difference observed may simply be a case of males taking more risks or having greater confidence in their ability to succeed without attending classes (Lukkarinen, 2016).

Hypothesis H2a: Personal blended learning experience using ICT has a positive influence on students' class attendance in the FA I course was not supported ($\beta = .203$, $p > 0.05$). Given that most instructors merely made soft copies of LRs available on the BL platform, the result highlights the reality that fruitful BL practices extend beyond the basic provision of rudimentary web-based resources (Atkinson, 2009).

Hypothesis H2b: Personal blended learning experience using ICT has a positive influence on students' class attendance in the FA II course is supported ($\beta = .219$, $p < 0.05$). In FA II, the BLA was extended to include study guides, continuous assessment marks, assignments, projects, tutorial questions, lecture notes and collaborative tools. Whereas these extensions do not necessarily constitute an effective or rich BLA, the results do suggest that when instructors negotiate the learning needs of students beyond the classroom walls, the environment created successfully engages students to the extent that it results in an increase in class attendance. Moreover, and given that this was a first extended BL experience for both instructors and students, the increase in class attendance is noteworthy.

Hypothesis H3a: Student–instructor interaction using ICT has a positive influence on students' class attendance in the FA I course is thus supported ($\beta = .453$, $p < 0.01$). With restricted use of Moodle, we can only surmise that instructor–learner interaction using other ICT had a positive influence on class attendance. Such a notion is in line with results from a study on the use of ICT by science teachers in classrooms typical of developing country contexts, and which concluded that when teachers and students can use ICT effectively to add value to teaching and learning, it results in an increase in student attendance (Draper, 2010).

Hypothesis H3b: Student–instructor interaction using ICT has a positive influence on students' class attendance in the FA II course is supported ($\beta = .423$, $p < 0.01$). In adding to the previous hypothesis acceptance, the positive effect in class attendance may be explained of better class organisation afforded by using a learning management system (Rodi et al., 2013). In addition, with further LRs available on Moodle, more scope for FTF interaction may have existed.

Hypothesis H4a: Classroom and course experience using ICT have a positive influence on students' class attendance in the FA I course is supported ($\beta = .509$, $p < 0.01$). As with hypothesis H3a, the result could possibly be attributed to the effective use of other ICT by the instructor, which adds to the students' classroom and course experience.

Hypothesis H4b: Classroom and course experience using ICT have a positive influence on students' class attendance in the FA II course is supported ($\beta = .224$, $p < 0.05$). Earlier results indicated higher class attendance scores in the FA II course. With higher class attendance indicative of a higher level of engagement (López-Perez et al., 2011; Rodi et al., 2013), we are somewhat surprised at the lower β value reported for FA II compared to FA I, particularly since research has reported students to find BLAs interesting and useful (Murphy and Stewart, 2015). However, it may simply be a case of students making strategic use of the BLA, or that other factors are at play.

Hypothesis H5a: Collaboration and social experience using ICT have a positive influence on students' class attendance in the FA I course is not supported ($\beta = -0.068$, $p > 0.05$). In the absence of an extended BLA, the result is not unexpected.

Hypothesis H5b: Collaboration and social experience using ICT have a positive influence on students' class attendance in the FA II course is not supported ($\beta = -0.09$, $p > 0.05$). Whereas a greater willingness from students to collaborate with peers in a BLA environment has been reported (Bawaneh, 2011; Mustafa and Hasan, 2015; Al-Ani, 2013), it is noted that collaborative activities need to be carefully nurtured by the instructor (Guzer and Caner, 2014), and together with a first offering, this may well explain the current result.

Hypotheses H6a and H6b: Student–course engagement has a positive influence on students' class attendance in the FA I and FA II courses are supported ($\beta = .303$, $p < 0.05$ and at $\beta = .266$, $p < 0.01$ respectively). The results are in disagreement with a study on the effects of BLAs where no significant change in students' attitude towards a university course was reported (Yushau, 2006) but is in agreement with proven arguments that (a) computer-based practices increase student engagement (Delaney et al., 2010; Montgomery et al., 2015) (b) the provision of a BL environment not only supported students' active participation in the course activities, but makes the content of the course, homework and online projects interesting and useful (Gecer and Dag, 2012) and (c) in BLAs, class engagement show a meaningful improvement when compared with only the FTF learning approach (Mustafa and Hasan, 2015).

5 Summary of results and discussion

This paper reported on the results of an investigation into the respective effects that a restricted and an extended BLA had on class attendance scores in two final-year undergraduate FA courses. In comparing the two BLAs a significant difference was reported between students' class attendance scores for FA I and FA II, with attendance higher when an extended BLA was followed. Furthermore, the extended BLA not only improved class attendance, but did so for a challenging academic subject. The result thus extends previous research (Burgess, 2008), which reported BL to partially benefit part-time students studying a difficult subject, to include increased class attendance of full-time time students. Although not an extensive BLA implementation, the results appear to support the belief (Tseng and Walsh, 2016) that 21st century learners desire to learn using a digitally-rich curriculum.

Over and above offering valid predictive models for ensuring increased class attendance when a BLA is introduced, a slight gender BL effect on class attendance with the impact greater for female students (Kwak et al., 2014; Kazu and Demirkol, 2014), is confirmed. When a restricted BLA was followed, the collective influence of student–instructor interaction using ICT, classroom and course experience with ICT and student–course engagement had significant and positive influences on class attendance scores. These findings confirm previous research on the factors of successful use of ICT in FTF classrooms (Rugutt and Chemosit, 2005; Fichten et al., 2015; Venkatesh et al., 2016).

When an extended BLA was followed in the 2nd semester (FA II), the same three constructs, as well as personal BL experience, were found to have a collective and positive influence on class attendance scores. As with the restricted BLA, no relationship was reported between collaboration/social experience and class attendance score. Asynchronous collaboration, however, is not easily achieved (Rockinson-Szapkiw and Wendt, 2015; Rennstich, 2019), and in a first offering of collaboration tools in the extended BLA, the result is perhaps not entirely unexpected.

6 Conclusion

It is evident that in the context studied, classroom attendance for a difficult academic subject improved when the BLA was extended, even if the approach was not necessarily rich and comprehensive. The current results thus extend evidence-based studies which have shown student performance to be higher in BL as opposed to either fully online or FTF approaches (Siemens et al., 2015) to include classroom attendance. Future studies would consider impact of class attendance on open and distance learning, and speech-based learning as an extension of (Blessing et al., 2021; Ayo et al., 2014; Inam et al., 2017). In closing, it is noted that the adoption of technology always requires a rethink of the teaching and learning model to be offered. Different models may well result in different BL effects, just as a larger-scaled study will allow valid generalisations (a limitation of the current study) to be made. At minimum, instructors offering demanding academic subjects and not yet employing BL as a teaching and/or learning tool should take note of our results.

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A comparative analysis of shared technological mobile facilities in Africa

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Abstract

This paper presents a review of existing solutions for addressing rural digital skills scarcity and proposes a novel idea for a solution that can both address rural challenges and equip high school students with skills to be future-ready. Using narrative review qualitative methods of in-depth analysis, the authors exploit the reasons and implications of the shared mobile facility. This study explores a shared mobile facility solution that can reach students who are technologically “left behind”. The study contributes to understanding rural populations' digital skills gaps and the consequences if nothing is done. Implementing the proposed solution will contribute to implementing advanced digital skills training projects in rural South Africa.

Keywords: mobile classroom, digital skills training, digitruck, rural areas.

Category: Digital Transformation, information technologies in Education, Human-computer interaction, ICT for sustainable development

1. Introduction

Historically disadvantaged communities, especially in rural areas, remain underserved in the fourth industrial revolution (4IR) in South Africa (DBSA, 2022). South Africa is one of the most unequal societies, evidenced by the digital skills gap between urban and rural areas. Rural areas are particularly affected because they cannot keep pace with the rapid development of digital connectivity. After all, Internet and broadband infrastructure rarely reach these areas (Frans & Pather, 2021; Duma, 2015:142-148). Rural communities' limited access to affordable digital tools such as smartphones and tablets is due to low literacy rates, poverty, and low household incomes (Frans & Pather, 2021). The limited availability of information due to the digital divide results in inadequate service delivery in Education (Maphosa, 2021).

Rural schools face numerous challenges such as lack of government funding and resources, scarce resources, inexperienced teachers, and teaching multiple grade levels. Therefore, learning in these institutions cannot proceed as usual because students are either failing or dropping out of school (Duma et al., 2021). Many rural schools are dilapidated, with vandalised buildings, and lack of essential services such as electricity and water (Pillay, 2021). While South Africa is participating in 4IR and lagging, the country needs to build digital skills and the necessary infrastructure to reap the benefits of digital transformation (Pillay, 2021).

Despite South Africa's digital policies around schools' access to broadband, the reality is that many schools do not have access. The lack of educators in computer literacy in the country is another issue. A study by Shikalepo (2020) found that students in rural areas have almost no Internet access. On the other hand, students in urban areas have access to the Internet and use online learning with fewer interruptions. Imagine a group of people who grew up in rural areas without ever using a computer; they are digitally illiterate. Rural schools should have access to Internet-enabled technology, but they must first learn how to use a computer, as a first step toward digital literacy (Duma et al., 2021).

Sustainable Development Goal 4 (SDG 4) calls for “achieving inclusive and equitable quality education and promoting lifelong learning opportunities for all” (United Nations, 2022). During the COVID19 pandemic, approximately 90% of primary and secondary school pupils could not attend school due to a lack of digital access, social support, and resources (Trahar et al., 2020). Therefore rural schools could not participate in online classes because survival took precedence over knowledge acquisition. These challenges make it extremely difficult for rural people to join 4IR and adapt to a technology-heavy future.

Many industries worldwide are transformed by digital automation, artificial intelligence, and other digital technologies that promote economic growth, social progress, and cultural advancement (Ministry of Communications and Digital Technologies, 2020). Several policies have been implemented in various sectors, including Education and economic development, to develop national digital and future capabilities in South Africa (Department of Communications and Digital Technologies, 2020).

Currently, no practical design explicitly targets students in rural South Africa to address the previously mentioned challenges. The primary objective of this study is to design and implement an educational facility that will help students in rural South Africa learn skills that will make them employable in the age of digital transformation.

Urbanisation is a severe problem in South Africa. An estimated 80% of the population will live in urban areas by 2050. Many rural residents are moving to the city for a better life, educational opportunities, and economic opportunities. (Mlambo, 2018). However, not all rural residents have the means to move to the city, so concerted efforts must bring upliftment and inclusion in these areas. While the rest of the world is participating in or preparing for the gig economy, rural South Africans must also be among those equipped to do so. This paper aims to contribute to possible innovative solutions for including disadvantaged communities in the fourth industrial revolution.

This paper is structured as follows: Section 2 discusses the background and related work. Section 3 describes the methodology. Section 4 presents the finding and discussion. Lastly, Section 5 concludes the paper and offers future work recommendations.

2. Background and related work

At the basic education level, Strategy Element 1 aims to develop curricula that build a broad range of digital skills and adapt to changing knowledge needs; build capacity for all educators by ensuring that they are equipped with digital skills; and provide the necessary infrastructure to enable digital skills and ensure that it is operational. Under the third pillar of the strategy, employers and educational institutions will work together to empower workers and students alike to prepare for 4IR. Strategy Element number 4, recognises that many vulnerable groups (race, gender, geography, and poverty) have a digital skills gap; it aims to empower communities and individual citizens to participate in 21st-century society. Recently, the Sustainable Development Goals Fund (SDGF, 2022) promoted digital literacy as one of the critical indicators of SDG 4 to be included in the SDGF. Students with access to quality digital education are more likely to close the achievement gap between boys and girls and reduce social inequalities. In addition, digital education technologies can be a primary means to facilitate global collaboration between boys and girls and open up future employment opportunities for those using them (SDGF, 2022) hence the rationale of the target group being high school students. These opportunities are encapsulated in the National Digital and Future Skills Strategy (2020).

As defined by the DBSA (2022), digital literacy refers to a person's ability to demonstrate critical thinking and awareness while possessing the necessary technical skills to effectively use modern

technologies in the workplace, at home, and in society. Consequently, digital literacy encompasses cognitive and affective competencies and technical ones. Execution and problem solving require a combination of technical, cognitive, social, and emotional competencies (van Laar et al., 2017).

According to Fisher (2022), technological progress is increasing exponentially, but digital adoption and transformation occur at a snail's pace. The gig economy, defined as a free market system where positions are temporary, and companies employ people on a short-term basis, will dominate almost all industries in the coming decades (Lutkevich and Gillis, 2022). Recently, the coronavirus, and its subsequent imposed restrictions on people, to stay and work indoors have changed the traditional work model. As a result, it is safe to assume that the gig economy is in full swing. Fisher (2022) has pointed out that the nature of the workplace has changed from predominantly decentralised to predominantly hybrid, allowing anyone to work from anywhere. This gives previously disadvantaged and rural communities a chance to participate in the economy, provided they are adequately equipped to perform tasks.

Existing jobs in sub-Saharan Africa are predicted to become obsolete due to new technologies such as artificial intelligence, machine learning, and Big Data (Fisher, 2022). Job creation is expected to decline in the future (Rainie and Anderson, 2017). At the World Economic Forum and elsewhere, experts have spoken about the potential for future job losses and the need for significant changes in learning environments and Education. In these environments, workers are kept up to date with the changing world of work. Even those currently employed have realised that they must constantly acquire new analogue and digital skills to remain employed and employable.

The question of whether South Africa is prepared to meet the enormous demand for digital skills in the coming decades, remains. According to Fisher (2022), a survey by Wits University found that South African technology companies are struggling to fill positions that require software developers and computer network engineers, programme developers, and systems engineers. To prepare for these new jobs, the National Digital and Future Skills Strategy (2020) has identified current and future opportunities that require digital skills (Table 1).

Table 1: Future jobs and required digital skills

Future Job	Technology
Business intelligence engineer. Database architect, quantum computing. Digital executive positions	Algorithms
Application Developer, Machine learning, Robotic Process Automation UI/UX Developer	Artificial intelligence
Digital Communications, Digital Media designer, digital marketing specialist	Digital communications
Security tool specialist, Project Manager, scripting specialist	Cybersecurity
IP Network engineer, digital systems development specialising in hardware interfacing	Internet of things

Source: Future jobs and required digital skills (NSDFS 2020)

Next section presents the methodology adopted in this paper.

3. Methodology

The narrative review was used to identify and analyse recent studies on digital skills training solutions. A narrative review aims at summarising or synthesizing previous literature on a particular subject (Pare & Kitsiou, 2015). In this paper the narrative review was applied because it provided insight into the different solutions implemented to train digital skills. The selection of papers was unstructured; the only criteria was for the articles to focus on solutions so that they can be compared and also identify the gaps in the digital training solutions.

At the onset a search was conducted using the following search strings":

"digital skills" AND "rural" OR "South Africa" using Scopus and Web of Science databases. The table below presents the results from the search string.

Table 2: Narrative review search

Database	Search string	Final results
Scopus	"Digital skills" AND "rural" OR "South Africa"	711
	"mobile" AND "digital skills" AND "training" AND "digital divide"	232
Web of Science	"Digital skills" AND "rural" OR "South Africa"	845
	"mobile" AND "digital skills" AND "training" AND "digital divide"	2
	"mobile" AND "digital skills" AND "training"	17

Source: Authors

The final results were obtained after using the following filters

Table 3: Search filters

Criteria	Value
Publication years	2017-2022
Language	English
Publication type	Article or Proceeding Paper or Book chapters
Research areas	Education, computer science & Development Studies

The articles were exported to Citation Management software, RefWorks. Articles were perused and selected in an unstructured manner because the paper sought to find existing solutions for digital skills training within a shared mobile facility.

The next section presents the findings from the narrative review

4. Findings & Discussion

4.1 Previous solutions

Countries around the globe have initiated solutions to prepare their citizens for a digital future. A comparative analysis of previous solutions is listed below to ascertain the feasibility of incorporation into a solution.

Cambodia: has initiated a motorcycle solution that "carries" the signal from village to village (Luo and Chea, 2018).

Rwanda: Using only drones, a Harvard Ph.D. student in Rwanda has developed a blood supply delivery system that can reach even the most remote parts of the country (Khanna and Gonzales, 2021).

Smartphones are used to control drones. Safe dispatch and landing could be confirmed using fixed-winged drones with dual propellers, which assisted in achieving the goal of dropping blood in rural areas. Using drones is a good possibility for distributing the signal to rural areas and combating problems around connectivity; however, the infrastructure associated with the implementation is enormous. A launch pad and landing pad are required. These stations need to have drone pilots to ensure a successful flight. South Africa is highly regulated, and the amount of red tape in government may delay the implementation. Furthermore, foreign objects penetrating the airspace of rural areas may be frowned upon, especially by people who have not been exposed to modern technology.

India: Many of India's interventions have included public Wi-Fi hotspots, which have increased Wi-Fi coverage across the country (Shruti and Chaudhari. 2021). There's no need to get a permit or subscribe for anything. In addition, rural areas in India now have access to high-speed Internet. Their citizens could access services because of this (Shruti and Chaudhari. 2021).

Kenya: digitruck Using a digital truck, Kenya's Ministry of Information and Communication Technology (ICT) has taught young people how to use computers and other digital devices. Teaching youth how to use computer programs like word processing, as well as how to search for work online, is a primary goal of the truck. The focus is split because one of the other focus areas is how to recycle e-waste.

SchoolNet: Telkom, SchoolNet, Feature IT, and Mustek were all involved in this project. Witbank Premiere School, which is situated on a farm without cell phone coverage, now has an ICT lab, which is a boon to the community members who previously had to travel to the nearest town to receive phone calls. Teachers and community members were allowed to learn about digital technology in the ICT lab, providing training to help them become better digital citizens (School Net South Africa, 2017).

Good Work Foundation project: A project funded by the Good Work Foundation aims to bring world-class digital Education to rural Mpumalanga, supporting approximately 8000 learners each week. Children could take classes in English, maths, computer, and environmental literacy at the centre. In addition, at least 90 minutes of training per week was provided to community members. According to the findings, the Hazyview Digital Learning Campus improved by more than half (Sello, 2022). Table 4 below shows a comparison between implemented solutions, specifically in relation to the proposed solution.

Table 4: Comparison of mobile shared technology facilities

Objectives	Digitruck	Scooter	Farm-Telkom	Good work foundation
Tutors	✓	x	x	✓
Energy efficiency	✓	✓	✓	✓
Infrastructure	✓	x	x	✓
ICT equipment	x	x	✓	✓
Software	x	x	x	✓
Data/internet/wifi	x	✓	x	✓
Programming language	x	x	x	X
Digital skills training	x	x	x	X

4.2 Criticism of previous initiatives

The focus of past initiatives has been primarily on connecting people to the Internet and teaching them how to use computers, to compensate for deficiencies in general Education. Basic computer

skills have been introduced to the rural poor, although not on a large scale. Sello (2022) pointed out that the introduction of tablets, computers, and infrastructures is not the easiest way to further educate people seeking digital careers when digital skills are lacking. Analytics engineers, database architects, AI transformation specialists, digital forensics experts, and robotics engineers are just a few of the occupations listed in the National Digital and Future Skills Strategy (2020).

These solutions are not sufficient to address issues such as employment in the above areas, which the workforce will be moving toward, according to Le Haar et al., 2017. The review of the literature identified several gaps. These include:

- Misalignment of solutions and gaps, as solutions are currently very focused on the present and not the future in terms of the fourth industrial revolution and knowledge gap analysis
- Several initiatives focus on basic digital skills, which are not necessarily the holistic answer to the digital skills gap in Africa. While the efforts are laudable, they are not enough to close the gap, especially in marginalised areas. The projects assume that the beneficiaries are within the radius of the solution—those who do not remain digitally disadvantaged.
- The initiative only touches the tip of the iceberg of the digital divide and does not consider 21st-century capabilities, thus offering a pseudo-solution to a deep-seated problem.
- None of the technologically shared mobile facilities equip participants with programming languages.
- Among the gaps is the inadequacy of the teaching content on ICT.
- Some facilities have incorporated tutors and supported a social constructivist approach.
- Initiatives do not address rural areas and the technological skills needed to make the African continent fit to participate in the gig economy.
- There are no targeted interventions to develop critical skills for the 21st century, and many students are left behind.

The findings of this review can serve as a basis for developing targeted systematic questions that focus on areas of interest, such as building and designing a common technological mobile facility with advanced content to teach digital skills. Based on these findings and gaps the solution is discussed in the next section.

Proposed solution

The proposed solution for rural South African students consists of a bus reaching rural areas with computer workstations inside (Figure 2). Solar panels on the bus's roof serve as the power source, providing a constant energy supply. A local programming tutor to teach Python will be stationed on the bus, enabling knowledge transfer. This allows for social impact because the tutor understands the language and culture of the students. Additionally, “the traveling salesperson algorithm” will support the solution. The beneficiaries of this solution are high school students aged between 14 years and above.

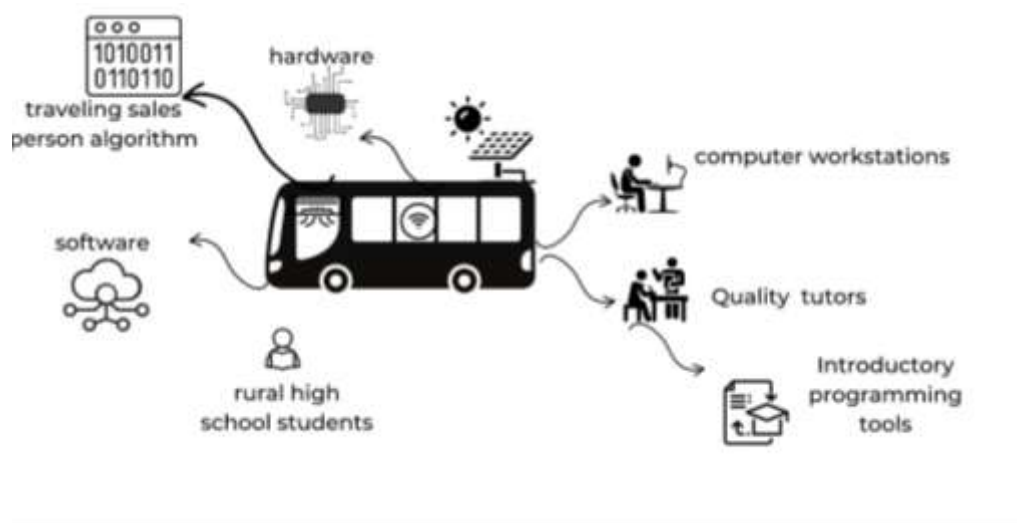


Figure 1: Proposed solution

The vehicle is air-conditioned to ensure that users are comfortable during their sessions as pictured below.



Figure 2: Bus interior workstation

5.1 Why is Python the preferred programming language?

The jobs of the future will require skills such as critical thinking, problem-solving, attention to detail, accuracy, and abstract thinking. These skills are acquired through computer programming. The acquisition of basic computer knowledge and skills is a good start. However, it is not a holistic solution and therefore the solution should focus on advanced digital skills, which can aid in ending the poverty cycle for rural students and their families.

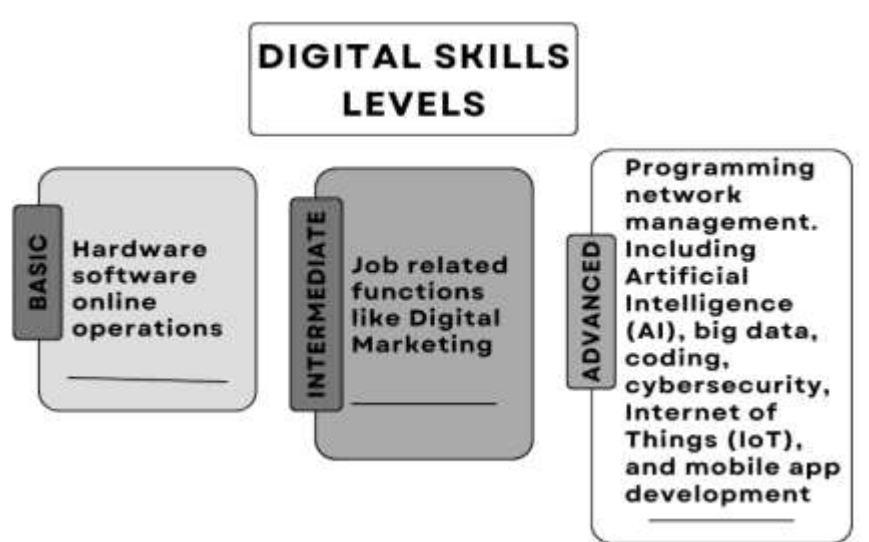


Figure 3: Levels of digital skills. Source: James (2021)

Python is considered to be one of the best machine-learning languages because of its support and flexibility. It uses general-purpose programs and task-specific scripting languages to create powerful yet easy-to-code machine-learning applications (Horntvedt & Akesson, 2019). Employers highly demand Python (Ellis et al., 2019). They also believe Python is the most popular programming language due to its clean syntax and built-in features. Vineesh Cutting & Stephen (2021) supports the idea of Python's usability and emphasises that it is user-friendly and open source. Moreover, it does not require a unique platform, and its library is extensive. Open source software eliminates additional costs and requirements that are not affordable for most people in emerging markets, especially in rural areas.

The extensive nested library, procedure, and object orientation avoid repetitive manual tasks and increase usability, which Ling et al. (2021) emphasise when learning a new programming language and is an essential factor in generating interest in studying computer science in the future. In addition, Python is ideal for acquiring rudimentary concepts of program design, cytoarchitecture, data structures, programming, problem-solving, the science of reasoning, and basic design techniques, which are fundamental concepts for 21st-century skills and future jobs. The concept of logical and computational thinking as a means to improve the competitiveness and innovation of countries is strongly supported by (Ling et al., 2021), and therefore programming is an essential skill. Even if someone does not intend to program in the future, the language is still an asset because it focuses on data and not so much on programming. Python is beneficial because it teaches individuals problem-solving and logical thinking, which are definite future skills (Le Haar 2017). However, there is criticism that it is slower than Java, C, and C++, but its advantages far outweigh its disadvantages.

In a study conducted by Ling et al., (2021), the results showed that students who learn Python have higher *motivation* to learn and greater self-confidence. In addition, students' irrational beliefs of being accepted and loved by everyone were reduced. In contrast to Java students, Python learners have better learning performance.

Pen and paper practice models can counteract learning difficulties and dropout rates (Ade-Ibijola, 2018). This work is vital as a mobile facility has limited capacity, and practice models are critical for learning sustainability. Ade-Ibijola's work on the automatic generation of Python programmes is crucial in combating issues related to learning difficulties, failure and dropouts, and incorrect learning styles. Considering the standard of Education may be a challenge for rural students. The exercise programs generated by Ade-Ibijola 2018's work and found at <https://tinyurl.com/pythonprogramgenerator> are central to this research and solution.

5. Limitations

The study is limited to current initiatives in South Africa and Kenya. Still, it can serve as a basis for future research and design, as most initiatives are implemented where the government has given a direction or where someone has seen the needs of the people. Therefore, no clear, tailored, and documented strategy will benefit the African child and ensure their sustainability.

6. Conclusion and future work

These listed solutions address one dimension of a multifaceted problem. It addresses the connectivity issue. Connectivity without guidance and teaching skills is not a holistic solution and does not fuel the agenda for equipping children of Africa with digital skills to participate in the Gig economy. Future work should include programming in the mother tongue of learners and thus eradicating the possibility of misinterpretation due to translations.

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Analysing the Utilisation of the Open-Source Software in the Namibia Government Secondary Schools.

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Abstract.

One of the main goals of the Ministry of education is to ensure that every learner that goes through secondary school has acquired basic computer literacy. In the achievement of this goal, the ministry has introduced subjects such as Office practice, Information communication, and Computer studies into the secondary school curriculum. The purpose of the study was to analyse and provide recommendations towards the utilisation of open-source software in Namibia government secondary schools. Hence, the study employed a qualitative approach. In addition, an open-ended questionnaire was used as a data collection method. Data were analysed through thematic analysis by identifying common patterns, themes, topics, or ideas frequently coming up in the data set. The findings are a Lack of functional computers, the Ministry of education's limited ICT Support, software administration challenges, computer maintenance plan, educational ICT policies revision, and internet connectivity challenges. Therefore, the study outlines several recommendations towards the use of open-source software in Namibia government secondary schools.

Keywords: *Information and Communication Technology, ICT in secondary school; Proprietary software; Open-source software; the utilisation of open-source software in secondary schools*

1. Introduction

ICT has been considerably accepted within various areas such as government, business, and education as an enabler of most services that promote innovation and development individually or at a national level (Ngeze, 2017). In education, ICT has proven to be a changemaker as it improves the communication between teachers and learners, digitalises most of the manual work, and increases productivity in government secondary schools (Pima, 2019).

In Namibia, government secondary schools are dominated by the age group 14 -18 years, spread in grades from 8 – 12. This age group is one of the active emerging adaptors of ICT through portable devices such as laptops and cell phones and the use of online platforms in their daily lives (Santos, Ramos, Escola, & Reis, 2019). Concurrently, the government is putting effort in place to ensure that there is an integration of ICT in teaching and learning example, ensuring that schools and regional educational centres are equipped with necessary ICT tools, learners without portable devices are not left out from the use of ICT in the process (Mominó & Carrere, 2016). However, some government schools still face challenges such as a lack of ICT infrastructures or lack of resources this all hinders the effective use of ICT in improving the quality and access to education (Muhammad, Tumburku, Muza, & Gwandu, 2019).

The adoption of ICT in an educational setting can be viewed as a project with several stages of implementation such as in primary schools, secondary schools, and institutions of higher learning (Neofotistos & Karavakou, 2018). This study will mainly focus on the secondary school level. The application of ICT in government secondary schools provides quality and accessible learning platforms

(Attuquayefio, 2019). This has led to the government equipping secondary schools with ICT resources and infrastructures such as the internet, computer labs, hardware, and software (Waluyo, 2019). Software is a critical component of ICT as in their absence computers cannot function. Software as components of ICT can be categorised as proprietary or open-source (Sood, Shipra, & Soni, 2016).

Proprietary software is copyrighted software that is sold with several restrictions on its use and redistribution by the developer, publisher, or vendor. (Anand, Krishna, Tiwari, & Sharma, 2018). The advantage of using proprietary software is that they come with lifetime technical support, maintenance, and several upgrades from the developer, publisher, or vendor (Charednychenko, 2018). Despite the advantages, concerns about restrictions, cost, and demand for better-performing systems have open possibilities to explore the use of open-source software in secondary schools (Kosur, 2015). Currently, proprietary software in Namibia government secondary school contributes to many challenges that are impeding the learning and teaching of ICT-related subjects. Some of these challenges are lack of sufficient ICT tools, lack of or inadequate training for teachers to use ICT, and financial issues faced by schools (Mathevula, 2015). Thus, this study calls for the use of open-source software over proprietary software due to some of the challenges discussed above.

Open-source software is free software created by a community of programmers which gives the right to users to copy, modify or redistribute the software without violating copyright infringement (Sood, Shipra, & Soni, 2016). An open-source software system reduces software piracy, saves costs, and is supported in all refurbished computers, this allows schools to have access to the latest information even the ones with a poor financial position. (Pezer, Lazić, & Odak, 2017). With so many benefits open-source software can offer, it is very important to study how we can utilise them in secondary schools so we can leverage its benefits. The utilisation of open-source software will help eradicate the high cost of proprietary software maintenance in government secondary schools.

Therefore, the study intends to analyse and provide recommendations towards the utilisation of open-source software in Namibia government secondary schools. The following objects underpinned the study. (i) To analyse how computer labs are set up and maintained for ICT-related subjects in Namibia government secondary schools, (ii) Research objective 2: To assess the role of open-source software in teaching and learning the ICT subjects at Namibia government schools. (iii) Research objective 3: To identify and examine factors that could impact open source software utilisation in Namibian government secondary schools.

2. Literature Review

This section focuses on the review of related work. The review was based on four themes/keywords namely (1) ICT in secondary school (2) Proprietary software (3) Open-source software, and (4) The utilisation of open-source software in secondary schools. The keywords were identified according to the objectives and problem statement

2.1 ICT in secondary school

In Namibia, ICT has been integrated into the schools' curriculum. For secondary schools, ICT is promoted in all subjects across the curriculum and is specifically integrated through Computer Studies, Office Practice, and Information Communication subjects. In South Africa, most schools have received computers, internet access, and other technologies from the government to promote the use of ICT in secondary schools (Mathevula, 2015). In Nigeria, a study shared that, the federal government has implemented an ICT policy aimed to ensure that learners can choose computer studies as an elective course in secondary schools (Oshionebe & Ushie, 2011). This all indicates how governments are putting measures in place to ensure that their respective countries have a functional ICT system in secondary

schools. This could be attributed to the fact that ICT can intensify the quality of education by ameliorating learners' motivation and engagement, ensuring that basic skills are acquired at the right stage in the learning process which then plays a role in achieving a learner-centered approach (Meenakshi, 2013). The integration of ICT in schools requires technical resources such as software for computers to function appropriately. There are two types of software a school can adopt to use, proprietary and open-source (Pankaja & Raj, 2013).

2.2 Proprietary software

Proprietary software is computer software licensed under exclusive legal rights of the copyright developer, this can be a single person or business called a vendor. (Sood, Shipra, & Soni, 2016). Proprietary software is quality software that comes with guaranteed upgrades, maintenance, and technical support from vendors (Charednychenko, 2018). However, even when technically supported, there have been some drawbacks to adopting proprietary software in schools which includes: (1) the school buying the proprietary software does not have access to the source codes, (2) the school needs to be buying upgraded versions which sometimes don't even support legacy systems and (3) higher licenses renewal fees.

When it comes to government secondary schools the above proprietary software challenges have impeded the teaching and learning of ICT subjects. Schools are finding it hard to acquire or maintain proprietary software (Simataa, 2015). The ever-increasing cost of proprietary software has opened doors for schools to opt to adopt the use of open-source software (Kosur, 2015). Thus, the need for Namibian government secondary schools to resort to open-source software as a means of minimizing high license fees.

2.3 Open-source software

Sood, Shipra, and Soni (2016) in their study define Open-source software as software whose source codes are made available to users with inclusive freedom to run, copy, distribute, or even modify the software under its open licensing policy. Open-source guarantees many benefits such as (1) better quality, (2) higher reliability, (3) more flexibility, (4) lower cost, and (5) an end to proprietary vendor lock-in (Isteleyev, 2016). Panakaja and Raj (2013) acknowledged open-source software comes at a reduced cost as it does not require licensing or upgrade fees. This is due to that most open-source software support is available through online communities through blogs, forums, and other social media platforms.

2.4 The utilisation of open-source software in secondary schools

It is reported that open-source software can reduce the costs of computer maintenance at secondary schools by 20% and it can provide other non-financial benefits like the freedom to choose the right type of software to adopt (Kosur, 2015). In India, the government has launched IT@School one of the biggest open-source projects so far in the world. The IT@School project is aimed to improve the traditional way of teaching and learning in secondary schools through the implementation of open-source software (Thankachan & Moore, 2017). While in Zanzibar, to bridge the digital divide gap in secondary schools, the use of open-source software is being integrated into all subjects (Waluyo, 2019). In Portugal, the secretary of state for education launched a program to uninstall all proprietary software in secondary schools and replace them with open-source software (Mota & Seruca, 2015). The initiative was viewed as a way to cut the licensing fee and allow compatibility with old systems in schools.

In Namibia, little has been done to adopt open-source software in government secondary schools. However, in his study, Simataa (2015) reported that by the year 2005 Namibia government with

guidance from a non-profit society organization SchoolNet Namibia had developed an ICT policy for Education, the document was to act as guidance on how to integrate ICT in schools.

3 Methodology

This study was only focused on government secondary schools in the Khomas region. Khomas is the capital region and with a higher percentage of ICT implementation in secondary schools, the Khomas region provides a baseline to assess the utilisation of ICT in government secondary schools. There are 34 secondary schools in the region of which 20 secondary schools offer ICT subjects (Computer Studies and Office practice) as promotional subjects. Therefore, the study was mainly focused on secondary schools that offer ICT subjects as a promotional subject, because such schools should have at least minimum ICT infrastructures to offer these subjects. Among the twenty (20) identified schools, only teachers who had taught the ICT-related subject for at least six (6) months or more were allowed to participate in the study. This was done to ensure that data is collected from participants who have sound knowledge of the study.

An open-ended questionnaire was used as a data collection technique. An open-ended questionnaire was selected primarily because it allows the respondents to share their knowledge, feelings, and ideas on the area under study. The open-ended questionnaire was designed based on the research questions. This was done to ensure that the questionnaire is in alignment with the research objectives.

The questionnaires were administered online through a google form. The main advantage of google forms is that participants can respond to the questionnaire wherever they are as long as they have internet connections. In total 25, questionnaires were sent out and only 10 participants responded.

4 Data Analysis

In this study, data were analysed through thematic analysis. Thematic analysis is a qualitative data analysis method that involves a researcher analysing the data collected in the open-ended questionnaire by identifying common patterns, themes, topics, or ideas frequently coming up in the data set (Herzog, Handke, & Hitters, 2019). The Thematic analysis will be carried out based on a six-step model adopted from a study by (Peel) 2020 as follows:

Stage 1: Collect the data

Data was collected using an open-ended questionnaire which was administered through google forms. An email with the letter of consent, ethical clearance certificate, and a link to the questionnaire was sent to the participants. The questionnaire was sent to 25 participants of which 10 gave feedback. The individual responses were downloaded from the Google platform and printed out to enable ease of reference and management of data corpus. For easier identification and referencing of the responses, the questionnaires were named QS1, QS2, QS3, QS4, QS5, QS6, QS7, QS8, QS9, and QS10.

Stage 2: Engage with the data

The researcher engaged with the data by reading each participant's response line by line. During this process, the researcher cleaned the data by correcting grammar errors, and incomplete word sentences, and inserting appropriate punctuations. This stage of the researcher engaging with the data enabled the researcher to get familiar with the participants' responses. Familiarisation with collected data is important as it enables the researcher to be immersed in participants' responses and allows for ease of theme identification.

Stage 3: Code the extracts from the data

At this stage, the researcher identified themes from the collected data. To identify themes, the researcher was guided by the research objectives. Therefore, the researcher searched for patterns based on the frequency or emphasis of the concept by the respondents. However, some of the themes were identified based on the uniqueness of the response provided and not necessarily on the frequency of occurrence.

Table 1: The table below presents the themes.

Theme1	Acquisition of computer resources
Theme2	Computer labs Management
Theme3	Lack of ICT implementation strategies
Theme4	Proprietary software administration
Theme5	Computer studies teachers Training
Theme6	Technical support
Theme7	Outdated computers infrastructures
Theme 8	Lack of support from the Ministry of Education

Stage 4: Generate the code categories from the codes

Table 2: The table below presents the themes.

Theme1	Acquisition of computer resources	
Theme2	Computer labs Management	
Theme3	Lack of ICT implementation strategies	
Theme4	Proprietary software administration	
Theme5	Computer studies teachers Training	
Theme6	Technical support	
Theme7	Outdated computers infrastructures	
Theme8	Lack of support from the Ministry of Education	

Stage 5: Conceptualise the themes from the categorized coded extracts

Theme 1: Acquisition of computer resources

Government secondary schools acquire their computer infrastructures from different stakeholders. The main acquisition of computer resources comes from the ministry of education, which is the ministry responsible for the country's education needs. However, some of the infrastructures are acquired as gifts from donors. One of the respondents shared that *"the computers we use were donated by the Americans through the Millennium Challenge Account program (MCA) (QS8:2)"*. The acquisition of computer infrastructures from donors has always been welcomed by the secondary school community considering the government's limited resources.

Theme 2: Computer labs Management

Computer labs are classrooms designed to provide easier access to technology in teaching and learning ICT-related subjects in schools. Different schools have their unique computer lab layout mostly influenced by the schools' infrastructures and resources. This was evident as some respondents stated that *"Our computer labs have a computer on every desk in the room (QS3:3)"* and *"we have a good computer lab setup and enough computers for all learners (QS4:3)"*, While another respondent alluded that *" We do not have a computer lab but rather just a classroom that we substitute, since we do not have computers at school (QS9:3)"*. The management of computer labs is left utterly to schools where the ICT teacher plays a major role. Most respondents shared that *"The computer studies teacher is responsible for managing the computer labs (QS4:4(a)), (QS7:4(a)), and (QS9:4(a)) "*. Computer Teachers are currently facing several challenges in managing computer labs. one respondent stated that *"There is a limited resource from the government to support in managing computer lab (QS1:5(b))*.

Theme 3: Lack of ICT implementation strategies

ICT implementation strategies are plans and strategies put in place to guide the process of integration and utilisations of ICT tools in secondary schools. The ministry of education is responsible for the ICT implementation strategies and thus mandated to put in place implementation strategies that will guide secondary schools on software installation, software upgrades, hardware replacement, ICT tools procurement, setting up schools' networks, security, backups, IT Auditing and ICT training strategies for both learners and teachers. The ministry of education understands the importance of the implementation strategies and has led to the development of the National ICT policy which includes TECH/NA! a comprehensive implementation strategy to guide the integration of ICT in schools. However, the ministry faces enormous challenges such as outdated ICT policy, creating educational content, poor policy implementation, and failure to regulate ICT in schools. One respondent shared that *"Some of the challenges we encounter is not having all the necessary types of equipment in place, for instance, the computer lab does not have an internet connection, so learners cannot use the computers in the lab for research purposes which is a challenge, especially for the grade 11 and 12 computers studies' learners that have coursework (QS4:5(a))"*. while another respondent shared a similar view *"The computers are not enough and learners have to share, and the available ones are old and have declined in their processing capabilities (QS3:5(a)) "*. This is evident that the Ministry of education is slowly integrating the policy and there is a need to accelerate the implementation plan to improve access and quality of education in the country.

Theme 4: Proprietary software administration

Proprietary software is a widely used type of software in secondary schools. Some of the proprietary software used in government secondary schools are Microsoft operating systems, and Microsoft suite applications such as word processors, spreadsheets, databases, and desktop publishing. One of the respondents shared that *"We are currently using Microsoft Windows 7 and have either Microsoft office 2010 or Microsoft office 2013 running on our endpoints (QS4:6(a))"*. However, the use of proprietary software in secondary schools is hindering the teaching and learning of computer studies in schools as in some cases, learners do not do computer practical's because the software is expired or schools can't afford to purchase the latest packages. According to one of the participants: *"Some of our computers the Microsoft packages license has expired making computer not usable (QS2:7(a))"*. Another respondent argued that *"We have computers that do not have application software installed (QS10:7(a))"* while another respondent shared that *"the cost of proprietary software especially developer support, security issues Customisation and licensing fees are the biggest drawbacks of any*

proprietary software (QS4:7(a))". Some of the challenges such as the lack of proprietary software due to license non-renewal have led to difficulties for teachers using unlicensed software. A respondent shared that *"Computer studies teachers have become the recent victims of violating the copyright of certain application software by pirating them just to continue teaching the Namibian child (QS10:7(b))"*.

Theme 5: Computer studies teacher Training

Computer studies teachers are at the forefront of integrating ICT in secondary schools, they are responsible for revising their old pedagogies to merge ICT in teaching and learning, which then develop active secondary schools that encourage collaborative learning, networking, and cooperative interaction. One respondent shared that *"The Computer studies teacher is responsible for maintaining the ICT labs/PC at the schools (QS5:4(a))"*. This is evident that typical computer studies need not only subject content knowledge but also need to understand the dynamics of the PC administration which will include ICT tools support, maintenance, and security. Therefore, ICT teachers should receive ICT training to enhance their skills to successfully carry out their day-to-day jobs. A respondent shared that *"It is costly to contract someone from outside to maintain our computers, therefore, computer studies teachers should be trained to do basic maintenance which could improve the performance (QS3:5(c))"*. ICT training will allow computer studies teachers to develop skills and knowledge to better address the current challenges faced in the education system such as lack of technical support as teachers themselves will have the necessary skills.

Theme6: Technical support

Once the technology is installed, there is a need for technical support which can be maintenance and support. Maintenance may include diagnosis, repair procedures replacement, and preventative measures done on ICT infrastructures, A respondent shared that *"Some of the challenges we face are that computers have become very slow, some are broken and need to be repaired, and some do not have softwares installed and there is no one to do it for us (QS10:5(a))"*. Maintenance is done to maximise the efficiency of both hardware and software which prevents avoidable downtime. However, Computer software and hardware can be temperamental sometimes if not well maintained they will fail and data can be lost in the process. One of the respondents shared that the *"National Education Technology Service and 4 Support Centre (NETSS) is responsible to support schools technically but in most cases, ICT teachers provide Technical support to the school (QS10:4(a))"*.

Theme7: Outdated computers infrastructures

Outdated computers refer to deprecated hardware or software components that are used by schools instead of the upgraded or latest version. Outdated systems no longer serve their purpose or are no longer manufactured. Most secondary schools have outdated computer infrastructures because of a lack of funds to upgrade or purchase new computer systems, and some schools do not have the necessary skills to do regular maintenance and upgrades to their infrastructures which has led to some not working properly or not working at all. When a computer system is outdated, they are likely to crash or experience system downtime and, in the process, decrease learners' interest and productivity. One respondent shared that *"We are struggling to teach practical components as we have no working computers at school (QS9:7(a))"*. Some schools face challenges with the legacy system such as compatibility with the latest systems and high-cost maintenance. One respondent alluded that *"Latest versions of computers must be made available to schools as they increase efficiency and productivity in schools (QS7:9)"*. New versions will also spark interest in learners' ICT-related subjects.

Theme8: Lack of support from the Ministry of Education

The Ministry of education is long seen as the torchbearer in integrating ICT in secondary schools, this is done by developing frameworks, and policies, and providing funds that will support the proper integration of ICT in secondary schools. However, the Ministry of education has failed to make adequate funds available to support secondary schools' ICT needs which in some cases has led to schools discontinuing offering ICT-related subjects. One respondent shared his views as follows *"The ministry of education should make funds available to support our computer infrastructures (QS5:5(c))"*. The support the ministry of education provides to secondary schools improves not only the ICT infrastructures but also closes the gap of the digital divide. In cases where the ICT budget is a bottleneck, the Ministry of education should create a strong relationship with stakeholders in education to come to their aid through donations. One respondent shared that *"The ministry should play a key role in finding donors who can help in resolving current ICT challenges faced by schools (QS7:5(c))"*. It is worth noting, the Ministry of education and stakeholders should come together and create necessary ICT-related projects that will support ICT integration in secondary schools.

5. Findings and interpretation

Based on the analysis done above, findings were identified. The findings represent the most critical factors that affect the application of open-source software in government secondary schools. The findings are a Lack of functional computers, the Ministry of education's limited ICT Support, software administration challenges, computer maintenance plan, educational ICT policies revision, and internet connectivity challenges. The findings are discussed in more detail below.

5.1 Lack of functional computers

Functional computers are computers capable of carrying out the basic computer functions of input, processing, output, and storage. The ability of the computer to offer basic functions is very important as it promotes the effective use of computers in secondary schools (Sangrà & González-Sanmamed, 2016). When computers are effectively used in secondary schools it provides room for teachers to enhance learners' motivation in learning and keep up with the ever-expanding digital era. However, the secondary school faces challenges such as computers that either has one or more basic functions that are not operating (Ghavifekr, Kunjappan, Ramasamy, & Anthony, 2016). The most prevalent non-function component is the lack of software, this could be attributed to the high cost of purchasing or renewal of proprietary software. Therefore, Government secondary schools can improve the state of the computer in schools by adopting the use of open-source software. Open-source software allows schools to install free software that has the same or better capabilities as proprietary software. Open-source software will reduce the percentage of the number of non-functional computers in secondary schools since the software will be freely available.

5.2 Ministry of education limited ICT support

ICT support in a secondary school may include donations, funding, and technical support. The Ministry of education is the government department responsible for providing ICT support to secondary schools. The ICT support provided by the Ministry of education includes (1) Technical support services, (2) Technical consultation services, (3) Hardware and PC repair services, (4) ICT training, and ICT information supply services. The ICT support is aimed to promote the use of ICT-related technologies in schools as means to improve the quality of the educational setting and the learning outcome that translates to a knowledge-based society (Muianga, 2019). The ever-increasing demand for ICT in schools has proven to be very hard for the ministry of education to handle, donations and funding

have decreased and some schools have now gone over 10 years without receiving any. Secondary schools face a huge challenge in terms of technical support, the ministry has no system currently in place to ensure that schools' computer systems are all connected and up and running all the time. Some schools that can afford have taken it upon themselves to keep their system up and running without the intervention of the ministry of education. This type of arrangement can be very costly and does not entirely guarantee the quality needed by schools. Therefore, the adoption of open-source software in government secondary schools will benefit the Ministry of education because developing an open-source software adoption model that will guide how schools will implement and support related ICT tools. The support will include the Ministry of education setting up the regional centre that will keep supporting schools in their day-to-day use of ICT infrastructure.

5.3 Software administration challenges

Software administration is the ongoing management of software applications in secondary schools, which includes the installation of new software, software update, and upgrading of existing software. Software administration provides a platform that allows schools to have updated, recent software versions across the schools, making it easier for teachers to implement the curriculum. However, the government secondary school are challenged with software administration as they do not have personnel such as IT technicians that can administer their software. Consequently, some schools know the software they need but there is no IT technician in their areas to give assistance and their teachers have limited knowledge in software administration. Some of the software administration challenges are attributed to a lack of funds as some of the government schools could not afford the software's latest version because they are expensive to purchase.

5.4 Computers maintenance plan

Computer maintenance entails all strategies put in place to have a computer system in good working condition (Mehdiyev, 2017). At the time of this study, secondary schools did not have a computer maintenance plan. There are different types of computer maintenance: (1) routine maintenance which includes all the activities that need to be carried out regularly to make computers work faster and more secure, (2) Breakdown maintenance which is the type of maintenance performed when the computer system fails, and (3) Preventative maintenance refers to the action taken to lessen the computer system from failing (Chen & Wang, 2018). The main objectives of maintenance plans are to improve computer efficiency, reduce downtime, and optimise resource utilisation. The Maintenance plan will allow secondary schools to keep records of all hardware, the ones in very good condition and the ones that will need to be replaced due to malfunctioning or that require necessary routine upgrades. The Maintenance plan will lay out the necessary information to schools on how to protect their ICT tools from theft and on ways to dispose of the broken ICT tools.

5.5 Educational ICT policies revision

Educational ICT policies are a road map that outlines how ICT should be implemented in a school setup (Sezen-Gultekin & Hamutoglu, 2020). ICT policies will guide the procurement of ICT tools, security, and ICT Training. The benefits of ICT policies are that it sets out a set of procedures that schools must follow to ease the integration of ICT in their schools. Proper integration of ICT in schools improves learners' understanding, improves the quality of education offered at the secondary level, and thereby the economy of the country is boosted indirectly (Francis, Ngugi, & Kinz, 2017). The implementation of ICT policies does not always go as planned, there are factors internal and external that challenge the proper implementation of ICT policies. Internal factors such as attitude towards ICT implementation, understanding of ICT use, and technological and readiness to use ICT. The External factors such as ICT equipment, technology availability, and lack of technical support. Therefore, it is

very important for the ministry of education to periodically visit the ICT policies and update them based on current and future demands.

5.6 Internet connectivity challenges

There are different types of internet connections such as digital subscriber lines (DSL), wireless hotspots, cell phone networks, and dial-up (Chirwa, 2018). Internet connectivity has opened myriad new opportunities for secondary schools. One of the huge advantages of secondary schools having good internet connections is that learners and teachers have access to a variety of information from different sources across the globe (Chirwa, 2018). However, There have been some challenges in implementing internet connectivity in government secondary schools, some schools have no internet connections at all some schools are connected through the agreement between the Ministry of education and a Namibian Internet service provider (NISP) internet initiative but the network's capacity to transfer data between devices or the internet within a particular period is very low leading to schools not leveraging on the use of the internet. When the internet connection is a challenge in school access to information is limited which compromises the quality of education delivered at schools. As the demand for fast internet increases in schools, the ministry should renegotiate the agreement with NISP to improve the bandwidth and extend internet to schools that are not yet benefiting from the initiative.

6 Recommendations

- The Ministry of education should resort to the use of open-source software as a way to promote ease of access and equity of ICT in secondary schools. Access and equity have become very serious issues in secondary schools whereby some schools are failing to use ICT effectively or do not have funds to purchase the software. To ensure schools have access to the same resources the ministry should make provisions to adopt the use of open-source software as a way of promoting education for all learners.
- The Ministry of education should prioritise the availability of fully furnished computer labs at every secondary school. Furnished computer labs provide access to basic ICT tools needed to promote the use of ICT tools in teaching-learning. The availability of ICT tools enhances learners' interest in ICT-related subjects which will promote innovation in secondary schools. The more secondary school learners are involved in innovative projects it creates a better understanding of technology in schools which will lead to learners being competitive on a global stage.
- The ministry of education should set up an ICT steering committee that should oversee the development of ICT in all schools. The committee will also be responsible for developing the best practice needed to promote the use of ICT in schools aimed at the adoption to use of open-source software in secondary schools. The adoption of open-source software means schools can have more software available to all learners, and issues of the digital divide are solved leading to teaching and learning. This will enable schools with poor financial standing to at least have some ICT tools properly working. The committee should promote education for all secondary schools regardless of their backgrounds.
- For government secondary schools to leverage the many benefits ICT can bring to the education system, secondary schools teachers need more training on the utilisation of ICT in teaching and learning. Training will pave way for teachers to enhance their knowledge of the use of several ICT tools, this improves the ICT competence of the teachers allowing them to improve the quality of education. Quality education that involves the use of ICT tools in secondary school will promote the use of ICT by learners.
- The ministry of education which oversees the development of ICT in schools should develop an ICT in education conceptual framework. The framework will be a set of tools that will

support the education system to improve the quality and access to education. The framework is needed to act as the overarching document that guides secondary schools in effectively implementing and maintaining ICT in their respective schools. This allows the ministry of education to keep track of successes and failures attributed to the use of ICT in secondary schools.

- The ministry of education should establish a fundraising committee that will help in raising funds and donations for schools to improve ICT infrastructures in schools.
- Broader research that will cover the whole country is needed to give a clear state of ICT implementation in government secondary schools. There is a need for the ministry of education to be aware of the current state of ICT in secondary schools at a national level. This will allow the ministry of education to do better planning in improving the state of ICT in the country.

7 Conclusion

The study contributes to the knowledge of ICT (open-source software) implementation in schools. An understanding of ICT implementation enables the appropriate selection and implementation of open-source software and an understanding of the impact it can have in higher schools. Open-source software can play a major role in education as more schools can use ICT-related technologies at a lower cost. Open source software gives freedom learners to explore a wide variety of applications for free. The variety of applications exposed to the learners can promote innovation in schools at a very young tender age.

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The Risk Implications of Ineffective Use of Human Resource Information Systems in the South African Public Health Sector

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Abstract

The pursuit of relevance in the market has led many organisations to consider several strategies. One of these strategies is the adoption of information technology (IT) for effective human resource management. The utility of human resource information systems for workforce management continues to attain significant research interest without commensurate attention to how HRIS can be effectively utilised for workforce management and retention in the South African public health sector. Thus, we set out to investigate the risk implications of not having a dedicated HRIS in the South African public health sector using four healthcare facilities in the Western Province. We argue that the benefit of information technology is sustained if a proper understanding of how it can be better deployed is achieved. A partially integrated mixed method research was employed; four public healthcare facilities were purposively selected in the Western Cape Provincial Department of Health and Wellness of South Africa. Interviews were conducted involving forty-one participants while the questionnaire was completed by forty-six participants. All the participants were purposively selected from the four healthcare facilities chosen for the study. The study found that the risk involved in the ineffective use of HRIS stems from factors such as lack of access to the system, lack of effective training, and lack of upgrades. These factors do not bode well for a sector that should add to the growth of the economy by identifying, hiring and retaining a skilled workforce. A dedicated support strategy to improve firstly, the utility of HRIS, and secondly supporting the overall health sector are ways of averting risk within the health facilities. The recommendation is a proposed guideline for effective HRIS for workforce management in public healthcare facilities. Future research directions are flagged.

KEYWORDS: HRIS, Human Resource Information System, Health Workforce, Healthcare management, Risk management, South African Healthcare

JEL Classification: D81; I15; J53; O15; O32; Q55

1. Introduction

The effective management of workers through an information system (IS) such as a human resource information system (HRIS) is regarded as a facilitating change management drive within organisations, and such changes could be influenced by several risk factors which may include competitors, internal and external clients and the general environment of the organisation (Udekwe, 2016; Yusif, Hafeez-Baig, & Soar, 2019). Workers and the way they are managed are considered significant mechanisms in any change initiative. Essentially, in human resource management practice, HRIS is regarded as a change enabler (Kolatschi, 2017),

which supports organisations to achieve strategic objectives (Muhammad, Shah, & Azhar, 2021).

HRIS is a technology that is used in acquiring, storing, analysing, retrieving, and distributing human resource information (Kavanagh, Gueutal, & Tannenbaum, 1990:13). The need as well as risk implications of ineffective HRIS to manage and retain workers in South African public healthcare facilities is high (Pouransari, Al-Karaghoul, & Dey, 2016), often leading to several research activities. Interestingly, even though the benefit of using HRIS in the health sector has attained significant research attention, there is yet a lack of studies on the effective use of HRIS for workforce management and retention in the South African public health sector (Arefin & Hosain, 2019).

Several South African based studies (for example Wright, Mahony, and Cilliers (2018); Matimbwa and Masue (2019); and Sirili, Mselle, Anaoli, and Massawe (2020)) have identified the inadequacy of HRIS for workforce management and retention in the public health sector. Matimbwa and Masue (2019) believe that access to and regular upgrades of HRIS are part of the reasons for the poor management of workers. Management of workers for duty allocation and monitoring is attributable to a management system such as HRIS as argued by Sirili et al. (2020) for its capacity to minimise the complexities and risks of managing a skilled workforce. As a public institution, public healthcare facilities are essential for managing human lives (Gerber, 2019). Practically, the sector is also known as one of the most treasured and significant sectors for economic growth and development. An economy that does not consider human lives as precedence in its economic growth might find it difficult in achieving its objectives (Narayan, 2015; Ntsala & Dikotla, 2019). Considering this importance, there have been calls from several researchers such as Tursunbayeva, Pagliari, Bunduchi and Franco (2015); Tjoflåt et al. (2018); Hidir, Zunaidi and Pattiasina (2020); Pieris and Preena (2020); and Harizanova, Dimcheva and Foreva, (2021) to: (1) identify the risk implications of poor management of workers in the public healthcare facilities; (2) further study ineffective skilled workforce management and retention in the public health sector; and (3) unravel how to strengthen HRIS use in healthcare.

The retention of workers in public healthcare facilities using HRIS is an imperative strategic exercise to strengthen the delivery of dependable healthcare services (Sultan, Mannan, & Jabeen, 2021). The absence of a skilled workforce in a health facility is risky. Using HRIS to manage such risk has been flagged by Joseph (2014) as a significant strategy initiative that improves HR risk management and decision making.

This research sought to investigate the risk implications of not having a dedicated HRIS in the South African public health sector using four public healthcare facilities in the Western Province. The research question guiding the study is: What are the risk implications of the use of HRIS to monitor and retain skilled workers in the health sector? The sub-question is: How can HRIS be used to eliminate risk factors in the management of healthcare workers?

2. Literature Review

In this section, we briefly discuss HRIS benefits, complexity and risks in relation to human resource management.

2.1 HRIS benefits and complexity

The effective utilisation of HRIS could result in several benefits such as streamlining HRM operations; improving efficiency in HRM for better service delivery, and transforming into a better strategic partner (Ruël, Bondarouk, & Looise, 2004). These identified benefits could relate to a reduction in various HR risk factors and also ensure that the information obtained in the HRIS could be helpful in extenuating HR risks (Joseph, 2014). Employees have the ability to use HRIS; but they must be trained continuously to reduce the risk of HRIS system failure, through the availability of computers and modern communication tools. A low level of system security does increase the risks of HRIS usage (Rathee & Bhuntel, 2021).

Bhargava (2014) emphasizes that the complexity of HRIS increases costs, with a higher degree of organisational interaction and thus a higher risk of relying completely on technology to identify suitable talents. However, Hosain (2017) indicated that some aid received by organisations on the use of HRIS can be regarded as savings and information security, including the reduction in costs of searching for job applicants, risk management, financial planning, position control, attendance reports, personnel planning, promotion planning, information security to name a few.

Anang, Gandhi, and Sucahyo (2021) mention that information security could be referred to as machinery that ensures security, integrity and availability of information assets. Thus the mechanism could be realised through the implementation of education, training and awareness, policy and technologies. Anang et al. also pointed out that the 3 basic concepts of information security are confidentiality, integrity and availability of information would be achieved if there are effective risk management procedures available.

2.2 Understanding risks within the context of HR

The need for suitable identification and administration of several risk elements gave popularity to the field of risk management in organisations (Joseph, 2014). Risk is defined as “uncertain future events that are left unchecked, which could adversely influence the achievement of organisations aims and objectives (Naidoo, 2002:117). Hagigi and Sivakumar (2009:287) also define risks as the “uncertainty inherent in potential outcomes of an organisation”. In other words, risks comprise events, consequences (positive or negative) and probabilities (uncertainty) as it affects an organisation. It can be argued that risks are the “probability of a loss or loss occurring” (Becker & Smidt, 2016:150). It is further described as the combination of the possibility of unexpected events occurring with the impression that it will occur if the need arises. It could also be interpreted as the possibility of a loss occurring. Risks are further referred to as the range from those that focus on the potential negative outcomes and lack of certainty in an organisation. Most people argue that risks are

representative of variable outcomes which is either positive or negative (Anang et al., 2021). However, negative uncertainty is a term usually labelled as a risk.

According to Sheung and Yazdanifard (2014), there are different sources of risks i) decision/indecision, ii) organisational cycles/seasonality, iii) economic/fiscal changes, iv) market/service preference, v) political pressures, vi) regulations, vii) competition, and viii) technology. These sources of risks, if not managed properly, will have a negative impact on organisations' achievements.

Risk management is referred to the process of identifying the risk of weaknesses to information systems, organisational infrastructures, and actions that are taken to minimise risks to a reasonable limit in organisations (Anang et al., 2021). For risks to be managed effectively they must go through processes which include risk identification, risk assessment, risk control and risk financing. Baker, Ponniah, and Smith (1999) emphasize that risk management involves the identification, analysis, evaluation, control and monitoring of risk and uncertainty to avoid or minimise the negative impact on organisations. The implementation of risk management was driven with the aim of preventing losses, mainly financial, and also securing achievements of organisational objectives (Becker & Smidt, 2016).

According to Joseph (2014), risk management in HR is described as a systematic approach to recognising and addressing workers' problems that could have a negative impact on organisational objectives. For example, if an employee decides to resign, it poses a high risk which could affect the operation of the organisation. Thus, human resource managers have a big role to play in addressing the situation and awareness of HR-related risk concerns (Becker & Smidt, 2016). One of the critical aspects to take into account is that organisations need to be aware of the risks involved in managing workers; the effective management of workers has risks associated with it (Meyer, Roodt, & Robbins, 2011).

The risk of security breaches presents significant challenges for HR management. However, organisations can be liable for fraudulent actions caused by data breaches and employees can be stigmatised if negative personal data is leaked. Thus Zafar, Randolph, and Martin (2017) emphasize that HRIS are prone to creating habit-based security risks at the individual or organisational level based on reasons such as:

- HRIS contain information that employees are likely to access from multiple devices/locations
- HRIS contain information that employees often access under stressful conditions
- HRIS passwords are typically complicated and complex, which warrants that some people might write their passwords on paper or store them on their phone/computer. They need aids to reduce cognitive load
- Many HRIS functions are routinely conducted which creates habitual behaviour
- Combining information from multiple databases and applications warrants that a breach in one is likely to create a breach in other systems which can elevate system risk in an organisation

Muriithi, Gachunga, and Mburugu (2014) are of the view that risk and security management are crucial functions that could be derived by HRIS in maintaining highly sensitive individual data and multi-platform security aspects, which are perhaps the most important factor that needs to be taken into consideration when acquiring an HRIS. Thus, Zafar et al. (2017) believe that security, education, training, and awareness programs that organisations implemented show that most unintentional mistakes result from habitual behaviour that promotes unthinkable responses. However, there is a gap between the expectation of strategic plans and HRIS information security management (Anang et al., 2021). The need to conduct further studies on the role that unconscious habits play in the security of HRIS is required.

2.3 Summary of previous research

A search of recent (2018-2022) HRIS-related studies in Africa/developing countries yielded 27 related works listed in Table 1 below.

Table 1: HRIS-related studies between the year 2018-2022 in Africa/developing countries

S/N	Authors, Year	Topic	Research aims/goals	Research Outcomes
1	Menant, Gilibert, and Sauvezon (2021)	Application of acceptance models to HRIS literature review	The study aimed to (i) review the effectiveness of TAM and UTAUT models used to identify new technologies for better HRIS acceptance by employees. (ii) to understand the importance of the human-machine relationship as it contributes to its acceptance in the HR Development environment	There is a positive relationship between the effectiveness of TAM and UTAUT models, through the development of (i) technological structures (security, system response time and data quality), (ii) user satisfaction and (iii) organisational structures. However, such a relationship needs to be accomplished through HRIS technology
2	Fashoto, Ajiboye, Owolabi, Metfula, and Fashoto (2018)	Assessment of the readiness of academic staff of an institution for performance evaluation using HRIS	The study focused on the use of the TOE Framework to identify the reasons for the lack of readiness of workers in the application of the HRIS framework for performance evaluation of workers.	The unavailability of ICT services, poor ICT skills, irregularities in the system and absence of organisational competitive advantage are significant factors that mitigate effective HRIS application. There is a need for an effective HRIS for faster, fairer and more accurate than the paper-based system

S/N	Authors, Year	Topic	Research aims/goals	Research Outcomes
3	Ngwenya, Aigbavboa, and Thwala (2019)	Benefits of HRIS in South African organizations'	The study aimed to assess the impact of HRIS benefits within the HRD of organisations in SA	The study revealed that HRIS is a managerial IS that is in accordance with the legislative labour relations governance. It also provides a strong vision of the corporate enterprise, which saves time and minimises errors caused by humans
4	Siyam, Diallo, Lopes, and Campbell (2019)	Data to monitor and manage the health workforce	This study presents a National Health Workforce proposal for a global strategy on HR for health workforce by the year 2030. This is to standardise the architecture of health workforce information and also enhance interoperability among systems in the sector	The outcome is a healthy labour market framework for the national health workforce system using various information systems indicators. This will assist to implement policies that will enhance the health workforce development and future planning, specifically to deliver universal health coverage and SDGs
5	Udekwe, Iwu, de la Harpe, and Daramola (2021, B)	Descriptive literature review of HRIS adoption in the health sector of South Africa	For better management of employees, HRIS is flaunted as a solution for effective and efficient health service delivery. This paper is a descriptive literature review that determines HRIS adoption in SA, however, research within the context of HRIS adoption in the health sector of SA is still limited	The SA health sector has not fully embraced the HRIS technology and as a result, the sector is suffering from employee dissatisfaction, brain drain, and maladministration. There is a need for investment in HRIS research, sufficient funding and infrastructural support in the health sector of SA for an efficient sector in place
6	Nachit and Okar (2020)	Digital transformation of HRM: A roadmap	Digital transformation aims to assist HR management to achieve strategic goals and improve the time, cost and quality of the HR services. In a modern organisation. Digital transformation is supposed to assist the HRD in hiring, compensating, assessing workforce planning and training	There are different digital transformation types in HR field. However, this research attempts to identify and analyse several HR digital transformation roadmaps and the relationship between eHRM, smart HR, cloud computing and HRIS. The lack of effective digital transformation in HRIS could have a negative impact on the HRD performance

S/N	Authors, Year	Topic	Research aims/goals	Research Outcomes
7	Maamari and Osta (2021)	Effect of HRIS implementation on success on job satisfaction and work engagement in SMEs	To link HRIS's successful implementation to a reduction in the discrepancy in job involvement and engagement to a certain extent as it affects employees' work satisfaction. However, there is a negative correlation between HRIS implementation and job satisfaction	HRIS users with high education and training tend to display a more open approach towards using the system and seeing the implementation succeed. Also, managers could display low enthusiasm toward HRIS success because of their low-level involvement. It also fosters resistance to change in the use of HRIS. There is a need to have successful HRIS implementation that will facilitate the supervisors' work routine for employees' satisfaction
8	Kyungu and Kyule (2021)	Effect of HRIS on the performance of an organisation in Nairobi	The research made use of UTAUT, Diffusion Innovation Theory, and Resource Based-view Theory to determine the effect of e-record keeping systems and e-personnel administration systems on their performance	The e-record keeping system, e-performance administration system and e-recruitment system have a significant effect on the performance of an organisation. The organisation need to work towards ensuring full adoption of electronic information recording and retrieval system, proper communication channels, succession planning, and demand and supply of manpower, for effective systems in place
9	Tom (2020)	Effectiveness of HRIS in an organisation in Bangalore	To show that operational administration utilises HR systems to monitor the listing and arranging of workers, HRIS can assist to bolster different HR practices through workforce arrangement, staffing, pay programs, pay instruments and pay financial plans to name a few	The result shows the need for valuable insight into the success and effectiveness of HRIS in organisations

S/N	Authors, Year	Topic	Research aims/goals	Research Outcomes
10	Gwambe (2020)	Exploring the benefits of HRIS at a Municipality in South Africa	The purpose of this study was to explore the benefits of HRIS in SA municipality through TAM Framework. The study further emphasises the municipal policy and practices on how employees could be attracted through HRIS to enhance the organisational performance and productivity	The study found various HRIS benefits that are enjoyed by end-users including time-saving, real-time information, accurate reporting, self-service options, paperless system, and strategic decision making. On the issue of perceived usefulness, the study found that some workers perceived HRIS as useful. Some end-users find challenges faced by the complexity of some HRIS modules, such as e-recruitment and e-careers. A recommendation of increased training intervention, have a more user-friendly and also reduce manual paper-based HR system
11	Tesha (2020)	Factors implementing the adoption of HRIS in an organisation in Tanzania	The study aimed to examine the factors influencing the adoption of HRIS through four categories namely; ICT infrastructure, cost-effectiveness, leadership and ICT resources	The study revealed that the presence of ICT infrastructure, leadership influence, financial resources and skilled personnel influenced HRIS adoption is required. A recommendation that organisations should have HR functions in a single database to make it easier for managers to have information that is timely and accurate for effective decisions
12	Schultz (2021)	Future role of HRM in South Africa during 4IR	To present South African HR practitioners' views about the future and the role of HRM in the Fourth Industrial Revolution (4IR) from a qualitative perspective. It was observed that HR practitioners play a major role in the 4IR, but concepts on how their role is enacted remain scanty	The South African HR practitioners should be prepared for the future world of work through technology-driven, data-driven, ethically driven, change-driven, business-driven, human-machine collaboration and resilience. This will assist in adding value to the organisation in the 4IR technology

S/N	Authors, Year	Topic	Research aims/goals	Research Outcomes
13	Arakelian et al. (2022)	Getting HRIS right: A case study of Uganda	The study aimed to prove that with the tremendous investment in HRIS in the health department, there is an uneven adoption and engagement of HRIS at the national and sub-national levels owing to a high level of data disintegration, lack of interoperability, and defective data sharing practices	The lack of progression in the development of the HRH information system is attributed to a lack of system capabilities, incentives and motivation for effective HRIS. Perhaps a better understanding of what is virtuous in terms of HRIS functionalities to address the issues concerning human resource management is instructive
14	Davarpanah and Mohamed (2020)	HRIS implementation and influence in an institution in Malaysia	The research sought to develop and test a theoretical model to explain the implementation and influences of HRIS in a tertiary institution. This is focused on user satisfaction and situational familiarity that predicts user-perceived HRIS benefits	The findings will assist researchers and HR practitioners in exploiting user-perceived benefits and satisfaction through HRIS implementation. The research also advances toward understanding the role of HRIS in supporting human capital performance and productivity improvement
15	Johnson, Carlson, and Kavanagh (2020)	HRIS: Basics, applications and future directions	HRIS book that provides a thorough introduction by showing how organisations of today can leverage HRIS to make better workforce decisions and also manage talents more effectively	This will assist students, staff and management to deal with technical HR information and also assist in dealing with a balanced approach to HR issues at various levels of establishments
16	Suharti and Sulistyono (2018)	Implementation of HRIS and its benefits for organisations	The objective of this study was to examine the effect of the implementation of HRIS on-time efficiency, cost efficiency, quality of information, and managerial satisfaction	This shows that the lack of effective implementation of HRIS affects time efficiency and managerial satisfaction. Also, the proposition concerning the implementation of HRIS affects cost efficiency and quality of information. This requires a need for effective HRIS with confidential information and cost-effectiveness initiated

S/N	Authors, Year	Topic	Research aims/goals	Research Outcomes
17	Kiruja (2021)	Influence of HRIS on the performance of organisations in Kenya	The study's goal was to understand how the lack of integration of training in HRIS and lack of access by the workers affect employees' performance	The recommendation is that organisations should fully utilise training resources by putting a fair amount of training needs assessment in place. Also, an automated training and development system will progress, if it is designed to meet the organisational strategy and implementation
18	Barišić, Poór, and Bach (2019)	Intensity of HRIS usage and organisational performance	The focus of the study was to investigate the relationship between HRIS intensity and their impact on organisational performance, through the development of several regression models using global data sets with the involvement of numerous organisations around the world	It was revealed that the strongest impact on organisational performance is achieved through the strength of HRIS usage and the number of functionalities. Also, the improvement in the management and their impact on organisational performance could be attributed to intensified HRIS usage
19	Mabaso (2020)	Model of effective use of HRIS in South Africa state owned organisation	Despite the investment in HRIS at the state owned organisations, they still face challenges such as job applications and recruitments are still manually processed. This signifies a costly implemented HRIS is not effectively utilised, which impacts service delivery in the state owned organisations	This shows that there are inconsistencies with existing literature on the state owned organisations context in SA. Also, models that theoretically explain the factors that should be considered for effective utilisation of HRIS in state owned organisations are flagged in the study
20	Magagula (2020)	Perception of employees on the use of HRIS in recruitment and selection at an institution in SA	The study aimed to explore employees' perception of the use of HRIS by identifying the advantages and overall perception of using the HRIS for workforce selection and recruitment functions	It recommended that the institution should integrate HRIS into its HR activities through (i) recruitment and selection, (ii) job analysis, (iii) HR planning, (iv) training and development, (v) compensation, and (vi) succession planning. These integrations are yet to be accomplished

S/N	Authors, Year	Topic	Research aims/goals	Research Outcomes
21	Nyathi and Kekwaletsw e (2022)	Realizing employee and organisational performance through eHRM use in developing countries	Despite the embryonic stage of eHRM in Africa, there could be a positive effect of eHRM on employee and organisational performance which is complemented by HR best practices that impact positively on their performance	The need for attention on the role of organisational workforce performance in explaining organisational gains. Also, a model that could lead to an increased workforce and organisational performance is required
22	Koech (2022)	Relationship between HRIS and management of human capital at an organisation in Kenya	This study aimed to access the relationship between HRIS and management of human capital specifically on (i) training information system, (ii) recruitment information system, (iii) performance management information system, (iv) self-service information system, and (v) human resource planning information system	It revealed that training IS, recruitment IS, performance and management IS, self-service IS, and HR planning IS have a positive influence on the management of human capital. A recommendation is to develop a strategy of ensuring that HRIS are customised to suit the company's HR processes for effective systems in place
23	Blom, Du Plessis, and Kazeroony (2019)	Role of e-HRM in diverse workforce efficiency in South Africa	This study questioned how technological changes could impact eHRM to optimise and support diversity in an organisation	The study revealed a disconnection between eHRM, workforce and the organisation which is affecting their efficiency performance. This requires further study to identify ways to improve the humanistic approach toward eHRM implementation. Also, technology should be integrated not only focusing on operational efficiencies but also the management of diversity in an organisation
24	Ramírez and Tejada (2022)	Stakeholders' perception of impact and benefits of HRIS in Spanish institutions	The study focused on stakeholders perception of impact and HRIS benefits in a Spanish institution setting	The study concludes that a well-implemented HRIS has the potential to enhance human capital efficiency and management, and could also help HRM practitioners to get a better understanding of current usage, benefits and problems facing HRIS implementation

S/N	Authors, Year	Topic	Research aims/goals	Research Outcomes
25	Simms (2020)	Strategies for implementing HRIS for non-profit organisations	The study explored how the lack of implementation of HRIS could lead to the inability of linking HR with other processes within an organisation	The recommendation is for executives to incorporate financial flexibility in their organisational strategy through an increase in the investment capacity on IT systems to achieve effective HR functions and Organisational performance. Such changes will include improvements in workforce retention, recruitment, hiring and enhancing HR performance to secure organisational sustainability
26	Udekwe, Iwu, de la Harpe, and Daramola (2021, A)	Systematic literature review of HRIS usage in the health sector of South Africa	This paper explored the preponderance of research in the spheres of HRM, HRH, workforce management, use of information systems/technology within the health sector of South Africa	The study realised that there is a low level of research on HRIS in the SA health sector, focusing on HRIS impact, implementation, effectiveness, motivation, competence, adoption, retention, migration, digital records, IT and IS in the healthcare setting. However, it suggests further studies to improve HRIS in the health sector
27	Matimbwa and Masue (2019)	Usage and challenges of HRIS in Tanzania public sector	Targeting a southern African nation, this study explored usage and challenges of HRIS in the public sector for the purpose of achieving public sector productivity	The recommendation is that government should increase the budget of health departments to support adequate development of HRIS, strengthen coordination between different departments responsible for HRIS management for speedy information flow, accurate and timely employees' data

The publications listed in the table above differ from the current study in terms of focus/perspective and scope. The current study is focused on the risk implications of ineffective HRIS in the public health sector of South Africa. We believe that this study offers a significant academic contribution to the body of knowledge on HRIS.

3. Methodology

The research was conducted using a partially integrated mixed methods research. This refers to using both the quantitative and qualitative strands for analysis and comparison; essentially

using one strand of data to inform the other (Saunders, Lewis, & Thornhill, 2019). This was adopted owing to the insufficient amount of quantitative data collected. A pragmatic paradigm with an abductive approach was followed (Saunders et al., 2019; van Rossenberg, Cross, & Swart, 2022). Descriptive and exploratory research designs were followed due to the methodological precedence of Beadles II, Lowery, and Johns (2005); and Muhammad, Shah and Azhar (2021) who investigated HRIS-management-related concerns in other sectors and countries. Thus, descriptive and exploratory research designs were used to gain a new perception of the risk implications of ineffective use of HRIS in the management of skilled workers in South Africa's public healthcare facilities.

3.1 Research strategy

Multiple cases and survey research strategies were followed with the use of four purposively selected public healthcare facilities in the Western Province of South Africa. 41 people were interviewed while 46 questionnaires were completed for this research. The participants included medical and non-medical personnel. The qualitative data was collected through interviews which were transcribed and analysed. The Atlas-ti tool was used to identify the themes in the interviews transcripts which aided the data analysis (Barry, 1998; Smit, 2002; Scales, 2013; Zamawe, 2015). The quantitative data were collected using a Likert scale questionnaire and analysed using SPSS (Burns & Burns, 2008; Zaman, Radu, Răpan, & Berghea, 2021).

The interview and questionnaire items were drawn from the gaps identified in the literature concerning key risk elements that related to the use of HRIS, such as HRIS functionalities.. These identified key elements enabled the realisation of the questions and objectives of the study.

The data collection process started at the beginning of the year 2020. The interviews and questionnaires distribution were simultaneously conducted. The interviews and questionnaire distribution were scheduled for completion within four months. However, the data collection stretched out for over a year due to the COVID-19 pandemic.

3.2 Ethics

Kothari (2004) emphasizes that ethics deals with a communal contract between the researcher and the participants, which consists of i) voluntary participation, ii) no harm to the participants, iii) anonymity, iv) confidentiality, v) deception, vi) beneficence, vii) justice, viii) informed consent and ix) right to privacy. The above-mentioned ethics agreements were adhered to in this research. Ethical clearance was approved for the study by the Western Cape Provincial Department of Health and Wellness (WCPDHW) of South Africa, the Faculty of Informatics and Design (FID) and the Research Integrity office of the Cape Peninsula University of Technology (CPUT), South Africa. To participate in the study, participants were required to consent to participation. Codes were also used to identify the participants and the healthcare facilities that participated in the research.

The table below shows the healthcare facilities and the number of interviewed participants represented in codes:

Table 2: The codes representation of healthcare facilities and the interviewed participants

S/NO	Healthcare facilities	Interviewees codes	Frequency	Percentage	Valid percentage	Cumulative percentage
1	A Hospital	A1 – A9	9	22.0	22.0	22.0
2	B Hospital	B1 – B15	15	36.6	36.6	58.5
3	C Hospital	C1 – C13	13	31.7	31.7	90.2
4	D Hospital	D1 – D4	4	9.8	9.8	100.0
TOTAL			41	100	100	

4. Findings, Analysis and Discussion

This study's main goal was to understand the risk implications of the ineffective use of HRIS to monitor and retain skilled workers in the health sector. The sub goal was to find out how HRIS can be used to eliminate risk factors in the management of healthcare workers. A mixed-method was used to collect the data. Figure 1 below depicts the quantitative data collected, Figure 2 provides that of the qualitative data while Figure 3 provides the summary of the data analysis in themes.

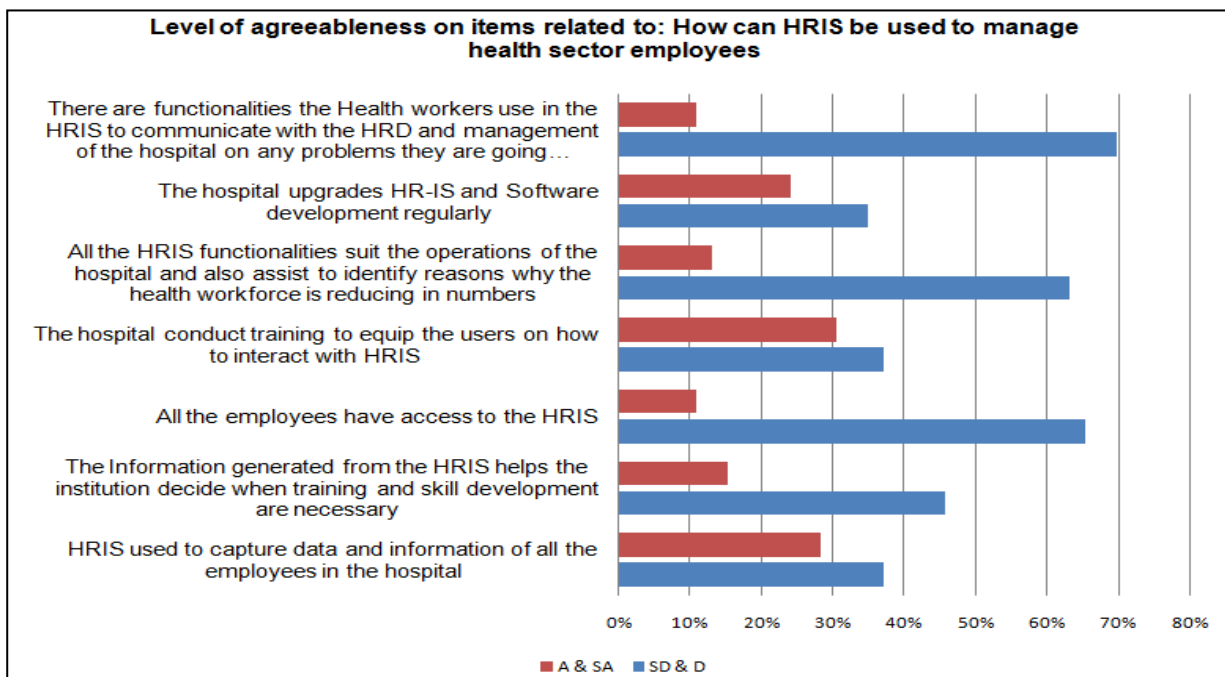


Figure 1: Summary of quantitative data

4.1 Quantitative analysis

In Figure 1, 70% of the participants seem to disagree that there are HRIS functionalities used by healthcare workers to communicate with the HRD and management. Could this be a result of a lack of technological advances in public healthcare facilities? However, there is also a high level of disagreement at 63% of the participants on the issue of HRIS functionalities to suit the operation of the healthcare facilities and also assist in identifying reasons for a high rate of resignation in the South African public healthcare facilities. Perhaps this could be attributed to the risk of a low level of satisfaction with the current HRIS to manage the healthcare workers in the sector (Al-Mutawa & Manuel, 2022).

Additionally, in Figure 1, a disagreement of 35% of the participants on regular upgrades of HRIS used in public healthcare facilities was identified, also, 65% reported that not all the employees have access, which also corresponds with the other 37% response that not all the employee's information is captured in the HRIS used by most South African public healthcare facilities. Incidentally, these negative responses from the respondents show that there are lapses in the effectiveness of HRIS to manage skilled healthcare workers in South Africa. This could also be due to the non-proper structuring of the system to meet the expected requirements of effective skilled workforce management (Dilu, Gebreslassie, & Kebede, 2017).

A further disagreement of 37% responded that training to upskill workers is not conducted through the HRIS, which also corresponds with the 48% response that the current HRIS does not assist the healthcare facilities to identify people that are due to be trained. Ideally, this is also an issue that shows the lack of effectiveness and dependency on the HRIS used in the South African public healthcare facilities to make decisions relating to skilled healthcare workforce training.

Furthermore, a response of 11% demonstrates a likely failure of existing HRIS to assist in attending to issues relating to effective skilled workforce management, which points out to weak criticism resolution, poor employee progress procedures and weak reaction to HR-related issues. Perhaps this could be attributed to the high level of skilled workforce turnover rate in the facilities which is a risk factor.

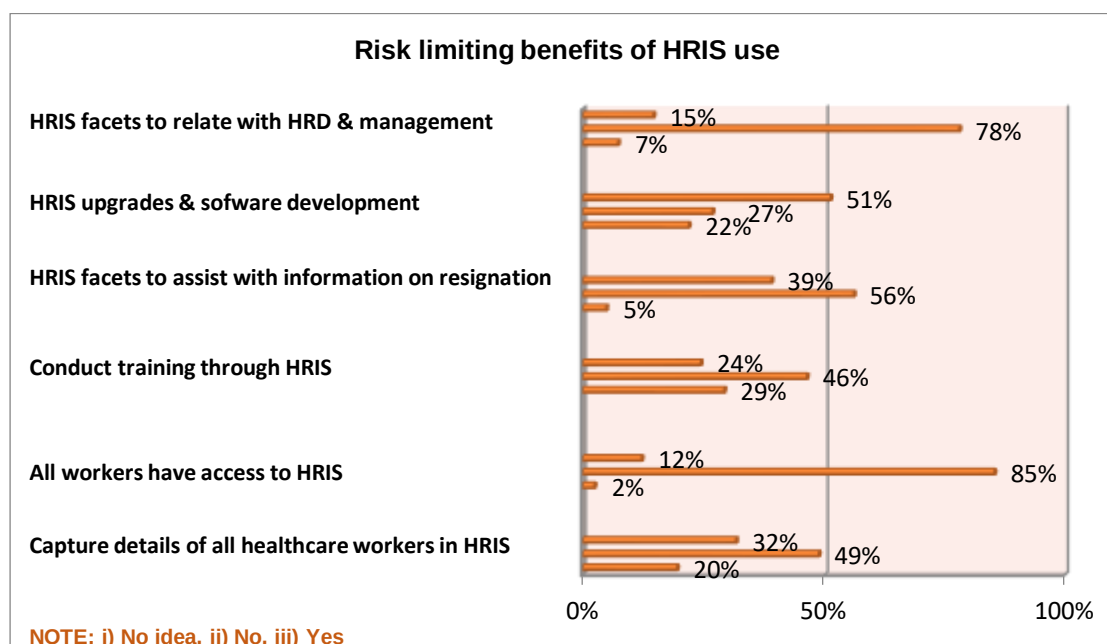


Figure 2: Qualitative findings on risk limiting benefits of HRIS use

4.2 Qualitative analysis

4.2.1 HRIS facets for healthcare workers to relate with the HRD and management

In Figure 2, 78% of the participants seem to respond to the fact that they do not have HRIS facets to relate to or communicate with HRD and management. This indicates that the healthcare facilities do not realise how useful the HRIS could be when people are allowed to lodge complaints and relate information to HRD and management through the HRIS. On that note, **Interviewees B4 and B10** mention that no HRIS facets exists which health workers can log in to relay HR-related messages to HRD and management. Things are done manually in various healthcare facilities. There are risks associated in doing things manually. The view of participants B4 and B10 shows that healthcare management still has a long way to go in technologically competing with the high income countries' healthcare system.

4.2.2 HRIS upgrades

Knowledge of HRIS upgrades was portrayed to the participants in Figure 2, 51% indicated their unawareness of HRIS upgrades, and 27% responded to the fact that the public health has not upgraded the current HRIS for a very long time. These responses could be attributed to not regarding the skilled healthcare workers as critical to be managed through an upgraded HRIS. On this basis, **Interviewees A2, A7 and D3** mentioned that the current HRIS has not been upgraded for a very long time and the fact that the system does not meet the test of time with the latest technology is a risk factor. However, **Interviewee B13** believes that they do update other information systems used in most public healthcare facilities on regular basis, but still make use of old HRIS. The responses from Interviewees A2, A7, D3 and B13 seem to

suggest that the South African public healthcare facilities prioritise upgrades of other IS's used in facilities and care less about upgrading HRIS. It shows that they support the HRIS with manual processes which have risk implications.

4.2.3 HRIS facets to assist with resignation information

This category was critical in finding out if there are HRIS facets to assist in providing information on reasons for a high rate of skilled workers' resignations in public healthcare facilities. In Figure 2, 56% of the participants responded that there are no HRIS facets used to provide information on why people are resigning in large numbers from the public healthcare facilities. This corresponds with 39% response of their not being aware of the existence of such HRIS facets. Could this be attributed to a lack of knowledge on the importance of effective HRIS to support strategic decisions in public healthcare facilities? Essentially, **Interviewees B2 and B13** highlight that they do not have HRIS facets to identify reasons for skilled workers' resignations, but they do conduct exit interviews, and the risk implication is that such interviews are not being used for strategic decisions relating to skilled workforce reduction in public health facilities.

4.2.4 Health workforce training through HRIS

Conducting numerous training in the public healthcare facilities should be regarded as part of the HR duties to assist in monitoring the skilled workforce performance. However, in Figure 2, 29% of the participants mention that they do not make use of HRIS to monitor and conduct training in the facilities. Also, training on the use of HRIS was portrayed as 46% responded that they do not conduct regular training for HRIS users as well as 24% indicated their unawareness of any form of training to upskill the users of HRIS. Could this be a result of a lack of upgrades and not putting the upskilling of healthcare workers as a priority in facilities? Not conducting training through HRIS and also not conducting regular training for HRIS users is a symbol of the lack of seriousness of management in having an effective HRIS to support skilled workforce management. This could be a risk for sustainable healthcare. Ideally, **Interviewees C3, C8, A1, B3 and B15**, gave their opinion that training on HRIS should be for the users only, but the system is not upgraded for frequent training to be conducted. Also, training on clinical functions is manually conducted and monitored in facilities. The comments from the interviewees show that the South African public healthcare facilities do not make use of HRIS to identify people that are eligible for training because training is not conducted through the system. Also, HRIS is still old which deprives regular training of the users.

4.2.5 Health worker access to HRIS

Access to HRIS was dominated by the responses in Figure 2, 85% indicated that the entire skilled healthcare workers do not have access to HRIS. 12% also mentioned that they are not aware of those that have access to HRIS. This portrays a lack of effective management decisions and technological advances in HRIS in facilities. On that basis, **Interviewees A1, A3 and A4** gave their opinion that the current HRIS used in the South African healthcare facilities, is not sophisticated to allow the use of self-service facets to make HR submissions. **Interviewees B2, B7 and B14**, also mention that most public healthcare facilities do not have

an HRD and do not make use of HRIS. Only certain people in the regional hospitals' HRD have access to HRIS. Unfortunately, things are done manually in most public healthcare facilities. The above responses from participants indicate that the lack of upgrade of HRIS makes it impossible for entire workers to have access. Also, the fact that most public healthcare facilities still depend on manual HR processes implies a risk facing the public healthcare facilities. However, this is attributed to the lack of effective management decisions and technological advances of HRIS in public healthcare facilities.

4.2.6 Capture details of all skilled workers in HRIS

The capturing of the entire skilled healthcare worker's information in HRIS was considered critical in the sustainability of healthcare facilities through an IS. In Figure 2, 49% of the participants responded that the current HRIS used in the public healthcare facilities in South Africa does not have details of the entire skilled healthcare workers. Also, 32% indicated that they are not aware of what goes on in the HRIS due to their unfamiliarity with the system. Could the unfamiliarity be attributed to the lack of awareness of HRIS relevance in public healthcare facilities? Ideally, **Interviewees C2, C4, B7 and B8** mentioned that the current HRIS is not used to capture the information of the entire skilled healthcare workers in facilities, only the permanent worker's details are captured on HRIS. This is an indication that the HRIS is not useful in managing the entire skilled healthcare workers. Lack of familiarity with the system poses a risk of its own in monitoring and evaluating data captured in the system. Figure 3 below summarises the risk factors of ineffective HRIS use in the public healthcare facilities:

4.3 Summary

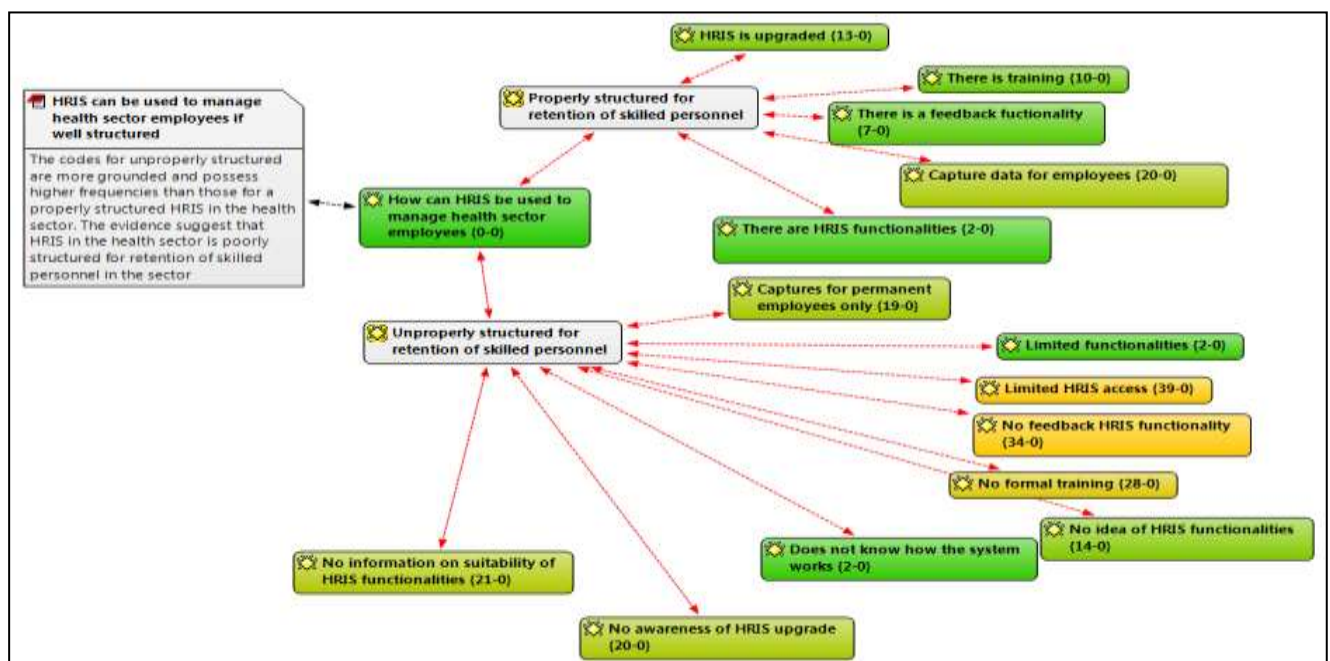


Figure 3: Summary of HRIS usage and the risk implications in the public healthcare facilities

A summary of the HRIS usage in the management of skilled workers in the healthcare facilities derived from this research is provided in Figure 3 above. The results suggest that the lack of effective use of HRIS for the management of healthcare workers can be attributed to improperly structured management and retention of skilled workers. However, this improperly structured is attributed to non-capture of entire workers' details, limited HRIS functionalities, limited workers' access, no formal training, no awareness of upgrades, no capturing of entire health workers' information and no information on sustainability.

4.3.1 A close inspection of Figure 3 suggests the following:

The improper structure could create a risk of the ineffectiveness of HRIS to manage skilled healthcare workers. These improper structures can be associated with not capturing the entire workers' details on the system, not conducting training through the HRIS, not upgrading the HRIS system, and not allowing the entire workers' to have access to HRIS through self-service. The lack of sophisticated HRIS usage in public healthcare facilities translates to the use of a manual process to support human resource management. A participant (**Interviewee A4**) said: the current HRIS used in the healthcare of South Africa is not sophisticated to allow the use of self-service facets.

Another response pointed out that not all employees' information is captured on HRIS which signals the lack of effective management of entire skilled healthcare workers. A participant (**interviewee B8**) said: only permanent workers are captured on HRIS, Locums and Contract staffs are not captured.

Most of the participants still believe that the current HRIS used in public healthcare facilities is not appropriate to compete with the high income countries' healthcare setting. **Interviewee C13** said: that the system is still manually supported which poses a risk, devastating and discouraging. They need a well-structured HRIS for better and more convenient workforce management.

4.4 Discussion

On the issue relating to HRIS facets and human resource management, it was noted in Figure 2 that 78% of the interviewed participants responded that there are no HRIS facets that workers can use to relate with HRD and management. A further 15% of the interviewed participants made it known that they are not aware of the existence of such HRIS facets because of their unfamiliarity with the system. Thus, in Figure 1, 70% of the participants responded negatively to an HRIS facet that exists that workers use to relate with HRD and management, which corresponds with the response in Figure 2. These could be attributed to a lack of awareness and the use of manual systems to support HRIS. This further signifies the lack of effective HRIS in the South African healthcare facilities that workers can relate electronically with the HRD and management. Therefore, this research corresponds with Heikkilä (2013) in their notion that HRIS should be an automated HRM system through a web-based application to change the idea of communication among HR workers, employees and

management to move from a face-to-face to a technology-based relationship for better management of their workforce.

Lack of HRIS upgrade was also identified as a risk. In Figure 2, 51% of the interviewed participants indicated their unawareness of any form of HRIS upgrades due to their unfamiliarity with the system, 27% also gave a response that the current HRIS has not been upgraded for a very long time. Additionally, in Figure 1, 35% of the participants from the quantitative side also gave a negative response that the current HRIS used in healthcare in South Africa has not been upgraded and is still outdated. This is an indication that the South African public healthcare facilities have not upgraded their HRIS which is a risk factor and also a negative impact on skilled workforce management (Monica & Reddy, 2020). This argument supports Gebre-Mariam's (2018) view that the use of non-internet-based HRIS with no regular upgrades is a risk factor that hinders the effectiveness of the system in terms of cost and bureaucratic delays in processing human resources-related matters.

Based on HRIS facets to assist in identifying reasons why skilled healthcare workers resign from the sector, in Figure 2, 63% of the interviewed persons gave a negative response to the existence of HRIS facets, and 39% also gave their opinion that they are not aware of such facets because of their unfamiliarity with HRIS. Surprisingly in Figure 1, 63% of the participants also disagreed with existing HRIS facets that explain the reasons for a high level of resignation in the public healthcare facilities. This shows that there is a lack of effective use of HRIS to monitor and control the level of skilled workforce resignation in the sector. Interestingly, 5% of the interviewed participants made mentioned that they do conduct exit interviews with those that are leaving the sector but, such interviews are not properly documented in the HRIS for effective decisions which pose a risk to the facilities. This argument corresponds with Mahlulo's (2020) view that exit interviews assist in identifying reasons why employees resign and such information needs to be documented electronically for effective decisions, risk management and record purposes.

The effect of training to equip skilled healthcare workers on the use of HRIS and also conducting other forms of training on clinical functions through the HRIS was portrayed to the respondents. However, in Figure 2, 46% of the interviewed participants gave a negative response by disagreeing with the existence of regular training to equip the HRIS users, and 24% also indicated their unawareness of such training in existence, At this juncture, a correspondence from 37% of participants in Figure 1, also disagreed on the availability of regular training to equip users and the entire skilled workers on how to make use of HRIS. Could this be a result of depending on the manual interventions which pose a risk and also demoralising to the skilled healthcare workers? Interestingly, 29% of the participants in Figure 2 as well as 30% in Figure 1, both did agree that they conduct regular training on the use of clinical equipment and other forms of clinical functions, but such training is not conducted through HRIS, which is still a risk in the management of skilled workers through HRIS. This study corresponds with Mwarey, Hafner and Nyamupachitu (2014) as well as Nagadeepa and Shaji (2021) believe that the lack of sufficient technological resources to implement training

skills to empower workers results in a high rate of workforce turnover and retention challenges including a risk to the image of the organisation.

The issue of access to HRIS by the entire skilled healthcare workers was pointed out to the participants. Thus, the majority of interviewed participants (85%) (See Figure 2) responded negatively to the notion that skilled healthcare workers have access to HRIS. A follow-up response was 12%, indicating their unawareness of such information because they do not have access and do not know what happens in HRIS. This also signifies the lack of automated systems, lack of sufficient computers and sophisticated ISs in place to run the affairs of the HRD and to allow workers access to self-service and other facets to make HR submissions. Also in Figure 1, 65% disagreed that the skilled healthcare workers have access to HRIS, which corresponds with the response from the 85% in Figure 2. Perhaps, there is a lack of effective use of HRIS that skilled healthcare workers can access from their workstations to make HR requests and submissions rather than manual processes. This study corresponds with Grant and Vogt (2015) in their opinion that the success of an organisation to compete in the labour market depends on the satisfaction of their workers to ensure an effective system that is fully automated and IS structures where workers can have access to HRIS in any workstation and also eliminate manual HR functions, submissions and other related HR processes.

The capturing of entire skilled healthcare workers' details in HRIS was highlighted, in Figure 2, 49% of the interviewed participants disagreed that they capture the entire skilled workforce details on the HRIS, only the permanent staff are captured. Other 32% indicated their unawareness of who is captured and who is not captured because they do not know how the system works. Coincidentally, in Figure 1, 37% of the participants also gave a negative response that all the skilled workers are captured on HRIS. This is an indication that the Locums and contract staff are not captured and also, there is no other IS used to manage that kind of staff. It is also of the notion that the South African public healthcare facilities do have a huge number of contract staff in their system, yet they cannot be managed through the HRIS. Surprisingly 20% of the interviewed participants as well as 28% of the questionnaire participants, both gave a positive response that all skilled workers are captured on HRIS, however, those responded participants are not working in the HRD, which could mean that they do not understand the system, what happens in the system and who is captured in the system, due to their lack of knowledge of the system. This makes it difficult and unreliable to monitor and manage the entire skilled healthcare workers in South Africa through HRIS. This argument is in line with Arasa (2019), who mentioned that the idea of not capturing the entire worker's details in the HRIS and also not allowing workers access creates a high level of risk, dissatisfaction and also difficulty in managing the entire worker's for effective service delivery. There is a need to eliminate manual HR documentation and improve in automation of things for an effective HR system in place.

5. Conclusion and Recommendation

5.1 Conclusion, recommendations, and future research opportunities

Effectiveness of HRIS could be an enabler for skilled workers' efficiency and productivity in the sector. Harnessing skilled workforce efficiency would require an effective HRIS to assist in the transformation of public healthcare through the monitoring and managing of skilled workers. The majority of the participants were able to acknowledge the importance of improved HRIS and so it can be argued that not having such HRIS poses a risk factor in the healthcare facilities. From the study, it is deduced that HRIS was not properly structured for skilled workforce management and retention in South African public healthcare facilities. The improper structure of HRIS was attributed to a lack of upgrades, lack of improvement, limited functionalities, limited access, lack of sufficient training, and not having entire skilled healthcare workers' details on the system for effective management decisions. We conclude therefore that for these reasons, the public healthcare facilities could not effectively utilise HRIS for proper management and retention of skilled healthcare workers.

A re-evaluation of the extent to which information systems can facilitate improvement and how such an improvement could contribute to the management of skilled workers and progression of the healthcare facilities in general is a call that the administrators of the public health sector must make. Afterall, from the study and extant literature, we understand that to have a proper structure in place would require an improved HRIS so that skilled workers can have access to HRIS. This would assist in easily managing the entire skilled health workers through HRIS with an effective risk management process.

A significant opportunity for further research in this area has emerged from this study. In this study, it was noted that irregular upgrades to an information system could pose significant risks to an important sector such as health. Thus, it may be prudent to explore the feasibility options of regular upgrades of information systems technologies considering the escalating cost of these technologies in a developing economy.

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Defining Open Government Innovation: Perspectives from Academia and Industry'

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Abstract

Open government, open innovation and open data are key concepts used to describe transparency and sharing of information. However, open government innovation has not been clearly defined in the literature. The purpose of this study was to define open government innovation based on the perspectives of professionals from academia and industry. Focus group discussion was used to gather data from the participants who took part in the study. The findings suggest key components of open government innovation include transparency, accountability, collaboration and digital technologies; and a definition of open government innovation was suggested. From an academic perspective, the study forms the basis for defining open government innovation. From a practical perspective, governments can apply these practices when trying to establish open government innovation.

Keywords: open government, open data, open innovation, open government innovation.

1. Introduction

According to Wootten & Kiss (2019), the meaning of “open government” depends on the viewpoint of the person. Nevertheless, it is widely accepted that open government makes it easier for people to access government-related data and take part in decision-making. According to Caplan et al. (2015), there are more complex connections between open data, “open government” and transparency than the word may imply. Caplan (2015) goes on to argue that while some government data sharing relating to weather, transportation, or health inspection may not encourage governance accountability, it might nonetheless accomplish other goals.

Beyond e-government, the idea of “open government” ensures a larger perspective and is connected to the crucial change of governments to become more approachable, transparent, engaged, and cooperative (Hansson et al., 2015).

In contrast to the simplicity of use of the technologies used to call for participation in such efforts, Alarabiat et al. (2021) note that there are a variety of variables that drive individuals to participate in open government projects depending on the significance and results of such participation. The consumption gap has been highlighted by the majority of Open Data Initiatives' restricted supply-side focus, which is relatively typical. The government is advocating for information while the response from potential users (people, civil society, and enterprises) has been anything but lukewarm (Ohemeng & Ofosu-Adarkwa, 2015).

According to Chesbrough et al. (2006), open innovation is “the use of purposeful knowledge inflows and outflows to accelerate internal innovation and, accordingly, to increase the markets for external application of invention.” Open data is defined as information that is easily accessible and accessible without limitations (Murray-Rust, 2008). The fact that public access to government data has increased in most nations has sparked new developments (Jetzek et al., 2014). This

implies that implementing open government principles can result in open government innovation.

While various definitions have been provided for open data, open government and open innovation, the core concept of *open government innovation* is not well defined in the literature. The purpose of this study was to define open government innovation from the perspectives of academics and industry experts. The findings provide the core concept of open government innovation which defines what open government innovation is. The findings contribute to the academic literature on open government innovation by providing a working definition of what open government innovation is and it also contributes practically by providing professionals working in government services a working definition to establish open government innovation.

This paper is structured as follows: Section 2 presents the literature review. Section 3 presents the methodology. Sections 4 and 5 present the findings and discussion of the study. Section 6 concludes the study.

2. Literature Review

According to Kopec & Sheldrick (2020), open government is a policy that aims to change how information flows between the government and its constituents, enabling individuals to engage with, modify, and reuse that information. According to Meijer (2019), cultural and structural hurdles may be recognised from a government viewpoint. Cultural barriers can include a closed government culture, a fear of misunderstandings, and a concern about security risks. According to Meijer (2019), structural impediments also include a lack of political will or leadership, a lack of standardisation in open data policies, a lack of priority within the organisation, and a lack of resources for information publishing.

"Open data" refers to the creation of data repositories based on state-created and collected information that may be simply and freely accessed by people, businesses, and NGOs (Kopec & Sheldrick, 2020). According to Kopec & Sheldrick (2020), open data and information access provide the means for citizen participation and engagement, which in turn improves accountability.

According to Safarov et al. (2017), in order to accelerate the use of government data by citizens, it is necessary to build an infrastructure that can handle big open government data and better social mechanisms. Additionally, operational issues, technological difficulties, and administrative delays frequently compromise open government data programmes. Data accessibility and reusability may be constrained by technical, legal, and budgetary constraints, among others. The execution of OGD projects might potentially face a number of difficulties relating to the organisational, cultural, legal, and technological settings (Ubaldi, 2013).

2.1 Factors influencing open government innovation

Government organisations throughout the world have started open government programmes to create their data and associated information that must be accessible to the general public (Schmidhuber, 2019). Additionally, governments, development agencies and organisations and citizens are increasingly connecting funding, governance, and assistance to the establishment of a more open and transparent government (Wirtz, 2015).

The following categories are used by Adnan et al. (2019) to categorise the variables impacting the adoption of open government: (1) Technology Dimension - This technical component is described as a technology feature that affects the adoption choice or process, (2) Organizational Dimension: This refers to the organisational attribute or internal procedure that influenced the adoption choice. (3) Managerial Dimension: This refers to the higher-ups' or managers' attitudes about adoption in an organisation, (4) Individual Dimension - According to earlier studies, individual traits including the availability of human capital, competence, knowledge, and experience are crucial for technological adoption. The fifth dimension, the environment, deals with outside forces affecting adoption.

2.2 Challenges of open government adoption

The difficulty of open government data as an innovation, according to Ruijer (2016), is in figuring out how to scale up the availability of open data: innovation niches are developed but "regime shifts" do not occur.

According to Nam (2015), open government is anticipated to provide social and economic benefits through the public's usage of government information. However, as open government matures, it may confront more administrative and technological problems.

According to Kopec & Sheldrick (2020), obstacles to the adoption of open government include a lack of financial resources, inadequate time, non-functional websites, restrictive regulations and a lack of readily available information. The process of publishing data is fraught with difficulties, such as the lack of openness toward data due to organisational capabilities and culture, legal and regulatory issues, particularly those pertaining to privacy and security, technical difficulties like the lack of supporting infrastructure due to fragmentation, knowledge and shortage of skills among public managers involved in all phases of the data production process (Gascó-Hernández et al., 2018).

2.3 Empirical review of open government adoption

The US and UK governments, which provide data that may be used and freely exploited by non-governmental organisations, activists, real estate developers, IT firms, people, and organisations, are some of the most well-known practitioners of open government, according to Maseh & Katuu (2017). The UK government has shown a commitment to promoting openness throughout the world, enhancing transparency by, for example, making statistics on public spending and crime available to the public, and this has resulted in substantial progress toward open government in the country (Kumm et al., 2022).

The concept of open government is still not widely accepted or used in Africa. The open government initiative has generally been slow to catch on in African countries, largely due to the poor performance of many African governments (Jetzek, 2014). Indicators like "corruption, poor service delivery, and undemocratic governance" are sustained by systems that keep information hidden from the public and bureaucracies that give a small number of public officials near unrestricted power (Jetzek, 2014). According to Maseh & Katuu (2017), African countries such as Africa, Tanzania, Kenya, Liberia and Ghana are making progress in the area of open government.

According to Kopec & Sheldrick (2020), open government is clearly linked to the idea that accountable democratic governments should not work in secret but rather that all government information should be made available to the public. However, the Namibian government has the

concept of open government, but it lacks the capacity to fully implement it (Murotua et al., 2020). Additionally, there are a few rules that regulate or control what information must be published, as this is overseen by the Namibia Central Intelligence Service. Despite Namibia's emphasis on offering services online (Maseh & Katuu, 2017), The websites or portals of the Namibian government present all the proposals of certain Offices, Ministries and Agencies (OMAs) or what they have to provide with the idea of information access and decision-making openness (Maseh & Katuu, 2017). The development of new technology platforms for interacting and communicating with individuals has the potential to change the character of the democratic interaction between governments and those they rule, claims Kopec & Sheldrick (2020). However, this is to promote openness and combat corruption. The Republic of Namibia Anti-Corruption Commission (2020) makes information on the instances of corruption and the accusations made against the suspects available online. According to Gascó-Hernández et al. (2018), three key democratic activities have been linked to open government data in the public sector: keeping an eye on government actions to advance transparency and accountability; deliberating and discussing alternative policy options; and taking part in the creation, delivery, and evaluation of government services.

3 Methodology

This is a qualitative study and the study population consisted of academics and industry experts, particularly in the government domain. Participants were purposefully selected to include people who had experience and knowledge of open government and innovation.

3.1 Data collection

Data collection was done through focus group discussion. Five experts were selected to take part in this study. Kruger & Casey (2000) explain that 5-8 participants are enough to take part in focus group discussions if they have enough experience on the subject. For this study, participants had a minimum experience of 10 years and are knowledgeable in the domain of open government and innovation. Hence, 5 participants were enough to gather the required data. Names of participants were codified to EXP 1, EXP 2, EXP 3, EXP 4 and EXP 5. Descriptions of the participants are provided below:

- EXP 1 is a Senior Lecturer with 10 years' experience and does research in e-government.
- EXP 2 is a Deputy Director with 15 years' experience working in a government organisation.
- EXP 3 is an Associate Professor with 20 years' experience and does research in e-government.
- EXP 4 is a Director with 13 years' experience working in a government organisation.
- EXP 5 is an IT Analyst with 16 years' experience working in a government organisation.

The questions were open ended which gave room for participants to answer the questions. Before the focus group discussion, the researcher interacted with the participants to understand their level

of understanding of the subject. The focus group discussion was recorded. The focus group discussion lasted approximately fifty minutes.

3.2 Data analysis

The recordings were transcribed. Thematic analysis was used to analyse the findings.

Themes that emerged from the study include:

3.2.1 Key components of open government innovation

3.2.1.1 Transparency

3.2.1.2 Accountability

3.2.2 Alliance between citizens and the government

3.2.2.1 Citizen

3.2.2.2 Government

3.2.3 Innovation using digital technology

4. Results

- The findings of the study have been categorised under three themes that emerged from the data analysis and these include key components of open government innovation.

4.1 Key components of open government innovation

Participants were asked to describe what they think open government innovation is, based on their experiences. The majority of the participants believed that transparency and accountability are core components of open government innovation. One of the participants explained:

“Open government innovation is a transparent process that ensures that the government provides information about actions, budget and performance.” (EXP 1).

Another participant added:

“Open government innovation occurs when a government opens up about government processes, proceedings, documents, and data for public scrutiny and involvement.” (EXP 4).

In terms of accountability, a participant stated:

“Accountability is important, the government is made accountable by making government data open.” (EXP 5).

The participants also explained that for innovation to occur in government, data must be made transparent for citizens to see. The participants also explained that accountability is a core element of open government as it ensures that government delivers on their promises.

4.2 Alliance between citizens and the government

Participants were asked to describe people they think should be involved in open government innovation. All participants believed that citizens and the government should collaborate in open government innovation. One of the participants explained:

“The government is important in this process because they are one of the key drivers.” (EXP 1).

Another participant stated:

“Citizens should work with the government to implement open government innovation. Citizens should be able to take part in government decisions such as using their expertise, based on the data provided by the government, to create innovation.” (EXP 3).

One participant stated that the *“government could run public competitions about innovative ideas and use those ideas to develop the country.” (EXP 2)*

Participants were asked to discuss what the role of the involved parties would be. Participants explained that citizens would be sharing ideas, sharing expert knowledge and also using data and resources provided by the government to make informed decisions. Participants explained that the government can take a more active approach by sharing important information with the citizens, taking their ideas into consideration and make decision making transparent.

It was also indicated that intellectual property rights from innovations can be shared reasonably between citizens and the government.

4.3 The inclusion of digital technologies

Participants were asked to discuss how innovations could be developed through open government. All participants indicated that digital technologies are relevant for innovation to take place in open government. Some of the participants stated:

“I don’t think there is innovation without technology. For innovation to take place, there should be elements of digital technologies for example sharing information through online platforms like a website. Without the website, people will not be able to see information shared” (EXP 3).

Another participant added:

“If citizens do not have the technology how will they access the website? Before innovation can take place, citizens must be exposed to technology, the truth is we have to break the digital divide, empower people and make our society technology accessible. It is one thing for us to have information available on a website but another for people to access them on their device.” (EXP 4).

A participant stated:

“I agree. The use of digital technologies like mobile phones, mobile apps, computers are key tools for innovation. I am going to emphasise on what [EXP 3] has said, sharing this information on websites, websites are not only places where government can share information, there is an emergence of social media platforms, mobile phones, sms, WhatsApp, the government can use these to share information and people can also share ideas with the government using these platforms.” (EXP 5).

One participant explained:

“My opinion is that experts can contribute through developing innovative digital tools like AI and machine learning towards solving key problems based on ideas given by citizens. In reality, the government alone may not be able to make all the decisions but with people involved it mighta difference through digital innovations.” (EXP 4)

5. Discussion

The objective of this study was to define open government innovation from the perspective of professionals in academia and industry. To the best of the researchers' knowledge, this is the first time such a study is being conducted from an empirical point of view. This study extends the knowledge of open government innovation with a perspective on the core elements of open government innovation. The findings revealed that components such as transparency and accountability are elements of open government innovation. This is in line with previous studies that suggest that open government needs to be transparent and accountable to its citizens (Kulsum et al., 2022).

It was also noted that collaboration between the government and the citizens is of uttermost importance for open government to work. This is in line with the findings of Murotua et al. (2020) which suggested that citizens are open to collaborating with the government. This suggests that citizens are likely to participate in making key decisions about their countries. Governments should ensure that citizens are able to participate actively through activities that will enable them to participate. When citizens participate in open government innovation, they should be able to take part in sharing intellectual property rights when they participate in innovation creation. This is evident from the study by Mu & Wang (2022) that acknowledging the intellectual property rights of citizens who have created ideas for solving problems is something that needs to be actioned. Mu & Wang (2022) suggests that a lot of strategies and commitment need to be put in place for this to be achieved.

The study revealed that digital technologies cannot be excluded from open government innovation. The emergence of Artificial Intelligence (AI) and social media platforms are starting points for open government innovation. Citizens and the government can share ideas, collaborate and innovate using digital technologies such as mobile phones, websites and social media platforms. However, citizens are more likely to engage with these platforms if they are sure that there would be a positive outcome. This is in line with previous studies that suggest that citizens will participate in e-government services if it is favourable to them (Alarabiat & Wahbeh, 2021).

Digital inclusion is an important factor in open government innovation, however, digital divide is a common problem in different parts of the world (Kumm et al., 2022; Wang et al., 2022). A strategy for digital inclusion to ensure that open government innovation is implemented needs to be provided.

A definition of open government innovation should include elements of transparency, accountability, collaboration and digital technologies.

5.1 A definition of open government innovation

Based on the findings of the study open government innovation can be defined as:

A government practice with the aim of being transparent and accountable to the public while collaborating with citizens about key decisions of the state and incorporating the ideas of the citizens to create novel solutions to problems within the state; as such, benefits of these novel solutions are reasonably shared with citizens.

5. Conclusion

The study provided a definition for open government innovation based on the findings from academics and professionals from the industry. The study found that open government innovation encompasses various terms and characteristics that embodies transparency, accountability, collaboration and innovation.

From an academic perspective, the study forms the basis for defining open government innovation. From a practical perspective, governments can apply these practices when trying to establish open government innovation. One limitation of this study is that the definition of open government in this study focuses on the context of government services and does not capture how other sectors work. It would be interesting to see how this definition is applied in empirical studies.

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Digital Ecosystems in Financial Services driven by Embedded Finance Platforms in South Africa

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Abstract

Context: Technology, business models, regulation, and strategy performs a substantial role in the end design of banking services and products.

Problem: Digital technology start-ups in the form of fintech' are now developing products and services traditionally developed by banks using disruptive strategies and business models. Banking still remains an essential service, but it has evolved over the years since the introduction of fintech's into the financial services ecosystem. This new wave of innovation within the financial services industry is driven by embedded finance. Embedded finance means that financial services are embedded into digital channels and experiences of 3rd parties with the underlining services still offered by the bank. This shift has led to the creation of digital ecosystems being created in financial services whereby banks are creating partnerships with ecosystem participants like digital start-ups (fintech's) to distribute their products. The ecosystem is enabled through digital platforms in the form of API marketplaces. Not much research exists on the study of digital ecosystems in financial services driven by embedded finance platforms.

Approach & Objective: The research paper provides insights on how digital ecosystems are being created within the financial services industry driven by embedded finance regulation and market activities in developing markets like South Africa with applicability to other developing markets.

Keywords: Digital Ecosystems, Embedded Finance, Digital Economy, Digital Tech Start-ups and Digital Platforms.

1. Introduction

Embedded finance has taken off globally as a result of regulatory reform as well as due to commercial opportunities being pursued by banks. Outdated bank approaches and commercial models are being tested in favour of new innovative and disruptive business models that allow an easier flow of customer data that encourages banking services to be distributed across the financial services ecosystem. Embedded finance encourages greater collaboration between banks and regulated 3rd party fintech's. Banks will remain but there is evolving to that of the ecosystem partner providing access to core banking capabilities like governance, processing, compliance and regulatory licenses. The regulated 3rd party or end distribution partner then provides the customer experience. This allows banks to target and access new customers by leveraging their 3rd party distribution partner's digital channel/platforms [Skinner, 2020]. Financial services markets like South Africa and other markets are no different. Traditional banks in South Africa are faced with growing opposition from fintechs within the ecosystem that provide the products and services usually provided by banks. South African banks are now confronted with the prospect of implementing digital ecosystem approaches in the form of embedded finance. Regulatory reform in markets like the United Kingdom and Europe through the PSD (Payment Services Directive) has fast-tracked digital ecosystem adoption in financial services by creating additional opposition into the payment value chain dominated by incumbent banks and card platform service providers like Visa and Mastercard. Embedded finance (in Europe) came about as a result of the Payment Services Directive that

sought to introduce competition into the financial services domain [Mas-Colell, 1995]. Since the European Union regulators introduced the Payment Services Directive (PSD), this transformed the way banks provide payment services. The directive's resolve was to allow greater competition and involvement by non-banks in the payment ecosystem while also focusing on greater protective measures of customer data while articulating the rights and obligations for payment providers and users.

1.1 Research Problem and Objective:

Research Problem: Digital ecosystem creation in financial services driven by embedded finance regulation has been a reality since 2007 [Donnelly, 2016]. Inadequate research insights exist on how banks and non-banks have been embracing ecosystem thinking working together leveraging digital platforms and forming partnerships. This remains uncharted territory and is filled with challenges and can be problematic if embarked on or executed unsuccessfully with damaging implications for the entire financial services value chain [Wullweber, 2020]. It is with this context that this research has been conducted thus to provide further insights into how digital ecosystems are being created which can serve as a guide for financial services markets globally looking to embark on embedded finance. This research help guide financial services, stakeholders, and practitioners, while also providing new knowledge for researchers interested in this topic. The research provides insight into digital ecosystems being adopted in the financial services market in South Africa.

Research Objective: With limited academic research on this topic with a South African context, makes digital ecosystems adoption difficult to grasp from both a benefits and risks perspectives.

Objective 1: To identify key differences in the digital ecosystems strategies and business models selected by South African banks in relation to their peers in the rest of the globe.

Objective 2: To comprehend the motivation behind the difference in digital ecosystems strategies and business model selection and adoption by South African banks in relation to their peers in rest of the globe.

Objective 3: To establish the significance of benefits and risk determination in the choice of digital ecosystems strategy and business model selection for South African banks in relation to their peers in rest of the globe.

The research provides clarity on the following: Providing insight into digital ecosystem approaches driven by embedded finance strategies and business models adopted by banks in South Africa and digital tech start-ups (fintech). In addition, providing a comparison between digital ecosystems driven by embedded finance approaches and commercial models selected and adopted by South African banks in contrast to their peers in rest of the globe.

2. Literature Review:

Changing financial services landscape: Embedded finance adoption globally has ushered in a new way of provisioning access to banking services, allowing banks to explore new business models and strategies that embrace embedded finance and ecosystems thinking [Creswell, 2003]. This shift has led to the creation of digital ecosystems being created in financial services whereby banks are creating partnerships

with ecosystem participants like digital start-ups (fintech) to distribute their products. The ecosystem is enabled through digital platforms in the form of API marketplaces. In addition, out-dated bank approaches and commercial models are being challenged [Omarini, 2018 B].

The rise of embedded finance - Embedded finance origins: As noted in the introduction that in 2007 the European Union legislated a policy called the Payment Services Directive (known as PSD) [Mas-Colell, 1995]. This legislation requested incumbent banks to open up the payment value chain to regulated nonbanks. Banks had to develop Application Programming Interfaces (API's) and share that with regulated nonbanks. This then ushered in a way for embedded finance permitting banks to provide their banking capabilities to third parties using API's (application programming interfaces).

Embedded finance with a South African context: South Africa does not have any Payment Services Directive (PSD) regulation in place, but banks in South Africa due to their competitive nature has taken the opportunity to embrace embedded finance for commercial reasons. [Croxson, Jon Frost, Gambacorta, Vallett, 2021]. Embedded finance offers South African banks the ability to extend their services beyond their own digital channels but allows them to extend their services digitally on channels belonging to their ecosystem partners and corporate customers. Banking can now be offered as a service via 3rd party digital platforms.

For banks to embrace embedded finance, the following needs to be considered: Introduction of new open commercial models that allow banks to embrace open innovation. Open innovation takes place when companies leverage of ideas and solutions from outside of the organization to design products, co-creating with external stakeholders to develop innovative products and solutions [Gozman, Daniel, Hedman, Jonas, Sylvest, Kasper, 2018].

Alignment of API marketplace with ecosystem Strategy: To define an embedded finance approach and ideal commercial model, banks would first want to outline their ecosystem strategy, thus focusing on answering the following questions [Gupta, Malinverno, O'Neill, Santoro, Jain, 2020]:

- a) Why is it important to work with partners within the digital ecosystem to develop new and innovative products versus building these innovations themselves?
- b) Who are the partners within the ecosystem worth working with?
- c) From a revenue generation perspective, which API's will drive the most commercial value?
- d) From a pricing strategy perspective, what will drive the greatest commercial value? value?

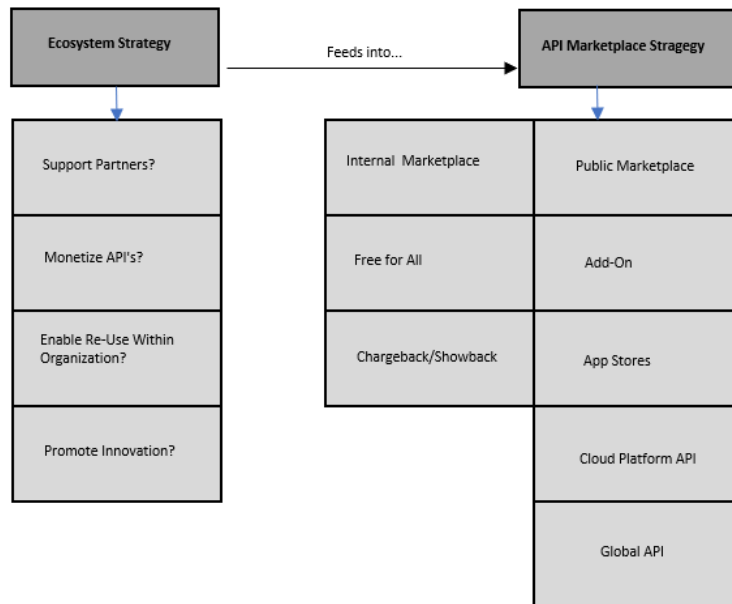


Figure 1: As adapted from [Gupta, Malinverno, O'Neill, Santoro, Jain, 2020] - Aligning API Marketplace With Your Ecosystem Strategy

Embedded finance fosters a greater partnership between banks and non-banks which means that banks no longer have to develop all products and services themselves (which could be costly) but rather leverage and access these products and services from 3rd parties (and vice versa) within financial services ecosystem. [Creswell, 2003].

Introduction of digital technology start-ups in the financial services ecosystem: Digital technology start-ups in the form of financial technology (fintech's) entered the financial services ecosystem due to the perceived opportunity and gap left by incumbent banks providing enhanced customer experiences and value-added services [Arner, Barberis, Buckley, 2015]. These new market entries by digital technology start-ups in the form of financial technology (fintech) have disrupted outdated banking commercial models, thus banks are now responding to this disruption by pursuing digital ecosystems driven by embedded finance commercial models and approaches which is paradigm shift from conventional banking. [Arner, Barberis, Buckley, 2015]

Shifting paradigm: Banks are unbundling their services and discovering new commercial models taking an ecosystem thinking approach. Banks are applying the following options: Comply, Expand, Compete or Transform. Under the Compete and Transform options, banks can see this as an opportunity to introduce approaches and commercial models that can generate new sources of revenue and access customers that they would not typically have had access to through partnerships with digital technology start-ups like fintech's [Cortet, Rijks, Nijland, 2016].

The emergence of new digital ecosystem models: Traditional banking business models are evolving from banks having to develop financial service products and then selling these products to their customers [Omarini, 2018 A], new platform-based commercial models include banks developing platforms where their products are accessible on the platform (through embedded finance API marketplaces). This allows

for several new ecosystem participants like digital technology start-ups to co-create new products with the bank. Thus, allowing the bank to access new market opportunities [Omarini, 2018 A].

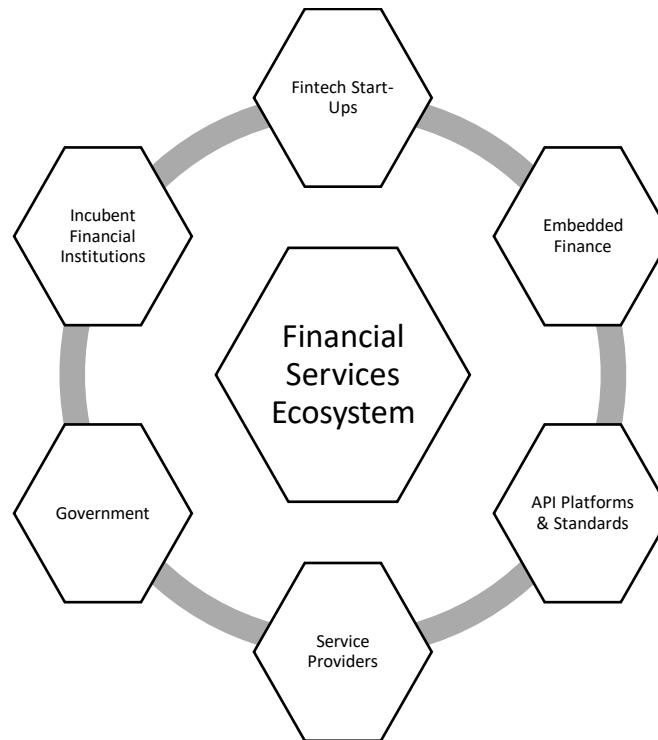


Figure 2: Financial Services Ecosystem Enablement Elements [Arner, Barberis, Buckley (2015)]

3. Research Methodology

The research conducted followed a qualitative approach that applied inductive logic. Since the study focused on the subjective realities of the research participants, this feedback was used to best understand the current realities facing South African banks in their quest to create digital ecosystems driven by embedded finance digital platforms co-creating with digital tech start-ups (fintech's) in respective markets.

To ensure the reliability of the research approach, the researcher applied for a literature review [Creswell, 2003]. Hence, the researcher examined high-quality literature sources that pertain to the topic under focus. Part of the actions included a assessment of the topic scope, an valuation of the subjects from whom data was collected, and the nature of instruments during the data collection process. By evaluating these subjects through the lens of the current body of information, research composed during the study process now contributes to the overall global body of knowledge on digital ecosystems driven by embedded finance but from a South African financial services viewpoint which is appropriate to other markets globally which have similar attributes to South Africa's financial services structure.

The primary data collection points were done through the preparation of interviews with expert professionals on embedded finance who have first-hand knowledge of implementing strategies and business models pertaining to embedded finance at various banks in South Africa. Key to this method was to grasp how embedded finance digital ecosystems and platforms were being adopted in South Africa

The secondary data points assembled played a key role in validating and adding perspective to the primary data gathered during the research study. Secondary data was gathered by examining data available in the public domain on the global banks and technology businesses that have embraced embedded finance [Saunders, Lewis, Thornhill (2012)].

The analysis strategy for this study applied an inductive method that leveraged details from the examination of raw data to develop a model of concepts through the interpretation made by the researcher to allow findings to emerge from the substantial themes. The research study followed an analysis approach that started with unpacking the raw data provided through the interview transcripts.

Qualitative research is more often than most subject to scrutiny due to the degree and assessments used to address matters of reliability, validity, and generalizability not applicable in the manner as quantitative research and require the inclusion of methodological strategies to validate consistencies and applicability of the findings and clarifications. The presentation of details from the analysis of in-depth interviews with various contributors ensured that their viewpoints were accurately captured and discovered clues for the influence of their words or actions providing a check for interpretive validity of the primary source of data for the project.

Results Model: Through a series of questions used to examine the research theme which included a background around embedded finance, acceptance scenarios, key drivers, embedded finance standards, implementation methods, and risk factors associated with embedded finance. The method included reading through each of the transcripts provided by the research participants, then annotating each of the data points and conceptualizing the data. Data points collected during these engagement sessions were then analyzed using an inductive method of analysing interview transcripts. A thematic content approach was used to identify and exclude biases as well as to establish the predominant impressions of the data [Canary (2019)]. Key here was to find common patterns across the data set. Further qualitative analysis methods included making use of narrative analysis to highlight significant aspects of each of the data sets provided by the research contributors. In addition, the examines process included segmenting the data and analyzing the segments. The results were then enhanced by focusing on key patterns identified and adding supporting literature to enhance each of the key data points identified.

Ethical Considerations: The researcher did not coerce the sample members to take part in the study. Instead, ensure that the respondents willingly through consensus granted to share information relevant to the study. Each of the research contributors freely signed the agreement form, which described the rights and limitations of the respondents. The aim was to assure that their participation in the study was voluntary. The researcher ensured that research participants' privacy and confidentiality were protected by removing their names from the interview scripts.

Research Sample Market Selection: The research sample market selection was South Africa. South Africa represents a developing/emerging market that is in its infancy stage of implementing embedded finance digital platforms. This case study represents a growing number of financial services digital ecosystems that have yet to formally implement embedded finance digital platforms due to the lack of regulation. Thus, banks in South Africa (due to their competitive nature) have taken the initiative to future proof its businesses by creating digital ecosystems around their traditional banking models thus embracing embedded finance digital platforms and co-creation with digital tech start-ups.

A key driver for embedded finance digital ecosystems platform adoption that encourages co-creation with digital tech start-ups (fintech's) has been regulation due to financial services regulators wanting to create more competition that allow new entries into the financial services value chain like digital start-ups as is the case of the UK with the introduction of the Payment Services Directive [Mas-Colell (1995)] regulation which aligns to the Competition Markets Authority (CMA) objective, thus one would find that adoption would be based on compliance with the regulation like PSD2. The South Africa financial services ecosystem represents a market driven approach in the absence of regulatory policy that does not exist like PSD2 in the UK.

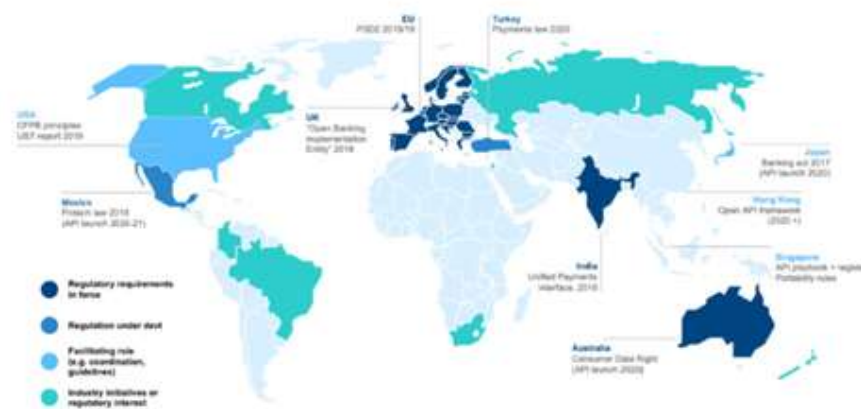


Figure 3: As adapted from [Corcoran (2020)], *Approaches to Embedded/Open Banking-finance Regulation*

4. Results Findings:

Research findings align to research objectives: The research objective (1) was to establish key differences in the digital ecosystems approaches and commercial models selected by South African banks in relation to their peers in rest of the globe. The findings highlight the growing importance of banks in South Africa looking for new commercial opportunities to grow their business. Embedded finance offers banks the opportunity to extend their services to 3rd party digital channels. In doing so they then have the ability to earn transactional revenue from application programming interface (API's) requests which translates into transactional revenue. One good example of this is a bank offering its personal lending product in a form of an API onto a 3rd party platform, this means that the 3rd party can now offer personal lending to their customers and on their digital channel (embedded lending). This commercial-driven approach differs from that taken in other markets like the United Kingdom which applied a compliance-driven approach to embedded finance as legislated by the European Union's Payment Service Directive. Australia's banking sector also applied a compliance-driven approach versus Mexico who's commercial-driven approach aligned to that of South Africa.

The research objective (2) was to grasp the rationale behind the difference in digital ecosystems approaches and business model selection and adoption by South African banks in relation to their peers in rest of the globe. The findings highlight that competition for revenue opportunities amongst banks are key driver for embedded finance adoption in South Africa in the absence of PSD regulation. Financial inclusion also featured as a strategic driver for embedded finance adoption by South African banks.

The research objective (3) was to establish the importance of benefits and risk determination in the choice of digital ecosystems approach and commercial model choice for South African banks in relation to their peers in rest of globe. The results highlight the following benefits; access to new revenue prospects for banks, improved customer experiences, customer centricity and loyalty, growing provision of banking services to underserved communities. The risks include cyber security, deficiency of interoperability of standards causing lack of rationality & collaboration between banks (in the absence of regulation), lack of skills within the embedded finance domain, and reputational risk.

5. Discussion

This section provides a detailed view of the findings taking into consideration both primary and secondary data points as it articulates the comparison between digital ecosystems driven by embedded finance approaches and commercial models by South African banks, in relation to their global peers.

Research Aim	Research Objectives	Research Results: Primary Data Point: Data gathered on South African Banks from research participants	Research Results: Secondary Data Point: Data gathered on banks in Europe, North America, Asia & Middle East from research literature
<u>Research Aim:</u> To provide a comparison between digital ecosystems driven by embedded finance strategies and business models selected and adopted by South African banks in comparison to their peers in rest of globe	<u>Research Objective 1:</u> To establish key differences in the digital ecosystems strategies and business models selected by South African banks in relations to their peers in rest of globe .	<u>Commercial Driven:</u> New Revenue Driven. In the absence of PSD2 regulation (adoption drivers in the UK & EU) for the South African market forcing banking institutions to adopt embedded finance. South African banks are choosing to adopt embedded finance for the commercial opportunities that it could offer. With increasing pressure on South African banks to generate revenue and grow customer acquisition numbers, banks are experimenting with embedded finance strategies and business models to help generate new revenue by offering banking as a service model to 3rd parties like fintech's and their corporate customers. This allows banks to leverage these partners to access new customers. <u>Customer Experience Driven:</u> South African banks are also developing embedded finance API marketplaces [Carter, 2019] to allow the bank to extend its digital banking offering to 3rd party partners like digital neobanks, fintech partners or corporate bank customers through the use of API's embedded in the digital applications of these partners thus to offer enhanced customer experiences for banking services beyond its own traditional banking platforms. This approach allows for customer centricity by allowing the customers of these 3rd party parties to access banking services through the channel that they prefer. An example of this is a bank's personal loan application process embedded into a 3rd party e-commerce platform thus allowing customers using the 3rd party e-commerce platform to apply for a bank loan within their shopping experience.	<u>Compliance Driven:</u> Europe: The Payment Services Directive (PSD2) in Europe applied to banks, third party payment providers and electronic money providers that facilitate access for 3rd parties to transactional data and payment services [Corcoran , 2020]. This regulation required these institutions to adopt embedded finance standards. Australia: Consumer Data Rights Bill: The Australian Government passed its legislation on 1 August 2019 to provide new rights for consumers and small businesses to their data from July 2019. The Treasury Laws Amendment (Consumer Data Right) Bill 2019 (Cth) (Act) provides a new "Consumer Data Right" (CDR) which will have a major impact on the banking sector. The CDR relating to banking data is usually referred to as Embedded finance [Dentons , 2019]. <u>Customer Experience Driven:</u> Europe: [Finextra , 2020] in their research article titled "<i>Embedded finance moves from compliance challenge to commercial opportunity</i>" published in May 2020 suggests that European financial institutions are spending between €50-€100 million on Embedded finance initiatives, with spend exceeding €100 million for nearly half (45%) of 290 financial institutions. The opportunity to improve customer the experience was the biggest driver for Embedded finance spending. <u>Commercial and Customer Experience Driven:</u> Mexico (North America): Mexico joined a group of nations globally that passed embedded finance regulations. It did this to help drive access to financial services for 48% of its unbanked community. Mexico currently has a 52% banked population and has thus embarked on embedded finance for commercial reasons to help drive access to financial services. [Tomaney, 2018]. Mexico has regulated that any banking provider must open to provide fair access to data if they want to secure or retain their banking license. Embedded finance in Mexico also focusses on driving valuable and enhanced digital engagements for consumers of financial service products.
	<u>Research Objective 2:</u> To understand the rationale behind the difference in digital ecosystems strategies and business models selection and adopted by South African banks in relation to their peers in rest of globe	<u>Competition & Financial Inclusion:</u> Competition for revenue opportunities amongst banks will be a key driver for embedded finance adoption in South African in the absence of PSD2 regulation. Acquiring new customers through the creation of new products thus to drive access to new revenue lines is a key business objective and value driver for the implementation of embedded finance. <u>Competition initiated by the South African Reserve Bank through its National Payment System Framework and Strategy - Vision 2025:</u> The South African Reserve Bank in its National Payment System Framework and Strategy Vision makes mention of banks and non-banks (including FinTech firms) competing for the full range of payment services across the entire payments value chain under the same legal and regulatory frameworks. Embedded finance allows for the opening of the payments value chain using API's for banks and non-banks (Fintech's/Third Party Payment Providers) to all play a role in the payment transaction. One such example is the introduction of instant electronic funds transfer (EFT) payments as part of the bank's embedded finance strategy offered through its API marketplace. Nedbank (South African bank) has taken the lead on this, working with Third Party Payment Providers to offer its EFT Payment API in a sandbox environment. https://apim.nedbank.co.za/static/payment	<u>Compliance Driven:</u> - <u>PSD2 Driven:</u> A key driver of PSD2 regulation was to allow for greater competition in the payments value chain dominated by traditional players like banks and card payment providers (Visa & Mastercard). <u>Customer Experience & Commercial Driven:</u> Banks in Europe, North and South America and Asia adopted open banking to offer a differentiated digital customer experience to end customers. Mexico is worth mentioning. BBVA Mexico in alliance with Uber Mexico launched an embedded finance capability that allowed Uber drivers to access transactional banking and lending directly through the Uber platform instead of accessing these services via a traditional bank platform. This resulted in a seamless digital customer experience for Uber drivers to access loans for purchases like fuel (as an example). This is also an example of embedded finance being used for commercial purposes thus allowing banks like BBVA Mexico to extend its banking services beyond its traditional banking platforms thus to possibility generate new revenue through new distribution channels like Uber [BBVA, 2019].

	<u>Financial Inclusion:</u> Financial inclusion features as a strategic goal of the South African Reserve Bank and can be used as a rationale to help drive the adoption of embedded finance by allowing financial institutions to offer their services to third parties partners that focus on developing financial inclusion propositions in addition to the bank's own financial inclusion propositions. Financial inclusion involves access to electronic payments but also access to savings, credit, and insurance services. It may also involve providing better access to cash services (e.g. cash-in and cash-out remittance schemes) to increase confidence in formal financial products and provide an evolution toward electronic payments for underserved communities. <u>Customer Experience:</u> Offering a differentiated digital customer experience by offering embedded finance "bank as a service" offering is another rationale reason behind embedded finance as this allows South African banks to co-create new digital experiences with their partners (Corporate customers, Fintechs and Digital Neobanks).	
<u>Research Objective 3:</u> To establish the importance of benefits and risk determination in the choice of digital ecosystems strategy and business model selection for South African banks in relation to their peers in rest of globe	<u>Benefits & Risks</u> The following benefits have been identified as justification points for the adoption of embedded finance strategies and business models by South African banks: <u>Access to new revenue opportunities for banks:</u> Embedded finance offers South African banks the ability to generate revenue from non-traditional distribution channels by embedding their banking services into third-party applications. This will allow the bank the opportunity to generate new streams of revenue from new distribution channels. <u>Enhanced customer experiences:</u> Embedded finance allows banks the ability to offer digital banking experiences beyond their own platforms thus the ability to co-create new digital customer experiences with partners will be possible. <u>Customer Centricity and Loyalty:</u> Banks adopting embedded finance will have the ability to create stickiness and loyalty from its corporate customers as it will have its banking services embedded into its corporate customer's platforms thus making it difficult for these customers to switch away from the bank. <u>Growing provision of banking services to underserved communities (new market opportunity through financial inclusion):</u> Embedded finance allows banks to embrace financial inclusion and create new market opportunities by attracting new customers (through its partners) that it would not necessarily have had access too. The following risks have been identified (associated with embedded finance): <u>Cyber Security:</u> Opening access to banking services and customer data through embedded finance will attract cyber criminals. Thus, banks implementing embedded	<u>Benefits & Risks</u> The following benefits have been identified as justification points for adoption of embedded finance strategies and business models by banks globally: Access to new revenue opportunities for banks. Enhanced customer experiences: Customer Centricity and Loyalty: The following risks have been identified Cyber Security Reputational Risk

		finance strategies and business models must ensure that their platforms are secure. <u>Lack of interoperability of standards causing lack of coherence & collaboration between banks (in the absence of regulation):</u> Embedded finance API standards and customer services standards play a key part in overall quality of service to customers. In the absence of these interoperability of standards, it might cause friction points between banks and thus frustrate the end consumer of these embedded finance services. <u>Skills:</u> Lack of business and technical skills to implement embedded finance proposition and solutions <u>Reputational Risk:</u> By offering out bank as a service embedded finance strategies and business models opens the bank up to reputational risks should its partners (Fintechs) or customers (corporate customers) using these banking services through API's not deliver to the end customer in line with legal obligations set out in the partner agreements.	

South African banks are taking a commercially driven tactic to implement digital ecosystems driven by embedded finance commercial models and approaches with the business objective of producing new income prospects. With growing pressure on South African banks to produce revenue and grow client acquisition numbers, banks are experimenting with embedded finance approaches and commercial models to help produce new revenue by offering banking as a service model its ecosystem parties like fintech's and their commercial clients. This allows banks to leverage these partners to access new customers. Digital ecosystems thinking driven by embedded finance offers South African banks the ability to generate new revenue prospects, the focus should be on driving transaction volumes through embedded finance capabilities before profit can be made. Competition for revenue prospects amongst banks will be a key driver for digital ecosystems thinking and embedded finance adoption in South African in the absence of PSD2 the regulation. Attaining new customers through the creation of new products thus to drive access to new revenue lines is a key commercial objective and value driver for the implementation of embedded finance.

6. Conclusion

Business model progression: Banking as a Service (BaaS), Banking as a Platform (BaaP) embedded finance approaches and commercial models might be new to South African banks but are not foreign in the technology platform market globally. Bank as a Service (BaaS) models form part of a platform as a service approach. Platform as a service (PaaS) or application platform as a service (aPaaS) can be best defined by using an example from the global technology companies like Amazon, Google, Microsoft, Alibaba that offer its business customers the ability to launch digital products without having to invest in building the technology infrastructure themselves which could be very costly. It does this by offering cloud computing services that enable its customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure typically associated with developing and launching digital

products [Hurwitz, Kaufman, Halper, Kirsh, 2012]. Banking is no different, embedded finance allows banks to offer platform as a service (PaaS) or application platform as a service (aPaaS) business model and strategies that can enable its corporate customers and other financial technology (fintech's) companies who would like to offer banking services but would not want to go through the regulatory process of obtaining a banking license as well as incur the costs of building a bank from scratch. Platform-based business models for part of a digital transformation evolution [Thomas, Zhao, 2019]. The traditional model in banking meant that banks would develop banking products for its customers, then use their distribution channels to sell these products which include its own digital channels. Platform-based banking business models allow banks to develop banking products offered not only through its own digital channels but also through their ecosystem partners' digital platforms. It also allows its ecosystem partners to digitally offer their products on bank marketplaces. Platform-based business models are also used to disrupt incumbent business models. The GAFAM (Google, Amazon, Facebook, Apple & Microsoft) which are platform-based businesses are disrupting traditional banking business models by offering access to financial services through its platforms due to massive amounts of data insights that they have traditional bank customers. Platform-based digital ecosystems embedded finance business models take different shapes. South African banks are opting to take the Collaborate, Partner, and Build approach

Implications: In the absence of extensive academic research on digital ecosystems driven by embedded finance for the South African financial services sector, this research serves as a guide and foundation for further study on this topic. Future research topics could include financial inclusion, it being a driver for embedded finance adoption and growth within the financial service sector. Moving from embedded finance to include a broader financial services implication to include open finance and open data. As mentioned in this research study that the lack of any formal regulation on embedded finance in South Africa has resulted in South African banks adopting embedded finance for commercial reasons. It is beneficial for policymakers in South Africa to leverage insights from this research as well as insights from other markets globally that have implemented embedded finance. Policymakers in markets like Mexico (as an example) decided to implement embedded finance to help drive financial inclusion as 52% of Mexicans do not have access to a bank account and over 10% do not have access to formal saving mechanisms. Mexican policy makers implemented embedded finance by adopting standardized API's based on UK standards and then ran a hackathon to identify what will best work for them and their financial services ecosystem (API standards). Due to limited insights being available on embedded finance adoption in South Africa, this research study provides insights for banking professionals and executives looking to implement embedded finance strategies and business models. The diagram below illustrates (high-level view) of best practises to pursue in becoming an Open Bank.

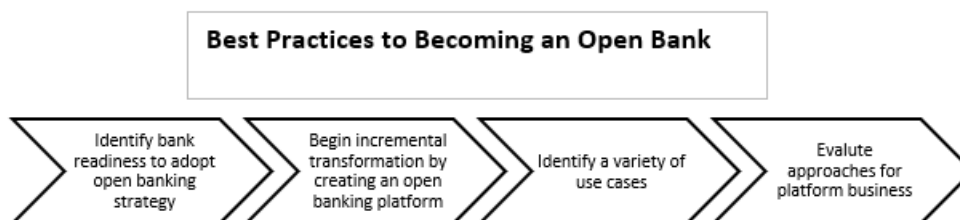


Figure 4: As adapted from [Cohen, Malinverno 2019] Industry Vision: Bank CIOs, Identify Your Readiness to Embark on Embedded finance, Best Practise to Becoming an Open Bank

Recommendations: It is recommended that further research be done on embedded finance from an implication perspective for research to understand the effects of embedded finance since being adopted in South Africa and other markets globally. Embedded finance provides many benefits for banks and customers but also presents risks on many different levels thus further research will help guide policy makers, banking professionals and the broader ecosystem. The implications of South African regulation like POPI (Protection of Personal Information) and its implications for embedded finance, open finance and open data must be fully understood. In markets like Australia, research identified use cases for embedded finance focused on enhancing customer experiences and financial decisions through the creation of data solutions like generic comparison, personalised comparisons, financial management and lending [ANZ, 2017]. Policy makers globally are taking a leading role working with banks and the financial services ecosystem to formulate policies that enable embedded finance. This is being done for various reasons, but the research gathered during this study suggests that drivers include financial inclusion, creating greater competition in the market as well as helping financial service customers by empowerment them through financial management tools to help them better manage their finances. These drivers align to the policy makers in South Africa (National Treasury and South African Reserve Bank Vision 2025). It is recommended that policy makers also undertake further research on the implications of embedded finance for South Africa as adoption increases in the absence of formal regulation. Collaboration between stakeholders within the South African ecosystem will be essential before deciding on standards for South Africa. As mentioned in the study research that Mexican policy makers implemented embedded finance by adopting standardised API's based on UK standards then ran a hackathon to identify what will best work for them and their financial services ecosystem (from an API standards perspective). It is essential for policy makers in South Africa to work with its ecosystem partners in financial services sector to put in place both technical and customer support standards for embedded finance to ensure greater interoperability and adoption of embedded finance for it to achieve its Vision 2025 objectives. It is also recommended that policy makers in South Africa continue to collaborate with their global peers in other markets where embedded finance has been implemented to share learnings and best practises. It is recommended that the greater collaboration is required between banks in South Africa as a collective view will help policy makers. Greater collaboration on technical standards and well as customer support standards is required.

Weakness of the Research: Due to embedded finance not being formally regulated in South Africa compared with other financial service markets, this makes adoption of embedded finance voluntary for South African banks, thus the key drivers then become commercial versus compliance. Due to it being done on a voluntarily basis means that not many banks in South Africa have made known their efforts on embedded finance to the public. The research insights gathered were done from participants and research literature that accounts for just over 60% of South African tier one banks. In addition, little academic research on this topic exists for the South African financial services market. Due embedded finance being in an emerging state for South African banks versus full adoption, this means that a limited pool of human capital has been deployed to embedded finance activities. This then limits the expertise base that exist on this topic with a South African bank context. The research gathered during the study leveraged the human resource pool available, but it was limited to four key embedded finance professionals that have first-hand experience implementing embedded finance at various banks in South Africa.

Future Research: Digital ecosystems thinking driven by embedded finance presents South Africa's financial services sector with many opportunities as well as risks thus it is essential for additional research

on this topic to be done considering the impact of financial services contribute to the South African economy. Future research topics could include the following which has both relevances to South Africa as well as the rest of the world:

Financial inclusion: It is a driver for embedded finance adoption and growth within the financial service sector.

The transition from Embedded Finance to Open Data has wider industry implications beyond financial services.

Embedded finance implications and effects since adoption.

Concluding Remarks: In the absence of meaningful research on embedded finance in a South African context, the research study provides a useful foundation for how best digital ecosystem thinking driven by embedded finance can be implemented in South Africa with traditional incumbent banks working with its ecosystem partners like digital tech start-ups. The research study also serves as a guide and benchmark for banking executives, professionals, regulators, practitioners, and academics in South Africa as well as other emerging markets and financial services sectors that have similar dynamics to South Africa wanting to implement embedded finance strategies and business models. The research also highlights weaknesses in the research as well as future topics to consider. The research will help enhance the global body of knowledge on digital ecosystems driven by embedded finance as well as provide context on the key drivers for embedded finance adoption in markets where regulation does not exist.

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Designing a Supervisory Real-Time Tracking System for Namibian Children

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Abstract.

Child-based disappearances; abuse and suicides are still a predominant dilemma in Namibia, with the majority of the cases resulting from poor parental supervision. Accordingly, there is a need for alternative ways to supervise children, especially during outdoor activities where the chances of them wandering far from home are quite high. The immediate objective of this research was to design and develop an android-based supervisory tracking system for children in Namibia, as a means to improve parental supervision. In addition to the geo-tracking component, an audio sentiment analysis features to predict the likely hood of depression signs in children was integrated. This study used spatial data, like global position system (GPS) coordinates and utilized text-based data provided by Google's speech-to-text feature. The GPS coordinates were captured using an inbuilt GPS module within the tracking device.

Keywords: child tracking system, real-time remote tracking, natural processing language, software design

2 Introduction

In Namibia, poor child supervision has been a concern not just for parents but the society in general (Sharley et al., 2019). In modern countries, the use of tracking systems to assist parents in the supervision of children has significantly increased. Most parents use tracking systems when their children leave the house to play or go to school. Currently in Namibia little is known or researched about the use of tracking systems to complement natural child supervision.

Most parents either let their children play unsupervised or hire childcare workers to look after them. However, the continuous child-based disappearances and abuses are a reality faced in Namibia. Some children tend to play far from home and at times they never get the chance to get back home. Child-based violence and child abductions are increasing at an alarming rate in the country (Mutanga, 2020). Unfortunately, due to the laws in Namibia, parents usually must wait for 24 hours before they can open a case on a missing child. In some cases, it is a bit too late (Ikela, 2018).

Tracking systems' applications are crucial in several fields, but not extensively explored (Stanley & Granick, 2020). Tracking systems or simply location-based systems uses include but are not limited to, tracking objects such as parcels or vehicles, tracking animals in conservancy parks, as well as tracking people (this includes mainly children and senior citizens) (Kolakowski et al, 2020). Although tracking systems have been studied in detail, insufficient attention has been paid to how they can be used to not just keep track of children's whereabouts, but to monitor any sign of depression in their speeches in the Namibian context. This is evident as Namibia continues to face various cases of abuse, disappearances and suicides involving children (Mutanga, 2020). Most cases are due to poor or no supervision. Children's supervision can be vastly complemented with a tracking system that incorporates natural language processing to monitor children's speeches.

This study attempted to develop and construct a real-time tracking system that parents in Namibia could use as a tool to monitor children to combat these acts of violence against children in Namibia. A real-time tracking system will help parents keep track of the geographic location of children (Geo tracking) and their

whereabouts. The study also attempted to implement audio sentiment analysis as one of the system's features to predict the likely hood of depression signs in children.

2. Literature review

2.1. Tracking system architecture

Tracking systems differ vastly, not only in application but also in their architectural design. The application defines the design and architecture to be used. The main distinctions between tracking systems lie in whether they fall under any 5 categories of tracking systems. A tracking system can either be categorized as a SIM-based, network-based, Handset-based, Wi-Fi-based or Hybrid system (Tao et al., 2012). Petre et al. (2017) explored the uses and application of WIFI-based tracking systems, suggests that it is a quite useful type when comes to indoor tracking. Similarly, SIM-based, network-based, and handset-based tracking systems have some distinguishing unique features and advantages. However, research conducted by Ganorkar (2020) suggests the use of hybrid-based tracking for systems that require live tracking, which is GPS-based. Due to its high accuracy compared to other available types and due to its ability to track over long distances with some degree of accuracy. Common hybrid tracking system architecture makes use of components such as a GPS Module and GPS receiver at the Physical layer.

2.2. Existing tracking system for people

Tracking systems or simply location-based systems apart from being widely used for assets and vehicle tracking have been used to monitor and track children and old people (Fung et al,2019). In the past years, it has become a trend to implement a tracking system for people using mobile technologies. One way to understand tracking systems is to review the way they have been used and implemented over time. Common tracking systems for people make use of two subsystems one which resides in the tracking device and another which is used by the individuals tracking and monitoring. A study conducted by Patel et al.(2018) explores a fascinating way to implement and improve tracking systems for people. The study took full advantage of hybrid-based system functionalities and suggests the use of Arduino hardware to perform improved tracking systems for people. Similarly Muhe and Jasim, (2021) have conducted identical research on tracking systems for people and the conclusion suggests that tracking systems are practicable and can be customized. Furthermore, the studies also imparted that current tracking systems for people are not necessarily hardware dependent.

2.3. Traditional children supervision

Child supervision usually falls under two categories, namely passive and active(effective) supervision. The type of supervision and implementation depends on the child being supervised and the family structure (Cookston,2000). According to Sutherland et al. (2019), active supervision always involves continuous monitoring of children, which includes having someone constantly close to the child, knowing where the child is, their companions and activities being performed. Common active supervision practices include environment setup, monitoring, listening and anticipation of child behaviors. While passive supervision involves less intensive and intrusive supervision, less monitoring and less engagement with the child. Both types of supervision have some emergent advantages. However, Guinness et al.(2019) briefly examined active supervision, their study provided an overview of active supervision and its importance. Unlike passive supervision, the study suggests that active supervision reduced 50% to 80% of children-related

misconduct and child-related problems. Similarly, Haydon et al.(2019) reaffirm the effectiveness of active supervision compared to passive supervision and suggest that active supervision requires the use of tools, and techniques to benefit from it.

Although active supervision is more effective, it is usually just applicable to toddlers and preteenagers. Passive supervision is usually effective when dealing with old adolescents, generally because they are psychologically and physically more mature than younger children (Cookston, 2000).

2.4. Sentiment analysis as a system feature

Sentiment analysis has been used by several other disciplines to analyze hidden meanings and emotions in people's texts or speeches. As a result, has been part of the crucial features of many clinical, financial, management as well social media systems (Tang et al., 2015). Attributing sentiment analysis to a system may include examining people's opinions, feelings and emotions, preferences, tastes, and future behaviours.

For this study, sentiment analysis was used as a module of tracking system to examine children's speeches to assess the possibility of suicides or signs of mental breakdown due to distinct types of abuses. Similar research has been made, in which sentiment analysis is used to examine people's possibility of committing suicide and signs of depression. As demonstrated in Birjali's et al. (2017) study, sentiment analysis can be used to examine hidden suicidal thoughts or depression patterns found in multimedia content. The research developed a classifier that helps predict users that are likely to commit suicide, using users' information found on social media such as posts and texts. The study used sentiment analysis algorithms as well as machine learning algorithms to fully implement the classifier. As a result, it was found that 67% of the contents shared by the test samples were suicide-related or at risk of committing suicide. Identically Jung et al (2017) carried out similar research, which focused on adolescents' depression ontology. Overall, both studies showed promising results. However, during Birjali's et al. (2017) study, even though it produced satisfactory results, the overall accuracy was not optimal. The main differences lay in the sources of the sample data dataset. Sentiment analysis can be a powerful feature for sentiment mining within a system, depending highly on the quality of the data being examined.

Another aspect when implementing sentiment analysis as a component of a system one usually must choose between its available techniques or incorporate both based on system requirements. Gupta et al. (2021) conducted research that analyses all the sentiment analysis techniques, namely machine learning-based, and lexicon-based, and both attempt to perform sentiment mining. The machine learning technique usually employs supervised and non-supervised algorithms. While lexicon-based focus solely on non-supervised algorithms.

3. System design approach

3.1. Design strategies

Software design strategies are used to effectively translate user requirements into actual software artefacts (Stol & Fitzgerald, 2018). This study makes use of both functional design as well as object-oriented design. Functional design strategies involve seeing the whole system as a set of subsystems, known as functions. This design strategy divides the system into smaller functions with their roles (Cervantes & Kazman, 2016). Object-orientated design strategies involve the use of entities and their characteristics, whereby this design strategy views the

system as a group of objects and classes which share different forms of relationships and characteristics (Filipova & Vilão, 2019). The rationale behind this selection is that the tracking system uses a client and server model. Therefore, the server-side is making use of a functional design, while the client-side is making use of an object-oriented design.

3.2. User requirement

The requirements of the system were gathered during the requirement engineering phase. This phase includes understanding the domain in which the system will operate and how its current operations are done to create requirements. Techniques such as document analysis and user observation were used to compile a list of requirements for the proposed system. Document analysis involves the study of existing documentation of a similar process; system or solution to extract relevant information that may be used to create useful functional requirements (Bowen, 2002). User observation includes monitoring users and how they operate in the domain being studied (Geogy & Dharani, 2016). The table below illustrates the system's functional requirements.

Table 1: A sample list of the tracking system's requirements.

Functional requirements
• Geographic Location tracking
• Movement monitoring
• Child speech monitoring
• Topographic view of children
• Parental alert

3.3. Use case

A use case is a graphical representation of a user's possible interaction with a system, system interaction with another system or system interaction with its environment (Fowler, 2004). The use case for the proposed system depicts how all the actors involved interact with the system.

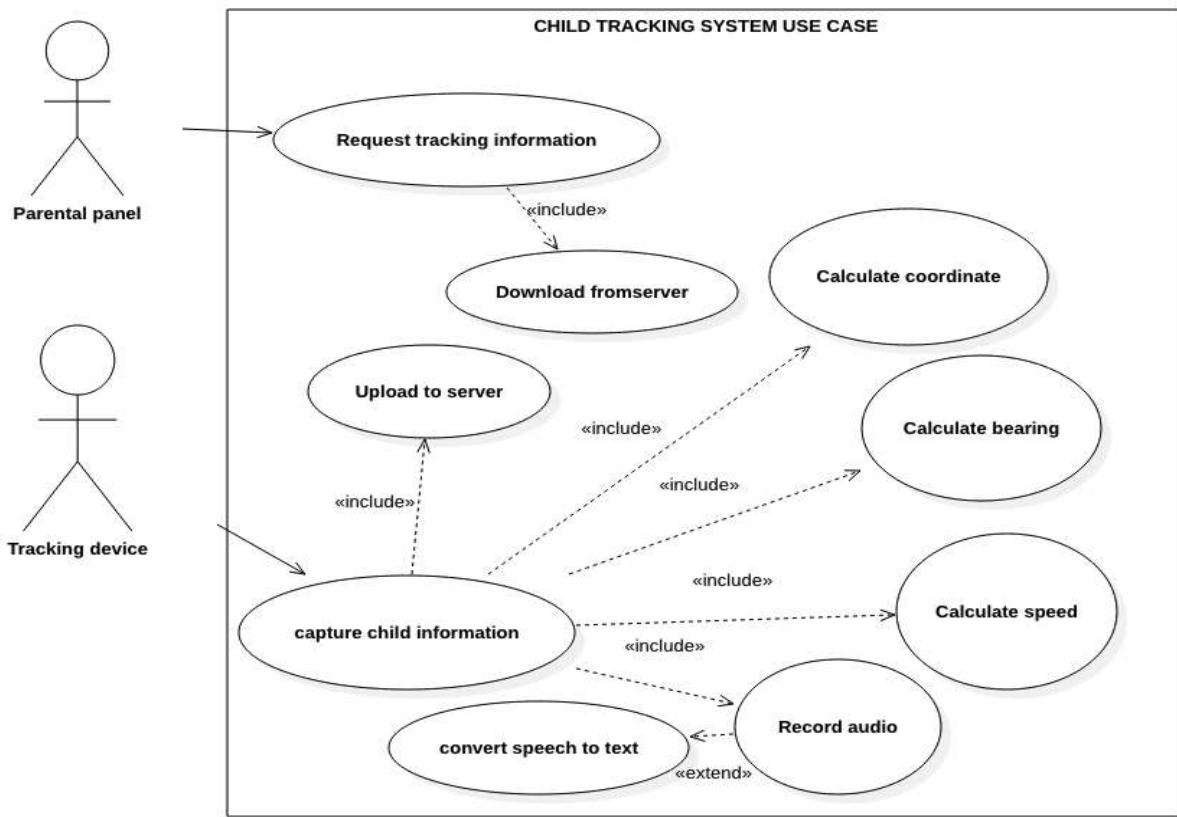


Figure 1: Tracking system use case (Author's perspective).

3.4. Use case

A data flow diagram is used to graphically represent the flow of data in a system (Aleryani, 2016). And was used to represent the flow of data within the proposed system. Data flow diagrams are composed of various levels of data abstraction namely level 0, level 1 and level 2 and up to level 3 or even higher depending on the project and system being depicted. Most often it is very unlikely and uncommon to use DFD level 3 or higher (Bani-Ismael & Baghdadi, 2019). The proposed system is described using the first two levels as follows.

3.4.1. DFD Level 0

Level 0 is also referred to as a context diagram. It provides a minimal overview of the whole system being analysed (Bani-Ismael & Baghdadi, 2019). The DFD level 0 as depicted in figure 2 demonstrates a basic overview of the tracking system. It depicts the external elements of the system as well as its main functional process. The child application on the devices as well as the parental application act as external

entities. That is, they act as an external system that stimulates the main process at the server with different inputs, both nodes act as external actors.

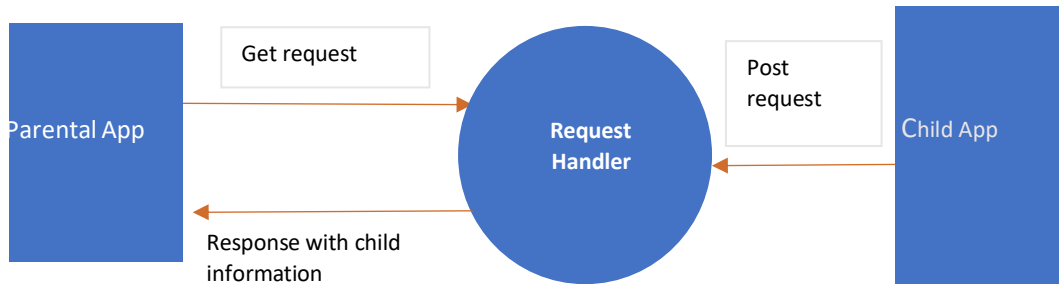


Figure 2: DFD level 0 (Author's perspective).

3.4.2. DFD Level 1

DFD Level 1 depicts a more detailed description of level 0, with a more detailed flow of information within the system (Aleryani, 2016).

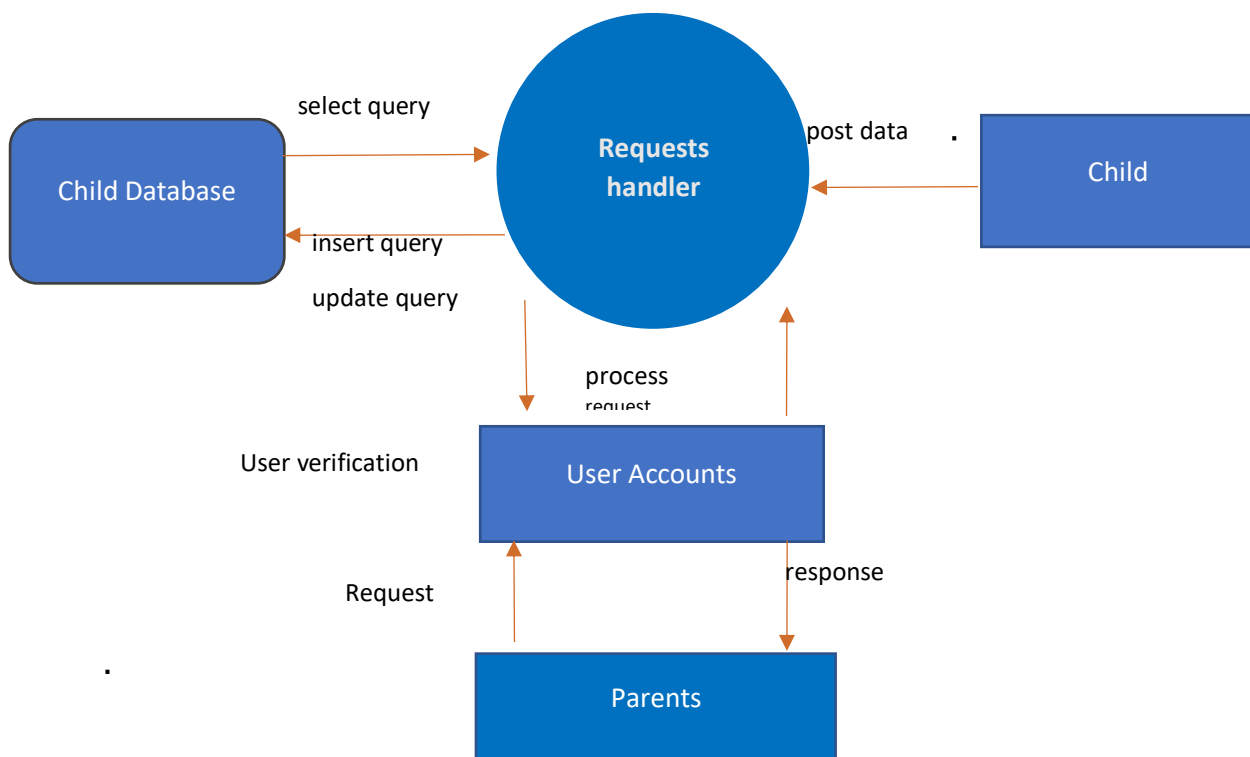


Figure 3: DFD level 1 (Author's perspective).

Figure 3 above depicts level 1 of the tracking system with a more specific flow of data and source of data throughout the system's lifecycle. It includes elements such as data store and types of queries being executed. Request processing acts as the main process for the entire system, it receives and validates parents' HTTPS requests from the parental application. Similarly, it also receives incoming data from the

child's device. This design allows the data from the child tracking device to be continuously updated onto the database and sent to the child's respective parent in real-time.

3.5. Use case

An entity-relationship diagram refers to a model used to depict the relationship between different entities in a system's database (Rashkovits & Lavy, 2021). An ER diagram is used to describe the logical representation of the database of the system, which includes its entities and the relationship between them. Later, these entities are converted into database tables to store system data.

The main entities involved in the proposed system as illustrated by figure 4 include child, parent, location, report, and voice notes entity. Generally, a system being developed for production purposes would be made up of more entities and much more complex relationships.

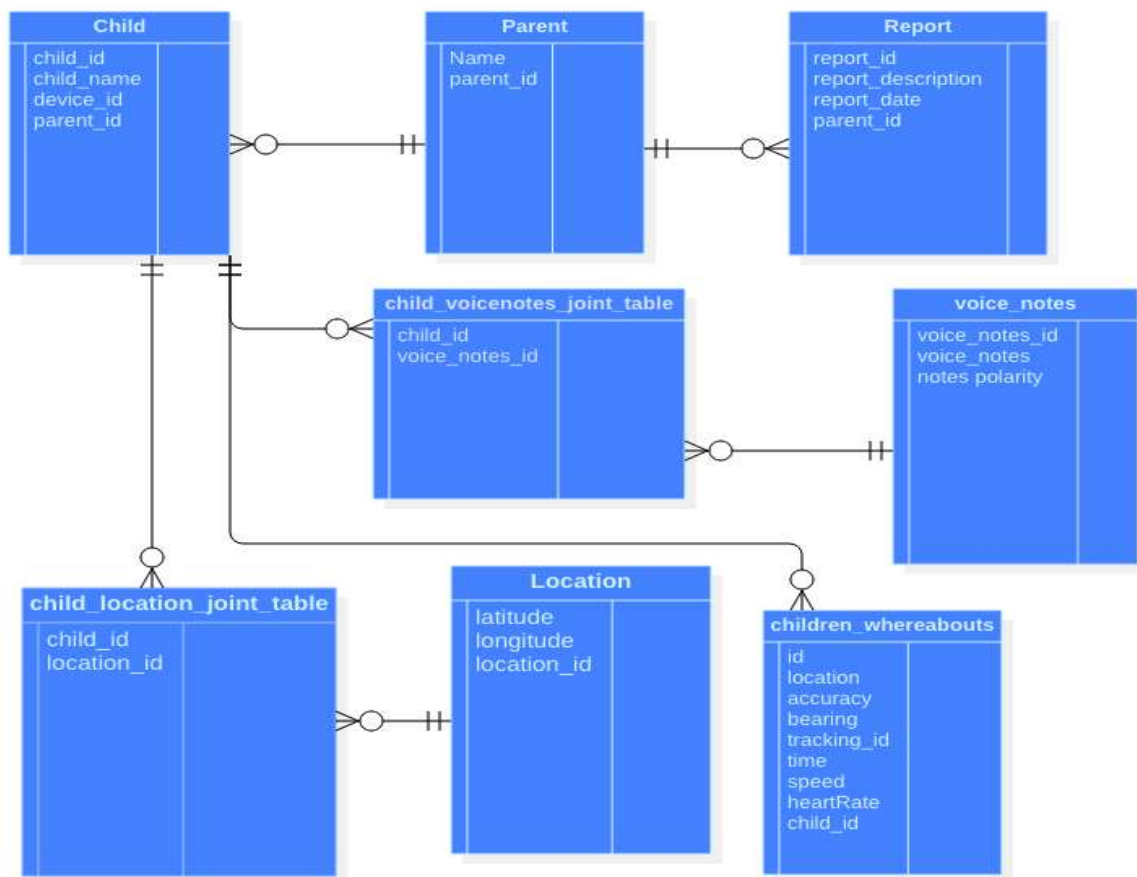


Figure 4: Entity Relationship Diagram for the proposed system (Author's perspective).

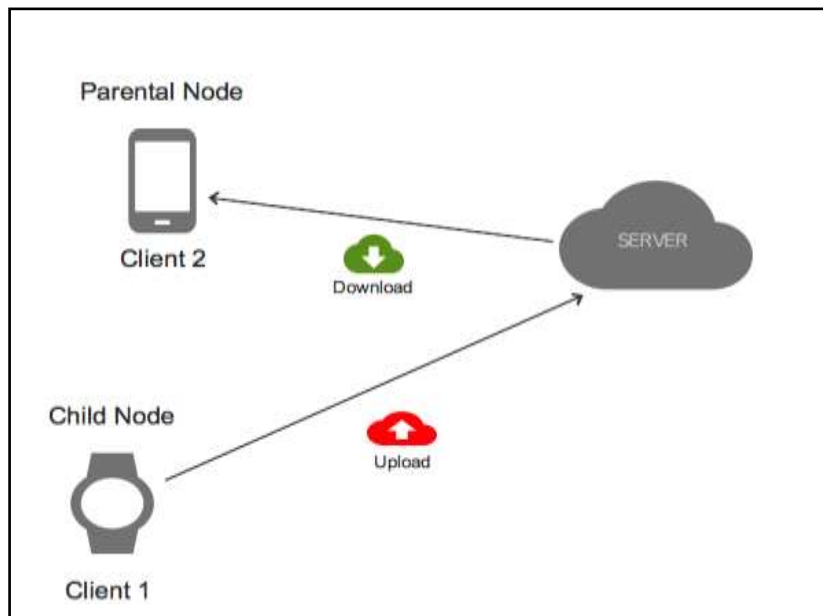
4. Prototype deployment and implementation

The proposed system was developed using an Integrated Development Environment (IDE). IDEs are coding tools that can be used for but are not limited to high-level programming (Jackson, 2017). The IDE used for this study was Android studio. The rationale behind this decision was the fact that it is open source and contains several free resources and libraries available for developers. The proposed system was implemented using 2 programming languages, namely Java and PHP. The server side was implemented

using PHP which is a server-side programming language, and the mobile version was implemented using Java.

The final prototype employs a Client-Server model to communicate with subprograms of the system. A client-server model refers to a distributed system structure that divides tasks between providers (Servers) and service requesters (Clients) over a computer network (Ali et al, 2020).

Figure 5: Overview of the tracking system network architecture. (Author's perspective)



The final system has one centralized server and two client applications. The client applications run solely on android devices (Min SDK version:22 and target SDK version:30). Both client applications operate on separate Hardware as follows:

- I. One of the client applications operates on the tracking device (android wearable devices for children). The android device was used due to the hardware requirements for the proposed system which are outlined as follows:
 - Processor: MTK6580 1.3GHz, Quad Core
 - Memory: 16 GB + 1 GB
 - Sensors: Pedometer, GPS, Heart Rate Monitor
 - SIM Slot: (Nano SIM) GSM 850/900/1800/1900MHz WCDMA 850/2100MHz
 - Wi-Fi: Wi-Fi 802.11 b/g/n

- Media: Microphones

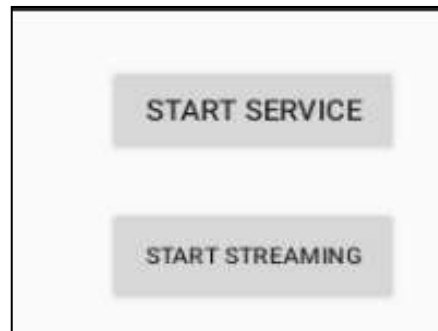


Figure 6: UI for the wearable device

The UI for the wearable is simplistic in the sense that, there is not much interaction with the user, and most of the tasks performed by the application are done as a background process. The user simply needs to start the service and the app runs periodically in the background.

- II. Lastly, the second client application operates on mobile phones and acts as a parental panel for parents. It receives information regarding the wearable device, by sending a request to the server.

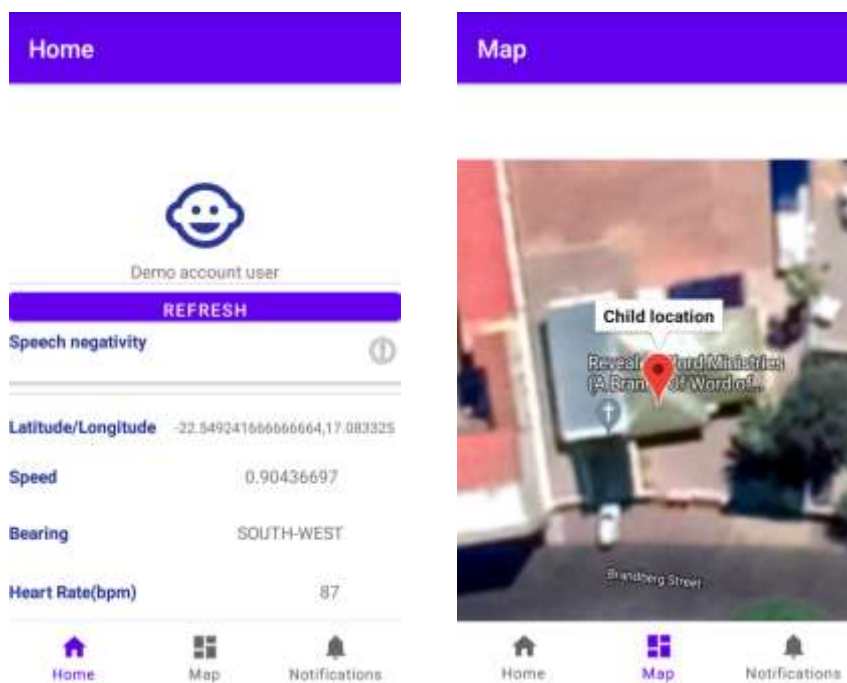


Figure 6,7: Screenshot of final prototype parental user interface

The parental interface lets parents monitor the child in a topographical view, check their speed, bearing, speech negativity and heart rate. The parents also get notifications based on their pupils' movements.

4.1. Tracking Device

A tracking device was a wearable smartwatch device with android OS installed. The devices also have inbuilt GPS and GSM modules. As well as most of the android's sensors, such as **Motion Sensors** (this includes an accelerometer, gyroscope, step counter and gravity sensors), **Position Sensors** (this includes all the sensors in this category), **Environment Sensors** as well as **body Sensors**. The device is depicted in figure 8 below.



Figure 8: Wearable device used for the tracking process

The device can operate for a full day if in an idle state. That is a state where the screen is not being used or interacted with continuously.

5. System testing

This study considered basic software acceptance testing techniques, to evaluate the final prototype and assess its effectiveness and performance from the developer's perspective as well as from the end-user perspective. Acceptance testing is a type of testing used to determine if a software system has met the requirements specifications (Garousi et al, 2020). Software testing techniques such as Alpha, beta, and comparison testing were performed.

5.1. Alpha Testing

Alpha testing is usually performed by the lead developer team before exposing the prototype to the end user. During this phase, major errors and bugs found were fixed. Major steps during this phase included: problem simplification and bug clustering. Problem simplification is the process of eliminating portions of the software code that are not related to the present bugs to facilitate debugging and fixing errors (Lebeuf et al, 2018). Lastly, bug clustering is a process of grouping similar bugs into classes and finding solutions to only one bug from each class (Testmatick, n.d.) The rationale for this is that the concept of bug clustering assumes that bugs from the same classes have the same cause, therefore fixing one bug will eventually solve the problem in one class.

5.2. Beta Testing

Beta testing involves a selected group of end-users using the prototype system and evaluating it. It provides a complete overview of the true experience gained by the end-users while using the prototype software (Abhijit et al, 2012). During this phase, all the responses were recorded using an evaluation survey.

5.3. Comparison Testing

The comparison testing involved comparing the prototype software with similar existing software. For this study Find My Kid mobile application was used. The comparison testing considered the following criteria, functional features and non-functional.

6. Data analysis and results

All the tracking device collected data were stored on a remote server. Table 2. shows a sample of some data collected by the device. The database table includes columns such as location (as latitude and longitude), speed of the device in meters per second, and the accuracy of the location generated by the GPS module, bearing as floating-point numbers, speed, tracking ID and time.

Database: id17765480_atts, Table: children_whereabout, Purpose: Dumping data

id	location	accuracy	bearing	tracking_id	time	speed	heartRate
26	-22.585041666666665,17.055	6.3	0	1000PCTN2019	Tue Nov 02 07:37:43 GMT+02:00 2021	0	81
27	-22.58506,17.055003333333333	6.5	0	1000PCTN2019	Tue Nov 02 07:37:46 GMT+02:00 2021	0	78
28	-22.585073333333337,17.055003333333333	6.7	0	1000PCTN2019	Tue Nov 02 07:37:49 GMT+02:00 2021	0	81
29	-22.585053333333335,17.055018333333333	6.5	0	1000PCTN2019	Tue Nov 02 07:37:52 GMT+02:00 2021	0	90
30	-22.585028333333337,17.055036666666667	6.6	0	1000PCTN2019	Tue Nov 02 07:37:55 GMT+02:00 2021	0	93
31	-22.584896666666667,17.05503	5.9	0	1000PCTN2019	Tue Nov 02 08:54:31 GMT+02:00 2021	0	82
32	-22.584893333333337,17.055041666666668	5.4	0	1000PCTN2019	Tue Nov 02 08:54:34 GMT+02:00 2021	0	77
33	-22.585011666666666,17.055116666666667	6.3	0	1000PCTN2019	Tue Nov 02 08:54:43 GMT+02:00 2021	0	89
34	-22.584983333333335,17.055053333333333	5.2	0	1000PCTN2019	Tue Nov 02 08:54:46 GMT+02:00 2021	0	81
35	-22.584961666666665,17.055001666666666	4.3	299.9	1000PCTN2019	Tue Nov 02 08:54:49 GMT+02:00 2021	0.6995075	76
36	-22.584946666666664,17.054983333333332	3.8	284.8	1000PCTN2019	Tue Nov 02 08:54:52 GMT+02:00 2021	0.3078039	73
37	-22.584958333333333,17.05498	3.6	266.61	1000PCTN2019	Tue Nov 02 08:54:58 GMT+02:00 2021	0	68
38	-22.584971666666668,17.055	3.6	142.66	1000PCTN2019	Tue Nov 02 08:55:07 GMT+02:00 2021	0	56
39	-22.58499,17.055018333333333	3.7	142.66	1000PCTN2019	Tue Nov 02 08:55:10 GMT+02:00 2021	0	55
40	-22.58499,17.055036666666667	3.9	142.66	1000PCTN2019	Tue Nov 02 08:55:13 GMT+02:00 2021	0	56
41	-22.584945,17.055065000000003	4.4	142.66	1000PCTN2019	Tue Nov 02 08:55:19 GMT+02:00 2021	0	57
42	-22.584915000000002,17.055051666666667	4.4	142.66	1000PCTN2019	Tue Nov 02 08:55:22 GMT+02:00 2021	0	57
43	-22.584895,17.05505	4.4	142.66	1000PCTN2019	Tue Nov 02 08:55:25 GMT+02:00 2021	0	58
44	-22.584890000000005,17.055068333333335	4.8	142.66	1000PCTN2019	Tue Nov 02 08:55:31 GMT+02:00 2021	0	62
45	-22.584935000000005,17.055018333333333	4.8	142.66	1000PCTN2019	Tue Nov 02 08:55:34 GMT+02:00 2021	0	65
46	-22.58488,17.054983333333332	4.9	142.66	1000PCTN2019	Tue Nov 02 08:55:40 GMT+02:00 2021	0	60
47	-22.584845000000005,17.054968333333333	5	142.66	1000PCTN2019	Tue Nov 02 08:55:49 GMT+02:00 2021	0	66
48	-22.584856666666663,17.054968333333333	4.9	142.66	1000PCTN2019	Tue Nov 02 08:55:52 GMT+02:00 2021	0	67
49	-22.58485,17.054913333333334	5.2	142.66	1000PCTN2019	Tue Nov 02 08:55:58 GMT+02:00 2021	0	75
50	-22.58484,17.054921666666665	5.2	142.66	1000PCTN2019	Tue Nov 02 08:56:01 GMT+02:00 2021	0	69
51	-22.58484,17.054983333333333	5.3	142.66	1000PCTN2019	Tue Nov 02 08:56:04 GMT+02:00 2021	0	69
52	-22.584836666666668,17.054873333333333	5.6	142.66	1000PCTN2019	Tue Nov 02 08:56:07 GMT+02:00 2021	0	69
53	-22.584846666666667,17.054851666666664	5.8	142.66	1000PCTN2019	Tue Nov 02 08:56:10 GMT+02:00 2021	0	62

Table 2: Exported database table holding the tracking device collected data

The location was generated as latitude-longitude and was translated to the actual location using android libraries such as Google Maps. All the locations generated were updated after every 3 seconds, and the mean difference between every successive coordinate is 3 meters. The accuracy of each successive coordinate is expressed in meters as well, the android location accuracy is defined as the radius of 68% confidence (Android documentation, n.d). That is, if a circle is drawn at the centre of a specific location's coordinate (latitude and longitude) with a radius equal to the computed accuracy, then there is a 68%

probability that the true location is inside the circle. So, it is ideal to have location results with a small radius for better identification of the actual child's location (device location).

Furthermore, the device also submitted bearing values calculated in degrees. In inland navigation, the true bearing to a location is the angle measured in degrees in a clockwise direction (Android documentation, n.d). Similarly, on Android devices, a bearing or horizontal direction of travel plays the same role as that of the true bearing. The bearing can be any value between 0 degrees to 360.0, with 360 indicating north, 90, 180, and 270 indicating east, south, and west respectively and 0.0 indicating no direction or stationary position. The bearing guaranteed easier identification of the actual location of the device. It reduces the margin errors of finding the actual location. On the parental panel, the actual bearing values were translated to their respective cardinal points.

Additionally, speed, time and heart rate were also submitted by the device and stored remotely. This is to efficiently influence parental prescriptive actions based on the tracking results. The speed was taken in meters per second (m/s) and provided great insight into the child's whereabouts. That is, a speed between 0-2 meters per second usually indicated walking or a stationary position, while anything beyond 4 meters per second indicated that the device was in a motor vehicle.

6.1. Testing analysis

For the prototype developed, a comparison testing was carried out against an existing similar system known as Find My Kids. Although they both serve the same purpose. Both systems differed in the number of functional features as well as non-functional. The disparity between both systems was mainly because the prototype system only considered features with the highest priority for implementation. Thus, excluding some features not relevant to the study. Both systems serve as a tracking system for children. However, they both differ in how they manipulate child data as well as how they represent the information to parents.

Table 3: Feature comparison of prototype against Find my kids

System	Functional features	Non-Functional features	Total number of features
Prototype system	8	5	13
Find My Kids	6	10	16

7. Speech sentiment

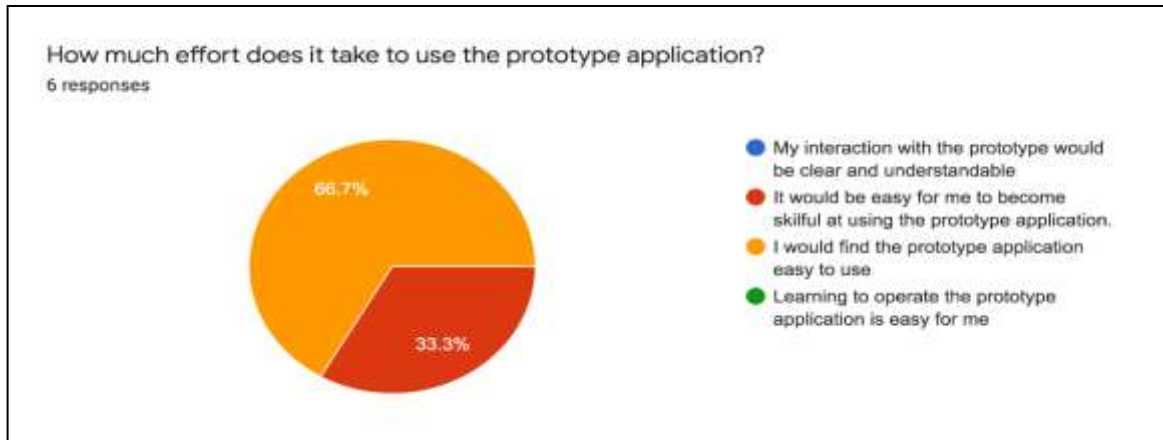
The system performed sentiment on the speeches by primarily recording audio files, and then submitting them to the Google Cloud Speech-to-Text engine to be transcribed into text. Mashly (2020) compiled a dataset having different suicide notes and phrase depictions of depression, this dataset was used as the base dataset for the sentiment classifier. The rows of the dataset were labelled as follows: possibly depressed and not depressed using VADER.

The final sentiment score yielded an accuracy of 0.50, the final accuracy changed considerably after continuous data pre-processing. Further data pre-processing could furtherly improve the sentiment score.

8. User review

The study had the participation of six parents who tested and evaluated the system and provided preliminary insight into the prototype of the proposed system. They were all invited to use the prototype and answer the questionnaire. The figures below provides a summarized results of the questionnaire.

F



igure 9: Usability responses

Figure 9 illustrates the participants' views on the usability of the prototype of the proposed system. The user interface seemed simple and easy to navigate for most of the participants.

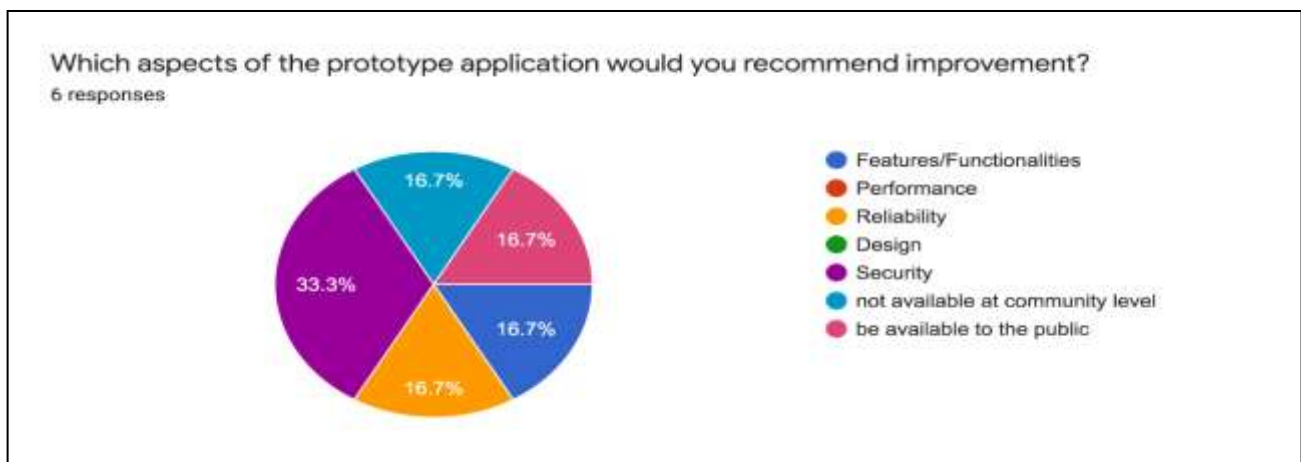


Figure 10: User's recommendations

Figure 10 depicts a few of the aspects of the prototype that the users thought could benefit from some improvements and amendments.

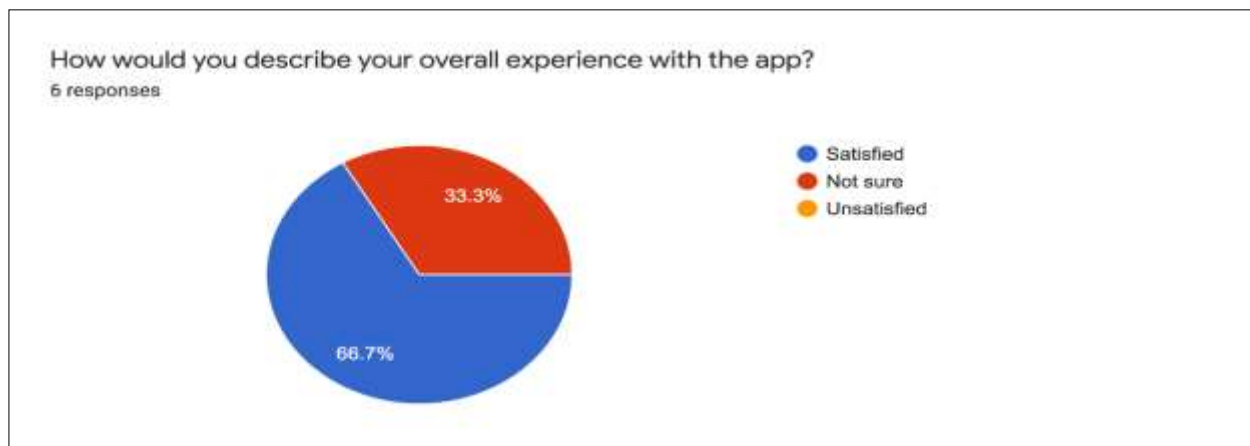


Figure 11: Overall user experience

Figure 11 shows the results of overall user experience and satisfaction. More than 60% of the users were satisfied with the overall experience.

9. Recommendations

The outcome of this research provided the relevance of the tracking system as a tool to aid parental supervision in Namibia. The research made use of a wearable device that might not be accessible to most households. That is an aspect of the research worth considering, the implementation of a similar tracking system using a more affordable tracking device. That is, using a tracking device that is accessible to lower-income households in Namibia and the use of a less obvious tracking device.

10. Conclusion

This research focused on the development and design of a supervisory real-time tracking system for the Namibian parents, a constructive research design coupled with an interpretivism theory was adopted. The research was carried out as an initiative to mitigate predominant child-based disappearances and abuses. The research attempted to reinvigorate the need to address these undesirable occurrences against children.

The research objectives were met by developing a supervisory tracking system with natural language processing features, with a final intent to be able to not only supervise children's whereabouts. But, to dive deeper and keep track of their mental being as well as using sentiment in speeches.

The final artefact and results showed a satisfactory outcome. That is, the research revealed that children in Namibia can be supervised to a certain extent using a tracking system and that although the final solution will not necessarily deal a final blow to the underlying problem, it can surely provide more options to parents and more arsenal to try to move around the problem. Additionally, the final tracking system features provided crucial information that could be used to not only prevent the disappearance involving children, but it could also to facilitate finding missing children.

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Educational Technology for Sustainable Development in the Era of Covid -19 Pandemic in Nigeria: Problems and Prospects

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Abstract

The paper discussed educational technology for sustainable development in the era of covid -19 pandemic in Nigeria: problems and prospects. Literature review was used as a method of gathering information on covid-19, education, educational technology, sustainable development, problems and prospects. Also, the objective of the study was to determine the role of educational technology towards sustainable development and its disruption in education sector. Related problems on educational technology identified in the study are lack of technology leadership, lack of training programmes for facilitators, lack of proper mind set towards integrating emerging technologies into classroom teaching and learning on the part of students and lack of enlightenment programmes for stake holders in education and the society at large on the need to support ICT integration in Nigeria education for sustainable development. The prospects focused on developing educational curriculum blue print that will review schools calendar, introduce new ways of acquiring skills and knowledge in line with information communication and technology (ICT) via internet applications platforms that will re-bounce back what was loss during covid-19 crisis. Lessons learnt from the pandemic also provided ways on how to strengthen and develop greater resilience to absorb future shocks and rebuild back crisis proof educational training such as technical vocational education and training (TVET) and ensure better preparedness to achieve vision 2030 agenda for sustainable development in Nigeria.

Keywords: Education, Educational technology, Sustainable development, Covid 19 Era, Problems and prospects.

1. Introduction

The corona virus known as covid -19 pandemic originated from the city of Wuhan in China, it became a major public challenge not only in China but also countries all over the world. According to Adelakun (2020) the pandemic lead to break down of most of the human activities that could be responsible for development and sustainability in various parts of the world, Nigeria is not an exception. The covid - 19 pandemic affected economies and societies around the world and caused an unprecedented fall in economic activities, loss of working hours, and sharp rise in unemployment and underemployment. The situation jeopardizes the accomplishment of Sustainable Development Goals (SDGs) in particular Goal 8: "Promotes sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all". And its target 8.5, which calls for achievement by 2030, of full and productive employment and decent work for all". The covid -19 pandemic has disrupted education and training at all levels with

complete closure of training institutions in the vast majority of countries. Most educational institutions including those in TVET were lockdown due to covid – 19 measures, teaching and learning moved from classroom to remote means, facilitated by the internet, television, radio, or print materials. Remote learning is a weak substitute for hands on experience. Technical vocational education and training (TVET) programmes have particularly been hard hit, given their unique focus on work – based learning and the acquisition of practical skills which is closely related to educational technology practical – oriented course in education. TVET can contribute to economic recovery by ensuring that it rapidly identify and respond to such skills needs. However, conducting assessments and TVET certification became a problem as the hallmark of the programme focuses on practical skills and work readiness, for instance, countries like Austria, France had to cancel or postponed theoretical and practical examinations or rely on past results and continuous assessments to determine grades or assume that assessment take place after covid – 19 measures were relaxed while Moldova was ready for online examination system.

In the light of covid - 19 crisis, there is no doubt that the pandemic has caused serious set- back on the development of Nigeria education system. Schools were locked down indefinitely, school calendar was disrupted, and reduction in economic development of the country affected funding of education, hence, families in Nigeria faced economic hardship and tough times as a result of the lockdown, many students dropped out of school and take to other means of livelihood. Indeed, the pandemic was a trying period for Nigerian families. It hit the sustainable development of Nigeria while education and technology were used as means to mitigate the negative impact of the pandemic on education system.

Education and technology are important tools responsible for the growth, development, wellbeing and sustainability of any society in the world. This can be actualized through information communication and technology integration (ICT). The integration of innovative technologies into classrooms enhances learning motivation which is critical for successful attainment of set of learning objectives (Edeh, 2019). Education is a strong factor that can determine the success of a sustainable driven development. According to UNESCO (2000) “education refers to the total process of developing human ability and behavior”. It further explained that education is an organized body of knowledge designed to communicate a combination of skills, understanding and values for all activities of life. Education is used to solve human problems, improve life and make it more comfortable. It is a formidable tool for man’s survival and one of the many ways man employ to bring all round development. Classroom teaching and learning can enhance student performance through application of various educational technology media.

Educational technology is the modern method of teaching and learning using instructional facilities as well as strategies in organizing academic work. Pedagoski (2015) defined educational technology as a systematic and organized process of applying modern technology media to improve on the quality of education. Educational technology is also a practical – oriented course in education. It exposes students to skills acquisition such as craft work, photography, computer, video coverage, videotaping (recording). It afford students opportunity on graduation to fend for themselves, be self-employed, self-reliance, independent, active participants and contributors to nation building and economic empowerment. Educational technology is seen as a veritable

tool for fostering development and acquisition of entrepreneurial skills for economic growth and sustainable development of any society.

The role educational technology play in the advancement and sustainable development of any society cannot be over emphasized. The advent of educational technology based ICT has proffered solutions to most societal and education challenges faced in Nigeria. In recent times, through the use of internet, open and distant education has been made possible and became the order of the day even in the face of Covid 19 pandemic. UNESCO (2020) reported that public and private stakeholders in TVET promptly forged partnerships to increase the availability of accessible distance learning solutions, develop new training programmes and allocate additional resources for mitigating skills and labour shortages in sectors heavily affected by covid -19 crisis. It implies that one can still be in a particular location on the globe and still access information. Furthermore, with the use of educational technology, students can study material independently through developed instructional computer packages repeatedly through replay. It has made teaching and learning easy through application of various modern educational technology devices or platforms. The development and growth of computers and internet applications has not only helped to track down students and teachers progress in terms of teaching and learning but also lead to sustainable development in Nigeria.

Brundland Commission (1987) (formerly known as the World Commission on Environment and Development WCED) defined sustainable - development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development should not only aim at improving the quality of life, but also compliance with the capacity of the ecosystems, and the earth as a whole. Sustainable development suggest developing a global consciousness rendering an account of caring for the needs of citizens. Sustainable development has three components: environment, society, and economy. The well-being of these three areas is intertwined not separate. Sustainable development also implies devising a social and economic system which ensures that real income rise, educational standard increase, health of a nation improves and the general quality of life is advanced. Otamiri, et al (2021) sees sustainable development as that which guarantee the protection of environment and resources today and tomorrow. The authors explained that it is self -sustaining and meets the needs of present and future generation. Some measures of quality sustainable development include, level of education standard, availability of housing, life expectancy, adult literacy, others are general human comfort, low poverty level, increase in educational level, high level of equality, high literacy level, good health care and health care infrastructure among others.

2. Problems of Educational Technology in the Era of Covid-19 Pandemic in Nigeria

The problems of educational technology in an effort to contribute to sustainable national development in the era of covid -19 pandemic include;

Lack of Leadership – leaders lead without vision, stakeholders in education find it difficult to sit together and deliberate on measures that will help facilitate the use of technology in teaching and learning for enhanced sustainable development. Leaders are restrained from effecting the statutory obligations that guides the implementation of the full scale of educational technology in Nigeria.

Lack of Training for facilitators - Training is a way of updating knowledge of teachers, the current modern technology applications has not been taking into consideration. With this back-drop, teachers find it difficult to see the potency of technology in education. Infact, no teacher under the new dispensation of information, communication and technology ICT (digital age) can really undertake teaching that will contribute meaningfully to sustainable development without training programmes and continuous up-keep by relevant authorities.

Lack of proper mind set – The major problem faced with emerging technology integration into class room teaching and learning in Nigerian schools is that students may be reluctant to learn the new technology as a way of advancing knowledge especially acquiring computer education skills. Computers being the tools for educational technology are limited in Nigeria schools. Many schools in Nigeria are still using the traditional approach of teaching and learning. This method of teaching and learning does not give students enough room or time to interact, sometimes it leads to boredom and makes learning drudging. The method has indeed hampered the learning ability of a child hence, made effort of teacher who tried to impact knowledge futile.

Lack of ICT enlightenment programme - The advent of computer into Nigeria initially came with some level of resistance especially in work environment like government offices and banking sector where such action was perceived as a deliberate attempt by government to lay off workers from their jobs. The idea of introducing computer was to enhance productivity, save time, cost and also increase economy growth and sustainability as it where with other developed nations of the world like Japan, USA among others (Aniah, 2022).

3. Prospects of Educational Technology in the Era of COVID – 19 Pandemic in Nigeria

Interestingly, the advent of educational technology has greatly assisted in proffering solutions to most of the challenges faced in education sector and other human endeavors.

Improvement in knowledge Assimilation - The integration of new technology into education has brought about great tremendous improvement in impartation and assimilation of information. This is a laudable development and provide more understanding about means of making teaching and learning more effective and appreciative. For example during the era of covid – 19 when schools were lock down, virtual or online education programmes within Nigeria and around the globe continued e.g. Educational conferences and economic conferences to address pressing issues that affect or bother on national development were held at various locations in Nigeria using virtual technology applications. Furthermore, journal papers for publication both national and international progressed steadily during the pandemic era.

Enhanced Computer Skills – Through educational technology instruction, computer development skills among students as well as determining measures of ascertaining the level of learning on the part of students and the quality of learning output or performance improved. The new technology has not only improved education standard but has helped to address some urgent and pressing problems in Nigeria by linking its citizens to internet thereby gained useful information that enhances national development and sustainability e.g. during covid -19 there were exchange of useful ideas through internet particularly on health related issues for control and to forestall future outbreak of diseases such as the establishment of Sirra leone National Ebola Training Academy, World Economic Forum (2020) also call for rapid training of

communities health workers to contribute to covid – 19 health responses in USA and UK to serve as example for other nations to emulate.

4. Conclusion

The study established that the integration of new technologies using educational technology - base as a tool has greatly helped in addressing challenges experienced by Nigerians as a result of the outbreak of covid -19 and also advanced measures to absorb future incidents e.g. by developing educational curriculum blue print to address education issues such as prolonged closure of schools, technical vocational education and training (TVET) skills acquisition programme to reduce unemployment, hunger and also provide good health programmes for the nation.

5. Suggestions

The following suggestions if adhered to, it will strengthen preparedness for future crisis:

1. Government should invest in the development of adequate crisis response plans for education sector from national down to the provider level.
2. Enhance access to education and training through improved internet infrastructure and ensure affordable connectivity.
3. Develop and maintain easy access to distance learning platform, collaborate with private education technology sector and the national level.
4. Deliver relevant training and skills to young people and adults to meet current and future needs, increase efforts to reskill and up-skill workers with a view to rebuilding back better and achieve vision 2030 agenda for sustainable development.

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Improving Access and Use of Library Resources and Services through Gamification

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Abstract

Gamification in the Library refers to the use of game elements to engage people. It has to do with changing behavior and creating emotional links through games to stimulate the emotional balance of the library's user community. Gamification brings users closer to the physical and digital worlds. Computer games can be used to reach out to users and encourage them to take advantage of the visual and auditory experiences that computer games provide. Games tell stories and provide information while also encouraging critical thinking and problem-solving skills. Games have literary value and aid in the development of language skills. Literacy activities related to learning to read, write, and spell can be provided by educational games to children/parents. Games can help players expand their vocabulary and learn about word etymology. Games also have cathartic properties, allowing players to release aggressive emotions in the virtual world rather than the real one. It increases participation in activities while also attracting users to an organization. Gamification is a trend that is affecting industries other than library science; it is frequently used for marketing, education, and other purposes. Gamification is the use of game elements in non-game environments. Libraries are experiencing a drop in patronage, so they are looking for new and innovative ways to improve their services and satisfy more patrons.

Keywords: Gamification, library, literacy, Game and innovation.

1. Introduction

The process of transforming typical academic components into gaming themes is known as gamification in education. Gamification attempts to make learning into a game by theming all components of your classroom in a game metaphor; make your class feel like one big first-person game. Always keep in mind that the goal is to improve learning by increasing student engagement.

To theme your classroom in a gaming metaphor, choose a theme (for example, medieval times, fantasy mystic, space battles, military, spy/secret agent) and refer to everything in your class with gaming terms (student=player, assignment=quest, grade=quest points, class party = game reward). Games have existed in all human civilizations. Humans have even been defined as *homo ludens*, a concept proposed by Huizinga in 1955 [1]. Human beings are defined as men, women, or children of the species *homo sapiens*, who differ from other animals in their superior mental development, ability to articulate speech, and upright stance and reasoning. Based on this, he deduces the concept of game as a free activity that exists consciously outside of "ordinary" life, as "not serious," but intensely absorbing to the player.

According to Brumels et al. (2008), the evolution of digital technologies, particularly the transition from traditional games to video games, has been critical in increasing user enjoyment and engagement (2008).

According to Brumels et al. (2008), the evolution of digital technologies, particularly the transition from traditional games to video games, has been critical in increasing user enjoyment and engagement. Indeed, with the widespread adoption of social media and mobile technology, the presence of games in our daily lives is more than a foregone conclusion in the twenty-first century.

In the Library, gamification refers to the use of game elements to engage people. It has to do with changing behavior and developing emotional bonds that connect them to both services and space. In a broader sense, it is to use games to stimulate the user community's emotional balance. Gamification allows users to interact with both the physical and digital worlds. Indeed, with the widespread adoption of social media and mobile technology, the presence of games in our daily lives has become more than a given in twenty-first-century society. Jesse Schell (2010), a well-known game designer, envisions a future in which video games are an integral part of our daily lives. It's a process with no way out. Based on these precedents and the omnipresence of games, as well as society's interiorization of game mechanics, gamification emerges almost organically to extract characteristics from games to incorporate them into other environments. Nick Pelling 2002 defined the first approach as the use of game-like accelerated user interface design to make electronic transactions both enjoyable and fast. However, the term has evolved significantly since then, now encompassing a wide range of games with varying objectives.

Board games like chess, checkers, and Candyland have long been available in libraries. They are now turning to computer games to reach audiences who are accustomed to the visual and auditory experiences provided by computer games.

According to the American Library Association, there are numerous reasons for libraries to use gamification to reach out to children, young people, and even adults who are hesitant to pick up a book. The level of attention and personal involvement a person has with an activity is the most important indicator of a student's knowledge attainment. The more involved your students are in the learning process, the more they will internalize the skills they learn. According to gamification research, using gamification in the classroom increases student engagement. Consider the following when gamifying the classroom for the sake of engagement:

These include:

- Video games present information and tales.
- Playing games helps foster critical thinking and strengthen problem-solving abilities.
- There is literary significance in games.
- Social games can aid in enhancing linguistic abilities.
- Literary exercises pertaining to reading, writing, and spelling can be offered to kids through educational games.
- Playing games can increase vocabulary and teach word etymology to participants.
- Players can let out their angry feelings through gaming instead of in the real world, which has cathartic benefits.
- Gamification fosters competitiveness, which can boost participation.
- Gamification encourages student choice and innovation, which raises engagement.
- Gamification helps students to quickly track their progress toward academic goals and provides them with rapid feedback (via peer feedback, progress bars, badges, teacher response, etc.).
- Due to these factors, gamification is an excellent method for enhancing students' overall educational experiences.

- Gamification is a development that affects a variety of fields besides library science; it is frequently applied to marketing, education, and other areas.

The goal of gamification, a relatively new trend, is to adapt game concepts to non-game environments to engage audiences, add some fun to routine tasks, and reap the motivational and cognitive benefits. The potential of gamification has been tapped by numerous industries, including business, marketing, and e-learning, but the digital healthcare sector has also started to do so.

2. Literature Review

A survey of the literature was done, focusing on works primarily indexed in Google Scholar, Scopus, and Web of Knowledge. Gamification, games, designs, frameworks, models, strategies, and engagement were the important phrases. Although the most of them are from the past four years, the search of the literature on gamification design and frameworks was not established in a short amount of time. Case studies, reviews, studies, and references obtained from bibliographies were shortlisted, along with definitions of frameworks. Only eighteen of the twenty-two candidate frameworks that were initially examined matched the study's requirements. These specifications refer to a formal definition of a skeletal support utilized as the foundation for something being produced (partial or complete gamification design process for engagement purpose in generic or business contexts). Be aware that in some instances, for a single framework, numerous sources have been examined, and even we have gotten in touch with the authors to ask questions about specific details.

A three-dimensional perspective has been used to classify the frameworks after investigation.

- Background: academic and non-academic.
- Scope: finish gamification procedures with a narrow focus on a single phase or stage.
- Approach: tailored for a particular business context or suitable to a broad range of situations (generic).

3. The Classification of the Gamification Framework

To account for player differences and social influences, he suggests the following steps: determine why gamification is necessary (based on stakeholders' and business objectives), identify players' motivational profiles, set goals and objectives, describe skills, track performance, define lenses of interest, and playtest before polishing.

The most well-known design framework, however, is described in Werbach and Hunter's Six Steps to Gamification (2012) and is referred to as 6D. This framework begins with a characterization of the business goals, moves on to target expected behaviors, describes the players, creates activity loops without forgetting the fun, and then deploys the gamification system with the proper tools. Takes a little inspiration from the MDA game design framework developed by Hunicke et al., though not explicitly. This is demonstrated by the Pyramid of Gamification Elements, which suggests the following pertinent elements: dynamics, components, and mechanics. It serves as the foundation for several additional gamification design frameworks.

Marczewski, in contrast, proposed a less complex framework in 2012. It is named GAME. There are two phases to it. The first step is planning and designing, which entails obtaining vital data via a survey, such as the sorts of users in the gamification setting (Hedax user type, based on Bartle's (2005)). The optimal strategy for achieving goals and fostering engagement is then developed, while user activities and results are measured. The RAMP framework, which he created, is used by him (Relatedness, Autonomy, Mastery, Purpose). Over time, the design needs to be enhanced. After contacting the author, this review has been updated to reflect changes to the framework that were later published in other media.

Furthermore, based on Human-Computer Interaction (HCI) concepts, Marache-Francisco and Brangier (2013) outline a Gamification design methodology [26]. Outside of the gamification approaches and components, they highlight several dimensions that might be used to construct a precise framework. The descriptions include the sensory-motor dimension, the motivational, emotional, and commitment dimensions, and the cognitive components of interaction. Based on these, the design process is composed of two main iterative steps: the context analysis (User-Centered Design) and the iterative conception of the gamification experience. Additionally, a toolbox for gamification (called Core Principles) to aid designers in the procedure is mentioned.

In contrast, De Paz (2013) offers a series of stages or generic recommendations for gamification that can be used in any kind of project. Werbach and Hunter's Six Steps to Gamification seem to have had a significant impact on the values of this framework. Three stages make up the proposal's guidelines: establishing the company objectives (preparation), deciding on the fundamental design, and utilizing gaming features. The system must be built and run for implementation and maintenance. Metrics use is advised by this strategy as well.

A contrasting suggestion is made by Robinson and Bellotti's taxonomy (2013), who assert that while various frameworks in the literature can be useful for a gamification design, they do not quite fit their needs. According to the authors, "common gamification features do not provide a compact, time-saving but sufficiently comprehensive presentation in terms of the numerous parts of the user experience that they support." They establish six types of gamification features that draw inspiration from numerous reliable literature sources. General frames, general rules and performance frames, social aspects, incentives, resources, and limits, and finally feedback and status information make up these categories.

Currently, the methodology used in Francisco-Aparicio et al. (2013)'s framework [allows, on the one hand, to establish the kind of game mechanics activities should include to satisfy the psychological and social needs of human motivation (SDT). On the other hand, it seeks to evaluate the success of the gamification process based on the enjoyable criteria: the qualities defining playability and the level of development in achieving desirable results while employing a quality service style. According to their functional perception, games are split into three components in this framework: the game core, engine, and interface. End-user analysis, identification of key objectives and cross-cutting issues, implementation, and effectiveness analysis are the key actions that are suggested.

Versteeg (2013) presents a condensed paradigm for moral persuasive gamification design that is solely focused on the ethical viewpoint. This combines the most important aspects of the following techniques with a normative ethical framework (moral design). It is based on the ethical golden principles that a

designer should never violate in the moral design framework developed by Berdichevsky and Erik Neuenschwander in 1999. Additionally, it provides an approach for examining the moral implications of persuasive technology, like Fogg's (2002). The procedures are as follows: establishment of moral standards and ideals, conceptual research, involvement of key players, evaluation, and iteration.

Furthermore, Yu-kai Chou is recommended using the Complete Gamification Framework Catalysis (2013). According to him, the gamification process is a design that prioritizes the role of human motivation in the decision-making process. The design is essentially human-centered (as opposed to function- focused design to get the job done quickly). The method is built around an octagon shape, with eight core drives on each side. These eight drives are: epic meaning and calling, development and accomplishment, creativity and feedback, ownership and possession, social influence and relatedness, scarcity and impatience, unpredictability and curiosity, and loss and avoidance.

A Framework for Sustainable Gamification Impact is what Al Marshedi et al. (2015) suggest. This strategy seeks to make the desired impact of gamified applications more lasting. It is primarily based on three theoretical frameworks: SDT, Pink's drive motivation factors (2011), and Csik-Flow Szentmihalyi's Dimension Theory (1990). In addition, it emphasizes user-centered design (UCD). According to the authors, it is a method for integrating purpose, mastery, relatedness, flow, competence, and time; it serves as a guide for designers who want to produce experiences that are pertinent, and that people will be interested in for a long time.

To study the numerous gamification techniques used in e-Health and to address the advantages and disadvantages of this developing field, a thorough literature review was carried out. Then, a total of 46 studies from various sources were considered and carefully examined. The findings indicate that serious gaming and gamification were primarily discussed in papers that were chosen in relation to chronic disease rehabilitation, physical exercise, and mental health. Despite receiving a lot of attention in the previous several years, there is still a lack of reliable empirical data in the subject of gamification in e-Health. Additionally, it has been demonstrated that most of the serious games and e-Health applications explored only produce short-term interest through extrinsic rewards. The development of e-Health solutions must be based on well-researched ideas that take advantage of the core experience and psychological impacts of game mechanics if gamification is to realize its full potential.

Playing in the Past: A History of Games, Toys, and Puzzles in North American Libraries by Scott Nicholson, published in 2013, is one article that has been often cited in the literature. Since games have been used in libraries for well over a century, Nicholson's piece is a great place to start if you want to learn more about the actual and potential effects that games can have on libraries. Despite the recent focus on gaming in libraries, Nicholson's study demonstrates that this practice has existed in libraries for much longer. In fact, libraries began offering gaming options to their users as early as the 1800s. Games were initially incorporated into library gaming programs as a measure of social reform so that libraries could provide their patrons healthy activities to pass the time. Libraries created video games that taught players moral principles to further promote good behavior (Nicholson, 2013).

One of the first game services provided by public libraries in America was organized chess clubs and tournaments. In the future, particularly during the Great Depression, American libraries gathered toys and leased them to kids who couldn't purchase their own, as well as hosting puzzle competitions with cash

awards for the winners. After then, there was a greater need for activities as libraries turned their attention to serving younger clients who required help with school projects and as libraries grew in popularity as social hubs (Nicholson, 2013). A lot of the thinking underlying contemporary library gaming programs and game collections was undoubtedly built on these ideas and practices.

Bellotti et al. (2013) provide a thorough explanation and discussion of motivation and other elements. The constructivist methodology as outlined by Vygotsky (1978) and Bruner (1982) is appropriate for gaming (Ratner & Bruner, 1978). Constructivist teaching and learning strategies are strengthened using online games like Minecraft EDU (<http://minecraftedu.com/>) (Overby & Jones, 2015; Shapiro, 2014a; Games in the Classroom, n.d.; Hill, 2014). The fact that more people are downloading educational mobile games like SimCity and Minecraft ([http://www.simcity.com/en_US/SimCity Edu](http://www.simcity.com/en_US/SimCity_Edu)) supports the need to investigate the relationship between BYOD and educational gaming.

The popularity of games like SimCity EDU and Minecraft EDU shouldn't give the notion that games, and gamification are just useful for "precise" or "hard" disciplines; art and humanities will still gain from "non-linear networked communication" (Shapiro, 2014b). The recent momentum surrounding the development of digital humanities will undoubtedly take the educational potential of games and gamification seriously (Editors' Choice: Digital Humanities and Game Studies Round-Up | Digital Humanities Now, n.d.).

The popularity of Minecraft EDU and SimCity EDU among younger generations surely increases acceptance among educators (<http://blog.stcloudstate.edu/ims/?s=mincraft>) (Malykhina, 2014). Ulicsak and Wright (2010) point out the lack of consistent pedagogical research in the field of educational games and draw attention to the contrast between earlier behaviorist-based educational games and more recent attempts to transition educational games to experiential, situated, and socio-cultural pedagogical models.

Unfortunately, despite the growing academic interest in games and gamification in education, it is still difficult to apply these ideas widely in practice. There is a contradiction between the research that claims gamification and gaming are beneficial and necessary, and the need to conceptualize it from many theoretical learning viewpoints (Turkay, Hoffman, Kinzer, Chantes, & Vicari, 2014; Vrasidas, & Solomou, 2013). The overall reluctance of the instructors to include gaming and gamification into their curricula is another significant aspect (Perrotta, Featherstone, Aston, and Houghton, 2013, p. 18).

Researchers show that gaming as a teaching tool is based on strong learning concepts including ongoing practice, distinct goals, and quick feedback in their thorough literature study on gaming in education. Games have been shown to offer opportunities for individualized learning and 21st century skills. The way and when that pupil's study is changing as well as what they must learn (McClarty, Orr, Frey, Dolan, Vassileva, & McVay, 2012).

The National Foundation for Education Research (NFER) Program, based in Britain, tried to map the activities and efforts to integrate game-based learning into the current educational practices as well as to determine the role of game-based learning in the educational process, which is reflected in the NFER report. The Serious Games Institute, another British company (<http://www.seriousgamesinstitute.co.uk/>), attempts to offer useful advice, publications, and solutions. According to <http://eai.eu/transaction/serious-games>, the European Alliance for Innovation (EAI) is also supporting

research on "serious games". Serious games are being investigated by the Wilson Center in the United States (<http://www.wilsoncenter.org/publication-series/serious-games>). The Center for Games & Impact is housed in educational institutions like Arizona State University and has a broad range of academic and practical competence. The Center for Digital Games Research, which focuses on digital media and games from a multidisciplinary perspective, is sponsored by the University of California (Bolkan, 2015). The above-mentioned conflict between the potential of games and theoretical viewpoints, as well as the dichotomy between theoretical study and the absence of widespread practical application, can only be overcome by such centers at educational institutions.

Government and academic support are no longer enough to organize and develop educational gaming; now, companies like Gamestar Mechanic (<https://gamestarmechanic.com/>), which focuses on gaming and how-to-make games in educational settings, have the support of organizations like E-Line Media (<http://elinemedia.com>), the Institute of Play (<http://www.instituteofplay.org>), and the MacArthur Foundation (Shapiro, 2014b). The educational sector is transitioning from client-based (Scratch, <http://scratch.mit.edu/>, and Alice, <http://www.alice.org>) to the next, cloud-based / social level of game production, like MineCraft and SimCity, thanks to opportunities like Gamestar Mechanic. According to Anderson, & Dron in their book's first chapter, the evolution of gaming on the cloud is like the change from "one-to-one" to "many-to-many and multi-way interaction" and matches the opportunities provided by social media (2014, p. 10).

According to Ulicsak and Wright (2010), who make a valid point, "just because some players learn these qualities playing the game, does not suggest that either that the majority of players are also learning these skills or that it should be used in a leadership development program." A simulation that is only used for instruction, on the other hand, could not be particularly enjoyable. The substance of the software may be aggravating, despite having computer game-like three-dimensional graphics and motion capture animations (p. 19). Granic et al. (2014, p. 74) refer to the "chocolate-covered broccoli" problem as a fundamental challenge with the transition of games from the entertainment world into education: "the games look great, they are good for you, but they ultimately fail to work because the creative game dynamics that induce transportation and immersion are missing, making them simply not fun" (Granic, Lobel, & Engels, 2014, p. 74).

Online games like SimCiy 'EDU' and MinCraft 'EDU' as well as console games like Sony, Xbox, and Nintendo should be taken into consideration while using gaming for educational reasons (Perrotta, Featherstone, Aston, and Houghton, 2013, p. 7). A thorough strategy to games and gamification is required, one that goes beyond online and console games and considers the BYOD movement and how to use personal mobile devices in ways that support game-based learning. The new options for assessment in the gamification process and in game-based learning must also be understood by this all-encompassing approach. Finally, the planning of a game-based learning process must account for student engagement and their capacity to develop educational games. According to Kapp (2014), adding arbitrary, superficial game components should not constitute gamification of learning technique (p. 52).

The game-based learning movement can be a costly and time-consuming procedure. The educational institutions with the funds to invest both time and resources are few. It is wise to arrange for institutions like academic libraries to be at the forefront and, consequently, the center of such activities. It is also wise to promote and affirm departmental cooperation and resource pooling to launch game-based learning.

As articulated by Vygotsky, Piage, and other thinkers from the last century, gaming is at the foundation of constructivism. A rapidly growing number of organizations and centers focused on governmental and educational institutions work to streamline the tremendous burden of bringing game-based learning by integrating the vast gaming industry and complex educational environment. To develop and apply game-based learning (GBL) in education, it is required to adopt guidelines and rules from organizations like NFER Research Programmed, such as the principles and mechanisms of GBL. (Perrotta, Featherstone, Aston, and Houghton, 2013, p. 8).

4. Games in Libraries: Why and How

Games should be a part of libraries' collections and programming for several reasons, according to the literature. First off, games frequently have educational or recreational purposes as their main objectives. While games can often achieve both purposes to varied degrees, they typically focus on just one of them. According to Phetteplace and Felker (2014), a wealth of educational research demonstrates that people learn best when they are actively involved in the learning process and when information is presented in a context that allows them to see how and where it is applied. Games are capable of both (p. 20).

Secondly, after-school gaming programs in schools have shown how games may help kids improve their social skills by allowing older and younger students to interact as well as more experienced students to assist less-adept players in understanding complex game rules and concepts (Copeland, Henderson, Mayer, & Nicholson, 2013). Thirdly, playing games can have a good impact on conduct (Elkins, 2015).

Fourthly, as was already said, the growing acceptance of digital technology and video games necessitates that players develop the "21st century skills of critical thinking, problem solving, cooperation, and information and media literacy" (Elkins, 2015, p. 59). Again, those who live in poverty do not have access to the digital games that their peers play daily. James Paul Gee emphasizes the obligation of the library, "the great social equalizer of reading," to fulfill a similar need using digital technology, particularly because less fortunate kids are "falling behind in new and vital 21st-century media skills" (Gee, 2012, pp. 63-64). By offering access and media mentoring to these kids, librarians may solve this problem. Through these methods, the widening "digital gap" will be reduced (Gee, 2012).

4.1 Games in Public Libraries

The best places to introduce gaming initiatives are public libraries. These initiatives encourage patrons to use the library's other services and promote community involvement in the institution. Games and competitions with a gaming theme are regularly included in summer reading programs. Seniors who have time for activities can also access gaming services at public libraries (Nicholson, 2013). In addition, gaming clubs offer resources for involving the neighborhood. Kat Werner (2013) claims that the program "appeals to adolescent guys, a population that is often difficult to draw into the library," and that these initiatives have "made the library more accessible and inviting". Teenagers are attracted to the library because they feel that we value having them here (p. 796). For instance, the library consented to host the well-known card game Yu Gi Oh at the mother's request because it already owned other Yu Gi Oh products. Her program was the result. They allocated a certain amount of time each week for a group to play the game; as a result of the program's success, they started to offer other gaming programs (board games, video games). Programs like the ones Werner outlines might undoubtedly help other libraries. She also

recommends that libraries hold gaming competitions to draw in more participants. Tournaments offer chances for fund-raising and promoting the library's gaming program (Werner, 2013).

4.2 Games in School Libraries

The usage of games and the support of gaming clubs can be quite beneficial for school libraries. The article "Three Different Paths for Tabletop Gaming in School Libraries" (Copeland et al., 2013) details the experiences of numerous schools that include gaming in their programs and can serve as motivation for other school librarians who seek to incorporate games into their programs. In the article, word and language skills are taught in one school's elementary classes through games like I Spy and Apples to Apples. A large-scale role-playing event that simulates the "Trial of Socrates" is held at a school in Arizona. Students spend months studying the history and literature of Socrates' historical period to be ready for this game. The article mentions other school libraries that have successfully introduced after-school gaming initiatives that let students use their critical thinking abilities to learn the rules of the game and how to play it. Additionally, these programs give pupils the chance to develop good sportsmanship, and the article offers numerous methods for handling poor sports (Copeland et al., 2013).

When it comes to incorporating gaming into a school library, Aaron Elkins (2015) advises "starting small and working your way ahead as you give gaming an opportunity to flourish in your school library" (p. 62). Elkins also advises school librarians to participate in and familiarize themselves with popular games, particularly digital and video games, so they can talk about them with the kids they work with and build closer relationships with them. In addition, it is crucial for school librarians to collaborate with instructors to select games that are as beneficial to students' requirements as possible because gaming offers "very stimulating informal learning environments to further strengthen those learners' information literacy skills" (Elkins, p. 63). (Elkins, 2015, p. 63; Nicholson, 2013, p. 351).

4.3 Games in Academic Libraries

As a result of learning about the advantages of gaming programs, many academic libraries now regularly plan game nights and amass game collections for loan. Blodgett and Bremer (2014) outline their program at the Rodney A. It is a helpful paper for any academic librarian looking for advice on beginning gaming programs. University of Minnesota Morris' Briggs Library. They stay open later on Fridays once a month for a game night that features standard board and card games as well as occasionally unique, more complicated games like speed dating and indoor putt-putt. They started hosting game evenings to draw in students who wouldn't typically go to the library and to give the kids a more casual opportunity to interact with the staff. They discovered that the implementation of this program did achieve their objectives, and they discovered that effective student engagement depends on the event's publicity (Blodgett & Bremer, 2014).

There are various ways that academic libraries include games into their collections and programming. There has been a trend to start supplying video and digital games to student consumers or to increase that offering. While some academic libraries gather video games to satisfy students' leisure demands, other academic libraries gather video games to complement the course content of programs teaching how to create video games. For access to video games and activities involving video games, one library offers a gaming station (Robson & Durkee, 2012). Furthermore, game collections that contain readily available digital, video, and tabletop games for students make sense as academic libraries' attention

continues to turn toward students and their needs and as the library is seen as a more important learning space (Nicholson, 2013). Orientation programs for new students and lessons on information literacy are now being supplemented by games and activities from academic libraries (Phetteplace & Felker, 2014).

5. Implementation Issues with Games Programs

When libraries want to start providing gaming services to their users, a number of concerns are frequently brought up. According to Nicholson (2013), some librarians themselves are reluctant to buy games because they fear that doing so will give the impression that they are wasting money. In other places, he notes that librarians who did not have proof of the implementation of successful game programs in other libraries found it more difficult to persuade administrators to fund gaming programs (Nicholson, 2008). The inevitable rise in noise levels brought on by active gaming must also be taken into consideration when planning a gaming program. Werner (2013) points out that since game programs can be loud, it's critical to choose locations and/or times where noise disturbances will be at a minimum.

Once programs are put in place, more difficulties arise. For instance, game theft has happened in some libraries. Additionally, there is a chance that parents who believe that games, particularly video games, have problematic content, will object (Werner, 2013). Additionally, because many video games and gaming systems are pricey, budgetary limitations may prevent the collection from expanding (Elkins, 2015). Additionally, it's crucial to avoid choosing games that place an excessive emphasis on their educational value while underplaying their quality; frequently, game designers for educational purposes are so focused on imparting knowledge that they neglect to create the ultimate gaming experience (Forsyth, 2012; Phetteplace & Felker, 2014).

6. Conclusion

Ellen Forsyth (2012, p. 166) concludes by saying that games are an effective technique to get people interested in concepts and one another. There is no doubt that game collections and gaming applications are quite useful for all kinds of libraries. They can serve as educational resources, forms of amusement, and platforms for fostering social interaction and community. To include games into libraries, librarians will need to discover outstanding resources that can help them set rules, create collection policies, organize events, and answer any objections that might be raised. All those actively involved in library work might be motivated and inspired by the success stories of their colleagues.

Games that are meant for "leisure usage" rather than teaching must be used to teach (Perrotta, Featherstone, Aston, and Houghton, 2013, p. 6). Although delivering learning games, whether they be "educational" or "leisure-use" ones, is an important step, learning also involves a lot more work. The lack of restrictions on instructional content is what determines the success of the gaming business, in addition to the massive financial support that education lacks. It is not easy to incorporate gaming and gamification into education; games that are enjoyable but have bad substance are not desirable (Ulicsak and Wright, 2010); and vice versa, games that have engaging content but fail to engage students are also powerless to help students learn. In other words, the games have the "chocolate-covered broccoli" problem they look wonderful, they're healthy, but they fall flat because they lack inventive game mechanics that encourage immersion and transportation, which results in a lack of enjoyment (Granic, Lobel, & M. E. Engels, 2014, p. 74). Therefore, it seems important to start by acknowledging the increasing complexity and interactivity of games before developing equally complex models to explain how gaming influences

players in pertinent cognitive, social, and emotional domains. This is because the question for psychological research on gaming is not whether games are "good" or "bad" for us (Granic, Lobel, & M. E. Engels, 2014, p. 74).

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A systematic literature review on Information Technology and Knowledge Management as enablers to innovation in higher education institutions.

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Abstract

Continuous innovation is very vital in higher education institutions specifically for growth and institutional survival. A number of factors inclusive of Information Technology (IT) and Knowledge Management (KM) enable such innovation in higher education institutions. Information Technology provides a platform for knowledge sharing, an important Knowledge Management process reported in literature. The aim of this review is to evaluate the enablers to innovation in higher education institutions so that these institutions can be innovative, especially in developing countries. The article reviews literature published between the year 2010 and 2022 from accredited sources inclusive of journal articles, textbooks and other accredited sources. The following keywords were used in the search criteria: 'innovation, higher education, enablers, information technology, knowledge management and knowledge sharing.' To be specific, the articles used in this review were published in the Electronic Journal of Knowledge Management and other journals that focus on Information Technology and Knowledge Management, specifically in higher education. The findings confirm that both Information Technology and Knowledge Management enable innovation in higher education institutions. The review findings further confirm the importance of investing in Knowledge Management and embrace the power of Information Technology in the institutional functions. Properly investing in Information Technology and Knowledge Management certainly improve a higher education institution's innovation capabilities. The review therefore recommends the adoption of Knowledge Management practices supported by appropriate Information Technology in higher education institutions.

Keywords: innovation, higher education, Knowledge Management, Information Technology, knowledge sharing, Communities of Practice.

1. Introduction

Higher Education Institutions (HEIs) promote quality education and effective transfer of knowledge to solve problems. To improve the innovation capabilities of the HEIs, the enablers to such innovation should be explored further (Supapawawisit, Chandrachai and Thawesaengskulthai, 2018). Since HEIs are regarded as knowledge-intensive organisations (Howell and Annasingh, 2013), investing in Knowledge Management (KM) improves the organisational performance. Information Technology (IT) on the other hand enables academic professionals in HEIs to interact and share knowledge (Chege et al, 2020). Innovation is very important for organisational growth, more precisely for HEIs. Swanger (2016) describe innovation as a system that improves an already existing process and Elrehail (2018) define innovation as an institution's overall capability to continuously renew its products and services. This innovation takes

place in different ways such as creation of new products and services as well as improving already existing processes, especially in HEIs where knowledge is created and shared.

The innovation process encourages academics to explore, research and identify new things and better ways of problem solving. Nowacki and Bachnik (2016) highlight that continuous innovation is imperative for all HEIs so that these institutions become competitive in their market place. It is therefore not an exaggeration that innovation creates institutional value and recognition. Moreover, innovation is important for improved decision-making, institutional growth and institutional sustainability. Some of the technological innovations in higher education include virtual reality, artificial intelligence, social media in education and cloud computing for education (Castro, 2019). Some of the most visible forms of innovation in higher education include electronic learning, mobile learning and blended learning. Various teaching and learning strategies that could be used to enhance teaching include the use of smart boards, flipped classrooms and teaching through collaboration. Therefore, institutional innovation is dependent on knowledge that is created through knowledge sharing. Wenger (2014) maintains that the more individuals share knowledge in academic Communities of Practice (CoP), the more innovative the institution becomes.

Several scholars proffer divergent perspectives on innovation but Lee and Trimi (2018) as well as Nowacki and Bachnik (2016) agree that innovation is dependent on the knowledge possessed by academics in HEIs. According to Obeidat, Masadeh and Aqqad (2017), innovation in higher education involves new technologies, new inventions, recent research publications and improved teaching and learning processes. Thus, knowledge is a catalyst and critical motivator for innovation in all HEIs. Since the ultimate goal of innovation is improved services (Torugsa and O'Donohue, 2016), collaborating through knowledge sharing is vital. From the submissions, it is evident that the new forms of innovation will not come only from new technologies, but from new forms of collaboration.

Nowacki and Bachnik (2016) deduce that social, technological and institutional innovation is essential in all HEIs across the world. An institution's innovativeness depends on its human resources, organisational culture, organisational structure and the technology that enable the operations. Innovation in higher education should therefore look beyond efficiency and contemplate on effectiveness. Global forces that require innovative research and innovative pedagogies currently confront higher education. HEIs continuously strive to capture and secure their competitive advantage in the global economy. This research contributes to advancing literature on the value of IT and KM in HEIs of developing countries. This review is guided by the following two objectives, which sought to:

- Evaluate the enablers to innovation in higher education institutions.
- Recommend the adoption of IT and KM in higher education to bring about innovation.

The study answers the following research question:

Research question

To what extent does Information Technology (IT) and Knowledge Management (KM) contribute to innovation in Higher Education Institutions (HEIs)?

2. Methods

The study systematically reviewed extant literature published between the year 2010 and 2022 from different sources including accredited journal articles, textbooks and other online learning material with the aim of understanding IT and KM as enablers to innovation in HEIs. The Electronic Journal for Knowledge Management (EJKM), the International Journal for Innovation (IJI) and other education and IT related journals were used to source literature in this study. The review looks at the different ways HEIs could be innovative. Academic databases like Scopus help to combat predatory publishing and protect the integrity of the scholarly record (Meho and Yang, 2007). The following keywords were used to search the articles: 'innovation, higher education, Information Technology, Knowledge Management and knowledge sharing'. In total, 30 highly cited articles, 4 contemporary textbooks and other online sources were reviewed for an informed understanding of the enablers to innovation in HEIs. Several scholars (Martin-Martin et al, 2018) consider Scopus as a high quality source for contemporary literature as it includes almost all the science journals. Therefore, the researcher used Scopus during literature searching to guarantee the trustworthiness of the literature review findings.

3. Review findings

Information Technology (IT) and Knowledge Management (KM) are some of the important enablers to innovation in HEIs (Castro, 2017; Fullwood et al, 2013). It is important to note that the enablers to innovation reviewed in this article are not the end-all. Wang and Noe (2010) suggest that the realisation of innovation in HEIs rests on effective knowledge sharing, an important KM process which permits the free exchange of ideas and knowledge. Mahapatra et al (2016) suggest that for innovation to take place, HEIs should look at ways of transferring knowledge among academics and this is supported by appropriate Information Technology. KM is an important process in higher education to bring about innovation (V Nair and Munusami, 2020). Thus, it is therefore not an overstatement that research is critical for knowledge creation and innovation. As education continues to shift towards e-learning and m-learning, collaboration will certainly open doors for collaborative creativity (Kumar Basak et al, 2018). The next section reviews IT and KM as enablers to innovation in HEIs in general.

3.1 Information Technology (IT)

Information Technology (IT) provides a platform for archiving the knowledge (Massingham, 2014; Daniela et al, 2018). The technology mentioned here should not be seen as a replacement for people with a wealth of knowledge and experience. In this 21st century, technology is embedded into teaching and learning (Christensen and Eyring, 2011; Daniela et al, 2018). Information Technology (IT) allows e-learning and m-learning, the contemporary teaching methods which have just become pervasive these days. HEIs should therefore invest in simple technology which is user-friendly for the academics. Such technology should be updated regularly to meet with the global technological trends (Massingham, 2014; Alshehri and Cumming, 2020). According to Englund et al (2017), teaching with technology is central to successful implementation of educational technologies in HEIs. Thus, properly investing in IT creates competitive advantage for the HEIs specifically in developing countries.

HEIs can develop Knowledge Management Systems (KMS) supported by IT to improve their core missions of research, teaching and learning. Alshehri and Cumming (2020) underscore that IT enhance teaching, learning and research. The integration of an institution's knowledge processes with its business processes of academic delivery will substantially enhance an institution's performance. Technological enablers are motivated by new opportunities to implement new technology into the institution's daily operations. We can therefore reason that upgrading and updating new technology in a HEIs is bound to improve its innovation capabilities. Research and journal publications are seminal circuits for knowledge sharing which is an important factor for innovation (Zhang, Ning and Barnes, 2016). In this digital era, research is supported and enabled by modern IT. Therefore, HEIs are changing the ways in which they operate and the ways they integrate the new technologies into their core operations of academic delivery.

3.2 Knowledge Management

According to Gao, Chai and Liu (2018), KM is about creating organisational value and contributing to strategic issues such as growth and sustainability. All the issues mentioned by Gao et al (2018) here are very vital in HEIs to bring about innovation, especially in developing countries. The KM processes offer ways of capturing, storing and re-using an institution's knowledge. The professionals within the academic team focus on the generation of a new architecture of knowledge. Girard and Girard (2015) underscore that the key resource in KM is people with relevant work experience. It is therefore important to question what make these people in the HEIs so exceptional. KM philosophers like Nonaka and Takeuchi (1995), define KM as an organisational process which facilitates the capturing, sharing and effectively using organisational knowledge. The definition by Nonaka and Takeuchi (1995) confirm that KM is an organised process that enables information and knowledge to grow, flow and create institutional value.

Several authors (V Nair and Munusami, 2020; Gao et al, 2018) concur that the KM process creates, shares and manages organisational knowledge. From the submissions above, we can infer that KM is one of the most important enablers to innovation in HEIs and the process focuses on creating and sharing knowledge. It therefore becomes clear that value-creation in HEIs lie in KM capabilities to share and re-use knowledge. Nowachi and Bachnik (2016) confirm that knowledge sharing is at the centre of institutional innovation because knowledge is shared with the right person at the right time to improve organisational performance. Individuals, specifically academics should therefore be willing to share their knowledge with others, enabling continuous learning to take place and this certainly benefits the HEIs. At this juncture, HEIs should have policies embedded in the system to support and promote innovation. One way of promoting innovation in HEIs is to invest in KM (Stenius et al, 2016). Ujwary-Gil (2011) advise that effective KM and innovation policies should be embedded into the organisational structures and culture. Institutional management should therefore support KM and innovative activities as stressed by Becerra-Fernandez and Sabherwal (2014) who posits that all KM undertakings in HEIs require executive support.

4. Implications and recommendations

4.1 Information Technology (IT)

Investing in IT paves a way to creating a competitive advantage for HEIs. Farinha et al (2018) describe competitive advantage as the ability of an institution to perform better than its competitors do. Performing better than the competitors is one of the strategic objectives of any HEIs in the world. IT should not be seen as a replacement for people with valuable knowledge and experience (Massingham, 2014; Alshehri and Cumming, 2020). However, IT should be seen as an enabler to HEI functions of creating and sharing knowledge. From the literature review findings (Alshehri and Cumming, 2020), we can confidently

confirm that IT provides a platform for collaborative knowledge-sharing in HEIs. Since technology is integrated into teaching and learning, the same technology should be upgraded and updated regularly to improve an institution's innovation capabilities.

4.2 Knowledge Management (KM)

The objective of KM in HEIs is to promote knowledge re-use (Ramjeawon and Rowley, 2017). As a matter of fact, KM avoids repetition of tasks in HEIs. Moreover, KM provides a way to capture and store an institution's knowledge from experienced academics in this case. According to Al-Husseini and Elbeltagi (2018), all HEIs are competing for survival and growth. Therefore, it is not an overstatement that KM is very important for HEIs to grow and survive. According to Dee (2016), institutional learning involves the knowledge, skills and abilities that develop as a result of an institution's overall experience. Thus, KM plays a pivotal role in HEIs' success through effective organising and monitoring the KM assets related to intellectual capital. Creating conditions that encourage collaboration in higher education is a prerequisite for institutions to innovate and adapt to change (Givens and Stocker, 2020). Therefore, KM boosts collaboration and knowledge-sharing within the HEI. We can therefore underscore that knowledge-sharing is a weighty concern in HEIs. We can further add that KM increases learning and innovation capabilities of academics within a HEI.

5. Conclusion

The literature review findings indicate that technology positively influences innovation and HEIs' performance. Information Technology provides harmonising insights to identify the best approach when aligning learning goals with technology-based implementations. It was established that HEIs should advance in both IT and KM to be innovative and competitive in the higher education landscape. Information Technology (IT) permits evidence-based pedagogy and personalised adaptive learning. Several scholars (Castro, 2019; Chege et al, 2020) submitted that KM tools and techniques significantly help the HEIs to meet their competitive goals. Therefore, it is vital for HEIs to invest in both Knowledge Management and Information Technology. The study also established that KM facilitates organisational learning (Fullwood et al, 2013) and this definitely accelerates innovation. We can therefore conclude that KM boosts collaboration and knowledge sharing among academics in HEIs. The study therefore recommends that HEIs align their Information Technology with Knowledge Management so they improve their operations and come up with innovative practices of teaching and learning.

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Students' Outlook to Online Teaching and Learning: A Case Study of Post Graduate Diploma in Education Students in a Nigerian University

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Abstract

The study examined Students' Outlook to Online Teaching and Learning in a federal-owned University in Nigeria. A descriptive survey research design of case study type was adopted for the study. A total of 59 students formed the population of the study sampled purposively, including students exposed to online teaching and learning due to the COVID-19 Pandemic. Three research questions were formulated to guide the study while testing one hypothesis at a 0.05 level of significance. Data were collected with an adapted structured questionnaire divided into two sections. The research questions were answered using descriptive statistics of pie chart, mean and standard deviation, while the hypothesis was tested using one-way ANOVA inferential statistics. The results showed students' average preparedness and experience for online teaching and learning occasioned by the COVID-19 Pandemic with an average rating of the quality of lectures received. This translated to a positive outlook to online teaching and learning. Government crowdfunding for education, leveraging free online training by lectures and a tech-savvy curriculum for teacher education were recommended, among others.

Keywords: E-learning, Teaching and Learning, Experiences, Performance, University education, Teacher Education; 4IR

1. Introduction

Higher education institutions in Nigeria also referred to as tertiary institutions, are saddled with the responsibility of human capital development to ensure the availability of requisite skills in key economic areas while supporting the a knowledge-based economy. Higher education in the country poised for proper value orientation; intellectual capacities development and adequate level of environmental consciousness for a wholistic community engagements and relevance (Federal Republic of Nigeria, 2013; Ogunode & Musa, 2020). These aims are achieved through developing a curriculum by the National Universities Commission, the government parastatal responsible for establishing minimum standards, monitoring the quality of higher education in Nigeria leading to accreditation decisions (Ogunode & Musa, 2020). The Nigerian higher education system comprises the university and non-university sectors comprising polytechnics, monotechnics, and colleges of education. The university sector is either federal, state or privately managed, categorised into four generations (Ejoigu & Sule, 2012; Iruonagbe et al., 2015). About one-quarter of universities in the country are federal government-owned, housing about 68 per cent of Nigerian students (The Quality Assurance Agency for Higher Education, 2019; Lembani, 2019). This statistic is not without implications for facilities for teaching and learning, which have been reported to be far below the requirements in terms of infrastructure (Briggs, 2013).

Teaching and learning in federal-owned universities were deployed following the conventional practice of face-to-face interaction, while freely available online courses on platforms such as edX and Coursera were not popular among university undergraduates (Abdulmajeed et al., 2020). However, the need for online

teaching and learning, also known as e-learning or online teaching and learning, became more pronounced due to the COVID-19 Pandemic, which necessitated national lockdowns in the country as experienced internationally (Hub, 2020; Tokede & Appah, 2020; Mhlanga & Moloi, 2020; Oladele et al., 2022). While the e-learning mode can be regarded as a viable solution to continued teaching and learning during the COVID-19 Pandemic lockdown period, institutions adopted this mode with little or no preparation Oladele et al. (2022); aggravated by poor funding (Ejoigu & Sule, 2012; Amaghionyeodiwe & Osinubi, 2012; Ogunode & Musa, 2020). With this situation, universities in Nigeria, like the experience of other developing African countries, were left struggling to keep above board (Lembani, 2019; Abdulmajeed et al., 2020; Hub, 2022). This situation was reported to be aggravated by the lack of technological skills required for designing electronic course materials for delivery in a distance and online learning environment among lecturers (Ogunmakin, 2018; Oladele et al., 2021). To facilitate a progressive learning curve, a survey of students' outlook to online teaching and learning becomes necessary.

2. Literature Review

E-learning is defined as an innovative and learner-centred approach for delivering electronically mediated instruction leading to interactive learning environments while leveraging the internet and digital technologies boundless by place and time (Ajadi et al., 2008). E-learning is described as learning that is partially or entirely deployed through the internet asynchronously, synchronously or as a hybrid (Tokede & Appah, 2020). E-learning has been implemented extensively in tertiary institutions in developed economies of the world 100% Information Communication Technology (ICT) based universities known as Virtual Universities (Ajadi et al., 2008). ICT refers to the totality of methods and tools used for electronic data processing applicable for educational purposes (UNESCO's International Institute for Educational Planning, 2019).

In Nigeria, the National Teacher Institute (NTI) and National Open University (NOUN), sponsored by the Federal government in 1976 and 2002, respectively, are the most widely known higher institution that leverage e-learning to deploy distance learning with satellite campuses all over the country (Osunde & Omoruyi, 2004; Ogunmakin, 2018). Abdulmajeed et al. (2020) reiterated that while NOUN appears to have an e-learning platform for students, they have a sparse MOOC platform with just two active courses in Media and Information Literacy and History and Philosophy of Science. This situation is a pointer to low e-learning engagements. Also, fourteen of the conventional federal-owned universities deploy some of their courses through the distance learning mode, some of which are the University of Ibadan (the first), University of Lagos, Lagos- UNILAG, Obafemi Awolowo University, Ile-Ife- OAU, University of Maiduguri- UNIMAID, University of Abuja, Ahmadu Bello University, Zaria- ABU, Federal University of Technology Minna, FUTMINNA, University of Ilorin- UNILORIN, among others (National Universities Commission, n.d.).

The mode of delivery of instructional materials at NOUN is through multimedia (voice, data, graphics, video) ICT gadgets such as television and radio broadcasts transmission electronically over fixed-line (telephone or leased lines) terrestrial, VSAT wireless communications, open-source learning management system, e-mail and social media platforms (Ogunmakin. 2018; Lembani, 2019). Also, UNILAG has a Unilag-XuetangX MOOC platform with 19 courses, while the UNILORIN centre runs on the Learning Management System with a course (B.Sc Computer Science) as its flagship programme (University of Lagos, 2021; Centre for Open and Distance Learning, 2022). These practices have become necessary for continuous leapfrogging in the fourth industrial revolution (4IR) era with a plethora of technology-driven platforms with a carefully integrated algorithm, data analytics, and internet of things (IoT) which the education

sector must carefully leverage for teaching and learning (Schwab, 2016; Fisk, 2017; Oladele, 2022). A case was also for adaptive learning systems for instructional design and teaching and learning purposes which leverage 4IR tenants of automation, sequencing, Assessment, real-time data collection, and self-organisation (White, 2020; Oladele et al., 2022).

Distance and online education in Nigeria are considered a major and vital educational advancement for the countries teeming population with opportunities for continuing education while supporting the limited carrying capacity of federal-owned conventional institutions of higher learning (Ejoigu & Sule, 2012; Jimoh, 2013; Ogunmakin, 2018; Lembani, 2019). The increasing number of open and distance learning centres implementing e-learning at the higher level of education in Nigeria undoubtedly brings significant changes in the teaching and learning processes in most parts of the world, widely supported by improved technology, availability of smarter devices which changed the scenario of learning (Ogunmakin, 2018). Abdulmajeed et al. (2020) stressed that online teaching and learning had been developed with the potential to scale education, making it affordable and accessible. These advantages are not without their impending challenges, such as poor IT infrastructural provision, socioeconomic/cultural issues, mass unawareness, low computer literacy level, high cost for internet access and ICT gadgets, inadequate budgetary allocation, steam-age equipment and curricula and textbooks, a dearth of research financing, poor lecturers remuneration among others (Folorunso et al., 2006; Ejoigu & Sule, 2012; Iruonagbe et al., 2015; Lembani, 2019; Abdulmajeed et al., 2020; Ogunode & Musa, 2020; Oladele et al., 2021). Solving these challenges must be prioritised and handled holistically by all relevant stakeholders through home-grown solutions enhanced by technology transfer mechanisms.

Another key issue raised by Iruonagbe et al. (2015) and Lembani (2019) is the education-industry skills mismatch, with most Nigerian graduates regarded as half-baked. This situation was a major basis for the Shanghai Academic Ranking of World Universities (ARWU) for 2017, with less than 10% of Nigerian universities in the top 2000 world's best universities, and neither does the Nigeria premier university have a place among the best universities in Africa. There should be not much ado about the lack of respect for Nigerian certificates abroad while Nigerian students excel studying abroad, which has become a frequent option for Nigerians who can afford the related costs. It is no surprise that Nigeria has the most transnational students in Africa, with approximately 71,351 students pursuing studies in more than 70 countries (World Education Services, 2022; UNESCO Institute of Statistics, 2022). Higher learning institutions' major role is physical and intellectual human capital development. However, this role can be rated as under-assumed with tertiary institutions' institutional failure due to skill mismatch and poor graduate quality (Iruonagbe et al., 2015; Okafor, 2020). An unstable academic calendar aggravates this situation due to incessant strike action caused by disagreement between university academic unions and the government on issues bothering educational standards and lecture welfare, leaving university students out of schooling for months (Okwa & Campbell, 2011; Ejoigu & Sule, 2012; Iruonagbe et al., 2015; Ogunode & Musa, 2020). These occurrences raise the question of the extent to which the importance of education is rated for human capital and national development in Nigeria.

Empirical studies have shown that e-learning holds solutions for the development of an array of skills believed to help enhance the students' academic excellence through self-paced learning and access to an array of learning information while acquiring soft skills such as communication skills including writing, reading, and speaking, problem-solving skills, improve self-discipline/dependency relevant to the world of work and life-long learning (White, 2020; Oladele et al., 2022). The gains from online teaching and learning are equally impacted by the lenses through which students view technology for educational

purposes in Nigeria, supported by Bates (2014) submission that gadgets alone do not make the future. He stressed that the decision of what kind of life to adopt applicable to educational technology remains political, shaped by personal decisions. Folorunso et al. (2006) identified mass unawareness, low computer literacy level and cost as the critical factors affecting the acceptability of educational technology. This submission strengthens the importance of examining students' outlook to online teaching and learning.

Teacher education is either Students' outlook to online teaching and learning in this study was conceptualised as their preparedness for, experience with and how they rate the quality of online teaching and learning. Outlook can be either positive or negative. Bates (2014) viewed online teaching and learning as the future of university education. Algoedt (2020) examined the next lines of action for online learning and education through a positive outlook. Ayanwale and Oladele (2021) examined online learning indicators and learners' satisfaction during the covid-19 Pandemic. Findings from the study revealed content, learners' and system quality as essential ingredients in ensuring satisfactory online teaching and learning engagements. A study by Darkwa and Antwi (2021) revealed that classroom learning was more effective than online learning in Ghana; however, with a non-statistically significant difference. University students' satisfaction and outlook towards forced remote learning during a global pandemic by Abdullah et al. (2022). The study reveals the need for continuously improve their online delivery strategies and practical crises-centered strategies. Collado (2022) examined learner readiness to engage in non-traditional modes of schooling with a focus on ensuring access to quality education even during emergencies. The current study is poised to examine students' outlook construed via online teaching and learning students' preparedness, experience and lecture quality rating aimed at facilitating a progressive learning curve.

3. Theoretical/Conceptual Framework

This study adopts the novel learning theory of connectivism that stresses the need to combine thoughts, theories, and general information while leveraging educational technology. Students' constant connectedness via technology provides the opportunities to make choices about learning (Western Governors University, 2021). Described as a new learning theory for the digital age, the appropriateness of this theory to this study is premised on the availability of smart solutions such as Google Assistant, Siri, and Alexa, among others, fast gaining relevance for seeking answers and finding information (Kop & Hill, 2008; Herlo, 2016). This enables smart learning which is a sharp contrast to the realities two decades ago when students rely heavily on print media (Siemens, 2004).

According to connectivism, learning advances internal construction of knowledge to content from external networks relevant for smart instructional purposes. In connectivism, students are seen as "nodes" in a network. A node refers to any object connected to another object, like a book, webpage or person. Connectivism is based on the theory that learning is achieved through sustained connections between various "nodes" (Downes, 2007; WGU, 2021). As explained by Siemens (2004), this theory is apt as many learners will move into various, possibly unrelated fields throughout their lifetime. Furthermore, most learning is no longer formal, while informal learning remains a significant aspect of a variety of learning experiences through communities of practice, personal networks, completion of work-related tasks and a continual process. More importantly, learning and work-related activities are no longer separate, and technology rapidly alters how things are being done (Wardynski, 2019).

Students are at the centre of the teaching-learning process and their outlook to the e-learning is germane for evaluating progress. Generally, the construct outlook is defined as a mental attitude or point of view and the probability, expected condition or outcome of something (Educalingo, 2022). Rajasekaran et al. (2019) examined outlook of university students and their profession strategy focused on understanding the mentality of students undergoing arts and science programs with respect to their career plan. A more localised study was carried out by Obuezie et al. (2019) to construe students' outlook through the extent of social media use on for educational and national development in a Nigerian University. In this study, students' outlook is measured through their preparedness, experience and rating of the quality of online teaching and learning at the university education level. In doing this, their response to the questionnaire consisting of three sections (preparedness, experience and rating of the quality of online teaching and learning) were summed in measuring the construct outlook. Applying the learning theory of connectivism to examining the outlook of PGDE students to e-learning technology holds the potential of re-defining and shaping classrooms.

4. The Problem Statement

Students in public institutions in Nigeria battled to learn online in the face of the Covid-19 Pandemic (Ogunode & Musa, 2020; Tokede & Appah, 2020). Although, commendable progress has been made with providing vaccines to curb the spread of the Covid-19 Pandemic. However, re-infection is still possible considering rapidly emerging variances (WHO, 2021; Pandey et al., 2021; Wang, 2022; Pulliam et al., 2022). This situation strengthens the fact the world still must complement vaccines with social distancing while re-considering lockdowns when necessary. Like other parts of the world, the education sector in Nigeria took to online teaching and learning with the aid of computer technologies (Algoedt, 2020). While this has been a solution to ensuring that teaching and learning continue during the lockdowns amidst other measures, it exposes students to all contents equally, leaving them to find their footing while fighting their fears with technology usage. The questions of the extent to which learning is achieved also remain at large. The main objective of the study was to examine Nigerian university students' outlook to online teaching and learning achieved through the following questions with a hypothesis listed below:

1. To what extent are PGDE students prepared for online teaching and learning in the surveyed Nigerian Universities?
2. What are the PGDE students' experiences with online teaching and learning in the surveyed Nigerian Universities?
3. How do PGDE students' rate the quality of online teaching and learning in the surveyed Nigerian Universities?

H_{01} : There is no significant difference in students' outlook to online teaching and learning based on the medium of instruction.

5. Materials and Methods

5.1 Design

The descriptive survey research design of case study type was adopted for the study. The case study type involves an in-depth study of an individual or group of individuals which lead to testable hypotheses while allowing for in-depth study of rare phenomena or occurrence (Schoch, 2020). This research type is deemed appropriate for collecting information from respondents through their responses to carefully designed and validated questions electronically applicable to this research (Ponto, 2015). The research

design also accommodates uniqueness with data gathering, probabilistic sampling for ascertaining representation of the population of interest, standardisation of measurement and ease of data analysis (Owens, 2002; Avedian, 2015).

5.2 Study Population and Sampling

The study population were students in public higher institutions of learning in Nigeria, while the target population were sixty-one postgraduate students in education registered for the 2020/2021 academic session and who experienced online teaching and learning. The purposive sampling technique was employed, and the inclusion criteria were students who experienced online teaching and learning due to the Pandemic. This target population were of keen interest considering that they experienced the e-learning with little or no preparation.

5.3 Study Instrumentation

The instrument used for data collection was a Students' Outlook to Online Teaching and Learning Questionnaire "SOOTL" adapted from the Technology Adoption for Teaching and Learning Questionnaire premised on the unified theory of acceptance and use of technology model with an overall reliability coefficient of 0.96. The original instrument available at <https://osf.io/tzxjr> consists of two sections. Section one presented brief background information to the study, and Section two consisted of seven loose items with corresponding response formats and three themed items on Student preparedness for online teaching and learning with 14 items, Student experience with online teaching and learning with 21 items and rating the quality of lecture with 12 items on a four Likert response scale of Strongly Agree, Agree, Disagree and Strongly Disagree. The adapted instrument retained Section 1 with demographic statistics of exposure to e-learning and online mode of instruction. Similarly, Section 2 of the adapted instrument retained the themed items on three Student preparedness for online teaching and learning, Student experience with online teaching and learning and rating the quality of lectures. The instrument was adapted in line with the study research objectives. The instrument was deployed and collated electronically via Google forms.

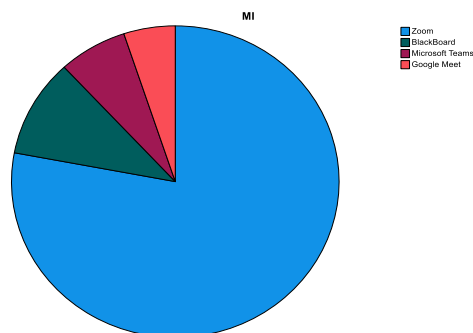
5.4 Data Analysis

The demographic statistics of the collated data were analysed using descriptive statistics presented with pie charts, while research questions were also answered using descriptive statistics of mean and standard deviation. Finally, the hypothesis generated for the study was tested using inferential statistics using a one-way Analysis of Variance. All reported analyses were implemented in Statistical Package for Social Sciences (SPSS) version 28.

6. Results

A total of sixty-one students studying at the postgraduate level participated in the study. However, 2 of the respondents indicated that they had not experienced online teaching and learning, invalidating their response. As such, responses from fifty-nine participants were included in the analysis, while the demographic information on Mode of Instruction is presented using pie charts as shown in Figure 1.

Figure 1: Pie Chart showing the Modes of Instruction (MI) participants were exposed



Source: Author's computation based on data collected (2021)

Figure 1 shows that most (fourty-six of fifty-nine) of the students constituting 78% of the total population of the study were instructed using Zoom while the remaining 22% were exposed to Blackboard- 10.2%, Microsoft Teams-6.8% and Google Meet- 5.1%.

6.1 Answering Research Questions

6.1.1 To what extent are students prepared for online teaching and learning in the surveyed Nigerian Universities?

Students' preparedness was assessed with a 14-item scale with issues bothering having a personal computer, access to the internet, access to uninterrupted power supply, exposure to using google collaboration tools, experience with using zoom meetings before the contact session commenced, having a functional e-mail address, being conversant with using e-mail for communication, being used to surfing the internet for learning contents, access to other device/gadgets for effective participation in online teaching and learning aside from the pc, having enough time to participate in online teaching and learning fully, cost implication(s) on data bundle for seamless participation in online teaching and learning, experience in using the chat box and other facilities of different platforms for meaningful engagement during online classes, experience with other platforms aside zoom for meetings prior the commencement of the contact session and positive disposal to e-learning. The responses to the scale, which had a four-point response format of Strongly Agree, Agree, Disagree and Strongly Disagree, were transformed and recoded as Low: 1, moderate: 2 and High: 3 and analysed using mean and standard deviation. Therefore, the Assessment of students' preparedness for online teaching and learning was based on an average mean response of 2 as the benchmark for assessing the result shown in Table 1.

Table 1: Extent of students' preparedness for online teaching and learning

	N	Mean	Std. Deviation
SP	59	1.7966	.78300
Valid N (listwise)	59		

Author's computation based on data collected (2021)

As shown in Table 1, students' preparedness for online teaching and learning had a mean of 1.80 and a standard deviation of 0.78 (approximated to 2 decimal places, respectively). This result shows that students were moderately prepared for online teaching and learning, which they were exposed to due to the COVID-19 Pandemic.

6.1.2 What are the students' experiences with online teaching and learning in the surveyed Nigerian Universities?

Students' experiences with online teaching and learning was assessed with a 21-item scale with issues bothering on conversancy with WhatsApp as a mobile electronic technology to facilitate online teaching and learning interaction with the lecturer, using google forms for taking assessments, using google docs for submitting assessments, mode of data access (institutional or personal), using functions from different instructional platforms while in class, resolving internet issues while connecting to online classes, availability of technical support during online classes, access to clear and legible presentations during online classes, adequacy of time to jot down points during online classes, opportunity for questioning during online classes, access to lecture playbacks after the online learning process, the extent to which technology hampered learning, Lecture information was effectively disseminated during the class, surfing the internet for contents to support learning, ease of taking online assessments, availability of timely feedback after taking my online Assessment, access to the lecturer before and after online classes, ease of access to course materials before the online classes, access to educative and informative interactions and discussions with other students and working independently. The responses to the scale, which had a four-point response format of Strongly Agree, Agree, Disagree and Strongly Disagree, were transformed and recoded as Poor: 1, Good: 2 and Excellent: 3 and analysed using mean and standard deviation. Therefore, the Assessment of students' experiences with online teaching and learning was based on an average mean response of 2 as the benchmark for assessing the result shown in Table 2.

Table 2: Students' Experiences with Online Teaching and Learning

	N	Mean	Std. Deviation
SE	59	1.6610	.73368
Valid N (listwise)	59		

Source: Author's computation based on data collected (2021)

As shown in Table 2, students' experiences with online teaching and learning had a mean of 1.66 and a standard deviation of 0.73 (approximated to 2 decimal places, respectively). This result shows that students' experiences with online teaching and learning due to the COVID-19 Pandemic were rated as good.

6.1.3 How do students rate the quality of online teaching and learning in the surveyed Nigerian Universities?

Students' quality rating were assessed with a 12-item scale with issues bothering on timely commencement of the lecture, access to lecture slides after online classes, clarity of lecture content presentation, lecturer's communication skills, adequacy of course content coverage, availability of revision window before taking the final examinations, availability of Learning resources to support online classes, engaging lecture presentations (with suitable images and backgrounds), room for student feedbacks during online classes, simplicity of contents dissemination, support for accomplishing class tasks, and courteousness of student-teacher interaction during online classes. The responses to the scale, which had a four-point response format of Strongly Agree, Agree, Disagree and Strongly Disagree, were transformed and recoded as Poor: 1, Good: 2 and Excellent: 3 and analysed using mean and standard

deviation. Therefore, the Assessment of students' rating of online teaching and learning quality was based on an average mean response of 2 as the benchmark, as shown in Table 3.

Table 3: Students' rating of the quality of online teaching and learning

	N	Mean	Std. Deviation
SE	59	1.6610	.73368
Valid N (listwise)	59		

Source: Author's computation based on data collected (2021)

As shown in Table 3, students' online teaching and learning quality ratings had a mean of 1.58 and a standard deviation of 0.70 (approximated to 2 decimal places, respectively). This result shows that students rated the quality of online teaching and learning due to the COVID-19 Pandemic as good.

6.2 Hypothesis Testing

H₀₁: There is no significant difference in students' outlook to online teaching and learning based on the medium of instruction.

Students' responses on preparedness for, experience with and quality rating of online teaching and learning were transformed to obtain data on their outlook to online teaching and learning, based on which the hypothesis generated for the study was tested using the Analysis of Variance inferential statistics at a significant level of 0.05. The results are shown in Table 3a with the descriptive statistics, and Table 4b with the one-way ANOVA summary reported.

Table 4a: Mean and Standard Deviation of responses on online teaching and learning medium of instruction

	N	Mean	Std. Deviation
Zoom	46	77.3478	21.59961
Blackboard	6	73.3333	21.62098
Microsoft Teams	4	72.0000	9.34523
Google Meet	3	96.0000	12.28821
Total	59	77.5254	20.82303

Source: Author's computation based on data collected (2021)

Table 4a depicts that the instructional medium of Zoom had highest number with (N= 46; M = 77.35, SD = 21.60), followed by Blackboard with (N= 6; M = 73.33, SD = 21.62), next to Microsoft Teams with (N= 4; M = 72, SD = 9.35) and lastly Google Meet with (N=3; M = 96, SD = 12.28) respectively.

Table 4b: One-way ANOVA Summary table on Students' Outlook to Online Teaching and learning based on Medium of Instruction

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1252.944	3	417.648	.961	.418
Within Groups	23895.768	55	434.469		
Total	25148.712	58			

Source: Author's computation based on data collected (2021)

As shown in Table 3b, the one-way ANOVA statistics were used to establish whether there was a significant difference in their mean scores or not. The result remarked a non-statistical significant value with ($F(3) = 0.961$, $p = 0.418$). Therefore, the null hypothesis was not rejected. This finding implies that students' outlook to online teaching and learning was not influenced based on the medium of instruction.

7. Discussion of Findings

Findings from the study show that students were moderately prepared for online teaching and learning, which they were exposed to due to the COVID-19 Pandemic. The moderate preparedness could allude to the prevailing digital era, also known as the Fourth Industrial Revolution (4IR), comprised of millennials/Generation Y and Z- Born between 1981 to 1996 and 1996 and 2010, respectively (Darkwa1 & Antwi, 2021). These generations are tech-savvy, which is a favourable factor for ease of transitioning to online learning. This finding aligns with that of Oladele et al. (2022), which revealed a high level of preparedness of students in Science, Technology, Engineering and Mathematics disciplines for online teaching and learning due to the COVID-19 Pandemic. Also, the 4IR being characterised by a proliferation of high-end ICT gadgets forms another spot for the recorded student's preparedness (Mhlanga & Moloi, 2020). This assertion is supported by a study which revealed that student's own computer devices with access to the internet but with doubts about the service integrity of their internet connection (Collado et al., 2022). While internet access is central to online teaching and learning, its integrity is equally important to ensure a smooth online session for knowledge maximisation from instruction. The finding of this study is opposed to that of Soriano et al. (2022), which revealed that students' preparedness level was poor, indicating that students are not fully equipped or ready for online learning.

The COVID-19 Pandemic can be regarded as an awakening call to Federal-owned universities in Nigeria, which have been complacent with the conventional face-to-face mode of instruction in contrast to universities in developed countries (Bates, 2014; Abdulmajeed et al., 2020; UK-AID, 2020). One of the determining factors for determining the world standard for higher education is access, which is greatly facilitated through online education Ajadi et al. (2008). Therefore, online teaching and learning is a sure direction for Nigeria's much-needed adaptation, transformation, reformation and revitalisation of qualitative university education (The Quality Assurance Agency for Higher Education, 2019). The study finding on preparedness is unarguably shining a positive light. However, efforts should be geared towards institutional support for gadgets and internet access provision to achieve high student preparedness for online teaching and learning. Considering that e-learning holds potential for the developed requisite skills for students' academic excellence Oladele et al. (2022), online teaching and learning would also go a long way in solving the problem of skills mismatch while enhancing graduate quality.

This result shows that students' experiences with online teaching and learning due to the COVID-19 Pandemic were rated as good. The moderate level of experience with online teaching and learning can be

alluded to as non-exposure prior to the Pandemic resulting in a rushed transition from the face-to-face instructional model. Little wonder, Nigeria is the largest country with overseas education for those who can afford it (World Education Services, 2022; UNESCO Institute of Statistics, 2022). This finding shows a need for improving students' experiences with online teaching and learning driven by world-standard educational facilities that can also attract foreigners to study in Nigeria with the potential of increasing the country's Gross Domestic Product of the country just like developing countries like South Africa and developed ones such as the UK which is leveraging overseas education for economic development (The Quality Assurance Agency for Higher Education, 2019; Lembani, 2019). The Quality Assurance Agency for Higher Education (2019) stressed the need for a sustainable funding model at all levels be implemented appropriately to be able to upgrade one-third of facilities for teaching, learning and research to meet international standards. Doing this would be instrumental to meaningfully improving students' experiences with online teaching and learning, which is fast becoming the new normal in developing countries (Bates, 2014; Fisk, 2017). Therefore, educational funding must be a front-burner agenda for the Nigerian government in budgetary allocations for education and other relevant stakeholders.

This result shows that students rated the quality of online teaching and learning due to the COVID-19 Pandemic as good. This finding points to an average performance level which unarguably leaves room for improvement. Having students rate the quality of online teaching and learning gives objective views of the situation. The lecturers and all concerned stakeholders should treat this finding with a high level of sincerity. This finding aligns with that of Oladele et al. (2021), who revealed that the capacity of lecturers in Nigerian universities for online teaching and learning was average. These findings convey a dear need for ICT training for lecturers, without which they cease to be qualified teachers, and for optimal performance with online teaching and learning. Lecturers in Nigeria largely support their teaching and research from their meagre salaries compared to their counterparts abroad, even at the professorship level (Aondofa, 2021; Academic Positions, 2022). Hub (2020) stressed the need for institutional funding to provide much-needed support to lecturers to improve the quality of online teaching and learning meaningfully. Through qualitative online teaching and learning, Nigerian universities can compete favourably with those in the development world. This assertion is not without implications for the quality rating of Nigerian University certificates abroad (World Education Services, 2022).

Lastly, the finding of this study implies that students' outlook to online teaching and learning was not influenced based on the medium of instruction. Though there was no significant difference in students' outlook to online teaching and learning based on the medium of instruction, results showed a heavy reliance on Zoom technologies used to deploy online teaching and learning. While Zoom technology undoubtedly can be used for educational purposes, there are other platforms, such as Blackboard, Microsoft Teams, and Google Classrooms which are dedicated educational technology platforms for adaptive content quality leading to improved pedagogical delivery, increased classroom engagement and better media design to support online teaching and learning (Pugliese, 2016). There is no gain-saying the fact that the cost implications for these dedicated platforms may be far-reaching. A solution to this problem is using free platforms such as Google Classrooms, which was reported to have a high prospect for online instructional delivery for higher education in Sub-Sahara Africa (Oladele et al., 2021). While any serious government would prioritise educational funding, the onus is on various institutions to devise innovative ways to fund higher education in a digital age.

8. Conclusion and Recommendations

This study concluded that students were averagely prepared for online teaching and learning occasioned by the COVID-19 Pandemic with a barely above-board experience laced with an average rating of the quality of lectures received. Also, students had a positive outlook to online teaching and learning, which is a pointer to improvements with future e-learning engagements. However, some measures are necessary to realise the gains of online teaching and learning in Nigeria, some of which are highlighted below:

1. The government should prioritise educational funding in Nigeria for universities to fully support students in terms of the provision of ICT gadgets and the internet required for online teaching and learning.
2. There should be a synergy between ICT and data service providers as necessities for e-learning through industrial partnership to ensure the least cost.
3. Nigerian universities must leverage crowdfunding for university infrastructural improvement and lecturers' support to meet world university standards.
4. Lecturers should leverage many free online resources and training to boost their effectiveness and tech-savviness by deploying lectures electronically.
5. Technology literacy should be integrated into the Nigerian University Curriculum in line with world best practices.

8.1 Limitations and directions for further research

This study, like other research, has some limitations. Firstly, several constructs can be used to access students' outlooks; however, this present study was limited to students' preparedness, experiences and lecture quality rating. Furthermore, the study was limited to Nigeria and largely described the context of online teaching and learning during the heat of the COVID-19 Pandemic. Even in Nigeria, the study was limited to Postgraduate Diploma in Education students in a Nigerian University, which further limits the generalisation of findings. Therefore, the authors suggest future studies involving many more educational institutions for wider comparability. Since students had no prior experience with online teaching and learning before the COVID-19 Pandemic, this situation can also affect their responses. Lastly, a conclusion was drawn from primary data collected from students. Future research may draw analogies by collecting primary and secondary data from students and lectures.

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Information and Communication Technologies Readiness and Acceptance among Teachers in Vocational Enterprises Institutions in Abuja, Nigeria

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Abstract

The study determined the level of Information and Communication Technologies (ICT) readiness and acceptance among teachers in Vocational Enterprise Institutions (VEIs) in Abuja, Nigeria. Two research questions were raised and answered and two null hypotheses were formulated and tested at .05 level of significance. The research design used for the study was descriptive survey research design, specifically, using cross-sectional study. The population of the study was 154 respondents consisting of all the 91 male and 63 female teachers from the six VEIs, one each from the six area councils in Abuja. Total population sampling technique was used to select the whole population of the study. The instruments used for data collection include: Technology Readiness Index (TRI) and Educational Technologies Acceptance Index (ETAI). Cronbach's Alpha statistical technique was used to determine the reliability index of the instruments and found to be .89 and .90 respectively. The study employed the use of mean to answer the research questions and independent sample t-test to test the null hypotheses using Statistical Package for Social Sciences (SPSS) version 25. The study found low level of ICT readiness and acceptance among teachers in VEIs in Abuja, Nigeria with grand mean of 2.40 and 2.37 respectively. The study also found no substantial dissimilarity between the level of ICT readiness and acceptance of male and female teachers (Substantial value >.05). Based on the findings, the study recommended among others that the Federal Capital Territory Administration should develop a framework for enhancing the ICT readiness and acceptance among teachers in VEIs in Abuja, Nigeria.

Key Words: Information and Communication Technologies, Readiness and Acceptance

1. Introduction

In Nigeria education system, Vocational Enterprises Institutions (VEIs) are establishments permitted by the Nigerian Federal Government to deliver a proper substitute path to education. National Board for Technical Education (NBTE, 2012) stated that the VEIs are aimed to broaden patronage to Technical and Vocational Education and Training (TVET), help to address industrial needs and make citizens self-empowered. The aim of VEIs seems unachievable due to the low academic achievement of students in trade subjects that might be associated with the failure of teachers in using technology to teach. Summak *et al.* (2020) noted that the low achievement of students is associated to many factors that includes teachers' negative attitudes and unwillingness to utilize Information and Communication Technologies.

Utilization of Information and Communication Technologies (ICT) in teaching encompasses using software or applications for delivering contents of learning physically or virtually. The use of ICT plays important role in enhancing students' academic achievement by giving them the likelihoods to actively participate in teaching and learning process (Dieck & Jung, 2018). This entailed that, using ICT in teaching could aid

to addressing the students' low academic achievement. Considering the significance of ICT in teaching, ascertaining the factors for ensuring ICT integration into schools such as VETs is a good step to enhance quality teaching and learning. Dindar *et al.* (2021) stated that teachers' willingness and attitudes is a key factor in ensuring the use of ICT in classroom. This implies that teachers' willingness to adopt ICT in classroom directly indicate their level of technology readiness.

Technology readiness is teachers' tendency to embrace the use of ICT in classroom for teaching. The readiness of teachers to use ICT is positively influenced by optimism and innovativeness while negatively influenced by discomfort and insecurity (Parasuraman, 2000). Ensuring the use of ICT into schools cannot be achieved without teachers' readiness. According to Christensen (2012), the readiness of teachers to use ICT is important for making the right choice of schools' educational technologies. Therefore, readiness of teachers to use ICT is regarded as a unique factor for ensuring the use of ICT in classroom. Nihat and Murat (2021) confirmed that, readiness of teachers to use ICT has a direct effect on their acceptance of ICT.

The teachers' acceptance of ICT is associated with the degree to which ICT is accommodated into classroom in order to improve the academic achievement of students. According to Scherer *et al.* (2019), for the academic achievement of students to be improved, teachers' acceptance of ICT is considered as the chief factor (Cabero-Almenara *et al.*, 2021). Thus, ICT acceptance of teachers is regarded as determinants of enhancing the academic achievement of students. Kamal *et al.* (2020) also established that the use of ICT in classroom is basically challenging without acceptance of ICT by the teachers. Therefore, this study is important as it sought to provide more insights on teachers' ICT readiness and acceptance in VETs in Abuja, Nigeria.

2. Statement of the Research Problem

To promote the accessibility to TVET, the Nigerian government established the VETs. Unfortunately, achieving the goal of VETs is questionable with the low academic achievement of students. Edusys (2022) confirmed that non-integration of ICT in teaching leaves teachers with no option than to employ the use of words to express teaching. Consequently, this has contributed to the low academic achievement of students in VETs simply because the use of words to express teaching is found to make learning passive. However, overcoming this challenge necessitates educational establishments such as the VETs to fully integrate ICT into classrooms. According to Dindar *et al.* (2021), the attainment of integrating ICT in classroom depends largely on the readiness and acceptance of teachers. Hence, empirical evidence on the ICT readiness and acceptance among teachers is important in the integration of ICT in classroom. It is against this backdrop that the study sought to determine the level of ICT readiness and acceptance among teachers in VETs in Abuja, Nigeria.

3. Aim and Objectives of the Study

The study aimed at determining the level of ICT readiness and acceptance among teachers in VETs in Abuja, Nigeria. Specifically, the objectives of the study sought to determine:

- The teachers' level of ICT readiness in VETs in Abuja, Nigeria.
- The teachers' level of ICT acceptance in VETs in Abuja, Nigeria.

4. Research Questions

The following research questions were raised and answered to guide the study:

- What is the teachers' level of ICT readiness in VETs in Abuja, Nigeria?
- What is the teachers' level of ICT acceptance in VETs in Abuja, Nigeria?

5. Hypotheses

The following null hypotheses were formulated and tested at .05 level of significance to guide the study:

- There is no substantial dissimilarity between the level of ICT readiness of male and female teachers in VEIs in Abuja, Nigeria.
- There is no substantial dissimilarity between the level of ICT acceptance of male and female teachers in VEIs in Abuja, Nigeria

6. Methodology

The study used descriptive survey research design, specifically, using cross-sectional study. The cross-sectional study involves the collection of data from a population at one specific point in time (Maninder, 2016). This design enables the researchers to ascertain teachers' level of ICT readiness and acceptance at a time. 154 respondents comprising 91 male and 63 female teachers from all the six VEIs in the study area constituted the population of the study. The whole population of the study were selected using Total population sampling technique. The instruments used for data collection include Technology Readiness Index (TRI) by Parasuraman (2000) and Educational Technologies Acceptance Index (ETAI) by Martínez-Abad *et al.* (2019). The TRI consists of 45 items to determine teachers' technology readiness and the ETAI consists of 35 items to determine teachers' technology acceptance. The reliability index of the instruments were recorded as .89 and .90 using Cronbach's Alpha statistics. Mean was used to answer the research questions while the null hypotheses were tested using independent sample t-test. All data analysis were carried out using Statistical Package for Social Sciences (SPSS) version 25. The real limit of numbers was used to make decision on the research questions decision regarding the null hypotheses was based on comparing the generated p-value and the stated level of significance (.05).

7. Results:

7.1 Research Question One

What is the teachers' level of ICT readiness in VEIs in Abuja, Nigeria?

Table 1 contained data for answering research question one.

Table 1: Mean responses on the teachers' level of ICT readiness in VEIs in Abuja, Nigeria

				N1=91, N2=63
Items	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
1	2.39	2.50	2.44	Disagreed
2	2.35	2.50	2.41	Disagreed
3	2.38	2.44	2.40	Disagreed
4	2.37	2.46	2.40	Disagreed
5	2.35	2.47	2.40	Disagreed
6	2.37	2.41	2.38	Disagreed
7	2.36	2.47	2.40	Disagreed
8	2.35	2.50	2.41	Disagreed
9	2.41	2.50	2.45	Disagreed
10	2.42	2.53	2.47	Disagreed
11	2.36	2.53	2.43	Disagreed
12	2.31	2.57	2.42	Disagreed
13	2.35	2.50	2.41	Disagreed
14	2.35	2.49	2.40	Disagreed
15	2.31	2.53	2.40	Disagreed
16	2.34	2.44	2.38	Disagreed
17	2.32	2.50	2.40	Disagreed
18	2.31	2.55	2.41	Disagreed
19	2.38	2.55	2.45	Disagreed
20	2.41	2.52	2.46	Disagreed
21	2.39	2.47	2.42	Disagreed
22	2.35	2.47	2.40	Disagreed
23	2.36	2.41	2.38	Disagreed
24	2.35	2.44	2.38	Disagreed
25	2.32	2.44	2.37	Disagreed
26	2.35	2.41	2.37	Disagreed
27	2.34	2.44	2.38	Disagreed
28	2.32	2.47	2.38	Disagreed
29	2.39	2.47	2.42	Disagreed
30	2.41	2.53	2.46	Disagreed
31	2.34	2.50	2.40	Disagreed
32	2.29	2.53	2.39	Disagreed
33	2.32	2.50	2.40	Disagreed
34	2.32	2.47	2.38	Disagreed
35	2.31	2.50	2.39	Disagreed
36	2.32	2.41	2.36	Disagreed
37	2.31	2.47	2.38	Disagreed
38	2.30	2.52	2.39	Disagreed
39	2.37	2.52	2.43	Disagreed
40	2.40	2.52	2.45	Disagreed
41	2.39	2.50	2.44	Disagreed
42	2.35	2.50	2.41	Disagreed
43	2.38	2.44	2.40	Disagreed
44	2.37	2.46	2.40	Disagreed
45	2.35	2.47	2.40	Disagreed
Grand Mean	2.35	2.48	2.40	Disagreed

Keys: N_1 = Number of male teachers, N_2 = Number of female teachers, $\bar{X}_1$ = Mean response of male teachers, $\bar{X}_2$ = Mean response of female teachers, $\bar{X}_A$ = Average mean response of male and female teachers.

Table 1 revealed that male teachers had grand mean value 2.35 and female teachers had grand mean value of 2.48 with average grand mean value of 2.40. This indicated low teachers' level of ICT readiness in VEIs in Abuja, Nigeria.

7.2 Research Question Two

What is the teachers' level of ICT acceptance in VEIs in Abuja, Nigeria?

Table 2 contained data for answering research question two.

Table 2: Mean responses on the teachers' level of ICT acceptance in VEIs in Abuja, Nigeria

Items	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
1	2.39	2.50	2.44	Disagreed
2	2.35	2.50	2.41	Disagreed
3	2.38	2.44	2.40	Disagreed
4	2.37	2.46	2.40	Disagreed
5	2.35	2.47	2.40	Disagreed
6	2.32	2.41	2.36	Disagreed
7	2.31	2.47	2.38	Disagreed
8	2.30	2.52	2.39	Disagreed
9	2.37	2.52	2.43	Disagreed
10	2.40	2.52	2.45	Disagreed
11	2.34	2.50	2.40	Disagreed
12	2.29	2.53	2.39	Disagreed
13	2.32	2.50	2.40	Disagreed
14	2.32	2.47	2.38	Disagreed
15	2.31	2.50	2.39	Disagreed
16	2.38	2.36	2.37	Disagreed
17	2.37	2.39	2.38	Disagreed
18	2.36	2.42	2.38	Disagreed
19	2.42	2.42	2.42	Disagreed
20	2.42	2.52	2.46	Disagreed
21	2.39	2.47	2.42	Disagreed
22	2.35	2.47	2.40	Disagreed
23	2.36	2.41	2.38	Disagreed
24	2.35	2.44	2.38	Disagreed
25	2.32	2.44	2.37	Disagreed
26	2.36	2.53	2.43	Disagreed
27	2.31	2.57	2.42	Disagreed
28	2.35	2.50	2.41	Disagreed
29	2.35	2.49	2.40	Disagreed
30	2.31	2.53	2.40	Disagreed
31	2.34	2.44	2.38	Disagreed
32	2.32	2.50	2.40	Disagreed
33	2.31	2.55	2.41	Disagreed
34	1.38	1.55	1.45	Disagreed
35	2.41	2.52	2.46	Disagreed
Grand Mean	2.32	2.45	2.37	Disagreed

Table 2 revealed that male teachers had grand mean value of 2.32 and female teachers had grand mean value of 2.45 with average grand mean value of 2.37. This indicated low teachers' level of ICT acceptance in VEIs in Abuja, Nigeria.

- **Hypothesis One**

There is no substantial dissimilarity between the level of ICT readiness of male and female teachers in VEIs in Abuja, Nigeria.

Data for testing hypothesis one is presented in Table 3.

Table 3: T-test analysis for the testing substantial dissimilarity between the level of ICT readiness of male and female teachers in VEIs in Abuja, Nigeria

	Levene's Test for Equality of Variances		t	df	t-test for Equality of Means				
	F	Sig.			Sig. (2-tailed)	Mean Dissimilarity	Std. Error Dissimilarity	95% Confidence Interval of the Dissimilarity	
								Lower	Upper
Equal variances assumed	5.420	.021	-1.312	152	.192	-.11233	.08564	-.28154	.05687
Equal variances not assumed			-1.279	121.224	.203*	-.11233	.08782	-.28619	.06152

Table 3 revealed that the substantial (two tailed) value for the test of equality of mean with variance not assumed was .203 which is greater than the state level of substantial (.05). This implied that, there was no substantial dissimilarity between the level of ICT readiness of male and female teachers in VEIs in Abuja, Nigeria. Hence, hypothesis one was retained.

• Hypothesis Two

There is no substantial dissimilarity between the level of ICT acceptance of male and female teachers in VEIs in Abuja, Nigeria.

Data for testing hypothesis two is presented in Table 4.

Table 4: T-test analysis for testing substantial dissimilarity between the level of ICT acceptance of male and female teachers in VEIs in Abuja, Nigeria

	Levene's Test for Equality of Variances				t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Dissimilarity	Std. Error Dissimilarity	95% Confidence Interval of the Dissimilarity	
								Lower	Upper
Equal variances assumed	2.440	.120	1.405	152	.162	-.12454	.08864	-.29967	.05059
Equal variances not assumed			1.386	127.081	.168*	-.12454	.08983	-.30229	.05321

Table 4 revealed that the substantial (two tailed) value for the test of equality of mean with variance not assumed was .168 which is greater than the state level of substantial (.05). This implied that, there is no substantial dissimilarity between the level of ICT acceptance of male and female teachers in VEIs in Abuja, Nigeria. Hence, hypothesis one was retained.

8. Findings

1. The teachers' level of ICT readiness in VEIs in Abuja, Nigeria was low
2. The teachers' level of ICT acceptance in VEIs in Abuja, Nigeria was low
3. There was no substantial dissimilarity between the level of ICT readiness of male and female teachers in VEIs in Abuja, Nigeria
4. There was no substantial dissimilarity between the level of ICT acceptance of male and female teachers in VEIs in Abuja, Nigeria

8.1 Discussion of Findings

Finding on the level of ICT readiness among teachers in VEIs in Abuja was low. This entailed that the tendency of teachers in VEIs in Abuja to embrace and use ICT to accomplish teaching goals is minimum. The finding is similar to the findings of Summak *et al.* (2020) on technology readiness of primary school

teachers in Turkey that revealed teachers' technology readiness level was low. However, the finding differs from the findings of Badri *et al* (2014) in their study titled technology readiness of school teachers: An empirical study of measurement and segmentation that revealed 64.9 percent of participants are technology ready while 35.1 percent are not. The educational implication of this finding is that the integration of ICT in schools cannot be guaranteed.

Furthermore, result on the test for substantial dissimilarity between the level of ICT readiness of male and female teachers in VEIs in Abuja, Nigeria shows not substantial. This suggests that both male and female teachers in VEIs in Abuja shared the same level of ICT readiness. The result is similar to the findings of Summak *et al*. (2020) that shows no substantial dissimilarity between the mean responses of male and female primary school teachers in Turkey on their technology readiness. However, Badri *et al* (2014) revealed that male teachers demonstrated a higher overall technology readiness score than female teachers which signified that substantial dissimilarity was found in gender.

Finding on the teachers' level of ICT acceptance in VEIs in Abuja, Nigeria was low. This simply indicated that the growing interest of in integrating ICT into classroom among teachers in VEIs in Abuja is insubstantial. The findings of Cobo-Rendon *et al*. (2021) presented similar finding in their study titled longitudinal analysis of teacher technology acceptance and its relationship to resource viewing and academic performance of college students during the COVID-19 pandemic that found low technology acceptance among teachers. In order words, Timothy (2009) found high level of technology acceptance in education among pre-service teachers. The finding implies that using ICT to enhance the academic achievement of students in VEIs in Abuja is challenged.

Furthermore, finding on the test for substantial dissimilarity between the level of ICT acceptance of male and female teachers in VEIs in Abuja, Nigeria shows not substantial. This indicates that both male and female teachers in VEIs in Abuja shared the same level of ICT acceptance. The result is similar to the findings Cobo-Rendon *et al*. (2021) found no statistically substantial dissimilarities between male and female teachers' scores on technology acceptance. Though, the finding differs from the findings of Timothy (2009) that found substantial dissimilarity between the level of technology acceptance of male and female pre-service teachers.

9. Conclusion

Based on the findings from the study, insight into the level of ICT readiness and acceptance among teachers in VEIs in Abuja, Nigeria is provided. The study revealed that, both male and female teachers shared similar level of ICT readiness and acceptance. The findings of this study are particularly important for stakeholders in the development of framework for enhancing the ICT readiness and acceptance among teachers in VEIs in Abuja, Nigeria. However, it is concluded that if the identified low level of ICT readiness and acceptance among teachers in VEIs in Abuja, Nigeria is not properly managed, the integration of ICT in classroom can hardly be achieved.

10. Recommendations

Based on the findings from the study, the following recommendations were made:

- The Federal Capital Territory Administration should develop a framework for enhancing the ICT readiness and acceptance among teachers in VEIs in Abuja, Nigeria.
- The heads of VEIs in Abuja should encourage teachers by making the use of ICT compulsory in order to enhance their ICT readiness and acceptance.

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Information Communications Technology (ICT) as a factor enhancing Information Dissemination on Climate Change in Public Libraries in North – Central Nigeria

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Abstract

The study seeks to establish the indispensable role of ICT as a correlate to effective Information Dissemination on Climate Change in Public Libraries in North – Central Nigeria. The study was anchored on five objectives which are (1) To find out if they know about climate change; (2) to find out if they know about the associated problems of climate change; (3) to find out the ICT tools they can use in public libraries to disseminate information on climate change; (4) to find out how they can use the tools to disseminate information on climate change to their users; (5) to find out how disseminated information to their users with ICT tools can help in mitigating climate change problems. Total enumeration or census population technique was adopted, to use the total population of staff which were 242 according to retrieved copies of questionnaires. A hypothesis was tested at 0.5 level of significance and data was analysed using frequency tables and percentages and mean rankings. The hypothesis was analysed using Pearson product moment correlation coefficient to determine the relationship of the independent variable to the dependent variable. The findings from the objectives were that the ICTs were the only anchors on which Information on climate change, its problems and mitigations could be effectively disseminated. Based on all the findings of the study, it was concluded that the public libraries in North-Central Nigeria really need ICT tools to be able to disseminate climate change information to users.

Keywords: ICT, Information dissemination Climate Change, Public Libraries, North-Central Nigeria

1. Introduction

Climate change refers to long term changes in temperatures and weather patterns. The changes may be natural but since the 1800's human activities have been the causative issue affecting climate change. Climate change is a general term that describes the changes in the Earth's climates, at local, regional, or global scales, and can mean the results of these changes. In recent decades, climate change is most often used to describe changes in the Earth's climate driven mostly by human activities, since the pre-Industrial era, which is caused by burning of fossil fuels like coal, oil, and natural gas, which produce heat trapping gases. There is depletion of forests, causing fast abundance of carbon dioxide concentration in the Earth's atmosphere. Climate change is a general that describes changes in the Earth's climates, at local, regional, or global measures. It can also mean the results of these changes. According to Lawrence and Hassnot (2017) 'climate change' describes changes in the Earth's climate caused by human activity. Since the pre-Industrial period 1850 onwards, the burning of fossil fuels and removal of forests, caused fast increase in carbon dioxide concentration in the Earth's atmosphere.

Climate change is one of the 17 targets of sustainable development goals (SDG) goals precisely SDG goal 13 called Climate Action. The SDG goals were the footprint to attain a better and more sustainable future for all. They targeted the global problems like poverty, inequality, climate change, environmental degradation, peace and justice. It is a collection of 17 interlinked global goals designed to be a shared blue print for peace and prosperity of people and the planet, now and into the future. SDG13 is one of the 17 sustainable development goals established by the United Nations Assembly in 2015 and are intended to be achieved in 2030. Their mission statement: Is a shared blue print for peace and prosperity for people and the planet now and into the future.

Climate change is increasing the frequency and intensity of extreme weather conditions like heat waves, droughts, floods and tropical cyclones, and increasing water management problems, and depleting agricultural production and food security. Health risks are increased, critical infrastructure is destroyed and the provision of basic services as water, sanitation, education, energy and transport are paused. The current period of warming is occurring more rapidly than any past events. It is clear that humanity has caused all of the global warming by releasing heat-trapping gases commonly referred to as greenhouse gases to power our modern lives. Zarin et.al (2016) This is being done by burning fossil fuels, agriculture and land-use and other activities that trigger climate change. Greenhouse gases are at the highest levels ever since the last 800,000 years. This rapid rise is a problem because it's changing our climate at a rate that is too fast for living things to adapt to (Liu et.al. 2015)

Climate change involves not only rising temperatures, but also extreme weather events, rising sea levels, shifting wildlife populations and habitats, and other negative effects. There is an stunning scientific agreement that global warming is mostly man-made. Climate scientists have come to this agreement harmoniously. One of the biggest causes is by far the burning of fossil fuels – coal, gas and oil – which have increased the concentration of greenhouse gases such as carbon dioxide in the atmosphere. The use of fossil fuel results in production of massive quantity of carbon-dioxide. The carbon-dioxide increases the global warming resulting into climate change. It Increases size of arid areas and triggers dearth of food. Climate change affects the rainfall patterns, in addition to activities like clearing land for agriculture, which is resulting to increase in planet to temperature. Scientists are linking greenhouse gases and global warming like linking smoking and lung cancer.

Climate change is now altering every country in every continent. It is disturbing national economies and upsetting lives, costing people, communities and countries dearly today and even more tomorrow (Pecl, et.al, 2017). People are feeling the enormous effects of climate change, which includes changing weather patterns, rising sea level, and more intense weather activities. The greenhouse gas emissions from human activities triggering climate change and keeps rising and now at their highest levels in history. If care not taken, the world's average surface temperature is estimated to increase over the 21st century and is likely to go more than 3 degrees Celsius in this century. Some parts of the world is expected to warm even more. The poor and defenceless individuals are more largely hit by this problem (Pecl, et.al, 2017).

Other problems of climate change are that anthropogenic or green gas emissions as a result of environmental change triggered by people's activities directly or indirectly have risen since the pre-industrial era driven largely by economic and population growth, and are now higher than ever. The world is warming at a dreadful rate negatively tampering with our ability to grow food. Storms, floods hurricanes and droughts are escalating, oceans are warming and becoming more acidic, ice is disappearing, and the seas are rising. All countries must take all reasonable steps to reduce emissions to the full extent of their abilities, wealthy countries must lead the way, by decarbonising their economies faster, than developing countries. States must also take all needed measures to help everyone within their territory to conform to the foreseeable and unavoidable effects of climate change, thereby decreasing the effect of climate change on their human rights. This should be done whether or not the state is responsible for those impacts. States have duties to protect people from evils caused by climate change. Climate change problems must be handled, quickly and as humanely as possible. Afforestation is one practice that can help humanity.

Afforestation could be used to mitigate the impact of climate change. It is the establishment of a forest or stand of trees where no trees previously were. Many governments and non-governments organisations join in afforestation programmes to build forests and boost carbon capture. Afforestation can fight the challenge of global warming, soil erosion, pollution and maintenance of biodiversity and ecological balances. It can reduce atmospheric carbon -dioxide, increase soil quality to avoid or retrograde desertification. It also produce habitats to local wildlife, creates wind brakes, support soil health, and may improve water quality.

Cutting down on consumption of diaries products, meats and eggs, and going vegan is a great mitigation alternative It would recreate the carbon footprint and lower the bad impacts of diet in the environment. It can greatly bring down the environmental effect, bringing plant-based foods which bring in fewer greenhouse gas emissions'. Using renewable energy sources like solar, wind, and small hydro-carbon, help cities create viable transport like rapid transit, and electric vehicles. Another advantage of using renewable sources of energy is the capacity of the source to protect the population from the negative impact of environmental pollution to the society. Solar and wind power shields the society through low carbon-dioxide production. Renewable energy comes from sources the Earth can naturally refresh like crops and biomatter. Other areas of mitigation are walking, cycling, or taking public transport because the world's roads are filled with vehicles that are burning diesel or petrol. Walking or riding a bike instead of driving has the ability to reduce greenhouse emissions and also help health and fitness (Locateli. et.al 2015).

A lot have been discussed so far about climate change and some of its impacts, and mitigation measures, preliminary investigations from the researcher discovered that some individuals innocently do not know that a lot of the natural disasters like floods, heat waves, landslides global warming, desertification etcetera are as a result of climate change. They equally do not know that there is a phenomenal disaster called climate change in the World generally and then Nigeria and North-Central particularly. There is therefore dire need to disseminate climate change information to all and sundry in the whole country generally and in North-Central Nigeria

particularly. This cannot be done without the use of the public library which is called the layman's university because of its ability to accommodate all and sundry.

The public library is the local centre of information, making all kinds of knowledge and information readily available to its users. A public library is an organisation established, supported and funded by the community, either through local, regional or national government or through some other form of community organisation. It provides access to knowledge, information and works of the imagination through a variety of resources and services and is also available to all members of the community irrespective of race, nationality, age, gender, religion, language, disability, economic and employment status and educational inclination. Adebayo et.al (2018). The public library provides services based on equality of access for all, irrespective of age, race, sex, religion, nationality, language or social status. They also provide services and resources for users who cannot, for any reason, use the regular services and materials, for example, linguistic minorities, people with disabilities or people in hospital or prison. All age groups must find information resources pertinent to their needs. Resources and services have to include all necessary appropriate media and modern technologies as well as traditional materials. High quality and relevance to local needs and conditions are rudiments. Resources must reflect current trends and the growth of society, as well as the memory of human endeavor and imagination. Resources and services should not be subject to any form of ideological, political or religious censorship, nor commercial pressures. Gill et.al (2001) Dissemination of information especially climate information would not be very successful in the public library without the use of ICT tools. Adebayo et.al (2018).

The ICT tools are the latest technology or devices and concepts used in Information and Communication Technology in public libraries. Public library staff use many types of ICT tools to communicate, create, disseminate, store, and manage information. Information Communication Technology (ICT) continues to be a motivation in the issue of national advancement and development. Information, as power is effectively an infinite resource and a necessary tool needed for the evolution of all sectors in any country. It is therefore, imperative that use of ICT in libraries would go a long way in quenching the information needs of the citizens. It is worthy of note, that the emergence of ICT has impacted greatly on the quality of information provided through libraries. It also enables proper and adequate provision of library services to library users from all disciplines. In this 21st century, the drastic role of ICT in library operations cannot be over emphasized. Many library routines and operations that were initially performed manually are now being converted to computerised operations which means, applications of ICT techniques to providing better and faster services to the end users. Gill et.al (2001)

A nation without functional libraries and information centres may lack access to climate change information that would enable her sustainable development. In this era of globalization, in which the world is connected, information gains its power through permanent storage and wide distribution, which could be achieved through ICT. According to Janakiraman and Subramaniah (2015), the world now experiences a digital scenario in which ICT has changed the possibilities of the library job promotions and has brought changes to expected library performances. ICT is a generic term that refers to the technologies that are used to collect, store, edit and communicate

information in various format (Raji, 2018). The use of ICT improves access to digital information, narrows down the digital divide and also improves standard of living.

Adoption of ICT in libraries is a way of improving on information services provided in libraries. This is an era, when people need to access timely information with ease, and this can only be done through the application of ICT to library services. It is also a way of contributing to sustainable development of the nation, especially in the area of climate change information, since timely and effective provision of climate change information can assist in building up a society that is safer to live inside. ICT as an enabling tool, can assist libraries in provision of information on climate change which is very paramount to development of the various sectors in the nation concerning environmental factors and their implications for healthy living and safety in the nation.

ICTs help libraries to collect, process, retrieve and disseminate information that has to do with climate change. ICT equipment like CD-ROMs, E-mails could help in libraries to dissemination information on climate change. Digitization of information resources which includes converting print resources to electronic format is done , using ICT.

Other benefits of ICT in libraries as stated by Ashikuzzaman (2014) include:

- Giving fast and quick access to information.
- Giving access to users any time to lay hands on necessary information
- Enabling users access to bounty information from different sources like websites, internet, CD-Roms, and many others.
- ICTs help for easier, faster, cheaper and more effective library operations generally since Computers can be used for different activities like information generation, processing, storage, analysis and dissemination

Electronic Mail (E-mail) is largely used in the internet for sending and receiving of messages called mails. The mails are sent are by electronic devices. This ensures faster and cheaper means of electronic communication. Therefore climate change information could be processed by public librarians and sent into the mail boxes of public library users who can be anybody. Since the public library is the lay-man's university, such information would benefit the common man. The ordinary man does not know that cutting trees for firewood causes deforestation which is a causative negative impact of climate change.

World Wide Web (WWW) is an internet- based resource facility. Climate change information could be stored in Websites of the computers of the public libraries. Staff of the public libraries could send links of websites containing climate change information to their users This could assists individuals, organisations or institutions that are affiliated to public libraries find useful information on climate change especially as regards mitigation. Other important information on climate change could be given to users through the websites of other organisations or institutions that are climate change conscious. The web helps nations or organisations information retrieval to mitigate climate change.

Video Conferencing could be arranged to help people at different locations to hold conferences on issues that educate people on the dangers of climate change and possible mitigation means.

Data communication network is convenient as it does not require much financial expenses for conducting and organising conferences between two participants situated at remote locations (Mishra and Mishra, 2014).

Online Public Access Catalogue (OPAC): It is the computer form of library catalogue to access information materials in the library. It is an online database of materials held by a library or group of libraries. It is a computerised library catalogue made available to the public. Most OPACs are accessible over the internet to users all over the world (Mishra and Mishra, 2014). OPAC catalogues are available online and usually accessed freely. It is useful for finding books internationally for acquisition, and bibliographic data verification. The same applies to monographs and periodicals. OPAC could be very useful in locating information resources that would help deal with climate change and its mitigation.

Other ICT services a modern library uses for dissemination of climate change information are CD-ROM facilities, document supply services, CAS, SDI services, with the help of telecommunication technologies. Telephone, video text, facsimile or fax, library networks, online retrieval services could all be used in disseminating climate change information. information communication technology could assist in removing barrier of distance, time and boringness of manual efforts in library routines. The advancement in technology will continue to help libraries in assembling and disseminating information on climate change and possible mitigation. (Tekale, Veer & Rathod, 2010)

Libraries do well in helping to fasten access to global information and knowledge resources, ICTs are helpful tools used in giving of value- added information that help all the sustainable development programmes, and climate change specifically. Many institutions and organisations in addition to libraries meet many problems while trying to use ICTs to their services, but, giving information is important for the positive evolution of any country. It is therefore important that, efforts are made to enable usability of ICTs in all sectors of the nation especially as regards ICT and library services for information dissemination about climate change. It is based on the foregoing that the researcher decided to embark on this study to see how ICT in public libraries can enhance information dissemination on climate change in public libraries in North-Central Nigeria. Information and communication technology is the application of technologies consisting of hardware, software, network and media for collection, storage processing transmission and presentation of information in vocal, textual, pictorial and multimedia formats, (Igwe, 2011). ICT is a term used in the library to refer to application of computers and other technologies to library practices such as acquisition, storage, organization and dissemination of information. The world has become a global village and with ICT, many library users now have access to vast sea of information, without necessarily investing much time or energy. The process of generally and distributing information is now being facilitated through the use of ICT. This would help the dissemination of information about climate change.

Aina, Okunnu and Dapo-Asaju (2014) postulated that ICT is a term used to describe the ability to access information with the use of telecommunication -based Internet resources. ICT provides the ability to create, organize, manipulate and access information from remote locations across

the globe, within a short time. ICT involves incorporation of a range of technologies that are used to support communication and information dissemination. Saidu, Tukur and Adamu (2014) described ICT as the use of computer-based technology and internet for making information and communication services available to a wide range of users. The term is broadly used to refer to a range of technologies including telephones, e-mail and so on. Central to the range of technologies is the internet, which provides the mechanism for transporting data in a number of formats such as text, images, sound and video. ICT is system that enables information to be collected, analysed, processed and disseminated. information communication technologies (ICTs) are new technologies that cannot be ignored in Africa. ICTs are tools that must be employed to achieve and sustain development. The advent of ICT is indeed a boost the library services as it now assists many librarians to use their ICT potentials to reach out to library users as it concerns information dissemination on climate change.

1.2 Problem statement

Climate change affects everything from geopolitics to economies to migration. Climate change has many problems, some of the problems specifically identified with climate change are that climate change is increasing the frequency and intensity of extreme weather events such as hotter temperature, heat waves, droughts, floods, more severe storms, desertification, and tropical cyclones, aggravating water management problems, and reducing agricultural production and food security. Health risks are increased, critical infrastructure is damaged and the provision of basic services as water, sanitation, education, energy and transport are interrupted. The current period of warming is occurring more rapidly than any past events.

A reference to preliminary investigations shows that some public library staff do not know that some of the afore-mentioned identified problems of climate change were problems that humanity has been facing as result of climate change . The bigger and more worrisome problem is that people do not know that the global warming, heat waves, floods, high temperatures, to mention but a few are all the consequences and impacts of climate change. People also do not know that there are things they can do to mitigate the effects of climate change. There is urgent need to sensitise the people and government on the need to use the public library which is a layman's university to give the average Nigerian, information on climate change. Such information would be widely distributed to everybody if ICT tools of computer and all its accessories are used to distribute it globally over wires, wireless, and cables across networks, and all telecommunication devices. It is against this backdrop that the researcher decided to study Information Communications Technology (ICT) as a correlate to effective Information Dissemination on Climate Change in Public Libraries in North – Central Nigeria so that there would be good knowledge and information on climate change, mitigation and adequate preparedness in case of unforeseen future disaster so that humanity is not taken unawares.

1.3 Objectives

1. To find out if they know about climate change
2. To find out if they know about the associated problems of climate change

3. To find out the ICT tools they have in public libraries to disseminate information on climate change
4. To find out how they can use the tools to disseminate information on climate change to their users
5. To find out how disseminated information to their users with ICT tools can help in mitigating climate change problems

1.4 Hypothesis

One null hypothesis was tested in study at 0.05 level of significance

1. There is no significant relationship between ICT in public libraries of North- Central Nigeria and climate change with its associated problems.

2. Methodology

This study adopted descriptive survey correlation design which seeks to establish the relationship that exists between two or more variables. Direction and magnitude of the relationship between the variables was indicated which was found to be strong and positive, that is the effect of the independent variable on the dependent variable.

2.1 Population of the Study

The population of the study is the 251 public library staff in North-Central Nigeria

242 respondents returned their copies of questionnaire giving it a response rate of 96% there 96% representing the 242 represents 100% of the total population

Total enumeration technique or census technique was employed so as to use the total population of public library staff as respondents. This is because the researcher sees climate change problems impact and mitigation as an evil gospel that must be preached, so that humanity and biodiversity do not eventually go into extinction.

2.2 Data Collection or Research Instruments

The questionnaire was the main instrument for the study. It was designed under different research questions. The five point likert scale of Strongly Agree (SA), Agree (A), Strongly Disagree (SD) and Disagree(D) were used to determine the average responses of the respondents.

2.2.1 Validity and reliability of the instruments

In order to ensure face and content validity of the questionnaire two professors in the Department of Library and Information Science vetted the questionnaire even with the ASSU strike . It was pretested and corrected by administering some copies to library staff of National library Minna.

The Cronbach Alpha method was used to determine the reliability coefficients of each of the research questions. The values obtained were 0.84 for RQ 1, 0.81 for RQ 2, 0.75 FOR RQ 3, 0.72

for RQ 4 and 0.68 for RQ 5(RQ is Research questions.) Research questions were used to obtain the alpha values since the work had just two variables.

2.3 Method of data analysis

The data in the study with respect to the objectives were analysed using descriptive statistics of tables, percentages, frequency and mean, while inferential statistics of Pearson Product moment correlation coefficient was used to determine the relationship between the variables. The socio-demographic information and research questions were analysed using descriptive statistics of frequency, counts and percentages and means.

3. Result and Discussion

This section focuses on analysis and presentations of results, tables and graphs on the topic Information Communications Technology (ICT) as a correlate to effective Information Dissemination on Climate Change in Public Libraries in in north -central Nigeria". SSPSS 23 Statistical Statistical package was utilised in this research. A total of two and hundred twenty (251) copies of questionnaires were distributed to the seven public libraries in North Central Nigeria. Out of the two hundred and fifty- one (251) copies of the questionnaires distributed among the seven public libraries, two hundred and forty -two (242) copies were retrieved from the seven public libraries. They were valid for the purpose of the research, and this represent 96% returned rate; that is $[(242/251)*100 = 96\%]$ Table 2 shows the breakdown of the return rate.

Table 1: Public libraries in North- Central Nigeria with their staff population

S/NO	STATE	POPULATION
1	Benue State Library Board	46
2	Kwara	47
3	Nassarawa	25
4	Niger	36
5	Plateau	41
6	FCT	31
7	Kogi	25
	TOTAL	251

Table 2: Sex of the Respondents

Gender	Frequency	Percentage
Male	158	65.3
Female	84	34.7
Total	242	100

3.1 Objective one

Table 3: Do you know about Climate Change

A. There is hotter temperature globally as a result of global warming								
B. As a result of human activities heat trapping gases or green- house gases to power our modern lives have been released								
C. Since the past 800,000 years the green - house gases are at their highest levels								
statement	Strongly disagreed	Disagreed	Undecided	Agreed	Strongly Agreed	Weighted Sum	Mean	Rank
Q1A	0(0.00)	0(0.00)	8(3.3)	73(30.2)	161(66.5)	1119	4.63	1 st
Q1B	0(0.00)	0(0.00)	10(4.1)	118(48.8)	114(47.1)	1072	4.43	3 rd
Q1C	0(0.00)	0(0.00)	10(4.1)	94(38.8)	138(57.0)	1096	4.53	2 nd

From the Table 3, values in the parenthesis are percentages of the frequency counts. Ranks are allocated to each climate change information awareness based on the greater mean.

The result from table 3 shows the Climate Change information awareness among public library staff in North Central Nigeria. From the Table3, it is observed that in each case, larger percentage of the sampled respondents agreed to the statements in the table. The responses are ranked based on the higher values, from the result in the table 3, it is observed that the respondents ranked the statement *there is hotter temperature globally as a result of global warming* as first information about Climate Change among library staff in North Central Nigeria that has the highest level of awareness because of its highest mean of 4.63. Secondly they ranked the statement *since the past 800,000 years the green - house gases are at their highest levels* as second information about Climate Change among library staff in North Central Nigeria that has the second highest level of awareness because of its 2nd higher mean of 4.53 and lastly, they ranked the statement *as a result of human activities, heat trapping gases or green- house gases to power our modern lives have been released* in the studied area *as the information with the same level of awareness with statement 2 because it has the same mean of 4.53*. Thus, from the results, which answered the research question 1, they know about climate change but probably what they did not know was that the public library with aggressive use of ICT can be used to disseminate information concerning it to its users. They were not conscious of the fact that some of the ICT tools like Computers and other telecommunications -based internet resources can be used to give online reader advisory services to users about climate change. *Flash drives, WWW, video conferencing and the printing technology can be employed to store and disseminate climate change information to users who visit the library or routed to their Email*. Computers, OPAC, CD-ROMS, DVD'S, Smart phones, Printers, Scanners, Internet, Websites, Mobile Apps can be used to disseminate information on climate change and its associated problems.

3.2 Objective Two

Tab 4: What are the problems of climate change?

A. Nearly all land areas are seeing more than hot days and heat waves	
B. Higher temperatures, extreme weather events, shifting wildlife population and habits are problems of climate-change.	

C. Burning fossil fuels like coal natural gas and oil which has increased concentration of green- house gases like carbon-dioxide in our atmosphere are problems.

statement	Strongly disagreed	Disagreed	Undecided	Agreed	Strongly Agreed	Weighted Sum	Mean	Dec
Q2A	0(0.00)	0(0.00)	10(4.1)	70(28.9)	162(66.9)	1120	4.63	1 st
Q2B	0(0.00)	0(0.00)	10(4.1)	70(28.9)	162(66.9)	1120	4.63	1 st
Q2C	0(0.00)	0(0.00)	10(4.1)	94(38.8)	138(57.0)	1096	4.53	2 nd

From the table, values in the parenthesis are percentages of the frequency counts. Ranks are allocated to each climate change information awareness based on the greater mean.

The result from table 4 shows the problems of climate change in North Central Nigeria. From the table, it is observed that in each case, larger percentage of the sampled respondents agreed to the statements in the table. The responses are ranked based on their averages. From the result in the table, it is observed that the respondents ranked the statement *nearly all land areas are seeing more than hot days and heat waves statement A and higher temperatures, extreme weather events, shifting wildlife population and habits are problems of climate- change* 4.63 highest mean as first problems of climate change in North Central Nigeria. And lastly, they ranked the statement *Burning fossil fuels like coal natural gas and oil which has increased concentration of green- house gases like carbon-dioxide in our atmosphere are problems* as least problem in the studied area. Thus from the result, the research conclude based on the responses that Nearly all land areas are seeing more than hot days and heat waves, and higher temperatures, extreme weather events, shifting wildlife population and habits are bigger problems of climate- change in the study area because of their higher mean values of 4.63. These problems can be mitigated by dissemination of climate change information to users by the public library staff using ICT devices.

3.3 Objective 3

Tab 5. What ICT tools could be used to disseminate information on climate change and its problems?

A) Computers, OPAC, CD-ROMS, DVD'S, Smart phones, Printers, Scanners, Internet, Websites, Mobile Apps can be used to disseminate information on climate change and its associated problems SA| A| SD| D | U

(b) Scanners could be used to digitise information resources which involves converting print resources to electronic forms which is an ICT tool to send information concerning climate change across networks.

SA| A| SD| D | U

(c) flash drives, WWW, video conferencing and the printing technology can be employed to store and disseminate climate change information to users who visit the library or routed to their Emails. SA| A| SD| D | U

statement	Strongly disagreed	Disagreed	Undecided	Agreed	Strongly Agreed	Weighted Sum	Mean	Rank of statement
Q3A	0(0.00)	0(0.00)	10(4.1)	71(29.3)	208(86.0)	1119	4.62	2 nd
Q3B	0(0.00)	0(0.00)	7(2.9)	27(11.2)	208(86.0)	1166	4.78	1 st
Q3C	0(0.00)	0(0.00)	10(4.1)	71(29.3)	161(66.5)	1119	4.62	2 nd
4.68								

From the table, values in the parenthesis are percentages of the frequency counts. Ranks are allocated to each climate change information awareness based on the greater mean.

The result from table 4 shows that all the afore-mentioned ICT tools can be used to disseminate information on climate change by public library staff of North Central Nigeria. From the Table,4 it is observed that in each case, larger percentage of the sampled respondents agreed to the statements in the table. The responses are ranked based on their averages or means. From the result in the table, it is observed that the respondents ranked the statement(B)highest mean of 4.78, statement (C)*Flash drives, WWW, video conferencing and the printing technology can be employed to store and disseminate climate change information to users who visit the library or routed to their Email* as 2nd with mean of 4.62 statement(C), and statement (A) 2nd with mean of 4.62 .This shows all are ICT tools that can be used to disseminate information on climate change. Thus from the result, the research concluded based on the respondents that ICT tools used to disseminate information on climate change and its problems are: Flash drives, www, video conferencing and the printing technology can be employed to store and disseminate climate change information to users who visit the library or routed to their Email in the study area.

3.4 Objective 4

Tab 6: How further can these tools be used to disseminate information on climate change

A. Computers and other telecommunications -based internet resources can be used to give online reader advisory services on how to reduce the land clearing activities for agriculture, which causes deforestation and makes the average temperature of our climate to increase. B. Provision of web access to OPAC makes it easier for climate information to be supplied to users about acidity and global mean sea level, when it continues to rise as to the devastation and impact it will have on human life, human health, food, water, housing and livelihood. C. Provision of web access to OPAC makes it easier for climate information to be supplied to users about acidity and global mean sea level, when it continues to rise as to the devastation and impact it will have on human life, human health, food, water, housing and livelihood								
	Strongly disagreed	Disagreed	Undecided	Agreed	Strongly Agreed	Weighted Sum	Mean	Rank of Decision
Q4A	0(0.00)	0(0.00)	10(4.1)	24(9.9)	208(86.0)	1166	4.82	1 st
Q4B	0(0.00)	0(0.00)	10(4.1)	71(29.3)	161(66.5)	1119	4.62	2 nd
Q4C	0(0.00)	0(0.00)	34(14.0)	24(9.9)	184(76.0)	1118	4.62	2 nd
4.687								

From the table, values in the parenthesis are percentages of the frequency counts. Ranks are allocated to each climate change information awareness based on the greater mean.

The result from table 5 shows how further the listed tools can be used to disseminate information on climate change. The responses are ranked based on their averages. From the result in the table, it is observed that the respondents ranked the statement (A)highest with mean of 4.82 *Computers and other telecommunications -based internet resources can be used to give online reader advisory services on how to reduce the land clearing activities for agriculture, which causes deforestation and makes the average temperature of our climate to increase* as first tool that can be further used to disseminate information on climate change in North Central Nigeria. And lastly, they ranked the statements(B and C)2nd highest with means of 4.62 respectively, *Provision of web access to OPAC makes it easier for climate information to be supplied to users about acidity*

and global mean sea level, when it continues to rise as to the devastation and impact it will have on human life, human health, food, water, housing and livelihood. As least tool that can be further used to disseminate information on climate change in the studied area. Thus from the result, the research conclude based on the respondents that computers and other telecommunications - based internet resources can be used to give online reader advisory services on how to reduce the land clearing activities for agriculture, which causes deforestation and makes the average temperature of our climate to increase in the study area.

3.5 Objective 5

Tab 7: How can Information disseminated to users with ICT tools help in mitigating climate change problems

A. It will lower the use of fossil fuel of oil, natural gas and coal that cause global emission and concentrate more on wind, solar and other renewable sources B. Communities will become conscious of increasing afforestation to create forests since forests absorb carbon-dioxide which causes global warming C. Save energy at home by using LED bulbs and energy efficient electric appliances, hanging clothes to dry instead of using a dryer, walking or cycling instead of driving that would greenhouse gas emissions.								
	Strongly disagreed	Disagreed	Undecided	Agreed	Strongly Agreed	Weighted Sum	Mean	Dec
Q5A	0(0.00)	0(0.00)	9(3.7)	48(19.83)	185(76.0)	1143	4.71	1 st
Q5B	0(0.00)	0(0.00)	10(4.1)	94(38.8)	138(57.0)	1096	4.53	2 nd
Q5C	0(0.00)	0(0.00)	10(4.1)	94(38.8)	138(57.0)	1096	4.53	2 nd

From the table, values in the parenthesis are percentages of the frequency counts. Ranks are allocated to each climate change information awareness based on the greater mean.

The result from table 6 shows how Information disseminated to users with ICT tools help in mitigating climate change problems in North Central Nigeria. From the table 6, it is observed that in each case, larger percentage of the sampled respondents agreed to the statements in the table. The responses are ranked based on their means. From the result in the table, it is observed that the respondents ranked the statements in (A) highest with mean of 4.71 *it will lower the use of fossil fuel of oil, natural gas and coal that cause global emission and concentrate more on wind, solar and other renewable sources*. As first, on how Information disseminated to users with ICT tools help in mitigating climate change problems in North Central Nigeria. Statements in B and C with lower mean 4.53, Statements that *Communities will become conscious of increasing afforestation to create forests since forests absorb carbon- dioxide which causes global warming*, and *Save energy at home by using LED bulbs and energy efficient electric appliances, hanging clothes to dry instead of using a dryer, walking or cycling instead of driving that would greenhouse gas emissions* as least means on how Information disseminated to users with ICT tools help in mitigating climate change problems in the studied area. The result of the research concluded based on the responses that, Information disseminated to users with ICT tools help in mitigating climate change problems in North Central Nigeria : it will lower the use of fossil fuel of oil, natural gas and coal that cause global emission and concentrate more on wind, solar and other renewable sources in the study area.

Tab 8 Correlation Analysis Showing relationship between ICT and climate change with its associated problems

		Q5A	Q5B	Q5C
Q5A	Pearson Correlation	1	.408**	.748**
	Sig. (2-tailed)		0.000	0.000
Q5B	Pearson Correlation	.408**	1	.805**
	Sig. (2-tailed)	0.000		0.000
Q5C	Pearson Correlation	.748**	.805**	1
	Sig. (2-tailed)	0.000	0.000	

From the table Q5A, Q5B and Q5C are used to represent the following statements

- A. It will lower the use of fossil fuel of oil, natural gas and coal that cause global emission and concentrate more on wind, solar and other renewable sources
- B. Communities will become conscious of increasing afforestation to create forests since forests absorb carbon- dioxide which causes global warming
- C. Save energy at home by using LED bulbs and energy efficient electric appliances, hanging clothes to dry instead of using a dryer, walking or cycling instead of driving that would greenhouse gas emissions.

**** Correlation is significant at the 0.05 level (2-tailed).**

The result from table 7 shows the correlation analysis of relationship between ICT use in libraries for disseminating information on climate change with its associated problems. From the table 7 it is observed that there is significant positive correlation between ICT use in information dissemination on climate change with its associated problems in public libraries since their P-Values are all less than 0.05 level of significance, shows there is a strong positive relationship between use of ICT tools for information dissemination on climate change and its associated problems in public libraries in North-Central Nigeria, therefore the null hypothesis that says there is no significant relationship between Use of ICT for dissemination of information on climate change in public libraries is hereby rejected

3.6 Discussion of Findings Based on the Objectives

Objective question 1: sought to find out If the staff of public library in North -Central Nigeria know about Climate change

The study revealed that they know about climate change having agreed to all the questions that indicate the existence of climate change like there is hotter temperature globally as a result of global warming, As a result of human activities heat trapping gases or green- house gases to power our modern lives have been released, Since the past 800,000 years the green - house gases are at their highest levels and these statements are in consonance with the views of Lawrence and Hassnot (2017) about some characteristics of climate change. These characteristics of climate change can be publicised or disseminated with the use of ICT tools on climate change like CD-ROM's, OPAC catalogues, DVD'S, Smart phones, Printers, Scanners, Internet Websites etcetera. Mobile Apps can be used to disseminate information on climate change and its associated problems. Scanners could be used to digitise information resources on climate change which involves converting print resources to electronic forms which are ICT tools to send information concerning climate change across networks. flash drives, WWW, video conferencing and the printing technology can be employed to store and disseminate climate change information to users who visit the library or by it routing to their Emails. These statements are in

consonance with the views of Janakirame and Subra(2015), Aina and Dapo 2014 which are major contributions of the study to show that ICT tools could genuinely be used to disseminate climate change information

Objective 2: sought to find out If the staff of public library in North -Central Nigeria know the problems associated with climate change

The study revealed that that major problems includes but not limited to the fact that nearly all land areas are seeing more than hot days and heat waves, higher temperatures, extreme weather events, shifting wildlife population and habits are problems of climate change, burning fossil fuels like coal natural gas and oil which increased concentration of green- house gases like carbon-dioxide in our atmosphere are problems. These statements are in consonance with the views of Zarin et.al (2016) and Liu et.al 2015 as to what constitute some major problems of climate change. DVD'S, Smart phones, Printers, Scanners, Internet, Websites. mobile Apps can be used to disseminate information on climate change and its associated problems. Scanners could be used to digitise information resources which involves converting print resources to electronic forms which is an ICT tool to send information concerning climate change across networks. flash drives, WWW, video conferencing and the printing technology can be employed to store and disseminate climate change information and its problems to users who visit the library or by it routing to their Emails. These statements are in consonance with the views of Janakirame and Subra(2015), Aina and Dapo 2014 .The contribution to the study is that the aforementioned ICT tools could be used to disseminate information on climate change problems

Objective 3: sought to find out What ICT tools that could be used to disseminate information on climate change from the public libraries.

The study revealed that to disseminate information on climate change and its problems, the public library can use Computers, OPAC, CD-ROMS, DVD'S, Smart phones, Printers, Scanners, Internet, Websites. Mobile Apps can be used to disseminate information on climate change and its associated problems. Scanners could be used to digitise information resources which involves converting print resources to electronic forms which is an ICT tool to send information concerning climate change across networks. flash drives, WWW, video conferencing and the printing technology can be employed to store and disseminate climate change information to users who visit the library or by it routing to their Emails. These statements are in consonance with the views of Janakirame and Subra (2015), Aina and Dapo 2014 and the contribution to the study is that the ICT tools could genuinely disseminate information on climate change. The contribution to the study is that ICT tools can have a positive effect on climate change information dissemination.

Objective 4: sought to find out, how further the ICT tools can be used to disseminate information on climate change, The study revealed that;

Computers and other telecommunications -based internet resources can be used to give online reader advisory services on how to reduce the land clearing activities for agriculture, which causes deforestation and makes the average temperature of our climate to increase. Provision of web access to OPAC makes it easier for climate information to be supplied to users about acidity and global mean sea level, when it continues to rise as to the devastation and impact it

will have on human life, human health, food, water, housing and livelihood. These statements agree with the views of Saidu Tukur and Adamu (2014) The contribution to the study is that ICT tools can have a positive effect on climate change information dissemination thereby corroborating the title that ICT can be a major factor at enhancing climate change information dissemination.

Objective 5: sought to find out how Information disseminated to users with ICT tools help in mitigating climate change problems

The study revealed that;

It will lower the use of fossil fuel of oil, natural gas and coal that cause global emission and concentrate more on wind, solar and other renewable sources, Communities will become conscious of increasing afforestation to create forests since forests absorb carbon- dioxide which causes global warming , Save energy at home by using LED bulbs and energy efficient electric appliances, hanging clothes to dry instead of using a dryer, walking or cycling instead of driving that would greenhouse gas emissions. These statements agree with the views Adebayo et.al 2018 and Igwe 2011. The contribution to the study is that ICT tools can have a positive effect on climate change information dissemination as regards mitigation especially with incorporation of ICT tools like computers, OPAC, CD-ROMS, DVD'S, Smart phones, Printers, Scanners, Internet, Websites. Mobile Apps can be used to disseminate information on climate change and its associated problems and strategies for mitigation.

4. Conclusion

Based on all the findings of the study the public libraries in North-Central Nigeria really need ICT tools to be able to disseminate climate change information to users so that every body would know about climate change and its problems, so as to plan on how to mitigate them

4.1 Recommendations

Based on the findings of this research, the author makes the following recommendations

The funding authorities of all the public the North- Central Nigeria should as a matter of deliberate policy flood all the public libraries with all manners of ICT equipment that will expedite information dissemination of climate change Information,2 sensitise people on the problems they cause which is plaquing humanity, and (3) sensitise people on how to go about mitigating these problems (4) The public library staff should also add the usage of mass media for adequate information dissemination on climate change and its mitigation.

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Massive Open Online Courses Adoption Model for Corporate Training in the South African Private Sector

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Abstract.

Massive Open Online Courses (MOOCs) are free online courses available for different categories of learners to enrol on different courses of their choice that allow them unrestricted participation. MOOCs provide a platform for interactive forums and is essentially known for self-paced learning, flexibility, and interactivity. However, for MOOCs to be well acknowledged by all learners regardless of their social economic backgrounds, they should be provided at platforms that provide a good learning experience at low bandwidth and offline. Much as this is so, fewer organizations have leveraged MOOCs for corporate training to enrich their employees needs and customized to fit their environments. The main aim of this study was to develop a model for the adoption of MOOCs for corporate training in private sector which model will help to serve as a proper guideline and support to enable organizations to use it for training purposes to enhance skills needed for effective execution of duties. Several private organizations were used for data collection and data was quantitatively analysed. The model was validated using inferential statistics and descriptive analysis. The results indicated that perception and attitude toward technology, teaching styles, and technology control are key influencing variables of MOOCs for corporate training. This study contributes in extending the importance of MOOCs for corporate training. By developing a model to address the adoption and use of MOOCs for corporate training, provide insights into the appropriate MOOCs platforms, and develop guidelines for corporate training in all organisations.

Keywords: MOOCs, Distance education, Learning in the private sector, Online learning

1. Introduction

Information and communication technology (ICT) have turned out to be typical element in aspects of life. The advancements in the utilization of the electronic media has influenced people's lives and this has no exception to education. The use of Information technology (IT) in education includes but not limited to support for instrumentation and services, policy development, coaching and capability building, academic content, distance learning, digital acquirement and skills development, observation and evaluation, and analysis and development activities. The increasing use of personal computers (PCs) and the advent of the internet for enhancing the nature of training by making education more applicable to life, has been viewed as a perfect model by educational institutions.

The use of MOOCs for workplace training and learning has not yet been extensively researched. Researchers such as (Wang, Paquette & Baker, 2014; Mullen, Byun, Gadepally, Samsi, Reuther & Kepner, 2017) allude that there is a limited number of research that has been conducted to address MOOCs adoption and actual usage especially in corporate organizations. This calls for

more research of MOOCs adoption for corporate training. More so organizations need to have proper guidelines that enable them to have successful adoption of MOOCs.

Karnouskos (2017) indicates that the use of MOOCs needs intensive understanding and continuous support, alluding that much as this is so, there is still fewer models that have been designed to inform its adoption, especially for corporate training. Additionally, Oyo and Kalema (2014) also indicate that the increasing debate on the use of technology for teaching and learning has left the MOOCs adoption and usage debate unattended to. From this understanding, the technology gap of MOOCs adoption for corporate training, the study therefore sought to design an appropriate model that could be used by organizations to develop competencies through corporate training. The contribution of this study is model for corporate MOOCs adoption for training in the South African private sector

2. Related Work

Different studies (Kerr, Dale, and Gyurko, 2018 ; Antonaci, Henderikx, and Ubachs, 2021) developed a design frameworks for an adaptive MOOC that complements the MOOCs format with blended learning. The design frameworks consists of a design model and a series of learning design principles which can be used to design in- service courses for teacher professional development. The frameworks has been evaluated by alpha-testing and beta-testing, and the relationship between design principles and the intended, the implemented and the attained designs has been analysed. The recommendation system is supplemented by a 90 minutes guidance session with a teacher in order to further support the technical recommendation system. During the guidance session, the student's self-assessment is reviewed, and the teacher provides additional guidance on how to choose from the adaptive themes and navigate within the MOOC platform.

Ziegenfuss, Furse, Sykes and Buendía (2019) carried out a study to evaluate the design and implementation of an international faculty development MOOC about flipped teaching. Qualitative and quantitative data, such as traditional MOOC analytics, interviews, and Concerns-Based Adoption Model (CBAM) survey data, were collected as respondents learned how to flip instruction. This study indicates that measures of online engagement, such as number of clicks and number of online discussion posts, do not necessarily translate into a change in attitudes about teaching practice. Adult respondents (teachers, faculty, and researchers) in this MOOC presented as strategic learners and applied personalized approaches for their own teaching development while learning in a MOOC.

MOOCs researchers such (Azevedo & Marques, 2017; Dousay& Janak, 2018; Pant, Lohani and Pande, 2021) highlight several factors that are essential for its successful MOOCs adoption and usage. They indicate that adoption of MOOCs is governed by the diversity' of approaches that MOOCs respondents have when engaging with its activities. This allows MOOCs to be relevant to people with different organizational cultures, technological backgrounds, varying technological infrastructure, learning styles, and other distinctive characteristics. The studies also indicated that perceptions of the users, such easiness to use and usefulness of MOOCs, play a critical role for its adoption.

3. The MOOCs concept

The idea of MOOCs was developed with an intent to resolve challenges associated with accessibility of higher education. MOOCs have been essential in expanding access, marketing and branding of educational courses and pedagogies as well as a source of revenue for higher education (Yuan & Powell., 2013). MOOCs have recently received a great deal of attention as they promote learning in virtual environments as well as supporting connectivity as a learning theory for the digital age (Zur & Friedl, 2021). Similarly, MOOCs also support the generative theory by allowing collaborative learning with digital technologies and open educational resources (Dousay & Janak, 2018).

With the advancement of instructive assets both in industry and colleges, MOOCs have quickly moved into a position of significance within organizations and in people's daily lives. For instance, with respect to 21st Century abilities, learning at work must be a constant and profoundly individualized process (Kang, Cha & Ban, 2018). This implies that with MOOCs organizations can customize the learning content to specifically benefit their employees. Self-directed learning in the working environment is increasingly becoming significant, more especially when formal and casual learning can be consolidated (Zur & Friedl, 2021).

4. Factors influencing adoption of MOOCs

This study identified the factors that influence the adoption of MOOCs for corporate training as an online educational technology to support employees training. A review of the literature indicated that there are several models/theories of technology adoption, such as the Theory of Reasoned Action (TRA), the Theory of Planned Behaviour (TPB), Social Cognitive Theory (SCT), the Technology Acceptance Model (TAM) and others. The current study adapted the Technology, Organization and environment (TOE), Diffusion of Innovation (DOI) and MOOCs analysis theory (MAT) for the theoretical framework; the reason for this choice is explained in the next section.

According to the TOE theory, the process by which a firm adopts and implements technological innovations is influenced by the technological context, the organizational context, and the environmental context (DePietro, Wiarda, & Fleischer, 1990). These three elements present "both constraints and opportunities for technological innovation". Thus, these three elements influence the way a firm sees the need for adoption of new technology.

Diffusion of innovations is a theory that seeks to explain how, why, and at what rate new ideas and technology spread. The DOI Theory, developed by Rogers (1995), is one of the oldest social science theories. It originated in communication to explain how, over time, an idea or product gains momentum and diffuses (or spreads) through a specific population or social system.

The employee's perception within the MOOCs must be considered when assessing their adoption and usage. This study aimed to reflect on factors that influences the adoption of MOOC to propose an analysis framework of MOOC adoption (MOOCs Analysis Theory) (Azevedo & Marques, 2017). According to Yang et al. (2017), the employees' decision of continuance in MOOC seem to be influenced by several factors, such as: system quality, that is, the functionality and reliability of the MOOCs supporting technologies. The context of MOOC, the data collection and analysis techniques will allow to test and refine the framework, which is of particular importance since

there is a scarcity of empirical research on the MOOC phenomenon particularly considering the respondents' perspectives (Gamage, Fernando, & Perera, 2015).

When considering the adoption and usage of MOOCs for corporate Training, additional factors need to be considered. The study then follows other researchers by extending the theories to study technology adoption in the context of e-learning, and uses these 3 theories namely: TOE, DOI and TAM, with relevant variables found to be significant in MOOCs adoption and use. There are other variables that are used to extend our theories since they have been found to be significant in influencing MOOCs adoption and use from several studies. This study explored different factors and categorized them in four categories namely, technology, organization, individual and social as indicated in table 1 below.

Table 1: Factors influencing technology adoption

TECHNOLOGY	ORGANIZATION	INDIVIDUAL	SOCIAL
Infrastructure	Scale of Massiveness	Trust,	Learning custom
Network Reliability	Policies	Awareness	Networks' effect
Hardware	Technological Support,	Attitude	Guidance
Software	Funding,	Motivation	Exposure
Internet Quality	Credits Recognition	Experience	
Technical Support	Openness	Behaviour	
System Quality	Change Management		Online Course Conditions
Online Platform			Proper help and Assistance
Perceived Ease of Use			Internet Infrastructure Proper User Interface

4. Conceptual Model

From the three underpinning theories discussed above, the conceptual model for this study was derived. In the conceptual model, the technological factor was reconceptualized into two different perspectives namely, users' perception towards technology and the technological characteristics. The users' perception towards technology included relative advantage, complexity and cost whereas the technological characteristics included compatibility, reliability, scalability and security. On the other hand, the organizational and environment factors were only presented with their subconstructs without further categorizations. The same applied to the pedagogical and behaviour intention. The conceptual model was developed as shown in Figure 1 below.

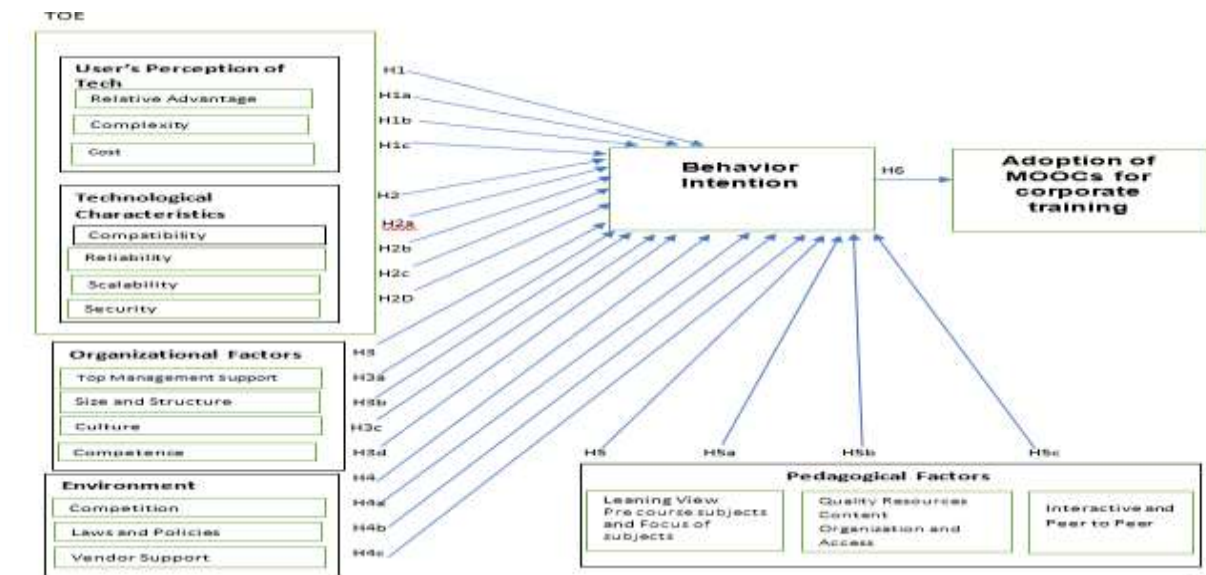


Fig 1: The Conceptual Model

4.1 Hypothesis development

As illustrated in figure 1 above, six hypothesis were created with technological factors having seven sub-hypotheses where three were for users' perception towards technology and four for technological characteristics. The organizational factors had four sub hypotheses and the environmental factor had three. On the other hand, the pedagogical factors had three sub hypotheses.

5. Research design and Methodology

This study sought to develop a model for the adoption of MOOCs for corporate training. Literature was reviewed extensively on corporate MOOCs, available MOOCs platforms and success factors on the adoption of MOOCs for corporate training. From the reviewed literature, a conceptual model was developed based on which the hypotheses were developed. Because of the nature of data intended to be collected, this study followed a quantitative approach to collect data from several organizations using a close-ended questionnaire. Individual respondents were selected by using inclusive sampling where all employees in each business unit within Glencore

mines were requested to participate in the study. Statistically this leads to about 50 respondents from each operation. Since this study is quantitative, six business units were selected to achieve an agreeable statistical sample for a quantitative approach (Hair, Ringle & Sarstedt, 2013). From the six business units of approximately 50 employees, a population of the study was estimated to be 300 respondents. Hence by using the Krejcie and Morgan's (1970) tool for determining sample sizes for finite population, for the six business units with over 300 employees a sample size of 175 was targeted as the minimum. Because of the nature of data intended to be collected, questionnaire with close-ended questions was used. Basing on Creswell (2018), a questionnaire was used to provide evidence of patterns amongst larger sample to support the secondary data collected from the literature. This enabled the study to identify and describe the variability in different factors. Data for the survey was collected using closed-ended questionnaire.

The questionnaire used in the study was considered reliable because the alpha coefficient was 0.949 which is greater than the minimum required value of 0.7 (Pallant, 2020). The study targeted professional who were involved in the training and usage of training services and systems due to their awareness of the functions and procedures involved in training and system services delivery. The largest number of contributions in terms of departments were business systems which made up 18.89% of the respondents. A good number in general followed with 18.33%. General administration contributed 15.56%. Human resource and data management departments followed with 11.67% each. A small number of contributions came from human resource development with 8.5% project activation with 0.8% and senior programme managers with 0.8%. All these roles are involved in the development lifecycle and that suggests that they are aware of development methodologies being used in their organizations and in the IT industry.

5.1 Regression Analysis

Regression is a statistical method of identifying which variables have impact on a dependent variable that signifies the topic of the study. Hair et al. (2013) allude that regression analysis allows a researcher to confidently determine which variables matter most, which one can be ignored, and how the involved variables influence each other within the study. Table 2 illustrates the model summary that shows the overall performance of the regression model and its overall prediction to the adoption of MOOCs for corporate training.

Table 2: Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.853 ^a	.727	.628	.69003	.727	3.944	18	161	.000

a. Predictors: (Constant), BI, Sec, ORGTMS, EnvCompn, Rel, Cost, EnvVS, ORGCul, EnvLPGF, ORGSS, Scal, RA, COMPY, ORGCompce, PEDLV, PEDInter, PEDQR, COMPX

18 independent variables that were suggested to have an influence on the adoption of MOOCs for corporate training, 12 were found to be significantly influencing whereas the six were not as illustrated in figure 3 below. On the other hand, the testing of the multicollinearity using

the variance inflation factor (VIF) indicated that all the values of VIF were less than 10 which showed that multicollinearity did not exist. According to Hair et al. (2013), a construct is said to have a significant contribution to the overall prediction of the model if its critical ratio is ($-1.96 \leq t\text{-value} \leq +1.96$) and p-value is $< .05$.

Table 3: Regression analysis coefficients

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
1 (Constant)	1.475	.566		2.607	.010		
RA	.260	.122	.127	2.129	.026	.340	2.944
COMPX	.724	.346	.737	2.094	.038	.335	2.985
COMPY	.088	.148	.083	.599	.550	.322	3.105
Cost	-.208	.105	-.069	-1.984	.045	.422	2.370
Rel	.004	.106	.005	.042	.967	.350	2.854
Scal	.199	.155	.142	1.282	.202	.352	2.842
Sec	.132	.120	.112	1.098	.274	.413	2.422
ORGTMS	.326	.123	.167	2.651	.016	.402	2.490
ORGCul	.900	.179	.732	5.030	.000	.304	3.289
ORGCompce	1.107	.248	1.124	4.454	.000	.468	2.137
ORGSS	-.258	.130	-.108	-1.988	.040	.265	3.770
EnvtCompn	1.025	.340	.908	3.017	.003	.348	2.384
EnvtVS	-.113	.100	-.118	-1.139	.256	.401	2.495
EnvtLPGF	.176	.129	.164	1.359	.176	.297	3.364
PEDLV	-.789	.192	-.687	-4.113	.000	.454	2.204
PEDQR	-1.643	.299	-1.631	-5.490	.000	.349	2.865
PEDInter	-.866	.413	-.730	-2.100	.037	.336	2.976
BI	.140	.042	.404	3.345	.018	.348	2.873

a. Dependent Variable: MOOCsAdoption

5.2 Discussion and interpretation of the findings in relation to the hypothesis

The first hypothesis **H1**: Users' perception towards technology when mediated by behaviour intention influences MOOC adoption for corporate training. This hypothesis was **Accepted**. Perception and attitude toward technology, teaching styles, and technology control also influence adoption. This is supported by (Bahar & Asil, 2018) which identified instructor's characteristics that include timely response, self-efficacy, technology control, focus on

interaction, attitude toward e-learning, attitude toward students, distributive fairness, procedural fairness, and interaction fairness.

H1a: Relative advantage when mediated by behaviour intention influence MOOC adoption for corporate training. This hypothesis was **Accepted**. This finding indicates that when adopting a technology, comparison should be made to see its benefits and advantages over the systems that was in place before. The results of this study support that of Yang et al. (2017), who stated that a higher relative advantage offered by a technology /innovation /system will have a positive association with its adoption.

H1b: Complexity when mediated by behaviour intention influence MOOC adoption for corporate training. This hypothesis was **Accepted**. Complexity has been identified as a key factor that influences a user's decision to accept or reject a new technological innovation (Tahrini, Arachchilage, Masa'deh & Abbasi, 2015). This implies that individuals will be attracted to technological innovations they perceive as easy to use and will be less eager to use those that they perceive as difficult to use.

H1c: Cost when mediated by behaviour intention influences MOOC adoption for corporate training. This hypothesis was **Accepted**. This finding implies that cost savings is a key benefit of MOOCs adoption. This is so since MOOCs are free, and learners may register and complete a programme without paying any money. MOOCs development themselves do not confirm a cost-saving benefit, at least not at an early stage of adoption (Zur & Friedl, 2021).

H2: Technological characteristics when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Rejected**. The findings of this study are contrary with those of other researchers such as (Al-Araibi et al., 2016 ; Al-Fraihat et al., 2017) who alluded that rich medium is one that allows for both synchronous and asynchronous communication and supports a variety of didactical elements.

H2a: Compatibility when mediated by behaviour intention influences MOOC adoption for corporate training. This hypothesis was **Rejected**. This means that perceived compatibility is not a significant factor on the adoption of MOOCs. The implication of this findings supports what other researchers such as Namestovski et al. (2018) indicated that most recent systems are developed to operate on various platforms, which has rendered the compatibility factors to be less significant in the adoption of many technological innovations. However, other researchers such as (Rogers, 1995; Dousay & Janak, 2018) indicate that perceived compatibility had a significant optimistic influence on adoption of MOOCs.

H2b: Reliability when mediated by behaviour intention influences MOOCs adoption for corporate training. This hypothesis was **Rejected**. The implication of this finding is that being an online system, the availability and reliability of MOOCs will entirely depend on the availability of the internet. This makes MOOCs to be dependent of the internet and to be less influenced by the reliability as a variable. However, the findings of this study are contrary to the findings of

researchers (Jouicha, Berrada, Bendaoud, Machwate, Miraoui & Burgos, 2020) who indicated that reliability plays an important role in the MOOCs adoption.

H2c: Scalability when mediated by behaviour intention influences MOOCs adoption for corporate training. This hypothesis was **Rejected**. The finding implies that scalability as measure of a system's ability to increase or decrease in performance and cost in response to changes in application and system processing demands is dependent on internet space provided by the internet service providers. The findings of this study are not in agreement with those (Jouicha et al., 2020) who emphasized the importance of scalability in technology adoption.

H2d: Security when mediated by behaviour intention influences MOOCs adoption for corporate training. This hypothesis was **Accepted**. The findings of this study are in agreement with those of (Marques & Azevedo, 2017; McGill et al., 2014) who alluded that security also goes hand in hand with awareness and sensitization of users and that without awareness users may have different concerns such as trust, security, privacy, and effort expectancy of the system.

H3: Organizational factors when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Accepted**. Management needs to buy-in and also support IT budgets for successful adoption of a technological innovation. The findings of this study also support those of other previous researchers such as (Dousay & Janak, 2018; Yang et al., 2017), who alluded that MOOCs by nature do not charge users who are taking the courses, so the organizations need to find the feasible strategies to maintain sustainability implying that in the adoption of MOOCs, organizational factors play a core role. Hence, funding and change management are vital in the successful adoption of MOOCs.

H3a: Top Management support when mediated by behaviour intention influences MOOCs adoption for corporate training. This hypothesis was **Accepted**. This implies that without top management support and buy-in, there will always be a conflict between IT objectives and organization's business goals. The findings of this study support those of (Alharbi & Lally, 2017) who indicated that top management support as the involvement and participation of top-level leaders is critical for any innovation within an organization.

H3b: Organizational size and structure when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Accepted**. The findings of this study are in agreement with those of Barteit et al. (2018) who allude that the major issue in MOOCs adoption is the consideration of the size of an organization, and that there is a need for better organizational support technically as MOOCs will run basing on the internet and if poorly planned to may fail to satisfy large organization settings.

H3c: Culture when mediated by behaviour intention influences MOOCs adoption for corporate training. This hypothesis was **Accepted**. The findings of this study are in agreement with those of (Barteit et al., 2018 ; Alharbi & Lally, 2017) who indicated that adoption of any IT system may come with changes which do not only need to change the business process but also the culture of the organization, social setting and the way people behave. Putting that into consideration, organizations need to prepare themselves well in advance for change in culture to avoid confusion and resistance to adoption of a technological system.

H3d: Organization's competence when mediated by behaviour intention influences MOOCs adoption for corporate training. This hypothesis was **Accepted**. Organizational competencies are those competencies needed in the organization that will lead it to excel and remain competitive in the market. The findings concur with Kerr, Dale & Gyurko (2018) who also alluded that competence is essential for making sure that organizations have consistent performance standards for employees, which can help with employee engagement and retention and such is key to innovation's adoption success.

H4: Environmental factors when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Accepted**. Environmental factors are related to social or external factors which may influence the technology adoption and implementation behaviour. This finding concurs with Barteit et al. (2018) who indicated that environment factors when coupled with availability of financial support and management's commitment, poor infrastructure, and personal challenges, may impede success of a technological implementation.

H4a: Competition when mediated by behaviour intention influence MOOCs adoption for corporate training. The hypothesis was **Accepted**. MOOCs, like any other e-learning innovation, is intended to boost knowledge through teaching and learning. This implies that MOOCs for corporate training will improve employee's competencies and skills, making its implementing organization very competitive. This finding of this study is in agreement with those of Alharbi and Lally (2017) who indicated that corporate training MOOCs are tailored to fit the organization's goals and objectives and once employees utilize them, such an organization will achieve a competitive advantage.

H4b: Laws and policies when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Accepted**. This finding is in line with Kasse and Balunywa (2013), who noted that lack of skills and sufficient human capacity contributes to low e-learning implementation as these will impact on the proper following of set laws, policies, standards, and procedures. Policies are needed for guidance in running organizational programmes and also in aligning the IT objectives with the strategic business goals.

H4c: Vendor support when mediated by behaviour intention influences MOOCs adoption for corporate training. This hypothesis was **Accepted**. This finding is in support of Dousay and Janak. (2018); Ma & Lee. (2019) who noted that vendors' readiness to provide support to adopting organizations is a key factor in technology adoption and implementation.

H5: Pedagogical factors when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Accepted**. The findings of this study are in agreement with those of Sigama and Kalema (2018) who noted that having a well-thought-out pedagogy improves the quality of teaching and learning, which is one of the key requirements for online learning as it helps learners gain a deeper grasp of fundamental material.

H5a: Learning view, focus of subjects and pre course subjects when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Accepted**. This finding of this study concurs with Al_Rahmi et al. (2021) who also alluded that pedagogical issues, such as focus of subjects, quality resources, timing, and flexibility, are amongst the key factors that need to be paid attention to if MOOCs are to be adopted and implemented successfully.

H5b: Quality resources, content organization and access when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Accepted**. These results support studies such as (Zur & Friedl, 2021; Al-Fraihat et al., 2017) which argued that quality of resources includes the provision of learning materials with the content, which is relevant and up-to-date, and those factors are key in MOOCs adoption.

H5c: Interactivity and peer-to-peer when mediated by behaviour intention influence MOOCs adoption for corporate training. This hypothesis was **Accepted**. The finding is in agreement with those of researchers (Al-Araibi et al., 2016; Al-Fraihat et al., 2017) who also alluded that a rich medium is one that allows for both synchronous and asynchronous communication and supports a variety of didactical elements.

H6: Behaviour intention influences MOOCs adoption for corporate training. This hypothesis was **Accepted**. This finding studies like (Kwon & Zmud, 1987; Rogers, 2005) which have cited individual behaviour as a cause of acceptance or resistance of the innovations. Figure 2 above shows the final deduced model with the rejected hypotheses excluded.

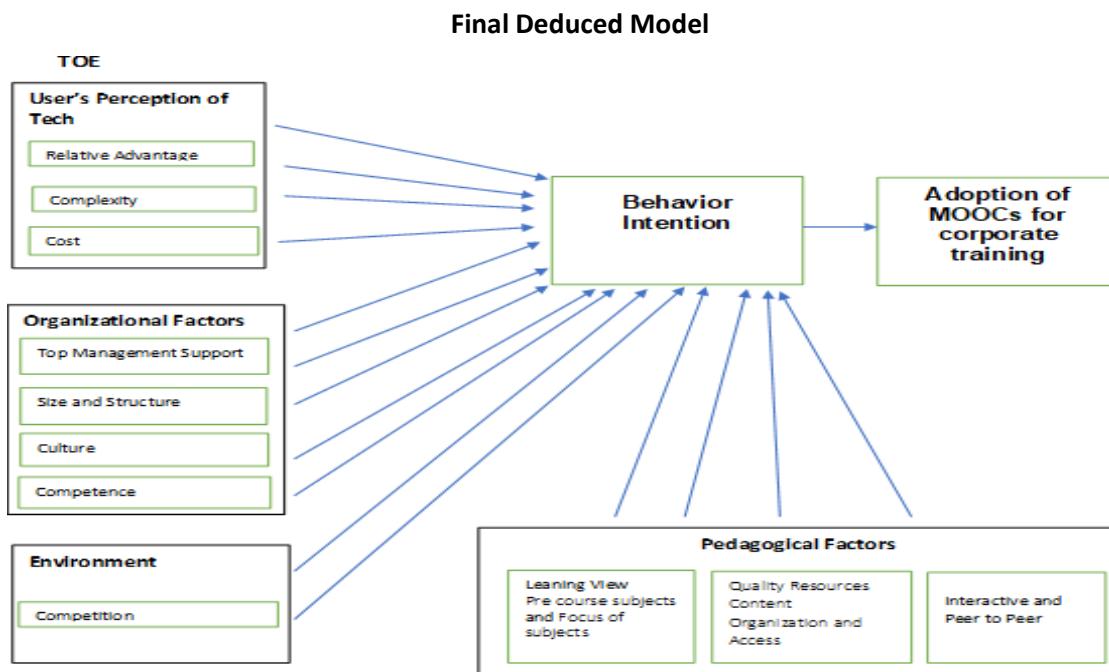


Figure 2 : The Final Model

5. Contributions

The study realizes the existing gap from the literature by building in the theory and developing a model to address the adoption and use of MOOCs for workplace training. The study observed and depicted current research trends in MOOCs, hence it acknowledges that little or no research has been conducted for the use of MOOCs for corporate training and as results there is still lack of an appropriate model. Furthermore the study used empirical evidence to develop the corporate MOOCs adoption model. The observed evidence and literature collected in this study

are of a significant contribution to the private sectors using MOOCs for training and development. These findings provide insights into the appropriate MOOCs platforms needed for corporate training in all organisations. With this appropriate model or guidelines developed, the study contributes and acts in as a reference point for organizations and businesses that want to utilize MOOCs for corporate training.

6. Recommendation

Research by quantitative method, could not fully explore the problem of the application and use of technology for training purposes. Therefore, it is recommended that a qualitative study with data collection methods like interviews and open-ended questionnaire carried out in the future to provide more comprehensive results in technology developments and training.

The empirical advantage is that both qualitative and quantitative methods can be used with confidence to discover and identify new constructs to be included in the develop of the model to exploit the adoption and usage of MOOCs in a corporate world. The current research has shown that the experience or sense of usability is qualitatively different for different groups, and if so, it would be helpful to have a choice of categories or categories appropriate for each context.

7. Conclusion of the study

The ever-changing and rapidly changing training and learning needs, technological transformation, and growth, and change and advancement in business drive organizations to remain competitive in the world of technology and business. The need to provide quality internal training and learning to employees is of great importance to organizations. The online learning method has been revolutionary in providing quality learning faster and faster. The objective of the study was to determine the factors influencing the adoption of MOOC for corporate training as an online education technology to support employee training. Several factors have been identified, discussed, and examined that positively contribute to the adoption of MOOCs for corporate training.

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Leveraging Technological Innovation and Creativity in Music Industry: A Case Study of Windhoek 'Backyards' Music Studios

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Abstract

Technology revolutionised the music industry and, consequently, many music entrepreneurs thrived. The study surveyed the working life of 18 early career music makers and promoters. The purpose of the survey was to examine information on the artists' and producers' perspectives on the use of technology and challenges in music production in Windhoek 'backyard' music studios. This information is crucial as it is presently lacking. This study investigated the creative and innovative use of technology in music recording in Windhoek's informal settlements, Namibia. To this end, it presents the results of ethnographic observations and semi-structured interviews about technology use in Katutura informal settlements. A qualitative research approach informed the study. The ethnographic observations precisely focused on the artists and producers' day to day musical activities and technological practices. It was also imperative to survey their time management and social media engagement. The study identified and examined several distinct technologies used in music production and distribution. Notably, Digital Audio Workstations and digital devices or gadgets (Computers, Headphones, Microphone, MIDI-Controller, Amplifier and Studio monitors). Through the findings of the investigation, it can be concluded that currently internet, social media and Namibian owned digital music distribution platforms largely dominated the promotion and marketing of music in Katutura. This entails Namibiamusic.com, Donlu Africa and PlayBit. We also explained how the participants produce and distribute music using technology and the how differences in income and educational level led to technological apartheid and creative reuse of technology. We additionally find the connections, or lack of, between creativity, innovation, and technology in those contexts.

Keywords: Technology, Innovation, Creativity, Music Production, Distribution

1. Introduction

There is an increasing interest in music production in Namibia and technology is undoubtedly the enabler of music entrepreneurs thrive in this competitive market. To improve their lives, careers and enhance their musical impact on society, music artists need to embrace technology (Everts & Hitters, 2021). Leveraging the power of technology, innovation, creativity, and entrepreneurialism can further improve their music business models and be the cheerleaders (Schediwu & Bhansing, 2018). Indeed, music and music-making technology are inextricably linked (Rick & Erik, 2022). It is widely seen at musical events or scenes, and it is further used by music entrepreneurs to compose and distribute their music (Everts, 2021). However, there is limited research on the relationship between technologies and creativity in music in the Namibian context. On that note, this study aimed to analyse the use of technology or tools required in the practice of music production, distribution, and promotion in the informal settlements of Windhoek City, the 'Back-yard' studios by the upcoming artist without formal education. Further, this paper aims to close the gap in knowledge on music production in Namibia by collecting valuable information on the three core

fundamental areas of any economic activity, which are production, distribution, and consumption of local music. Understanding how upcoming Namibian artist use technology in informal settings can give insights into improvement and promote creativity and innovation amongst low-income music groups.

To accomplish this objective, a survey was carried out late in 2020 and was completed in early 2021 to collect valuable information and give more insight on the subject under discussion. In this case, data was gathered in Katutura informal settlements where most of the upcoming artist are characterised by poor living conditions and low income. The survey received a statistically significant number of responses, and such replies were, however, kept confidential, thus the identity of the respondents was not revealed. To shed further light on the current practices in local music production, distribution and consumption, the survey collected the views and data related to practices of the artists and producers who received less or didn't receive any formal education on technologies used for music production, distribution, and marketing. This includes those who simply use their personal computers to go on the internet to learn how they can use technology to produce music and download tools that they think will be helpful in music production. In addition, to achieve the intended results the study further observed and examined different technologies that local artists and producers use and how they use them to produce, distribute, and promote their music in the single market. It was evident that most artists and producers in Katutura distribute, promote music using different social media platforms, digital music services as well as other different digital means such as CDs. Unlike cassette tape that was used in the past, today's ways of distributing music (Jackson et al., 2011). Today, music production distribution and promotion are driven by technology innovation.

Many musicians in Namibia who made it into the music industry claim to have made it from the Katutura area, as the starting point of their career. These artists and producers, have at some point spend long hours in their bedroom studios, learning new digital skills to skilfully produce, distribute, and promote their music. This involves using their desktop or personal computers and mobile phones, learning from the internet, and creating digital media as well as marketing their products in different ways on social media platforms such as Facebook, Instagram, and WhatsApp. Apart from using social media, artists in Katutura use local online music streaming and download platforms such as namibiamusic.com, Donlu Africa and PlayBit to distribute and promote their music.

Despite energetic research discussions about what innovation in Namibia means such as the one that was held at Technology Innovation Bazaar held at the Namibia Business Institute on the 22-23 May 2019, it is evident that there is limited research on the relationship between technologies and creativity in Namibia. Nonetheless, none explores grassroots-based technology innovation. Hence, this unique study explores innovation in the context of creativity in local music and present a wider academic understanding of grassroots innovation.

2. Materials and methods

A. Research design and methods

Each study undertaken applies a research method or methods to solve the research problem uniquely or systematically. In this paper, researchers adopted a qualitative approach with a case study research design to describe participants' view on the use of technology in creating and distributing music. The research paradigm used is constructivism and interpretivism for

qualitative research. This allowed researchers to assess experiences, perceptions, attitudes, and or opinion of participants in words. Interpretivist helps with understanding the phenomena through the meanings that people assign to them (Gulati et al., 2016). The main theoretical framework used is phenomenology. According to Ilonga et al.(2020), “Phenomenology is used to find phenomena and unearth previously unrecognized or undiscovered affairs, as it survey the experience and meaning of phenomena”.

B. Research population

This study’s target group is upcoming artist and producers in Katutura, Namibia. It is challenging, however, to give the exact total number of artists and producers in Katutura since the number of artists/producers gradually changes as time goes. The study focused on artists and producers, whereby artists/producers are not necessarily technologically trained. This can show how artists/producers use their knowledge in the absence of technology education to accomplish their task in their music career.

C. Sampling

Sampling refers to selecting a subsection of the total population. In this, study, researchers focused on Namibian musicians and beats producers who are breathlessly trying to strengthen a career with their move in the music industry and who, in other words, cannot be recognised as pure amateurs, but are not established musicians either (Everts & Hitters, 2021). Techniques used to select participants were probability sampling, snowball sampling. Snowball was used to find potential participants that will be recommended by the contacted participants. The researchers started with two artists from Katutura that are known to them and then asked these participants for referrals until they managed to collect data from twelve participants. The sample size has been determined using Taro Yamani Formula, therefore found sufficient to generalise the finds.

D. Research instruments

Group interviews and direct observations were used to describe phenomena related to participant’s use of and experiences with technology at hand. The survey was divided into three sections to collect different information. Section A was geographical information of artist or producers while Section B was analysing the technology used in music production. Last, was section C that investigated the tools used in music distribution and promotion. The questions on the final version of the survey were crystal clear, answerable, straightforward, and unbiased.

Interviews were used to gather in-depth information on participants’ opinions, thoughts, and experiences about the use of technology in the music industry. Interviews conducted over five months focused on understanding the different technologies participants use and how they use them. Semi-structured interviews were used to help the researcher uncover the stories behind the artist’s and producers’ experiences with technology and get in-depth information about music and technology. The researcher prepared a topic guide before contacting interviews. The researcher prepared questions before the interview and used the topic guide throughout the interviews.

The interview topic guide began with the interview topic, which consisted of the introduction of participants and their role in music. The next discussion was about finding out how participants started using technology and then, the researcher asked questions like when they started using technology, what they were using it for, and what motivated them to use it.

The next discussion was about where technology comes in, during the participant's musical practices. The interviewer asked the participants to think back to their last (most recent) day when they produced/ distributed or promoted their music by using technology. The interviewer asked the participants to explain all the different technologies they used from the time they woke up on that specific day until they went to sleep. In addition to that, the interviewer asked them to further explain how technology helped them to accomplish what they were doing.

The next discussion was about how they use technology in music. The interviewer asked about any other technologies that participants or someone they work with use, apart from what was mentioned. When the participants list those other technologies, the interviewer asked the participants to mention what each technology was used for, how they or the person they work with use them, how other people are involved in using those technologies and they were also asked to demonstrate how they use them. The interviewer asked how participants found out about those technologies and asked the participants to mention the technologies they wish to use and give the reason why.

The next discussion was about the education and training those participants received, which helped them to learn how to use technology. Participants were asked how they learn about using technology and explain if they were taught.

The next discussion was about how they make sure their products reach the targeted audiences. Participants were asked about the platforms they used, how they use them, where they learned how to use them, and how they come up with the best strategy to reach their target market. Participants were also asked to explain how other artists from their area do it to reach their audiences and how they do it differently from their competitors.

Another discussion that was done during the interviews was about how technology helps the participants work with other people or express themselves to other people using technology. Participants were asked to explain the challenges that technology helps with and the difficulties that technology introduces. Participants were also asked to discuss how they experiment with technology, give examples of how they have experimented with using technology to do something connected to music.

The next discussion was about how participants used technology to do something new or original. They were further asked to give their views on the new ways to use technology or describe a certain way of using technology to make something new. At the end of each interview, participants were asked if they would like to say something.

Each interview took roughly 30 minutes and occurred during the daytime at places chosen by participants, such as at their homes and in the music recording studios. All interviews were done in English. The researcher audio-recorded interviews with an iPhone voice memo and at the same time the interviewer took notes.

Observations were used to help the researcher observe and understand how artists and producers use different technologies. Units of analysis focused on individual artists and producers. Observations were made at the recording studios, on their Facebook accounts, Instagram accounts, and WhatsApp chats as well as WhatsApp groups. Observations took more than 14 months. The following section will give more insight into the extent of data collected and analysed.

3. Results and Discussions

A. Demographic variable of participants

Researchers recorded the characteristics of the subject studied: age, and gender. The purpose is to understand participants' age group. Below is the statistical analysis of demographic data of participants.

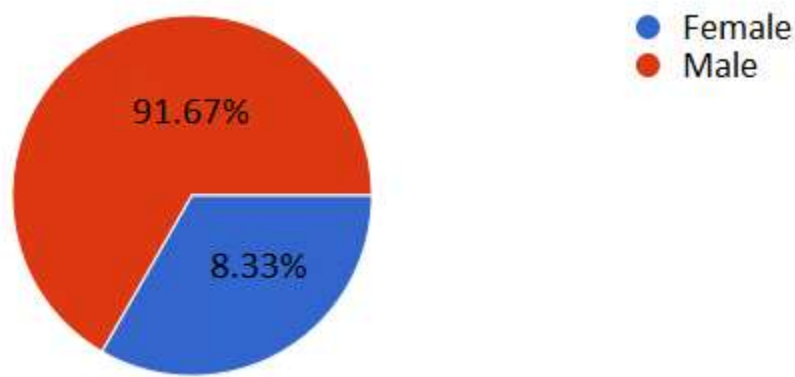


Figure 6. Demographic data

Participants recruited in the study includes eleven (91.67%) men and one (8.33%) woman. This shows that the more man is active in backyard studios.

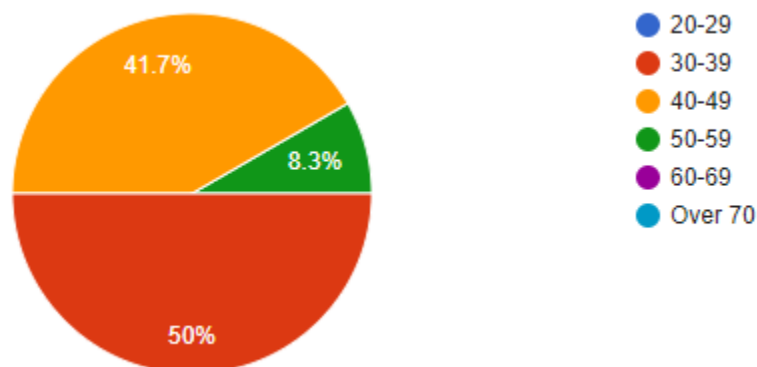


Figure 7. Age Group

Majority of the participants (50%) have indicated that they are at the range of age of 30-39 years old, followed by the age group of 40-49 years. It's only one participant who indicated to be at the age of 50.

According to the Namibia Society of Composer and Authors of Music (NASCAM), an organisation that administers the rights of musicians in Namibia indicated that artists and producers registered with them by 2019, only 30% are women comparing to active man. Among the twelve participants, there is an artist who is a producer, an artist who is an online music store co-founder, two online music platform co-founders, a producer, and the other seven artists. From the perspective of male researchers, it appeared that female artists were more likely to sing and very few female artists use technologies to produce and distribute music. Participants recruited are English, Herero and Oshiwambo speakers because those are the languages typically understood by the researchers. Participants recruited have been doing music and released at most two albums with all songs registered with NASCAM. There is no specific music genre from which participants were recruited, meaning they came from different types of music genres ranging from Hip-Hop, R&B, Soul, Kwaito, Hikwa, etc. The music store co-founders recruited were mentioned by the artists in the interviews.

B. Participants' circumstances as artists and producers in Katutura

Most of the artists grew up in villages in Namibia and moved to the capital city (Windhoek), where they live in the informal settlements of Katutura. Their involvement with music and the use of technology started just after high school. They use personal computers and mobile phones to access online and offline platforms to help them in music production, distribution, and marketing. Like others living in Katutura, they have low incomes. However, even if they don't have enough money to afford different technologies, they must try their best to adapt to different technologies to be able to make it in the music industry. It is not easy to own a personal computer, laptop, or smartphone. Most people afford these types of gadgets only after high school, once they become adults, and then it is only the time when they start using technology. Once they manage to get smartphones or access to computers, it becomes a challenge to get on the internet since it requires Wi-Fi or mobile data to get connected and be able to access online resources. Most participants in the study argued that technology is good to use when you know how to use it. Technology requires time as you need to learn how to use it and you must spend much more time for you to be able to master something. Producers explained that they spend almost all their time learning on their own about how to use different tools for making beats.

E. Music genres

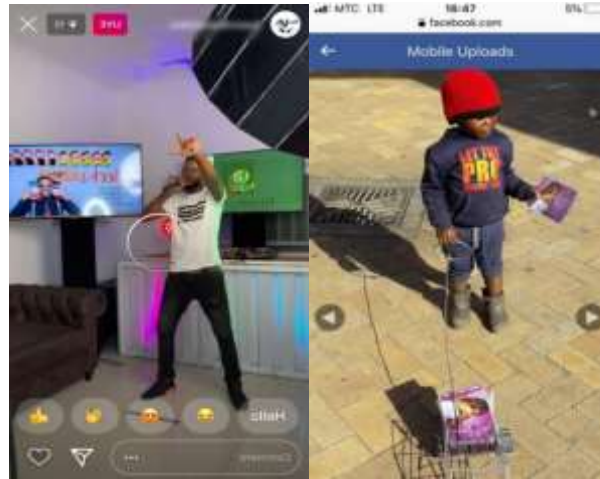
Artists and producers from Katutura produce music of different kind of genres including hip-hop, Kwaito and Hikwa. Kwaito is currently one of the popular music genres in Katutura. Kwaito is a variant of house music mixed with African sounds and samples. This is a music genre that was first established in South Africa and later introduced in Namibia. Hikwa is a music genre that was established by a Namibian rapper, it was engineered by combining Hip-Hip and Kwaito. The creation of these music genres involved technology to mix and perfect the sounds of these music genres. Technology played an important role during the invention of Hikwa music in Namibia.

F. Role of the internet in the music industry

The internet plays a major role in the music industry in the Katutura area. Recording artists use their laptops, personal computers to access online media such as to download the software they need to use for making beats. They also use the internet to access learning materials such as YouTube tutorials, exploring different social media platforms as well as connecting with

other artists in different geographical areas. Also, the internet is critical in promoting and distribute music content. For instance, one artist expressed that, “without the internet, you cannot do anything. Without the internet, it is much more challenging to produce, distribute and promote music in Katutura”. Indeed, “Informal online music learning opportunities can also take a pointed curriculum focus as the means to developing musical understanding” (Marcel, 2007). Figure 1 below illustrates how the certain artist uses social media to stream live performances and request customers to support them by buying their CDs.

Figure 8: Music Promotion on social media



Source: Instagram, Facebook

G. Local Music Streaming

Digitization has increased the number of new products that are created and made available to consumers (Kessler, 2013). Artists from Katutura distribute and market their music with local music store such as namibiamusic.com, link <https://www.namibiamusic.com/>, Donlu Africa link, <https://www.donluafrica.com/> and PlayBit (Mobile Application for iOS and Android). Namibiamusic.com is the first Namibian online music store. This website is designed to solely promote Namibian music. One of the founders of this website who is an artist explained:

“The reason why I decided to come up with this website is that, when I talk about my music or introduce myself as a musician to people in Namibia, they used to ask me to send them my songs via WhatsApp. That prompted me that there is a need for an online music platform in Namibia”.

Users stream and download music and music videos on this website for free. Founders of this website created its Facebook page, Instagram account, WhatsApp Group and Twitter account where they share the links of the items as soon as they are uploaded. Apart from sharing the links on those social media platforms, they also post-release dates of albums and singles. For artists to promote their music with this website, they are charged a small fee, which founders describe as just a maintenance fee, because all they use it for is to pay the monthly hosting costs. This website receives up to 5 000 streams per month.

Donlu Africa is a Namibian online music store. This platform allows artists to sell their music online. Users stream music for free and they will be required to pay per song if they want to download. Donlu Africa accepts music from both Namibian and international artists provided that, music to

be sold on Donlu are not available elsewhere on the internet for free. The founder of Donlu emphasized that:

“At first I thought artist management was the problem in Namibia, I tried to manage an artist and later on, I realized that there was still something missing. I decided to come up with something specifically designed for Namibians. I decided to come up with a streaming platform. One of our core values is listening to users and artists, we assess that, if it works, we then implement it”.

PlayBit is a music streaming mobile application that is developed and owned by a local mobile app developer. Artists promote their music on PlayBit at no cost. PlayBit is available for both Android and iOS devices. This app offers both online and offline music play. With this app, users can customize a playlist for themselves, pick different colors schemes and change the look or layout of the application to suit their desires. The abovementioned features are one of the unique features making it different from other music apps. Users can also browse hundreds of playlists packed with different music genres, including local genres. The developer indicated that everything on PlayBit is custom created and he added that:

“PlayBit is one of the most convenient ways to listen to Namibian music and I came up with PlayBit to benefit the Namibian artists. Namibian artists depend on benefiting from their music by selling CDs. The problem is, CDs gets duplicated and, in the end, artist don’t get income from their music. With PlayBit, you cannot make it a copy. To stream or download music on PlayBit you have to pay and that money will go to the artist”.

With PlayBit, users can stream over 10 000 music tracks on their application. This music app offers three different packages for its customers. There is PlayBit free, PlayBit Premium and PlayBit buddy packages. PlayBit Premium package costs US\$ 3. 99 per month and it comes with unlimited music online and offline play. PlayBit Free cost users zero charges and it comes with free music streams, music shuffle play and occasional ads. While the PlayBit Buddy costs US\$5.79 per month and it comes with access to unlimited music play, unlimited offline play, music downloads, no ads and customers can connect up to six of their PlayBit profiles. There are more than 1 000 music albums on PlayBit.

H. Challenges of piracy and responses in Katutura

Digitization is disrupting several copyright-protected media industries, including the music industry (Kumar & Parikh, 2010). While technologies make it possible for artists and producers to promote and distribute their music, technology makes piracy possible too (Pritchard & Vines, 2013). New media have affected the production and dissemination of music (Häkkilä et al., 2016). When artists print out their music albums on CDs, it happens that only a few CDs get sold and someone makes duplicates of their CDs and sells them at a cheaper price. An artist can have their music playing all over, but the original album was not bought that much. They have identified a couple of fake albums in the CD jukeboxes in Katutura. Downloading or streaming music using online platforms, such as Napster, Google Play Music, is done elsewhere, where people have broadband internet connection (Zhang, 2021). If they upload their songs on YouTube and other platforms, someone downloads that music and converts them to the format whereby they will be able to be shared and be used in jukeboxes and laptops. In the end, people will not buy the original album anymore because they already got the songs. There are music consumers in Katutura that always have some software to download music and share them via WhatsApp groups. The

effort of downloading and transferring music without payment weakened copyright protection, making it difficult for record companies to protect their content (Bers, 2001).

Piracy of digital media is a grey area for many and often those who are consuming pirated content are not aware that they are doing so (Avle et al., 2017). In Katutura, if one person happens to buy an original CD or if they happen to get access to an original CD, they will then share those songs with the WhatsApp groups. Members of the group will share those songs on other WhatsApp groups as well as using offline channels such as transferring to laptops. The more people get access to the music from social media it makes the less enthusiastic to buy original albums because they know if they buy an album today, tomorrow they will receive it via WhatsApp so it is just better to wait until they get it from WhatsApp. Preventing piracy is one of the biggest challenges facing Katutura music owners. Kumar & Parikh(2013) indicated that the increase in unlicensed music consumption is worrisome because it could lead to a drop-off in music owners' incomes and consequently to a possible reduction in the supply of innovative music.

I. Being ahead with new stuffs

Sometimes it happens that, WhatsApp users receive the new releases earlier than others. People who are always ahead of others with novel and new music in Katutura attracts followers, followers would always like to see what's new by checking what that person has updated on their WhatsApp status, WhatsApp group, on Instagram and other platforms. When a new song is uploaded on a WhatsApp group, group members normally thank the person who uploaded it. This makes some people get motivated to find new kinds of stuff because whenever they share them, they get rewarded with positive responses and which makes them feel appreciated. When people have responded positively to the new kinds of stuff that they shared, that motivates them to find new things not just for personal benefit but for sharing with others as well.

J. Challenges of using technology

Technological change has brought fundamental opportunities to the recorded music industry (Marcel, 2007). "Technology is building and killing the music industry at the same time," said hip-hop artists. One day, this artist was sending his unreleased song to the producer to make final touches on it. He mistakenly sent it to a WhatsApp group and by the moment he deleted it from the group, people have already shared it. People then started playing the song before it was released. That song was regarded as the hottest in the album and has affected the sales of the album. When he released the album, people told each other that there is no need to buy an album because the song that they heard before didn't catch their ears.

Most of the music consumers in Katutura have little knowledge about technology and distrust online payment systems. When artists promote their music by telling their fans to buy their music online, most people have safety concerns about online payment systems such as PayPal. Most of them don't even have credit cards. In the end, even if the person wanted to buy that music, they might not buy them anymore just because they are scared of scammers on the internet. Some people feel like buying the song that you like is better than buying the entire album, but the problems come here that buying a single is done only online through some processes that they don't understand very well. It can then happen that, they might not buy the whole album because it requires more money and they might not buy a single on an online music shop because they don't know how PayPal works, so they will just wait for the songs that will be dropped on WhatsApp groups. Artist hardly prints single releases on CDs.

K. "Backyard" (Bedroom) Studio and Other Set-ups

Many local artists and producers gather in small backyard bedroom studios to make music with different equipment connected to a computer (See Figure 2). Apart from a computer, there is also an Audio Interface, Studio Monitors, an External Hard Drive, MIDI-Controller, Microphone, Headphones and an Amplifier. Their computers are loaded with Digital Audio Workstations (DAW) such as Logic, Pro Tools, Reason Studios, FL Studio and many other tools that are used to make beats. When one producer was asked why and why he was using the computer he said: *"I started with a laptop but was not comfortable with that one, the screen is too small and I couldn't work with it for a long period, at the moment, I am fine with this desktop, desktop computers have even better performance than laptops, later on, I would like to shift to Mac as it is much better than the Acer desktop that I am using now."*



Figure 9: Backyard studio setup

Source: (Captured and Contributed)

3. Conclusion

This article gave full descriptions of the findings of ethnographic observations and interviews carried out in Katutura. Ethnographic observations focused on the artists and producers' day by day musical and technological activities, including their time spent in studios and on social media. It also thoroughly explained the findings from different technology practices involving music and this includes local digital music platforms, computers, smartphones, social media, and the internet at large. These technologies dominated the learning, production, and promotion process of music in Katutura. It was also discovered several local artists owned digital platforms that facilitate the distribution and consumption of music in Namibia, such as are namibiamusic.com, Donlu Africa and PlayBit, which is a mobile application. This investigation's results are expected to contribute to the understanding of the important promoting and grassroots innovation. It was recommended that further research be done in other corners of Namibian towns. It has also been found that most of the musicians are not just involved in creative activities such as writing and recording songs, but also to do other activities, such as marketing music and technical

activities such as distributing merchandise. More research is needed to find out about other work activities of musicians in Katutura where technology is involved and to explore how they value those activities. In addition, recommendations based on findings and observations are that artists must consider embracing innovative methods and cutting-edge technology in music production and distribution to improve quality, reach a wider audience in this ever-changing media environment and increase revenues emanating from the sales of their music in digital media. It has also been found out that more men are using technology in music than women. We then conclude that female musicians need to be empowered in technology for them to enjoy the same benefits that male musicians are enjoying from using technology.

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A Graph Colouring Solution to the Timetable Problem with Hard Constraints in Higher Education Institutions

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Abstract.

With the ever-increasing number of students in tertiary institutions and the negative effects of overcrowded and non-optimal classrooms being further understood. It has become increasingly important to develop a system which can correctly and optimally create timetable solutions for each individual student within these tertiary institutions. We note that solutions to this problem have been proposed in various capacities. We will briefly look at some of these algorithms and their results. Our main objective is to investigate further, particularly with respect to students across multiple subjects and faculties. We propose a graph colouring method to solve the problem with a particular focus on hard constraints surrounding different faculties and degrees. Multiple timetables will be generated and cross-validated against each other for accuracy and error reduction. We successfully generate graphs using our algorithm and show an example timetable.

Keywords: Timetable problem, stochastic gradient descent, machine learning, graph colouring, higher education institutions.

1. Introduction

The University Timetabling problem is a popular and ever increasingly prevalent NP-Complete problem which has been emerging in the field of Computer Science. With the continuous development of Tertiary Education in most developed and developing countries, there has been a significant increase in the number of students and teachers occupying spaces within these tertiary institutions. With the rise in numbers, so too has the need for an optimal and efficient solution to create a schedule for the allocation of students and teachers based on multiple factors such as their studying disciplines and the time and location of their classes, while avoiding unfeasible conflicts within the system. A major reason for the need to solve this problem arises from the need for the most optimal teaching conditions in Universities. It has been shown by research done by (Khan & Iqbal, 2012) that overcrowding in classrooms has a direct negative impact on student learning. Additionally, too many students in venues which are too small result in a decrease in learning quality (Carlson, 2000) and often weaker students who require more assistance are left ignored (Tahir et al., 2019).

Due to the popularity of the timetabling problem, there have been many attempts to solve or provide more optimal solutions by different researchers. Examples of such attempts are namely, a graph colouring, but in an exam timetabling capacity by (Hussin et al., 2011), and the genetic algorithm by (Ahmad et al., 2018) and (Jha, 2014). Both of these approaches have been implemented successfully but subject to their own limitations.

We wish to build upon the research done by others by expanding the scope of the graph colouring algorithm. We will apply the algorithm to create a timetable for class scheduling for an entire year, not limited to just the exam period. We will also be using a unique greedy approach to our colouring algorithm which could prove more time efficient for larger universities.

We will generate our graph by making pairings of shared subjects between students as vertices and then connecting these vertices by edges depending on the overlap between students and their subjects. We will then apply our greedy colouring algorithm to colour our generated graph. We will be evaluating our results by means of cross validation and examination of chromatic number over random order colouring of our graph.

Ideally a University should be able to generate a timetable for each student and lecturer which should ideally allocate subjects to times and venues whilst avoiding major conflicts, such as having two different subjects in the same venue at the same time. Currently many Universities do not have an automatic way to generate such a timetable and in some cases, manual computation techniques are being used to create these student and lecturer timetables. This is not ideal as the nature of the Np-Hard problem means that a manual computation will be highly non-optimal and even contain possible errors and overlapping constraints. The nature of South African Universities, where there are multiple faculties and schools all existing on the same campus is the primary focus for this paper. Due to the large number of students because the University campus is so large, there tend to be a large variety of varying numbers of students per degree and even per subject. This makes an optimization for class sizes a significant problem to solve. The creation of such an algorithm will contribute by demonstrating the possibility of fully automating the scheduling procedure, providing universities with a inexpensive solution to their timetabling problems and encouraging further research and development in the area. In the following sections we will explain background information and terminology as well as look into the related work in depth. The Methodology and Results of the research will follow thereafter.

2. Background

In this section, we will discuss Graph Colouring, NP problems and crossvalidation. Graph colouring itself is a ubiquitously used algorithm in the real world with multiple applications. Some examples of the applications are scheduling in sport and pathfinding in robotics. While graph colouring can be used to find a solution to our problem, it definitely is not the only solution as proven by the volume of literature on the topic.

3. NP Problems

In terms of complexity, the problem of creating the timetable itself is said to be NP Complete but the optimization of the timetable is NP Hard (Ganguli & Roy, 2017). A NP problem is defined as a problem that can be solved by a Non-deterministic Turing Machine in Polynomial time. An NP Complete problem 'X' is one that can be solved within NP and is reducible to X in polynomial time. A NP Hard problem 'Y', however, can be reducible to 'Y' in polynomial time but is not necessarily in NP. This means that the problem cannot be solved in polynomial time until $P = NP$. These types of problems are computationally intensive to solve without the use of computers and algorithms as they usually involve a large and irregular solutions space.

3.1 Graph Coloring

Graph colouring works by first generating a graph with multiple vertices. In this case, each vertex would represent a subject for which there is at least one student enrolled for. We would then generate relationships between the vertices and connect these relationships via edges. We pick a vertex to begin the colouring process and colour that vertex with one of our available colours.

We then move to the next vertex and colour it with another colour such that there are no adjacent vertices with the same colour. Two adjacent colours which are the same would represent a clash within our constraints for this problem. To optimize this, we traverse all vertices while trying to use as little colours as possible but also adhering to our specified hard constraints and as many soft constraints as possible. The application of this theory has been used in various other practical situations such as automatic sudoku solvers.

Vertex Colouring and Edge Colouring: The two most common forms of Graph Colouring are the Vertex and Edge Colouring algorithms. In Vertex colouring, we colour each vertex of a graph such that no adjacent vertices have the same colour. In Edge Colouring, we assign a colour to each edge instead, such that no adjacent edges have the same colour. For this paper we will be investigating Vertex Colouring.

There is some important terminology to consider when looking at graph colouring algorithms.

- *Proper Colouring* refers to a graph that has been coloured where every edge and every vertex have been assigned different colours.
- *Chromatic number* of a graph G is the minimum number of colours needed for a Proper Colouring of G .
- *K-Colorable* refers to a graph that has been coloured with at most K colours and is a Proper Colouring.
- *K-Chromatic* refers to a Graph G that is coloured with its chromatic number, i.e. Using the minimum number of colours.

Greedy Graph Colouring The Greedy Graph Colouring Algorithm works on the basis of Brooks' Theorem.

For every connected graph G that is not an odd cycle or a complete graph:

$$\chi(G) \leq \Delta(G).$$

Greedy Colouring will traverse the graph one vertex at a time and at each vertex it will assign the first available colour which is not in use by any of its adjacent neighbours. Due to how this works, Greedy Colouring does not always necessarily produce graphs which have the minimum number of colours possible. At most for a graph of maximum degree x , where degree is the number of edges connecting to a vertex, a greedy algorithm will produce a maximum of $x + 1$ colours.

3.1 K-Fold Cross Validation

We will be evaluating the results of our model by using cross-validation procedures. In particular we will be using a specific type of cross-validation known as k-fold validation. In this form of cross-validation we will run our algorithm a fixed number, or k , times. Each of these iterations is called a 'fold'. We perform

analyses on each individual fold, compare them to each other and ultimately we average the folds to get a final fold. In our case, we might not be able to get an 'average' timetable or graph, so we will have to pick the most frequent result. The purpose of this cross-validation is to protect our model against overfitting. The process of running multiple iterations ensures our results are consistent and reduces the overall error of our model.

4. Reated Work

4.1 Graph Coloring Approach to Exam Timetabling

If we look at a University Exam timetabling solution proposed by (Hussin et al., 2011) which is conceptually similar to that of a University Scheduling Timetable. A graph colouring approach was proposed and implemented. The algorithm was used to generate a timetable for foundation students in Multimedia University, Malaysia for trimester 2 in the years 2009/2010.

The algorithm works by following steps required for graph colouring. Subjects are divided into main foundations, for example: Sciences, Commerce, Law. The subjects are divided and sorted further by intakes, since the University has multiple intakes in an academic year. A colour is then assigned to each intake. After this is done, a further colour is then assigned based on subjects. An objective function is used to measure how well soft constraints are satisfied and we assume all hard constraints are fulfilled. A conflict matrix is used to check where constraints possibly overlap. Each exam is represented by a vertex and edges represent conflicts (Hussin et al., 2011). This will allow us to find the minimum number of colours apply to vertices so that no two adjacent vertices have the same colour (Rahman et al., 2009) The algorithm managed to generate an Exam timetable and improved on the current system offered by the university, which did not consider any soft constraints in its calculations. It was able to schedule exams for a maximum of 1323 students per slot compared to the old maximum of 1263 per slot. However, the final algorithm did end up ignoring most of the soft constraints and some hard constraints, showing that further optimality and research can still be done on the topic with regards to the graph colouring method. Furthermore, this could be extended to university class timetabling, and not just exam timetabling, which would be a lot larger, and more robust.

4.2 Genetic Algorithm

Another popular algorithm which has been examined in a classroom scheduling approach by (Ahmad et al., 2018) and (Jha, 2014) in exam timetabling, is that of the genetic algorithm. The exam timetabling proposed by (Jha, 2014), looked at student data from the engineering department of Ibra college of Technology in the year 2011-2012 but opted for a generalized solution, and the classroom scheduling approach by (Ahmad et al., 2018) also opted for a more generalized approach. Genetic Algorithms are a specific type of evolutionary programming which draw heavy influence from the principles of Darwinnian biological evolution. These algorithms were formalized by John Holland in 1975 and have since gained traction with advances in technology and computational power since then. They are particularly useful in problem solving given large irregular search spaces with multiple solutions (Colorni et al., 1990) The algorithm functions by generating a selection of feasible timetables and selects the fittest timetable from the selection as its basis for iterating upon. Fitness is determined by the number of soft constraint violations as we assume all hard constraints are always met for a timetable to be considered feasible. It makes use of various genetic operators such as crossovers, mutations and selection in its iterative process.(Jha, 2014). In both algorithm implementations, the algorithm defines a chromosome, which is an initial sample on which the various evolutionary operators will act on. This chromosome is represented

usually as a bit string, but can be represented as a mapping as in the case of (Jha, 2014). The initial sample or initial population is initialized randomly based on input the data used. The evaluation or fitness function which is used to select the fittest of the feasible time table is given by the equation $f = 1/1+x$ where x is the collective sum of conflicts and constraints. We will now investigate the evolutionary operators

Selection

Selection or Reproduction is the operator which is usually applied first on a population after its fitness value has been calculated. (Jha, 2014). Selection is the process in which the timetable with the highest fitness function value is picked to be used for the iteration phases. *Crossover and Mutation*

In the crossover stage, two strings are compared to each other and recombined to produce a more optimal string (Ahmad et al., 2018). This is done to iterate the chromosomes and generate better ones across generations. After the crossover stage, the fitness is recalculated. If the fitness value is higher than its original string, the algorithm will stop and conclude that an optimal solution has been reached. If the fitness value is lower, however, the Mutation operator will be called. The mutation operator will alter values in the chromosome and then recalculate fitness again. If the fitness value is higher than the original string, the algorithm will stop. If not, however, the algorithm will loop back to the Selection phase. Both papers produced a satisfactory timetable with 0 conflicts and a fitness score of 1. Indicating that maximum fitness had been achieved. Both algorithms were run using fairly small sample sizes, with the one by (Ahmad et al., 2018) consisting of 54 lecturers over 36 courses with 12 venues and 20 periods. This would serve as a good proof of concept for extending the implementation of the algorithm to a University scale, especially in a South African university where students number in the thousands and courses in the hundreds. Both algorithms could stand to optimize further with the implementation of additional soft and medium constraints.

4.3 Other Algorithms

Some examples of other algorithms which have been used are a Ordering Heuristic Model by (Rahman et al., 2009) which operated by combining graph colouring heuristics with a squeaky wheel optimization framework. A Tabu search method by (Lawal et al., 2014) which uses the metaheuristic local search method to perform its timetabling optimization. A local search procedure with constraint programming was implemented successfully by (Soni et al., n.d.).

5. Research Question

The Question we wish to address here is: Can a graph colouring approach be used to solve the University Timetabling problem with a specific focus on class scheduling instead of exam scheduling for an entire faculty of students with vastly different majors and subjects? To solve this question we will create a timetable for every student while adhering strictly to a set of hard constraints and loosely to a set of soft constraints. Hard constraints must always be adhered to and soft can be adhered to when possible but are not necessary. For this stage of the Research we will be investigating if it is possible to generate such a timetable using graph colouring and as such we will not be adding too many additional soft and medium constraints.

The optimization of this problem would ensure that all of the Hard constraints are fulfilled along with as many and soft constraints as possible. Additionally we want to solve the problem by using a graph colouring approach particularly using vertex colouring and a greedy colouring approach. Our most

important hard constraints are: A student cannot be assigned more than one room at a given time slot, a student may not have more than one subject at a given time slot and a single room may only be assigned a single subject.

6. Purpose Statement

By solving the above problem we would create an applicable solution to the timetabling problem in situations where we are dealing with varying degrees and subjects being offered in the same faculty. This would allow universities to automatically generate timetables for students and lecturers in a much more efficient manner leading to less unnecessary cost overheads and additional time for other University matters. This research would also seek to deepen the understanding of a graph colouring algorithm, particularly with respect to the timetabling problem. The contribution to the other timetabling literature could be a helpful addition to further research in the area.

7. Research Methodology

7.1 Data

Since the timetabling problem in general is non-specific and can apply to a multitude of scenarios, the data used for testing is entirely synthetic. It was manually curated to be data which could occur in a University setting and not purely random so we could still achieve relevant results. Our data consists of a selection of students and the courses which they are enrolled for in a semester. This is scalable and there is no limit on how many subjects a student can or cannot take. Since we created this dataset, we did not have to do any explicit pre-processing on it except ensuring that it is in the correct format for our algorithm.

Our Graph Colouring Algorithm was run on three distinct datasets. A trivial case consisting of a small number of students in the same major with the same curriculum. A case where we had multiple students across multiple majors taking fixed curricula. Finally we have a complex case where we added students on a general degree path who could take whichever subjects they wanted to.

7.2 Graph Structure

Firstly we create a graph consisting of vertices and edges. A vertex is created for each available subject. We iterate through the dataset and create pairings between subjects dependent on how many combinations of True entries we have per student. If there is a True value between two subjects for a student, we create an edge to represent a relationship between the two vertices. Once all edges have been drawn, we consider our initial graph complete.

7.3 Greedy Coloring

The next part of the Algorithm will traverse each vertex in order and assign an appropriate colour depending on which colours are available. The algorithm works by starting out with a list of available colours available for use and an empty list of forbidden colours. It iterates through each vertex and at each vertex it will check the neighbours of the vertex. If there is a neighbour with a colour, it will add that colour to the forbidden colours list and assign the next available colour in the available colours list. After

a vertex has been coloured, the algorithm will proceed to the next vertex and repeat the colouring process.

7.4 Cross-Validation and Testing

We implemented K-fold cross validation to ensure our generated graphs are accurate. The algorithm was run 10 times for each different test case and the graph which appeared most frequently was manually selected. We also used a shorter algorithm to randomize the order in which the vertices are coloured. We ran this 10 times to check if we would get a consistent chromatic number for each random colouring. This is important, as aforementioned, the greedy algorithm might not necessarily give us the most optimal solution depending on the order in which the vertices are coloured. This allows us to evaluate the consistency of the algorithm's performance.

7.5 Limitations

Since we are using a greedy algorithm, our colouring solution might not necessarily be the most optimal.

8. Results and Future Improvements

In this section we will discuss the results of the algorithm as well as future improvements that can be made.

8.1 Trivial Dataset

The first dataset which was tested was the trivial dataset consisting of a small number of entries from a single major all enrolled for the same subjects. The dataset contains 6 vertices as it has 6 possible subjects a student can be enrolled for. Based on this, we can see the graph has a chromatic number of 6. We now apply our colouring algorithm to the graph. In this case, 6 different colours had to be used to properly colour the graph. Our random colouring algorithm returned a consistent number of 6 colours, indicating optimal colouring.

The second dataset we wish to look at is the dataset containing students from different faculties on a set curriculum. This dataset contains 12 vertices for 12 possible subjects. Based on this, we can see the graph has a chromatic number of 12. We now apply our colouring algorithm to the graph.

p 6 different colours had to be used to properly colour the graph, the same as the trivial case, despite having a much higher chromatic number. Our random colouring algorithm returned a consistent number of 6 colours, indicating optimal colouring.

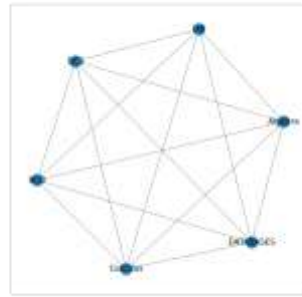


Figure 1: Trivial Graph

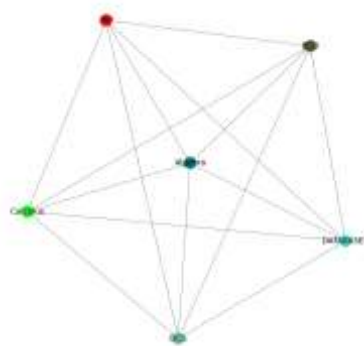


Figure 2: Trivial Coloured Graph

Finally we wish to look at the most complex dataset where we have added in students who are free to choose whichever subject they would like to take. We have still limited the dataset to contain 12 vertices for 12 subjects. Based on this, we can see this graph also has a chromatic number of 12. We now apply our colouring algorithm to the graph.

Here, 7 different colours had to be used to properly colour the graph, which is closer to our chromatic number but still significantly lower. Based on this, our algorithm is colouring quite optimally. Our random colouring algorithm also returned a consistent number of 7 colours showing that the algorithm is being coloured optimally.

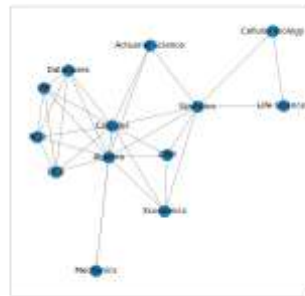


Figure 3: Set Curriculum Graph

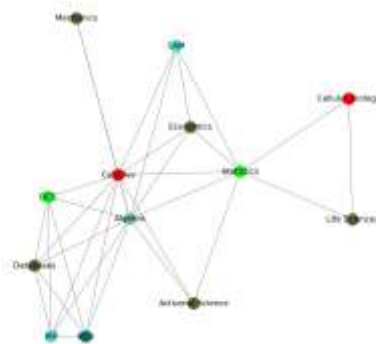


Figure 4: Set Curriculum Coloured Graph

Finally we can use our coloured graphs to then generate an appropriate timetable for students:

We can see subjects with many students overlapping multiple faculties such as Algebra and Calculus have to be assigned to separate days and other subjects which are relatively degree specific such as Mechanics and Statistics able to be scheduled concurrently with each other. There are no conflicts with our hard constraints detailed earlier, so we can conclude that the algorithm is working as intended.

9. Future Improvements

There are many future optimizations and features which can be added to this algorithm to make it more practically useable in everyday situations. Firstly and importantly, we need to develop a method to generate an average graph across multiple iterations of our algorithm.

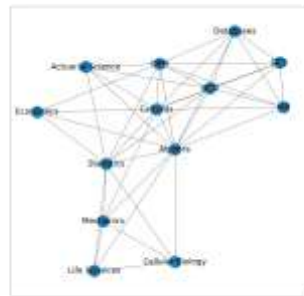


Figure 5: General Course Students Graph

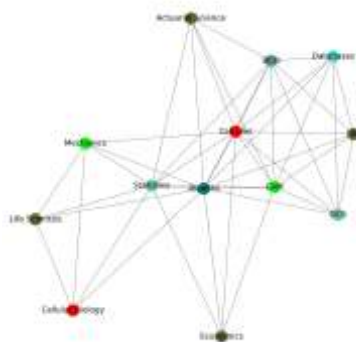


Figure 6: General Course Students Graph

This would give us more reliable results. For future additions, we could cater for venue sizes and match numbers of students with appropriately sized venues. For example, there would generally be more students taking Algebra and Calculus than there would Statistics or Cellular Biology. We could also add break periods so students have appropriate gaps between their subjects. The problem in general can contain many soft constraints as demanded by a specific institution, all of which would be grounds for future improvements.

10. Conclusion

The aim of this research was to provide a solution to the University Timetabling Problem using a Graph Colouring approach, particularly with regard to multiple students from multiple degree majors. We accomplished this by creating a non-planar graph of our problem space where subjects were represented by vertices and the relationships between them by edges. We then coloured the graph iteratively, vertex by vertex, using a greedy colouring algorithm. With this approach we were successfully able to generate properly coloured graphs as well as timetables for our synthetic data.

	Room 0	Room 1	Room 2
2021-11-14 10:00:00	Databases	Mechanics	Statistics
2021-11-14 12:00:00	None	None	None
2021-11-14 14:00:00	IAP	CAM	Cellular Biology
2021-11-14 16:00:00	Calculus	None	None
2021-11-15 10:00:00	DCS	None	None
2021-11-15 12:00:00	Algebra	None	None

While our greedy algorithm provided satisfactory results, it has yet to be tested on a large, real-world dataset, which may be able to provide further insights into its performance. There is also the possibility of future research where we could use a recursive colouring algorithm instead of our greedy algorithm. A recursive algorithm would check the colours of all previous vertices while assigning colours to its current vertex. This could give us a more optimally coloured graph at the cost of time complexity. We could potentially try to use Edge colouring instead of Vertex colouring, however, for this problem having each subject as a vertex is the more logical option.

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Towards the Development of a Token Recognizer for a Yorùbá-based Programming Language

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Abstract

Experimental development of a programming language that uses the lexicons of the Yoruba language has been attempted. This was done in the belief that an indigenous African language-based programming language would enhance the comprehension of computer-based problem-solving processes by indigenous students and teachers. However, the modern orthography of the base language was not considered in the implementation of the programming language. The orthography of a standard Yoruba language consists of the basic alphabets of the language as well as some diacritical marks whose presence or otherwise indicate the pronunciation of an alphabet. The present study is on the development of a token recognizer for a Yoruba-based programming language that takes into cognizance the modern orthography of the base language. Yoruba is one of the indigenous African languages, being the first language of more than 30 million people in the southwest of Nigeria.; and spoken by more than 100 million people globally. Appropriate regular expressions were designed to specify the lexical structure of the Yoruba-based programming language, a state transition diagram was also drawn to show how the basic tokens of the language in a given source program will be recognized, while implementation of the system would be carried out using Python programming language. In readiness for the actual implementation of the system, the expected output of a correct modern Yoruba token recognizer is presented in this paper.

Keywords: Lexicon, Orthography, Programming language, Token, Yoruba language

1. Introduction

Programming languages (PLs) are notations for the description of algorithms and data structures for computer machines and people. The role of a PL is that of enabling a programmer to express abstract ideas in a language that a computer machine can understand (Olatunji, 2019). The list of valid words or strings in a given language is called the language's lexicons.

Compilers and interpreters are the common processors developed for the implementation of a PL (Olatunji, 2006). A PL's token recognizer (also called a scanner or lexical analyzer) is usually the first routine or subsystem of most PL processors. A token of a programming language is the smallest unit of a source program, that is, a program in a non-machine language. Examples of PL tokens are keywords, identifiers, literals, and so on (Olatunji, 2014; Aho et al, 2007). In the parlance of formal grammar from whose theories the study derives its philosophy, tokens of a programming language are the terminal symbols of the language.

A token recognizer conventionally scans each source program statement, character by character, in order to build up and classify the tokens of the source language in the program. In addition, a token recognizer eliminates 'redundancies' in the source program, such as comments and blanks characters) from a source statement. Errors in the source program statements, such as illegal characters are also reported (Olatunij 2019).

It has been observed that most real-life PLs borrowed their lexical items from the Asian and European languages, however, there is a paucity of research information on the development of a PL with lexicons of an African indigenous language like Yoruba. Experimental development of an African native language-based PL, using Yoruba as the base language, was attempted by (Olatunji et al, 2019, 2021) in the belief that such a PL would facilitate the comprehension of computer-based problem-solving processes by indigenous learners and instructors. This belief has also been corroborated by other research studies (UNESCO, 2007; Pflepson, 2011; Silva et al, 2020).

However, the work of Olatuni (2019) did not consider the modern orthography of the standard Yoruba language. Words in the standard Yoruba language do not only consist of the language's alphabet but also some diacritical marks whose presence or absence on an alphabet denotes the way the alphabet is to be pronounced. The standard Yoruba is the one that is studied in formal schools and spoken during news broadcasts on television and radio. Yoruba is one of the indigenous African languages, the mother tongue of more than 30 million people in the southwest of Nigeria.; and is spoken by more than 100 million people globally (Eludiora et al, 2015).

This present study aims at developing a token recognizer for a PL that uses standard Yoruba lexicons with the correct tonal or diacritical marks. Successful development of a token recognizer for the Yoruba-based PL will facilitate the remaining effort in the design and implementation of a full-scale Yoruba-based PL. Adoption of the PL, when fully implemented, will definitely increase the functional load of the Yoruba language and thus serve as an effective strategy that will:

- enable indigenous learners and teachers to quickly grasp the intricacies involved in problem-solving processes that are computer-based.
- prevent the predicted genocide of indigenous African languages, including Yoruba (Awobuluyi, 2014; Azeez, 2013)
- ensure the continuity and relevance of Yoruba language and other African languages in the age of ICT and increasing globalization; and also
- bridge the digital divide between the developed and underdeveloped/ developing countries of the world (Olatunji, 2019)

2. Review of Literature

2.1 The Yoruba Language

Yorùbá is a tonal language (Olumuyiwa, 2013), having three contrastive tones: h(igh), l(ow), and m(id) (the default tone). Every syllable must have at least one tone. Tones distinguish the

meaning of words and are indicated by the use of the acute accent for high tone (⟨á⟩, ⟨ń⟩), the grave accent for low tone (⟨à⟩, ⟨̀⟩); mid is unmarked. Examples are:

- i. Kọ (h) - to build
- ii. Kọ (m) - to sing
- iii. Kọ (l) - to reject

Due to colonization by the British, some Yoruba words were borrowed from English. Examples are *ṣọọsi* (church), *télọ* (tailor) and *béba* (paper). Some Yoruba words were also borrowed from Arabic as a result of influence of Islam. Examples are *àdúrá* from “al-du’a” (prayer) and *Sérià* from “Shari’ah” (punishment).

The present orthography of Yorùbá makes use of the Latin script, modified by the use of the digraph and certain diacritics (Olumuyiwa, 2013). A digraph is a pair of characters used to represent one phoneme (distinct sound) or a sequence of the phoneme that does not correspond to the normal sound values of the two characters combined. The only example is ‘gb’. A diacritic is a mark or sign added to a letter in order to change or distinguish its sound values. For example, À and Á are respectively pronounced with low and high tones.

The alphabet of the standard Yoruba orthography consists of 25 uppercase letters and 25 lower case letters. The upper case letters of the Yoruba alphabet are:

A B D E Ě F G GB H I J K L M N O Q P R S \$ T U W Y

The lowercase symbols of the Yoruba alphabet are:

a b d e ě f g gb h i j k l m n o q p r s \$ t u w y

Three of each of the upper case and lower case letters carry an under-dot sign. These are Ě, Q and \$ for the upper case letters and ě q and \$ for the lower case letters. These letters are also pronounced differently from their equivalent without the under-dot sign. The tonal signs are usually placed on the vowels in the alphabet, with the exception of the letter i. The vowels in the Yorùbá upper case letters, in addition to I, are:

A, E, Ě, O, Q and U.

The pronunciation of the letters without diacritics corresponds more or less to the phonetic notation based primarily on the Latin alphabet.

2.2 Related works

A design and implementation of an indigenous African language-based programming language were carried out by Olatunji et al (2021). The Yoruba language was used as the case study in their work. The study was embarked upon with the belief that the availability of a programming language in one’s mother tongue will enhance the teaching and learning of computer programming, especially at the primary and junior secondary school levels. However, as noted

earlier, in their work, the modern orthography of the Yoruba language was not considered. This is the major gap in their work that the present study is trying to address.

Qalb is a functional PL that was developed by Nasser (2012). The PL was based on the lexicons of the Arabic language. It does not make use of the ASCII character set for its encoding. The PL can be used to write meaningful computer programs in the Arabic language. The development of Qalb was motivated by a strong desire to challenge the tradition in which the design of most popular programming languages is predominantly based on the lexicons of the English language. Such a tradition, as noted by McAllister (2013), makes learning programming very difficult for students whose native language does not use the Latin alphabet as does the English language. The token recognizer in the present study makes use of the Yoruba alphabet from which its lexical items are formed.

Ajayi, Adagunodo and Aderounmu (2007) developed an interpreter that translated a sequence of instructions written in the Yoruba language to machine-understandable instructions. The interpreter, according to Ajayi *et al.* (2007), is a simple language having its features derived from the more commonly interpreted languages like BASIC. The work of Ajayi *et al.* (2007) is similar in a number of respects to this study, however, their approach is quite different from ours. While for implementation, they employed interpretation; in this research, compilation is the approach to be used for implementation. The present study is a subsystem of a compiler.

Dolittle is a PL whose keywords are based on the Japanese language. It was developed in 2000 (Yoo et al, 2006) as an object-oriented educational programming language that is suitable for children in both elementary and secondary schools. The programming language was written in Java and does not require elaborate declarations. The programming language whose token recognizer is being considered in this study will be a structured PL that uses Yoruba words and is designed for programming by primary and junior secondary school children.

Other native language-based programming languages include the Hindawi programming system, Ezhil and Rappira (Olatunji, 2019). The Hindawi programming language enabled programs to be written in Indic languages like Hindi and Bangla (Kumar, 2011). Ezhil is an interpreted Tamil-based programming language that was targeted at junior high school students. The language was developed by Annamalai (2013). Rapiirra consisted of Russian-based keywords (Dadhich, 2006). Most of these native language-based programming languages, like the one being considered in this study, were developed for pedagogical reasons.

3. Methods and Materials

The character set and reserved words of the programming language (PL) were respectively formed from the basic Yoruba alphabet and standard Yoruba words. The lexical items of a subset of the Yoruba-based programming language were specified by defining necessary regular (type-3) grammars using the Backus-Naur Form (BNF) notations. The lexical structure of a PL determines which group of symbols or characters are treated as identifiers, reserved words, operators, and so on. A subset of the design of the PL that is relevant to this present study is

shown in Figure 1. The BNF definitions for variables (Feriebu) and numbers (Nomba) are the ones given in Figure1.

For the implementation of the Token Recognizer, a state transition diagram, shown in Figure 2, was drawn to recognize the basic tokens/lexical items of the PL. In the diagram of Figure 2, D stands for digits (0-9), L stands for letters of the Yoruba alphabet (a-y, A-Y), DELIM represents single character delimiters [(,), +, -, /, *, <, >, = comma], excluding the single quote (') and exclamatory mark (!). EOL stands for end of line character, VC stands for any valid character among digits, letters, delimiters and the blank character; IVC stands for any character not in the set of VC, while 'Others' mean any character that is not part of the lexeme for a particular token category. INT, RWD, IDN, DEL and SLT respectively stand for internal representations of integer, reserved word, identifier, delimiter and string literal.

Definition of <Nomba> (Number) and <Feriebu> (Variable)

```
<Nomba> → <Dijiti> [ { <Dijiti> }4 ]
<Feriebu> → <ABD> [ { <ABD> | <Dijiti> }6 ]
<Dijiti> → 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
<ABD> → A | B | D | E | Ě | F | G | 'GB' | H | I | J | K | L | M | N |
O | Q | P | R | S | Š | T | U | W | Y |
a | b | d | e | ě | f | g | 'gb' | h | i | j | k | l | m | n | o | q | p | r | s | š |
t | u | w | y | <ABDTona>
```

```
<ABDTona> → á | à | é | è | ó | ò | ù | ú |
```

```
À | Á | É | È | Ó | Ò | Ú | Ù
```

Note:

The definition of <Nomba> implies it cannot be greater than 99999, while a <Feriebu> which is an identifier cannot be more than 7 characters long.

Figure 1: Production Rules for <Nomba> and <Feriebu>

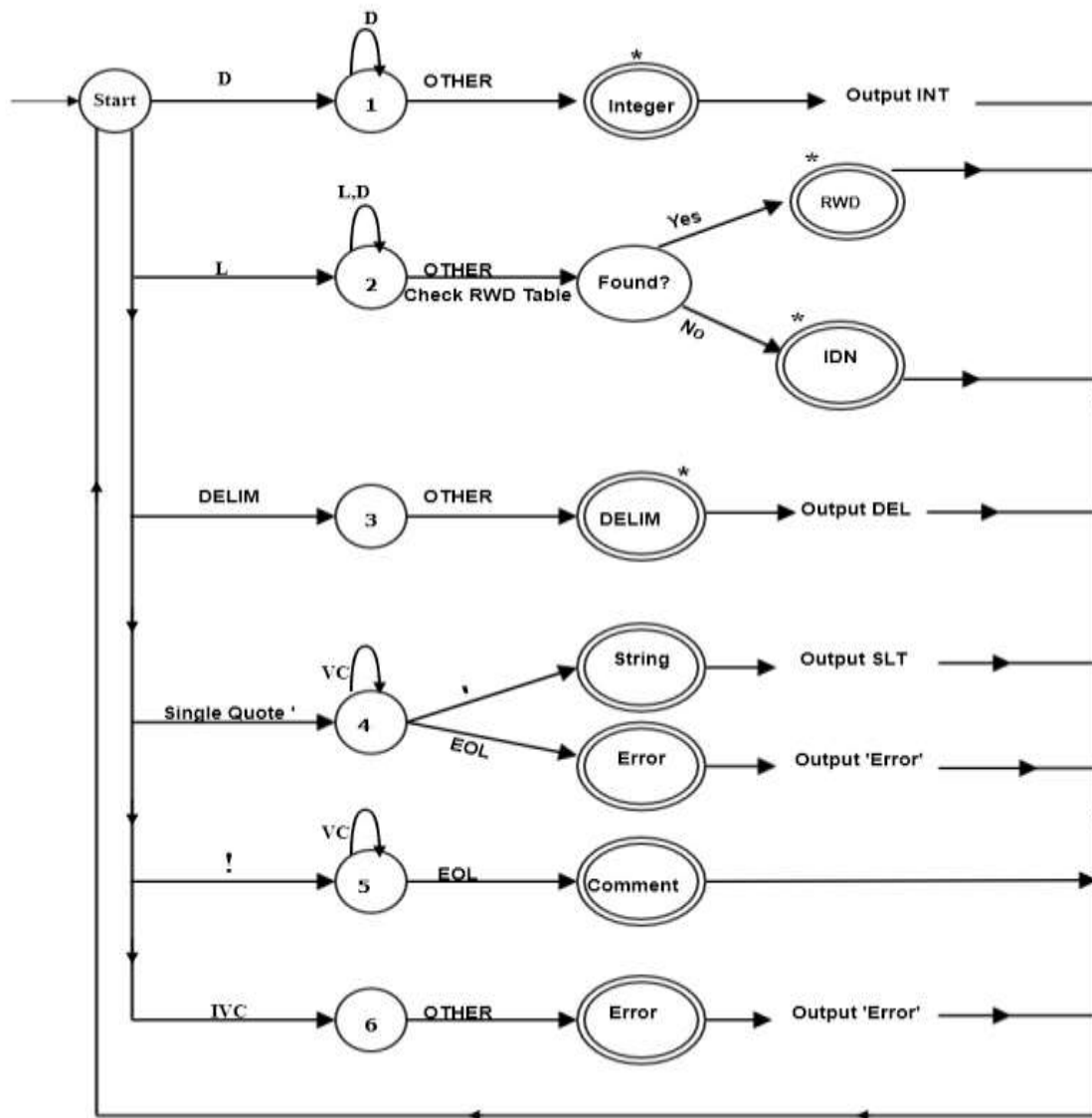


Figure 2: State Transition Diagram of the Token Recognizer

The Python Programming language will be used for the programming of the Token recognizer. Furthermore, input to the system includes;

- Yoruba-based Source program statements
- Table of terminal symbols (that is, the programming language's reserved words, operators and delimiters).

While the output that will be produced by the system (the token recognizer) includes:

- File of Tokens – which consists of uniform symbols (tokens) found in the source program

- b) Table of uniform symbols for each statement in the source program. Each entry in the table consists of the actual token and its category (such as an identifier or a literal). A sample is shown in the result section of this paper.
- c) Comment and Error File. The file contains comments on each source statements in the program along with detected errors in the program. The comment indicates the lexical correctness or otherwise of each source statement.

A text editor, such as a notepad, will be used for the entry of source statements in the Yoruba-based PL. A sample fictitious source program is given in Figure 3. Each source statement is contained in one line.

Dèbó = Adé
Adé = 5
Jèki abd45yu = 55W / Q4 ') ihjkl + 'mnop' * ! rst < u1 W
Abd = 4 (+
!Abd = 4 (E+ma) >Z – Gbóló / Q2
Abd = 4 (E+ma) >Z – Gbóló / Q2

Figure 3: Source Program in Yoruba for Testing the System

4. Result and Discussion

Figure 3 is a fictitious source program in Yoruba that can serve as input to the system. If the system is tested with the source program in Figure 3, a sample output that will be produced for statement 3 in the source program is as shown in Figure 4. Figure 5 is the output that will be produced for the entire source program of Figure 1.

Figure 4 contains the different tokens recognized in the source statement 3 along with their token categories (reserved word, identifiers and so on). In the test data, an exclamatory mark (!) precedes a comment statement, while a string literal is enclosed within two single quotes. Figure 5 shows that characters Q and Z in statement 3 of Figure 3 are correctly recognized as being invalid characters in the alphabets of the Yoruba language.

OUTPUT OF THE TOKEN RECOGNIZE FOR THE YORUBA BASED PROGRAMMING LANGUAGE

Statement 3 : Jẹkí Abd45yu = 56W / Q4' -) ilijkl + 'mnop' * !rst < u1w

S/N	Actual Token	Token category Internal Repr
1.	Jẹkí	Reserved word
2.	Abd45yu	Identifier
3.	=	Operator/Delimiter
4.	56	Integer
5.	W	Identifier
6.	/	Operator/Delimiter
7.	4	Integer
8.	-) ilijkl +	String Literal
9.	Mnop	Identifier

Statement 3 : Jẹkí abd45yu = 56W / Q4 ' -) ilijkl + 'mnop' * !rst < u1w has been processed

Press any key to continue / F1 ka tẹ Bọtini kan lati tẹsiwaju

Figure 4: System's Output for Statement 3 in the Source program of Figure 3.

System's Produced Comments & Error File

Àbájàde Şişe Ayèwo Síntáasí Akókó Ninù Purogiràamù Yí

= = =====

Àsìsé ni ilà 3 : Q jẹ Kàràkitá Àjeji

Àsìsé ni ilà 3 * | rst < u1 w Literal Òlòrọọ yii Ko dara to o

Òrò Alaye ni ilà 5 : !Abd – 4 (E+ma) >z – Gbògo / Q2

Àsìsé ni ilà 6 : Z jẹ Kàràkitá Ajeji

Àsìsé ni ilà 6 : Q jẹ Kàràkitá Ajeji

Lexical analysis of the program is completed with Errors!!

Şişe àyèwo Síntáasí Àkókó ninù Purogiràamù yi ti pari –

SUGBON Wàhálà diẹ wa !

Figure 5: System's Output for the programmer (using Figure 3)

5. Conclusion and future work

Successful development of a token recognizer for a programming language (PL) with the lexicons and orthography of a standard Yoruba language will fast tract the full development of a compiler for such a Yoruba-based PL. Such a PL will provide an indigenous platform for teaching computer programming to indigenous pupils of junior secondary schools. This study is on the development of a token recognizer and not on the implementation of a complete compiler for the Yoruba-based PL. The next step in this study is to embark on the full implementation of the system using Python PL or any other suitable PL.

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Developing a Cybersecurity Framework for the Namibian Banking Institutions

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Abstract

Managing the banking sector in Namibia presents a herculean task to regulators charged with its regulation oversight on cyber risks. The management of cybersecurity takes on greater complexity in considering multinationals with global partners and operations in countries with varying levels of cybersecurity sophistication. With the increase of cyber-attacks worldwide and banking institutions being key targets, the degree of risks from cybersecurity threats that banks are facing has grown rapidly in recent years. The increasing threats place sensitive data and organisational security at risk. This is exacerbated by the absence of a recognised cybersecurity framework that can safeguard the online transactions of financial data between banks and customers in the banking sector. Therefore, this paper proposes a development of the Namibia Banking Cybersecurity Framework (NBCF) to guide banking institutions in safeguarding the online transactions of financial data between banks and customers was developed. The researcher analysed various international cybersecurity frameworks and used literature review and the semi-structured interview results to inform the design of the proposed NBCF.

Keywords: online transactions, cyber-attacks, security frameworks, digital products.

1. Introduction

In modern times, banking institutions have adapted modern advances of doing business electronically. In Namibia, all banks to date have implemented electronic banking and mobile banking in one way or the other. As a result of technology evolution, technologies such as on-line banking and e-commerce have resulted in financial transactions amounting to millions of dollars happening across network connections, in the cyberspace, increasing the risk of Internet computer fraud in the banking sector due to online banking services (Bhasin, 2015). By doing business in a more connected world and providing more digital products increases the banks' risk of successful attacks and it is not about if an attack will occur but when it will occur. The risk is thus increased on the back of the Fourth Industrial Revolution.

In Namibia at present, there is no official national cybersecurity strategy (Dutton, Goldsmith, Saunders, Varese, & Von Solms, 2019). However, in February 2020, the Ministry of Information and Communication (MICT) with the assistance of the Commonwealth Secretariat, devised some of the components of the cybersecurity strategy. The Namibian government is thus in the process of finalising its cybercrime related legislation which includes the draft Cybercrime Bill and the draft Data Protection Bill. The Electronic Transactions Act (ETA) was approved in 2019 and implemented in 2020 (Ministry of Information and Communication Technology, 2020).

The increasing cyber threats places sensitive data and organisational security at risk. This lack of cybersecurity measures and best practices make companies easy target of hackers. According to Kaspersky (2020), about 2.9 percent of malware attacks globally targeted Namibian banks. Namibia is lagging in cybersecurity international trends and policies, and it does not have the technical nor financial ability to deal with the threats. This has therefore necessitated the need of a cybersecurity framework as this will go a long way to curbing the menace of cybercrimes

2. Objectives

The objective of this study was to identify and evaluate various patterns of cybercrimes associated with online transactions in the Namibian banking institutions and develop a cybersecurity framework to guide Namibian banking institutions in managing online financial transactions.

3. Methodology

This study used a Design Science Research Methodology (DSRM) to develop the proposed NBCF. This approach was adopted to produce an artefact (cybersecurity framework) which was shaped to address the cyber threat problems in the banking sector of Namibia. Various cybersecurity frameworks were analysed in section 4 and literature review and the semi-structured interview results were used to inform the design of the proposed Namibia Banking Cybersecurity Framework. The design science research processes, stated by Peffers, Tuunanen, Rothenberger, and Chatterjee (2007) was applied in this study.

4. Cyber Security Frameworks

A cybersecurity framework is, essentially, a system of standards, guidelines, and best practices to manage risks that arise in the digital world. Some of the security frameworks mostly used by many organisations to curb cybersecurity challenges include the following:

4.1 National Institute of Standards and Technology (NIST) cybersecurity framework

NIST is a framework of the United States government for improving critical infrastructure cybersecurity. Since NIST framework focuses on business objectives and drivers, it assists organisations by identifying, assessing, and managing cyber-risks. The NIST framework is therefore, designed to shape standards for any organisation in any sector or community such as for the private and government sector and not only for the critical infrastructure organisations.

There are three aspects to the NIST cybersecurity framework: the framework core, profile and implementation tiers. The framework core refers to a set of cybersecurity events which provide a set of desired cybersecurity outcomes for sectors with critical infrastructure. Five functions make up the framework's core, namely identify, protect, detect, respond, and recover (National Institute of Standards and Technology, 2018). The use of this voluntary framework helps in improving the cybersecurity of the critical infrastructure and guide individual organisations in increasing the cybersecurity posture, identify and prioritise scenarios for improving IT security through risk assessment, target state and assess progress in cybersecurity (Teoh, Mahmood, & Dzazali, 2017). Thus, in the banking sector, the framework could enhance cybersecurity resilience and provide improved safeguards for the banking institutions' client accounts and data.

4.2 The CPMI-IOSCO cybersecurity framework

The Committee on Payments and Market Infrastructures (CPMI) and the International Organisation of Securities Commissions (IOSCO) in 2016, issued regulation on cyber resilience for financial sector infrastructures (Crisanto & Prenio, 2017) for the United Kingdom and United States. According to Crisanto and Prenio (2017), “for jurisdictions with specific regulatory requirements for cyber-risk, the usual starting point, as with any other general regulation on other risks, is for banks to have a documented cybersecurity programme or policy” (p. 6). These requirements for cyber-risk therefore are based on the CPMI risk management groups.

4.3 ISO/IEC 27001:2013 Standards on Information Security Management Systems

Another prominent technical standard in the cyber and information security community is the International Organisation for Standardisation and the International Electrotechnical Commission (ISO/IEC) 27000 series. ISO/IEC 27001:2013 is a well-known expert committee designed for the development of international management systems standards for information security well known as the implementation of an information security management system (ISMS) in organisations and has been implemented by many organisations world-wide (IEC, 2013). ISO/IEC 27001 has been developed for protecting organisations’ information assets.

For the purpose of this research, the main focus of interest is the normative references of the standard, which references control objectives and controls totalling up to one hundred and fourteen controls (114), excluding the security controls clauses’ title containing main security categories and control objectives. In consideration of the organisation’s information security risk environment, these controls should be reviewed and considered by organisations interested in implementing this standard. It is therefore, crucial for organisations applying the ISO/IEC 27001:2013 standard to identify applicable controls with relevance to their importance and the application to their business processes and thus any omission to these controls should be appropriately justified and documented.

4.4 Center for Internet Security (CIS)

In March 2018, CIS controls version 7 was released, which is the latest twenty important cybersecurity recommendations. The CIS controls are the in-depth-defence security best practices created by IT experts from an extensive range of sectors to mitigate cyber-attacks against systems and networks (Center for Internet Security, 2018). CIS provides cyber defenders access to security standards, best recommendations of security controls and best practices. It looks at the most critical risk areas that organisations need to mitigate to enhance the organisation’s current security state. The CIS controls concentrate on the most important and beneficial security activities that any organisation can implement in order to provide world-class cybersecurity solutions that prevent and respond to cyber incidents quickly. The fundamental goal of the CIS controls is to improve the organisation’s knowledge and capabilities to prevent, notify, and respond to cyber-attacks.

The CIS has five critical tenets of a strong cyber-defence system namely, (1) offense informs defense, (2) prioritization, (3) measurements and metrics, (4) continuous diagnostics and mitigation and (5) automation. CIS controls version 7 has 7 key principles, and it looks at the current cybersecurity threat

landscape that all organisations are encountering. It was also well aligned with other frameworks, such as the mapping to NIST Cybersecurity framework discussed in 4.1 above and the controls are adaptive, relevant, helpful, measurable and flexible for various organisations of all sizes considering securing its systems and data. The CIS controls V7 consist of 20 controls that organisations all over the world can adopt to remain cyber secure.

4.4 A framework for the Governance of Information Security in Banking System frameworks

The ISG framework is an integration of several governance frameworks available today such as the Federal Financial Institutions Examination Council (FFIEC), Control Objectives for Information and Related Technology (COBIT), the International Organization for Standardization (ISO) 27002, and Payment Card Industry - Data Security Standard (PCI-DSS), the Corporate Governance Task Force (CGTF), Information Systems Security Association (ISSA), and the Corporate Information Security Working Group (CISWG). The ISG framework can be used as a starting point by banking sector to govern information security by developing guidelines and implementing controls to protect banking information assets from the cybersecurity threats. It is outstanding that not one of the frameworks cover all information security governance components, "some of the framework such as PCI Security standard is very specific to operational level. Some other frameworks, such as ISO 27002 or the COBIT, also detailed technical practice security standards, which have the character of basic configuration and operation of IT systems and only indirectly affect information security" (Ula et al., 2011, p.5). The framework is categorised into three levels which are strategic level, tactical, operational level, and technical level.

5. Cybersecurity issues in the Namibian Banking Sector

In order to understand cybersecurity issues in the Namibian banking sector the researcher purposefully selected six banking institutions in Namibia. Interviews were used as a means of data collection. The population used for this study consisted of 8 IT staff from 6 licenced commercial banks in Namibia who include Information security manager, Information security specialist, network engineer, IT risk analysts and system administrators. The researcher utilised structured questions where a set of questions were used in order to give all interviewees the same context of questioning to probe for clarity of the subject matter. Responses from all the participants assisted in understanding their perceptions and experiences on the adoption of cybersecurity frameworks in their respective banking institutions and how they think the Namibian banking sector can mitigate cyber risks and attacks.

Table 1: Outcomes obtained from the interviews conducted

Cyber Security Issues	Description
Types of cyber-attacks experienced	Phishing, social engineering, vishing, smishing, spear phishing, spoofing and website compromise, distributed denial-of-service (DDos) attacks
Main vulnerability for cyber-attacks	People remain the weakest link, phishing and vishing scams, spear phishing attacks to employees, lack of user awareness training, misconfigurations of systems, lack of two-factor authentication, no implementation of basic information security practices and lack of implementation of firewall policies.
Information security awareness	Lack of information security training, awareness and policies

From the interviews conducted it was discovered that the banking institutions are exposed to multiple cyber-attacks daily, where scammers attempt to hack their systems or plant viruses that impact system availability. The various cybercrime patterns include phishing, vishing, smishing, spear phishing, spoofing, website compromise, and distributed denial-of-service (DDos) attacks. In regard to information security awareness, the interview results highlighted that banking institutions lack targeted information security awareness campaigns which should better suit the needs of their employees in an effort to build a stronger cybersecurity culture. Their employees are the first line of defense against cybersecurity attacks. The main key is therefore ensuring that employees are adequately informed of how to identify and respond to cybersecurity risks and a cybersecurity awareness training program is one of the best ways of promoting a cybersecurity culture. The awareness training program will create more effective and targeted training campaigns that will strengthen the banking institution's human firewall. The interview results also underlined that most users do not understand the fundamentals of incident reporting as well as the bank's specific processes and policies. Establishing incident reporting processes helps banks in developing plans to prevent incidents from happening again. Therefore, the proposed framework was intended to address the mentioned cybersecurity issues.

6. Design and development

The researcher reviewed existing literature to obtain secondary data that provided the foundation for the proposed framework. In this regard, NIST cybersecurity framework, ISO/IEC27001: 2013 and the Framework for the Governance of Information Security in Banking System frameworks were used as guidelines. These three frameworks were selected based on the needs and core security areas that are essential for the financial institutions. An analysis of these frameworks is given in section 4. Given the issues discovered from primary data in the context of the banking sector in Namibia it became necessary to select three most appropriate frameworks and use them as the foundation of the proposed cybersecurity framework for the banking sector of Namibia

6.1 The proposed framework

In order to design and develop the framework, the existing cybersecurity frameworks and standards were evaluated through literature review to identify any gaps within them. In addition, semi-structured interviews conducted with bank employees also helped to identify gaps within frameworks and standards

applied within the Namibian banking processes. The proposed framework comprises of seven components with corresponding subcomponents. The seven components are identification, classification, protection, detection, response, recovery and compliance. The subcomponents are specific areas of security domains with corresponding security objectives which cover a wide variety of security elements and key areas. Numerous cybersecurity issues as illustrated in table 1 were identified from data analysis. To solve these issues, a Namibia Banking Cybersecurity Framework which will serve as guidance to safeguard online transactions of financial data between banks and customers was developed. Figure 1 represents the proposed Namibia Banking Cybersecurity Framework (NBCF) with all the 7 components and security activities.

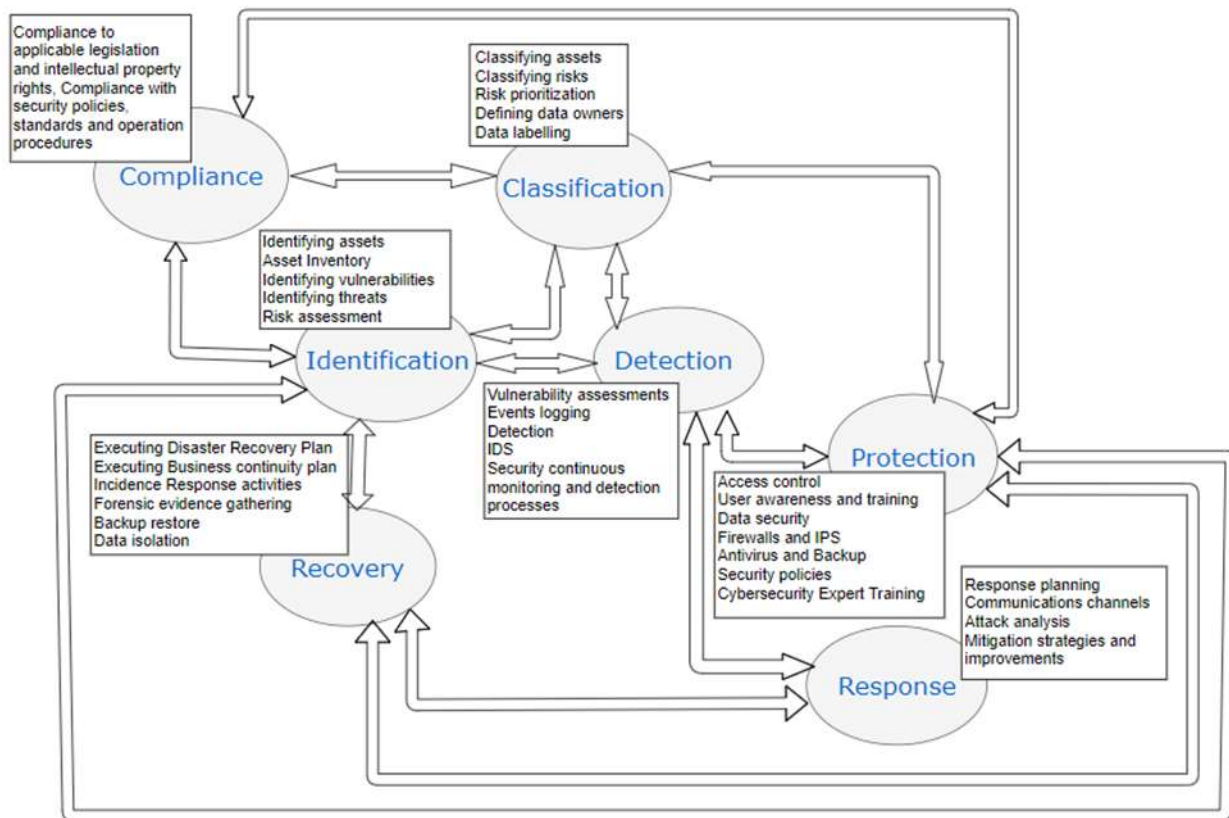


Figure 1: Proposed Namibia Banking Cybersecurity Framework (NBCF)

6.2 Framework Evaluation

This study adopted the expert review technique in order to evaluate the usability and adaptability of the framework. The primary purpose of the evaluation, in addition to gaining insights into the significance of the framework is to enable the determination of its merit, worth and relevance using a set of metrics. The evaluation tool was designed with reference from literature and a pilot study was conducted. An online google form evaluation questionnaire was developed. The review was carried out by a small group of field experts who analysed the framework to identify any potential usability issues.

The evaluation was aimed at verifying and confirming the validity and reliability of the NBCF framework. The weighting process measurements were contained in five evaluation criteria namely relevance, applicability, usability, adaptability and understandability. Based on the feedback obtained from the expert reviewers, the framework is considered to be highly relevant, applicable, usable and understandable in combating cybersecurity issues in the Namibian banking sector.

6.3 Framework description

The proposed NBCF provide cybersecurity risk management strategies to both technical and managerial audiences. The proposed framework advocates for cyber resilience with the focus on cybersecurity risk management and respond to and recover from cyber events to minimise business disruption and financial losses. By implementing the framework, organisations will be able to build cyber resiliency, where systems and operations are designed to detect cyber threats. Table 3 explains how the framework components were identified from literature review and data analysis. Furthermore, Table 3 also summarises the components' function, relationships and significance.

Table 2. Component's relationship, reference and significance

Component	Component function and relationship	Importance in Namibian Financial Banking Institutions	Reference to literature review and data analysis
Identification	Identification of critical assets. <i>This is the first component and it relates to the classification, protection, detection, recovery and compliance components.</i> Activities in this component include: Identifying assets e.g. data, users/people, networks, servers, etc.; asset inventory; identifying vulnerabilities; identifying threats; risk assessment; and identifying risk mitigation strategies which are aligned with the organisational strategic goals and objectives. Asset identification plays an important role in an organisation's ability to quickly correlate different sets of information about assets. The goal of asset identification is to proactively gather all necessary information about an organisation's assets that can be useful in responding to a threat affecting that asset. Asset identification leads to classification of assets and subsequently to the deployment of required protection mechanisms.	• Critical assets are assets that sustain the business e.g. data, users/people, networks, servers, etc., Knowledge of their existence helps to proactively gather all necessary information about the assets that can be useful in responding to a threat affecting that asset. It also helps in identifying risk mitigation strategies which are aligned with the organisational strategic goals and objectives. • All critical assets associated with information and information processing facilities should be identified and an inventory should be maintained. • Critical assets have a high risk of failure and, major consequences such as reputation concerns, legal penalties and compliance issues. • Therefore, it is important for financial institutions to have an understanding of its critical assets. • It is also important to perform vulnerability assessments in order to effectively identify risks and vulnerabilities in computer networks, systems, hardware, applications, and other parts of the businesses.	According to Security Intelligence 2016, many financial organisations neither identify nor classify data based on sensitivity and criticality (refer to chapter 4, section 4.2.3). As a result, financial organisations lack an understanding of which information assets matter to them most so as to provide appropriate security. Therefore, the identification of critical assets becomes the first step towards data protection and privacy. In addition, this can serve the institution from legal penalties due to compliance to industry regulations and laws. Identification component is inspired and adopted from NIST framework and the Governance of Information Security in Banking System.

Classification	Classification of critical assets. <i>This component relates to the identification, protection, detection and compliance components.</i> Activities in this component include: Classifying assets; classifying risks; risk prioritization; defining data owners and data labelling. <i>Asset classification</i> is used to identify the appropriate value and protection levels. Asset classification may comply with relevant regulatory and industry-specific mandates, which may require classification of different data attributes. For example, the Cloud Security Alliance (CSA) requires that data and data objects must include data type, jurisdiction of origin and domicile, context, legal constraints, sensitivity, etc. Asset classification leads to assets protection and subsequently monitoring mechanisms.	• Classification of critical assets helps in understanding of which assets matter most to an organisation. • Classification of critical assets that are key to the survival of the business. • Classification of critical assets helps in applying appropriate level of protection to information assets.	After identification of critical assets, they are classified. This component is adopted from ISO/IEC 27001: 2013 framework. According to this framework, Information should be classified in terms of legal requirements, value, criticality and sensitivity to unauthorised disclosure or modification. In addition to that, appropriate set of procedures for information labelling should be developed and implemented in accordance with the information classification scheme adopted by the organization.
Protection	Application of security controls to identified and classified critical assets. <i>This component relates to identification, classification, detection and compliance components.</i> Activities in this component include: access control; user awareness and training; training of cybersecurity experts; data security; firewalls; IPS; antivirus; security policies; and system backups etc. The quality of the overall protection of assets depends on the organisational environment, threats and vulnerabilities. Asset protection may	• Security controls and safeguards are applied in a systematic and consistent manner to critical assets based on the level of criticality of the asset to the organisation. This will enable the Namibian banking institutions to safeguard their assets in conjunction with the identified issue of data protection and privacy.	After classification, information assets are provided with appropriate level of protection. This component is adopted from NIST framework, ISO/IEC 27001:2013 and the framework for the Governance of Information Security in Banking System as described in chapter 2. According to NIST cybersecurity framework, organisations should develop and implement appropriate safeguards to ensure delivery of critical services. Examples of such safeguards include identity management and access control; awareness and training; training of cybersecurity experts; data security; information protection processes and procedures; maintenance; and protective technology. ISO/IEC 27001:2013 standard

	comply with relevant regulatory and industry-specific mandates, which may require protection of different data sets.		emphasizes on identifying organisational assets and defining appropriate protection responsibilities in an attempt of ensuring that information receives an appropriate level of protection in coordination with its criticality to the organisation. The Framework for the Governance of Information Security in Banking System advocates for increased third party security as such as cloud service providers since most financial institutions have the tendency of using technology services from which puts banking systems at risk.
Detection	Detection of the occurrence of a cybersecurity event/breach. <i>This component relates to identification, classification, protection, and response components.</i> Activities in this component include: vulnerability assessments anomalies and events logging and detection; IDS; security continuous monitoring; and detection processes. Detection is the practice of analysing the entirety of a security ecosystem to identify any malicious activity that could compromise the network or data confidentiality, integrity and availability. If a threat is detected, then response actions must be enacted to properly neutralise the attack/threat before it can pose damage to the asset/assets.	Security breaches should be detected in a timely fashion in order to reduce/stop the extent of the damage.	This component is adopted from NIST cybersecurity framework and the framework for the Governance of Information Security in Banking System as described in chapter 2. According to NIST cybersecurity framework, organisations should develop and implement appropriate activities to detect the occurrence of a malicious cybersecurity event as this enables timely mitigation/response to security threats, breaches and attacks. The framework for the Governance of Information Security in Banking System emphasises on performing vulnerability assessments of network systems and applications periodically in order to detect security loopholes so as to act in a timely fashion.
Response	Responding to detected cybersecurity breaches as they occur. <i>This component relates to detection and recovery component.</i>	Containing the impact of a potential cybersecurity incident is essential to the survival of the business. Additionally, it helps in avoiding future incidents.	This component is adopted from NIST cybersecurity framework, ISO/IEC 27001:2013 and the framework for the Governance of Information Security in Banking System as described in chapter 2. NIST framework advocates on developing and implementing appropriate activities to take action

	Activities in this component include: response planning; communications channels; attack analysis; mitigation strategies; and improvements. Responding to security attack and threats is an important aspect of information security. The ability to recognise network intruders or other malicious adversaries in a timely fashion enables the organisation to effectively recover from security events and effectively mitigate damage.		regarding a detected cybersecurity incident. ISO/IEC 27001:2013 framework advocates that procedures should be established to ensure a quick, effective and orderly response to information security incidents. The framework for the Governance of Information Security in Banking System emphasises performing dynamic simulations to threats in order to assess incidence response readiness and effectiveness.
Recovery	Recovering from cyber-attack incidents. <i>This component relates to identification and response components.</i> Activities in this component include: Executing Disaster Recovery Plan/Business Continuity Plan; Incidence response activities; forensic evidence gathering; restore plans; data isolation; and compliance issues etc. Recovery helps to create an effective system to manage business disruptions and to be able to contain the impact of a potential cybersecurity incident.	Recovering from cyber-attack incidents helps the organisation to resume services after a disruption in order to reduce losses or avoid legal penalties. A recovery plan also helps the business in defining and meeting the defined Recovery Point Objective (RPO) and Recovery Time Objective (RTO). This helps the organisation to minimise data loss and service loss.	This component is adopted from NIST cybersecurity framework, ISO/IEC 27001:2013 and the framework for the Governance of Information Security in Banking System as described in chapter 2. NIST framework focuses on the development and implementation of appropriate activities to maintain plans for resilience and to restore any capabilities or services that was impaired due to a cybersecurity incident. ISO/IEC 27001:2013 standard emphasizes on establishing organisation's business continuity management systems. The framework for the Governance of Information Security in Banking System focuses on initiation of action plans and mobilisation of resources to remediate following a cyber-incident.
Compliance	Compliance to various industries, national and international laws and regulations. <i>This component relates to identification, classification and protection components.</i> Activities in this component include: Compliance to applicable legislation intellectual property rights; compliance with security policies and standards and operation procedures. To ensure secure operations and the proper protection of sensitive	Financial institutions are subjected to comply with a number of industry, national and international laws and regulations. Failure to adhere to some of these laws and regulations may result in serious negative consequences for the business operations.	This component is derived in reference to ISO/IEC 27001:2013 standard. According to this standard, an organisation should avoid breaches of legal, statutory, regulatory or contractual obligations related to information security and of any security requirements through compliance. Some of the legislation, regulations and laws that the Namibian banks must comply to include, Bank of Namibia Determination of Information Security (BID-30); Payment Card Industry - Data Security

	data, financial institutions are normally expected to comply with local and international regulatory security compliance requirements.		Standard (PCI-DSS); Financial Intelligence Act (FIA); Know Your Client (KYC); Anti-Money Laundering (AML); Protection of Personal Information Act (POPI Act); and General Data Protection Regulation (GDPR).

7. Benefits

This study serves the basis to continue to expand and update the locally recognised cyber security body of knowledge. This framework supports efforts to deal with complex and emerging cybersecurity issues in the banking sector by providing a baseline of security objectives and activities to be implemented. The framework draws on standard methodologies used to assess various types of cyber risks and can be easily applied at the individual and organisational level as implementation guidelines are provided.

8. Conclusion

The main research goal of this study was to develop a cybersecurity framework for the banking sector of Namibia. This was achieved by creating and evaluating the proposed NBCF framework for the Namibian banking sector. Additionally, the analysis showed that cyber-risk is an emerging threat for all financial institutions. The study provides a roadmap to deal with cybersecurity issues in the Namibian banking sector and it contributes to the cybersecurity body of knowledge in the banking sector.

The study findings indicate that there could be positive change in strategies used by IT and compliance professionals to mitigate cyber threats and promote cyber resilience in the Namibian banking institutions. Improvements in the protection of their critical assets may strengthen confidence, trust and reputation in the community and society. The study findings identified key factors necessary for an improved cybersecurity strategy for protecting banks and the developed Namibia Banking Cybersecurity Framework (NBCF) will also go a long way to building cyber resilience. The increased occurrence of successful cyber-attacks has resulted in the disruption of key utility services and loss of personal financial data. This study provided an exploration and contextual analysis of strategies in cybersecurity and developed a framework for the banking institutions which will provide a high-level, strategic view of an organisation's cybersecurity risk management and will be of assistance to IT and compliance professionals in these banking institutions. Successful protection of critical infrastructure benefits banking institutions and customers by ensuring that key services are sustained during crisis events. This success also contributes to improving and enhancing the IT body of knowledge by protecting sensitive industry and customer's data that enables the continued flexibility in using modern technologies. In addition, the study findings may help improve employee behaviours towards cybersecurity and compliance. Lastly, once the banking institutions adopt and implement the framework, future research should be performed to find out about its flexibility, implications on Bank of Namibia (BoN), relevant cyber laws and governance.

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Designing a Security Model for Ehealth System in Namibia

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Abstract

Delivering services online has been embraced worldwide and even in developing countries including Namibia. Namibia has been rated as growing technology readiness however when it comes to the Global Digital Health Index where usage of digital technology for health is accessed, monitored, and tracked Namibia has no indicators. Furthermore, in recent years Namibia has been ranked as one of the African countries most targeted by cybercrime, necessitating the need to protect its online services including eHealth systems. It is against this background that this paper presents the process followed in designing a security model for eHealth system in the Namibian public health sector. The study followed the 5 phases of the Design Science Research paradigm by Vaishnavi and Kuechler to design the model. Quantitative data was collected via experimentation with the designed eHealth system. Qualitative data were collected through open-ended survey questionnaires and desktop reviews to establish whether there are measures in place that aim at mitigating security vulnerabilities in the eHealth system as well as to design security components to constitute a secure eHealth model. A secure model will benefit all patients whose medical records are captured, transmitted, and stored electronically in the public health institutions' eHealth system. Patients will be confident that their medical records are kept safe with minimum exposure, and this will give Namibia's public health sector a good reputation. In the future, a similar study should be carried out in Namibia's private health sector to enable a nation to integrate its Health system.

Keywords: Information security, eHealth system, vulnerabilities & threats, security model, electronic health record.

1. Introduction

In 2011, Namibia moved from the traditional way of delivering health services by implementing the Integrated HealthCare Management System (IHCMS) at public health institutions in line with world trends (Smit, 2011).

The systems allow for efficient service delivery and access to patient records by all practitioners centrally, however at the same time eHealth systems make it easier for cybercriminals to gain access to healthcare records and other personal information (Fernández-Alemán¹, 2022). The eHealth systems are critical infrastructure and subsequently have been targeted by cybercriminals. There are incidents of eHealth security breaches recorded everywhere in the world. For instance, in June 2020 South Africa's Life Healthcare was hacked by cyber-criminals, a situation that caused the Healthcare to run from the backup system, causing the hospitals and administrative offices to function with some delays, affecting its business processing system, admission system as well as email servers. (Reuters, 2020).

The HIPAA journal of February 2020 titled 2019 Healthcare Data Breach Report stated that there was an enormous escalation in healthcare data breaches in 2019 compared to 2018. In the year 2019, about 510 healthcare data breaches were reported, representing 196% increase from 2018 (HIPAA, 2020). One of the Healthcare institutions hacked in 2019 was the American Medical Collection Agency (AMCA), the hacker accessed the AMCA system and stole the client's sensitive data. The breach

impacted many individuals, and it was the hugest healthcare data breach reported in 2019 (HIPAA, 2020).

No cases of eHealth security breaches have been reported in Namibia yet, however, according to the International Telecommunication Union (ITU), the United Nation (UN) body for ICT, in 2020 it has classified categorized Namibia in its Global Cyber security Index (GCI) as a potential haven for online criminals (Ndumbu, 2021). This is due to the fact that the GCI 2020 titled, measuring commitment to cybersecurity, Namibia was ranked number 155 among 194 ITU members' states and regional ranking Namibia ranked 32 among 43 African countries measured for their commitment to cybersecurity (ITU, 2021). The aim of the GCI report is to understand better countries' obligations and commitments to cyber security, identifying gaps, encourage countries to incorporate cyber security good practice, and provide useful insights for the countries to advance their cyber security postures (ITU, 2021).

According to the Kaspersky (2021), Namibia was positioned under 10% - 20% of those countries vulnerable to online infection. Kaspersky computes the percentage of Kaspersky users on whose computers Web Anti-Virus was triggered during the quarter under assessment the output data gives an indication of the hostility of the environment in which computer operates in. Still based on the same report, Namibia fell in the range of 35% - 40% of countries where users are at a higher risk of local infection (Kaspersky, 2021). The report indicates that Namibia is vulnerable to cybercrimes, hence the need to secure its online services including eHealth.

Namibia is one of the African countries with cyber threats as reported by INTERPOL's partner Trend Micro from January 2020 to February 2021 (Stephen & Sharif, 2021). Through literature review and previous studies on assessment of security requirements done on eHealth system implemented in Namibian hospitals, the problem was identified as: **Namibia lacks security models to guide the Ministry of Health and Social Services on implementing eHealth security requirements.** (Mbala & Bhunu Shava, 2017). The next section looks at some ways addressing this challenge.

Different models for securing eHealth systems

Patient's personal information could be shared between different healthcare stakeholders, which may lead to privacy disclosure. Hence there's a need to improve healthcare delivery quality by adopting convenient security models that enforce proper access control as well as other eHealth security mechanisms. Tab.1 outlines some of the eHealth security models that have been designed to secure patient records. The eHealth Models discussed in Tab. 1 lack mechanisms to measure accountability as well as verification of users registered in the eHealth application system. Thus, this paper presents the process followed to design a model for securing the eHealth system in order to mitigate information security threats in Namibian eHealth systems.

Table 1: Strength and weakness of the existing eHealth security models

eHealth Security Model	Strength	Weakness	Sources
Context-aware Access Control Security Model (CARE)	Accessing of data in the database is controlled by the use of Extended Role Based Access Control (ERBAC). There's Session Handler Module (SHM) responsible for establishing sessions between the client and the server. Secure communication such as Transport Layer Security (TLS) or Secure Socket Layer (SSL) exist.	When used in pervasive context-aware environment, it got some limitations. Hence to provide dynamic access control decision, it is necessary to integrate a context model into the policy model.	Mishra (2014) Keys et al. (2020)
Trusted Virtual Domain (TVDs)	It ensures that sensitive data is protected all the way to the end users from centrally managed secure networks.	This model did not address security mechanism such as patient authentication, an anonymity and nonrepudiation	Lohr, Sadeghi, & Winandy (2010).
Ciphertext-Policy Attribute-Based Encryption (CP-ABE)	CP-ABE offers fine-grained medical records access control.	The drawback of this model is the embedment of the access policy in the ciphertext, meaning any user whose attribute satisfy the police can decrypt the ciphertext.	Methanol & Rajeswari (2017) Meng, Cheng & Wang (2021)

7. Research Design

This section of the paper outlines the application of the 5 step DSR process by Vaishnavi and Koehler 2004, which deemed fit for the study to attain 5 outputs. Which are the proposal, tentative design, artefacts, performance measuring and the results.

Step 1: Awareness of the problem

Involved identifying the problem, through literature review and a previous study on assessment of security requirements done on eHealth system implemented in Namibian hospitals, the problem was identified as: **Namibia lacks security models to guide the Ministry of Health and Social Services on implementing eHealth security requirements.**

Despite the fact that the study reveals some of the security controls meets expectation, the ministry is still vulnerable to cyber incidents since most of the security controls are not effective. This basically means the Namibian eHealth care system is susceptible to security breaches hence the need to design a security model for eHealth system in Namibia. The model objectives are:

1. To offer security mechanisms and ensure that the patient's EHR is protected during its inception, during transmission and during storage.
2. To ensure that patient's data confidentiality and data integrity is maintained.

The next section discusses suggestion stage that deals with component identification, component relationship as well as concept mapping.

Step 2: Suggestion

Suggestion is an innovation stage where through a novel configuration of a new element or an existing one, a new functionality is envisioned (Vaishnavi, 2017). Therefore, the researcher has managed to identify the major components of the proposed model as well as the key stakeholders to be involved in the model design. The identification the components was guided by the Business Model for Information Security (BMIS). The Business Model for Information Security addresses inconsistency definitions of security within an organization by introducing Information Security as a common language through system thinking principles and by roles definition (ISACA, 2009). Tab.2 shows identified components of eHealth Security Model in accordance with BMIS elements.

Table 2: Identified components of eHealth Security Model in accordance with BMIS elements.

BMIS Elements	Identified components of an eHealth security model
Organization	Medical Institution (MOHSS)
Process	Security policies and standards
People	Medical personnel, patients, and IT personnel
Technology	eHealth System (Web directory, Encryption Algorithm & Role Based Access Control (RBAC), eHealth card plus eHealth card reader machine.

Fig. 1 illustrate the relationship between all identified components of an eHealth security model.

Figure 10: Model components.

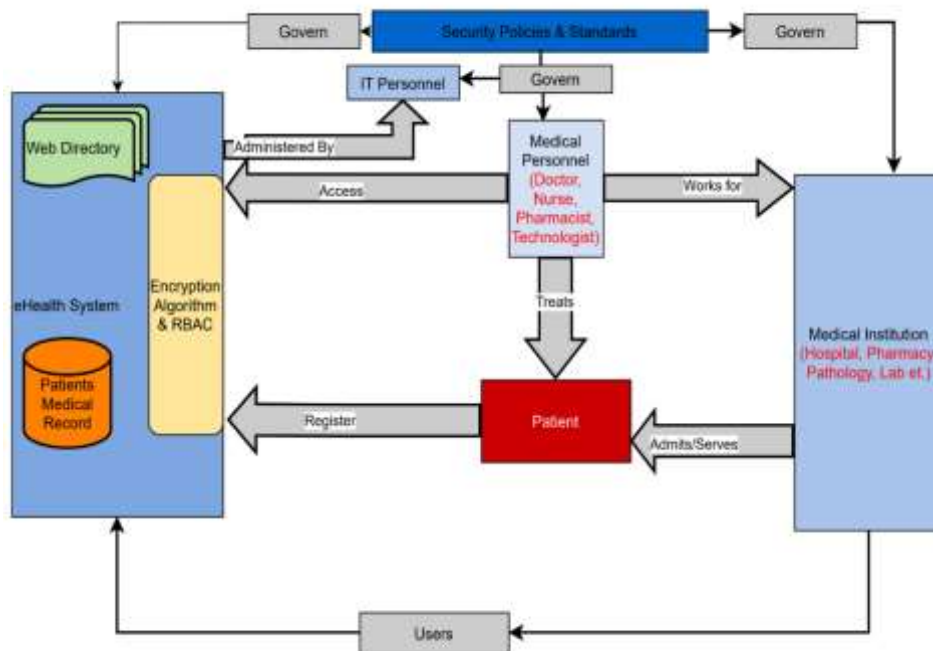
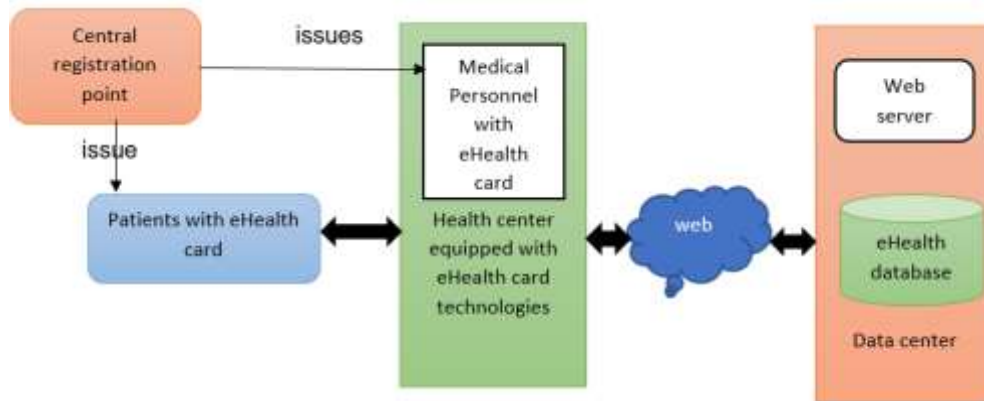


Fig.2 shows a tentative model for the proposed model. The medical entities got registered and issued with eHealth card which they can use to access the eHealth system via the web application.

Figure 11: A tentative model for the proposed eHealth security model



Step 3: Development

At this point the conceptual design was demonstrated by implementing it. The proposed model was developed using the hardware and software components defined in Tab.3. The hardware part of this model consists of an eHealth card and a card reader, while the software part consists of a web-based application for information management system and an eHealth card software module for authentication purpose. The web-based application is implemented with XAMPP technology which stands for cross-platform, Apache, MySQL, PHP and Perl. The entire system security is enhanced with Encryption Algorithm, RBAC and audit log.

Table 3: Hardware and software incorporated in the proposed model.

Hardware	Software
eHealth card (e-card)	web-based application (XAMPP) + HTML
eHealth card reader machine (e-card reader machine)	eHealth card software module (C# .Net framework)

The proposed eHealth security model caters for verification, authentication, authorization as well as accountability as presented in Fig. 3.

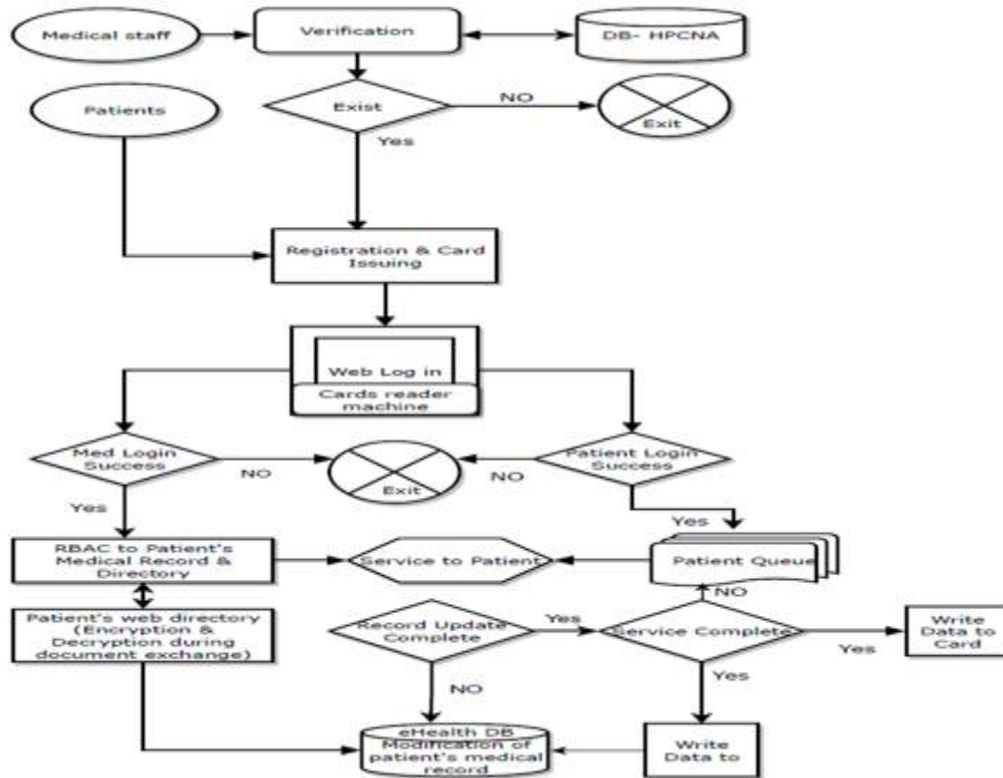


Figure 3: The proposed eHealth security model before evaluation

Step 4: Evaluation

6.4 : Evaluation and model refinement

For this study the proposed model is evaluated before implementation, the evaluation was based on the model design specification and also on the security & usability of the developed eHealth web application. Basically, there are three main categories of eHealth evaluation: Usability Evaluation: the ease-of-use in the system; Logistics Evaluation: management and upkeep of the system plus costs and Technical Evaluation: functionality, security and scalability of the system (Lo, 2012).

The model evaluation was carried out with the aid of questionnaires. Data was collected using close-ended questionnaires. Three sets of questionnaires were distributed to three different groups of people. The first set of questionnaires were distributed to Information Security Experts and the objectives of evaluation: To assess the proposed model on whether it offers sufficient security to the exchange of health information; and to solicit knowledge from experts that can be used to improve the artifacts security mechanism.

The second and third set of questionnaires were distributed to the IT and medical personnel at the MOHSS, specifically at a state hospital in Windhoek. The objective of the second and third questionnaires was to measure the model's usability in the Namibian public health Sector. Expert review technique is adopted in this study focusing on the usability and adaptability of a Security Model for eHealth System in Namibia. The model is evaluated to determine its merit, worth and relevance, using a set of metrics. Tab 4 presents the key suggestions from the experts.

Table 4: Comments/suggestions and Improvements made on the model.

Experts	Comments/Suggestions	Improvements made
Expert 2	It would be beneficial if people working in Health Information System are also part of the model evaluation to enable diverse input of people in different profession other than IT operations to allow for future model improvement, this can be recommended as future work.	After this comment questionnaires were deployed to the MHOSS
Expert 6	Some of the flow lines are not clearly labelled i.e. they are blank, how can those be interpreted?	Proper labelling were made.
Expert 6	It has to be clear on the flow-lines of your model, what is responsible for deciding when a service is complete or not? Does an incomplete service always entail it's the patient that has to be send back to the queue, what if it's the medical personnel that didn't complete their records update processes	Modification on the model drawing was made by adding another decision making diagram to cater for this comment. Another diagram was also added that guarantee that service is complete after medical personnel update record.
Expert 6	What action follows a failed verification on the patient? That has to be indicated on your model as you indicated on the medical staff?	Decision making diagram was added that indicate whether patients verification failed or not, the patient cannot be denied healthcare service.
Expert 6	It's a little bit confusing who is being issued the card, is it the patient or the medical staff or both? If it's both, why is there only a reading system for the patient's cards only, yet there a flow to registration and card issuing for both.	The card reading system was moved at the centre where it cater for both medical staffs and patients.
Expert 7	Mostly the missing part (Availability) requires attention as the system is dealing with patients. The system should henceforth guarantees the up-time. Patients need information anytime and anywhere. etc	Availability exclusion was a decision made together with the supervisor to be excluded at this stage of the study, however it can be recommended as future work for the developed system to be tested.
Expert 8	Improvement should be done on the processes, and the flow of information between all stakeholders	This comment was not clear, however more labelling on the flow chart were added to define the flow.
Expert 9	Some of these questions require supporting data/info in order to allow the answer to be provided with the right analysis and assessment. Supporting data to make the right assessment is necessary, and it does not appear to be so in your survey. So the answer given so far are pretty much based on thin air....and sometimes guessing game.	The developed eHealth web application catered for this comment.

6.5 Experimentation

After the model drawing was evaluated by the experts, it got developed into an eHealth web application. The technical evaluation focused on security aspects of the proposed eHealth system. The evaluation covered areas such as the effectiveness of authentication, the effectiveness of

authorization which is access control mechanisms and the availability of logs for accountability measures as well as general security on the web application such as inclusion of Transport Secure Layer (TLS). Usability evaluation was also covered.

This evaluation was carried out by the IT personnel and medical personnel at Windhoek Central Hospital (WCH).

Table 5: Overall evaluation of the proposed model.

Statements	Participant Responses
Overall the model is efficient.	28.6% of the evaluators strongly agreed and 71.4% agreed that overall the model is efficient. This means if the model is implemented it would function efficiently.
Overall the model is operational	22.2% of the evaluators strongly agreed, while 56.6% agreed that the model is operational and 22.2% disagreed. This means that during the refinement of the model the researcher had to make sure that the model reaches its optimum operation by incorporating the feedback received.
Overall the model is well designed & developed	33.3% of the evaluators strongly agreed, while 44.4% agreed and 22.2 % disagreed that the model is well designed and developed, thus the researcher needs to improve the design and development of the model taking into account the comments made.
Overall the model is relevant & needed.	55.6% of the evaluators strongly agreed, while 33.3% agreed and the remaining 11.1% disagreed that the model is relevant and needed for the public health care system. The outcome shows that the model is needed, and relevant for Namibia. However the model refinement resembles the real life scenario and cater for the least participants that represent 11.1%.
Overall the model is useful.	22.2% of the evaluators strongly agree and 77.8% agreed that the model is useful. We thus recommend the Health services to adopt it for implementation.
Overall the model is adaptable.	55.6% of the evaluators strongly agreed, while 33.3% agree that the model is adaptable. However 11.1% disagree citing that the model is not adaptable, thus the model will be refined to improve its adaptability.
Overall the model requires improvement.	22.2% of the evaluators strongly agreed, while 55.6% agree and 22.1% disagreed that the model requires improvement. It was imperative to take the feedback into consideration, as such improvement has been made during the refinement process.

6.6 The refined eHealth security model

Based on the evaluation processes, the suggestions and comments from the experts were carefully considered and addressed as areas of improvement. Some comments were already tackled earlier in the research, some influenced the changes in the model and the rest were to do with the alignment of factors in the model. The final model is presented in Fig. 4.

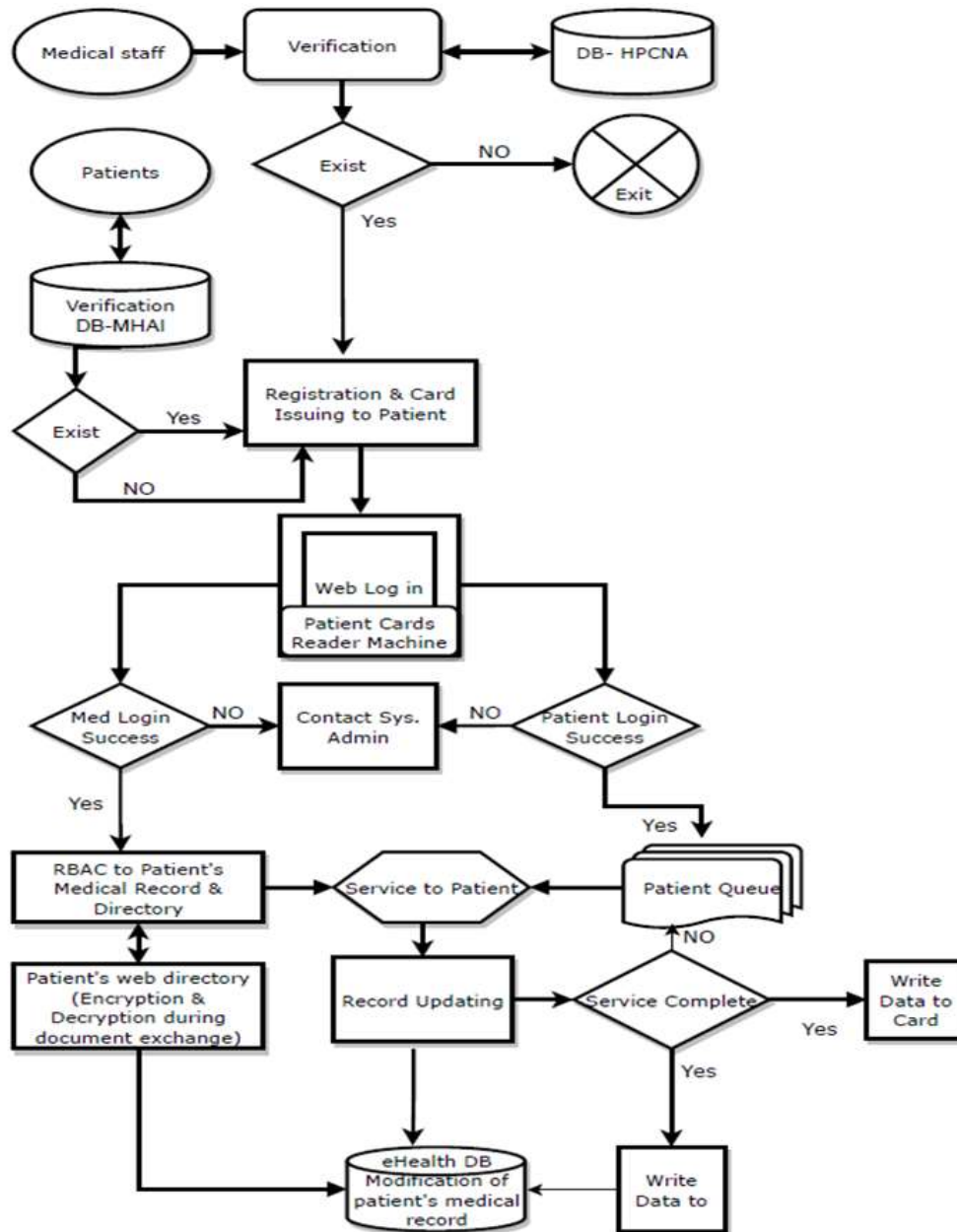


Figure 4: Refined ehealth security model.

6.7 The developed web application evaluation.

The proposed eHealth security model got further developed into an eHealth web application which is implemented with XAMPP technology that stands for cross-platform, Apache, MySQL, PHP and Perl. The entire system security is enhanced with Encryption, RBAC and audit log. For evaluation purpose the researcher presented the eHealth web application developed to the IT team of Windhoek Central Hospital as well as some of the medical team by demonstrating how the application works. Thereafter, the IT team and the medical team were asked to practice using real life scenario, whereby the IT personnel registered medical staffs & a patient in the system, assigned them roles and gave them login credentials. The Medical team were then asked to logon to the system and attend to the patient as per the normal practice, from the nurse to the doctor then to the pharmacist. The researcher shared

with the participants the link to the proposed web application to experiment with the system and complete the evaluation questionnaires.

6.8 Web application evaluation outcomes

The outcome of the proposed eHealth application evaluation showed that the system offers confidentiality of the patient's data. The system allows the administrators to set up individual profiles with usernames and passwords for those who will access the system. To minimize the number of users accessing the eHealth application and ensure confidentiality of the patient's sensitive information not all employees of the MHSS got to register into the system. Other scholars have echoed the same sentiment that medical confidentiality is attained through technical and operational controls within a covered entity and this means incorporating security measures that controls access to patient's data and protect such data from disclosure, loss & alteration (George, 2019).

Another notable security feature incorporated in the proposed eHealth web application is the secure communication channel. The communication between the web server and the client is done via HTTPS (Hypertext Transfer Protocol Secure) which is a secure protocol. HTTPS protocols use an SSL (Secure Socket Layer) a certificate that enables secure communication between the web server and web browser by encrypting the data being exchanged thereby shielding patient's sensitive information from being accessed during transit between the server and the client (Harnish, 2020). The SSL/TLS connections use a client/server model where the connection between the server and the client needs to be established, which is referred to as SSL/TLS handshake and for a complete handshake it means based on the set requirement of both parties (client & Server), the server has authenticated the client and the client has authenticated the server and this is what is called mutual authentication (Team, 2021).

The SSL/TLS does not only allow the system to perform authentication but also offers data integrity and data protection and all communications amidst doctor, patient, IT administrator and eHealth system are secured through end-to-end encryption by IPsec (O'Brien, et al., 2018). Other security features that the proposed eHealth application includes and evaluated to be effective, each user has a unique password, auto-generated by the system to access the EHR. Patients are only allowed to modify their demographic information to avoid them having access to their medical record. The Audit Trail tracks or log does exist as well to capture access to medical records and the administrator has the ability to restrict user access to the Audit Trail. The researcher carefully considered suggestions and comments from the experts and addressed them as areas of improvement whereby some of the comments and suggestions influenced the changes in the model as presented in Fig. 4. The key finding of the evaluation is that the proposed model does offer data confidentiality and data integrity in order to secure the eHealth system and mitigate information security threats in Namibian eHealth systems.

7 Conclusion

The paper focused on designing a security model for eHealth system in Namibia with the aid of the 5 steps of DSRM. The proposed eHealth security model offers a secure alternative way of storing, transmitting and accessing patient's medical record electronically. In that manner patient's medical history can be accessed efficiently at every public health centre. Apart from securing the patient's electronic record, the proposed model gives an environment-friendly platform in the public health sector since it has the potential to replace paper-based patient's medical record which is prone to littering. Patients will be confident that their medical records are kept safe with minimum exposure and this will give Namibia's public health sector a good reputation. The proposed model promotes

centralization, it eliminate dubious and unqualified medical personnel and it gives an environment-friendly platform. In the future, similar study needs to be carried out in the country's private health sector. Further research is required in implementing the development of eHealth cards module as well as card reader machine aiming at developing a mechanism which can. The proposed eHealth application need to be connected to Ministry of Home Affairs and Security so that the records are pulled from there and enables easier issuance of death certificate.

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Big Data Applications in Personalised E-learning for Distance Learners at Namibia University of Science and Technology

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Abstract

In a world where digital transformation is taking over, novel methods of communicating, teaching, and acquiring knowledge are correspondingly enhancing. New technologies offer flexibility whereby teaching and learning are no longer confined to a specific time slot or geographical location. As a result, distance learning is gradually becoming the new mode of study for many, particularly in high-learning institutions with many institutions adopting Learning Management Systems (LMS) as a way of delivering content using the web. To keep up with the changing world, methods of delivering knowledge should also improve by offering the convenience of a personalised learning style via the LMS. The conventional distance learning methods have always been a one size fits all approach, which disregards learners' style of learning. With emerging technologies of big data analytics, learning can be tailored to each learner's learning style by analysing data generated during their interaction with the LMS. The adoption of Big Data in distance learning will offer hints on how to individualise specific eLearning experiences to provide the best results for learners. This paper aims to review existing literature considering distance learning as empowered through LMS and emerging paradigms such as big data and recommend how it can be applied to NUST distance education. The main contribution of this review will be a decision basis for instructional designers, system designers, facilitators, and administrators for distance learners and LMS on some pointers on the research direction for on-demand technology solutions.

Keywords— *Big Data, Personalised E-learning, Distance Learners, Learning analytics*

1 Introduction

One size fits all approaches to learning would not yield the best results for learners. In assessing the effects of successful eLearning, implementations Mehta et al., (2019) point out expected outcomes, costs and expected key players in the social environment as equally important attributes to consider. One of the key ingredients to be highlighted in the design and implementation of an effective eLearning system should be learner preferences. This formulates the basis of bring all other ingredients together and delivering the right mix for effective learning experiences.

Distance learning platforms such as Udemy and Coursera are becoming popular. Distance learning, which might have been an option for a certain group of learners like those who were engaged at work and preferred learning on a flexible and part-time basis, became the best alternative even for those that has an opportunity to enroll on full time basis. When conventional learning environments succumbed into lockdowns under regulatory measures to curb the pandemic, distance learning gained its popularity sharply, inviting many innovative approaches to ensure learners' experiences are understood and enhanced in a customised way.

For meaningful engagements of learners on distance learning modes, understanding unique learning preferences, capabilities, and pace are equally important variables to put into consideration. Such variables are important ingredients towards the customisation of learning content and how LMS' are designed and could be improved. Learning customisations for distance learners aids in predicting learners performance, improve the desing of learning materias, leading to increased leaners rentention rates. The vast datasets collected by most LMS platforms could be harnessed through big data analytics towards enhancing learning experiences.

The main contributions of this paper to the existing body of knowledge of Big Data and E-learning could be summarised as follows: -

- Outlining the role of big data in enabling personalised learning for distance learners.
- Contextualising the application of learning analytics to a case study setting – NUST's distance learning offering.
- Proposing a healthy interaction among the key players in the eLearning ecosystem, to leverage the potential of big data analytics.

This paper is organised as follows: Section 1 is the introduction of the main concepts followed by Section 2, which covers literature on distance learning giving the context of learning requirements and Big Data with the focus on its application to distance education personalised learning and its contextual application for our case study. Section 3 is a summary of the proposed personalised E-learning for the distance learning ecosystem, leveraging big data potential. The paper is then concluded in Section 4.

2 Literature Reviews

2.1 Distance Learning

The mode of distance learning at university level has existed since the 18th century and its progression and evolution is traced to 300 years to date (Kentnor, 2015) . Distance learning adopts an approach opposite to face to face mode. Instead of gathering learners from various locations into a classroom, distance learning reaches out to learners at their desperate location (Guri-Rosenblit, 2005). The conventional method of distance learning heavily relied on postal services (Pandey, 2013). Learning material and assessment were distributed via the post office. The process was very slow and took long for learners to get response from their instructors.

Progressive technology innovations have reformed distance learning, where combinations of multimedia learning contents such as slides, audio and video are accessible via the Internet. The technology enabled real-time interaction between learners and the instructors by creating a virtual classroom environment, forming a new paradigm to the learning experiences for various learners that could be scattered over different geographical locations.

As pointed out by Guri-Rosenblit (2005), e-learning technology is a relatively a new phenomenon, that permits the integration of electronic media for learning purposes, ranging from add-on functions of conventional classrooms to full substitution for the face-to-face meetings by online encounter. In view of this, Kentnor (2015) clarified that the version of distance education can be viewed as online education which utilised computers and the Internet as the delivery mechanism with at least 80% of the course content delivered online. Although this is his outlook on this new technological phenomenon, Guri-Rosenblit (2005) on the contrary emphasized that distance education and e-learning do in fact overlap to a certain extent, they are not identical. Her argument is that distance education signifies the physical separation of learners from their instructors at least at a certain stage of the learning process.

2.2 Context Setting

Distance education has become an accepted mode of learning in Namibia, especially at Namibia University of Science and Technology (NUST), one of the leading technological

universities in Namibia. Distance learning at NUST is facilitated through the Centre of Open Lifelong Learning (CoLL) with the aim to transform the conventional role of knowledge transfer to learners who are physically located away from the campus (Mowes et al., 2005). CoLL serves all distance learners country wide by distribution study material and assessing learners via the distance centers across the country via Moodle LMS.

At NUST, Moodle was rolled out in 2010. The technical component of the system is managed by the Department of Information and Communication Technology (DICT) while the operational aspects is managed by the Teaching and Learning Unit (TLU), a unit that deals with teaching affairs at the institution. Most of the courses offered at NUST are linked on Moodle and the study materials are shared with learners on this platform, mostly as PowerPoint slides, with a few courses delivered using blended learning using videos and audios.

Although efforts were made to adopt various teaching methods to cater for various learner's learning needs, teaching is a one size fits all at NUST. Instructional designers, course developers and course instructors work in silo and in a one size fits all approach. Instructors prepares and upload the same study contents on Moodle for both full time learners, part-time learners, and distance learners with the expectations to fit their learning styles and meet the course learning objectives. This highly disadvantage the distance learners as they are expected to obtain the same results as the learners that attend classes and can engage with their instructor and reveal their learning styles which an instructor can adopt to.

2.3 Big Data Applications for personalised learning

The use of big data in LMS further has the potential to personalise learning. It's an approach to learning that has always been linked to the earlier era of face to face learning, where learners have one on one contact with the instructor, tailoring the methods of teaching to cater for every learner (Maseleno et al., 2018). In today's era, the word personalised learning relates to online learning, using learners' learning patterns and tailor the learning content to these patterns. It's an approach to learning that is guided by individuals' methods of learning, by compiling a profile of each learner's pace of learning and use this profile to guide study content development.

According to Amaral et al., (2013), personalised learning is a three-part process, primarily consisting of instructional planning which promotes deeper learner learning understanding of each learners, identifying learning needs and interests and lastly provisioning of suitable learning experiences that match each learner's unique learning profile. To attain personalised learning, combining the 3-part process with learning analytics is mandatory (Maseleno et al., 2018). This enables instructors to successfully predict the learners' future performances in their studies this process.

The analysis is usually a descriptive approach that detail information about date, time, and duration of learners' digital movements on LMS (Iskandar, 2018). Additionally, it reveals digital trails of how long learners spend on reading a document on LMS, watching a video or duration taken to complete an assessment (Alyahyan & Düşteğör, 2020). Other statistical analysis that can be revealed are details about learner's overall performance rate, prediction to succeed in the course learner's overall completion rate of a course as well as learner's interaction with peers and the instructors (Iskandar, 2018).

Learning analytics does not only focus on data relevant to learners but the course the learner is engaging with. It utilises analytical techniques to improve learner learning outcomes by targeting better instructional, curricular as well as supporting resources, interventions and learning culture empowerment (Elias, 2011). This force both instructors and learners to be highly engaged when

developing material based on the evaluation of educational data which consequently improves teaching and learning. Processes of learning analytics are depicted in Figure 1.

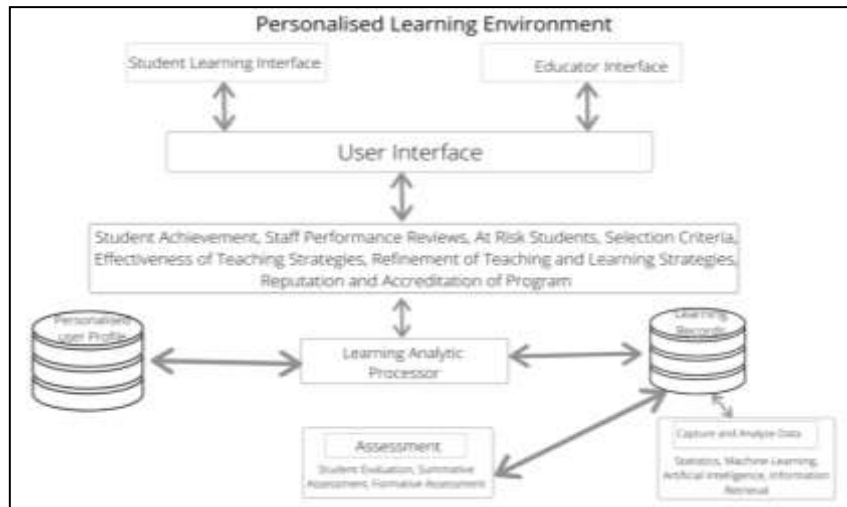


Figure 1: Learning analytics in personalised learning environment (Maseleno et al., 2018)

LMS combined with learning analytics tools provides a personalised learning environment is a valuable tool in supporting personalised learning process. Firstly, the user interface provides a friendly environment for learners to access the learning system. With every interaction, data is generated in them generating for instructors to analyse and consequently provide feedback to learner about improvements performance review and importantly for instructors to tailor their teaching strategies based on the learner's profile.

2.4 Big Data Application to our case study

To eliminate these discrepancies in learning, Moodle can be used as a tool to personalise learning for distance learners by analysing data produced by learners when interacting with the system. A study conducted by (Moore, 2019) identified a framework to be considered when implementing personalised learning in distance/online learning. This framework with eight (8) dimensions serves as a guide to consider prior to implementing a successful personalised learning using e-learning experience. The framework could be tailored to NUST's environment and guide in adopting bigdata technologies in their e-learning to personalise learning. The dimensions are as follows:

1. **Pedagogical:** This dimension addresses issues related to instructional content design and implementation (Moore, 2019). It's an inclusive term that defines what a teacher does to influence effective learning (Whiteside et al., 2017). NUST can adopt this dimension by be applying personalise learning via learning analytics by building learners' profiles using data as a guide to personalised learning. This data may include, for example, each click made while watching a lecture video or reading online content, time taken to complete such, click made while attempting an answer online assessment, posts discussion forum and access to other links provided for further reading. This helps in analysing their cognitive patterns that guide instructors in knowing their learners and tailor learning based on their learning behaviour. Activation of this setting on Moodle and this putting the necessary infrastructures in place will change distance learning experience at NUST.

Moodle, being the LMS used at NUST has Learning analytics features incorporated (Scapin, 2018). It has an embedded learning analytics that leverages machine learning for analysis to make future learning predictions based on past activities With Moodle already in place, Analytics for distance learners at NUST can be activated to improve learners learning experience online. Additionally, learning content development should include instructors, Data analytics and instructional designers.

2. **Technological:** This dimension addresses the environment and tools needed that hosts and analyse data on e-learning. The environment includes the hardware, software and network infrastructure. Learner 's interaction with LMS leaves a lot of digital traces behind (Scapin, 2018). This data is usually unstructured and massive that it requires huge storage space and dedicated analytical technologies to unveil patterns for decision making. The following technological tools are a requirement
(a) Storage

Although there exist multiple NoSQL databases suitable for unstructured data, a study conducted by Dahdouh et al., (2017) recommended the use cloud computing for e-learning data storage and processing due to the high maintenance of hardware recommended. Cloud computing is defined by Baharuddin et al., (2021) as management hardware, software and databases for data storage that is situated on a distant place. The cloud provides the infrastructure and resource required for big data deployment and the technologies to process such data. Considering that NUST has no adequate infrastructure for learning analysis deployment, the cloud would be the best environment to host their learning analytics.

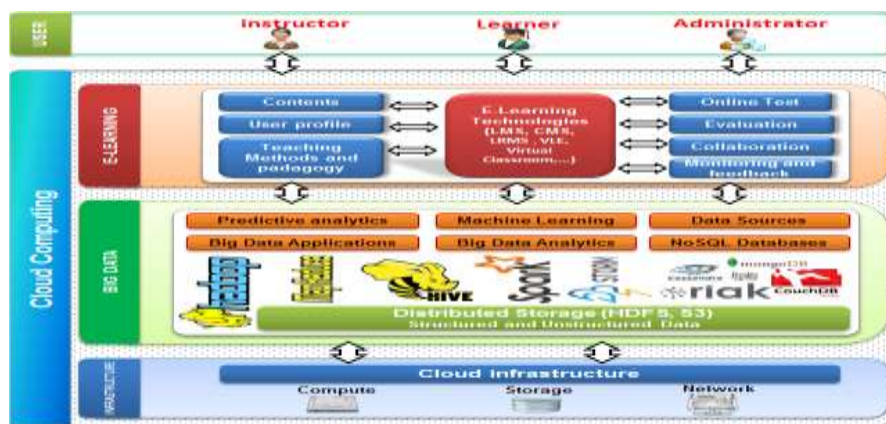


Figure 2: Approach for using Big Data Technologies in e-learning systems (Dahdouh et al., 2017)

(b) Big data Technologies

Huge data volumes require a dedicated environment and tools to uncover hidden data meaning. There are multiple Big Data processing and analytical technologies however the most common ones are Hadoop Map Reduce, Spark, Hive and Pig. All these come with varying characteristics therefore selecting a technology will be based on the institutions' needs.

(c) Learning Data Analytics

Learning analysis is achieved by using specialised analytical tools and techniques on large data and varying data to reveal meaning and conclude on the behaviour based on the data patterns. Learner interaction with Moodle leaves behind digital tracks of data that can be analysed to discover patterns and learner's behaviours towards learning using appropriate analytical models. With these models, one can predict the best learning method and advise correctly (Baker & Siemens, 2022). Such predictions could address issues such as learner's possibilities to drop studies and attributes related to learners learning preferences, such as group, peer to peer or discussions.

Moodle being the commonly used LMS in the high education sector worldwide and at NUST has built in analytical tools that could improve distance learning at NUST. Although these tools are activated on Moodle, many instructors are not aware of their existence and potential benefits since they are not enforced in the institution. Such tools are report, logs, activity reports and participation report. Additionally, several learning analytic tools can be integrated in Moodle as suggested by (Dimopoulos et al., 2013) to assess learner's performances such as GISMO, MOClog, Excel Pivot tables and Analytics and Recommendations. These tools support instructors to evaluate the design of online content and identify opportunities for improvement of such content to match learner's learning needs.

3. **Interface Design:** This dimension covers the requirements for the look and feel of the LMS and its friendliness to the users. To enhance user experience of Moodle, the administrators need to make it favourable and easy to use with all features easily accessible.
4. **Evaluation:** Evaluation address the assessments of learners, instructions, programmes, and content development (Corbeil et al., 2017). Evaluation is performed to determining if the LMS still serves the purpose it was developed for. At NUST the current LMS need to be evaluated to fit all the features that support learning analytics. The evaluation needs to be inclusive off all stakeholders.
5. **Management:** Address the issues of upkeeping and updating of the LMS. Management of LMS ensures that quality control in content delivery by assuring those recent technologies are incorporated for security and performance.
6. **Resource Support:** The support dimension addresses the technical and human support required to operate on the LMS successfully. An example of support that is suggested by (Corbeil et al., 2017) includes the following: web-based support, online tutorials, telephonic support, news journals, podcast, support issues related to data collection, data storage, data analysis and data mining.
7. **Ethic:** The availability of the Internet and study material online, the likelihood for the academic fraud in LMS is big. This fraud can be committed by plagiarism, copyrights and privacy violation, the ethical issue dimension in LMS should therefore be able to address the issues of content design and implementation by addressing all the possible ethical issues.
8. **Institutional:** Prior to a big data-based implementation of LMS (Corbeil et al., 2017) suggested that administration and academic affair need to be addressed for a smoother operation. The administrative affairs addressing issues of learner services,

payments, and assessment grades, while academic affairs should address issues related to matters pertaining to accreditation and faculty support. Additionally, this dimension Institutional issues should also address matters pertaining to data ownership and usage.

3. Proposal

Big data analytics give the potential to provide customised solutions if non-generalised approaches are employed. This helps in addressing some of the dangers facing many educational communities today, which fall trap to the blind borrowing syndrome of solutions. There is no harm in learning best practices from elsewhere, but to ignore the basis of the application variables being adopted is risky. There are variables to consider for effective implementation of distance learning solutions which are not one sided. The developers of distance learning solutions, education administrators, distance learners themselves and other key stakeholders need to be actively engaged in the process. The quality of data availed towards understanding learner preferences for instance, has ripple effects on dimensions for consideration and the practical implementation of such solutions.

In this section we are outlining some proposals for the eLearning developers, education administrators and distance learners towards maximising the potential of big data analytics in availing the desired results. Our focus is on how to achieve personalised learning experiences for distance learners. It is a collaborative effort which calls for all key players to be active and execute their roles in the entire cycle from data creation, collection, analysis and meaningful implementation. The success of personalised learning is evidence-based driven than a guesswork endeavour.

2.5 eLearning Developers

ELearning developers hold the central role of converting user generated data into functional solutions that are earmarked to meet each distance learner's personalised needs. Additionally, the need to avail administrative analytics data for various education administrative calls from finance, learner records management to learner progress monitoring. This is simply expressed in Figure 3.

Consideration should be paid to the smart education framework presented by (Punithavathi & Geetha, 2020) as it supports the learner-centred learning approach which helps focus attention and resources to what the learner really need than what the system can simply provide. This is further confirmed by (Lambert, 2020) in their review of (Massive Open Online Courses (MOOCs), which revealed that, learner-centred was one of the ingredients for successful MOOCs, which depicted an understanding of the needs of marginalised learners, while also providing more sustainable and distributed learner support. There may be diverse challenges to address before the adoption and implementation of some elearning solutions as hinted by (Barteit et al., 2020).



Figure 3: Interaction among key players for personalised learning (source: authors)

2.6 Facilitators

These recommendations will cover Facilitators/Lecturers. As ingredients for success, using ICTs alone will not suffice personalised learning. As echoed by (Rao et al., 2020), the catalyst for effective personalised learning experiences in LMS is not only to share course related material but also creating collaborative platforms for learners to engage among themselves. Distance learning should thrive in a rich environment both in terms of content options, learning approaches, and technological diversity, hence appealing to different learning styles.

Some technical courses demand more than theory-based content. Facilitators are compelled to therefore adopt more visualisation tools such as Augmented Reality (AR) to provide interactive learning (Kaur et al., 2020). This will enable meaningful data analytics on performance, engagement, learning outcomes and a diverse range of other measurable variables that could be harvested from interactions with AR.

2.7 Education Administrators

As the administrative arm of the education ecosystem whether physical or virtual, their role may be concerned with aligning with best practices. If we consider the pedagogical aspects outlined towards learning for adaptive learning: community of practice; interactive and discursive understanding; pattern recognition and identifying points of intervention; resourcefulness, security and well-being; and critical praxis (reflection and practice) (Didham & Ofei-Manu, 2020). These require real-time analysis of contextual data. An eLearning system powered with big data analytics capabilities will not only be a rescuer in this scenario but a must have additive.

By leveraging on big data analytics, administrators will be able to customise learning packages to the affordance of various learners, thereby creating an inclusive approach to learning and economic goals alignment. Instead of treating learners with a blanket approach, more contextual administrative attention can be given to learners, such as payment terms of tuition fees and availing the necessary administrative support where needed. In the case of NUST, the centres across the country could avail more gadgets for learners' access and helping in bridging the digital gap.

2.8 Distance Learners

Being the central focal point for the source of data needed in the design of personalised learning solutions, every interaction of a distance learner with the eLearning system is crucial in building up a rich profile that could help in customising the learning preferences, recommendations and improvements, where needed. For a complete experience, the combined analysis of eLearning interactions and how other key players respond to specific learner requests, actions and activities online, equally contribute to pieces of data that needs to be cemented together for a complete learning experience, which is not only generic but specific to the individual learner, hence personalised.

3 Conclusion

This paper discusses the potential in adopting personalised learning using learning analytics at for distance learners at NUST. The study adopted a framework recommended by (Corbeil et al., 2017) that identified 8 digestions for successful learning analytics. This paper additionally recognised of how big data revolution has positively impacted distance learning by availing information leading to improved learning experience. Other applications of big data in other industries and highlighted in this paper. Finally, a proposal on the successful adoption of learning analytics at NUST is recommended.

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Integrating business intelligence systems with customer relationship management systems. An approach for Business Organisations.

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Abstract

Gaining new and maintaining existing relationships with customers is the main goal of customer relationship management in any organization. CRM systems give users and top management access to customer information so they may make informed decisions to enhance an organisation's service delivery. Today, significant analysis may be done on gathered customer data using advanced analytics, through Business Intelligence (BI). By doing this, decision-makers or users can get the relevant customer information at the appropriate time. BI can turn raw data into concrete figures and reports for effective decision making. Even though some CRM systems offer basic analytics, it is not sufficient to leverage available customer data. Therefore, this study aims to take such concept into consideration and determine an approach for using BIS in CRM in business organisations. The study is qualitative with the aim of testing concepts of the benefits of integrating CRM with BI. The study has empirically tested a conceptual model against the success factors and benefits of integrating CRM along with BI. The findings suggest that benefits and goals of CRM and BI complement each other perfectly because they both improve and help understand customers behaviour and enhance customer satisfaction.

Keywords: Business Intelligence, Customer Relationship Management, Customers, Data, Technology, Information Systems

1. Introduction

Business intelligence (BI) is a process for gathering, storing, analysing, and providing access to data to help organizations make better decisions. BI systems can provide real-time or near-time information that can be used to improve operational efficiency, track and predict financial performance, and understand and respond to customer behaviour.

BI systems are often integrated with customer relationship management (CRM) systems to provide a complete view of the customer. Customer Relationship Management, or CRM, is a business strategy designed to improve customer satisfaction and loyalty. CRM systems are used to manage customer data, track customer interactions, and automate sales and marketing processes. By integrating Business Intelligence systems with CRM systems, businesses can gain insights into customer behaviour and preferences, identify opportunities for upselling and cross-selling, and better understand the ROI of their marketing campaigns. This integration can help organisations better understand customer needs and preferences, identify cross-selling and upselling opportunities, and improve customer service and support.

Business Intelligence (BI) provides the organisation with specific knowledge, to determine the market's potentials and to guide its vision, goals, and plans. This assists the organisation in resource allocation and efficient use of its knowledge base for better planning. Business intelligence implementation requires ongoing communication through all customer-facing channels, including the internet and email. This is a method of managing customer relationships to ensure their satisfaction (Rasoul & Mohammad , 2016). The company's ability to evolve, learn, and grow will determine how

successful it is in the future. Without the use of modern business information systems, especially those that embrace the concept of business intelligence (BI), information and communication technologies, and electronic networks, it is impossible to do this. These elements are essential for establishing a "learning company" that can fight off competitors from around world with the use of BI applications as a strategic advantage (Baileti & Tanev, 2018).

In nearly every industry and corporation, the customer is considered as the most significant stakeholder (Willian, 2019). When businesses successfully manage customer relations, they are more likely to attract, keep, and satisfy their valuable customers (Buttle, 2019). Introducing digitisation may help businesses develop strong ties with their clients. It can also elevate and guide such interactions in a variety of ways.

There is a solid connection between quality customer data, Customer relationship management and Business Intelligence. High-quality customer data, customer relationship management, and business intelligence are closely related. However, quality of the data is a problem in CRM, because it comes from several sources (Akoka et al., 2019). IT infrastructure and processes are required for data improvement, and BI may help by reducing the cost of IT infrastructure through eliminating pointless operations (Shinde & Sunjita, 2018).

The main objective of this study to develop an approach for integrating Business Intelligence Systems (BIS) in Customer Relationship Management (CRM) for business organisations. The outcomes of this research will highlight various advantages that businesses organizations anticipate from using CRM and BI. This research will be a significant contribution to the field of CRM and BI integration because there is a shortage of empirical knowledge in this area. It will also open possibilities for future research in developing the framework to guarantee seamless CRM and BI integration. The study will also serve as a guide to other student researchers who may want to conduct further research on this subject matter.

2. Literature review

2.1 Common Issues with CRM

Data in CRM comes from various sources and channels, which frequently results in a collection of low-quality data (Akoka et al., 2019). Issues with data quality in CRM make it difficult for organisations to fully benefit from what CRM has to offer (Reid & Catterall, 2015). Improved CRM utilization results in better customer relationship management since data management is a crucial component in decision making. The success of the business is highly associated with effective customer data management and the quality of the customer satisfaction. (Soltani & Navimipour, 2016).

Another problem with CRM is that, although the system contains a significant amount of data, it lacks powerful analytical skills (Bull, 2016). Even though businesses are good at communicating and connecting with customers, using data analysis tools to create an in-depth understanding of the customer is necessary to succeed in the market. (Zamil, 2017). From this discussion, though CRM has a lot of data, utilization of that data, is a challenge. Hence, users can not get all the data driven insights.

2.2 Benefits/Goals of Business Intelligence

BI offers benefits such as (Chaudhuri et al., 2016; Chen & Popovich, 2017; Watson & Wixom, 2018):

1. Avoiding redundant data management methods reduces costs.
2. Timely delivery of data
3. Using advanced analytics to make better decisions

4. Enables business strategies (for example, organisation transformation, new customers identification, and customer retention)
5. Use of BI tools helps in having trusted data in place
6. Management of business performance, such as the use of scorecards and dashboards
7. personalized customer offers
8. Provides a holistic view of the customer.

2.3 BI and CRM theoretical framework

Figure 1, BI and CRM integration, partially adapted from Chaudhuri et al. (2016); Baars & Kemper (2018), shows how CRM and BI may be combined. The CRM system allows consumers to connect with them in a variety of ways, including face-to-face, emails, and phone calls, and making it possible for data to be collected from these sources (Baars & Kemper, 2018). According to Buttle (2019) Customer-facing operations such as marketing, sales, and services can all be automated with CRM. From the BI architecture, data from CRM systems and other systems is fed into BI tools, for advanced analytics to get data driven insights.

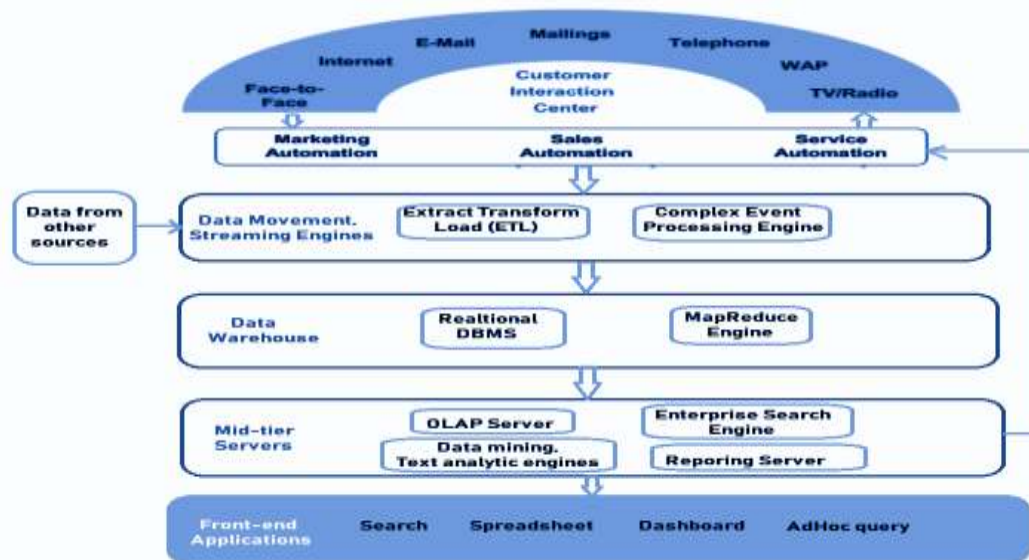


Figure1: BI and CRM integration Framework

Source: Baars and Kemper (2018, p. 143); Chaudhuri et al. (2016, p.90)

2.4 Success Factors for integrating Business Intelligence with other Systems

Success of BI in an organisation depends mainly on following factors (Watson & Wixom, 2018; Phillips et al., 2015): Ensuring proper usage of information by users/ decision makers

1. IT infrastructure, trainings, and other support from the organisation
2. Alignment of BI strategies with business goals, objectives and strategies
3. Proper governance of issues like data quality, funding, and project management

3. Methodology

3.2 Research Design

This study was conducted using the qualitative research method. According to Crossman (2019), qualitative research is type of social science research that gathers and analyses non-numerical data to better understand social life by studying particular groups or areas and respond to questions about experience, meaning, and perspective.. For this study, a case-based study is conducted in an interpretive way. The empirical results were interpreted in respect of previously published research done in the field and the case study findings.

A total of fifteen (15) participants from IT and BIS departments in City of Windhoek were interviewed to ensure that different perspectives were obtained, responders' primary responsibilities and roles were not the same. Judgmental (Purposive) also known as selective, or subjective sampling was used to select the participants. Judgemental sampling is a technique that relies on the judgement of the researcher when choosing who to ask to participate (Taherdoost, 2016).

In this study interviews were used as data collection method. The interviews were conducted in person whenever possible, however if this was not possible due to unforeseen circumstances, the interviews were conducted over the phone. The interviews were recorded with a phone, the primary goal of recording the interviews, is to increase accuracy because the interviewer might not recall everything (Hofisi et al, 2017). These interviews followed a semi-structured format with the goal of participating in a two-way discussion. The responses were not only answers to the questions, but the reasons for those answers were also established or asked during these interviews.

For this study, the researcher selected the qualitative data analysis method to analyse the data gathered from the interviews that were conducted at the case site. Thematic analysis is a method for identifying, classifying, and interpreting meaningful patterns (themes) in a dataset (Clarke, 2017). The researcher used thematic analysis to identify and understand common or group meanings and experiences. (Taherdoost, 2016). The researcher needed to find relevant connections between CRM and BI, as well as the answers to the research questions using the data. The coding technique was used to analyse the data. The first step was to get to know the data, after the researcher was familiar with the data, the data was coded. Coding is a process of identifying specific text sections, typically phrases or sentences, and assigning quick labels, or "codes," to explain what those texts are about (Ibrahim, 2012). The researcher looked through the codes generated, identified the patterns among the codes and then came up with themes.

The themes obtained were data, success, customer relationship, CRM, technology, data analysis, communication, Strategy, Enterprise etc, based on related patterns. These themes were further classified into customer knowledge, system integration, business intelligence, customer-oriented processes, and enterprise-wide strategy. These concepts represent key elements of the study.

4. Results

To improve customer relations with the organisation is, it is important for the organisation to have a customer-centred approach (Watson & Wixom, 2018; Phillips, 2015). It was clear from the interviews that each interviewee had the customer in mind. Thus, it may be said that the case site (City of Windhoek) is focused on its customers. System-functional integration is one of the criteria for a successful BI and CRM integration (Chen & Popovich, 2017). There is formal communication between City of Windhoek departments and employees, according to certain participants. System-functional

integration enhances information exchange among stakeholders and departments, making sure that everyone is viewing the most recent data in real time.

One of the success factors of integrating CRM and BI is an enterprise-wide strategy. According to most participants, "workers across different departments are trained and informed on the relevance and utilization of this systems" (Chen & Popovich, 2017; Watson & Wixom, 2018; Phillips, 2015). Therefore, all system users can use it efficiently and obtain results quickly. Some of the participants said that because system updates and improvements are completed on schedule, the most recent information is always available. This shows that the system's users—the company's employees react to change well and are willing to experiment with new ideas and technologies. The findings indicate that, proper guidelines and processes are put in place to ensure that quality data from different information systems and databases is used by BI for analysis. According to Baars & Kemper (2018), processes ensure that high quality, well filtered, clean data comes from BI Analytics.

One of the participants stated that data extraction is difficult when merging CRM and BI, which is consistent with findings. The process of pulling source data is the first step in the integration of numerous systems (**Datta & Thomas, 2019**). But it can become challenging and time-consuming if the formats, patterns, and types of the data sources differ. Since processing cannot start until the data is converted to the same format. The data must first be transformed to be compatible with the target system after retrieval before any analysis can be performed. One of the respondents noted that data extraction "may be time costly, delaying the reaction time of the result". Scalability is another problem when merging BI with CRM (**Chen & Popovich, 2017**). Majority of participants said that BI and CRM integration can result in extremely dense data. Since data is consumed from several sources into a single system, the volume of data is increasing rapidly. It may slow down response time and clog the system.

Data integrity is top priority in every data integration strategy, even though data quality is an advantage of the integration (**Baars & Kemper, 2018**; Datta & Thomas, 2018). An ongoing issue that can impact the entire integration cycle is poor data quality. Corrupt data from various CRM databases may be sent to BI since some systems do not filter out clean data (Baileti & Tanez, 2018; Buttle, 2018; Shinde & Sunjita, 2018). According to one of the participants, processing improper analytics and erroneous data can result in corrupt information being provided to decision-makers and downstream systems.

The paper empirically tested a conceptual model of how Customer Relationship Management CRM) can be leveraged by Business Intelligence (BI). The outcome of the data analysed, showed full support of the proposed approach. The results were consistent with the existing literature, regarding the positive effect BI has on CRM and decision making. BI enables decision makers to make strategic decisions that can improve their competitive advantage and enhance customer satisfaction.

4. Business Benefits

There is general agreement that integrating BI with CRM has assisted organisations in using CRM more productively. BI can be used for target campaigns, ensuring that the right customers receive tailored offers. Research suggests that BI systems complement other systems like CRM to help organizations attract new customers while retaining and expanding their current clientele. (Chaudhuri et al., 2016; **Datta & Thomas, 2018**; Fjermestad, 2019). This enables the automation of marketing procedures.

The most obvious benefit is that it can help to improve customer relationships by providing organisations with a more complete view of their customers. This, in turn, can lead to better customer service and improved customer retention rates as noted previously in this paper.

In addition, integrating BI and CRM systems can also help to improve operational efficiency within businesses. For example, by having a single view of customers, businesses can avoid duplication of effort and reduce the time and resources required to manage customer data. Additionally, integrating BI and CRM systems can help businesses to better understand their customers' needs and behaviours, which can lead to more targeted marketing campaigns and improved sales conversions.

Data from multiple sources, including the CRM system, are made available for advanced analytics through BI. BI assists in the generation of trustworthy information and enhances client segmentation by combining data from numerous sources. (Watson & Wixom, 2018; Phillips et al., 2015; Fjermestad, 2019). This enables BI reports to deliver the precise client information that the user has requested. Additionally, BI can deliver real-time reports based on the simultaneous data receipt. Decision makers can, as advised, use the real-time reports offered to obtain actionable information at the appropriate time, which can enhance the decision-making process. (Chaudhuri et al., 2016; Chen & Popovich, 2017; Negash, 2018). Additionally, BI facilitates communication between several departments, which improves information exchange across the departments..

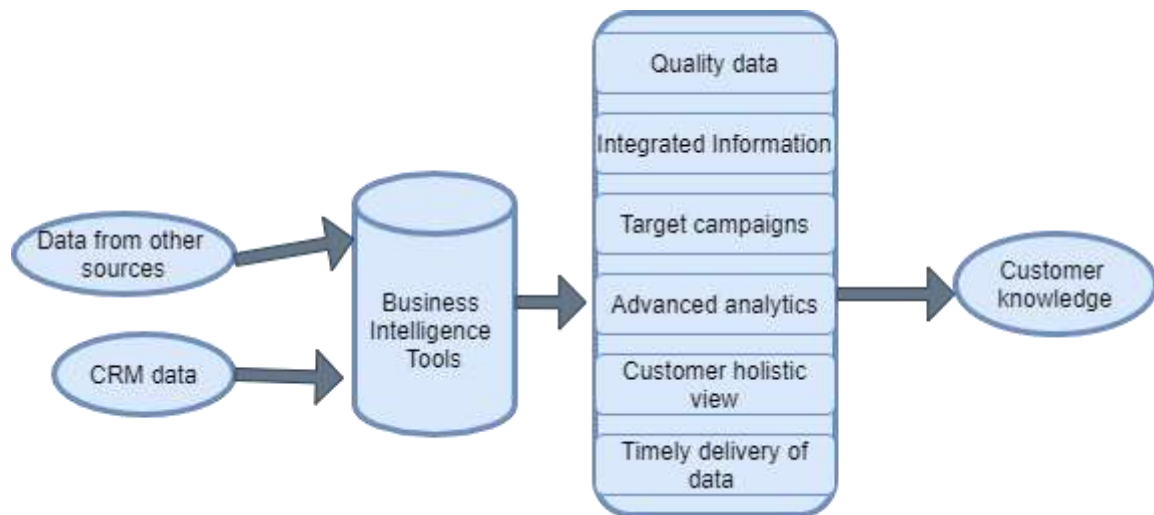


Figure 2: BI and CRM integration business benefits

5. Approach for integrating Business Intelligence with Customer Relationship Management

Organisations are increasingly looking to integrate their business intelligence (BI) and customer relationship management (CRM) systems in order to gain a more holistic view of their customers. There are many benefits to be gained from such an integration, including increased customer insights, improved customer service, and increased sales.

However, integration can be a challenge, as these two systems often have different data formats and structures. In addition, CRM systems tend to be geared towards transactional data, while BI systems are more focused on analytical data. As such, it is important to carefully plan the integration process

in order to ensure that the data from both systems is compatible and that the resulting system meets the needs of the organisation.

The first step in integrating BI and CRM is to understand the data requirements of each system. This includes understanding the structure of the data, as well as the specific fields that are required. Once this information is gathered, it is then possible to map the data between the two systems. This mapping process will identify any gaps in the data and will also help to determine how the data should be transformed in order for it to be compatible with both systems. Once the mapping is complete, the next step is to load the data into both systems. This can be done using a variety of methods, including manual entry, ETL tools, or even direct database connections.

Prior to implementing BI systems in organisations, a general vision for these systems must be established (Olszak & Ziemba, 2014). The systems must also be connected to corporate goals.

The stages for integrating BI with CRM according to (Olszak & Ziemba, 2014) are as follows:

Stage 1: Develop a business intelligence implementation strategy

At this stage, organisations' informational demands are specified while important IT decision-makers and specialists are also taken into consideration. The creation of data import methods is required to ensure that a data warehouse is routinely updated to integrate data from sources such as transaction systems (Meyer, 2011). All data should be able to be imported through such processes, and users should be able to do incremental imports that only need to process data that has reached source systems since the previous import.

Stage 2: Identification and Preparation of Data for the BI System

The sources of data that can be used to meet business needs must be specified at the stages of identifying and preparing data (Hsu, 2014). Finding internal source such as paper files, information technology resources, and intellectual resources as well as external ones focused on consumers, suppliers, and shareholders and confirming the validity of the sources are necessary for this specification. At this point, every database and information system used in a certain organisation must be diagnosed: ERP and CRM (Liautaud & Hammond, 2014).

Stage 3: Selection of BI Tools

The choice of a BI tool may prove to be challenging. The following factors must be considered when picking a BI tool: functionality, complexity of solutions, and compatibility (Meyer, 2011). It's also important to keep in mind that an organisation's information needs will change over time, BI technologies should therefore be current enough to match organisational requirements in a few years (Liautaud & Hammond, 2014).

Stage 3: Implementing the BI System

The difficulty and level of the system's popularity heavily influence this effort (Rasoul & Mohammad, 2016). Most of the work, though, is spent creating a customized BI application that will suite the organisations CRM. The required time is used to create each interface as well as to ensure that the entire BI application is logical and consistent. Building a data warehouse, which will serve as both a store for future studies and a foundation for the BI system, is another crucial step in the architecture of BI (Hsu, 2014).

Stage 4: BI "consumption" stage

Analyses and comparisons of data are done at this stage. Users should exercise great initiative at this level. Users should be able to write analyses and reports, ask pertinent questions, and

evaluate results based on newly emerging needs. Analysing information from CRM and other data sources enable the business to have a paranoic view of a customer. Consultations with other decision-makers and personnel are frequently necessary before choosing a final course of action (Datta & Thomas, 2019).

6. Conclusions

The study has empirically tested a conceptual model against the success factors, benefits and challenges of integrating CRM along with BI. The findings suggest that benefits and goals of CRM and BI complement each other perfectly because they both improve and help understand customers behaviour and enhance customer satisfaction. The study helped identify the advantages and challenges of integrating CRM and BI in an organisation. According to the findings, businesses can benefit from integrating CRM and BI.

The challenges of CRM and BI integration include large data quantities and speed reductions, but overall, the advantages outweigh the disadvantages. Benefits include comprehensive reports and departmental information exchange with partners, and stakeholders, allowing all users to access the same data instantly. Since analysis using BI systems aids in obtaining a clear picture of the consumer, improved customer segmentation is possible, allowing for more precise campaign targeting. Therefore, it can be concluded that using CRM and BI helps organisations better manage their customer relationships by combining people, processes, technology, and data. To ensure the successful integration of CRM and BI, there are some factors that must be addressed. These factors include proper guidelines and procedures for preserving the integrity of the data. The innovation and openness to implementing new tools and technology at the organisational level are key factors in the effective integration of CRM and BI. Finally, engagement is essential for successful integration of business intelligence and customer relationship management. Therefore, there is need from industry for business organisations to implement and integrate CRM and BI.

2.2 Limitation and future research

This study is limited to qualitative analysis and data is collected from interviews only. Furthermore, sampling was purposeful rather than random, hence making harder claims of strong judgement and the study was limited to City of Windhoek employees only. These limitations need to be addressed by future research through application of alternative methods in a variety of different contexts and with larger numbers of different subjects to verify and generalise current findings. Future research could be carried in customer data privacy and how it is affected by BI and CRM integration.

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Assessing the implications of ICT Projects Vendor Lock-in to the Namibian Government Digital Transformation

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Abstract.

The government of Namibia has several strategic goals such as Vision 2030, Harambee Prosperity Plan II and Fifth National Development Plan (NDP 5). In its quest to achieve its strategic goals, the government through its various line Ministries has deployed several ICT systems projects such as the Tax Administration system (ITAS) and the Immigration-population registry system. The ICT systems projects are part of the e-government initiatives targeted towards digitising government services and processes, consequently making these services more accessible and affordable to citizens and business partners as well as promoting transparency. Most often, the government ICT systems projects are not produced in-house but are outsourced to foreign vendors, originally residing outside the country. Upon completion of systems development and implementation, the line ministries hardly take ownership of the implemented ICT systems in terms of future maintenances and support, as these systems continue to be in the hands of the vendors resulting in vendor lock-in. The process of vendor lock-in has several implications to our government Information Systems landscape, such as skills growth and data security. Despite this, within our government-computing environment, limited research has been conducted to unpack this matter. This study addressed the research question: what are the implications of information systems vendor lock-in to the Namibian government's digital transformation efforts/initiatives? Using a qualitative multiple-case study with an open-ended questionnaire for data collection, this study aimed to investigate the primary causes of vendor lock-in for most of our Government ICT systems projects. Additionally, the study looked to understand the implications vendor lock-in has on the government IT landscape's future growth and development.

Keywords: e-government, Digital Transformation, ICT systems projects, vendor lock-in, implications

1. Introduction

In the 21st century, the role of Information and Communication Technology (ICT) in organisations has radically shifted from just being a support function to accelerating business process automation. Nowadays, ICT has become a fundamental driver of business model innovation. Tang (2021) asserted that with the advancements such as big data and analytics, cyber security and artificial intelligence, ICT is capable of redefining organisations' operating models, driving sales growth and increasing their competitive advantage. Alhassan and Soui (2021) reported that ICT plays a pivotal role in organisations' survival and competitive advantages as such customers expect value-adding and quick and easy solutions to their problems. Nowadays, this is all possible as ICT has the power to process large amounts of data, analyse such data and automate routine processes to improve performance over time (Sanina et al., 2021).

The unlimited potency of ICT has led to many organisations including governments embarking on digital transformation. Digital transformation has become a necessity for governments as an approach to strategically use emerging technologies and develop effective and efficient digital public services

(Eom & Lee, 2022). Digital transformation is concerned with the use of information, computing, communication, and connectivity technologies to radically change or improve organisation processes and environment (Vial, 2019). Margiono (2021) explained that digital transformation has the potential to change an entire organisation from its strategy, structure, process, and culture. Thus, digital transformation should not be viewed as a technical component affecting only the IT department but rather as a component affecting change to an entire organisation's operations due to the application of digital technologies.

The government of Namibia in its quest to provide effective and efficient services to its citizens and business partners is transforming digitally. This transformation is evident from the development and implementation of ICT projects through the government's various ministries and agencies. Examples of these ICT projects include Integrated Tax Administration System under the Ministry of Finance and the Population Registry System at the Ministry of Home Affairs (Amukugo & Peters, 2016; Shaanika & Amunkete, 2021). The deployment of these ICT projects has promoted ease of service accessibility through online interactions. For example, with the deployment of the Integrated Tax Administration System, taxpayers are now able to do their tax filling electronically from anywhere. Practically, it has become imperative for governments of countries to streamline public processes by transforming digitally.

The Namibian government embarked on its digital transformation journey implementing ICT projects as part of its e-government initiatives. According to Nakale and Chikohora (2020), the Namibian government started with e-government services in line with the United Nations' sustainable development goals. The government embarked upon these digitally transformative services since 2002. However, across the Namibian government ministries, ICT Projects are often not developed in-house but outsourced to external vendors. A study by Nehemia-Maletzky and Iyamu (2018) on software development challenges revealed that since the inception of the National Development Program (NDP) more than 15 years ago, the Namibian Government continues to outsource most of its ICT projects development and implementation activities to foreign companies. According to Shaanika and Maletzky-Nehemia (2017) the shortage of IT skilled resources leads to the outsourcing of many software and infrastructural projects to the more technologically advanced countries such as China and Malaysia. Indeed, IT outsourcing is viewed as a strategic decision by organisations that are challenged with implementing IT solutions due to limitations of knowledge and specific skills (Poletto et al., 2020).

Outsourcing ICT projects has benefits as discussed in Mehta and Mehta (2017) and Poletto et al. (2020), however, within the computing environments of the Namibian Government Ministries, it has led to vendor lock-in (Shaanika & Maletzky-Nehemia, 2017; Nehemia-Maletzky & Iyamu, 2018). From the perspective of cloud computing, vendor lock-in occurs when customers depend on a single cloud provider's technology implementation and cannot easily adopt a different vendor without challenges such as costs, legal constraints, or technical incompatibilities (Pellegrini et al., 2018).

Studies on government digital transformation are broad and focus on different aspects (Eom & Lee, 2022). However, this study identified a gap on ICT projects vendor lock-in implications to the Namibian government's digital transformation. This study argues that vendor lock-in has implications to government digital transformation and there is a need for academics and practitioners to understand these implications. Understanding the implications of government ICT projects vendor lock-in will be beneficial, enabling informed decision to the government as it strives to provide digitally oriented services, towards the achievement of its various strategic objectives. In understanding the challenges as presented above, this study is addressing the following research question: what are the

implications of information systems vendor lock-in to the Namibian government's digital transformation efforts/initiatives?

This paper is structured as follows: the introduction is provided in section one. Section two presents a review of literature in the area of government's digital transformation, e-governments and ICT projects outsourcing. In section three, we unpack the research approach that underpinned this study. Section four covers the analysis of the data that was collected, and a discussion of the findings is presented in section five. Section six presents the implications of the findings and lastly, in section seven the conclusion is drawn.

2. Literature Review

2.1 Government Digital Transformation

Globally, governments, driven by their aim to provide technologically centred services are pursuing digital transformation. The term digital transformation has been defined differently across organisations and in literature. The different definitions are informed by individuals and organisations knowledge and understanding of the concept. Vial (2019, p. 121) defines digital transformation as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies". While according to Alhassan and Soui (2021), digital transformation is about organisations constantly innovating their business environments in order to keep up with the customers' demands and the advancements in digital technology. Nonetheless, with the many definitions found in literature: the commonality among these definitions is that: digital technologies and significant changes are the two key ingredients of digital transformation (Eom & Lee, 2022).

Several governments, both in developed and developing countries are digitally transforming their business and operations. The government of Ajman transformed digitally to increase government efficiency and productivity, and to meet the federal e-government standards (Ghazaleh & Ahmad, 2018).

The Namibian government has embarked on digital transformation through the implementation of e-government ICT projects. The e-government projects implemented by the Namibian government include systems to automate business processes. The most notable are systems that provide web-based services, such as health information systems, information systems for automating tax services, such as the submission of annual tax returns and information systems for conducting financial processes such as payroll and paying government suppliers (Nengomasha & Shuumbili, 2020). These ICT systems projects are implemented to digitise government efforts and advance e-government initiatives to improve public service delivery.

2.2 ICT Systems Projects Vendor Lock in

The Namibian government is challenged with a lack of manpower and the ICT skills required to advance e-government initiatives (Shaanika & Maletzky-Nehemia, 2017). Other governments around the world (Dhaoui, 2021; Napitupulu et al., 2018) have equally observed these challenges. The challenges of not having enough manpower and the necessary skills to develop and implement e-government projects have given rise to the outsourcing of ICT projects to external vendors to aid in the processes. There has been an observation of the high usage of vendors from foreign countries for the development and implementation of Namibia's e-government initiatives (Nengomasha et al., 2010).

The government enters into outsourcing agreements, hopeful that upon system development and implementation completion the local team will be able to take over system support and maintenance. Unfortunately, this is not always the case as the intended skills transfer between the vendors and the government ICT staff oftentimes does not always materialise (Shaanika & Iyamu, 2018; Shaanika & Maletzky-Nehemia, 2017). This could be attributed to incomprehensive policies and guidelines to guide the process of skills transfer.

Without the local team taking over systems maintenance and support, vendors can make it difficult for governments to sever these relationships as they find ways to make it necessary for the governments to become dependent on their continued services (Shawosh & Berente, 2019). The difficulty of severing relationships with external vendors results in an indefinite continuation of these relationships, which in turn results in vendor lock-in. The consequence of vendor lock-in is a client being indefinitely dependent on the products or services of a vendor (Pellegrini et al., 2018; Rózańska & Kritikos, 2019). With vendor lock-in effect, a client is unable to change to the services of or request the assistance of a different vendor (Rózańska & Kritikos, 2019). The e-government project developed by a vendor might not support or be compatible with other projects implemented within the government computing environment (Sadoughi et al., 2020), as different projects are developed in silo and by a multitude of external vendors (Angula et al., 2019).

Some of the e-government ICT systems projects developed in silo by multiple vendors can result into un-interoperable systems. Interoperability has been of concern for decades and varying definitions exist. Wegner (1996) defines interoperability as “the ability of two or more software components to cooperate despite differences in language, interface, and execution platform” (p. 285). Angula et al. (2019) define interoperability as “a property referring to the ability of diverse systems and organizations to work together (inter-operate)” (p. 4). The overarching commonality being the ability to exchange data between disparate systems. According to Oumkaltoum et al. (2019), interoperability within e-governement systems can be viewed from various angles: data (content, context and meaning of data); technical (application and processes); semantic (meaning and understanding remains between sender and receiver); and organisational (inter-organisational collaboration as) angles. The consequence of systems not being able to cooperate and exchange information is the presence of multiple standalone systems, which can result in vendor lock-ins with the multiple vendors. Each vendor provides support and maintenance for the specific system that they have developed.

When a need to add new functionalities to existing e-government projects arises, the government is forced to approach the vendor that developed the project, as only that vendor can provide the required services (Petalidis, 2018). The governments are left with little or no options but to be dependent on the vendors for the continuation and success of their e-government initiatives.

Governments also find it difficult to maintain their e-government projects that are locked into external vendors. This difficulty arises due to government critical operational data and processes documentation usually remaining in the hands of the vendors, even when the project implementation has been completed (Collington, 2021). When the government does not have ownership of the operation data and processes documentation, the vendor remains with maximum power of the developed system. Consequently, the government continues to rely heavily on the vendor's services for systems maintenance and upgrades. This reliance on the vendor leaves the government with minimal power to negotiate service fees (Mosweu et al., 2019). The inability to negotiate service fees becomes very costly to the government as the vendor can charge exuberant fees and the government is unable to switch to a different vendor to avoid the costly charges. Even with costly charges and

other challenges, governments remain vendor-locked in into different external vendors, which can have implications on the governments' digital transformation initiatives.

2.3 Implication of Vendor lock-in to Government Digital transformation

The Namibian government comprises various ministries and offices that are responsible for various areas of interest, from finance and health (Amukugo & Peters, 2016; Shaanika & Maletzky-Nehemia, 2017). Each ministry and office has its mandate and responsibilities, which could benefit from digitalisation. Achieving those mandates and responsibilities often results in the acquisition of ICT systems projects to cater for ministerial specific needs (Amukugo & Peters, 2016). However, with the ever-growing number of IS/IT systems, this leaves the overall government IT landscape riddled with silo based IS/IT systems (Garises & Quenum, 2018; Kapepo & Yashik, 2018; Shaanika & Amunkete, 2021). According to Shaanika and Maletzky-Nehemia (2017), most of the IS/IT systems are acquired by specific line-ministries as the need arises through outsourcing to external vendors. However, these acquisitions often do not conform to a set Technology roadmap nor specific standards that can lead to an effective e-government landscape (Hazineh et al., 2022). A Technology roadmap is an effective approach for the alignment of strategic objectives and technology considered key components for organisational success (de Alcantara & Martens, 2019), this also includes the strategic management plan for IS/IT acquisitions. This lack of alignment leads to unusable IS/IT systems across the IT Landscape once the integration or replacement by an integrated IT/IS system occurs.

There however, also exists instances where legacy systems form part of the core IS/IT systems and cannot be replaced (Shaanika & Amunkete, 2021). These legacy systems tend to be uninteroperable with newly acquired IS/IT systems, leaving troves of data untouched, unusable or resulting in extra costs to convert the data through third-party middleware to plug into newer systems (Opara-Martins et al., 2016). Overall, this creates financial, maintenance and security challenge as patches often mean re-writing systems code for integration (Shaanika & Maletzky-Nehemia, 2017) interoperability and portability (Sadoughi et al., 2020). In addition, this lack of interoperability has a negative effect on the efficiency of service delivery within the public sector. Systems tend to be requested for specific projects and needs and not part of an existing Technology roadmap, there also tends to be a lack of system ownership by the IT personnel (Shaanika & Maletzky-Nehemia, 2017). Notwithstanding, the negative implications of bottlenecking, and gatekeeping, privacy concerns (Shaanika & Iyamu, 2018) and system ownership also lead to greater technology acceptance. System ownership within e-government can also be looked at from the angle of citizens that are often the beneficiaries of these IS/IT systems (Malodia et al., 2021). A study on the readiness of citizens to adopt and use e-government systems reported that, there is often limited or late communication about e-government applications that direct use implications for citizens (Tahiru et al., 2020). As such, citizens are not involved nor consulted in the design of such systems, resulting in a lack of system ownership and citizen empowerment (Malodia et al., 2021). In light of the above challenges, businesses and governments alike tend to prefer systems from one vendor as part of their digital transformation (DT) strategies, this however, can lead to vendor-lock-in. Hietala et al. (2021) posit that governments can leverage on their buying power to force standardization or conformity to existing interoperability guidelines if they exist. However, as (Shaanika & Amunkete, 2021) put it, "The high number of outsourced IS/IT within the ministries is attributed to various factors including: lack of internal IS/IT software development skills and lack of management support towards local expertise" (section 5, para. 8).

Vendor lock-in has implications to the overall success of government digital transformation initiatives. The inability for governments to switch between vendors is equally tied to various factors. These

includes: high cost of switching; interoperability of systems within the IS/IT landscape; lack of awareness about existing systems and vendors; lack of a centralised management of IS/IT systems within governments; inertia; and the perceived lack of IS/IT expertise locally (Ganes et al., 2021; Malodia et al., 2021; Oumkaltoum et al., 2019; Sadoughi et al., 2020; Shaanika & Iyamu, 2018). In the era of a globally connected society, change is a constant, which is driven by transformation. This transformation can be met with issues of inertia. Inertia in this context is the propensity for resistance to change (transformation) (Vial, 2019). According to Margiono (2021), there is a need to address the issue of inertia to ensure a smooth orchestration of the transformation process. Often inertia is looked at from the resistance of employees or management of an organisation that has embarked upon a DT strategy. However, vendor lock-in can be perceived as a form of inertia that has the implication of stopping the required digital transformation.

3. Research Approach

To achieve the aim of the study which was to investigate and understand the implications of ICT systems Project Vendor lock-in to the Namibian Government's digital transformation initiatives, the study employed a qualitative research approach. Qualitative research studies participants' subjective meanings as they happen in their natural environment. Haven and van Grootel (2019) explain that due to its flexibility and subjectivism, qualitative research approach does not test hypothesis. Rather qualitative research aims to understand why things happen the way they do.

In this qualitative study, multiple cases were studied. With multiple cases, individual cases form a particular collection of cases because of the common condition under study (Stake, 2013). The use of multiple cases was not for comparisons but rather to broaden the scope and gain an in-depth understanding of the ICT systems projects outsourcing and their implications across the government ministries computing environments. To achieve this, four Ministries were studied. To maintain anonymity and to protect the identity of the ministries, the ministries have been given pseudonyms and referenced as Ministry A, Ministry B, Ministry C and Ministry D for the purposes of this study. The ministries were selected because they have acquired some of their main information systems by outsourcing design, development, and implementation activities to external vendors.

For data collection, open-ended questionnaire was used. Open-ended questionnaire was selected as the technique as it allows for rich subjective qualitative data that enables for participants varied meanings and experiences to be collected. The technique allows the multiple realities that participants attribute to the phenomena under study to be gauged (Busetto et al., 2020). Semi-structured interviews were preferred for the study but due to the participants time constraints and inability to commit to interviews, open-ended questionnaires were employed. To mitigate the limitation of open-ended questionnaires, which is the inability to seek clarity from the participants, where clarity was required, the authors followed up with short phone calls to seek clarity from the participants.

Data was collected from various participants across all the four ministries, both from IT and other business departments e.g., Finance. The criteria for selecting participants was that they should have been in their position for five years or more. In this study, 5 years was viewed to be a sufficient period for a participant to be knowledgeable about the operation of the outsourced system. In total nine participants took part in the study.

The questionnaires, participant information forms and consent forms were distributed to the participants via email. In total 15 questionnaires were distributed and nine completed questionnaires were received after multiple efforts of following up through emails and telephone calling by

researchers. The received questionnaires were organised for data analysis by labelling them with a case name and ascending numbering based on the order they were received. For example, MinistryDF2 represents the 2nd feedback from case Ministry D.

4. Analysis and Discussion

The analysis was carried out interpretively. Interpretivism aims to understand the subjective meanings, which persons associate to things. The interpretive approach allows for in-depth individual experiences rather than considering generalised measurements or expectations (Alharahsheh & Pius, 2020). Data from the four cases was combined during the analysis and the findings. The focus was the outsourcing of ICT systems projects to the external vendors. Below, the interpretive approach is carried out line-by-line for each question.

1. Have you been involved in government ICT systems projects? (*involved includes also being part of selection committee, development, or you support and maintain the system*) Kindly list the projects:

The selection, design, development, implementation, support and maintenance of ICT systems projects involves various actors. This is primarily because ICT systems are complex, socio-technical objects that requires skills and collaboration of different actors. Consequently, the actors that were involved in the ICT systems projects were from business and technical domains. The inclusion of both business and IT actors in the ICT projects allows for broader understanding of the solutions, ultimately bridging the gaps between business and IT strategies. One of the participants shared her views as follows: *"As an accountant I was seconded to be part of the project and worked closely with the systems developers to help them understand the beneficiary payment process"* (MinistryAF4).

2. How many of this government ICT systems projects were outsourced to external vendors?

Different types of ICT systems were found across the various Ministries computing environments. The systems are deployed to support the ministries strategic goals, ultimately enabling process efficiency and effectiveness. A participant shared that: *"currently, I am supporting three ICT projects E-procurement project, Website revamp project, Trader Web portal"* (MinistryBF2). However, the government ICT systems projects were not always developed in-house. Meaning some of systems were outsourced to external vendors. Among the cases studied, all ICT projects were outsourced.

3. Are the external vendors local or foreign companies? If foreign, state their nationality.

The vendors to whom the ICT projects are outsourced can be either local or foreign. This study refers to local vendors as companies that are Namibian owned and managed, whilst foreign vendors as companies that are managed and owned by foreign nationals and mostly operating and having headquarters outside the country. A participant shared that: *"In our ministry we have five systems and all were outsourced to external vendors outside the country"* (MinistryBF5). In addition, systems were also outsourced through a joint venture partnership – whereby a local company partner up with a foreign company in terms of resources such as skills, finances and infrastructures and collaboratively work together to deliver the project. A participant opined: *"the projects I maintain were both outsourced to external vendors, but all the external vendors are usually in joint ventures with local companies"* (MinistryDF4). Many local companies saw joint venture partnerships as a mean of partaking in bigger government projects that are always awarded to foreign companies.

4. Briefly, explain the primary reasons that led to the government ICT systems projects being outsourced?

The ICT systems projects were outsourced to external vendors due to various reasons that were driven by technical and non-technical factors. The technical factors included: Lack of technical infrastructures from local companies and non-technical factors included lack of skills and expertise from the local teams and political driven agendas by those in power. The use of foreign vendors by the government for some of the ICT projects was viewed as a lack of support and trust in the local people expertise. Management power was higher lighted as a critical factor for the outsourcing of ICT systems projects; leveraging their negotiating power to ensure approval and overall support for outsourcing.

In addition, some of the systems were deemed to be too complex and could not be awarded to local teams, as such they do not have the necessary infrastructures, or the magnitude of the project requires teams that have dealt with a similar case. A participant shared some of the reasons why systems are outsourced as follows: *"The government institution does not have enough human resources to implement the system, the system requires expertise that the government organisations does not possess and the implementation of the system is critical, and the time required to implement it demands an experienced team"* (MinistryDF4). These views are supported by another participant as follows: *"Government had insufficient skilled people to manage the complex systems, therefore, they decided to Outsourced vendors to work together with their ICT team"* (MinistryDF8).

5. How many of the outsourced projects were successfully implemented? Based on your experience what do you believe were the main factors that lead to the government ICT systems project's success?

The implemented ICT projects, whether developed internal or outsourced is not always guaranteed to be successful. Government ICT systems projects are deemed successful when all the business, functional and system requirements as stipulated in the requirements document have been implemented, tested and the ICT systems are executing business scenarios, which they were intended for.

Many factors play a critical role in the successful implementation of ICT. These factors are interdependent and should thus not be dealt with in isolation during project implementation. Most often non-technical factors are given less priority compared to technical parts in computing environments. However, without non-technical components ICT systems will cease to exist. A participant shared that *"the system I am maintaining is successful because the vendors had staff members who are well knowledgeable and have practical experience with similar projects making it easier for them to complete projects of same nature easily"* (MinistryAF5). Another participant opined, *"Success factors was proper project management and continuous monitoring of project activities"* (MinistryAF1). One of the participants emphasised how non-technical factors were the primary reason for the project success: *"Top management support drives the success too, as the teams take the project seriously and funding is availed"* (MinistryDF4). Successful implemented projects promote confidence among stakeholders leading to organisations reaping benefits of their IT investments.

6. Briefly discuss some of the challenges that you encountered with the external vendors during the government ICT systems projects' development, implementation and maintenance phases.

Within the ministries, collaboration with external vendors during the development, implementation, and support and maintenance phases is often faced with challenges. A

participant shared their views as follows: *“External vendors perform the technical work in isolation and only come present the output and progress. Moreover, the composition of the teams doing the actual work does not involve the IT teams of the government institution. Therefore, vendors keep knowledge and skills amongst themselves. Furthermore, if the IT team in the government institution wants to be involved, they get the bare minimum information from the vendors. This might be that the vendor wants to stay in business, because if they teach you everything then you will not need them”* (MinistryDF4). Another participant shared that *“some requirements were changed by client, which led to the pro-longing of implementation phase, and developers were not really eager to transfer knowledge since they needed to ensure the requested changes are completed without causing much delay to the project”* (MinistryBF2). The challenges impede successful operation of ICT systems and thus the need for organisations to strategize approaches to manage the challenges. These challenges are often experienced and known by the technical team, who then reports them to management for their intervention. Understanding the implications and availability of resources influences how challenges are managed.

7. After the external vendors have implemented the government ICT systems project, who is responsible for systems support and maintenance? Briefly explain why.

The development and implementation of ICT systems is not a once off activity. The implemented systems need to be maintained and supported after the implementation phase. System maintenance and support refers to the management of hardware and software which includes debugging application bugs, updating system patches and creating modules interfaces and troubleshooting all challenges as they occur during the system lifespan. After systems implementation, the norm is that the owners of the systems take over maintenance and support activities from the external vendor. However, within the Namibian ministry computing environment this is not always the case as such some systems continues to be supported by the external vendors. A participant shared that: *“Presumably, the line ministry was supposed to maintain the system, however functional changes that occur are always being escalated to the external vendor.”* (MinistryCF3). Another participant shared *“as the internal employees handle the basic support (i.e., adding users, monitoring logs and performing backups) and the external vendor handles the escalated or complex support (i.e., workflow reengineering, version upgrades and system errors)”* (MinistryDF4).

The differentiation in support levels is sometimes enshrined in the contracts between the government and extremal vendor. A participant shared that *“The way the contracts were initially set up is a key factor. Ministry staff to perform level 1 support and thereafter the consultants will provide support to issues beyond level 1.”* (MinistryCF7). Lack of appropriate trainings and access to source code was viewed to be the primary reason for continuous support and maintenance by the external vendors. This is alluded by a participant as follows: *“The ICT project after implementations need consultant support for a longer period due to lack of expertise. For some systems, once the source code is in possession of the IT, then they can manage the systems internally”* (MinistryBF2). Generally, support and maintenance is contracted to the external vendors but there are cases/instances, where vendors offer support and training to the internal employees until the employees are ready to support the systems. A participant shared that: *“Vendors get to offer support and train government staffs until they are confident enough to continue supporting and maintaining the system”* (MinistryAF5). External vendors maintaining and supporting the ICT projects leads to budget overruns, due to the continuous extension of their contracts. Extending external vendor contracts comes at a costly price, as the extensions take place until internal employees are to maintain and support the systems themselves.

8. Briefly share with us instances where you had to switch support and maintenance to another vendor?

The agreements between the Ministry and the external vendors do not always work out successfully as intended. When the external vendor is not delivering as per the agreements, their contracts are often terminated, and a replacement is sought. Ministries have found themselves needing to switch to different vendors when they perceive the cost of maintenance offered by the vendor to be too high and beyond their budget. A participant alluded that: *“switching support and maintenance can mainly occur due to cost in maintaining the hardware and software”* (MinistryBF2). Nonetheless, the process of switching support and maintenance to another vendor has countless implications and the ministries are not always ready to face them. A participant shared that: *“Changing support becomes an issue, especially with customised systems that are specific to the government organisations. The knowledge base of how to best support and maintain the system is best known by the vendor and an organisation fears that the system might collapse if vendors are changed.”* (MinistryBF6). Another participant shared why it becomes difficult to switch vendors: *“some systems are developed based on the vendor's manufacturer products. For example, the CISCO configuration will only run on CISCO devices. Another example is an Oracle-based information system that only runs or performs best on Oracle-based operating systems and hardware. Thus, switching support and maintenance can be cumbersome and risky”* (MinistryDF4). The severity of changing vendors is further elucidated by participant stating that *“the only way to change is to completely get a new vendor and new system”* (MinistryBF9).

9. Briefly explain about some of the challenges that you encounter with the various systems developed and implemented by the external vendors in your organisation?

Due to each business process uniqueness, the ministry's computing environment consist of several ICT systems developed by different external vendors. Each ICT systems play a critical role in the achievement of the ministry objectives. However, the ministries often encounter challenges with the various systems implemented and a lack of support. A participant shared that: *“There was a lack of system documentation which made it difficult to understand how the system was developed and offering adequate support on the system”* (MinistryCF3). System documentation is a critical component of ICT projects as it is a living document which technical people refer to study the system code and understand its functionality. Another participant shared about the challenges as follows: *“Most of our technical infrastructures are CISCO based and if anything breaks you cannot replace it with any other brand otherwise your system will not work. As a result, the organisation is forced to keep buying expensive CISCO devices. The only workaround is to remove the entire system, which is not an optimal solution because of the prior investment”* (MinistryDF4). The various challenges lead to vendor lock-in and an IT ecosystem with incompatible systems. A participant shared that: *“when you are subscribed to for example Oracle their system might not be compatible with third-party hardware and software, this forces you to stick to their products which have exorbitant licensing costs”* (MinistryDF4). Not only are the systems incompatible, but the technology used to develop them also gets obsolete overtime and with limited and no access to the source code Ministerial IT personnel may not be able to maintain those systems. *“When a certain contract ends some companies, they no longer offer support hence as new technology evolves, software's or applications also needs an upgrade”* (MinistryBF6).

4. Findings

Based on the analysis that was carried out in section 4 above, various factors impeding the successful deployment of the outsourced government ICT system projects were found. The factors, which

includes: employees level of involvement, levels of vendorism, similar project exposures, collaboration challenges, project scope creep, support and maintenance level differentiation and ease of switching vendors are interdependent. The factors are discussed below.

4.1 Employees level of involvement

With the ICT projects outsourced to external vendors government employees join the projects at different levels. The level at which employees get involved influences how well they integrate into the project team and become familiar with the system being developed. Government employees were either involved in the outsourced projects at initiation or towards project completion. Most often, the government employees become involved when the project is nearing the handover phase.

The delay in getting employees involved in the project from its inception results in diverse challenges; as the employees are not always well equipped to take on full responsibility of the project once the external vendors' contracts have lapsed. The government employees are often only able to provide basic user support services and are still reliant on external vendors to provide more complex systems support and maintenance. Thus, the late involvement of the government employees has implications on skills transfer and the maintenance and support of the systems implemented.

4.2 Levels of vendorism

Vendors within government outsourcing for ICT systems projects comes in multiple forms. Emanating from local private sectors and foreign vendors as well. With projects that are more complex there has been a propensity for the creation of joint ventures between local private companies that may not have the experience in complex projects with foreign experienced companies. In some instances when local vendors get ICT systems projects, they sub-contract third parties. Often, these sub-contractors are only responsible for certain work packages, and once they are done, they drop out of projects leaving multiple challenges in terms of overall support and handover.

There also exists a perception that the Office of the Prime Minister, which is mainly responsible for governmental information technology operation is considered as an external vendor. OPM is considered as an external vendor by other ministries employees as its characterised by certain patterns of behaviour which includes, requests for requirements documentation from internal IT personnel, late responses to e-mail communications, etc. as experienced with other external vendors. This phenomenon is interesting as the expected outcome would be a collegial collaboration between OPM and other ministries and not a vendor-based association.

The levels of vendorism have implication for the overall success of the IT/IS projects. From skills transfer not happening as in the case for sub-contracting to a lack of continuity as in the case of vendors disappearing after implementation of projects without proper training or handovers. Therefore, perpetuating the dependency of government to vendors for complex projects due to lack of complex project exposure among other factors.

4.3 Similar projects exposure

Depending on the magnitude of the ICT system project, similar project exposure is considered one of the primary factors when awarding a project to a vendor. In this regard, the rationale is that the vendor has been exposed to similar business scenarios and is thus viewed as having the necessary experience required to manage ICT projects of the same nature. Thus putting the vendor in a better position to deliver a successful project.

The lack of project exposure among the local workforce (government employees and local private sector companies) leads to ICT systems projects being outsourced to foreign vendors. When it comes to the local workforce, there are two levels of project exposure, which affected to whom the projects were outsourced. The first level is the government staff employed by the line ministries and had no expertise or exposure to similar projects. The second level is local companies that also have no practical record of executing projects of the same nature. The actors at both levels have no similar project exposure. Alternatively, to be awarded government ICT systems projects, local companies often form joint ventures with foreign companies that have a reputable record in implementing similar projects elsewhere. With the joint venture, the involved companies form a collusion by pulling resources (skills, funds, infrastructures) together towards the successful completion of the project. Many local companies view joint ventures as an opportunity to gain exposure and build up a credible profile for acquiring future government ICT systems projects of similar complexity.

4.4 Collaboration challenges

Working with external vendors comes with different challenges, which include communication and transfer of skills from the external vendors to government employees.

External vendors are not always conversant in the official language of the country in which they have been contracted to develop ICT projects. Due to the language barriers, there were challenges, such as understanding some wording from each other, owing to different accents. The language barriers between team members often leads to misinterpretation and miscommunication about the project requirements. As a result, the ICT projects often encounters various delays due to government employees and external vendors going back and forth refining the requirements. Collaboration challenges are further exacerbated by the different working time zones. Different time zones contribute to collaboration challenges when external vendors return to their home countries and the government is still dependent on them for maintenance and support. The difference in time zones between vendors home countries and Namibia can impact the urgency with which required maintenance can be provided.

Also, during collaboration, transfer of skills is a challenging process. External vendors do not always work harmoniously along with the internal employees to ensure a smooth transfer of skills and when they leave, employees find it difficult to work efficiently on the systems. The diverse communication challenges impacting projects' development stages have a direct effect on skills transfer as the vendors are not always able to clearly communicate different aspects of the system to the internal employees.

4.5 Project scope creep

All projects encounter change over their lifetime, and it is worth noting that not all changes are bad. However, the constant change to the project scope without appropriate management and assessments of the implications to the entire project objectives leads to scope creep. The government ICT systems projects are often scope creeped as stakeholders keep adding requirements after the projects have kicked off. Many factors such as starting a project without clear requirements, undocumented requirements and poor communications between the project manager and team members attributed to misunderstandings, which would concurrently lead to scope creep.

Consequently, projects keep expanding in terms of the scope, time and other resources required for timely completion. Due to scope creep, some of the government ICT systems projects failed to meet deadlines and encountered excessive budget overruns. The continuous changes in the projects

scope after the projects began to yield a lack of trust in the government employees' project management skills and costly government technological investment.

4.6 Support and maintenance level differentiation

Ex-post ICT systems projects' implementation includes support of users and the maintenance of implemented systems. With the outsourcing of systems development, line-ministry government employees tend to get involved in projects at different levels. In some instances, line-ministry employees are relegated to level one systems support, dealing with mundane and routing end-user functions like password changes or systems configuration onto end-user computing devices. Another level of support is the technical environment, which consists of ensuring that servers running the developed software are up and running.

There remains a level of non-involvement in the actual information system maintenance by the government employees. This could be attributed to government IT employees not having access to the source code to effect feature implementation and development. Thus, leaving ministries at the mercy of vendors for maintenance and support, which often results in vendor locking. The level of involvement is sometimes stipulated within the outsourcing contracts, which has a negative impact on the overall sustainability and ease of vendor switching.

4.7 Ease of switching vendors

In the development of ICT projects, diverse programming languages and hardware infrastructures are utilised. This diversity allows for custom development of ICT systems. However, should a vendor not be able to supply or maintain the custom system, switching to different vendors can prove difficult. Oftentimes, the only way to change a vendor is to completely get rid of the system and implement a new one, which is not always a feasible option. Even when cheaper quotations for systems hardware infrastructures, maintenance and support can be sourced, there is usually incompatibility with the existing systems.

Switching to a different vendor comes with its own challenges, as the new vendor may still develop a system, from which it will still be hard to switch from. Therefore, due to the cost implications and other challenges the government often remains with the vendor that has developed the system. Thus, the government continues being reliant on a vendor even beyond their initial contract.

5. Implications of the findings

In practise, outsourcing government ICT systems to external vendors has a series of implications affecting technology, process, people, and culture that constitutes ICT system projects. From the technological perspective, one of the main implication is systems interoperability due to the systems heterogeneity. Systems heterogeneity refers to the deployment of different systems from different vendors. With systems heterogeneity, each system is supported and maintained uniquely according to the vendor's specifications. Ultimately, systems heterogeneity contributes to systems interoperability whereby various systems deployed within the Ministries are unable to communicate and thus their continuous operation in silo. Having ICT systems that are not communicating, means there is no sharing of data among the organisational units. Consequently, this defeats the purpose of timely effective communication.

Systems interoperability cripples the Ministry computing environment with legacy-outdated systems. On another hand, legacy systems are costly to operate and maintain as the technological

infrastructures (hardware and software) necessary for maintaining them are no longer supplied on the market.

From the people perspective, Systems ownership by the local people continues to be lacking if they are only brought into the projects in the final phases. The inclusion of local people only in the final phases of the projects creates gaps in their knowledge and understanding of the systems functionality. Not having access to systems, documentation worsen the situation, as the government employees have no supporting documents to enable self-learning. Thus, systems documentations are living documents necessary for business continuation when new employees are recruited, and the vendors are no longer working on the projects.

Culture plays an integral part in the success of ICT systems project. It governs communication styles and work ethic among employees. Culture either contribute to a timely delivery of an ICT project or delays its completion. On the one hand, government employees might be used to slower pace due to bureaucratic administration processes, while private companies might have a faster deliverables/ Key performance indicators pace. On the other hand, different style of working based on work culture and national cultures might also hinder projects.

There is a necessity to find a balance between outsourcing systems and their implications to the Ministry ICT innovation and growth. Otherwise, it becomes difficult to venture into ICT innovation and growth when the ministries are entangled into previous vendors contracts.

6. Conclusion

This paper contributes to the phenomena of vendor lock-in within government ministries. It brings to light the implications that vendor lock-in has on governments' digital transformation efforts and as well as the negative impact, it can have on public service delivery. Data was collected from four ministries in Namibia. The findings of the study have been discussed in section 5.

The study empirically revealed that governments outsource the development of ICT systems projects to external vendors due to their workforce not having all the necessary skills to develop the projects in-house. The outsourcing of the ICT systems projects is intended to advance e-government initiatives and provide an opportunity for government employees to gain exposure for acquiring systems development skills. These system development skills are critical towards empowering the government employees for future ICT systems projects development and enable them to fully maintain the systems after vendors hand over the projects.

This study is a lesson to both technical and business employees involved with the implementation of outsourced ICT projects. It aims to interrogate the different factors that result from the outsourcing of government ICT systems projects. Many factors are not easy to detect due to the nature of ICT projects. Thus, this study provides the basis to foster understanding and provoke a deeper interrogation of the various factors (technical and non-technical) that could impede the future digital growth and innovation as a result of outsourcing. We propose that future research focuses on the extent to which the Namibian government and other governments at similar e-government/digital transformation developmental stages are vendor locked.

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Investigation into The Challenges of Implementing Scalable Big data Technologies and Techniques

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Abstract

The age of big data is here, and the effective managing of this data can determine whether an organisation succeeds or falls behind its competitors. In more extreme cases it can determine how effectively a country can manage a pandemic, as we have seen with the COVID-19 pandemic. Dealing with big data presents many challenges but equally these are accompanied with several solutions with the use of available technologies. Furthermore, technology regarding managing big data is widely available and has evolved over the past few years. The current research dives into the different technologies currently being used by industry practitioners in Namibia and the different challenges they encounter in regard to their respective approaches. Additionally, a short online survey was also conducted to investigate the knowledge of relevant stakeholders in terms of big data technologies in the Namibian context. Findings of the research indicated that reasoning with respect to a predefined set of resources is no longer relevant (i.e., computing, storage, and main memory). Instead, using scalable technologies and techniques, data processing algorithms and processes must be designed with unlimited resources in mind. Finally, this study also recommends that to address the issue of big data processing industry practitioners must desert the use of outdated technologies and to encourage one another to employ scalable technologies. Additionally, all stakeholders should employ a more technical and practical approach when conducting research in this field as well as providing incentives for individuals utilising scalable big data technologies.

Keywords: Data management, Hadoop, Scalable, Big data, Data analytics and Technologies

1. Introduction

According to Doty (2021) data is the new gold and with the continuously growing amount of data available because of the internet, it easy to see why. It is essential to store, process and analyse this data to make sound decisions in very important industries like finance, medical and science. Furthermore Rouse (2019) defines big data as a collection of organised, semi-structured, and unstructured data that may be used for advanced analytical tasks like machine learning, predictive modelling, and data mining. The three V's are frequently used to describe big data:

- The tremendous **volume** of data in a range of environments.
- The large **variety** of separate data formats that are commonly stored in big data systems
- The **velocity** at which information is created, gathered, and analysed.



Figure 1: How much data is generated each minute in 2019. Source: (Tucker, 2022)

Velocity is further explained by Abu-Salih et al. (2021) as the collection of data at high speeds, near real-time, and in real-time from diverse data sources. Saleh et al. (2018) furthermore stated that in recent years, businesses have generated, received, processed, and stored a massive amount of data from a variety of sources, including databases and the Internet. Moreover, Abu-Salih et al. (2021) states that the velocity of data necessitates advanced solutions capable of storing, processing, managing, and analysing streams of heterogeneous data and inferring value on motion. Big data is retrieved from data sources such as enterprise applications, social media feeds, email systems, and papers produced by employees. Big data is a data-driven technology that analyses massive volumes of data to extract usable information from the data in order to make predictions based on that data Koo et al. (2020) explained.

In a separate article, Saleh et al. (2018) describes big data management as the procedure of storing, managing and handling of large amounts of data. Furthermore, Saleh et al. (2018), explains that big data has several characteristics and has a tendency to change in format; It is sometimes clear or complicated, organised or unorganised, secure or vulnerable. As a result, sophisticated, unique, and flexible analytics are required to deal with the challenges of collecting and analysing a diverse set of big data islands, which are rapidly growing because of the massive amounts of data generated by tracking sensors, social media, transaction records, etc (Abu-Salih et al., 2021). Rouse (2019) continues to mention, big data solutions must be personalised to an organisation's specific demands. A do-it-yourself project that involves information technology and data management teams to piece together a specific collection of technologies and tools.

The current research dives into the different technologies currently being used by industry practitioners in Namibia and the different challenges they encounter in regard to their respective approaches. Additionally, a short online survey was also conducted to investigate the knowledge of relevant stakeholders in terms of big data technologies in the Namibian context. The rest of the article is structure as follow, Literature Review, Methods, Results and Discussions, and Conclusion.

2. Literature Review

2.1 Introduction

Discusses different literatures regarding the challenges big data presents and provides an in-depth evaluation of different technologies available to deal with these challenges. These challenges are linked to different aspects concerning big data like technology, availability of data and integrity, scalability and developer skill sets to name few. This chapter also discusses the different big data technologies available for industry practitioners to utilise in order to tackle a number of challenges that arise when trying to manage big data.

2.2 Challenges of processing big data

2.2.1 Scalability

Scalability is one of the most prominent of issues when it comes to big data management. According to Al-Sai et al. (2019), scalability refers to the ability to supply resources in an appropriate manner to meet business needs when required. Additionally, Saleh et al. (2018) emphasised the scalability issue by stating that to address data volumes that are growing faster than computer resources, businesses must reassess their design, structure, and data processing components.

Furthermore, Jayashree and Abirami (2018) state that scalability is a serious issue that has persisted for many years because big data involves significant amounts of data. The reason for this is because parallel data processing technologies that were once employed to preserve and analyse data are no longer useful when data sizes continue to grow at an exponential rate.

2.2.2 Storage

The problem with storage is emphasised by a paper written by Jayashree and Abirami (2018) where they reported that some cloud models are in the early stages of development, hence the storage problem has persisted for so long. Another problem connected to storage is that with data being replicated, more data is collected from a variety of sources and devices and it's critical to avoid data duplication, which wreaks havoc on the analysis stage.

Furthermore, according to a study by Saleh et al. (2018), the location where big data will be kept is also a huge concern for organisations. As a result, emerging storage models such as flexible web services featuring petabyte-scale data stores have difficulties in terms of ensuring minimal input/output delay from big data repositories.

2.2.3 Privacy

According to Saleh et al. (2018), privacy breaches happen when security procedures are inadequate. Furthermore, Saleh et al. (2018) argue that because most of the information in the datasets is vital, and therefore security breaches should be a top priority for firms, as they can cause major privacy problems and risk the safety of employees and customers. Hence, Koo et al. (2020) reported that if the information to be acquired is sensitive such as personal information, there may well be legal implications, and thus the subject collecting the data should be careful and collect in accordance with the nature of the collected data.

2.2.4 Lack of skill set

New skills are being demanded as new technologies enter the market. According to a study conducted by Saleh et al. (2018), real-time data mining and analysis demands a high level of technical proficiency to be accurate and useful. Furthermore, Al-Sai et al. (2019) contends that a significant constraint to extracting value from Big data would be a scarcity of skills and Big data professionals. Furthermore, Michael and Miller (2013) (as cited in Al-Sai et al. 2019) reported that a lack of skills is a direct consequence of the slow adoption of Big data, leaving a gap related to the need for adequate preparation and expertise people who support the adoption process. Finally, the study by Gao et al. (2015) (as cited in Al-Sai et al. 2019), noted that, because Big data is still relatively new, finding and hiring big data experts is very difficult and expensive.

2.2.5 Inaccurate and incomplete data

When it comes to big data, the data being analysed must be complete. According to Saleh et al. (2018), big data is useless if it isn't used to improve decision-making. The term uncertainty can be used to explain data inaccuracy and incompleteness, and uncertainty is defined as a scenario with unknown or poor information (Hariri et al., 2019). Hence, organisations must undertake data management activities such as data gathering, extraction, and recording, data cleansing, data integration and aggregation, data representation and analytics, including modelling, analysis, and interpretation (Saleh et al., 2018).

Data that will be used to do analysis will come from diverse sources and of different formats (Saleh et al., 2018). Hence, according to Saleh et al. (2018) it could be comprised of incorrect information, duplication, and contradictions.

2.3 Scalable Technologies or Big data Processing

2.3.1 Apache spark ecosystem

According to Shaikh et al. (2019), Apache Spark is a sophisticated Big data processing tool that uses a hybrid framework. Furthermore, according to Shaikh et al. (2019), Apache Spark is a hybrid framework that supports stream and batch processing capabilities. More importantly, Shaikh et al., (2019) claim that even though Apache Spark follows many of the same principles as Hadoop's MapReduce engine.

Apache Spark has a few drawbacks. DataFlair (2019), mentions that Apache Spark lacks file management systems and thus must rely on other databases, and when it does use HDFS, it inherits all of the HDFS's drawbacks, such as the inability to deal with small files. Another disadvantage is the cost; DataFlair (2019) elaborates that in-memory capability can cause a bottleneck when cost-efficiency is required during big data processing. Spark requires a lot of RAM to run in-memory, so its price is quite high.

2.3.2 Hadoop ecosystem

Hadoop is an open-source project led by Apache. It was created with the goal of processing large amounts of data in a timely, efficient, and cost-effective manner Ajah & Nweke, (2019). Hadoop can deal with both unstructured and structured data. Hadoop is user friendly and extremely scalable. Moreover, Ajah and Nweke, (2019) states that Hadoop YARN broadens Hadoop's ability to support a wide range of applications, minimize Hadoop's limitation to only running MapReduce applications. As a result, real-time analytics, dynamic querying and data streaming applications are all possible with Apache Hadoop due to YARN (Ajah and Nweke, 2019). Ajah and Nweke (2019) also mentioned Common, which is an important component of the Hadoop ecosystem.

2.4 Data mining technologies

2.4.1 RapidMiner

RapidMiner allows you to access, load, and analyse any sort of data (Ratra and Gulia, 2019). Thus, according to Ratra and Gulia (2019), data, such as text, static images, and media, can either be structured and unstructured. RapidMiner extracts valuable information from structured data and also convert unstructured data into structured formats. Furthermore, Ratra and Gulia (2019) state that RapidMiner supports over 35 different file formats, including URL's, ARFF and SAS.

2.4.2 Mozenda

According to Ratra and Gulia (2019), Mozenda offers technology, which can be given as code (SaaS and on-premises choices) or as a managed service, that allows customers to take unstructured internet data and turn it into structured formats for data analysis. Mozenda is as a tool that does internet scraping. Internet scraping is a technique for extracting data from the internet using a computer. Mozenda converts website data into structured data using a point-and-click code tool.

2.4.3 Octoparse

Ratra and Gulia (2019) state that, Octoparse is the ultimate tool for information extraction its cable of web locomotion, information movement, and information mining. Hence, the Octoparse internet scraping program, users will have the ability to convert the entire "internet" into structured information. Additionally, Ratra and Gulia (2019) report that the Octoparse team has never slowed down in making information more available and prepared for everyone in order to achieve autonomous internet scraping in the real world.

2.5 Data storage technologies

Table 1: (Comparison table between Hadoop, Spark, and MongoDB)

Criteria	Hadoop	Spark	MongoDB
Processing Model	Batches	Mini Batches	Single document
Latency	High Latency	Very Low Latency	Low
Fault Tolerant	Uses Replications	Uses RDD	Replica Set
Supported Languages	Java	Scala, Java, Python	C++
Batch Framework	HDFS	Core Spark API	BSON
Security	Highly Secure	Less Secure	Secure
Advantages	Storage and processing speed, low cost, Secure	Scalable, High Speed, Powerful Caching	Expandable
Weakness	'Name Node' is the single point of failure	Expensive, few number of algorithms, small file problems (HDFS)	Fault Tolerant issue
Hardware Cost	Cost is more	Cost is more	Cost Effective: Single product

Source: (Ratra and Gulia, 2019)

2.5.1 Hadoop Distributed File System (HDFS)

Hadoop Distributed File System (HDFS) is a filesystem designed for storing very large files with streaming data access patterns, running on clusters of commodity hardware Abu-Salih et al. (2021). According to Abu-Salih et al. (2019), HDFS is best suited for write-once, read-many-times processing. It is expensive, highly reliable hardware isn't required; instead, readily available hardware on the market is a viable option when constructing Hadoop Ecosystems. One issue to be aware of is that HDFS may not be the best choice when an application demands low-latency data access (Abu-Salih et al., 2019). If the data set comprises of a large number of small files, it is not a good idea to utilise HDFS to store the data since HDFS stores files to a block that is often set to 128MB (by default) or 256MB, resulting in storage waste.

2.5.2 Apache Spark

Apache Spark is an open-source technology developed by the AMP science lab at UC Berkley says Ratra and Gulia (2019). The technology is defined as framework with stream processing abilities. Apache Spark is built on planned exploitation of a number of Hadoop's MapReduce engine's principles. In addition, according to this Spark focuses entirely on accelerating process and instruction execution workloads by providing full in-memory computation and processing enhancement. Hence, the speed of spark is 100 times faster than Hadoop's. RDDs (Resilient Distributed Datasets) is the model used by Apache Spark.

2.5.3 MongoDB

MongoDB is a JSON-based database that was first released in 2009. It is developed in C++ and is based on JSON documents states Ratra and Gulia. (2019). According to Ratra and Gulia (2019), the MongoDB database is used to store data that does not have a set schema. The database does not have a predefined format like tables in relational databases, but rather data is stored in BSON form documents.

2.6 Data analysis technologies

2.6.1 Python

Python, according to Ginde et al. (2017), is a general-purpose programming language designed for readability. Furthermore, python offers the greatest strength in its diverse set of libraries for doing various tasks such as data extraction, text processing, and machine learning methods. Furthermore, a number of built-in tools and frameworks for data analysis, including Pandas, Scipy, Scikit-learn, and Numpy makes data pre-processing and analysis simple. However., scalability is a big concern. In addition to Python's scalability limitations, Ginde et al. (2017) claims that Python's performance in big batch processing does not make it a desirable tool.

2.6.2 R language

Ginde et al. (2017) diverts to R and describes it as mainly designed for statical analyses. Its primary goal is to improve mathematical modelling and assist in the development of analytical prototypes. R offers a less complicated way to access various machine learning and mathematics functions. One downside to R is its slowness in analysis and data processing when compared to Python.

2.7 Conclusion

The challenges industry practitioners face when dealing with big data are not limited to the ones identified in this literature review. What is promising is the fact that, because of the ever- evolving technologies it is possible to deal with the different challenges that arise. Therefore it is essential to adopt a scalable Big data platform.

3. Methods

3.1 Exploratory research

The current study adopted exploratory research, because this type of approach allows the researcher to be creative to gain the most amount of insight on a subject. Additionally, the researcher wants to use an outside audience for this research, this will give the researcher a good opportunity to know what works and what not a productive method to use is. Additionally, it makes for a clearer grasp

about what the aims of a research team should be during an investigation. Furthermore, anyone performing research from outside sources will benefit from having this material on hand.

Additionally, according to QuestionPro (2018), exploratory research is a method of research that is used to study a problem that is not well defined. Dudovskiy (2016), states that here, the researcher's willingness to change path in response to the discovery of new information or insight is crucial.

3.2 Sampling

Sampling can be explaining as a principle used to pick a specific group of individuals within a wider population (Dudovskiy, 2016). Additionally, Beaudry and Miller (2016) explain a sample as a subset of a population that is meant to represent this population. The sample is made up of 5 industry practitioners (IT professionals) both male and female. The target group includes individuals in the industry of Computer Science namely data scientist.

3.3 Methods and tools for data processing

To gather the information needed for the investigation, the researcher used both the primary and secondary research methods. The Primary research methods used by the researcher was a questionnaire and an online survey. The questionnaire was distributed via email. All participants that were selected are experts in the field of data analyses. Furthermore, the online survey was distributed via a website called survey monkey, this was to give the respondents an easily accessible tool for quick responses.

The researcher used Python's Jupyter notebook to do data analysis. This software allowed the researcher to create different visualizations of the data collected via the primary research method which was the questionnaires. Additionally, Microsoft excel was used to do various task such as preparing and managing the data collected via the questionnaires to do different visualisations.

3.4 Research delineation

The research study was limited to five (5) industry practitioners, more specially data scientists and big data experts that use different types of technologies to process big data. The inclusion of data scientists and data analysts is, because of the lack of big data experts in the region where the study was conducted.

4. Results and Discussion

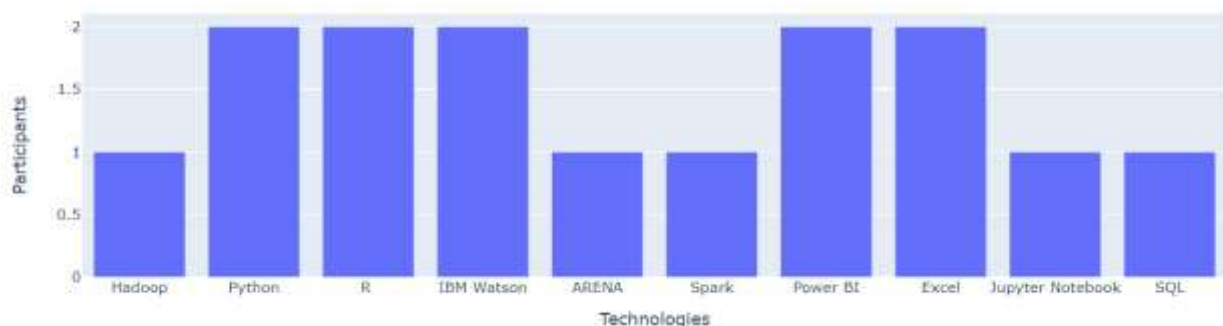


Fig. 2: Technologies used by the industry practioners

Fig.2 shows the technologies currently being used by the five (5) industry practitioners. The technologies mostly used are Python, R Language, Power Bi and Excel with at least two (2) participants naming them as the technologies they use currently.



Fig. 3: type of storage used by the industry practioners

Fig.3 shows that out of the five (5) participants that answered the questionnaire 80% make use of scalable approach when it comes to storing data. On the other hand, none of the participants make use of only storing data “In-house”. The Hybrid and Cloud approach allows practitioners the ability to only use the amount of storage they require; they can acquire additional storage if needed.



Fig. 4: Performance bottlenecks faced by the industry practioners

The participants could select more than one answer. As the pie charts shows 45.5% of the participants chose High CPU usage as the most common performance bottleneck, and the least experience performance bottlenecks are High disk usage and High disk I/O.

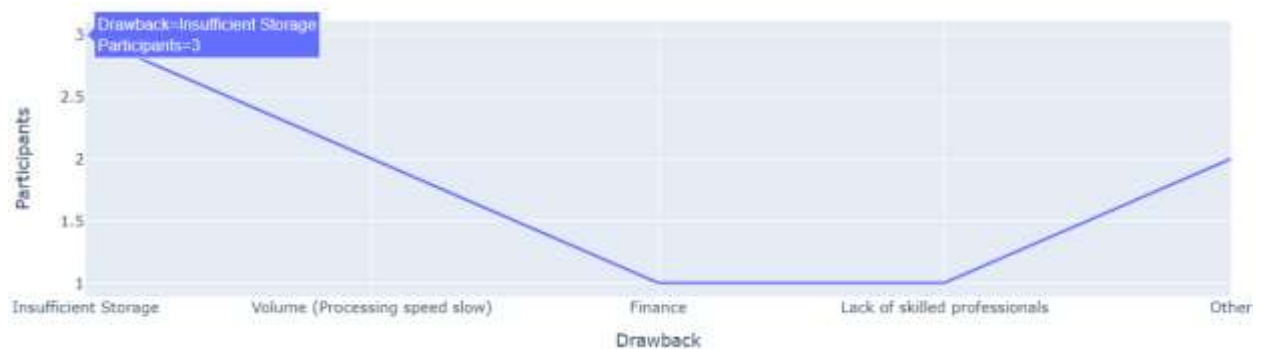


Fig. 5: Drawbacks of the systems used by industry practioners

Fig.5 shows that 3 out of the 5 participants link their technology's drawbacks to the lack of storage it possesses. Whereas 1 participant stated that the drawback of their systems is financial, which means the cost to implement and maintain these technologies are not feasible to the implementor. Additionally, 1 out of the 5 participants claimed that the lack of skilled professionals is a key concern, this implies that the individuals' task with implementing these technologies do not have the required knowledge.

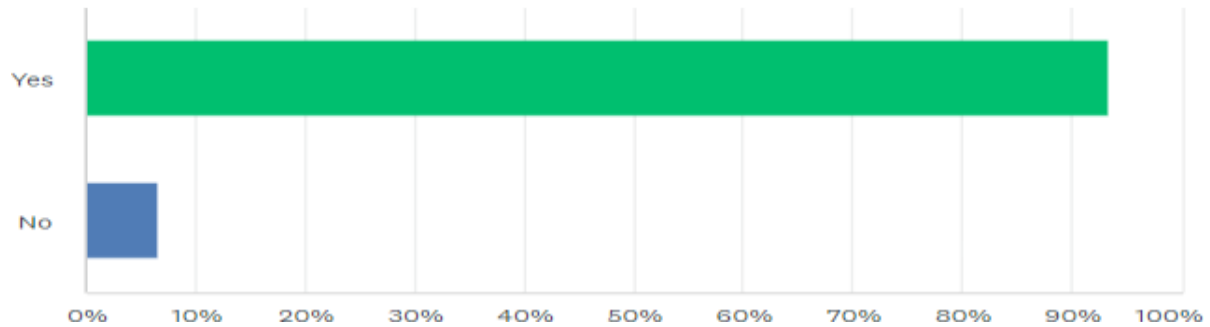


Fig. 6: Are you familiar with Big data?

Fig. 6 shows the responses of 15 IT professionals that were asked whether they are familiar with big data. The responses show that majority of IT professionals are aware of what big data is because 93.33% percent of respondents said they are familiar with big data.

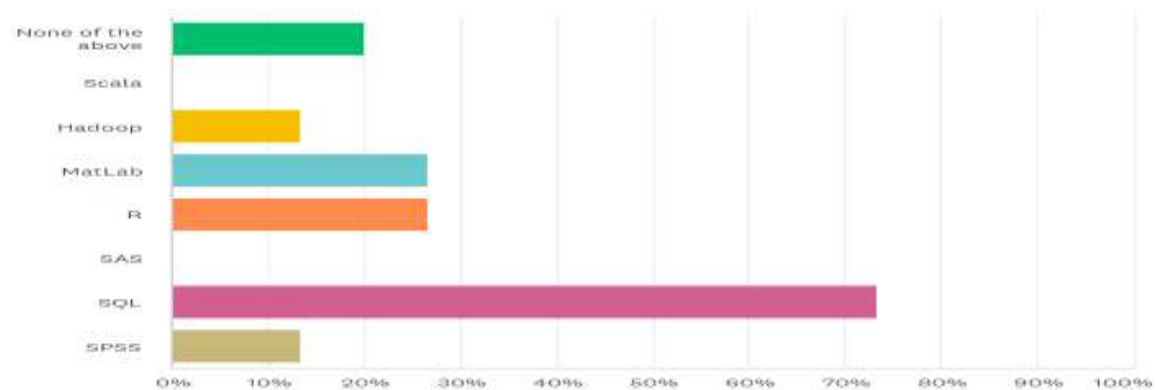


Fig. 7: Which of these technologies are you familiar with? (Choose one or more)

Fig. 7 Shows that most respondents are familiar with SQL and this no surprise because this is the most widely used technology in regard to storing data and query for specific information. 73.33% of the respondents stated that they know SQL but more positively 26.63% of participants are knowledgeable with R and Matlab which are very important technologies in big data analytics.

5. Conclusion

Regarding the first aim of the study: Identify the different challenges when dealing with big data, the results identified a variety of different challenges namely Privacy, Scalability, Incomplete data, Storage, and a lack of required skills from industry practitioners

In accordance with the second aim of study: Understanding and investigating the traditional big data processing applications and techniques, the study identified and reviewed two big data processing ecosystems, the Hadoop ecosystem, and the Apache Spark ecosystem.

As to the third aim: Investigate what technologies industry practitioners are currently using for processing large amounts of data and the challenges they face, the literature review grouped the technologies into three categories, Data acquisition technologies, Data storage technologies and Data analysis technologies.

For the fourth objective: Investigate the knowledge of IT experts in terms of big data skills and tools, the results revealed that very few industry practitioners use any of the technologies reviewed in this study. Only 3 technologies (R, Hadoop and Spark) reviewed in the study are being utilised by the participants, with one participant making use of two of those technologies.

The overall results of the present research provide convincing evidence of how the available technologies can deal with the different challenges that arise when dealing with big data.

Given these findings, it seemed reasonable to conclude by saying that there is a general need to adopt the new technologies available for big data processing, because the age of big data has arrived and is an essential part of any organisation. If the results of the study are a true representation of the overall population's approaches with regards to big data processing, then the need to implement scalable big data technology is of paramount importance within the research area (Namibia). Failure to implement any form of scalable technology whether for big data mining, storing, or analysing will most certainly result in ineffective big data processing.

5.1 Recommendations

Considering the foregoing, the researcher desires to suggest some recommendations that, if followed, could result in some positive modifications to Namibia's existing approaches when it comes to big data management. Industry practitioners and important stakeholders in big data should:

- Replace current, less scalable techniques to big data processing in favour of new approaches based on a wide range of scalable technologies that will enable businesses and industries to realize big data's full potential.
- Take more practical approaches when it comes to addressing different aspects of big data. This implies that all stakeholders should employ a more technical and practical approach when conducting research in this field.
- Encourage each other to implement big data processing ecosystem like Hadoop and Spark.

5.2 Further Research

The study has identified various researchable areas that individuals working to create scalable big data technology should investigate further. The study's findings demonstrated how existing solutions are geared to address the majority of the issues that arise when dealing with big data. However, this research does not provide solutions to one of the problems identified, privacy. Privacy is a problem that cannot necessarily be solved by the introduction of new a technology. This study can be used as a starting point for future in-depth investigations. More research is needed to determine the best approaches to deal with the issue of privacy.

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Academic Dishonesty in Remote Teaching, Learning and Assessment: A Single Case Study of the Namibia University of Science and Technology

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Abstract.

Higher education institutions (HEIs) made significant investments in digital technologies, platforms, and infrastructures as a response of the COVID-19 pandemic because they saw them as the most practical way to continue offering services in the face of widespread lockdowns and travel restrictions. The majority of HEIs were not, however, ready for the rapid shift from conventional face-to-face teaching, learning, and assessment to remote teaching, learning, and assessment (RTLA) on such a large scale. In RTLA, traditional systems for upholding academic integrity were frequently non-existent, ineffective, or poorly thought out. There is a consensus that RTLA will persist after the COVID-19 pandemic in some capacity, necessitating the use of a risk-based approach to look into academic integrity. Based on a case study of a higher education facility in Namibia, this action research study was conducted. The Eaton (2021) 4M Framework for Academic Integrity served as the foundation for the data collecting and analysis technique for this article. According to this framework, academic integrity can be examined at the micro, meso, macro, and mega levels. The micro level refers to the individual, the macro refers to the institution, and the meso level refers to faculties, departments, and other entities (that is, the community level). According to our findings, there are divergent views on how digital technology affects academic integrity. The findings also demonstrate that views of an increase or decrease in academic integrity infractions are moderated by transparency, organizational structure, and governance frameworks. The study also showed that while HEIs take academic integrity seriously, they are equally concerned about any reputational harm, which is why we had to anonymize the institution.

Keywords: Academic Dishonesty, Academic Integrity, Remote Teaching, Higher Education

1. Introduction

The topic of academic dishonesty has been widely studied in a variety of multidisciplinary studies, but its conceptualisation remains challenging. Bachore (2014) and Denisova-Schmidt (2020) among others, point out that academic dishonesty is symptomatic of the lack of academic integrity and other forms of unethical behaviour. According to McGregor (2020), dishonesty in higher education can be the result of several factors. These include poorly designed systems; students and staff who do not fully understand what constitutes unethical behaviour; lack of consequences; or people in difficult situations who find shortcuts attractive solutions. Academic dishonesty manifests where individuals exploit vulnerabilities for private gain to the detriment of others and, as a result, undermine the integrity of the systems they are abusing (McGregor, 2020). Thus, from an academic point of view, actions such as cheating and plagiarism benefit the perpetrator, and they have the potential to undermine the credibility of qualifications that even hardworking students possess.

As a response to the shutdowns and other restrictive measures imposed by countries because of the COVID-19 pandemic, there has been a substantial uptake and investment in digital technologies, platforms, and infrastructures within universities (Garcia-Morales, Garrido-Moreno, Martin-Rojas, 2021). In most cases, most institutions were not prepared for the transition on such a massive scale, but they had very few options available to them to continue offering teaching, learning and

assessment. As a result, the academic systems for ensuring academic integrity online were often absent or poorly designed, providing fertile ground for academic dishonesty to manifest.

Just like other global institutions of higher learning, the Namibia University of Science and Technology (NUST) underwent rapid migration to digital platforms, as a pandemic coping mechanism, of academic processes such as student recruitment, teaching, learning, and assessment, as well as accounting for research outputs. Among some of the measures adopted, some courses that were previously assessed through a diversified strategy that included continuous assessment and examinations were converted to continuous assessment (CASS) only, in which assessments were conducted online due to the prevailing restrictions. For many stakeholders, there was an anticipation that digital technologies would provide more openness to the university's teaching, learning, and assessment procedures, making it easier to detect dishonesty. For example, recording the teaching and learning process makes online learning content more transparent and reviewable. Furthermore, the availability of large data sets allows for the application of data analytics in education.

However, there were concerns about the potential impact of this online assessment on academic integrity. According to the literature, cheating is one type of academic misconduct that has been highlighted as a big issue at all universities, exacerbated by the shift from centrally monitored face-to-face assessments to decentralized online exams (Hartmann, Hobert & Schumann, 2021; Gamage, DeSilva & Gunawardhana, 2020; OECD, 2020). Other researchers, on the other hand, argue that the shift to online teaching and learning has reduced academic dishonesty (Bashitialshaer, Alhendawi & Avery, 2021; Harris, Harrison, McNally & Ford, 2019).

2. Problem Statement

Higher education institutions (HEIs) made significant investments in digital technologies, platforms, and infrastructures as a response of the COVID-19 pandemic because they saw them as the most practical way to continue offering services in the face of widespread lockdowns and travel restrictions. The majority of HEIs were not, however, ready for the rapid shift from conventional face-to-face teaching, learning, and assessment to remote teaching, learning, and assessment (RTLA) on such a large scale. In RTLA, traditional systems for upholding academic integrity were frequently non-existent, ineffective, or poorly thought out (Garca-Morales, Garrido-Moreno, Martin-Rojas, 2021). There is a consensus that RTLA will persist after the COVID-19 pandemic in some capacity, necessitating the use of a risk-based approach to look into academic integrity. Academic dishonesty has sparked the curiosity of a varied set of researchers in the digital age. While the problems and questions, contradictions, and possible interconnections between the digital revolution and academic dishonesty have received much attention in the literature, unfortunately, the unintended implications of digital transformation on academic dishonesty remain understudied. This paper seeks to answer the following questions:

3. Research Questions

1. What is the impact of remote teaching and learning on academic dishonesty?
2. Which factors enhance or reduce academic dishonesty in remote teaching, learning and assessment?
3. How does digital transformation impact academic integrity systems?

4. Literature Review

It is generally agreed that digital transformation has an impact on academic dishonesty. However, there is no consensus on the nature of this influence. Landri (2018), Bashitialshaer, Alhendawi, and Avery (2021), as well as Harris, Harrison, McNally, and Ford (2019), believe that digital transformation and the diffusion of digital technologies reduce academic dishonesty. They claim that high levels of digitalization increase public awareness and information, allowing for better risk detection. Additionally, they argue, the presence of a digital audit trail makes it more difficult to commit fraud. Researchers who hold this viewpoint believe that datafication and digitalization of teaching, learning, and assessment processes will make them more visible, thereby strengthening various institutional governance processes. Ouedraogo and Sy (2020) argue that digitalization does not promote dishonesty; rather, it is the bureaucratic procedures that accompany digitalization that are the source of dishonesty. Their perspective is particularly relevant to this research because NUST is undergoing an organizational reorganization that will re-align its bureaucratic processes. As a result, it is critical to anticipate potential issues with academic integrity breaches that may arise because of such an endeavour.

Despite recognizing the potential good influence of digitalization, some researchers remain sceptical. Landri (2018) focuses on the concept of transparency, arguing that it does not always deliver the desired result. They argue, for example, that while data and information are important for attaining transparency, they are not necessarily perceived in the same manner by various people and institutions. Furthermore, they argue that if an institution's internal procedures are not transformed, openness might weaken trust and accountability, leading to perceptions of excessive surveillance and control. Shelly (1998) adds to the issue by arguing that digitization encourages dishonesty because it provides criminals with a level of anonymity, allowing them to engage in corrupt behaviour.

Pereira et al. (2020) suggest that digital transformation is a significant driver of human socio-cultural evolution, with digitalization providing opportunities for improving societal well-being but also posing the risk of unintended consequences. Sheik et al. (2021) claim that, while traditional forms of academic dishonesty can be reduced or even eliminated through increased accountability and transparency, as well as digital trace, new forms of academic dishonesty, such as cyber-fraud, skilled personnel exploitation of digital records, and cyber-attacks, are on the rise. However, Sheik et al. (2021) believe that the increased engagement provided by digital platforms, as well as the ability to automate certain processes, will help to eliminate academic dishonesty in the long run. In this study, we suggest that increased learner connectivity (e.g., through texting apps or social media) outside the learning platform will raise the potential for collusion and other forms of cheating, especially in a remote teaching and learning environment where assessment control through proximity-based monitoring and observation is limited. While we accept that proctored digital examinations are a possibility, certain stakeholders are concerned about problems such as surveillance and control. Furthermore, most resource-constrained universities in underdeveloped economies find these solutions prohibitively expensive.

4.1 Dishonesty

Dishonesty, in its various forms, has been getting attention from researchers in a multi-disciplinary literature based on the understanding that dishonesty is linked to governance (Jain, 2001). Dishonesty is normally associated with public office and in environments where officers have high levels of discretionary power, in an environment where there are possible economic benefits, and there is low probability of detection. However, Glendinning, Ori and King (2019), widens the scope of dishonesty to include non-public actors as well. In their view, where an individual experiences certain financial,

emotional, and other pressures, and has an opportunity and appropriate justification for acting in a particular way, they may engage in corrupt activities. In this regard, in higher education we can also have dishonesty perpetrated by various stakeholders. Quandt (2009) identifies the principal forms of academic dishonesty as plagiarism and the various forms of cheating, research fraud and financial fraud. Awaah (2019) argues for a broader definition of academic dishonesty to include the failure to provide marks of interim assessment scripts in time, the failure of lecturers to teach the entire syllabus before the end of the semester, the failure of lecturers to present course outlines to students at the beginning of the semester, failure to arrive on time at lectures, or failure to show up at all, i.e., all practices that compromise on academic quality and short change the learner. However, these behaviours may not be considered academic dishonesty in other countries or higher education systems. In this paper we agree with Awaah (2019) that academic dishonesty, including every form of unfair practice within an academic environment that undermines academic integrity and may provide undue advantage to an academic stakeholder, may be considered as academic dishonesty.

Several articles have attempted to identify the causes of academic dishonesty. From the students' viewpoint, access to good universities is often limited, leading to lesser-qualified students possibly illicitly gaining admission in collusion with external agents or internal staff. However, once admitted, these students may struggle with their studies, leading them to seek all possible ways, including unethical ones, to obtain their degree, which they regard as a necessary tool for employment. From the faculty perspective, issues relating to poor remuneration led them to seek out ways of increasing their income, either within the university or from outside. Altbach (2005) further identifies the Internet as another source of potential problems since it provides great latitude for shady practices. Thus, in an era when teaching, learning and assessment has had to rapidly transition to online settings with minimal or no adjustments to governance structures in most higher education institutions of learning, it is pertinent to understand the potential impact this transition has had on academic dishonesty.

4.2 Transparency of Online Instruction and Assessment

Transparency is the practice of being open and honest with people, no matter how tough that might be. From a digital standpoint, transparency may be achieved by making information available, hence improving responsibility. However, there are differing perspectives on the impact of transparency on dishonesty. According to Naurin and Lindstedt (2010), just making information available will not prevent dishonesty if other factors for accountability such as awareness and structural systems are lacking. Other experts, however, are more favourable on the impact of transparency on dishonesty. Coroian and Criado (2012) did a study that investigated whether information and communication technology (particularly e-Government) improved transparency and accountability and restricted dishonesty in developing nations. The outcomes of their investigation supported this general premise. However, they proposed that the non-digital methods within institutions were still significant in encouraging more transparent practices. While the potential of digital technologies to enhance transparency and thereby reduce dishonesty has been noted, Mackey and Cuomo (2020) advise caution and suggest that digital technologies that enhance transparency and accountability are still underdeveloped, thereby reducing their impact on reducing dishonesty. Therefore, Mackey and Cuomo (2020) advocate for more effort in investing in digital technologies to improve their impact on transparency.

5. Methodology

The data collection and analysis strategy for this paper is based on Eaton's (2021) 4M Framework for Academic Integrity. According to this framework, academic integrity can be analysed at the micro level (that is, the individual level), meso-level (that is, at the level of faculties, departments, and other units), macro level (that is, at the institutional level) and the mega level (that is, the community level). The micro-level focuses on the perceptions and roles of key stakeholders such as students, faculty members, library staff and academic support staff who have a first-hand experience of academic integrity and dishonesty. The meso-level focuses on getting input from faculty and academic units as well as non-academic units such as the library, academic integrity office, student affairs department, teaching and learning centres as well as student-wellness centres. The macro-level focuses on the policies and procedures while the mega-level is concerned with the role of parents, families and other stakeholders who provide support to the learners.

The unit of analysis selected here is at the meso-level, that is, at the level of faculties, departments, and other units that are directly impacted by academic dishonesty activities. Therefore, instead of having a broad survey that seeks to determine the perceptions of various students such as students, lecturers and administrators, the research collects data from people in key positions, such as student representatives, and leaders of teaching, learning and assessment units within the institution. During data collection, an interview guide was employed to increase reliability. In addition, case study approaches were used to document the entire research process. The transcripts were auto coded using Microsoft Teams' Artificial Intelligence transcript generation system and they were verified by the researcher to ensure objective and reliable coding of the results.

a. Informant selection

This study's informants include the Associate Deans of teaching and learning, Head of examinations, the teaching and learning unit officer responsible for the digital platform, the Assistant Registrar for academic Affairs, Director for Information and Communication Technologies, Student Representative Council leadership, and Lecturers. We sent an invitation to the participants through a group email to the above-mentioned professionals who typically deal with academic dishonesty within the institution following the following inclusion criteria: the informants should be involved in the detection, investigation, and resolution of academic dishonesty. The informants were not selected for purposes of statistical representation (Eisenhardt, 1989), but because of the preconditions that they are knowledgeable of what is taking place in terms of academic fraud because of the offices they hold, which also enables comparability of the collected data (Yin, 2018).

Participant Characteristics

Participant	Roles
Associate Dean – Teaching and Learning/Heads of Departments	They are responsible for investigating suspected cases of dishonesty. In any disciplinary procedures, they are the complainant and key witness.
Head of Examinations	Is responsible for the integrity of all assessments of the institution
Director of ICT	Is responsible for all the technology infrastructure for remote teaching, learning and assessment.

Student Representative Council	Represent the students. If students are dissatisfied, they act as the first point of contact in terms of complaints.
Lecturers	Are primarily the ones who detect the suspected cases of dishonesty
Registrar's department	Are responsible for disciplinary procedures and ensuring that the policy environment is up to date.

Table 2: Participants and their roles

b. Data Collection

Expert interviews with structured, guideline-based questions were used to obtain data. Interview questions prepared were exploratory and open-ended with keywords for asking probing questions and follow-up questions (Kvale and Brinkmann, 2009). The questions were inspired by Cox and Beele (2016)'s Insight to Action Framework (Gagnon and Caya, 2020)

The acquisition of implicit practice and experience-oriented knowledge was the purpose of the interviews. Because of the current Covid-19 situation, all interviews were conducted in March and April 2022 via Microsoft Teams and Zoom in discussions. Interviews were recorded to provide a more accurate and comprehensive assessment of the interview. Each interview lasted approximately 60 minutes. Data collected from the informants was coded to protect anonymity and to ensure the informant's confidence and willingness to provide information and thoughts in a flexible and unstressed manner (Cooper and Schindler, 2014).

c. Ethics

Approval for this research study was obtained from the human subjects. Permission was also received from the Registrar's department, which acts as the Internal Review Board at NUST. An informed consent form was read, discussed, and signed before beginning the interview. A copy of the interview transcript, together with the informed consent form was shared with the interviewee to verify accuracy of the information.

d. Data Analysis and Reporting

The primary source data evaluated in the study was in the form of interview transcripts. The analysis presented here draws on interviews with an Associate Dean for Teaching and Learning (Representing the instructors and examiners), a member of Student Representative Council (representing the student body), the Head of Examinations, the Assistant Registrar for Academic Affairs, one External Moderator (representing the quality assurance community) and the Director for Information and Communication Technologies (who is responsible for the digital infrastructure). The findings were summarized within subjects and then across subjects to find patterns and commonalities. To enhance external validity, we will host a workshop for interested parties to present and discuss the study's findings, in addition to presenting the findings to a scientific audience.

6. Results and Analysis

e. What is the impact of remote teaching and learning on academic dishonesty?

Our results show that there are conflicting ideas about whether online instruction increases or decreases academic dishonesty. There is a temptation to assume that this divergence is probably a result of differences in understanding the affordances of digital technologies because of differing academic backgrounds in digital technologies. However, the background of the subject does not seem to be a factor in the subject's opinion about the affordances of digital technologies being a factor in the mitigation of academic dishonesty. For instance, Subject 3, who has extensive training in information technology, is of the opinion that online instruction does increase academic dishonesty.

On the other hand, Subject 1, who also has a strong IT background, believes that digital technologies can reduce academic dishonesty by providing more transparency to the operations of teaching, learning and assessment. According to Subject 1, it is rather the non-technological factors such as collusion among students and the absence of effective governance and supervision that lead to academic dishonesty.

On close inspection, it seems that this position is echoed by the rest of the subjects, who identify that in its present format, the digital learning platform does not have the functionality that allows the lecturers to identify that the student who is writing the assessment is indeed the one supposed to be doing so. In addition, even though some lecturers would require their students to initially turn on the web camera to identify the student, bandwidth constraints limit the continuous application of this feature, hence, for a large part of the online assessment, there is an opportunity for students to consult other sources or have someone replace them to take the assessment. Thus, the respondents identify this lack of digital mechanisms for direct observation or proctoring of the assessment process as a potential red flag and thus are of the opinion that online instruction increases academic dishonesty (Subject 2, Subject 4, Subject 5 and Subject 6).

Some subjects also reported that the technology can reduce incidents of cheating. For instance, certain features such as copying and pasting answers or navigating back to a previous answer can be restricted by applying the proper technological settings on the platform, as was noted by Subject 6. However, it seems as if the rapid transition to online instruction did not give the institution enough time to ensure that the necessary governance modalities were in place. Therefore, some subjects reported that there were inconsistencies in the application of these technological interventions, with some lecturers applying the interventions while others did not. This point is supported by Subject 2 who noted that “there wasn’t enough time for the institution to prepare to prevent these incidents. Therefore, some lecturers, especially part time lecturers, who had limited knowledge of the system, could not take advantage of the features the system provided.” Subject 1 notes that digital platforms have a lot of possibilities for reducing academic dishonesty. They posit that the problem is not the technology itself, but rather a lack of adequate support. Subject 3 advances that in the absence of enforcement mechanisms, the policies that exist will not bear any results. They would therefore want to see more support from the management team in terms of development of relevant policies and their implantation. This call coincides with the concern expressed by Subject 2 that the current procedures and policies were developed for face-to-face interaction and will need to be reviewed so that they are relevant for the digital era.

f. Which factors enhance or reduce academic dishonesty in remote teaching, learning and assessment?

i. Organisational Structure and Academic Dishonesty

Our results show that organisational structure has a direct influence on the relationship between online instruction and academic fraud/dishonesty. One reason for this, according to Subject 4, is that the restructuring exercise sought to change the organisational structure of NUST to reduce costs. This was in response to reduced funding and a reduction in student fees arising from students who prefer to study on a face-to-face basis and as a result are deferring their studies. As such, the restructuring exercise aimed to merge some units and faculties to cut costs. For example, the Examinations Department was previously responsible for the administration of quality examinations. The department had a direct interest in issues related to academic dishonesty and integrity. However, with the restructuring exercise, they have been required to take on additional functionality, such as organising the graduation, sometimes without additional staff being added to the complement. Their capacity to respond to academic fraud may have been compromised.

ii. Governance systems and academic dishonesty

With respect to the effect of governance systems on the impact of online instruction and assessment on academic fraud/dishonesty, we found that instead of the Examinations office being responsible for the administration of assessments, this responsibility was assumed by faculties and lecturers when the institution transitioned to fully online teaching, learning and assessment. This resulted in weakened governance systems. For example, there were some cases where even some of the primary quality assurance officers, such as the head of department and external moderators, did not review the assessments before they were administered to the students. As a result, NUST, in this respect was vulnerable to acts of academic dishonesty.

Another important governance issue that was raised by the subjects was the issue of perceived weak enforcement systems, such as weak investigation and disciplinary procedures. According to one of the respondents, the actions taken when incidents of academic dishonesty were reported were not very visible, thereby discouraging the actors from making reports, if they believe that no consequences will be meted out. Indeed, one respondent confirmed that very few incidents of academic dishonesty were acted on as compared to the time of face-to-face instruction. The reasons for such weak enforcement systems could be varied. However, one subject postulated that to successfully prosecute such cases, there is need for solid evidence since wrongfully accusing a student can have severe negative consequences for all parties. In addition, there was also the impression on the part of the respondents that there was inadequate training to sensitise people, especially the lecturers, on what needs to be done when misconduct is suspected.

Another finding of this research is that NUST's disciplinary procedures are cumbersome and not friendly to the lecturers. To institute disciplinary procedures, lecturers must gather water-tight evidence, which they did not always find easy to do. In addition, the lecturer subjects highlighted that the current governance systems require lecturers to account for any failure rates that are below a certain threshold, and implementation of the penalties recommended in the policy documents can contribute to lower pass rates. Since the lecturers must account for these low pass rates, they end up not fully implementing the policies and procedures, resulting in an environment where academic fraud is seen as if it is not being penalised. However, Subject 3 contradicts this and recalls some students being suspended or de-registered during the recent period.

Another observation from the study is that some lecturers and external moderators did not have adequate training to carry out their oversight roles. As a result, there are fears that some incidents of academic fraud were not detected because of lack of capacity. There was also the sentiment that the restructuring exercise resulted in positions not being filled. As a result, some members of the management team who were supposed to enact governance did not have the right skills or were overloaded by other tasks or roles they had assumed. Therefore, factors related to the system of authority and accountability in the organizational structure through which authority is exercised were perceived as not reducing dishonesty. Targeted treatment of dishonesty will only succeed if it is aimed at reforming the structural factors inherent in good governance.

Finally, the subjects said that administratively, the issue of collecting evidence for purposes of disciplinary action is viewed as taxing on the investigating officer (Subject1, Subject2 and Subject3). Not only is the process labour intensive but there is no incentive for undertaking investigations, since in most cases, if the students are penalised and they fail the course, the lecturer is likely to suffer reputational damage in addition to being held accountable for the failure of the students.

g. How does digital transformation impact academic integrity systems?

The COVID-19 pandemic transformed teaching, learning and assessment; digital technologies are no longer “nice-to-have” but essential tools for successful facilitation of instruction and assessment. This is because of the affordances of these digital technologies, such as, the assumed transparency that digital technologies and platforms bring to teaching, learning and assessment. For example, this study confirmed that digital technologies enhance transparency by allowing an audit trail which can be reviewed later to be established and to be used for detecting academic fraud acts. In addition, the study subjects pointed out that the recording of the entire teaching and learning process is something positive that would reduce the incidence of academic fraud and corrupt activities.

However, there are mixed views about whether the nature of transparency afforded by the digital platform increases or decreases academic fraud or dishonesty. For instance, Subject 2 and Subject 3 believed the digital platform reduced transparency; in their view, transparency is “the ability by the instructor to observe the student’s actions during the assessment.” Since face-to-face assessments allow an invigilator (the person in the examination room responsible for conducting a particular examination session in the presence of the candidates) to monitor what the students are doing, there is transparency of student behaviour during the face-to-face assessment process, as opposed to online assessment where the students are at home or other off campus environments, where the invigilator does not know what the student is doing since they cannot observe the process. By the same token, if students are face-to-face, they can also observe others, including the invigilator, and this has a moderating effect on incidents of academic fraud.

This view is supported by Subject 2 who argues that there was less transparency online. According to them “the whole digitalizing thing has decreased transparency because there is very little proof of certain things, whenever you try to investigate something.” They noted that if a moderator 4 was suspected of not having carried out their work in the face-to-face moderation process, there would be documentary evidence that the moderation process was or was not done. With online assessments, this is not as transparent. Nevertheless, the digital learning platform enabled the examinations

department to pick up that some moderators had submitted a report, but the system log indicated that they had not logged on to carry out the moderation.

7. Discussion

This discussion is based on the research model proposed in this paper. The model had two major independent variables, that is, the impact of online instruction and assessment on academic fraud/dishonesty; and the impact of transparency of teaching and learning on academic fraud/dishonesty. With respect to the first proposition, the respondents were quite concerned that there is more academic fraud or dishonesty (in the form of student cheating) now that the institution has adopted online teaching instruction and assessment than before, regardless of the number of adjudicated cases. The respondents also hold that organisational structure related factors, such as the restructuring of the institution and the lack of new or appropriate governance to deal academic fraud in online settings are partly to blame for this situation. Therefore, online instruction has increased, not decreased, dishonesty, and that is in part a consequence of restructuring and in part a consequence of the lack of appropriate governance.

On the transparency side of our research model, the picture is not so clear, in part because of some confusion about the practical nature of transparency. But it is also the case that the evidence, such as it is, suggests that transparency that is afforded by the technology is not being leveraged or exploited, in part due to structural and governance problems. Here the problems are more of the digital platform not being configured to take advantage of transparency where it exists. Since the restructuring exercise is still in its early stages, the respondents could not provide much evidence to either support or disprove the impact of organisational structure and governance on academic fraud/dishonesty.

My view of the problem is that while digital technologies and platforms allow the lecturers to view what time the student is doing the lesson, and what time the student stopped doing the lesson, thereby providing a deeper and more accurate level of transparency of student effort, the lack of collaboration and coordination, and laxities in management of operations are seen as possible factors that could give the impression that there is no transparency even though digitalization has the potential to “greatly improve almost every sector, not only attendance, but it can also with things like plagiarism.” In the following sub-sections, I discuss the propositions in more detail.

7.1 The Impact of Online Instruction and Assessment on Academic Fraud/Dishonesty

There is a common expectation in higher education institutions that digital technologies can enhance engagement and connectedness of lecturers and students, who take full advantage of these technologies to achieve better outcomes, including reducing academic dishonesty. However, rather than viewing the affordances of digital technologies that are the cornerstone of online instruction and assessment as a possible contributor to academic dishonesty, the subjects of the study seem to emphasize the human-centric aspects of the institution, including governance structures, collaboration, and the role of management support as key factors that have a bearing on academic dishonesty. By understanding them and taking actions to counteract them, digital learning leaders can drive progress in fighting academic dishonesty.

7.2 The Impact of Transparency on Academic Fraud/Dishonesty

This study has revealed the multi-faceted and complex nature of the concept of transparency of instruction and assessment. On one level, transparency issues are closely related to governance issues

such as the delegation of responsibilities and the monitoring of the achievement of the results within an organisation. Our conclusion, from the responses obtained in the interviews, is that digital technologies have blurred the responsibility lines. It is not uncommon to find an issue that structurally belongs to one unit, overlapping with a completely different unit. For instance, at NUST, the TLU is responsible for teaching and learning support and they are also responsible for administering the digital learning platform, while the Centre for Open and Lifelong learning (COLL) is responsible for coordinating distance learning. With the transition to online instruction and assessment, distance learning has evolved from the previous paper-based format to online instruction as well. Such a dual governance structure creates opportunities for academic fraud to go unnoticed since the accountability is not clear.

With respect to transparency being a mechanism to allow public scrutiny of data by providing access to information, digital technologies have proved that they can assist a lot in this respect. Notable examples identified by the respondents include transparency arising from recorded videos that can facilitate quality assurance officers to review the work done in teaching and assessment. The automatic generation of an audit trail also helps to make the whole process auditable, possibly reducing dishonesty. However, the major finding in this respect is that technology is a tool that is only effective if organisational structure is clear and open.

7.3 Governance Systems' Influence on the Impact of Online Instruction and Assessment on Academic Fraud/Dishonesty

One of the lecturers highlighted that NUST's disciplinary procedures are cumbersome and not friendly to them. The lecturers end up being held accountable for the failings in the implementation of governance procedures. Moreover, there indications that some lecturers were setting up questions that simply required recalling or memorizing of facts. Such questions were previously detected through internal and external moderation mechanisms. However, because of the ad-hoc way in which the transition to fully online instruction and assessment was carried out, this governance practice was not being conducted as diligently in online instruction environments as was the case during the face-to-face scenario.

Governance tools, such as guidelines and policies, while being a step in the right direction, are only effective if action is taken when an incident of academic fraud is detected. This action should be supported by appropriate deterrent measures. Where no action is taken, there is no deterrent effect. This position is corroborated by Subject 2, who confirms that the last disciplinary cases for academic dishonesty were during the face-to-face era. The problem could be that there are not enough small penalties to allow students to learn through trial and error that they will easily find out and thus correct their private calculus on the costs/benefits of cheating. As Subject 3 indicates, the penalties are mostly very severe ones such as students being suspended or de-registered. Based on the evidence presented in the findings, the researcher cannot conclude one way or the other whether the governance systems' influence on the impact of online instruction and assessment on academic fraud/dishonesty, and thus the researcher calls for more research in this respect.

7.4 Governance Systems' Influence on the Impact of Transparency of Online Instruction and Assessment on Academic Fraud/Dishonesty

One of the principles of governance is assigning responsibility for dealing with academic dishonesty. When the teaching, learning and assessment was being handled on a face-to-face basis, it was clear that the examinations office was responsible for the quality assurance of the processes along the assessment cycle (that is, checking the quality of the paper, whether the paper is at the right level for

the students, and covers all learning objectives; invigilating the exams to ensure no cheating takes place; checking that no unfair practices have taken place during the marking of the students' work, etc.), and of all major assessments that contributed to the final grade. However, the rapid transition to the online platform brought with it some challenges on assigning this responsibility.

7.5 Organisational Structure's Influence on the Impact of Online Instruction and Assessment on Academic Fraud/Dishonesty

This research reinforces the notion that lack of transparent procedures at each level of the administrative ladder generates opportunities for dishonesty. More specifically, the lack of clear procedures in supervision and disciplinary matters allows the expansion of phenomena such as ghost teachers or teacher absenteeism. monopoly and discretionary power. If the organisational structure is not effective, then g monopoly situations and discretionary powers foster dishonesty. Although some preliminary insights could be obtained in this regard, it is still too early to determine the impact of the restructuring exercise since this is still an ongoing exercise. However, it is important to recognise that the impact of organisational structure on online instruction and assessment could be a potential problem in the future and thus needs constant monitoring and possibly further study to determine the impact on academic fraud/dishonesty.

7.6 Implications of the Results

In terms of implications for NUST and practice, the study has revealed that academic dishonesty is an important topic that needs to be addressed at the institutional level. A study that includes all the four levels of Eaton's 4M framework of academic integrity is necessary. Moreover, the concept of academic dishonesty will need a broader study to include other areas other than academic dishonesty in assessments, but rather, the entire academic cycle from admission to graduation.

8 Conclusion

In conclusion, this study has revealed that academic dishonesty is an issue that is topical and relevant for lecturers at NUST. While the scope of research for this article focused on dishonesty in academic assessment, according to Accreditation and Quality Assurance Bodies (AQABs) a more holistic study responding to dishonesty in the following areas of the teaching role, student admission and recruitment credentials and qualifications, and research and publication will be necessary.

8.1 Study Limitations

This study is based on one institution only, thereby limiting the generalisability of the results to the wider context. However, despite these limitations, the study has positive contributions to theory and practice. Cases from a single country, according to Orkodashvili (2009), might be used to assess dishonesty issues in other countries or regions. As a result, this case of dishonesty at a Namibian university may be interesting and instructive for other institutions within Namibia and other countries dealing with comparable issues. While transparency is assumed as an affordance of digital technologies that should also help in dealing with academic dishonesty, the understanding of transparency as a concept needs further unpacking. The study revealed that not all lecturers are aware of the affordances of digital technologies and more needs to be done to bring clarity to the concept.

A significant limitation of this study is that it focuses only on the meso-level of the institution, that is, it focuses on the perceptions and roles of key stakeholders such as students, faculty members, library

staff and academic support staff who have a first-hand experience of academic integrity and dishonesty.

8.2 Directions and Areas for Future Research

Based on the discussion presented above, the following areas for future research reveal themselves. First, the scope of the study could be extended to the all the four levels of Eaton's 4M Framework (micro, meso, macro and mega levels). At the meso-level, there is need for research that will focus on determining the potential vulnerability of units within the university such as departments, faculties, and other support units. Since the respondents felt that it is too early to determine the impact of the structural changes being implemented at NUST, this is a good candidate at the meso-level future research to also investigate the impact of structural re-organisation of institutions in response to budget cuts. In addition, planning and delivering academic programs is mostly the responsibility of faculties and departments. At these levels, a variety of responsibilities, processes, teaching and learning functions, and governance aspects interact to maintain academic integrity and this interplay needs further investigation. Furthermore, more research can be conducted on the effect of transparency, and the moderating effect of organisational structure as well as governance systems in increasing and decreasing dishonesty since in this research, we could not conclude one way or the other.

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Application of Blockchain Technology for Business Process Management

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Abstract

Blockchain technology has the potential to transform business processes with its offering of numerous possibilities. This paper investigated the application of blockchain technology for business process management. It also x-rayed the challenges/barriers of applying Blockchain technology by business organisations for business process management. The study applied a qualitative approach by employing purposive and snowball sampling technique to select participants. Interviews were carried out telephonically and through zoom while data was collected, transcribed and analysed. The study's findings revealed that Blockchain Technology (BCT) has numerous benefits for organisations, as a result of the BCT's decentralised structure and immutability. However, challenges such as lack of awareness, cost of technology, trust and privacy concerns should be addressed, as they are major concerns for business and hence influencing them on BCT adoption.

Keywords: Blockchain, Business Process Management, Technology, Distributed Ledger

1. Introduction

Blockchain technology has in recent times gained so much public attention and has generated a lot of revolution in the areas in which it is being implemented (Yli-Huomo et al., 2016). The introduction of blockchain technology has widened various technology application areas and opened new opportunities for business expansion. The evolution of Blockchain Technology (BCT) has brought about a revolution in business management and new forms of organizational strategies through the use of advanced software and computer systems.

A blockchain is known as a public ledger where public transactions are stored in a chain (Downey et al., 2018). Blockchain technology has the capability to change organisational processes in a business environment and also change the environment in which Inter-Organisational Business Processes (IOBP) are operating. An Inter-Organisational Business Process consists of an organised group of joined activities executed by more than one organisation for the actualisation of a common business goal (Risius & Spohrer, 2017).

Blockchain, as an emerging technology, allows business organisations to share common resources not minding the need to establish trust among them. It has attracted the attention of a variety of industries including the banking industry, manufacturing industry, advertising industries and even the education sector (Davidson et al., 2016). This is an indication of the on-going efforts at enhancing this technology in order to increase its usability and profitability to ensure its value addition in different industries (Risius & Spohrer, 2017). As a new and emerging technology, little research seems to have been carried out on its business value, specifically in business process management. Past studies carried out focussed more on managing workflows in contract (Downey et al., 2018). Privacy issues (Zyskind et al., 2015), banking (Saheb & Saheb, 2021), and social interaction (Pazaitiset al., 2017). Unlike the previous studies, this study investigated how Blockchain technology can drastically impact business process management automation of business organizations, especially in the fourth industrial revolution era. The study also explored the practical applications of smart contract functions experiencing limitations in current business process management.

2. Research questions

Previous works have shown various areas of application of blockchain technologies in business process management (Essex, 2021). The enormous interest in the deployment of this emerging technology has skyrocketed in recent years (Vadgama & Tasca, 2021). In order to explore the use of Blockchain Technology in business process management in this qualitative research, the following research questions were asked;

- How can Blockchain Technology be applied to business process management?
- What are the challenges of Blockchain application to business process management?
- Does Blockchain Technology have a future in Business process management?

The first question was designed to identify opportunities for Blockchain technology in business process management from literature and industry. The second question addresses the challenges that have led to the limited adoption of blockchain technology in business process management. Finally, the third question investigate the future prospects of blockchain technologies in business process management.

3. How Blockchain Technology works

Blockchain technology has the power to impact most transactions related to assets, information, and documents (Nofer et al., 2017). This is possible through the concepts of trust and ownership: thus, when this concept is overhauled in business processes in comparison to a traditional transaction in which a central third-party entity or system is considered trustworthy and thus manages validation (Nofer et al., 2017). The existing distributed certification and trust mechanism in Blockchain Technology, paves way for the above possibility. The distributed certification and trust mechanism has three main features as defined below:

- i. **Dedicated peer-to-peer system:** this is a network that comprises a configuration with peer nodes owned by independent parties (which could be business organisations) and each node keeps a complete updated copy of the blockchain ledger locally.
- ii. **Electronic subscription of each transaction:** this is a unique signature that is only associated with the user who initiates the transaction.
- iii. **Consensus mechanism:** this creates trust among nodes that directly participates in the consensus algorithm performing verification and confirmation activities of the transactions initiated by the user.

Every time a new transaction occurs on the blockchain, a record of that transaction is added to every participant ledger. The transaction is usually recorded with an immutable cryptographic signature called hash. Characteristics of the technology are illustrated in Fig 1.

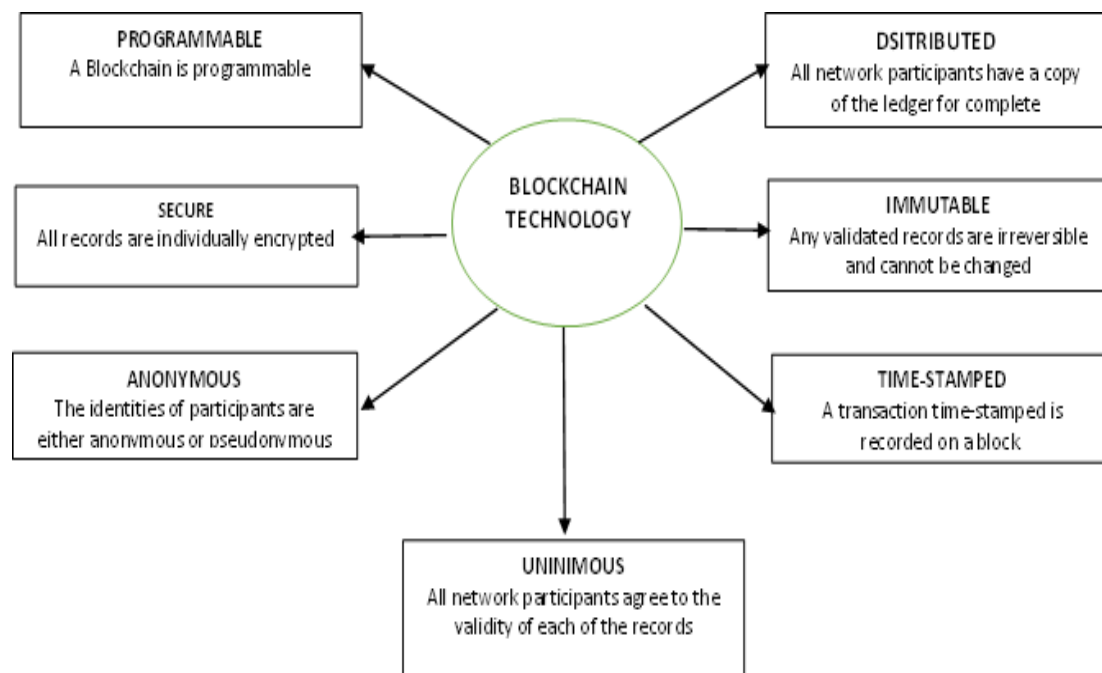


Figure 1: Characteristics of Blockchain technology (Source: Euromoney, 2020)

It is worthy to place emphasis however, that blockchain technology is still at its infant stage on which concrete and valuable projects are being launched. In order to mitigate some limitations in Blockchain technology, research is still ongoing particularly on improvements in the aspects of speed and scalability capabilities, level of protection of personal data and cost of transactions. Improvements and insights achieved from the on-going research will go a long way to improving business processes, as business organisations implement the technology.

The following properties of blockchain technology identified above make it a suitable technology for pharmaceuticals supply chain where central verification of supplies, protocols, quantity, origin, etc. are required (Vadgama, 2019). The present protocols of verifying signatures, tracking, hierarchy of approvals and logistics create a significant bottleneck traditionally (Vadgama, 2019). This situation is more critical in areas that affect public health such as immunization and vaccination. The fast diminishing boundaries presented by ecommerce platforms suggest another important reason to employ the blockchain technology in business process management. Currently many ecommerce platforms transaction still go through national banks platform (Hughes et al., 2019).

- Business process management and Blockchain

Business Process Management (BPM) can be defined as the philosophy of process thinking that can proffer solutions to business problems (Jeston & Nelis, 2014). One important focus of BPM is in the area of process management using methods that enhance effective and efficient provision of better products and services to customers (Schmiedel, et al., 2020). According to Schmiedel, et al., (2020) and as demonstrated in Fig 2, BPM affects organisations directly and its solutions can be applied for a variety of reasons including;

- Increase in efficiency and effectiveness
- Enhanced customer satisfaction and friendliness
- Enhanced predictability and manageability
- Shortened throughput time
- Improvement in quality, risk control and management.

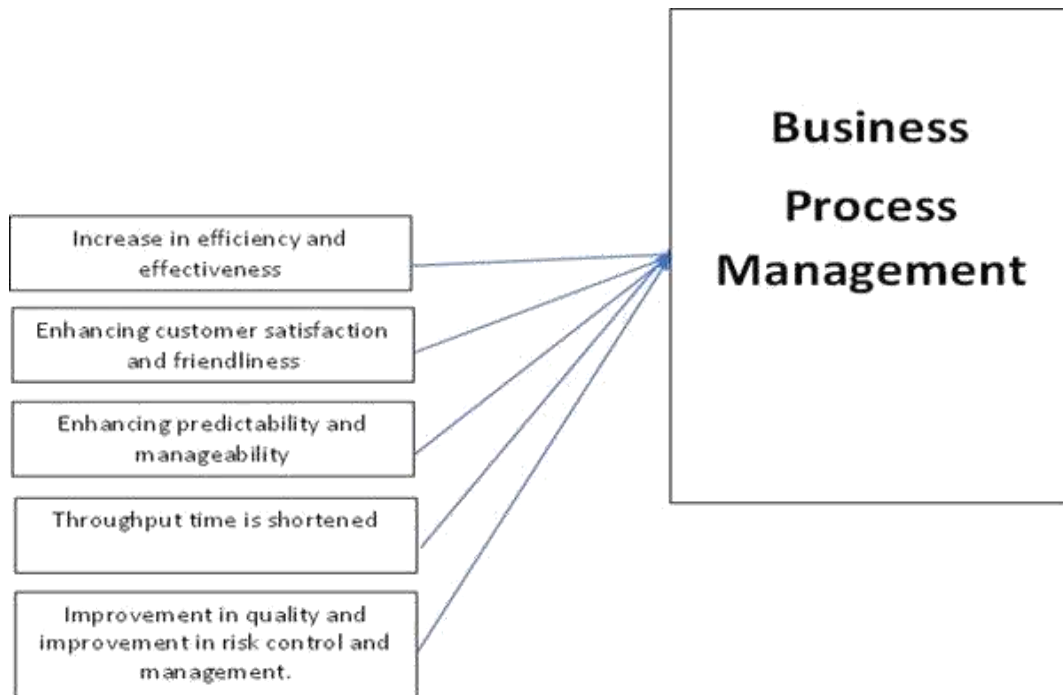


Figure 2: Effects of BPM on organisations.

The essential nature of business process in contemporary business organisations brings about business process management (BPM). Given the advancement in technology and being implemented in business processes, BPM and Information Technology (IT) seem to be tightly integrated: thus, giving good grounds for the integration of Blockchain technology into business process management.

Notwithstanding the fact that Blockchain Technology has been applied more to financial services and bitcoin cryptocurrency implementation (Antonopoulos, 2014), the research community and business organisations are currently making efforts to apply it to a variety of areas. For instance, in recent years, Blockchain technology has been considered as a technology that could improve the development of inter-organisational business processes and management (Nofer, et al., 2017). Furthermore, Nofer, et al., (2017) noted that several Blockchains are currently being adopted in various sectors so as to facilitate the operation of new business processes. Presently, Blockchain appear to be applied in securities trading and settlement, insurance, music distribution etc.

Considering that business organisations are operating in a fast-changing economic environment that results to enormous amount of transactions taking place among the business organisations, Blockchain network has the capacity to support these transactions through streamlining value-exchanges efficiently and at a very low cost (Roeck, et al., 2020). Furthermore, in order to ensure transparency of transactions that occur outside the internal system (of a business organisations), BPM platforms can be integrated with Blockchain network: thus possibly providing authenticity of information flow from one business organisation to the other. The introduction of Blockchain technology therefore create's new peer-to-peer BPM system that results in a more efficient value-added chain (Ivanov et al., 2021) and hence enabling a collaborative process with shareholders in an efficient manner.

Numerous Blockchains can be created through the execution of smart contracts in a decentralised network in which business organisations that work together are connected to smart contracts to assist them to exchange assets when agreed conditions are met between these organisations (Stark, 2016). This is an option that allows business entities to make their business rules and also stipulate penalties when agreements are not met. To ensure the integrity of the workflows the network, then all parties within the network must conform to the said set rules. . The use of smart contract reduces the need for any third party interference and maintains a copy of the contract that cannot be altered by all or the concerned parties. This therefore indicates decentralization of Blockchain's as a core strength, as a copy of the database file is owned by all parties involved in the transaction. In order to ensure the integrity of each copy, a consensus algorithm is required. The consensus algorithm allows the participants to ensure that each added block is legitimate. It also prevents attackers from compromising and forking the chain (Coindesk. 2017). Nakamoto (2008) suggested using a proof-of-work approach, in which a hard cryptographic puzzle must be solved by miners.

Other ways in which Blockchain technology can enhance both business process and business process management is demonstrated as follows in Fig 3:

1. Collaborative business process

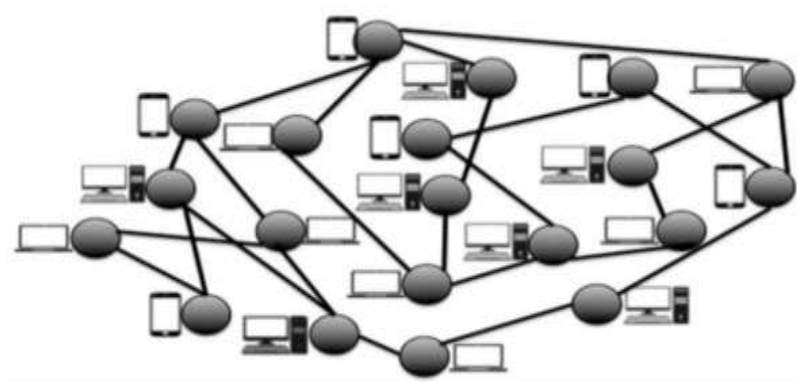


Figure 3a: Blockchain network for collaboration

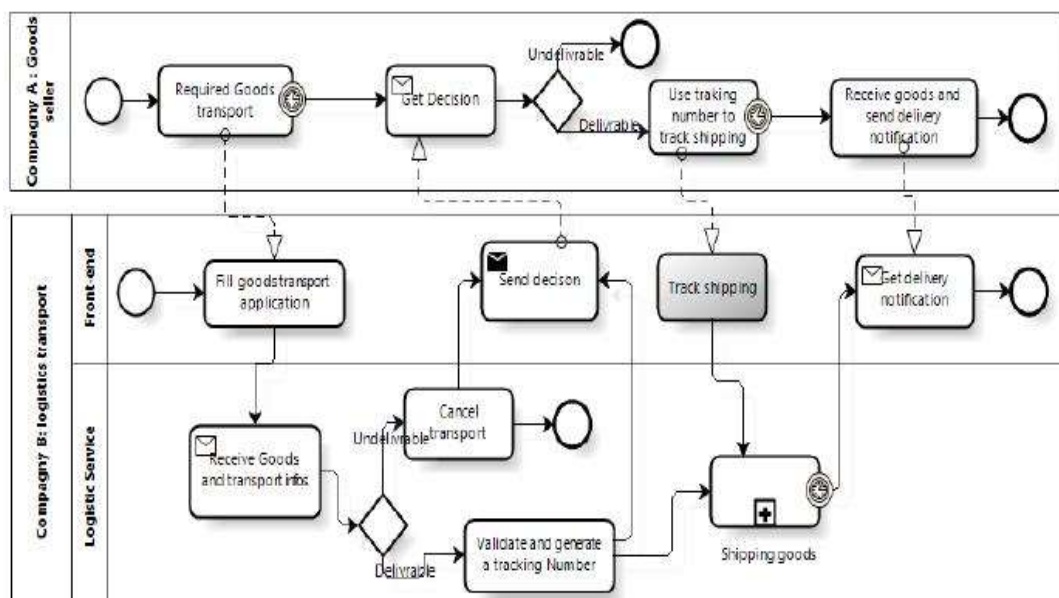


Figure 3b: Practical collaborative business management process from (Ouedraogo et al., 2015).

The multiple supply chain members' lanes are connected by this collaborative business process's organizational structure as shown by fig. 3b. This BPM method tags shipping according to its established protocols. Multiple channels are connected to global information about the collaborative environment. While defining the collaboration agreement between partners, restricted access control features can also be defined.

Collaboration between business organisations is usually very difficult and complex. The difficulty is usually due to communication gaps or lack of trust. This makes business organisations struggle to work effectively and efficiently. However, smart contracts are easily audited and distributed ledger provided by Blockchain can enhance the efficiency of third parties working in a collaborative manner within the same process. The visibility and accessibility provided by blockchain for all approved participants, makes it easier to share information and documentation in real-time (Stark, 2016). Furthermore, BPM-Blockchain solution contains a decentralised power of accessibility which makes it very easy for business organisations involved to work together and various business processes at the same time without involving third parties for continuous updated information from one another.

ii. Payments

Blockchains have the capability to allow the payments to be executed automatically. Business organisations that utilise over the counter (OTC) transactions usually benefit from this aspect of Blockchain integration. These organisations greatly benefit from the distributed ledger Blockchain networks that are being used.

iii. Security

Blockchain is known for its great security features and will be an added value when implemented into the business process management system. Blockchain technology has the power to limit what information is accessible to a specific party in the chain. The addition of more blocks to the chain triggers more encryption which continuously enhances security. Therefore, in summary, blockchain technology is a digital ledger that contains the totality of transactions that occur in a peer-to-peer network. The benefits of the smart contract and digital ledger are already being tapped by organisations and its security features, payment and collaborative process enhances business process management.

5. Barriers of Blockchain Technology (BCT)

In as much as there are numerous benefits of blockchain technology, its debate on its use is still ongoing in the academic domain (Ivanov et al., 2021; Pournader et al., 2020; Wanget al., 2018). One of the barriers of BCT is the unwillingness of business organisations, particularly top management to support its usage (Mathiyazhagan & Haq, 2013). Considering the fact that Blockchain is still being explored, business organisations are still hesitant to take the risk (Ivanovet al., 2019).

Another barrier is data privacy concerns. This is because most business organisations are sceptical about distributing sensitive data and transaction records in a network. This according to Roeck, et al., (2020) makes most business organisations unwilling to use blockchain network for transactions.

Lack of trust is another aspect that causes barriers in adopting Blockchain technology. This is due to lack of legislation on blockchain. If there is appropriate legislation, business organisation will be willing to adopt and use this innovative technology. Meaning that regulatory uncertainty which (Yeoh, 2017) noted as Blockchain usage barrier is a challenge for Blockchain adoption. Other aspects that is worth noting as barriers include unfamiliarity with technology (Tschorsch & Scheuermann, 2016; Li & Wang

2017; Queiroz & Wamba, 2019; Kamble et al., 2020), technology infeasibility (Yeoh, 2017); Deshpande et al., 2017; Mistry et al., 2020), Uncertain benefits (Apte, & Petrovsky, 2016; Firica, 2017), Dependence on Blockchain operators (Queiroz & Wamba, 2019; Kim, 2018; Paech, 2017). The said barriers have been summarised in Table 1.

Table 1 Barriers of Blockchain Technology (BCT)

Barriers	Sources
1 Unwillingness of business organizations, particularly top management to support its usage	(Mathiyazhagan, & Haq, 2013; Ivanovet al., 2019)
2 Data privacy concerns	(Roeck, et al.,2020); Li & Wang, 2017).
3 Lack of trust	(Yeoh, 2017; Queiroz & Wamba, 2019)
4 Unfamiliarity with technology	(Tschorsch, & Scheuermann, 2016; Li & Wang, 2017; Queiroz & Wamba, 2019; Kamble et al., 2020).
5 Technology infeasibility	(Yeoh, 2017; Deshpande et al., 2017; Mistry et al., 2020).
6 Dependence on Blockchain operators	(Queiroz & Wamba, 2019; Kim, 2018; Paech, 2017).

6. Research Design

Purposive sampling was used to determine experts who are knowledgeable in the field. Considering the challenging of possible reaching enough experts in specialized areas, such as BCT in a short time, the snowball sampling technique was used to reach more experts on incremental basis until the required saturation point of participants was reached (Creswell & Clark, 2017). According to Saunders et al., (2009) five (5) to twenty-five (25) respondents are recommended for a semi-structured interview. Therefore, this study adapted the principle of saturation point (Saunders et al., 2009). In all eight (8) respondents were selected and semi-structured interview technique used for data collection. Telephonic and zoom interviews were used to collect the data. With permission from the respondents, the interview sessions were recorded, transcribed and analysed. Before analysis, the transcription was sent out to the respondents for correctness in the data as collected. The experts selected for the data collection comprised of two (2) Blockchain consultants, two (2) Blockchain researchers, two (2) Blockchain developers and two (2) industry experts.

7. Summary of Data Analysis findings and discussion

Data was collected and analysed based on the research questions that guided the study. The research questions are;

- How can Blockchain Technology be applied to business process management?
- What are the challenges of Blockchain application to business process management?
- Does Blockchain Technology have a future in Business process management?

7.1 Application of blockchain Technology in Business process management

Blockchain technology has the potential to create value and transform the way business organisation's function. However, as noted by (Kemmo et al., 2020). for Blockchain technology to be used and applied by any business organisation, the organisation must decide on the necessity of its usage and the risk involved in its application and implementation. This, according to the interviewees is very necessary. The participants noted the organisations must also seek to know the potential of Blockchain technology, the value and transformation capacity of the technology in their business processes. Therefore, according to the interviewees, when an organisation decides to implement Blockchain, there must be feasibility studies in order to determine if blockchain is required in the organisation. This will ensure that the value or/ and the potential of Blockchain in the business processes, is known (Kemmo et al., 2020). Kshetri (2018) described multiple use cases of blockchain technology in supply chain, starting from proof of concept to successful implementations of BT to support product tracking, GPS location by multinational shipping company – Maersk in collaboration with technology like IBM (Kshetri, 2018). Alibaba the ecommerce company also got a mention in the cases included in the study. The start-ups sector appeared to have been the early adopters of Blockchain technologies seems to be payment, especially the use of Bitcoin (Hsu, 2022) it's been a bold step that big enterprises are cautious to implement. The tracking of products and maintaining inventory updates are areas innovative companies have used blockchain technologies extensively.

7.2 Import Clearance Processes

Application of Blockchain Technologies in importing and exporting goods industries is practical as the sector involves high level of physical paper document processing. While there are digitization of the various supply chain processes, shipping and port clearance documentations, the issue of trust still ensures the use of paper.

Project such as Silsal have found block chain most suitable solution for cargo clearing at the ports, this is a pilot project that store each shipment documents on a distributed ledger for all participants viewing and processing based on clearly defined permissions. This technology allows for transfer of cargo ownership and in this particular situation a partnership between Port of Antwerp and Abu Dhabi replaced shipment documentation with blockchain technology (Li & Zhou, 2021). Similar trends are occurring with global giants like DHL, UPS and Fedex (BLOCKCHAIN: Key Developments & Implications (2022); Accenture, 2020) who are exploring opportunities to integrate blockchain technology in their shipment processes, all of these to help remove complexities from their operations.

The development of logistics management solutions for environmentally controlled supply chains to support temperature or humidity has been primarily focused on the healthcare industry although there is significant overlap with the requirements from the retail industry. Two Swiss start-ups are particularly prominent in this space are Modum and Ambrosus.' They use multiple sensors to monitor

environmental temperature and humidity of products. This data is then encrypted, and signed and embedded on a tagging device e.g. RFID and to the blockchain ledger. This creates a distributed duplicate of the defined product conditions, which is maintained as needed. The generated data is then recorded as a function of timed time intervals (hourly) or at specific events (e.g. on receipt into a warehouse, or upon loading into a delivery vehicle). The copies of the data are available to all participants based on defined permissions – for example, warehouse workers are able to check product detailed trail while a customers are limited to reviewing the summary view of key the product journey. The startup Modum have tested blockchain technology in a unique partnership with Swiss Post for transportation of temperature-controlled pharmaceutical products. This pilot instance took place 2019, and it involved the transportation temperature sensitive products with temperature controlled boxes. The sensors used were tagged MODSense, the unique selling point of the solution was temperature readings on a distributed ledger technology registry at each stop in the supply chain.

Whilst it is still in development, this IoT integration with blockchain might also be helpful in guarding against counterfeit or substandard products, and biopharmaceutical manufacturers could use it to capture and record interactions with regulators.

7.2 Challenges of blockchain application to business process management.

Several researchers have asserted that Blockchain technology is still in infancy and more clarity is needed at this stage in order to win the confidence of business organisations (Lemieux, 2016; Iansiti & Lakhani, 2017; Hackius & Petersen, 2017; Saberi, et al., 2019). This also aligns with the assertions of a majority of the participants who stated that a lot needs to be done to gain the confidence of business organisations to use the technology. The participants also noted that business organisations are sceptical about using the technology due to the fact that most of their concerns are still unanswered to satisfaction. For instance, as in Fig 4, there is the concern of data privacy, awareness, government inability to take a stand and make regulatory policies, cost of technology, and trust among users, scalability issues, effectiveness and efficiency of the technology. The above uncertainty is in consonance with the findings of some researchers who have pointed out a variety of BCT barriers associated with its non-acceptance (Deshpande et al., 2017; Kshetri & Loukoianova, 2019; Lakshmi & Sricharan, 2019; Shermin, 2017; Min, 2019).

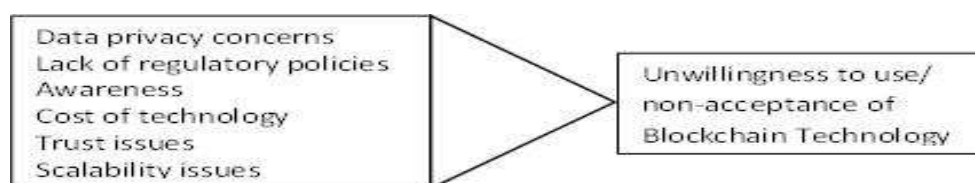


Figure 4: Concerns of Blockchain Technology

Putting into consideration the review of literature on the barriers of adopting Blockchain technology for business process management and the result of the interviews, one would sum up the challenges of adoption of Blockchain for business process management in the diagram in Fig 5.

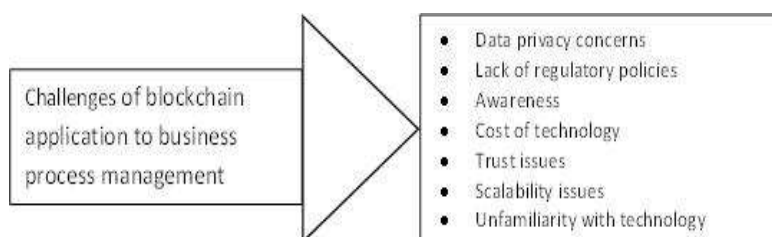


Figure 5: Challenges of Blockchain Technology

7.3 Does Blockchain technology have a future in Business process management?

A majority of the participants are of the view that Blockchain technology has a future in business process management. For instance, one of the participants noted that Blockchain technology can bring about better quality assurance and auditing, as Blockchain technology can be able to identify problems particularly in the manufacturing and distribution processes and track the origin of the problems more effectively and efficiently.

Similarly, the participants of this study, noted that Blockchain technology has endless possibilities due to its nature and benefits in the aspects of decentralized systems, transaction transparency, data privacy and cost effectiveness.

In a nutshell, the future of Blockchain technology as noted by the participants looks great, considering its already growing promise in a number of organisations (Kambleet al., 2019). Organisational culture may also have a role to play in the future of Blockchain Technology. This is so because, how an organisation operates, including its Information Technology strategy/policy, can go a long way to determining its quest for improved technology vis a vis Blockchain technology.

Currently, there is ongoing research around the globe on the benefits of Blockchain technology for business process management and this is further necessitated by the fact that Blockchain technology can be used for planning and controlling activities in recruiting and personnel placement, market strategies deployment, and improvement of production or cash cycle (Pal et al., 2021). The above findings indicates the major role that blockchain technology will play in the future of business process management, considering finding solutions or mitigating to the minimum (if not eliminated), the concerns raised by business organisations

For practical purposes, globally, Blockchain technology applications are relevant to support payment services, as many banking services have become digitalized. BCT will consolidate the existing systems and automate the bureaucratic processes. It will also enhance the most needed ingredient in payment solutions, trust. In line with previous studies BCT will help democratize banking and payment systems to many Africans.

Contrary to previous studies that have looked at BCT in settings with infrastructure, this study engaged participants in resource constrained settings and observed that BCT applications is not limited by the state of infrastructure on the continent

8. Summary of findings and discussion

This study aimed at assessing the application of Blockchain technology for business process management. Three research questions were formulated and a qualitative research design applied to find answers to the research questions. The study found that the awareness of Blockchain technology is limited and this limits the willingness to adopt the technology. Furthermore, the participants were of the view that privacy issues, data security, trust and scalability are major concerns to business organisations and that solutions be found to them to accelerate BCT adoption. They also noted that clarity on the technology is needed at this stage since the technology is in its infancy. Therefore, business organisations needing to adopt Blockchain technology needs to carry out feasibility studies on the need for the technology in their organisations.

The results of this study aligned with similar previous studies on the subject, Mendling (2018) described the BCT application in BPM in relations to phases of identification, discovery, analysis, redesign, implementation, execution, monitoring, and adaptation. This study did not look at the phases of BCT however analysed the holistic adoption of the technology in organizations' business process management interventions. Just as this study recommended more studies in diverse areas of BPM adoption, it is important to highlight the best way BCT can help organizations determine aspects

of BPM to adopt. Currently most interventions identify individual organizations' needs, while there is possibility for the technology to do cumulative identification of multiple companies with possible combination options (Mendling et al., 2018).

The study did not evaluate the possibility of redesigning the entire concept of BPM, the implementation of BCT has a chance of redesigning the BPM approach, due to its decentralized nature (Mendling et al., 2018). The participants did acknowledge the rapid changing nature of the technology however knowledge of the volatile nature of the technology is still a niche knowledge and requires for it to be truly democratized for easier adoption and integration by broader population (Hsu, 2022; Chowdhury et al., 2022).

Considering that the technology is still developing, a lot of trials and experiments are required. That notwithstanding, the technology is receiving a lot of attention globally and was recently added to Gartner's hype cycle of emerging technologies (Holotiuk et al., 2017). The full potential of the technology is still not being harnessed (Kemmo et al., 2020). Considering the findings of this study and previous studies, it must however be noted that, Blockchain technology has come to stay. It is therefore recommended that business organisations leverage on its benefits and make the most of it.

This study could not demonstrate extensively how blockchain technology could be adopted or the ease of adoption of Blockchain technology in business process management, especially in supply chain management of multiple sectors. It however showed the experiences of the experts in the blockchain technology pilots. Some other studies identified probable ways the BCT could be further researched (Mendling et al., 2018). The available options mentioned were how to develop a diverse set of execution and monitoring systems on blockchain, how to devise new methods for analysing and engineering business processes based on blockchain, and how to redesign processes to leverage the opportunities granted by blockchain, just to mention a few (Mendling et al., 2018).

9. Conclusions

This study explored the challenges and opportunities to promote the understanding about Blockchain technology and its importance in Business process management. This was necessary as Blockchain technology is increasingly spreading globally and, business organisations are thinking of the inherent potentials the technology has for business process management. Considering that the study collected data from experts and that the experts were identified by the snowball approach, interpretation of the study's result should be done in context: thus, generalisation of the results should be done with caution. Considering that the study applied a qualitative approach and hence used small sample size, future study should consider applying a quantitative approach with a larger sample so results could be compared for a better understanding or/ and validation. The study addressed the three questions it set out to address and provided the current state of adoption of the Blockchain technology for business processes management in both organizations and industries.

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A Deep Object Detection and recognition Under Uneven Illumination Conditions

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Abstract

For the past decade, Artificial intelligence and Computer vision has been replaced in many manual inspections. In Today's world, many smart cities use artificial intelligence in their surveillance system to track and identify objects. Due to some conditions, these systems are giving a poor performance in some cases. The first problem is lower performance because of poor illumination conditions or changes in the illumination. The second one is the sluggish quickness of its operation. This work mainly concentrates on developing a customized Deep Convolutional Network (DCN) to accelerate the object detection process under uneven illumination conditions and evaluate the network's performance. This method is tested on standard datasets and compared with other traditional methods and observed to be more robust and effective for several video sequences.

Keywords: Illumination-Correction, Deep network, Object detection and tracking.

1. Introduction

To keep safe and protective environment in public places, government need efficient tracking and monitoring systems to identify the objects. Many smart cities are using Intelligent Video Surveillance (IVS) in their research works [1]. IVS systems are used to detect and track the objects with in the time in large gatherings. For real time tracking and in critical decision situations, IVS was deployed with embedded hardware platforms which were reinforced by edge and fog extenuation algorithms. Usually, IVS contains five categories like Acquisition [2], Target-Detection [3], Tracking [4], abnormal detection [5], and data analysis [6]. Object tracking will be applied to evaluate the state of the object and its size and position from the provided vided sequences.

From past few years, several number of object detection and tracking approaches were proposed [7] - [10]. In all these methods, problems like identifying the objects, recognition, altitude detection and tracking methods were debated and resolved. These methods minimize the occurrence of false positive and increased the accuracy of detection. Though many changes done to these methods, still there are some problem in tracking and detection. The interest of tracking the object detection mainly affects due to the changes in illumination. For example, in figure 1(a) the red color box represents the ground truth objects which are identified by two different procedures which are marked with blue and green boxes.

In figure 1(b) it clearly observed that the object is been wrongly identified when the illumination is changes brusquely. Illumination variation is major predominant problem, which is often occurs in many real time video sequences in surveillance systems due to this, performance of object detection and tracking algorithms will be degraded and it shows its impact on employed video sequences. Sometimes rapid changes taken place in illuminations due to flash lights which leads to over exposure and shadowing whereas dim or poor lighting conditions leads to low exposure, with this, it's observed

that the main reason is variations in illumination which leads to failure in detecting the tracking the algorithms. Thus, it was endorsed to employ the illumination correction algorithms before processing the video frames to track and detect algorithms.



Figure 1: (a) Object detection red box represents ground truth, blue and green boxes represents detection outputs (b) The impact of illumination change is shown as object is wrongly identified

In many recent works, tracking and detection methods were employed Discrimination Correlation Filter (DCF), and use HOG (Histogram of Oriented Gradients) features for detection procedure [11]. Yet, the performances of these methods were still low under different illumination conditions. So, thorough research was conducted on different illumination changed video sequences. In this paper, adaptive illumination correction algorithms for video sequences were discussed. Where it acts like a preprocessing mechanism before performing the actual detection procedure. In this article some contributions were made for detection and tracking process like

- i. In first part, adaptive illumination correction algorithm and how its effects on identifying the objects will be discussed.
- ii. In second part, customized deep network framework was designed for video sequence.

2. Adaptive illumination correction (AIC) model for video sequences

This model objective is to improve the perceptibility and visibility of image or video frames which is affected by dim light and jagged exposure circumstances. Often, these images were categorized by its noise levels and irregular spatial distributions. Generally, to enhance the dim light images or video sequences, low or middle level intensity values will be boosted and higher intensity values will be altered and minimized. While altering the intensity values, necessary care should be taken so that noisy elements may not be amplified.

Here contrast levels will be improved locally but not globally. However, it's recommended to balance the global intensity of image.

Generally, pixel values of images or video sequences acquired in dim light conditions are considered by very low dynamic range and not matched with those sensed and displayed devices which are employed. So, it's suggested to initially normalize the values, so that, full dynamic range will be utilized.

For most of the images it is sufficient to linearly scale the pixels to fall in the range of [0 1] by transforming them by following equation

$$I^{\gamma} = I_{\max} \times \left(\frac{I}{I_{\max}} \right)^{\gamma} \quad (1)$$

Where I^{γ} is the output corrected image intensity values of the input 'I' intensities. Based on the changes in the values of the γ , the output image is altered.



Figure 1: Impact of Gamma on illumination changes (a) With original $\gamma=1$ (b) with $\gamma=0.3$ (c) with $\gamma=0.5$ (d) with $\gamma=1.2$

With the conventional Gamma correction using equation (1) has certain limitations such as (i) Selection of Gamma value require expertise (ii) Uneven lighting or illumination is not considered and not treated with this method (iii) Over exposure may occur for certain values of Gamma which is irrelevant and optimal illumination may not be retained. So to overcome such limitation, this work has adopted Global Statistics Local Adaptive Dual Gamma Correction approach which is mentioned in [12]

The algorithm is stated as follows

Step 1: Convert the true color video frame (RGB) into HSV color format

Step 2: Perform log transformation to the 'V' component in HSV/HSI which is represented as

$$V = \log(V + 1)$$

Step 3: Perform 2D-DWT (Discrete Wavelet transform) to transformed 'V' component and extract 'LL' (low frequency details) from it.

Step 4: Extract illumination features from 'LL' sub band like

- (i) Global statistic Luminance feature (GSLF)

(ii) Spatial Luminance distribution feature (SLDF)

Step 5: Perform dual Gamma correction $\gamma_{du} = \gamma_a * \gamma_b$

Where γ_a Gamma obtained with SLDF and γ_b Gamma obtained with GSLF

Step 6: Modify the LL components as $LL' = LL_{max}^{1-\gamma_{du}} * \gamma_{du} * LL^{\gamma_{du}-1}$

Step 7: Perform inverse wavelet and logarithmic transformation to obtain modified "V" component

Step 8: Obtain the modified RGB components by

$$R'(x,y) = \frac{V'}{V+1} R(x,y)$$

$$G'(x,y) = \frac{V'}{V+1} G(x,y)$$

$$B'(x,y) = \frac{V'}{V+1} B(x,y)$$

Where V, R,G,B are original and V',R',G',B' are modified components

The algorithm retains similar output at different illumination conditions which is a primary concern in surveillance videos



(a) Under illuminated by 80%



(b) Under illuminated by 90%



(c) Over illuminated by 120%



(d) Output of AIC



(e) output of AIC



(f) Output of AIC

Figure 2: Visual performance of the Adaptive Illumination Correction (AIC) with dual Gamma correction (a)(b)(c) represents globally varying illumination (d)(e)(f) Output of the algorithms where all are almost similar.

With the inclusion of the algorithm, the low illuminated dark images are enhanced while over illuminated images are adjusted so that the outcomes are almost similar in all the conditions.

3. Deep networks for Object Detection

These days, DNN (Deep Neural Networks) are widely using by researchers because of their ability to learn in identifying the objects. by knowing its parameters, these networks are achieving high accuracy. These networks achieved notable results in several computer applications which includes object identification, segmentation and object classification [13]- [17]. Yet, in some cases of videos, direct applying of these image models to object identification was difficult because of variations in illumination, blur conditions, video defocus and other obstructions. When compared to image detectors, many videos contain more information due to this, video objector pays strong role in object detection. In spite of these challenges, it's very complex to design the model which effectively exploits the temporary information in videos.

Deep neural networks use CNN (Convolutional Neural Networks) for promising results in separation of background problem under stimulating conditions. Some authors introduced [18] CNN to execute segmentation procedure for video sequences. Here foreground objects will be separated irrespective of their temporal characteristics and CNN able to accomplish the segmentation depends on the spatial features itself because incoming samples were independent to each other. By using CNN, unique features were selected and transmitted into classifier to segment the objects which are moving. Finally, fully designed framework will be applied to obtain the segmented portion. In the same way, some authors [19] presented a method, basing on the triplet CNN for multi stage background feature embedding by using encoder and decoder model. In this method, a pre-trained network like VGG-16 was adapted under triplet framework in encoder section to decompose the image into several scales and excerpt the features by using very limited samples.

Many traditional methods were proposed by different authors for objet detection namely RCNN (Region Based Convolutional Neural Network) these type works based on the regions but they are very time consuming [20]-[21]. Other type is YOLO (You Only Look Once), in these variants are very fast and they are very efficient [22]- [23].

Third type is SSD (Single Shot Multi-Box Detector) based variants which merges the advantages of other two types [24]- [25]. These networks face number of limitations while moving the objects. These networks include processing of high resolution frames and removes stationary objects from other video scenes. Novelty of designed network as follows

- In this work, we took the advantage of data properties which intends to enhance the decision boundaries and makes accurate classification basing on the classifiers that was designed by using only labeled data.
- To reduce the over segmented errors, connected regions were segmented accurately.
- Coarse to fine grained moving object detection framework was presented, through combing the illumination correction algorithm with Deep Convolutional Neural Networks.

4. Proposed frame work

The entire process flow of the proposed approach is depicted in figure 3. The input video sequence may be occluded or not however the input video is processed for frame separation and the frames are processed for AIC, thus obtained optimal contrast values of video frame is directed for object detection using Deep network framework as shown is figure 4.

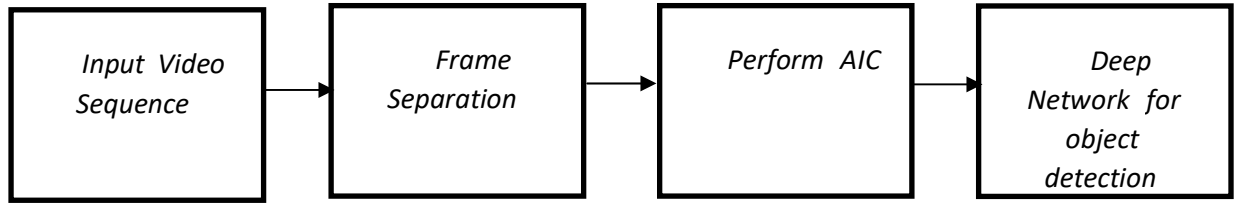


Figure 3: Generalized block diagram of the proposed approach

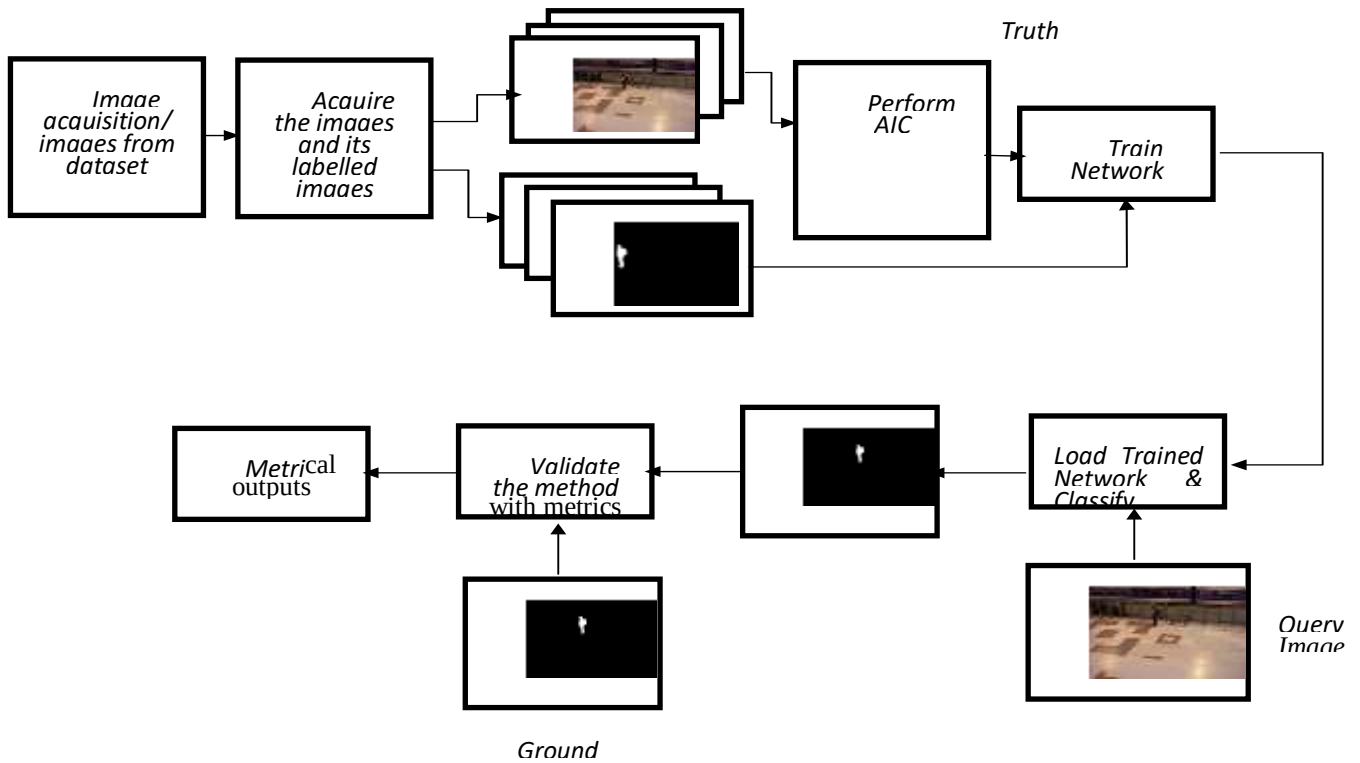


Figure 4: The proposed framework of object detection with customized DNN

The frames acquired from the acquisition device are rescaled to 224x224 which is an optimal resolution for most of the deep convolutional networks and also useful for comparing the results with pre trained networks. The video frames are labeled which are fed parallel to train the deep Network. These frames in parallel with labeled images are forwarded to customized Directed Acrylic Graph (DAG) network for training. To accomplish the training process, the deep network requires huge amount of samples, which are created during the data augmentation process. During this process the samples are rotated and scaled; so that thousands of samples representing the object region and back ground region can be generated under multiple scenarios. Along with the training samples the respective labeled images are provided to the network making it to distinguish the difference between the foreground and background regions.

The network architecture is an encoder and decoder network which is depicted in figure 5, which consists of series of layers where the input frame is fed to the input image layer followed with 2D convolutional layer, Batch normalization, rectified linear unit and maxpooling. The input size to the

layer is $224 \times 224 \times 3$ dimension which is forwarded to 2Dconvolutional layer with filter size of 3×3 of 64 filters. Max-pooling layer is employed to preform down sampling the elements by dividing the batch elements into rectangular regions where the maximum of each batch is considered.

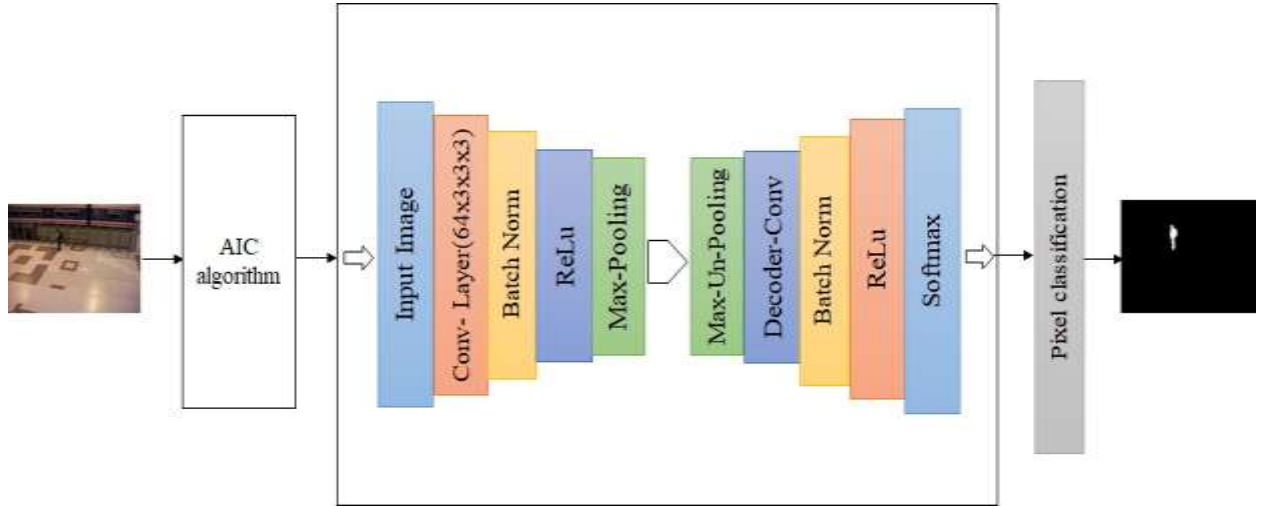
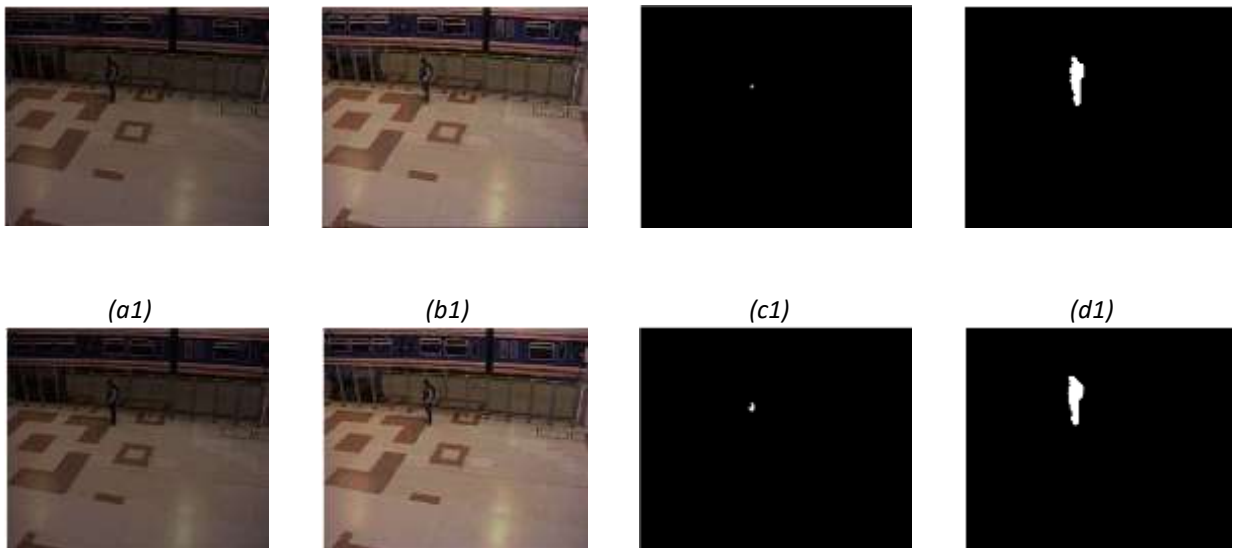


Figure 5: Network architecture of the designed DNN

For training the network the labeled images are provided with the intensity levels of '0' for the background and '255' for the foreground regions. Stochastic gradient descent with momentum type of solver is used with 50 epochs each of 100 iterations is used to train the network. At soft-max layer the loss function of 'weighted cross-entropy' is used to classify the pixels. Finally, the pixel classification layer is used to mark the pixels as label '1' or '0' based on the probabilities that are attained.

4. Impact of AIC algorithm on object detection

This section discusses about the impact of adaptive illumination correction on the segmentation of the object in the video sequence.



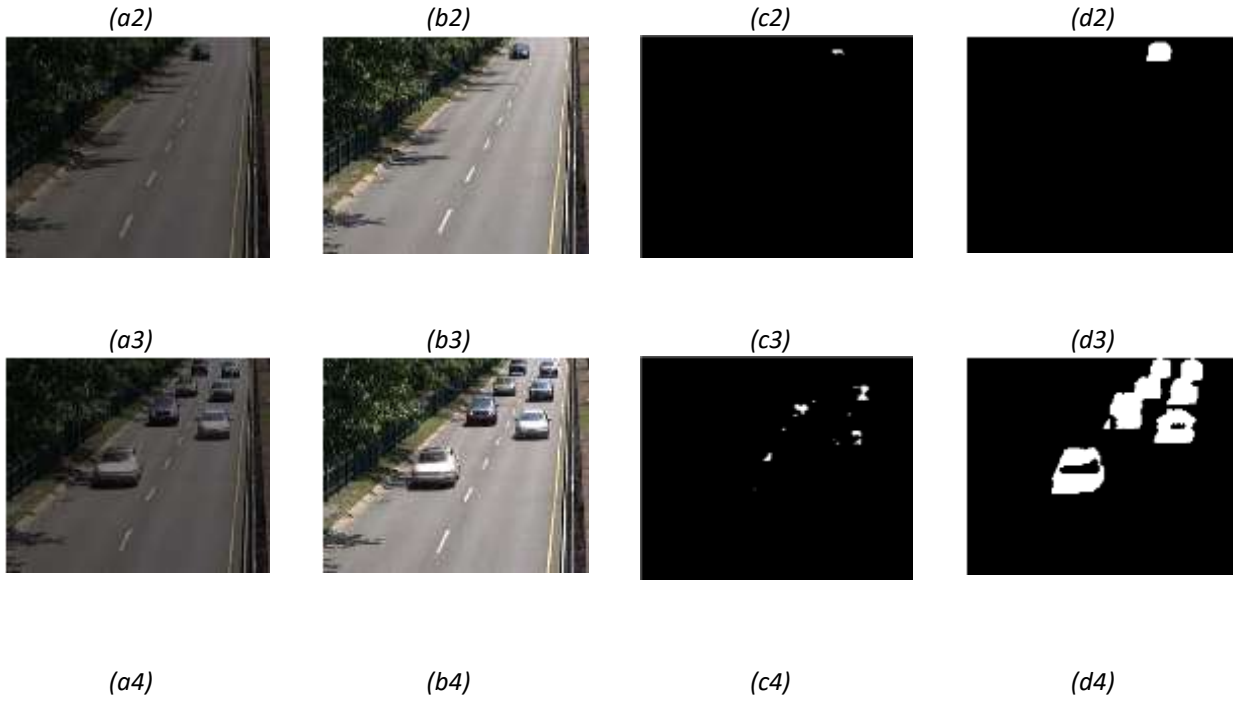


Figure 6: Impact of illumination correction on segmentation (a1) - (a4) shows the low illuminated images (b1) (b4) shows the frames after performing AIC algorithm (c1) -(c4) Degraded segmented output obtained without illumination correction (d1) -(d4) Segmented outputs after illumination correction.

In figure 6, it can be observed that when the illumination is not properly corrected the segmented output from the object detector is not appropriate and it is diminished as seen in columns (c1) -(c4). These outputs are no way convey any information regarding the objects in the frame, however it can also be observed that using the proposed AIC algorithm the frames are accurately corrected which when directed to the object detector could able detect the major portions of the object as segmented patches. This shows the importance of including the proposed AIC algorithm along with customized trained deep network based object detector.

5. Experimental Result analysis

The validation of the proposed work is performed with multiple video sequences which are taken from [28], these video sequences are scaled to constant resolution 224x224x3 such that it is compatible to pre-existing networks. For evaluating qualitative analysis of the approach, in this work several metrics like Re (Recall), Sp(Specificity) FPR (False Positive rate) FNR (False Negative rate) , Pe (Precision) and F-measure [29]. Tables 1, 2, 3 shows the metrical analysis of the proposed AICOD network, results obtained with VGG16 [30] and Resnet 50 [31] networks.

Table 1: Results obtained with proposed AICOD network

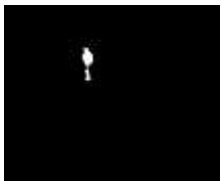
Image	Segmented Output	Metrics						
		Recall	Specificity	FPR	FNR	PWC	Precision	
		0.9761	0.99	0.009	0.02	1.03	0.86	0.91
		0.987	0.986	0.013	0.012	1.31	0.90	0.943
		0.935	0.99	4.0e-4	0.065	0.08	0.93	0.93
		0.92	0.98	0.011	0.079	1.265	0.68	0.88
		0.98	0.99	0.001	0.01	0.09	0.913	0.93
Average		0.972	0.987	0.006	0.02	0.63	0.901	0.935

Table 2: Results obtained with pre-trained VGG16 [34] network

Image	Segmented Output	Metrics						
		Recall	Specificity	FPR	FNR	PWC	Precision	F-measure
		0.86	0.99	0.003	0.13	1.98	0.97	0.914
		0.78	0.99	0.0014	0.23	3.2	0.98	0.86
		0.87	0.99	0.0011	0.125	0.19	0.84	0.85
		0.68	0.99	0.0011	0.41	2.63	0.98	0.73
		0.86	0.99	8.0e-4	0.08	0.24	0.80	0.89
Average		0.868	0.99	0.001	0.12	1.13	0.914	0.885

Table 3: Results obtained with pre-trained Resnet 50 [35] network

Image	Segmented Output	Metrics						Fmeasure
		Recall	Specificity	FPR	FNR	PWC	Precision	
		0.72	0.99	2.6e-4	0.30	4.61	0.99	0.81
		0.706	0.99	7.6e-4	0.29	4.45	0.98	0.82
		0.65	0.99	1.05e-4	0.34	0.38	0.98	0.78
		0.63	1	0	0.36	0.50	1	0.77
		0.617	1	0	0.38	0.51	1	0.76
Average		0.66	0.994	0.0025	0.33	2.09	0.99	0.78

The tabulated results depict the average values obtained for proposed AICOD methods and state of art methods in terms of multiple metrics. In this paper, only few frames outputs were presented which are compared against each other. Figure 7, 8 shows the performance analysis of the proposed method and its superiority when compared with VGG16 and Resent50. It can be observed that the proposed method attains higher recall, specificity and F-measure values and retains very low error rate in terms of FNR and PWC. The comparative analysis shown in figures 7,8 proves that the method could able to retain an improved value by 0.2~0.3 for Recall,

0.1~0.2 for F-measure which is a considerable achievement.

7. Conclusions

This paper presents an adaptive illumination correction with object detection mechanism for surveillance videos. The method mainly aims to adaptively correct the input low illuminated frames by verifying the quality of the input frame blindly. The corrective process is a iterative mechanism that aims to adjust the contrast values until the quality of the frame is improved. By doing so, even the objects in the low illuminated frames can be effectively detected. The method is integrated with customized DAG deep neural network that mainly focuses to identify and segment the objects in the frames. The experiments were conducted with one and multiple objects in the frames. From the observation it can be concluded that even the multiple objects are detected there are segmentation blobs that overlap with neighboring objects. This problem has to be rectified with effective training options and mechanisms. However, for object detection and tracking this may not reflect for a serious level. On other hand the individual objects are perfectly detected which shows an incredible improvement in performance analysis when compared against state of art networks.

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Understanding Word Order for Analyzing Paraphrasing in Marathi Sentence

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Abstract.

Paraphrase identification is a technique of detecting the variety of expressions that communicates the same meaning or intention in different sentence. Intention paraphrasing is very important in text summarization, machine translation, question answering, natural language understanding, word net building, ontology, plagiarism detection, author identification. Corpora for Marathi paraphrase is developed as such dataset for Marathi are not available. Cosine similarity is applied for calculating similarity among the paraphrase sentences (original, paraphrase). Levenstein distance method on sentences is applied to check how much a given sentence required stages to change to the paraphrase sentences to original text. Word level differences are also calculated using Levenstein distances method. For the experiment BERT mean embedding is used.

Keywords: Paraphrase, Marathi, levenstein, cosine, similarity, word, sentences,

1. Introduction

Language being a tool of communication reflects the thoughts, needs, or expression of a person to others. The way we communicate actually many times determines the different meaning of the same sentence (uttered) or different sentence making the same sense. It is that makes a sentence analysis a difficult or complex task when texts are lexically or syntactically modified to differ in appearance but retain the same intention is called “paraphrasing”. Paraphrasing helps to present a single concept in multiple ways making sense of using various permutation combinations or synonyms of words, paraphrase can be generated, extracted, or identified based on the application where it is applied. Paraphrase generation involves the use of synonyms of a word including changing the word sequence and grammatical structure also without changing the meaning whereas paraphrase extraction is a process of compilation of various words or phrases, which have the same meaning or same intention. Paraphrase identification is a technique of detecting the variety of expressions that communicates the same meaning or intention. Paraphrasing is very important in text summarization, machine translation, question answering, natural language understanding, word net building, ontology, plagiarism detection, author identification. This paper tries to highlight the importance of understanding word order in a Marathi sentence to better analyze paraphrasing. As very negligible work on Marathi word order and paraphrasing are seen, thus the present work tries to put emphasizes on word order for the Marathi language, as it is a very important stage for many applications involving natural language processing.

2. Paraphrase Detection

For this paper paraphrase detection is considered as the point of the study; in general, three main types of paraphrase detection are observed lexical, phrase and sentential paraphrase.

2.1 Lexical Level

It is the method where words are the focus point of paraphrasing, synonyms of words are used to identify the same purpose in the sentence if we see more in-depth other than synonyms, hypernym is mostly used as synonym (collection, gathered) hypernym. (Grandpa & Grandparents)

Examples in Marathi,

- A. □□ --□ □□ □
- B. □□□□ --□□□□
- C. □□□ --□ □□□
- D. □ □ --□ □□ □□

2.1 Phrase Level

It is the expression of different phrases having the same semantic context; it focuses on syntactic phrases and pattern collection with connected factors.

Examples in Marathi,

- 1) □□□□□□ □□ □□ □ □□□.
- 2) □□□□ □□□ □□□□□ □□□.

2.3 Sentential paraphrase

It is a more complex one as sentences are totally interchanged with other sentence but both (original & paraphrased) represents the same meaning.

Examples in Marathi,

- 1) □□ □□□□ □□□ □□□□□□.
- 2) □□ □□□□ □□□ □□□□□□.

During this study, it is observed that similarity is mainly calculated using semantic & statistical methods on the language most commonly used statistical techniques are Jaccard Similarity, and Cosine Similarity, while Universal Network Language(UNL) graph is semantic similarity measure. It is mostly applied when working on similarity word order is not given much attention. The Word order of a sentence actually emphasizes the existence of the word & its association phrase in the sentence. This makes a way for the sentence, making a way to reconnect with the sentence with its intention.

Word order: it is found that a given language may allow using of a permutation of a given combination of words into sentences. These resulting sentences, 1) may have the same meaning or same intention or concept, 2) may have different meaning or intention, 3) may have a common structure (grammatically) correct but the meaning is not applicable.

- I. Ram likes flowers
- II. Flowers are favorites of Ram
- III. Rama's favorites are flower
- IV. Flowers like ram

The above sentence (1, 2, 3) are semantically and syntactically correct. But the fourth sentence is only syntactically correct but semantically different. (As we can say in this case incorrect). Thus, word order becomes immensely important to detect paraphrasing in sentences. According to Ashok R. Kelkar, an important question arises while studying word order. 1) First is whether the word and the sentence are the only necessarily contagious or solid combination in sentence utterance. 2) The second question is concerned with the relevance of the grammatical structure of the generated sentences. 3) The third question refers to whether really the sentences have the same meaning or to they mean roughly the same thing. 4) the fourth question is whether in the sentences the word /phrase are of negligible meaning difference. 5) The fifth question in the sentence the connection between the words carries & original , the meaning difference.

Literature Survey

Sr.No.	Title Of Research Paper	Technique	Result
1.	Efficient Hybrid Semantic Text Similarity using WordNet and a Corpus. [1].	In this research, the paper author defines the TSM (text similarity measure) technique. The proposed TSM is based on information content and Word Net semantic relations. TSM defines exact word match, the length of both sentences in a pair, and the maximum similarity between one word and the compared text.	Significant at the 0.05 level.

2.	Sentence Similarity Measuring by Vector Space Model [2].	In this paper, the author described the implementation of a sentence similarity measuring algorithm. During the implementation of the technique, there was a need of identifying a suitable lexical database and a text parser. For this purpose, the Author used Word Net, Lexical Database, and Stanford Core NLP text parser. Instead of using Stanford Parser Author shifted to Stanford Core NLP Parser due to the enhanced capabilities of lemmatizing features.	The overall result has gotten from the authors that are 0.37 %.
3.	Language Independent Paraphrases Detection [3].	They developed the Probabilistic Neural Network (PNN), Which is used to train Jaccard, Cosine Similarity, and length normalized Edit Distance language.	The overall result has gotten from the authors that are 0.915.
4.	A Semantic Similarity Approach to paraphrase Detection [4].	JCN word similarity with the matrix.	The overall result has gotten from the authors that are 82.4%.
5.	Paraphrase Identification on the Basis of Supervised Machine Learning Techniques [5].	Combination of lexical and semantic features.	The overall result has gotten from the authors that are 79.6%.

6.	Paraphrase detection using string similarity with synonyms [6].	Use of synonyms in text-similarity metrics.	The overall result has gotten from the authors that are 70.6%.
7.	Paraphrase Detection based on Identical Phrase and Similar Word matching [7].	Author Develop the similarity matching(SimMat) metric combined with 8 MT metrics	The overall result has gotten from the authors that are 77.6%.
8.	Paraphrase Detection in Hindi Language using Syntactic Features of Phrase [8].	Levenshtein Distance method used for similarity score calculation for Detection paraphrases in the Hindi language and removing overlapping words Authors used the Random forest classifier and different machine learning algorithms.	The overall result has gotten from the authors that are 89.7%.
9.	Paraphrase Identification Using Weighted Dependencies and word semantics [9].	Calculate similarity and dissimilarity scores using dependencies	The overall result has gotten from the authors that are 72.41%.
10.	Paraphrase detection using Semantic relatedness based on Synset Shortest path in WordNet [10].	Semantic relatedness approach.	The overall result has gotten from the authors that are 71.1%.
11.	Detecting Paraphrase in Indian Languages (Malayalam) [11].	In this Research paper Author Calculated the cosine similarity score using a model named Bag of Word and a threshold for calculating the paraphrase score.	The overall result has gotten from the authors that are 0.80444.

12.	Paraphrase Identification of Malayalam Sentences [12].	In this research, semantic Measures and Statistical Measures are used to detect the paraphrases.	The overall result has gotten from the authors that are 0.9%.
13.	Detecting Paraphrases in the Marathi Language [13].	In this paper, the author used the Statistical Similarity (this system uses four statistical methods for Statistical Comparison Which are Jaccard, Cosine, Word Order, Smo matrix Similarity.) and Semantic Similarity.	The overall result has gotten from the authors that are 82%.
14.	Learning Paraphrase Identification with Structural Alignment [14].	In this research, the author used a hybrid representation of attributed relational graphs to encode lexical, syntactic, and semantic information. They also used three important components of the method graph extractor, structural aligner, and similarity estimator.	The overall result has gotten from the authors that are 76.9%.
15.	A Novel Approach to Paraphrase Hindi Sentences using Natural Language Processing [15].	They developed a technique for reframing Hindi sentences using NLP. The main steps involved dividing the paragraph into sentences, tokenizing the sentences into	

		words, applying reframing rules, and then combining the results to form new paragraphs. Author Creating paraphrases by applying antonyms and synonyms replacement.	
16.	Paraphrase Identification on the Basis of Supervised Machine Learning Techniques [16].	They developed feature vectors around lexical and semantic similarity attributes to train SVM, k-Nearest Neighbors technique, and Maximum Entropy classifiers.	The overall result has gotten from the authors that are 76.6%.
17.	CFILT-CORE: Semantic Textual Similarity using Universal Networking Language [17].	Define a syntactic and word-level similarity method combined with a semantic extraction method, which was based.	The overall result has gotten from the authors that are 0.764.
18.	Factors affecting sentence similarity and paraphrasing identification [18].	In this research, the author used K-means clustering, Agglomerative clustering algorithms, and weighting methods. It also used the word-embedding model.	0.79% by using the KMS algorithm

The literature survey done on paraphrasing , following observation can be seen:

- Major work is done on English language as well in Chinese ,Spanish, German .Still a lot of Challenges are there.
- If we see Indian Scenario ,a very few research work is seen on Indian Languages like Hindi, Bengali ,Punjabi, Telegu and Tamil. But no such work has been seen on Marathi.

Thus the present work will be boosting the research on Marathi Language Processing. For these a corpus is developed and parallel to this semantic database based on sentence is also created.

3. Proposed System

The proposed system first selects sentences from daily usage , its similar sentence is created by using appropriate semantic words. The whole sentences are then grammatically checked ,then a a similarity detection on the sentences are applied to the percentage of similarity. The detail working is explained below. The flow diagram of the proposed system is shown in figure 1.

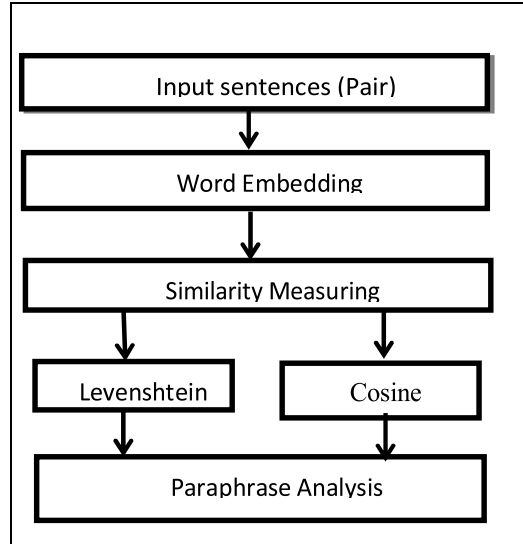


Figure 1: Flow diagram of Proposed system

4. Corpus Development

As presently no corpus is available for paraphrasing in Marathi, so we developed simple and compound sentences, where for each given sentence, a new sentence was created without changing the meaning. Mostly subjective words were replaced by semantic equivalent word and the sentence was reframed.

Example: 1) मी तुमचा सदैव ऋणी राही .

2) मी तुमचा सदैव आभारी असे .

The proposed methodology is to find the similarity ratio and to user validate data. The present difference(dissimilarity) is calculating on sentences using levenstein method, even how many steps are required for changing the paraphrased back to original is also located.

4.1 Input Sentence

The pair of sentences are taken as input. each pair going to the processed for finding the similarity.

4.1.1 Word embedding

Word embedding is one of the most popular representation of document, semantic and syntactic similarity, relation with other word. Word embedding can be obtained using a set of language modeling and feature learning techniques where sentences or words from the vocabulary are mapped to vector of real numbers. The BERT mean embedding is applied to the sentences.

4.4.2 Similarity Measures

The similarity measure is the measure of how much alike two data objects are. Similarity measure in a data-mining context is a distance with dimensions representing features of the objects. If this distance is small, it will be the high degree of similarity where large distance will be the low degree of similarity. The similarity is subjective and is highly dependent on the domain and application. For example, two fruits are similar because of color, size, or taste. Care should be taken when calculating distance across dimensions/features that are unrelated. The relative values of each element must be normalized, or one feature could end up dominating the distance calculation. Similarity is measured in the range 0 to 1 [0, 1].

4.1.3 Cosine Similarity

Similarity between two vectors of an inner product space that measures the cosine of the angle between them is called as Cosine similarity.

$$\text{similarity} = \cos \angle A, B = \frac{A \cdot B}{\|A\| \|B\|} = \frac{\sum_{t=1}^n A_t * B_t}{\sqrt{\sum_{t=1}^n A_t^2} \sqrt{\sum_{t=1}^n B_t^2}}$$

Cosine similarity metric finds the normalized dot product of the two attributes. By determining the cosine similarity, we would effectively try to find the cosine of the angle between the two objects. The cosine of 0° is 1, and it is less than 1 for any other angle. It is thus a judgment of orientation and not magnitude: two vectors with the same orientation have a cosine similarity of 1, two vectors at 90° have a similarity of 0, and two vectors diametrically opposed have a similarity of -1, independent of their magnitude. Cosine similarity is particularly used in positive space, where the outcome is neatly bounded in [0,1]. One of the reasons for the popularity of cosine similarity is that it is very efficient to evaluate, especially for sparse vectors.

4.1.4 Levenshtein distance

Levenstein distance is a string metric for measuring the difference between two sequences. It is also converts the number of steps required to convert the given string to the targeted one ie.it also helpful to edit distances. We can calculate how many insertion, deletion, substitution are required to change one word into the other.

$$\text{lev}_{a,b}(i, j) = \begin{cases} \max(i, j) & \text{if } \min(i, j) = 0, \\ \min \begin{cases} \text{lev}_{a,b}(i-1, j) + 1 \\ \text{lev}_{a,b}(i, j-1) + 1 \\ \text{lev}_{a,b}(i-1, j-1) + 1_{(a_i \neq b_j)} \end{cases} & \text{otherwise.} \end{cases}$$

Where

a = String 1, b = String 2 i = the

terminal word portion of String1.

J = the terminal word portion of String2.

4.1.5 Result & Evaluation

For finding the levenstine distance the original sentences and word along with synonyms in paraphrase sentences needed to be tagged to understand the position shift required. As no standard POS tagger is available in Marathi. Firstly, a rule based Marathi pose-tagger is developed. The accuracy of the POS-tagger was tested by training it with 3000 sentences and testing with 1000 sentences, validating it using 100 sentences. The overall accuracy of the POS-tagger is 82% which is sufficient to proceed with it. the input sentences as pair (original, paraphrased),100 pairs of sentences was passed from the developed POS-tagger, then word level and sentence level levenstine distance, that is step required to convert from original to paraphrased one is calculated as show in table 2 and table 3.

Table 2: Single word similarity result

id	Word pairs	Result
1	□□□□□ = □□□□□.	6
2	□□□□□. = □□□□□.	8
3	□□□. = □□□□□.	9
4	□ □. = □□□ □.	5
5	□□□□. = □□□.	4
6	□□□. = □□□□.	4
7	□□ = □□□	3
8	□□□□□□. = □□.	6
9	□□□□. = □□□.	3
10	□□. = □□ .	5

Table 3: Sample Cosine similarity and levenshtein distance at sentences level.

Id	Sentences pair	Cosine result	levenstine result
1	□□□□□□□□ □□□ □ □□ □ □ □. □□□□□□□□ □□□□□□ □□□□ □□□.	0.25	7
2	□□□ □□ □□□□□□ □□ □□□. □□□ □□ □□□□□□ □□□□ □□□.	0.7302	6
3	□□ □ □□ □□□□□□□□ □□□□□□ □□ □□□. □□ □ □□ □□□ □□□ □ □□□ □□□	0.6681	5
4	□□□□□□ □□ □□□□ □□□ □□□□. □□□□□ □□ □□□□ □ □□□□.	0.79999	6
5	□□ □□□ □□□□□□□□ □□□□ □□. □□□ □□□□□□□□ □□ □ □□.	0	5
6	□□□□ □□ □□□ □□□□□ □□□□□. □□ □□ □□□ □□□□ □□□□□.	0.25	5
7	□□□□□□ □□□□□□□□ □□□□□. □□□□□ □□□□□□□□ □□□□□.	0.75	5
8	□□□□□ □□□□□□□□□ □□□□□□. □□□□ □□□□□□□□ □□□□□□.	0.7999	9
9	□□□□ □□ □□□□□□ □ □ □□□. □□□□ □□ □□□□□□ □□□□□□ □□□.	0.7999	7
10	□□□□□□□□ □□□ □□□□□□ □□□□ □□□□□. □□□□□□□ □□□ □□□ □□ □□□□ □□□□□.	0.5999	7

Table 4: Single Word similarity result

Total no of words	Levenshtein average
100	5.09

Table5: Sentence similarity result

Total no of sentences	Cosine average	Levenshtein average
100	0.5234	5.59

5. Conclusion

Paraphrasing is one of the technique where same sentence can be represented in the different form may be due to situations, need or way the explain a concept that make it true that the meaning of the sentences are not change just it is reframed many times just the important terms are replaced with the synonymy words in the development of fetching the level of paraphrasing for Marathi it was found that no such database is available firstly synonymy based databased was created a pose- tagger also developed to get the tag of the words. For finding the levenstine distance and cosine similarity of sentences we have used the rule based Marathi pose- tagger which gives the 82% accuracy. Hundred (100) pairs of sentences are passed from the developed POS tagger. then word level and sentence level cosine similarity and Levantine distance is calculated. Average of levenstein distance and cosine similarity at sentence level is 0.5234, 5.59 respectively and levenstine distance at word level is 5.09

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Milk Powder Analysis for Protein Content Estimation Using FieldSpec4 Spectroradiometer.

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Abstract

The proposed study focuses on use of spectroradiometer for the analysis of milk powder in order to predict the protein content in it. There are number of milk powder brands available in the market. The 10 brands are collected as samples for analyzing it for protein content. A regression technique was used to meet the goal of quick and non-destructive detection of protein concentration in the milk powder samples. Milk is full of nutrients like protein, calcium, vitamin D, vitamin B12, potassium, vitamin A, riboflavin and phosphorus. Protein is an important component of milk powder. There are number of milk powder brands available in market. These brands are analyzed for protein content using FieldSpec4 spectroradiometer. A regression technique was used to meet the goal of quick and non-destructive detection of protein concentration in milk powder. The PLSR technique is used for predicting the protein content from the milk and the coefficient (R^2) obtained was 0.981.

Keyword - ASD FieldSpec4, Milk Powder, Protein, Hyperspectral

1. Introduction

The spectroscopy is very useful for determining, detecting, analyzing and quantifying the structural as well as molecular composition of sample. NIR spectroscopy was used to analyze moisture and non-fat particles from the samples. Before evaluating Visible and near-infrared reflectance spectroscopy (Vis/NIR) data, it is crucial to decide the proper pre-processing technique on that data. Vis-NIR is a well-established technology for agricultural and food product ingredient analysis (Di Wu, Shuijuan Feng, Xiaojing Chen, 2008) (Nagarajan et al., 2006). The non-destructive optical approach based on Vis/NIR Spectroscopy was assessed for non-destructive measurement of moisture, fat, protein, total solids, etc. It is also helpful for analyzing the constituents of cheese, milk powder and milk.

Milk powder consists of number of constituents like proteins, carbohydrates, lactose, etc. There is increase in the use of milk powder for preparing variety of products. The consumer always judges the quality of milk powder by touch, smell, taste, etc. Widespread applications of milk powder make it necessary to study milk powder constituents. As a result, a device for detecting components in milk powder which is rapid, accurate, non-destructive, and quantifiable is required. So, the proposed work focuses on use of Spectroradiometer FieldSpec4 for the estimation of protein content in the milk powder samples. The protein content is an important component of milk powder. The goal of this study is to use NIR as a fast and low-cost technique to predict the protein content in the milk powder using partial least squares (PLSR) technique. The purpose of this study was to learn how to predict regression coefficients and loading weights for protein in the milk powder.

2. Literature Review

The aim of the current work is to analyse the milk powder samples for the estimation of protein content. The spectral data is collected using ASD Fieldspec4 Spectroradiometer in dark room conditioned laboratory. There are various applications where ASD FieldSpec4 was used successfully for analysis depending on the need of that application. Some of the significant studies done by different researchers using FieldSpec4 are mentioned: The soil samples were analyzed for finding lead and nickel by analyzing spectral measurements. The statistical approach and regression model was used to predict the lead and nickel from soil samples(Pawar* & Deshmukh, 2021). The minerals are identified using hyperspectral images and validated using Fieldspec4 Spectroradiometer for Lonar Crater and also proving the significant facts about the Lonar crater(Gore et al., 2021). Plant leaves are analyzed for disease prediction and deciding the level of severity for that plant using FieldSpect4(Randive et al., 2019).

The determination of moisture content in milk powder samples were analyzed using NIR diffused reflectance mode. The authors used calibration model for the moisture content analysis. The Short-wave NIR in the range 800 to 1050 nm is used for the determination of fat, proteins and carbohydrate in milk powder. The authors used quantitative analysis method of partial least squares (PLS) and least squares support vector machine (LS-SVM) for this analysis (Wu, He, Feng, et al., 2008). Other study focused on the use of NIR Spectroscopy proving SNV was a useful pre-treatment for raw milk powder spectra. The short-wave NIR is a rapid and low-cost technique to determine carbohydrates content of milk powder both LS-SVM model and partial least squares (PLS) model were established based on whole short-wave NIIR region, then Analytical Spectral Devices (ASD) (Wu, Feng, Chen, et al., 2008).

NIR and MIR Spectroscopy techniques were used to determine iron and zinc content in milk powder samples. Selected NIR and MIR variables were input to PLS and LS-SVM. For both the models, MIR variables gave better results than NIR variables

Ultrafiltration and Diafiltration processes were applied for concentrating proteins present in the defatted milk. This process was used for manufacturing the milk protein concentrate (MPC) powders. This study suggests that increase in calcium and casein contents decreases the stability of proteins by negatively influencing the manufactured MPC powders(Meena et al., 2021).

Milk powder was analyzed for studying different constituents(Wu, Feng, Chen, et al., 2008) like protein(Inácio et al., 2011), melamine(Liang et al., 2020)(Lu et al., 2009), fat(Wu, Feng, & He, 2008), carbohydrates(Wu, He, & Feng, 2008). Other studies finds the effect of heating on protein content of milk powder samples(Ye et al., 2017). research on NIR and MIR Spectroscopy techniques were evaluated to determine calcium content in milk powder, to compare the predication abilities of LS-SVMmodels by UVE-SPA and only selected by UVE and the full Spectral variables [10]. Quality of milk powder is analyzed by using image fractal analysis and particle size is compared with the results of this fractal analysis (Smoczyński, 2020).

The proposed work focuses on predicting amount of protein content from milk powder.

3. Methodology

The milk powder samples are collected from local market. The FieldSpec4 spectroradiometer is used to collect the spectral data for these samples. 10 scan for each sample is captured through gun of fieldspec4. Then mean spectral signatures for each sample is built using ViewSpec4 software. The wavelengths collected using fieldspec4 were pre-processed and then PLSR regression technique is used for finding the protein content in each sample. The methodology is shown in figure 1.

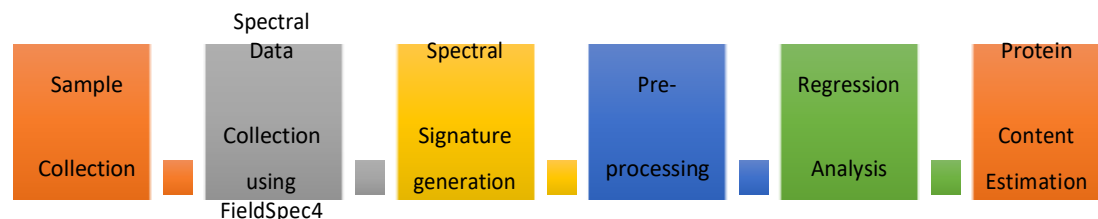


Fig. 1 Methodology

3.1 Sample Preparation: Ten different types of milk powder were purchased from local market Aurangabad. Each sample was filled to the brim with milk powder and stored in identical glass containers (65mm in diameter, 14mm in height).

3.2 Spectral Measurements Using FieldSpec4: Spectra signatures of each and every milk powder samples were collected using the FieldSpec4 at visible-near infrared wavelengths ranging from 350nm to 2500nm. The spectrum scanning method was carried out in a dark room to reduce the impact of outside light.

The instrument's sample interval and spectral resolution are 1.4nm for 350-1000nm and 2nm for 1000-2500nm, respectively. Each 100gms of milk powder was used for analysis. This device uses a halogen light as a light source to illuminate the samples using fibre-optic cable with an 8° field-of-view. Reflectance spectra of milk powder samples were obtained using reflectance light.

The RS3 spectral acquisition system was used to capture reflectance spectra of milk powder samples with wavelengths ranging from 350nm to 2500nm. A standardised white spectral on panel with 100% reflectance was used to increase signal and calibrate the accuracy. For each milk powder sample, progressive scan was used. The total 10 milk powder samples were collected for analysis and each of which was examined ten times under the FieldSpec4 spectroradiometer. So total 100 scans of milk powder samples were analyzed further using PLSR algorithm. The statistical mean spectra of these scans were built using the ViewSpecPro software, and it was recorded as the spectrum reflectance of the specific milk powder samples.

3.3 Data Pre-Processing: - The spectral signatures of all milk samples are captured and stored in .asd format. These spectral signatures were pre-processed with the help of ViewSpecPro software. The spectral signatures were then transformed into ASCII format and then to.xlsx format for further analysis using RS3 software.

On the spectral data, a few spectra pre-processing strategies, including first derivative, were applied. The mean spectral signatures of 10 milk powder samples are shown in figure 2.

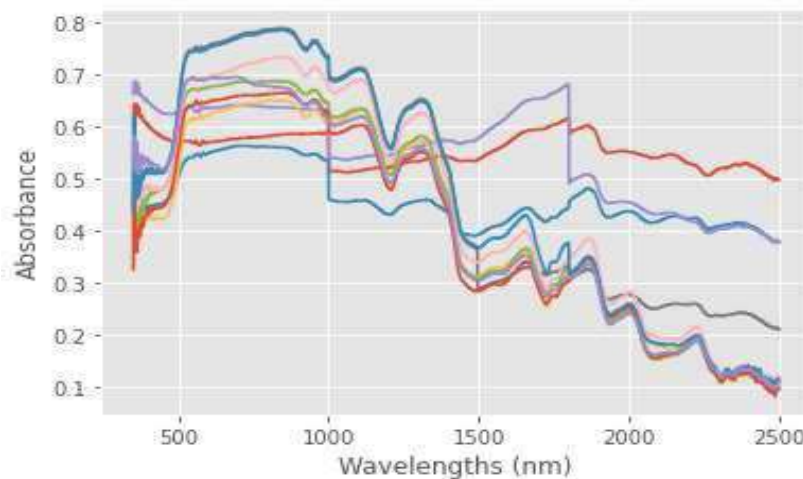


Fig 2. Mean spectral signature of all 10 samples

3.4 Data modelling: - The protein contents are predicted and cross-validation of all samples were used in the calibration. A total of 10 samples were randomly divided into two sets. The calibration of milk powder reflectance was done and the protein content was predicted using a PLSR-based analysis.

3.5 Partial Least Square Regression: -PLSR is a popular regression method for spectral analysis that employs a multivariate predictor (x) and the response of milk protein powder, real estate (y). The following are the equations.

$$Y_m - Y_p = \frac{Y_m - Y_p}{n}$$

where , Y_m denotes the measured value of the protein,

Y_p denotes the predicted value,

Y_{mean} is the mean of the measured values,

n denotes the number of measured Predicted values with $i=1,2, 3...n$.

3.6 Prediction Accuracy: - The milk powder samples were separated into calibration and validation data sets, and the model's prediction accuracy for the calibration and validation data sets was assessed using R^2 (coefficient of determination).

4. Result and Discussion

The PLSR model is used to predict protein from reflectance. It takes into account the complete spectral signature and reduces it to a few components, which is then used to

estimate protein. After applying first derivative pre-processing to data, R2 of 0.91 and RMSE of 0.008711 were seen for calibration and 0.92 and RMSE of 0.001624 were observed for validation after using Python programming to build up a relationship between milk powder protein and hyperspectral data.

Figure 3 shows plots of R^2

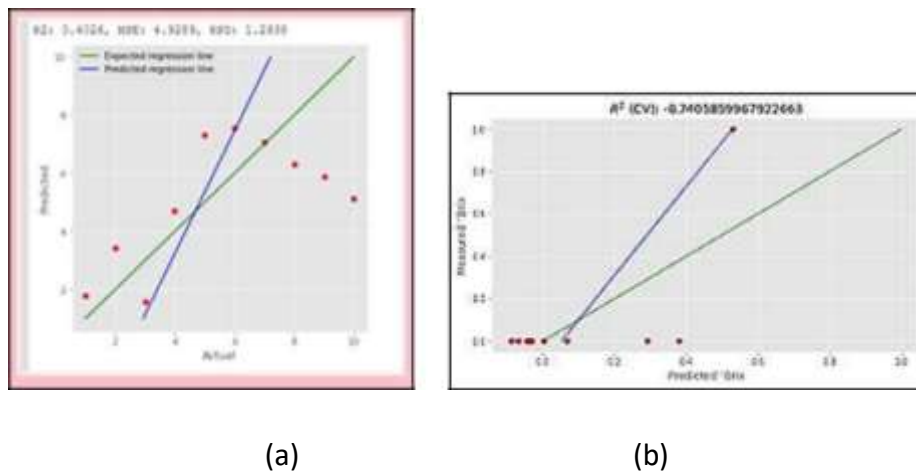


Fig 3. Regression Plot for (a)Calibration (b) Validation

Figure 3 shows the Performance of PLSR Models plots the measured and predicted Protein concentrations for the calibration and validation data sets, respectively, using PLSR Analysis. The validation set's R^2 values are higher and the RMSE values are lower than the calibration set's comparable values.

The GUI showing Protein estimation is shown in figure 4.

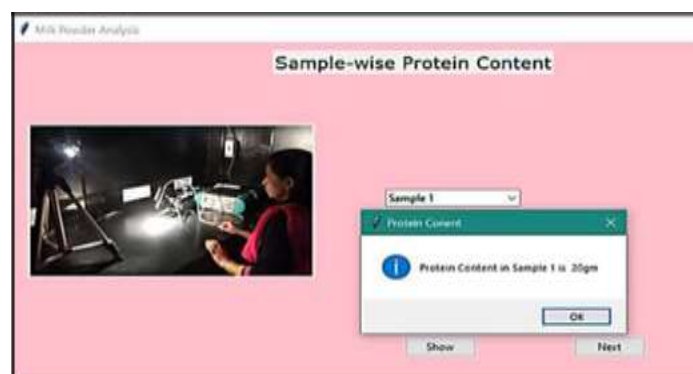
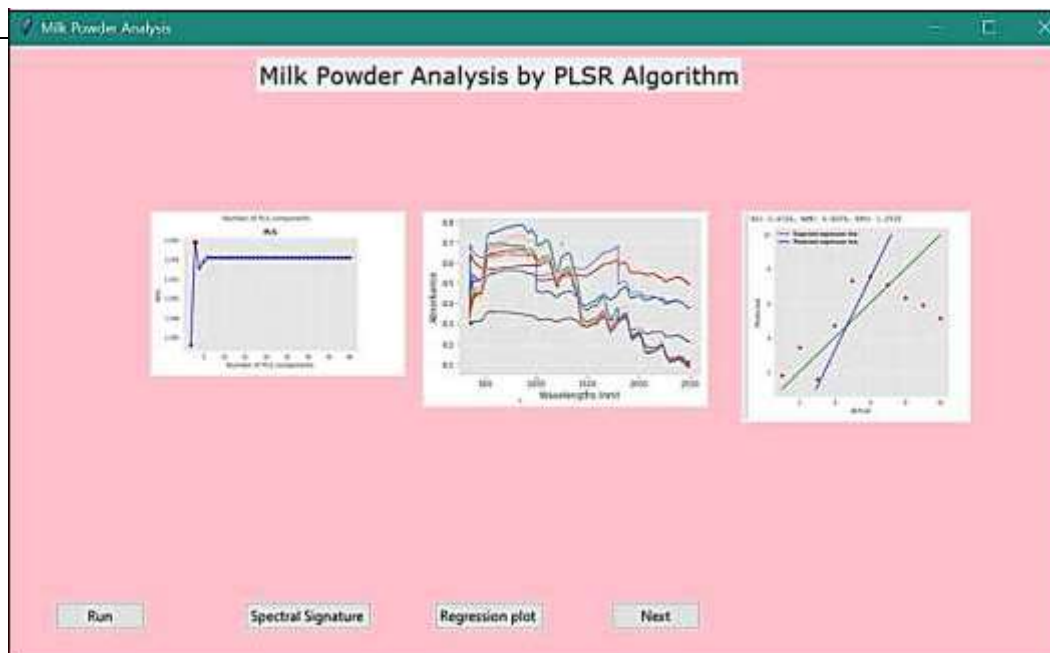


Fig. 4 Protein Estimation for Sample 1



GUI displaying regression plots is in Figure 5.

Fig. 5 Regression Plots in GUI

The protein content of all milk powder samples is shown in table 1.

Table 1. Actual vs. Predicted Protein Content

Milk Powder Sample	Protein Mentioned on Pack in gm Actual	Predicted in gm
Sample 1	20	20
Sample 2	19	20
Sample 3	18	19
Sample 4	16	16
Sample 5	26	21
Sample 6	26	19
Sample 7	26	19
Sample 8	18	19
Sample 9	26	19
Sample 10	20	19

The graph for Actual vs. Predicted protein content is shown in figure 6.

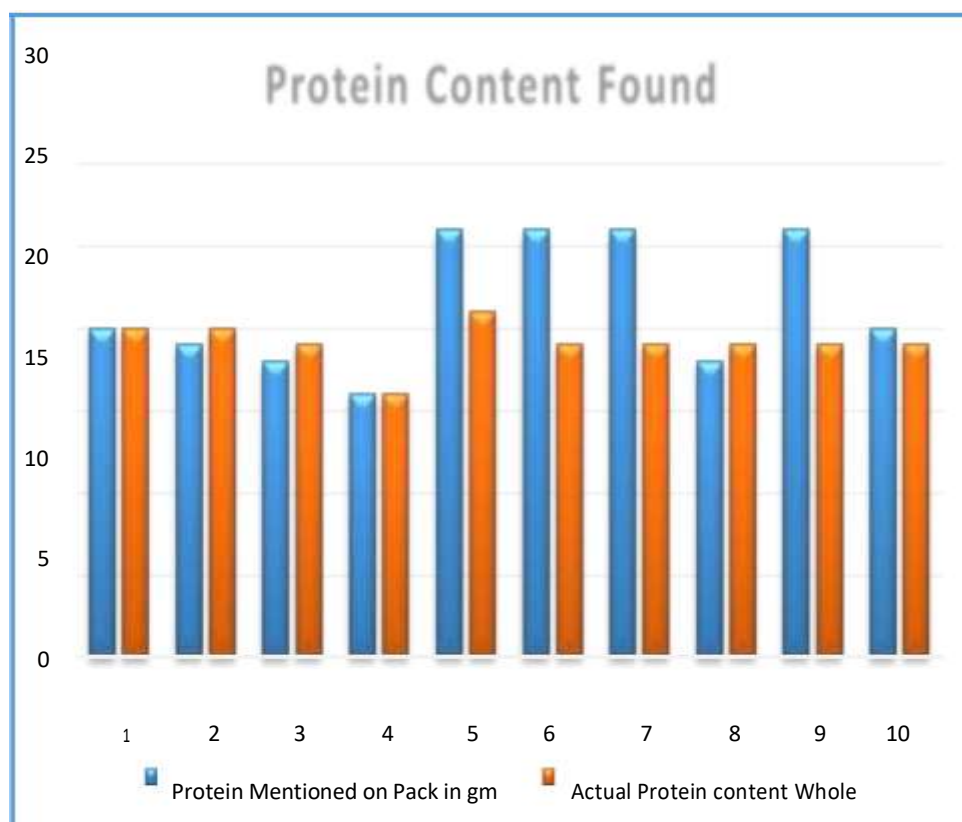


Fig. 6 Graph of Protein Content

5. Conclusions

The spectra of ten distinct milk powder samples showed significant differences. We employed VNIR reflectance spectroscopy to determine the protein content in milk powder. The proposed work makes use of ASD FieldSpec4 instrument to capture the spectra of the gathered milk powder samples and got 906nm, 949nm, 987nm, 1002nm, 1025nm wavelengths showing major reflectance for protein content. This work demonstrates that combining Vis-NIR Spectroscopy with PLSR can estimate protein with a reasonable level of precision. Vis-NIR Spectroscopy provides a practical, simple faster and non-destructive technique for predicting the protein in the milk powder samples.

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Analysis of Short Answer in Question Answering System for Online Descriptive Examination

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Abstract

Globally due to the COVID-19 situation, the examination was taken online. The majority of online exams are objective exams, however, it is challenging to auto-correct a subjective exam. As checking the answer found in the subjective type-examination has many things to be considered like spelling mistakes, grammatical errors, words missing or extra words added, and the meaning of the answer. The system that is present today does not handle this type of answer and generates the result as wrong. The Microsoft team template was used for conducting the test. In this paper, we analyze the performance of student answers with model answers. The responses were checked manually and analyze the performance. The analysis was done in two ways: Part of speech Tagger and Levenshtein distance. The first stage is to use the Part of speech Tagger for tagging the student's answer and then check the model answer type with the student's answer type, and calculate the percentage of nouns and verbs and secondly calculate the distance using Levenshtein amongst the answers. Observation during the experiment is that 85% of answers are noun oriented which helps in matching between the answers. The results of the Levenshtein distance are used to calculate the performance of the system for that accuracy and precision measures were considered.

Keywords: Levenshtein distance, Natural Language Processing (NLP), Part of Speech (POS) Tagger, Question Answering (QA)

1. Introduction

The Question Answering System tends to be used to automatically generate the correct and valid answer to the question that is asked by the user in natural language still which is a challenge under natural language processing. The QA system is a type of information retrieval. Presently the QA system does not show the result as an accurate answer rather than multiple pages of documents are given as a response. Most of the QA work is seen to in English, Chinese, Japanese, etc., and also for Indian languages like Hindi, Marathi, Telegu, Bengali, etc. (Gupta & Gupta,2012).

QA System has many different types of application areas like online examination systems, the interaction between humans and computers, language learning, taking out information from a large document, etc. (Pundge et al.,2016).

The fundamental problem with descriptive examination is that students may use different words, or synonyms, to construct their explanations, examples, and descriptions, but they must all have the same meaning and score in order for the answer to be correct (Kankhar et al.,2021). Also, the problem in a descriptive examination is how many or how long the sentences are present in an answer.

During the Covid-19 pandemic, one of the major effects was seen on the educational system. The globally online medium was used for the teaching and learning process. In an online educational system, even examination is a vital part of the system. As examination plays an important role in analyzing and evaluating student performance. The online examination still is performed with the help of an objective-type question (MCQ, One-word answer, Fill in the blanks, and answer in one sentence). Auto evaluation of one-word answers, fill-in-the-blanks, and answers in one sentence is not possible even in the widely used platform like google classroom, Microsoft team, etc.

In this paper, we focused on descriptive-type questions (one-word answers and answers in one sentence) under objective QA because the system auto-checks the objective part mainly MCQ (Multiple Choice Questions). In MCQs, the response is chosen based on a choice. The assessment of descriptive-type questions were performed manually. For an automatically correct assessment of the answer, a lot of effort was required, this paper presents an experiment carried out in this direction. The system failed to correctly check the student's subjective responses and generate incorrect performance. We compute the measures after analyzing the effectiveness of student responses with model answers.

1.1 Types of Question Answering Systems:

The question-answering system is divided into two types:

i. Open domain:

Open-domain QA system has no restrictions on topics. The question is on any type, any subject and it has no limitation to areas. The open-domain QA system is used to generate the answer that is asked by the user. It returns the answer in the form of short fragmented text.

ii. Closed domain:

The closed domain question answering system contains questions belonging to a specific area. The close domain question answering system is easy to handle because the topic of the question is limited and accepts the limited question. This paper's QA system had a closed domain, meaning that only questions from a certain area were collected.

2. Literature Review

The preparation and execution of online exam evaluations for Islamic Religious Education Learning were discussed in this paper (Azis et al., 2022). They employ case study methodology and qualitative research. Researchers employed procedures like observation, interviews, and documentation to gather data. The outcomes of this piece are Islamic Religious Education Learning Assessment Evaluation Planning at SMA NU 05 Brangsong.

In the paper LSTM (Long Short-Term Memory) network was examined by Lokhande et al and a Siamese modification of it was shown for Labelled data consisting of pairs and patterns of varying lengths. Methodology considered the correct response before analyzing how the correct response and the provided response differ in terms of semantics. They used word embedding vectors supplemented with synonymic information to the LSTMs (Lokhande et al., 2022).

The paper presented a text analysis-based automated method for evaluating descriptive test answers. The paper outlines a system for evaluating response sheets fairly. The ultimate score for each response was determined by using the concepts of text summary, text semantics, and keyword summarization. The Siamese Manhattan LSTM is the foundation of the text similarity model (MaLSTM). This strategy was discovered to be quite effective for implementation at a facility or university (Bahel & Thomas, 2021).

The Educational system is changed over the last years, and they used an online type of education. They analyze the online examination under the closed domain. This paper analyzed the correct answer and also calculates the spelling mistake that occur during the answer submission. In an online question-answering system the automatic evaluation is done with the help of word similarity (Kankhar & Mahender, 2021).

The difficult work of text-based question answering (QA) involves coming up with concise, specific responses to consumers' inquiries. The primary goal of this study is to propose a potent method for learning to interact between questions and texts and to represent information in several layers. They give a thorough overview of the various models that have been presented for the QA task in this study, including both the more established deep neural network perspective and the more recent information retrieval perspective. In order to compare various strategies, they also give results from the literature that is currently available and introduce well-known datasets for the task (Abbasiantaeb & Momtazi, 2021)

In school, college and universities, student performance is calculated using the examination. Some university examination is taken online using multiple-choice questions but student knowledge in many courses require to measure the conceptual, representation and problem-solving. This paper focuses on descriptive-type questions and automatic assessment is done. The E-assessment is done and generates the result based on keywords (Kadam et.al., 2020).

The online subjective examination is a very complex task because it takes more time. The assessment of this examination is a hectic task for calculating the result because understanding the subject is more important. This paper focuses on two issues length and paraphrasing which depends on the answer and also extracts the pattern that is obtained from the answer (Dhokrat & Mahender, 2012).

This paper focused on the descriptive answer and checks the grammatically correct answer. The descriptive answer contains a single sentence that has no spelling errors. They used the graph for representing the student answer and similarity measure to allocate the marks (Kaur et.al., 2013).

Aditi Tulaskar. et al proposed a system that calculates the percentage accuracy and depending on that allocates the marks to the student. The students submit the answers to the question and the answer is stored in the database. The student's answer is checked with keywords and synonyms of that answer. The spelling mistake and grammatical errors are also checked and finally assigned the grade to the student (Aditi Tulaskar et.al, 2017).

3. Methodology

The proposed Question Answering system is developed for auto assessment of one to two line-based answers. In this system, the questions were prepared by the teacher along with the model answer. The student submitted the responses to the questions. The responses to the question was accurate, but it returns as incorrect because some mistake was present in the response. So, we came up with that responses. The system checks the responses but it is generated as wrong so we manually check the responses.

The data was analyzed in two ways: POS Tagger and Levenshtein distance. The POS tagger was applied for extracting the linguistic aspects. After that, calculate the Levenshtein distance between the model answer and the student's answer, to know how much paraphrased is the student's answer. This methodology is used to check the responses that submitted by the student are correct but the system generated an incorrect result.

The flow of the process is shown in figure1 and the detailed process is explained in the below section:

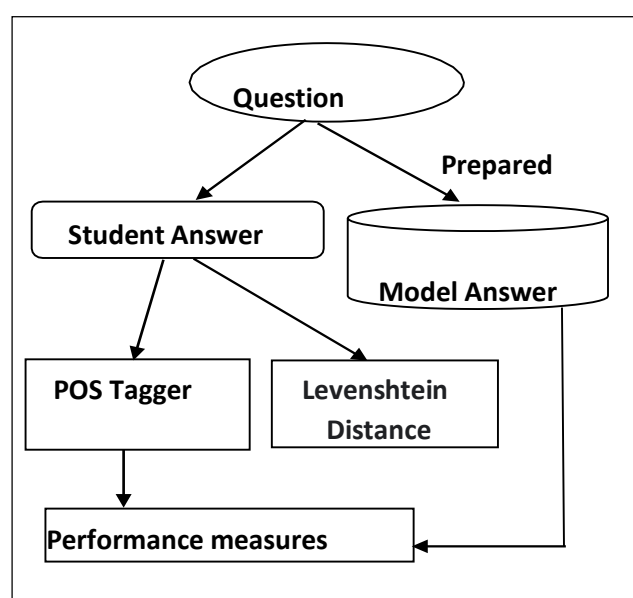


Fig. 1: Flowchart of the system

3.1. Question:

The question is used for the request of the information. The question is created by the teacher. The answer to the question is accepted by the student and the also teacher prepared a model answer. The Microsoft team conducted the test and the question of the test was from the account subject of 12th standard Central Board of Secondary Education (CBSC).

3.2. Student Answer:

The student gave the answer to the question which was collected online. The student's answer is checked with the model answer, if they are matched then the answer is correct. Sometimes the student's answer is correct but they are marked as incorrect because of case

sensitivity, grammatical error, a spelling mistake, or an extra word added or missing in the answer. This problem occurs in the Microsoft team and also in Google form. For checking the correct answer first we converted all answer are given in lowercase as no abbreviations were found in answers. So the case sensitivity is not an issue for the present system. We apply the POS Tagger to student answers and check the type of answer in this system. Calculate the noun and verb present in the student's answer. We also used Levenshtein distance to calculate paraphrased answers.

3.3. POS Tagger:

The POS tagger is used to get the linguistic approach of the answer as it tags the words. POS tagger is necessary for checking correct sequence of answers. It is used for extraction of answers and marked the word with noun, verb, adjective, etc. In the question-answering system, the answer contains a combination of nouns or verbs. The POS tagger gives a large amount of information about the word. To check the answer we used the n-gram of size 1 as the unigram, size 2 as the bigram, and size 3 as trigram, etc. This model is used to understand the answer.

Below is the sample, when applying POS tagger to model answer type and student answer:

3.3.1. Correct answer:

The answer is marked as correct when the model answer and student answer exactly matches. Fig. 2 shows sample of correctly matched answer.

```
Model answer
[('market', 'NN'), ('orientation', 'NN')]
student answer
[('market', 'NN'), ('orientation', 'NN')]
```

Fig.2: Correct Answer

3.3.2. Correct but some Errors:

Answers are marked as correct with some errors when a grammatical error, a spelling mistake, or an extra word added or missing in the answer. Fig.3 shows extra word added in the student answer rather than the model answer.

```
Model answer
[('unity', 'NN'), ('of', 'IN'), ('command', 'NN')]
student answer
[('principal', 'NN'), ('of', 'IN'), ('unity', 'NN'), ('of', 'IN'), ('command', 'NN')]
```

Fig 3: Correct but some error

3.3.3. Wrong answer:

The answer is marked as incorrect when model answer and student answer does not match at all. Fig.4 shows the wrong answer.

```
Model answer
[('Workforce', 'NNP'), ('analysis', 'NN')]
student answer
[('manpower', 'NN')]
```

Fig 4: Wrong answer

3.4. Levenshtein distance:

We used the Levenshtein distance to check the similarity between model answers and student answers which yields the percentage of paraphrases. The answer submitted by the student is checked with its model answers and generates the result.

Below is the formula for calculating the Levenshtein distance:

$$lev(a, b) = \begin{cases} |a| & \text{if } |b| = 0, \\ |b| & \text{if } |a| = 0, \\ lev(tail(a), tail(b)) & \text{if } a[0] = b[0] \\ 1 + \min \begin{cases} lev(tail(a), b) \\ lev(a, tail(b)) \\ lev(tail(a), tail(b)) \end{cases} & \text{otherwise} \end{cases}$$

(1)

Below is the sample of the Levenshtein distance:

3.4.1. Correct Answer:

When the model answer and student answer exactly matches then Levenshtein distance is generated result as 1.

Fig. 5 shows the sample of Levenshtein distance of correctly matched answer.

```
-----:Sample_File1 Data:-----
market orientation
-----:Sample_File2 Data:-----
market orientation

market orientation    market orientation
1.0
```

Fig 5: Correct Answer

3.4.2. Correct but some Errors:

Answers are correct but some errors are present like grammatical error, a spelling mistake, or an extra word added or missing in the answer then Levenshtein distance is between 0 and 1.

Fig.6 shows the Levenshtein distance of extra word added in the student answer rather than the model answer.

```
-----:Sample_File1 Data:-----
Unity of Command
-----:Sample_File2 Data:-----
unity of comand

Unity of command    Unity of comand
0.875
```

Fig 6: Correct but some error

3.4.3. Wrong Answer:

The Levenshtein distance of the wrong answer is a negative value. Fig.7 shows the distance of the wrong answer.

```

-----:Sample_File1 Data:-----
workforce analysis
-----:Sample_File2 Data:-----
manpower

workforce analysis      manpower
-5.2222222222222222
    
```

Fig 6: Correct but some error

The below table shows the sample of the Levenshtein distance of the student's answer:

Table 1: Levenshtein distance of the question

Stud ent	Q.1	Q.2	Q.3	Q.4
Stud 1	1	No	1	1
Stud 2	- 6.4375	1	1	- 4.82608695 7
Stud 3	- 2.833333 333	- 1.454545 455	- 4.64285714 3	- 3.22222222 2
Stud 4	- 4.666666 667	- 0.611111 111	1	0.89473 6842
Stud 5	- 5.911764 706	1	1	0.11111 1111
Stud 6	- 2.894736 842	1	1	- 2.47619047 6
Stud 7	- 5.045454 545	No	1	- 2.35483871
Stud 8	1	1	1	- 4.69565217 4
Stud 0	1	1	0.57142 8571	- 5.83333333 3
Stud 10	- 3.193548 387	1	- 6.78571428 6	- 3.88888888 9

Table 1 shows the Levenshtein distance of the student's answer. In this table, we observed that, if the student's answers match with a model answer then generate the result as 1 value, if not match then generate the negative value, and if any grammatical error or spell mistake or any extra word is added or any word missing in the answer but the answer is correct then the result is a positive value between 0 and 1.

3.5. Performance Measures:

The POS tagger is helpful for understanding the position of the word to make a meaningful sentence. The correct student answer depends on the total number of nouns and verbs. So that we calculate the percentage of nouns and verbs. We calculate the percentage of nouns and verbs in 4 questions.

The below formula is used to calculate the total percentage of nouns and verbs present in the answer:

$$\% \text{ of noun or verb} = \frac{\text{Total number of nouns or verbs}}{\text{Total words}} \quad (2)$$

The Levenshtein distance generates the output in the form of positive and negative values. The range is between 0 and 1 for a positive value. We check the performance using the Accuracy and precision

Accuracy is the ratio of the combination of both true and false values in the form of positive and negative.

The below formula is used for calculating the accuracy:

$$\text{Accuracy} = \frac{T.P + T.N}{T.P + F.N + T.N + F.P} \quad (3)$$

Precision is the positive predicted value. It is used to calculate how the actual result is close to the predicted result. It is calculated using true positive and false positive values.

The below formula is used for calculating the precision:

$$\text{Precision} = \frac{T.P}{T.P + F.P} \quad (4)$$

4. Result and Evaluation:

The paper has a total of 63 responses and 20 questions out of which we used 4 descriptive questions. First, calculate the POS Tagger for answer 1 that is submitted by the student. All answer has of noun type and also the model answer is a noun. A total of 83 words in the student's answer are of noun type. The second model answer is also a noun and the student's answer is also a noun type. 110 words in Student's answer are nouns. The third model answer is noun and adjective. The student submits the answer, if they are correct but contain any grammatical error or spell mismatch they are also a noun. A total of 56 are noun types and 64 are adjectives. The verb is not present in the answer to Question third. The fourth model answer contains a noun and the student's answer is also a noun. A total of 75 words are nouns. The synonym of the answer, misplaced word, and grammatical error are also generating the resulting noun. The below section discusses the results:

4.1 Noun and verb words:

Below table 2 shows the percentage of POS taggers for noun and verb words:

Table. 2: Percentage of noun and verb words

Question No.	Percentage (Noun)	Percentage (Verb)
Q.1	97.65	2.45
Q.2	99.09	0.008
Q.3	46.66	0
Q.4	100	0

4.2 Performance of system using Levenshtein distance:

We calculate the accuracy of a student's answer depending on the total correct answer, correct but some error, wrong answer, and not solved the answer using Levenshtein distance. Below table 3 shows the result of accuracy:

Table 3: Accuracy of Answers

Question No.	Accuracy
Q.1	68%
Q.2	52%
Q.3	46%
Q.4	43%

We calculate the precision of the student's answer depending on the correct answer and correct but some errors.

The below table 4 shows the result of precision:

Table. 4: Precision of Answers

Question No.	Precision
Q.1	95%
Q.2	93%
Q.3	71%
Q.4	76%

5. Conclusion

The question-answering system is well-suitable in the closed domain. The analysis of the closed domain has a limited area to find what type of question the user asked. The data are collected from students and calculated their performance. First, apply the POS tagger to the student's answer and check how many nouns and verbs are present in the correct answer, and then calculate the percentage of each question. After calculating, we observed that answers contain 85% of nouns and the remaining contain verbs and adjectives. Then we calculate the Levenshtein distance of the student's answer and calculate the accuracy and precision based on the correct answer, correct but some errors and wrong answer. Accuracy contains all the values of actual and predicted. Precision is useful for calculating the success of prediction. The overall performance of the system shows that the accuracy of the answer is 52% and the precision 84%.

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Bi-model System Failure Analysis: A Case Study of Aircraft Wheel Braking System.

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Abstract

It is now common that engineering systems are embedded with software to provide further functions and features to meet up with societal and industry demands. It is imperative that such systems are built with reliability in mind right from the infancy stage of design through to completion. However, investigating the hardware and software components of a computer-controlled system for failure is currently a challenging problem in engineering. In addition to the process requiring grounded knowledge of both traditional and software engineering, software failure analysis is not as well established as hardware failure analysis. This paper designed a software model of a computer-controlled system from an existing hardware model of the system, using the UML class diagram, and thus, shows the failure analysis of a computer-controlled system using Failure Mode and Effect Analysis (FMEA). The aim is to demonstrate the individual analysis of the separate systems (hardware and software) that would cause overall (composite) system failure. This allows the failure of the composite system to be viewed from two perspectives and therefore the engineers involved could focus on improving the system from each perspective. The approach in this paper is demonstrated on an Aircraft Wheel Braking System (AWBS). Firstly, the hardware analysis is performed. Secondly, the software analysis is performed using developed class diagram of the AWBS. The Hardware FMEA result shows the AWBS components' failure modes and their effect on the system, thus each component's failure can lead to the top system failure mode. While the software FMEA result shows the AWBS software failure modes and their effect on the system. Thus, the class failure modes for each software operation were obtained, and the top-class failure mode is presented. This study can be used as a guide by system analyst, when conducting failure analysis at the architectural stage of a computer-controlled system.

Keywords — Hardware model, Software model, Failure modes, and FMEA.

1. Introduction

Advances in Science and Technology have made it possible for electrical and mechanical systems to have embedded computer systems. Embedded computer systems comprise an operating system and software programs incorporated into the hardware system (Azizah & Nursyazana, 2014). These systems are referred to as computer-controlled systems. Examples of such systems are avionics, brake by wire, electronics, aviation systems, etc. In our context, a bi-model system is referred to as a computer-controlled system, comprising of separable models of hardware and software. Bi-model systems are complex engineering systems of software and hardware components that interact with each other (Mahmood et al., 2019).

Qualitative failure analysis techniques such as “failure mode and effect analysis (FMEA)” (Deyun et al., 2016, A), “failure mode effect and criticality analysis (FMECA)” (Chang & He, 2016), preliminary hazards analysis (PHA) (Anthony, 2008), event tree analysis (ETA)” (Andrew & Dunnett, 2004), and Fault Tree

Analysis (FTA) (Clifton, 1999), have demonstrated significant value in previous years and are still deployed widely in safety assessment practices. These tools are used in traditional engineering disciplines to analyse hardware failure. However, their application and how they could be applied to analysing software is new.

FMEA is defined as a process of analysing system fault from a single component to the entire system (Papadopoulos et al., 2011). FMEA is termed a bottom-up approach that starts at the bottom to the top; it begins the failure investigation from the basic components and then propagates upwards to the entire system. However, as the complexity of modern systems increases, the use of FMEA techniques in safety assessment is becoming more difficult and problematic. To help curb such difficulties, automatic tools such as HiP-HOPS (Papadopoulos, 2000, A), AltaRica (Zhu et al., 2011), etc, have been developed to assist with the analysis. However, analysing a bi-model system still remains problematic as analysis may only be one sided - hardware only. Therefore, it will be helpful to have the two separate systems individually analysed for failure, where respective engineers could focus on improving them to the overall improvement of the composite system.

In this paper, we demonstrate the use of FMEA for analysing both hardware and software models of a given system separately. The paper establishes that both models can be analysed using FMEA from where further analysis, which is beyond this paper, can be performed to improve the system. The approach of using FMEA to analyse software systems is built upon work conducted by (Nggada, 2012, A) and (Lazarus & Nggada, 12).

This paper is structured as follows. Section 2 discusses related reviews of FMEA Techniques. The method for bi-model system failure analysis is discussed in section 3. Section 4 presents the system case study. The result for the hardware failure analysis is presented in section 5. While section 6 defines the software model, section 7 presents the result for the software failure analysis. Conclusions are drawn in section 8 which include discussion for future work.

2. Related Work

There are several related approaches conducted by researchers to address the potential cause of system failure. FMEA approaches are commonly used in engineering industries. As systems grow and increase in complexity, it becomes problematic and time-consuming to analyse failure using classical techniques. Thus, more safety analysis techniques and software tools were derived from classical techniques to enhance system reliability and to reduce the ample time consumed in analysis.

The aerospace industry adopted the FMEA technique in the 1960s and it was the first industry to apply the technique to the Apollo missions (Deyun et al., 2016, B). Ford Motor Company used FMEA to find potential faults in an automobile system in the 1970s. Other automotive industries later adopted the use of FMEA in the 1980s after the ISO- standard for FMEA was developed by General Motors and Chrysler Corporation (Ronald & William, 2007). FMEA is a traditional method of system failure analysis. Its role is to detect possible failure occurrences preferably at the design stage. It helps to detect errors or failures that may affect system dependability. FMEA identifies hidden faults generated from system components (Papadopoulos et al., 2004).

The FMEA method of system analysis can be applied in the analysis of complex system using different approaches such as the functional, interface, and detailed FMEA approaches. These approaches can be performed at the system design stage, development stage, and data availability (Dyadem, 2003). (Wang et al., 2017) proposed a method of FMEA to analyse electronic devices. This method was conducted using “annotating functional roles”. The functional roles were assigned according to the component function. However, the failure modes and causes of failure of the electronic devices are analysed

according to their roles. The battery of an avionics system was used as an example.

3. Method for Bi-model System Failure Analysis

Figure 1 describes the method for bi-model system failure analysis. The process for the hardware-software system design model and FMEA techniques presented by Ejembi & Nggada (2022) was adapted for this paper. The method proceeds further to state the assumption required to select weak components based on their level of severity.

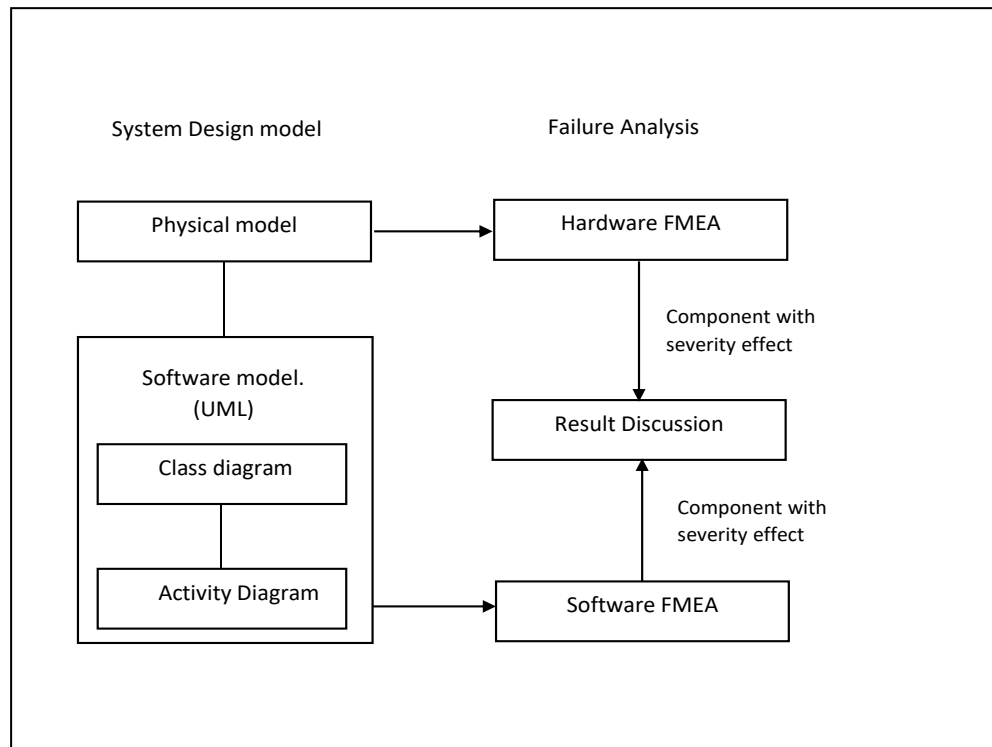


Figure 1. Method for Bi-Model System Design and Failure Analysis.

Once system analysts have determined the failure behaviour of all components, they can then further classify the components under their respective severity effect. The severity effect helps to identify components based on their dependability. Components with weak dependability can either be scheduled for maintenance practice or be reconfigured by introducing a redundant component.

Once the system software model is designed, it is relevant to assess the severity of deviations of components function at the output level. An output function refers to the function that interacts directly with the system environment. The system environment refers to operators and other elements outside the system boundaries. The severity of failure can be defined according to its consequences to the system and the environment. The severity effect is classified based on the following categories: Catastrophic, Critical, Marginal, and Negligible. These classes are assigned to the failure categories established by IEC-61508 (1998).

We assigned the classes of severity effect on the system output deviation based on the following assumptions (Sharvia, 2011):

- Components that have the possibility of switching to their redundant component, at the event of failure, are classified under “Marginal” severity effect.
- Components with least or no effect on the system output function, at the event of failure, are

classified under “Marginal or Negligible” severity effect.

- Components that have direct effect to the system, at the event of failure, are classified under “Critical or Catastrophic” severity effect.

For further design iteration, it is important to identify components with their severity effect on the system and the environment. These components can therefore be analysed further with the use of classical techniques of the system failure analysis.

4. Case Study (Aircraft Wheel Brake System)

The method for Bi-model system failure analysis established in this paper was demonstrated on a complex system model: the Aircraft Wheel Brake System Model (AWBS). The AWBS found in Nggada (2012, B) was adapted for this paper. AWBS consists of several components such as the Hydraulic pressure pumps (Green, and Blue pump), valves (Green, Blue, Selector, Accumulator, Manual meter valve, and Command/ Anti-Skid CMD/AS meter valve G and B.), braking system control unit (BSCU), and the Mechanical pedal. As shown in Figure 2, each component of the AWBS has inputs and output functions, that receive and transfer signals to the other components.

The system (AWBS) is connected to an aircraft's landing gears. AWBS provides a braking function on the main gear wheel during taxiing and landing. After landing, the aircraft's ground braking system can be controlled manually either with the use of brake pedals or an auto brake. During wheel traction, the brake pressure is controlled by the auto brake. This enhances safety by providing continuous deceleration. The hardware model of AWBS adapted from (Nggada, 2012, C), is as seen in Figure 2 below.

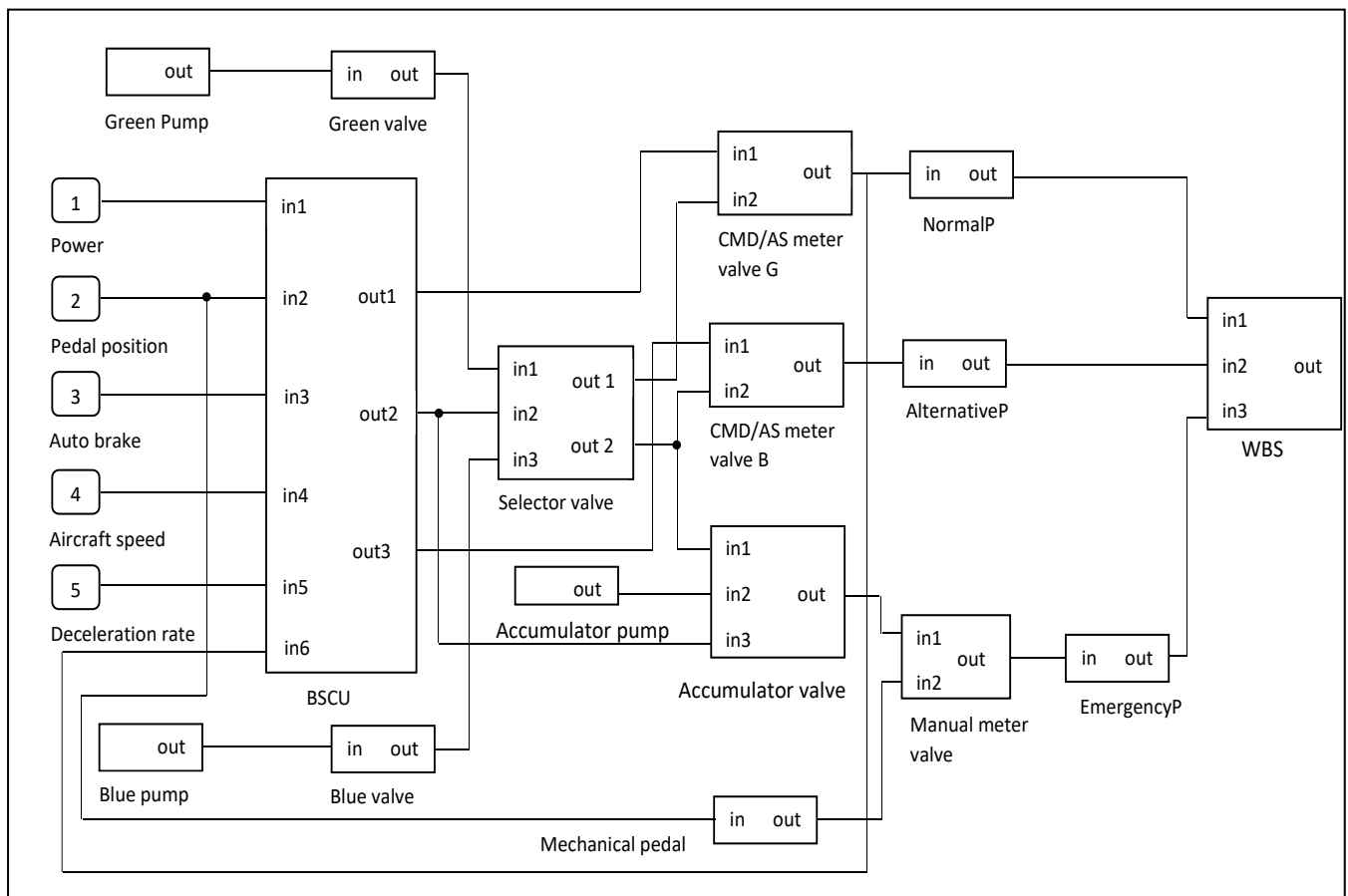


Figure 2. Aircraft Wheel Brake System, (Nggada, 2012)

The BSCU computes commands (braking and anti-skid) and transmits the command signals to the suitable braking network. When the auto brake is true, the “Aircraft speed and Deceleration rate” are activated. The BSCU also takes feedback from several units along the system modes lines (Normal and alternative mode). It has a two-power inputs interface, which receive power supplies from distinct power sources. The power is supplied separately to the redundant command and monitor units of the BSCU. These units are the major part that control the BSCU component. The command unit is the input signal, which consists of the power, auto brake, Aircraft speed, and Deceleration rate. During skidding, the pressure applied to the brake is reduced automatically by the BSCU.

The Green pump provides hydraulic pressure when the system is in normal braking mode, while the blue pump supplies pressure to the system at alternative modes. The isolation valve (Green valve and Blue valve) controls the pressure from the green pump and blue pump. The Selector Valve takes the two-pipe pressure as input and supplies the pressure to the CMD/AS meter valve G and CMD/AS meter valve. The CMD/AS meter valve G measures the amount of Normal brake pressure and adjusts the valve position to output the required amount of pressure, using the command issued by the BSCU. The brake pressure is further transmitted to the Wheel Braking System (WBS) through normal pressure “Normal P”. The CMD/AS meter valve B also measures the amount of alternative brake pressure received from the alternative hydraulic line and adjusts the valve position to output the required amount of pressure based on the command issued by the BSCU. The brake pressure is further transmitted to the WBS through alternative pressure “Alternative P”. The manual meter valve functions as a pressure regulator between the selector valve and the Accumulator pump. In the case of pressure failure on CMD/AS meter valve G, a signal is sent to the BSCU to switch the AWBS into alternative modes and the braking process continues in this mode.

The accumulator valve is a redundant component installed in the AWBS functional model. It connects the pipes coming from the selector valve and the accumulator pump. In the case of no pressure or pressure below the threshold limit, the AWBS enters emergency mode, and pressure from the Accumulator pump is released to the Accumulator valve, and the braking pressure is transmitted to the Manual meter valve. The Manual meter valve also receives input and pressure from the Mechanical pedal, which serves as an extra safety measure. The Manual meter valve regulates pressure from the Selector valve and the Accumulator pump. The pressure is therefore transmitted further to the WBS through emergency pressure “Emergency P”.

To analyse the hardware model of the AWBS, the failure modes expression for each component was determined as shown in Table 1 relative to braking failure as the system top event. The failure expressions used are as defined in Papadopoulos (2000, B). They are specified as lists of internal failure modes of the components and lists of deviations of parameters at component outputs. The BSCU has two types of internal failure modes, which are related to the monitor and command units. The analysis in this work was specifically focused on the component’s internal failure and omission function of the braking pressure.

Table1: AWBS Hardware Components with Corresponding Failure Modes Expression.

Component	Failure modes Expression
Green pump	GreenPumpFailure
Green valve	GreenValveFailure
Blue pump	BluePumpFailure
Blue valve	BlueValveFailure
Selector valve	SelectorValveFailure
CMD/AS meter valveG	CMDASMeterValveGFailure
CMD/AS meter valveB	CMDASMeterValveBFailure
Accumulator pump	AccumulatorPumpFailure
Accumulator valve	AccumulatorValveFailure
Manual meter valve	Manual MeterValveFailure
NormalP	NormalPFailure
AlternativeP	AlternativePFailure
Emergency P	EmergencyPFailure
Mechanical pedal	MechanicalPedalFailure
WBS	WBSFailure
BSCU	BSCUCommandFailure or BSCUMonitorFailure

5. Hardware Failure Analysis

The hardware FMEA of the AWBS was performed manually, and the result showed how the hardware failures contribute to the omission function in the WBS. The hardware failure of the green pump, blue pump, green valve, blue valve, and meter valve does not have a direct effect on the AWBS, and their Severity can be classified as marginal. Consequently, in the event of failure, the system can still transit to either an alternative or emergency mode of operation.

The internal failure (CommandFailure and MonitorFailure) of the BSCU and Selector Valve components have direct consequences on the AWBS function. This is because their functions are primarily critical to the AWBS pressure output.

Table 2: Hardware FMEA of AWBS.

System Failure Mode: Braking Failure of AWBS				
System-Components	Component Failure mode	System Effect	Severity	Mitigation
Green pump	GreenPumpFailure	O-AWBS	Marginal	The system should switch to alternative modes.
Green valve	GreenValveFailure	O-AWBS	Marginal	The system should switch to alternative modes.
Blue pump	BluePumpFailure	O-AWBS	Marginal	The system should switch to emergency mode.
Blue valve	BlueValveFailure	O-AWBS	Marginal	The system should switch to emergency mode.
Selector valve	SelectorValveFailure	O-AWBS	Catastrophic	The system should switch to a manual redundant component
CMD/AS meter valveG	CMDASMeterValveBFailure	O-AWBS	Marginal	The system should switch to alternative modes.
CMD/AS meter valveB	CMDASMeterValveBFailure	O-AWBS	Marginal	The system should switch to emergency mode.

Accumulator pump	AccumulatorPumpFailure	O-AWBS	Catastrophic	The system should switch to manual operation.
Accumulator valve	AccumulatorValveFailure	O-AWBS	Catastrophic	The system should switch to manual operation
Manual meter valve	Manual MeterValveFailure	O-AWBS	Catastrophic	Consider redundant system
NormalP	NormalPFailure	O-AWBS	Marginal	The system should switch to alternative modes
AlternativeP	AlternativePFailure	O-AWBS	Marginal	The system should switch to emergency mode
Emergency P	EmergencyPFailure	O-AWBS	Catastrophic	Consider redundant component
Mechanical pedal	MechanicalPedalFailure	O-AWBS	Catastrophic	Consider redundant component
BSCU	BSCUCommandFailure	O-AWBS	Catastrophic	Consider redundant component
	BSCUMonitorFailure	O-AWBS	Catastrophic	Consider redundant component
WBS	WBSFailure	O-AWBS	Catastrophic	Consider redundant component

The Hardware FMEA result in Table 2 shows the AWBS components' failure modes and their effect on the system. The components' failure modes can be expressed by their respective failure expressions indicated in Table 1. The severity of the failure mode for each component was presented, as seen in Table 2. The system will switch to an alternative mode of operation when the effect of failure is marginal. However, When the failure effect is catastrophic, the system will be reconfigured to the required mitigation. It is of utmost importance to investigate the failure modes of the AWBS software component since the failure modes of the hardware will directly affect its software. Thus, to conduct the analysis, we start by designing the software system model, using the annotations from the hardware model. The software model was designed to clearly define the system functions and their respective failure expressions. The model was designed with the use of the UML class diagram.

6. Software Model Description of AWBS

The UML is a modified language developed from system modeling language (SysML) (Edward et al., 2016, A). It was recognised as a standard language for software development and design. UML mostly uses diagrams to model system structure and behaviour. Examples of the UML diagram include the class, package, object, use case, state machine, activity, and sequence diagram, etc. The UML class and activity diagram were employed for these studies because they provide more information on software description for the system case study. i.e., the class diagram models the clear view of the system structure and its attributes, while the activity diagram presents the behaviour of the system in terms of software and could indicate software failure propagation which is not the focus of this paper.

The class diagram was derived from the physical model of the AWBS shown in figure 2. Let us now define some notations that will enable us to describe the class diagram in the form discussed in the next section. Figure 3 illustrates the basic elements of the notation.

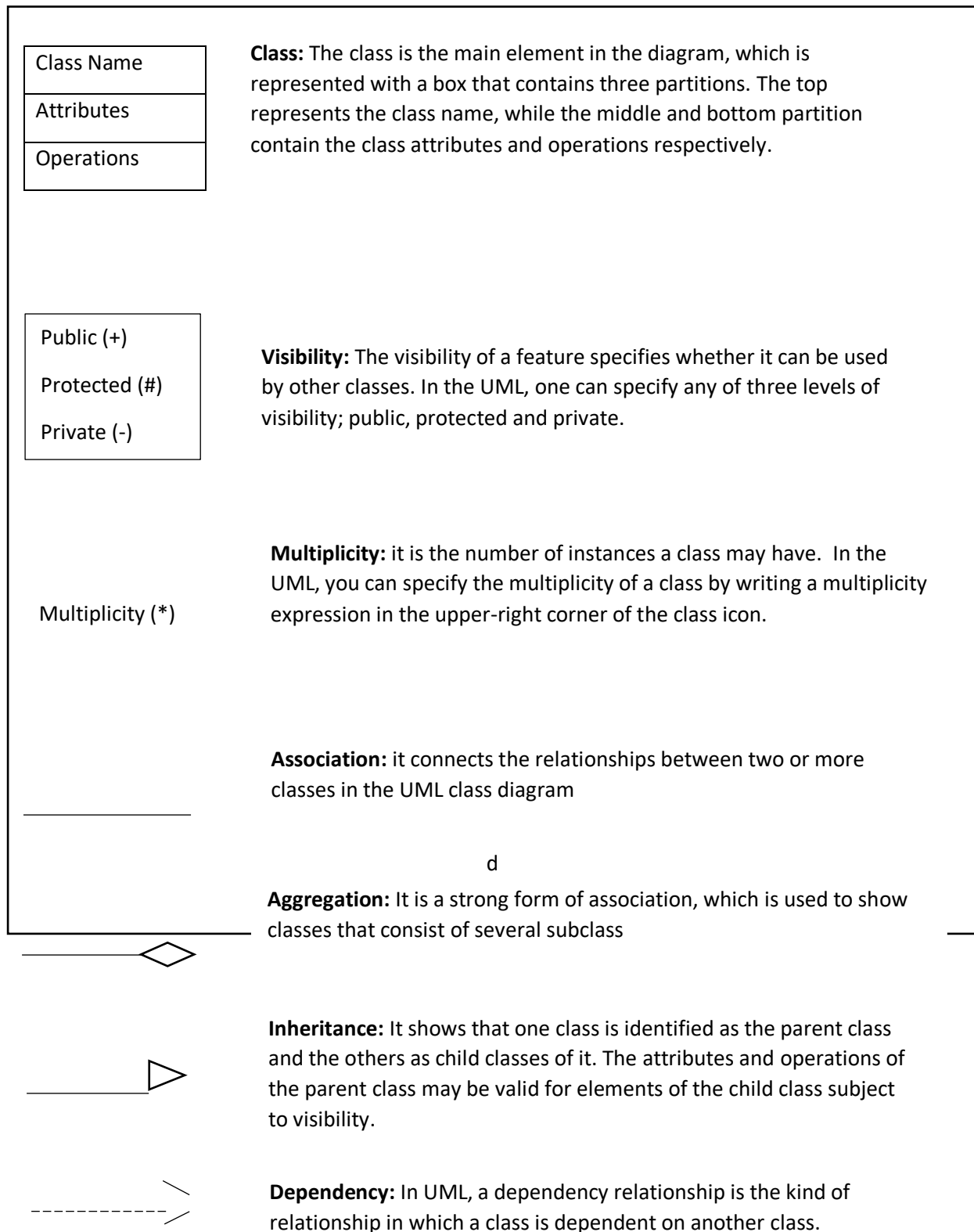


Figure 3: Notation for Class Diagram

According to the notation, a class diagram of a system or a sub-system is composed of the classes, which are the main elements of the diagram, and are represented with a box that contains three partitions. The top represents the class name, while the middle and the bottom represent the class attributes and operations. At the most abstract level, the attributes define the class structural features, while the operation defines the class behavioral features. The class attributes and operations can be specified in the model based on their respective visibility. Example of class attribute and operation, with their respective visibility are discussed in Edward et al., (2016, B). The other class notations such as the association, aggregation, Inheritance, and dependency define the relationship between the classes and subclasses in the diagram, while the multiplicity presents the number of objects that will participate in the relationship as well as the number of instances of one class related to one instance of the other class.

Using this notation, it is possible to represent a physical model of the AWBS as a UML class diagram. To enable the development of such model, we used the “UMLet tool for fast UML diagrams”. This tool contains a graphical editor that supports the proposed notation. In practice, whenever we wish to develop a UML class diagram for a system, we select the class diagram icon from the tool and command the tool to create a new canvas, where we can draw the class diagram. See, for example, Figure 4.

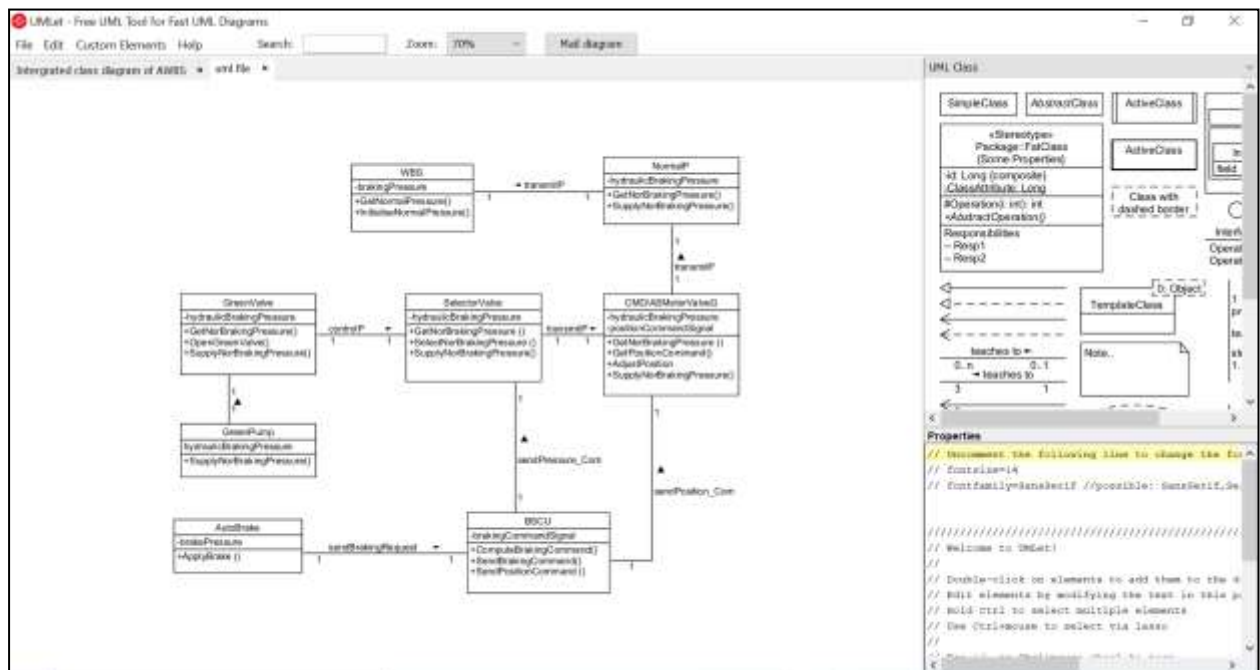


Figure 4: The UMLet modelling editor

Figure 4 presents an example of class diagram for the normal mode of operation of an AWBS. From the example above, we design the class diagram using the notation located at the right corner of the UML class tool. We enter the required information to the diagram through the command line properties located below the notation. The same tool is used for the modelling of the complete modes of operation for the system, as seen in the next section.

6.1 Assessment of Failure at Class Level.

As the modelling of the class diagram proceeds, we identify the basic software components from the hardware model. In this study, we assumed that the hardware and software components are the same. However, the software components are represented as class in the UML class diagram. The failure behaviour of these classes is analysed using FMEA techniques. The FMEA techniques examine the

origins of the software failure within the software components itself. The software failure is referred to as the deviation of parameter at the class output. In other words, it examines the failure behaviour of the classes by considering the software failure at the class level. Moreover, each class can also respond to failure events generated by other classes linked to the class via the relationship elements.

A class, for example, may detect deviation from its input parameters. However, the absence of braking pressure or a pressure below threshold limit generated by a class in AWBS class diagram, can cause a deviation of its class operation. Moreover, the class can mitigate the propagation of such failure. At low pressure level, for example, the class may automatically transit to alternative mode of pressure supply. This illustration clearly represents a case of omission and value failure. However, this study focuses on the omission failure at class level.

To capture the behaviour of the class in the failure domain, we adapted the used of the FMEA techniques. The FMEA is used to examine the failure modes observed in the class operation. Beyond that, however, the method provides a systematic way to examine the detection, the failure effect, and mitigation. Furthermore, a proper description of the class diagram is required for the FMEA examination. For example, a fragment of the class diagram for the AWBS, which represent the green pump and green valve class is presented in figure 5.

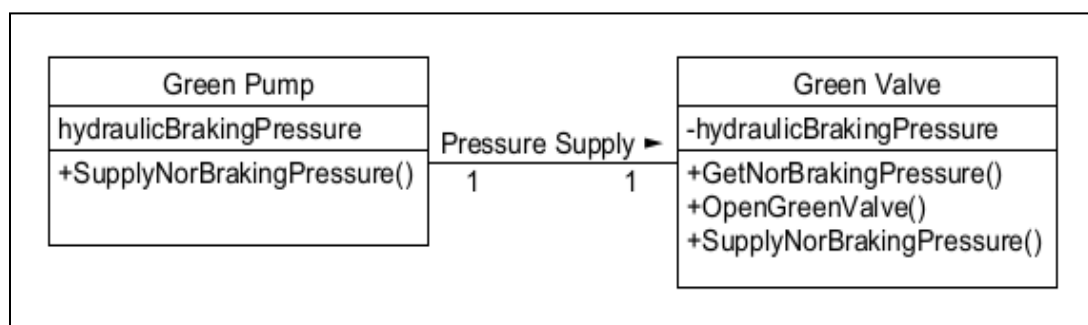


Figure 5: Fragment of the AWBS class diagram

Figure 5 contains a fragment the class diagram of AWBS, it involves the green pump and green valve class. The green valve gets normal braking pressure from the green pump, if there is absence or low braking pressure at the input level, then a failure mode will be examined and recorded at the FMEA table. The failure modes could possibly be defined as Omission of braking pressure at the input level. The FMEA table records how the software task responds to the omission of the class operation. In other words, the table shows how malfunctions of the class operation can affect the performance of the class. The class diagram for the system case and FMEA are presented in the next sections.

6.1 Modelling AWBS Based on Class Diagram

Figure 6 illustrates the class diagram of the AWBS hardware model which provides the basis for the analysis. It can be noticed that all the components of the hardware modelled are defined as the classes. For example, the green and blue pump hardware components are represented by the green pump class and the blue pump class in the model. The representation continues with all the other components. Each class in the model has an attribute which describes the properties of the class. The AWBS braking pressure is one of the properties of the system, which is the main focuses of this paper. Hence, we define the class attributes based on their types of pressure and input command signal. For example, we allocate hydraulic pressure as an attribute to the green and blue pump, while the command signal is defined as the attribute for the BSCU class.

The AWBS components functions are basically used as the software function in the model. And each component function in the hardware model is defined as an operation in the operation box of the class diagram. For example, a hydraulic pressure is supplied by the green pump class, as seen in figure 6. The class attribute determines the amount of hydraulic pressure that will be supplied by the same class before it can be transferred to another class in the model. This model basically uses the association element as the relationship between one UML class and the other. For clarity, the element connects the software classes by adhering to the connection pattern designed in the hardware model.

The generalized UML Class diagram was designed based on Matlab/Simulink format, as described by Guo & Tan (2009). The brake pedal, BSCU, Selector Valve, and WBS classes appear to have a primary function in all modes of AWBS operations. However, the system's three modes of operations are connected to those components, as seen in the class diagram, shown in Figure 6.

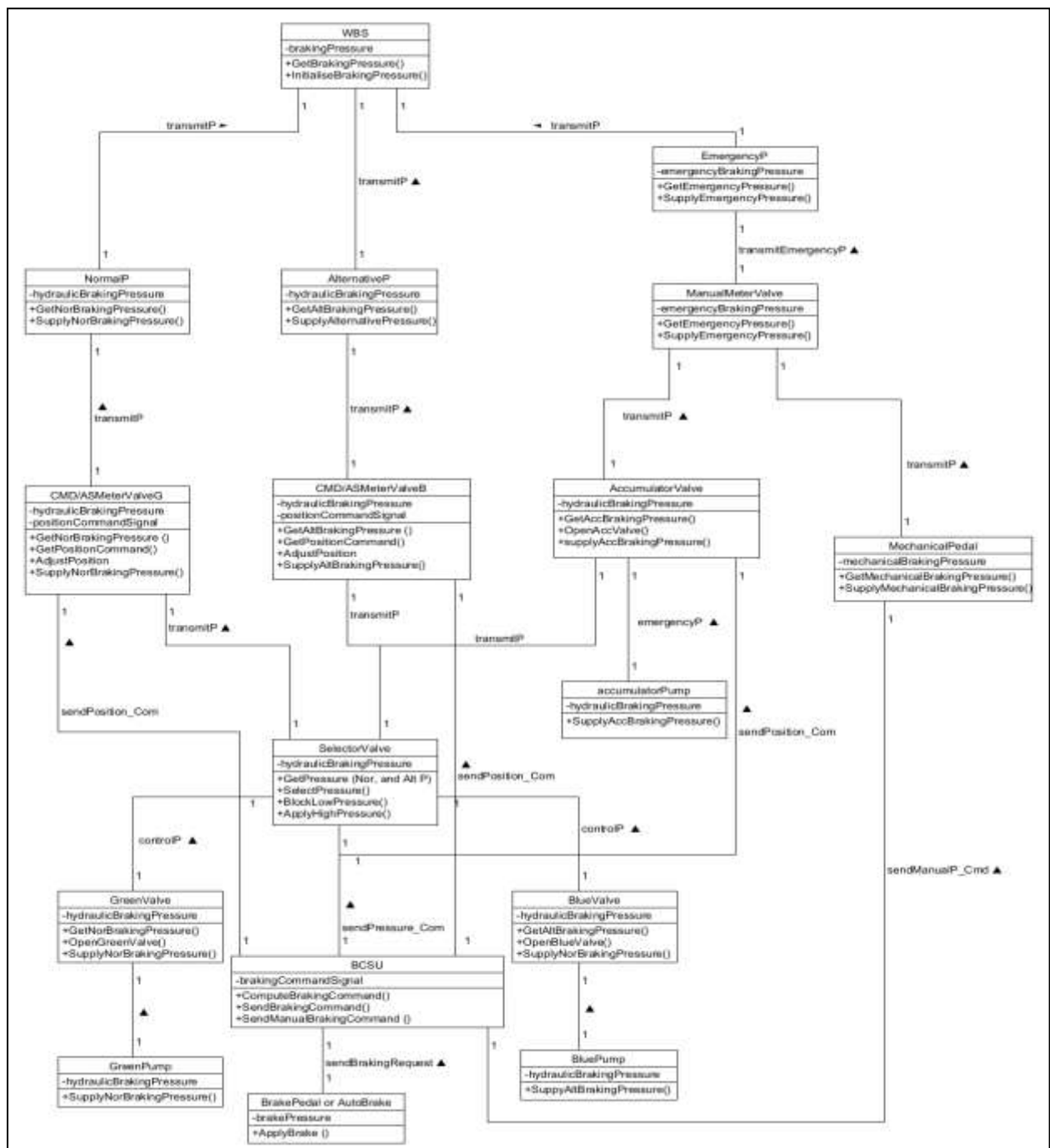


Figure6: Class Diagram for AWBS.

The braking request is sent from the brake pedal class to the BCSU class. The BSCU class computes the request and sends the signal to the selector valve class. The selector valve's main operation is to receive braking pressure, select the pressure of high threshold value and then block low pressure. The green pump class supplies the normal hydraulic braking pressure and transmits the pressure through the green valve class. The pressure is then received by the selector valve class and transmitted to the CMD Meter Valve G class. This class receives a position command signal from the BSCU class and then adjusts the position class to suit the amount of pressure required to go through the normal pressure line. The amount of normal hydraulic braking pressure supplied by the system is then sent to the WBS class for initialisation.

In the event of braking failure, the alternative mode of operation for the AWBS is activated. Moreover, the blue pump class supplies pressure to the blue valve class. The pressure is controlled through the valve shut, and then send to the selector valve class. Whereas the selector valve class receives the alternative pressure and blocks the normal pressure. The pressure is then transmitted to the CMD/AS Meter valve B class. The BSCU class sends a position command to adjust the position of the meter valve B class, thereafter, the valve transmits the pressure to the alternative pressure line. The pressure is then initialised at the WBS class.

In the event of braking failure, the system will transit to emergency modes of operation. Braking pressure command signal is sent by the BSCU class to the selector valve, causing the valve to automatically block the input supplying less or no pressure. However, this will cause the accumulator pump class to automatically supply the accumulative braking pressure to the accumulative valve class. The pressure will then be transmitted as emergency pressure to the manual meter valve class, and further, be transmitted to the emergency pressure line. However, this emergency pressure is received by the WBS class for initialisation.

In the event of braking failure, mechanical braking pressure is supplied by the brake pedal to the mechanical pedal class. The mechanical braking pressure is then transmitted as emergency pressure to the manual meter valve class. The emergency pressure is further transmitted to the emergency pressure line, and later initialised at the WBS class.

Possible failure is generated for each class, if there is no pressure supply to the class, and /or when the pressure supplied is below the threshold limit. For example, if the green pump supplies less hydraulic pressure to the green valve, the green valve class will develop a deviation in pressure, which will lead to its failure. By this illustration, the observed class failure modes could be defined as the omission of braking pressure at class output level. Furthermore, the FMEA technique examines the class failure modes generated for each class operation. The failure modes are presented in the FMEA table, as seen in section 7.

7. Software Failure Analysis

This section adopts the use of FMEA techniques to investigate the failure modes of the software system. The software FMEA table can either be obtained manually or automatically with the use of software tools. However, we use the failure modes generated during class operation, presented in the design class diagram, to manually obtain the FMEA result for the AWBS, as shown in Table 3. Since FMEA is the bottom to the top approach to failure analysis, we started the failure investigation from the bottom of the class diagram, then proceeded to the top components as shown in Figure 6.

The omission of braking pressure at the class level (O-in) leads to the omission of braking pressure at the system level (O-AWBS), as presented in table 3. The omission of braking pressure command from the BSCU class and the selector valve class has a direct effect on the braking pressure at the WBS. Therefore, the severity of the system failure is assumed to be catastrophic.

Table3: Software FMEA of AWBS.

System Failure Mode: Braking Failure of AWBS					
Class	Operation	Class Failure Modes	System Effect	Severity	Mitigation
GreenPump	SupplyNorBrakingPressure()	None	None	None	None
GreenValve	GetNorBrakingPressure()	Omission (O-in)	O-AWB	Marginal	The system should switch to alternative modes.
	OpenGreenValve()	None	None	None	None
	SupplyNorBrakingPressure()	Omission (O-in)	O-AWB	Marginal	The system should switch to alternative modes.
BluePump	SupplyAltBrakingPressure()	None	O-AWB	Marginal	The system should switch to emergency mode.
BlueValve	GetAltBrakingPressure()	Omission (O-in)	O-AWB	Marginal	System should switch to emergency mode.
	OpenBlueValve()	None	None	None	None
	SupplyAltBrakingPressure()	Omission (O-in)	O-AWB	Marginal	The system should switch to emergency mode.
SelectorValve	GetPressure()	Omission (O-in1, O-in2 & O-in3)	O-AWB	Catastrophic	The system should switch to a manual redundant component
	SelectPressure ()	Omission	O-AWB	Catastrophic	The system should switch to a manual

		(O-in1, O-in2 & O-in3)			redundant component
	BlockLowPressure()	Omission (O-in1, O-in2 & O-in3)	O-AWB	Catastrophic	The system should switch to a manual redundant component
	SupplyHighPressure()	Omission (O-in1, O-in2 & O-in3)	O-AWB	Catastrophic	The system should switch to a manual redundant component
CMD/ASMeterValveG	GetNorBrakingPressure()	Omission (O-in1 & O-in2)	O-AWB	Marginal	System should switch to alternative mode.
	GetPositionCommand()	None	None	None	None
	AdjustPosition()	None	None	None	None
	SupplyNorBrakingPressure()	Omission (O-in1 & O-in2)	O-AWB	Marginal	The system should switch to alternative modes.
CMD/ASMeter valveB	GetAltBrakingPressure()	Omission (O-in1 & O-in2)	O-AWB	Marginal	System should switch to emergency mode.
	GetPositionCommand()	None	None	None	None
	AdjustPosition()	None	None	None	None
	SupplyAltBrakingPressure()	Omission (O-in1 & O-in2)	O-AWB	Marginal	The system should switch to emergency mode.

AccumulatorPump	SupplyAccBrakingPressure()	None	None	None	None
AccumulatorValve	GetAccBrakingPressure()	Omission (O-in1, O-in2 & O-in3)	O-AWB	Catastrophic	System should switch to manual operation
	OpenAccValve()	None	None	None	None
	SupplyAccBrakingPressure()	Omission (O-in1, O-in2 & O-in3)	O-AWB	Catastrophic	The system should switch to manual operation
ManualMeterValve	GetEmergencyPressure()	Omission	O-AWB	Catastrophic	Consider redundant system
	SupplyEmergencyPressure()	Omission (O-in1 & O-in2)	O-AWB	Catastrophic	Consider redundant system
NormalP	GetNorBrakingPressure()	Omission (O-in)	O-AWB	Marginal	The system should switch to an alternative mode
	SupplyNorBrakingPressure	Omission (O-in)	O-AWB	Marginal	The system should switch to an alternative mode
AlternativeP	GetAltBrakingPressure()	Omission (O-in)	O-AWB	Marginal	System should switch to emergency mode
	SupplyAltBrakingPressure()	Omission (O-in)	O-AWB	Marginal	The system should switch to emergency mode

Emergency P	GetEmergencyPressure()	Omission (O-in)	O-AWB	Catastrophic	Consider redundant component
	SupplyEmergencyPressure()	Omission (O-in)	O-AWB	Catastrophic	Consider redundant component
MechanicalPedal	GetManualBrakingCommand()	None	None	None	None
	SupplyMechBrakingPressure()	Omission (O-in)	O-AWB	Catastrophic	Consider redundant component
BSCU	ComputeBrakingPressure()	None	None	None	None
	SendBrakingCommand()	None	None	None	None
	SendManualBrakingCommand()	None	None	None	None
WBS	GetBrakingPressure()	Omission (O-in1, O-in2 & O-in3)	O-AWB	Catastrophic	Consider redundant component
	InitialiseBrakingPressure()	Omission (O-in1, O-in2 & O-in3)	O-AWB	Catastrophic	Consider redundant component

The FMEA result in Table 3 clearly shows the operations, its failure modes, and effect on the AWBS. The result defines the class severity effect based on the assumptions made in section 3, and the mitigations for each class are presented with respect to their severity effect. Those classes that developed marginal severity during failure, cause the system to switch to other modes of operation. While those with catastrophic or critical severity effects may cause hazard to both the system and the environment. The failure modes expression for each class is presented in Table 4.

Table 4: AWBS software class and failure modes expression.

Class	Failure Modes Expression
GreenValve	O-in
BlueValve	O-in
SelectorValve	At out1: O-in1 or O-in2
	At out2: O-in3 or O-in2
CMD/ASMeterValveG	O-in1 or O-in2
CMD/ASMeterValveB	O-in1 or O-in2
AccumulatorValve	(O-in1 or O-in2 and) or O-in3
ManualMeterValve	O-in1 or O-in2
NormalP	O-in
AlternativeP	O-in
EmergencyP	O-in
MechanicalPedal	O-in
WBS	(O-in1 and O-in2 and O-in3)

Table 4 above shows the failure modes expression for the AWBS software class. The expression is specified as lists of deviations of parameters at the software component outputs. The GreenPump, BluePump, AccumulatorPump, and AutoBrake class are not stated in the table because they are the starting point of pressure supply and do not have a defined software failure mode.

The analysis provides information that can help in identifying software failures or failure combinations and their severity to the system. Since the AWBS is a complex system and has more than one mode of operation, it will be strenuous to decide whether the basic causes of failure or failure combination of all the modes of operation analysed with the FMEA technique, can lead to the system failure. A study can be conducted to further analyse the weak components identified in the FMEA results.

8. Recommendations and Conclusion

The evolution of hardware and software architecture of complex systems constitutes immense challenges in failure assessment and has revealed insufficiencies in traditional safety analysis techniques. These challenges can be addressed by designing the hardware and software models of the system separately before considering the use of the classical analysis techniques for its failure investigation. This is exactly what this paper demonstrates by using the UML class diagram to design the software models from an existing hardware model of the system case study- AWBS.

The classes describes the static part of the software system, while the activity diagram describes the functional view of the system. It is recommended to design a software models from the hardware architecture of a mechatronics system, during failure analysis process. This process will increase accuracy during software FMEA analysis.

FMEA was conducted separately on each component of the hardware and software models of the AWBS. The analysis result for the AWBS system models presented in this paper clearly show the hardware and software components' failure modes and their severity on the entire system function, which lead to the top system failure mode.

This paper has demonstrated the possibility of performing hardware and software analysis separately on a given case study. This is particularly useful in improving the design of computer-controlled systems. A proposed further work built upon this possibility is to investigate the FMEA results of both hardware and software models, and to establish an approach to mapping both analyses.

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Classification of Honey Botanical and Geographical Sources using Mineral Profiles and Machine Learning

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Abstract

This paper proposes a machine learning-based approach for identifying honey floral and geographical sources using mineral element profiles. The proposed method comprises two steps: preprocessing and classification. The preprocessing phase involves missing-value treatment and data normalization. In the classification phase, we employ various supervised classification models for discriminating between six botanical sources and 13 geographical origins of honey. We test the classifiers' performance on a publicly available honey mineral element dataset. The dataset contains mineral element profiles of honeys from various floral and geographical origins. Results show that mineral element content in honey provides discriminative information useful for classifying honey botanical and geographical sources. Results also show that the Random Forests (RF) classifier obtains the best performance on this dataset, achieving a cross-validation accuracy of 99.30% for classifying honey botanical origins and 98.01% for classifying honey geographical origins.

***Keywords:** Honey botanical origin classification, honey geographical origin classification, mineral elements machine learning; random forests.

1. Introduction

Honey is a nutrient-dense food with several health advantages. It can be categorized into monofloral and polyfloral based on its botanical origin. Unlike polyfloral honey, monofloral honey derives from a single plant source. Mislabelled honey floral sources frequently deceive consumers. As a result, honey authenticity relies on determining the botanical and geographic origins of the honey to guarantee its quality and safety.

In numerous investigations, various approaches for classifying honey floral sources have been proposed (Al-Awadhi & Deshmukh, 2021, A). Traditionally, beekeepers used melissopalynological analysis to identify honey botanical origins. Using a microscope, pollen grains in honey are examined to determine the honey botanical source. Melissopalynology is often accurate, although it takes a long time and requires much effort. Sample preparation and highly-trained specialists are also required (Corvucci et al., 2015). Modern analytical techniques like hyperspectral imaging spectroscopy with machine learning have been used to classify honey botanical sources (Al-Awadhi & Deshmukh, 2021, B), but this technology does not provide information about trace elements in honey. Honey contains various mineral elements at different concentration. The purpose of this study is to examine the efficacy of Machine Learning (ML) algorithms for categorizing honey floral and geographical origins based on mineral element concentration. This research establishes various ML models, such as Support Vector Machines (SVM), Decision Trees, Linear Discriminant Analysis (LDA), Logistic regression, Quadratic Discriminant Analysis (QDA), and Random Forests. It compares their performance on a public honey mineral element dataset.

Utilizing mineral element profiles for identifying honey floral and geographical sources has been considered in some previous works. For example, (Alina et al., 2021) used Soft-Independent Modeling

of Class Analogy (SIMCA) and LDA to classify two geographical origins of honey using isotope ratio analysis coupled with mineral elements. The SIMCA and LDA models achieved classification accuracies of 77% and 85.65% using mineral element profiles. Using isotope coupled with mineral elements, SIMCA and LDA obtained 99% and 98% classification accuracies, respectively. (Squadrone et al., 2020) employed Principal Component Analysis (PCA) and Analysis of Variance (ANOVA) to discriminate between five honey floral sources using 24 mineral elements. The ANOVA analysis showed a significant difference between honey botanical origins using the mineral element content. According to the PCA analysis, the first two PCs explained 77.44% of the variance in the dataset. (Karabagias et al., 2019) utilized LDA and K-Nearest-Neighbors (KNN)-based models for discriminating five botanical origins using mineral element profiles. The authors obtained 67.8% and 78.9% cross-validation accuracies using LDA and KNN, respectively. LDA achieved a cross-validation accuracy of 79.4% using seven mineral elements for classifying various honey botanical origins (Karabagias et al., 2018). Multivariate analysis of variance (MANOVA) and LDA obtained a classification accuracy of 83.8% for classifying four geographical origins of citrus honey using 13 mineral elements (Karabagias et al., 2017).

The dataset utilized in this study consists of 429 instances representing three types of samples: (1) pure honey, (2) adulterated honey, and (3) sugar syrup (Luo, 2020). The falsified honey samples were generated by mixing pure honey samples with sugar syrups at different concentrations. There are six floral sources and 13 geographical origins from which the honey samples come. The floral sources of the honey were Acacia, Rape, Chaste, Linden, Jujube, and T. cochinchinensis (TC). The geographical origins of the pure honey were Liaoning, Shanxi, Jilin, Commodity, Shaanxi, Hebei, Hubei, Henan, Heilongjiang, Jiangxi, Shandong, America, Inner Mongolia. The dataset includes 15 attributes which are 12 mineral element measurements, sample type, botanical origin, region, and level. The mineral elements are Aluminum (Al), Boron (B), Barium (Ba), Zinc (Zn), Calcium (Ca), Strontium (Sr), Iron (Fe), Phosphorus (P), Potassium (K), Sodium (Na), Manganese (Mn), and Magnesium (Mg). Figure 1 and figure 2 show the percentage of the floral and geographical sources of the honey samples in the data set, respectively. The dataset contains missing values for some samples where some mineral elements were not detected (ND). Two previous works on this dataset (Liu, 2021) (Templ & Templ, 2021), but they focused on applying ML techniques to discriminate between pure and impure honey samples. In this study, we use various ML models for classifying the floral and geographical sources of the honey samples.

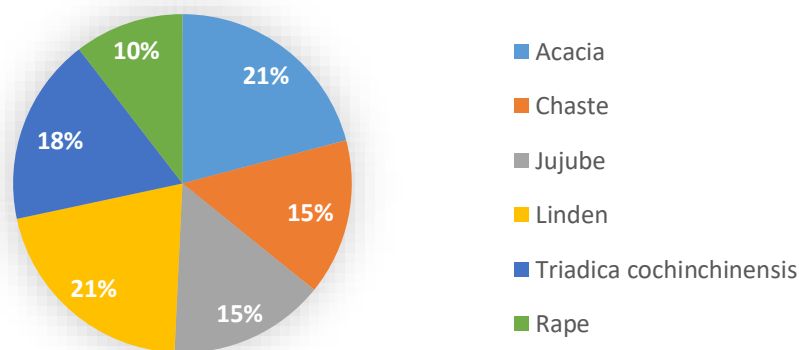


Figure 12: Percentage of the floral sources of honey samples in the dataset

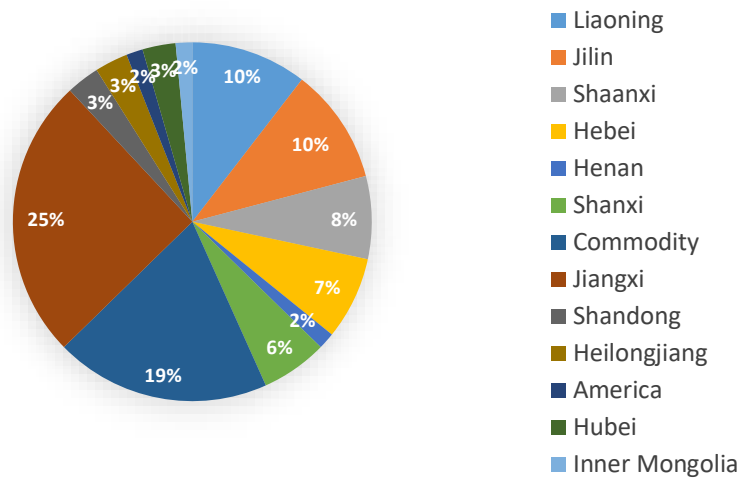


Figure 13: Percentage of the geographical origins of honey samples in the dataset

The remainder of this study is structured as follows. Section 2 describes the proposed approach. In Section 3, the experimental results are presented. Section 4 gives an analysis of the acquired results, and Section 5 concludes the paper.

2. Proposed Approach

The honey floral source classification method proposed in this paper, depicted in figure 3, comprises two main stages: preprocessing and classification. These two stages are described in detail in the following subsections.

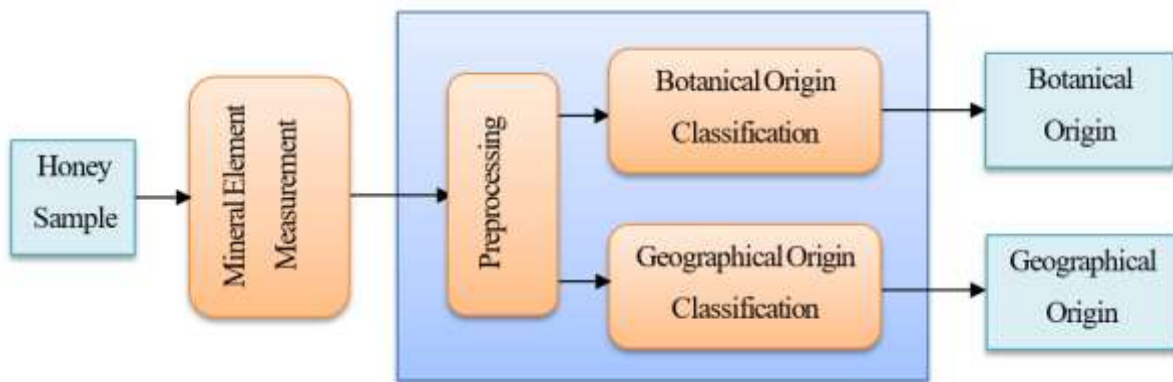


Figure 14: The suggested system's block diagram

2.1 Preprocessing

This phase consists of two steps. The first step entails filling missing values in the dataset with zeros since these missing values represent the absence of mineral elements in honey samples. Since data normalization helps improve the classification performance of ML models, we normalize the attributes in the dataset to the interval between zero and one using the min-max normalization method (Singh & Singh, 2020) given by equation 1.

$$X'_o = \frac{X_o - \min(X_o)}{\max(X_o) - \min(X_o)} \quad (1)$$

where X_o and X'_o are the original and normalized values, respectively.

2.2 Classification

We use various supervised machine learning models to discriminate between honey botanical and geographical origins in this phase. The ML models are SVM, LDA, QDA, Logistic Regression, Decision Tree, and Random Forests. SVM is a supervised ML model first introduced by (Cortes and Vapnik, 1995). It has been successfully used in many classification problems. There are three common functions: linear, polynomial, and radial that can be used as kernel functions of SVM. In addition, SVM is distinguished for its generalization capability and can also be utilized to solve regression problems. LDA is a linear supervised ML model used to extract and classify features. An essential aspect of LDA is changing the original features into a new dimensional feature space where the distance between classes is maximized and the variance with each class is minimized (Tharwat et al., 2017). QDA is a nonlinear variant of LDA suitable for linearly inseparable datasets.

Logistic Regression (LR) is an ML predictive analytic approach that can solve classification tasks based on the probability concept (Tsangaratos & Iliam, 2016). A Decision Tree is a supervised learning model that can solve classification and regression problems. Decision tree-based classifiers are easy to interpret, work with numeric and categorical attributes, and solve binary and multi-class problems (Safavian & Landgrebe, 1991). Like decision trees, Random Forest (RF) is a supervised learning approach capable of carrying out both classification and regression tasks. The RF algorithm is based on the construction of many decision trees. The trees vote for the class with the most votes (Breiman, 2001).

To assess the ML models' performance, we employed 10-fold cross-validation accuracy. Cross-validation has the advantage of avoiding model overfitting. The performance criteria employed were the correct classification accuracy, precision, recall, and F-measure. Precision is the proportion of precisely anticipated positive observations relative to the total number of positive observations expected. We define the recall metric as the proportion of correctly predicted positive observations to all actual class observations. The F-measure represents the weighted mean of precision and recall. Consequently, this Score produces both false positives and false negatives. F-measure is a useful performance metric, especially for uneven data sets.

3 Results

We report the achievement of the ML models for identifying honey floral and geographical sources using mineral element profiles in this section.

3.1 Classification of Honey Botanical Origins

We assessed how well the ML models performed in distinguishing the botanical origins of honey using the original dataset, which includes instances of pure and impure honey and instances of sugar syrups. The performance of ML models was also evaluated using the pure and impure honey subsets.

3.1.1 Classification of Honey Botanical Origins using Pure Honey Dataset

The classification performance of the models for identifying the botanical origins of honey using the pure honey dataset is shown in Table 1 and Figure 4. Results reveal that the random forest classifier achieves excellent performance for discriminating between honey floral sources, where it got the

highest classification accuracy of 99.50% outperforming other classifiers. On the other hand, the SVM classifier achieved the lowest accuracy of 70.65% for classifying the botanical origins of pure honey samples. The logistic regression and decision tree classifiers performed well on this dataset, where they achieved similar classification accuracies near 93%. The linear discriminant analysis classifier did not perform well on this dataset, but the quadratic variant of LDA performed well where it achieved a classification accuracy of 91.54%.

Table 3: ML classifiers performance for identifying honey floral sources using the pure honey dataset

ML Model	Accuracy	Precision	Recall	F-Measure
SVM	70.65	0.705	0.706	0.696
LDA	75.12	0.764	0.751	0.750
QDA	91.54	0.918	0.915	0.914
LR	93.53	0.937	0.935	0.936
DT	93.03	0.935	0.930	0.931
RF	99.50	0.995	0.995	0.995

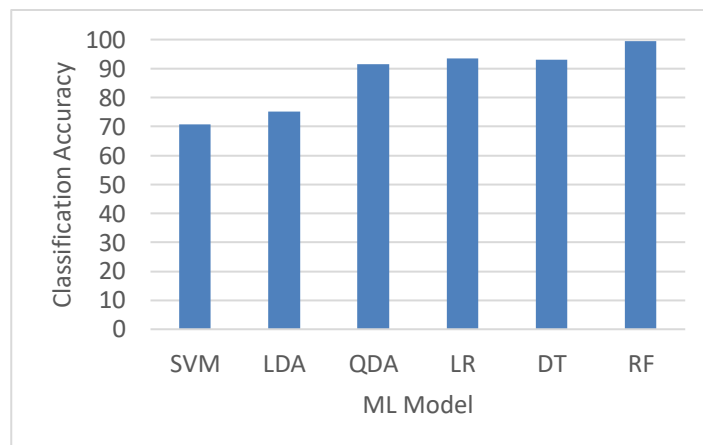


Figure 15: ML classifiers' performance on the pure honey dataset

3.1.2 Classification of Honey Botanical Origins using Adulterated Honey Dataset.

Table 2 and Figure 5 illustrate the achievement of the machine learning algorithms for identifying honey floral sources using the adulterated honey sample dataset. The random forests classifier was superior to its performance using the pure honey dataset, achieving the highest classification accuracy of 99.44%. The performance of the SVM model has improved on this data set, where it obtained an accuracy of 99.22%, outperforming the decision tree classifier. The LDA classifier obtained an accuracy of 92.22%, similar to the SVM classifier, but the quadratic variant of LDA got a better accuracy of 94.44%. The logistic regression classifier obtained an outstanding performance of 97.22% on this data subset, outperforming its performance on the pure honey sample dataset.

Table 4 ML classifiers performance for identifying honey floral sources using the impure honey dataset

ML Model	Accuracy	Precision	Recall	F-Measure
SVM	92.22	0.928	0.922	0.922
LDA	92.22	0.923	0.922	0.923
QDA	94.44	0.951	0.944	0.946
LR	97.22	0.973	0.972	0.972
DT	87.22	0.876	0.872	0.873
RF	99.44	0.995	0.994	0.994

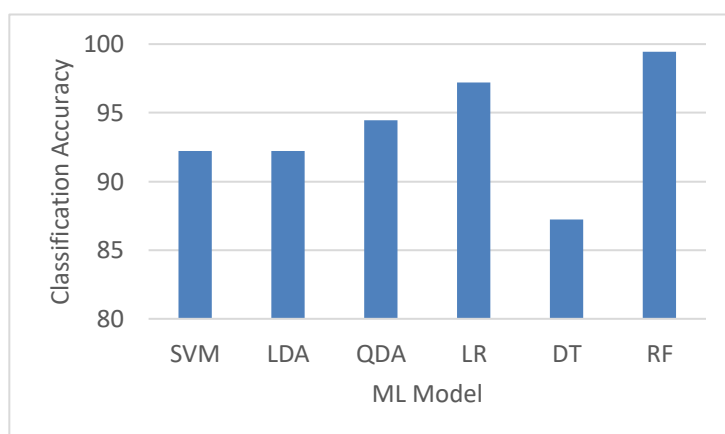


Figure 16: ML classifiers' performance on the adulterated honey dataset

3.1.3 Classification Honey Botanical Origins using Original Dataset

Table 3 and figure 6 show the achievement of the ML classifiers for identifying honey floral sources using the original dataset, which contains instances of pure and impure honey samples and instances of sugar syrup. Generally, the ML models show outstanding performance in identifying honey floral sources using mineral element profiles. The RF-based classifier achieved the highest prediction accuracy of 99.30%, outperforming other classifiers. The accuracy achieved by the random forest classifier on this dataset is slightly lower than the accuracy achieved on the pure and impure honey sample datasets since the original dataset includes instances of sugar syrup samples and pure and impure honey samples. The LDA classifier obtained the lowest accuracy of 75.82% on this dataset, but the nonlinear LDA obtained better performance indicating the dataset is linearly inseparable. The decision tree classifier obtained a cross-validation accuracy of 94.84%, similar to the accuracy obtained by QDA.

Table 5: ML classifiers performance for identifying honey floral sources using the original dataset

ML Model	Accuracy	Precision	Recall	F-Measure
SVM	77.93	0.793	0.779	0.779
LDA	75.82	0.779	0.758	0.762
QDA	94.60	0.947	0.946	0.946
LR	90.85	0.909	0.908	0.909
DT	94.84	0.949	0.948	0.940
RF	99.30	0.993	0.993	0.993

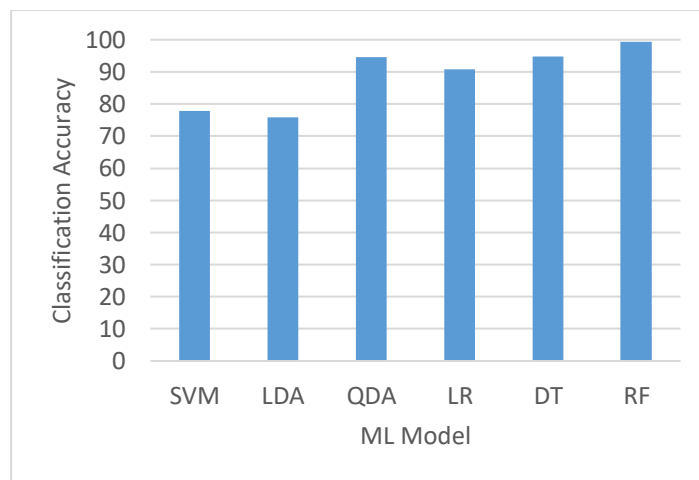


Figure 17: ML classifiers' performance on the original dataset

Table 4 displays the detailed performance of the RF model for each floral source. The results demonstrate that the RF-based classifier successfully classifies the acacia, chaste, and TC honey samples and sugar syrup samples with 100% accuracy. Besides that, the random forest classifies honey samples from other botanical origins with a high accuracy near 98%.

Table 6: Random forests detailed performance by class

Class	TP Rate	FP Rate	Precision	Recall	F-Measure
Acacia	1.000	0.000	1.000	1.000	1.000
Chaste	1.000	0.003	0.984	1.000	0.992
Jujube	0.983	0.000	1.000	0.983	0.992
Linden	0.986	0.000	1.000	0.986	0.993
Rape	0.980	0.003	0.980	0.980	0.980
TC	1.000	0.003	0.985	1.000	0.992
Syrup	1.000	0.000	1.000	1.000	1.000

3.2 Classification of Honey Geographical Origins

In this subsection, we present the achievement of the ML models for discriminating between the geographical origins of honey. We used the pure honey sample dataset to evaluate the effectiveness of the ML algorithms since the geographical regions of the adulterated honey samples were not provided in the original dataset. Table 5 and figure 7 show the achievement of the ML classifiers for discriminating between the geographical sources of honey. The results indicate that the random forests model achieved the best performance with a cross-validation accuracy of 98.01% for discriminating between honey geographical origins, outperforming other classifiers on this dataset. While SVM and the two variants of LDA performed poorly on this dataset, the decision tree classifier performed better with a correct classification accuracy of 83.58%. Some precision and f-score values are missing for the SVM and QDA since these two classifiers could not classify instances of honey samples from some geographical origins.

Table 7: Performance of ML models for classifying honey samples to their geographical origins

ML Model	Accuracy	Precision	Recall	F-Measure
SVM	42.79	?	0.428	?
LDA	57.71	0.611	0.577	0.581
QDA	62.69	?	0.627	?
LR	76.62	0.781	0.766	0.765
DT	83.58	0.836	0.836	0.833
RF	98.01	0.981	0.980	0.980

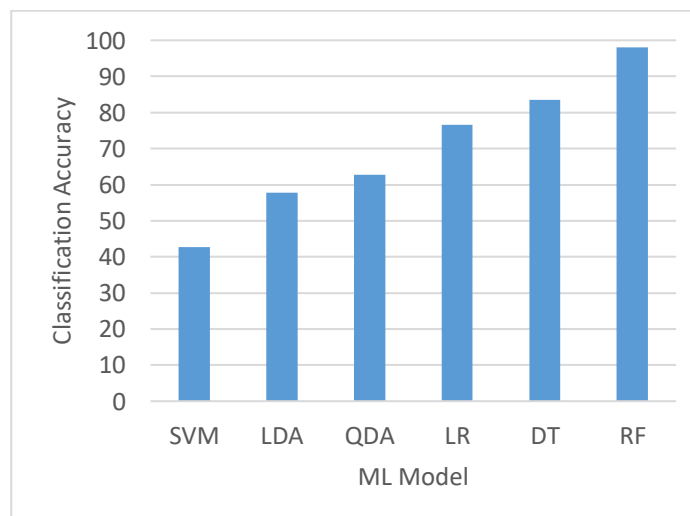


Figure 18: Performance of ML models for classifying honey samples to their geographical origins

Table 6 displays the effectiveness of the Random Forests model for identifying the geographical sources of honey samples in the dataset. The results demonstrate that the random forests model accurately classifies nine geographical origins with an accuracy of 100%. Besides that, the random forests model

classifies three geographical origins with high accuracy near 97%. The random forests model classifies the American geographical origin with a low accuracy of 67%.

Table 8: Detailed accuracy of RF classifier for each geographical origin

Class	TP Rate	FP Rate	Precision	Recall	F-Measure
Liaoning	1.000	0.011	0.913	1.000	0.955
Jilin	0.952	0.000	1.000	0.952	0.976
Shaanxi	1.000	0.000	1.000	1.000	1.000
Hebei	0.933	0.000	1.000	0.933	0.966
Henan	1.000	0.000	1.000	1.000	1.000
Shanxi	1.000	0.000	1.000	1.000	1.000
Commodity	0.974	0.006	0.974	0.974	0.974
Jiangxi	1.000	0.007	0.981	1.000	0.990
Shandong	1.000	0.000	1.000	1.000	1.000
Heilongjiang	1.000	0.000	1.000	1.000	1.000
America	0.667	0.000	1.000	0.667	0.800
Hubei	1.000	0.000	1.000	1.000	1.000
Inner Mongolia	1.000	0.000	1.000	1.000	1.000

4 Discussion

This research employed several supervised ML algorithms for classifying honey floral and geographical sources using mineral element profiles. Before classification, we filled missing values of some attributes with zeros since these missing values represent the absence of mineral elements in some honey and sugar syrup samples. After that, we normalized the dataset attributes since normalization speeds up ML model training and helped produce consistent results. To classify honey floral and geographical origins, we used linear classifiers, such as linear-kernel SVM, LDA, and logistic regression, and nonlinear classification models, such as decision trees and random forests. Generally, results show that ML models show an outstanding performance in classifying honey botanical and geographical origins using mineral element profiles. The nonlinear classifiers outperformed linear classifiers confirming that the dataset is linearly inseparable. The random forests model had the best cross-validation accuracy when distinguishing between botanical and geographic sources. Most classifiers, except random forests, performed well for identifying honey botanical sources but performed poorly in recognizing honey geographical origins because floral sources in the dataset were fewer than the geographical origins. Results show that ML models can identify honey botanical origins whether the honey samples were pure or impure with various sugar syrups. Table 7 compares the results of the proposed approach to the results obtained in previous work. Results reveal that the method proposed in this study achieves the highest cross-validation accuracy for classifying honey botanical and geographical origins, outperforming the models developed in previous work.

Table 9: Comparison with previous work for classifying honey botanical and geographical origins

¹BO: Botanical Origin, ²GO: Geographical Origin, ³ME: Mineral Elements, ⁴GOC: Geographical Origin Classification, ⁵BOC: Botanical Origin Classification.

Reference	Aim	BO	GO	ME	ML Models	Accuracy
D. Alina et al. [4]	GOC ⁴	12	2	7	SIMCA	77%
					LDA	85.65%
S. Squadrone et al. [5]	BOC ⁵	5	-	24	PCA ANOVA	VAR (PC1, PC2) = 77.44 %
I. K. Karabagias et al. [6-8]	BOC	5	5	9	LDA KNN	67.8% 78.9%
	BOC	various	-	7	LDA	79.4%
	GOC	-	4	13	LDA	83.8%
Proposed System	BOC GOC	6	13	11	Random Forests	BO = 99.30% GO = 98.01%

4. Conclusion

This research established a machine learning-based approach for distinguishing honey floral and geographical origins using mineral element profiles. The developed system consists of two stages: preprocessing and classification. The preprocessing stage involves filling missing values and normalization. We used several supervised ML models for discriminating between honey botanical and geographical origins in the classification phase. Experimental findings show that mineral element profiles provide robust discriminative information that machine learning models can classify various honey botanical and geographical origins. Results also reveal that adulterating honey by different sugar syrups has no significant impact on the performance of ML models for classifying honey flora and geographical sources. Findings also demonstrate that the random forests classifier achieves the highest classification accuracy on this dataset for discriminating between honey botanical and geographical origins.

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Multimedia Systems, Social Media and Media Relations in Private Universities

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Abstract.

The focus of this paper is on the dynamism of Media relations. Media relations is becoming more dynamic in providing news subsidy on behalf of their organizations to prospective students, target customers and consumers through the multimedia systems and social media. Corporate organizations, educational institutions, businesses entities' public relations officers must learn how to use multimedia and social media in a way that is consistent in this digital age to attract customers, consumers and prospective students to their organizations. This paper used descriptive survey methodology ; driven by Mediamorphosis Theory and Technological Determinism Theory of Marshall McLuhan. The findings show that multimedia and social media are veritable technological tools of communication to reach out to prospective students for admission drive and e-learning environment. Private Universities should operate at least three social media accounts in any of these platforms - Youtube, Instagram, Facebook, Twitter, Phoneix, Ayoba and others. Multimedia systems should be used for networking and collaboration with other institutions both home and abroad. When selecting social media platforms media relations officers should choose platforms that their target prospective students operate to relate and offer them admission opportunities without stress.

Keywords: Multimedia System, Social Media, Media Relations, Private Universities.

1. Introduction

A Multimedia System is a system capable of processing multimedia data and applications. It is characterized by the processing, storage, generation, manipulation and rendition of Multimedia information services.

Media relations is an arm of public relations in organisations for the purpose of informing the public of an organization's mission, policies and practices in a positive, consistent and credible manner. This means coordinating directly with the people responsible for producing the news and features in the mass media. The goal of media relations is to maximize positive coverage in the mass media without paying for it directly through advertising. Social media are now special tools in reaching out to the youth especially target undergraduate that seek for admission in private universities. Social media are being used by billions of people around the world and has become some of the veritable advertising outlets for private universities such as Thomas Adewumi University to create awareness to attract student attention.

Boyd & Ellison, (2008) see social media as a platform which allow business owners and their target clients, customers and consumers do relate together for awareness creation and visibility of services and products. Coremetrics (2010) is of the view that social media is one of the fastest growing marketing channels in the world. This has resulted in the transition within the advertising and marketing communications industry from a one way communication in the media to an interactive approaches towards synergistic integration of companies and higher

institutions strategic communication to reach out to target customers. In opposition to the paid online media advertising (banner, text and search), social networks marketing (SNM) involves viral consumer-to-consumer communications by creating company 's brand fan pages and managing promotions and public relations within the most popular social media networks, such as Facebook, YouTube and Twitter, Facebook, for example, according to report, they have about 2.38 billion monthly active users and 1.56 billion daily active users as of March 31 as at 2019 (Facebook,2019). Evans (2009) opines that such social networks applications such as service sharing and voting, collaborative design and service launch announcements may provide relevance, immediacy and convenience to customers, as publicity and brand name recognition to the company. Internet Advertising Bureau (2010) also observes that this marketing medium has a lot of advantages to educational institutions such as Thomas Adewumi University due to its moderate school fees and the flexibility in which the University media relation officers can make use of the social networks for both marketing and new programmes development to attract more students .

2.0 Methodology

This paper used descriptive survey for the study. Wimmers and Dominick, (2006) see descriptive survey as research designed to obtain pertinent and precise information concerning the existing status of phenomena and whenever possible, to draw valid generalisations for the facts discovered without making any interference or control over the situation. Such type of studies are restricted not only to fact finding but may often result in the formulation of important principles of knowledge and solution of significant problems concerning local, state, national and international issues. Edafejrhaye and Ogunwuyi (2022) opine that descriptive surveys collect and provide three types of information:

- (i) of what exists with respect to variables or conditions in a situation;
- (ii) of what we want by identifying standards or norms with which to compare the present conditions or what experts consider to be desirable; and
- (iii) of how to achieve a goal, by exploring possible ways and means on the basis of the experience of others or opinions of experts.

Descriptive surveys investigate phenomena in their natural setting. Their purpose is both immediate and long range. They constitute a primitive type research, and do not aspire to develop an organized body of scientific laws. Such surveys, however, provide information useful to the solution of problems and at times provide data to form the basis of research of a more fundamental nature to drive social media advertising.

2.1 Literature Review

The Literature review for this work covers conceptual, theoretical and empirical frameworks.

2.2 Conceptual Analysis

Thomas Adewumi University

Thomas Adewumi University (TAU) is one of the private Universities in Nigeria. It is located in Oko - Irese town near Omu-Aran town in Irepodun Local Government Area of Kwara State.

The founder, Engr. Dr. Johnson O Adewumi of Thomas Adewumi University undertook to establish a University as a logical progression of its efforts in the provision of qualitative education at the primary and secondary school levels. The ethos of Thomas Adewumi University is excellence and the institution aims to become a major and key player in the delivery of University education of the highest quality in Nigeria as well as to produce graduates that would benefit themselves and the human capital for the rapid and much socio-economic development of the country. It is a University that is fully engulph in green energy and multimedia utilization. Like every other new private universities that are out to get more students, multimedia and social media are some of the tools of advertising the media relations department should use to reach out to their prospective students.

2.3 Multimedia Systems and Applications

A Multimedia System is a system capable of processing multimedia data and applications. It is characterized by the processing, storage, generation, manipulation and rendition of Multimedia information. A Multimedia systems has four basic characteristics according to Pavithra, Aathilingam and Prakash (2018).

1. Multimedia systems must be computer driven. Producing the content of the information – e.g. by using the authoring tools, image editor, sound and video editor Storing the information – providing large and shared capacity for multimedia information. Transmitting the information – through the network.ω Presenting the information to the end user – make direct use of computer peripheral such as display device (monitor) or sound generator (speaker).
2. Multimedia systems are integrated in one set. All multimedia components (audio, video, text, graphics) used in the system must be somehow integrated. Every device, such as microphone and camera are connected to and controlled by a single computer. A single type of digital storage is used for all media type. Video sequences are shown on computer screen instead of TV monitor.
3. The information they handle must be represented digitally. Digitization process involve in transforming an analog signal to digital signal.
4. The interface to the final presentation of media is usually interactive. Interactivity means:
 - 1: Interactivity strictly on information delivery. Users select the time at which the presentation starts, the order, the speed and the form of the presentation itself.
 - 2: Users can modify or enrich the content ofω the information, and this modification is recorded.
 - 3: Actual processing of users input and the computer generate genuine result based on the users input.

Multimedia Systems Devices

Capture Devices

1. Video Camera
2. Video Recorder
3. Audio recorder and microphone
4. Keyboards
5. Mice
6. Graphics tablets

7. 3D input devices
8. Tactile sensors
9. VR devices
10. Digitizing/Sampling Hardware

Multimedia Storage Devices

Storage Devices

1. Hard disk drive
2. Zip drive
3. Compact Disc
4. Digital Versatile Disc
5. Bluray Disc and others.

Multimedia Display Devices

1. High resolution monitor
2. High quality speakers
3. Colour printer

Communication Networks

1. Ethernet
2. Token Ring
3. Fiber Distributed Data Interface (FDDI)
4. Asynchronous Transfer Mode
5. Intranets
6. Internets Projector

2.4 Applications of Multimedia

Education

Pavithra et al (2018) posit that multimedia combining respective media in a set for information dissemination and use in the field of education and training. Even in conventional method we use audio visual for imparting education, where charts, models etc. were used. Nowadays the classroom demand is not limited to that accepted method instead it needs audio and visual media. The multimedia incorporates all of them in one system. For the use of multimedia as an education assistance the PC integrated a high quality display. This has advanced the improvement of a wider scope of computer based training.

Multimedia in Training

This multi-purpose system and intelligent tutoring systems is handy in training students in various areas ranging from the mathematics to a difficult surgical process for medical students. Clear audio/video clips could be seen during training section.

Science and Technology

Multimedia had a broad application in the field of science, researchers and industrial technology. The multimedia system is competent of transferring audio/video in addition to the regular text. It is even capable of sending message and formatted multimedia documents. At the same time the multimedia also helpful in live coverage and interactive interview through live broadcasting. It manages the time and cost. And it can be arranged at any moment even in emergencies. It is adequate for communication and conference meetings.

Medicine

In medicine, doctors can get trained by looking at a virtual surgery or they can simulate how the human body is affected by diseases spread by viruses and bacteria and then develop techniques to prevent it. Multimedia applications such as virtual surgeries also help doctors to get practical training.

Multimedia in Business

The business application of multimedia includes, product demos, instant messaging. Some of the excellent applications are voices and live conferencing. A multimedia can make a audience come live. It is widely used in business programmes. Such a program can be used by artisans and traders. There are a number of easy to use authoring programmes and tools that can even let workers to create their own program. There are a number of applications available being used to run such programmes.

Multimedia in Games

One of the most exciting applications of multimedia is games. Now days the live internet pay to play live sport with multiple players has become popular. Actually the first application of multimedia system was in the field of soccer entertainment and in the video game industry. The integrated audio and video effects make various types of games more entertaining.

Creative industries

Creative industries use multimedia for a variety of purposes ranging from fine arts, to entertainment, to commercial art, to journalism, to media and software services provided for any of the industries listed below. An individual multimedia designer may cover the spectrum throughout their career. Request for their skills range from technical, to analytical, to creative.

Language Communication

With the spread and development of the English language around the world, it has become an important way of communicating between different people and cultures. Multimedia technology creates a platform where language can be taught. The traditional form of teaching English as a second language (ESL) in classrooms have drastically changed with the prevalence of technology, making easier for students to obtain language learning skills. Multimedia motivates students to learn more languages through audio, visual and animation support. It also helps create English contexts since an important aspect of learning a language is developing their grammar, vocabulary and knowledge of pragmatics and genres. In addition, cultural connections in terms of forms, contexts, meanings and ideologies have to be constructed. By improving thought patterns, multimedia develops students' communicative competence.

With the above overwhelming applications of multimedia the media relations officers could exploit together with the social media to boost the status and image of Thomas Adewumi University to attract and train more students.

2.5 Media Relations

Richard Weiner (1990) views media relation as a branch of public relations which promote mutual relations of organizational interest, visibility, activities and influence. Onabajo (2005:13) defines media relations as a two-way operational link between an organisation and the media, comprising the press, radio and television. The organisation, on the other hand, supplies information and provides facilities to the media on request while, on the other hand, it takes steps to initiate comments and news. This rightly implies that media relations are concerned with corporate organisation's deliberate and conscious effort at seeking and achieving the cooperation of the media. Organisations need this profitable relationship to splash off negative media coverage.

Nkwocha (1999:43-44) sees media relations as public relations function which establishes and maintains mutual understanding, goodwill, co-operation, respect and support between an organisation and the mass media practitioners/owners with the aim of achieving public relations objectives. He further isolates the objectives of media relations to include establishing and sustaining cordial relationships between an organisation and media houses; ensuring that organisations get sufficient and positive coverage of their products, services and activities; and to explain organisations' policies and actions to media men particularly in crisis situations.

Purpose of Media Relations

The main goal of media relations is to communicate an organization's newsworthy message, story or information via the appropriate media outlets. By serving as a credible, third-party endorsement, media relations is a powerful tool that can enhance brand's reputation thus, influence positively the perceptions and behavior of your target audience. In addition, media relations can help achieve specific business goals, such as:

- a. Building greater brand awareness
- b. Enhancing Corporate Image.
- c. Positioning organization and its experts as thought leaders
- d. Growing the online presence or visibility of corporate brand
- e. Attracting more business patronage

Hence , media relations officers in Thomas Adewumi University can make land mark achievement by attracting more student through the social media.

2.6 Social Media

Social media are digital media in the internet through which people communicate socially. Some examples of Social media are facebook, twitter, Whatsapp and may others. Smith (2013) argues that social media enables the development of the relationship between marketing and public relations by enabling a greater capacity of interaction and relationship cultivation.

Sinclair and Vogus (2011) affirm that large companies are regarding social media sites as strategic tools and some businesses are even hiring employees to oversee their social media pages:

Consumers are no longer passive receivers of marketing messages; instead, they are using Facebook, MySpace, YouTube, and Twitter to voice their opinions-both positive and negative” (Sinclair and Vogus 2011, 293).

Since social media sites can be exploited for the information it provides on consumer behaviour with regards to their purchasing intentions, research further suggests that businesses should incorporate social networking sites into their business model or promotional mix.

Mangold and Faulds (2009) recommend that social media should be regarded as an integral part of an organization’s integrated marketing strategy and should not be taken lightly. Valentini and Kruckeberg (2012, p. 11) argue that social media must be at the heart of public relations activities because social media can enhance organization relationships by increasing and improving community relations. Zhang, Jansen, and Chowdhury (2011) emphasise that businesses should have a brand presence on many different social media sites to increase their consumers. Businesses are realizing the need to create their own brand presences on social media not only to control some of its brand marketing, but also to stay informed and keep track of the consumer-generated comments about their brand. According to Curran et al. (2011), social media sites such as Facebook are better than other advertising avenues because it stores information for all its users thus ensuring marketing reaches a retailer’s target market.

Curran et al. (2011) avow that almost one in every thirteen person in the world is an active Facebook user, which points to the potential of finding a ready market for any product or service. Heinonen (2011) sees the platform as a vital stage for retailers and marketers to be aware of the factors that affect consumer attitudes and motives because consumers are increasingly creating content about brands, something previously controlled solely by companies. Hence, media relations officers in private universities should exploit the social media for visibility and admission drive.

3.0 Theoretical Framework

This work is anchored on the technological determinism theory of Marshall McLuhan and Mediamorphosis Theory

3.1 Technological Determinism Theory by Marshall McLuhan

Technological determinism is defined as an approach that identifies technology, or technological advances, as the central cause of element in processes of social change (Croteau and Hoynes, 2001). Technological determinism is a reductionist theory that presumes that a society's technology drives the development of its social structure and cultural values. The term is believed to have been coined by Thorstein Veblen (1857–1929), an American sociologist. The most radical technological determinist in the United States in the twentieth century was most likely Clarence Ayres who was a follower of Thorstein Veblen and John Dewey. William Ogburn was also known for his radical technological determinism (Talabi, 2015).

The first major elaboration of technological determinism according to Solo-Anaeto & Babafemi, (2015) came from the German philosopher and economist Karl Marx, whose theoretical framework was based upon the idea that changes in technology and productive technology are the primary influence on the organization of social relations, and that social relations and cultural practices ultimately revolve around the technological and economic base of a society. Marx's position has become embedded in contemporary society, where the idea that fast changing technologies alter human lives is all-pervasive.

The Theory Assumptions

According to McQuail (2005), technological determinism theory lies on the following assumptions:

1. Communication technology is basic to society. It is the life blood of any society.
2. Technology drives change in all forms of media industries.
3. Each technology is tilted towards particular communication forms, contents and uses.
4. The sequence of invention and application of technology influence social change.
5. Communication revolutions engender social revolutions.
6. New media undermines old bases of power.

As a theory, technological determinism explains that when new systems of technology are developed; the culture or society is immediately changed to reflect the senses needed to use the new technology. It predicts that with every new technological equipment, members of the society change and adapt to that technology. They probably will dispose of older technological equipment and rush to get new ones. This is on the belief that it will affect their status in the society. Members of the society can either use the technological equipment or software to sustain their culture or use it to embrace another culture which is not their own (Wacyman, 2002; Solo-Anaeto & Babafemi, 2015; Asekun-Olarinmoye, Ibbi & Edafejrhaye, 2018).

There is a simple cause and effect analysis between the introduction of new technology, the way the media operates and the changes in society's way of thinking, feeling, or acting. This

theory provides an insight into the use of internet and social media for communication in modern times. Following the internet and its advantages in easing communication, more and more users are getting on with the social media, especially young people who are the target of private university's admission. There are more than 1.32 billion monthly active users (as of June 2014) on the Internet (Tufts University, 2015, Solo-Anaeto & Babafemi, 2015).

Technological determinism seeks to show technical developments, media, or technology as a whole, as the key mover in history and social change. Most interpretations of technological determinism share three general ideas:

- a. That the development of technology itself follows a predictable, traceable path largely beyond cultural or political influence
- b. that technology in turn has "effects" on societies that are inherent, rather than socially conditioned or produced because that society organizes itself to support and further develop a technology once it has been introduced (Ukonu, Nkoro, & Agbo 2013; Edafejrhaye, 2016).
- c. Younger generation are glued to social media for information and advertising needs (Edafejrhaye, 2022).

3.2 Mediamorphosis Theory

The term Mediamorphosis was coined by Roger Fidler in 1990 but propounded as a theory in 1997 by the same scholar. Fidler offered the theory as a comprehensive framework that charts the evolution and interaction between media forms for communication. In this case: between old versus new media technologies for online advertising, teaching i.e. classroom lectures with textbooks and virtual education using computers, the internet, and blogs. According to Fidler (1997), Mediamorphosis is "the transformation of communication media, usually brought about by a complex interplay of perceived needs, competitive and political pressures, and social and technological innovation". The term is also known as digital metamorphosis i.e. the transformation from oral literature to digital media.

Assumptions of the Theory

The assumptions are:

1. New media do not arise instantaneously or devoid of external influence. New innovations are linked to old ones. To put this in a context, adoption and acceptance of social media blogs for teaching was necessarily a result of limitations associated with the conventional methods of teaching advertising. Hence; evolving new ways of persuasive communication to reach out to younger generation is in order as Yusuf (2010) observes.
2. When new media emerges the old ones do not die; they continue to evolve and adapt and retain the traits from the domain from which they evolved. Thus, the use of blogs for teaching is not to replace the conventional method, rather to complement and function as an effective supplement to it. Social Media will continue to remain a complimentary factor to the traditional media even in media relations.

Relevance of the theories

Technological determinism and Mediamorphosis theories posit that new technology drives society and influences social changes; society members adopt and change to fit to new

technological inventions. This can be said to be the case of international broadcasting being used as tool of international diplomacy as observed by Edafejrhaye (2016) and social media as a new means of quick communication (solo-Anaeto & Babafemi, 2015). Users of Social media keep increasing by the day. Ohiagu and Okorie (2014) put the figure at “25 percent of the global online population has joined social media networking sites” especially among young people who embraced whole heartedly as major means of communication. It is seen as a sign of social relevance and being trendy to be on social media. For youths, one has to be on these platforms to connect with people, to know the latest news, style, and trends because there is a new technological break forth communication gadget, hence; private universities in Africa should exploit this digital revolution.

3.3 Empirical Frame work

Yusuf (2010) research on the title “Beyond Socialising: Blogging as a teaching aid for Mass Communication writings classes” shows that advancement in technology, specifically in the area of multimedia aided by internet has generally brought about new ways in human interaction. Blogging; is fast becoming a popular tool for self-expression, online advertising and empowerment by internet users and has proven to be useful in helping students cultivate the needed writing skills for both paid-for and non-paid-for journalism professions. This study seeks to explain using blogging as an aid in teaching mass communication courses, including critical and reviewing writing, organizational writing and other forms of writings for journalism. The researcher employed Mediamorphosis theory to explain the interaction between old versus new media technologies for teaching. The researcher concluded that using social media blogging in teaching courses in journalism as a teaching aid can increase the productivity of teaching activity and therefore recommended its use among the teachers of journalism and writing for the mass media.

In the same same vein, Ojobah, Frank, Agim and George (2021) research not only see social media as a persuasive social outlet but also useful tools to communicate solution for national insecurity. The study used case study and content analysis methodology. And recommended that the social media should be protected and enhanced to function.

3.4 How to Exploit Social Media for Thomas Adewumi University Growth.

Deirdre (2012) rightly observes that whenever social media meet with Public relations communication unites with technology. Therefore, the media relations meeting with social media is a blessed union in this discourse. The following are some of the ways social media could be used to advance Thomas Adewumi University.

1. Pop up advert messages. As people open the social media page advert message will pop up in form of audio visual.
2. Streaming and banner advert messages below the line.
3. Promotional rebate to encourage more students to be attracted. For instant when the school float a rebate for four years for departments that have few students such as the the faculties of physical and social sciences in this manner:
“FIRST 20 STUDENTS TO REGISTER IN 100 LEVEL TO PAY HALF OF THE SCHOOL FEES”. And this is well advertised in the various social media platforms; it will go a long way to boost the school population in no distance time (Akinfolami, John and Edafejrhaye, 2022).
4. Create special interactive discussion blog to discuss about the school programmes.

3.5 Benefits of Multimedia Systems and Social Media in Media Relation Convergence.

Akinfolami et al (2022) highlight the usefulness of social media. According to them using social media as information tools, media relations officers will make communication faster and easier.

Prospective students can easily contact the University for quick admission.

They will create wide spread information about the school and its programmes of study.

They will enhance mutual interactive communication students' parents and the University.

They will enhance admission drive because social media are quick channels to reach out to youths.

They facilitate 24- hour advertising service without payment

Social media are special avenue for promotional rebate to attract more students. However, in every endeavour there may be some initial challenges which must be overcome in the process of time.

Facebook Relationship Boosters

Deirdre (2012) points out some benefits people can enjoy from facebook and twitter platforms. They are:

1. Share exclusive promotions and information about product discounts for only Facebook fans.
2. Engage directly with a community by creating a Facebook group to spark passion and action with your consumers, bloggers, and other constituents.
3. Create an engaging environment in which consumers interact with the brand and their peers, from "likes" and comments on wall posts to trivia and contests/sweepstakes.
4. Drive traffic from your brand fan page to helpful information on the company's website (leading to content your Facebook fans requested).
5. Create unique content you can't find on any other networks.
6. Build a community in which consumers can engage with the brand in fun activities through Facebook customized applications.
7. Use Facebook as a brand stream to maximize the brand's presence through status updates.
8. Address customer service questions and allow customers to chat with customer service representatives or company experts.
9. Develop a community that encourages feedback for research purposes, listening to the conversations between active community members.

Twitter Relationship Boosters

For Twitter relationships boosting, Deirdre (2012) has this to say:

1. Twitter share newsworthy information related to your brand that interests the community, keeping community members updated about the brand's activities.
2. Link to content that's not only interesting, but also has the potential to go viral. (This may or may not be directly related to your brand.)

3. Recognize, thank, and reward customers, bloggers, media, and other stakeholders for sharing your brand information and activities.
4. Develop conversations and engage in dialogue around industry topics for thought leadership.
5. Engage in conversations to help people by answering questions, addressing concerns, and aiding consumers in the decision-making process.
6. Promote your own community members' content including their articles, blog posts, videos, podcasts, and so on, which help to build stronger and mutually beneficial **relationships.
7. Share special offers and discounts by offering links directly to those promotions on brand landing pages.
8. Engage with influencers/bloggers, and build new relationships that lead to increased awareness and coverage/endorsement of your brand.
9. Find and follow journalists to stay abreast of what they tweet to better understand their interests for possible editorial coverage.
10. Create virtual events/Twitter chat sessions through hashtag discussions.

4.0 Conclusion.

As media relations officer working in private universities we need to identify our target audience and know the media that they operate, it is by so doing we can reach out to our target students. Although, it may be difficult initially to measure the effectiveness of the social media platform in accomplishing our aim, by and large, the use of social media and the multimedia systems will help create awareness and promote social networking with other institutions. It will also boost the school image both home and abroad and reduce cost of adverts.

4.1 Recommendations.

As media relations officer in Thomas Adewumi University the following recommendations are hereby suggested:

The University should operate at least three social media accounts in any of these platforms Youtube, Instagram, Facebook, Twitter, Phoneix, Ayoba and others. Let there be pop up advertising messages about the school all the time.

When selecting social media platforms we recommend media relations officer to choose platforms that their target prospective students operate. The social media should have a monitoring personnel standby to relate and answer prospective students inquiry. The school should continue to boost international networking using the multimedia systems.

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Inference in Bayesian Network in Modelling Word Sense Disambiguation for Sesotho sa Leboa

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1. Abstract

The main problem in the study of Word Sense Disambiguation (WSD) is linking context and senses to an ambiguous word. WSD is the problem of conveying suitable connotation (sense) to a given word in a transcript. Determining the ambiguity of words is a fundamental problem for understanding requirements and their related tasks. WSD is an open Natural Language Processing (NLP) problem, despite enthusiastic determination in probing the problem, the fact remains that no large solution exists in Sesotho Sa Leboa language to date, and no reported accurate WSD system has been built. The paper describes the challenges faced in making the linkage using Bayesian Network to model context and senses for an ambiguous word. The Bayesian Network (BN) is a depiction of a joint probability distribution of a collection of arbitrary variables as well as a probable underlying link. The objective of this study is to model joint conditional probability distribution of the output variable after examining the latest evidence of the lexical ambiguity of the word. In this research, BN is constructed manually with acquaintance of the fundamental sphere. Hence, it computes the probability of WSD when polysemy and homonymy is observed using variable elimination (VE) algorithm as a modest and universal inference technique. Probability graphic model with python library outperforms joint probability distribution computation using chain rule and direct method that multiply CPT and sum out variables.

Keywords: Bayesian Network, Chain rule, Causality, Directed Acyclic Graph, Inference

1. Introduction

Bayesian networks (BN) are graphical models whose nodes characterise random variables and the edges signify conditional reliance of a directed acyclic graph (DAG) and an equivalent conventional conditional probability tables (CPTs) (Rama et al., 2017). The work conducted by Maragoudakis et al., (2003a) concentrate on the stochastic modelling of part of speech disambiguation that describes the stochastic model using Bayes theorem. A number of probabilistic models emphasise ambiguity, presenting partiality that an ambiguous response can be projected by the probability of the analysis (Jurafsky, 2006).

This research intends to construct a Bayesian network for word sense disambiguation, then use variable elimination algorithm to compute marginal probabilities efficiently. There exists numerous algorithms to operate Bayesian networks to produce posterior values, such as Symbolic Probabilistic Inference (SPI) algorithm, variable elimination algorithm and bucket elimination which all focus on algebraic operations, and those which focus on graphical properties dealing with junction trees (Cozman, 2000).

Bayesian network (BN) model is known as a compliant practise for language modelling, because it can achieve a powerful language feature set in the background of a probability prototype (Maragoudakis et al., 2003b). A language terms the world in a diverse way and all depends on culture and historical conditions. The language that the people speak affects and reflects their view of the world.

Due to language variety, literature proves that there is no common resolution for a certain NLP task. Dialects in Sesotho Sa Leboa and others do not have adequate assets to build statistical NLP models (Tsvetkov, 2017a). South Africa is a country with 11 official diverse languages, which nine are Resource Scarce Languages (RSLs), in exception of English and Afrikaans (Holy et al., 2017a).

A low-resource language is basically a language missing huge monolingual or equivalent corpora and/ or physically constructed semantic resources adequate for developing statistical NLP requests (Tsvetkov, 2017b). Majority of South Africans strive to retrieve information transcribed in their inborn languages on the Grid, which hinders social economic growth (Holy et al., 2017b).

It is important to build NLP resources for the low-resourced languages for the following reasons, commercial value, social-good reasons such as –identifying outbreaks of diseases, translation systems, speech interfaces, dialogue systems, educational applications, emergency response applications, and monitoring democratic processes (Tsvetkov, 2017b).

Sesotho Sa Leboa as a Bantu language has a sizable corpus with only one diacritically marked character and no tonal markings, however, the LexDif column nevertheless shows a hard disambiguation problem (Pauw et al., n.d.). In order to build excellent NLP models, large volumes of training information is required for a sophisticated language-engineering (Tsvetkov, 2017b).

2. Related Works

The literature of Loubser & Puttkammer, (2020) addressed the implementation of neural network for four core technologies namely part of speech tagging (POS), named entity recognition (NER), compound analysis and lemmatization for ten resource scarce languages in South Africa. Furthermore, it concluded that neural networks can be feasible for completions of essential machineries for morphological low resourced South African languages, however, implementation measured is not normally outstanding to existing machine learning standards, excluding combination evaluation.

Maragoudakis et al., (2003) experimentally evaluated BN for Part-Of-Speech tagging of Greek language text and compared it to the Hidden Markov method. The model was trained using lexical as well as related information on annotated dataset, and furthermore, model amplified to infer on the unseen words, which depicted an accuracy of 96% for POS tagging.

A novel Bayesian model was presented on Kamper et al., (2016) and employed a modest vocabulary of digital task to work on rigid-dimensional embeddings of speech that fragments and clusters unstructured speech into theorized elements of word. Study of (Ennajari et al., 2021) has shown an augmented benefit to analyse unstructured dataset to obtain structured labelled dataset knowledge that is important. Bayesian embedded spherical topic model (ESTM) determines effectiveness of modelling unstructured dataset for multiple natural language processing tasks able to encode context and dealings among words and point probabilistic model to mine meaningful subjects (Ennajari et al., 2021).

Bayesian network's representation contains a graph with peaks that correspond to variables and collection of constraints named structure learning with two approaches namely, score based and

constraint based (Dojer, 2016). Furthermore, this literature work solves problem of structure learning using Bayesian networks from data by modifying discrete scoring functions to manage continuous and mixed dataset. Suzuki, (2014) suggested a scoring technique which allows continuous data to be computed by sequence of discretization with decreasing granularity.

The study of (Shen et al., 2018) estimated probability distribution through Bayesian network from real healthcare data to construct medical ontology probabilistic inference. Moreover, the study established feasibility of computerized building of health network topology from medical documents by computing ontology-based diagnosis classification.

Li et al., (2021) resorted to stochastic variational inference algorithm for cross contextual word embedding to deal with enormous dataset, since Inference of Bayesian graphical model approximate posterior distribution of latent variables on monitored data. The proposed stochastic inference simply handles large corpus and outperforms traditional Bayesian inference algorithm.

Stochastic variational inference for Bayesian deep neural networks (DNN) ask for specification of priors and estimation of posterior distributions for neural network weights, that is a challenging difficult issue (Krishnan et al., 2019). Nevertheless, research propose Model Priors Extracted from Deterministic DNN (MOPED) which is a technique that select meaningful prior distributions over weights.

Bayesian inference model estimate posterior distribution of parameters so that statistics model agree with the data (Linka et al., 2022). Furthermore, maximizes prior-weighted likelihood in standings of error among data and model to extrapolate distributions of parameters. BN gives flexible and robust graphical structure in a probabilistic methodology known as directed acyclic graph after acquiring hierarchy of risk factors (Tang et al., 2022).

Algebraic Bayesian Networks (ABN) associated with Bayesian Belief Networks which is a Directed acyclic graph(DAG) has ability to effectively process uncertainty problems and perform diagnosis or predictions (Krishnan et al., 2019; Liang et al., 2019). Furthermore, conditional probabilities are computed by the strength measured between nodes in DAG which represent variables and arcs which signify presence of direct causal influences.

BN is recognized as a “belief networks” or else “causal networks” are defined as a graphical model that represent multivariate probability distributions represented in a directed acyclic graphs (DAG). BN is a tool to model and reason with uncertain beliefs and consist of qualitative component named directed acyclic graphs and quantitative element in the structure of CPTs to compute the dependencies among variables and their parents in the DAG (Darwiche, 2008). The BN model semantics are determined by the Markov condition or assumption which states that every variable is conditionally autonomous of its offspring given its parents (Cozman, 2000). Loosely specified, it is presumed that a node has no sway on nodes which do not come down from it, equivalently stating Markov blanket a node is conditionally independent of the BN. In general, mathematical expression is given as:

$$\begin{aligned}
 P(x_0 \dots, x_n) &= P(X_1 = x_n \nabla \dots \nabla X_n = x_n) \\
 &= \prod_i P(x_i | \text{parents}(X_i))
 \end{aligned}
 \tag{1}$$

The definition of conditional probability is fundamental to the subject of word sense disambiguation (WSD) and from the derivation of the Bayes Theorem the research can obtain the joint marginal distribution of parameters or perhaps a mathematical formula to obtain the predictive density of the future observation (Carlin & Louis, 2009)(James, 2011).

The variable elimination algorithm $VE(\emptyset, X, E, e, \sigma)$ is formally defined as a loop over the variables as ordered and eliminated in that ordering (Kuleshov & Ermon, 2020). VE is a modest and universal inference technique in PGM. The VE algorithm computes $p(X/E=e)$ from a discrete Bayesian network (Zhang & Poole, 1994a).

$\emptyset$ – convention of CPTs

X –enquiry variables

E – monitoring variables

e – subsequent monitored values

σ - eradication collation for variables

Hence, the $VE(\emptyset, X, E, e, \sigma)$ algorithm is stated as (Zhang & Poole, 1994b):

- Multiply factors with appropriate CPTs while σ is unoccupied
- Eliminate the 1st variable v from σ
- $\emptyset$ equal sum-out ($v, \emptyset$)
- $p(X, E = e) = \text{the product of all factors } \Psi \in \emptyset$
- return $p(X, E = e) / \sum_x p(X, E = e)$

3. Research Methodology

This research study experiments with Bayesian belief network algorithm. It considers the Bayesian Network formulated in Fig. 1 and Fig. 2 with the goal to compute joint probability distribution for the network; therefore, uses variable elimination algorithm as a basis for inference. In the first place, this study applied method to multiply CPTs and sum out variables for the Bayesian network. Secondly, a chain rule for Bayesian network is used to compute the probability. Thirdly, probabilistic graphical model as a module in python library is implemented to give the prior and posterior marginal for the corresponding variables given below: `

P = Polysemy word

H = Homonymy

A = Ambiguous word

C = Context

S = Senses

Table 1: The study makes use of the notational conventions denoted

Symbol	Notation Meaning
$W = A$	Word assumed ambiguous
$S_1, \dots, S_k$	Senses for W
$C_1, \dots, C_i, \dots, C_j$	Contexts of W
P	Probability
$\hat{S}$	Candidate sense

Conditional probability using Bayes Theorem for the Sense (S) given that an ambiguous word (W) occurs can be written as:

$$Pr(S|W) = \frac{Pr(S \cap W)}{Pr(W)}$$

$Pr(S \cap W) = Pr(S|W)Pr(W)$ (2) If S and W are interchanged then this becomes

$$Pr(W|S) = \frac{Pr(W \cap S)}{Pr(S)}$$

$$Pr(W \cap S) = Pr(W|S)Pr(S) \quad (3)$$

Hence, we can equate Eq. 2 and Eq. 3

$$Pr(S \cap W) = Pr(W \cap S)$$

Therefore,

$$Pr(S|W)Pr(W) = Pr(W|S)Pr(S)$$

Which gives Bayes Theorem

$$Pr(S|W) = \frac{Pr(W|S)Pr(S)}{Pr(W)} \quad (4)$$

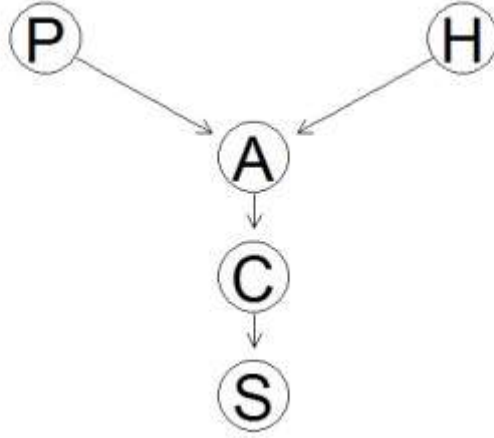
$Pr(W)$

If $\{S_1, \dots, S_n\}$, $S_i \cap S_j = \emptyset$ ($i \neq j$) is mutually exclusive events, one of which must occur given that another event B occurs, then conditional probabilities for Bayes' Theorem is given as:

$$Pr(S_i|W) = \frac{Pr(W|S_i)Pr(S_i)}{Pr(W)}$$

$$Pr(S_i|W) = \frac{\sum_{n=1}^n Pr(W|S_i)Pr(S_i)}{\sum_{n=1}^n Pr(W|S_n)Pr(S_n)} \quad (i = 1, \dots, n) \quad (5)$$

Figure 1: Bayesian Network



Using Eq. 1, the research can in principle calculate the Joint Probability of binary states and in a hierarchical statistical model outline the joint distribution which represents the given Bayesian Network in Fig. 1:

$$\begin{aligned}
 Pr(C, S, A, H, P) &= Pr(C, S|A, H, P)Pr(A|H, P)P(H, P) \\
 &\approx Pr(C, S|A)Pr(A|H, P)Pr(H)Pr(P) \\
 &\approx Pr(C|A)Pr(S|A)Pr(A|H, P)Pr(E)Pr(P)
 \end{aligned} \tag{6}$$

The inference mechanism based on Bayes' Theorem in Eq. 5 is employed to render the WSD theory as objective as possible while the rules of probability are strictly applied. Since the research solve a problem of inference in graphical model, the research determines the probability that a given lexical ambiguity word can be disambiguated to find the correct sense of the word using probabilistic model as given in Fig. 1 as a Bayesian Network. Inference of a general Bayesian Network through variable elimination is given by the query in Eq. 7 which gives an elimination order of latent variable to be marginalized.

$$Pr(X_1, e) = \sum_{x_n} \dots \sum_{x_3} \sum_{x_2} \sum_{x_1} \prod Pr(X_i|Pa_i) \tag{7}$$

4. Research Results

4.1 Computation by multiplying CPT factors and sum out variables for Bayesian network

The calculation of marginal probability based on $VE(\emptyset, \mathbf{X}, \mathbf{E}, \mathbf{e}, \boldsymbol{\sigma})$ for the BN in Fig. 1 using Eq. 7 for the variable $P:H \rightarrow A \rightarrow C \rightarrow S$:

The computation of marginal probability based on $VE(\emptyset, \mathbf{X}, \mathbf{E}, \mathbf{e}, \boldsymbol{\sigma})$ for the Bayesian network in Fig. 1 using equation (7) for the variable $P:H \rightarrow A \rightarrow C \rightarrow S$: or net <-
`model2network("[P][H][A|P:H][C|A][S|C]")` in R

$$Pr(S) = \sum_c \sum_a Pr(c|a)Pr(c)Pr(c|a)Pr(s|c) \sum_{p:h} Pr(p)Pr(a|p:h)$$

$$Pr(S) = \sum_c Pr(c)Pr(s|c) \sum_a Pr(c|a)p(a)$$

$$Pr(S) = \sum_c Pr(c)Pr(s|c)p(c)$$

$$Pr(S) = \sum_c Pr(s|c)p(c) \tag{8}$$

Computing the marginal over variable S $\theta(S)$

where T represent True and F represent False

P	$\theta(P)$
T	0.8
F	0.2

P	A	$\theta(A P)$
T	T	0.6
T	F	0.4
F	T	0.9
F	F	0.1

P	C	$\theta(C P)$
T	T	0.4
T	F	0.6
F	T	0.8
F	F	0.2

C	S	$\theta(S C)$
T	T	0.4
T	F	0.6
F	T	0.8
F	F	0.2

Prediction: $\Pr(S|P)=?$ What is the probability of finding the correct sense? of an ambiguous word given polysemous and homonymous word? i.e. What is the joint probability distribution for $\Pr(S|P)$?

The process to compute the query $\Pr(S|P)$ is referred to as inference in this research.

Query: $\Pr(S|P)$?

Elimination order: $\sigma - P, H$

Goal: $\Pr(A, C, S)$

Initial factorization of joint probability distribution (Theorem 4.1) of Fig. 1 is: $\Pr(P, H, A, C, S)$

Then variable elimination is applied for marginal probability distribution

$\Pr(C|S) \Pr(C|A) \Pr(A|P, H)$ algorithm (Theorem 4.2):

$$\Pr(P, H, A, C, S) = \Pr(C|S) \Pr(C|A) \Pr(A|P, H) \text{ Inference}$$

process:

Eliminating variable (P:H):

P	$\sum_C \sum_a \Pr(c a) \Pr(c) \Pr(c a) \Pr(s c) \sum_{p:h} \Pr(p) \Pr(a p:h)$
T	0.66
F	0.34

Eliminating variable (A):

A	C	$\sum_c Pr(c)Pr(s c) \sum_a Pr(c a)p(a)$
T	T	0.264
T	F	0.396
F	T	0.272
F	F	0.068

Eliminating variable (C):

C	S	$\sum_c Pr(c)Pr(s c)p(c)$
T	T	0.237
T	F	0.396
F	T	0.272
F	F	0.068

C	$\sum_c Pr(s c)p(c)$
T	0.427
F	0.0596

Joint probability distribution computation for the variable Sense (S) gives a probability of 42% to disambiguate an ambiguous Polysemy word.

Prediction: $Pr(S|H)=?$ What is the probability of finding the correct sense? of an ambiguous word given polysemous and homonymous word? i.e. What is the Joint probability distribution for $Pr(S|H)$?

The process to compute the query $Pr(S|H)$ is referred to as inference in this research.

Query: $Pr(S|H)$?

Elimination order: $\sigma - P, H$

Goal: $Pr(A, C, S)$

The computation of marginal probability based on $VE(\emptyset, \mathbf{X}, \mathbf{E}, \mathbf{e}, \sigma)$ for the Bayesian network in Fig. 1 using equation (7) for the variable $H \rightarrow A \rightarrow C \rightarrow S$:

$$Pr(S) = \sum_c \sum_a Pr(c|a)Pr(c)Pr(c|a)Pr(h|c) \sum_p Pr(h)Pr(a|h)$$

$$Pr(S) = \sum_c Pr(c)Pr(s|c) \sum_a Pr(c|a)p(a)$$

$$Pr(S) = \sum_c Pr(c)Pr(s|c)p(c)$$

$$Pr(S) = \sum_c Pr(s|c)p(c) \quad (9)$$

1.1 Computing the marginal over variable S $\theta(S)$

H	$\theta(H)$
T	0.9
F	0.1

H	A	$\theta(A H)$
T	T	0.6
T	F	0.4
F	T	0.9
F	F	0.1

C	S	$\theta(S C)$
T	T	0.4
T	F	0.6
F	T	0.8
F	F	0.2

H	C	$\theta(C H)$
T	T	0.4
T	F	0.6
F	T	0.8
F	F	0.2

Eliminating variable (H):

H	$\sum_c \sum_a Pr(c a)Pr(c)Pr(c a)Pr(h c) \sum_p Pr(h)Pr(a h)$
T	0.63
F	0.37

Eliminating variable (A):

A	C	$\sum_c Pr(c)Pr(s c) \sum_a Pr(c a)p(a)$
T	T	0.252
T	F	0.378
F	T	0.296
F	F	0.074

Eliminating variable (C):

C	S	$\sum_c Pr(c)Pr(s c)p(c)$
T	T	0.226
T	F	0.037
F	T	0.207
F	F	0.022

C	$\sum_c Pr(s c)p(c)$
T	0.433
F	0.059

Joint probability distribution computation for the variable Sense (S) gives a probability of 43% to disambiguate an ambiguous Polysemy word.

4.2 Computation of joint probability distribution using chain rule

Using chain rule for Bayesian network, research compute the probability of each instantiation in Fig. 2 as a product of parameters.

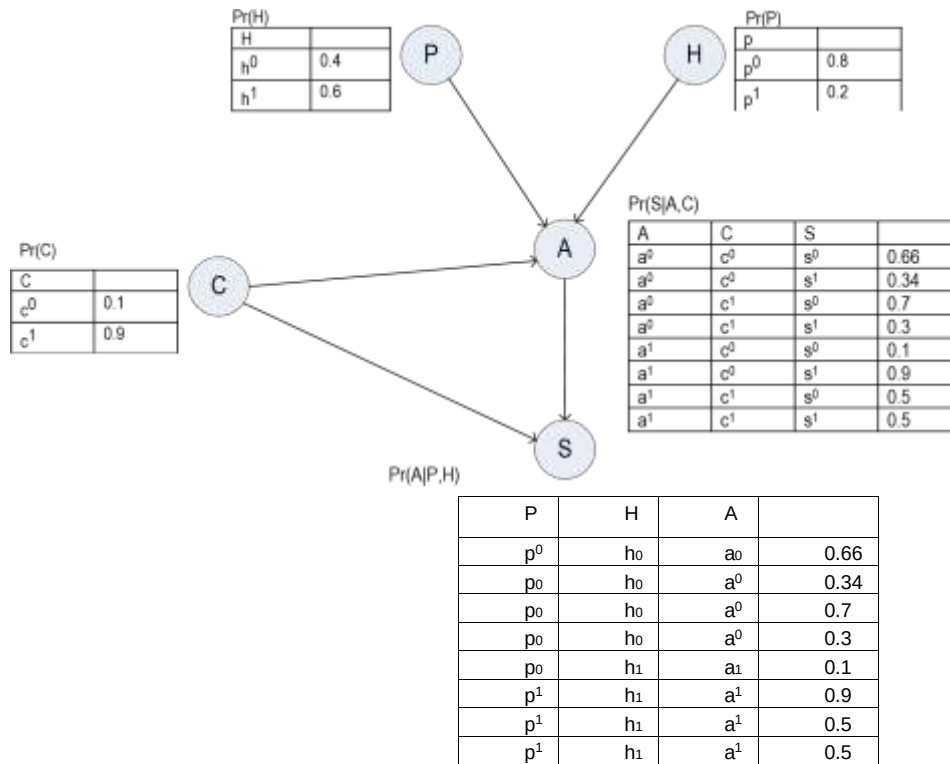


Figure 2: DAG with parameterized CPT

$$\Pr(p, h, a, c, s) = \Pr(p) \Pr(h) \Pr(a|p, h) \Pr(s|a, c) \Pr(c) \quad (10)$$
 To compute inferences as:

$$\Pr(p^0, h^1, a^1, c^1, s^0) = 0.8 * 0.6 * 0.3 * 0.9 * 0.1 = 0.01296$$

The results shows $\Pr(P|S) = 0.01296$, which is essentially the probability that correct sense of the ambiguous word can be found.

4.3 Computation using Probabilistic Graphical Model (pgmpy) python library

The python module pgmpy answer inference or map queries over graphical models such as DAG. The research creates Bayesian model using pgmpy with python library from Fig. 2 with conditional probability table distribution parameters. Each given variable in Fig.2 has CPT parameters associated with. The model is built and then tested for correctness. Thereafter, variable inference algorithms are automated to solve inference query.

Query 1: # Lets find probability of “the word being ambiguous” solver.query(variables=['A'])

```
+-----+-----+
| A | phi(A) |
+=====+=====+
| A(0) | 0.7894 |
+-----+-----+
| A(1) | 0.2106 |
```

Query 2: #Lets find probability "through evidence to support first query"

`solver.query(variables=['A'], evidence={'P': 1})`

```
+-----+-----+
| A   | phi(A) |
+=====+=====+
| A(0) | 0.3564 |
+-----+-----+
| A(1) | 0.6436 |
```

Query 3: # Find dependency features between variables using the model

```
(S ⊥ H, P | C, A)
(S ⊥ P | H, C, A)
(S ⊥ H | P, C, A)
(H ⊥ P, C)
(H ⊥ C | P)
(H ⊥ P | C)
(H ⊥ S | C, A)
(H ⊥ S | P, C, A)
(P ⊥ H, C)
(P ⊥ C | H)
(P ⊥ H | C)
(P ⊥ S | C, A)
(P ⊥ S | H, C, A)
(C ⊥ H, P)
(C ⊥ P | H)
(C ⊥ H | P)
```

4.4 The Network for Lexical Disambiguation

A natural language parser input a sentence and computes the labelled syntactic tree structure corresponding to the interpretation of the sentence. As an example, input sentence: "**Mosadi o noka seshebo ka letswai**" will give syntactic tree structure as:

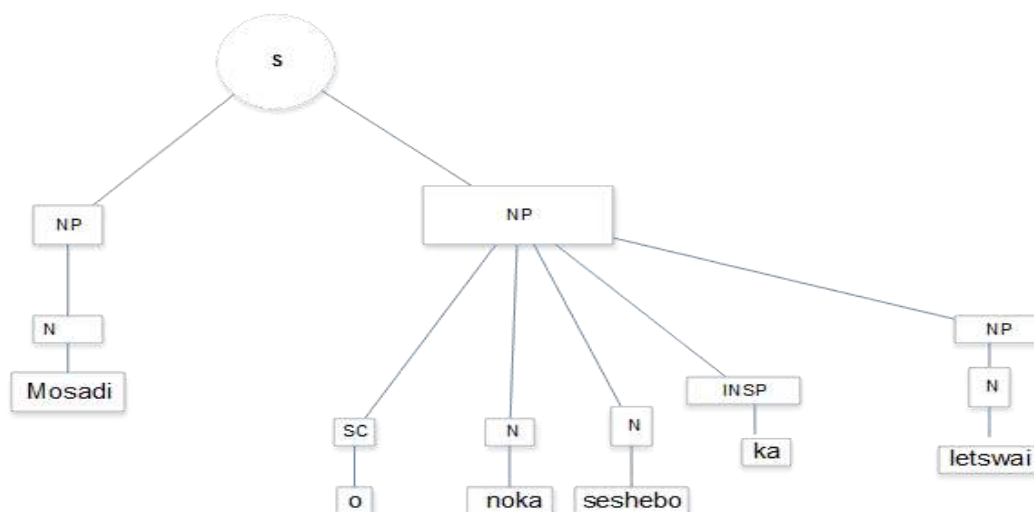


Figure 3: Parse using CFG

The first step in constructing a Bayesian network, such as Fig. 3 is to determine its structure which defines each node's dependency relationship with the rest of the network. In our model, we are making these independence assumptions based on the structural relationships between words. Context-Free Grammar (CFG) is the most famous model used when it comes to developing a parser.

5. Conclusion

This research conclusions proves possibility of using Bayesian inference network to solve word sense disambiguation in Sesotho sa Leboa language. However, BN proves competitive in regression problems, as compared to classification problem. Computation time for BN rises as the data size increases. This BN estimates computed in this study are reliable to identify senses out of the given context. Joint probability distribution computed with probability graphical model serves as a basis for inference with good performance, as compared to chain rule and direct method that multiplies CPT and sum out variables.

BN are models; for instance, if we are assessing the probabilities of several potential understandings of an ambiguous expression, the network will permit us to calculate the posterior probability of every interpretation as each portion of evidence comes. In addition, the usage of BNs as a probabilistic estimator grants us to integrate any sort of evidence; syntactic, and semantic. This will permit us to describe the syntactic probabilities captured by graphical models like CFGs, while enhancing them with other probabilities.

In future, Stochastic variational inference for Bayesian deep neural networks which dominate classification problem will be considered with large dataset.

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Analysis of Pharmaceutical Solid dosage forms using Machine Learning and Chemometrics Techniques

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Abstract

Paracetamol or Acetaminophen is more prescribed medicine from doctors and medicinal experts in pharmaceutical industry as it is commonly used as pain killer as well as for reliving the body fever. Due to this there are more chances for counterfeiting of Paracetamol medicines. In this research work we used Near Infrared Sensor in the form of ASD FieldSpec4 Spectroradiometer having 350-2500 nanometer broad spectral range. Spectral database in the form of spectral signature of pharmaceutical samples was collected by ASD FieldSpec4 Spectroradiometer. The chemometrics and Savitzky golay filter with First and Second derivative preprocessing techniques was used for sample preparation. For analysis of pharmaceutical data the PLSR Regression model is proposed and for validation of results the cross validation having 10 fold technique is used. The model showed the good results and high accuracy as 99% in this work.

Keywords: Partial Least Square Regression (PLSR), Active Pharmaceutical Ingredients (API), Near Infrared Spectroscopy (NIRS), Paracetamol, Excipients, Root Mean Square Error (RMSE), Gas Chromatography Mass Spectroscopy (GCMS), High Performance Liquid Chromatography (HPLC).

1. Introduction

Counterfeit medicines or Falsified medicines is one of the critical problem all over the world. According to the World Health Organization (WHO) the worldwide revenue of falsified medicines is around 200 billion dollars (USD). In pharmaceutical the counterfeiting of medicines can be type of underdoes, overdose or having wrong Active Pharmaceutical Ingredients (API) or the API is not present. Due to counterfeiting of medicines sometimes it causes to people to lose their health as well as money. Such a falsified medicines can not only cause serious illness but death also (Lawson, G., Ogwu, J., & Tanna, S. (2018), Dégardin, K., Guillemain, A., Guerreiro, N. V., & Roggo, Y. (2016)., Shinde, S. R., Bhavsar, K., Kimbahune, S., Khandelwal, S., Ghose, A., & Pal, A. (2020, July), Kandpal, L. M., Tewari, J., Gopinathan, N., Stolee, J., Strong, R., Boulas, P., & Cho, B. K. (2017). To identify this type of counterfeit or fake medicines is challenging task. In pharmaceutical domain, to identify this type of medicines numerous different types of techniques are available. It can be detected by technical experts or the person who is working on it.

Techniques like visual inspection of packaging medicines, using some traditional laboratory methods and some nondestructive techniques (Kandpal, L. M., Tewari, J., Gopinathan, N., Stolee, J., Strong, R., Boulas, P., & Cho, B. K. (2017), Patel Priyanka P, Sanghadiya Divyang G, Tank Bharat M. (2013). Through visual inspection sometimes it is impossible or hard to detect falsified medicines. In traditional methods such as physical and bulk property is tested. The laboratory famous chemical methods are Chromatography, Colorimetry, Gas Chromatography Mass Spectroscopy (GCMS), High Performance Liquid Chromatography (HPLC), and so on (Bonfilio, R. B. D. A. M., De Araujo, M. B., & Salgado, H. R. N. (2010). In pharmaceutical industry chemical methods are mostly preferable like HPLC and GCMS. This methods have some

disadvantages like it consumes a lot of time for sample preparation and also it is nondestructive technique due to this we cannot reuse the sample (Bolje, A., & Gobec, S. (2021). Now a days Spectroscopic technique is most famous, effective and widely used in pharmaceutical industry due to its numerous advantages (Belugina, R. B., Monakhova, Y. B., Rubtsova, E., Becht, A., Schollmayer, C., Holzgrabe, U., Kirsanov, D. O. (2020). It is fast and nondestructive and accurate technique preferably use for analysing, finding counterfeit/fake, substandard medicines qualitatively and quantitatively analysing the pharmaceutical materials. Due to its effective use and many advantages compare to other techniques its increases its participation in pharmaceutical studies (Razuc, M., Grafia, A., Gallo, L., Ramírez-Rigo, M. V., & Romañach, R. J. (2019). Spectroscopic techniques does not need any sample preparation and also it can obtain the information directly from the sample. It also eliminate the stapes to use organic solvent for sample preparation. Spectroscopic techniques have so many advantages, so its reduce the analysis time and the total analytical error associated to methodology (Said, M. M., Gibbons, S., Moffat, A., & Zloh, M. (2019). In Spectroscopic technique there are numerous techniques are available like Raman Spectroscopy, Near Infrared Spectroscopy (NIRS), and so on.

NIRS is widely used in pharmaceutical industry according to the previous study and advantages. Compare to other Spectroscopic technique NIRS techniques showed good accuracy and efficient technique (Boiret, M., & Chauchard, F. (2017), Gupta, R. S., Deshmukh, R. R., Randive, P. U., Kshirsagar, A. V., & Kayte, J. N. (2018). NIR Spectroscopy having the spectral range between 700-2500 nanometer (nm), it can be used in multidisciplinary way and in various applications area like Environmental Study, Geology Mining, Defense and Intelligence, Soil analysis, Vegetation analysis, Commercial agriculture, Biomass analysis, Food Analysis, Nutraceuticals and dietary supplements, Pharmaceutical material analysis, and so on (Becht, A., Schollmayer, C., Monakhova, Y., & Holzgrabe, U. (2021). In this research work, we used NIR Spectroscopy for Pharmaceutical materials analysis. In pharmaceutical domain, the NIRS is used for identification of single active components from pharmaceutical ingredients, identification of counterfeit drugs, blend uniformity, moisture content, particles size, chemical determination from solid as well as liquid components, and so on. According to the previous work and many researchers review the NIR techniques have tremendous use and advantages in pharmaceutical sector (Gupta, R. S., Marathwada, B. A., Omeer, A., Deshmukh, R. R., Kayte, J. N., Randive, P. U., & Janse, P. V. (2018) Alcalà, M., Blanco, M., Moyano, D., Broad, N. W., O'Brien, N., Friedrich, D., Siesler, H. W. (2013). NIR Spectroscopy have numerous applications and its efficiency and giving good accuracy in results with the help of chemometrics techniques, researchers and pharmaceutical industry widely uses this technique . Principle of NIR Spectroscopy is, after analyzing the samples it gives the output in the format of Spectral signature data. To evaluate this Spectral data, we need some statistical as well as various chemometrics techniques according to the objective of work (Roggo, Y., Degardin, K., & Margot, P. (2010).

2. Materials and Methods

2.1 Sample Collection

Pure Paracetamol drug as an Active Pharmaceutical Ingredient and the Common excipients (Magnesium Stearate, Micro Crystalline Cellulose, Maize Starch Powder, Lactose, Talc (Chaudhari, S. P., & Patil, P. S. (2012), Haywood, A., & Glass, B. D. (2011)] are obtained from Srinath College of Pharmacy, Bajaj Nagar, Aurangabad and Department of Chemical Technology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. Plain Paracetamol tablets

(Calpol 500 and 650mg) are purchased from local pharmacies from various locations from Aurangabad City, Maharashtra.

2.2 Sample Preparation

Paracetamol is commonly used medicines and it's the most commonly reported counterfeit medicines [Said, M. M., Gibbons, S., Moffat, A. C., & Zloh, M. (2011)]. We experimented with total 40 paracetamol tablets, 20 tablets as Calpol 500mg and 20 tablets as Calpol 650mg that having Paracetamol as an active component and excipients for binding tablets.

Molecular Formula: Paracetamol ($C_8H_9NO_2$) (Pawar, P. Y., Sandip, H., Megha, S., & Arti, A. (2013), Behera, S., Ghanty, S., Ahmad, F., Santra, S., & Banerjee, S. (2012).

The following Items are used for sample preparations in figure1.

- Mortar and Pestle are used to crush the tablets into powder form.
- Petri dish is used to hold the sample for experiments
- Spatula is used to transfer the powder from mortal to petri dish



Figure 1: Lab Apparatus

ASDFieldspec4 Spectroradiometer is used for capturing hyperspectral data of samples. The device have many applications in Remote Sensing domain and it can be used for different types of applications like. Geology and Mining, Defense, Environmental, Material Analysis, Agriculture, etc. From Agriculture and Material Analysis the ASDFieldSpec4 device is using for Soil, Plant, Biomass, Commercial Agriculture, Food analysis, Nutraceuticals and Dietary Supplements, Pharmaceuticals analysis[Gupta, R. S., Deshmukh, R. R., & Kshirsagar, A. V. (2021)]. In this research work, we used this device for Pharmaceuticals applications. The below Figure2 and Table1 shows the major specification of ASDFieldSpec4 Spectroradiometer device.

Table 1 Specification of ASD FieldSpec4 device

Spectroradiometer Name	ASD Field Spec 4 Std. Resolution Spectroradiometer
Spectral Range	350-2500 nanometer
Sampling Interval	1.5 nm @350-1000nm , 2nm @ 1001-2500nm
Spectral Resolution	3 nm @ 700nm , 10nm @ 1400/2100nm
Detectors	VNIR (350-1000 nm), SWIR1 (1001-1800nm), SWIR2 (1801-2500nm)
Input	Direct Mounted Fiber optic (25 degreeFOV), optional narrowed FOV fiber optic lens available to change the FOV
Wavelength Accuracy	0.5nm



Figure 2 ASD FieldSpec4 Spectroradiometer

2.3 Experimental Setup and Spectral Data Collections

The pure paracetamol drug and common excipients were collected in a 50 gramme airtight bag. Calpol 500mg and 650mg tablets were crushed using a mortar and pestle. The samples were placed in the air pack bags using a Spatula. Spectral data in the form of Spectral signatures of each sample was collected using an ASDFieldSpec4 standard resolution Spectroradiometer in the Multispectral/Hyperspectral Research Lab, Department of Computer Science and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. In the fully equipped dark room available in the research lab, samples were scanned using reflectance mode to reduce the noise and the effects of the external light. Spectroradiometer and tungsten halogen light were used

with a 45 degree incidence angle. For the sample holder, a borosilic petridish sized 100mm*16mm in diameter was used. The Spectroradiometer was turned on and kept to warm up for 30 minutes. After that, the connected laptop was turned on and the included RS3 software was opened. RS3 software is helps to collect samples database in the form of Spectral Signature. In the first step Standardized White Reference panel was used to optimized device sensors and calibration accuracy. After successfully optimized the device then Pure Paracetamol, Excipients and Calpol Tablets powder samples was placed one by one in the borosilic petri dish and its spectral signature was collected from spectral gun having 8 degree field of view (FOV) that is connected with device with the help of fiber optic cable. 40 Scans were taken from each sample with sampling interval 1.5 nanometer per spectrum at wavelength range 350- 1000nm and 2 nanometer per spectrum at wavelength range 1001-2500nm. The spectroradiometer sample scanning time per sample was 100ms.



Figure 3 Experimental Setup

2.4 Pre-processing of Data

Pure Paracetamol drug, Common Excipients and Calpol tablets Powder was analyzed by ASDFieldSpec4 Spectroradiometer and Spectral signature of each sample was acquired with the help of RS3 software. The ASDFieldSpec4 device is controlled by RS3 software comes with the device for acquisition of Spectral Signature of any kind of material. After acquisition of Spectral signature can be viewed and processed by using some chemometric and Statistical techniques with the help of ViewSpec Pro software that was also came with ASDFieldSpec4 Spectroradiometer. For each sample 40 utterances or scans was taken and convert this asd files into single mean file by using ViewSpec Pro software, and this Mean files was used for further processing. At first the Pure Paracetamol drug asd files was taken for preprocessing and statistical analysis. All 40 utterances of Pure Paracetamol drug is open in ViewSpec Pro software

and converts these files into one Mean file, Figure4 shows the Mean of Spectral signatures of pure Paracetamol and Paracetamol Tablets.

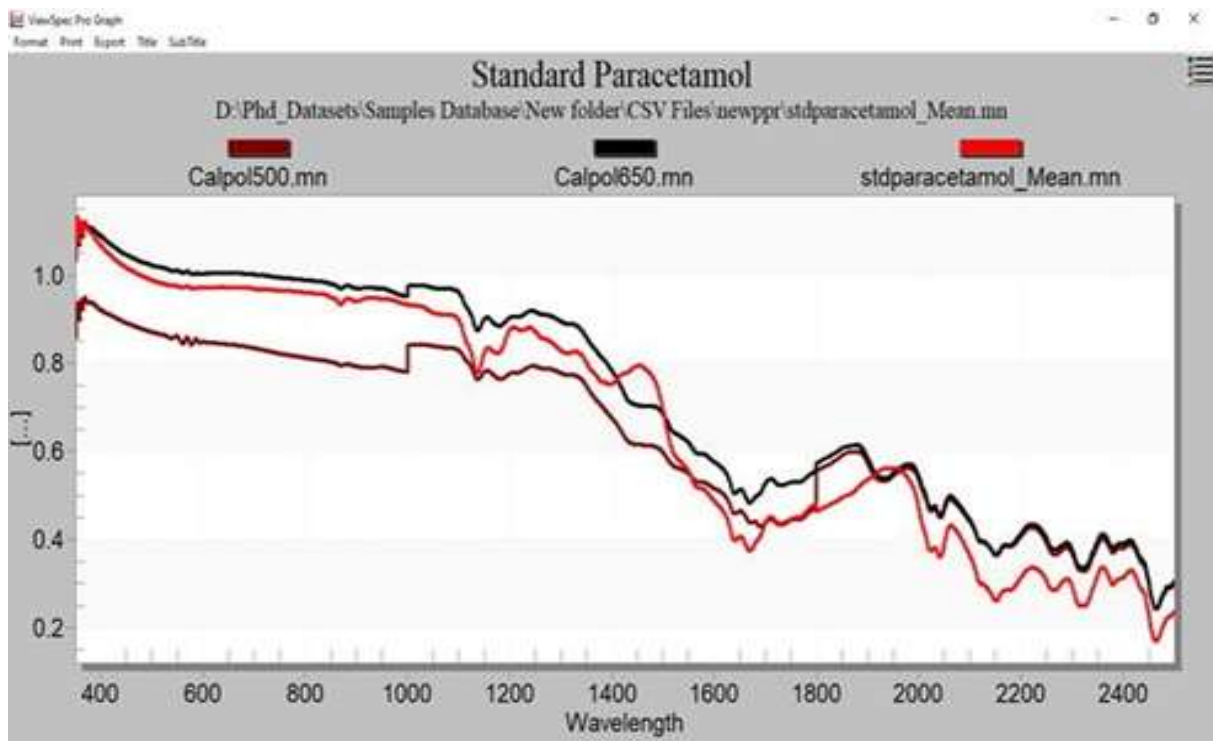


Figure 4 Mean of tablets and Paracetamol

The Splice correction and Smoothing is required to explore the information of Spectral bands (Schlegel, L. B., Schubert-Zsilavec, M., & Abdel-Tawab, M. (2017)). For this Savitzky-Golay filter is applied with 1st and 2nd derivative as preprocessing technique, Figure5 shows the second derivative spectral signature of sample. The above same process is applied with all remaining samples.

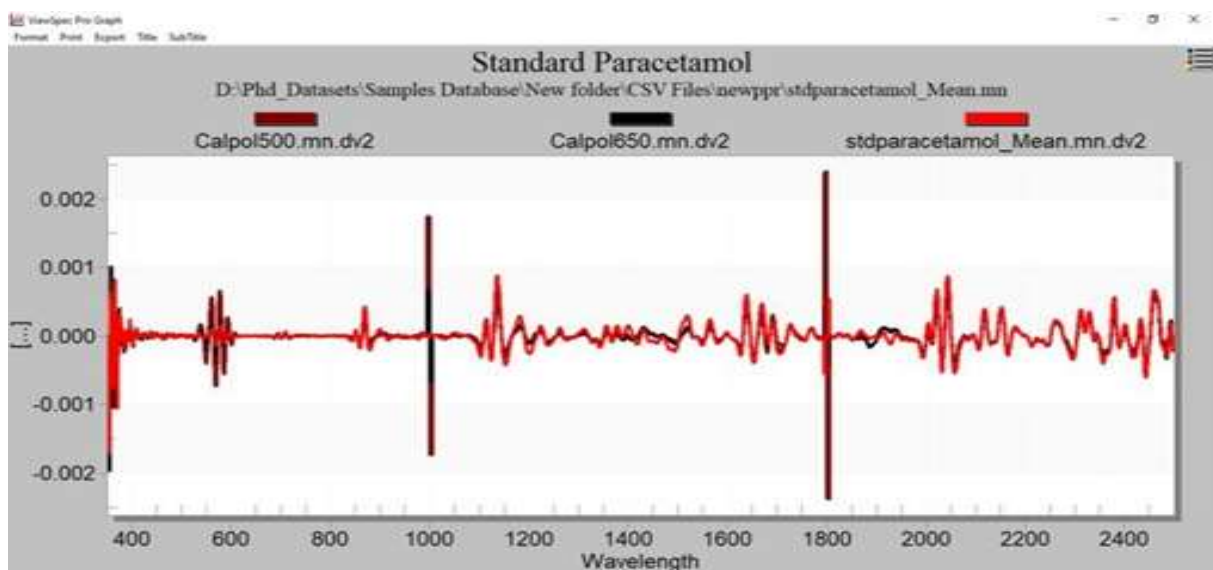


Figure 5 2nd derivative Spectra of samples

2.5 Chemometrics Techniques

To identify the counterfeit or falsified pharmaceutical materials by using spectroscopic techniques, the chemometric tools and methods are used. The data acquired by spectroscopy was continues wavelength bands data. To analyze this huge amount of data the Principal Component Analysis is a technique to project and distribute data (Borchert, S., Henck, J. O., & Siesler, H. W. (2003). Chemometrics techniques are used in a multidisciplinary way to analyze large complex chemical data obtained by spectroscopic devices (Pino-Torres, C., Maspoch, S., Castillo-Felices, R., Pérez-Rivera, M., Aranda-Bustos, M., & Peña-Farfal, C. (2020), Biancolillo, A., & Marini, F. (2018). Chemometrics techniques extract the information from spectral data obtained by NIR spectroscopy by using mathematics, multiple statistics technique and used some computational techniques and Machine Learning and Deep Learning algorithms. Chemometrics is multidisciplinary way to extract the information from large amount of data like NIR is a continues wavelength data from it chemometrics uses various approach to analyze this type of data (Mekasha, Y. T. (2020). Chemometrics applications have two broad categories. One is Qualitative and another is Quantitative. According to study and purpose the various tools are available. Basically the common steps to apply chemometrics models on data are:

1. Sample Preparation and Data Collection
2. Preprocessing of data for input
3. Analysis of data by using model
4. Calibration and Validation

The first step is important and critical step, in this the actual data is collected by the instrument. The data can be measured physically, Spectroscopy measurement, Chromatographic measurement through various chemical methods like HPLC, GCMS, and so on (Ruffin, C., King, R. L., & Younan, N. H. (2008). After data collection in first step, the preprocessing is required. The purpose of this step is to remove the noise from data, remove irrelevant information that is not useful for actual analysis etc. There are several preprocessing techniques are available like, Savitzky- Golay filter with derivations, Derivative processing, Baseline correction, Mean centering, Normalization, Multiplicative signal correction, smoothing, etc. The famous techniques are Savitzky-Golay filter with derivative processing (Singh, I., Juneja, P., Kaur, B., & Kumar, P. (2013). In this research work as preprocessing technique we used Savitzky-Golay filter. After Preprocessing the model is selected according to the dataset and purpose. This can be decided whether you want to analyze sample by qualitatively or quantitatively. To develop and use this model the basic two techniques can be used Supervised and Unsupervised technique. Local Weighted Regression, Multiple Linear Regression, Neural Networks, Artificial Neural Network, Partial Least Square, Principal Component Regression, Support Vector Machine, and other models are used in quantitative chemometrics. Following model selection, the data is split into two classes: calibration and validation. Calibration and validation of data are required in qualitative and quantitative analysis. Model creation and model selection are dependent entirely on calibration data, and validation data is used to test the predictive performance of the chosen model. Usually, the calibration and validation data ratios are 25% and 75%, respectively. When the dataset used for calibration is also used to validate the model, it is known as cross validation, and it is bad. New data is needed for true validation.

2.5.1 PLSR Regression

Regression is a technique use to analyze the relationship between dependent and independent variable and to check how they are contributing and are related to producing a outcome together. In our pharmaceutical database the Spectral dataset have the values in continues nature, due to this problem we required the regression. Regression is a predictive modelling technique used to predict the value of the dependent variable when the independent variable is known, or to predict the effect of an independent variable on the dependent variable. The several regression techniques are available for making predictions based on various parameters such as the number of independent and dependent variables, the shape of the regression line, and the type of dependent variable. Partial Least Squares Regression (PLSR) is a quick and effective technique for covariance-based regression analysis. It is useful for regression problems with a large number of independent variables and a high likelihood of multicollinearity between the variables. The PLSR technique reduces the number of variables to a manageable number of predictors, which is then used in regression (Biancolillo, A., & Marini, F. (2018), Cheng, J. H., & Sun, D. W. (2017).

2.5.2 Dataset Preparation

Dataset was prepared that having total 160 samples. For each sample 20 utterances was taken by ASD Spectroradiometer. As showed in Table2, Standard Paracetamol sample stored as Label 1, Calpol 500mg tablet labeled as 2, and so on. All the samples stored in Coma Separated Value (CSV) format file and the complete file as dataset was given as the input to the proposed PLSR model.

Table 2 Dataset

Label	Sample Name
1	Standard Paracetamol API
2	Calpol 500mg Tablet
3	Calpol 650mg Tablet
4	Magnesium Stearate
5	Microcrystalline Cellulose
6	Maize Starch
7	Talc Powder
8	Lactose

3. Result and Discussion

The dataset was provided to the proposed PLSR model in CSV formatted file, then the Savitzky golay filter with 1st and 2nd derivative was applied as a preprocessing technique and 8 components was given to the PLSR model. Then we fit the regression to dataset by predicted and validated values in the form of X and Y. In this work we have dataset having 160 samples only but to apply machine learning techniques the dataset should be huge. So to overcome this problem we perform 10 fold cross validation to test the predictive ability of our proposed model. The Table3, showed that the model gave good accuracy and efficiency. Model showed high values for Coefficient of determination (R^2) and low values for Root Mean Square Error

(RMSE) and it is consider that the performance of model is satisfactory (Shinde, S. R., Bhavsar, K., Kimbahune, S., Khandelwal, S., Ghose, A., & Pal, A. (2020, July).

Table 3 PLSR model results

Class	Values
R2 calib:	0.998
R2 CV:	0.996
RMSE calib:	0.010
RMSE CV:	0.025

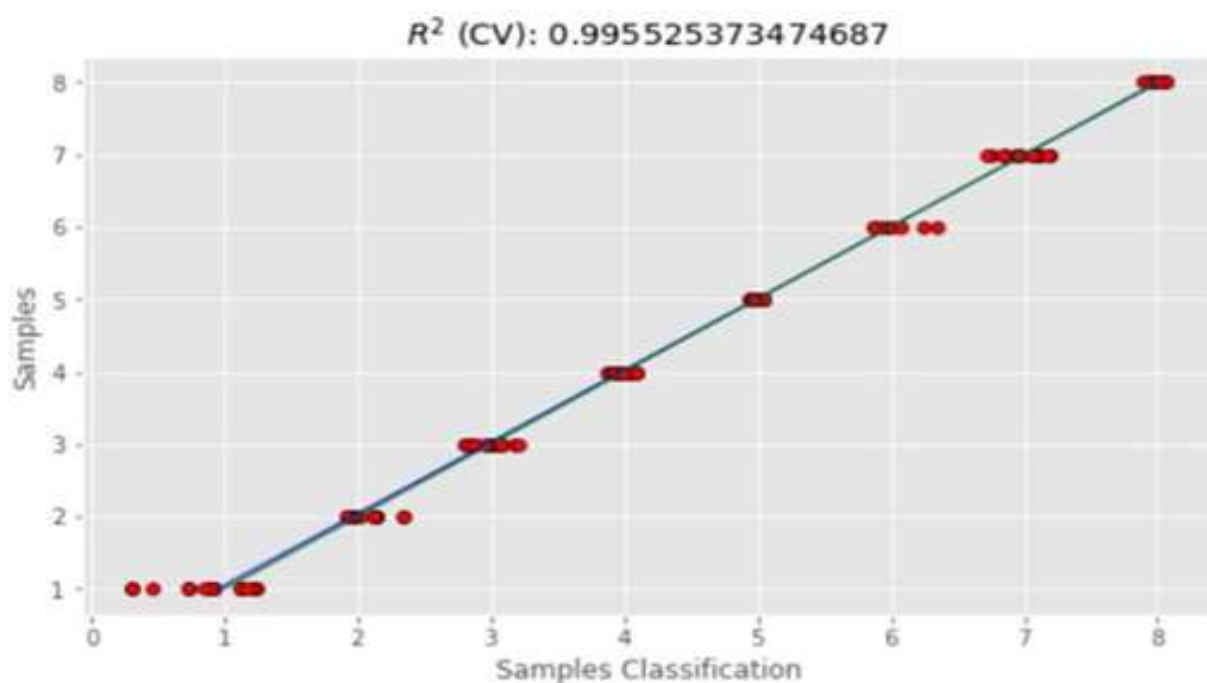


Figure 6 Regression Plot of model

Figure 6 showed the regression plot of model. We have total 8 class of samples that having basic excipients and pure Paracetamol drug and Paracetamol tablets having different quantity. The plot showed all samples underlies between regression lines. Pure paracetamol and paracetamol tablets having the main contain as paracetamol API and it showed near to each of them in plot. Excipients are different from each other so they are somehow far from other samples. R2 calibration value of model is 0.998 and the R2 validation value of model is 0.996 and RMSE value is low. This showed that the proposed PLSR regression model with 8 Components given good result as 99% accuracy.

4. Conclusion

Counterfeiting of medicines is a serious problem all over the world. Paracetamol as active ingredient in medicine is widely used in pharmaceutical industry over the world due to its efficiency and uses. Analyze the Paracetamol medicines that having different quantity of Paracetamol as API, we used Calpol 500mg and 650mg tablets. Common excipients (Magnesium Stearate, Microcrystalline Cellulose, Maize Starch, Talc Powder, Lactose) and Pure Paracetamol as standard drug used in this study. All the samples analyzed and collect their Spectral data with

the help of ASD FieldSpec4 Spectroradiometer having 350- 2500nm Spectral range. Dataset was prepared from collected Spectral database with proper labeling and PLSR regression model is proposed with 8 components. The model was trained by calibration and validation process up to the maximum accuracy is given by model. As result showed the proposed model is efficient and given the high accuracy as 99% in this work.

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Effects of Cellulose Nanocrystals on Construction Materials: Meta-analyses Quantification using RevMan Software

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Abstract

Producing ordinary Portland cement is unsustainable due to its energy intensity and substantial greenhouse gas emissions. There is a need for alternative green building materials to ensure the sustainability of the construction sector. Further development is needed to optimize the industrial feasibility of green building materials. The commercial viability of green construction materials can be improved by cellulose nanocrystals (CNC)- a novel reinforcing agent. The overall effects of CNC on construction materials must be quantified to strengthen its application in green construction materials. Although the literature qualitatively reviewed the CNC effects in conventional construction materials, its overall magnitude was not quantified. Hence, this study aimed to quantify the aggregate influence of CNC on the mechanical characteristics of building materials using meta-analyses. Based on systematic reviews, the results of qualifying studies were inserted into the meta-analyses using the Review Manager (RevMan) software. The forest plots showed that CNC exhibited positive effects on the mechanical properties of building matter with negligible publication biases. Sensitivity analyses confirmed that CNC improved construction materials' compressive and flexural strengths. The study implied that CNC could be applied to enhance the mechanical properties of green construction materials to strengthen their commercial viability. Meta-analyses were found to optimize engineering research and development. Therefore, this study presents an empirical framework to use meta-analyses as a research tool.

Keywords: cellulose nanocrystals, meta-analyses, review manager software, green building materials, sustainable construction, geopolymer construction materials

1. Introduction

Concerns relating to the environment remains a primary issue affecting the construction sector (Imbabi et al., 2012; Roopchund, 2021). Substantial energy is required to produce ordinary Portland cement (OPC). In addition, OPC production substantially contributes to greenhouse gas emissions (Komnitsas, 2011). Unique green options to OPC are needed to ensure the construction industry's long-term sustainability. One such feasible option to OPC is that of fly ash-geopolymers (Komnitsas, 2011; Imbabi et al., 2012). Yet, additional investigations must be undertaken to ascertain how to enhance these green construction materials for commercial viability. Cellulose nanocrystals (CNC) as a reinforcing agent can improve the viability of green construction materials.

This study systematically reviewed CNC as a strength-enhancing binder for building materials. Although previous research investigated CNC applications in building materials, its effects on the mechanical characteristics of construction materials have not been consolidated and quantified. Such findings can inform decisions to optimize and commercialize novel green construction materials using CNC as an enhancement factor. To decrease this knowledge gap, three aims were proposed in this study (Roopchund, 2021). Firstly, consolidate the literature for the meta-analysis using the Review Manager (RevMan) software. Secondly, to statistically quantify how CNC impacts the strength of building

materials using RevMan. Thirdly, to develop a universal framework to perform meta-analyses as an engineering research tool using RevMan software.

It is argued that CNC positively impacts the strength of construction materials, implying that it can enhance novel green construction materials as OPC alternatives for the continuing feasibility of the construction sector.

2. Literature Review

2.1 Outlining the Construction Sector's Status Quo

According to Imbabi et al. (2012), there are several concerns challenging the construction industry: dwindling fossil fuels, meagre source materials, environmental issues, greater demand, and a stationery global economy. Imbabi et al. (2012) further asserted that producing OPC accounts for 6% of the total commercial carbon emissions, and contributes 5 to 7% of the total global warming emissions (Singh & Middendorf, 2020). Hence, it is crucial to produce green building materials that are environmentally friendly. According to Komnitsas (2011), the characteristics of green building materials include durability, being bio-based, ability to be created from recycled materials, and exhibiting marginal emissions and toxicity.

Geopolymers are green construction alternatives produced from either industrial by-products, and natural minerals or effluents that are minimally processed to provide binding agents (Komnitsas, 2011). Additionally, the production of geopolymers uses industrial aluminosilicate by-products with minimal environmental impacts (Singh & Middendorf, 2020), enabling energy savings and carbon dioxide reductions. Hence, geopolymers are regarded as green construction materials. However, the technology must be improved to optimize the likelihood of industrial applications (Komnitsas, 2011). The study of Singh & Middendorf (2020) indicates that geopolymer production is uncertain with respect to reaction impurities, phase transformation, and their effect on strength development. Therefore, additional research is required in these areas.

2.2 Cellulose Nanocrystals (CNC) to Improve Building Materials

CNC is an unfolding biomaterial with high-strength properties. CNC is produced using acid hydrolysis of lignocellulosic feedstocks. It is notable that waste feedstocks from the forestry, paper, and timber sector can be used to create CNC (Roopchund, 2021). It is known that CNC can be applied to better the industrial feasibility of geopolymer building materials by merging the use of reinforcing bio-additives in building materials (Pacheco-Torgal, 2016) with the worldwide materialization of green geopolymer building materials (Imbabi et al., 2012; Komnitsas, 2011; Singh & Middendorf, 2020).

Cao's et al. (2016a) study researched how CNC affected the microstructure of cement. The study developed a unique centrifugation technique to quantify the adsorbed and free CNC concentrations. More than 94% of the CNC was adsorbed, which demonstrated consistent dispersion inside the cement's matrix. The cement porosity reduction of 1.2 to 1.6% was due to greater matrix hydration. However, the marginal decrease in porosity failed to justify the energy-intensive sonication dispersion, despite the inversely proportional relationship between the cement porosity and compressive strength (Roopchund, 2016).

The research of Cao et al. (2016b) determined how the dispersion of CNC impacted the cement's strength. The study focused on the CNC agglomeration potential. According to Cao et al. (2016a), agglomeration prevents CNC dispersion inside the cement matrix, resulting in air entrapment, voids, and pores. Agglomeration was prevalent when the CNC concentration was greater than 1.35%. Considering that the 0.18%, CNC concentration was optimal for strength development, a comparatively low CNC concentration can optimally develop the cement strength. Strength improvements of up to 50% were

caused by ultrasonication dispersion, showing its effectiveness in flexural strength improvement. Although this study was based on cement, ultrasonication dispersion can be extended to geopolymers as green building materials to obtain better strength properties.

Two uncertainties prevent the commercialization of geopolymers: technical (Singh & Middendorf, 2020) and financial (Imbabi et al., 2012). The following reviews outline the advantages of incorporating CNC in building materials. Despite the research focus being on the addition of CNC to OPC, the logic can extend to geopolymers.

The research of Barnat-Hunek et al. (2019) determined how the physical properties of concrete were affected by CNC. CNC substantially bettered the concrete's resistance to freezing-thawing (exceeding 14-fold), which is remarkable for building materials that need to resist adverse climates. As expected, CNC altered the morphology and reduced the cement pores. Such findings aligned with those in the study of Cao et al. (2016a). In summary, CNC changed the cement's microstructure and interface characteristics, which improved the density.

Like the research of Cao et al. (2016a), the study of Dousti et al. (2019) determined how cement's strength development and porosity was affected by CNC. The strength was determined under tension and compression over eight weeks. CNC reduced the surface area by 66% and the porosity by 33%. Within 24 hours, these combined effects enhanced the tensile and compressive strength by 60%. These findings are important in building applications that require quick strength development. This study was notable as it outlined how CNC affected the hydration of cement. In addition, similar findings were found in the research of Mazlan et al. (2016), in which a 45% improvement in the cement's strength was achieved. Similar results were found in the investigations of Barnat-Hunek et al. (2019) and Roopchund et al. (2022).

The overall trend observed in the studies of Cao et al. (2016a), Cao et al. (2016b), Mazlan et al. (2016), Lee et al. (2019a), Dousti et al. (2019), and Barnat-Hunek et al. (2019), is that CNC improved the mechanical characteristics of the respective building materials under investigation. The study of Liu et al. (2019) used nitrogen adsorption analyses and X-ray computed tomography to investigate how CNC affected the compressive strength of cement. CNC was found to enhance the structure of the cement pores.

The study of Lee et al. (2019b) determined how CNC affected the mechanical performance and shrinkage rate of construction materials. As suggested in the studies of Cao et al. (2016a), Cao et al. (2016b), and Lee et al. (2019a), the CNC underwent ultrasonication dispersion. It was found that the best CNC dosage was 0.8% by volume as it resulted in the best mechanical performance and rate of shrinkage. As observed in the previous studies of Cao et al. (2016b) and Roopchund et al. (2022) a minute CNC quantity achieved the most favourable mechanical properties in the building material. Furthermore, the implication was that minuscule CNC quantities are required for thermal resistance applications. Despite the literature trends showing positive CNC effects on the mechanical properties of building materials, no overall quantification of the CNC effect was made.

3, Materials and Methods

The purpose of a meta-analysis is to extract knowledge from several studies to validate a proof from the literature (Glass, 1976). Aligned to the recommendation that additional research can improve the mechanical properties and aid the development of green building materials (Zhuang et al., 2016), the meta-analyses quantified the aggregate CNC reinforcement effects on the mechanical traits of building materials. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline

(Kamboj, 2016) was employed to conduct the meta-analyses using the Review Manager (RevMan) software.

3.1 Using RevMan to undertake Meta-Analysis

Using the Review Manager software (RevMan version 5.4), one overall meta-analysis and two sensitivity analyses quantified the CNC effects on the compressive strengths and flexural strengths of building materials. The outlined procedure that follows (Arnqvist & Wooster, 1995) can be universalized.

1. Create and save a new review simulation.
2. Insert the titles and publication years of the comprising literature studies.
3. After capturing all the literature data, the "tree view" will show the data.
4. Add, name and save a new comparison under the "Data and analyses" section.
5. Compare the specific treatment to the control.
6. Select the "add outcome under the new comparison" option to add an outcome under the comparison.
7. Specify the data type as "continuous." Thereafter, specify the mean, standard deviation, and experimental run number for the compared data sets (treatment vs. control). The integrated statistical function in Microsoft Excel can be used to calculate these statistical parameters.
8. If the research studies being compared are similar concerning the treatment and control, use a "fixed effect" analysis model.
9. Retain the default confidence interval of 95%.
10. Open a new "Data and Analysis" outcome.
11. Select "add study data" to insert the studies of interest.
12. Specify the statistical parameters outlined in step 7 for the treatment and control studies for each literature source. Perform these statistical calculations in Microsoft Excel to ensure accuracy.
13. RevMan will calculate the I^2 and P-heterogeneity values for the study group. The I^2 value quantifies the heterogeneity of the studies to each other, while the P-value indicates how substantial the heterogeneity is.
14. The forest plot, which represents the individual study effects, automatically appears. The forest plot is a graphical indication of whether the literature studies favored the treatment or the control. The aggregate effect is represented by the diamond.
15. Export the results from the software (forest plot, funnel plot, and statistical parameters).
16. The overall meta-analysis included literature studies concerning strength responses using CNC reinforcement. Thereafter, sensitivity analyses were used to separate the flexural and compressive strength responses.

3.3 Data Analysis

The forest (confidence interval) plot graphically represents the individual literature studies encompassed by the meta-analysis (Egger et al., 1997a; Lewis & Clarke, 2001; Kamboj, 2016;). Individual studies are symbolised by blocks at the point estimates of the treatment effects with horizontal lines extending on either sides. The horizontal line provides a confidence interval, while the block's area is proportional to the study's weight (Alderson et al., 2004). The diamond on the plot symbolises the overall effect size, representing the aggregate effect of the individual studies. The diamond's location indicates whether the desired effect is caused by the the control or the treatment. Considering different research settings, methodologies, durations, and countries during the experiments, heterogeneity exists (Alderson et al., 2004), and is measured by the I^2 value.

Should the confidence interval not pass through the line of no effect, the result is deemed statistically significant (Alderson et al., 2004). Forest plots can also be used for sensitivity analyses to compare smaller sub-groups of data. The control and treatment sides of the forest plot are separated by the vertical line of no effect (Kamboj, 2016). The desired results are found in the favored side of the plot.

Such information indicates if the treatment being applied would yield the desired results based on the literature without needing experimental studies research prior to an investigation.

The effect size against the sample size is graphically represented in the funnel plot (Kamboj, 2016). Publication biases in the meta-analysis are detected by funnel plots. The presence of a publication bias is detected by three observations on a funnel plot: when the funnel is filled by the plot (Kamboj, 2016), asymmetry, and the presence of negative studies located in the left corner of the plot (Alderson et al., 2004). Asymmetry can be caused by factors such as selection biases, poor methodologies, true heterogeneity, and poor effect measures (Alderson et al., 2004).

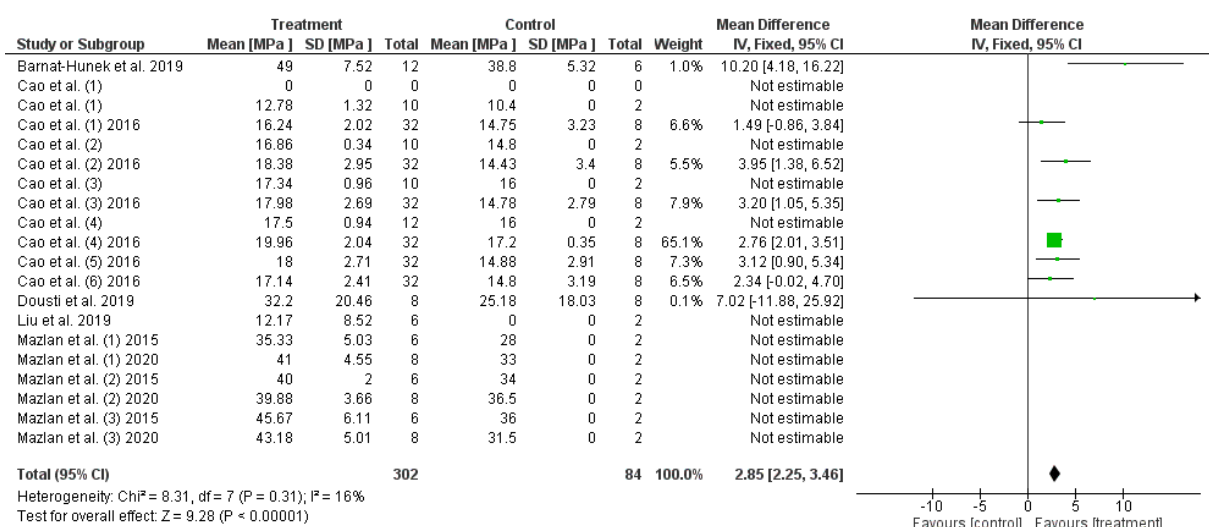
4. Results

The RevMan results encompassed the inputs (mean, standard deviation, and investigational runs for the treatment and control) and outputs (heterogeneity, mean difference, and weight). Some studies had single control samples (Cao et al., 2016a; Cao et al., 2016b; Liu et al., 2019; Mazlan et al., 2015; Mazlan et al., 2020), thus nullifying the standard deviation (Roopchund, 2021).

4.1 Overarching Meta-analysis

The individual study effects (square blocks) in the treatment region are shown in Fig. 1 (the overall meta-analysis forest plotFigure). The location of the study effects implied that the treatment was favored by each literature study. Consequently, the overall effect (the diamond) was located in the treatment region. These parameters suggested that improved building materials strength can be obtained using CNC reinforcement as the treatment. Hence, CNC reinforcement in building materials would yield improved flexural and compressive strengths. The confidence intervals of most of the individual studies failed to cross the line of no effect. Hence, these results were statistically significant. The 16% overall heterogeneity was relatively low, which suggested homogeneity among the individual study results comprising the overall meta-analysis.

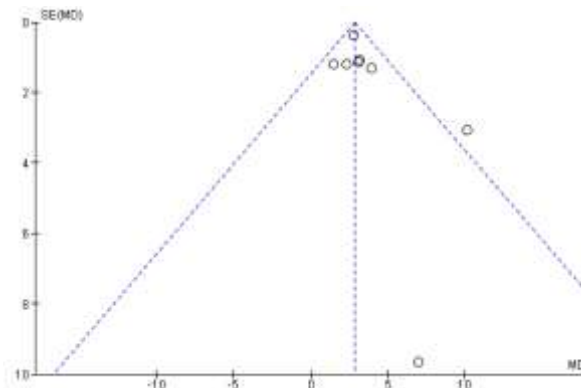
Figure 1: Overall Forest plot of CNC reinforcement



An even distribution of studies at the inverted funnel's apex was found in the overall funnel plot (Fig. 2). Additionally, the two traits suggesting a possible publication bias were absent: the funnel

filling with the plot and negative studies in the plot's left corner (Alderson et al., 2004). These phenomena certainly suggested the non-existence of a publication bias.

Figure 2: Overall funnel plot of CNC reinforcement



4.2 Sensitivity Analysis 1 (Compressive Strength)

Fig. 3 and Fig. 4 shows the meta-analysis and forest plot for the compressive strength sensitivity analysis, respectively. The CNC reinforcement (treatment) was found to favor compressive strength, as shown in the forest plot. According to the forest plot, the study of Dousti et al. (2019) was insignificant from a statistical perspective. Nevertheless, Barnat-Hunek's et al. (2019) study, showed that the treatment was favored. There was no heterogeneity = and the funnel plot exhibited no publication biases.

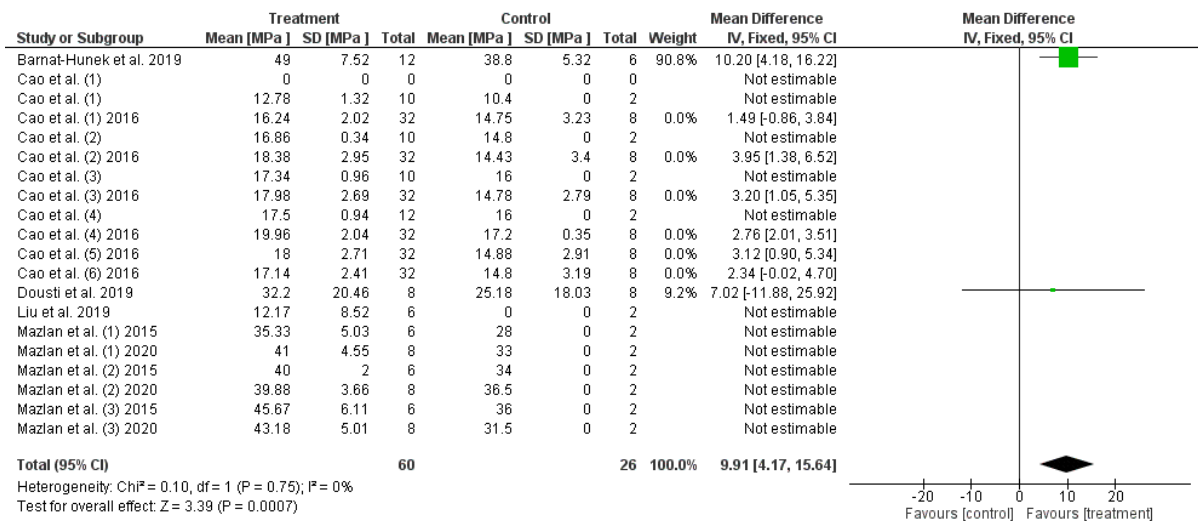


Figure 3: Forest plot of CNC reinforcement (compressive strength)

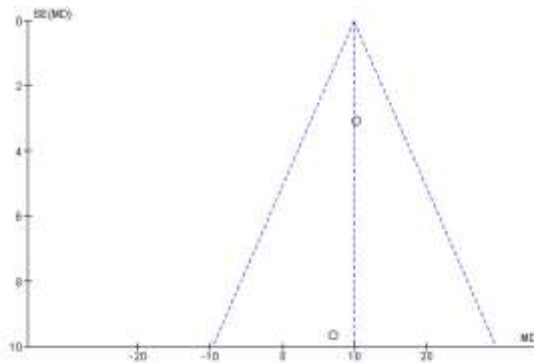


Figure 4: Funnel plot of CNC reinforcement (compressive strength)

4.3 Sensitivity Analysis 2 (Flexural Strength)

The meta-analysis and forest plot for the flexural strength sensitivity analysis are shown in Fig. 5 and Fig. 6, respectively. The influence of CNC reinforcement on the flexural strength of building materials was shown in the second sensitivity analysis. The treatment was favored by all five studies, indicated by the aggregate effect on the treatment region. 80% of the studies comprising this sensitivity analysis were statistically significant, with 0% heterogeneity. The funnel plot showed an even distribution of individual studies without any publication biases. Consequently, these findings validated the sensitivity results.

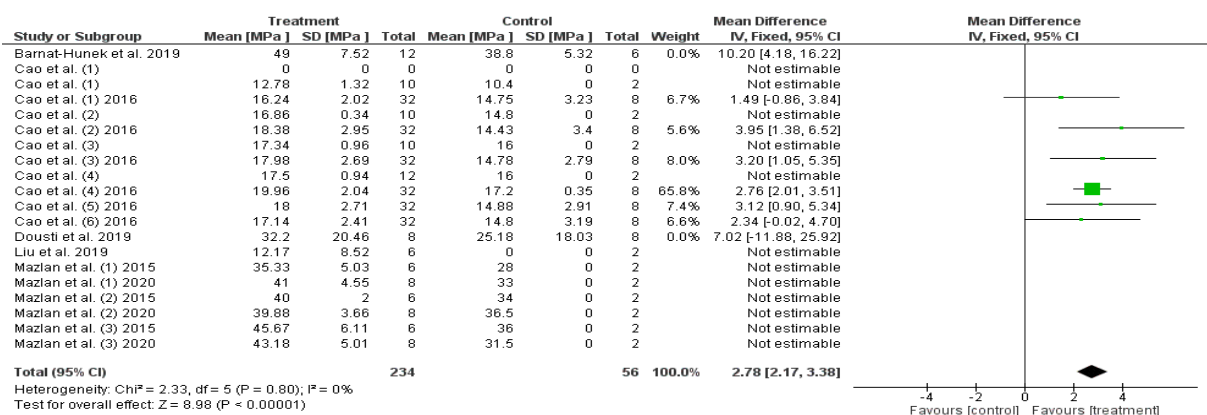


Figure 5: Forest plot of CNC reinforcement (2nd sensitivity analysis)

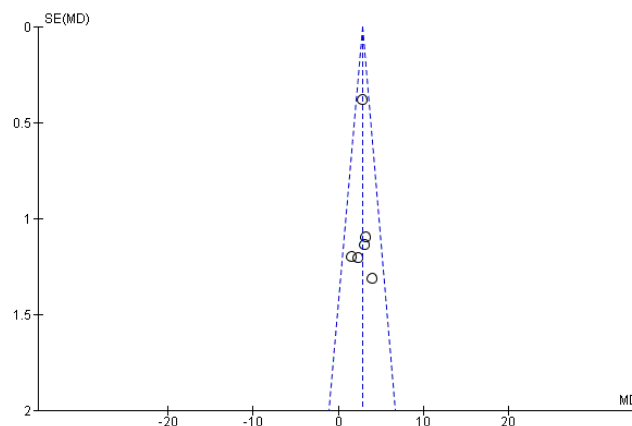


Figure 6: Funnel plot of CNC reinforcement (2nd sensitivity analysis)

5. Discussion

According to the overall meta-analysis, CNC reinforcement (as the applied treatment) was favored. The sensitivity analyses showed that CNC improved the compressive and flexural strengths of the construction materials. Hence, these results quantitatively proved the benefit of investigating CNC reinforcement in green building materials. Such results are pertinent to industries attempting to employ CNC reinforcement to develop green construction materials. The overall authentication of CNC reinforcements in building materials mirrored literature studies (Mazlan et al., 2016; Cao et al., 2016a; Cao et al., 2016b, Barnat-Hunek et al., 2019; Lee et al., 2019a; Lee et al., 2019b; Dousti et al., 2019; Liu et al., 2019).

To authenticate the reliability of the results, three measures can be considered. Firstly, the PRISMA standard was followed throughout the study. Secondly, the RevMan funnel plots showed no publication biases. Thirdly, the literature studies comprising the meta-analysis were statistically significant. These factors proved that a meta-analysis is an objective quantitative tool based on standard statistical procedures (Arnqvist & Wooster, 1995).

Considering that the meta-analyses proved the feasibility of CNC in enhancing green building materials, the recommendation of Zhuang et al. (2016) was fulfilled. A framework ensuring constant development and production of CNC-enhanced construction materials is recommended for future research (Singh & Middendorf, 2020). The study also recommends CNC characterization to determine the effects of varying categories of CNC on the derived reinforced geopolymers. There are no limitations or assumptions to achieve the presented results.

6. Conclusions

Green construction materials can replace unsustainable OPC. However, further development is needed to narrow the gaps between the laboratory-scale and industrial-scale production of green construction materials. Meta-analyses can quantify literature to determine overall treatment effects, thus eliminating extensive laboratory studies. Additionally, meta-analyses can be used to lead additional experimental research by improving the experimental conditions and ranges. Such optimizations can be exploited in fields that require fast and accurate results.

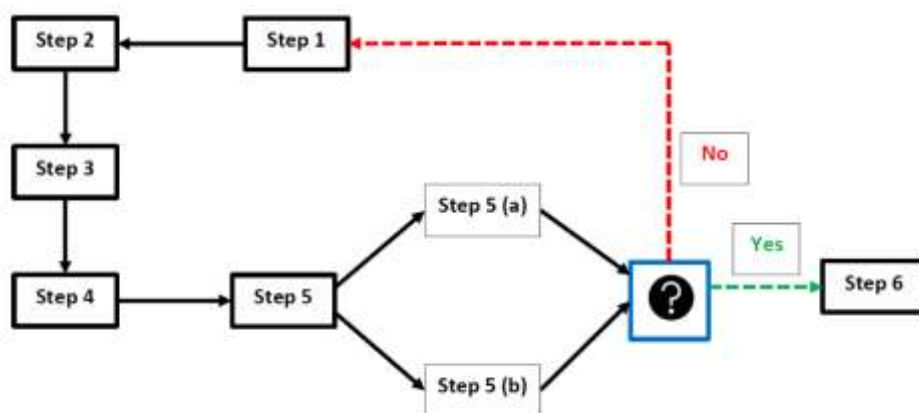
The implication is that industrialists and academics can employ meta-analyses to streamline their developments. Overall, the use of the RevMan software, and its associated methodology, were beneficial, as the meta-analysis addressed the study's argument.

Stemming from the research undertaken herein, the following framework (of empirical nature) is suggested to perform meta-analyses (Fig. 7) and can apply to multi-disciplinary studies:

1. Collect the relevant experimental data from the literature.
2. Extract the pertinent data for the control and treatment studies.
3. Calculate the mean and standard deviation for each literature study.
4. Input the statistical values from the above step into the meta-analysis.
5. Analyze the two software products: (a) the forest plot and (b) the funnel plot.
6. The forest plot will ascertain the aggregate effect's location, which predicts if the treatment being applied will produce the desirable outcome.
7. The funnel plot must be checked for publication biases (indicated in Fig. 7 by the question mark). If desirable results are not observed in either step 5 (a) or 5 (b), revert to step 1. Otherwise undertake step 6.

The empirical framework outlined above can be used to co-ordinate future experimental research to improve the effect of the treatment to be applied.

Figure 7: Empirical framework schematic for undertaking meta-analyses



When developing green building materials, the key stakeholders are construction industry leaders, researchers, the government, and industries producing the waste precursors. Meta-analyses can be used by researchers to secure reliable results and expedite their research activities. These results can assist construction industrialists to expedite the development scale-up of green building materials. Funding can be provided by the government to construction industry leaders as incentives for decreased carbon emissions. Finally, the waste-producing industries can provide them to green construction material manufacturers instead of environmental-degrading disposal.

The findings addressed the argument as CNC reinforcement underwent statistical validation to optimize the flexural strength and compressive strength of construction materials. Hence, it is beneficial to perform additional research to investigate CNC reinforcement on the mechanical properties of green building materials.

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A Systematic Review of WAVE Water Treatment Design Software and Related Technologies

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Abstract.

The water treatment industry needs customized solutions. Despite the advancement of water treatment technologies, proposed designs must pass pilot trials before industrial implementation. Technology piloting is costly and time-consuming. Water treatment software tools can optimize processes through simulation to meet the industry's need for rapid process solutions, thus saving time and money. However, not many studies demonstrate the requirements and capabilities of water treatment design software. Hence, this study aims to demonstrate the ability of the Water Application Value Engine (WAVE) software to design a demineralized water production plant for a Biorefinery process. The feedwater data was input in WAVE. The ultrafiltration (UF) and reverse osmosis (RO) process operations were specified, and the required water output was specified. WAVE simulated the process and provided the water quality exiting each process operation. The UF reduced the total suspended solids in the feedwater, while the RO lowered the total dissolved solids, thus reducing the ions by 98.56%. This ion removal ensures that the process equipment is protected from corrosion while yielding a high-quality product in the biorefinery process. Several design warnings were issued, analyzed, and mitigated. The study concluded that WAVE could effectively design and simulate new water treatment processes. Additionally, WAVE can serve as a diagnostic tool to optimize existing water treatment plants. The findings implied that Engineers and Academics could use WAVE to meet the industry's demand for rapid and accurate process solutions. The reported methodology can serve as an empirical guideline for WAVE and similar software tools.

Keywords: water treatment plant design, software simulation, water application value engine software, process optimization, software diagnostic tool

1. Introduction

Effective water treatment for chemical processes is crucial for high-quality products and for preventing process equipment corrosion (Liu et al., 2019). While demineralized water is easily procured for laboratory-scale, water treatment plants must be developed to produce demineralized (process) water for industrial processes.

A steady demineralized water supply was required to upscale a novel cellulose nanocrystals production process. Hence, a water treatment plant was required to treat municipal water to demineralized water standards. The previous studies of Niemi & Palosaari (1994) and Cardona et al. (2005) showed that water treatment design entailed precise and lengthy programming. In this study, a relatively new software, Water Application Value Engine (WAVE), was employed to design the water treatment plant within a short period. The input requirements, simulation methodology, and software results undergo analysis and discussion with respect to the literature. Furthermore, the software was reviewed according to the following evaluation criteria: simplicity of the user interface, ease of use, quick, accurate and reliable simulation outputs, and cost effectiveness.

This study aims to review WAVE as a prospective water treatment design tool with respect to other design tools identified in the literature. Discernment regarding the efficacy of the software can aid the design and optimization of industrial water treatment plants to supply process water. The hypothesis put forth was that WAVE can output a technically and economically efficient water treatment plant design.

2. Methodology

WAVE is free software established by DuPont Water Solutions with extensive water treatment applications. WAVE modeled the ultrafiltration (UF) and reverse osmosis (RO) unit operations. Considering that Gauteng (South Africa) was selected as the plant location, the Ekurhuleni and Johannesburg Metro Municipal water analyses were sourced from Rand Water's data repository. The data was subsequently averaged for the input analysis. The water treatment flowsheet was configured by specifying the unit operation sequence. No pre-filtration step was envisaged as the turbidity of municipal water is lower compared to raw water sources, including river or rainwater.

The first unit operation specified was the Ultrafiltration (UF) unit. Thereafter, the second stage to be specified in the water treatment process was the reverse osmosis (RO) operation. Traditionally, a final polishing stage proceeding RO is employed to eliminate residual ions in the RO permeate. However, polishing operations were not selected in this design for two reasons. Firstly, the product water can conform to the process water quality standards with sufficient maintenance of the UF and RO units. Secondly, the plant's operational and capital costs will increase. After specifying the plant configuration, the municipal water type was selected, and 75 m³/day of product water was specified.

The municipal water quality was specified by inputting the source water data. A 20°C design temperature was used, while a temperature range between 10°C to 40°C was defined. Considering that the input values were estimates with missing source data and unbalanced averages, WAVE then automatically balanced the ions. Thereafter, the UF stage's configuration and layout were automatically specified. The strainer specification, product flowrate, feed pumps, module selection, design cycle intervals, and chemical dosing details are shown (Fig. 1).

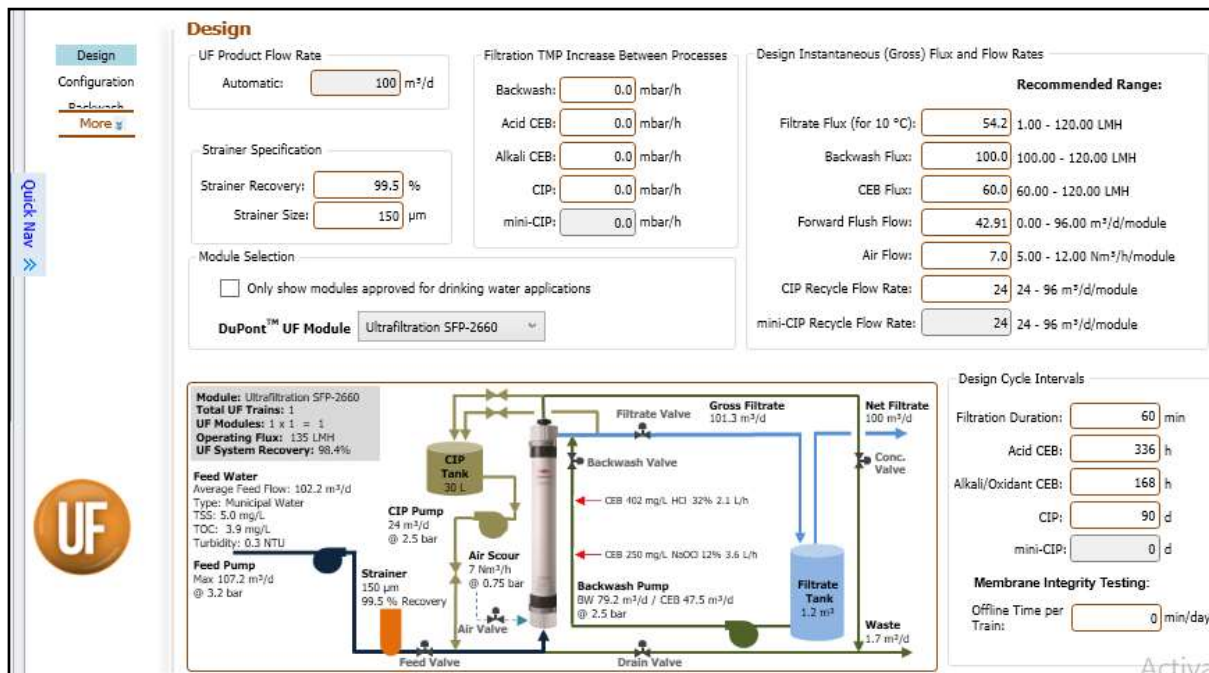
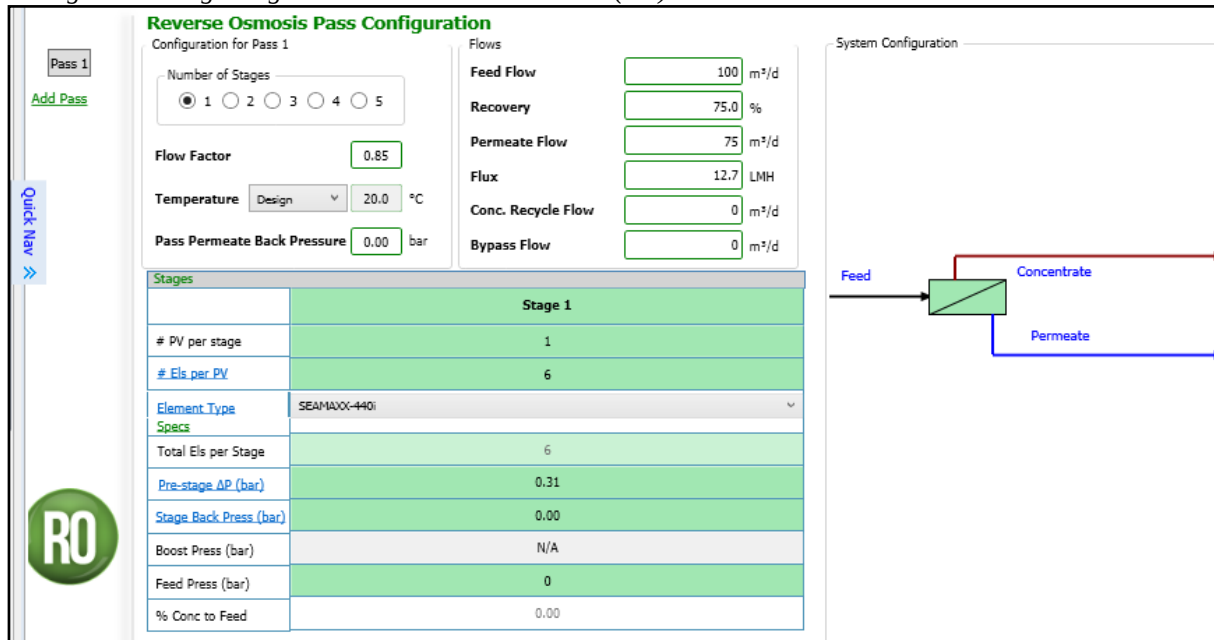


Figure 1: Specification of the Ultrafiltration stage

The UF design summary report was then produced (Results, Fig. 3). It was noteworthy that WAVE specified the reverse process details. These reverse process details included the backwash, chemically enhanced backwash, and clean-in-place procedures because the operational efficiency decreases with the acculation of suspended solids on the surface of the membrane. The backwash procedure pumps water through the membrane opposite the forward operation in regular intervals. The backwash dislodges the accumulated suspended solids from the membrane surface. However, backwashes lose their potency over time. Hence, regular chemically enhanced backwash procedures are required to sustain the membrane's performance.

Additionally, regular clean-in-place procedures are performed more frequently. The clean-in-place procedure is more thorough in relation to the chemically enhanced backwash. A single RO stage was allocated to reduce the plant's capital expense and footprint. WAVE recommended the RO element type. WAVE performed the RO design based on this specification and the UF results (Fig. 2).

Figure 2: Design Stage Schematic- Reverse Osmosis (RO)



3. Literature Review

UF and RO membrane technologies have been extensively researched over the last two decades. Rautenbach et al. (1996) piloted membrane technologies (RO, nanofiltration, and crystallization) for the treatment of dumpsite leachate. The permeate recovery rate of 97% indicated the membrane technology's feasibility in water treatment applications. The 8.3 kWh/m³ permeate power consumption was deemed relatively low and therefore feasible compared to evaporation. Notably, membranes were considered "modern wastewater treatment" technologies (Rautenbach et al., 1996). At that time, UF and RO were optimized for reduced energy, capital and operational investment costs, better recoveries, and zero discharge (Rautenbach et al., 1996). These focal points were addressed in further studies (Clever et al., 2000; Lorain et al., 2007; Knops et al., 2007; Sun et al., 2015; Loganathan et al., 2015; Ho et al., 2015).

Typically, UF is used as a pretreatment operation for RO (Clever et al., 2000; Lorain et al., 2007; Knops et al., 2007; Sun et al., 2015; Ho et al., 2015; Loganathan et al., 2015). The research of Rosberg (1997) focused on UF as a pretreatment for RO and nanofiltration. UF was an expensive emerging technology at that time, and sand-filtration was preferred. Recent studies show that reduced UF costs made it the favoured RO pretreatment (Lorain et al., 2007; Sun et al., 2015). RO problems include precipitation, adsorption of organic fouling, colloidal dust deposition, and biofouling (Rosberg, 1997). UF pretreatment can eliminate these problems. Hence, it is notable that the study of Rosberg (1997) perceived UF to be the ideal preliminary treatment for RO.

The study of Clever et al. (2000) used pre-filtration, UF, and RO to treat river water to yield process water. The pre-filtration removed suspended matter to prevent clogging of the UF membranes. The results demonstrated high availability and definitive plant operation. The system reduced microbes and suspended particles from river water, providing high-quality permeate (< 0.05 NTU). Considering these

results, a commercial plant was implemented for a steel company. The operational insights based on the pilot plant study were used in the industrial plant.

The study of Knops et al. (2007) provided an economic validation of the UF-RO configuration for seawater treatment. The higher UF operating cost was previously viewed as an obstacle. Hence, the study recommended a new UF membrane to reduce operating costs by 2-7%. The UF operating costs, UF membrane investment amortization, increased output, and operating cost reduction revealed the economic aspects of the recommended system. WAVE automatically provides cost analyses of proposed designs, enabling rapid monitoring. If the budget is exceeded by the cost, the design can be adjusted to achieve cost effectiveness.

Like the study of Knops et al. (2007), the study of Lorain et al. (2007) determined the pretreatment benefits of membrane technologies in seawater treatment. To prevent membrane fouling, the RO silt density index must be less than 3 (Lorain et al., 2007). The study used a pilot unit to combine sand filtration, UF (pretreatments) and RO. The silt density index of the seawater ranged between 6.1 and 6.4. After UF, the silt density index ranged between 1.2 and 2, compared to 5.8 to 5.9 for sand filtration. Using sand filtration, the RO permeability decreased by 28% over 30 days, and the chemical cleaning interval occurred every 12 to 18 days. Using UF, the RO operated for 20 days in the absence of chemical cleaning. Based on these results, UF was experimentally supported as an effective pretreatment for RO.

In the study of Loganathan et al. (2015) the combined UF-RO arrangement was examined for the treatment of basal aquifer water to produce synthetic oil. The study aimed to attain zero-liquid discharge by incorporating evaporation and crystallization operations. The evaporation-crystallization unit effected evaporation of water within the RO reject flow, causing salt crystallization. According to laboratory-scale and pilot-scale tests, feed softening was required in the evaporator to eliminate scaling. Overall, the zero-liquid discharge approach effectively produced freshwater and minimized brine discharges. Although crystallization is recommended in water treatment plants, WAVE does not enable crystallization simulations.

Hybrid systems use coagulants and flocculants to aid pretreatment. Ho et al. (2015) piloted inline coagulation-UF. The study is novel as most pretreatments employ a strainer before the UF. To clump and remove dissolved organic matter from the treated water, coagulants such as ferric chloride, polyaluminium chloride, and aluminium chlorohydrate are used. Specifically, ferric chloride yielded the greatest removal of dissolved organic carbon (approximately 60%) and the highest phosphate (99%) and silica removals (14%). Similar to the research of Ho et al. (2015), the investigation of Sun et al. (2015) combined various pretreatments, including dual-stage sand filtration, UF, and ferric chloride flocculation. The UF effectiveness was evaluated by the membrane-specific flux. Combining ferric chloride flocculation with UF decreased the specific flux throughout a chemically enhanced backwash. Additionally, ferric chloride flocculation/dual-stage sand filtration/UF steadied the specific flux throughout a chemically enhanced backwash compared to ferric chloride flocculation/UF only. Despite the advantages of hybrid technologies, designers are limited as WAVE cannot simulate them.

Sievers et al. (2017) recommended combining customized process technology to meet water treatment demands instead of standard solutions. Hence, the use of software to design water treatment plants is anticipated to facilitate quick customized solutions. This assertion supports the use of WAVE in this study to design the required water treatment plant. Furthermore, Sievers et al. (2017) outlined a vision for 2030 to overcome technology shortcomings. The most critical research target is "continuous optimization of production systems" to decrease pollution loads and water demand. Hence, water treatment design software can optimally design new plants and optimize existing plants for improved performance. WAVE can achieve both purposes.

Software simulations are expected to provide a virtual reality of processes in the fourth industrial revolution. This advancement can eradicate the requirement to implement pilot plants for commercial trial runs. In this review phase, simulated research was reviewed with respect to WAVE. The study of Niemi and Palosaari (1994) established a flowsheet to simulate UF and RO technologies. Although much research was performed on pilot plant studies during this time, this study was among the first to apply simulation. UF and RO membrane separation models were developed to calculate the membrane area, permeate flux, and solute rejection, while the UNICORN program simulated the stream matrix. Polynomial equations were fitted to experimental data, and mass transfer prototypes were used to determine the rejection and permeate flux. Although this flowsheet simulation approach was previously practical, mass transfer equations and parameter fitting tools are integrated into modern software packages. In addition, the study's software tool required comprehensive input data, which is not needed by current simulation packages. Both advantages are offered by WAVE.

As with many studies in which UF is employed as a preliminary treatment stage to RO (Lorain et al., 2007; Sun et al., 2015), the study of Cardona et al. (2005) combined UF and a two-stage RO system to treat seawater. Excel was used to simulate the plant using Visual Basic macros. This simulation technique differed from WAVE in two ways. Firstly, WAVE enables specification of the pass numbers and stages for UF and RO configurations. Secondly, the preliminary treatment phase outlined in the study of Cardona et al. (2005) was designed on a different program to the primary simulation.

In contrast, WAVE automatically incorporates the pretreatment phase within the design configuration. The study of Cardona et al. (2005) perceived UF to be an energy efficient technology- which sharply contrasted the notion that UF is costly in the investigation of Rosberg (1997) conducted earlier. Considering this perception shift, the cost efficiency of membrane technologies in water treatment has improved over time.

RO membrane scaling is a widespread concern investigated in the research of Karabelas et al. (2020). The water industry is challenged by inadequate techniques to evaluate the potential for feedwater scaling, selection, improving scaling control strategies, and observing membrane scale-formation while the process is running (Karabelas et al., 2020). Hence, the study outlined RO scaling mechanisms, monitoring, and mitigation procedures. The scale deposition rate per unit membrane-surface-area was identified as the most suitable parameter to model and quantify infant scaling. The study recommended developing a predictive tool during the early design and optimization of RO-plants.

Furthermore, the study suggested combining membrane-scaling test results with module simulations. It is notable that WAVE can produce scaling design warnings. Aligned to the suggestions of Karabelas et al. (2020), the WAVE software can manipulate the initially specified parameters to yield improved operation outputs.

Despite the novelty of the information provided in the literature studies (pilot plants and simulations), no water treatment plant study has been demonstrated using recent software simulation and design tools. Furthermore, the trouble-shooting capabilities and analysis of design results have not been reported in previous research. Hence, this study aimed to design a water treatment process capable of producing process water for a new biorefinery process using WAVE as a case study.

3. Results and Discussion

3,1 Ultrafiltration Design

Figure 3: UF Design Summary

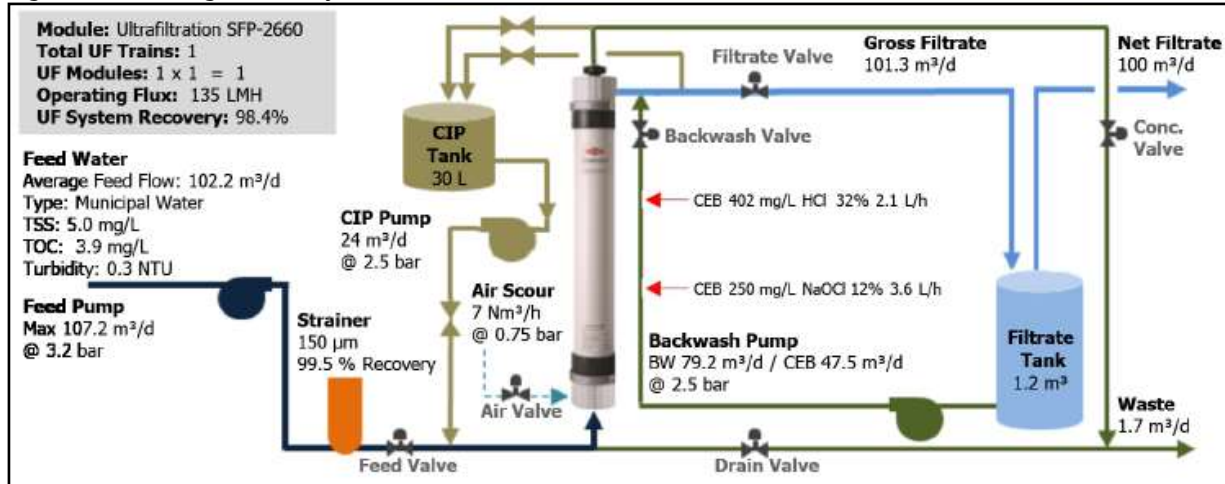


Table 1: Comparison of UF Input and Output Streams

Parameter	Feed	Permeate
Temperature (°C)	20.0	20.0
Turbidity (NTU)	0.3	< 0.1
Total suspended solids (mg/L)	5.0	0.0
Total organic carbon (mg/L)	3.9	3.5
Silt density index	0.2	< 2.5
Total dissolved solids (mg/L)	449	449
pH	8.1	8.1

Considering the absence of a pre-filtration stage, the WAVE software recommended a 150 micron strainer to remove suspended solids at a rate of 0.5 m³/day. If not removed, these suspended solids would obstruct the UF membranes. The UF detailed design report (Fig. 3) showed the forward and reverse operation cycles (backwash, chemically-enhanced backwash, and cleaning-in-place). The UF flowsheet also incorporated the suggested strainer. Additional UF parameters comprised the membrane pressure ratings, pump hydraulics, electrical costs, and dimensions of the storage tank. It is notable that each specification is critical to implement the design.

The UF permeate and feed results (Tab. 1) demonstrated that the total suspended solids in the UF output stream were completely removed. Considering that the UF's purpose was to eliminate the source water's suspended solids, this result was anticipated. The decreased total suspended solids in turn reduced the turbidity by 67%. Although the total organic carbon was slightly decreased, the UF operation did not affect the source water's total dissolved solids. The total dissolved solids reduction was expected through the subsequent RO operation. WAVE issued two UF design warnings. According to the warnings, the trans-membrane pressure and filtration flux values were slightly above the design limits. However, considering that the backwash frequency and feed flowrate can be altered to eliminate the warnings, the mentioned result was not deemed a concern.

Additional indications in the design report included the backwash cycles and filtration mode. Additionally, the valve and pump conditions were outlined as functions of the UF action steps (backwash,

chemically-enhanced backwash, and cleaning-in-place). Outlining such UF actions is advantageous for control and instrumentation engineering, which requires a comprehensive background regarding the interrelations between the valve and pump functions of each step. The utility and chemical costs (dosing chemicals, service water, and electricity) concluded the UF design report (Tab. 4). The recommended dosing chemicals maintain the water pH within desirable ranges to intercept the scaling of membranes. The daily chemical and utility costs were comparatively low (\$ 2.26) aligning to a specific water cost of \$ 0.023 per cubic meter.

3.2 Reverse Osmosis Design

Table 2: RO Stream Information

Stream	Description	Flow (m3/day)	Total dissolved solids (mg/L)	Pressure (bar)
1	Raw feed to RO system	100.0	444.2	0.0
2	Net feed to Pass 1	100.0	444.3	5.2
4	Total concentrate from Pass 1	25.0	1,755	4.6
6	Net product from RO system	75.0	3.05	0.0

Table 3: RO Ion Removal

Ion	Feed	Permeate	% Removal
Ammonium	0.63	0.02	96.83
Potassium	6.93	0.10	98.56
Sodium	25.46	0.33	98.70
Magnesium	17.97	0.08	99.55
Calcium	44.59	0.19	99.57
Strontium	17.18	0.07	99.59
Barium	4.91	0.02	99.59
Carbonate	3.22	0.00	100.00
Bicarbonate	313.3	2.16	99.31
Nitrate	0.05	0.01	80.00
Chloride	4.34	0.05	98.85
Fluoride	0.07	0.00	100.00
Sulfate	5.58	0.01	99.82
Total dissolved solids	444.2	3.05	98.56

Table 4: Cost Comparison between UF and RO

Parameter	Daily cost (\$)		Specific (per m ³)	
	UF	RO	UF	RO
Service water				
• Feed water	0.23	3.50	-	-
• Wastewater disposal	1.50	17.26	-	-
Electricity cost	0.86	1.6	-	-
Specific energy	-	-	0.10 kWh	0.24 kWh
Chemicals				
• Citric acid	0.01	-	-	-
• Sodium hypochlorite	0.01	-	-	-
Feed pump	-	1.63	-	-
Utility and chemical cost	2.26	22.4	-	-
Specific water cost	-	-	\$ 0.023	\$ 0.298

WAVE suggested one RO train. Generally, the train and pass numbers depend on the source water contamination in terms of solutes removal. The municipal water source was expected to contain fewer

solutes than others, such as seawater (Cardona et al., 2005; Lorain et al., 2007; Knops et al., 2007; Sun et al., 2015). Therefore, the single train, single pass RO system output by WAVE was considered accurate.

Unlike the comprehensive flowsheet output for the UF configuration (Fig. 3), no corresponding RO output was produced. The RO stream information was specified in Tab. 2. Notably, the total permeate dissolved solids decreased from 443.2 mg/L to 3.05 mg/L (98.56% reduction). The notable total dissolved solids reduction in the permeate enables it to be used as deionized (process) water for industrial processes. Therefore, this result validated the single-pass specification that was initially input.

Considering the doubled capital cost that would arise from implementing a standby RO train, it was not suggested. The operational RO system is equipped with regeneration capabilities, such as regular backwashes, chemically enhanced backwashes, clean-in-place, and the (optional) dosing of antiscalants and anti-foulants. Hence, the no-standby recommendation was validated from a technical viewpoint. The total system recovery of 75% was deemed sufficient to supply deionized water to the Biorefinery production process in the required quantity.

WAVE issued two RO design warnings: the element recovery exceeded the maximum limits and the concentrate flowrate fell below the minimum limits. Similar to the UF design, these warnings outlined that the performance of the physical system would not completely conform to the simulated system. These warnings are concerned with the UF product volume being passed through the RO. A holding tank is therefore proposed to store the UF permeate, thus ensuring that the RO system's booster pumps have sufficient water supply for the RO membranes. Consequently, the holding tank configuration will allow the RO system to meet the minimum element recovery limits and concentrate flowrate.

Additionally, WAVE showed solubility warnings that are linked to the dissolved solids' possible scaling of the RO membranes. WAVE recommended dosing antiscalants into the water supplied to the RO membranes to counteract these warnings. The antiscalants are recommended for direct dosage into the proposed UF holding tank to mitigate the simulation warnings in question. Considering that the simulation warnings allows for mitigation factors to be implemented, this strategy can be categorized as predictive maintenance.

The feed and permeate solute concentrations are indicated in Tab. 3. The last column shows the percentage reduction caused by the RO operation. As anticipated, RO caused a substantial solute reduction (exceeding 97%). The ions reduction in turn reduced the total dissolved solids by 98.56%.

The costs of the UF and RO were equated (Tab. 4). The daily RO chemical and utility costs summed to \$ 22.4, which was approximately ten times the corresponding UF chemical and utility costs. Considering the greater power requirement to reach the sizeable differential pressure across the RO to eradicate the dissolved solids, this steep cost difference is justified. As a result, the projected specific cost per cubic meter of RO water was \$ 0.298. Additionally, the wastewater disposal cost exceeded that of the UF system because the salt reject stream requires treatment prior to release into the environment. As recommended in the study of Loganathan et al. (2015), crystallization can be used to achieve these zero liquid effluent discharges.

This study perceived two major shortfalls concerning the WAVE software. Firstly, the software lacks the capability to simulate hybrid pretreatment methods (Sun et al., 2015; Ho et al., 2015). Hence, hybrid pretreatment methods cannot be simulated within the main water treatment design. Secondly, the WAVE software cannot model crystallization processes to treat the salt reject streams. Again, separate simulations will be required outside WAVE if crystallization is required.

In spite of these shortfalls, the WAVE software enabled the comprehensive design of the water treatment plant to supply deionized (process) water to the Biorefinery plant. A cost effective and simplistic design methodology using the WAVE software was performed, which validated the study's hypothesis. Contrasting the earlier simulation models found in the studies of Niemi & Palosaari (1994) and Cardona et al. (2005), the WAVE simulations are possible without too many inputs being required. There are no limitations or assumptions to achieve the presented results. Overall, WAVE performed well according to the established evaluation criteria relating to user efficiency, cost efficiency, and results reliability.

4. Conclusions

Considering that water treatment plants can be simulated using design software such as WAVE, this eliminates the reliance on pilot plant trials to gain insights about a process prior to commercial implementation. This finding implies that time and money can be saved for stakeholders such as Engineers and Academics. Each WAVE simulation presents a unique water treatment design specific to the problem being addressed. This degree of customization addresses Sievers' et al. (2017) concern regarding the infeasibility of water treatment designs that are not customized to individual requirements.

WAVE enables the 2030 water treatment industry goal of Sievers et al. (2017) concerning the ongoing improvement water treatment designs. In addition, the WAVE software predicted design issues, enabling effective mitigation measures. Hence, the hypothesis was validated regarding WAVE's ability to undertake the process water production plant to supply deionized water to the new Biorefinery production process.

There are two main practical implications of this study. Firstly, the efficient design of new water treatment processes can be done using the WAVE software. If there are no actual source water analyses, the designer can employ historic water quality analyses. Secondly, WAVE can be used as a diagnostic tool by implementing mitigation measures in response to design warnings to optimize existing water treatment plants.

The detailed design steps outlined in this study form a practical guideline for stakeholders to undertake effective and practical design studies using WAVE. The mitigation factors and analysis of the design results further guide the logic applied when designing new water treatment plants or optimizing existing ones. It is recommended that other water treatment plant simulation software be demonstrated for future research. In addition, crystallization technology must undergo development to simulate zero liquid effluent discharge scenarios.

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The Effects of Volatile Features on Digital Evidence Preservation

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Abstract.

Digital evidence has become extremely relevant in criminal, civil, and cybercrime cases. In criminal proceedings, the scope of digital evidence is broader, it is not limited to network activities alone, it may also include traditional evidence captured in digital format in specific cases, (Wu & Zheng, 2020). There seem to be conflicting views among digital forensic analysts on whether digital evidence can be flawlessly manipulated. Many people get the impression that this can be true, (Freiling & Hösch, 2018). Furthermore, (Freiling & Hösch, 2018) state that digital evidence can be tampered with or corrupted based on the manipulator's skills and expertise, and the manipulation can be unnoticeable despite the knowledge and competence as well as special equipment of digital forensic experts. Internet of Things forensics, Social Media Forensics, and Cloud Forensics are other domains where digital evidence can be acquired and used to solve cybercrime. Digital evidence has the following volatile features; is latent, fragile, easy to modify, can easily traverse jurisdictional borders, is time-sensitive and machine-dependent in many ways, and maintaining it comes with unique challenges, (Lone & Mir, 2019). The main conclusion from this paper is the volatility of digital evidence, solutions to manage the challenges of handling digital evidence, and the principles applied in the handling of digital evidence as well as other methods and tools used to preserve the integrity of digital evidence.

Keywords: Digital, Evidence, Forensics, Volatile, Preservation

1. Introduction

Any data or information processed by electronic media that strengthens or defends a theory regarding the state of digital artifacts or digital events of possible relevance and is admissible in court is classified as digital evidence, (Stoykova, 2021). Digital evidence has become extremely crucial in cybercrimes and criminal cases. Cybercrime has become more prevalent, and law enforcement officers are compelled to explore for precise digital evidence. Several digital forensic operations can be used to uncover crimes, (Sadiku et al., 2017). Any data assigned to a specific device or sent by information technology and telematics systems that have certain operational significance can be regarded as digital evidence, (Amato et al., 2019). Scientific evidence in digital format refers to any data provided to corroborate or reject a concept to specify how a crime transpired, as well as to demonstrate the intent or justification. Digital evidence according to ISO/IEC 270337:20126 is any type of information that may be retained or transported digitally, (Amato et al., 2019), and, digital evidence is any digital data containing credible facts that validate or disprove an incident.

Due to the volatile and transient nature of digital evidence, preserving it as evidence that is subsequently acceptable in court is fraught with challenges in both practice and law, (Camilleri, n.d.). She further states that it should be noted that digital evidence differs from other types of physical evidence in that it can be altered and modified relatively easily, and errors in the processing and maintaining of digital data could cause it to change therefore jeopardising its integrity and validity and compromising its legal worth. Therefore, the integrity of digital evidence is crucial during forensic investigations.

This paper aims to discuss the description of digital evidence, principles that should be maintained when handling digital evidence so that it can be preserved for court admissibility, and the literature review on the volatile features of digital evidence as well as the challenges usually encountered when handling digital evidence. Furthermore, this paper discusses other domains of forensics such as Internet of Things(IoT) Forensics, Cloud Forensics, and Social Networks (Media) Forensics, and challenges with

evidence acquisition and preservation. Tools that are used to search, collect and preserve digital evidence are also mentioned in this paper as well. The paper contributes to highlighting how the volatility of digital evidence affects its preservation and admissibility in court.

The rest of this paper is structured as follows; related work on the volatility of digital evidence, cybercrime and other emerging technologies, description of digital evidence, and volatile features of digital evidence. Challenges of handling digital evidence, possible solutions to mitigate the challenges, tools used to search and preserve digital evidence, and conclusion.

2. Related work

Information retained or transferred in a digital format that can be trusted in a court of law, is known as digital evidence. Hard drives, cellular phones, flash drives, routers, and mobile and GPS devices can contain digital evidence, (Riadi, 2018). He further states that if not managed appropriately, digital evidence can become delicate, volatile, fragile, and vulnerable.

When collecting digital evidence, copies of the original evidence should be made and subsequent testing and analysis should be done on the duplicates to conserve the genuine source of evidence and safeguard it from unintentional destruction or malicious tampering, (Camilleri, n.d.).

Digital evidence is intangible by nature, requiring appropriate support such as Optical storage devices, hard drives, and other media to retain it. In addition, it is volatile, easily distributed, subject to manipulation and modification in an untraceable and uncontrollable setting, and reproducible in a possibly endless several copies, (Amato et al., 2019).

It is often extremely simple to manipulate digital data on purpose. For example, freely accessible graphic design tools can be used to alter and manipulate pictures and video footage, whereas more skilled hacking can alter databases and websites, and discovery of such in these circumstances can be evaded by amending the audit file or log, (Camilleri, n.d.). Furthermore, after digital evidence has been captured, it can also be altered and corrupted or destroyed remotely through wireless networks.

3. Cybercrime and emerging trends in digital forensics

The practice of acquiring and examining data from computer systems, storage media, and networks in order to submit it as evidence in court is known as digital forensics, (Sachdeva et al., 2020). They, (Sachdeva et al., 2020), further state that, digital forensic technologies are employed to conduct investigations and provide solutions to crimes involving computers such as phishing, and financial crimes, together with crimes against humans like laundering of money, and child abuse, whereby the evidence may be stored in computers.

3.1 Internet of Things (IoT) Forensics.

The Internet of Things (IoT) is defined as the overall network of interconnected devices as well as the technology that enables the communication between those devices and the cloud and within those devices, (Sachdeva et al., 2020). Modern IoT systems with networking features provide a broad variety of benefits for consumers and commercial applications. IoT systems are still vulnerable to numerous cyber security attacks, and threats like Ransomware & Denial of Service attacks, the disruption of the Internet of Things networks, etc, (Sachdeva et al., 2020).

The first step in IoT forensics is to determine the origins of evidence that is already available, and then the investigator needs to identify which devices recorded pertinent data, (Mrdovic, 2021). He further states that it is crucial to know how the IoT communicates with its environment. This will allow the investigator to assess which other possible sources of data to identify, and learn where and in what

format the data is saved. It is vital to consider limitations to data acquisition such as legal, proprietary standards, and physical constraints, before gathering evidence.

When gathering evidence from IoT devices operating in a multi-tenancy environment, there are relatively few options available for producing forensic images of the target IoT device, (Janarthanan et al., 2021). Additionally, using conventional methods like hashing to preserve acquired data is not a challenge, however, in an IoT setting, maintaining the crime scene is a huge challenge. It would be extremely difficult to determine the extent of compromise and limits of a crime scene due to real-time and autonomous exchanges of IoT nodes.

3.2 Cloud Forensics

Cloud forensics is the branch of network forensics that applies digital forensics to the cloud. Since the data is spread across various locations, it is more difficult to find digital evidence, (Raja Sree & Mary Saira Bhanu, 2020). System logs, application logs, database logs, user authentication logs, etc, are a few instances of data sources. The intensity of attacks on cloud services increased significantly, according to the 2020 Trustwave Global Security Reports as cited by, (Ali, Memon, Dhomeja, Djokic, 2022). Cybercriminals can carry out massive unlawful activities while being very far away from the target and remain unidentifiable. Examples of such crimes are password cracking, the use of botnet command and control, intrusion attacks, dissemination of harmful content, etc, (Ali, Memon, Dhomeja, Djokic, 2022). They further state that cloud services are susceptible to attacks from both domestic and international cyber criminals. Because criminals conceal the evidence of their illegal activities and profit from the lack of cooperation from international police, the challenge of identifying, intervening, and tracking hostile acts has presented a significant challenge to collecting evidence by law enforcement agencies.

The actual act of collecting digital evidence in cloud computing presents difficulties on a fundamental level, (Barrett, 2020). Few choices are available for the analyst in cloud architecture for remotely imaging the virtual machine, and administrative login details are expected for the setup of a forensic investigator who will work remotely.

The investigator acquires digital evidence from SaaS, IaaS, and PaaS which are the three distinct cloud service models. By accessing log files such as application logs, authentication logs, etc, the SaaS model keeps track of each user's VM information. The PaaS model locates the evidence for logs that is specific to an application and may be accessible via API, malware alerts, etc, (Raja Sree & Mary Saira Bhanu, 2020). The IaaS model keeps track of system-level logs, network traffic, storage logs, firewalls, etc.

In order to arrive at a well-supported conclusion, the analyst carefully examines the acquired evidence and integrates, compares, and consolidates data. Wherever the evidence is stored, both physical and logical files are analysed by the analyst. To preserve the evidence from tampering, a Chain of Custody is used, (Raja Sree & Mary Saira Bhanu, 2020).

3.3 Forensics of Social networks (Media)

Many people regularly use social networks, which have improved methods of information sharing and communication. Online social networks offer a variety of features such as online friends, personal browsing, private or group messaging, personal voice or video calling, video-conferencing, media sharing, management of events, and video blogging, etc, (Zainudin et al., 2021). Social media websites are even being employed by government organisations for official communications and interactive media.

Users are now vulnerable to online threats resulting from criminal activities because the majority of events now take place on online networks. The use of online social media can be exploited to perpetrate many various types of crimes such as identity theft, cyberstalking, child pornography, fake news

dissemination, financial fraud, etc. With the advancement of digital technology, criminals are getting more sophisticated, and if an investigation into their alleged crimes is conducted, they will make sure that they are evadable and untraceable. As a result, it is crucial to develop a more organised methodology that digital investigators will use to analyse online social media crimes in order to ensure that digital evidence is admissible in court,(Zainudin et al., 2021).

Technical obstacles have made it challenging to acquire evidence from Social Media networks, criminals engage in Ant-forensic tactics to conceal evidence or divert focus from their activities during an investigation. Encryption, residual data wiping, steganography, data storage space hiding, and covert channeling are some of the techniques used to hide evidence,(Forensics & Fakiha, 2020). Tools applied in the investigation process may likewise be attacked by the criminals, Denial of Service attacks like compression bombs, and zipped file bombs are frequently used to attack the digital forensic tools used in an investigation. Attacks typically aim to discredit the integrity of the acquired evidence or to entirely obliterate it.

Legal challenges such as jurisdictions where legal frameworks are inadequate when it comes to crimes committed on Social Media, and privacy rules concerns make it difficult for digital forensic investigators to collect evidence and solve these crimes. The other challenge is, the amount of data available on social media for analysis is enormous, without jeopardising the quality of evidence, the digital forensic investigator must determine crucial details. Therefore, there is a critical need for the development of ever-improving technologies, methods, and qualified investigators to use them in the fight against cybercrime.

4. Digital evidence

Cybercrime has become a serious threat to everyone at an alarming rate. Digital evidence is the most crucial part of every cybercrime scene as it serves in determining the accused person's guilt or innocence. The extensive use of digital devices and the rise of cybercrime has led to digital evidence becoming extremely relevant in criminal and civil cases. Pornography, phishing, financial crimes, prostitution, identity theft, and impersonation are all examples of cybercrimes with which digital evidence is associated, however, digital evidence is now employed to convict all types of crimes, (Riadi, 2018).

In criminal proceedings, the scope of digital evidence is broader, it is not limited to network activities, and may include traditional evidence captured in digital forms in specific cases, (Wu & Zheng, 2020). To establish a connection between suspects or accused and the related crimes they are suspected of being involved in, cybercrime investigations predominantly depend on digital evidence, (Ali et al., 2022).

The following principles must be observed and maintained when handling digital evidence, (Sommer, 2022). ;

- (i) Digital evidence must be collected in a lawful approach.
- (ii) Before handling digital evidence, professionals or personnel involved must undergo the required training program on how to handle and process digital evidence.
- (iii) Any activities or procedures applied to digital evidence should not alter its data. Whenever access to the original data or changes to the system settings are required, only authorised professionals/ personnel should be able to do so, and even those professionals should be able to defend their actions.

- (iv) Wherever possible, any operation or activity that necessitates accessing or modifying the original data should be documented and witnessed by another professional or personnel member.
- (v) All operations done while dealing with digital evidence should be recorded and kept on file so that they can be audited. The same operations should be repeatable by an impartial external third party and produce the same results.

Digital evidence must be pertinent, substantial, and credible to be admitted in court, and its facts should vastly exceed prejudicial effect, (Krishnan, 2019). He, (Krishnan, 2019) furthermore states, that digital evidence is indeed not different in terms of validity and substance, even though it could be replicated with ease and edited frequently without raising suspicion or without leaving any proof and this can pose distinct competency challenges.

5. Volatile features of digital evidence

The following characteristics of digital evidence make it a continuous difficulty for forensic professionals who seek to uncover it and examine it in pursuit of truth, (Romero et al., 2019). ;

- Unstable and volatile
- Unattributed
- It is plausible to make a copy of it
- It can be changed, manipulated, and corrupted
- Vulnerable and prone to being deleted

Digital evidence is latent in nature, because of this, it can only be seen, analysed, presented, and understood using tools. It is fragile and time-sensitive, sometimes it can exist for a short time, hence easier to mishandle, corrupt and destroy, (Alruwaili, 2021). It can be easily misinterpreted, therefore making it misleading and false, and it is easy to replicate and disseminate, which makes maintaining confidentiality difficult. Digital evidence is highly volatile and can be changed as compared to physical evidence, (Schneider et al., 2020). Furthermore, it can be altered unknowingly without leaving apparent traces that are obvious, (Warken, 2018). It is not visible to untrained personnel, and therefore can only be found in locations reachable by specific tools and specialists. Moreover, seized devices can be wiped clean, which means that evidence can be wiped clean remotely before the investigator has access to the evidence. Digital evidence can be perishable in its existence, for example, network logs, a user's browsing history on the internet, posts on social media, instant messaging, cached data, or data that has been erased can all be wiped if not preserved on time, (Considerations, 2021).

7. Challenges of handling digital evidence

Digital evidence, in comparison to physical evidence, has several distinct qualities, including how easily it can be copied, modified, transported, and corrupted. It is often contested in court because of how it is gathered, inspected and reviewed, analysed, and displayed, with parties opposing how the digital device in question was obtained or alleging that it was examined and processed incompetently, (Anderson et al., 2021). The fact that digital evidence's physical attributes can be easily tampered with, as well as the gadgets retaining it, and the lack of necessary technical expertise makes it difficult for courts to authenticate its accuracy and integrity, (Wu & Zheng, 2020).

Given its fragile and volatile structure, acquisition and managing of digital evidence is a major task, and because of these characteristics, any unforeseen modification can create irreversible damage and jeopardise its reliability, (Tsai, 2021). Moreover, it is crucial to note that small or insignificant alterations in the digital form either man-made or accidental or natural disasters are difficult to identify and commonly overlooked by forensic officers.

Preventing data loss at the crime scene is one of the most serious threats in handling digital evidence. The investigator at the crime scene may be compelled to choose between preserving digital evidence that is more vulnerable to lose and other evidence that is less susceptible to destruction, (Camilleri, n.d.). Additionally, if a live system is restarted or shut down, or if the device is turned off or unplugged from the network, volatile data on Random Access Memory will be lost.

Outdated procedures and techniques concerning documentation, collection, analysis, and preservation of digital evidence are also one of the challenges in handling digital evidence, (Mehta, 2018). Furthermore, technical challenges such as encryption, data hiding in storage space, operating in the cloud, and steganography affect the handling of digital evidence, (Mugisha, 2019). It is also worth noting that a lack of training for forensic investigators can lead to errors when detecting, collecting, and storing digital evidence.

8. Possible solutions

Digital evidence's credibility and reliability are crucial to its acceptance or admissibility in courts, (Wu & Zheng, 2020). According to, (Wu & Zheng, 2020), The authenticity of digital evidence is defined as the digital data or information collected from an electronic device as a true and factual, and exact depiction of initial or original data stored on the device. The integrity of digital evidence on the other hand refers to the electronic gadget and data to be presented as digital evidence is the same as the one that was first identified and taken into custody. Therefore, adequate and comprehensive digital evidence should be assured before and after its acquisition by forensic experts, and it should be protected by the relevant agencies throughout its custody.

Below are some possible solutions that can mitigate the challenges of handling digital evidence and its volatility.

- To protect the original evidence from accidental damage or malicious tampering, copies of the initial evidence should be made during the evidence-gathering stage, and any future investigations and analyses should be done on these duplicates.
- To avoid manipulation and corruption of digital evidence remotely, Faraday shielding may be used. Faraday shielding uses wire mesh bags/Faraday bags to separate electronic gadgets and other cordless devices and hinder radio waves from accessing the captured gadget or leaving via the bag from the seized device. This prevents data from being corrupted or transformed remotely while it is in the possession of the investigators, (Camilleri, n.d.).
- Hashing is another solution that can be used to maintain the integrity of digital evidence.
- It is a method of testing and verifying whether collected and stored digital data has been manipulated. For the data collected, cryptographic hash values are generated, and the data should yield the exact same hash values when submitted to the same hashing algorithm at a later point in time, (Camilleri, n.d.).
- Older or conventional methods used in the recording process in forensic laboratories, should be revised and improved by incorporating digitalised Chain of Custody blockchain technology to mitigate the threats of accidental modification and malicious manipulations, (Casey & Souvignat, 2020).

- Digital evidence procedures at the basic training level should be incorporated into academy training for Law Enforcement agencies to assist first responders at a crime scene with basic skills and knowledge on how to handle digital evidence, (Cooper, 2015). In addition, investigators' training and equipment should be updated on a regular basis to assure that they are employing and utilising the most up-to-date technology.

In addition to the above-mentioned solutions for mitigating the challenges of handling digital evidence, some principles can be applied, and other methods that can be used to preserve the integrity of digital evidence for court admissibility.

The following principles must be observed and maintained when handling digital evidence, (Sommer, 2022). ;

- (i) Digital evidence must be collected in a lawful approach.
- (ii) Before handling digital evidence, professionals or personnel involved must undergo the required training program on how to handle and process digital evidence.
- (iii) Any activities or procedures applied to digital evidence should not alter its data. Whenever access to the original data or changes to the system settings are required, only authorised professionals/ personnel should be able to do so, and even those professionals should be able to defend their actions.
- (iv) Wherever possible, any operation or activity that necessitates accessing or modifying the original data should be documented and witnessed by another professional or personnel member.
- (v) All operations done while dealing with digital evidence should be recorded and kept on file so that they can be audited. The same operations should be repeatable by an impartial external third party and produce the same results. Below are some of the methods that can be used to address the challenges of handling digital evidence;

7.1 Chain of custody

The sequential paperwork or collection of documents that show the seizure, acquisition, possession, control, transfer, processing, and disposition of physical or digital evidence is referred to as the Chain of Custody, (Yankson & Davis, 2019). Chain of Custody is one of the methods used to preserve digital evidence. It provides assurance of the credibility and reliability of the evidence collected and presented, (Yunianto et al., 2019). During digital forensic investigations, how digital evidence is extracted, preserved, and documented is dependent upon the principles of the Chain of Custody and the volatility of the evidence. The Chain of Custody should uniquely identify the evidence. Computers, phones, and other storage media can be identified by recording the manufacturer's name, model number, and serial number. If no unique identifier exists, evidence can be tagged, labeled, or barcoded for that specific purpose, (Considerations, 2021).

The Chain of Custody should at the very least include the (following, (Considerations, 2021). ;

- i. The individual who is in charge of gathering or accepting the evidence.
- ii. The source where the evidence came from
- iii. The date and time, as well as, where necessary the time zone details.
- iv. Unique identifiers for digital evidence.
- v. The tools and methods that were employed to gather the evidence.
- vi. Any further document that the entity requires

7.2 Blockchain technology

Another solution to mitigate the above-mentioned challenges of handling digital evidence is to make use of Blockchain technology. Blockchain is defined as an open decentralised ledger that can efficiently and permanently record transactions or operations between two parties. Blockchains are digitally decentralised ledgers of cryptographically or signed transactions in sequential or chronological order that are grouped into blocks and are fully open to anyone in the blockchain retail, (Sathyaprakasan et al., 2021). Every blockchain includes a hash of a prior block, as well as a time frame that records when a file was created and modified, (Alruwaili, 2021). He, (Alruwaili, 2021), further states that the security on the blockchain is so high that no one, not even those who created the file or document will be able to alter it once it is captured into the system. Features of blockchain are decentralisation, authenticity, reliability, accountability, transparency, and consistency that are needed by the traditional Chain of Custody, (Tsai, 2021). Some of the examples of Blockchain technology are; Block-DEF: A secure digital evidence framework using blockchain, (Tian et al., 2019). The Application of Blockchain of Custody In Criminal Investigation Process, (Tsai, 2021), CustodyBlock: A Distributed Chain of Custody Evidence Framework, (Alruwaili, 2021).

7.3 Tools used to search and collect digital evidence.

Digital forensics uses a variety of tools for the processing, preservation, detection and discovery, analysis, and documenting of digital evidence, as well as legal procedures, submissions of verifiable or factual evidence discovered, and expert testimony, (Sachdeva et al., 2020). Digital forensic investigations necessitate specialised toolkits to gather, protect, preserve, and transport digital evidence, forensic investigations must be fully equipped with the necessary equipment. Depending on the device's operating system and the type of electronic device under investigation, the analyst will use different tools.

7.3.1 Write Blocker

The use of write blockers enables read-only access to data storage systems without risking the integrity of the data. The digital forensic investigator duplicates or clones the drive by writing every component of the drive to a blank hard drive after a write blocker has been configured to prevent any data from being written to a suspect's hard drive.

Write blockers can be found in both software and hardware, (www.uomustansiriyah.edu.iq, 2018). Write blockers function similarly whether they are software or hardware, they prevent attempts to write to the actual storage media. The primary distinction between software and hardware write blockers is that the software Write Blockers are installed on a forensic computer, whilst the hardware write blocker has the blocking software installed on a microchip on the physical blocker device, (www.uomustansiriyah.edu.iq, 2018).

7.3.2 Autopsy

Autopsy is a digital forensic diagnostic tool that can examine original data, E01 disk image, internal drives in a device, and directories successively to identify probable origins of an incident, (Sachdeva et al., 2020). It is an application with a GUI that enables users to examine the hard drives of computers and smart mobile gadgets. The design of Autopsy permits the inclusion of new programs or customisation of some existing programs in python or Java, and functions as web server, and is accessible through an HTML browser, (Sachdeva et al., 2020).

Features of Autopsy:

- Timeline analysis -uses a visual displaying platform to showcase all incidents to pinpoint the activities that took place.

- Search using keywords- it sets up a few modules to scan files containing particular phrases or words and look for frequent terms, and patterns used for the extraction of data.
- Web application Artifacts- to distinguish user behaviour from web activities carried out by the user employing popular websites.
- Registry analysis- use Register Ripper to uncover facts and retrieve documents.
- LNK file analysis- to locate shorter ways for attaining admission to documents.

There are benefits to using Autopsy

- Fast- it uses a variety of components to execute all background functions simultaneously and delivers results immediately as they are completed.
- User friendly- it is easy to set up and install with wizards provided to help through every step of the installation process.
- Versatile and adaptable- can be designed with different modules that are also accessible to third parties, examples of these modules are hash filtering, data carving, web artifacts, etc.

7.3.3 Encase

Encase is a forensic tool used for investigation in Law enforcement and private companies to collect, examine and report on evidence,(Shah & Paradise, 2014). It has the following features:

- Encase uses E01 and L01 to store forensic evidence.
- Can work on different operating systems like Windows, Linux, and Unix.
- It can also be used to conduct investigations offsite.
- Thorough forensic analysis- evidence that would go undetected with other tools can be uncovered by using Encase. It can now analyse EXT4 and HFSX file systems, encrypted drives, iOS physical images, etc, and in addition, an email investigation platform is also available.
- Findings can be compiled- analysts can create templates for every case type, audience, and purpose using report features that clients can easily program.

These among other many benefits are the features of Encase,(Opentext, 2019).

7.3.4 FTK Imager

FTK imager is an open-source Windows-based product that has the ability to collect and analyse digital forensic evidence by making exact copies of the disk(disk imaging) of the original evidence without altering it,(Alwis, 2018). The source of evidence remains unchanged, allowing the analyst to copy data much more quickly and preserve the copied image for further investigation.

7.3.5 Oxygen Forensics

Oxygen forensics is a digital forensic tool that enables the automatic collection and examination of data from mobile devices using iOS, Android, and other mobile operating systems,(Sachdeva et al., 2020). For a thorough and organised investigation of data evidence, it permits extraction and processing of social media platforms like Instagram, Facebook Meta, WhatsApp, Telegram, etc,(Sullivan, 2019). The program can be expanded to include additional capabilities for investigating connected gadgets like smartwatches and other latest technologies as well as encrypted data associated with any criminal conduct or illegal activity.

The examples of tools mentioned above do not exhaust all the available tools used in digital forensics investigations and evidence collection, they only high lights some of the commonly used tools.

8. Conclusion

This paper discussed the description of digital evidence, and how it is becoming increasingly prominent in criminal and cybercrime investigations and prosecutions. Digital evidence is fragile, easy to tamper with, and corrupt and destroyed through inappropriate management and analysis. As a result, extra caution should be exercised when preserving digital evidence, neglecting to do so the evidence will be deemed useless and inadmissible in court and result in erroneous conclusions about a case. Other domains where digital evidence can be found include Internet of Things (IoT) forensics, Cloud forensics, and Social network (media) forensics; the same techniques for evidence preservation for court admissibility should be used in all of these cases. There are principles to be applied when handling digital evidence, possible solutions that can be used to mitigate the challenges of handling digital evidence, and other methods that can be used to preserve the integrity of collected digital evidence. Write Blockers, Autopsy, Encase, Forensic ToolKit Imager, and Oxygen Forensics are some of the tools used to search, acquire and preserve digital evidence. Future research work will focus on the models used to preserve volatile digital evidence for admissibility in Namibian courts.

The future work is intended to focus on the design of a model to preserve volatile digital evidence for admissibility in Namibian courts. According to Tredger, C. (2019), Namibia is vulnerable to cybercrimes, making it the most targeted country in Africa, therefore investigations need to be conducted to find solutions that will curb cybercrimes by ensuring that the evidence collected at a crime scene is admissible in court and the offender is prosecuted.

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Mobile Apps for Smart Cities: A Systematic Review of Google Play Store and Apple App Store

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Abstract

Smart cities have played a huge role in communities since their inception, and mobile apps have proven to be tools that citizens can use to access the services that governments provide to the inhabitants of these smart cities. The purpose of this paper was to systematically review the apps for smart cities on Google Play Store and App Play Store. 23 mobile apps met the inclusion criteria. The findings revealed that smart cities' apps have been developed in various countries on different continents, and they are used for many services including transportation, accessing information, sustainable development and tourism. The gaps were highlighted and suggestions for future work were made. The findings could potentially help governments with plans for developing smart cities' apps to identify which areas need to be explored.

Keywords: Mobile apps, Google Play Store, Apple App Store, Smart Cities.

1. Introduction

The way information is shared and provided to citizens has changed due to the development of information and communication technologies (ICTs). Information access has become easier and faster, and it has become important for people in the digital era (Rachmawati et al., 2021). With ICT advancement, the mobile application was introduced.

Mobile application development is a rapidly growing sector with a global positive impact (Islam et al., 2010). Amalfitano et al. (2013) defined a mobile application as an enclosed software designed for a mobile device and performs specific tasks for mobile users. Kaur & Kaur (2022) noted that mobile devices are utilitarian, user-friendly, and accessible. Thus, it has made them popular and useful for people to use.

In the last few years, there has been an increasing number of mobile applications developed for smart cities. Dameri (2013, p. 2459) defines a smart city as "a precise geographical area, in which high technologies such as ICT, logistics, energy production, and so on, cooperate to create benefits for citizens in terms of wellbeing, inclusion, and participation, environmental quality, intelligent development. It is governed by a diverse pool of subjects, able to state the rules and policy for the city government and development." With this definition, citizens are the main beneficiary of smart cities. The definition also suggests that smart cities are services provided by the government to citizens.

Various apps have been developed on Google Play Store and App Store to support citizens in government services. While there has been a review of technologies used for smart cities (Ma et al., 2018; Fong et al., 2019), there is a dearth of research reviewing mobile apps published in Google Play Store and Apple App Store. The types of apps used for smart cities deployed on Google Play Store and Apple App Store are not known. The aim of this paper was to systematically review mobile apps published in the Google Play Store and App Store to explore the types of smart cities' apps that have been deployed in Google Play Store and Apple App

Store. The findings could show apps that already exist and identify the gaps which need to be addressed in the new apps focused on smart cities.

This paper is structured as follows: The research strategy, research question, and research data analysis and synthesis are described in Section 2. The results are presented in Section 3. The findings are presented and discussed in Section 4. The Discussion and conclusion are presented in Sections 5 and 6 respectively.

2. Materials and Methods

2.1. Search strategy

A systematic search was conducted to identify the apps used in the study. A search was conducted on Google Play Store and App Play Store. Keywords include smart city and government smart city. The search was conducted between August and September 2022.

2.2. Inclusion and exclusion criteria

The study included apps focused on services provided by the government and published in English, and it excluded game-based apps, apps in languages other than English, apps not focused on providing government services and apps focused on providing conference services. Based on the definition of smart cities by (Dameri, 2013), apps were excluded if they did not meet the definition of providing services for the purpose of meeting the needs of citizens in a particular city. Individual and business apps were excluded.

2.3. Research question

The study aimed to answer the research question: what are the functionalities of smart cities' mobile apps deployed on Google Play Store and App Play Store?

2.4. Data analysis and synthesis

A narrative synthesis of the findings was presented.

3. Results

A total of 289 apps were retrieved during the search (see Fig. 1). 15 duplicate apps were removed, and 72 apps were removed during the initial screening. 202 full apps were reviewed based on the eligibility criteria. 23 apps were included based on the inclusion and exclusion criteria.

3.1. Characteristics of included studies

A systematic search was conducted to identify the apps used in the study. A search was conducted on Google Play Store and App Play Store. Keywords included smart city and government smart city. The search was conducted between August and September 2022.

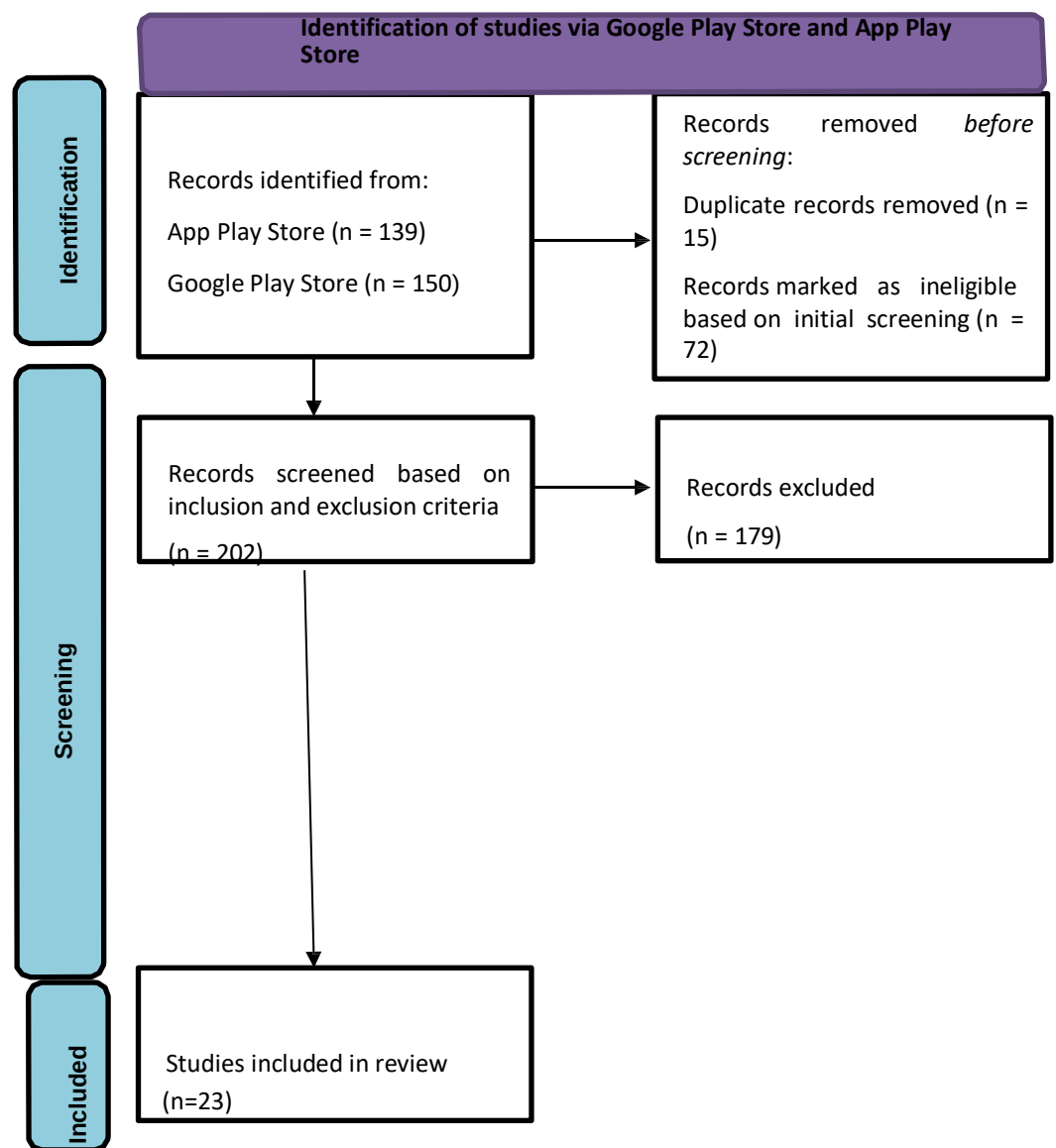


Figure 1: Inclusion and exclusion criteria based on PRISMA (Trico et al., 2018)

4. Findings

4.1 Initial apps

A total of 289 apps were retrieved from Google Play Store and App Play Store. After removing the duplicates and ineligible apps based on the exclusion and inclusion criteria, we were left with 23 apps. The screening process is presented in Fig. 1.

4.2 Study characteristics

The mobile apps originated from 14 countries namely; Pakistan, South Africa, United Arab Emirates, Portugal, Liberia, Germany, Greece, Philippines, Malaysia, Kenya, Saudi Arabia, Hungary, India and Australia. With Australia, India and Pakistan taking the lead as shown in Fig. 2.

All smart cities' apps included in the study were free apps. Most of the apps have focused on various areas such as sustainable development, municipal services, emergency services, creating petitions, government worker management, information, tourism, citizen engagement, public services, complaints, transportation, identification, government services, covid alert, digital verification, service requests, e-waste collection bookings, resident id, reporting. Most of the apps focused on information, tourism, public services and transportation, identification, government services, covid alert, digital verification, service requests, e-waste collection bookings, resident ID and reporting. As shown in Fig. 3, most of the smart cities' apps focused on information, tourism, public services and transportation.

Many of the apps were available on both Google Play Store and App Play Store while one app was only available on Google Play Store and two apps were only available on App Play Store as shown in Fig. 4.

Countries

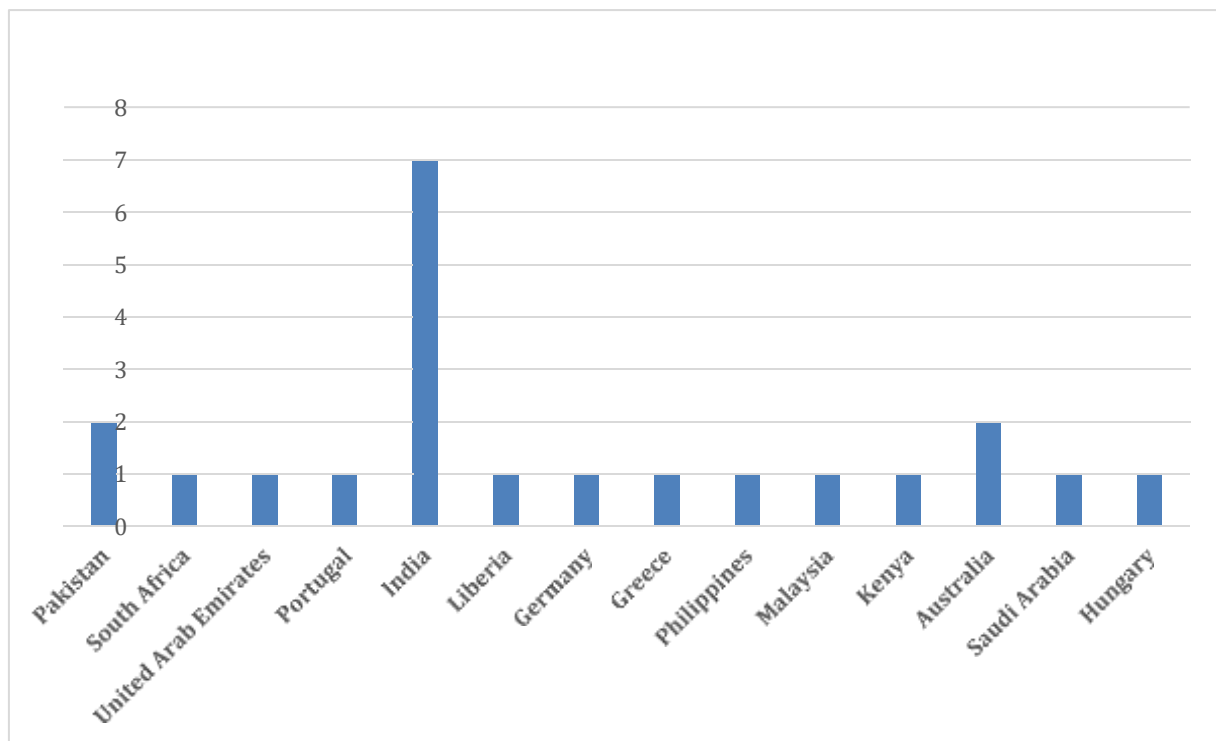


Figure 2: Countries where the apps originate

Table 1: Study Findings

App name	Description	Country	Problem addressed	Payment type	Domain	Platform
Smart City Digital	Capital Smart City Islamabad is an app that provides sustainable development to citizens	Pakistan	In view of the growing housing demand in the twin cities, intends to build a quality housing project on M2 Motorway near New Islamabad International Airport falling on the eastern route of China Pakistan Economic Corridor (CPEC).	Free	Citizen engagement	Google Play Store and Apple App Store
MySmart.City	The app empowers citizens to log issues relating to the city, call emergency services and create petitions	South Africa	The app addresses the lack of engagement that enables citizens to communicate with government services	Free	Municipal services, emergency services, and creating petitions	Google Play Store and Apple App Store
Smart Employee App	The app allows government workers to apply for leave, and permissions, finding and contact a colleague, and approve procedures.	United Arab Emirates	The lack of a platform for managing government workers' needs	Free	Government worker management	Google Play Store and Apple App Store
SMIITY	SMart Interactive cITY aims to provide local information and context to citizens and tourists. With SMIITY, citizens receive notifications about a monument, a piece of art or some historical information.	Portugal	The lack of information about tourism	Free	Information, Tourism	Google Play Store and Apple App Store
Surat Smart City	Surat Smart City is an informative mobile application developed by Surat Smart City Development Limited, an SPV of Surat Municipal Corporation. The mobile application	India	The lack of information update about the city	Free	Tourism	Google Play Store and Apple App Store

	enables the citizens to stay updated with the latest happenings and project details under the Smart City Mission.					
Smart City Liberia	Smart City Liberia is a mobile and web-based directory assistance application that enables subscribers to search and find almost anything within Liberia. By doing so, we are collectively transforming Liberia into a One-Stop-Shop digital nation.	Liberia	The lack of information for citizens about the country	Free	Information	Google Play Store and Apple App Store
MyGov	MyGov is Government of India's innovative citizen engagement platform for direct citizen participation in governance by providing an avenue for channelizing their ideas, comments, and creative suggestions to Central Ministries and associated organizations.	India	The need for citizens to participate in policy formulation and program implementation to usher in an era of direct participatory democracy.	Free	Citizen engagement	Google Play Store and Apple App Store
Smart Vijayawada	Vijayawada smart city mobile app by Vijayawada Municipal Corporation has been created for the citizens of Vijayawada, with an intention of providing them a channel to know about their city and connect with their government.	India	Using this mobile application, users can view various information about Vijayawada, like tourist and shopping places, restaurants, hotels, hospitals, pharmacies, coaching centers, schools, and colleges, etc in the city. Users can also get to know the latest news about Vijayawada and can also keep a tab on the various events going on in the city.	Free	Public services	Google Play Store and Apple App Store
UMANG India	UMANG (Unified Mobile Application for New-age Governance) is envisaged to make e-governance 'mobile first. It is developed by the Ministry of	India	The need to have an evolving platform designed for the citizens of India to offer them access to the pan-India e-Gov services from the Central, State, and Local Bodies, and Agencies of government on app, web, SMS, and IVR	Free	Public services	Google Play Store and Apple App Store

	Electronics and Information Technology (MeitY) and National e-Governance Division (NeGD).		provides easy access to a plethora of Indian government services ranging from Healthcare, Finance, Education, Housing, Energy, Agriculture, Transport to even Utility and Employment and Skills.			
Smart City Liberia	Smart City Liberia is a mobile and web-based directory assistance application that enables subscribers to search and find almost anything within Liberia	Liberia	The lack of a One-Stop-Shop digital nation.	Free	Information	Google Play Store and Apple App Store
eCitizen Kenya App	Kenyan Citizens and Foreign Residents can now apply for Kenyan Government to Citizen (G2C) services and pay via mobile money, debit Cards and eCitizen agents efficient using eCitizen Kenya App	Kenya	The need for a system to ease G2C services	Free	Public services	Google Play Store
Pakistan Citizen's Portal	Pakistan Citizen's Portal is an integrated citizens grievance redressal system connecting all government organizations both at federal and provincial levels.	Pakistan	The need for a system that will serve as carrier of complaints to their respective offices across all over Pakistan. Eventually, the citizen feedback will be linked to an officer's performance and promotion. The App will serve as complementary channel between citizen and government.	Free	Complaints	Google Play Store and Apple App Store
The GOV.SA App	App aims to be a one-stop platform that provides access to all government services and information for KSA citizens and residents.	Saudi Arabia	The need for the residents to access information in an online platform.	Free	Information	Google Play Store and Apple App Store
SmartCity Budapest Transport	The app offers transportation information service to the public	Hungary	The app addresses the inability to connect online as users can connect to transportation services online.	Free	Transportation	Google Play Store and Apple App Store
Sarawak Smart City	This app offers tourism guide, bus and truck information to the public	Malaysia	The need for guided tourism	Free	Tourism	Google Play Store and Apple App Store

	provided by Sarawak State Government					
myGovID	The app allows people to identify themselves in order to sign into government services online	Australia	The need for identifying citizens digitally	Free	Identification	Google Play Store and Apple App Store
PCMC Smart Sarathi	A sustainable two-way citizen engagement platform that enables citizens to pay taxes, make complaints, buying and sell.	India	The need to provide a two-way engagement with citizens	Free	Government services	Google Play Store and Apple App Store
COVA Chd	An app developed by the government to enable citizens to become aware of covid 19 reporting mechanisms	India	The need for covid 19 awareness and reporting	Free	Covid alert	Google Play Store and Apple App Store
eZug	This is an app that focuses on verifying identities of citizens which enable them to identify themselves on e-Government platforms	Germany	The need to digitally identify citizens on e-Government platforms.	Free	Digital verification	Google Play Store and Apple App Store
Government of Gujarat Services	This is a mobile app that focuses on making citizens aware of government services online	India	The need for awareness of government services online	Free	Online services	Google Play Store and Apple App Store
City On	This is an app that allows citizens to access public services	Greece	The need for citizens to be able to access public services online	Free	Public services	Apple App Store
Woollahra Council	This app allows citizens to manage service requests and e-waste collection booking online	Australia	The need to manage service requests and e-waste collection booking online	Free	Service requests and e-waste collection bookings	Google Play Store and Apple App Store
LiveLoveLiloan App	This app allows people living in Liloan to access information, access as Resident ID, transportation services and reporting	Philippines	The need for a community to have a digital platform where access to information is easy	Free	Information, Resident ID, transportation and reporting	Apple App Store

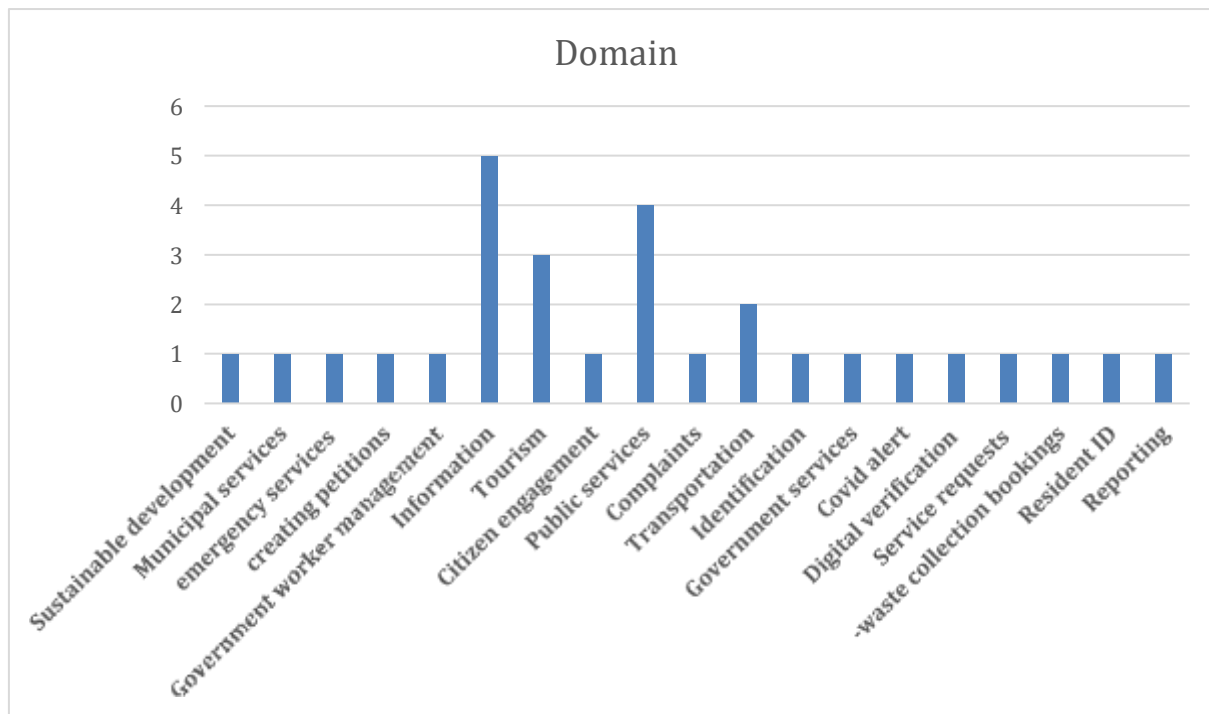


Figure 3: Domain

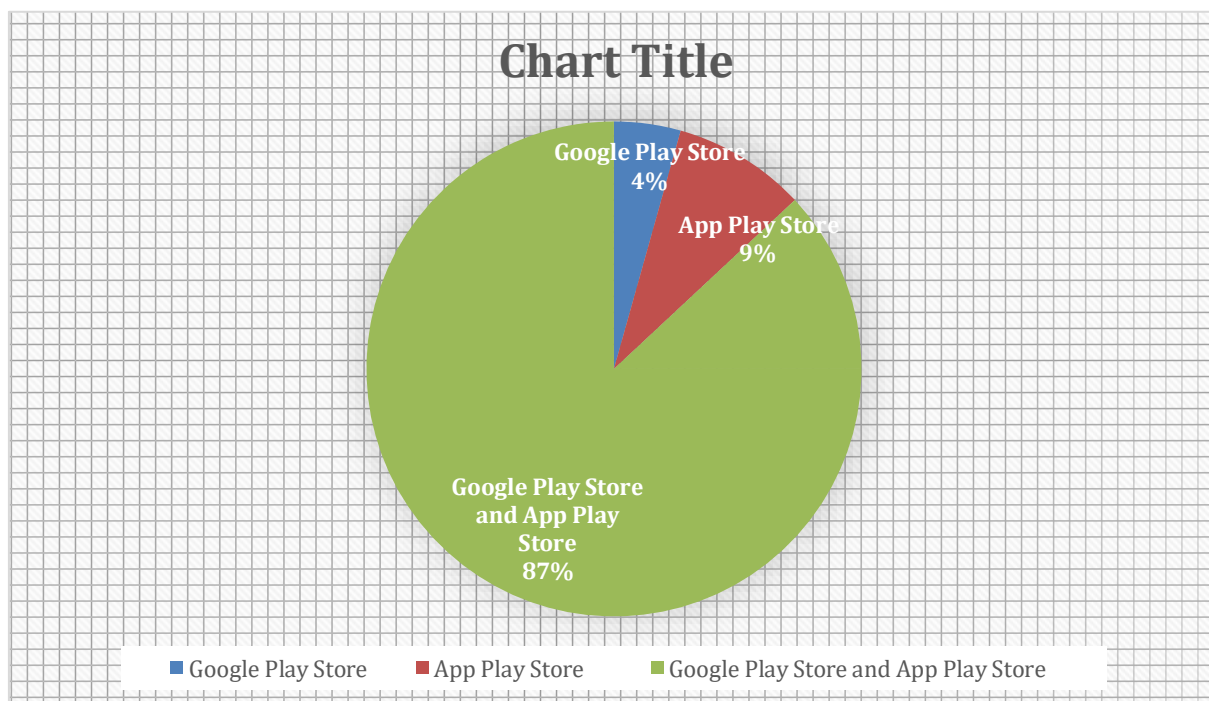


Figure 4: Types of app

5. Discussion

The purpose of this paper was to systematically review mobile apps published in Google Play Store and Apple App Store to explore the types of smart cities' apps that have been deployed in Google Play Store and Apple App Store. A narrative synthesis of the findings was provided. 23 papers met the inclusion and exclusion criteria and as such were included in the study. The findings contribute to the body of knowledge on smart cities and the use of mobile apps. To the best of the researchers' knowledge, this is the first time, smart cities are being reviewed from the perspective of mobile apps on the play store.

The findings suggest that mobile apps for smart cities have been developed in different contexts. Different continents such as Africa, Europe, Asia, and Australia. This shows that smart cities have been applied in different parts of the world. Although studies suggest that Singapore is rated as a country with the highest number of smart cities (Planet Crust, 2022) this finding seems to contradict the findings of the study which did not identify any smart city mobile app in Singapore. Asian countries, however, had the highest number of apps in smart cities in this paper. Although South Africa and Liberia government authorities have developed mobile apps for smart cities, there is a need for more African countries to explore smart cities' apps.

Many of the apps were focused on information, tourism, public services, and transportation. This is in line with studies that suggest that transport systems are important in smart cities (Bubeliny & Kubina, 2021). Information sharing is vital to government services and as such this has been incorporated into smart cities' apps. Tourism benefits the government and boosts the economy. Smart cities' apps focused on tourism are beneficial to the government. Hence, they are a good mechanism to boost tourism.

Most of the apps included in the study were cross-platform apps. Studies have cited the benefits of cross-platform apps. The advantage around cross-platform development is that it provides the opportunity for different users using different operating systems to use the app, which provides more accessibility. However, research suggests that cross-platform development may affect the performance of the software (Biørn-Hansen et al., 2020).

There was a dearth of apps focusing on healthcare services to citizens, with only one app focusing on covid alert. Apps that enable citizens to utilise healthcare services would be appropriate. Generally, there was a lack of apps focused on integrating sensor data. Mobile apps being developed for smart cities should focus on integrating data from sensors to provide robust data. There was a lack of apps focused on the use of Artificial Intelligence (AI) mechanisms to address problems related to smart cities' apps.

Smart cities are generally designed to serve as a mechanism to improve the lives of the residents in a geographical area and the decisions making processes. There was generally a lack of apps around using smart cities to provide employment opportunities, water and water quality management, as well as accessing public services in sectors such as education. The concept of privacy and security was not generally described in the context of these apps.

6. Conclusion

In conclusion, the aim of this paper was to systematically reviewing mobile apps published in Google Play Store and Apple Play Store to explore the types of smart city apps that have been deployed in Google Play Store and App Store. Despite the paper meeting the aim of the paper, the researchers noted a few limitations.

The findings of the study are based on the results of the inclusion and exclusion criteria and as a such, the findings of the search may be limited. For future work, more smart cities' apps need to be developed in different countries, especially in Africa. Despite a few apps being used in this part of the world Integrated smart apps need to be developed to cover several areas of the economy. More advanced techniques such as linking to sensor data and the use of AI need to be incorporated into these apps to make the apps dynamic.

Although smart cities' apps are available, there are areas smart cities' apps have not been designed to solve which include healthcare, managing health, hospital appointments, and gaining access to healthcare services. Although exploring the performance and technicalities of smart cities' apps on Google Play Store and Apple App Store was not the objective of the study, it is an area that can be explored in future research.

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Comparative Evaluation of Network Reconfiguration and Capacitor Allocation in Radial Distribution Network Performance Improvement

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Abstract.

Significant power losses and a subpar voltage profile compromise the performance of the radial distribution networks. The radial distribution system's performance can be upgraded by utilizing different techniques. The two least expensive techniques, which are network reconfiguration and capacitor placement, for diminishing power losses and upgrading the radial distribution system's voltage profile, which boost the system's performance, are thoroughly analyzed in this paper. The methodology involves formulating an objective function that minimizes the overall real power loss in a radial distribution network while subject to equality and inequality requirements, which are addressed by the dingo optimization algorithm for each technique. A standard IEEE 33-bus network was utilized as a test case, and simulations were performed utilizing the MATLAB/SIMULINK package. The outcomes demonstrated that network reconfiguration outperformed the capacitor placement technique, with total real power loss diminished by 36.76%, versus 34.44%, for the capacitor placement technique. Moreover, compared with the minimum voltage magnitude obtained with the capacitor placement technique, which was 0.9393 p.u., the least voltage magnitude obtained with the network reconfiguration technique was 0.9824 p.u. Therefore, network reconfiguration is a smart choice for improving the efficiency of radial distribution networks.

Keywords: network reconfiguration, capacitor allocation, dingo optimization algorithm, voltage profile, power loss

1. Introduction

Power system researchers and engineers are tenacious in their pursuit of increasing the effectiveness of the radial distribution networks by proposing a variety of methods for mitigating losses in the radial distribution networks. Most of the radial distribution networks' rising power loss, which fundamentally affects the entire power system, is the essential driver behind this effort. The utilization of flexible alternating current transmission system regulators, network reconfiguration (Okelola et al., 2021), the deployment of dispersed generation (Adepoju et al., 2021), capacitor installation (Okelola et al., 2022), and other approaches are among the most prominent solutions that have been proposed for minimizing power losses in distribution systems. According to (Salimon et al., 2022, Sadeghian et al., 2020, and Al Samman et al., 2020), network reconfiguration and capacitor deployment are the easiest, least expensive, and most straightforward strategies for addressing power loss issues and boosting the voltage magnitudes in distribution networks. Most underdeveloped countries worldwide are forced to resort to one of these two techniques because of their low implementation costs. Some

other industrialized nations are exploring these two strategies for minimizing power losses because of the benefits indicated above.

Although capacitor deployment has the potency to diminish power loss and boost the voltage magnitudes in distribution networks, the capacitors must be deployed optimally to achieve the desired objectives. Failure to optimize capacitors on radial distribution networks may result in over or under-injection of reactive power into the radial distribution networks, which will result in the networks' performance degradation. Capacitor deployment in radial distribution networks is an optimization issue that can be addressed by using any of the robust optimization techniques that have been proposed in the literature over the years. In the literature, researchers have examined capacitor allocations to enhance the operation of radial distribution networks.

Network reconfiguration, on the other hand, is the restructuring of the radial distribution systems with the primary aim of enhancing their performance. It involves changing the state of the sectionalizing and tie switches to redistribute power flow in the networks so as to diminish losses and boost the voltage magnitudes of the radial distribution networks. In the reconfiguration process of a radial distribution network, there are several network topologies that improve the performance of the network. However, one of these topologies results in the optimal network performance improvement. Hence, network reconfiguration of a radial distribution network is an optimization problem that should be tackled using any of the optimization strategies proposed in the literature. No load should be disconnected from the supply throughout the reconfiguration process, and the network's radiality should be retained after reconfiguration. Several research papers have been published in the literature that use various optimization methodologies to address the problem of network reconfiguration in radial distribution networks.

2 Literature review

(Okelola et al., 2022) employed a whale optimization approach to address the capacitor allocation problem, with real power loss and loss reduction cost as the objective functions to be minimized. In (Abd Elazim & Ali, 2018), a mine blast algorithm (MBA) was presented for the optimum placement and size of capacitors in different distribution networks. First, the nodes that were ideal candidates for adding capacitors were chosen using loss sensitivity factors. Using the proposed MBA, the capacity and position of capacitor units were determined from the chosen buses. The function's objective was to reduce total expenditures and, as a consequence, increase yearly net savings. (Tamilselvan et al., 2018) used a flower pollination algorithm to proffer solution to the capacitor placement issue in a distribution network. This challenge was intended to decrease total power loss and deployment costs by optimizing capacitor location and size. (Lohia et al., 2016) provided a genetic algorithm-based technique for optimum capacitor position and sizing in a distribution grid, with the goal of loss mitigation and voltage magnitudes augmentation. The presented method was validated using the IEEE 33-bus distribution test system. (Abul'Wafa, 2014) presented a hybrid of a fuzzy expert system for capacitor allocation and real-coded GA (FRCGA) for capacitor size to improve voltage stability for optimum capacitor position.

The WOA approach was introduced in (Reddy & Reddy, 2018) to handle the feeder reconfiguration issue in a distribution system with the goals of reducing total real loss and maximizing energy savings. (Abubakar et al., 2019) described an improved evolutionary algorithm to address the issue of reconfiguration for a typical distribution system while accounting for losses and total voltage magnitude deviations. (Reddy et al., 2017) presented a Grey Wolf Optimization (GWO) method to

tackle the reconfiguration issue in distribution systems utilizing a fitness function relating to the optimum combination of switches. The objective function was defined to address the reconfiguration issue by minimizing real power loss. (Salkuti, 2021) offered a multi-objective-based optimum network reconfiguration strategy with the goals of reducing overall operational expenses and network power loss. The multi-objective crow search method was used to tackle the optimization issue.

According to the literature reviewed thus far, no research has been identified to have examined the potency of these two affordable approaches to boosting the performance of radial distribution networks in order to validate the most successful one that can be used. As a result, a comparison of these two methodologies is worthwhile. This article compares network reconfiguration and allocation of capacitors in radial distribution network performance enhancement utilizing IEEE 33 as a test system. The simulation platform for the investigation was the MATLAB/SIMULINK software suite. The innovative aspect of this study is the use of a novel dingo optimization algorithm (DOA) to handle the optimization challenges of the two approaches.

3. Problem formulation

3.1 Objective function

The network's total real power loss, represented as the sum of losses in all line segments of the network as provided by Eq. 1, is the objective function to be minimized.

$$OF_{\min} = \sum_i^{n_b} |I_i|^2 R_i \quad (1)$$

where, n_b = total number of branches, $R_i = i^{th}$ branch resistance and $|I_i| = i^{th}$ branch current magnitude.

3.2 Constraints

The equality and inequality constraints to which the objective function is subject are as follows:

3.3 Power flow equations

These are the power flow equations given by Eqs. 2 and 3.

$$P_{Gi} = P_{Di} + \sum_{j=1}^{n_b} |V_i| |V_j| [G_{ij} \cos \theta_{ij} + B_{ij} \sin \theta_{ij}] \quad (2)$$

$$Q_{Gi} = Q_{Di} + \sum_{j=1}^{n_b} |V_i| |V_j| [G_{ij} \sin \theta_{ij} - B_{ij} \cos \theta_{ij}] \quad (3)$$

where V_i and V_j = voltage magnitudes, P_{Gi} and P_{Di} = real power generated and demanded, Q_{Gi} and Q_{Di} = reactive power generated and demanded, and θ_{ij} = voltage angle difference, G_{ij} = line conductance and B_{ij} = line susceptance.

3.4 Bus voltage limitation

The standard voltage limitations are stated in Eq. 4.

$$V_{\min} \leq V_i \leq V_{\max} \quad (4)$$

3.5 Radial topology

The distribution network must be radial and devoid of meshes. In most circumstances, all loads are served continuously. Closing all ties yields the total number of main loops as:

$$N_{\text{main loops}} = (N_b - N_R) + 1 \quad (5)$$

The number of sectionalising switches

$$N_R = N_b - 1 \quad (6)$$

where, N_b = bus number, N_R = branch number.

After solving the power flow equations utilizing the Newton Raphson approach, which has been shown to be particularly resilient and successful in radial distribution system solutions, the objective function is obtained. An approach based on the bus incident matrix A was used to examine the radiality limits for a certain configuration, where a graph may be expressed in terms of an incidence matrix.

3.6 Reactive power constraint of capacitor

The size of the each of the installed shunt capacitors is constrained within the limits below;

$$Q_{SC(\min)} \leq Q_{SC} \leq Q_{SC(\max)} \quad (7)$$

where $Q_{SC(\min)} = 100$ kVar and $Q_{SC(\max)}$ is 75% of the overall reactive power load (Ali et al., 2016).

3.7 Capacitor penetration limitation

The total real power supplied by the installed capacitor should be less than 75% of the overall network reactive demand.

$$\sum_{l=1}^m Q_{SC}(l) \leq 0.75 \times \sum_{i=1}^{n_b} Q_d(i) \quad (8)$$

4. Dingo optimizer

Dingoes are intelligent, sophisticated, and gregarious animals. They are expert hunters that live in groups of 12–15. The social system is highly organized, with the alpha at the top. They can be differentiated depending on their tasks, which include decision-making, sleeping quarters, and hunting. The Alpha is the pack's most dominant and strongest member, as well as its leader. The pack is compelled to obey the alpha's decision. In most circumstances, all pack members lower their tails to bow to the alpha (Bairwa et al., 2021). If a dingo is not an alpha or beta, it is considered subordinate. These subordinates follow the alphas and betas. Scouts will be in charge of monitoring the regions and informing the group if any hazard or circumstance emerges. Hunters will help the alphas and betas capture animals and feed the group. According to researches, dingoes have a great sense of communication. They communicate by sensing changes in the strength of sound in the air. Dingoes have an unusual social feature in group hunting, which makes its applicability to social behavior even more intriguing (Bairwa et al., 2021). The phases of hunting techniques are as follows: chasing and approaching, harassing, encircling, and attacking. DOA, which does evolution optimization, also statistically studies dingo hunting behavior and social structures.

4.1 Mathematical models

The dingo optimization is performed using a mathematical description of the encircling and attacking of prey.

4.2 Encircling

The mathematical Eqs. 9–13 are used to model the dingoes' encircling behavior.

$$\bar{D}_c = |\bar{A} \cdot \bar{P}_p(x) - \bar{P}(x)| \quad (9)$$

$$\bar{P}(i+1) = \bar{P}_p(i) - \bar{B} \cdot \bar{D}(d) \quad (10)$$

$$\bar{A} = 2 \cdot \bar{a}_1 \quad (11)$$

$$\bar{B} = 2\bar{b} \cdot \bar{a}_2 - \bar{b} \quad (12)$$

$$\bar{b} = 3 - \left(I * \left(\frac{3}{I_{\max}} \right) \right) \quad (13)$$

where, $\bar{D}_c$ = separation between the prey and dingo, $\bar{P}_p$, $\bar{P}$ = prey and dingo position vectors, $\bar{A}$, $\bar{B}$ = coefficient vectors, $\bar{a}_1$ = random vector, $\bar{a}_2$ = random vector, $\bar{b}$ = at each iteration, it decreases linearly from 3 to 0, $I = 1, 2, 3, \dots, I_{\max}$.

4.3 Hunting

The dingoes' hunting behaviours are modelled mathematically by Eqs. 14–19.

$$\bar{D}_\alpha = |\bar{A}_1 \cdot \bar{P}_\alpha - \bar{P}| \quad (14)$$

$$\bar{D}_\beta = |\bar{A}_2 \cdot \bar{P}_\beta - \bar{P}| \quad (15)$$

$$\bar{D}_o = |\bar{A}_3 \cdot \bar{P}_o - \bar{P}| \quad (16)$$

$$\bar{P}_1 = |\bar{P}_\alpha - \bar{B} \cdot \bar{D}_\alpha| \quad (17)$$

$$\bar{P}_2 = |\bar{P}_\beta - \bar{B} \cdot \bar{D}_\beta| \quad (18)$$

$$\bar{P}_3 = |\bar{P}_o - \bar{B} \cdot \bar{D}_o| \quad (19)$$

Individual dingo intensity is calculated by Eqs. 20-22:

$$\bar{I}_\alpha = \log \left(\frac{1}{F_\alpha - (1E - 100)} + 1 \right) \quad (20)$$

$$\bar{I}_\beta = \log \left(\frac{1}{F_\beta - (1E - 100)} + 1 \right) \quad (21)$$

$$\bar{I}_o = \log \left(\frac{1}{F_o - (1E - 100)} + 1 \right) \quad (22)$$

where, F_α and F_β = α and β -dingo fitness values, respectively, and F_o = other dingo fitness value.

4.4 Attacking prey

If there is no update on the victim's position, dingo has concluded the search by attacking the target. In order to mathematically design the technique, $\bar{b}$'s value must decrease linearly. It should be noted that $\bar{b}$ also reduces the changing range of $\bar{D}_\alpha$.

4.5 Searching

Dingoes hunt for prey depending on where the group is located. They constantly advance in pursuit of predators and engage them in combat. Therefore, $\bar{B}$ is utilized for random values,

where a value less than -1 denotes a prey that is evading the hunter and a value greater than 1 denotes a prey that is being approached by the pack. The DOA can scan targets globally using this method. A further element of DOA that raises the prospect of exploration is $\bar{A}$.

5. Application of dingo optimization algorithm to network reconfiguration

The DOA was implemented to solve the problem of network reconfiguration using the following steps:

Step 1: Enter network line and load parameters, including tie switch and DOA variables.

Step 2: Determine the network's basic loops.

Step 3: Determine the upper-bound and lower-bound of each tie-switch.

Step 4: Initialization

In the application of the DOA technique, a dingo is a potential solution consisting of radial configuration. A population of n dingoes is denoted as:

$$D = \begin{bmatrix} D_1 \\ D_2 \\ \vdots \\ D_n \end{bmatrix} = \begin{bmatrix} TS_1^1, \dots, TS_{NTL}^1 \\ TS_1^2, \dots, TS_{NTL}^2 \\ \vdots \\ TS_1^n, \dots, TS_{NTL}^n \end{bmatrix} \quad (23)$$

Each dingo in the population can be represented as:

$$D_i = [TS_1^i, \dots, TS_{NTL}^i] \quad (24)$$

In the equations, $TS_1, TS_2, \dots, TS_{NTL}$ are the tie switches in the fundamental loops.

Each dingo D_i in the population has the following initialization at random:

$$TS_i = \text{round} [TS_{lower,r1}^i + \text{rand} \times (TS_{upper,r1}^i - TS_{lower,r1}^i)] \quad (25)$$

where $r_1 = 1, 2, \dots, NTL$, $r_2 = 1, 2, \dots, m$ and $r_3 = 1, 2, \dots, m$. $TS_{lower,r1}$ and $TS_{upper,r1}$ are the minimum tie-switch and maximum tie-switch which are encoded in the fundamental loop r_1 .

Step 5: Evaluation each dingo's fitness

A radial configuration check is carried out for the dingo population. A non-radial arrangement has an infinite fitness function. The Newton-Raphson technique was used to compute the load flow for each dingo and to determine the fitness function, which is used in this study to represent the power loss. The following results are derived depending on the fitness function settings (power loss):

- (i) the Dingo with the best search (D_α)
- (ii) the Dingo with the second-best search (D_β)
- (iii) the Dingo search results afterwards (D_o)

Step 6: Updating the dingoes status

For $i = 1: D_n$

Update the latest search agent state using the set of Eqs. 14–19

Step 7: Estimation of the fitness of updated dingoes

The updated dingoes undergo a radial configuration check. A non-radial configuration has an infinite fitness function. To determine the power loss, load flow was applied to the dingoes (objective function and fitness function).

Step 8: Determination of the dingo fitness values

Record the value of S_α, S_β and S_o

Record the value of $\vec{b}$, $\vec{A}$, and $\vec{B}$

Step 9: Termination criterion

Updating of the Dingoes status are continuously carried out until the maximum iteration number was reached.

6. Application of dingo optimization algorithm to capacitor allocation

The DOA technique was implemented to solve capacitor allocation problem using the following steps:

Step 1: Enter the network's line and load data, including the DOA parameters.

Step 2: Initialization. A dingo is a possible solution for the DOA application that consists of capacitor locations and sizes. An illustration of n dingoes in a population is given as Eq. 26.

$$D = \begin{bmatrix} D_1 \\ D_2 \\ \vdots \\ D_n \end{bmatrix} = \begin{bmatrix} bus.Cap_1^1, \dots, bus.Cap_m^1 & size.Cap_1^1, \dots, size.Cap_m^1 \\ bus.Cap_1^2, \dots, bus.Cap_m^2 & size.Cap_1^2, \dots, size.Cap_m^2 \\ \vdots & \vdots \\ bus.Cap_1^n, \dots, bus.Cap_m^n & size.Cap_1^n, \dots, size.Cap_m^n \end{bmatrix} \quad (26)$$

Each dingo in the population can be represented as:

$$D_i = [bus.Cap_1^i, \dots, bus.Cap_m^i \quad size.Cap_1^i, \dots, size.Cap_m^i] \quad (27)$$

Eq. 27 demonstrates that each dingo's solution vector has two components. The bus number chosen for capacitor positioning is represented by the first portion, while the sizes of the capacitors are represented by the second part.

Also, in the Eq. 28, $bus.Cap_1, bus.Cap_2 \dots bus.Cap_m$ are the buses chosen for the placement of capacitors; $size.Cap_1, size.Cap_2 \dots size.Cap_m$ are the sizes of the capacitor units in kVAR to be incorporated at the buses.

In the DOA, each dingo can be regarded as a solution which is randomly generated in the initialization. Therefore, each dingo, D_i of the population is randomly initialized as follows:

$$bus.Cap_i = round \left[bus_{lower, r_1}^i + rand \times (bus_{upper, r_1}^i - bus_{lower, r_1}^i) \right] \quad (28)$$

$$size.Cap_i = round \left[size_{lower, r_2}^i + rand \times (size_{upper, r_2}^i - size_{lower, r_2}^i) \right] \quad (29)$$

where $r_1 = 1, 2, \dots, m$ and $r_2 = 1, 2, \dots, m$. Except for the slack bus, capacitors can be placed on any bus in the distribution network. Due to the inequality restriction of Eq. 7, the size of each capacitor is from 150 kVAR to the maximum power of the capacitors, with the lower and higher limits of placement being from bus 2 to the final bus of the network.

Step 5: Evaluate each dingo's fitness

Utilizing the Newton-Raphson approach, the load flow for each dingo is calculated in order to obtain the fitness function, which is used in this research to represent the loss. The following outcomes were derived depending on the fitness function's magnitudes:

- (i) the dingo with the best search (D_α)
- (ii) the dingo with the second best search (D_β)
- (iii) the dingo search results afterwords (D_o)

Step 6: Updating the dingoes status

For $i = 1: D_n$

Update the latest search agent state using the set of Eqs. 14–19

Step 7: Estimation of the fitness of updated dingoes

Load flow is performed the dingoes to obtain the power loss (objective function and fitness function).

Step 8: Determination of the dingo fitness values

Keep track of S_{α} , S_{β} and S_{γ} values

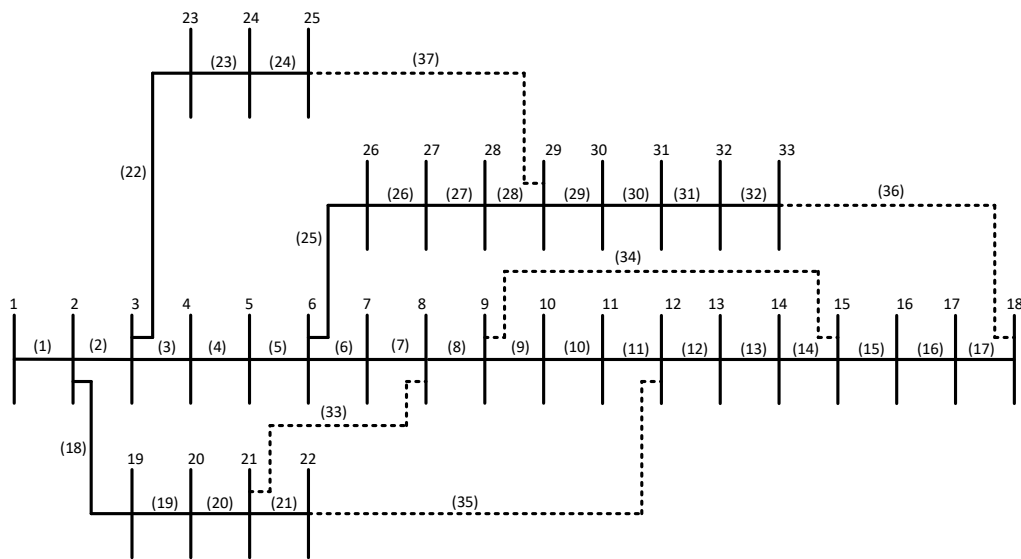
Keep track of $\bar{b}$, $\bar{A}$, and $\bar{B}$ values

Step 9: Termination criterion

Until the maximum iteration number is reached, the dingoes' status is updated continually.

Fig. 1 shows the one line diagram of IEEE 33 bus network on which the two techniques were validated. For the network reconfiguration technique, the continuous lines represent sectionalizing switches and broken lines representing tie switches. The data for this radial distribution network were obtained from Dharageshwari & Nayanatara, (2015).

Figure 1. IEEE 33-bus network



7. Results and discussion

Simulations were performed for each of the strategies using 200 iterations, 50 searching agents, and a minimum and maximum of 2 and 25 attacking dingoes, respectively. On the network, a total of three capacitor units were assigned. Tab. 1 highlights the simulation findings for the network reconfiguration approach, while Tab. 2 gives the simulation results for the capacitor allocations. The switches that opened, resulting in optimal network reconfiguration, were 3, 7, 11, 12, and 24 in Tab. 1. Fig. 2 portrays the ideal reconfigured network for visual assessment and better comprehension. Fig. 2 demonstrates that following reconfiguration, no bus was segregated from the supply, demonstrating the effectiveness of the DOA approach in resolving the optimization problem. According to Tab. 2, the ideal capacitor locations following optimal allocation were buses 12, 24, and 30, with optimal capacities of 342, 711, and 1014 kVAR, respectively. The simulation results are discussed in two subsections to better understand the comparison of the two techniques.

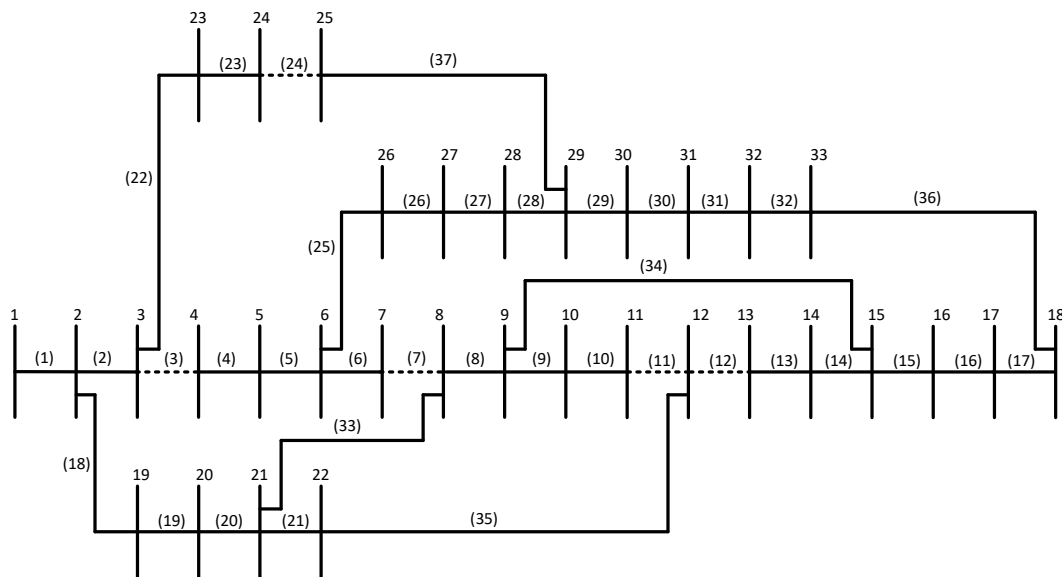
Table 1. Simulation results for network reconfiguration method

	Before reconfiguration	After reconfiguration
Tie switches:	33, 34, 35, 36, 37	3, 7, 11, 12, 24
Real loss:	202.7052 kW	128.1941 kW
Real loss minimization:		36.7583 %
Least voltage:	0.91308 pu	0.98237 pu

Table 2. Simulation results for capacitors allocation method

Capacitor Size (kVAr)	Location
342	12
711	24
1014	30

Figure 2: IEEE 33 network after reconfiguration



8.1 Voltage profile comparison evaluation

Fig. 3 depicts the voltage profile for the base case, network reconfiguration method, as well as the capacitor allocation method for visual inspection of the results and better understanding. The least voltage magnitude, which occurred at bus 18 for the base case, which was 0.9131 p.u., was significantly improved to 0.9896 p.u. for the network reconfiguration technique and 0.9393 p.u. for the capacitor allocation technique, which implies that the bus 18's voltage magnitude increased by 7.7% for the network reconfiguration method compared with 2.3% for the capacitor allocation method. After network reconfiguration, the least voltage magnitude now stands at 0.9824 p.u. on bus 10. Similar to this, following capacitor allocation, bus 18 still had the lowest voltage magnitude, 0.9393 p.u. According to a critical analysis of Fig. 3, the

overall network voltage profile was significantly enhanced by the network reconfiguration approach compared to the capacitor allocation technique. When comparing the voltage magnitudes for the network reconfiguration method and the capacitor allocation method, there was a noticeable improvement starting from bus 2 to bus 17, and from bus 23 to bus 33. To boost the bus voltage magnitudes of radial distribution networks, the network reconfiguration method has thus far proven to be significantly more effective than the capacitor allocation method.

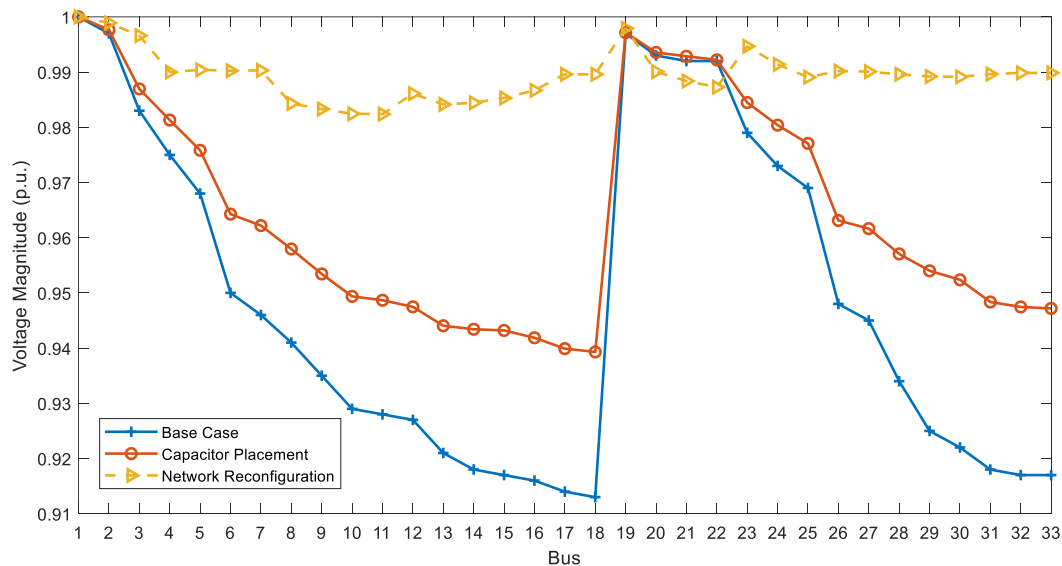


Figure 3: Voltage profile comparison

8.2 Real power loss comparison evaluation

The base case, the network reconfiguration technique, and the capacitor allocation method's total real losses are shown in Fig. 4. The base case real power loss was 202.71 kW, as illustrated in Fig. 4. With the network reconfiguration technique and the capacitor allocation method, this loss was decreased to 128.19 and 135.16 kW, respectively. The real power loss was decreased by the network reconfiguration technique by 36.76%, compared to 34.44% for the capacitor allocation method, in terms of percentage power loss reduction. This suggests that the capacitor allocation technique did not significantly lower the overall real power loss compared to the reconfiguration method. In other words, real power losses in all branches were much lower when the network was efficiently reconfigured than they were when capacitors were ideally placed across the network. Again, the network reconfiguration technique outperformed the capacitor allocation method by greatly improving the network's performance while significantly reducing overall real power loss.

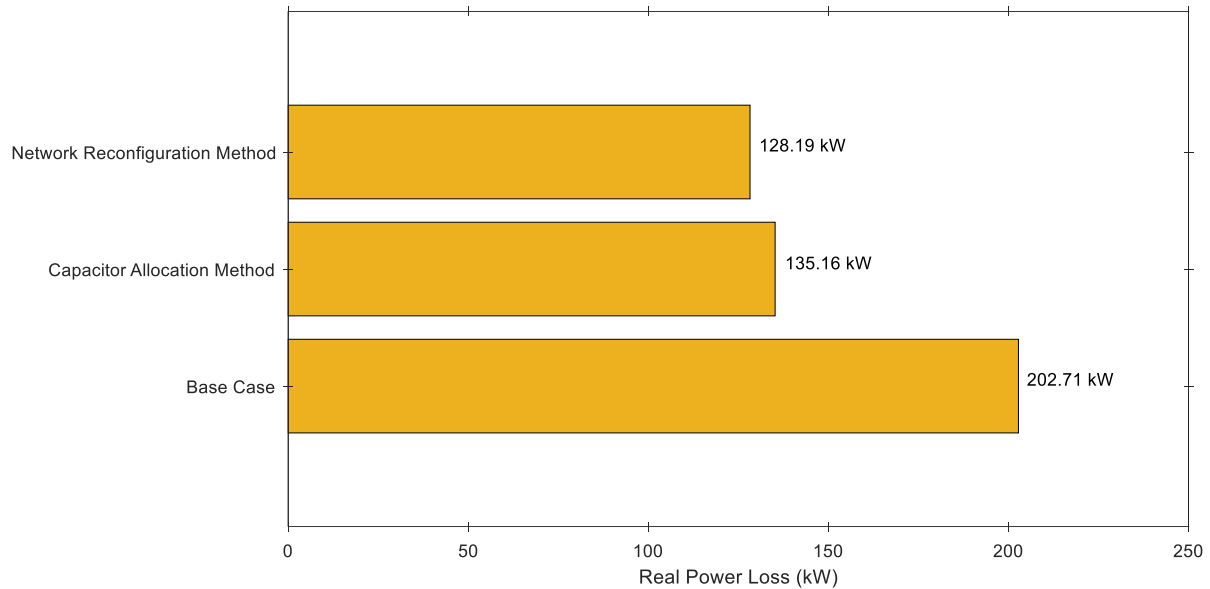


Figure 4: Real power loss comparison

9. Conclusion

The network reconfiguration and capacitor allocation methods, which are arguably the cheapest and easiest techniques to use to boost the radial distribution system performance, have been compared and evaluated in this research. The IEEE 33 bus was employed as a test network, and a novel DOA approach was applied to address the optimization issues of the two methods. According to the simulation findings, the network reconfiguration approach beat the capacitor allocation method in terms of boosting the voltage profile and diminishing the overall real power loss. Therefore, compared to the capacitor allocation approach, the network reconfiguration method is a smart choice for improving the performance of the radial distribution networks.

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A Novel Feature-Based Music Recommendation System Considering the Uniqueness of Musical Items

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Abstract.

Some music recommendation systems do not consider the uniqueness of song items well enough to be able to classify these by the general mood and feel they may give off. The purpose of this report is to thus create a system that attempts to solve this problem and create a model to categorise each musical item by mood using their content-based features. The model of choice is the Gaussian Maximization Model since it allows the creation of inferences modelled in a computationally efficient way. The dataset to be explored is the publicly available Spotify dataset which comes with pre-processed content-based features of different songs from the era 1920- 2020. Once this is done, I will then compare the different silhouette scores and Bayesian Inference Criterion (BIC) score obtained by this model with the score obtained by KMeans clustering algorithm which serves as the benchmark model we hope to improve on.

Keywords: Music recommendation systems, content-based, mood-based clustering, Gaussian mixture models, silhouette score

1. Introduction

Music acts as a vice for people to relate the way that they feel (or want to feel) both instrumentally and/or lyrically. Whether you need a song to listen to on the bus on the way to work, or one that will give you that extra pump at the gym or even to help you relax after a long hard day, music has become super accessible to each and every single one of us for any possible need we might have right at our fingertips. Music streaming platforms such as Youtube Music, Spotify, Apple Music and many more have planted themselves as the mediums of choice for accessing music and have made it possible for us, the general public, to store a unique music library within our profiles (R. E. S. Panda & Paiva, 2010). Most recommendation systems today commonly classify music based on their metadata (i.e. the name of the artist, album, year of release, genre etc.).

Such a method has its conveniences however, the disadvantage is also obvious in that it ignores the users' direct emotional needs and the type of music that may be fitting to accompany those needs. This is linked to music's audio content i.e the music's vocality, melody, rhythm etc. (Wang & Wang, 2014) of songs which is what gives song pieces an overall theme/feel. This forms the basis of the motivation behind using contentbased features of song pieces within a music recommendation system.

The principal objective of conducting this research is to classify music by mood using their content-based features. The songs used in this study was from the publicly available dataset provided by the popular music streaming service, Spotify. I will be modelling this content as a parametric probability distribution problem with the hypothesized outcome being that this music recommendation system - using content-based features obtained directly from Spotify - can be used to recommend similar sounding songs to a user.

2. Related Work

Music Emotion Models

Paper/Author	Model
Hevner (1936)	Hevner's categorization of emotions: the adjective circle
Russell (1980)	Russell's Arousal-Valence 2D Plane
Yang et al. (2006)	Thayer's Arousal-Valence 2D Plane
R. Panda et al. (2015)	MIREX Mood Classification Task

Table 1: Table Showing Key Papers Featured in This Section

The relationship between music and emotions is a long-standing study by psychologists across the world since emotions are as complex as humans because of the differences in the ways that we each interpret and resonate with the world around us. Models that have been suggested can be split into two distinctive groups (R. Panda et al., 2015) :

Categorical Models: These typically refer to adjectives that can be used to classify emotions into groups for example (joyful, melancholic, anxious etc)

Dimensional Models: These on the other hand, consider multidimensional spaces where each space consists of clusters with synonymous words to classify emotions.

A famous example is the 2D geometric model called 'Russell's Circumplex Model of emotion' analogous to a compass (Russell, 1980) in which the vertical plane measures the level of arousal (intensity of the associated emotional state) from low to high and the horizontal plane describes the level of valence (the extent to which an emotion is positive or negative). An example of interpretation is that happiness would be interpreted as +arousal +valence, anger as +arousal -valence, depression as -arousal valence and calmness as -arousal +valence. The figure can be found at figure 1.



Figure 1: Russell's Circumplex Model of emotion (Seo & Huh, 2019)

Another well-known example is in the renowned paper of researcher Kate Hevner (Hevner, 1936) whereby a survey was conducted in which subjects were to write emotional adjectives that they felt in relation to the musical piece that was playing. Hevner then grouped descriptive adjectives into 8 clusters and laid them out in a circle as seen in figure 2.



Figure 2: Kate Hevner's Adjective circle (Hevner, 1936)

Thayer's model of music is an application of the above mentioned circumplex model in that it shows music's energy and stress as measures analogous to arousal and valence. Energy refers to the volume and/or intensity of the musical piece and Stress refers to the tonality and tempo of music. They can be divided into four groups: Exuberance (high energy, low stress), Anxious (High stress, high energy), Contentment (low energy, low stress), and Depression (low energy, high stress).

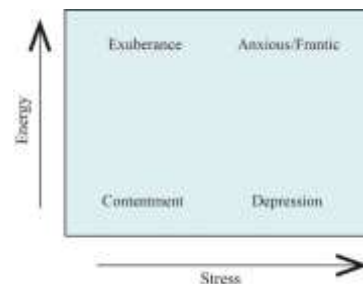


Figure 3: Thayers Model (Seo & Huh, 2019)

Similarly, utilising another taxonomy model of mood (Yang et al., 2006) influenced by Thayer shows a 'Music Emotion Variation Detection' scheme which basically translates results obtained from the fuzzy vectors used in the classification model into values representing valence and arousal as described above.

2.1 Feature Analysis

Music is both social and psychological (T. Li & Ogihara, 2004) and frontend data (artist, album, genre etc) is no longer enough for the characterization and assembling of similar songs. In order to create a successful music classification model, it is crucial to extract reliable audio signals from musical data. An observation was made (T. L. Li et al., 2010) that symbolic musical data ⁵ provides information that is usually readily available - these include the note onsets, note offset, intensity, and many more precise musicological descriptions of the songs -. For audio music, however, only the recorded sound signal is available. There are vast techniques that can be used to extract music data from various sources. Some of these include: content-based acoustic feature extraction, symbolic feature extraction, text-based feature extraction (Ajoodha, 2015) with content-based techniques being the best and most note-worthy approach in extracting features that are not only relevant to the context of the signal of the audio piece, but also to genre classification problems. Content-based feature

extraction methods make for better classification accuracy which subsequently maximises the speed at which music information is retrieved. The following list shows some of the relevant content-based features that can be extracted (R. Panda et al., 2015) which control the mood perceived by a listening ear. Namely:

- Timbre: spectral and/or harmonic richness
- Pitch: high/low
- Vibrato: extent and/or speed
- Timing: tempo and its variation
- Melody: range (small/large)
- Mode: major/minor
- Dynamics: crescendo/decrecendo
- Musical form: complexity and/or repetition
- Interval: small/large
- Harmony: consonant/complex-dissonant
- Rhythm: regular-smooth/firm/flowing-fluent/irregular-rough
- Articulation: overall staccato/legato,
- Loudness:high/low volume
- Tonality: chromatic-atonal/key-oriented

Table 2: Table Showing Key Papers Featured in This Section

Paper/Author	Data
T. L. Li et al. (2010)	GTZAN dataset
Ajoodha et al. (2015)	GTZAN dataset
Ajoodha (2015)	GTZAN Genres
R. Panda et al. (2015)	Mirex-like dataset
Model	Accuracy
CNN	84%
Naive Bayes	53.2%
K-nearest neighbours	72.80%
Multilayer perceptron	75.2%
Support vector machines	75.4%
Random forests	75.7 %
Linear logistic regression models	81.00%
Naive Bayes	53.2%
Support vector machines	32.50%
Multilayer perceptron	63.70%
Random forests	66.7 %
K-nearest neighbours	72.80%
Linear logistic regression models	81.00%
NaiveBayes	38.3%
NaiveBayes*	44.8%
C4.5	55.9%
C4.5*	57.3%

K-nearest neighbours	41.7%
K-nearest neighbours*	56.7 %
Support vector machines	52.8%
Support vector machines*	64.0%
Results in terms of F-measure and utilises all features as well as selected features (denoted by *)	64.0%

These features, although relevant, are not always easily and readily accessible and researchers have made use of manual feature selection methods (Yang et al., 2006) which subsequently improved classification accuracy as it removes , iteratively, the worst/least helpful features ensuring that the most optimal number of features remain.

The main goal of performing a similarity search is to allow the collection of music that is similar in sound and overall ambience, together. The utilisation of sound signals is therefore, justified since it is found that digital or analog audio signals of the same genre share similar characteristics such as comprising of similar instruments, rhythmic patterns and a similar pitch distribution (T. Li & Ogihara, 2004).

2.2 Existing Music Emotion Retrieval Models

The key to successful music recommendation systems are those that provide each individual user tailored music recommendations. One way to do this is by giving them the ability to select context-specific moods. These user-specific mood tags prove to be relevant when considering Music Information Retrieval (MIR) and Park et al. (2006) notes this importance for accurate suggestions of music that the person might enjoy. A Bayesian Fuzzy Network was the classification method of choice in which Park et al. (2006) used this as a means of context inference. This idea was therefore creatively extended by authors such as Kim et al. (2011) in which they showed the relationship between mood tags and the Arousal-Valence plane by means of a K-Means Clustering algorithm and frequency histograms for each mood class.

Paper/Author	Data
Kim et al. (2011)	Independent Survey and program
Wang & Wang (2014)	The Echo Nest Taste Profile Subset
Yang et al. (2006)	Independent Collection of popular western,s Chinese and Japanese song
Liu et al. (2017)	Music Spectrogram
T. Li & Ogihara (2004)	Jazz and Classical Music Dataset
Kaur & Kumar (2017)	
Koolagudi et al. (2012)	Speech Audio Spectral Features Model
Model	Accuracy
K-Means Clustering	-

Deep Belief Network (DBN)	-
Fuzzy KNN	68.2%
FNM	71.34%
CNN	-
SVM	70.9%
AEM	70 - 83%
Gaussian Mixture	-

Table 3: Table Showing Key Papers Featured in this research.

Problems that typically arise is the fact that content-based classification methods usually rely on what is known as collaborative filtering(songs recommended to users based on what other users who enjoyed the same music listened to next) which has the downfall of not being inclusive of less "popular" music when creating these recommendations (Park et al., 2006) (Wang & Wang, 2014). A way of mitigating this is perhaps joining collaborative filtering with content features of audio in order to improve and maximize the performance of the recommendation system (Wang & Wang, 2014) with results that show a significant improvement in accuracy using deep learning techniques (namely, a Deep Belief Network(also a PGM)) which excludes the exclusive reliance on collaborative filtering that previous classifiers required. Extending the use of neural networks in model training, is the use of Convolutional Neural Networks with a SOFTMAX classifier as a means to analyse the mood of the song (Liu et al., 2017). Features were extracted from music spectrogram with the output being the same dimension space as emotion tags that the audio is tagged with.

Another publication proposed to characterize music emotion detection as a set of binary classification problems due to the fact that a single music sound can have more than one label i.e. it could be classified as both "happy" and "exciting" (multi-label classification) (T. Li & Ogiwara, 2004) . Each binary problem is then developed with a classifier that is based on the projection of the training data. These binary classifiers are then run on the test data individually and are selected according to some predefined threshold.

Gaussian Mixture Models (GMM) was researched to have its benefits when performing this task (Koolagudi et al., 2012) in that an Emotion Retrieval Model on the spectral features of speech audio was developed which are then sorted into vectors. These vectors are then split into training and testing data for the GMM in which the output becomes the emotion recognised by the system. This model works by utilising an Expectation Maximisation Algorithm which can be used to estimate the parameters of class labels since these are unknown and is therefore known as the latent variable of the problem (Koolagudi et al., 2012). The algorithm initialises the set of parameters arbitrarily and in what is known as the "E-Step", utilises these arbitrary values to estimate the missing output. In the "M-Step", these estimates are used to re-estimate the parameters. This process is continues until convergence.

3. Methodology

As explored from the above literature, this paper looks at utilising an unsupervised machine learning clustering model. In particular, a probabilistic algorithm known as the Gaussian mixture model is used to train the dataset as the outcome is unknown. This algorithm is a generative process whereby a mixture of probability distributions are used in order to predict unknown parameters from this specific

dataset. Specific insights of this methodology are explored further in the relative subsections that follow.

3.1 Dataset Description

The dataset of choice is from a popular music streaming service , *Spotify*. This platform has made public the audio features of approximately 160000 songs that were released within the years 1920 - 2021 housed on the platform *Kaggle*. This removes the extra step of performing feature extraction on different sounds as this has already been done. The feature-set is described in Table 4 each ranging from 0.0-1.0 where applicable.

Table 4: Table showing the features kept (upper portion) and the features eliminated (lower portion). Column two describes each feature respectively

Features Maintained	Description
valence	'positiveness' of a song
acousticness	how acoustic the song is
artists	song arist
danceability	tempo, beat strength, rhythm, stability, regularity
energy	intensity and activity of song
instrumentalness	amount of vocals in song
liveness	probability of song taking place live
loudness	how sound is perceived (quiet - loud)
name	song title
speechiness	spoken bits of a song
tempo	speed of song
Features Removed	Description
year	Song release year
duration ms	song duration
explicit	how explicit the song is
mode	notes used in a song
key	major/minor scale of song
popularity	song popularity
release date	date song released

3.2 Models

The aforementioned features provided will be normalized, to ensure that all values are processed in the the same way within the same range to avoid corrupt results. The feature set will then be used for training and testing the model and will be split into 2 groups: 70% for training and the remaining 30% for testing if the model gives the right output.

3.2.1 Gaussian Mixture Model

This clustering technique is trained to work with the specific dataset in question where it takes subsets of the data and assess the normal distribution of each group. It then sorts data points that belong to the same distribution, together. In order to estimate the parameters, the classifier makes use of an iterative Expectation Maximization(EM) algorithm used for each Gaussian component and the mixture weight.

3.2.2 Bayesian Graph Model

As an extension to the above algorithm of creating different clusters for similar songs, Bayesian Graph Models will provide a computationally efficient way of creating inferences on the learned model of the exact probability values for song queries. A significant improvement is eminent when utilising graph models (Dang & Shirai, 2009) if there are rich relationships that exist between songs. In this case, the causal relationship that exists between each class is modelled with each content-based feature of the songs that belongs to that cluster as edges. Since Bayesian Models produced higher accuracy (Dang & Shirai, 2009) against other graph models, this made it a plausible option to improve this model. Each music item will have some probability of belonging to each cluster where the greatest probability generated infers the belonging of that song into that particular class. Figure 4 shows this structure.

3.3 Evaluation Techniques

Since the ground-truth of the different categories that each song may belong to is unknown, it is important to see how well/ poorly this clustering technique performs. Therefore, a comparison between two accuracy techniques will be compared in this study: Silhouette Coefficient and Bayesian Information Criterion (BIC) to obtain the most accurate number of mood clusters for our particular dataset.

3.3.1 Silhouette Coefficient

This technique measures the goodness of fit of the GMM model with values ranging from -1 to 1 where we can interpret the values as follows:

- 1:** Means that the clusters are well apart from each other and we can easily distinguish each cluster from the next
- 0:** Means that there isn't a significant distance between each cluster
- 1:** Means that the GMM clusters were not correctly assigned.

3.3.2 Bayesian Information Criterion

This scoring method works well on models that utilizes maximum likelihood estimation. The aim is to get as low a score as possible as this means that the hypothesized model is favoured. Instead of randomly choosing the number of classes that would be appropriate for classification, tests were run in this study where various numbers of cluster components were chosen along with the type of covariance(spherical, tied, diagonal or full) the GMM model has. The number of these components which generated the best score was then selected as the optimal size.

	Covariance_Type	N_Components	Silhouette_Score
0	spherical	2	0.305337
1	spherical	3	0.312650
2	spherical	4	0.289264
3	spherical	5	0.289975
4	spherical	6	0.311544
...	...	...	...
147	full	35	-0.079418
148	full	36	-0.072755
149	full	37	-0.083967
150	full	38	-0.060680
151	full	39	-0.083865

152 rows x 3 columns

Table 5: Silhouette Table showing score generated using different sized clusters run until convergence

4. Results and Discussion

Figure 7 show some of the visual discernment of the scores calculated from the data when different sized components were tested. The Silhouette Coefficient shows the greatest score of 0.322... when the number of clusters is set to 4. The GMM models was then generated using these results for further investigation. As seen on figure 7 , the model did not produce a clean and simple representation of the data points sorted into their respective clusters. However, an important factor to acknowledge is that this was in fact a multi-variable dataset with 9 features used for classification. This means that this is a very compact view of the generated clusters and that higher dimensions would be required for better visualizations. Nonetheless, the algorithm managed to successfully group similar songs together.

Table 6: Table summarizing best silhouette score evaluation obtained by each model when tested against various cluster sizes.

Model	No. of Clusters	Best Silhouette Score
GMM	4	0.322...
K-Means	2	0.315...

Since we do not have the ground truth of the correct number of mood clusters of this recommendation system using content-based features, an explicit measurement on how the GMM model performed could not be obtained. This is why different iterations of the number of clusters was performed so that the best score could then be taken as the one to represent this dataset. The inferred classes generated by the training data was used to classify the testing data and the accuracy achieved by the models GMM and K-Means was then calculated. The latter model was used as the bench mark by which GMM was expected to perform better against. Table 7 shows a summary of the figures obtained.

5. Conclusion and Future Work

The aim of this paper was to create a music recommendation system that uses content based features to classify songs by mood. The Spotify Music dataset which is publicly available was used. Since the ground truth of the different mood clusters was not given, this was treated as an unsupervised machine learning problem using Gaussian Mixture Models utilizing the Expectation-Minimization Algorithm. The Bayesian Inference Criterion score was calculated on a GMM cluster with 4 components in an attempt to assess how the algorithm performed. Since both the silhouette score and the Bayesian Inference Criterion were considered and since both of these evaluations are the best to use for this type of problem, optimal GMM clusters were obtained as per research question. It was found for this particular dataset, songs can be classified into 1 of 4 moods.

A possible extension of this research would be to integrate this model within Spotify's already-setup APIs whereby a user specific playlist can be generated automatically. This can be done by perhaps calculating the Euclidean Distance between each song - the shorter the distance, the similar the songs may be which can then be sorted in descending order and be given as an output playlist. The top 50 (or any number to the users preference) would then be picked and returned in a tracklist. Due to time constraints, modelling these moods onto an emotion model could not be conducted and hence could improve quality of this paper to represent that explicitly.

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Mapping Chordal Progressions from the Magnitude Spectrum to Symbolic Notation

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Abstract.

This paper addresses the problem of automatic identification of chordal progressions from audio by presenting the application of Machine Learning techniques to map chordal progressions from the magnitude spectrum to symbolic notation. Five different machine learning techniques are used to map the chordal progressions, namely: Naive Bayes, Support Vector Machines, Random Forests, Logistic Regression Classifiers and Multilayer Perceptrons. The results showed that the Multilayer Perceptron achieved the highest accuracy of 99.48 percent, and Naive Bayes achieved the lowest accuracy of 50.15 percent. This paper shows the capability of real-time machine learning models to identify chordal progressions given noisy wav files.

Keywords: Algorithmic Music Composition, Signal Processing, Content-based, Machine Learning, Symbolic Notation

1 Introduction

The art of music composition has been around for years, creating the most exquisite pieces, and recently there have been attempts to train computers to compose music. In this paper, music composition will not be looked at directly, but rather a method that aids music composition - namely, mapping chordal progressions from the magnitude spectrum to symbolic notation. Chords are a vital component of songs, and thus having efficient means of extracting chordal progressions from audio clips is imperative for music analysis.

There has been extensive research in Chord Recognition Systems (Ni, McVicar, Santos-Rodriguez, & De Bie, 2012) which focus on identifying chords from audio signals, Algorithmic Music Composition (Marsden & Ajoodha, 2021) where a computer learns how to compose its own music, and Music Genre Classification (Ajoodha, Klein, & Rosman, 2015) where a computer learns to classify a piece of music according to its genre. However, research is limited in terms of Chordal Progression Recognition Systems, (Carsault, Nika, Esling, & Assayag, 2021), which identifies the progression of one chord to the next in audio clips.

The benefits of this include, and are not limited to: searching for songs based off of its chordal progressions, composing music and identifying emotions based off of someone's voice. By using chordal progressions instead of chords, searching for songs becomes key independent, thus adding a level of generalization and reducing the level of variance of labels to the models.

Despite the fact that the current methods for approximating chords are quite accurate, the accuracy is dependent on noise. Noisier audio tracks result in misidentified notes, missed notes, additional notes or repeated notes. This inaccuracy can create multiple issues for example: when performing music composition, the algorithm might learn from the repeated notes and compose music in this style, or it might add non-harmonic notes that it learned from this noise. This might also create problems when transcribing music resulting in sheet music that has discrepancies in it, leading to musicians playing incorrect melodies from the sheet music.

The purpose of this research is to explore fast data driven machine learning techniques that successfully predict the chordal progressions of a noisy piece of audio. The report details the implementation of five machine learning models by discussing the preprocessing, model training and evaluation information.

The contributions made in this paper are as follows:

- Five machine learning models that identify chordal progressions from audio files.
- An investigation into whether specific chords are commonly mistaken for other chords when performing chordal progression identification.

The paper begins with a Background Section, explaining important music theory concepts, then continues to Related Work, detailing previous papers which have dealt with similar research topics. Next, this paper looks at Methodology, detailing how each model is set up, followed by the Results to showcase the observations made in running the algorithms. The paper continues with a Discussion Section comparing the different models with regards to certain performance criteria, and finishing with a Conclusion section discussing whether the paper addressed the problem of identifying chordal progressions.

2. Background

In order to understand the lines of this research, it is important to understand a few concepts and terms used in music theory. The following concepts can be found in (Dunbar, 2010).

2.1 Chords

A chord is a harmonic set of pitches or frequencies played simultaneously, and labeled according to the seven notes A, B, C, D, E, F, G. Not only is a chord a certain combination of harmonic notes centered about a root note, but it can also be major, minor, diminished or augmented, depending on the interval between each note. A chord is major by default, and major chords are referred to as happy sounding chords, where the interval between the first two notes is two whole notes, and the last two notes is a whole note and a half, compared to the sad sounding minor chords which are denoted by a small m, and the middle note is lowered by half a step, eg: Am (A minor). A chord is diminished when the fifth note of a minor chord is lowered by half a step, and a chord is augmented when the fifth note of a major chord is raised by a half step.

In addition to a chord being either major or minor, chords can also be associated with the term ``flat'' or ``sharp''. These terms mean that the root key of the chord, for example the note A in the A chord, is transposed (shifted) down by a semi-tone (by a half step) if it is flat, or up by a semi-tone if it is sharp. A flat chord is indicated by the $\flat$ symbol, and a sharp chord is indicated by the $\sharp$ symbol.

All of these combinations of chords make the problem of identifying chords accurately more challenging due to the fact that some chords are built off of other chords and many chords overlap with the same composition of notes apart from a few slight differences.

2.2 Chordal Progressions

A chordal progression is a succession of chords. Chordal progressions are labeled using roman numerals. In order to calculate a chordal progression, two chords from the same key are taken and the jump between one chord to the next indicates its progression.

2.3 Octaves

An Octave is the interval between one note and another which has double the frequency of the first note. On a piano, an octave consists of seven notes along with their respective flats and sharps: A, B, C, D, E, F, G. Octaves are labeled from left to right, with the leftmost octave (the deepest sound) being one.

2.4 Spectral Representation

The spectral representation of sound is a visual image of the frequencies that the sound consists of, and the respective intensities of those frequencies. To obtain the spectral representation, the raw audio track is passed into a form of mathematical transform, such as the Fast Fourier Transform, and each amplitude per time is deconstructed into the frequencies encapsulated in that amplitude, and the intensity of each frequency. The image shows a frequency at a point of time in the audio. This frequency does not necessarily represent a singular note, but rather the sum of the frequencies of all of the notes played simultaneously at that time. An example of spectral representation of an audio clip is depicted in Figure 1.

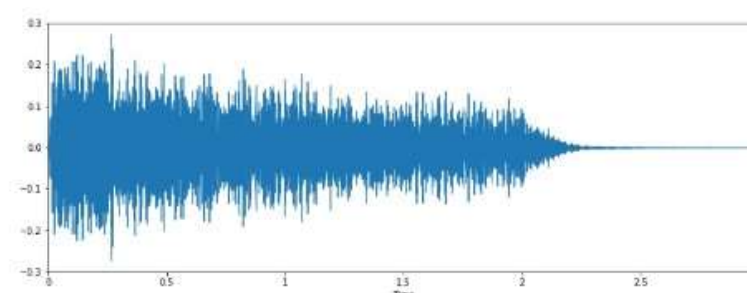


Figure 1: An example of Spectral Representation of an audio file.

2.5 Symbolic Representation

Symbolic representation can be presented in a number of ways. One option is through the use of letters for notes as seen with the use of chords, discussed above. It can also be drawn as sheet music as indicated below in Figure 2, where each black dot represents a note, and the notes are arranged in a specific formation along black horizontal lines.



Figure 2: An example of a piece of Sheet Music.

Each note can be drawn differently indicating rhythm and duration, with certain cues indicating loudness, tempo, pitch, etc. Chord Progressions themselves also have a unique way of being represented, either being represented by the chords one after the other, or more commonly represented as a set of Roman Numerals indicating the jump from one chord to the next (the Chordal Progression), for example: C F G would be written as I IV V.

2.6 Circle of Fifths

The Circle of Fifths is an important concept in music theory that relates to chordal arrangements (Clough & Myerson, 1986). It organizes the twelve chromatic pitches into a sequence of fifths by placing chords with similar key signatures near each other. The Circle of Fifths can be used to describe the musical relationships between pitches, and is useful for musical composition as it can be used to obtain pleasant sounding chordal arrangements by traversing clockwise or anticlockwise around the circle of chords. A diagram showing the Circle of Fifths is shown in Figure 3.

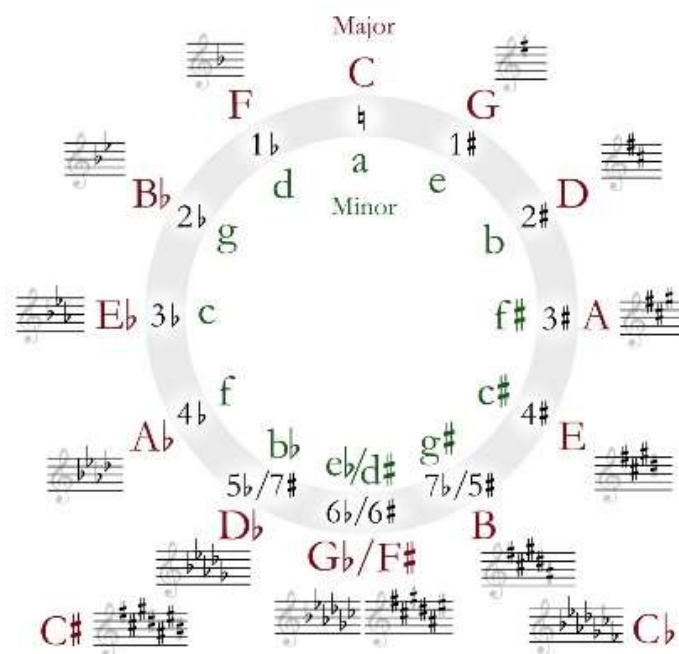


Figure 3: A visual representation of The Circle of Fifths

3. Related Work

There is limited research on identifying chordal progressions using machine learning techniques. A few papers have demonstrated the use of chordal progressions in order to predict something else, for example Recognising emotions based off of chordal progressions, (Cho, Lim, Kim, & Lee, 2016), however, the majority of research focuses on identifying chords instead of chordal progressions. One paper that looks at identifying chord progressions used human vocals as its database in contrast to the piano audio used in this paper (Parncutt & Reisinger, 2021). In the following paragraphs, different machine learning models from different papers are investigated and compared with

regards to strength and weaknesses for predicting chords and composing music. This information gives an indication of which models would be beneficial for chordal progression prediction.

- **Recurrent Neural Networks (RNN's)**

(Boulanger-Lewandowski, Bengio, & Vincent, 2013) demonstrated that RNN algorithms triumph over deep belief networks and Harmony Progression Analyzers (HPA's) by comparing the chord overlap ratio (OR) and the weighted average overlap ratio (WAOR). The RNN achieved 93.6% for WAOR and the HPA achieved 82.7% WAOR. Papers by (Boulanger-Lewandowski et al., 2013) and (Sigtia, Boulanger-Lewandowski, & Dixon, 2015) take the magnitude spectrum and initially convert it into chords or notes from frequencies by making use of the Fourier Transform or Constant-Q Transform respectively. By viewing how RNN affects the composition of music as a whole, It was observed from (Wang, Jiang, & Yang, 2017), that using the RNN model for composition is greater than randomly picking notes, however incorporating the Long-Short Term Memory Model (LSTM) does improve the results. This fact is backed up by (Sigtia et al., 2015), which incorporated LSTM in its language model and achieved 75.5% WAOR.

- **Long-Short Term Memory Models (LSTM's)**

The LSTM model is a special case of RNN which has a greater temporal memory than the RNN, for this reason, it has become quite popular for algorithmic music composition. As mentioned above, (Wang et al., 2017) incorporates LSTM's in its research, and boasts of the remarkable influence of LSTM's in learning longterm dependencies and cadences in chordal progressions by showing a 58% Test Accuracy. Further papers that explore LSTM models for music composition uncover remarkable results. By extracting the chord embeddings, the chords form a resemblance to the Circle of Fifths, which is an important concept of musical theory that describes chordal arrangements (Brunner, Wang, Wattenhofer, & Wiesendanger, 2017; Tan, 2019). The contribution of this paper is the fact that the model was capable of learning such an imperative concept of music theory.

Not only are LSTM's useful for music composition and learning chordal progressions, but they also prove useful in improving the structure of already composed pieces, as shown by (Medeot et al., 2018). This paper reiterates the nature of the LSTM to learn long-term dependencies, and uses that information to increase the probability of encountering longer and more distant patterns in existing compositions, (Medeot et al., 2018).

LSTM's have also been implemented in chord recognition systems, as demonstrated by (Hori, Nakamura, & Sagayama, 2017), who achieved 82.3% accuracy. Here, three different LSTM models were compared to each other and the stacked bidirectional encoder-decoder LSTM network was the most successful. Before the LSTM is implemented, the audio data is initially pre-processed by using the Constant-Q Transform and then that data is passed into the model. The results only looked at LSTM models, and didn't show comparisons between different machine learning algorithms, so it's difficult to judge how well this algorithm works on chord recognition systems in contrast to other methods that exist.

- **Hidden Markov Models (HMM's)**

Most of the chord recognition papers mention Hidden Markov Models (HMM's) as either being the primary model investigated or as a benchmark to weigh the primary models against. (Lee & Slaney, 2006) use HMM's as a primary model, and the idea of different accuracies based on different

instruments that are trained and tested is introduced. This paper also differs in that the model handles symbolic data such as Musical Instrument Digital Interface (MIDI) files to create audio files, which it then uses in the model, instead of using audio files from the start. The reason for this is that symbolic files are easier to perform harmonic analysis on. By using symbolic data, (Lee & Slaney, 2006) manage to avoid the problem of noise and solely focus on training the model to identify chords, thus providing more accurate results.

(Chen, Shen, Srinivasamurthy, & Chordia, 2012) also uses HMM as its primary model and uses the ConstantQ Transform, like (Lee & Slaney, 2006), to attain input to inject into the HMM model, achieving 84.23% WAOR. This paper uses the Bayesian model as its Benchmark as well as a state-of-the-art research paper that uses a Harmony Progressions Analyzer (HPA) as its model (Chen et al., 2012). Research by both (Boulanger-Lewandowski et al., 2013) and (Chen et al., 2012) demonstrate that the HMM model outperformed the Benchmark models, but not significantly. In comparing the results between these 2 papers, there are some contradicting results, more specifically with regard to the HPA model having different accuracies listed. This contradiction makes it unclear whether the HPA model has a higher accuracy than RNN, or not.

There have been papers that explored using HMMs in music composition (NavarroC'aceres, Rodríguez, Milla, P'erez-Lancho, & Corchado, 2017), however, not many papers use this model due to the fact that it does not capture long term musical dependencies, and overall results in pieces that sound artificially made. One way that (Navarro-C'aceres et al., 2017) navigated this issue, was to incorporate human collaboration with the model. The model incorporates human preferences by collaborating with user input to generate melodies. It uses a Case-Based Reasoning Architecture, and concludes that the system is able to generate music which is adapted by user interference. Regardless of the fact that HMM's are not the best models for music composition, it does appear to be quite popular and effective in chord recognition.

4. Methodology

4.1 Data Description

The dataset used is Piano Triads Wavset Dataset from Kaggle (Roberts, 2021). The dataset consists of 432 3-second piano audio files of a chord, each labeled according to the chord played. The chords in the dataset consist of major, minor and diminished chords for octaves two-seven, meaning that there are no augmented chords. When the data is read into an array format it has 66150 features, which is computationally heavy to compute. The data consists of Wav files instead of MIDI files, to test how the models manage against noisier data. The dataset then undergoes either a Short-time Fourier Transform, or a Constant-Q Transform which reduces the number of features to 1560 from 66150, which is much more computationally light. Then a new dataset of dimensions 77160x1560 is created by taking the difference of the chords, and labeling it according to its progression. The data is then split into training and test data in the ratio 70:30. This new dataset is quite large, which could cause overfitting.

4.2 Feature Extraction

In order to ensure that the correct features are extracted to train the models, two transforms are used on the images. First the Short-time Fourier Transform is performed on the dataset, before the differences between the data is computed as the new dataset. Next, the Constant-Q Transform is

performed on the images. The performance of both transforms are compared against each other for each model to decide which features are the most helpful.

4.3 Short-time Fourier Transform

The Fourier Transform decomposes functions that are dependent of space or time, to functions that are dependent of spatial and temporal frequencies. With regards to the research done in the following papers, this means that the Fourier Transform takes in the magnitude spectrum and breaks it up into the frequencies that the magnitude spectrum comprises of. In other words, the Fourier Transform takes a clip of audio, and breaks it up into notes and keys and chords by taking the amplitude of the audio at a specific time, and decomposing the amplitude into frequencies, and the intensity of these frequencies.

The Short-time Fourier Transform divides a longer time signal into shorter segments of equal length and then computes the Fourier transform separately on each shorter segment.

4.4 Constant-Q Transform

The Constant-Q Transform is similar to the Fourier Transform however it does take longer to compute. Unlike the Fourier Transform, the Constant-Q Transform only deals with frequencies that are audible to the human ear. The Constant-Q Transform is more difficult to implement, as it comprises of a varying number of samples that are used for calculations for each frequency. Because Constant-Q is effectively amplitude or phase over log frequency, a frequency of 0 cannot exist, which may create problems in the implementation of the algorithm, depending on what the system is doing with the transform.

5. Evaluation of Results

In this section, five metrics are used to evaluate the performance of each model. The metrics are as follows:

- Program Run Time: measures execution time of training and prediction the model.
- Precision Score: ratio of correctly predicted positive observations to the total predicted positive observations
- Recall Score: the ratio of correctly predicted positive observations to all the observations in a class
- F1 score: the weighted average of Precision and Recall
- Cohen's Kappa Score: measure inter-rater reliability for qualitative items taking into account the possibility of the agreement occurring by chance.

For the tables below, the following Key is provided:

- PRT: Program Run Time
- PS: Precision Score
- RS: Recall Score
- F1: F1 Score

- Kappa: Cohen's Kappa Score
- NB: Naive Bayes Model
- SVM: Support Vector Machines
- RF: Random Forest Classifier
- LR: Logistical Regression Classifier
- MLP: Multilayer Perceptron

The performance of the models on the Short-time Fourier Transform data is shown in Table

Table 1: Performance of the models after a Short-time Fourier Transform is applied to the data.

Model	PRT	PS	RS	F1	Kappa
NB	0.50	0.4180	0.4173	0.3995	0.3169
SVM	86.77	0.9752	0.9749	0.9749	0.9700
RF	20.07	0.9509	0.9499	0.9499	0.9402
LR	62.01	0.9334	0.9326	0.9323	0.9196
MLP	15.13	0.9914	0.9914	0.9913	0.9897

The performance of the models on the Constant-Q Transform data is shown in table 2.

Table 2: Performance of the models after a Constant-Q Transform is applied to the data.

Model	PRT	PS	RS	F1	Kappa
NB	0.46	0.5196	0.5015	0.4926	0.4158
SVM	44.38	0.9884	0.9883	0.9883	0.9861
RF	18.75	0.9902	0.9901	0.9901	0.9881
LR	59.23	0.8349	0.8354	0.8335	0.8036
MLP	13.48	0.9948	0.9948	0.9948	0.9938

• Naive Bayes Model

The Naive Bayes achieves 51% accuracy in less than 1 second, which is considered fast. It performs better with the Constant-Q data. It was observed that there are a number of misidentified labels, of which progression II has the highest number of misclassifications. These misclassifications are due to the fact that the Naive Bayes classifier assumes that features are independent of one another, however this is not the case with an audio clip.

It was observed that that Eb and G are often confused with each other when the model is trying to classify the chordal progression. The Naive Bayes model seems to struggle when the second chord of the chordal progression is an Eb, and appears to predict incorrectly that the second chord is an Eb more than the other misclassifications.

• Support Vector Machine

The Support Vector Machine achieves 99% accuracy in 44 seconds, which is considered quite fast, but not as fast as the Naive Bayes. It performs better with the Constant-Q data. It was observed that the majority of the misidentifications appear where the model predicts progression I , where the progression was actually progression VII which is not too significant as the difference in chords are

roughly one note apart. The model also misidentified progression IV as II (which is a more significant error) and III as IV (which is also roughly one note apart).

It was observed that most of the misclassifications of the chords consist of misclassifying the chord as Cs and F instead of Eb.

- **Random Forest Classifier**

The Random Forest Classifier achieves 99% accuracy in less than 20 seconds, which outperforms the Support Vector Machine both in speed and accuracy. It performs better with the Constant-Q data. It was observed that the majority of the misclassifications appear where the model predicted progression I, where the progression was actually progression VII (less severe misclassification) and progression III (more severe misclassification).

It was observed that the most misclassifications arise where the model predicts that the second chord in the progression is Eb, but it is actually Cs. The second most misclassifications arise when predicting F instead of Eb and Bb instead of B.

- **Logistic Regression Classifier**

The Logistic Regression Classifier achieves 93% accuracy in over a minute, which is slower than the other models. It performs better with the Short-time Fourier Transform. It was observed that most of the misclassifications occur where the model confuses progression V and progression III (which is approximately two notes apart), as well as predicting progression IV instead of VI (which is also approximately two notes apart), and predicting progression II instead of IV. It was observed that the model struggles to identify whether a progression is progression IV or not.

Multilayer Perceptron
The Multilayer Perceptron achieves a maximum of 99% accuracy when the dimensions are (10,10) for the hidden layers. It performs better with the ConstantQ data. From the confusion matrix in Figure 14, It was observed that the majority of the misclassifications occur where the model confuses progression III and progression II (which is not severe). The model also had a few misclassifications by predicting progression VII instead of I (which is also not severe).

6. Discussion

- **Performance**

The only model that performs better using the Short-time Fourier Transform is the Logistical Regression Model. The rest of the models perform better using the Constant-Q Transform. The Naive Bayes Model performs the quickest, however it yields the lowest accuracy, reaching less than 50% with the Short-time Fourier Transform. The model that takes the longest time is the Support Vector Machine or the Logistical Regression Classifier depending on whether the Short-time Fourier Transform is used or the Constant-Q Transform. The model that is the most accurate overall is the Multilayer Perceptron with an accuracy of 99.48%.

The performance of all of the models above show that chordal progressions can be picked up in noisy audio using simple machine learning models in real time. This shows potential and with adaptation could be incorporated in music analysis software.

- **Computational Cost**

For feature extraction, the Constant-Q transform is more computationally heavy than the Short-Time Fourier Transform, however, the Constant-Q transform produces more accurate results. This creates a trade-off between speed and accuracy in the model. With regards to the models, the Logistic Regression Classifier and the Support Vector Machines are more computationally heavy than the rest of the models.

- **Contribution**

In contrast to (Parncutt & Reisinger, 2021), which centered its research around human vocals as data, this paper focused on piano chords to train on. In contrast to many Chord Recognition Systems, such as (Lee & Slaney, 2006), the data used in this paper is Wav files instead of MIDI files, which incorporates noise. MIDI files result in better performance of models due to its structured and clean format, however, voice notes of phones and music is generally MP3 format which is noisier than MIDI files, therefore creating a model that performs well on noisier audio has potential applications with MP3 songs and voice notes.

This paper has been able to show insight into which chords are commonly confused, such as G and Eb. This paper has provided 3 successful machine learning algorithms to predict chordal progressions, namely: SVM's, Multilayer Perceptrons and Random Forest Models. Alternatively it has shown that Naive Bayes is not suited for chord progression identification, and Logistical Regression performs decently but not as well as the other three models. Despite the fact that it appears that G and Eb are often misidentified, upon further investigation, this misclassification attested to the fact that there was significantly more data for Eb chords than G chords, and thus much less training to identify G chords, which led the model to assume that the unidentifiable chord was an Eb. Once the bias was removed, there appeared to be no pattern with regards to chords being more likely to be misclassified.

- **Future Recommendations**

Despite the promising results, the models have limitations. The data consists of a single instrument instead of multiple, so it might not generalize with other

data. In addition the audio clips only had one chord played, meaning that if an audio clip had multiple chords, the data would have to be formatted to allow only one chord per audio sample. When training the models, the root chord is incorporated into the data already, however if this were to be used with a song, the root chord would first have to be calculated and the difference between the root chord and every other chord in the song would be calculated.

Further research can be made on using the same techniques on different instrument data, and perhaps combining different instruments into one dataset and measuring how well the model performs.

6. Conclusion

This paper has presented multiple promising machine learning models that successfully recognise the chordal progressions of noisy audio in real time. In addition, it can be concluded that chordal structures have no influence on chordal progression identification.

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Design of an Immersive Virtual Reality Simulation for Training Small Businesses in South Africa: Storyline and Content

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Abstract

Traditional training has little success in developing businesses or including them in digital participation in the face of technological advancements. Immersive virtual reality simulations, however, have shown positive and effective results in other disciplines. Small businesses continue to underperform and lack the capabilities critical to success. In the face of high unemployment, small businesses are considered job creators, accounting for about 63% of jobs in Organisation for Economic Co-operation and Development (OECD) countries, and therefore urgently need training in entrepreneurial skills in a transformational manner. This paper presents the role-play and content of an immersive virtual reality (VR) simulation for small business training in South Africa and evaluates its relevance and effectiveness. The expected outcomes of this immersive virtual reality simulation are a comprehensive understanding and real-time experience of learning and executing core business skills, self-confidence, and readiness to run businesses with the right mindset. The storyline and content design presented in this paper are qualitative and narrative, while the evaluation of these two is quantitative; hence, a mixed methodology was used. The evaluation was conducted through questionnaire feedback from fifty small business owners and secondary data from the literature.

Keywords: Immersive environments, virtual reality, simulation, small business, training, entrepreneurship, AI.

1. Introduction

On average, small businesses in Organisation for Economic Co-operation and Development (OECD) countries contribute 70% of job creation, 60% of business value-added, and create the newest jobs (Abisuga-Oyekunle, et al., 2020; OECD, 2017). Nevertheless, their growth is limited as they lack business management skills (Ayyagari et al., 2011). Despite various government initiatives to develop small businesses, success is limited due to a lack of visual illustrations, training videos, and other interactive and adult-friendly training methods (Mthethwa et al., 2019). However, training small business owners remains critical to equip them with the necessary business skills (ILO, 2017; Nwaeke & Obiekwe, 2017; Visser et al., 2016).

Small and medium-sized enterprises (SMEs) are considered engines and essential drivers of economic growth, employment, and innovation (Ibeh et al., 2019; Magwentshu et al., 2019; Neneh & van Zyl, 2017; Pedron, 2022;). However, 75% of new SMEs fail to succeed genuinely (Neneh & van Zyl, 2014). Moos & Sambo (2018) argue that the failure rate in South Africa is as high as 80%. And at an average of 8.2% per year (McKenzie & Paffhausen, 2019). This is due to low and moderate entrepreneurial orientation (EO) levels and even lower business growth levels. EO refers to processes, practices, and decision-making styles for entrepreneurship and management skills (Coltorti & Venzani, 2017; Mrasi et al., 2018).

Entrepreneurial orientation requires skills and knowledge, to be strategically competitive and innovative (Neneh & van Zyl, 2017; Wang et al., 2020), hence the need for training. Most South African SMEs find marketing, and digital marketing a challenge due to a lack of business skills, knowledge, equipment, and fear of technology which are essential (Amjad, 2022; Kallier, 2017; Radipere & Scheers, 2005; Ramasobana & Fatoki, 2018).

Conventional training has been offered for years, but to date has not produced significant results for entrepreneurs (Amjad et al., 2020; Hu & Hu, 2022). Thus, it is necessary but not sufficient. It requires significant time for attendance and lacks adequate practice and implementation of what is learned to see immediate results (Mthethwa et al., (2019).

This paper proposes an immersive virtual training environment for small businesses to solve the problem of inadequate traditional training. The simulated environment is shown in Section 2.6 and Figure 1.

2. Background and related work

2.1 Introduction

The South African Department of Trade and Industry (DTI) defines small businesses by categorising them based on their turnover and the number of employees, subject to established thresholds. These are categorised according to specific industry codes under the revised BBEEE, Broad-Based Black Economic Empowerment Amendment Act (2013). Therefore, different thresholds for the different sectors are categorised by industry codes. The Small Business and Development Agency (SEDA) simplifies the definition, as shown in Table 1.

SEDA was established in 2004 under the Ministry of Trade and Industry and gradually evolved until it was fully integrated in 2009. In 2014, its mandate and functions were transferred from the DTI to the Department of Small Business Development (DSBD). This paper, thus, defines a small business as one with 21 to 50 employees and an annual turnover of between R3 million and R25 million and includes the below categories of very small and micro businesses.

Table 1: Definition and Classification of Small, Medium, and Micro Enterprises

Enterprise Size	Number of Employees	Annual Turnover
Medium	51 – 200	< R4m - R50m
Small	21 – 50	< R3m - R25m
Very Small	6 – 20	< R200k - R500k
Micro	0 – 5	< R150k

Source: Adapted from Local Government Sector Education and Training Authority (2017:12-13); Small Enterprise Development Agency (2016:79).

2.2 Background, definitions of Immersive, Virtual Reality (VR), and Simulation

Virtual reality (VR) overlaps the real world with a visual plane, best defined by Cant et al. (2019) and its variants. VR uses computer technology to create a 3D world that is interactive and looks real. Virtual simulation is a scenario in which real people use simulated systems to mimic the real world to learn. This allows the user to do what they would do in a real situation and make mistakes without real-

world consequences. The learner can repeat what they have learned until they have perfected or approximated it.

The immersive simulation recreates a real situation with all the feelings and emotions (Cant et al., 2019). Immersive virtual reality simulation is a combination of all the terms. One is fully immersed in this created real situation, including all emotions, and goes through a simulated interactive scenario. This allows one to repeat what they have learned until they fully understand it.

2.3 Previous solutions

2.3.1 Conventional business training

Various institutions, universities, government agencies, and businesses have offered small business training programs, but conventional. However, conventional training has produced very few or insignificant results in terms of increased sales and profits (McKenzie, 2021; Mthethwa, 2019). Artificial intelligence applications are needed outside the classroom to include non-students, such as entrepreneurs in public (Xu & Babaian, 2021).

2.3.2 Immersive virtual reality simulation training

Several programs have been conducted in virtual reality, but few with immersive elements, and to our knowledge, none for small business training. Those with immersive elements are found primarily in the medical, nursing, therapy, and engineering fields (de Souza-Junior et al., 2020; Georgiou et al., 2020; Gillespie et al., 2021; Perron et al., 2021; Qiao et al., 2021).

2.4 Criticism of the previous solutions

Artificial Intelligence (AI) in entrepreneurship has entered businesses as an intelligent analytical tool and inspired new ways of thinking (Hazen et al., 2014), and an opportunity for African entrepreneurs, yet still have a long way to go (Taura et al., 2019). Most small businesses are run by sole proprietors (ILO, 2017; Shirokova et al., 2016), making it difficult to leave the business for days of off-site training. Those who do find time to attend perceive the training as expensive, not hands-on, and disjointed (Cacciotti et al., 2016; Zhang et al., 2014). In addition, comprehension and understanding are minimal or have no long-term benefits (Nabi et al., 2017).

Despite increasing technology like ICT, conventional methods persist (Wu et al., 2018). Access to these types of training is restricted by affordability, and conventional education is criticized for lacking visuals and immersiveness to enable adequate understanding, comprehension, and implementation (Mthethwa et al., 2019).

2.5 Related Work

2.5.1 VR in Nursing and health sciences

This has shown positive results in treating diabetic patients with enhanced ultrasound (Gillespie, et al., 2021; Sygel & Wallinius, 2021), where nursing students have seen an increase in knowledge. Using the VR instrument, nursing students could gain accurate visual understanding and valuable insight (Sapkaroski et al., 2019). They were successful in VR -assisted blood collection and decontamination (De Souza et al., 2020).

Immersive virtual reality simulations are being used in architecture and engineering to improve critical skills in the workplace, classroom, and other settings.

2.5.2 VR in Communications

Virtual Counselling Application using Artificial Intelligence (VCAAI). Case studies have found positive results from immersive virtual reality training in communication. The University of Singapore's artificial intelligence virtual counselling application (VCAAI) was developed for nursing students as part of the core communication course (Shorey et al., 2019). After one year and additional VR training for another two years, positive results were reported with room for improvement on the communication flow and a drawback on lack of emotions summarised in table 2 below:

Table 2: Evaluation results

Positive Feedback	Negative Feedback
A worthwhile experience	Mismatched expectations with frustrations
Enhanced preparedness and confidence	Interrupted communication flow
Enabled effective communication skills practice	Emotionally lacking

Source: (Adapted from Shorey et al., 2019)

2.6 Proposed Solution

Taura et al. (2019) argue that there are performance gains in some African areas and companies that show a positive correlation between technology and performance. They fail not only because of inadequate resources but also because of poor application of technology. Inventions such as the recently launched Python Bot in South Africa, a chatbot designed to teach students a Python programme, are needed to change how to do things (Okonkwo & Ade-Ibijola, 2020). Darwin's theory of evolution proves that the species that respond most quickly to change have been able to survive (Prameswari & Budiyo, 2017). This is also true for traditional education to become effective.

The three pillars of effective learning, drawn from educational technology and learning sciences, are behaviourist, cognitive, and situational perspectives (Ertmer & Newby, 2013; Fatani, 2020; Greeno et al., 1996). This has evolved into construction, cognition, and community of practice (Ertmer & Newby, 2013). Effective learning requires a combination of theory and practice, a departure from traditional origins. Construction or behaviourism involves learning by association, behaviour, and connection. This involves the physical and digital construction of theories and models as neural networks are formed through the learning process. Cognitive learning involves sensing, observing, simulating, and deriving new predictions from experience and conversation (Wang, 2018). Situational or collaborative learning is learning through the diffusion of knowledge among people in shared practices and environments, such as communities, tools, books, etc. Thus, the proposed solution incorporates all these pillars of effective learning.

2.6.1 Storyline

Studies from various disciplines on immersive virtual reality advocate the need for realistic interactions, and visual, simulated, and real-time experiences (Albastaki et al., 2020; Giogiou et al., 2020; Nguyen et al., 2020). The immersive experience of VR has been shown to enhance the overall experience and performance.

A “serious gaming approach” is used. It has proven to be effective in several ways. It involves the "gamification" of complex concepts, making learning palatable (Ade-Ibijola et al., 2022). This approach to learning is interactive and fun. It is envisioned that small businesses will have access to on-demand training through immersive virtual reality simulations. The storyline consists of two role players in the form of avatars. The new business owner and an existing business owner. Each role is shown in the diagram in Figure 1 (below). Each role has a different training program.

Figure 1 below shows the structure of the proposed immersive simulation environment. It shows the two roles and the navigation through the sections. The roles are discussed in 2.6.2.

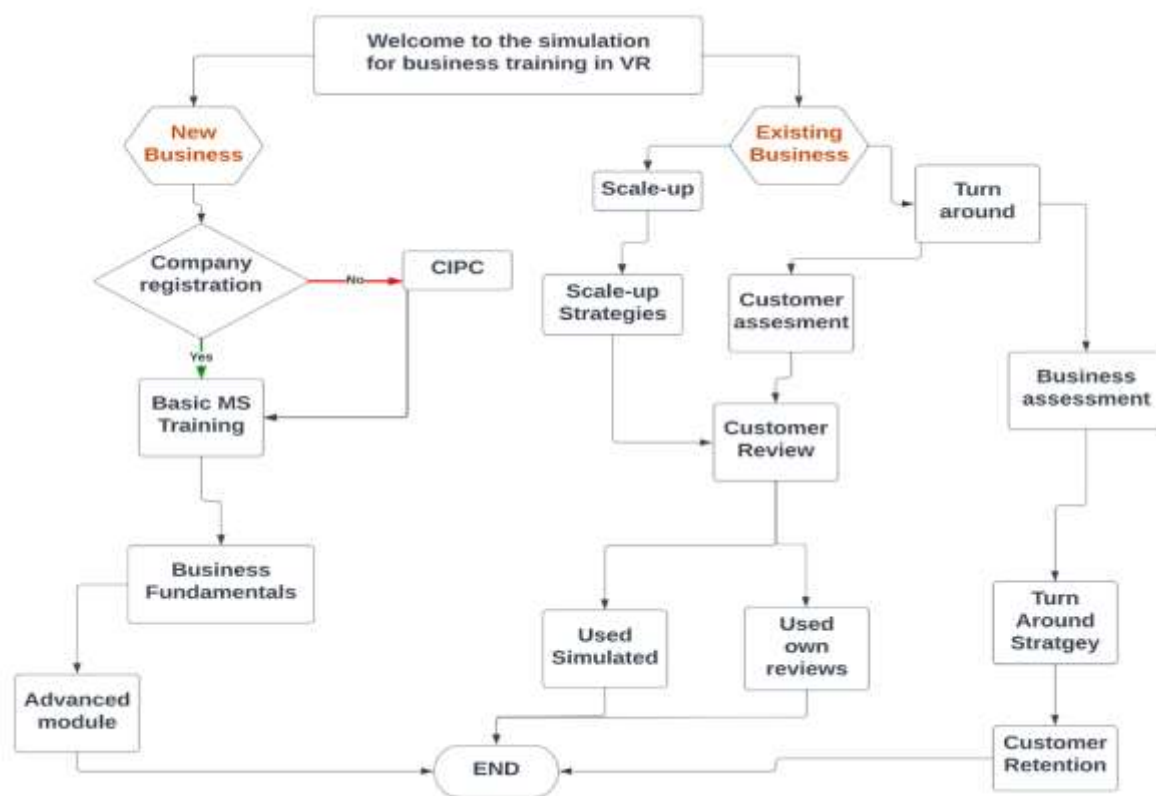


Figure 1: Proposed simulation structure and component. Source: Author's composed.

2.6.2. Storyline and role-playing

The entrepreneur enters the simulated environment (with labelled icons embedded with images and voice prompts) and selects an avatar to represent his or her role (Figure 1). The choices are as follows:

A new business owner, who wants to learn how to run a business and/or is ready to register their business,

An existing business owner, who requires turnaround, growth, or scale-up strategies.

2.6.2.1 Role of new simulation to the business

If the entrepreneur is a new business owner, click on this new business icon. A voice prompt explains and defines a business, its types, structures and departments, and their tasks. When they are ready to register their own business, they are automatically redirected to the country's business registration portal (CIPC). They are directed directly to training if they are not ready to register. This starts with Microsoft packages, i.e., Microsoft (Ms) Word, Excel, PowerPoint, Outlook, and Access.

2.6.2.2 Role of an existing business owner

The participant plays an existing business owner who can choose between two options depending on his goals. The first option is for a participant who wants to turn around a business that is not profitable or has declining sales and needs assistance in solving the problem. The second option is for a participant who has the goal of growing or scaling up their business from their current position.

The participant who chooses the first option will be referred to the turnaround strategies and quizzes to help them identify the factors contributing to the demise of their business. This includes the evaluation from the customer's and the business's point of view. When evaluating customer reviews, the participant has the option of using existing reviews from their company in real time or using simulations of reviews from the virtual environment. Strategies for increasing customer satisfaction, loyalty, and retention are then presented.

Assessing the existing business from a business perspective evaluates the business in terms of its core processes, systems, the value created, configured, and captured, competitive advantage, costs, revenues, and input changes required to transform the business, retain customers, and attract new customers. The second option takes the participant through a journey of various scale-up strategies and growth innovations, including financing strategies and options. The focus is on market opportunities, value propositions, early adoption, and growth financing options.

2.6.3 Content of the immersive VR simulated training

The training content focuses on the core competencies a company needs to create value and sustainably make money. These are derived from a variety of sources, including.

1. Microsoft packages,
2. Keeley's Doblin model of the ten types of innovation,
3. Michael Porter's business models and generic strategy, and
4. Alex Osterwalder's business model and value propositions,

The modules covered in the simulation are the basic Microsoft packages, fundamental, and advanced modules.

2.6.3.1 Basic Microsoft packages

This module includes Microsoft packages, including Word, Excel, PowerPoint, Access, and Outlook. They are part of the company's enabling process and support the work team in the Doblin model and key resources in the Business Model Canvas.

The purpose of the MS packages is to teach participants the basics such as invoicing, creating employee databases, business emails, and proposals. Each packet begins with a practice prompt on

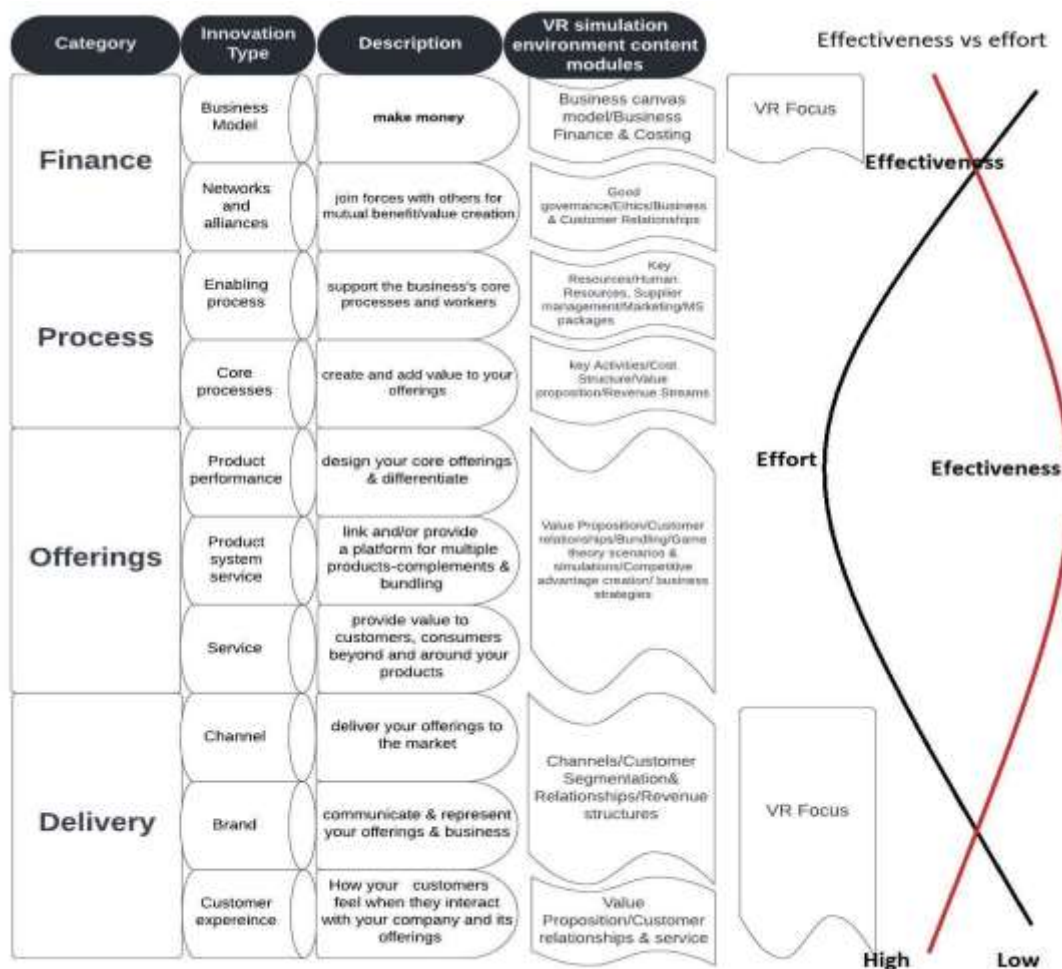
creating a document, spreadsheet, PowerPoint presentation, database, and email, with templates embedded for guidance. This is followed by multiple-choice quizzes and the opportunity to try again if mistakes are made.

2.6.3.2 Fundamental modules

This module covers the business model canvas, value proposition, communication, business writing, good governance and ethics, customer service, human resource management, digital marketing, and supplier management. Each module includes a summary followed by the game theory scenarios and problem-solving.

The Doblin model, as shown in Figure 3, describes the ten types of innovation based on the four business aspects: Finance, Process, Offerings, and Delivery (Keeley et al., 2013; Keely, 2019). The Business Model Canvas simplifies the business model on one page, which the Doblin model suggests, but is formulated differently (Jasieński & Rzeźnik, 2016). These authors have identified similarities between the two models by breaking down the segments of the business model to the Doblin model. The effectiveness and effort charts show that less effort was spent on the business model and delivery, suggesting more effectiveness.

Figure 2: Doblin model – Ten types of Innovation & Simulation content



Source: adapted from Keeley, 2013; Jasieński & Rzeźnik, 2016; Hanshaw & Osterwalder's 2015 business model canvas

Thus, a Business Model Canvas encompasses all types of innovation while focusing on the aspects of the Doblin model that have been neglected. For simplicity, Immersive VR simulation will focus on the business model canvas, which is about making money, and delivery, which focuses on the customer, segmentation, revenue structures, and value proposition.

A value proposition is a component of the Strategy Canvas that helps a company refine, position, or align its products with customer needs. The purpose is to understand how value is created and captured (Hanshaw & Osterwalder, 2015).

2.6.3.3 Advanced business modules

These are most relevant to existing businesses that want to grow and scale. They cover entrepreneurship and innovation, finance and cost accounting, strategic business expansion, supply chain, and fundraising methods. They incorporate Porter's generic competitive strategies (Whittington et al., 2019, pp. 210-232).

3. Methodology

3.1 Research Design

The storyline and content design presented in this paper are qualitative and narrative, while the evaluation of these two is quantitative; hence, a mixed methodology was adopted.

3.2 Sampling

3.2.1 Study population

The study population consists of 100 small business owners. This is the number invited to participate in the questionnaire, of which 50 responded.

3.2.2 Sampling procedures

The sampling procedure was purposive and used a Google form questionnaire for small business owners. They were sent the link to the questionnaire.

3.2.3 Inclusive criteria

Participants were selected using the non-probability method. The criteria were a selection of active and existing small business owners, who have attended some business training, and were willing to participate.

3.2.3 Sample size

Fifty small business owners. This number diligently responded.

3.2.4 Data Collection

Data was collected using Google Forms for easy access, electronic capture of responses and beneficial analytic ability, and accessible graphs. The data collected was current and anticipated perceptions of the value of conventional training and the proposed VR simulation, conventional training experiences

and their comparisons to the proposed VR simulation, and evaluation of the proposed VR design and content.

3.2.5 Design of the Questionnaire and data collected

This was self-designed with a mix of open-ended questions and multiple questions. They were shown the simulation design and story content and asked to provide feedback by answering the following questions:

- Traditional training is done face-to-face. How does this proposed training solution (using VR) compare to traditional training?
- What obstacles do you face by attending traditional Entrepreneurship training?
- Would you prefer virtual immersive training because? (Rank according to preference)
- Have you seen or understood the concept of VR?
- Which words represent how you feel about this type of training?
- Do you think this type of experiential training, will add value to your business?
- How does the scheduled (face-to-face or online training) affect the day-to-day running of your business?
- How do you think interaction with such an environment will help you in your business?
- How practical do you think the proposed solution is for small business and Entrepreneurship Training?

In the next section, we present the results and discussions resulting from the responses of participants to these questions.

4. Results and discussion

The results of the storyline and role-play evaluation show that 84% of the entrepreneurs consider the proposed solution valuable for their business and believe it will boost their confidence in real-life situations. 16% were unsure, but none of the participants answered that it does not add value, and ten could not say how the interaction will help them, see figures 3 and 4, respectively. This high percentage shows that they see potential in the design and content and are looking for a change in how they learn.

Do you think this type of experiential training, will add value to your business?
50 responses

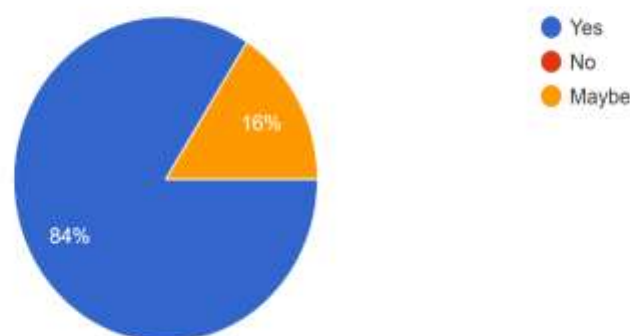


Figure 3: VR training will add value to entrepreneurs (Yes/No)

How do you think interaction with such an environment will help you in your business?

50 responses

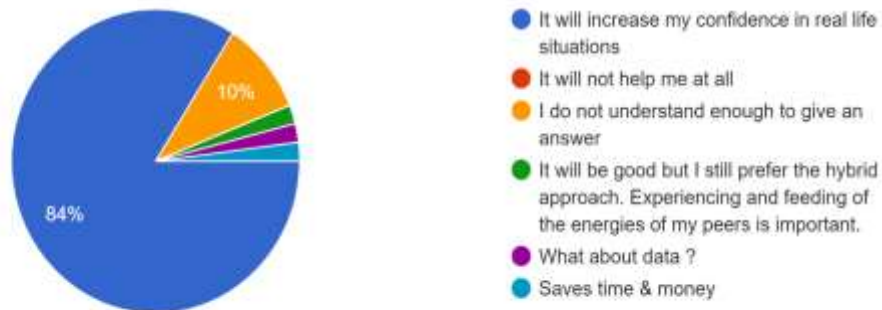


Figure 4: Ways VR environment will help entrepreneurs

Traditional training is done through face to face. How does this proposed training solution (using VR) compare to traditional training?

50 responses



Figure 5: Benefits of VR training simulation compared to traditional training

Figure 5 shows that 76% find the proposed solution more interesting than the traditional training, while 12% could not find any difference. Even more interesting, 58% and 52% used the word "exciting" and "curious" to express how they feel about the training VR, and 22% found it futuristic, while 2% were afraid and worried that it might not work. This explains the 84% of preference rate in figures 3 and 4 above, as they find the design and content exciting and the ability to add value.



Figure 6: Words representing how participants feel about the proposed solution

Figure 6 captures their emotions and thoughts about the immersive VR simulation, the highest being excitement, and curiosity at 58% and 52% respectively. This indicates that while excited about the new solution which looks and sounds better than the current type of learning, they are curious about how it will actually work in reality. Those concerned and scared are very low, 2%.



Figure 7: The effects of face-to-face & online training schedules on businesses

In figure 7, they gave reasons why conventional training is unsuitable. The most important reason is the time they have to take away from their business (64%), followed by the impact on their cash flow (38%), while only 26% answered that it has no impact. These results are confirmed by Figure 8.

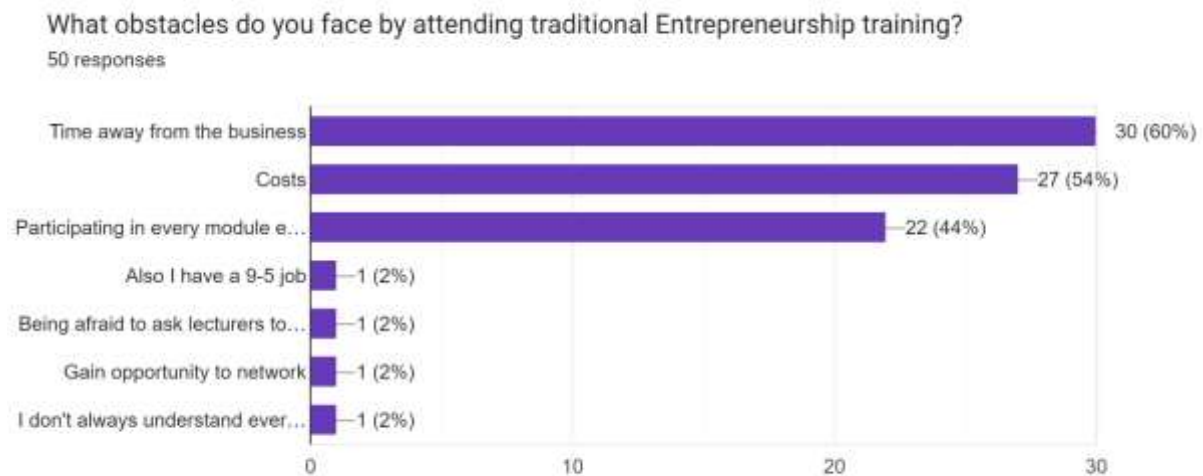


Figure 8: Disadvantages of traditional training

Figure 8 shows that the obstacles entrepreneurs face with conventional training are time, cost, and attending sections that are not relevant to them but that they must complete because they are mandatory to complete the training, with 60%, 54%, and 44% respectively, 2% citing other reasons.

How practical do you think the proposed solution is for small business and Entrepreneurship Training?

50 responses

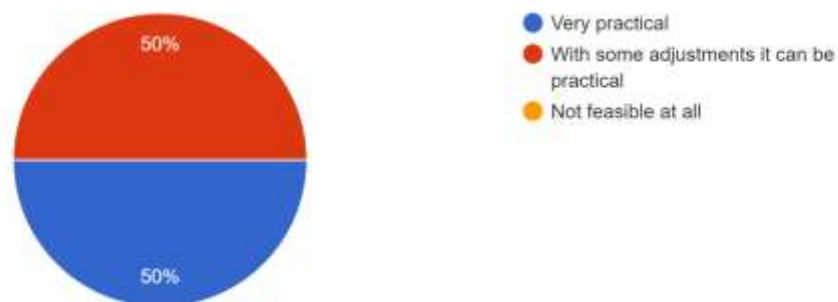


Figure 9: Perception percentage of VR training practicality

In contrast, only 50% of respondents thought it was practical, while the other half thought it could be with some adjustments (Figure 9). None thought it was not feasible, indicating that it is relevant and practical or almost practical. With some adjustments, the majority would find it practical.

Would you prefer virtual immersive training because? (Rank according to preference)

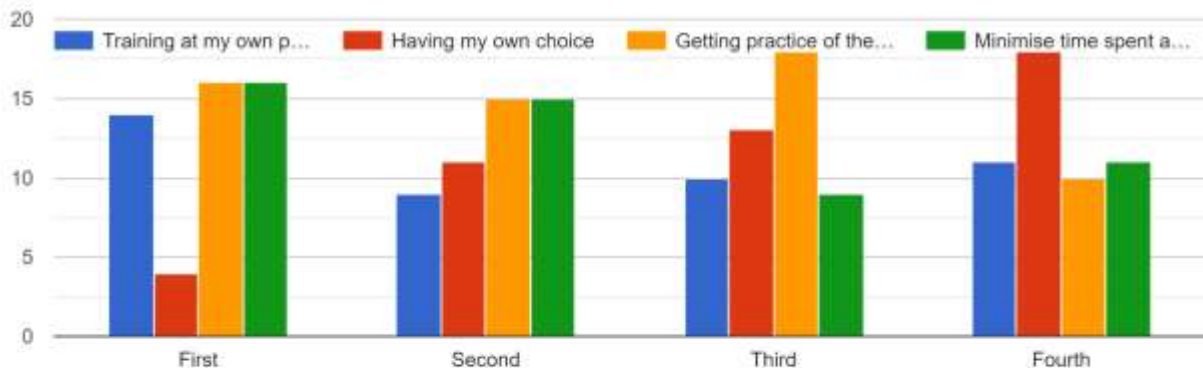


Figure 10: Reasons entrepreneurs prefer the proposed VR training method

Figure 10 shows how they rank the benefits of VR. The top two are that they can make their own decisions and learn with practical, real-world solutions, followed by minimizing time and training at their own pace.

2. Conclusion and future work

The storyline and content of the Virtual Reality training simulation proposed are qualitative and narrative. The evaluation is quantitative, using a questionnaire. The storyline and content were presented to fifty small business owners. They were asked to answer a questionnaire through Google forms to evaluate its relevance and effectiveness. Thus, using a mixed methodology.

There was excitement, perceived acceptance, and value seen in the benefits of the proposed immersive VR training solution. Due to these results, the proposed immersive virtual reality simulation is relevant, practical and can be improved to become even more practical.

In future work, we will proceed to build an immersive virtual reality simulation environment.

Acknowledgments

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Word Sense Disambiguation Pipeline Framework for Low Resourced Morphologically Rich Languages

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Abstract

Resolving ambiguity problem is a prolonged natural language processing theoretical research challenge. Sesotho sa Leboa language is an official name for Sepedi or Northern Sotho language as known to be an official language among 11 others in South Africa spoken by 4.7 million people. Sesotho sa Leboa is an indigenous rich morphologically low resourced South African language which is a highly polysemous language, with words that have numerous context. Disambiguating polysemous words remain a challenging problem for computational linguistics research. Deficiencies of several polysemy assessments suggest that dealing with the sense distinctiveness versus polysemy problems remains an uncluttered academic issue. A practical problem in natural language processing applications is Word Sense Disambiguation which suffers drastically from shortcomings when working with ambiguous polysemous words. Therefore, Word Sense Disambiguation seeks both academic and practical results. Many Word Sense Disambiguation applications gives high accuracy for the English language, and poor accuracy for Sesotho sa Leboa language. In this research, Word Sense Disambiguation pipeline framework is developed for Sesotho sa Leboa low resourced morphologically rich language which addresses academic and practical problems of the polysemy problem. The proposed Word Sense Disambiguation pipeline framework shows pre-processing modules which is a process to reduce ambiguity from the unstructured text corpus that serve to input sentences. Hence, the researchers compute the probability of Word Sense Disambiguation when polysemy and homonymy is observed for cosine similarity measures using sentence transformer (SBERT) and Word2Vec algorithms (Skip-Gram and Continuous Bag of Words). Computation of cosine similarity measure shows SBERT outperforms other algorithms with 87% threshold which shows strong similarity between context and sense definition while Continuous Bag of Words gives cosine similarity threshold of 51%, outperforming Skip-Gram algorithms which has a threshold below 50% with two vectors approaching a perpendicular angle of 90-degrees orthogonally indicating that orientation of vectors do not match.

Keywords: Corpus, Continuous Bag of Words, Natural Language Processing, SBERT, Skip-Gram, Word Sense Disambiguation

1. Introduction

Word Sense Disambiguation (WSD) is a commission of categorising correct sense of the word used in a sentence, if the word has numerous senses (Bašić & Snajder, 2018). Furthermore, WSD addresses both polysemy and homonymy words. It is also referred to as a method to find precise word similarity of an ambiguous word in a specific context and WSD methodologies are categorized into three main classes – Knowledge base, Supervised and Unsupervised approaches (Ranjan Pal & Saha, 2015).

Word sense ambiguity problem are caused by word with numerous senses referred to as polysemous words. Polysemous words are difficult to investigate in searching for the correct lexical category and

the correct sense of the word. Kulkarni et al., (2012) argues that researchers in natural language processing (NLP) has recommended a pipeline technique to solve ambiguity problems. NLP pipelines can be processed separately, however, the researchers Jaafar & Bouzoubaa, (2016) in Arabic NLP recommends that one can call two or more pipeline tools in a sequential way, i.e. output of one pipeline can be an input into another pipeline tool. NLP pipeline components must be chosen based on a use-case sentence composition, which suggest that pipelines should be constructed with different strategies such as syntactic and semantic text analysis (Kulkarni et al., 2012).

WSD is identified to be a significant module in NLP pipeline which increase threshold of the obtained information (Torii et al., 2015). Agirre & Edmonds (2008) expresses WSD in NLP as the challenge of verifying which senses of the word is triggered by utilization of the word in a context, a practice active intuitively in human beings (Agirre & Edmonds, 2008). Nevertheless, devices process unstructured dataset and transform them into labelled data which must be evaluated in order to determine the correct senses (Popov, 2018). System that plans to manage natural languages as human beings do, should have context about words and their senses because senseful dataset are comprised of senseful words (Miller, 1995).

Sesotho sa Leboa language has 30 distinguishable dialects with conjunctive writing different to Nguni language, a linguistic word can have three orthographic units while Nguni linguistic word has bound and free morphemes which can be written as one linguistic word (FaaB, 2010).

Sesotho sa Leboa language is polysemous giving words that have various senses. Polysemy in Sesotho sa Leboa is of several types, including Part-of-Speech (POS), specialization, metaphoric, etc., each presenting challenges in WSD provisioning. Polysemy continues as a computing issue in public domain and linguistics research (Mmaseroka, 2006). As deficiencies of most polysemy assessments indicate that working with distinct senses and polysemy problem still is an open academic problem; and so, polysemy remains an open theoretical issue (Popov, 2018).

This paper outline proceeds first with introduction of WSD in relation to Sesotho sa Leboa polysemous words and orthographic writing. The second phase discuss literature review related to solutions that exists on WSD, how they have been applied and the existing approaches. Discussion on the research methodology follows with description of the experiment performed and presentation of the research result. Lastly the discussion and conclusions.

2. Related Literature Review

Word Sense Disambiguation (WSD) solutions has been provided through research for the English language, academic research has not much been done in Sesotho sa Leboa language, and many other African languages regarding word sense disambiguation. WSD solution is a key to designing Human language Technologies (HLTs) and Natural Language Processing systems. Sesotho sa Leboa language is considered a morphologically low resourced language, which is not well represented through digital language divide. It is imperative to leverage the language out through WSD solutions.

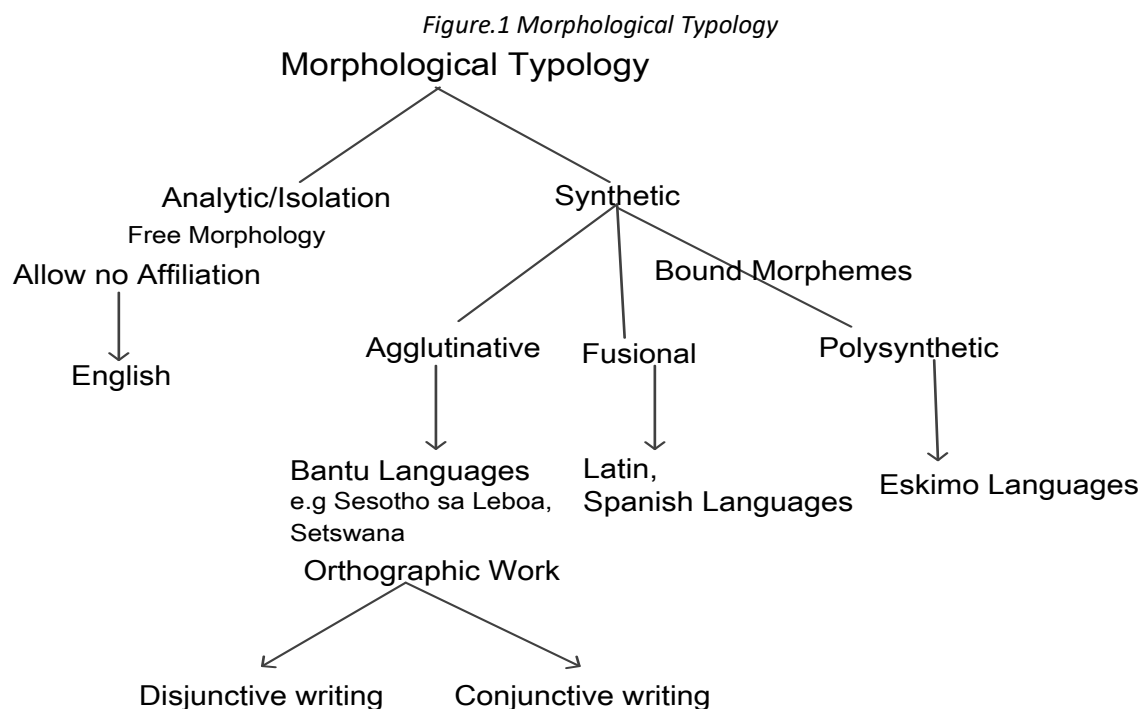
A number of WSD research focused on English language, and only few academic publications on WSD for Sesotho sa Leboa. A number of NLP pipeline tools like word segmentation, Part-of Speech tagging, Lemmatization, Multiword Detection and Named Entity Recognition has now been designed for Sesotho sa Leboa language, Nevertheless, the language lacks WSD pipeline to solve ambiguity. The NLP system is assessed in several levels namely: Morphological level, lexical level, syntactic level, semantic level, discourse level, and pragmatic level. The research considers WSD issues at the

semantic level which focus on how the context of the words within a corpus help to define the sense of words (Açikgöz et al., 2017)

South African languages are mostly considered morphologically low resourced with agglutinative data that can be used to design natural language processing (NLP) systems; the existing government has for the last 20 years gave assisted human language technologies (HLT) to develop NLP pipelines, which produced valuable language resources and applications. Language Resource Management Agency of the South African Centre for Digital Language Resources (SADiLaR) is tasked with language development in South Africa (Puttkammer et al., 2018).

Research by (Puttkammer et al., 2018) from the North-West University (NWU) designed NLP web services for ten South African languages which can be accessed through application programming interface (API) with a good web application. The technologies were designed and funded by National Centre for Human Language Technology (NCHLT) projects of South Africa in the Department of Arts and Culture.

Linguistic typology categorize language based on similarities in structure such as phonology, grammatical construction and word order, morphological process include affixation, to mention the few for creating words and word forms. Morphology is classified as a field of linguistic that study word structure and formation (Flanagan, 2013). Fig. 1, shows morphological typology (Giunchiglia, et al. 2018), which also classify English as an Analytic or Isolating theme with free morphemes which appear as independent words (Flanagan, 2013) . Further, Bantu language is classified as Agglutinative with bound morphemes which do not constitute independent words, but are attached to other morphemes or words. Bound morpheme are called affixes classified into – inflectional, derivational, prefixes, suffixes, infixes (Pirkola, 2001).



Sesotho sa Leboa, is a Bantu language in the Sotho group. The language is characterized by disjunctive orthography, mainly verb prefixal morphemes category. Suffixal morpheme follow conjunctive writing style, hence the language is considered to be semi-conjunctive. Furthermore, Bantu language is considered to be agglutinative and exhibit substantial inherent structural resemblance, though differ substantially in terms of orthography, due to both phonology and history (Pretorius & Pretorius, 2009; Flanagan, 2013).

The verb in Sesotho sa Leboa consists of infinitive prefix + a root + verb-final suffix. Example:

- Go bona (To see) – infinite prefix- go + root –bon, + and verb-final suffix –a
- Ba di bona (They see it) -
- Lesogana la sega (The young man then laughed) –
- Mošemane yo a kitimago (The boy who is running) – Infinitive prefix -Mo + root –šemane + root –Kitim + final suffix – a -go

Root is defined to be a lexical morpheme which is that part of a word that do not include grammatical morpheme and cannot occur independently as a word (Pretorius & Pretorius, 2009). In English structural words include prepositions, articles and pronouns generally assist verbs and nouns, whereas, in Sesotho sa Leboa many disjunctively written bound morphemes are function words and contribute to grammatical correctness of sentences (Rahab & Mothapo, 2019). The researchers cannot easily adopt a WSD tool for English to Sesotho sa Leboa as the language present new challenges compared to other Indo-European languages when defining the feature set.

WSD is a classification problem, where an ambiguous word is classified to its senses (Zopon et al., 2015). Target-word and All-word are approaches for WSD that disambiguate words using supervised approaches and unsupervised approaches (Zopon et al., 2015). The research aims to solve All-word WSD utilizing unsupervised classification methods.

The research consider polysemous words in which a lexical semantic contain more senses of the same word. For example, the word “Noka” in Sesotho sa Leboa has many senses. It can mean a hip or river or seasoning as applied below:

Mosadi o noka seshebo ka letswai (A woman is seasoning the food with salt)

Noka ya mma e bohloko (My mother’s hip is painful)

Noka e tletse ka meetsi (The river is full of water)

Kulkarni et al. (2012) argues that researchers in NLP has adopted a pipeline approach to solve ambiguity problems. NLP pipelines can be processed separately, however, the researchers(Jaafar & Bouzoubaa, 2016) in Arabic NLP recommends that one can call two or more pipeline tools in a sequential way, i.e. output of one pipeline can be an input into another pipeline tool. NLP pipeline components must be chosen based on a use-case sentence composition, which suggest that pipelines should be constructed with different strategies such as syntactic and semantic text analysis (Kulkarni et al., 2012). NLP text-based application comprises of a pipeline of pre-processing steps such as tokenization, stemming, part-of-speech tagging, named entity recognition, chunking, parsing, the morphological analyser, phrasal marker, word sense disambiguator (WSD), scanner and sentence boundary identification, just to mention the few (Bangalore, 2006).

Supervised learning approaches process structured information in the arrangement of annotated training corpus (Pal & Saha, 2015). This technique use machine-learning algorithms from sense-annotated data created manually or semantically annotated corpora to introduce induction principle for classification models to determining the appropriate sense for each specific context (Pal & Saha, 2015; Navigli & Velardi, 2005).

Assume $W = \{w_1, w_2, \dots, w_n\}$ as a data point with n features a set of All-word, the research aims to compute possible sense S_k to solve W among a set of $\{s_1, s_2, \dots, s_k\}$ senses. Eq. 1 defines Bayes theorem as:

$$P(S_k|W) = \frac{P(W|S_k)P(S_k)}{P(W)} \text{ for } k=1, 2, \dots, K \quad (1)$$

Where $P(S_k|W)$ is posterior probability and $P(S_k)$ is prior probability of class, and $P(W)$ prior probability of predictor. Applying Bayesian classifier to compute the correct senses is given by Eq. 2:

$$P(S_k) \prod_{i=1}^n P(w_i|S_k) \text{ for } k = (1, 2, \dots, K) \quad (2)$$

Where $P(w_i|S_k)$ is the feature (F_j) in the context given by $P(F_1, \dots, F_j)$ assigning W to the sense $\hat{S}$ for the largest value. Expressed mathematically in Eq. 3:

$$\hat{S} = \underset{k \in (1, 2, \dots, K)}{\operatorname{argmax}} P(S_k) \prod_{i=1}^n P(F_j|S_k) \quad (3)$$

There exist many approaches to solve WSD challenges for free morphology languages. Even though all approaches are excellent to solve the WSD problem, research study needs to prove that Eq. 3 can solve WSD problem for morphologically low resourced languages.

Skip-Gram model predict the context C_t around a given ambiguous word w_t (Sutor et al., 2019) expressed as:

$$C_t = w_{t-n}, \dots, w_{t-1}, w_{t+1}, \dots, w_{t+n}$$

Skip-Gram maximizes the total log probabilities across all T words expressed mathematically as:

$$\sum_{t=1}^T \log (P(C_t|w_t))$$

Which is further condensed as:

$$\log P(C_t|w_t) = \sum_{j=-n}^n \log (P(w_{t+j}|w_t)) \quad (4)$$

The mathematical formula in Eq. 4 reflects a soft-max procedure and it's asymptotically relational to the number of words.

The NB algorithm is a probabilistic model that makes use of Bayes rule and adopts conditional independence of features given the class label, it has been used considerable with success for WSD task (Bakx, 2006; Aliwy & Taher, 2019). NB approach categorizes text documents using two constraints named conditional probability of each sense (S_i) of a word (w) and the features (f_j) in the context (Bangalore, 2006; Shallu & Gupta, 2013). The appropriate sense in the context is represented by the maximum value assessed through the expressed formula (Pal & Saha, 2015).

$$\begin{aligned}\hat{S} &= \underset{S_i \in Senses_D(w)}{argmax} P(S_i | f_1, \dots, f_m) \\ \hat{S} &= \underset{S_i \in Senses_D(w)}{argmax} \frac{P(f_1, \dots, f_m | S_i) P(S_i)}{P(f_1, \dots, f_m)} \\ \hat{S} &= \underset{S_i \in Senses_D(w)}{argmax} P(S_i) \prod_{j=1}^m P(f_j | S_i)\end{aligned}\quad (5)$$

In the expressed Eq. 5, features are signified by m and probability $P(S_i)$ is computed from the frequency metrics in training set. The $P(f_j | S_i)$ is computed from the feature metrics.

CBOW model makes use of neighbouring words to predict probability of current words (Chen et al., 2022). CBOW is termed the reverse version of skip-gram model (Song, 2016). The CBOW likelihood function in Eq. 7 gives probability of most words which appears within a context and the vectors of the context are articulated as the total of the words in the context by the Eq. 6 and Eq. 7 (Nakamura & Kimura, 2019):

$$v(c_t) \sum_{u \in c_t} v(u) \quad (6)$$

$$p(c_t | w_t) = \frac{\exp(v(c_t) \times v(w_t))}{\sum_{w' \in V} \exp(v(c_t) \times v(w'))}, \quad (7)$$

where V is a set of matching words in the dataset. If Eq. 7 is maximized as a likelihood function, then $v(c_t)$ and $v(w_t)$ are similar.

Sentence-Transformers such as Sentence Bidirectional Encoder Representations Transformers (SBERT) which is a modification of the BERT network that gives an opportunity to compute cosine similarity between sentence embeddings and allow chromosome mapping of sentences into high-dimensional dense vector representations such that sentences with comparable semantic significance are closely matched (Patel et al., 2021). Sentence-transformer framework in python verifies similarity between original sentence and the context (Wahyutama & Hwang, 2022). Word2Vec, FastText, and Global Vectors for Word Representation (GloVe) which are traditional static word embedding approaches do not generate word embedding vectors that indicate the connotation of context (Seo et al., 2022). Sentence-Transformers computes sentence embeddings which are associated through cosine similarity technique to uncover sentences with similar meanings (Ramnarain-Seetohul et al., 2022).

3 Research Methodology

In this research an experiment is conducted using Word2Vec and SBERT to change words into vector shapes in order to discover value of vector nearness between words (Manalu et al., 2019). The experiment is conducted using existing library Gensim as an open-source tool to implement Word2Vec model with python programming language. The research experiment on SBERT, CBOW and Skip-gram architectures to compute vector representations of words. Inputs for similarity measure is a pair of words from the dataset (Manalu et al., 2019).

The corpus is obtained from South African Digital Language Resources (SADiLAR) as unstructured data stored as a text file, which is further filtered and cleaned. The researcher embarked on a process to pre-process the dataset. The researcher build the following pipelines for the pre-processing steps:

Special characters such as punctuation marks (points, commas, question marks, exclamation marks, numeric numbers) and other characters such as (\$, %, *, &, etc.) are removed before we start with tokenization (Imaduddin et al., 2019). Each word is tokenized to use it as a proper input, as researcher could not feed a word as a text string into a model. The tokenized dataset is used as a training dataset. Tokenization is a process to split input data strings into words or tokens (Sumedh Kadam; Aayush Gala; Pritesh Gehlot; Aditya Kurup; Kranti Ghag, 2018).

4 Model Evaluation

The research focus on intrinsic evaluation to assess implementation of word embeddings models. The tactic emphasis on assessing semantic and syntactic relationship among words that are being measured (Phua et al., 2020). Intrinsic evaluation focus on semantic and syntactic relations between words with aggregate computation based on correlation coefficient to serve an absolute standard measure (Phua et al., 2020).

The cosine similarity metric adopted in this research determines similarity between data objects from a dataset treated as a vector. Similarity measure is a function to compute the degree of similarity among data objects converted into vectors (Reshma et al., 2020). The mathematical formula below measures the similarity of vectors by the angle amongst two vectors (Tian & Lv, 2018):

$$\cos(\theta) = \frac{\sum_1^n (A_i \times B_i)}{\sqrt{\sum_1^n A_i^2} \times \sqrt{\sum_1^n B_i^2}} \quad (8)$$

Sentence Transformers, Eq. 5 for skip-gram and Eq. 7 for CBOW models helps the researcher to express the word in the equivalent vector form, thereafter Eq. 8 is used to compute the cosine similarity to sort output words that are contained by a particular threshold semantically similar to keyword.

5 Research Results

5.1 WSD Pipeline Framework

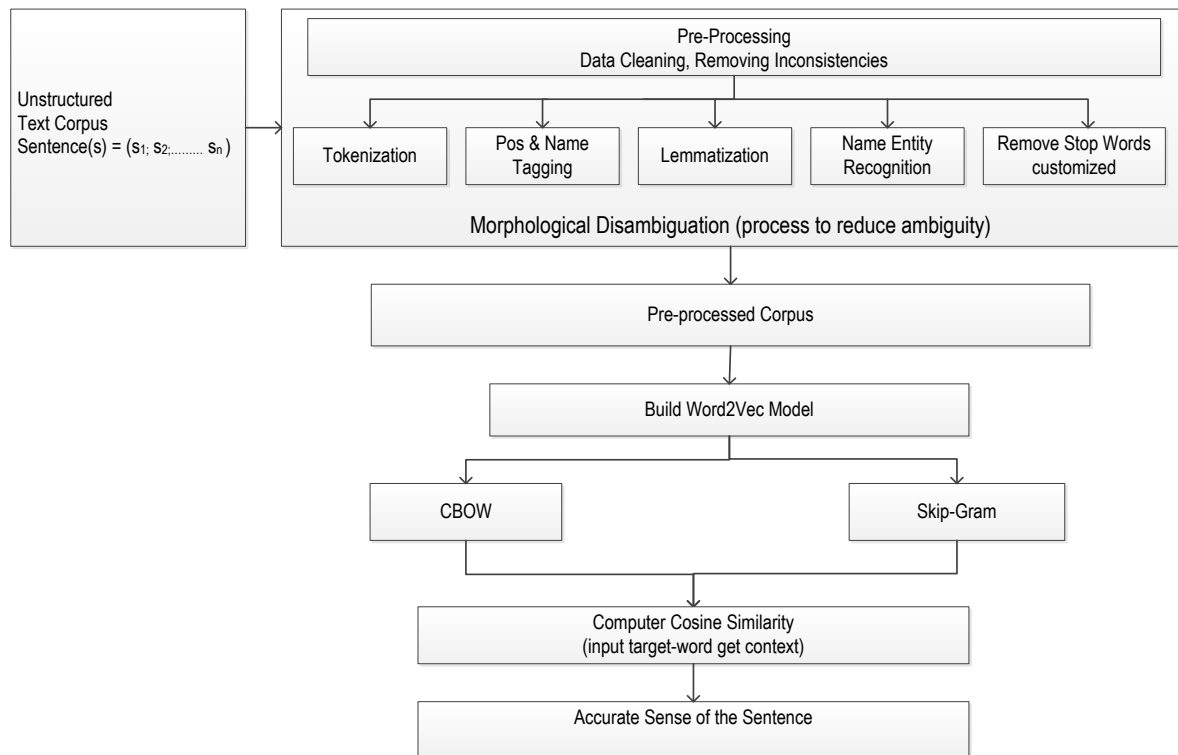


Figure 2. WSD Pipeline Framework

The proposed WSD pipeline framework consists of pre-processing pipeline as shown in Fig. 2, for cleaning the text which includes removing punctuation words, numerals, removing customized stop words, and tokenization which splits text into words (Gopal & Haroon, 2016)(Suleiman et al., 2019). The input is a plain unstructured text, which is pre-processed using the sub-modules for the NLP pipeline. The steps are significant to pre-process the original unstructured dataset as input to the pipeline. The Pre-processing pipeline transform unstructured text into labeled dataset by pre-processing of the input using tokenization, part-of-speech (POS) tagging, stop words removals, lemmatization, multiword detection and named entity recognition recognition (NER) steps (Manalu et al., 2019). The pre-processing help to minimizew ambiguity of words by extracting information from their morphology and context.

The pre-processing pipeline produce a pre-processed corpus, which is then used to build a training Word2Vec model. Continuous bag of words (CBOW) in experiment II (4.3) and skip-gram in experiment I (4.2) are two types of Word2Vec models that train words into word vector space model (Chen et al., 2022). Word2Vec model makes it feasible to compute semantic similarity as it utilizes neural network to learn word associations from the dataset. Word2Vec find the distribution of the expression for a target word by stipulating the context and further makes use of cosine similarity to calculate the similarity actions of the vectors (Reshma et al., 2020). Words with equivalent meanings have a tendency to have the identical word embedding (Manalu et al., 2019).

5.2 Experimental Results CBOW and Skip-Gram Model

Table 1: Words Distribution

# Sesotho sa Leboa Sentences	100964
# Sesotho sa Leboa words	2386351
Old Length	12196163
New Length After Removing stop words	9215488
Vocabulary Size	65272
Vector Size	100
Alpha	0.025

Tab. 2 and Tab. 3 show outputs from an experiment with CBOW and Skip-Gram Word2Vec model which is a popular word-embedding approach that effectively capture semantic and syntactic word similarities from the dataset.

Table 2: Word2Vec – CBOW Model Most Similar word

	Cosine Similarity	Angle
scorpion	0.6190912127494812	51.75
kings	0.6004844903945923	53.13
tsopotāje	0.5199252367019653	58.73
lehono	0.5128013491630554	59.2
bahlakudi	0.5065954327583313	59.60
dipolitikitāja	0.496658593416214	60.26
maphodiksa	0.4800688326358795	61.31
bosenyi	0.46610745787620544	62.54
mpahlwa	0.4615779519081116	62.54
turwa	0.45731163024902344	62.80

Table 3: Word2Vec Skip-gram Model

	Cosine Similarity	Angle
thetosello	0.2354934811592102	76.40
nkwane	0.23058441281318665	76.70
nokeng	0.23009748756885529	76.70
sebjaneng	0.22779503464698792	76.87
makgarebe	0.21069371700286865	77.87
masogana	0.20032326877117157	78.46
mahlong	0.1825927495956421	79.51
mabedi	0.17644529044628143	79.86
masea	0.1606215089559555	80.79
maoto	0.16003385186195374	80.79

5.3 Experimental Results Sentence Transformation model using SBERT

Table 4: Corpus with example sentence

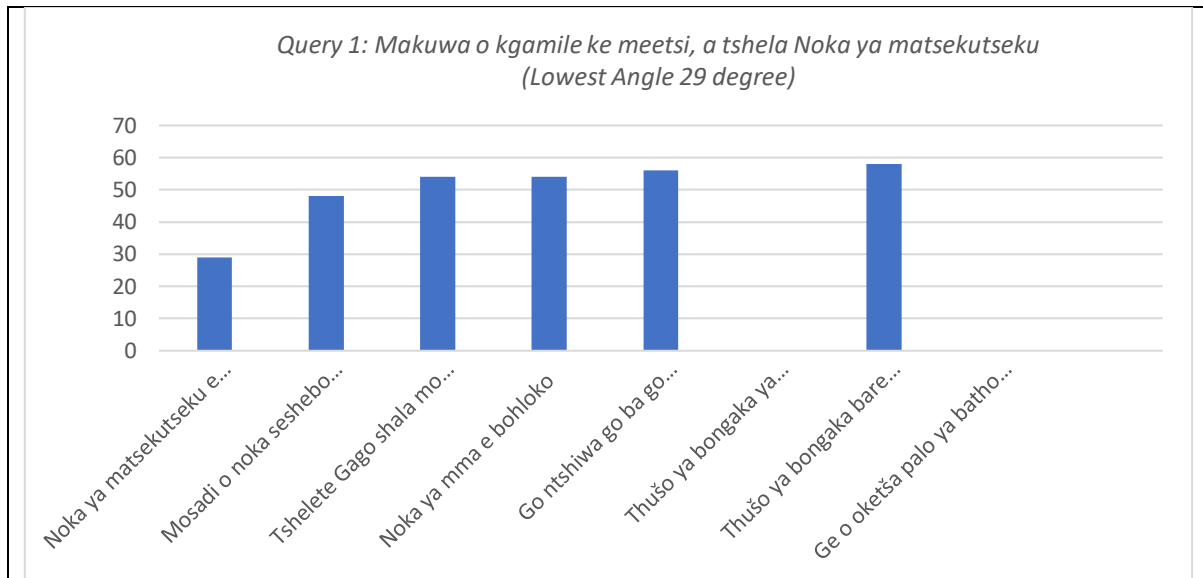
Thušo ya bongaka bare chelete yaka efedile gobona ngaka yabasadi
Ngaka ya meno ga epatele meno agodulela ruri kaganong kera goyepa marenini?
Go ntshiwa go ba go phumulwa ga bana mo go thuso ya bongaka ge ba fitile mengwaga ye masome pedi tee.
Ge o oketša palo ya batho go thuso ya bongaka gwa tura, tshetele ya namelela
Tshetele Gago shala mo karateng ya Ngaka, gae fiwe Rena ge e shetje
Mosadi o noka seshebo ka letswai
Noka ya mma e bohloko
Noka e tletse ka meetsi

Table 5: Query Sentences

Makuwa o kgamile ke meetsi, a tshela Noka ya matsekutseku
Thušo ya bongaka e gana ke ntsha meno
Thušo ya bongaka e ya tura

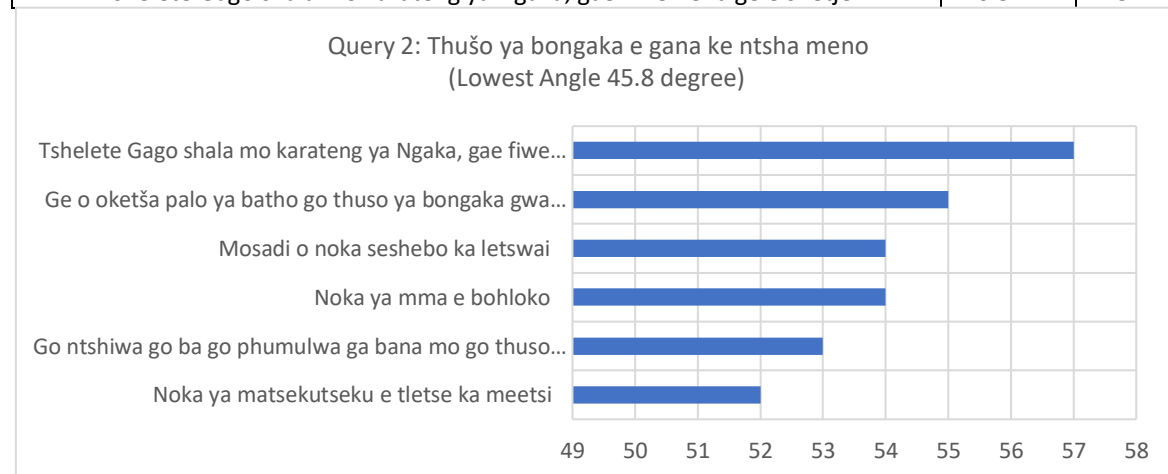
Table 6: Sentence Transformation with Cosine Similarity

tensor([[0.0166, 0.0903, -0.0653, ..., 0.0532, 0.0384, -0.0319], [-0.0340, 0.1257, -0.0600, ..., -0.0005, 0.0213, -0.0111], [-0.0244, 0.1753, -0.0683, ..., 0.0142, -0.0143, -0.0199], ..., [-0.0426, 0.0721, 0.0075, ..., 0.0341, 0.0358, -0.0382], [-0.0022, 0.0822, 0.0329, ..., 0.1045, -0.0037, -0.0240], [-0.0045, 0.1136, 0.0160, ..., -0.0249, -0.0235, -0.0544]])		
Query 1: Makuwa o kgamile ke meetsi, a tshela Noka ya matsekutseku		
Sentence	Cosine Similarity	Angle
Noka ya matsekutseku e tletse ka meetsi	0.872	29
Mosadi o noka seshebo ka letswai	0.662	48
Tshetele Gago shala mo karateng ya Ngaka, gae fiwe Rena ge e shetje	0.584	54
Noka ya mma e bohloko	0.579	54
Go ntshiwa go ba go phumulwa ga bana mo go thuso ya bongaka ge ba fitile mengwaga ye masome pedi tee	0.566	56
Thušo ya bongaka ya meno ga epatele meno agodulela ruri kaganong kera goyepa marenini?	0.56	55.9
Thušo ya bongaka bare chelete yaka efedile gobona ngaka yabasadi	0.526	58
Ge o oketša palo ya batho go thuso ya bongaka gwa tura, tshetele ya namelela	0.503	59.8



Query 2: Thušo ya bongaka e gana ke ntsha meno

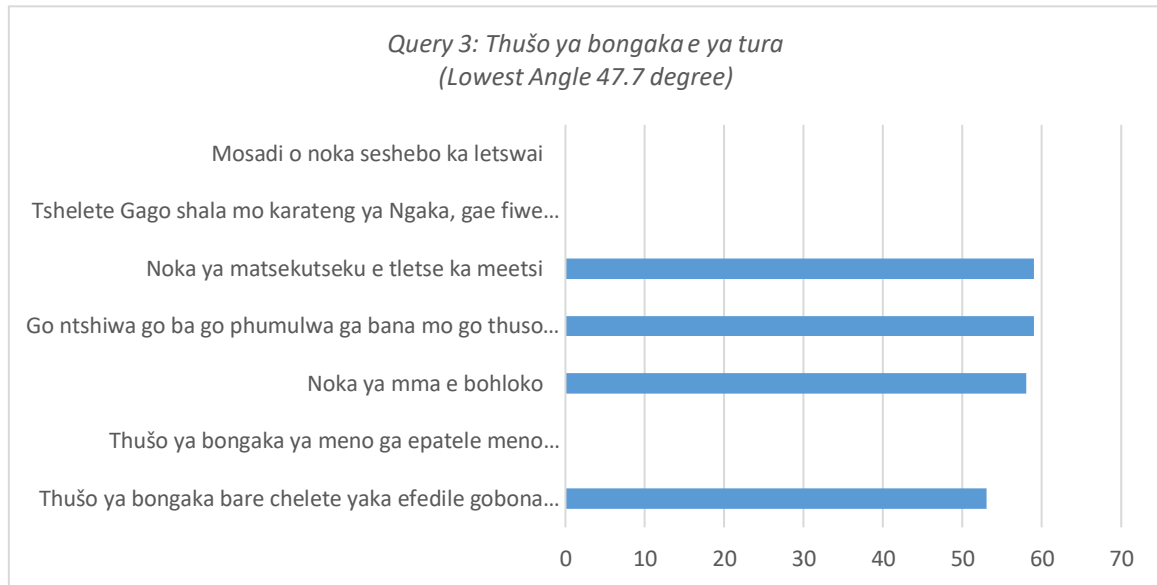
Sentence	Cosine Similarity	Angle
Thušo ya bongaka ya meno ga epatele meno agodulela ruri kaganong kera goyepa marenini?	0.697	45.8
Thušo ya bongaka bare chelete yaka efedile gobona ngaka yabasadi	0.622	51.5
Noka ya matsekutseku e tletse ka meetsi	0.619	52
Go ntshiwa go ba go phumulwa ga bana mo go thuso ya bongaka ge ba fitile mengwaga ye masome pedi tee.	0.608	53
Noka ya mma e bohloko	0.586	54
Mosadi o noka seshebo ka letswai	0.583	54
Ge o oketša palo ya batho go thuso ya bongaka gwa tura, tshelete ya namelela	0.575	55
Tshelete Gago shala mo karateng ya Ngaka, gae fiwe Rena ge e shetje	0.544	57



Query 3: Thušo ya bongaka e ya tura

Sentence	Cosine Similarity	Angle
Ge o oketša palo ya batho go thuso ya bongaka gwa tura, tshelete ya namelela	0.673	47.7

Thušo ya bongaka bare chelete yaka efedile gobona ngaka yabasadi	0.598	53
Thušo ya bongaka ya meno ga epatele meno agodulela ruri kaganong kera goyepa marenini?	0.579	54.6
Noka ya mma e bohloko	0.524	58
Go ntshiwa go ba go phumulwa ga bana mo go thuso ya bongaka ge ba fitile mengwaga ye masome pedi tee.	0.513	59
Noka ya matsekutseku e tletse ka meetsi	0.509	59
Tshelete Gago shala mo karateng ya Ngaka, gae fiwe Rena ge e shetje	0.474	61.7
Mosadi o noka seshebo ka letswai	0.474	61.7



6 Discussion and Conclusion

In this research study, it has been proved that word embedding solve word sense disambiguation (WSD) problems for Sesotho sa Leboa language. To disambiguate words in Sesotho sa Leboa, the Word2Vec model represents the context and each sense of the target word as a vector in a highly dimensional space, and cosine similarity metrics measure semantic relation between the sense definition and context of the ambiguous word. Word2Vec model gives good accuracy with English corpus, as compared to Sesotho sa Leboa corpus, future research will have to optimizes the algorithm and training model for better accuracy on WSD output.

The CBOW model performed well in this research study since the cosine value approach 1, and the angle becomes smaller, which means greater match between vectors giving similar orientation to two vectors. The threshold of CBOW model for this processed text document gives output value for cosine similarity higher than 0.5 which shows strong similarity between context and sense definition.

Skip-gram model gives cosine similarity value closer to 0, with two vectors approaching a perpendicular angle of 90-degrees orthogonally indicating that orientation of vectors do not match. The research results shows no opposite vectors with an angle of 180-degrees, since we do not have a cosine similarity of -1.

Sentence transformer models gives strong similarity setting a new state-of-the art algorithm that outperforms Word2Vec algorithms, as experiment shows a very high cosine similarity of 87%, with an angle of 29 degrees.

In future work, the researchers propose to perform word sense disambiguation using Embeddings from Language Models (ELMo) using Tensorflow-hub for optimization and FastText using Gensim to achieve character and morphological structure of the word.

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SDN-Enabled Data Offloading and Load Balancing in WLAN and Cellular Networks

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Abstract.

Communication Network is an ever-evolving field as new technologies that connect the world are adopted. There are many distinct types of networks, each of which is classified differently. Cellular networks are currently experiencing data explosion because of the ever-increasing bandwidth demands of today's mobile applications. This has resulted in traffic congestion and a scarcity of resources. The network must handle a high volume of traffic and serve many customers, which may result in poor service quality for users. A single access network struggles to handle such a tremendous volume of traffic. In this paper we present a traffic offloading and load balancing algorithm between cellular and Wireless Local Area Networks (WLAN) networks, to enhance the overall utilization of cellular network. The proposed algorithm uses software defined network (SDN) controller for making decisions of offloading users from a cellular network to a WLAN network, and to balance the load across access points (APs). Simulation results shows that the proposed data offloading scheme improves load distribution and throughput.

Keywords: Cellular, Networks, Load, WLAN, Algorithm

1. Introduction

Communication technologies have advanced rapidly in recent years, and have proven to be critical to modern civilization, particularly in the field of wireless communications. Mobile networks have progressed from 1G to 5G, and beyond, with considerable increase in coverage, throughput, and flexibility, from the 1980s to the present [1]. The advent of smartphones, tablets, laptops, and wearable devices which support multimedia applications, traditional cellular networks are witnessing unprecedented growth in mobile traffic, and demand for mobile data continues to rise [2]. Furthermore, future wireless communications will have to support a wide range of applications with varying functional needs, according to the report in [3]. Automation, live streaming, and interactive gaming, for example, are timesensitive, but other services, such as the Internet of Things (IoT), need many connections per unit area [3].

Both cellular networks and Wireless Local Area Networks (WLANs) are evolving to meet such huge connection and traffic demand. The deployment of the 5G network has begun, and a new generation of mobile networks has been deployed every ten years. This is aimed at providing higher capacity, lower latency, higher reliability, and greater mobility support than the previous generation. 5G needs to be more efficient and flexible. To support the enormous traffic volume and fulfil the Quality of Service (QoS) requirement of various user applications, future generation of cellular networks will require knowledge of user application requirements and real-time information sharing [1]. The goal of the 5G network is to create a connected society in which drones, sensors, wearables, and medical equipment all communicate with one another, allowing them to provide sophisticated services such as advanced security and telesurgery to end users [1]. It has been discovered that traffic from indoor/hotspot sites can account for up to 90% of overall traffic [6].

Offloading of mobile data to supplemental networks is one viable approach to coping with cellular network congestion caused by the exponential growth of user traffic. To relieve congestion and make

better use of existing network resources, mobile data offloading entails the use of complementary network technologies for transmitting data originally targeted to mobile/cellular networks [7]. The objective is to provide network users with high-quality service while decreasing the cost and impact of bandwidth-hungry services on the mobile network. The traditional approach of increasing network capacity by adding more network equipment is always available, but it is neither cost effective nor viable given the increasing demand for data services. As data traffic on mobile networks continues to grow at a rapid rate, mobile data offloading is expected to become increasingly crucial.

This research proposes a Software Defines Network (SDN) based data offloading and load balancing method for cellular and WLAN networks. Based on the number of users connected to the cellular base station and WLAN AP, as well as Received Signal Strength Indicator (RSSI), the scheme will decide on traffic offloading and load balancing. The controller receives load information from the WLAN APs and micro base station through the OpenFlow channels, and then makes offloading and load balancing decisions. For performance analysis, the proposed scheme is implemented in the Mininet-WiFi emulator.

Mininet-WiFi arose as a Mininet dependency, an OpenFlow/SDN emulator capable of adding virtualized stations and access points using normal Linux wireless drivers and the 802.11hwsim wireless simulation driver. The SDN paradigm is used in this emulator. It enables network administrators to specify network behaviour in a logically controlled manner using a controller that communicates with forwarding devices via the OpenFlow protocol [36].

Current cellular networks are overburdened by the surge in traffic caused by the proliferation of mobile devices and a variety of bandwidth-hungry smartphone applications (e.g., video streaming applications). This has resulted in cellular network congestion and, as a result, poor service quality for users. In some literatures, data offloading and load balancing techniques have been developed to solve the problem of mobile network congestion. However, existing data offloading and load balancing algorithms must be further explored and improved, as offloading without centralized management may not significantly increase overall network utilization and end users' quality of service. In a heterogeneous wireless network, flexible and programmable network management is required to ensure uniform policy and management across several access networks. In this paper, SDN has been introduced as a technology that enables high-level administration, flexibility, and control.

The focus of this research is to address the congestion problem caused by rapid traffic increase in cellular networks, using WLAN offloading. This is achieved by specifically addressing,

1. Development of a scheme for traffic offloading and load balancing based on SDN to enhance the performance of the cellular network.
2. Evaluation of the performance of the data offloading and load balancing algorithm using some network parameters.

The offloading and load balancing is between cellular networks and WLAN access points (AP). For the loss of generality, WLAN and Wi-Fi are used interchangeably in this paper. To imitate an SDN, the Mininet-Wi-Fi simulator was employed. Because there is no cellular network in this simulator, only Wi-Fi, a 300m Wi-Fi AP has been used in place of a micro-base station. Again, instead of programming the controller to incorporate offloading and load balancing functions, a default controller has been used, which basically makes offloading and load balancing decisions based on signal strength only. As a result, manual simulations using the simulator's mobility and handover modules has been employed to test the concept.

The rest of this paper is organized thus. Section 2 presents description of related works. In section 3, the system model and network analysis used for this work was presented. Section 4 present the simulation setup and performance analysis. Finally, section 5 gives the conclusion of the paper.

2. Related Works

In wireless networks, there has been an increasing interest in the study of data offloading and load balancing based on SDN. Duan et al proposed an SDN-based partial data offloading and load balancing method to relieve spectrum shortage concerns and network congestion issues. The algorithm uses the SDN controller's global view of the network to fulfil the objectives while taking network conditions and end-user QoS requirements into account. Their goal, though, was to use Wi-Fi whenever possible to limit cellular network usage. This is problematic because cellular networks are sometimes more suitable for some services than Wi-Fi.

Zhou et al implemented a Reverse Auction-based Incentive Mechanism (RAIM) to motivate nodes in Opportunistic Mobile Networks (OMNs) to provide data offloading services. Because OMN nodes are rational and selfish, they do not provide data offloading services if they are not adequately rewarded. As a result, the authors devised incentive mechanisms to encourage nodes to provide data offloading services. However, they did not incorporate software defined networking in their scheme.

The topic of load balancing using SDN have been tackled by many researchers in the past. For example, Kiran et al developed an SDN handover algorithm based on AP load. In their scheme, they used Mininet Wi-Fi emulator to construct topologies for their experiments. The simulation results showed a successful handover from an overloaded AP to a lightly loaded AP. Moreover, the throughput and latency parameters that they tested showed a significant improvement when the stations were connected to least loaded AP than to loaded AP.

To relieve network congestion and enhance traffic load balancing, Bo Fan and Zhengbing presented an intelligent software defined cellular vehicle-to-everything (C-V2X). By separating the network data plane from the control plane, their approach offers flexible and low-complexity traffic offloading. In comparison to existing systems, their architecture was able to dramatically enhance network speed, load balancing, and user service ratio.

Shiwei in [33] proposed a motion state estimation-based load balancing algorithm for heterogeneous network. The simulation results showed that the proposed algorithm effectively balanced the load in the heterogeneous network while also improving system efficiency. However, the research did not incorporate software defined networking.

Torres et al proposed a load balancing scheme combining a fuzzy logic controller algorithm with social awareness. However, their scheme did not incorporate software-defined networking. The works reviewed above showed performance improvements regarding traffic management in existing networks. Thus, this dissertation builds on the previous works by developing an algorithm for traffic offloading and load balancing between a cellular network and a Wi-Fi network.

Having critically analysed the strength and drawbacks found in other related works, this study focuses on data offloading and load balancing between cellular networks and WLAN access points to alleviate congestion concerns in wireless networks. This is done by using default controller which makes offloading and load balancing decisions based on signal strength only. As a result, manual simulations using the simulator's mobility and handover modules has been employed to test the concept.

3. System Model

The proposed system model is based on SDN. The system model consists of one micro cell base station, an overlay of N number of APs, and M number of stations (users) within the microcell's coverage area, as well as users connected to the APs and the micro base station. The logically centralized controller is connected to the microcell base station and Wi-Fi APs. Figure 1 shows the proposed SDN system model. The controller has a full view of the whole network topology and is aware of every flow in the network. The controller communicates with the APs using open flow to collect information such as, received signal strength, and the number of stations connected to each AP and micro-base station. The controller maintains this information.

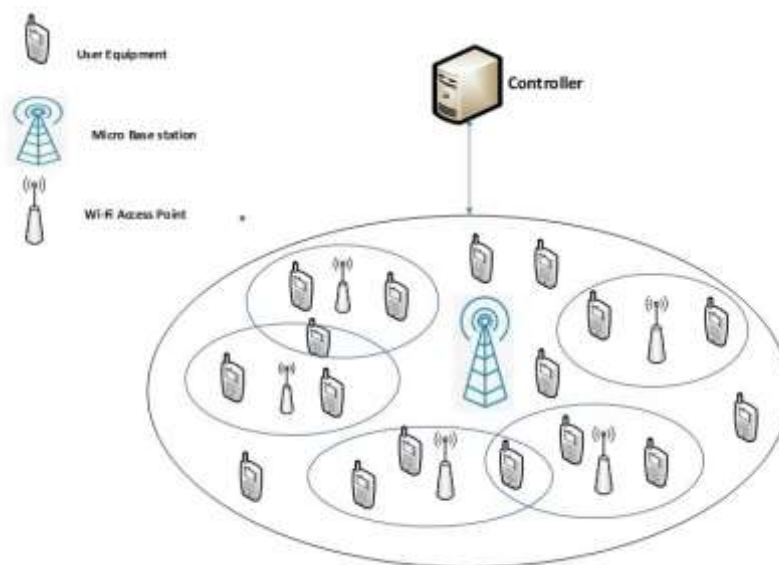


Figure 1: Proposed System Model

The proposed offloading procedure is described below. The procedure involves two important steps.

Step 1

The Wi-Fi APs and the micro-base station periodically send information about the number of users they are associated with and the signal strength of each of the associated devices, which is indicated by the RSSI, to the controller. The periodic information sent by the APs and micro-base station gives the controller a global view of the entire network. Thus, the controller has a list (which is constantly changing) of APs along with the number of users per AP and their signal strength, which enables it to make offloading and load balancing decisions.

Step 2

When a new user joins the network and requests for service, the Wi-Fi network is given priority. The goal is to reduce cellular network utilization by first determining if a Wi-Fi AP is accessible to which a mobile user may connect. Hence, alleviating cellular network congestion. The algorithm assesses each Wi-Fi AP's state and makes an association decision based on signal strength and the number of devices connected. The proposed method will first determine if the RSSI matches the minimal threshold criterion. The number of connected users is next checked to see whether it is fewer than the minimal

number of users that each AP should support. New users will be connected to any Wi-Fi AP with the least number of users and the acceptable signal strength. If no Wi-Fi AP meets the minimal requirements, the controller checks to see if the number of users connected to the base station is fewer than the threshold. If it is, the user is assigned to the micro-base station. The user will be refused service if the microcell base station is unable to accommodate its request.

There are two scenarios of load balancing investigated in this paper viz;

Scenario A

The system handles load balancing in addition to offloading. Consider the case depicted in Figure 2, with two APs, AP1 and AP2, having overlapping coverage. The number of users associated with each AP is shown in the Figure 2. There are six users connecting to the APs: usr1, usr2, usr3, usr4, usr5, and usr6. Three users are initially connected to each of the AP. Usr2, and usr3 that are connected to AP1 decide to terminate their sessions. Assuming that all these users are active and generate equal amounts of traffic; AP2 is considered overloaded in comparison to AP1 based on this assumption and the number of stations connected to each AP. To balance the number of stations on both APs, the controller decides to disconnect one of the stations from AP2 and transfer it to AP1. The result of AP2 handing over one user to AP1 is shown in figure 3.

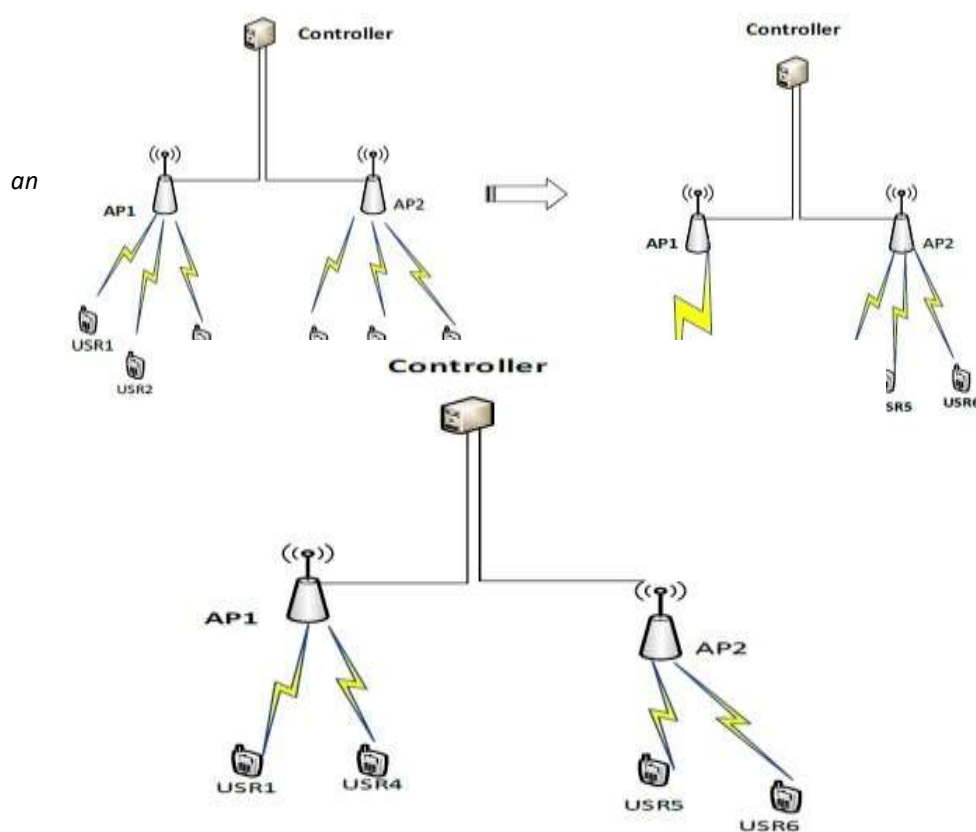


Figure 2:
Two
users on
AP
ended
their
sessions

Figure 3: Controller Moves One User (USR4) from AP2 to AP1

Scenario B

Consider another scenario, as illustrated in figure 4, with two APs, AP1 and AP2. There are four users connected to the APs: usr1, usr2, usr3, and usr4. The two APs have overlapping area. Three users are initially connected to AP2, whereas one user is connected to AP1. If all users generate the same amount of traffic and all users are active, AP2 is deemed highly loaded in comparison to AP1. If usr2 moves into the overlapping zone of the two APs, the controller will reassign usr2 to AP1. The result is shown in figure 5.

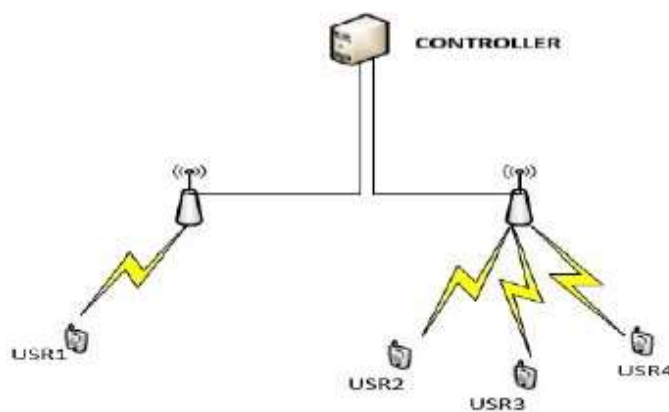


Figure 4: Users Connected to AP1 and AP2

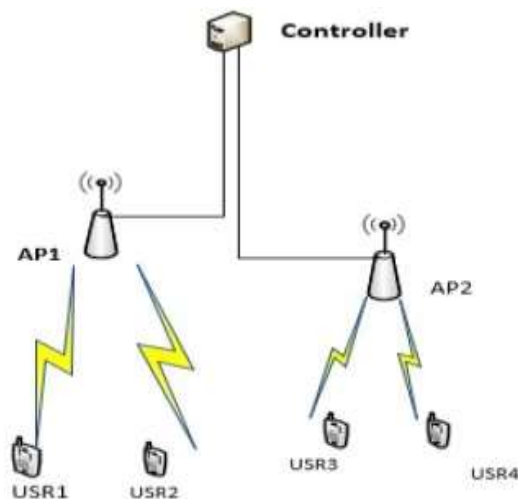


Figure 5: Controller Re-Assign Usr2 to AP1

4. Simulation Setup in Mininet-Wi-Fi and Performance Analysis

In the experiments, one microcell base station, two Wi-Fi access points, nine mobile stations, and one controller were used, and the network dimension was set to 700 m x 700 m. The simulation parameters are listed in Table 1. Table 2 shows the specifications for the cellular base station and Wi-Fi access points while Table 3 shows the specifications for mobile stations.

Table 1: Simulation Parameters

Parameters	Description
Number of Wi-Fi Access Points	2
Number of Micro Base station	1
Number of Users	9
Number of Controllers	1

Table 2: Micro Cell and Wi-Fi Specification

SSID	Range	Mode	Frequency	Position
Ap1-ssid	100 m	g	2.4 Ghz	'260,350,0'
Ap2-ssid (base station)	300m	g	2.4 Ghz	'350,350,0'
Ap3-ssid	100m	g	2.4 Ghz	'440,350,0'

Table 3: Specifications for Mobile Stations

Stations/users	IP Address	Interface	range
Sta1	10.0.0.1	WLAN 0	40m
Sta2	10.0.0.2	WLAN 0	40m
Sta3	10.0.0.3	WLAN 0	40m
.			
Sta9	10.0.0.9	WLAN 0	40m

The first experiment was conducted to measure the mobile stations' throughput while they were connected to the highly loaded base station. The experiment comprises of two Wi-Fi APs (AP1 and AP3), one base station (AP2), and nine stations. The stations were positioned within the range of the

base station. Thus, all the stations were connected to the base station, as shown in Figure 7. None of the stations connected to AP1 or AP3.

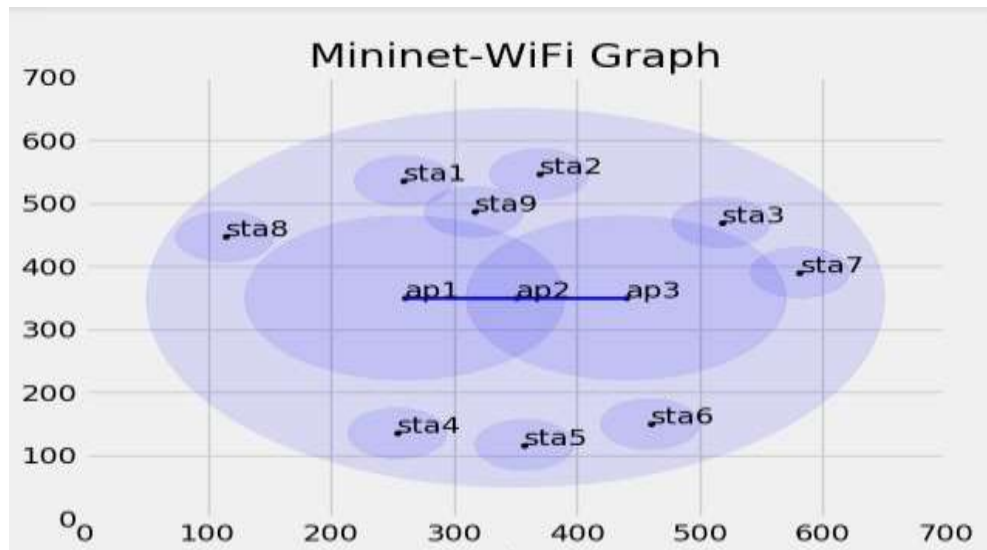


Figure 7: All Stations Connected to AP2 (BS)

Figure 8 depicts the number of stations associated with each access point and base station when the stations were connected to the base station based on signal strength. The graph illustrates that all the stations were connected to the base station since they were in the range of the base station, and it provided the best signal strength. Figure 9 depicts the results of stations that were connected to APs based on signal strength and load on each AP. When the load per AP was considered, the load was more evenly distributed than when stations were connected only based on signal strength.

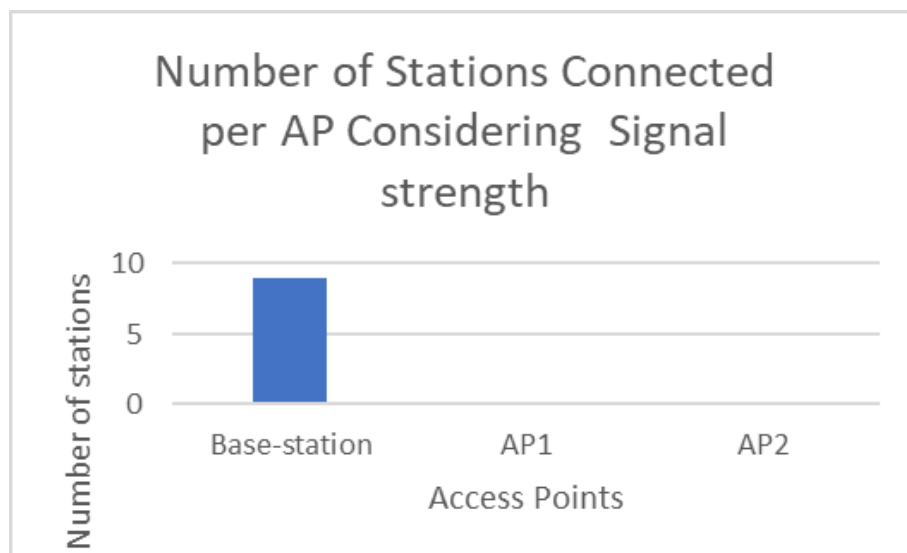


Figure 8: Number of Connected Devices Based on Signal Strength

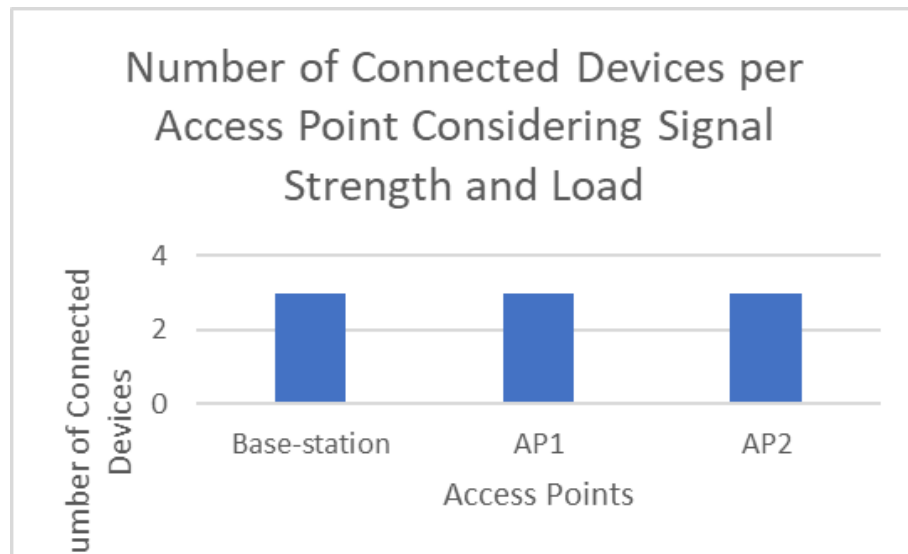


Figure 9: Number of Connected Devices Based on Signal Strength and Load

The figures 10 and 11 compare the throughput of test stations sta7, and sta9 while connected to a highly loaded base station with when they were offloaded to the least loaded APs. Figure 10 compares the throughput of sta7 when connected to a highly loaded base station to after it was offloaded to a Wi-Fi AP3 with the least number of stations. When connected to the base station, sta7's throughput was 6.58 Mbits/sec, but it increased to 18.4 Mbits/sec when connected to the least loaded AP3. Figure 11 indicates that while connected to AP1, sta9's throughput increased from 7.55 Mbits/s to 50.5 Mbits/s. Throughput increased when some stations were offloaded to the APs with the lowest number of users.

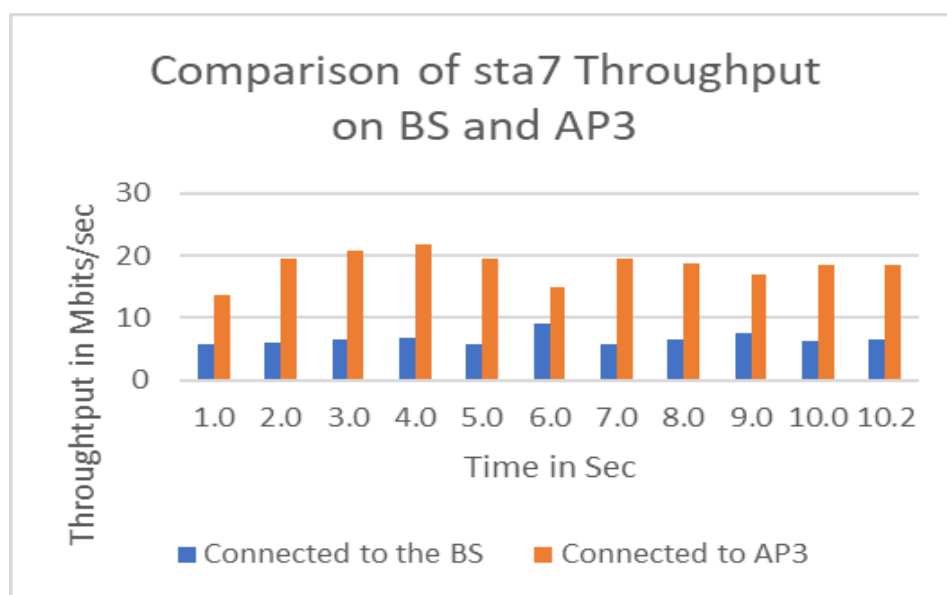


Figure 10: Throughput for sta7 Before and After offloading

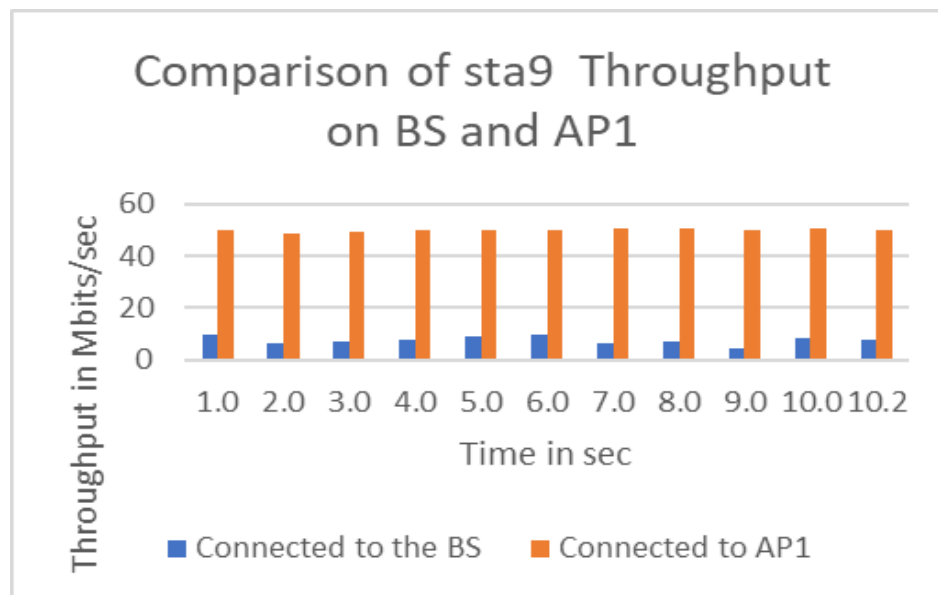


Figure 11: Throughput for sta9 Before and After Offloading

5. Conclusions

An SDN-based traffic offloading and load-balancing algorithm was developed for a heterogeneous network comprising of cellular and WLAN to decrease congestion in cellular networks. The proposed algorithm was simulated using the Mininet-Wi-Fi emulator. The performance of the proposed algorithm was evaluated using throughput and load distribution. The results shows that the proposed algorithm improved network's load distribution and device throughput.

The scheme implemented in this paper was designed and simulated for a simple network with basic network parameters. The following points are to be considered in future work:

- Other network parameters such as the amount of data offloaded, and the number of handover instances could be considered in future work.
- The aspect of using Pox controller for load balancing and offloading has not been implemented in this paper. This should be considered in the future work.

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Taxonomy of Vehicular Network Simulator Software

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Abstract

Vehicular communication network is an interconnection of vehicles or interconnection of vehicles and road infrastructure. Continuous increase in research into vehicular communications has led to the development of simulation tools and for the purpose of studying and analyzing vehicular networks. In this paper, we survey various simulator software adaptable to vehicular networks. Using different features, simulators were characterized and outlined to help researchers in deciding what tool to use. With this helpful characterization, researchers can easily make quick decisions, hence, saving time and energy.

Keywords: Simulator, Networks, Taxonomy, Vehicular, Communication.

1. Introduction

Mobile ad hoc networks are decentralized wireless networks which do not depend on already existing fixed networks or infrastructures. They are configured on the fly and their connection can easily be torn down. Mobile ad hoc networks also called MANETs are formed through nodes' participation in forwarding packets. MANETs are usually not permanent networks. The MANETs were launched in the 1970s, and since then, the technology has been on a consistent growth. Some examples of mobile ad hoc networks are vehicular ad hoc networks (VANETs), smartphone ad hoc networks (SPAN), internet-based mobile ad hoc networks (I-MANETs), wireless mesh networks, army tactical MANETs, flying ad hoc networks (FANETs), Navy ad hoc networks, wireless sensor networks (WSN). MANETs are usually self-organizing and reconfigurable networks.

2. Vehicular Ad-hoc Networks

The emerging trends in wireless communication have given rise to more datacentric applications requiring end-to-end connectivity (Midya et al., 2017) and (Shah et al., 2020). Vehicular communications have emerged as an important application of wireless technology. Vehicular communication networks are an interconnection of vehicles to achieve autonomous driving. Vehicular ad hoc Networks (VANETs) are a special type of mobile ad hoc networks (MANETs) which could be vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-network (V2N), vehicle-to-devices (V2D) and generally, vehicle-to-everything (V2X) (Demir et al., 2020; Mendiboure et al., 2019; Silva et al., 2017).

In recent times, a trend in hybrid connectivity is fast emerging. This trend is seen in vehicle-to-vehicle-to-infrastructure (V2V2I) (Fuqiang & Shan, 2010). This implies that vehicles are not only communicating among themselves or communicating with cellular towers, but they communicate among themselves and with network infrastructure also referred to as roadside unit (RSU) (Aljeri & Boukerche, 2020; Zhou et al., 2018).

Communication with network infrastructure allows vehicular clients access remote services over the internet. This has brought about V2V2I communication, a paradigm that is currently being researched in recent times (Arshad et al., 2017; Bhatia et al., 2020; Emara et al., 2018; Huang et al., 2020; Qu et al., 2018). Figure 1 shows the inter-vehicular communication and a V2I connection. Inter-vehicular communication is made possible via direct short-range communication (DSRC), while V2I communication is made possible by wireless access in vehicular environment (WAVE) which consists of 802.11p protocol (Gu et al., 2020; Hwang & Kim, 2020; Nazib & Moh, 2020; Sehlabaka & Kogeda, 2013; Zhou et al., 2018), among several other protocols.

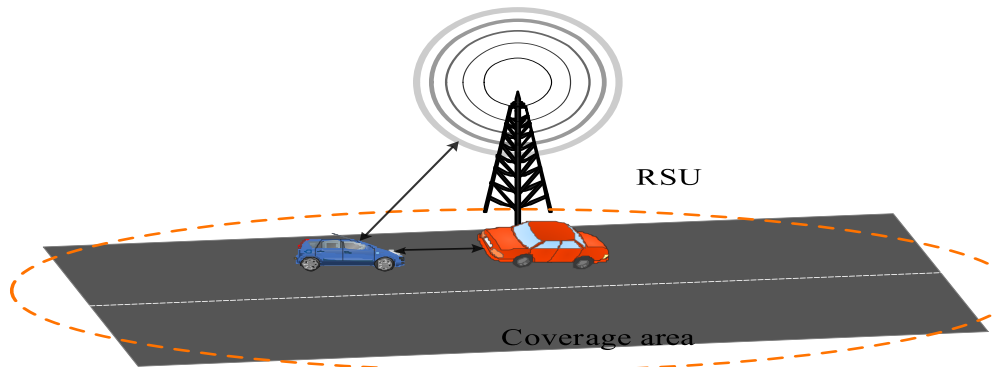


Fig. 19 Vehicle to vehicle to infrastructure communication

3. Simulation of Vehicular Networks

Simulation is the process of synthesizing or modeling real life scenarios using computer related tools. Simulation is cheap compared to building or developing prototypes. There are several simulation tools for VANETs available. They are either open source or commercial.

In (Ahmed et al., 2019), several simulators available for vehicular networks were highlighted. Some of them are VEINS, VsimRTI, VENTOS, EstiNet, iTERRIS, TraNS, NCTUns, Groovenet, MobiReal. The strengths and weaknesses of each of the simulation tools were also highlighted. In (Lim et al., 2016), the authors described some mobility simulators such as VISSIM, Quadstone Paramics and simulation of urban mobility (SUMO). MATLAB was also used together with SUMO to implement vehicular communication. In (Choudhury et al., 2016), vehicular communication simulators were grouped into: Traffic modeling, traffic management and communication network simulation. The traffic modeling can be achieved with simulators such as VISSIM traffic management is achieved by simulators such as MATLAB while NS 2 or 3 are used to simulate communication networks. There are also proprietary VANET simulators such as TSIS-CORSIM, Paramics, Daimler-Chrysler Farsi, Videlio, Carisma, Qualnet and OPNET. In Fig. 2, a flow of signal is depicted. Simulation of VANETs can be achieved in an integrated environment as demonstrated in (Martinez et al., 2011) and (Ching et al., 2020; Lim et al., 2016). The traffic generator, mobility generator and network simulator constitute the VANET simulation set up. They are connected by means of middleware. The middleware conveys traffic and mobility information to the network simulator by means of the middleware.

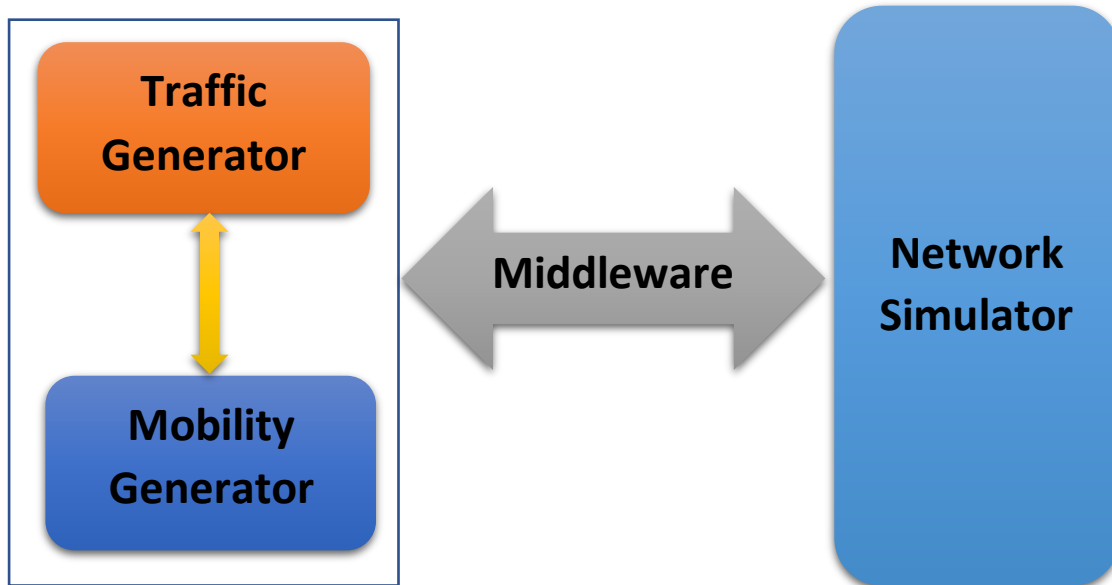


Fig. 2: The flow of signal in a VANET setup

4. Mobility Generators

Mobility generators are used to develop highly realistic road traffic models in vehicular networks (VANETs) simulations. Mobility generators generate close to real life traffic scenarios or traces which are used as input for network simulators/emulators. Mobility generators' inputs are: road model, traffic parameters such as maximum velocity, vehicle arrival and departure rates. The mobility generators produce trace information of every vehicle at any given time during the simulation period. Mobility profiles of vehicles are also provided by mobility generators. Mobility generators can implement street maps to enable simulations to be very similar to real life scenarios. Some mobility generators are SUMO, MOVE, CityMob, Freesim, Vanet Mobisim, STRAW, Netstream. Mobility generators allow for parameters such as street, number of lanes, map travel time to be set. A good number of mobility generators such as SUMO and Citymob have graphical user interface (GUI), this allows for easy set up. In (Midya et al., 2018), SUMO was used together with NS3.26 for implementing a cluster base handover in vehicular communication. SUMO was used to generate mobility while NS3.26 was used to implement the handover between any two mobile access gateway (MAG). Similarly, (Oladosu et al., 2019) implemented an optimized handover algorithm in NS 2.35 equipped with 802.11b/g. NS2 has the advantage of being compatible with different operating systems and not just Linux. It can be seen in (Gyawali et al., 2020) and (Choudhury et al., 2016), integrated simulation environments were designed and tested.

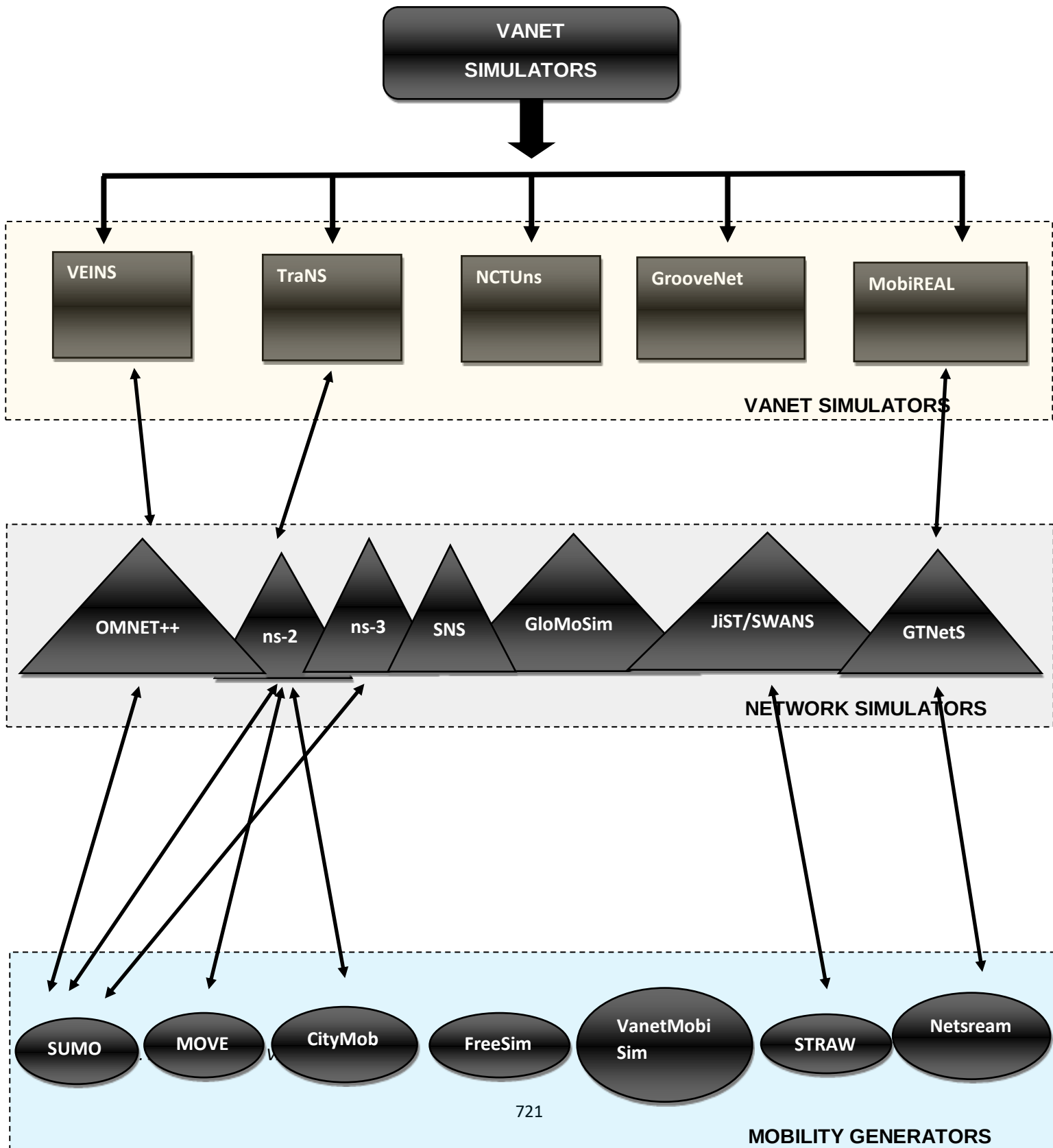
5. Network Simulators

Network simulators implement simulation of packets of data traffic. Network simulators execute source to destination transmission and reception of packets. Network information such as links, routes and channels are implemented by network simulators. The network simulators available were initially meant for Mobile Adhoc Networks (MANETs), hence, they require VANETs extension like mobility generators to enable them simulate vehicular networks. Examples of network simulators include: Omnet++, NS2, NS3, SNS, TraNS, GloMoSim, JiST/SWANS and GTNets. The GUI of a network simulator provides a means to specify the mobility trace interface (TRACI) parameters and network parameters.

6. VANET Simulators

VANET Simulation software provides network and road traffic simulation. VANETs enable integration of mobility generators and network simulators on a single platform. Before now, traffic simulation and

network simulation were implemented in two separate simulators. However, in recent times, simulation of both traffic and network is carried out on VANET simulators. Some VANET simulators are traffic and network simulation environment (TraNS), GrooveNet, National Chiao Tung University Network Simulator (NCTUns). Fig. 3 shows the taxonomy of VANET simulators. It also shows the network simulators that work with mobility generators to give a particular VANET framework.



7. Comparison among the various VANET simulators

In Tab.1., we outline the features of the various VANET simulators outlined in this work. From information available in literature, most of the VANET simulators are open source and are meant for research and academic purposes. They run on the major operating systems.

Tab. 10 Feature comparison of VANET simulators

	TraNS	GrooveNet	NCTUns	VEINS	MobiREAL
GUI	✓	✓	✓	✓	✓
Setup Difficulty	Moderate	Moderate	Hard	Easy	Easy
Network Simulator	NS-2	-	-	OMNET++	GTNetS
Mobility Generator	SUMO	GrooveNet	NCTUns	SUMO	MobiReal
Ease of use	Moderate	Hard	Hard	Moderate	Hard
Mobility models	Random and manual routes	Random, waypoint, explicit origin-destination, multi lane streets with lane changing	Random and manual routes	Random and manual routes	Probabilistic rule based.

8. Conclusion

In this paper, we have been able to survey various VANET simulators as seen in literature in a simplified manner. This paper therefore is a ready information source for researchers who wishes to carry out research in the field of vehicular communication networks. Having this handy information will help reduce the time spent on trying to search for simulators by researchers, and other users.

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Enhancing Salp Swarm Algorithm Based on Elite Opposition based Learning and Cauchy Mutation Strategies

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Abstract.

The significance of machine learning models for real life scenarios to design prediction model is outstanding. However, the nature of datasets available especially in biomedical domain calls for optimization strategies for effective and reliable solution. In view of this development, so many optimization algorithms are promising but not without limitations. For instance, the salp swarm algorithm (SSA), which is a higher level procedure algorithm, has demonstrated a lot of capacity to solve optimization challenges for prediction models. However, to solve an intricate optimization issues, the SSA is deficient with the dawdling convergence pace and a tendency of diminishing into sub-optimal results. Therefore, this research aims to enhance the algorithm using Cauchy mutation and elite opposition based learning strategies. The objective is achieved by fusing these strategies into the existing algorithm; thereby resulting to an enhanced SSA optimization algorithm christened *EOnCaSSA* in this paper. The search agents of 50, 100, and 150 were chosen for each bench functions and 300, 600 and 900 numbers of iterations were also chosen for each function. It is noteworthy that all the seven benchmark functions for unimodal functions have an optimum value of zero. The four evaluation metrics, which include the best, worst, average and standard deviation to determine and compare the performance of *EOnCaSSA* presents significant improvement over the tradition SSA. This implies that the enhanced algorithm can be employed to solve both simple and difficult optimization issues as it passes all the benchmark functions tests.

Keywords: Cauchy mutation strategy, elite opposition based learning strategy, *EOnCaSSA*, salp swarm algorithm, unimodal functions

1. Introduction

Presently, computer algorithmic strategies that learn patterns in data for predictive, diagnostic or analytics models have been constantly exploited by researchers across different real life scenarios; for example, in biomedical, bioinformatics and agriculture. Machine learning algorithms are such significant and promising examples that have been increasingly exploited to this effect. Consequently, an indispensable rate of success have been obtained but not without limitations (Malik, 2020; Zhang & Ling, 2018) While on one hand, the availability of raw datasets to be trained poses a serious challenge especially the biomedical data, on the other hand, the nature of the datasets in most cases naturally initiate some data engineering process (Saez, et al., 2021). This implies that for the learning algorithms to produce optimal results, some level of features engineering processes have to be initiated. Therefore, an effective and efficient machine learning based model is a function of how effective and reliable is the optimization strategies adopted or adapted (Faramarzi, et al., 2020). This fact forms the motivation of this research. There are several numbers of both existing machine learning and optimization algorithms.

Machine Learning (ML) algorithms as earlier noted have made an important contribution to different fields of research, such as disease prediction models. The algorithms predict disease based on the inputs or symptoms that are being fed into the models (Muthukumarasamy et al., 2021). For example, in order to measure the performance and the outcome of the Ebola disease fatality ratio, Forna *et al* (2021) focused on the scale and type of data omission by comparing different ML methods for estimating case fatality ratios. There are different types of machine learning algorithms which are; supervised learning, unsupervised learning, semi-supervised learning and reinforcement learning (Adamu & Awan, 2019). Naive Bayes, Linear Regression (LR), Support Vector Machine (SVM), Random Forest (RF), K-Nearest Neighbor (KNN) and Artificial Neural Network (ANN) are just few classification algorithms under supervised learning (Ray, 2019; Sharma & Mangat, 2016; Mallela et al., (2021). For instance the work of Soni *et al.* (2021) proposed an artificial intelligence approach for forecasting Ebola disease, so as to enhance disease detection via efficient data mining algorithms. However, the researchers admitted that the collection of more data on the disease is encouraged to further facilitate better results and improved accuracy. Consequently, owing to the natures, sizes, and formats of a given dataset, a better accuracy is always difficult to obtain; thus the need for features engineering processes.

Feature engineering processes entails data preprocessing, scaling, balancing and feature selection. In order to harp for a better model results, these processes are highly essential and inevitable. For instance, there are existing techniques or optimization algorithms that can be employed for feature selection. Salp swarm algorithm, particle swarm algorithm (PSO), bat algorithm, cuckoo search algorithm, grew wolf among others typical examples of algorithms used to optimally select attributes of a given dataset (Abualigah *et al.*, 2020; Ben-Chaabane et al., 2021; Hegazy *et al.*, 2020 more citations for others). Among all these algorithms, SSA, new efficacious meta-heuristic optimization algorithms is indeed promising for a robust predictive modeling especially in areas of biomedical and bioinformatics. It is used to select the best features in order to minimize redundancy of the given features, which in turn would reduce the complexity of the proposed network (Ben-Chaabane et al., 2021). However, SSA is limited by its susceptibility to fall into local optimal and slow convergence rate (Fan et al., 2020; there are other similar 2021 and even 2022 citations. put one or two more).

Therefore, considering these limitations, this research aims to enhance the SSA using the Cauchy Mutation and Elite Opposition Based Learning (EOBL) as framework to predict EBOV. The remaining sections of this paper are organized as follows: section 2 accounts for the related works while, the proposed algorithmic methodology is presented by section 3. Section 4 accounts for the discussion of the framework based on the methodology; and section 5 presents the conclusion of the paper.

2. Related Work

This section presents the related literature to the main subject matter, which is the salp swarm algorithm. Nonetheless, other related algorithms for optimal selection of features for a given dataset are equally considered in this section. As earlier stated, a robust and reliable predictive model for any real life domain is always a function of how effective is the feature engineering mechanisms deployed. In recent times Salp Swarm algorithm has shown great value in feature selection task (Hegazy *et al.*, 2020). In their literature, the researchers aim to review the traditional SSA and ISSA (Improved SSA) for better accuracy, reliability and convergence speed. Consequently, the improved SSA performed better than the other optimizer in terms of speed and accuracy. They therefore recommended that more improvement can be done to bring much better accuracy.

Wu et al. (2019) conducted a research which aims to make equal the local and global exploration and to prevent early changes in stagnation and convergence. The result shows high level of performance and the ability to withstand local optimum when evaluated with the SSA algorithm. It is recommended that it should be further studied and practically carried out in solving optimization problem in engineering. Similarly, Abualigah *et al.* (2020) carried out an in depth study of SSA and how the scholars are motivated in several applications to implement it in computer science domain. The study classified the SSA into theoretical and application aspects. The outcome shows that when the algorithm is stuck in local optimal, mechanism should be engineered to reduce the exploitations process and convergence rate. Some important tools like the adaptive mechanisms can be used to minimize the convergence speed in relative to number of enhancement in iterating the best solution. SSA can be applied across different spheres of real life domains and researches.

Furthermore, Nautiyal et al. (2021) in their attempt to enable closed and informed search ability using Gaussian and Cauchy mutations brought large steps to improve the global search ability. The results show that by checking several mutations and selecting the best SSA, at least 23 benches are used to analyze the problems with dimension of 30 & 100. The improved SSA shows a better result which can be utilized to check for optimal machine learning models structured and weights. Also, the research of Ben-Chaabane et al. (2021) aims to enhance the performance of blind digital modulation detection approach in the aspect of multiple-antenna systems of the algorithm using the Feature weight and ML model. In comparing to other algorithms, the result shows that the rate of convergence of the proposed ISSA is high for a good number of the test functions based on speed and precision. For features selection, it is advised that more preprocessing techniques in ML ISSA can be used.

It is evident that several attempts are constantly in place to improve the SSA by equally considering other similar algorithms. In view of this development, the research of Gurses et al. (2021) exploited several strategies of these algorithms that leverage on populations; they are but not limited to hybrid-slime mold algorithm and simulated annealing algorithm. By comparison of the results, it was reported in the literature that the probabilistic approaches outperforms the regular optimization algorithms used. In furtherance to improve the SSA, Tubishat et al. (2020) used opposition based learning development with local search algorithm of SSA to enhance its exploitation. In order to find solution to selection challenges and choose the overall features compactments of wrapper mode. It was deduced that on the overall 18 dataset used, the ISSA algorithm out performs the traditional SSA algorithm. Also, considering to choose few numbers of features, the level of originality shown by ISSA is premised on using LSA and OBL approach. However, the process of choosing additional features more than the other optimization algorithms is a major shortcoming in the proposed ISSA. The researchers therefore suggested that further check using real world challenges and dataset is highly recommended with classifiers.

More so, Soni et al. (2021) claimed to proposed a more robust hybrid predictive model for ebola virus in order to enhance the disease detection and increase the result accuracy of the system. Various accuracies were obtained from the various classifiers include the hybrid techniques after training the given dataset. The researchers therefore submitted that for a more improved results to be obtained, more dataset is consequently required; also encouraged interested researchers to hybridize the techniques used in their work.

In an effort to improve the SSA, the research of Fan et al., (2020) attempted to ameliorate the challenge of real time activity and precision of the traditional SSA, a new hybrid algorithm known as perturbation weight SSA was introduced. From the results it can be deduced that the hybrid algorithm is faster than the regular SSA. Similarly, Ibrahim et al., (2019) proposed the hybridization of Salp

Swarm algorithm and Particle Swarm Optimization (SSAPSO) so as to verify which of the best features can be used in different UCI datasets. Based on the accuracy measures, the ratio of the chosen features to the processor's time and other metrics used in checking the fitness performance of SSAPSO outperforms several other algorithms. It is recommended that the algorithm is applied in several other fields like signal processing and image processing.

3. The Proposed Methodology of the enhancing SSA

This research proposes the hybrid adoption of both elite opposition based learning and Cauchy mutation strategies as method to enhance the tradition SSA. The Elite opposition-based learning and Cauchy mutation algorithms are employed to produce arbitrary preliminary results for every iteration to enhance the multiplicity during the discovery process; and enhance the global search ability of the traditional SSA.

As stated earlier, Salp Swarm Algorithm is a recent higher level heuristic algorithm in which the development is inspired by the attributes of swarming salps. It's commonly described by a search method, which is easy and posses some sort of handling parameters. Conversely, to solve difficult optimization challenges, the SSA may be deficient with dawdling convergence pace and a tendency of resulting into sub-optimal outputs. To solve these problems, the Cauchy mutation would be applied to produce huge numbers of mutation to boost the global search potential. On the other hand, the elite opposition-based learning would be employed to create arbitrary preliminary solutions; each iteration is expected to increase the diversity during the process to discover optimal results.

The Salp chains are mathematically modelled by segmenting the Salp population as leader and followers. The leader guides the swarm during foraging while the follower follows (Mirjalili, *et al.*, 2017). In comparison to other swarm-based mechanisms, the location of Salp is described in an n-dimensional search space and n is defined as the given number of variables for the problem to consider.

The location of the leader is updated using the equation 1, which is defined as follows (Mirjalili, *et al.*, 2017):

$$x_j^1 = \begin{cases} F_j + c_1((ub_j - lb_j)c_2 + lb_j) & c_3 \geq 0 \\ F_j - c_1((ub_j - lb_j)c_2 + lb_j) & c_3 < 0 \end{cases} \quad (1)$$

where, F_j is the spot of the source of food in the j th dimension,
 ub_j shows the major hop (upper bound) of j th dimension
 lb_j presents the minor hop (lower bound) of j th dimension
 c_1 , c_2 and c_3 are arbitrary values between 0 and 1.

The coefficient c_1 as defined by equation 2, is the most significant factor in SSA in that it stabilizes the process of search space (Mirjalili, *et al.*, 2017).

$$c_1 = 2e^{-\left(\frac{4l}{L}\right)^2} \quad (2)$$

where,
 l stands for present iteration
 L denotes numbers of highest iterations

The position of the followers is equally revised using eq. 3, which is defined as (Mirjalili, *et al.*, 2017):

$$x_j^i = \frac{1}{2}(x_j^i + x_j^{i-1}) \quad (3)$$

Therefore, based on these strategies, Algorithm 1 presents the enhancement based on the existing algorithm.

Algorithm 1: An Enhanced SSA

Parameters: The initial population of the Salp (x_i); food source (fs); salp population's upper and lower bound (ub , lb) the elite opposition members (s_s); Elite Opposition Based Learning function $E_{fxn}(e_i)$; Cauchy_Mutation ($CauM$) function $C_{fxn}(c_i)$; random draw function ($Rand_{fxn}$)

Input: x_i

Output: fitness function (F_f)

Procedure:

```

1. Initialize  $x_i$  ( $i = 1, 2, \dots, n$ ) considering  $ub$  and  $lb$ ;  $s_s$ 
2. (if old  $fs > new\ fs$ ; update new  $fs$  else keep old  $fs$  )
3.   Compute  $F_f$  of each  $x_i$ 
4.    $F_f$  = the best search agent
5.   Update  $c_1$  by Eq. (2)
6.   forEach  $x_i$ 
7.     if ( $i==1$ ) then
8.       Update the position of the leading salp by Eq. (1)
9.     else
10.      Update the position of the follower salp by Eq. (3)
11.    end
12.     $Rand_{fxn}(x_i)$  // the starting point of enhancement
13.    if  $F_f(E_{fxn}(e_i)) \leq F_f(x_i)$  then
14.       $EOBL(e_i)$  //replace the salp with elite member
15.    end
16.    if  $F_f(C_{fxn}(c_i)) < F_f(x_i)$  then
17.       $CauM(c_i)$  // replace the Salp with the mutant agent
18.    end
19.  end
20.  update  $x_i$  // amend the salps based on the bounds
21. end
22. return  $F$ 

```

From the algorithm, parameters which include variables and functions such as salp population, random draw and Cauchy mutation functions are defined.

Steps 1 to 2 initialize the salp population by putting into consideration the major and minor hops so as to identify the food source for the salp. Elite members are equally initialized. If the condition is satisfied that is, identify the newly found food source. If the old food source is better than the new food source, update the new food source else keep the old food source. Then the algorithm proceed to compute the fitness function of the entire search space agents (the salp, elite members and the mutant agent) as indicate by steps 3 and 4. Consequently, the coefficient c_1 , which is the most significant factor of SSA is progressively updated as presented by Eq. 2.

For each salp, from steps 6 to 11 as long as the salp position is at index 1, the algorithm keeps updating the location of the leader using eq. 1; else update the location of the follower using Eq. 3.

The main ingredients of the enhancement starts from steps 12 to 17 by initializing the salp agents using the user defined random draw function $\text{Rand}_{\text{fxn}}(x_i)$. If the fitness function of the elite member is better than the fitness function of the ordinal Salp, then replace the Salp with the elite member. Similarly, if the fitness function of the mutant agent is better than the fitness function of the ordinal Salp then replace the Salp with the mutant agent. Finally, the salp agent is mended based on the upper and lower bounds of variable; and return the best salp agent via the fitness function as indicated by step 22.

More so, for simple illustration and understanding, Figure 1 presents the flowchart of the proposed algorithm's enhancement. The initial population of the Salp and the elite opposition members are initialized, and food source is equally identified. Then, the mutant agents are also initialized after generated by Cauchy method.

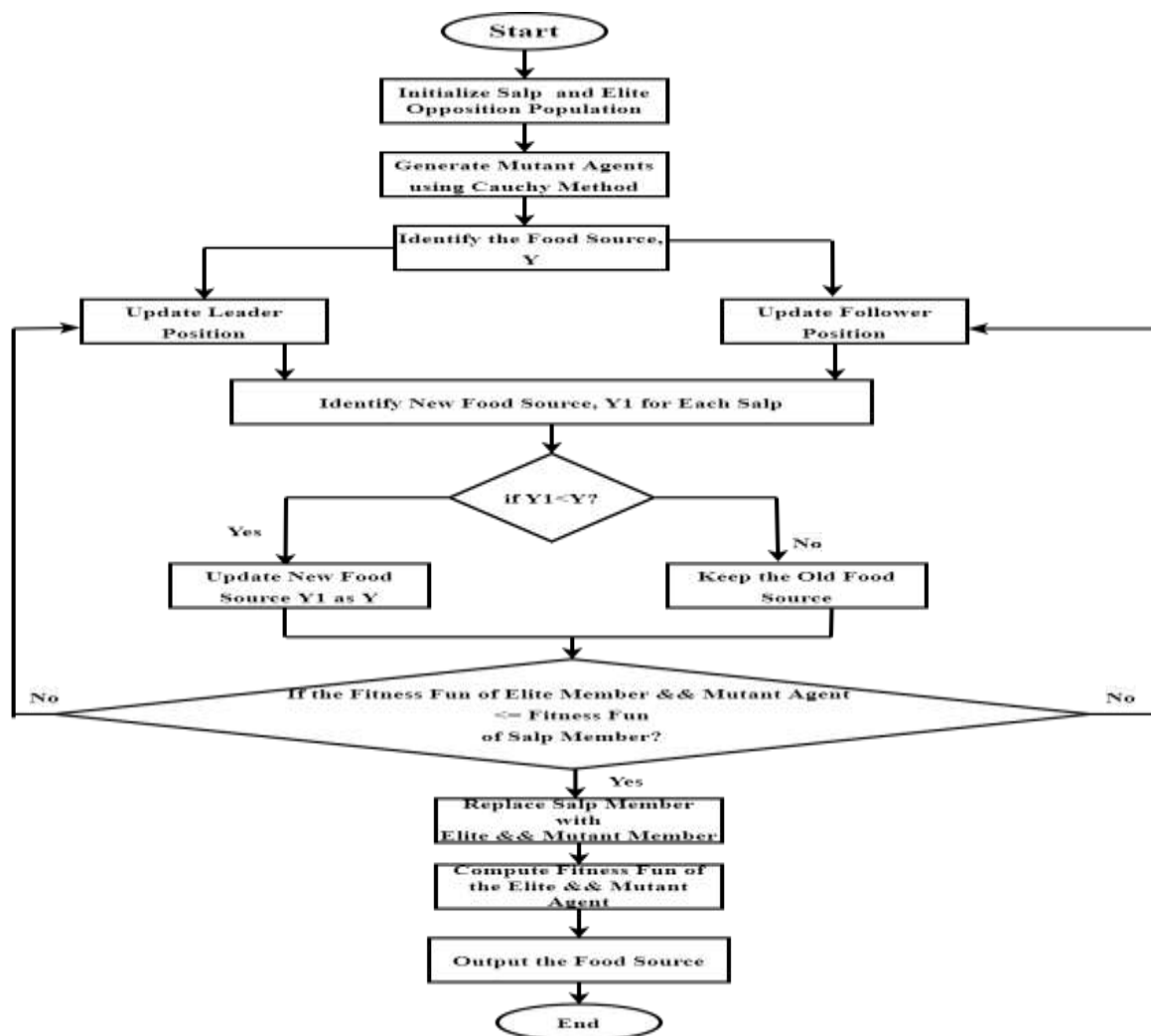


Figure 1: Flowchart of the Improved Salp Swarm Optimization Algorithm

The salp populations are categorized into the leader and followers. The leader and the follower's positions are initialized and then updated to their new positions. A new food source

named $Y1$ is found for the updated leader and followers. Furthermore, fitness functions are computed, updated for the new food source and compared with the fitness function of the old food source.

In the same vain, the fitness function of the elite members and the mutant agents are also computed and compared with the fitness function of the optimal food source of the salp that are not elite or mutant agents. If the elite members and mutant agents are better, the salp will be replaced with the elite member and mutant agent. This would enhance exploration and exploitation process of the SSA. Then, a new fitness function is computed, and the best search agent finds an optimal new food source.

4. Discussion

This section discusses the performances of Salp swarm algorithm, its improved version herein dubbed as Elite Opposition, and Cauchy based SSA (EOnCaSSA). More so, the results of the benchmark functions for unimodal functions are also discussed.

The performance of the enhanced SSA (EOnCaSSA) is proposed for fourteen benchmark functions however, only seven is able to be presented in this paper as the work is still in progress. Standard performance metrics such as the best, worst, standard deviation, and average were used to effectively compute the performance of the enhanced algorithm. The search agents of 50, 100, and 150 were chosen for each bench functions and 300, 600 and 900 numbers of iterations were also chosen for each function. It is important to mention that all the seven benchmark functions have an optimum value of zero. Therefore, performances are measured based on the closeness of the obtained values to zero.

It is observed from Table 2 that as the numbers of search agents and iterations progresses or increases, the performances of the algorithms increase. This implies that as the numbers of search agents' increases, more random, initial solutions are generated resulting from the application of the elite opposition-based algorithm to SSA. Furthermore, the application of the Cauchy mutation technique to the traditional SSA increases the searching and operation's ability of the existing SSA. Cauchy mutation generates a good number of mutations to optimize the global search strength of the existing SSA. Table 2 shows the results of the improved algorithm of unimodal test functions. These results were computed after thirty individual runs. All the performance metrics, including the worst, best, average, and standard deviation of EOnCaSSA, show significant improvement over the standard SSA. The worst, best, standard deviation, and average of the EOnCaSSA for all the benchmark functions exhibit lower values as compared to SSA. This implies that the improved algorithm can be employed to solve simple and difficult optimization issues as it passes all the benchmark functions tests.

Table 1: Results of the Algorithm on Unimodal Test Functions

Function	Search-Agent	Iteration	Original SSA				Modified SSA with Cauchy and EOBL			
			Best	Worst	Average	STD	Best	Worst	Average	STD
F1	50	300	1.05E-02	-0.03679	0.018979	-0.00084	6.34E-130	-1.75E-66	-9.18E-67	5.06E-67
	100	600	9.38E-10	-1.05E-05	3.99E-07	5.67E-06	1.57E-244	1.87E-125	9.13E-125	4.34E-125
	150	900	2.02E-10	-4.00E-06	-4.92E-07	2.59E-06	0	-2.11E-166	-1.09E-166	0
F2	50	300	0.040627	-0.04063	-0.0040624	0.012847	1.50E-65	-3.65E-67	-1.69E-67	9.52E-68
	100	600	2.48E-06	-1.31E-06	-6.77E-08	4.67E-07	5.90E-127	1.40E-129	4.20E-129	1.75E-129
	150	900	6.51E-07	-9.87E-08	2.53E-08	1.18E-07	9.26E-183	-1.00E-184	-7.01E-185	0.00E+00
F3	50	300	1.76E-06	-0.00109	2.97E-05	0.000847	2.87E-135	1.65E-71	1.21E-70	7.54E-71
	100	600	2.38E-11	-2.87E-06	4.41E-08	2.10E-06	5.98E-240	9.46E-124	5.28E-122	4.51E-122
	150	900	1.17E-11	-1.70E-06	-5.49E-08	1.30E-06	0.00E+00	3.23E-167	8.22E-166	0.00E+00
F4	50	300	8.36E-06	-8.36E-06	2.50E-06	5.44E-06	1.44E-68	1.41E-70	1.88E-69	1.25E-69
	100	600	3.23E-06	-3.23E-06	1.73E-07	2.21E-06	9.49E-122	1.96E-125	2.71E-124	1.95E-124
	150	900	8.63E-07	-8.63E-07	5.74E-08	4.81E-07	1.00E-179	1.84E-181	9.25E-181	0.00E+00
F5	50	300	125.0459	-0.92443	0.73592	1.4781	9.00E+00	1.06E-42	1.21E-41	6.02E-42
	100	600	7.0475	0.000527	0.13097	0.21975	9.00E+00	2.11E-92	9.36E-91	6.66E-91
	150	900	74.9216	-0.54364	0.83469	1.0029	9.00E+00	3.39E-134	7.78E-133	7.52E-133
F6	50	300	5.68E-11	-0.5	-0.5	2.40E-06	2.50E+00	-7.14E-46	-3.49E-46	2.42E-46
	100	600	8.58E-12	-0.5	-0.5	9.73E-07	2.50E+00	7.77E-94	2.48E-93	1.17E-93
	150	900	6.51E-12	-0.5	-0.5	6.68E-07	2.50E+00	-2.21E-113	-9.17E-114	6.15E-114
F7	50	300	0.0055919	-0.12042	-0.010465	0.08655	0.0006431	-6.88E-60	-3.88E-60	2.61E-60
	100	600	0.0033586	-0.12238	0.014447	0.082234	0.0025307	-2.48E-104	-1.51E-104	8.56E-105
	150	900	0.0027178	-0.10754	-0.0091155	0.083963	0.0015741	1.53E-141	1.45E-140	8.62E-141

However, the experiment is still work in progress as more cases beyond seven for multimodal test functions are currently considered. Figures 2 and 3 represent the parameter spaces and the convergence curves for functions 2 and 5 respectively as samples for unimodal test functions.

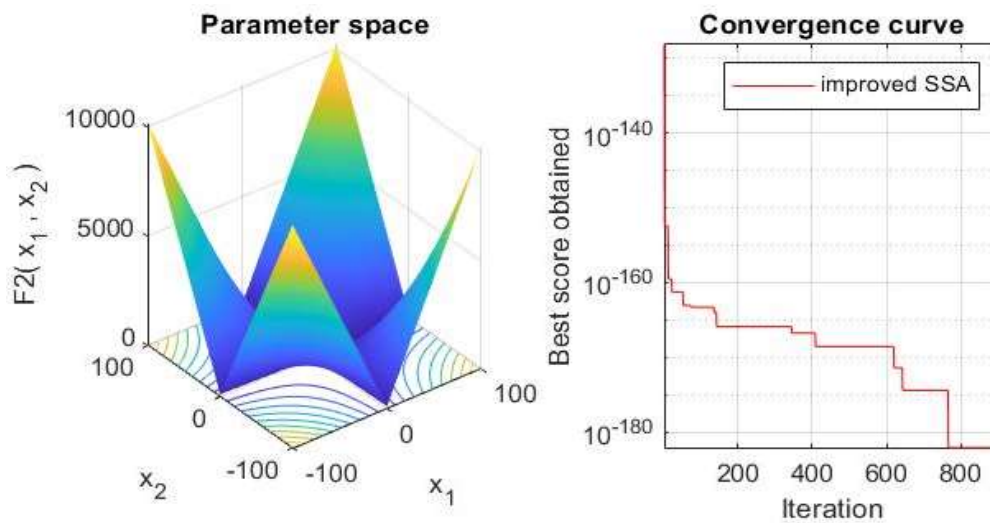


Figure 2: Convergence Curve and Parameter space plot of F2 at 900 iterations

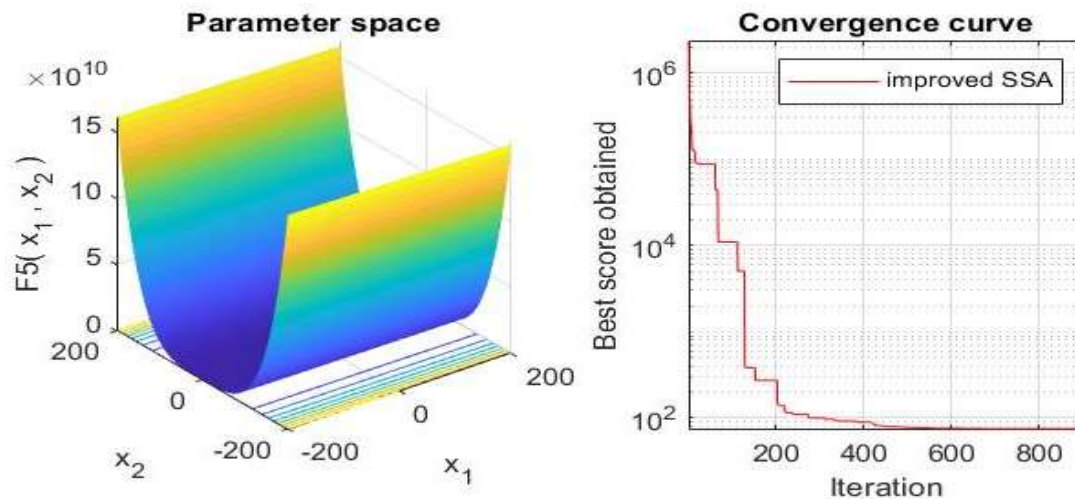


Figure 3: Convergence Curve and Parameter space plot of F5 at 900 iterations

5. Conclusion

SSA, a higher level heuristic algorithm is indeed promising in solving optimization problems for prediction or classification models. However, to solve difficult optimization challenges, the SSA lacks the capacity of fast convergence time and equally poses the tendency of declining into sub-optimal outputs. To solve the problems, this research aims to improve the algorithm using Cauchy mutation and elite opposition based learning strategies. This was achieved by embedding these strategies into the existing algorithm; consequently, yielding out an extended SSA optimization algorithm. The Cauchy mutation was used to create large numbers of mutations to amplify the global search strength, while elite opposition-based learning was applied to generate random initial solutions. Thus, the generated solutions for iteration improve the diversity during the exploration process. Search agents of 50, 100, and 150 were chosen for each bench functions and 300, 600 and 900 numbers of iterations were also chosen for each function. In the end, the results of the enhanced algorithm (EOnCaSSA) outperforms the traditional SSA across the four standard metrics for evaluation, which include best, worst, standard deviation, and average. This is because the seven benchmark functions for unimodal test functions have an optimum value of zero. It has established that performances are measured based on the closeness of the obtained values to zero.

As earlier stated, the experiment for the proposed EOnCaSSA is still in progress because more test functions of 8 to 14 would be carried out to create room for multimodal test functions. In that way, the robustness of EOnCaSSA would have been ascertained and affirmed. Similarly, in the nearest future the researchers hope to further use the algorithm to optimise a given set of Ebola virus's dataset for a more accurate prediction model.

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Improving the Accuracy of PCOS' Data Prediction Model Based on Data Balancing and Multilayer Feature Selection Strategies.

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Abstract.

The use of machine learning algorithms to design a model for PCOS prediction or diagnosis in a recent time is attracting an impressive magnitude of research attentions. Of course, the rationale behind this development is not farfetched as the disease is common in women of reproductive age, which causes infertility. Also the algorithms as top notch techniques for classification, are highly promising. However, attention has to be paid to the raw dataset used for training the models; this is because the strategies adopted for feature engineering processes have direct proportionate effect on the robustness state of the model. Meanwhile, significant efforts have been advanced towards this development but that does not foreclose adoption of more strategies for better accuracy of the model. To this end, this research aims to adopt multilayers strategies in terms of class balancing and feature selection to improve the accuracy of the existing PCOS's data. The strategies include the use oversampling and LASSO-Pearson's correlation techniques for class balancing and feature selection respectively for the proposed ensemble random classifier based model. The 97.80% accuracy result of the proposed model outperforms the rest of the other seven models used in the benchmark work. Therefore, careful attentions have to be constantly advanced towards the process of feature engineering, which include data preprocessing, data exploratory, data balancing and feature selection strategies for optimal result.

Keywords: PCOS model, LASSO-Pearson technique, Oversampling, Data balancing, Classifier

1. Introduction

Preterm abortions, infertility, anovulation and other issues have a significant impact on the world's female population today. It has been noted that Polycystic Ovary Syndrome (PCOS), a disorder common in women of reproductive age, plays a significant role in the causes of infertility. PCOS affects more than five million women globally who are of reproductive age. It is an endocrine condition defined by alterations in the levels of female hormones and aberrant in male hormone synthesis (Denny *et al.*, 2019). One of the most prevalent reasons of female infertility is Polycystic Ovary Syndrome (PCOS), which affects many women of reproductive age and even persists well after the child bearing years (Inan *et al.*, 2021).

To this effect, some clinical efforts such as in vitro fertilization (IVF) have been developed and exploited to address this challenge. In order to show how devastated the challenge is, the increasing number of couples seeking in vitro fertilization (IVF) globally has made infertility a global health concern. After multiple IVF treatments, some couples are still without children as a result of inaccurate diagnosis. IVF for women comes with additional dangers and costs. One of the most prevalent types of endocrine disorders in women of reproductive age is Polycystic Ovary Syndrome (PCOS). Consequently, anovulation and infertility could occur from this problem. Therefore, the clinical and metabolic markers that serves as an early indicator of the disease are part of the diagnostic or

prediction criteria (Mehrotra *et al.*, 2019). However, in order to ensure accurate and proper diagnosis of the disease indications; a lot of research efforts have been geared towards exploitation of the cutting edge technologies.

A ground breaking example of these technologies include the artificial intelligence (AI) specifically, machine learning models, which have the potentials to classify and predict the likelihood of PCOS disorder. Examples of these models include Support Vector Machine (SVM), Random Forest (RF), K-Nearest Neighbor (KNN), Naïve Bayes (NB), Multi-Layer Perceptron (MLP) and XGBoost (Abrar *et al.*, 2010; Cinar & Koklu, 2019; Khan *et al.*, 2021; Mustaqeem *et al.*, 2017; Sathe & Adamuthe, 2021; Zhang *et al.*, 2019). Of course, so many researchers in this field have been putting up several efforts in using these models to accurately diagnose the disease based on the given dataset. However, the level of accuracy has been hampered and distorted as a result of the imbalance nature of datasets or lack of robustness in decisively carrying out the process of feature engineering. In furtherance to this development, Inan, *et al.*, 2021 employed SMOTE and ENN as two strategies for data sampling; also, Chi square and ANOVA tests were similarly used as techniques for feature selection. All these efforts were carried out on the dataset obtained from kaggle repository for PCOS diagnosis model. The researchers trained and evaluated the PCOS dataset on seven classifiers where in the final analysis, extreme gradient boosting classifier is adjudged to be the best with accuracy rate of 95.83%.

Furthermore, based on literature; there are other similar techniques for class balancing that have been constantly employed for training models. Resampling techniques (such as random oversampling or random under sampling), sample weight and SMOTE are part of the most popular techniques to achieve class balancing (Arora *et al.*, 2020; Bae *et al.*, 2021; Pecorelli *et al.*, 2019). Similarly, lasso regularization is one of the prominent feature selection techniques that have been increasingly used for training models (Afrin *et al.*, 2021; Ghosh *et al.*, 2021; Muthukrishnan & Rohini, 2016). However, the technique is not sufficiently efficient to carry out optimum selection of features. In view of this development, there have been constant efforts to extend the use of Lasso algorithm either by improving it by manipulating variables or hybridizing with other reliable techniques as noted in some literature (Chen *et al.*, 2019; Luo *et al.*, 2021; Zhang *et al.*, 2021).

As a result of this feat, this research aims to improve the accuracy of the same dataset (both in features and data points) by employing the simple but reliable random over sampling data balancing strategy. Similarly, Least Absolute Shrinkage and Selection Operator (LASSO) regularization and Pearson's correlation feature engineering techniques are equally employed. Finally, ensemble random classifier is used as for the training of the PCOS' data model and the accuracy performs better than the seven model classifiers used in the benchmark research. Therefore, the remaining sections of the research are organized as follows: section 2 presents the account of the related works, and the proposed methodology is presented by section 3. Others are results discussion and conclusion, which are presented by sections 4 and 5 respectively.

2. Related Work

This section gives a brief related literature on Polycystic Ovary Syndrome and the application of machine learning models to proffer viable solutions in addressing the challenges of accurately predicting PCOS disorder in a given dataset. In the light of this, the literature of Denny *et al.*, (2019) aim at detecting and predicting PCOS at an early stage for an optimal and minimal but promising metabolic and clinical parameter. The research employed six traditional machine learning models which include but not limited to Naïve Bayes classifier method, Logistic Regression, K-Nearest Neighbor (KNN), and Random Forest classifier (RFC). In order to obtained optimal results, Principal Component Analysis (PCA) is used for the feature selection strategy. A total of 541 patient samples

were collected for this study, 364 cases were PCOS negative and 177 cases of PCOS positive and 23 features were used which include the reports on TVS, hormone profile and patients way of life. Evaluation was done in terms of Accuracy, Precision, Sensitivity/Recall, Specificity, F1-Score. The RFC outperformed other learning models with an accuracy of 89.02%.

The research of Mehrotra *et al.*, (2019) also aim to develop an automated screening system that would help in the early detection of the disease. Two classical machine learning models were used in their work, these are Bayesian and Logistic Regression classifiers. Feature selection was done via two sample t-tests to select a significant subset of original feature. Nine parameters were considered; and a total of 200 patients were considered for the study among where 50 patients were normal and 150 suffer from the disorder. The overall accuracy of Bayesian classifier is 93.93% as compared with logistic regression i.e. 91.04%. Similarly, Bharati *et al.*, (2020) focused on diagnosis of PCOS data in women based on some models which include Extreme Gradient Boost, Random Forest, Logistic Regression and a hybrid of Random Forest and Logistic Regression. A Univariate Feature Selection algorithm was employed as the feature selection technique to identify the important features and find their scores. A total of 541 samples with 43 attributes were gotten from Kaggle repository. Thus, the hybridized model performed better than other models in terms of accuracy (for 10 feature: 90.01%, for 14 feature: 89.27%) and recall using 40-cross fold validation (91.01%).

Furthermore, the literature Cheng & Mahalingaiah, (2019) carried out evaluation performance of two machine learning text algorithms (rule base classifier and gradient boost tree model) in the classification of PCOM in pelvic ultrasound. Feature extraction was done via Porter's Snowball Algorithm. The result of the evaluation shows that rule base classifier slightly outperforms the gradient boost tree model with an accuracy of 97.6% while the latter has 96.1%. The two classifiers estimated prevalence of PCOM with our population ultrasounds to be about 44% for PCOM absent, 32% for PCOM unidentifiable and 24% for PCOM present.

Similarly, five learning models, which include RF, LR, DT, SVM and KNN along with SMOTE were used in the research of (Dutta *et al.*, 2021) who proposed to detect and predict PCOS in a give set of data. Principal Component Analysis (PCA) was used for feature extraction with a total of 541 records having 41 attributes obtained from the UCI repository. The SMOTE based LR performed best in terms of accuracy, training time, F1 score, recall, prediction and area under the ROC of 97.11%, 0.010 sec., 98%, 98%,98% and 95.6% respectively.

In addition, the literature of Madhumitha *et al.*, (2021) proposed SVM, LR and KNN also a stacking ensemble of these three algorithms were employed to identify follicles and edges in images. Gabor wavelet was used as their feature extraction technique; thus, the hybridized model outperformed other models in terms of accuracy, recall and precision. Also, an automated ovarian classification method for classifying ovary into normal or not in an ovarian ultrasound image was proposed by (Nilofer & Ramkumar, 2021). The researchers made use of ANN, KNN, SVM and IFFOA-ANN; while Grey -level co-occurrence matrix was used in the extraction of features. The IFFOA-ANN outperformed other machine learning models used in terms of accuracy with 97.50%.

Hassan & Tabasum, (2020) employed the learning algorithms which include Support Vector Machine (SVM), Naïve Bayes (NB), Logistic Regression (LR), and Random Forest (RF) to diagnose PCOS based on clinical data of the patients. R-language was used for the implementation of algorithms, and RF performed best with an accuracy of 96%. The researchers thus submitted that further work can be done by making use of a larger size of data sets in the diagnosis of the disease. Also, the literature of Nandipati *et al.*,(2020) aim to know the features that play a role in the prediction of the PCOS disease

and to determine which machine learning model performs better in the detection of the disease. A dataset consisting of a total of 541 women through survey from consultations from doctors and clinical examinations were considered in this study. SPSS V.2.0 was used to extract 8 features from a total of 23 features consisting of both clinical and metabolic parameters. The Synthetic Minority Oversampling Technique (SMOTE) was used as the preprocessing technique in this study. Seven machine learning models were employed to evaluate the disease. Consequently, Random Forest performed best with an accuracy of 93.12%. Future study suggests to build a better model for the PCOS data set using 10 features and complete attributes.

The use of this particular PCOS dataset of 540 data samples with 41 features (columns) from kaggle repository is very prominent for developing PCOS model. The research of Inan *et al.*, (2021) premised their diagnostic model on the dataset through the use of seven learning models. They are SVM, KNN, RF, MLP, NB, adaboost and XGBoost; SMOTE along with ENN and chi square with analysis of variance (ANOVA) tests were used as data sampling and feature selection techniques respectively. Based on the results, XGBoost outperformed other models with an accuracy rate of 95.83%.

In conclusion, based on the related literature reviewed in this research, the proposed PCOS's data prediction is promising as the accuracy result outperforms the related literature of the same dataset and those with close range.

3. Methodology

The proposed methodology in this research is described as multi-stages approach, which ranges from data source to model evaluation. Figure 1 presents the detail stages involved along with the explanation.

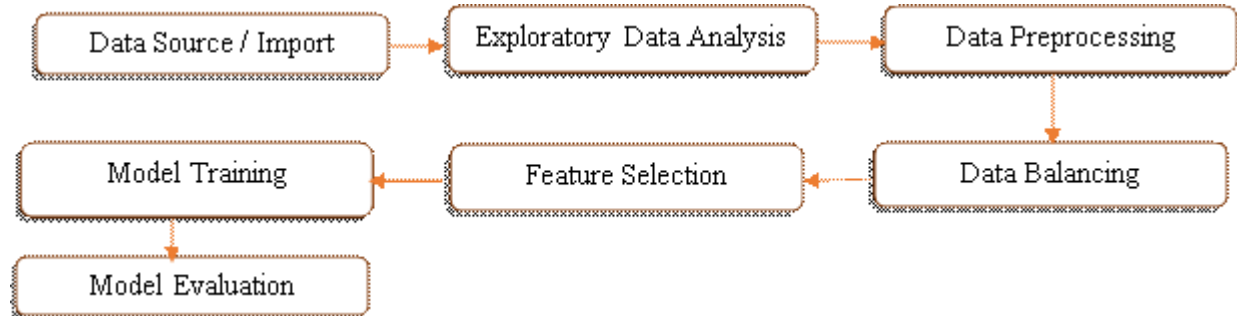


Figure 1: Multi-Stages Methodology

Following the proposed methodology as schematically presented by Figure 1, the dataset used in this experiment is obtained from kaggle repository, which is the same dataset used by the research of Inan *et al.*,(2021). The PCOS raw dataset consist of 45 features (attributes) and 541 data points (data samples); and they are imported from google drive since Google Collaboratory is the choice of environment for implementing the model. The dataset is in comma separated values (csv) format; and based on the data exploration and visualization, the dataset include 177 patients with the PCOS disorder and 364 with no disorder. That is, 177 Yes data points and 364 No data point respectively. However, with this analysis, it is obvious that the dataset is highly imbalanced; which can drastically reduce the overall prediction's accuracy or causes bias during predictions. More so, most of the features consist of floating point value with some features containing missing value that are not closely distributed. Therefore, data preprocessing such as data cleaning, data scaling and data balancing is required.

The data cleaning includes removing of inconsistency, missing value and irrelevant features such as patient file No, Patient ID from the dataset since they have zero impact on predicting PCOS status. Similarly, some features with non-floating values are converted into floating point values. This is to ensure data standardization (scaling) of features' value with highly distributed floating-point value. The Min-Max Scaling (value between 0 and 1) approach is adopted for this stage of the work. At this point, before features are selected, this research employs the technique of Random over Sampling for data balancing. This approach enables generation of data samples for the minority class (the 'Yes' class). Consequently, both classes would contain the same set of data points with 364 samples from each class. More importantly, this stage is necessary because if the classes of the data are not balanced, it would be difficult for the feature selection technique of Pearson correlation feature filtering to work properly.

The feature selection process includes extracting essential features or attributes that have high contribution to the final prediction class. Therefore, in this research Lasso Regularization and Pearson's Correlation techniques are considered. The raw dataset is first fed into the lasso regularization to extract important features by adding a penalty score or threshold on all the features. Similarly, Pearson's correlation feature technique is used for selecting best feature for dataset with numeric input and output. It's used in selecting the best features that can predict the dependent variable (output). Finally, the preprocessed and selected features of the datasets are split into training set (for training the model) and testing set (for evaluating the model) in the ratio of 75% and 25% respectively. While, the training data is fed into the ensemble random forest classifier, the testing data are evaluated considering the metrics of precision, recall, f1-score and support.

Python 3.9.0 forms the experimental environment for the implementation of this methodology. It is important to mention that this research focuses on techniques of data balancing and feature selection to improve the accuracy of the PCOS model. This is better represented by the algorithmic design in Table 1.

Table 1: Optimum PCOS's Feature Subset Algorithm

Algorithm3.1: Optimum Feature Subset Algorithm

Input: CSV Based PCOS Dataset

Output: Returns t_{ff}

Parameters: Python Packages and Classes such as *edu.stanford.nlp.tagger.maxent....*, *py.io.BufferedReader*, *py.io.FileReader* (list); input PCOS data (t); *preProcessFxn()*; *candidateTerms* (t_c); *featuresSubset* (t_f) *LASSO*(t_c); *minimalClass* (c); *maximalClass* (n); *randOverSamp*(c); *pearsCorr*(t_f); *optimumFeaturesSubs* (t_{ff}); *LSTM*(t_{ff})

Procedure:

```

1   Input  $t$ 
2   forAll  $t$   $preProcessFxn(t)$ 
3        $t_c \leftarrow preProcessFxn(t)$ 
4        $LASSO(t_c)$ 
5        $t_f \leftarrow LASSO(t_c)$ 
6       while  $c \neq n$ 
7           execute  $randOverSamp(c)$ ;
8            $c++$ ;
9       end
10       $pearsCorr(t_f)$ 
11       $t_{ff} \leftarrow pearsCorr(t_f)$ 
12      return  $t_{ff}$ 
13       $LSTM(t_{ff})$ 
14  end

```

From the algorithm as shown in Table 1, the raw PCOS dataset is inputted where each and all the inputted text is preprocessed to eliminate unwanted text; consequently, the text produced is known as candidate terms (t_c) as shown by steps 1 to 3. Thereafter, LASSO regularization techniques is employed as feature selection strategy where it acted as function on the t_c as input parameter. It thus produce result called feature subset (t_f) as presented from steps 4 to 5.

At this point, the second feature selection strategy, which is Pearson's correlation cannot be used due to the imbalance of the classes. From steps 6 to 9, attention has to be paid to the minimal class (c) by bringing to it a data resampling strategy herein named *randOverSamp* to populate the class. Thus, the algorithm execute the resampling method *randOverSamp(c)* and the number of the minimal classes start to increase until it is equal to the number of maximal classes. From steps 10 to 13, the second feature selection function called *pearsCorr(t_f)* which accept the output of the first feature selection strategy as input is invoked. Finally, it return an output described in this research as optimum feature subset (t_{ff}) where 75% of the dataset is used for the LSTM based model training.

4. Results and Discussion

This section discusses the results of the proposed techniques for dataset balancing and the multilayer feature selection. Finally, the results of the PCOS prediction model using ensemble random forest classifier and comparison with the related classifiers are also presented. The approach for the results analysis is premised on the proposed methodology sequentially, and the optimum feature subset algorithm. Thus, Figure 2 which denotes the exploratory data analysis is presented.

▼ Exploratory Data Analysis

```

1 yes_count, _ = dataset[dataset['PCOS (Y/N)']==1].shape
2 no_count, _ = dataset[dataset['PCOS (Y/N)']==0].shape
3 print(f'Yes Count : {yes_count} | No count : {no_count}')
4 print(f'PCOS DATASET {dataset.shape}')

```

```

➤ Yes Count : 177 | No count : 364
  PCOS DATASET (541, 45)

```

Figure 2: Exploratory of the Data

The essence of this Figure 2 that presents the exploratory view of the data analysis for each class count is to put forward a strong argument why there is need for a more strategic data balancing approach. From the Figure, patients with PCOS disorder are 177, while patients with no disorder are 364. This clearly establish the need to balance the data (class); thus, the strategy of random over sampling with imblearn. It randomly populate the minority class, which is the Yes class for the class to maintain balancing level. Furthermore, in order to have a well selected features, this research proposed the combined efforts of lasso regularization to extract very relevant features and Pearson's correlation technique for optimal feature selection. In view of this, the dataset is fed into the lasso regularization technique by continuously adding a threshold on all the features. Consequently, and based on experiments the best threshold identify during the series of trials is 0.004 as shown by Figure 3.

▼ LASSO REGULARIZATION

```

1 from sklearn.linear_model import LogisticRegression
2 from sklearn.feature_selection import SelectFromModel
3 # from sklearn import selecto
4
5 # set the regularization paramter c=1
6 logistic = LogisticRegression(C=1, penalty='l1', solver='liblinear', ran
7 model = SelectFromModel(logistic, prefit=True)
8
9 x_new = model.transform(X)
10 print(x_new)
11
12 select_colum = X.columns[X.var() > 0.004]
13 print('Number of column: ', len(select_colum))
14 print('columns : ', select_colum)
15
16 # Dropped colums have value of all 0s, keep other columns
17 # select_columns = selected_features.columns[selected_features.var() != 0]
18 # select_columns
19

```

Figure 3: The Implementation of Lasso Regularization

With the threshold of 0.004 as shown in Figure 3 to implement the effective selection of features by the technique, the result of the implementation is presented by Figure 4.


```

Number of column: 33
columns : Index(['Age (yrs)', 'Weight (Kg)', 'Height(Cm) ', 'BMI', 'Blood
'Pulse rate(bpm) ', 'RR (breaths/min)', 'Hb(g/dl)', 'Cycle(R/I)',
'Cycle length(days)', 'Marraige Status (Yrs)', 'Pregnant(Y/N)',
'No. of abortions', 'I beta-HCG(mIU/ml)', 'II beta-HCG(mIU/ml)',
'Hip(inch)', 'Waist(inch)', 'Waist:Hip Ratio', 'AMH(ng/mL)',
'PRL(ng/mL)', 'RBS(mg/dl)', 'Weight gain(Y/N)', 'hair growth(Y/N)',
'Skin darkening (Y/N)', 'Hair loss(Y/N)', 'Pimples(Y/N)',
'Fast food (Y/N)', 'Reg.Exercise(Y/N)', 'Follicle No. (L)',
'Follicle No. (R)', 'Avg. F size (L) (mm)', 'Avg. F size (R) (mm)',
'Endometrium (mm)'],
dtype='object')

```

Figure 4: The Result of Lasso Regularization

With the implementation of Lasso algorithm, 33 features were selected out of the original features of 45. Based on the result, it was observed that the features obtained are yet to be optimal; hence, the need for further action is required, which necessitated for Pearson's correlation.

Pearson's correlation feature technique is used for selecting best feature for dataset with numeric input and output. It's used in selecting the best features that can predict the dependent variable (output). The PC feature filtering allows the option of selecting numbers of features that are highly significant in predicting the output. After series of trials, the best 24 features were found to yield the best result.

After series of feature engineering processes, which include preprocessing, features selection, and data balancing where 24 optimum features were obtained. The dataset is split into 75% and 25% for training and testing respectively. The training set was fed into the random forest classifier tuning out an accuracy of 97.80% as shown by the model in Figure 5.

ENSEMBLE RANDOM CLASSIFIER

```

1 from sklearn.ensemble import RandomForestClassifier
2 rf_classifier = RandomForestClassifier()
3 rf_classifier.fit(X_train, y_train)
4 rf_classifier.score(X_test, y_test)

```

0.978021978021978

Figure 5: Accuracy Result of the Model

Based on figure 5, an accuracy of 97.80% is achieved using the ensemble random forest classifier. Similarly, the result of the model evaluation for precision, recall and f1-score were equally obtained as 99%, 96% and 98% respectively. Consequently, the accuracy result obtained was compared with the seven models used in the benchmark literature based on the same dataset. Table 1 presents the comparison results.

Table 1: Model Result Comparison

	Benchmark Models							Adopted Model
Models	SVM	KNN	RF	AdaB	XgB	NB	MLP	Ensemble RF
Accuracy (%)	93.75	87.50	92.71	92.71	95.83	93.75	92.71	97.80

Obviously, as shown by Table 1 the result of ensemble random classifier as the adopted model performs better than the seven models that were previously considered in the benchmark paper. For better representation, Figure 6 presents the summary result graphically.

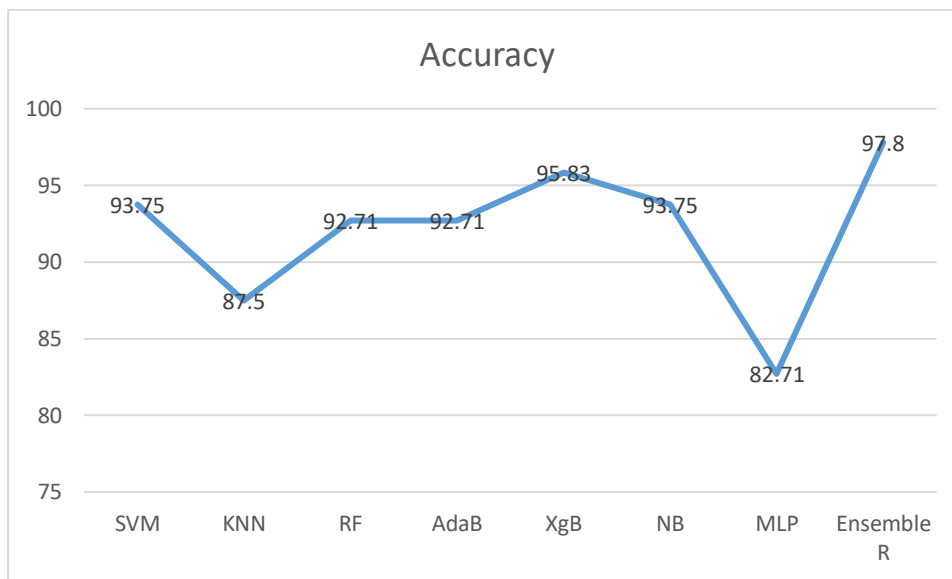


Figure 6: Model Accuracy Graphical Representation

As shown by the figure, the adopted ensemble random classifier (ensemble R) has the highest accuracy of 97.80% over the remaining models earlier used to classify the same dataset from the benchmark literature.

3. Conclusion

It is unarguable fact that in recent time there have been constant efforts geared towards having a better result accuracy for PCOS' data based on machine learning models. However, that does not foreclose a further attempt to improve on the accuracy. In view of this development, this research aims to improve the accuracy of PCOS's data prediction model by rigorously considering the proposed multi layers methodology. The methodology consist of seven stages ranges from data source, exploratory data analysis, data preprocessing, data balancing, feature selection, model training and model testing. The comma separated value dataset, which originally consist of 541 datapoints and 45 features is obtained from kaggle repository and imported via google drive. The data is scaled via min-max scaling approach; and random over data sampling was equally employed for class balancing. Lasso regularization and Pearson's correlation were the combined strategy for effective feature selection.

More so, owing to the sizeable numbers of learning models that the benchmark research had earlier employed, which include SVM, KNN, RF, MLP, NB, adaboost and XGBoost; the proposed model of this research was trained based on ensemble random classifier. The result of accuracy which is 97.80% performs better than all the other seven training models. However, this research experiment is still work in progress; interested researchers can exploit other robust feature engineering mechanisms to ascertain further, the reliability of the mechanisms deployed on this research. This is because researchers hope to employ word2vec or WordNet as data augmentation strategy to cushion balance for the given dataset to derive contextual knowledge. In other words, this anticipation would pave way for the deployment of robust networks (deep learning) models against the use of traditional learning models. Furthermore, in future it is intended to employ the mechanisms on other related datasets to validate their strengths.

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Performing Data Augmentation Experiment to Enhance Model Accuracy: A Case Study of BBC News' Data

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Abstract.

In natural language processing, text classification forms an essential task to be performed; as such, the use of machine learning algorithms have constantly become indispensable and significance to the research drive. However, the problem of solving text classification with the traditional models gets more challenging because of ambiguities associated with natural languages. A typical example is synonyms' concept mismatch, and other related issues that accurately attribute text to their related contexts. While a more robust model with an increased number of hidden layers such as LSTM is essential, because of the volume of data involved; exploration of strategies for data augmentation is highly significant. To this end, this research aims to employ semantic lexical database, called WordNet as strategy to augment the BBC news textual data obtained from kaggle repository. This is to pave way for a more efficient news data classification based on the proposed LSTM model. The total BBC news samples are 2,225 data points, and each data point is grouped into five different news categories, which include, technology news, business news, sport news, entertainment news, and political news. Experimental evaluations are carried out using the benchmark BBC news dataset; and the newly augmented dataset within the scope of this study. Consequently, the accuracy of the classification LSTM model for original news dataset and the augmented dataset are 90% and 95% respectively. Therefore, the proposed data augmentation strategy is promising for textual datasets.

Keywords: Data augmentation, WordNet, BBC news data, LSTM model, contextual meaning

1. Introduction

Presently, the application of artificial intelligence (AI) technique to any real life domain has significantly increased due to its overwhelming performance in providing solutions to complex problems. Conversely, the performance of deep learning models outweigh the classical machine learning techniques (Chlap et al., 2021). However, for an optimal performance of the (deep) models, it requires a larger volume of data for training. But the availability of huge volume of datasets in most cases are serious issues to contend with by researchers because of limited datasets (Duong & Nguyen-Thi, 2021). This is because to obtain a well annotated datasets, a lot of resources (in terms of time and costs) are involved. Thus, the need for data augmentation technique becomes inevitable to deal with the challenges of data sparsity during the process of text classification. Also, the techniques have severally served as booster for the accuracy of learning models (Hernandez-Garcia & Konig, 2018).

It is an undisputable fact that during the last decade, text classification, an indispensable task in natural language processing has witnessed constant attention from researchers as a result of the potentiality of both traditional machine learning and deep learning algorithms. Many of these models have been consistently employed to classify text, (news data classification) for example. Naïve Bayes (NB) is the first classification technique employed for the task of text classification (Li, et al., 2020). Afterward, other traditional models otherwise known as classifiers, such as Support Vector Machine (SVM), Random Forest (RF), and K-Nearest Neighbour (KNN) followed. Although, in a recent time

eXtreme Gradient Boosting (XGBoost) has arguably identified to possess the capability to produce far reaching accuracy as compared to the previous classifiers.

However, as the problem of solving text classification with the traditional models get more challenging; a more robust models with an increased numbers of hidden layers such as Long Short Term Memory (LSTM), Bidirectional Encoder Representation from Transformers (BERT), Convolutional Neural Network (CNN), Recurrent Neural Network (RNN) offer more potentials to deal with the problem (Dogru, et al., 2021; Joshi, et al., 2020). Although, some of the models (CNN) are not primarily designed for textual data classification. Therefore, news data classification such as the BBC textual sample dataset obtained from kaggle online repository in this research equally requires the techniques of data augmentation as a result of ambiguity in natural languages. Consequently, effective news classification strategy has to be deployed to obtain contextual meaning of news article. However, only limited numbers of research have been carried out in this regard.

Furthermore, as earlier stated, it is unarguable fact that the efficiency of the top notch models (such as LSTM) heavily relies on huge volume of datasets. Besides, the availability of all forms of data are actually scarce or limited (Shorten & Khoshgoftaar, 2019); although depends on the domain for the dataset. Consequently, the technique of data augmentation is promising to provide the needed palliative to cushion the efficacy of the deep learning models. However, based on literature, images type of data augmentation strategies have enjoyed better attention from the researchers than the textual forms. One of the fundamental reasons attributed to text based augmentation algorithms is the lack of generalized rules for natural language transformation owing to the ambiguity of natural language itself (Wei & Zou, 2019). Therefore, interested researchers resulted to devise a mechanism to augment textual data by translating sentences from one language to another (Yu et al., 2018). Other devised mechanisms used include data noising as smoothing (Xie et al., 2017); and predictive language mechanisms for replacement of synonym (Kobayashi, 2018).

Similarly, beyond data augmentation that is typically used in image classification by generating more image data, the technique is equally applied for textual data classification by also generating more data but leverage on different strategies (Duong & Nguyen-Thi, 2021). This is because data augmentation is more complex in textual form of data. More so, an improvement of original datasets either to increase the size, or process the relevant data in terms of contextual meaning or feature extraction via the strategy of data augmentation is not limited to a particular domain but across different real life scenarios. It cut across different spheres of domains such as biomedical (Geng et al., 2022); computational chemistry (Ulrich et al., 2021).

One of the primary strengths of data augmentation techniques largely lies on its ability to prevent overfitting. This is achieved by adjusting or amending the limited datasets to possess the qualities of big data (Shorten & Khoshgoftaar, 2019). Necessary precaution has to be observed when choosing the strategy of data augmentation because there is tendency of overfitting or poor performance during training when increased volume of augmented data are considered (Duong & Nguyen-Thi, 2021). This scenario may occur if the augmented data are closely similar or different from the original data. In view of this development, this research aims to exploit a semantic lexical database called WordNet (Chakravarthi et al., 2018) to augment the BBC dataset for the sole goal of contextual meaning of the data based on LSTM model. WordNet, a semantic lexical data source similar in structure as ontology has over time prove its capacity to close the gap of ambiguities associated with the natural languages (Jarrar, 2021). WordNet typically consist of three databases namely, nouns subnet, verbs subnet and adjective/adverb subnet databases in support with semantic relations; such as synonyms, hypernyms, hyponyms, holonymys, and meronymys (Fawei et al., 2019; Uthayan & Mala, 2015). An experimental

evaluation would be conducted to compare the results of LSTM model without augmentation strategy and LSTM model with WordNet data augmentation strategy. Finally, the remaining sections of this paper are organized as follows: section 2 accounts for the related work while, the proposed methodology is presented in section 3. Section 4 presents the discussion of the results based on the methodology; and section 5 presents the conclusion of the paper. STOP

2. Related Work

This section gives a brief related literature on data augmentation techniques on textual and images data, but with a close focus on the former. Expectedly, the techniques are not considered in isolation that is, the application of both machine learning and deep learning models for text classification are equally considered in this section. To this end, the literature of (Wei & Zou, 2019) aims to improve the performance of CNN-RNN based text classification model using easy data augmentation, which consist of random swap, random insertion, random deletion and synonym replacement. The researchers admitted that for efficiency use of EDA, a synonym dictionary (WordNet) would have improved its accuracy. However, they encountered challenge of computational accessibility. Similarly, the research of (Duong & Nguyen-Thi, 2021) acknowledged the significance of data augmentation for small dataset. Easy Data Augmentation (EDA) strategy that was first proposed by (Wei & Zou, 2019) was employed for the Vietnamese data. The objective of the technique is solely to obtained synonym replacement randomly in a given sentence of dataset based on logistic regression (LR) and support vector machine (SVM). However, the researchers admitted that the approach is deficient because it can increases the irrelevant sentences.

Furthermore, there are various techniques available for data augmentation. The survey work of (Feng et al., 2021) accounted for some of these techniques considered for natural language processing. They include EDA, feature space, as rule based technique; other techniques are model based techniques, and mixed sample data augmentation otherwise known as interpolation technique. Also, there is always a difficulty in the choice of appropriate data augmentation techniques consequently, experimental evaluation becomes inevitable to untie the quagmire of effective technique to choose. This is the motivation behind the work of (Porcu et al., 2020) who conducted an evaluation to compare the accuracy on the emotion recognition of the facial expression recognition systems. Geometric transformation and oversampling augmentations were considered on the CNN deep network specifically, the VGG16 based on the given datasets. However, generative adversarial networks (GAN) is observed to be deficient in relevant computational complexity.

Data augmentation approach was also reported to be used in the literature of (Shoaib et al., 2022) as a result of limited data available. The work whose aim was to classified brain tumors based on four CNN architectures got better accuracy with the augmented dataset. However, as a result of the data augmentation strategy adopted, the size of the dataset is still small, which inadvertently affects the accuracy of the deep networks based models. Besides, it is deficient in computational complexity as a result of the data size. More so, owing to the importance of classification techniques, Ahmed and Ahmed (2021) carried out a review work on some of the existing techniques or classifiers for categorizing digital news articles. The classifiers considered were Naïve Baiyes (NB), K-Nearest Neighbors (KNN), Logistic Regression (LR) and Support Vector Machine (SVM). The result of the experiment adjudged NB to be the best among the four classifiers; the rationale behind its performance is hinges on different sources of datasets. However, the researchers suggested that more accuracy can be obtained if word or term similarity ranking technique is adopted or adapted especially on a more volume of datasets.

More importantly, text data can emanate from different sources, which include news data, chats, web data, emails, social media, user reviews, to mention a few. No doubt, text is an extremely rich source of information. However, to classify or extract insights from text can be laborious and time-consuming, as a result of its unstructured nature; thus, classification techniques are required. According to the work of Minaee, et al., (2021), text classification can be performed either through manual annotation or by automatic technique. But with the rising scale of text data in industrial usage, automatic text classification is becoming increasingly significant. Automatic text classification techniques are categorized into two approaches. They are rule-based methods and machine learning (data-driven) based methods. More so, the volume of unstructured data in the digital space call for research attention in this present age. This development motivated the research of Dogru, et al., (2021) to advanced investigation on a reliable automatic text classification. On this note, the researchers employed the traditional machine learning classifiers such as Support Vector Machine, Gauss Naive Bayes, Random Forest, and Naive Bayes and the deep learning algorithm: CNN on two English news datasets. The result shown that the deep learning technique outperformed all the other four machine learning techniques on the two datasets. However, the specified value of Doc2Vec method as word embedding approach is not based on any known model.

Similarly, the work of Ramdhani, et al., (2020) canvasses the capacity of deep learning in handling text mining for natural language processing. This is why the researchers were motivated to employ the use of Convolutional Neural Network (CNN) for classification of Indonesian language. The experiment was carried out on four hundred and seventy two (472) Indonesian based news text data from different sources on four major classifications. These are technology, news headlines, entertainment, and sports. While the researchers hail CNN for its accuracy, they however, suggested for more datasets; and more importantly, an improvement by developing variation in the hidden layers. Besides, they suggested further that a different activation function aside sigmoid; and a different deep learning algorithm aside the CNN could be considered. In conclusion, no natural language processing's technique or algorithm is considered in the review work to handle the issue of natural language ambiguities for better accuracy.

Therefore, this research propose to employ WordNet, a semantic lexical database similar in structure with ontology as technique to perform data augmentation to infer the contextual meaning of the given dataset. The BBC dataset, which is 2,225 data points is obtained from kaggle repository.

3. Methodology

The multi-steps data augmentation-modeling (DAM) approach is the proposed methodology to achieve the objective of this research. The methodology consists of five phases, which include data import, data exploration, data preprocessing, data augmentation using WordNet, and model training with the enhanced dataset as represented by the framework of Figure 1.

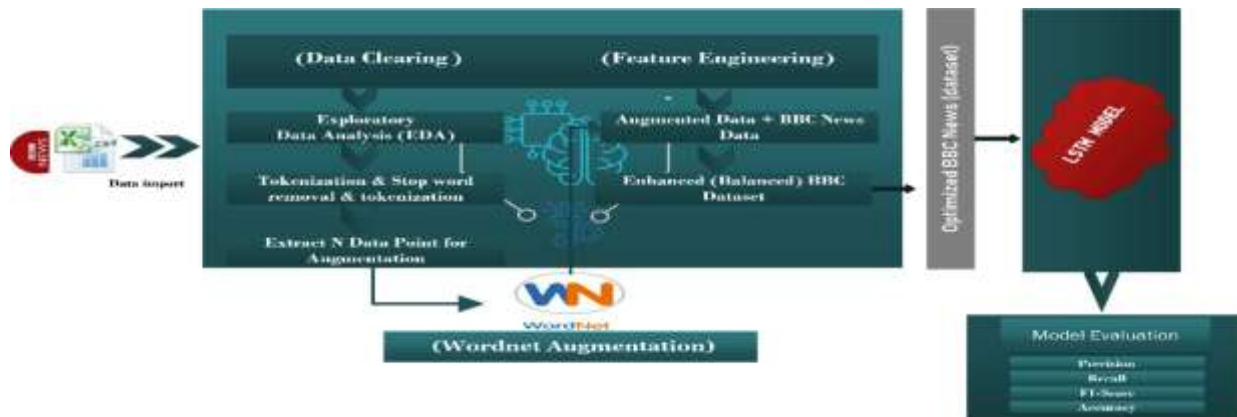


Figure 1: Conceptual Framework for the proposed Technique

From the left hand side of the framework of Figure 1, the initial phase of the methodology is to import the BBC csv dataset obtained from kaggle repository into google collaboratory environment for data science operation. The BBC news dataset contain one input feature (new content) and the output feature (the target class). The total BBC news samples is 2,225 data points, and each data point is grouped into five different classes or news group. This include; technology news, business news, sport news, entertainment news, and political news. The goal is to efficiently classify news articles into the news groups. Based on the statistical data after exploration, dataset's imbalance was identified. While sport and business news classes contain 511 and 510 data points respectively, entertainment news class contains the least data points of 386. Technology and politics news classes contain 411 and 417 data points respectively.

The significance of preprocessing stage otherwise known as data cleaning cannot be over stated because not every content of natural language's text is relevant. If the needful is not done, it can automatically affects the results of training models. The phase include the tokenization of document, removal of punctuation marks and stop words, and stemming of candidate terms. A clear example of result of this phase is <tv, future, hand, viewer, home, theatr> as shown in Figure 2. That is, after stop words (such as *in, the, of*) and punctuations (such as *@, \$, ^*) have been removed.

```

1 | 1. from nltk.corpus import stopwords
2 | 2. from nltk.tokenize import word_tokenize
3 | 3. st_words = stopwords.words('english')
4 | 4. from nltk.stem import PorterStemmer
5 | 5. import string
6 | 6. ps = PorterStemmer()
7 | 7.
8 | 8. def dataset_cleaning(text):
9 | 9.     # removing punctuation from the dataset
10 | 10.     text = ''.join([token for token in text if not token in string.punctuation])
11 | 11.     # tokenizing the dataset e.g ['tv', 'future', 'in', 'the']
12 | 12.     token = word_tokenize(text)
13 | 13.     # removing stopwords (words that had less meaning to the dataset)
14 | 14.     text = [ps.stem(t) for t in token if not t in st_words]
15 | 15.     return text
16 | 16.
17 | 17. bbc_data['clean_text'] = bbc_data['text'].apply(lambda x: dataset_cleaning(x))

```

	category	text	clean_text
0	tech	tv future in the hands of viewers with home th...	[tv, futur, hand, viewer, home, theatr, system...
1	business	wordcom boss left books alone former worlde...	[wordcom, boss, left, book, alone, former, worl...
2	sport	bigers wary of famril gambel leicester way ...	[bigers, wary, famril, gambel, leicester, way, rus...
3	sport	yeading face newcaste in fa cup premiership ...	[yeading, face, newcaste, fa, cup, premiership, ...]
4	entertainment	ocean s twelve raids box office ocean s twelv...	[ocean, twelv, raid, box, offic, ocean, twelv...

Figure 2: Data Preprocessing Phase

The Preprocessed data and cleaned text is represented with the feature name 'clean_text' as shown by the Figure 2. Further preprocessing includes converting the classes (technology, business, sport, entertainment, and political) into number representation (technology = 0, business = 2). This is done or achieved using Label-Encoding. Additionally, for any deep learning classification the following steps are critically important to maintain consistencies among data. They are tokenizer and word index, sequencing, and padding.

Lastly, WordNet Synsets was employed to augment the dataset to improve the prediction accuracy. That is, words synonyms and part of speech tagging were used to substitute words for generating augmented data point; and merge the augmented data point to the main BBC data point. This process is represented by the algorithmic design of Table 1.

Table 1: Algorithm Design for BBC' Dataset Augmentatio

Algorithm3.1: BBC Dataset Augmentation Algorithm

Input: CSV Based Dataset (News Text)

Output: Returns augmented datapoint

Parameters: Python Packages and Classes such as *edu.stanford.nlp.tagger.maxent....*, *py.io.BufferedReader*, *py.io.FileReader* (list); input news text (*t*); *tokenize()*; *stopWordsFxn()*; *wordNet*; *synsets()*; *List_of_Tokens(lt)*; *List_of_News (ln)*; *candidateTerms(cT)*

Procedure:

- 1 Input *t*
 - 2 $lt \leftarrow \text{Tokenize}(t)$
 - 3 $ln \leftarrow \text{stopWordsFxn}(lt)$
 - 4 $cT \leftarrow \text{wordIndexFxn}(ln)$;
 - 5 **Similar_concept[]** $\leftarrow \text{wordNet}(cT)$ // see breakdown from step 6 to 9
 - 6 **for All** *cT* **in** *List_of_News* :
 - 7 $\text{Synset} \leftarrow \text{invoke wordNet}[]$
 - 8 $\text{Similar\_Concept} \leftarrow \text{Append synonyms to } cT$
 - 9 Return augmented datapoint
 - 10 **End**
-

From the algorithm in Table 1, the sample BBC news dataset is inputted randomly where tokenization function acts on it to produce a data structure, in this case called list of tokens (*lt*) as shown by lines 1 to 2. Consequently, a preprocessing function is invoked so as to remove stop words; the result produced is referred to as list of news (*ln*) as presented by line 3. However, there is need to still further remove unwanted terms from the list. Thus, a user defined method, *wordIndexFxn(ln)* is used to perform word ranking and select the most ranking words, which constitute the candidate words (*cT*) as indicated by line 4. Lines 5 to 8 essentially introduce the use of the lexical database (WordNet) to perform the text augmentation in terms of contextual meaning to enrich the raw dataset. Finally, the similar terms which are the augmented data are appended to the initial concepts from the original dataset, which in turn serves as the input data for the LSTM based model training. The algorithm was implemented on python environment.

3. Results and Discussion

The algorithm is implemented using python 3.9.0 and the model experiment was performed in two folds; that is, LSTM model without WordNet, and with WordNet. Both models experiment were placed under the same configuration. For examples, number of embedding network layer, number of LSTM layer, number of dense layer, and same activation function was considered. Others include same loss, optimizer and metrics were used all through; lastly, the same 8 epochs (Number of training iteration) was used.

Firstly, an experiment of the LSTM benchmark training model was performed without WordNet and the result is shown by Figure 3.

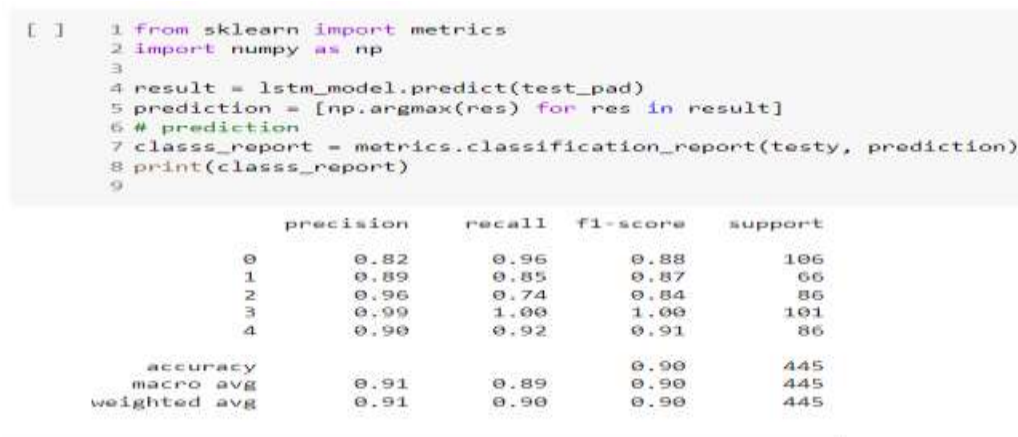


Figure 3: LSTM Benchmark Evaluation without WordNet.

The LSTM model evaluation reported an accuracy of 90% after eight epochs. The results of precision, recall and f1-score are 82%, 96% and 88% respectively.

On the other hand, the algorithm in Table 1 was fully implemented to provide data augmentation to the original dataset before training the model. As earlier explained, random sample was selected from the BBC news items; after preprocessing and tagging of the text, candidate terms was produced. Synsets and part of speech tagging were used to substitute words for generating augmented data points. Lastly, the augmented data points were merged with the original data points. Figure 4 shows the function call to WordNet routing to generate the augmented data points.

```
[ ] 1 from textaugment import Wordnet
    2
    3 wdn_aug = Wordnet(v=False ,n=True, p=0.5)
    4 # wdn_aug.augment('In the afternoon, John is going to town')
    5 # wdn_aug

'in the afternoon, trick is going to town'

[ ] 1 # def generate_aurgdata(dataset ,input_col_name, output_col_name , aug_obj):
    2 import numpy as np
    3 wdn_aud_data = generate_aurgdata(bbc_data, 'text', 'category', wdn_aug)

for [tech] : we are generating [110] arg data
for [business] : we are generating [1] arg data
for [sport] : we are generating [0] arg data
for [entertainment] : we are generating [125] arg data
for [politics] : we are generating [94] arg data
```

Figure 4: Augmented Data with WordNet

As clearly shown by Figure 4, the user defined function, *wdn_aug* of the wordnet receives a sample data to augment the five categories of the dataset. Through this function, augmented data of 110, 125, and 94 were generated for technology, entertainment and politics classes respectively. However, no data point was generated for sport class and only 1 data point was generated for business class because they both have maximum numbers of 511 and 510 data points respectively. This strategy is to ensure class balancing for effectiveness of results. A sample of the augmented data for technology class is shown by Figure 5.

20 # print(len(aug[category]-- tech]))

Execution completed.....

	category	text
0	tech	web pic storage market hots up an increasing i...
1	tech	nintendo adds media playing to ds nintendo is ...
2	tech	digital guru floats sub-\$100 pc nicholas negro...
3	tech	microsoft unveiling security peter microsoft i...
4	tech	us peer-to-peer pirates convicted the first co...

Figure 5: Sample of Technology Data Generated by WordNet

This is how the proposed WordNet generated augmented data for the categories of the news dataset with minimum data points. Consequently, the new augmented dataset was fed into the model with same configuration, an improved accuracy of 95% is obtained as shown by Figure 6.

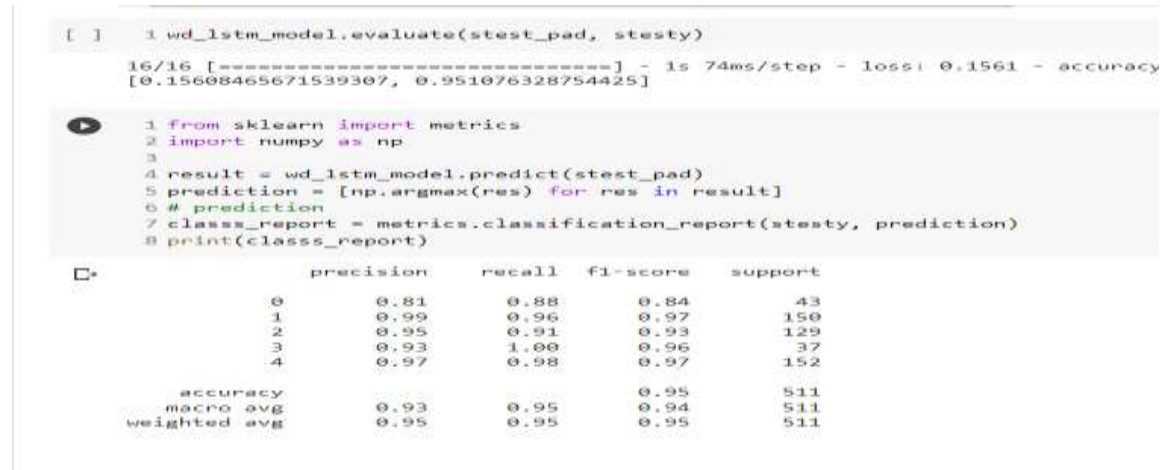


Figure 6: LSTM + WordNet Benchmark Evaluation

Figure 6 depicts the results of how augmented data were generated using WordNet Synsets to enhance the dataset for better prediction accuracy. However, the results of precision and recall tends to fluctuate although, depending on the iteration. The experiment is still work in progress because the researchers are currently employing word embedding algorithm (word2vec) to equally perform data augmentation experiment. Table 2 presents the results comparison of the model with and without WordNet.

Table 2: Comparison of Results Performance

Model/Data Aug. Strategy	Accuracy (%)	F1-score (%)
LSTM/None	90	87, 100, 91 (For iterations 1, 3 and 4)
LSTM+WordNet	95	97, 96, 97 For iterations 1, 3 and 4

Evidently, the proposed LSTM model with WordNet performs better than the ordinary LSTM model without data augmentation strategy as represented by the graph of Figure 7. The results of f-measure fluctuate as iteration 3 performs better than the proposed model; however, iterations 1 and 4 of the proposed model perform better.

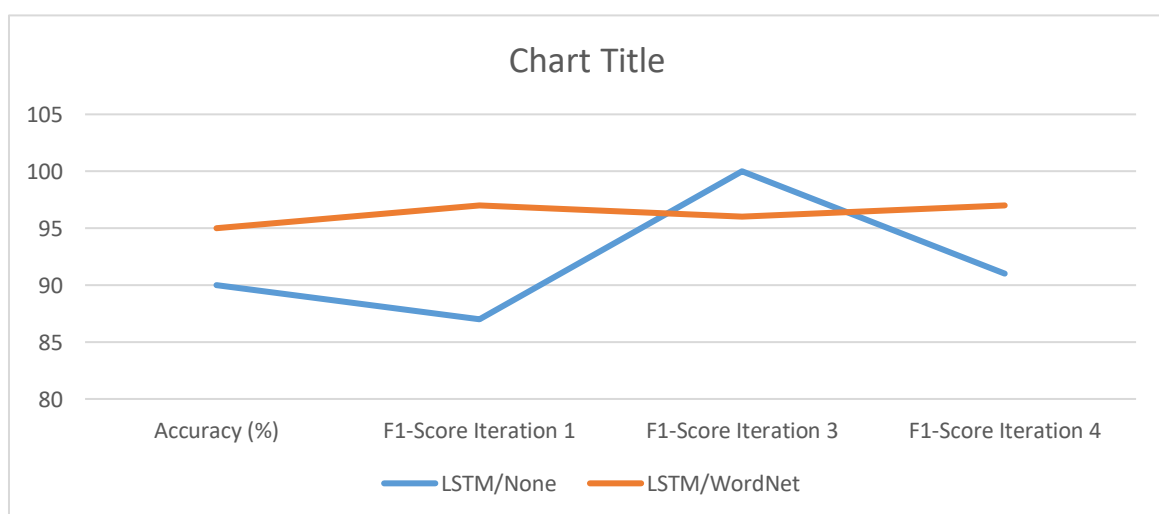


Figure 7: Graphical Comparison of Results

Figure 7 clearly presents the results comparison as depicted earlier by Table 2.

4. Conclusion

Data augmentation is an essential component of text classification in natural language processing. It has constantly demonstrates capacity to improve accuracy of models. However, based on literature some of the technique for data augmentation have shown superiority over others whether textual or images data. Therefore, there is need to perform experiment on any choice of technique to augment a given set of data. In lieu of this development, this research aims to perform experiment and ascertain the viability of WordNet (a semantic lexical data source) to augment BBC news dataset. The dataset, which consist of 2,225 data points was obtained from kaggle repository. Considering the size of the data, this research used the LSTM to design the news classification model. The news is classified into five categories, which include technology news, sports news, entertainment news, business news and political news. Series of preprocessing techniques such as removal of stop words and the user defined word tagging method were employed. At the end, a semantic based algorithm for data augmentation is proposed in this research. The proposed LSTM with WordNet model turns out an accuracy of 95% against 90% for LSTM model without any strategy for data augmentation.

Even though, WordNet has brought a significant improvement of accuracy on the same benchmark dataset, there is need to equally improve on the consistencies of precision and recall's results, which is a function of f1-score as they tends to fluctuate among the iterations. Meanwhile, this research is still work in progress as the researchers are currently using word2vec to ascertain the superiority of the two strategies. More so, in future the researchers hope to exploit other deep learning algorithms such as BERT with Attention mechanism to validate the strength of LSTM with and without data augmentation technique. Besides, Wikipedia data source may be more efficient to deal with compound words or phrases in a given dataset; and at the overall, related synonymous words in contextual meaning are expected to be produced.

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Assessment of the Application of ICT IN TVET Programmes in Technical Colleges in Niger State, Nigeria

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Abstract

This study assessed the application of ICT in TVET programmes in Technical Colleges in Niger State, Nigeria. It investigated the utilization of ICT in TVET's pedagogy and the TVET teacher's competency level. The study was guided by two research questions and one hypothesis. A descriptive survey design was used. The population consists of 122 TVET teachers. A 4-point scale validated questionnaire was used to collect data. For data analysis, Mean, standard deviation and t-test were utilized. Findings showed that, internet search engines (Goggle, Opera mini), are the only ICT resources applied in the teaching and learning process of TVET and TVET teachers are not competent in using majority of the items. Furthermore, there is no significant different between the mean response of TVET teachers with 5-10 years of experience and 11 years and above on the level of ICT competency. It is therefore concluded that ICT resources are grossly inadequate and therefore not applied in the teaching and learning process of TVET programmes in technical colleges. Hence, recommended that Government and other stakeholders should regularly and adequately train and motivate TVET teachers in the use of ICT to help improve the quality of ICT enabled TVET programme. Government should ensure adequate funding for the needed functional ICT resources and infrastructure in TVET programmes are put in place for the teaching and learning process.

Keywords: TVET programmes, TVET teachers, ICT, Teaching, Learning

1. Introduction

Our world is increasingly evolving thanks to technology and all facets of life continue to experience rapid changes as a result. Effective teaching and learning now depend on the usage of internet in the classroom. The internet enables interaction in the digital environment by providing access to information via telecommunications technology (Akturk 2020). Therefore, it is not surprising to observe an increase in the need for ICT applications in technical and vocational education and training (TVET) globally.

ICT is crucial for the modernization of education in every country, according to Madaki et al (2021). By enhancing the pedagogy and delivery methods of instruction, the accessibility of educational resources, and the promotion of fruitful interaction among students, ICT continues to enhance access to instruction. ICT modifies how concepts and procedures are conveyed to students during the teaching and learning process. It also gives students increased access to information, fostering a more positive attitude and sense of confidence in both teachers and students. Jaji (2020).

A key component of the Nigerian educational system is TVET. It was introduced in Nigeria with the mind to impart technical abilities for the country's economic, agricultural, industrial, and

commercial development (Okoye & Michael, 2015). TVET differs from other kinds of education in that it focuses on teaching and acquiring practical and applicable skills as well as fundamental scientific information for the advancement of the nation and the global community. According to Diao et al. (2021), TVET strives to support social development and promote employment, cultivate students' professional talent and spirit, and equip them with the skills necessary to behave appropriately in a variety of settings and take on personal and social obligations.

The use of ICT in TVET programs can be understood as a wide range of hardware and software that are used in teaching and learning systems, including multimedia systems, computer-based training systems, telecommunications systems, electronic performance support systems, as well as the internet with World Wide Web systems. According to Altakhynah and Abumusa (2020), the integration of ICT into the educational system creates a dynamic and proactive teaching-learning environment that can enhance the caliber and accessibility of the instruction given to students. The majority of TVET institutions in developing nations use traditional methods for delivering instruction and learning, requiring that students be physically present in the classroom and that the teacher serve as the primary source of information while the students merely act as consumers of it. A deviation from the norm is necessary given the present dynamics of education and the workplace.

By revitalizing both teachers and students in the classroom, ICT integration creates a dynamic learning environment, according to Saidu and Abubakar (2020). With the aid of ICT, teachers may effectively communicate abstract material, increasing efficacy and improving understanding. The adoption of various ICTs into the educational system and the subsequent understanding of the possible educational benefits are not, however, automatic processes. Teachers need to be adept at using ICT to provide lesson plans in order for this integration and use of ICTs in pedagogy to be successful. According to Paudel (2021), the process of applying ICT in teaching can be quite complicated and challenging when teachers are not equipped with competencies for teaching practices. Computer training enables teachers to acquire more knowledge, which in turn increases their confidence and improves their competency in using ICT for teaching. Computer use will be challenging and frustrating without the necessary expertise and understanding to complete fundamental tasks.

If implemented, the use of ICT in TVET programs would help to enhance the standard of instruction and training in technical and vocational programs and would be extremely advantageous to TVET teachers as it would enable them to quickly and easily produce and modify resources while preparing for their instruction process. Additionally, it would make it possible to differentiate instructional delivery strategies effectively and facilitate the provision of feedback. Thus, the class would be more pleasurable and engaging as a result of the students' increased engagement with and motivation for learning.

In schools with overcrowded student populations and inadequate facilities and classroom design, the traditional teaching approach struggles to keep up. Therefore, it is clear that the traditional educational setting does not appear to be appropriate for educating students to operate or to be productive in the workplaces of today's society, which is why ICT applications

have been incorporated into TVET programs. Therefore, study's aim is to ascertain the degree to which ICT is employed in teaching and learning and how the level of ICT competency of TVET teachers affects the use of ICT in TVET programs at technical colleges in Niger State, Nigeria.

2. Research Questions

The study was guided by the following research questions:

1. To what extent is ICT applied in the teaching and learning process of TVET programmes in Technical Colleges in Niger State?
2. What is the level of TVET teachers' ICT competency in TVET programmes in Technical Colleges in Niger State?

3. Hypothesis

For the study, a null hypothesis was formulated and tested at 0.05 level of significance:

H₀₁ There will be no significant difference between the mean response of TVET teachers with 5-10 years of experience and TVET teachers with 11 years and above experience on the level of ICT competency in TVET programmes in Technical Colleges in Niger State.

4. Methodology

Descriptive survey research design was chosen for the study as recommended by Check and Schutt (2012) for studies that use questionnaire to explore attitude and opinions of a specific population or representative sample on existing phenomena. The area of study was Niger State which has three senatorial districts /zones namely; Zone A, B and Zone C with seven technical colleges across the zones, six (6) of which are State technical colleges and one (1) Federal technical college: Government technical college Minna, Suleman Barau technical college Pandogari, Government technical college, Eyagi Bida, Mamman Kontagora technical college, Pandogari, Government technical college, New Bussa, Government technical college, Kontongora and Federal science and technical college, Shiroro. The research was conducted in each State technical colleges.

There are 122 TVET teachers in state technical colleges across Niger State who make up the study population. The entire population was studied as it was small to be sampled. The researchers and two research assistants who had been briefed on the purpose and details of the instrument, distributed copies of the instrument (validated questionnaires) to the respondents. 108 copies (88%) were retrieved after one week. To assess whether or not respondents were homogeneous with respect to the mean and research questions, the data were analyzed using arithmetic mean and standard deviation. While t-test was used to test the null hypothesis at a 0.05 level of significance. Items with a mean response less than 2.50 suggests that respondents use them less frequently or dispute that they are in use, whereas items with mean responses more than 2.50 indicates that respondents use them more frequently or agree that they are in use. For testing hypothesis ± 1.67 will be the critical value, any item that has its t-value equal or below t-critical was considered not significant, and any item that has its calculated t-value over t-critical was considered significant.

5. Results

Research Question I: To what extent is ICT applied in the teaching and learning process of TVET programmes in Technical Colleges in Niger State?

Table 1: Mean response on the application of ICT in teaching and learning process of TVET programmes in technical colleges in Niger State. N1=46, N2=62.

S/N	ITEMS	X ₁	X ₂	X _t	Remark
1	Audio clips are used for teaching and learning	2.4	2.1	2.3	Unutilized
2	Video clips for teaching and learning	1.6	1.8	1.7	Unutilized
3	Digital library for teaching and learning	1.4	1.9	1.7	Unutilized
4	Internet search engines (Google, Opera mini) to achieve self-directed learning	3.3	2.9	3.1	Utilized
5	Online group discussions/ forums	2.3	2.2	2.3	Unutilized
6	Online tutorial for self- learning	2.3	1.5	1.9	Unutilized
7	Online dictionary (Wikipedia) for teaching and learning	2.1	1.8	2.0	Unutilized
8	Computer simulation (simulating real world phenomenon in 3-D to demonstrate difficult, complex concepts) for teaching and learning	1.2	1.7	1.4	Unutilized
9	Educational games/video games in the classroom to improve manipulating skills and creative thinking	2.0	1.5	1.8	Unutilized
10	Online drill and practice session for mastery	1.8	1.6	1.4	Unutilized

KEY: X₁= average mean responses of TVET teachers with 5-10 Years' experience in technical colleges, X₂= average mean responses of TVET teachers with 11 years and above experience in technical colleges, N1= number of TVET teachers with 5-10 years' experience in technical colleges, N2= number of TVET teachers with 11 years and above experience in technical colleges.

According to Table 1, the respondents agreed with item 4 with a mean score above 2.50 as being utilized. While item 1, 2,3,5,6,7,8,9 and 10 disagreed with a mean score below 2.50 as being unutilized. This indicates that item 4 is being utilized in the teaching and learning process of TVET programmes in technical colleges in Niger State. While item 1, 2,3,5,6,7,8,9 and 10 are not used.

Research Question II: What is the level of TVET Teachers ICT competency in TVET programmes in technical colleges in Niger State?

Table 2: Mean response on the level of TVET teachers ICT competency in TVET programmes in technical colleges in Niger State. N1=46, N2=62.

S/N	ITEMS	X ₁	X ₂	X _t	Remark
1	I know how to download and view PDF file	3.2	3.0	3.1	Agreed
2	I know how to create document using Microsoft word	2.7	2.9	2.8	Agreed
3	I can save documents in the desired location on the desktop	1.5	1.8	1.7	Disagreed
4	I know how to retrieve documents from the place of storage on the desktop.	1.2	1.5	1.4	Disagreed
5	I know how to use web browsers to get access to information (Google, Opera mini among others)	3.6	2.8	3.2	Agreed
6	I can use Microsoft PowerPoint to present data	1.6	1.9	1.8	Disagreed
7	I know how to use spreadsheet software (Microsoft Excel)	1.2	1.8	1.5	Disagreed
8	I know to use a printer to print materials by myself	1.6	1.9	1.8	Disagreed
9	I know how to access educational materials from online libraries	1.4	1.5	1.5	Disagreed
10	I know how to send E-mails	3.6	3.0	3.3	Agreed

KEY: X₁= average mean responses of TVET teachers with 5-10 years' experience in technical colleges, X₂= average mean responses of TVET teachers with 11 years and above experience in technical colleges, N1= number of TVET teachers with 5-10 experience in technical colleges, N2= number of TVET teachers with 11 years and above experience in technical colleges.

Table 2 shows that the respondents agreed with items 1, 2, 5 and 10 with a mean score above 2.50 respectively. While items 3, 4,6,7,8 and 9 disagreed with a mean score below 2.50. Which implies that items 1, 2, 5 and 10 agreed to the level of TVET teachers' ICT competency in TVET programmes in technical colleges in Niger State. While item 3, 4,6,7,8 and 9 disagreed. Indicating a lack of ICT competency among TVET teachers.

Hypothesis I

There will be no significant difference in the mean response of TVET teachers with 5-10 years' experience and TVET teachers with 11 years and above experience on the level of ICT competency in TVET programmes in Technical Colleges in Niger State

Table 3: Analysis of the respondent's t-test results on the level of TVET teachers' ICT competency in TVET programmes in technical colleges in Niger State

S/N	ITEMS	SD ₁	SD ₂	t-test	Remark
1	I know how to download and view PDF file	0.92	0.85	1.15	A
2	I know how to create document using Microsoft word	1.10	0.92	-1.00	A
3	I can save documents in the desired location on the desktop	0.75	0.80	-1.99	NA
4	I know how to retrieve documents from the place of storage on the desktop.	0.51	0.74	-2.49	NA
5	I know how to use web browsers to get access to information (Google, Opera mini among others)	0.75	0.95	4.89	NA
6	I can use Microsoft PowerPoint to present data	0.83	1.11	-1.61	A
7	I know how to use spreadsheet software (Microsoft Excel)	0.42	0.74	-5.33	NA
8	I know to use a printer to print materials by myself	0.91	1.51	-1.51	A
9	I know how to access educational materials from online libraries	0.80	0.57	-0.72	A
10	I know how to send E-mails	0.88	0.69	3.83	NA

Key

SD₁= Standard deviation of TVET teachers with 5-10 years' experience in technical colleges

SD₂= Standard deviation of TVET teachers with 11 years and above experience in technical colleges

A= Accepted

NA= Not Accepted

The result shown in Table 3 indicates the comparison between the TVET teachers with 5 to 10 years' experience and TVET teachers with 11 years and above experience in technical colleges. Data showed that items 1,2,6,8 and 9 has a calculated t-value less than the t-critical value of ± 1.66 , hence hypothesis for these items were upheld at 0.05 level of significance. Expect for item 3,4,5,7 and 10 which has a t-calculated value above the t-critical value ± 1.66 , H₀ was therefore rejected for these items.

6. Findings of the Study

The following are the key findings of the study.

The research question 1's findings are represented in Table 1, which reveals that just a small portion of the items pertain to how much ICT is used in TVET programs at technical colleges

in Niger State during the teaching and learning process. The results showed that the majority of the application of ICT in the teaching and learning of TVET programs is only through internet search engines like Google and Opera mini, which helps to achieve self-directed learning as this process tends to increase teaching and learning quality, but is glaringly insufficient for effective application of ICT in TVET programs.

The results in table 2 connected to research question 2 showed that the respondents did not agree with the majority of the statements regarding the degree of TVET teachers' ICT competency in TVET programs in Technical Colleges in Niger State. The results indicated that most teachers lack basic ICT skills, including how to save or retrieve documents, present data using Microsoft PowerPoint, use Microsoft Excel, and access online databases of educational resources.

7. Discussion of the Findings

Findings from the study showed that ICT use in TVET programs at technical colleges in Niger State is extremely limited. When available, the TVET teachers lack the necessary skills to use the equipment and ICT resources, which seriously hampers their ability to fully implement TVET in these technical colleges. According to Ezenwanfor et al (2014) research, TVET teachers lack the necessary skills, and ICT infrastructure and equipment are woefully inadequate. This results in a low level of ICT resource utilization in TVET programs. Furthermore, his research showed that the government and administrators of educational institutions still give TVET lip service without actually recognizing its relevance. Given that, according to Igwe et al. (2021), the TVET sector in Nigeria continues to experience a severe lack of certified staff, equipment, and infrastructure, this demonstrates conclusively that there has been no demonstrable increase in the deployment of ICT in TVET programs.

ICT use in the classroom, according to Amin (2013), energizes both teachers and students, fostering an engaging and participatory learning environment. However, the results of this study demonstrate that TVET teachers lack ICT proficiency. Given that these ICT resources are not adequately made available in schools and that there are no training programs put in place by the government or school administrations to teach them to teachers who are willing to learn them, the majority of people do not understand the necessity of acquiring learning context-related competencies that these shifts in teaching and learning paradigms demand. Liverpool and Oti (2011) claimed that ICT in education promotes access to teaching by improving the pedagogy and techniques of instructional delivery and facilitates meaningful engagement among learners. Igwe (2022) added that the use of ICT resources has the potential to improve and widen access to education and training in TVET. When there are no operational procedures for the application of ICT in TVET programs, these advantages cannot be observed.

8. Conclusion

In conclusion, the use of ICT in TVET can be understood as the incorporation of ICT tools into TVET programs' teaching and learning processes. For effective teaching and learning, ICT usage in the classroom has evolved into a non-negotiable constant. Therefore, it is not

surprising to witness an increase in demand for ICT integration into TVET programs across the globe.

ICT resources are essential tools for strengthening and enabling observations, improving memory retention, and ultimately leading to better teaching and learning. ICT not only helps students study more but also supports teachers' efforts to impart knowledge and skills. With ICT, TVET programs' teaching and learning would be engaging rather than time-consuming and demanding.

The study's findings led to the conclusion that TVET teachers have a low degree of ICT competency. Therefore, an ICT training program should be carefully prepared to increase the basic ICT literacy of the current TVET teachers. In order for TVET programs to continue to be relevant and appealing, they must identify and introduce digital skills and capabilities for the evolving world of work and to take advantage of the opportunities presented by digitization. As a result, TVET policy makers, training providers, donors, and funding agencies need to concentrate on improving the overall ICT enablement in TVET programs.

9. Recommendations

The following recommendations were given in light of the study's findings;

1. TVET teachers should pursue acquisition of skills in using ICT resources by attending workshops, training programmes, and seminars for enhanced effectiveness.
2. Government and policy makers should train TVET teachers pre-service and in-service on ICT skills based on the 21st century requirements.
3. Government should ensure adequate funding for the needed functional ICT resources and infrastructure for TVET programmes are put in place for the teaching and learning process.

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Applying the NIST cybersecurity framework in developing a digital forensic incident response roadmap for the security sector in Namibia

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Abstract

A cybersecurity response can only be effective if it is done systematically while following an approved guide in the process. One way to achieve a sound cyber security response is by developing a Digital Forensics Incident Response roadmap. The security sector in Namibia does not have the capacity to respond effectively to cyber incidents and do not have structures in place designed to respond to such incidents. By developing a digital forensic incident response roadmap, an opportunity is created to change the cybersecurity landscape in the country. In conducting the research, literature in developing DFIR roadmaps were reviewed through primary and secondary sources such as library and online searches. A mixed method approach was adopted in gathering research information in the target population. A sample was chosen from a population of personnel in the security sector. The main objective of the study was to develop a digital forensics incident response roadmap for the security sector in Namibia. The study is significant in that; it provides information to principal staff members of the security sector in planning considerations of cybersecurity in Namibia. The study is expected to come up with suggestions and recommendations which may be adopted by government in efforts of addressing the issue. It covers the background, literature review, research methodology, related work, application of the NIST framework in developing a digital forensic incident response roadmap, conclusion, future work and recommendations on the same issue.

Keywords: Digital Forensic, Incident Response, Roadmap, Cybersecurity, Framework

1. Introduction

A cyber security response which is informed by an approved guide is necessary when designing an incident response roadmap. (Sharkov, 2020) defined a roadmap as a "yardstick" to assess the state of a community's cybersecurity initiatives and mind-sets, with the goal of assisting that community in understanding the measures required to strengthen its security posture. Similarly, (Johnson, 2017) asserts that a roadmap is a set of planning activities intended to plan a course from the present state of the art to a desired future state. By definition, a roadmap is a measure that creates the desired state based on the present state while outlining steps to be covered. A roadmap prepares an organisation to optimize its cybersecurity program while aligning security procedures with business objectives.

A Digital Forensics Incident Response (DFIR) roadmap prepares an organisation to respond and litigate cyber attackers. DFIR is a specialist area that focuses on detecting, resolving, and investigating cyber security issues. It combines the benefits of Digital Forensics and Incident Response which are independent disciplines. Digital Forensics is gathering, storing, and analysing forensic evidence to provide a complete picture of what happened. Meanwhile, Incident Response is generally focused on confining, halting, and preventing an attack (Sheward, 2018). When used together, digital forensics and incident response get an organisation back up and running while finding and correcting security flaws and, offers proof needed to prosecute criminals who attacked operations. As (Johansen, 2020)

explained, digital forensics deals with understanding the technical characteristics of the issue, finding the underlying cause, and detecting unidentified access or other malicious behaviour. He further explains that Incident response is an Information security function that employs digital forensics methodologies, tools, and procedures while also addressing other factors not covered by digital forensics. Factors such as identifying and fixing vulnerabilities, containing possible malicious software or exploits, and managing technical and non-technical human resources are all included in incident response.

The National Institute of Standards and Technology (NIST) cybersecurity framework is a performance-based, and cost-effective approach adopted by owners and operators of critical infrastructure to help them identify, assess, and manage cyber risks. As such, this paper applies the NIST cybersecurity framework in developing a Digital Forensics Incident Response roadmap for the security sector in Namibia. It is for this reason that applying the NIST cybersecurity framework in the development of a DFIR roadmap will result in addressing DFIR issues in the security cluster.

2. Methodology

The study reviewed literature related to the development of roadmaps in cybersecurity, particularly the application of the NIST framework on DFIR maturity in an organisation. In order to be relevant, various studies, reports, reviews, books, white papers, articles on cybersecurity roadmaps were analysed. The study further gathered data from a sample of the population in the security cluster through a mixed method approach.

3. Related work

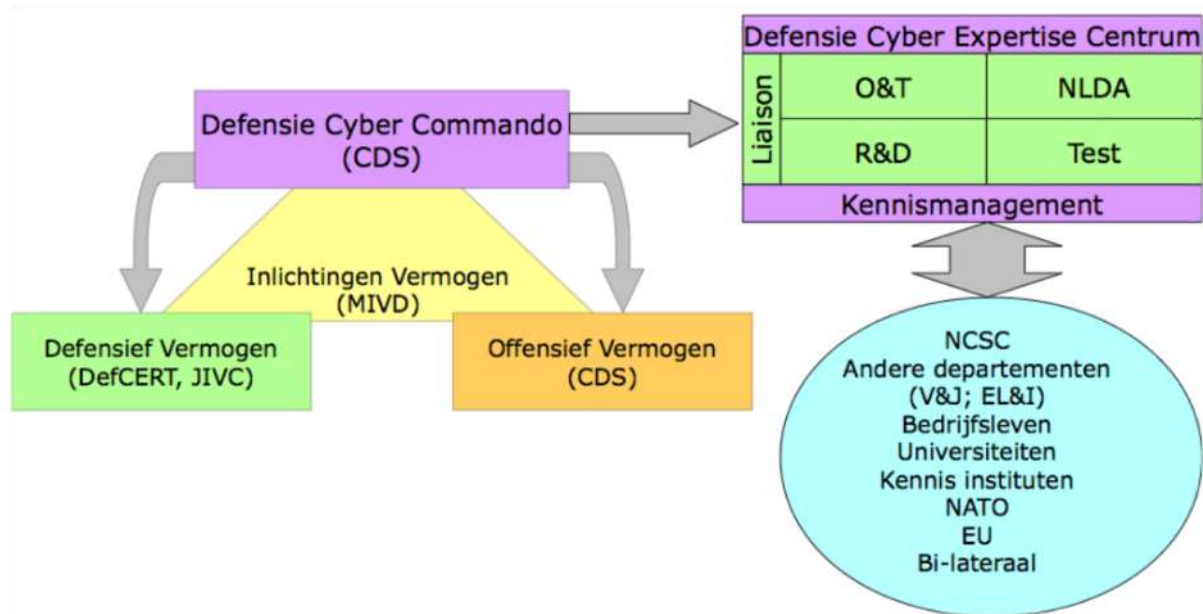
3.1 Initiatives for cyber incident response in Namibia

(Ronchi, 2017) argues that cyber security initiatives improves the safety and security of people in general. The argument clearly indicates that a country with a secure cyber environment goes a long way in guaranteeing its nation's safety and security concerns. A survey conducted by (Deloitte, 2018) asserts that initiatives for cyber incident in Namibia are regrettably low. This assertion is supported by (World Bank Group, 2019) who categorised the absence of an incident response institution at a national level as a threat to the country. To this effect, the government has acknowledged the importance of cyber incident response and has tasked the Ministry of Information and Communication Technology (MICT) to establish an institution with a mandate to coordinate and respond to incidents which are of cyber in nature. As such, the MICT along with several other agencies commenced the enactment of the Cybercrime legislation, consultation and drafting process of a national cybersecurity strategy for the Republic of Namibia which will act as guiding principle under which the incident response initiative will operate (World Bank Group, 2019).

3.2 The need to develop forensics incident response capability

Military incident response capability aids militaries in minimizing any threat posed by cyber-attacks, providing speedy and effective recovery, and preventing repeat occurrences. An example of a Military response initiative is emphasised by (Hammock, 2017) the Dutch Defence Computer Emergency Response Team (DefCERT) serves as a centralised entity to share incident occurrences and to employ protective mechanisms across Dutch defence information systems, also serves as a threat operations centre to liaise with the NATO Computer Incident Response Capability (NCIRC) organisation.

Figure 1: Dutch Armed Forces CERT



Source: Mrkoot (2014)

It can be seen from this example that incident response in the military should be prioritized when protection of information systems and the need for safe cyber environment are to be considered. (Goel, 2020) supports this notion by stating that cyber incident response initiatives assist nations to reduce the impacts of cyber-attacks and at the same time avoid their reoccurrences. (Mandia et al., 2003) developed the process model which covers seven phases of incident response. These process include pre-Incident preparation, detection of incidents, initial response, formulate response strategy, data collection, data analysis and reporting.

3.3 Cyber-security landscape in the Namibian security sector

During the 2017/2018 financial year budget speech for the Ministry of Defence, the minister of Defence highlighted the need for the parliament to approve the allocated budget in order for the Namibian Defence Force to develop capability for cybersecurity (Republic of Namibia, 2018). In its concept, cybersecurity encompasses all aspects undertaken by the security Sector to ensure a cyber-environment free of any cyber threat. This concept includes digital forensic incident response to which efforts are made to minimise or avoid the risk of a cyber-related incident.

Reporting cyber incidents is critical to the military's information security as it gives knowledge and insight into a cyber-incident that has occurred or is currently occurring. (Milley & Miller, 2019). According to the (World Bank Group, 2019) there is no national cyber incident framework in Namibia, similarly there is no legislation which allows an incident response to conduct its function. As such, there is no established forensics incident response capability in the security sector which should operate within national frameworks and legal frameworks of the state.

3.4 Digital forensics Inspired Incident Response (DFIR) approaches

The DFIR approach consists of a number of steps, including finding an initial attack path, assessing the degree of any breach, analysing the attacker's tactics and motives, and devising a remediation strategy. In the same process, digital forensics is used to perform a systematic investigation while documenting the chain of evidence for litigation and possible prosecution of the culprit. Several incident-related models have been developed with forensic investigations in mind and comprise of approaches to identify, collect, preserve, reconstruct, analyse, and document pieces of evidence, or potential pieces of evidence against information system incidents (Al Sabbagh, 2019). (Okereafor & Djehaiche, 2020) suggests multiple approaches to Digital Forensics Incident Response which tend to be procedures that are aligned with standard incident response drills. These approaches can be adopted in developing capabilities for the security sector in countering threats to the security mandate. Another approach to an incident response inspired by digital forensics is to maintain adherence to the legal framework regulating the cyberspace (World Bank Group, 2019). This will ensure that aspects of digital forensic are conducted within the ambits of established laws and frameworks.

3.5 Developing an incident response roadmap

An incident response roadmap is comprised of a triad consisting of people, technology and processes (Torres, 2015). The triad is the core requirement when developing an incident response roadmap. It is through identifying aspects contained in each component of the triad that an incident response roadmap can carefully be developed. According to (Amador et al., 2020) a roadmap connects different dots related to incident response in an organisation and is achieved by identifying points of common interest joining internal development ways to bring about common trusted operational environment.

3.6 Overview of the NIST cybersecurity framework

The NIST cybersecurity framework is a measure developed to integrate industry best practices and standards to assist businesses in managing their cybersecurity threats (NIST, 2018). Cybersecurity is a broad sector that comprises various facets which are created to protect organisations from cyber threats. The emphasis of the study is on digital forensic and incident response to which the NIST framework provides specific publications to address these areas. The framework consists three parts which are involved in the completeness of a cybersecurity posture of an organisation. These parts which make up the Framework are the Framework Core, Framework Implementation, and Framework Profiles. Each element of the Framework strengthens the link between cybersecurity operations and strategic objectives of the organisation (NIST, 2018).

Special publications provided by the NIST framework were developed to address specific cybersecurity issues in organisations. The special publication 800-61 and the special publication 800-86 particularly deal with measures to address incident response and digital forensics respectively (Salfati & Pease, 2022).

The Framework provides organisations on how to evaluate their cybersecurity risks and take particular steps to reduce them. It encourages them to look into the underlying causes and consider methods to improve, which helps companies respond to and recover from cybersecurity concerns.

1. **Application of the NIST framework in developing a Digital Forensic Incident Response roadmap**

A DFIR is a measure put in place by an organisation to provide protection and remedial actions in an event a cyber-incident occurs. Applying the NIST cybersecurity framework in developing a roadmap for DIFR provides guidance in systematic approaches which organisations can adopt when designing their DFIR capabilities (Filkins, 2021).

Frameworks such as the ISO 27001 and the Cloud Security Alliance (CSA) may be applied in developing a DFIR roadmap, however, their application is complex for organisations with a zero maturity level. The ISO 27001 provides 14 control categories with 14 controls (Candiwan, 2014) and is ideal for organisations that have an established cybersecurity maturity level while the CSA framework mainly provides security controls in the cloud (CSA, 2021).

The controls provided by the ISO and CSA may tend to be complex to be adopted by organisations which do not have a cybersecurity maturity level. As such, the NIST framework suits efforts of developing a roadmap to have DFIR capabilities. The NIST framework has five cybersecurity controls (NIST, 2018) which are best suited for organisations that are in the initial stages of developing a cybersecurity program. In developing the roadmap, a model is designed outlining the current cybersecurity environment of an organisation, the pillars to which the roadmap is designed for, what needs to be done to achieve the desired state and the timelines in achieving the desired state. The model is presented below:

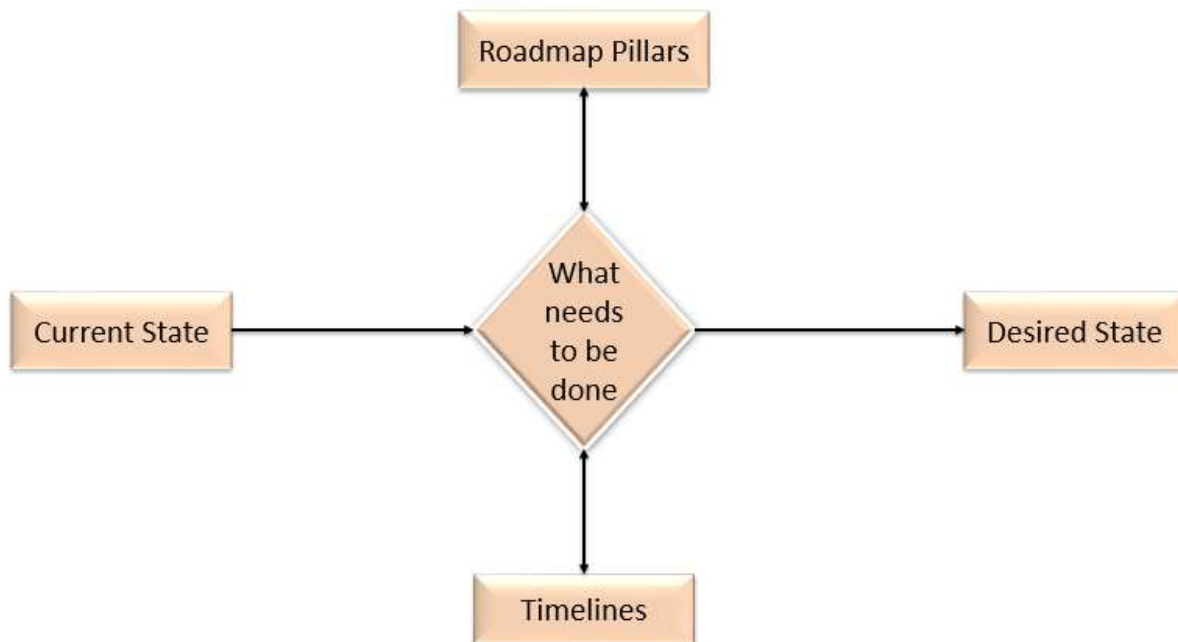


Figure 2: Model for designing a DFIR roadmap

When applied to the model, the three parts of the NIST framework ensures that the roadmap is developed to address security concerns from current state to desired end state. Below is the illustration of the application of cybersecurity framework:

1.1 Framework Core

In determining the desired state of a DFIR of an organisation, it is necessary to use the framework core as a guiding tool. The framework functions are; Identify, protect, detect, response and recover. These functions are critical in both the desired state and current state of an organisation's DFIR capabilities.

1.2 Framework Implementation

Under this part of the framework, the organisation determines the level of DFIR protection that exists in order to establish what has been done to improve the organisations's DFIR posture. Risk management gaps are identified and measures put in place to address the risks.

1.3 Framework Profile

Specific activities in the DFIR are outlined under this part of the framework. Outcomes or desired states are developed based on business objectives and current state in the cyber environment of an organisation. It is under this section of the framework where timelines in terms of the roadmaps are set. Timelines ensures that the roadmap should be followed according to a specific timeframe during its implementation.

2. Conclusion and future work

The security sector in Namibia need to embrace the use of technology in achieving their security mandate. In so doing, the need to establish cybersecurity maturity level is critical. One of the ways in which the security sector may ensure a sound cybersecurity maturity level is to develop a DFIR roadmap. Such an arrangement is meant to allow a systematic process of establishing cybersecurity levels in the security sector.

In developing the roadmap, the application of the NIST cybersecurity framework will ensure that the roadmap conforms to agreed international cybersecurity standards.

The paper discussed the application of the NIST cybersecurity framework in developing a cybersecurity forensic incident response roadmap. There are various other frameworks in place which are designed to achieve the same. It is therefore important to carry out studies that may establish how these frameworks can be applied in designing a DFIR roadmap. Particular emphasis should be on organisations which are in the initial stages of establishing cybersecurity capabilities.

3. Recommendations

A roadmap is an instrument which enable an organisation to systematically develop DFIR capabilities. The DFIR should be developed with consideration of approved international standards, procedures and best practices in mind. Therefore, considering various cybersecurity frameworks in use by organisations, the NIST framework is found to best suit to be applied in developing a DFIR roadmap for organisations without or in the initial stages of establishing DFIR capabilities. The roadmap should be used by all security sector players in developing DFIR initiatives in order to maintain consistency in the sector.

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Persuasive Systems to Increase Museums Turnout

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Abstract.

There has been an impressive advance in information technology that has seen many museums involved in the world's developments that can be used to improve the visitor experience. These developments are made by creating an interactive environment that has the potential to sustain visitors' interest in the museum, attract more visitors, and fulfil the museum's role of imparting knowledge and cultural education (Busch & Sieck, 2015). Namibian museums are still lagging in terms of implementing these new technologies. Namibian museums, such as the Independence Memorial Museum, are currently experiencing low attendance from locals. If the problem of low attendance at Namibian museums is not addressed, it may result in museum closures, a lack of knowledge about Namibian cultures and historical artefacts, and a decline in artistic inspiration. This study investigated the design, development, and implementation of a Persuasive Souvenir System (PSS) to determine whether PSS is a viable solution for increasing museum attendance in Namibia. The system was successfully developed and tested using a prototyping methodology. However, the system's persuasive power has yet to be fully explored.

Keywords: Museums, persuasive computing, RFID technology, location-based systems, and museums visit.

1. Introduction

The past few years have seen remarkable technological advances in different fields, such as the transformation of persuasion theory into persuasive computing technology. Persuasive computing technology is defined by Fogg (1999) as a "computing system, device, or application intentionally designed to change a person's attitudes or behaviour in a pre-determined way" (p. 27).

Additionally, Fogg (1998) describes persuasive computing technology as computer software or systems designed to allow people to engage; as a result, people are influenced to modify their behaviours or attitudes toward a certain object or action. According to Fogg (1998), there has been no research into how a computer can influence individuals. The closest explanation, according to Fogg (1998), is that the influence of computers on society is driven by nature and occurs automatically.

Persuasive technology has been utilized to effect positive change in a variety of fields, including health, security, and education (Fogg, 1999). It is also worth noting that an increasing number of data innovation applications and administrations are being built to influence users' mindsets and behaviours (Oinas-Kukkonen & Harjumaa, 2009).

The current paper presents findings from Nashandi's master's thesis (2020), in which she attempted to solve the problem of poor museum turnout in Namibian museums by using a persuasive strategy to attract more visitors.

The turnout at the Independence Memorial Museum (IMM) by local visitors is very low compared to their foreign counterparts. This information is based on statistical data (Figure 1.1) provided by the museum, which was generated from 2015 to 2018. The data shows that only a few Namibians visit museums. The statistics of visitors to the Independence Memorial Museum, whose impressive multi-

story building was inaugurated on the 20th of March 2014, reveal that figures of local visitors are low compared to the number of foreign visitors. Windhoek has the highest number of inhabitants out of the Namibian cities and the number of visitors to museums is worrisome (City of Windhoek, 2016), as only about 5% of the 400 000 people residing in Windhoek visit museums yearly, while the city received 1.5 million foreign visitors annually on average for the same period (Shikale,2020).

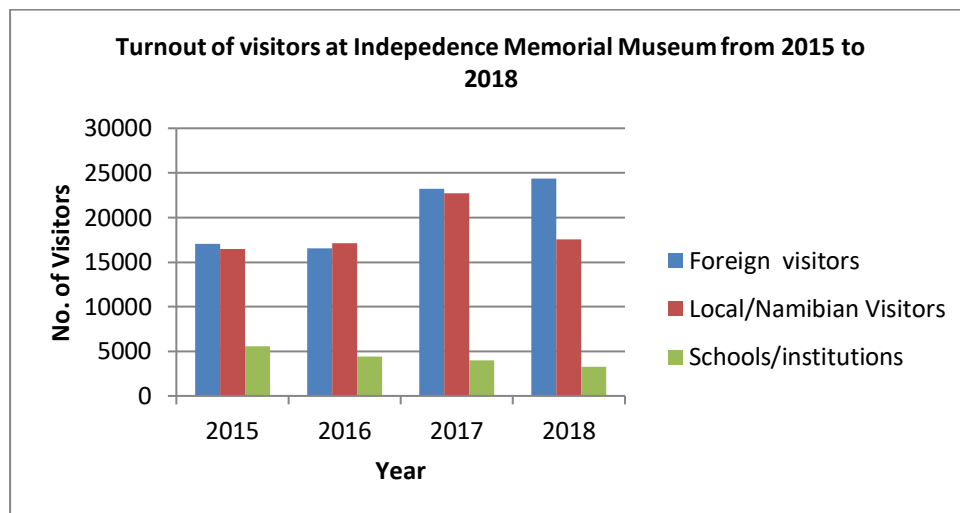


Figure 1.1 Graph of statistics on the turnout of visitors at Independence Memorial Museum 2015 -2018.

Source: National Independence Memorial Museum's statistic sheets by Museums Curators, 2019.

Given that Windhoek has the most schools in Namibia, the number of school trips to museums is equally low (4000 learners on average every year). Furthermore, results from an online questionnaire issued to 40 random residents suggest that just 50% of these individuals had visited museums, and 60% of those who have visited the museum have not returned. This illustrates that Namibians may be a long way from acquiring knowledge kept in museums. Even museum employees are concerned about the poor attendance at local museums. The findings of the pilot project, which aimed to collect preliminary data for this study through a chat with museum curators at IMM, found that the government is hesitant to contribute funds to the museums because they believe museums are underutilized by residents and that funds are being wasted (Curators I. M., 2019). Silvester and Pujatura (2016) also confirm that the popular museum guests to Namibian museums are non-Namibians.

Museums have been a part of the leisure venues where families normally choose to spend their free time for a few years now (Hood, 1983). Furthermore, Hood (1983) discovered that people's decisions to visit museums are influenced by a variety of factors, including a list of other leisure options and the benefits that the museum provides to visitors. As a result, museums must research visitor behaviour and what draws them to museums.

The integration of ICT into all industries has seen many museums in the world embark on extensive and continuous development of technological approaches to improve the visitor experience. This is done by creating an interactive environment that keeps attracting visitors to museums and sustains their role of imparting knowledge and cultural education (Busch & Sieck, 2015). In a museum, an interactive environment is achieved by the engagement between the user and the technology-based media that works according to the user's instructions. This media could be loaded with web

applications, information technology systems and 2D or 3D virtual media that is can be controlled by the user interactively (Dynamic Digital Advertising, n.d; Rajeev, 2019). However, Namibian museums still lack such technologies.

With technology advancements, there are numerous options for addressing poor museum attendance. Information technology solutions ranging from simple printed instructions to virtual and augmented reality with expanded usage of handheld devices are increasingly being employed to improve museum visitors' experiences and encourage them to visit museums more frequently (Hsi, 2004).

However, several studies have opted to leverage the concept of persuasive technology in the construction of games, storytelling, advertising, and social media awareness to attract museum visitors and retain museum visitors through the creation of an interactive experience (Cornelia et al., 2022; Ritter et al., 2021; Zu & Wang, 2022; Besoain et al., 2022).

Salamat and Khalili (2021) successfully used Fogg's behaviours framework to build a web-based game targeted at convincing young people to visit the National Museum of Iran museum's website, allowing them to explore the museum's cultural and educational content.

The study aimed to increase museum attendance in Namibia by developing and implementing a persuasive souvenir system (PSS) with the integration of Radio Frequency Identification (RFID) technology, which would identify and locate visitors in IMM and, eventually, other Namibian museums.

In achieving this aim, the study focused on the following research question and sub-questions:

RQ1. How can a persuasive souvenir system (PSS), with the integration of RFID technology for Namibian museums, be developed?

SQ1. How are the artefacts of museums exhibited to visitors in Namibian museums?

SQ2. How can the persuasive souvenir system (PSS), with the integration of RFID technology, be used as a solution to improve the current situation of low numbers of people visiting museums in Namibia?

The rest of the paper is organized into Persuasive souvenir and computing technology, methodology; findings; PSS development; results; benefits; and conclusion.

2. Persuasive souvenir and computing technology

A souvenir is "something you buy or keep to help you remember a holiday or special event" (Cambridge University Press, 2019, p. 1); whereas the Webster's New World College Dictionary (2014) explains that the term 'persuasive' came from a French word *persuasif*, which "came from classical Latin '*persuasus*', defined as "someone or something with the power to convince" (Webster's New World College Dictionary, 2014, p. 1). In the context of this study, persuasive souvenir system is defined as a system that is meant to convince museum visitors to repeatedly and constantly visit the museums and influence others to visit the museums by using a souvenir in a form of a personalised card or photo of their most interesting artefact as a convincing component. This idea is supported by Petrelli et al. (2017), who noted that a customised tangible gift or memento can prolong the relationship between museums and guests by advertising better approaches for exhibition halls to associate themselves with their guests, connecting them bodily and virtually using technology

According to Fogg (1999), influence has continuously been a piece of human involvement, example of

influencing things or people are such as anthems, books of scriptures stories, guardians and fitness coaches. Individuals have continuously looked for ways to impact others' demeanours and practices. Although most people oppose the thought of being influenced, they still favour individuals who are blessed with influential skills.

The past few years have seen remarkable technological advances in different fields and so many new technologies have appeared – the persuasion theory is not an exception. Persuasion has developed into a technology called persuasive computing technology, which Fogg (1999) defines as a “computing system, device or application intentionally designed to change a person’s attitudes or behaviour in a predetermined way” (p. 27). It is worth noting that there are pros and cons to every technological development. A computer is capable of persuading people but using technology to influence others also has some measures such as ethical considerations and people should be taught the ability to choose between good and bad persuasive technologies (Fogg, 1999). These limitations and ethical considerations regarding the use of persuasive technology have been explicitly listed, considered and addressed in this study.

The most prominent example is the study by Forget et al. (2008) that involves the creation of “Persuasive Text Passwords” (PTP), using a pin creation method with influential technology by haphazardly placing a haphazardly picked character into the client’s password. In addition, Toscos et al. (2006) designed a “chick clique” system that used persuasive technology to convince or influence young ladies who appreciate innovation and need the inspiration to keep themselves fit during their pre-adulthood.

It appears there is limited literature regarding the use of persuasive technology to influence museum visitors to visit or convince people in their network to visit museums (Forget et al., 2008; Toscos et al., 2006). In other words, there is quite minimal literature that directly includes persuasive technology as a component to increase turnout at museums, despite the fact that scholars have been attempting to find ways to enhance the experience of museum visitors by making use of technologies to make them more interactive and fun.

Available researches that looked at how persuasive technology could be used to influence museum visitors to visit museums are very limited to other continents rather than Africa where Namibia resides. The researcher could not find material written by Africans or developed solutions using persuasive technology that has been implemented in African Museums.

3. Methodology

A mixed data collection method was adopted for the study to increase the scope and range of the data to address the research problem and answer research questions. The study used both qualitative and quantitative data collection methods. Qualitative methods allowed the researcher to collect large amounts of verbal and written information from the respondents to gather data pertaining to the research problems and questions.

The researcher conducted a baseline study of the National Independence Museum visit, made observations, and took field notes. The purpose of observations was to understand how artefacts are exhibited in the museum, where the researcher observed the behaviours of museum visitors towards artefacts. The researcher was also interested in finding out whether there were any existing persuasive computing technologies at the museums to attract visitors. Observation as a method of data collection allows researchers to gather data through their senses (O'Leary, 2004). Qualitative

information was then converted to statistical data and analysed. In addition to observation, the researcher also used a web-based questionnaire that consisted of structured and semi-structured questions to collect quantitative data.

The study used random sampling to select the participants for the study, where everyone in the Namibian population had an equal probability of being selected (Creswell, 2009). The target population of the study was all Namibian Windhoek residents because of the location of the MMM. A total of 40 participants from Windhoek participated in the web-based questionnaire. Moreover, five staff members from the National Independence Memorial Museum were also sampled, and they participated in the study.

Data was interpreted by validating the accuracy of the information by reading through all the data and then looking for patterns among the data. This interpreted data was then used to come up with the requirements for the development of the Persuasive Souvenir System.

4. Technology Description

The persuasive souvenir system (PSS) makes use of identification and tracking technology, which aims to promote and boost the number of visitors to museums by rewarding them with souvenir cards consisting of a photo of themselves and that of their most attractive or interested artefact/gallery and a description thereof. The proposed PSS consists of the following hardware: a web camera, RFID readers (placed behind each artefact/gallery), tags, routers, a printer, a computer, and a central server. The above-mentioned hardware is used to achieve the following functionalities:

- Router - enables the communication between RFID and the computer.
- Web camera - takes photos of visitors
- RFID tags and readers - track visitors within the museum
- Central server - saves information about the visitor and artefacts/galleries
- Printer - print out the visitors' souvenir card
- Computer- host the PSS App

For the PSS to be able to select the most attractive or interesting artefact/gallery for the visitor and award the visitors with a souvenir card, upon entering the museum, the PSS should first capture the following information about the visitor: (1) facial/ID photo and (2) assign an ID to the RFID tag allocated to the visitor. The PSS could then track the visitor throughout their museum visitation journey, using the RFID technology through the assigned RFID tag. The tag should connect to the RFID reader placed behind each artefact/gallery within the museum. The PSS counts the amount of time a visitor spends admiring or viewing each artefact/gallery and sends the information to the database. The amount of time a visitor spends admiring the artefact/gallery is equal to the amount of time the RFID tag stays connected to a certain RFID reader. The database is hosted by the central server. In the end, the PSS should select one artefact out of all the viewed artefacts – on the basis that it has the highest viewing time. A souvenir card consists of a photo of the current visitor, their artefact of interest and a description of the artefact is generated. The visitor is required to pay a promotional fee for the souvenir card to be printed out.

This study posits, as motivated in its objective, that when a visitor spends more time in front of an artefact, they are more likely attracted or interested in that artefact/gallery in the museum. Therefore,

a souvenir of the most interesting, visited artefact can attract the visitor to revisit the museum or he could also stimulate the interest of others, close relatives or friends to visit the museum. Young children might be easily motivated by such opportunities, as observed in several piece of literature (Andre et al., 2017, Carr et al., 2018, Prentice et al., 1997). Figure 4.1 represents the hardware setup overview for the PSS and Figure 4.2 shows the system architecture for the PSS.

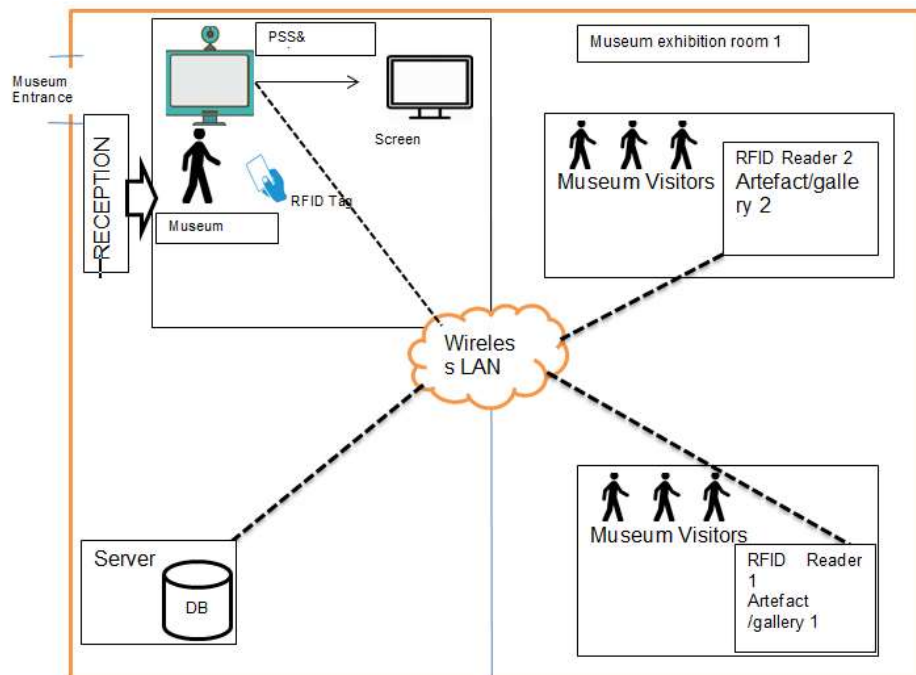


Figure 4.1: Hardware Setup Overview for the Persuasive Souvenir System.

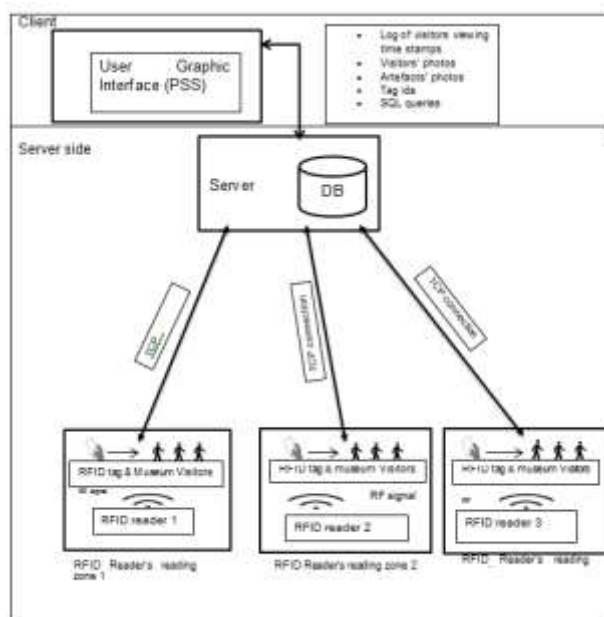


Figure 4.2: System architecture for the Persuasive Souvenir System.

5. Developments

The process adopted for the development of PSS is evolutionary prototyping. According to Pomberger and Weinreich (1994), “software prototyping is a bottom-up process: a few (simple) basic functions are implemented quickly, tested by the user, and improved, then additional user requirements are implemented, and the cycle continues until the product is finalised” (p. 3). During this process, staff members at the National Independence Museum acquired an understanding of the functions of the complete system and they could request changes or identify additional requirements.

The first prototype was created based on the results from the data collected through the observation session during the visit to the Independence Memorial Museum and the analysed data from the web-based questionnaire that was circulated earlier. The prototype allows users and the researcher to test the system until all the requirements and proposed changes are incorporated (Pomberger & Weinreich, 1994).

The PSS was developed using C# as a programming language. The graphical user interface for the PSS was created using Window forms. To display the souvenir card, PHP was used to create a web page. The souvenir card and the report are displayed in a form of a web page. A database was implemented and managed for this study, through the MySQL Workbench 8.0 database. The requirements for the software and hardware for the PSS are listed below:

Software requirements:

MySQL database, Client Computer-Windows 10, 8.1, 8, 7., GAO RFID Connection Tool, PHP, Notepad++, Browser, and XAMMP platform.

Hardware requirements:

Desktop PC with 8/16GB memory, a Core i5/i7 CPU, a 500GB hard drive, a GAO RFID reader, GAO RFID tags, a wireless router, and a LifeCam HD300 camera.

Figure 5.1 Persuasive Souvenir System main page



6. Results

The main objective of the study was successfully achieved, which was to develop a persuasive souvenir system (PSS) for Namibian museums, with the integration of RFID technology, using the Independence Memorial Museum as a case study.

The testing phase for the PSS concluded that the prototype functions well; however, the overall output (souvenir card) should be improved. The improvement of the souvenir includes adding decorative features to make it look more attractive. Users advised that consultation with graphic designers should be made to help with designing a more attractive souvenir card. Furthermore, some performance faults were found and need to be addressed as soon as possible. The performance fault detected was the delay in response time of the system to connect to the next RFID reader and extract the position of the visitor immediately after they have moved to the next artefact. The delay in response time was found to be equal to or less than a second; therefore, it will not extremely affect the result, but future improvements will be made.

To achieve the first sub-objective of the study, the researcher made several visits to the Independence Memorial Museum and Owela museum to observe how artefacts are exhibited to visitors. The findings contributed to the decisions on design in the development of the PSS.

The second sub-objective was to investigate the factors that could impact the use of the persuasive souvenir system in Namibian museums. The finding of this study suggests that the following factors could impact the use of PSS in Namibian museums: Lack of funds, Museum marketing strategy and Dedicated IT personnel to manage PSS.

The third sub-objective was how a computer-based solution could positively influence the number of visitors to museums in Namibia. This sub-objective was partially achieved: PSS was developed and tested for its functional and non-functional requirements. However, due to the limited time trial, and taking into account that there is a possibility of visitors taking longer time to decide whether they should visit the museum again or not, the prototype was not tested on how it could positively influence the number of visitors to museums in Namibia. As a result, the PSS prototype will be installed in National Memorial Museums for visitors to begin using it and testing whether the system is indeed capable of convincing visitors to return or whether the souvenir will be capable of convincing new visitors to begin visiting the museum.

7. Business Benefits

This study has the following benefits:

- It will provide the information required by museum employees, especially those who are responsible for managing artefacts and making decisions on which artefacts should be kept and exhibited in the museum. This information is generated from a report on the most and least viewed artefacts by visitors, based on the time visitors spend admiring these artefacts. The artefacts where visitors spend the least time should be replaced with new artefacts/galleries.
- It will add value to attempts by government officials and non-governmental organisations working on solving the low number of people who visit Namibian museums to find a lasting solution to the problem.

- It will make valuable academic contributions to the knowledge of the area of research for future researchers, who will enhance in finding new solutions toward the low turnout of Namibian museums.

8. Conclusion

The main objective of this study was to develop a persuasive souvenir system (PSS) for Namibian museums, with the integration of RFID technology, using the Independence Memorial museum as the case study. The PSS is used to track the amount of time visitors have spent focusing on each museum artefact. Based on the PSS, visitors were presented with a souvenir card containing two components: a visitor's image and the image of the artefact that the visitor has spent more time focusing on, with a text description of that artefact. Overall, the PSS has been successfully developed and satisfactorily achieved and fulfilled the specified objectives and requirements. The study also reviewed the state of the art in the fields of museums, persuasive computing, location-based systems and enhancement of museums visit. Furthermore, the study presented scientific critics towards existing solutions that aim at solving the low turnout at museums and proposed a new solution to increase the museum turnouts. However, due to limited time, the study could not prove if the PSS is indeed able to convince visitors to revisit the museum or to attract new visitors to the museum. The persuasive component evaluation is part of the future works and it will need to be tested in a long-term process.

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A Review on Real-Time Object Detection Models using Deep Neural Networks

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Abstract.

Object detection is one of the most common issues in computer vision. Various researchers have contributed to a number of application fields, including robots, self-driving cars, and video surveillance. The real-time object detection methods that use deep learning methods are reviewed in this work. Its purpose is to make the readers familiar with the pertinent information, literature, and most recent advancements in cutting-edge methods. Using three sets of keywords: Deep learning, object detection, and convolutional neural networks. This study reviewed electronic records that were gathered from the top scientific databases (IEEE, Google Scholar, Scopus, DOAJ, Science Direct, Elsevier, and other journal publications). The framework for object detection has two unique groups of detectors: conventional detectors and deep learning-based detectors. Deep learning object detectors come in two varieties: one-stage detectors and two-stage detectors. Two-stage detectors produce sparse area recommendations in the first phase before performing regression and classification, in contrast to one-stage detectors that perform classification and regression using dense anchor boxes without first constructing a collection of sparse regions of interest. Crop harvesting, object detector models for the blind, pedestrian identification on the road, traffic sign recognition and classification, text detection, and remote sensing target detection are all applications of object detection. We suggest creating a one-stage object detection model in our upcoming research to aid in directing blind movements.

Keywords: Deep learning, object detection, convolutional neural networks

1. Introduction

Deep learning (Alzubaidi et al., 2021) (Sarker, 2021) methods are built on artificial neural networks (ANNs) (Lecun et al., 2015). A deep learning-based method gained popularity after winning a computer vision competition handily in 2012. Since 2010, deep learning techniques have improved their performance in complex visual recognition tasks, and by 2015, they had surpassed human accuracy (Lecun et al., 2015). Traditional feature extraction techniques demand human interaction, but deep learning immediately learns from image data (Ahishakiye et al., 2021). Deep convolutional neural networks (CNNs) have achieved state-of-the-art achievements in terms of object detection accuracy and detection speed as a result of the development of deep learning technology in machine vision applications. CNN's capacity to automatically learn from and extract information from an input image is its main benefit (Junos et al., 2021). Computers can now observe, recognize, and evaluate objects in still images and moving images thanks to the study of computer vision. Applications of computer vision include face detection, face identification, pedestrian counting, security systems, vehicle detection, self-driving automobiles, and many others (Zhao et al., 2019) (Pathak et al., 2018). Object localization, object categorization, and object identification are a few computer vision concepts that are related to object detection processing (Kaur & Singh, 2022). In discriminative tasks, deep learning models have advanced significantly. This has been made possible by sophisticated processing, intricate network architectures, and easy access to enormous volumes of data. As a result of the development of convolutional neural networks,

deep neural networks have been effectively applied in Computer Vision applications such as image classification, object recognition (Szegedy et al., 2013), and image segmentation (Shorten & Khoshgoftaar, 2019).

One of the most popular problems in computer vision is object detection (Krizhevsky et al., 2012). The foundation of conventional object recognition systems consists of handcrafted characteristics and shallow trainable structures. The creation of complex ensembles, which combine a number of low-level image features with high-level data from object detectors and scene classifiers, can quickly stall their performance. In order to overcome the problems that traditional architectures have, more potent tools that can learn semantic, high-level, and deeper features are now being made available (Zhao et al., 2019). Identifying the locations of items in a given image (object localization) and the categories to which each object belongs (object classification) is referred to as object detection (Zhao et al., 2019). In this study, we will use the term "object recognition" to refer to both object detection (a task that requires an algorithm to pinpoint all of the objects present in an image) and object classification (a work that requires an algorithm to determine which item classes are present in an image) (Russakovsky et al., 2015). A quick, accurate, and versatile method of general-purpose item recognition is required. Since the introduction of neural networks, detection frameworks have improved in speed and accuracy. However, the bulk of detection methods are still restricted to a few types of objects (Redmon & Farhadi, 2017). Deep learning has become the most talked-about technology due to its success in applications including language processing, object identification, and picture classification (Srivastava et al., 2021). One of the study's sections covered a review and history of deep learning and its uses for object detection (Zhao et al., 2019) (L. Liu et al., 2020).

1.2 Research Objectives and Outline

This study provides an overview of the research that has been done on the existing object detection models and their applications, particularly in blind movements, which is motivated by the current advances and numerous significant studies in the field of real-time object detection models.

The rest of the article is organized as follows: In section 2, Materials and methods are discussed; section 3 discusses the results and section 4 discusses the conclusions and recommendations.

1.3 Significance

Due to the rapid advancements in machine learning, computing power, smart phone adoption, and highly dynamic real-world environments, it is essential to assess the efficiency of heterogeneous real-time object-detection models by considering their capabilities and how they can be used to address current problems.

2. Methodology

2.1 Materials and Methods

According to several review studies (Xie et al., 2019), (Hsu et al., 2012), (Hwang & Tsai, 2011), it is crucial to review publications from reliable data sources. In this work, a thorough keyword-based search for publications on object identification techniques was carried out in the top scientific databases, including Google Scholar, Wiley, Science Direct, Springer, IEEE, Scopus, Nature, Elsevier, and PubMed. This study also included relevant postgraduate theses.

2.2 Inclusion criteria

This study took into account studies that offered deep learning-based approaches to object detection. The PRISMA technique and flow diagram (Bakator, 2018) was used to find the pertinent research publications. The four steps of this approach are as follows: (i) the Identification Phase, which involved gathering content from diverse sources; (ii) the Screening Process. Duplicate articles were disregarded throughout this phase, and subpar articles were also eliminated. Phase of eligibility; (iii) To decide which articles could be subjected to more evaluation, an examination was carried out. The excluded articles were not eligible; (iv) The included phase is the last stage. This stage involved the analysis of the articles that were used in the study.

2.3 Exclusion criteria

Studies that involved object detection approaches other than deep learning methods have been excluded from this study.

3. Discussion of Results

3.1 Object Detection Models

The basic objective of object detection, one of computer vision's most effective applications, is to recognize and classify the items in an image (Kaur & Singh, 2022). The object detection framework divides detectors into two groups: conventional detectors and deep learning-based detectors. The two-stage detector and the one-stage detector are the two types of deep learning object detectors. Unified detectors (Chen et al., 2019) (Lin et al., 2020) (Tian et al., 2019) (Zhang et al., 2018) (C. Zhu et al., 2019) When performing classification and regression without first creating a sparse region of interest (RoI) collection, employ dense anchor boxes, whereas in two-stage detectors (He et al., 2020) (X. Li et al., 2019) (Lu et al., 2019) (Ren et al., 2017), Sparse region proposals are developed in the first stage of two-stage detectors, following which they are regressed and classified (Lu et al., 2020). One-stage detectors are more effective due to their straightforward architecture, although two-stage detectors still exceed them in terms of accuracy.

The accuracy gap still exists despite recent attempts to enhance one-stage detectors by copying the structural design of two-stage detectors (Lu et al., 2020). On the other hand, single-stage detectors treat object detection as a simple regression problem that accepts the entire image as input and simultaneously generates multiple bounding boxes and class probabilities. The model is hence considerably quicker than the two-stage object detectors (Junos et al., 2021). Two-stage detectors provide adequate accuracy, but their computation times are considerable. Therefore, one-stage detectors are advised to process in less time while maintaining adequate accuracy (Adarsh et al., 2020). While RCNN (Zhou et al., 2021), Fast RCNN (Girshick, 2015), and Faster RCNN (Xiao et al., 2020) (Ren et al., 2017) algorithms are instances of two-stage detector algorithms, SSD and YOLO with its variants are examples of one-stage model algorithms. According to the study (Lu et al., 2020), two-stage detectors are superior to one-stage ones in the following ways: 1) One-stage detectors have a class imbalance issue if no additional design is added because they immediately face every region on the image. On the other hand, two-stage detectors eliminate the majority of the unfavorable recommendations by selecting a small number of region proposals. 2) The head of the network (used for proposal classification and regression) can be larger with two-stage detectors because they examine

fewer proposals than one-stage detectors do. This makes it possible to extract richer features. Three) Two-stage detectors employ the RoIAlign operation to extract the location consistent feature from each sampled proposal, as opposed to one-stage detectors that might permit different region proposals to share the same feature and could lead to severe feature misalignment because of the coarse and spatially implicit representation of the proposals. 4) In comparison to single-stage methods, two-stage detectors do a double regression of the object location (once on each step). The fundamental issue that all one-stage detectors face, the mismatch between anchor boxes and convolutional features, significantly reduces one-stage detector performance (Chen et al., 2019). One-stage object detectors' inability to outperform top-performing, two-stage algorithms is primarily due to class imbalance, claims the study (Lin et al., 2020). The study suggested the focused loss, which adjusts the cross-entropy loss and concentrates learning on difficult negative examples, as a remedy. The creation of a fully convolutional one-stage detector and detailed experimental analysis proving that it reaches cutting-edge accuracy and speed were used to demonstrate the study's effectiveness. Figure 1. shows object detection techniques.

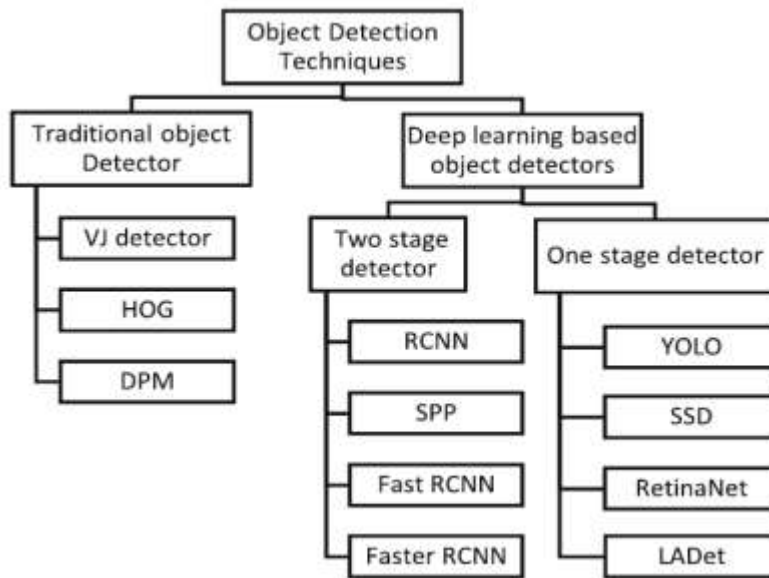


Figure 1: Object Detection Techniques
Adapted from (Kaur & Singh, 2022).

3.2 Review of Object Detection Models

3.2.1 One shot detection models

a) YOLO (You Only Look Once) and its variants

YOLO is a single object detection model (Redmon et al., 2016). The model is easy to construct and can be directly trained on whole images. Unlike classifier-based approaches, YOLO is trained on a loss function that directly relates to detection performance, and the entire model is learned at once. Yolo pushes the limits of real-time object detection as the fastest general-purpose object detector in the world. YOLO is suitable for applications that call for speedy and accurate object identification because it can be tailored to new domains. YOLO functions as a tracking system when coupled with a webcam, identifying objects as they move and change their appearance. However, YOLO imposes strong geographic constraints on bounding box predictions because each grid cell can only predict two boxes and one class. This spatial

restriction restricts the number of nearby items that our model can anticipate. Bird flocks, for example, are a good example of a little object that emerges in a group yet the model struggles to handle. Additionally, while the model learns to estimate bounding boxes from data, it has trouble generalizing to objects with novel or odd aspect ratios or configurations. The model also employs fairly coarse characteristics for predicting bounding boxes because our architecture incorporates numerous downsampling layers from the input image. The model was trained using a loss function that roughly represents detection performance, although our loss function treats errors in small and large bounding boxes equally. A small inaccuracy will typically go unnoticed in a large box, while a small error in a small box will have a far bigger impact on intersection over union (IOU).

The image is divided into SS grid cells with similar size using YOLOv1 (Redmon et al., 2016). A grid cell is in charge of object detection if the centroid of the object is located inside of that grid cell. Each cell may forecast a predetermined B number of bounding boxes with a confidence score. Each bounding box is composed of five values of x, y, w, h, and confidence score. In the paper, a modified YOLOv1-based neural network is suggested for object detection (Ahmad et al., 2020). Yolo-LITE, a real-time object identification model developed for mobile devices without a GPU, like a laptop or a smartphone, was proposed in the paper (R. Huang et al., 2019). (GPU). Real-time object identification is now more accessible to a wider range of devices thanks to YOLOLITE, a model that was created to offer a more compact, rapid, and efficient version of the original object detection algorithm YOLOV2. A state-of-the-art, real-time object identification system called YOLOv2 (YOLO9000) (Redmon & Farhadi, 2017) can identify more than 9000 different item types. In YOLOV2, batch normalization and convolution layers were merged to improve accuracy and reduce the overfitting problem. It is flexible enough to operate at different image sizes and enables a seamless trade-off between speed and accuracy. In order to address the problems with the YOLOv2 object identification model's excessive number of model parameters and poor performance on small-size objects, the study (R. Li & Yang, 2018) suggested an improved YOLOv2 object detection model. First, it improves the YOLOv2 by using depth-wise separable convolution instead of the YOLOv2's conventional convolution. There are 78.83% fewer parameters in the convolution layer. The feature extraction engine of Darknet19, which has problems identifying small objects, was upgraded to Darknet 53 in YOLOv3 (Redmon & Farhadi, 2018) to address the problem. The accuracy of the method was significantly improved in that study by the addition of residual block, skip connections, and up-sampling. The core of the feature extractors was again upgraded to CSPDarknet53 in YOLOv4 (Bochkovskiy et al., 2020), which significantly improved the accuracy and efficiency of the method. The most recent and effective version of the YOLO algorithm is called YOLOv5, and instead of using Darknet as its framework, it uses PyTorch (X. Zhu et al., 2021). Since the depth of the convolutional layer was decreased, another variation of YOLO v3 is known as YOLO v3-Tiny (Redmon & Farhadi, 2018). As a result, even though the running speed is significantly higher (around 442% quicker than the prior YOLO versions), the detection accuracy is reduced (Adarsh et al., 2020). An enhanced version of the YOLOv3 tiny network called YOLO-P (Junos et al., 2021) features a lightweight backbone made of densely coupled neural networks, a multi-scale detection architecture, and an anchor box size that has been optimized. The proposed YOLO-P model had a satisfactory mean average precision and F1 score of 98.68% and 0.97, respectively, based on the experimental results. The study recommended PP-YOLOv2, which performs

better than other well-known detectors like YOLOv4 and YOLOv5 in terms of speed and accuracy (X. Huang et al., 2021).

b) SSD

SSD (W. Liu et al., 2016) is a single-shot detector. It excels at striking a perfect balance between speed and precision of results. To create the feature map, the model computes a CNN-based model once on the input image. Additionally, it uses anchor boxes that are comparable to faster RCNNs at various aspect ratios and learns the offset rather than identifying the box. There are numerous layers in CNN, each of which uses distinct feature maps and processes data at varying sizes. As a result, it can find targets of various sizes. Even when input photos are of a small size, SSD beats other single-stage techniques in studies in terms of accuracy across a variety of datasets (Kumar et al., 2020).

c) Comparison Between YOLO and SSD

The image is not divided into random-sized grids by SSD as it is by YOLO. For each location on the feature map, it projects the offset of predefined anchor boxes (default boxes). Each box is a certain size, proportion, and location in relation to the relevant cell. Convolutionally, the entire feature map is covered by all of the anchor boxes. SSD and YOLO's anchors are slightly different from one another. Because YOLO uses anchors that can range in size from a single grid cell to the entire image, all of its predictions are based on a single grid. The SSD's anchors place a lot of emphasis on various pragmatic perspectives and dimensional ratios of its target shapes, but not nearly enough on goal size. Unlike the anchors of SSD, which are created using a simple method, the anchors of YOLO are calculated using k-means clustering on the training data. Although YOLO determines the confidence score to show confidence in the anticipated results, SSD does not use it. SSD performs this task via a unique backdrop class. A poor YOLO confidence score matches the anticipated SSD background class result. Both illustrate the impossibility of the detector ever discovering a target (Tan et al., 2021).

d) FCOS

FCOS (Tian et al., 2019) is a fully convolutional one-stage object detector that resolves object detection in a similar way to how semantic segmentation does so: by making predictions about individual pixels. Modern object detectors like RetinaNet, SSD, YOLOv3, and Faster R-CNN largely rely on pre-defined anchor boxes. Contrarily, FCOS is a proposal that is free of anchor boxes. By removing the predefined set of anchor boxes, FCOS completely eliminates the complex calculations related to anchor boxes, such as computing overlaps during training (M. Zhu et al., 2022).

e) FSAF: Feature Selective Anchor-Free

In comparison to its competitors that use anchors, the FSAF module (C. Zhu et al., 2019) operates faster and performs better. While adding the least amount of computational overhead when used in conjunction with anchor-based branches, the FSAF module can consistently beat the strong baselines over a range of backbone networks. FSAF outperforms the most cutting-edge single-shot detectors now available and significantly enhances strong baselines with little inference overhead.

f) RefineDet

RefineDet (Zhang et al., 2018) maintains efficiency comparable to one-stage approaches while beating two-stage methods in terms of accuracy. The two interconnected parts that make up RefineDet are the anchor refinement module and the object detection module. The former

especially aims to (1) filter out negative anchors to reduce the search space for the classifier and (2) coarsely adjust the sizes and positions of anchors to enhance initialization for the next regressor. RefinedDet needs an attention mechanism in order to improve performance even more.

3.2.2 Two-shot detection models

a) Region-Based Convolutional Neural Networks (R-CNN)

Region-based convolutional neural networks are referred to as R-CNN (Girshick et al., 2014). The model combines potent CNNs for object detection with region suggestions for object segmentation. This approach had a number of issues. Because it needs to categorize 2000 area suggestions, CNN training takes a while. Real-time implementation is not practical because it would take 47 seconds to execute each test image. One object detection approach that solves some of R-drawbacks CNN's is Fast R-CNN (Girshick, 2015). Similar to its predecessor, it uses region proposals, but CNN first creates a convolutional feature map from the image, which is then used to pick and warp region proposals from. In order for a fully linked layer to accept the distorted squares, they must be reformed using a RoI (Region of Interest) pooling layer to a preset size. Using a SoftMax layer and the RoI vector, the region class is then predicted. Fast R-CNN is quicker than its predecessor since it does not require the CNN to get 2,000 ideas for each execution. To create a feature map for each image, only one convolution process is used. The drawback of RCNN is that it processes many areas using CNN and uses three separate models to detect targets, which lengthens prediction time. Fast-RCNN uses a lengthy and time-consuming method. The outcome is that computation times are still rather long. For quicker RCNN, the object region proposal takes a long time. Different sorts of systems are operating one after the other. Therefore, the success of the operations that came before is necessary for the proper completion of the entire treatment (Adarsh et al., 2020).

b) Grid R-CNN

An novel framework for object detection called Grid R-CNN (Lu et al., 2019) accurately recognizes items by using a grid-guided localization technique. In contrast to standard regression-based techniques, the Grid R-CNN explicitly collects spatial information and benefits from the position-sensitive characteristic of a fully convolutional architecture. Grid R-CNN replaces the traditional box offset regression model in object detection by employing a grid-guided method for high-quality localization. Numerous tests show that Grid R-CNN performs at the cutting edge, particularly on challenging assessment criteria like AP at IoU=0.8 and IoU=0.9. Grid R-CNN also contributes to significant and ongoing advancement.

c) Mask R-CNN

Mask R-CNN (He et al., 2020) extends Faster R-CNN by incorporating an additional branch for object mask prediction on top of the existing branch for bounding box identification. Faster than Faster R-CNN by only a small amount, Mask R-CNN operates at 5 frames per second and is simple to train. Mask R-CNN is very straightforward to generalize to other issues; for instance, we can estimate human postures within the same framework.

3.3 Applications of Real-time Object Detection Models

An improved YOLO-based object recognition model for agricultural harvesting is presented in the study (Junos et al., 2021). The proposed model had a 98.91% accuracy rating when it came to identifying fresh fruit bunches of various ages. The extensive testing results show that the suggested YOLO-P model is effective in carrying out accurate and reliable detection at the palm oil plantation. The study (Kumar et al., 2019) suggested an object detector model for blind people to employ that is based on deep learning neural networks. With this method, objects can be located in webcam feeds, movies, and even still images. The accuracy of the model is more than 75%. Approximately 5 to 6 hours must be spent training this model. For real-time object recognition for a blind individual, the single-shot multi-box detector (SSD) technique was used in the model to achieve high accuracy and IOU. In order to observe people on the road, object detection is essential, according to the study (Kaur & Singh, 2022). Numerous application disciplines, such as robots, autonomous driving, and video surveillance, have engaged many researchers. The study also showed that face detection and identification, which has been the subject of much research, is one of the oldest applications of computer vision. Additionally, text detection, target detection for remote sensing, and traffic sign detection and classification all require object detection (Kaur & Singh, 2022). The study (Kaur & Singh, 2022) presents an object detection approach using deep learning neural networks to recognize objects in the photos. The study uses a multilayer convolutional network and an improved SSD approach to quickly and accurately recognize objects. A real-time object detection approach for blind people to use on any device running this model was suggested by the study (Kumar et al., 2019). A convolutional neural network and a single-shot multi-box detection method were used to create the suggested model. TPH-YOLOv5, which is highly effective in object detection in drone-captured situations, was proposed in the study (X. Zhu et al., 2021). For the visually challenged, a neural network model was suggested in the study (Potdar et al., 2018). Blind or visually impaired people rely heavily on their other senses, such touch and aural cues, to interpret their surroundings.

4. Discussions and Conclusion

Computers can now perceive, identify, and evaluate things in still photos and moving images thanks to the study of computer vision. Face detection, face identification, pedestrian counting, security systems, vehicle detection, self-driving cars, and other computer vision applications have all been used. The object detection framework divides detectors into two groups: conventional detectors and deep learning-based detectors. The two-stage detector and the one-stage detector are the two types of deep learning object detectors. Examples of one-stage model algorithms are SSD and YOLO in all of its versions, whereas examples of two-stage detector algorithms include RCNN, Fast RCNN, and Faster RCNN. Crop harvesting, object detector models for the blind, pedestrian identification on the road, traffic sign recognition and classification, text detection, and remote sensing target detection are some examples of applications for object detection. In our future work, it is proposed to optimize a YOLO object detection model that may help in guiding blind movements.

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Hybrid Method of Using Feedback from Users to Improve Music

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Abstract.

Automatic music classification relies primarily on traditional aspects of music encapsulated by content-based features. This means cultural aspects of music classification are not incorporated into the classification process. To improve classification, a hybrid method of using feedback from users is proposed to incorporate these cultural aspects. This paper proposes a pipeline of classifying music by genre using content-based features followed by the implementation of Q-learning. The GTZAN dataset is used to model four content-based classifiers, namely: Logistic Regression, Support Vector Machines, Multilayer Perceptron and Random Forests. The highest performing model was the Support Vector Machine (SVM) with an accuracy score of 75.50% based on a 10-fold confusion matrix, in line with other experiments in this field of research. Q-learning is used to further refine the predictions of the SVM by using user input to develop a Q-table with Q-values for each piece of music, associating it with a certain genre based on user feedback. This resulted in an accuracy score of 75.50%, like that of the SVM classification, indicating that Q-learning accuracy cannot overcome the initial classification introduced by the SVM predicted values.

Keywords: Music genre classification, Q-learning, recommendation, Content-based Features, Machine Learning

1. Introduction

Music classification is an area of research that has had many approaches and attempts at finding suitable solutions to automatic classification without human intervention. We live in a world where music streaming services use large databases to store millions of pieces of music for users to listen to (Ajoodha et al. 2015). Thus, for users to find the right assortment of music based on their tastes, it's common for music to be recommended by genre. Furthermore, hand-crafted labelling techniques (Nkambule & Ajoodha, 2021) have now become impractical with the sheer amount of pieces of music hosted by these services.

Automatic music genre classification overcomes these issues by using content-based features to classify pieces of music in a more objective way by making use of features inherent to the song itself. This form of labelling removes issues related to the subjectivity of genre classification that stem from meta-data (Ajoodha et al. 2015).

The work by Ajoodha et al. (2015) and Nkambule & Ajoodha (2021) indicate that the application of automatic labelling of pieces of music results in highly accurate predictions (81% and 80.8% respectively). De Mulder et al. (2004) also showed that reinforcement learning is also effective at mood classification of music by using the feedback from user after a recommendation is made. The recommendation system in Wang et al. also allows users to give indications on whether or not the recommended music is related to the genre requested (Hsu et al., 2014), further fine tuning auto-classification.

The aim of this paper seeks to explore how using well known and effective automatic music classification methods can be further improved by using Q-learning, a well established reinforcement

learning technique. This will allow for the recommendation music to a user and have them provide feedback on whether or not the piece of music fits in with the genre they requested.

Four music genre classification models are implemented using the GTZAN dataset, namely: naive Bayes, support vector machines, multi-layer perceptron, linear logistic regression, k-nearest neighbours and random forests. The most accurate of these classifiers is used to create initial values for the Q-table used by the Q-learning algorithm in order to bias the learning towards what was discovered by the classifier. Further updates to the Q-table will be made through the feedback provided by the user on the accuracy of the recommendation made according to the user requested genre.

Out of the four classifiers used, the support vector machine (SVM) obtained the highest accuracy score of 75.5% when using a 10-fold confusion matrix as the evaluation metric. The predictions made by the SVM are used to bias the Q-table of the Q-learning algorithm and after 1 000 000 iterations the 75.5% accuracy score was maintained.

While no increase in the accuracy was obtained, the experiments contained in this paper indicate that the use of a hybrid method for recommendation using Q-learning can, with some success, recommend relevant pieces of music. The contributions of this research are as follows:

- Produced models with high classification accuracy using only the mean and standard deviations for feature representation.
- Produced a reliable recommendation engine based on Q-learning reinforcement learning.

In the next section, the work explored in the compilation of this research is expanded upon including how the work is interrelated and how different approaches were taken to achieve classification and recommendation.

2. Related Work

Music recommendation is an area of study that has received immense attention due to the prevalence of online music stores and streaming services that allow users to play songs stored on the cloud. Genre classification allows users to easily find music that suits their taste, while recommendation systems come with the convenience factor of recommending music when the user is not quite sure what they would like to listen to. This opens the door for users to explore new pieces of music based on their listening preferences (Hsu et al., 2014).

2.1 Data

Currently in content-based approaches to music classification, the magnitude spectrum of a piece of music is used to find commonalities between genres of music based on the features present in the magnitude spectrum (Ajoodha et al., 2015; Nkambule & Ajoodha, 2021; De Mulder et al., 2004). In Ajoodha et al. (2015) and Nkambule & Ajoodha (2021), content-based features are extracted from pieces of music in the GTZAN dataset in order to use them as predictors for music genre.

In Hsu et al. (2014), 1000 30 second snippets are also used to develop the models in the paper, in contrast however the music is obtained from YouTube videos evenly spread across the 10 genres. De Mulder et al. (2004) uses an altered MAMI dataset, which includes 160 full length pieces of music that come from 6 genres instead of the original 11. The distribution of music in the 6 genres is as follows:

24 classical, 18 dance, 69 pop, 8 rap, 25 rock and 16 other tracks. Two papers use user feedback to refine these labels by using reinforcement techniques to classify based on genre in Hsu et al. (2014) and by mood in Stockholm & Pasquier (2009).

2.2 Features

Music classification typically makes use of four categories of content-based features in order for the models to differentiate between the genres, namely magnitude-based features, tempo-based features, pitch-based features and chordal progressions (Ajoodha et al. 2015). Ajoodha et al. (2015) and Nkambule & Ajoodha (2021) make use of all the categories named above to classify music into it genres, while Hsu et al. (2014) and De Mulder et al. (2004) extracted only magnitude-based features to conduct modelling.

In Ajoodha et al. (2015) along with De Mulder et al. (2004), the features extracted are represented as MFCC aggregations, area moments and feature histograms. Hsu et al. (2014) and Nkambule & Ajoodha (2021) make use of more aggregated feature representation, which includes the mean and standard deviation of the time-series data used.

In order to optimise the number of features used to train the models used, Ajoodha et al. (2015) and Nkambule & Ajoodha (2021) make use of information gain ranking to reduce the dimensionality of the training data. Hsu et al. (2014) instead uses principal component analysis to reduce feature dimensionality.

2.3 Models

In implementing automatic content-based genre classification, Ajoodha et al. (2015) and Nkambule & Ajoodha (2021) make use of six classifiers, namely: Naïve Bayes, Support vector machines, Multi-layer perceptron, Linear logistic regression, K-Nearest neighbours and Random forests. Support vector machines were left as future work in the classification work done by De Mulder et al. (2004), which instead chose to use Gaussian classifier, Gaussian mixture model, Iterative expectation maximization and K-Nearest neighbours. The Q-learning implementation in Stockholm & Pasquier (2009) is based on the Q-value update rule:

$$Q_{ij}(x,y) = Q_{ij}(x,y) + \alpha R, \quad (1)$$

where α is the learning rate and R is the reward obtained from user feedback. Gibb's measure is used to implement a Softmax selection policy in the paper with the following equation:

$$\frac{e^{Q_{ij}(x,y)/T}}{\sum_{x,y} e^{Q_{ij}(x,y)/T}}. \quad (2)$$

Hsu et al. (2014) opted to use multi-arm bandit approach to implements its reinforcement learning based recommender system. Both user feedback and the novelty of the piece of music is given by the following equation: (more implementation details can be found in the original paper)

$$U = U_c U_n = \theta^0 x (1 - e^{t/s}). \quad (3)$$

3. Evaluation

The predictively accuracy of the models used in Ajoodha et al. (2015) and Nkambule & Ajoodha (2021) was evaluated using confusion matrices. The probabilistic classifiers that obtained the most success in the two papers were Support Vector Machines with classification accuracy of 80.8% (Nkambule &

Ajoodha, 2021) and Linear Logistic Regression with a classification accuracy of 81% (Ajoodha et al. 2015). Other well known results are referenced in table 1, obtained from (Ajoodha et al., 2015).

Table **Error! Main Document Only.**: A table which summarizes related work to the problem statement.

Benetos and Kotropoulos (2008)	75.00%
Bergstra et al. (2006)	82.5%
Holzapfel and Stylianou (2008)	74.0%
Li et al. (2003)	79.7%
Lidy et al. (2007)	76.8%
Panagakis et al. (2008)	78.2%
Sturm (2013)	83.0%
Tzanetakis and Cook (2002)	61.0%
Ajoodha et al (2015)	81%
Nkambule and Ajoodha	80.8 %

Along with confusion matrices, De Mulder et al. (2004) made use of a lower and upper bound classification consisting of a random classification and human classification respectively. The lower bound model achieved an accuracy of 58% while the upper bound classification achieved an accuracy of 90%.

Reinforcement learning techniques use the feedback from users to improve the recommendation of music based on the requested genre. The two techniques explored are Multi-arm bandit with user genre preferences (Hsu et al., 2014) and in the case of Stockholm & Pasquier (2009), Q-learning based on the mood of a piece of music. In this report, emphasis is placed on using Q-learning to get a q-table that gives an indication of how high a user rates a piece of music into one of the 10 genres present in the GTZAN dataset.

4. Feature Analysis

Since content-based features are used to classify the pieces of music in the GTZAN dataset into their respective genres, time-series features are extracted from the piece of music itself in order to apply modelling (Ajoodha et al., 2015; Hsu et al., 2014). Features related to pieces of music broadly fall under four categories (Ajoodha et al., 2015; Nkambule & Ajoodha, 2021), namely:

- **Magnitude-based features:** timbral features that represent loudness of the piece of music by analysing its magnitude spectrum to find signal changes, noisiness and other spectral features.
- **Tempo-based features:** represents rhythm present in the piece of music by calculating the spectral energy (rootmean-square) of its signal.
- **Pitch-based features:** frequency of sounds present in the piece of music related to the different scales of pitch used in specific genres.
- **Chordal progression features:** use of the 12 component design matrix (chroma) where each component represents the intensity of a semi-tone in order to distinguish chords present in the piece of music.

4.1 Data

The dataset used in this report is the GTZAN dataset that comprises of 1000 pieces of music, with a length of 30 secs each. Each piece of music has a label based on one of the 10 genres of music it

belongs to. This dataset has been widely used in building music classification models that have high levels of accuracy (Nkambule & Ajoodha, 2021; Ajoodha et al., 2015).

5. Features

The specific GTZAN dataset used contains 57 features that each fall under one of the four categories of music related features. Each feature contains two dimensions, the mean of the feature across the 30 seconds of playtime, and the standard deviation of the feature across playtime. These aggregations are used to predict the genre each piece of music belongs to. Table 2 indicates the measure used to represent the feature and the category it falls under.

All the features were preprocessed using feature scaling and feature normalization before any modelling was done. Feature scaling is used to give uniformity to the range of values in the

Table 2: Features and their representation in the GTZAN Dataset

Category	Feature	Representation	Dimensions
Magnitude-based	Spectral-centroid	mean+variance	2
	Spectral-bandwidth	mean+variance	2
	Spectral-rolloff	mean+variance	2
	MFCC 1-20	mean+variance	2
Tempo-based	Tempo	single value	1
	Energy	mean+variance	2
Pitch-based	Zero crossing rate	mean+variance	2
Chordal progression	Zero crossing rate	mean+variance	2
	Harmony	mean+variance	2

features by forcing them to have zero mean and unit variance. The equation used in feature scaling is as follows:

$$X' = \frac{X - \mu}{\sigma} \quad (4)$$

where μ is the mean and σ is the variance.

Feature normalization is used to scale and shift the values of the feature in order to ensure that they fall within the range of 0 and 1. The equation used for feature scaling is as follows:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (5)$$

5.1 Feature Selection

To ensure the models implemented are highly performant as well as generalizable, feature selection is applied in order to remove features that are most informative and leave out those that are either redundant or do not contribute to the accuracy of the model. Embedded feature selection ranks said

features using their impurity-based importances. This is done by using a forest of trees classifier to calculate these feature importances. Figure 1 shows the sorted values obtained for the feature importances.

The chroma sftf mean feature has the highest importance however, a lot of the features carry similar values of importance. This leads to the decision to include all the features listed in section C, which will be shown later to be beneficial to the accuracy of the model without hampering performance.

6. Automatic Music Genre Classification

In this section, the features listed above are used to train four classifiers that will classify each piece of music of the GTZAN dataset into one of ten genres. Predictions made by the classifier with the highest accuracy will be used as a starting point for the Q-learning reinforcement algorithm to further improve its accuracy based on a q-table learned from user feedback. The four classifiers were chosen from Ajoodha et al. (2015) and Nkambule & Ajoodha (2021) because they were performant.

These off-the-shelf models include: logistic regression, support vector machines, multilayer perceptron and random forests. The results of this experiment are contained in table 3, where the accuracy for each model is based on the use of a 10-fold confusion matrix to evaluate the accuracy of the model predictions. The values in table 3 are averages obtained for the prediction accuracy across the 10 genres contained in the GTZAN dataset.

From table 3 the SVM is a marginal winner in terms of accuracy with a value of 75.5%, narrowly beating out the Multilayer Perceptron with an accuracy value of 74%. However, when one looks at the time taken for the Multilayer Perceptron to achieve that second place result, it is clear that the Support Vector Machine wins on that metric handily with a Time to Fit that is 40× faster.

The Logistic Regression and Random Forest classifiers are also close to one another in terms of accuracy, with 65.5% and 66.5% respectively. However, we also observe a gap in the Time to Fit model metric as the Logistic Regression model lags behind the Random Forests model by 3× the time taken to fit the model.

To illustrate how these accuracy values are calculated, the 10-fold confusion matrix of the Support Vector Machine model is shown in Figure 1. Each true label for a piece of music is compared to that of the predicted label across the entire data set. The accuracies for each genre label is aggregated into an average associated with each model.

As mentioned above, feature selection was not used in this report due to loss of accuracy performance when applied to the features used here. In table 4, the same models are run after tree-based feature selection is implemented.

There is a clear benefit in the Time to Fit Model metric across the board for the models, however this is at the detriment of the accuracy as all models dropped in that metric. This means feature selection should only be done when features have high dimensionality that makes them impractical to fit without reducing the number of features used.



Fig. 1. Figure representing SVM confusion matrix where the bottom axis represents the true genre labels for the pieces of music, while the left hand axis represents the genre classifications made by the SVM model.

7. Music Recommendation Engine

From the above classifiers, the obvious choice to use for the music recommender is the Support Vector Machine. Using the predicted genre classifications, a Q-learning algorithm will be used to further refine these recommendations for increased accuracy of the recommender.

Table 3: Parameters for each model used with SCIKIT-LEARN Functions.

Classifier	Parameters
Logistic Regression	default parameters
Support Vector Machine	C=3, max iter=500
Multilayer Perceptron	max iter=850
Random Forests	max depth=100

Table 4: Accuracy and the time to build each model in the study.

Classifier	Accuracy	Time to Fit Model (seconds)
Logistic Regression	60.50%	0.0382
Support Vector Machine	69%	0.0468
Multilayer Perceptron	69%	5.4346
Random Forests	64%	0.3346

. Q-learning

Q-learning is a popular implementation of reinforcement learning where a Q-table that maps a state to an action is developed where the values in the Q-table (Q-value) represent the responses from the user (Stockholm & Pasquier, 2009). When a piece of music is recommended to a user based on their response when prompted to choose one of the 10 genres in the GTZAN dataset, the user is given a chance to provide feedback on the recommendation. A 'Yes' response means the recommended piece of music fits in with the genre, whereas a 'No' response means the piece of music does not fit into the genre selected by the user (Stockholm & Pasquier, 2009).

The Q-value associated with a piece of music belonging to one of the 10 genres is updated based on the response from the user. The reward value is set to 1 with a Yes response, while a -1 reward value is set with a No response. The update rule for the Q-value is given by equation 6 (De Mulder et al., 2004) as follows:

$$Q(state,action) = Q(state,action) + \alpha R, \quad (6)$$

where state represents the genre the user wants to be recommended while action is one of the songs the recommender engine will recommend to the user. In order to balance the requirements of exploitation (recommend piece of music with highest Q-value) and exploration (recommend a new song the user might like), some random choice is implemented in order for the engine to explore more of the action space (Hsu et al., 2014).

Typically when implementing a Q-learning model, the initial values of the Q-table are small random values used to choose actions for the actor to take. In the music recommendation engine, the predictions made by the Support Vector Machine for a subset of music pieces are used to initialize the q-table instead.

The Q-value associated with the SVM predicted genre label of the piece of music is initialized with a value of 1 to give it a higher probability of being recommended for that genre. This value will be updated using the update rule in equation 6 to increase its recommendation probability further, or decrease it if it was incorrectly labelled.

The algorithm allows for the exploration of pieces of music in the list of songs used for testing the SVM classifier. This is achieved by defining an variable, with a value of 0.6, which is compared with a generated random value between 0 and 1. If the random value is less than , a random piece of music within the requested genre is recommended to the user (exploration). If however, is smaller than the random value, the piece of music with the highest Q-value within the requested genre is recommended instead (exploitation).

As we develop our strategy, we have less need of exploration and more exploitation to get more utility from our policy. Hence why as the number of iterations increases, decreases by 0.0001 for the algorithm to favour exploitation over exploration. A total of 1000000 iterations of the algorithm are execute, with the value decreased every 100 iterations. Execution of the algorithm took a total of 821.2443 seconds (13.7 minutes) to complete after the 1000000 iterations.

Evaluation

Reinforcement learning is based on the algorithm exploiting its priors to obtain as many rewards as possible. After each iteration, the rewards are accumulated in order to evaluate their trend over the

iterations. If the recommendation engine is learning which piece of music belongs to which genre, then it's expected that this plot will show steady increases in the reward over the iterations.

In order to evaluate the Q-learning implementation, the algorithm loops through all genres in each iteration and queries the recommender engine for a piece of music in that genre. Rewards of 1 are given when the recommendation fits the genre and -1 otherwise.

In Figure 3, the cumulative rewards increase overtime, indicating that the recommendations made by the recommendation engine match the user specified genre. The Q-table at the end of the algorithm is used to evaluate the accuracy of the genre labelling through a confusion matrix. This results in an accuracy score of 75.5%, similar to that of the Support Vector Machine, indicating no material increases in the accuracy despite using user feedback on the recommendations. The confusion matrix in figure 4 indicates just how similar the results are to those of the SVM in Figure 1.

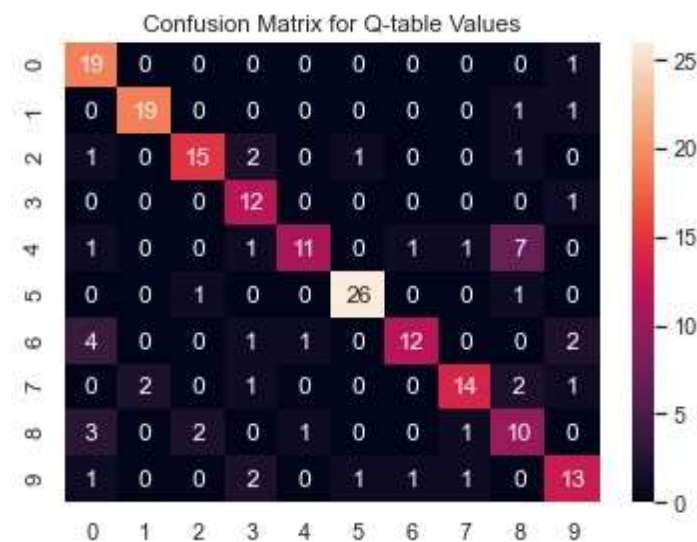


Figure ??: Figure representing confusion matrix based on each piece of music's maximal values in the learned Q-table. These values are based on user feedback regarding the accuracy of its genre classification.

8. Conclusion and Recommendations

The results obtained from this experiment indicate that there is a lot of potential in using automatic classification of pieces of music based on their genre. This is an area of study that has been widely explored but it still shows that room for improvement is possible when such accuracy in prediction is obtained from using an aggregated feature set of pieces of music with short length. However, in this experiment lower accuracy scores were obtained precisely due to the aggregated nature of the features used in the models.

While Ajoodha et al. (2015) obtained an accuracy high of 81.00% from the Logistic Regression classifier in their report, here the highest performing model (Support Vector Machine) managed to only obtain 75.5%. While it is not far off, it shows that using hand crafted features that are not aggregated allows for much greater accuracy results at the cost convenience of modelling.

The same can be said for Nkambule & Ajoodha (2021), where their highest performing obtained accuracies of 80.80% when also using a Support Vector Machine. Newer algorithms like XgBoost might do well here as well, since they are classifiers that rely on decision trees, perfect for this use case.

Love & Ajoodha (2019) propose the use of ontologies, which extract influences between objects, to find relationships between the genres since pieces of music typically straddle between genres. This would allow for the creation of a network of genre classifications for a piece of music, allowing it to have probabilities being in each class rather than a single classification.

The use of the SVM predictions to initialize the Q-table of the Q-learning algorithm before execution resulted in accuracy scores exactly the same as that of the SVM itself (75.5%) after 1000000 iterations. This indicates that despite the algorithm trying to alter the genres based on user feedback, it is not enough to overcome the initial biasing introduced to the Q-table.

Reinforcement learning performance is usually dependent on the number of iterations used to train the agent, and in the case with only 1000000 iterations it took nearly 14 minutes to complete execution. By using a higher number of iterations, it could be possible to increase the accuracy score of the genre labelling of the pieces of music (Stockholm & Pasquier, 2009).

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A Namibian Case Study on E-Mail Phishing: Proposing an E-Mail Phishing Awareness Approach

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Abstract.

Electronic mail (e-mail) has become the most used communication tool for both personal and business purposes across the globe. Email has been lauded for its' instant nature, accessibility from anywhere in the world, and availability on different communication devices. Apart from its popularity and effectiveness, it has its threats or disadvantages. To curb those threats, technical measures have been put in place by organisations. However, the effectiveness of these measures has been minimal as they do not perform according to the design. This is due to the fact that measures are usually compromised by humans. To curb the loss of sensitive organisational data, the solution will be to create email phishing awareness campaigns by sending spoofed emails to email users in selected Namibian organisations. The campaigns will determine the level of awareness, amongst users of each organisation and then perform a cross-organisational comparison between the email users. Thus, allowing for the provision of organisation specific training on e-mail security. Using the proposed Email Phishing Awareness Tool (EPAT) email user behaviour will be tracked and provide organisations with an on premises or cloud-based solution that is amendable as per the organisational needs. This study aims to increase email phishing awareness amongst organisations' email users to protect and prevent the loss of sensitive data using social engineering and to amend their behaviour towards the mitigation of email phishing attacks.

Keywords: Social engineering, email phishing, User behaviour, email phishing awareness

1. Introduction

Electronic mail (email) has been used by organisations and individuals to effectively, reliably and speedily communicate since 1971 (Mishra & Jain, 2012). Email is listed among the widely used personal and workplace communication tools (Alwanain, 2019). Moreover, email however has disadvantages or downfalls such as email phishing. Having provided ease of communication, email has quite a lot of technology exploitations meant to steal sensitive personal information (Gangavarapu et al., 2020). Email phishing is described by (Williams et al., 2018) as a successful penetration of an organisation, achieved by luring organisation email users to click on a malicious link or attachment contained in an email. On the other hand, Nakamura (2019) defined it as a semantic attack aiming at taking advantage of a user's naivety and stealing sensitive information when using electronic mail. Using social engineering techniques phishing is used to fraudulently capture a user's sensitive information such as usernames and passwords. Vayansky & Kumar (2018) perceive email phishing as a criminal activity, the oldest crime, and a dangerous threat to everyone using the Internet and are of the opinion that since nowadays information is stored online it makes it easy to steal if not well

protected. Phishing is a threat not only to corporates but to individuals as well (Payne, 2021). This was confirmed by Steve Kelley of Edgewave (an email security organisation) in his interview with (Matteson, 2019) on anti-phishing techniques.

Since it is classified as a threat to both organisations and individuals there is a need to prevent email phishing from prevailing (Alwanain, 2019). There are different techniques to address email phishing categorised in two groups namely technical and non-technical. Technical countermeasures commonly automatically detect email phishing using rules that are configured by administrators (Matteson, 2019). On the other hand, non-technical countermeasures are techniques that look at the aspect of humans as a solution to the protection of organisational data. An individual or organisation's overall security landscape is influenced by a user who is equipped with awareness, abilities and skills, these aspects change the user's behaviour and perception when it comes to the information security aspect (Shava and Greunen, 2015).

In cybersecurity studies, humans are considered the weakest link when it comes to the use of email just like any other technological system. Humans tend to relax some of the measures put in place and in the process sensitive data is lost or leaked, both intentionally and accidentally (Pike, 2019). The loss of sensitive data has a direct negative impact on revenue at times. Even though some organisations have e-mail policies that provide best practices on e-mail use, people and organisations do not pay attention to capacitate themselves or employees with the necessary Dos and Don'ts of email usage to close the gap that is left by the technical measures in place. With the use of email, organisations and people do not take the security issue into account.

The main contributions of this paper are to evaluate the level of email phishing awareness among Namibian email users, provide free organisational specific email phishing awareness and protect sensitive information from being leaked or stolen through the much-used communication tool which is email.

This paper is organised as follows, section 2 covers the review approach and section 3 details the overview of e-mail phishing, and section 4 covers the proposed email phishing awareness approach followed by section 5 which gives the results and analysis. Section 6 then concludes the paper as well as pointing to the future work on this subject.

2. Review Approach

Qualitative data collection is defined by Aspers & Corte, (2019) as a process used to improve the scientific study population by getting closer to the studied phenomenon. Qualitative data was collected from a study population to test the level of email user awareness.

The study was conducted on five (5) Namibian organisations in different fields of specialisation, Organisation A (a banking institution), Organisation B (a news Magazine), Organisation C (an IT consultant company), Organisation D (an IT security company), and the Organisation E (a water processing organisation) all in based in Windhoek the capital city of Namibia.

The sampling population of a total of 250 was conducted by selecting 50 members from each of the five organisations, to ensure equal presentation the selection was made from different departments with access to the organisation's email. This was done so to understand the awareness level of all departments of the organisational email users. Each member received a spoofed email meant to have originated from their superiors.

The analysis of the collected data was performed using the quantitative methods as the outcome was compared to other email users. A quantitative research method is defined as a method to analyse and quantify variables for the production of results of a certain study in the quest to answer questions such as who, why, what, where, how, etc. (Apuke, 2017).

The exercise results could be read in two ways, either on the tool's dashboard or a .csv file extracted from the tool. The following information is visible from the results; the number of users' that opened, read, or submitted the results. Open, means the email recipient opened the send email and or read the email, time indication is visible as to how long they took to open the email upon its arrival in their mailbox. Submit, means the recipient fell prey to the email and entered their sensitive information as per the request of the hacker.

Looking at each organisation's results, the analysis to classify the organisation's awareness level is achieved by how many users submitted their results and how long they took to open/ read the phished email. The organisations with more than 40 % responders that submitted the information is rated and considered as high risk when it comes to information security and the lack of email phishing awareness.

3. Email phishing overview

In this part of the paper, we are looking at what other researchers have to say regarding email phishing.

3.1 What is email phishing?

There are multiple definitions of email phishing. Phishing is a method used by attackers posing as affiliation to the user, to deceive an email user in providing them with sensitive information, for personal gains (Alwanain, 2019). Wanca & Cannon, (2016) defined email phishing as a social engineering activity (social engineering is the manipulation of a user in providing information under false pretence) to access a computer system or access to their banking institution. Email phishing is usually containing some fear and urgency to the mail recipient. With the covid-19 pandemic, phishing is said to be on the increase, with fear instilling emails send to victims (Sjouwerman, 2020).

Email phishing can happen in many ways one of the renowned such methods is email spoofing. Email spoofing is a form of social engineering. Email spoofing is described by (Harris et al., 2021) as an attack techniques tricking users to believe an email came from a trusted entity or person, achieved by amending the header of the email. Another method that could lead to email phishing is spear phishing, an action derived from a pre-defined purpose to attack an organisation (Muntode & Parwe, 2019).

3.2 Effects of email phishing

The use of digital and electronic modes of communication could lead to a loss of sensitive data or finances in the event it is not used with great care (Muntode & Parwe, 2019). Cyber criminals target specific computers for the sake of monetary gains or other kinds of deceit. Commission of a crime using stolen credentials could make an attacker get away with a money transfer crime by incriminating the organisation's accountant. The Attacker will not be identified as the credentials used are those of the accountant (Wanca & Cannon, 2016).

Wanca & Cannon, (2016) are of the opinion that irrespective of whether on a personal or professional capacity cybercrime victim's lives could lead to multiple negative impacts. They singled out a few and

gave a brief description of each; loss of time, trauma, financial loss, social consequences, business consequences and loss of productivity.

- **Loss of time** – victims are inconvenienced as a recovery from a phishing attack consumes a lot of time, confuses the victim, the time spent on the recovery depends on the harm caused by the attack.
- **Trauma** – identity theft because of email phishing could lead to a victim to withdraw from the community, they can lose trust in people, it leads to anger, powerlessness, frustration, could lead to lack of sleep and worse of all depression.
- **Financial loss** – direct and indirect loss of finances are common results of email phishing.
- **Social consequences** – a victim's relationships could be uncovered through phishing which could be exposed causing embarrassment to the victim and their families as well as other relationships.
- **Business consequences** – the intellectual property and customer data are at risk in a successful phishing attack. This could lead to clients losing trust in the organisation, leading to a loss of client line. Cyber-espionage because of employees interacting with malicious websites, accessed via the links in emails.
- **Loss of productivity** – a human being's productivity is mostly reduced after a cyber-attack, as they spend more time confirming and verifying the originality of each email.

4 Email phishing lifecycle or process

For a successful attack an attacker spent some time studying their prey or victim (Opazo et al., 2018). Upon a successful information gathering the attacker then launches the attack as shown in figure 1.

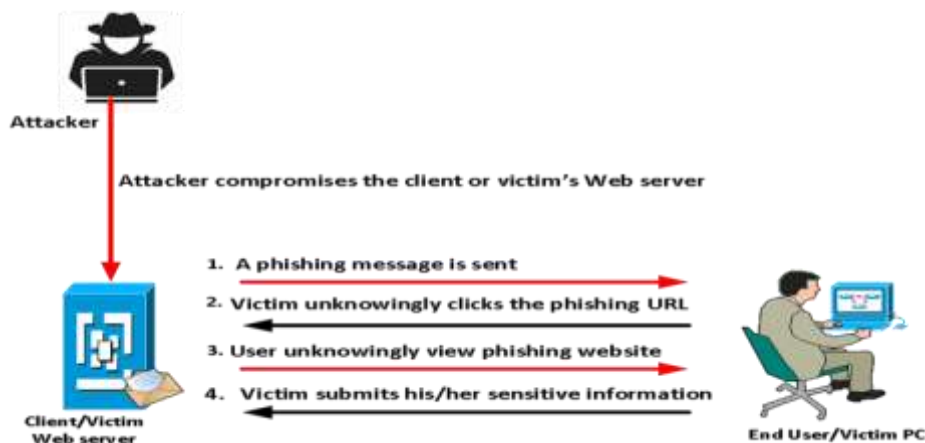


Figure: *Error! Main Document Only.* Email phishing lifecycle

The above figure shows the lifecycle of a phished email as briefly explained by the steps below:

1. Send a spoofed email; defined as a phishing and spam attack fooling the receiver that the message is coming from the receiver's associate be it an individual or organisation (Harris et al., 2021).
2. The message in the email urgently requires you to alter your sensitive information such as passwords, Personal Identification Number (PIN), etc and always threatens that failure to do so, you will be denied access to the system.
3. Part of the message is a link to the password, PIN or any sensitive information reset page (Muntode & Parwe, 2019).
4. In the event the user completes the password/ PIN or sensitive information changing act, the information is sent back to the attacker, which grants the attacker access to the user's

credentials, in the event of an organisation they then have access to the organisation's systems (Matteson, 2019).

5 Email phishing statistics

Email phishing is on an increase on a daily basis, especially during the ongoing Covid-19 pandemic (*Top 100 Companies in the Middle East Put Customers at Risk of Email Fraud*, n.d.). His observation was made during a study he conducted in the Middle East on the danger of email phishing and customer data exposure by the Forbes top-ranked 100 companies resulting in the following: 69 % of the companies uses Domain-based Message Authentication, of which it is believed that 31 % of such company clients' information is exposed and is used to victimise the clients through email phishing.

Namibia as a country is not spared by email phishing, it also suffered some attacks, the following are a few of the suffered attacks; Mr. Dos Santos a businessman suffered a blow as a certain Mr. Ricardo Nestor successfully transferred an amount of about N\$ 720 000 into his own account through Business Email compromise. The biggest recorded to date is believed to be the National Petroleum Corporation of Namibia (Namcor), at the end of 2018 who wrongly paid a total of N\$ 2.2 million into an Estonian bank account which was meant for a Malaysian supplier, using email spoofing (Smith, 2019). Olivier, (2017), reported that Standard Bank of Namibia suffered their greatest blow when through email phishing, employees transferred a total of about N\$ 300 million in a period of two hours.

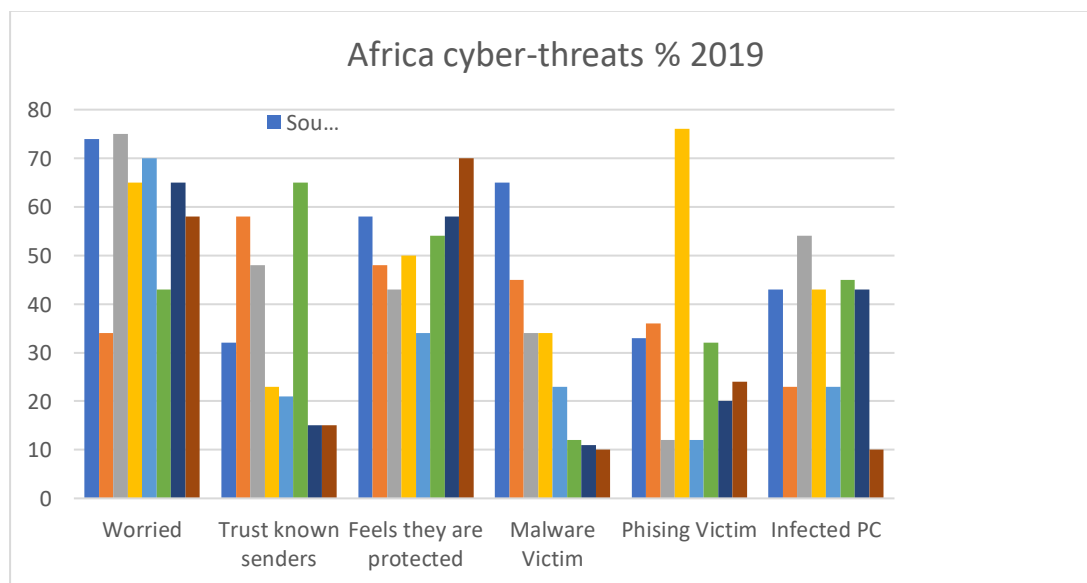


Figure: 2 Cyber threats in Africa 2019. Source: Press, (2020)

6 Email phishing countermeasures or solutions

It is a well-known fact that recovering of lost resources through email phishing or any other method is at times difficult and mostly impossible, therefore it is best to stick to the saying "Prevention is better than cure"(Opazo et al., 2018). It is believed that there are two different methods or countermeasures to email phishing namely; Technical and Non-technical (Irwin, 2020).

- **Non-Technical countermeasure**

Existing security systems are not widely implemented and cannot provide perfect protection against a technological threat that relies on social engineering for success, as systems are not designed to curb the complicated attacks (Opazo et al., 2018). Defeating security breaches through a person instead of technology is actually the most cost-effective approach and can also generate some of the highest success rates (Wanca & Cannon, 2016).

These solutions provide the email user with awareness, the user is trained at what to look at to spot a phished email, example to look at the heading of the email and look up the domain the email is coming from (Alwanain, 2019). Users may be educated through company programs to beware of phishing scams, links and attachments (Opazo et al., 2018). Innab et al., (2018) seconded their opinion that enough email phishing awareness instil correct and safe adaptation in employees on how to deal with suspected phished emails.

- **Technical Countermeasures**

These type of counter measures relies on machines or software based solutions, the solution is meant to automatically detect any phished email that meets rules set up by administrators (Matteson, 2019). They come in different types but we will describe only two; Secure Email Authentication (SEA) and Content Filtering (CF) as described by (Gangavarapu et al., 2020).

Content filtering is a method of going through the email content looking at a predefined automatic rule, using Machine Learning (ML), to classify the email as spam or phished email. The remaining emails are classified by passing unclassified rules for email by going through the mail content, these are done by comparing algorithm based rules effected by administrators (Madankar et al., 2016).

Sparkpost Academy, (2021) described Secure email authentication as a method of proving that an email is not forged by using technical solutions. Used to prevent email phishing and spam by blocking them.

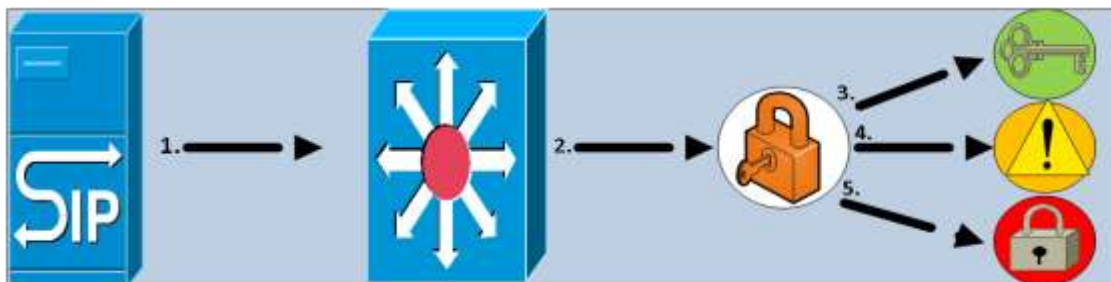


Figure: **Error! Main Document Only.** Secure Email Authentication steps. Source: (Sparkpost academy, 2021)

Figure 3 depict the steps involved to successfully perform SEA (Sparkpost academy, 2021);

Step 1: The Sender domain sets rules by setting a policy on how to authenticate its emails. The rules are published and authenticated by configuring the mail servers and all other technical infrastructures.

Step 2: The receiving email server checks the incoming email message details against its domain set of rules. Based on those rules the mail server performs authentication by;

Step 3: The server delivers/ allows the message if it meets are set rules. Or

Step 4: Flags the message for review or

Step 5: Rejects/ denies the message. Secure Email Authentication is considered to be an obsolete anti email phishing approach, due to its administrative overload (Gangavarapu et al., 2020).

These countermeasures are however deemed ineffective, as attackers continue to up their games and change their modus operandi on a daily basis and is of the opinion that administrators cannot create rules for any threats that they are not aware of (Irwin, 2020).

4. A proposed approach for E-mail phishing awareness

Prevention of data loss is achieved by providing effective awareness to organisation email users on email phishing (Alwanain, 2019). The proposed approach (Email Phishing Awareness Tool (EPAT)), is developed to curb the loss of organisation sensitive data. With EPAT email phishing campaigns are conducted to determine the level of email phishing awareness amongst email users. After determining the level of awareness EPAT compares and evaluates the results that is used to create and provide organisation specific training. In addition, EPAT should track the phishing awareness level amongst corporate email users. EPAT is developed to track user behaviours, measure awareness level, and provide organisation specific training on email phishing. The benefits of EPAT is the creation of email phishing awareness, the protection of personal and organisations' sensitive information and the reduction of email phishing. EPAT is an amendable solution to the ever-evolving email phishing, that is usable by organisations. It can be hosted on the cloud or on the organisation's premises.

5. Results and Analysis

The results of the survey yielded the expected results, that backs up the identified gap amongst Namibian organisation email user. The results are listed below from each organisation;

- i. Organisation B; out of the sent emails 60 % of the responded fell prey to the attack and successfully submitted their sensitive information. Twenty 20 % of them clicked the link but did not submit the required information. The last 20 % of the participants opened the email but did not click on the provided link. This ranked the organisation as a high risk when it comes to lack of email phishing awareness.
- ii. Organisation A, 80 % of the participants submit the required information, which is a big threat to the clients' finances and sensitive information ranking the organisation as a high-risk category.
- iii. Organisation C results were 20 % submitted the required information, 40 % read emails and 40 % clicked on the link without submitting the required information according to the analysis this organisation falls into the medium risk category.
- iv. Organisation E falls under the high-risk category as 40 % of the users submitted the required information, 40 % opened the email while the last 20 % clicked on the link without submitting the required information.
- v. The last organisation, Organisation D, yielded no results, during the exercise all emails went unopened. Upon investigations with the IT department we were informed that all emails were received, flagged and not sent to mailboxes by the IT personnel. This is one of the challenges experienced during this exercise as one cannot really evaluate the level when the intended audience does not receive the emails.

These results proved that email users in the Namibian organisation need awareness to secure the sensitive information which could lent in wrong hands. It proves that there is a need for awareness creation which Email Phishing Awareness Tool (EPAT) can create.

6. Conclusion

Email phishing is causing damage not only to individuals but to organisations as well. As much as it has been described in multiple ways, its effect is fatal to one's information. To get a clear picture of what it really is, we looked at what it is, how it works (its life cycle), and the effects it has on victims' health, finances, and performance.

The light was shed as to why people or attackers conduct email phishing, measures that are in place and what needs to be done to reduce, if not end email phishing. It has come to light that a solution needs to be put in place to combat the ever-rising cyber-crimes. Based on the previous research conducted it is concluded that humans are the last hope to prevent email phishing from prevailing. As humans are perceived as the last stage of any technological preformation requiring interaction, this can only be achieved when humans change their behaviour. In the event of not correct use, email benefits or advantages could be outnumbered by its disadvantage.

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Co-Designing an AI driven supervisory real-time tracking system for Namibian children

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Abstract

Children now live in a world where Artificial Intelligence (AI) seemingly permeates everything. AI, which can be defined as a group of powerful algorithms designed to collect and examine data in order to make predictions based on patterns found in the data, is increasingly being integrated into cyberspace. Children and their families are using digital tools to enhance their learning, sociability, and play. However, AI can have an influence on children's social interactions, educational programs, and online video viewing habits, through powering recommender algorithms. The enormous options offered by digital technologies may also increase children's exposure to potential dangers and harms associated with the Internet. The typical threats and harms that many children already experience offline might be amplified by being online, and the continuous availability of Internet risks can further heighten vulnerabilities. When considering the newly designed AI applications that children use on a daily basis, are they made with children's well-being in mind? Most of the Apps from social media, entertainment, and education that children use are AI-based, however; they seem to expose children to a plethora of cyber-attacks. Therefore it is imperative to create apps and solutions that safeguard children as they navigate online. The workshop then attempted to answer the question: How can we effectively implement AI in Child Online Protection?

Keywords: Child Online Protection; Artificial Intelligence; AI Solutions; Online Safety; Participatory Co-Design.

1. Introduction

The concept of co-design has been growing in its acceptability across various disciplines because of its ability to bring together the targeted user community with the researchers. Co-creation and co-designing of solutions is a step towards liberalized approaches to problem-solving (Nhinda & Bhunu Shava; 2021). Solutions are therefore built with direct inputs and interpretations from the actual users. Therefore, there is a demand-driven approach in comparison to the push-driven approach. This workshop was formulated to engage the key stakeholders in the child online protection ecosystem.

The main goals for the panel discussion and workshop were thus formulated as follows: -

1. Discuss ways in which AI can be implemented in Child Online Protection
2. Empower parents and children on how to reduce cyber threats
3. Provide effective AI-powered practices and solutions to address online risk for children
4. Co-design AI solutions for Child online protection

The rest of this submission is structured in three sections as follows: - methodology, workshop outputs and conclusion. The Methodology section details the condition for participation, the participants'

description, the panellists' questions and a summary of the duration of the workshop. The workshop outputs section outlines the outputs from the panel discussions and provides the details for the participatory co-design activities. The conclusion ultimately provides an overall summary of the key points from the workshop.

2, Methodology

2.1 Conditions for Participation

The participants in the workshop were samples from diverse backgrounds and different fields as well as different age groups whose goal is to improve children's safety online. informed by Nagyfejeo and von Solms (2020), successful technology adoptions need user-centred design approaches. Therefore, the workshop invited scholars, students, parents, and people from Government, Industry and Academia to participate as potential users to improve the technology acceptance. The only requirement was to be interested in improving the safety of children online. According to Maoneke et.al. (2018) and Gamundani et.al. (2015), children in Namibia are exposed to cyber risks both at home and school, thus a multi-stakeholder approach is needed in addressing the challenges.

2.2 Participants

Seven (7) participants registered initially, however, participants from the conference also participated in the workshop. Our participants ultimately ended up being fourteen (14) made up of one (1) industry practitioner, one (1) learner, five (5) students, one (1) Government official (social worker), one (1) teacher, three (3) Academics, and two (2) postgraduate students as facilitators. The fourteen participants were a mixture of males (6) and females (8) with different ages ranging from 16 to 50. The online registration for the workshop could be found in the appendix under workshop resources. Activity 1 of the workshop started off with a panel discussion to identify the issues at hand. The panel discussion took place in a hybrid setting where the workshop was facilitated for online participants and face-to-face participants. The chair began the session with an introduction and handed it over to the moderator who asked questions to the panellists and also allowed the participants to engage with the panellists. the questions asked were:

➤ Panellists Questions

- As an expert, what are the most recent findings in terms of cyber security and child online protection and what do you find as the key issues around child online protection and what would you say are the pertinent issues that need to be addressed?
- As a child do you feel unsafe online, what are your concerns when you access online platforms?
- As a caregiver do you get instances where you witness your pupils or students being affected by the experiences that they get online?
- As an expert when designing solutions to such issues, what needs to be taken into consideration in terms of being child friendly?
- From the ministry what are the pertinent issues right now as a government are you trying to address or what problems do you see in terms of how children are interacting online?

Activity 2 of the workshop was a participatory co-design that focused on design thinking, brainstorming and prototyping of the child online protection solution using AI (Reynolds-Cuellar &

Delgado Ramos, 2020). The best way to divide a large team is to split them into smaller diverse groups, during the panel discussion it was established that the participants came from different backgrounds. Therefore, when splitting them into groups we ensured that the groups had team members with different perspectives.

Due to the time span of the workshop, agile development was implemented, although there are numerous steps to follow, in this workshop the following steps were followed (Wrike, 2022):

1. **Conceptualisation:** the teams determined the scope of the project as well as planned out the conceptualisation of the possible prototype. Due to time constraints, this particular stage was only implemented once, as the beginning stage of the agile methodology.
2. **Inceptions:** in the inception phase, the teams then created a mock-up of the application on physical materials utilising posters, sticky notes, clay and markers. This is also known as the design process.
3. **Iteration:** Further input from stakeholders during the presentation section.

Although there are more steps in the agile methodology process in design, the workshop only implemented the first three as the iterative process usually takes the longest before development.

Duration

The workshop was conducted from the 23rd of November 2022 - 24th of November 2022 and the venue was HTTPS Building, 6th Floor, Media Room, Namibia University of Science and Technology, Windhoek, Namibia. Registration took place online. The workshop started off with a Hybrid panel discussion that took place on 23 November 2022 from 12:00 - 13:30, followed by the co-design session from 14:00 - 17:00 conceptualisation of the application. The next day the workshop continued where the inception and iteration process were implemented, this was from 08:00 - 13:30.

WORKSHOP OUTPUTS

Activity 1: Panel Discussion:

A panel discussion of parents, children, teachers and experts was held to discuss the aforementioned goals. The discovered problems that were prevalent included a lack of parental knowledge to supervise and educate children on current challenges regarding cybersecurity threats that can be committed against children online. Image 1 shows the panel discussion participants

Benefits

The benefits that can be attributed to the contributions received from the panel discussion in the context of child online protection can aptly be summarised as:-

- potential to reduce the likelihood of children's exposure to cyber threats
- pointers towards automating AI cyber security responses that protect children online.
- ingredients towards the design of a complete AI solution that can educate and empower parents and children on cyber security.
- actionable feedback on how to better the acceptance rate of the technology

Panellists feedback

The direct feedback from the panellists discussion is hereby listed here as a compilation of various stakeholder representation sentiments, inputs and design inputs for consideration.

- Involve parents in order to understand, supervise, and educate their children online;
- It is not easy for children to open up to their parents, children's wellbeing is the most important;
- If there was an application to detect emotions of children, monitor them where it is not invading their privacy but taking their safety into consideration;
- Parents usually do not know the know how;
- Reporting issues that could also be used in litigation and crimes that is viable - harvest credible digital forensics evidence;
- AI to flag bad keywords, train AI on new lingo, what data sets can be worked on;
- Get social worker involved too;
- Parents should know about the children's closest friends;
- Children want to understand the law and the rules so that they can be more aware of the dangers out there;
- Start with the young ones to establish healthy norms and boundaries about smart devices and social media;
- Filtering content on applications, track browsing history, inform about dangers on certain platforms;
- Educate the parents on how to talk to children and where to report cases;
- Know what trolls are on the internet, how to deal with them, hate speech and what that is and the impact of that, what materials and content to share and consume, what scams are out there and how to protect yourself;
- Can safety applications come standard with phones;
- Observe ethical issues;
- Rewarding system on the application.



Image 1: Participants of the panel discussion

Workshop Day 1: Session 2 (Co-Design)

The co-design session was informed by the panel discussion that identified the prevalent problem as the lack of know-how from our parents to educate children on the current challenges on cybercrimes that can be committed against children online.

Participatory Co-Design

The method that was used for the co-design session was participatory that included parents, children, teachers and experts. The best way to divide a large team is to split them into smaller diverse groups, during the panel discussion it was established that the participants came from different backgrounds. Therefore, when splitting them into groups we ensured that the groups had team members with different perspectives. Thus, the participants were divided into two groups and the following themes were identified and used to address the main objective of the workshop (for a video capture, check the link under workshop resources in the appendix).

Table 2: Workshop Thematic Outcomes

	Theme 1: Look and feel of the application	Theme 2: Problems that the application will be solving	Theme 3: Technical aspect of the application
Words, Feelings, Ideas	Responsive, should be rewarding, colourful, easy to use, informative, encourage cooperation, user-friendly, social media information, fun, playful, animated, expressive colours, simple, intuitive, efficient, secure, memorable Mobile driven, interactive, effective, modern, feeling safe, efficient in terms of user expectation, usable, simple to use, easy to learn, easy to use, educational, informative Multicultural, noninvasive, gendered, visually explanation, culture and demographically focused, multi-lingual,	Detect and Blocks explicit content (pornography, spam, cyberbullying, child online abuse, paedophile, online grooming, catfish, emotional abuse) Create Tips and awareness on Cybersafety Monitor internet traffic Vulgar language related captured & added to the database for updates Enhance critical thinking in kids Detect depression, Anxiety, suicider, self-esteem, authenticity, addiction Communication Barriers for parents Identify safety for children	Access to search History and chatbot tracker, Algorithm (age-specific), Delete Post/Pictures/audio and Reverse imaging(track) and IP address of perp, fake news and deny access Senser, Inclusive, Durable Filer, block explicit words/ phrases/ Pop-ups/ Apps (gambling) Alert parents for flagged words, inappropriate content and Apps Forensic capability, Location, Break time settings and Suggestion icon added Translator and learning App

	inclusive, accessible, dynamic Introduction on how the application will work, should be step by step, accessed from multiple devices, easy for parents to monitor, community for parents forum	Secure	Ethical consideration Verification of child age Biometrically using AI Information security, secure Protocols (SSL), Filtering Engine, Parental Control, Mitigation of threats and Database Components Easy Retrieval of Information, Cost Effective and App size

Workshop Day 2: Application Design Finalisation and Presentation (Co-Design)

Application 1:

Designed by group 1, this application features a signup and log in section on the application. This application prototype allows the parents to add the account of the child and is able to determine whether the child's online behaviour is good or worrisome. Also flags any suspicious activities of the child. If the child has good behaviour then a reward badge system will be given to the child whose profile is connected to the parent profile. This prototype also has a help system that is inclusive for parents or children with disabilities such as hearing impaired can read through the help option, and have sign language interpreters that will be able to sign the tutorials. There is also a video option that has audio enabled.



Image 2: Prototype of Application 1 from Group 1

Application 2:

Designed by group 2 has a profile sign up and login features that records history, cookies, theme and log out options. It filters the games, music, videos and learning experiences that children can have access too. There is also a chat feature between children and friends that is safer than other apps. There is a chatbot that helps parents with information on what to do and where to find information about online safety and other online dangers.

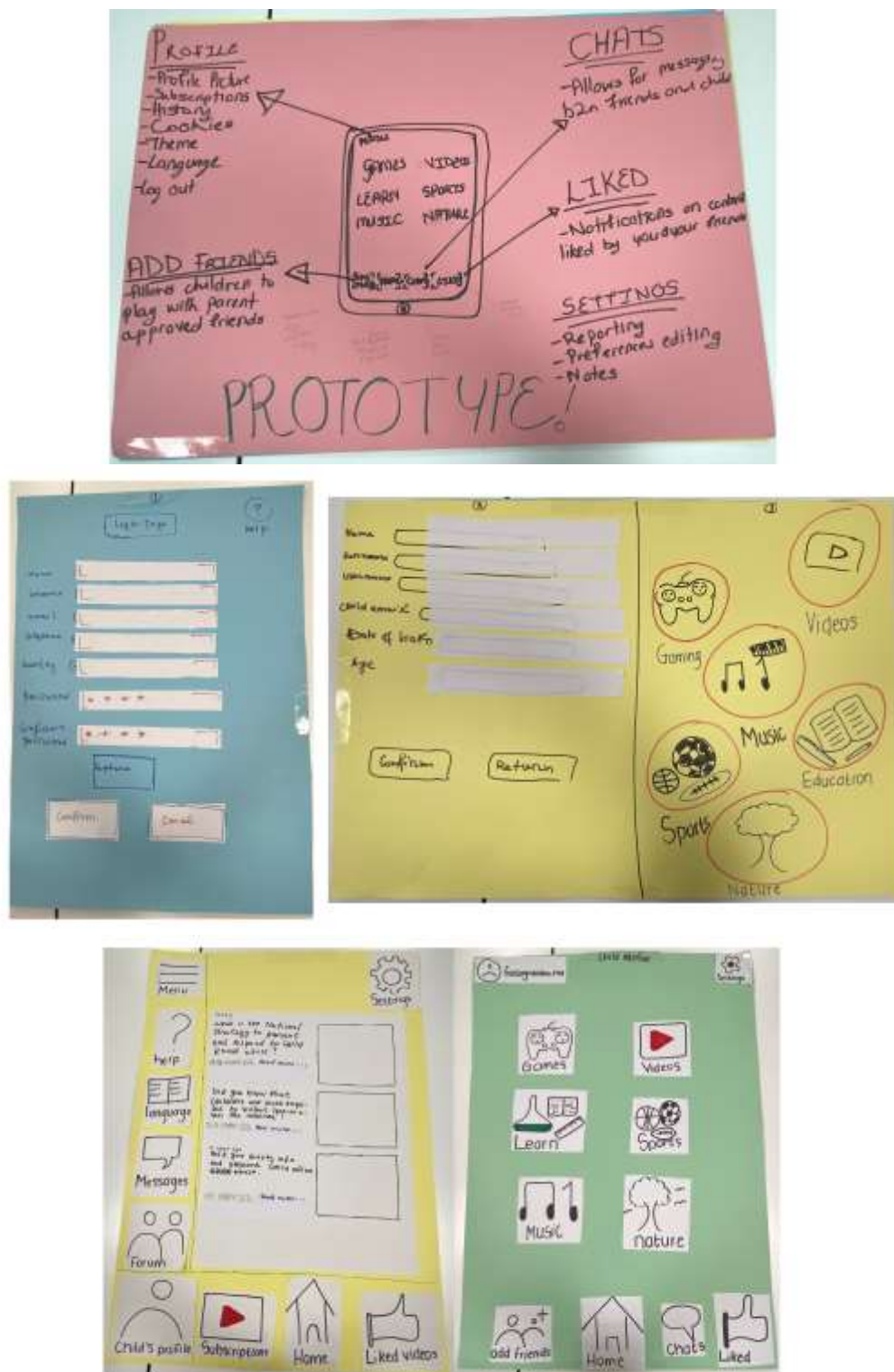


Image 3: Prototype of Application 2 from Group 2

Conclusion

The participants highlighted the need to develop real-time monitoring tools that will assist parents monitor and teaching their children online while also ensuring that children feel protected. It is also of utmost importance to ensure collaboration between researchers, parents and children to find a solution together. Child Online Protection is not only the responsibility of one person but of the community as a whole. This workshop along with the panel discussion has demonstrated that through teamwork, many known problems can be solved together and often unknown problems that one party is not aware of come to light and can also be solved together as a community. There is still a need to move from the phase of design to development and implementation. The way forward will be to put a team together and develop these applications co-designed by the participants. Once the application is ready, the participants will evaluate its efficacy and user experience before it is shared with a bigger community.

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Appendix: Workshop Resources

Online Registration Link: <https://forms.gle/idPGQ7dxjMcciErN6>

Workshop Themes recording: <https://youtu.be/8kLgL7Itxgs>

The Faculty of Computing and Informatics (FCI) offers Bachelor, Bachelor Honours, Master and PhD degrees in various specialisations in Computer Science and Informatics. The Faculty focuses on four main research areas: Big Data, Indigenous Knowledge in Digital World, Smart & Secure Environment and Digital Transformation.



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