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PAPER

Enhancing Practicality of Web-Based Mobile Learning in Operating System Course: A Developmental Study

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ABSTRACT

Web-based Mobile Learning can enhance the learning experience in various educational contexts. However, in operating system courses, practical challenges arise when implementing a web-based mobile learning platform, which impacts the effectiveness and accessibility of learning materials for students. To overcome these challenges, this research and development (R&D) aims to improve the practicality of web-based mobile learning in operating system courses. The research adopts a systematic 4D (Define, Design, Develop, Disseminate) model to identify and explore strategies to optimize the practicality of the platform. Data collected from lecturers and students showed a high average value of practicality, 88.33% and 88.35%, respectively. This research contributes to improving the practical aspects of web-based mobile learning, thereby enhancing students' learning experience and outcomes in the context of operating system courses.

KEYWORDS

web-based mobile learning, practicality, operating system course, development

1 INTRODUCTION

Web-based mobile learning has emerged as a promising approach to enhancing learning experiences in diverse educational contexts [1], [2], [3]. With the widespread use of mobile devices and the internet, learners can access educational content conveniently anytime and anywhere [4], [5], [6]. However, practical challenges in implementing a web-based learning platform on mobile devices may arise in operating system courses. These challenges can hinder the effectiveness and accessibility of learning materials, impacting the overall learning experience for students [7], [8], [9]. Previous research has identified several barriers to implementing web-based learning on mobile devices in operating system courses, such as technical challenges, accessibility limitations, and limited interactivity [10], [11].

In operating systems courses, where students require hands-on practice and interactive learning experiences, ensuring the practicality of web-based mobile

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learning platforms is crucial [12], [13]. Effective integration of practicality considerations, such as usability, acceptability, and logistical factors, can significantly impact the overall success and adoption of web-based mobile learning in operating systems learning [14], [15], [16]. Therefore, this development research aims to overcome these challenges and specifically improve the practicality of web-based learning on mobile devices in the context of operating system courses.

In each stage of the development process, practical considerations will be carefully examined and integrated to create a more efficient and effective learning experience [17], [18]. Data will be collected through surveys, interviews, and observations to assess the practicality of the web-based mobile learning platform [19], [20]. Feedback from students and instructors, along with logistical analysis, will be analyzed to identify areas for improvement and provide valuable recommendations [21], [22], [23].

The findings of this study are expected to contribute to the current body of knowledge regarding the practical aspects of web-based mobile learning in operating system courses [24], [25], [26]. Instructors and instructional designers can benefit from the results of this research, as it will provide practical recommendations for optimizing web-based mobile learning platforms, ultimately leading to improved learning outcomes and empowering learners with the skills and knowledge needed in the digital era.

In conclusion, this development study focuses on improving the practicality of web-based mobile learning in operating system courses. Overcoming the practicality challenges and optimizing the web-based mobile learning platform in learning operating system installation is considered very good for improving learning effectiveness in the information technology education study program; on the other hand, this research also seeks to encourage motivation and better learning outcomes for students taking operating system courses. The results of this research can contribute to the advancement of Web-based Mobile Learning, promoting accessibility, engagement, and overall learning effectiveness in an educational context.

2 LITERATURE REVIEW

The development of mobile web-based learning, particularly in operating system courses, has significantly changed how students interact with learning materials. In this literature review, we aim to explore previous research related to practices in the context of operating system courses, with a particular focus on development research [27], [28]. One of the key aspects to consider in improving mobile web-based learning practices is the design and development of learning materials [29], [30]. Various studies have emphasized the importance of creating interactive and engaging content tailored to the specific needs of operating system courses [31], [32]. This involves incorporating multimedia elements such as videos, simulations, and interactive exercises to facilitate understanding and practical application of operating system concepts [33], [34].

Problems in teaching and learning in the context of operating system courses require interactive and immersive approaches, as well as hands-on practice to understand complex concepts [35], [36]. Therefore, ensuring that web-based learning platforms on mobile devices can provide an effective and practical learning experience for students in operating system courses is important [37], [38]. Previous research has also highlighted several barriers related to the implementation of web-based

learning on mobile devices in the context of operating system courses [39], [40]. These challenges can include accessibility limitations, lack of in-depth interactivity, and other technical issues [41]. Therefore, this development research aims to address these barriers and focuses on improving web-based learning practices on mobile devices, especially in the context of operating systems courses [42], [43].

This research will identify and explore strategies to optimize web-based learning practices on mobile devices in the context of operating system courses [44]. Through a systematic development approach, this research will cover the design, development, and implementation stages of web-based learning on mobile devices. Practical considerations, such as availability and feasibility, will be carefully considered to create a more efficient and effective learning experience [45], [46].

However, similar research focuses more on increasing the effectiveness of the learning media developed [47], so the practicality aspect of the media used by lecturers and students is considered very good to be studied to increase student motivation and learning outcomes. It is expected that this research can improve the practice of web-based mobile learning in operating system courses. By considering the design and development of learning materials, ensuring usability and user experience, using authentic assessment, and promoting collaborative and personalized learning experiences, teachers and learning designers can create effective and practical mobile web-based learning environments. Future research should focus on investigating the specific impact of various strategies and approaches to further improve the practice and effectiveness of mobile web-based learning with the research target being students taking operating system courses in the information technology education study program of the faculty of teacher training and education at Universitas Muhammadiyah Muara Bungo.

3 METHODOLOGY

3.1 Research design

The research conducted is Research and Development (R&D) focused on enhancing the practicality of web-based mobile learning in operating system courses. It follows the 4D model, a systematic framework consisting of four phases: Define, Design, Develop, and Disseminate [48]. The 4D model allows for iterative development, testing, and refinement of interventions, contributing to the advancement and practical application of web-based mobile learning in the operating system course.

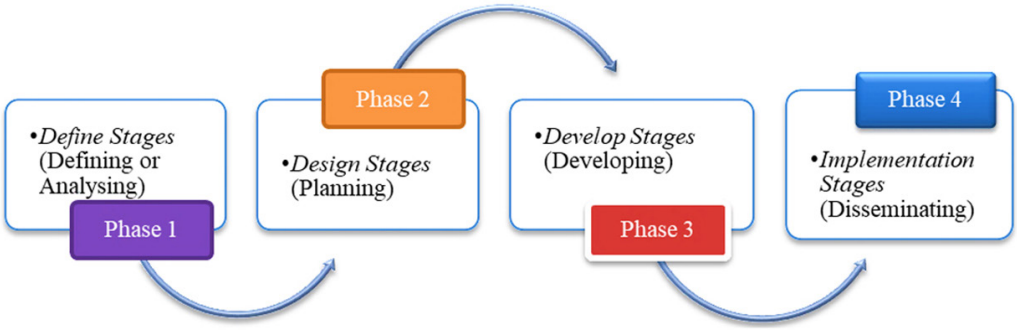

Fig. 1. Development procedure of web-based mobile learning

Define. In the Define stage, two main activities are carried out, namely observing, and examining the characteristics of the research population. Observation activities aim to gain an accurate understanding of real-life conditions, while the examination of population characteristics is important for determining the research sample to be included in the study. These activities are essential in providing clear guidance and setting the boundaries of the study, so that the research can be focused and relevant to the predetermined objectives. By making thorough observations and examining the characteristics of the population, the research can proceed with an informed approach that meets the expected objectives.

Design. In the Design stage, there are two important steps to be taken. The first step is to create a web-based learning media prototype in accordance with the operating system course syllabus. In this step, the learning content is adjusted to the material relevant to the syllabus. After the prototype is designed, the next stage focuses on the development of web-based learning media. In this stage, the operating system learning materials, from BIOS setting to the whole operating system installation process, were created using the prototype design as a reference. Through these steps, the research ensured a systematic approach and aligned with the targeted educational objectives and syllabus requirements. In this Design stage, the research instrument was also designed in the form of a questionnaire that would be used to measure the practicality of the learning media that had been developed. With this questionnaire, researchers can obtain useful information regarding the effectiveness and level of practicality of the web-based learning media that has been created.

Develop. In the Develop stage, there are several important activities to be done. First, researchers implemented the web-based mobile learning platform based on the previously designed framework. Next, we tested the web-based mobile learning media to a predetermined sample group of students. The purpose is to collect data and feedback on the practicality of the web-based mobile learning in improving students' ability to understand how to install an operating system correctly by applying the process stages that have been explained in the learning materials. This data and feedback will be used to evaluate the developed learning media and identify potential areas for improvement in the next stage. Through this Develop stage, researchers can produce a relevant and effective web-based mobile learning platform, which in turn can improve student learning outcomes in operating system courses. Thus, the Develop stage is a critical step in creating a learning solution that is useful and suits the needs of the students.

Disseminate. During the Dissemination stage, various activities were conducted to effectively share the research findings with relevant stakeholders. First, the researcher collected data through questionnaires administered to a sample group of university students. The collected data was then analyzed descriptively to gain meaningful insights. Next, the results of the analysis were interpreted and presented in a comprehensive research report. In addition, researchers prepared scientific articles for publication in reputable international journals. The primary objective of this stage is to disseminate and share the research findings with the scientific community and practitioners in the field of information technology education, particularly focusing on learning operating system installation. Through this effort, the researchers aspire to contribute to and facilitate the advancement of the information technology education study program by promoting the effective and efficient utilization of web-based mobile learning platforms.

3.2 Population and sample

The population in this study were 127 students of the information technology education study program, faculty of teacher training and education at Muara Bungo Muhammadiyah University, Indonesia, in semester 3 of the 2022–2023 academic year. This study used a simple random sampling technique where the sample used amounted to 43 students who took the operating system installation course.

3.3 Data collection instruments

The practicality instrument was used to obtain data on the level of usability of web-based mobile learning. This practicality instrument is described using Likert Scale. The practicality instrument grids for student and lecturer responses can be seen in Tables 1 and 2 [49].

Table 1. Lecturer response practicality instrument lattice

Aspect	Indicator
Learning Aspects	Clarity and suitability of learning objectives, competency maps for mobile learning materials
	Suitability and coverage of material with the learning objectives of the operating system course
	Applicability of the module as independent learning
Material Aspect	Coverage and factualization of the contents of the operating system course material
	The suitability and attractiveness of the contents of the operating system course material
Design Aspect	Readability of the text and the use of sentences used
	Ease of program operation
	Accuracy and clarity of multimedia display in supporting operating system course material
	Ease of understanding the material and motivating students

Table 2. Practicality instrument lattice of student response

Aspect	Indicator
Learning Aspects (Curriculum)	Clarity of identity and learning outcomes
	Suitability and fixity of material to be learned
	Clarity of web-based mobile learning material
Display Aspect	Attractiveness of web-based mobile learning elements
	Readability of layouts that make it easy for users to learn using web-based mobile learning
	Clarity of multimedia display supporting mobile learning material
	Attractiveness of mobile learning graphic display
Programming Aspect	Ease of program operation
	Ease of program interaction

The research aims to gather insights on the practicality of web-based mobile learning through questionnaires administered to students. These questionnaires are designed to elicit responses and opinions from students regarding the practicality of web-based mobile learning. The questionnaire comprises statements related to the practicality of web-based mobile learning, and students are provided with alternative answers. These alternatives include "strongly agree," "agree," "disagree," "strongly disagree," allowing students to indicate their level of agreement or disagreement with each statement.

The practicality of the learning module through e-learning is as follows.

a) Answer score with criteria: 5 = Very-Practical, 4 = Practical, 3 = Practical-Enough, 2 = Less-Practical, 1 = Not-Practical.
b) Determine the average score obtained by summing the values obtained from many indicators.
c) Giving practicality value with the formula:
$NA = S/M \times 100\%$
Description:
NA = Final score
S = Score obtained
SM = Maximum score
d) To determine the level of practicality of the learning module through e-learning, the criteria are shown in Table 3.

Table 3. Media practicality categories

No	Achievement Rate (%)	Category
1	85–100	Very Practical
2	75–84	Practical
3	60–74	Practical-Enough
4	55–59	Less Practical
5	0–54	Not Practical

4 RESULTS AND DISCUSSION

4.1 Design results

The next activity after analyzing the initial stage is to design and develop a web-based mobile learning prototype, which consists of: (1) Home Page; (2) Learning Content; (3) Learning Materials; (4) Learning Videos; (5) Online Chat. In more detail, the format of web-based mobile learning is explained as follows:

This page serves as the initial dashboard menu for the web-based mobile learning platform used in the operating system course. This interface is designed to provide access to the operating system course materials. The layout and design of the Main Page is made consistent, students who want to do online learning must log

in first by entering the username and password previously given by the lecturer teaching the operating system course. The visual representation of the main page interface design is presented in Figure 2.

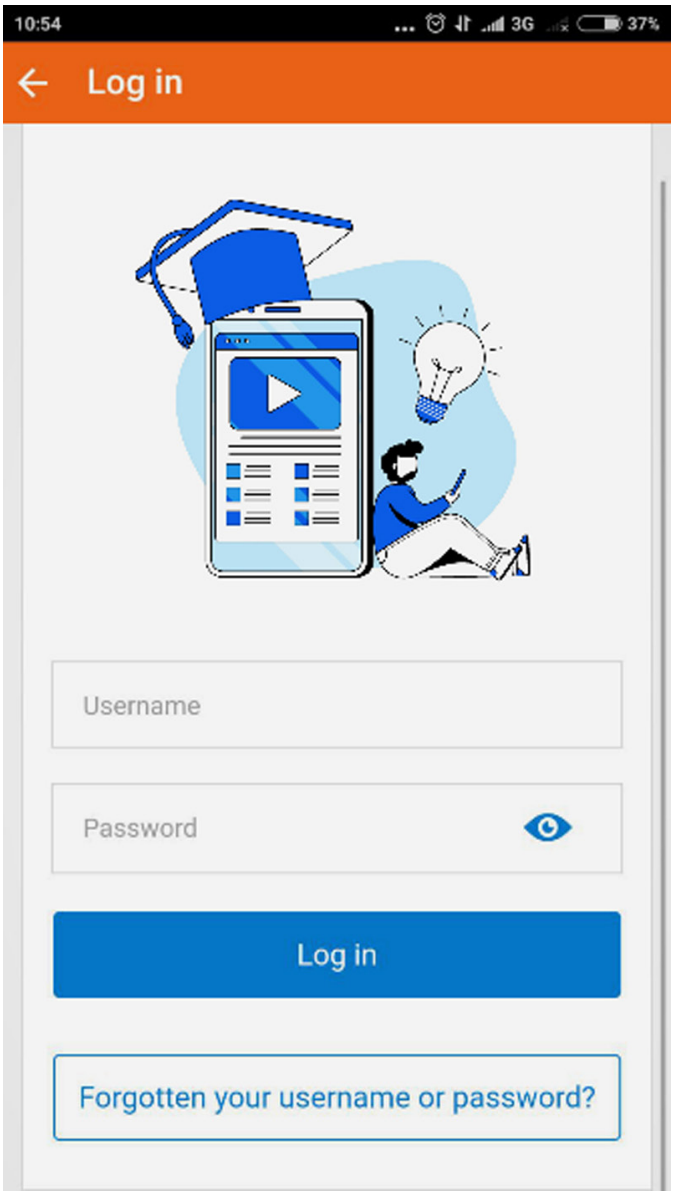

Fig. 2. Dashboard menu

The operating system installation material in the web-based mobile learning application is presented in the form of menu and icon displays, here is the mobile learning material menu: Timeline–Guidance; Main Page; Guidance Value; Notification; Personal Message; Guidance Calendar; Google Search; Guidance Card; YouTube Channel; School Information System; Developer; Settings; Log out, as shown in Figure 3.

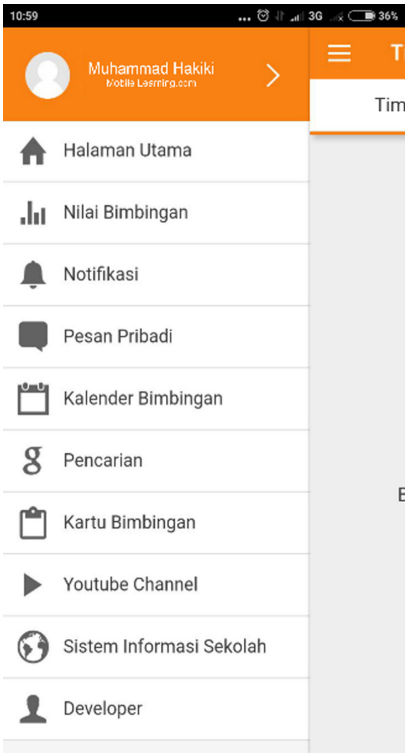

Fig. 3. Operating system installation material display

This learning material display displays operating system installation material that is adjusted to the syllabus consisting of all basic competencies in the odd semester of the 2022/2023 school year consisting of 18 meetings. This mobile learning has a download feature so that all downloaded materials can be read even though it is no longer connected to the internet network or in an offline state. The scope of the material contains all the scope of the operating system installation mathematics material, presented in the Figure 4.

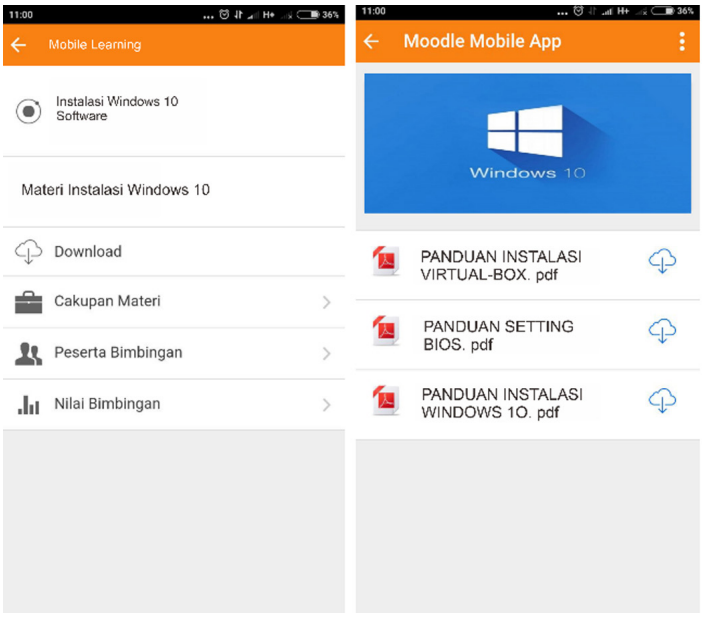

Fig. 4. Display of the contents of the operating system learning material

The online tutoring process is also supported by an online assignment collection feature. In addition to private messages, there are also communication channels such as online chat and discussion rooms for interactivity between users, as shown in Figure 5.

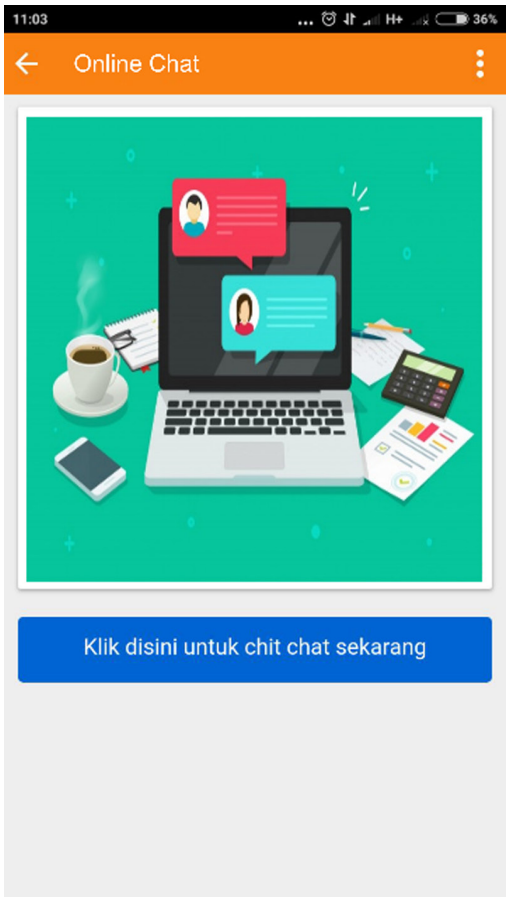

Fig. 5. Online chat

4.2 Research results

Analysis test trial data based on reliability test of practicality instrument. Based on the results of the reliability test of the practicality questionnaire, the following results were obtained.

Table 4. Recapitulation of reliability test of student practicality instruments

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
.936	.945	26

The results of the reliability test analysis in Table 4 using the IBM SPSS 21 program with a Cronbach's Alpha value of 0.936 with a very high interpretation. So, it can be concluded that the practicality questionnaire is reliable to measure the practicality of the web-based mobile learning developed from the students' point of view.

Practicality test data of web-based mobile learning

Lecturer response to the practicality of web-based mobile learning in operating system courses. The practicality of web-based mobile learning is closely tied to its ease of use. To assess practicality, a questionnaire was administered to a lecturer teaching the operating system course. The summarized results of the practicality assessment through web-based mobile learning are presented in Figure 6 below.

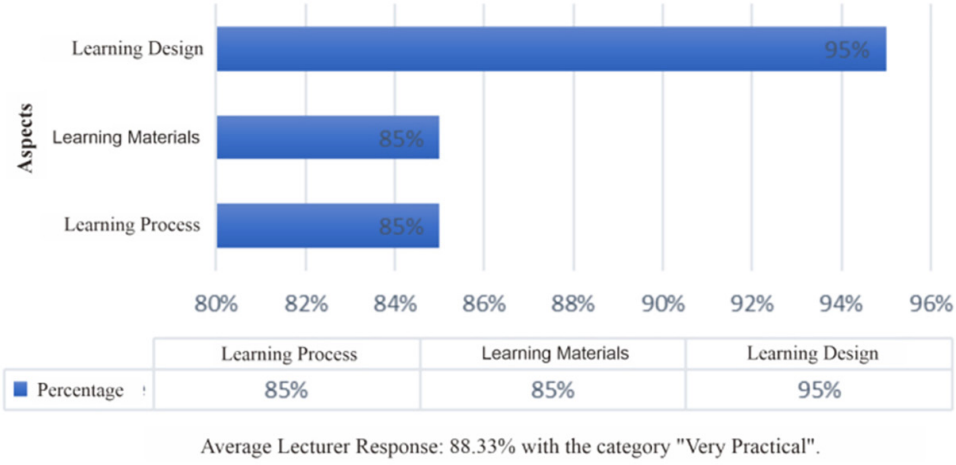

Fig. 6. Lecturers' response to the practicality of web-based mobile learning

The analysis of the data revealed an average practicality score of 88.33% based on the assessment of web-based mobile learning using a questionnaire administered to the lecturers. This high percentage indicates a highly practical interpretation of the developed media. Furthermore, the lecturer response questionnaire specifically focused on web-based mobile learning in operating system courses, resulting in highly practical outcomes.

Responses to the practicality of web-based mobile learning in operating system courses. The practicality of web-based mobile learning also relies on gathering feedback from students. This feedback is collected using web-based mobile learning in operating system courses, wherein students are asked to complete a questionnaire. The findings from the assessment of the practicality of the learning media are presented in Figure 7 below.

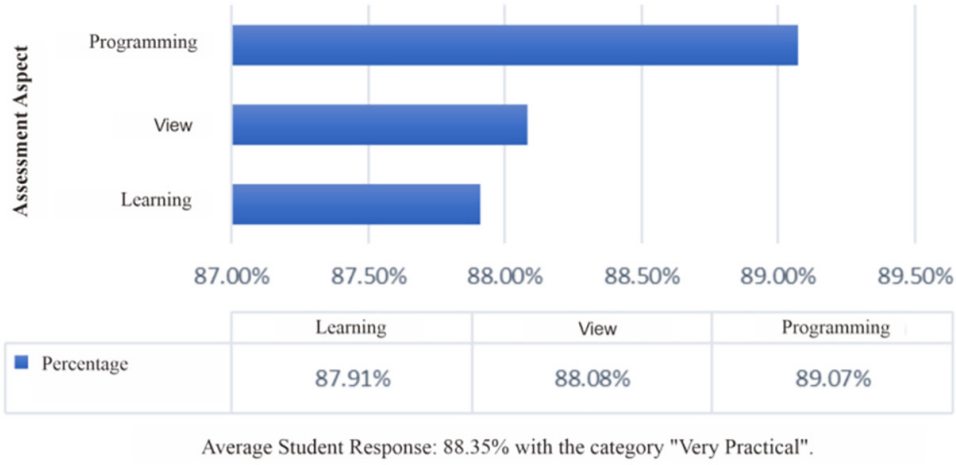

Fig. 7. Student response to the practicality of web-based mobile learning

Based on the data presented in Figures 6 and 7, the average practicality scores for web-based mobile learning, as assessed by both lecturers and students, were found to be 88.33% and 88.35%, respectively. These results indicate that web-based mobile learning in operating system courses falls within the category of "very practical."

4.3 Discussion

This research successfully identified challenges and strategies to improve the practicality of web-based learning on mobile devices, especially in learning operating system courses. Through a comprehensive development approach, we were able to address the issues of accessibility limitations, user interface, and logistical aspects to create a more practical and efficient learning experience. The advantage of this study compared to other studies lies in the high practicality score achieved for web-based mobile learning in operating system courses. Based on the data, the average value of practicality obtained from lecturers and students is 88.33% and 88.35%, respectively. This value indicates that the web-based mobile learning platform developed in this study has a high level of practicality. Compared to other similar studies [50], it was concluded that the average assessment of the practicality of Android-based Graphic Design learning media by students was 4.25 with an achievement level of 85.00 and was on good criteria (practical). This means that the practicality of Android-based Graphic Design learning media can be applied. Based on the results of research conducted on Android-based static and dynamic electricity learning media research, it states that static and dynamic electricity learning media are easy or practical to use by teachers and students.

The strength of this study lies in the high practicality score of "very practical" category with 88%, which indicates that the developed web-based mobile learning platform can overcome the challenges usually faced in operating system courses, such as limited access and user interface issues. The platform's design and implementation consider the specific needs of operating system courses, leading to a seamless and efficient learning experience. The high practicality scores also suggest that the developed web-based mobile learning platform addresses the challenges typically faced in operating system courses, such as accessibility limitations and user interface issues. This research considers the logistical aspects, affordability, and flexibility of accessing learning materials, which positively impact students' engagement and learning outcomes. By achieving a "very practical" category rating, this research distinguishes itself from other studies by providing a more robust and reliable web-based mobile learning solution for operating system courses. The platform's effectiveness in enhancing the learning experience and outcomes for students sets it apart as an exemplary approach in the field of information technology education. Overall, the high practicality scores obtained in this research highlight the superiority of the developed web-based mobile learning platform compared to other studies, making it a promising and effective solution for delivering operating system courses in diverse educational settings.

Although this study has limitations in the specific context studied, our findings make an important contribution to the development of web-based learning on mobile devices. It is hoped that the results of this study can guide educators and learning designers to create more effective and engaging learning experiences for students in the context of operating system courses. Looking ahead, future opportunities such as the integration of advanced technologies, personalized mobile learning, and increased internet access offer the potential to continue to improve the practicality

of web-based learning on mobile devices. By capitalizing on these opportunities and continuing to address emerging challenges, we can achieve web-based learning that is more adaptive, interactive, and relevant to the needs of students taking operating systems courses.

5 CONCLUSION

This research aims to develop Web-based Mobile Learning to improve learning effectiveness in operating system courses. However, when applied to operating system courses, practicality challenges may hinder the effectiveness and accessibility of learning materials for students. To overcome these challenges, this Research and Development (R&D) study adopted the systematic 4D model, focusing on the Define, Design, Develop, and Disseminate stages. Through a comprehensive approach, the research successfully identifies and explores strategies to optimize the practicality of the web-based mobile learning platform in the context of operating system courses. Data collected from both lecturers and students indicate high average practicality scores, reaching 88.33% and 88.35%, respectively. The study's findings contribute valuable insights and recommendations for enhancing the practical aspects of web-based mobile learning in operating system education. By carefully integrating practical considerations, such as user-friendly interfaces and accessibility features, the learning experiences, and outcomes for students in this context can be significantly improved. Ultimately, this research provides a stepping stone towards creating more efficient and effective web-based mobile learning environments, fostering better engagement and success for students in operating system courses. The findings also encourage educators and instructional designers to continue exploring advanced technologies and personalized learning approaches to further enhance the practicality and effectiveness of Web-based Mobile Learning in the evolving landscape of education. By continuously addressing emerging challenges, we can ensure that Web-based Mobile Learning remains a promising approach in modern educational practices.

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PAPER

Development and Creation of Ancient Sandstone Carvings Using 3D Software Tools and Mobile/ Tablet Devices

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ABSTRACT

In the area of Phayao Province that used to be part of the ancient Lanna Kingdom, there are unique works of art that can be found until today, which are sandstone carvings caused by religious beliefs resulting in works such as Buddha statues. These are art related to religion. Nowadays, these works of art have started to fade away and receive less and less attention from people. The creation of art objects in this research therefore uses the interpretation of the creative objects in line with people's lifestyles by selecting the lotus, which is a plant related to rivers, and is important in religion. In the lotus, which is interconnected and aligned with Buddhism, and in harmony with a way of life that aligns with the river, creative works are found in various forms, connecting people in Buddhism, including sandstone carving. In this creation, digital technology tools and methods are used to collect data to create a 3D work piece. Photogrammetry is used to record detailed proportions and information and customization of 3D work pieces. In these steps, mobile phone-type tools are used to collect image data to create the 3D work or an application is used to customize 3D work pieces from a tablet device to create prototypes of sandstone sculptures from the artisans that remain today. This can be seen in creating, maintaining, and recording digital data, creation, and the integration of knowledge. This demonstrates that today's tools and portable devices can help create more creative pieces of work and preserve art and culture.

KEYWORDS

photogrammetry, 3D artifact, sand stone art, 3D mobile creative, mobile design tools

1 INTRODUCTION

Belief and religion have existed for thousands of years in this world and have been the cause for the creation of many works of art, depicting beautiful things and using the creative potential of humans from generation to generation. Creative arts are directly inspired by names and religions, especially in Buddhism, where

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representations of the Buddha have been created and used by Buddhists to commemorate him. The Buddha statues are something that Buddhists believe in. Therefore, techniques and methods have been used to create exquisite figurines by choosing methods according to the aptitude of the developers of each race using different characteristics and materials, especially in the northern region of Thailand, which used to be part of an important kingdom in the region, the Lanna Kingdom. Sandstone Buddha carvings or creative works related to beliefs and religions, especially Buddhism, are said to have originated from the Phayao craftsmen families. This was influenced by Chiang Saen art, which is regarded as a major civilization of the Lanna civilization areas, mixed with the Sukhothai art tradition, bringing wisdom and the craftsmanship that is unique to the people of Phayao in carving sandstone to form a Buddha statue, bringing faith art and science to create exquisite craftsmanship. And it is considered the only source in the Lanna Kingdom in Thailand today where sandstone is carved in this style and technique. It was influenced by the art that was powerful in the neighboring kingdoms, both Sukhothai and the original area, the Chiang Saen Kingdom, which was created in the 19th century BC and prospered until the end of the 23rd century BC, and gradually faded away in the end. Only the remains of these works can be seen today.

The study of real sandstone carvings and art is a challenge due to its weight, which makes moving it around difficult, and also the fracture and erosion of the sandstone materials, especially ancient sandstone. In addition, there is no record or knowledge of the sandstone art of ancient Phayao craftsmen. Referring to records or information is therefore one of the problems in studying sandstone art. The absence of any such records or manuals about the skills of the ancient Phayao sandstone carvers is widely known to researchers and archaeologists on the topic. Knowledge was transferred from generation to generation orally and through practice. Nowadays, this knowledge is limited to only the elderly craftsmen who continue to practice this art, which is another factor concerning the art. Much of it may be lost or decayed over time.

The creation and study of art and antiquities information has been developed along with the use of technology to support it, allowing access to learning. As well as being an inspiration in terms of aesthetics for the audience to see such works more, it is beneficial to use technology, especially multimedia technology, to recreate and disseminate these ancient art pieces. Tools such as 3D technology and multimedia modeling help to develop these art forms by recording data with 3D tools and technologies such as process photogrammetry. The use of 3D programs to create and modify 3D workpieces is widely popular in the conservation and study of art objects. It is easier to work with tools such as smartphones that are now capable of taking better pictures thanks to improvements in the sharpness of photography, processing, and preserving the details of the image. There are also applications that can be used to take pictures and process images obtained from a mobile phone camera into 3D works as well, although the details of the work piece are not as detailed as those processed in the computer. This gives opportunities for creativity and process workflow. Photogrammetry has caused more widespread distribution, which will affect a wider group.

Creative forms of design and digital art are now more accessible to people through evolving tools. There are many models. In particular, creative tools that can be used on mobile devices such as smartphones and tablets have become a big aid and are the main factors today as we see more and more design and creative professionals turning to these mobile tools. A digital drawing tablet (also known as a graphics pad) is a type of input device that allows users to draw images, pictures, and sketches

directly onto it. It can be a standalone electronic device or one that is displayed on top of another screen, such as a TV or computer monitor. This technology allows for natural creativity without the constraints of traditional paper-based tools such as size, frame, line thickness, and so on. Touch capabilities on a digital drawing tablet allow users to interact with their work in near real-time by using their fingers instead of pens and brushes. [1] shows the trend of using tools from smartphones and tablets to support more creativity and has the opportunity to grow more and more according to the popularity of using smartphones that is increasing. It depends on the increasing popularity of the market and the number of users, plus supporting factors. The use of technology from the aforementioned portable devices is considered a good way to maintain and inherit arts and culture, and bringing these values of arts and culture to extend and further study and create will also help. Let these arts and cultures be inherited and integrate with the lifestyle of the next generation. Technology can go along with it appropriately. Craftsmanship emphasizes direct material production, which can more fully express a product's authenticity. This research proposes a modular concept process construction model in which a feasible method (i.e., integration of product design, method and craft process) is used to bridge the gap between craft process and product design. Modern craftsmanship is produced using a manufacturing mechanism that incorporates four design characteristics: material, module, innovation, and living technology. [2] The creation and development of new works of art for the preservation and passing on of art is another important process that will help these guidelines and works of art to exist in conjunction with the way of life of people well. Each of these creations has applications that support the creation and improvement of design work. Especially the creation of 3D work that has been developed to be used on more and more portable devices and help with the creation and use of improved 3D programming tools too.

2 LITERATURE REVIEW

It can be said that today's technology and tools to record and create 3D objects from real data are diverse and it is easier to use and access due to the availability of simple tools in the camera. A photo taken in a camera or a smartphone can be used in conjunction with widely available computer programs. There are also specialized tools such as 3D scanners, equipment to analyze objects and to make 3D images, etc. Creating and storing 3D object data is possible, and is a necessary part and a reason to support and give a great push to art objects.

Many technologies, such as structured light, time-of-flight scanning, laser scanning, computed tomography, and photogrammetry have been developed and used in the past decades to digitize the 3d model of the human form. [3] Photogrammetry is now regarded as a competitive technology in the field of cultural heritage documentation and recording. Image-based measurement tools enable the creation of realistic 3D models, which can be used in a variety of applications, including archaeology. [4] In recent times, the accuracy and time of digital photogrammetry processing software has been evaluated. These articles discuss photogrammetric reconstruction of sites, including building architecture. Photogrammetry is useful in cultural heritage applications not only for accessibility through 3D modeling, but also for archaeological recording. [5] Photogrammetry is currently an effective tool for quickly and cheaply obtaining geometrical information from digital imagery. Nowadays, the derived photogrammetric product is almost always a 3D image model, and two distinct techniques for modeling objects coexist successfully: 'virtual'

reality and 'visual' reality. While the texture and object shapes in the former do not have to correspond to real objects, the 3D models in the latter are physical object replicas that help one understand their corresponding real objects. Based on the images used to texture both objects and environments, derived photogrammetric models can provide real measurements as well as virtual and visual realities. [6]

Aside from that, combining photography and digital processing techniques yields exhaustive, precise results. The resulting documentation is intriguing because it represents a hybrid of techniques that results in a multiform, dynamic final product. As previously stated, these features enabled us to obtain graphic products related to art preservation and the creation of promotional materials. [7]

Such tools and techniques are not only used for data recording, transmission, and education, but can also be used for development.

Point of view invariance using a 3D model during the restoration process results in the generation of restored 3D models of faces appearing in icons allowing models to be used in a variety of programs such as virtual reality, animations, and artistic trends. [8]

Creating photorealistic three-dimensional (3D) models of real-world scenes and objects is a difficult problem that necessitates advanced computer science and graphics knowledge. Virtual museums and historical documentation have benefited from systems that can reconstruct the 3D model of cultural artifacts. [9]

The scientific approach to art has been revitalized by 3D digital models. They have revealed themselves to be tools for the formulation of complex hypotheses to be investigated in prehistoric archaeology as testing and validation tools in some of their applications. [10]

Present graphic design and visualization technologies can create versatile 3D interactive-immersive platforms for the virtual recreation of Cultural Heritage monuments that can be used for learning, dissemination, and explanation of Cultural Heritage. [11]

An advancement of digital surveying techniques for historical buildings and cultural statues has enabled the creation of precise 3D models describing the geometry of those structures for use in heritage documentation, preservation, and archaeological interpretations. [12]

The 3D creation application, the use of such strategies or technologies to encourage honesty and connect thoughts and stories from the technological process is thus extremely important and required in the manufacturing and fabrication of components to aid in the completion and operation of this work. Computer technology has advanced significantly since then. 3D images created with the proper software are extremely realistic and appear to be photographs. They are employed in the fields of popularization, education, and research. Scientists have recognized the value of digital 3D imaging as a tool for hypothesis testing and communicating research findings to the public. [13]

The use of tools and the application of technological devices make it more convenient to operate in the data collection process by using a smartphone capable of taking pictures for use in Photogrammetry. It enables people to be creative and use that process to think and create, as well as record, processes. Photogrammetry has become very prevalent.

A preliminary investigation into the applicability of smartphone photogrammetry in real-world conditions was also carried out. The smartphone method has a high level of precision for all specimens. To achieve acceptable trueness and precision, the smartphone photogrammetry method can be used. [14]

Furthermore, the dense clouds of the digital camera had a higher point density nearly three times that of the smartphone. This difference resulted in better geometrical detail representation and higher mesh quality. When compared to

the smartphone, the final textured models from the digital camera were of higher quality and had a more photorealistic appearance. The dense clouds and textured models on the smartphone, on the other hand, were of acceptable quality with the processing time and memory utilization parameters of almost every processing step in the photogrammetric workflow being generally less. [15]

Furthermore, network communication capabilities enable timely upload of field measurement results for data preservation and further processing. In conclusion, smartphones have benefits that include, but are not limited to, convenience, speed, ease of use, and low cost. These advantages of smartphones outweigh those of DSLR cameras. More importantly, the rapid development of smartphones, such as the LiDAR on the iPhone 12 Pro, has expanded the scope of smartphone applications in measurement and photogrammetry. [16]

Smartphone photogrammetry produces results comparable to 3D scanners and multi-camera approaches. Furthermore, it is low-cost because data collection only requires a smartphone. The simplicity of the setup would allow for immediate implementation of the methodology. [17]

Combining knowledge and technological tools to create for conservation is a concept that can act as a guideline for the integration of arts, culture, and technology to facilitate a greater connection to the public. Adopting and combining modern and accessible tools and technologies allows for creativity and the preservation of culture and art. It offers a wide range of options for today's generation of tools that empower more creative and digital production [18]. Designers of learning environments can repurpose existing technologies to create rich pools of identity artifacts, which can support educators' modes of participation and, finally, their contributions to the cultures to which they relate.

Furthermore, recent 3D modeling and printing experiences have demonstrated the need for a new level of expertise to assist archaeologists, architects, engineers, restorers, and conservators who require the use of digital technologies related to instrumental survey, 3D modeling, and solid printing. [19]

As a result, it is clear that accurate and scrupulous design and manufacturing of the artifacts' supporting structures is critical for both their fruition and effective conservation. Modern techniques and technologies efficiently adopted in those industrial sectors provide a solution to meet this need. [20]

In particular, the use of mobile tools for creativity is a trend that is becoming more and more popular among digital designers today due to the development of both hardware and software. They support the creative use of the tools and mobile devices to design and create more digital images, video, audio, 3D images, and other digital art.

The use of digital technologies, by demonstrating how the affordances of digital tablets and drawing apps can be more supportive of collaborative creativity than more traditional resources used in drawing tasks. It encourages further exploration of digital and non-digital resources in order to better understand how specific affordances shape the participation frameworks that emerge in collaborative creative work. [21]

This article discusses a variety of ways that digital technology can facilitate the conditions for creative ideas and their implementation. To summarize, computing technologies application and devices have the potential to improve employees' socio-emotional and instrumental support by allowing them to connect with a large number of people both inside and outside the organization. As a result, we anticipate that the more computing devices employees use, the more they will feel supported and encouraged, and the more creative their ideas will be. [22]

Digital creativity is a developing discipline with enormous potential. Many different types of works of art are supported through digital representation by digital creativity technologies. These technologies also allow us to capture, store, manipulate, and output these representations in order to create media forms that we can interact with. This convergence in digital creativity is built on the unity of underlying representational form and technological processing. [23]

It drives creativity and mobile tools enable creativity to begin at the moment of inspiration. As soon as you have an idea, you can begin bringing it to life in a way that feels as natural as a pencil and sketchbook, but with the versatility and power of digital creation and a constant connection to creative assets and collaborators. That's a revolution that's gaining steam by the day, and we're thrilled to be a part of it. [24]

3 RESEARCH METHOD

The research method used in this study aimed to integrate tools of mobile phone, applications, and photogrammetry techniques with artisan collaboration to facilitate the design and production of sandstone artwork. The following paragraphs provide a detailed explanation of the research method employed.

This research employed a method that combined the study of historical sandstone artifacts, smartphone-based photogrammetry, PC software for image processing and 3D modeling, retopology techniques, and collaboration with artisans using an iPad device. The study involved investigating the origin and significance of sandstone carvings, capturing detailed data of the artifacts using smartphone cameras and photogrammetry, processing the collected photos using specialized software, refining the 3D models through retopology, and making further adjustments and collaboration with artisans using an iPad and relevant application. This integrated approach aimed to enhance the design and production of sandstone artwork while preserving cultural heritage and embracing modern technology.

Overall, the research method employed in this study encompassed the study of historical artifacts, smartphone-based photogrammetry for data collection, PC software for image processing and 3D modeling, retopology techniques for improved mesh quality, and the use of an iPad device for further adjustments and collaboration with artisans. By integrating traditional craftsmanship with modern technology, this research method aimed to enhance the design and production process of sandstone artwork, ensuring the preservation of cultural heritage while embracing contemporary approaches. Each step of the research process is detailed with the following workflow

3.1 Study of artifacts carved in sandstone for product development

A study of the origin and information of sandstone art used for design and use. Most of the ancient sandstone carvings were created by Buddhists. These artifacts were created in Phayao Province and can be found in the old town of Phayao. These sandstone works of art were abandoned and deteriorated in the late 23rd century BC after the decline of the city of Phayao. Lifting and moving these tasks is difficult because it is fragile. Including the weight, these sandstone carvings can be found commonly in ancient sites and places in Phayao city.

Bringing these artistic creations to use for creation and design should take into account the beliefs and suitability of that art object. In the area of Phayao and nearby

provinces, people still have strong respect for Buddhism and persist in people's way of life with Buddha statues that are carved images of the Lord Buddha that are being worshiped. The statues are passed on to people who believe in Buddhism very much. Buddha statue means a figurative figure or a representation of the Lord Buddha and is a work of art created as a response to and serve the needs of Buddhism, to depict material philosophy and as an offering to the Buddha [25]. Therefore, taking Buddha statues to modify or bring them for use in homes or utensils may be contrary to the traditional beliefs and faith of believers in Buddhism.

Fig. 1. The lotus design in Buddha art made of sandstone

Apart from the lotus, other depictions related to Buddhism are also found in the art of ancient sandstone carvings, such as statues of animals, stone tablets and other sandstone carvings. The lotus is inextricably coupled with the art of Buddhism. As shown in Figure 1, the base of the Buddha statue uses lotus flowers with various designs.

Lotus is an important flower in Buddhism and hence commonly found. The lotus flower pattern contains lotus petals that is elaborate, beautiful and delicate, reflecting the transfer of the craftsman's spirit into the work as an offering to the Lord Buddha. The Lotus Flower in Thai literature is a book that most Thais regard as a well-written book with a pleasing cadence in the use of words and rhetoric.

Phayao craftsmen develop the concept using the nature of lotus plants that have grow in rivers and other water bodies to create products using a water basin to develop Phayao handicrafts in ancient lotus patterns. In addition, the Phayao sandstone carvers use lotus flowers as the prototype to create other artistic forms such as decorative patterns and offerings, all of which are related to Buddhist teachings or rituals. The styles of craftsmanship of Phayao sandstone carvers have also been applied to create works that can be seen in educational sites related to Phayao sandstone art in various places.

An analysis shows the use of proportions and motifs of the lotus and the nature of the lotus as a guideline for designing works related to water and tools and utensils used in everyday life by the people. Saving data into 3D parts can help make this operation and process easier and more convenient. In doing this work, a multi-part process has been brought together to reach the goal of research by both scientific and technological steps and methods, as well as the analytical process of sandstone carving art. Ancient Phayao, including the beliefs and characteristics of the art that has been created, are analyzed to create a new piece of work through the following steps and methods.

The study and interpretation of works of art in line with people's ways, and lifestyles. The lotus-shaped water bowl forms the base of the Buddha statue and has a typical pattern characteristic of the Phayao sandstone carving art. These are vertical lines resembling lotus stamens found in most of the lotus carvings of Phayao sandstone art creations. In addition, the lotus is regarded as the queen of water plants because it grows and blooms beautifully in the water. The life cycle of the lotus is therefore clearly consistent and related to the water. The lotus flower is clearly associated with Buddhism, as can be seen from its use as a motif, as the base of the Buddha statue, or in architecture. The lotus is also an important symbol that appears in Buddhist culture and traditions, including the use of lotus symbols as a medium to convey dharma content and stories or events in the Buddha's history through various fields of art. [26]

Based on the information related to this research, the researcher uses this as one of the elements to create this work. Using the concepts interpreted from the data gathered from the study, a basin was created because of the relationship between the lotus and water, the lotus flower was identified as a foundation or support for Buddhism. The form of the product can reach a people of different age groups, even more than the original works of art that are located in areas related to Buddhism. The creation of this work that mentions the lotus and water is consistent and related to the vessel or a basin type water support, which is a common utensil that reaches people and still has a meaning consistent with the lotus in the original art that was created.

3.2 Photogrammetry process by shot from smartphone

The process of collecting data of objects of art with processes and methods to create work pieces using photogrammetry starts by capturing the perimeter of the stone carving using a smartphone. The smartphone serves as the primary platform for field measurements and activities, allowing geologists to accelerate data acquisition and promoting the emergence of common file formats and field data storage repositories to use the resulting photos in the process photogrammetry in the next step. [27]

Research findings confirm the dependability of the self-calibration approach used in this study for both cameras. They also claim that smartphones can be used directly to collect onsite photogrammetric data for 3D modeling and measurement extraction for construction management applications. [15]

The data from the test shows that the use of high-definition mobile phone cameras or the technology used today can be used in the experiment to collect data in the process. The researcher used Iphone 13 Pro phone to collect photographic data in this research.

Photogrammetry, on the other hand, can be used as a low-cost alternative for optical 3D imaging. Other iOS apps for 3D scanning that use LiDAR technology and allow

the creation of 3D datasets based on triangulated meshes and photographic textures are currently available. The LiDAR technology used in Apple mobile devices is a relatively new feature, and it is expected that this technology, as well as the associated apps, will advance rapidly in the coming years. High-resolution and high-quality optical 3D imaging methods and devices are typically expensive. [15]

3.3 Photogrammetry process by PC software

The photos taken during when recording data are processed into 3D shapes using a photo processing program. The researcher has chosen to use a program for image processing, the Agisoft Metashape program. The creation and process of the program consists of the following steps.

a. Align Photo is a process in which the program organizes prepared photos into a rough structure of the object. This process compares each photo and other images that are close to the object.
b. Build Dense point cloud is a process that takes quite a long time to process because the program has to process the image thoroughly to create the structure of the object from various reference points of the image. The program will process the image into a structure of millions of dots and the color of the collected object, along with a reference of the color dots from the resulting photograph, similar to the previous step, but with the resolution of more objects.
c. Build Mesh is a step in which the program will create a surface between each point to create a 3D outline, which is another important step to visualize the resulting structure as a 3D object similar to the initial objects obtained.
d. Build Texture, the process of processing and analyzing the surface image of a 3D object that collects data in the form of texture, is the last step of the program before completing the process of saving the work piece as a 3D object.

3.4 Retopology, a 3D mesh form of photogrammetry

When the work piece in the form of a 3D work piece is completed, the next step will be a study. The researcher has selected parts in the lotus from the 3D work piece obtained from the process step. Photogrammetry plays an important part in molding and designing the structure of the new piece based on the pattern and original structure as much as possible in order to maintain the style and identity of the art of the ancient Phayao family by modifying and adjusting parts of the 3D parts obtained to create a 3D model. In such a process, the researcher has brought the proportions of the 3D work piece to be improved and corrected in the 3D program using the Autodesk MAYA 2019 program. Modifications will made to make it suitable and then arranged and assembled with other work pieces to be beautiful. 3D modeling is quickly becoming an important tool for preserving and reproducing cultural heritage artifacts. Such technology also enables the acquisition of high spatial resolution data, which is required to improve the efficiency of the reproduction process. [28]

The 3D model is edited and adjusted based on the model obtained from photogrammetry. It is a high-resolution model and a complex 3D structure with no order in order to obtain a work piece that can be customized and edited. Compose 3D makes working on the pieces with programs easier. Retopology or recreated polygom to

obtain a cleaner layout is primarily used to improve the quality of the polygonization, mesh simplification to reduce and control polygonal complexity, and mesh parameterization to improve UV maps. [29]

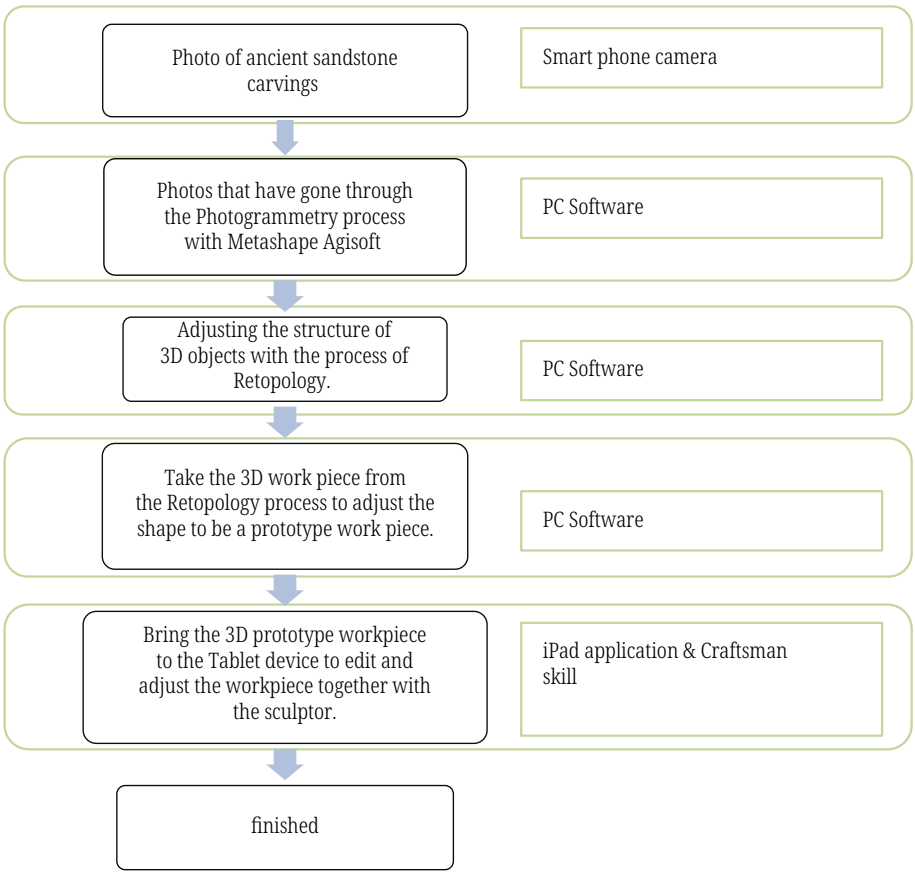

Fig. 2. Flow chart of research procedure with tool

3.5 3D improvement with iPad device

Once the prototype of the work piece in the form of a 3D work piece from editing and manipulating the structure according to the drawing of the bath is ready, the next step is for the researcher to take the model as a prototype to produce the actual pieces with sandstone carvings. The reference is the work of artisans who have inherited their specific techniques of sandstone carving with texture and specific characteristics. To make the new products similar to sandstone art in the past, the patterns obtained by recording the results with the 3D technique is used as reference. The resulting 3D prototype is imported and then exported as a file that supports 3D work improvement in the iPad device, to be used for adjusting the shape of 3D objects from the text. Propose and evaluate shapes from stone carvers through the Nomad application that has the ability to customize 3D work pieces, including editing and adjusting 3D proportions, emphasizing the working style of creating 3D models in the form of digital molding and embellishing with color. In addition, 3D files can be easily and conveniently transferred to other 3D programs. In this process, the researcher used the tool to adjust the proportions of the 3D work piece with the technician to improve the work piece structure in the pre-3D engraving.

The steps were modified to make them suitable for the stone carving process based on the nature of the stone to derive the desired style and the most suitable characteristics. A holistic knowledge of rural regeneration depending on multimedia and heritage requires a new vision based on a strong integration of approaches and tools. [30] The sandstone carver analyzed and assessed the possibilities from the original structure in order to select the suitable size of sandstone for production including the surface of the stone used to create a prototype piece. All of these processes cooperate both the skills and abilities of craftman and the process of using creative tools and technology from the charger in Figure 2 shown above.

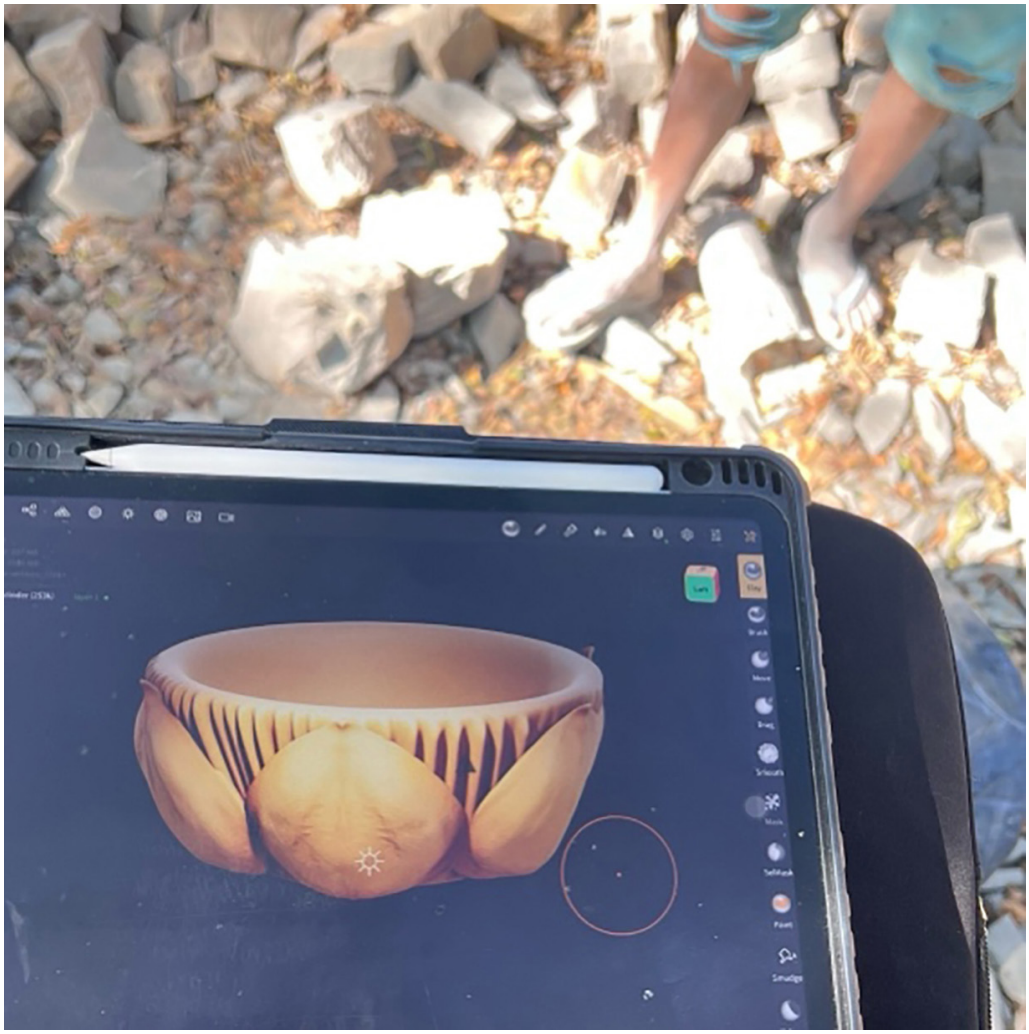

Fig. 3. Use of iPad for adjustment 3D model with Nomad application working with sandstone- craftsman in the process of craving sand stone

The sandstone carving is from the Phayao province, and carved by artists who inherited the knowledge that has been passed down from generation to generation to the present to creating works using skills and expertise. There was no technology or recording to transfer knowledge of this technique. This entire research is an initiative to create a small art work by using the talents and skills of each group of people who have been the link to the past to co-design, in addition to being a critical process in the creation of interventions focused on people, also enabling collaborative relationships in which trust, open communication, and mutual learning are important points

to work on for the process's success. This methodology is open to people's viewpoints and experiences, and it values everyone's information, and these steps are important when working on a project involving the preservation of cultural heritage. [31]

In this process, experts use the aforementioned application to work with artisans of this ancient craft; all of these artisans are elderly people who do not have much knowledge and expertise in technology or using a device such as a tablet that is considered a tool that has features that are easy to carry, has a large and clear display, and fast digital processing with better collaboration. In addition, the introduction of 3D images or data is also a facilitator of limitations in the creation and study of sand art that have problems with size and weight in the study.

Fig. 4. A final sand stone artwork

4 RESULT

Due to the production and creative process of stone carving, it is essential to use sandstone material specifically found in the province of Phayao. The size of the stone is crucial in creating and sculpting sandstone artwork, with a prototype based on an ancient Buddha sculpture with lotus patterns. The dimensions of the completed artwork are approximately 85 centimeters in width and 55 centimeters in height. It features a round top shape with a slightly curved and tapered base resembling a lotus flower. The created artwork has been derived and refined from the original prototype, with modifications made to the top area of the artwork to create a basin-like structure. The completed artwork measures 40 centimeters in width and 25 centimeters in height, adjusted proportionally and appropriately for practical usage as a water basin. As shown in Figure 4.

The design of the basin artwork is based on a 3D model created through a research process that involved data collection and subsequent processing using photogrammetry techniques. The model was then further refined, considering the structure, components, and proportions using 3D software before being implemented in an application for convenient design, modification, and customization on an iPad. This allows for easier on-site adjustments and modifications during the stone carving process. The users and stone carvers collaborated in analyzing the form

and possibilities of creating sandstone artwork, working together to modify the 3D model and refining the artwork during the collaborative process.

5 CONCLUSION

From the aforementioned work, a sandstone carving using the prototype from the 3D work piece resulted in a work piece similar to the basin shaped like a lotus as a base to support the Buddha statue by using the tools and technologies around us such as mobile phone photography to aid in the process of production and creation of works or the transfer of knowledge of art and culture. Photogrammetry was used to process the images of the ancient artifacts into 3D work pieces and to use them to edit objects with 3D programs. This was forwarded to a portable device, an Ipad, that currently supports applications to edit 3D work pieces. It can be used to improve the design for fieldwork in the production of work pieces and reach the accuracy and needs of sandstone carvers. Such procedures and methods can be made easier when tools such as mobile phones facilitate such operations. In addition, support for the use of 3D creative applications is like another part of the impetus for creators to play a role in terms of accessing art from cultures and other related things very easily even more. The creation of such work is educational, and helps to study the characteristics of traditional art and ancient artifacts.

Work piece data collection using technology helps with the process of improving and modifying parts of 3D objects by using digital multimedia tools to modify parts of 3D objects to become the prototypes of new objects and works. It is the original model for the construction of a new piece. In this case, it was a basin that is shaped like a lotus flower and is important in Buddhism. The synchronization of computer program tools and using the knowledge of ancient craftsmen to work together to create the process were critical. The resulting work piece has a pattern and appearance similar to that of the original lotus petal shape. It is not very similar to the prototype of the structure because of the nature of the stone used to build it. The original prototype size was different. The main factor of sandstone carvings in the ancient Phayao style is using a single piece of stone to carve the form, and not creating connections or assembling different portions to create the piece. Therefore, the initial characteristics of the sandstone used to create this still plays an important role in greatly affecting the work image. The result of the work piece obtained is the main purpose and the use of prototypes in the form of 3D structures for builders and sculptors of sandstone as examples is also a suitable option for creating work pieces because they can analyze the work and select stone models that are suitable for the design and be creative. In addition, such tools are used to adjust the designs to suit the workmanship and assess the suitability for the production method used. To create data and record the beautiful pattern of the sandstone art of Phayao craftsmen is another way to preserve such artwork to be used as a model. Such operations establish the benefits of using technology for simulation. Comparative selection by moving objects from the 3D program can be made easier and more convenient than ever by creating a better understanding of sandstone sculpting. It can be seen that the use of communication devices such as mobile phones and portable electronic devices such as tablets can aid in the preservation of arts and culture and creativity and is likely to play a role. In this issue, conducting more such research has also been found to be an important aid in connecting people.

Knowledge and creativity increased with efficiency and the development of these mobile devices, and the resulting output form has a function that can be used

by other groups of people. The benefit of producing this kind of work is in making art more accessible to people. This is another research that has linked ideas, skills and creativity of people in each generation in each era to create collaborative works, which is a concept that drives society to use capital in art, culture and technology appropriately.

6 LIMITATIONS

The research described has certain limitations that need to be acknowledged. Firstly, the lack of written records and manuals about the ancient Phayao sandstone carving technique makes it challenging to fully understand and replicate the traditional craftsmanship accurately. This limitation also extends to the scarcity of knowledge about the sandstone art of ancient Phayao craftsmen, leading to potential inaccuracies in the research. Furthermore, the research is focused on a specific region, the Lanna Kingdom in Thailand, and its ancient Phayao sandstone art. While this provides valuable insights into the local culture and heritage, the findings may not be directly applicable or representative of other ancient sandstone art traditions in different regions or cultures.

7 FUTURE RESEARCH

Conducting comparative studies between the traditional sandstone carving techniques and the results obtained using modern technology could provide valuable insights. This could involve analyzing the intricacies and nuances of ancient sandstone art forms compared to the digitally recreated ones, highlighting the strengths and limitations of each approach.

Investigating the impact of integrating modern technology into traditional art forms on the cultural heritage, local communities, and artisans' livelihoods would be valuable. Understanding how technology affects the dynamics of art preservation and dissemination in society can inform better strategies for sustainable cultural preservation.

Encouraging collaboration between historians, archaeologists, artists, technologists, and local communities could lead to more comprehensive research and ensure a holistic understanding of the cultural context and significance of ancient artworks.

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PAPER

Artificial Intelligence-Based Chatbot to Support Public Health Services in Indonesia

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ABSTRACT

The aim of this study is to build an artificial intelligence chatbot application to support public health services. The chatbot acts as an information service that can replace the role of humans. The analysis of functional needs was obtained from information submitted by one of the heads of public health centers in Indonesia. This study uses the Scrum method with pregame stages to produce a plan consisting of functional and non-functional requirements analysis and conceptual design of the chatbot, which will be developed using Unified Modeling Language (UML) diagrams. The process of finding answers uses the matching graph master technique, which is a backtrack matching that utilizes a depth-first search strategy. There are 6 topics of chatbot services, including service schedules, health information, registration, diseases, drugs, and early care services for chatbot users. Tests conducted on these 6 topics showed an average correct answer ratio of 93.1% out of a total of 251 questions. The result of the usability measurement on the chatbot application that has been built obtained a system usability scale value of 80.1, indicating that the developed chatbots are acceptable for use.

KEYWORDS

chatbots, artificial intelligence, AIML, graph master, chatbot to support public health services

1 INTRODUCTION

The Industry 4.0 revolution opens up opportunities for industries to implement artificial intelligence, process big data, and carry out software development [1]. This is not an exception in the field of healthcare [2], where it is crucial to focus on open access to information for the general public [3].

Indonesia faces potential risks in the field of health due to its dense population [4]. Based on the data available in Figure 1, the percentage of people who have experienced health complaints in the last month averaged 23%, indicating a relatively high rate of health complaints in Indonesia.

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Challenges in healthcare stem from various factors, including the shortage of healthcare personnel and the spread of various diseases, making it difficult for many countries to address health problems [5]. The inability of health workers in the field and insufficient health data documentation systems are also significant obstacles in the provision of services [6]. Professionalism is a fundamental aspect of healthcare, and the application of technology is a crucial part of providing professional services [7].

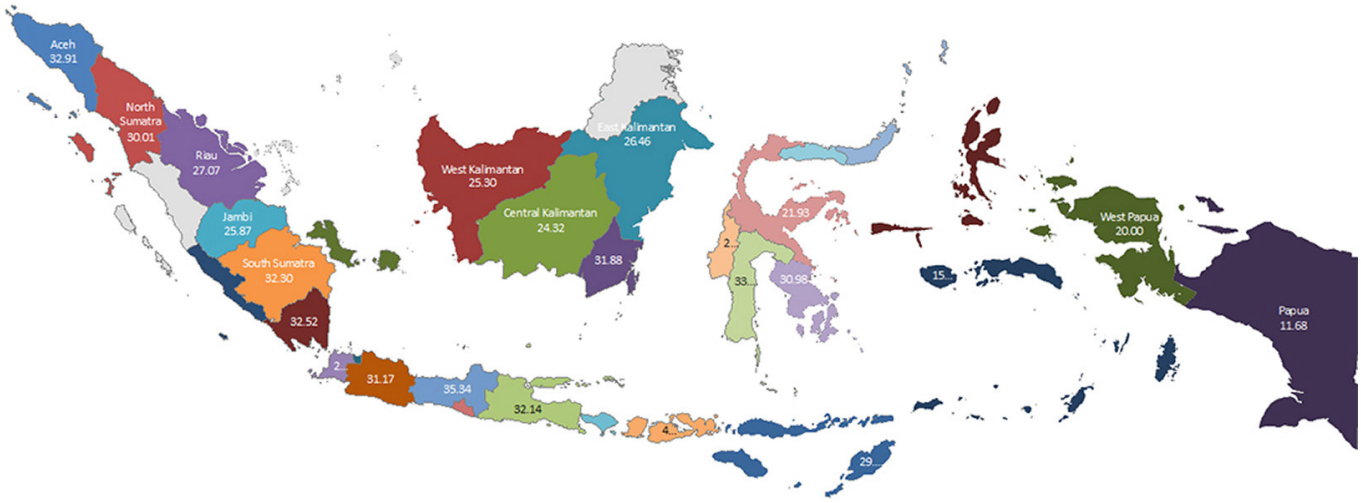

Fig. 1. The percentage of people who have experienced health complaints over the last month

Healthcare is currently at the forefront of the mobile revolution [8], and software in the healthcare field is growing rapidly with the increasing use of mobile devices, such as smartphones, in society [9], [10], [11]. This integration of technology has significantly improved human life activities [12], [13], making technology an inseparable part of daily life [14]. With the growing use of the Internet and the development of health-related technologies, such as telemedicine, telehealth, and telenursing, telemedicine has emerged as one of the alternative ways of providing health and nursing services.

Telemedicine or telehealth-based healthcare systems involving humans as operators still have limitations, including service hours and the officials' understanding in answering various questions, as well as problems with communication abilities. Chatbots serve as automatic communication machines to answer user questions [15]. They simulate human conversational language through computer programs [16] using a natural language approach [17]. The presence of chatbots can help organizations meet various needs [4], [18], and provide cost-effective and timely information services [3]. The ease and flexibility offered by chatbots make them highly valuable for users [19].

The application of chatbots as a medium or tool to provide information has been extensively researched. In 2020, [20] conducted research on online health medical suggestions designed with a modular system to adapt to various medical scenarios. In another study, [21] used cosine similarity calculations to classify questions and employed TF-IDF to determine the relevance of a question to the answers available in the dataset. Moreover, [22] utilized text and voice messages as input, which were then processed using machine learning to predict the type of disease experienced by patients and monitor health conditions in Covid-19 cases.

Open access to health information is a significant challenge. This research aims to develop chatbots that support the public in the process of searching for health information, thereby making access to health services easily accessible and increasing public satisfaction with health information services.

2 METHODS

In this study, the method used is Agile, which is one of the software development methodologies [23]. There are various frameworks within Agile, one of which is Scrum. Scrum was chosen because of its advantages in running design sprint iterations in a short period of time. It is designed to be fast, lightweight, and flexible [24]. The process of analyzing user requirements in Scrum is carried out at the beginning, taking input from the end user to initiate the Scrum process. Scrum is the most suitable method for developing chatbots because of its constant meetings that actively involve the team in the project [25]. The Scrum process involves three stages: pregame, game, and postgame.

1. In the pregame stage, there are two sub-stages: planning and architectural design. Planning involves discussions with the head of the public health center to determine the features that will be developed in the application. The architectural design sub-stage is where the software architecture is designed based on the features to be developed.
2. During the Game Stage, the activities carried out are analysis and design. The analysis is based on the planning done in the early stage of the pregame, resulting in the conceptual design of the system to be developed.
3. Postgame is the stage of demo and product delivery. Before the product is delivered, product testing is conducted to ensure it has been developed according to the user's needs.

The Scrum method is chosen because the daily meetings conducted at each sprint period can identify potential problems that may arise during the system development process and can be addressed by the entire team.

3 RESULTS

3.1 Pregame stage

At the pregame stage, an agreement was reached with the head of the community health center, which was discussed in terms of the proposed system flow, user needs, and functionality requirements.

A) *Planning*

1) *Functional Needs*

1. The application should be capable of managing a list of questions about public health services, including features to view, add, and delete questions.
2. The application should be able to provide answers to every question asked by the user.

3. The application should be able to save every question asked by the public into the database.
4. The application should display statistics of frequently asked questions.

2) *Non-Functional Needs*

1. The application should be available and operational 24/7 without any interruptions, with the ability to be updated at any time.
2. The application should have a high level of security, ensuring that every user can only access and modify their own data, preventing unauthorized access to others' accounts.

B) *Architectural Design*

Designing software systems is a lengthy process that can be carried out in various ways [26]. Unified Modeling Language (UML) diagrams are considered the main component in the software requirements engineering process and have become a standard reference in many companies [27]. The system's use case diagrams are drawn and explained in the following points. Use case diagrams describe the functional requirements of the system being developed and the relationship between the system and the external environment [26]. There are two actors involved in the system: the community, which is the actor that interacts most frequently with the chatbot to ask various health service-related questions, and the chatbot, which automatically answers each question based on the patterns stored in the database, previously inputted by the administrator. The use case diagram of the public health service chatbot is illustrated in Figure 2.

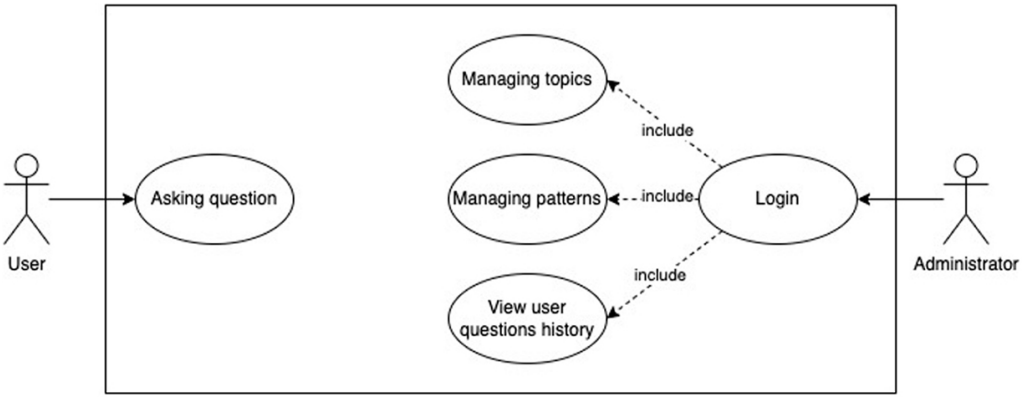

Fig. 2. Use case diagram of the public health service chatbot

3.2 Game stage

A) *Analysis*

The necessary datasets for chatbots are collected from the data available on the service procedures in the public health center. Additionally, data is obtained through interviews with health nurses. This data includes information on the types of health services, service times, health information, and the most frequently asked questions by the public, along with the corresponding answers given to those questions.

The dataset is stored in a database and will be called by the application in the form of a JSON file. An example of JSON files for healthcare topics is provided.

```
<category>
<pattern> * Dentist </pattern>
<template> Dentist services open on Mondays at 9 am
</category>

<category>
<pattern> * Dentist * </pattern>
<template> Dentist services open on Mondays at 9 am
</category>

<category>
<pattern> Dentist * </pattern>
<template> Dentist services open on Mondays at 9 am
</category>
```

The pattern is a question given by the chatbot user. The asterisk (*) sign in the pattern represents any word that is at the beginning or end of the pattern as show in Table 1.

Table 1. Sample question

* (Prefix Word)	Pattern	* (Last Word)
Tell me about	Dentist	
Is there a	Dentist	today?
	Dentist	there?

The answers to each question are grouped according to the topic of the question, and the number of patterns for each topic is shown in Table 2.

Table 2. Topics and patterns

Topic	Patterns	Description
Salutation	8	Initial conversation greeting from the system for chatbot users
Service Schedule	23	Questions about health services
Health Information	34	Questions regarding health information
Registration	26	Questions regarding registrations
Disease	28	Questions about disease
Drug	29	Questions about drugs

B) *Conceptual Design*

1) *Pattern Matching Method*

Graph master is a method used for storing stimulus-response categories from Artificial Intelligence Markup Language (AIML). To achieve efficiency in pattern matching and memory usage, AIML utilizes the graph master method [28], where all category tags <category> in AIML are stored in the form of a tree starting from the root node "*" to a certain path from a pattern.

Graph master is structured as a tree. When a client interacts with the bot (agent) and enters text as a stimulus, the graph master searches for matching categories and

associates them with the <pattern> function based on the context of the sentence, then produces an output <template> in response.

Graph master matching is a backtrack matching process that employs a depth-first search strategy. Depth-first search is a type of blind search, wherein the search explores nodes in depth, moving from the initial node to the most recent or until a match is found. In other words, it prioritizes visiting child nodes first.

The stages of the graph master Pattern Matching Algorithm are detailed in Figure 3 [29].

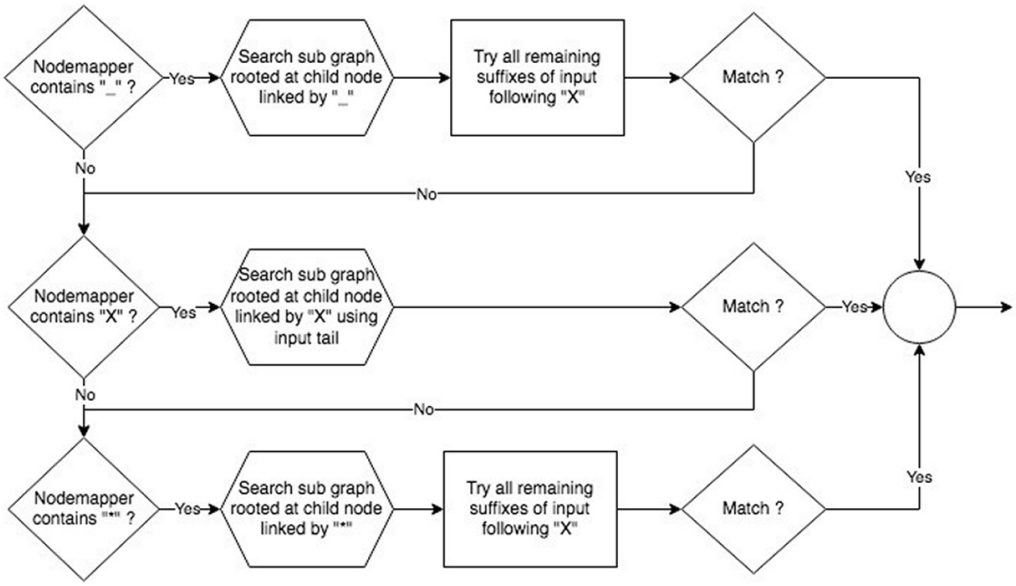

Fig. 3. Graph master pattern matching (source: www.alicebot.org)

C) *Chatbot Architecture*

The chatbot system consists of three entities: chatbot interface, chatbot backend, and database. Each of these entities cannot be separated. The chatbot interface serves as an application interface used by the user, and the text messages sent by the chatbot user will be processed by the backend using a pattern of matching, taking data from the database. The chatbot architecture is depicted in Figure 4.

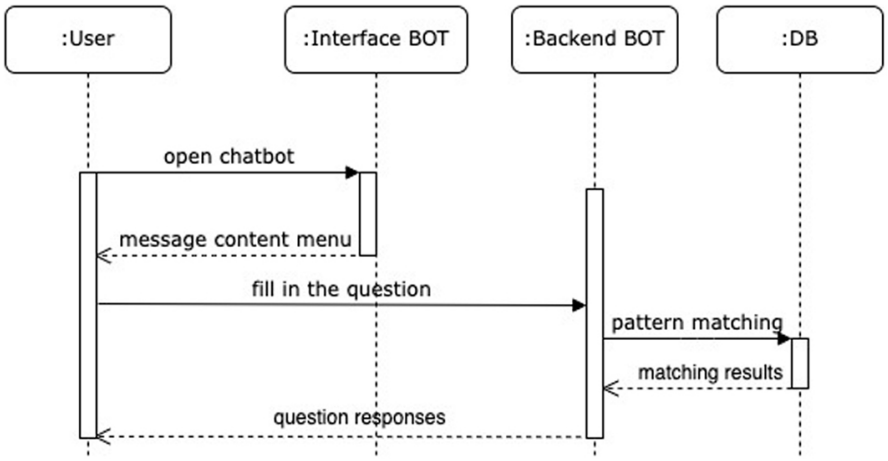

Fig. 4. Chatbot architecture

3.3 Post-game

A) *Application Demo*

The chatbot application test was conducted with 58 respondents, where each respondent interacted with the chatbot. However, not all respondents performed experiments on all existing topics. Tests conducted on 6 topics showed an average correct answer ratio of 93.1% out of a total of 251 questions, and a summary of the test results for each topic is presented in Table 3.

Table 3. Summary of the test results on each topic

	Topics					
	Salutation	Service Schedule	Health Information	Registration	Disease	Drug
Total Testing Topics	58	46	42	35	37	33
Correct Answer	58	42	39	34	32	30
Percentage of Correct Answers	100.0%	91.3%	92.9%	97.1%	86.5%	90.9%

Chatbots are designed to answer questions using the Indonesian language. Examples of chatbot test results are shown in Figure 5.

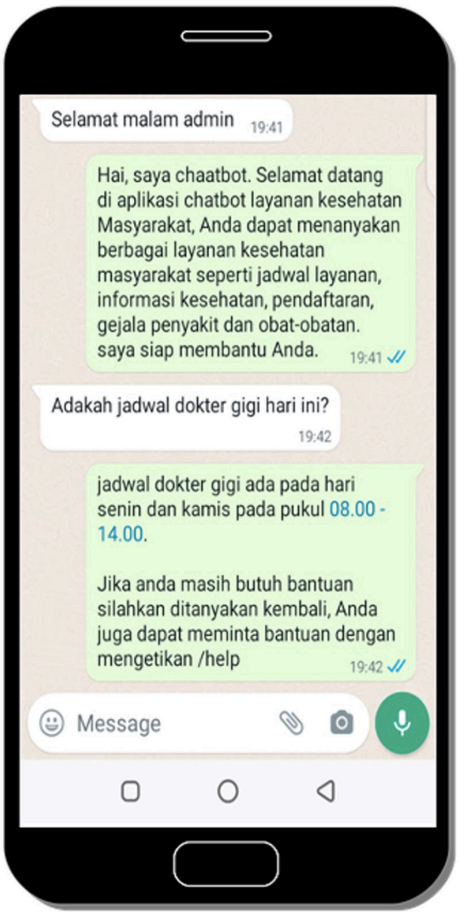

Fig. 5. The example of question and answer from chatbot

B) *Usability Measurement Results*

Usability measurement is done using the System Usability Scale (SUS). This method helps determine whether the system can be used properly [30]. Based on a thorough review of the collected data, the following points summarize SUS [31]:

1. SUS is dependable. Users consistently respond to the scale items, and SUS has been demonstrated to be more sensitive to variations than other questionnaires, even with smaller sample numbers.
2. SUS is accurate. In other words, it measures what it claims to measure.
3. SUS isn't a diagnostic tool. It doesn't explain what makes a system useful or not.
4. SUS scores return a value between 0 and 100, but they are not percentages The product's percentile ranking should be examined to determine how it compares to the competition.
5. SUS evaluates both usability and learnability. Although there is little association between SUS scores and task performance, it is not surprising that people's subjective evaluations may vary.

Figure 6 show grades for SUS performance.

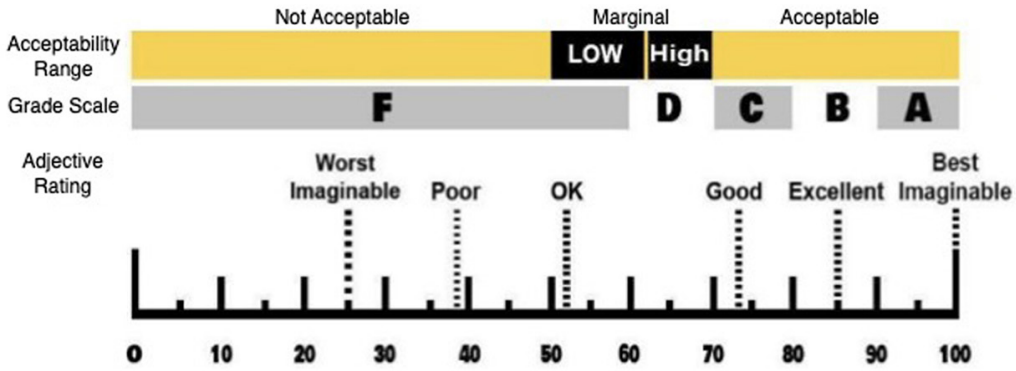

Fig. 6. Grades for SUS Performance

The usability measurement was carried out involving 58 respondents, with the characteristics of respondents shown in Table 4.

Table 4. Characteristics of respondents

Gender	Age	Total	Percentage
Male	15–25 26–35 36–45 46–55 >55	4 7 10 8 2	53.4%
Female	15–25 26–35 36–45 46–55 >55	5 12 6 3 1	46.6%

Based on the questionnaire results from 58 respondents, the measurement results of SUS are shown in Table 5.

Table 5. SUS Score

No	Question	Average Score
1	I think that I would like to use this chatbot frequently.	4.5
2	I found the chatbot unnecessarily complex.	1.9
3	I thought the chatbot was easy to use.	4.8
4	I think that I would need the support of a technical person to be able to use this chatbot.	2.0
5	I found the various functions in this chatbot were well integrated.	4.6
6	I thought there was too much inconsistency in this chatbot.	1.1
7	I would imagine that most people would learn to use this chatbot very quickly.	4.7
8	I found the chatbot very cumbersome to use.	1.1
9	I felt very confident using the chatbot.	4.9
10	I needed to learn a lot of things before I could get going with this chatbot.	2.5
	Total	32.1
	SUS Score (2.5 * Total)	80.1

From the results of the usability measurement on the chatbot app that has been built, an SUS value of 80.1 was obtained. This indicates that the developed chatbots are acceptable for use.

4 CONCLUSION

The study aimed to create chatbots based on artificial intelligence to support public health information services, addressing the difficulty of accessing information for individuals distant from health care facilities. The development of a chatbot was proposed as a solution. Several methods were considered for finding answers to user queries, including case base reasoning and brute force algorithms. However, the study opted to use the backtrack graph master pattern matching algorithm, employing a depth-first search strategy with Artificial Intelligence Markup Language.

The chatbots developed using the graph master pattern matching algorithm successfully interacted with users, resembling human interactions. The average success rate of correct answers reached 93.1% out of a total of 251 questions.

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PAPER

An Adaptive M-Learning Usability Model for Facilitating M-Learning for Slow Learners

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ABSTRACT

Mobile devices have evolved from communication tools to versatile platforms for various purposes, including learning. Usability is crucial for practical mobile learning applications, ensuring ease of use and expected performance. However, existing research on mobile educational apps has primarily focused on typical learners, neglecting the specific requirements of slow learners who face cognitive limitations. In this work, we fill this research gap by proposing an adaptable learning-oriented usability model (ALUM) for mobile learning apps specifically tailored to support slow learners. The research conducts a detailed usability analysis and systematic review to identify the problems users face and investigate how slow learners respond to learning apps in terms of efficiency, effectiveness, satisfaction, and learning outcomes. Twenty-four participants classified as slow learners evaluated the usability of 25 HTML-based learning apps. The evaluation revealed critical deficiencies in existing learning apps concerning the needs of slow learners, particularly in user-friendliness and learnability, leading to their dissatisfaction. We propose a model that leverages a hybrid recommendation system to address these challenges. The model incorporates a navigational graph, ontology, and item matrix to provide personalized topic recommendations, tailoring the content and delivery of educational materials based on individual needs and preferences. By enhancing the learning experience for slow learners, the proposed model aims to improve their learning outcomes. This research bridges the gap between academic research and practical applications in interactive mobile technologies. The adaptable learning-oriented usability model presented in this paper offers a framework for supporting slow learners, emphasizing its essential components and their interactions to enhance the learning outcomes for this user group.

KEYWORDS

mobile learning apps, adaptive approach, personalized recommendations, virtual environment, M-learning

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1 INTRODUCTION

Usability [1] refers to the ease of use and overall satisfaction a user experiences when interacting with a product, system or service. This concept is critical in designing and developing user-centred products, as it helps ensure that the intended audience can use the product effectively and efficiently. Good usability [2] considers user needs, cognitive processes, and feedback mechanisms to create an intuitive and user-friendly experience. Usability engineering [3] involves designing and evaluating interactive systems to ensure they are user-friendly, efficient, and meet user needs, resulting in enhanced user satisfaction and engagement. User experience (UX) [4] refers to a person's overall perception and attitude about using a particular product, system, or service. It encompasses all aspects of a user's interaction with a product, including the design, functionality, and usability, as well as their emotions and attitudes. UX design considers the user's needs, expectations, and satisfaction to create a product that meets their requirements and provides a positive and enjoyable experience [5]. The goal of UX design is to create products that are easy to use, efficient, and aesthetically pleasing, which can ultimately lead to increased user satisfaction and loyalty.

Learning disabilities impact a person's ability to learn and process information, despite having average or above-average intelligence. These difficulties can affect skills such as reading, writing, speaking, and problem-solving, making it challenging for individuals to succeed in school and life [6]. Some common examples of learning disabilities include dyslexia, dyscalculia, ADHD, and dysgraphia. These conditions are often neurological and do not result from insufficient effort or motivation [7]. People with learning disabilities may require specialized support and accommodations, such as extra time for testing or technical instructional methods, to succeed in their education and careers. The hierarchy of learning disabilities is shown the Figure 1. Gamification [8] can effectively enhance the learning environment for e-learning students. The study results confirm that gamification, consisting of elements, game dynamics, motivation, and game mechanics, significantly impacts e-learning usability. Furthermore, instructional design plays a partial mediating role in the relationship between gamification and e-learning usability.

Slow learners [9] need help to keep pace with their peers in acquiring and retaining information and skills. This can be due to various reasons, including learning disabilities, attention difficulties, socio-economic challenges, or limited prior educational experiences. While slow learners may require additional support and resources to succeed, it is essential to recognize that they have unique strengths and abilities [10]. Teachers and educational support professionals may use various strategies to support slow learners, such as providing additional one-on-one instruction, educational technology, and incorporating hands-on learning activities. Emphasizing the strengths and interests of slow learners can also help increase their motivation and engagement in learning [11]. With proper support, slow learners can make meaningful progress and succeed in their education and beyond. Recent years have seen a sharp increase in the global mobile app market. Downloads of mobile apps increased from 140.68 billion in 2016 to 230 billion in 2022 [12]. Mobile learning refers to delivering educational content and assessments through mobile devices such as smartphones and tablets. Mobile learning aims to provide learners access to education anytime and anywhere, making learning more flexible and convenient. Mobile learning can take various forms, such as self-paced online courses, gamified educational apps, and instant assessment feedback [13]. With the increasing availability and accessibility of mobile devices, mobile learning has the potential to revolutionize the way we think about and deliver education, providing opportunities for personalized and collaborative learning experiences.

ChatGPT's integration [14] in education highlights both its positive applications and potential negative impact. The findings emphasize the significant role ChatGPT and its derivatives can play in reshaping the education landscape. Incorporating ChatGPT into learning apps has the potential to revolutionize educational processes and create a new paradigm in education. The parents [15] are actively seeking to support their children's learning at home using mobile devices. However, it was also observed that parents generally need more knowledge about educational apps' developmental appropriateness and additional guidance in this area.

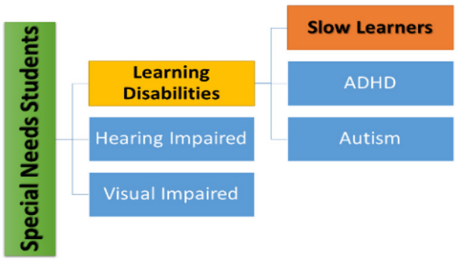

Fig. 1. Hierarchy of disabilities

Existing educational apps must improve their design to tackle slow learners' usability and learnability needs. Learnability is one of the most critical problems slow learners face, which is generally tackled through repeat exercises and more visualized content in usual pedagogical practice. However, mobile apps, especially educational apps, need to consider these issues in their design. The main objective of this work is to propose a learning-oriented usability model for slow learners. In addition to this, we aim to identify the significant issues faced by slow learners in existing educational apps. This paper is structured as follows: Section 2 describes the literature review and systematic review, section 3 shows the usability evaluation, section 4 shows the proposed usability model, and section 5 presents the conclusion.

2 LITERATURE REVIEW

The definition of usability is "the degree to which specific users can use a system, product, or service to achieve specific goals with effectiveness, efficiency, and satisfaction in a specific context of use [2]." Three criteria—effectiveness, efficiency, and satisfaction—were used to assess usability (as specified by ISO 9241). Generally, usability is an essential feature of mobile apps and software. To achieve the goal, usability cannot be ignored. One of the main reasons for the apps and software failure is a usability problem.

For this reason, usability testing or evaluation is used to find the usability problem, and it is helpful for the developer to improve the usability [16]. There are different methods for usability assessment, but the most famous forms are SUS (system usability scale) and SA (sentiment analysis). Criollo and his collaborators concentrate on the teacher's function in mobile learning. They point out that most innovation projects, such as the design and conceptualization of mobile applications, disregard the teacher's perspective, namely, if the teacher has received training to use mobile devices in the classroom [17]. However, they demonstrate the necessity of integrating mobile technology right from the start of the curriculum. A more extensive definition of learning anywhere and anytime, accessing content via any mobile device, is provided by Correa and colleagues (2021) in their overview of the context-aware study of m-learning and

u-learning processes [18]. The next generation of systems can customize content and educational strategies based on students' traits and learning preferences thanks to the ongoing advancement of mobile device technologies, more inventive computational techniques, and deep learning in virtual learning environments. An augmented reality application [19], "Atomik-3D", enhances the teaching of chemical elements to 5th-grade students. The Mobile-D methodology was used for development, and functional tests demonstrated positive results for surface recognition and usability.

To help slow learners become familiar with current technology usage, tablets are presented. It is intended to introduce tablet technology to slow learners to increase their desire for learning and help them develop a love of learning. They are unique children, so directing the slow learners toward a better quality of life is necessary. The study intends to do something other than accelerate the learning for slow people. Nevertheless, it encourages daring technology use daily and makes slow learners feel part of the most recent technological advancements [6]. The ability to learn "on the go" through mobile learning encourages student engagement and success [18]. Although mobile devices are simple to use, they are less practical for learning than desktop computers. Some learning management system (LMS) tasks could call for a more involved engagement procedure, which might be challenging to carry out using mobile devices. The small screen size is the primary cause of this problem. On mobile devices, typing and searching are challenging due to the limited screen size [20]. Small font size, dense text, and small text over complicated graphics are only a few examples of readability-related issues it causes. Reading and finding the necessary information on a little screen takes up too many cognitive resources. Three conditions must meaningfully satisfy children's mobile app development: development stages, content design, and digital engagements [21]. When increasing the number of functions, usability will decrease [22]. Learning app usability decreased as the age of the slow learners increased [23]. The PACMAD model defines three factors: user, task, and context of use [24]. For mobile applications, the model is an extended version of the Nielsen or ISO usability model [25]. The usability model comparison is described in Table 1. SentiML++ has undergone enhancements, including the incorporation of several new functionalities. These additions encompass the identification of targets at the sentence level [32], recognizing holders of sentiments, identifying topics, and distinguishing informal sentence structures. These improvements aim to provide annotators with greater flexibility, allowing them to choose from various taxonomies when annotating the subject of a sentence.

Using a mobile application with Augmented Reality technology substantially impacts elementary school students learning astronomy, significantly influencing the teaching-learning process [33]. Papadakis examines [34] the impact of four coding apps on young children's learning of Computational Thinking (CT) and Computational Fluency (CF). The author emphasizes the need for researchers and designers to make challenging decisions in creating software products that effectively facilitate CT and CF for young children. The developed game [35] significantly improved science learning outcomes for fourth-graders in Theme 1. Recommendations include proper use based on teachers' instructions, optimization and enhancement by teachers and provision of ICT facilities. CoSinE (Computer Simulation in Education) is an internationally peer-reviewed workshop [36] that focuses on the theory and practice of computer simulation in education. It seeks to investigate the utilization of AI, smart data processing, cloud-based personalized open education tools, adaptive learning environments, and intuitive learning platforms to foster creativity and ICT competency in line with European Research Area development. The study by [37] demonstrates the significant positive impact of the SMART-P training program on parenting knowledge and children's cognitive development. The quiz length strongly affects

the quantity of work completed in mobile-assisted language learning (MALL), with question sets between lengths 8 and14 being the most optimal [38].

Table 1. Comparison of usability models

Usability Model	Usability Factors	Description
Condos [26]	Navigation, content, information architecture, error prevention, presentation, input rate and visualization.	Content and presentation are not directly usability factors [27]. Used in the domain of e-commerce.
Coursaris and Kim [28]	The proposed usability dimensions are comprehensive.	This model is not tested to determine its accuracy and applicability.
mGQM [29]	Effectiveness, efficiency and satisfaction.	This model is based on goal questions metrics, so questions may be challenging to interpret for usability factors correctly.
Tan, Ronkko and Gencel [30]	This model is designed with nine usability factors and sixty- three criteria.	This framework is designed for companies who wish to develop usability and user experience instruments.
PACMAD [31]	Efficiency, effectiveness, learnability, satisfaction, memorability, error, and cognitive load	The addition of cognitive load is the main contribution of this model. The extended version of this model has 21 factors. All factors did not test to check their validity.

2.1 Systematic review of HTML learning apps

- **Searching and Screening Method**

The first step in usability testing and analysis is data collection. The two most popular and widely used operating systems for mobile devices are iOS and Android.

- **iOS and Android**

For its iPhone, iPad, and iPod touch devices, Apple Inc. developed the iOS operating system. The platform for managing and running native iOS applications is provided by proprietary software [39]. Android is an open-source operating system for mobile devices developed by Google. It is based on the Linux kernel and designed primarily for touchscreen mobile devices like smartphones and tablets. Android is widely used on many devices and supports many applications on the Google Play Store [40]. The apps storage size of iOS, apps rating and downloaded HTML learning apps from the Android platform are shown in Figures 2, 3 and 4, respectively.

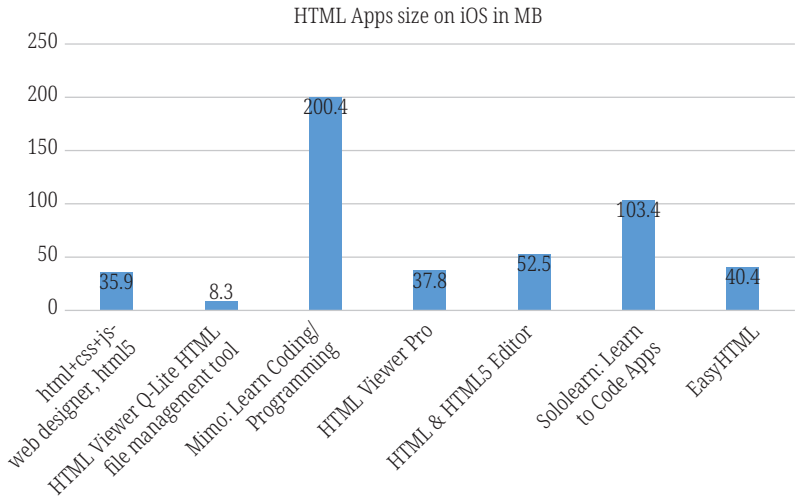

Fig. 2. HTML apps space required (IOS)

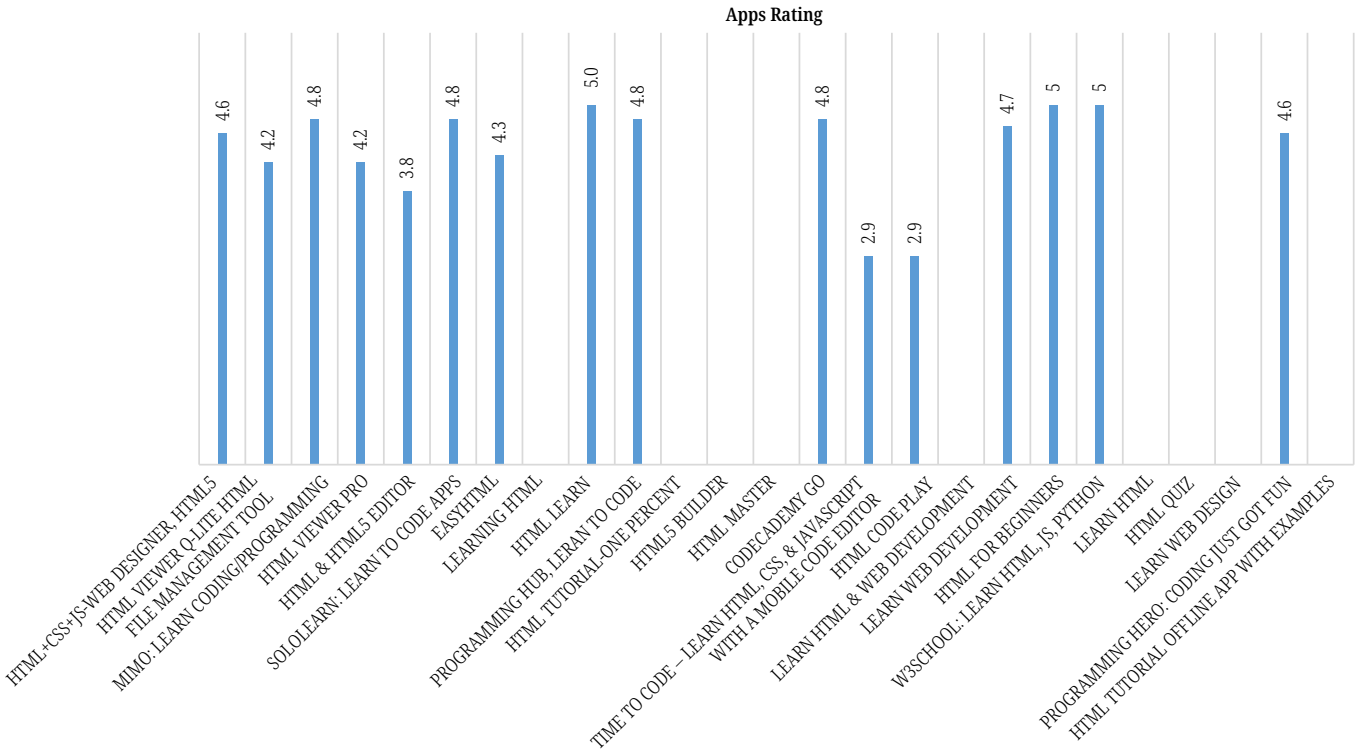

Fig. 3. HTML learning apps rating

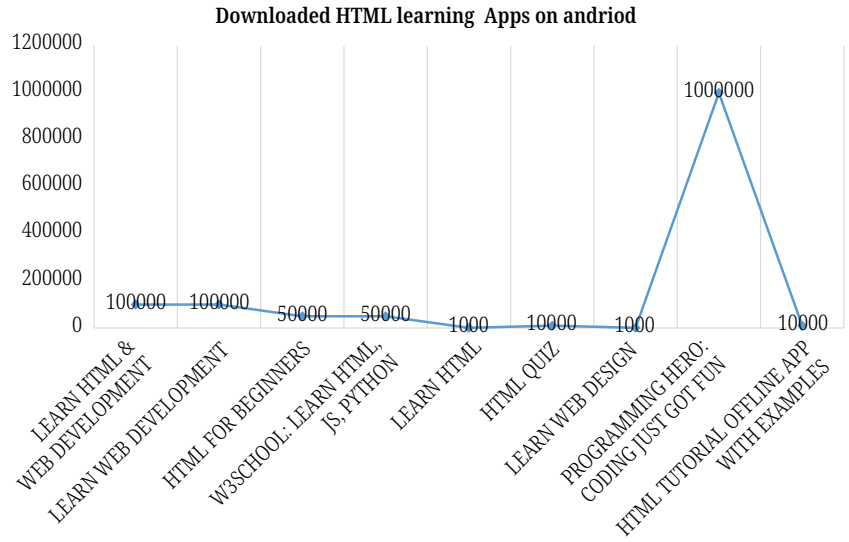

Fig. 4. Downloaded HTML apps review

3 USABILITY EVALUATION OF HTML LEARNING APPS

Usability evaluation measures a system's ease of use and user satisfaction [41]. It involves testing and evaluating a product or website's interface design, functionality, and overall user experience. The goal of usability evaluation is to identify areas for improvement and make recommendations for enhancing the

user experience. Usability evaluation is an essential aspect of the design process, as it helps to ensure that a product is user-friendly and meets the needs of its intended audience [42]. A study showed that 71% of usability evaluations of apps were conducted in laboratory settings due to the complexity of data collection in the field as users move physically [43]. An experimental usability evaluation method evaluates the HTML learning apps with users and experts. In this study, four groups (G1, G2, G3, and G4) were formed based on age limits, ranging from 16 to 55. Each group had three male and three female participants, resulting in 24 participants evenly split between genders, as suggested by Nielsen [44]. This study aims to evaluate the usability of learning apps for slow learners. HTML learning apps from iOS and Android are listed in Table 2, which are used for usability evaluation, and in Table 3 the questionnaire for usability criteria is presented. Table 4 shows the learning base task list with task code. The participants are given a Likert and dichotomous scale questionnaire and must respond with their responses [45].

Table 2. HTML learning app name for ios and android [46] [47]

HTML+CSS+Js-Web	Sololearn: Learn To Code Apps	HTML Tutorial – One per cent	HTML Code Play	Learn HTML
HTML Viewer Q – Lite HTML	EasyHTML	HTML5 Builder	Learn HTML & Web Development	HTML Quiz
Mimo: Learn Coding	Learning HTML	HTML Master	Learn Web Development	Learn Web Design
HTML Viewer Pro	HTML Learn	Codecademy Go	HTML For Beginners	Programming Hero
HTML & HTML5 Editor	Programming Hub	Time To Code – Learn HTML	W3school: Learn HTML	HTML Tutorial Offline App

3.1 Results and interpretation

This section discusses the results and their interpretation for usability evaluation according to the proposed guidelines suggested by ISO 25062:2006. The data analysis and graph generation are conducted using SPSS and R language in a Microsoft environment. Figure 5 represents the learning graph data showing mixed opinions on the suitability of educational apps for different learners. While a small percentage agreed (8%) or strongly agreed (21%) with their compatibility, a significant portion disagreed (23%) or strongly disagreed (22%). A considerable percentage remained neutral (27%). This highlights the need for further improvements in designing educational apps to cater to diverse learning needs. Figure 7 shows the standard deviation of six questions about learning, quality, stress and experience; the standard deviation measures the variability or dispersion of data points around the mean. This study's calculated standard deviations provide insights into participants' varying opinions and experiences. Figure 6 represents the UI engaging features, with most participants disagreeing (37%) or strongly disagreeing (5%). Only a tiny percentage agreed (3%), while the highest rate strongly agreed (32%). Figure 8 shows the mean score of nine usability factors navigation score is maximum, and the operability and help score is minimum; improvements are needed to enhance user engagement and experience.

Table 3. Usability evaluation criteria for HTML learning apps for slow learners

Main Factor	Questionnaire	Main Factors	Questionnaire
Efficiency	1. Does the application take extended load time? 2. Does the App hang, crash and freeze? 3. Is the time given to the user to respond appropriate? 4. How much time is required to complete individual tasks? 5. How much effort is required to complete individual tasks? 6. Error message is easily understandable in case of wrong Input	**Effectiveness**	1. Is it easy to interact with the UI? 2. Are options easy to use for slow learners? 3. Is the main menu or Home Page button available on all subsequent screens? 4. Does UI offer a visual representation of the loading process? 5. Does the app offer audio instructions?
Navigation	1. Slow learner can easily navigate across the interface? 2. The navigation keys are well understandable? 3. Does UI specify easy scrolling if such information is present? 4. Does UI provide an easy main menu for navigation? 5. Navigating through this app is easy. 6. This app provides good navigation facilities for information contents.	**Usefulness**	1. This app makes me more productive. 2. This App is useful. 3. App gives me more control over the activities in my life. 4. The app makes it simpler for me to complete the tasks I want to. 5. When I use this app, it saves me time. 6. App satisfies my needs 7. The app performs all of the tasks I would need.
Ease of Use	1. This app is simple to use. 2. This app is simple to use. 3. This app is user-friendly. 4. App requires the fewest steps possible to accomplish what I want to do with it. 5. The app's contents are clear and easy to understand. 6. I do not notice any inconsistencies as I use this app. 7. I can recover from mistakes quickly and easily. 8. I can use this app successfully every time. 9. I find the graphic interface easy to use. 10. This app is flexible.	**Learnability**	1. I learned to use this app quickly. 2. I easily remember how to use this app. 3. I quickly became skilful with this app. 4. Are the icon used in the UI related to the task? 5. Can the slow learner recognize the functions and their corresponding actions? 6. Is the UI using familiarized terms and easy language? 7. Does the app provide easy ways to return to the previous activity? 8. Is UI correlated with other apps and hence easy to learn? 9. Is proper information provided for various functions? 10. It was easy for me to start and learn how to use this app. 11. The information provided by the app is easy to understand. 12. I could use the app without reading the user manual. 13. Learning to operate the app is easy for me.
Satisfaction	1. To the best of my ability, I followed the instructions telling me how to code the HTML 2. I was able to write the code as instructed. 3. I found that coding on this app was unnecessarily complicated. 4. I used this app correctly. 5. I am satisfied with this app. 6. I recommend this app to a friend. 7. This app works the way I want it to work. 8. This app helps me be productive. 9. Are the user happy with the App layout? 10. Are all the screens consistent? 11. Does the UI provides features to engage slow learners?	**Operability**	1. Does the app offer the ability to change colour? 2. Does the font used in the app is appropriate and readable? 3. Does the app provide background music? 4. Does the app provide options to mute the audio? 5. Does the main menu button easily operable? 6. Does the main menu contain a link to all valuable tasks? 7. Is the icons' size set appropriately to be operable easily? 8. Does the app provide easy access to the mobile home screen? 9. The login section was straightforward and intuitive.
Help	1. The video tutorials on the app are helpful and precise for help. 2. Does appropriate help provided in UI where needed? 3. Does the app contain a help icon which is visible and understandable? 4. Whenever I make a mistake using this app, the help tab will appear. 5. The app helps to contact advisors.		

Table 4. Learning based task list with task code

Task Code	Task	Task Code	Task	Task Code	Task	Task Code	Task
T1	Open code editor	T2	Search HTML topic	T3	Add heading with subheadings	T4	Add paragraph
T5	Insert Table	T6	Insert marquee	T7	Insert input box	T8	Run the code
T9	Apply CSS	T10	Insert Line Break	T11	Insert Image	T12	Insert hyperlink
T13	Insert password filed	T14	Insert upload field	T15	Insert button	T16	Apply text formatting

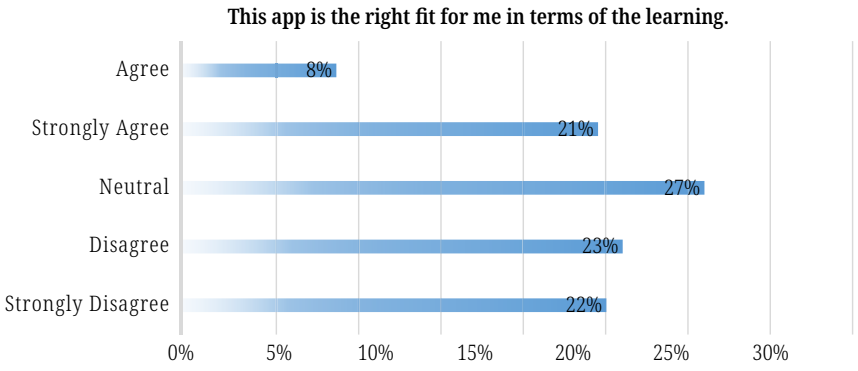

Fig. 5. Learning status

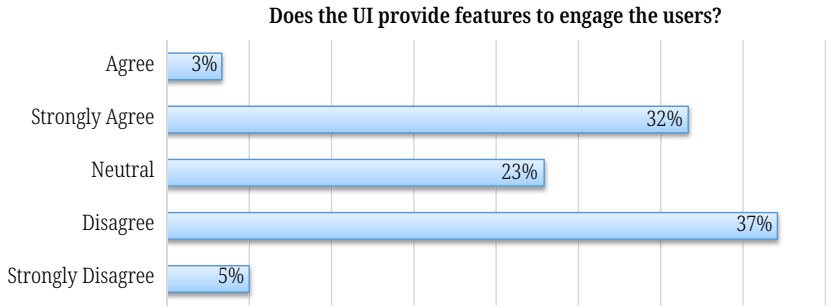

Fig. 6. Engagement status

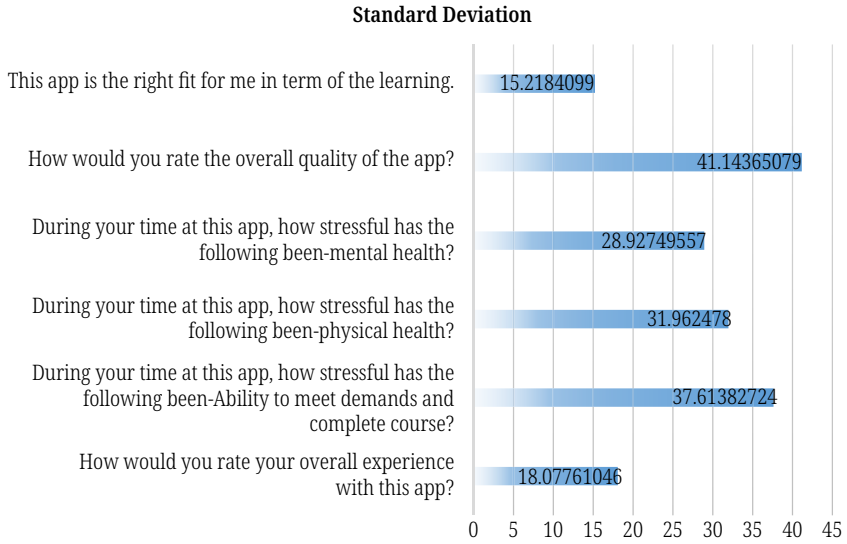

Fig. 7. Calculated SD

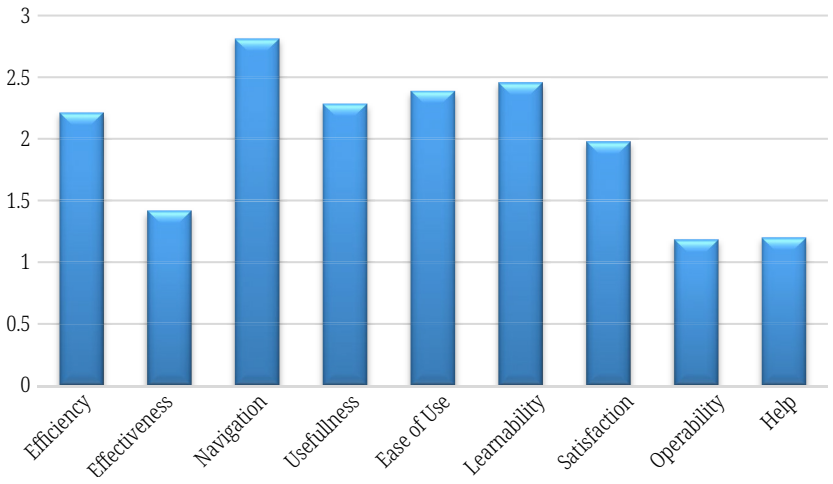

Fig. 8. Mean score of usability factors

3.2 Completion rate

The completion rate can be used to determine effectiveness. Effectiveness is considered a fundamental attribute of usability. Binary values '0' and '1' measure the point, '1' if users complete the task, or '0' will be used. Therefore, using this straightforward equation (equation 1), effectiveness may be expressed as a percentage.

$$Effectiveness = \frac{Number\ of\ tasks\ completed\ successfully}{Total\ number\ of\ studies\ undertaken} \times 100\% \quad (1)$$

Although a 100% completion rate should always be the goal, research [48] found that the typical task completion rate is 78%. (Based on an analysis of 1,100 tasks). Furthermore, it was found in the same study that the context of the work being evaluated had a significant impact on the completion rate.

3.3 Calculation of effectiveness

To calculate the effectiveness, there are 24 participants with 16 defined tasks, and Table 4 shows the details of the task. Figure 9 shows the successful completion rate; the minimum success rate is 21% for charge no 15, and the maximum success rate is 59% for task no 12. The overall average task success rate is 42%.

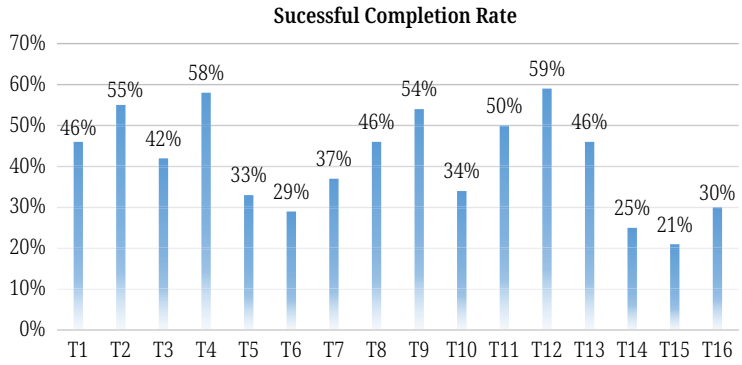

Fig. 9. Completion rate

3.4 Overall relative efficiency

The overall relative efficiency is calculated by dividing the time spent on a task by the number of people who finished it successfully. According to ISO-9241, product efficiency is defined as "resources spent by the user to ensure accurate and complete achievement of the goals". Table 5 represents the calculation of overall relative efficiency, and equation 2 illustrates the overall relative efficiency calculation. Figure 10 shows the overall efficiency. The equation is defined as

$$Overall\ Relative\ Efficiency = \frac{\sum_{j=1}^{R}\sum_{i=1}^{N} n_{ij} t_{ij}}{\sum_{j=1}^{R}\sum_{i=1}^{N} t_{ij}} \times 100\% \quad (2)$$

Where:

N = The total number of tasks (goals)

R = The number of users

n_{ij} = The result of task i by user j; if the user successfully completes the task, then $N_{ij} = 1$, if not, then $N_{ij} = 0$

t_{ij} = The time spent by user j to complete task i. If the mission is not successfully completed, then time is measured till the moment the user quits the task

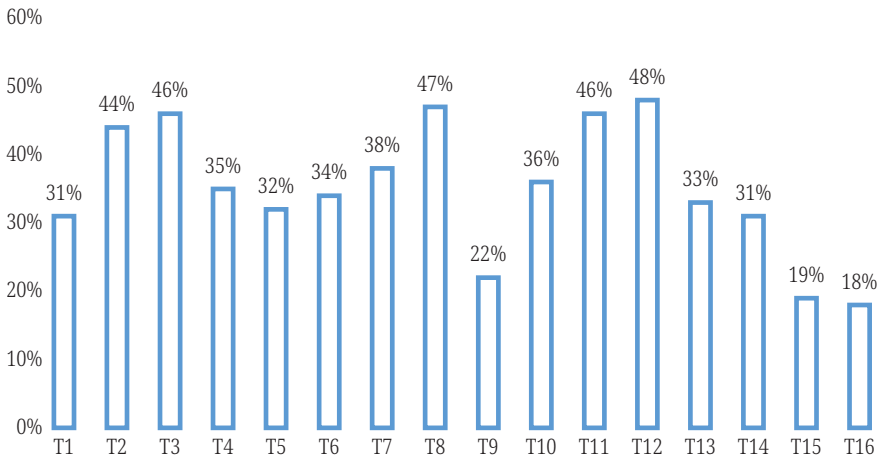

Fig. 10. Overall relative efficiency

Table 5. Calculation of overall relative efficiency

P#	N_{ij}	T_{ij}	P#	N_{ij}	T_{ij}	P#	N_{ij}	T_{ij}	P#	N_{ij}	T_{ij}
1	0	21	2	1	7	3	1	12	4	1	9
5	0	22	6	0	25	7	1	10	8	1	6
9	0	19	10	0	34	11	1	11	12	1	20
13	1	17	14	0	33	15	1	16	16	0	32
17	0	33	18	0	34	19	1	34	20	1	18
21	0	21	22	0	22	23	0	33	24	0	32

3.5 Identified usability issues

After usability evaluation, we found different usability problems that exist in the current HTML learning apps like no appropriate help being provided, poor icons which are not understandable, no interaction for maximum engagement, maritime issues, no learning assessment, no proper feedback and no proper learning contents, due to said issues, all said problems leading to the slow learner's dissatisfaction.

4 PROPOSED USABILITY MODEL

We summarized from the literature review that there is no usability model for specific users or users with learning disabilities, and no learning model exists for users such as slow learners. ALUM (Adaptable Learning-Oriented Usability Model) is proposed for the learning disabilities of 'slow learners' to enhance the learning experience using a hybrid recommendation system approach. Four usability factors are offered, including users, tasks, devices, and learning environment, all of which adhere to Human-Computer Interaction (HCI) principles. The dimensions are proposed on four factors: interface, content, icon, and navigational usability. Content usability and the learning environment factor are crucial components for designing learning apps. ALUM is addressing the learning needs of slow learners in the domain of learning apps using different features like users, devices, tasks, and learning environments. Figure 11 shows the proposed usability learning model for slow learners. Learning [6] through apps is more effective for slow learners than traditional learning. ALUM highly supports developers and stakeholders working on educational apps for slow learners. The aim of developing this model is to enhance the learning experience of slow learners through smartphone apps that provide easy access to educational content. Research has demonstrated that smartphone apps can significantly increase the motivation of slow learners in various learning environments, including classrooms. In this context, "user" refers to the individuals utilizing the apps for learning, while "task" pertains to the specific activities performed within the learning apps.

Additionally, "devices" refers to the actual devices used for learning. The learning environment is a critical and fundamental aspect of any successful learning system. The model also emphasizes crucial usability elements, including interface, content, icon, and navigational usability, all essential dimensions for effective learning apps. These components have been derived from the existing literature on learning app usability. Usability pertains to the ease and efficiency of using any product, and nowadays, various apps cater to diverse types of users and learners across different devices. Our target users are slow learners who face educational challenges. They need special attention for learning. They can be motivated to use other apps for learning if apps are easy to use.

The motivational model [29] is used for motivational purposes in learning. This model is known as the ARCS motivational model. As [29] mentioned, four major human characteristics motivate people: attention, relevance, confidence, and satisfaction. Slow learners' evaluation can be done using these elements by teachers or researchers for any learning task. Table 7 represents these motivational elements. The cognitive model is also integrated with mobile app learning usability. The mental model represents the learners' thinking, intellectual, reasoning, and decision-making capacities. These are task-driven and goal-oriented qualities. We can measure the learning environment's cognitive model [30], as mentioned in Table 6.

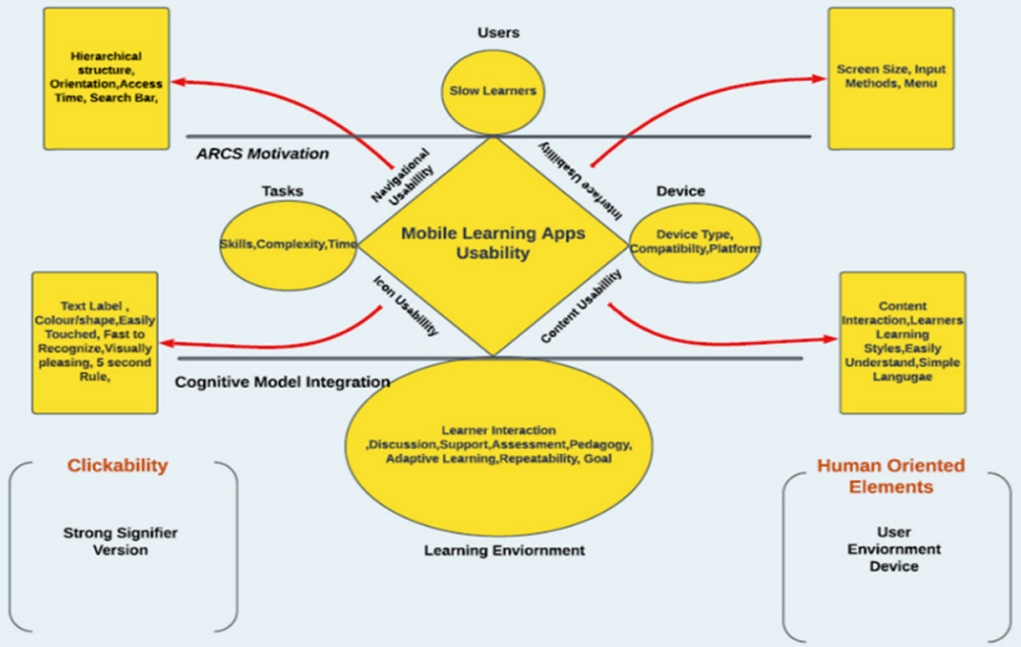

Fig. 11. Proposed usability model (ALUM)

Table 6. Cognitive model measuring quality units

Quality Unit	Explanation
Ease of Learning	This quality measures how easy or difficult it is to learn in/with a learning environment. This defines the cognition of learning app users/learners.
Knowledge Discovery	This quality measures the level at which a learning environment supports learners to learn and construct their knowledge through sense-making independently. This explains how cognitive a learning environment is to learners.

Table 7. Motivational elements

Major Categories and Definitions			
Attention	Capturing the interest of the learners	**Confidence**	Helping the learners believe/feel they will succeed and control their success.
Relevance	Meeting the personal needs	**Satisfaction**	Reinforcing accomplishment with rewards.

Users, environments, and devices are considered human-oriented elements [49]. Users or learners can use any smart device for learning in the learning environment. Clickability indicates the "strong" signifier versions for better execution. A robust signifier version makes the text readable to the users by clicking, so a strong signifier is recommended for fast and understandable execution. It is essential to consider the end users of the apps during the development phase. A user's previous experience must also be reflected in the development phase. Experienced users think of the shortcuts to complete the task, and novice users may prefer the simple way to navigate and find the function they need. Major components of the proposed learning usability model are described in Table 8.

Table 8. Usability learning model components

Major Component	Subcomponents	Description
1. User	Slow learners	The person who interacts with the app. Slow learners are learners who are educationally retarded. Our target users need to be faster learners.
2. Tasks	Skill	Tasks are vital for learning to enhance the learning of slow learners. Skill is a significant factor in performing any task. The study is the goal of the user.
	Complexity	Simple to complex tasks are used for slow learners to enhance their learning.
	Time	Time is critical to check the performance of the learners learning. Time should be monitored for each task, and errors can be counted for subsequent task attempts and efficiency.
3. Devices	Device Type	It is about the device type, like smartphone or tablet with size etc.
	Compatibility	This check is used to find the compatibility of the device with apps etc., and also indicate the device model.
	Platform	It is about the operating system like iOS and Android.
4. Learning Environment	Learners interaction	Interaction is significant in the learning environment of users and systems. GUI is used for exchange. The material should be interactive and understandable. The system must have clear instructions.
	Discussion	Discussion is very important for learning. Educational resources should offer conversation, debate, dialogue and group work. Slow learners respond positively to each other during discussion and peer learning, increasing academic performance [50]. Relationship building is slow learners' most effective instructional strategy [51].
	Support	The information should be easy to find and provide help at any navigational stage. Providing support in time is beneficial for [52] slow learners' confidence.
	Assessment	An assessment should be designed to find the slow learner's learning left.
	Pedagogy	It indicates the educational contents, multimedia resources, activities, social interaction and personalization. Activity-based learning is practical-based learning; slow learners learn effectively based on practical or activity. Learning disabilities have shown great interest in activity-based learning and improved [53] their performance.
	Adaptive learning	The system should provide adaptive learning at the learners' level.
	Repeatability	The system should be able to provide the learning contents multiple times as learners need. Slow learners may need to repeat information multiple times to grasp it fully. Therefore, it is essential to allow time for repetition. More time repetition benefits slow learners in learning and give them the confidence to learn [52].
	Goal	The learners should be able to set the goal and check their learning level.

Now four major usability factors, which are interface usability, icon usability, content usability and navigational usability, are explained here. Combining these factors will make learning apps more effective for slow learners.

1. **Interface Usability:** Interface is called a way of communication. Learners will learn more effectively if the interface is simple and appealing. Detailed instructions are not required to make it more effective, and interface elements should be designed carefully to make it natural for users. The interface should hide the complexities and make it easy to use interface which will be more attractive. The task will be executed quickly if the user interface is easy to use and learnable. Interface usability components are screen size, input methods and menu, which are explained in Table 9.
2. **Navigational Usability:** Navigation should be consistent across the tasks and functionalities of the learning apps. It makes the app easy to learn and use and reduces cognitive load. Different parts of navigational usability are recommended

for learning apps: hierarchal structure, screen orientation, access time and search bar. Further details are explained in Table 9.

3. **Content Usability:** Content is crucial for any learning. It indicates the material which is part of any learning app. Clear and precise contents are more effective for effective learning. Content should be understandable and written in simple language. Poor quality content would not sustain the learners' interest nor pay for effective education. Content usability is the combination of content interaction, the learner's learning style, and easily understandable and straightforward language which are explained in Table 9.
4. **Icon Usability**: Icon is a pictorial object on the screen used for interaction. Understandable and easily touched icons contribute to effective interaction and sustain the learners' interest. Icons with no text label would create a disturbance for the learners. Icon usability components are text label, colour/shape, easily touched, fast to recognize, visually pleasing and 5-second rule, explained in Table 9.

Table 9. Usability sub factors

Major Usability Factors	Sub Usability Factors	Explanation
1. Interface Usability	Screen size	Screen size impacts user behaviour and effect on user psychology.
	Input methods	The traditional keyboard is not available on most mobile devices. Simple data-entering options can be more effective for Input.
	Menu	The menu is the list of links. Options and sub-options should be in a series so users can use the menu for the desired function.
2. Navigational Usability	Hierarchal structure	A user may start from the home page and will go to the desired page. If the page hierarchy makes sense, this process should be easy. If not, the selected page will never be found.
	Screen orientation	Screen orientation is an essential factor in mobile app usability. For effective learning, landscape interaction is better than portrait.
	Access time	Minimum steps will increase the user's confidence to find the desired information. access time should be minimum.
	Search bar	The search bar allows users to enter a query and get the most relevant results.
3. Content Usability	Content interaction	"Content is King" by Bill Gates. Straightforward content engages the learners. Easily shareable content encourages learner engagement [54].
	Learner's learning style	Contents should meet the learner's level and learning style. The repeatability of contents should be available on the same page if desired.
	Easily understandable	Easily understandable content is more effective for learning [54].
	Simple language	Simple language engages the learners for a long time [55].
4. Icon Usability	Text label	Text labels are necessary for effective communication and to reduce ambiguity. Text labels must be present with icons to clarify their meanings. "A word is worth a thousand pictures" by Bruce Tognazzini.
	Colour/shape	Colour and shape are used to appeal.
	Fast to recognize	The icon should be fast to recognize.
	Easily touched	The icon should be easily touched and finger-operated.
	Visually pleasing	If the icon is visually pleasing, then it will be appealing.
	5-second rule	Take at most 5 seconds to understand the icon for effective communication.

4.1 A hybrid recommendation system approach

The proposed model leverages a hybrid recommendation system to provide personalized topic recommendations, incorporating a navigational graph, ontology, and item matrix.

- **Navigational Graph**

The navigational graph represents the learning materials, with nodes representing topics and edges indicating their relationships. Each bite is assigned a weight, reflecting the difficulty level of transitioning between subjects. Figure 12 shows the navigational graph with difficulty level.

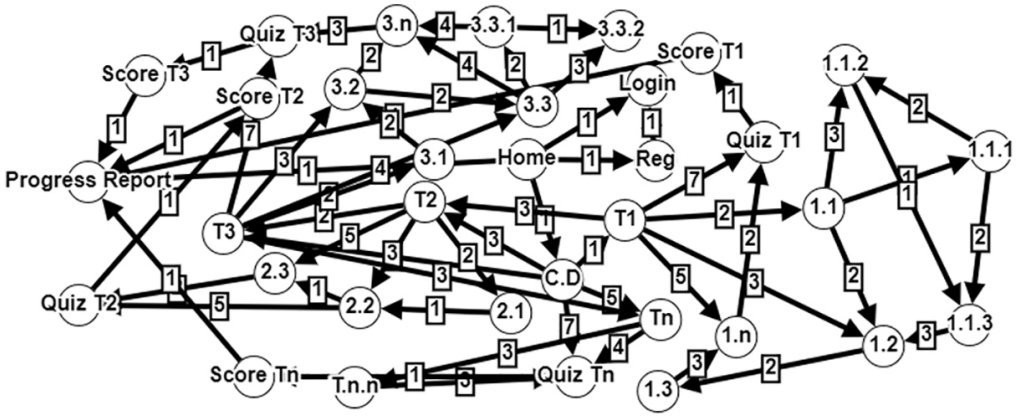

Fig. 12. Navigational graph

The graph lets the model determine each user's most suitable learning path, considering their previous knowledge and performance. The weight of an edge represents the difficulty level of the transition between two nodes. The importance of the border from node i to node j is defined as w (i, j). Then, the overall difficulty level of a given path in the navigational map can be computed as the sum of the weights of all the edges along that path. In mathematical notation, this can be written as:

$$\text{difficulty} = \Sigma w(i, j)$$

where the summation is over all edges (i, j) along the path.

The generic formula for calculating the weight of an edge in an adjacency matrix representing a navigational map of a learning app:

$$W(i, j) = f(D(i, j))$$

Where:

W(i, j) is the weight of the edge from vertex i to vertex j in the navigational map

D(i, j) is the difficulty level of the transition from vertex i to vertex j

f(x) is a function that maps the difficulty level x to a weight value, such as a linear or exponential function

In summary, the edge weights and the importance of w can be used in the HTML learning app to recommend new content that is personalized to the user's past behaviour and learning goals and gradually increases in difficulty as the user progresses through the topics.

- **Ontology**

The ontology serves as a knowledge base, organizing and categorizing topics, learning resources, and user-specific data. It captures the hierarchical relationships

between issues and facilitates efficient retrieval and recommendation of relevant educational materials. Ontology is shown in Figure 13.

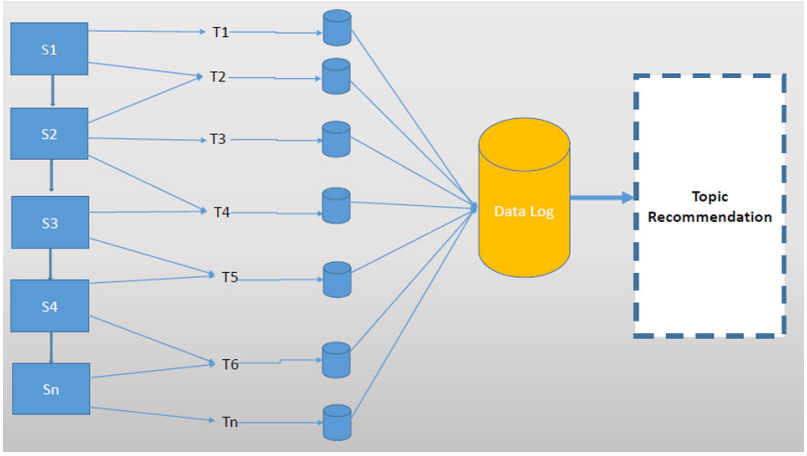

Fig. 13. Ontology

- **Item Matrix**

The item matrix stores user access data and test results over time. It tracks user progress, performance, and engagement with various learning materials. This data is utilized to assess individual learning patterns, identify areas of improvement, and personalize the recommendation process. Figure 14 shows the item matrix.

User	Topic	Difficulty	Time Spent (Module 1)	Time Spent (Module 2)	Attempts (Module 1)	Attempts (Module 2)	Quiz (Module 1)	Quiz (Module 2)	Score Test (Module 1)	Score Test (Module 2)
U1	T1(HTML Basics)	Easy	10 mints	15 mints	2	3	0	1		5
U2	T2(HTML tags)	Medium	15 mints	12 mints	3	4	1	1	8	6
U1	T3(HTML forms)	Hard	20 mints	18 mints	4	2	0	0		
U3	T4(HTML images)	Medium	10 mints	9 mints	2	5	0	1		8
U1	T5(CSS)	Hard	20 mints	20 mints	4	6	0	0		
U2	T5(CSS)	Hard	10 mints	16 mints	2	4	1	1	10	7

Fig. 14. Item matrix

- **Framework for Topic Recommendation**

The proposed model incorporates a layered framework for topic recommendation. The framework integrates collaborative and content-based filtering techniques to provide hybrid recommendations that leverage user behaviour and topic characteristics. The layers include the input layer, processing layer, recommendation generation and application layer. Explicit data refer to information like name, age and email address, and implicit data is derived from user actions like usage pattern, clicks and interaction data etc. Figure 15 shows the proposed framework for content recommendation.

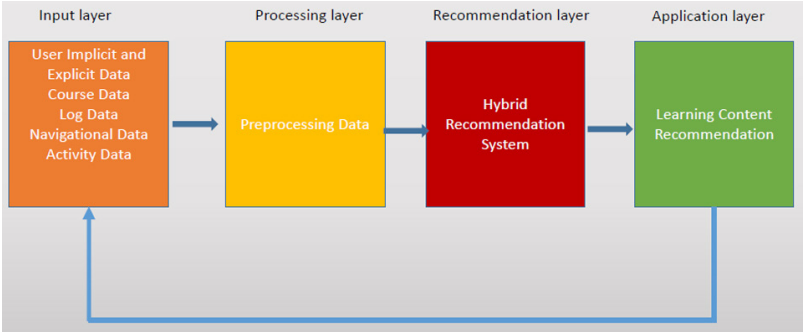

Fig. 15. Proposed framework

5 CONCLUSION

In this paper, we conducted a detailed systematic review of HTML learning apps for the mobile operating system iOS and Android. In the systematic review, we reviewed the app details like downloading space, app price, supporting languages, app rating, etc. Further, we performed the participant's (slow learners) based detailed usability evaluation of HTML learning apps using an experimental method. Slow learners participants were distributed between the age of 16 to 55, including males and females. The evaluation findings showed that the most critical issues existed in the interaction and functionality of the HTML learning apps.

Furthermore, HTML learning apps could be more effective in learnability, and proper learning help exists, leading to the slow learner's dissatisfaction. As a result of our usability evaluation, four major parts were identified: users, tasks, devices, and learning environment, with four usability dimensions: interface usability, content usability, icon usability, and navigational usability for the development of mobile learning applications of the slow learners. The proposed adaptable learning-oriented usability model offers a promising solution for supporting slow learners in their educational journey. The model aims to provide personalized topic recommendations tailored to individual learners' unique needs and preferences by leveraging a hybrid recommendation system. This paper outlines the framework and components of the proposed model and sets the stage for further research and development in this field. ALUM is expected to be a guideline for mobile app designers and developers to develop mobile learning apps for slow learners successfully. Developing M-learning for slow learners involves addressing limited attention spans and comprehension challenges. It requires individualized pacing, clear instructions, and visual aids for enhanced engagement. Personalized feedback, motivation strategies, and continuous evaluation are essential for optimizing the learning experience.

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PAPER

Optimizing Clustering Approaches in Cloud Environments

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ABSTRACT

This study focuses on the challenge of developing abstract models to differentiate various cloud resources. It explores the advancements in cloud products that offer specialized services to meet specific external needs. The study proposes a new approach to request processing in clusters, improving downtime, load distribution, and overall performance. A comparison of three clustering approaches is conducted: local single cluster, local multiple clusters, and multiple cloud clusters. Performance, scalability, fault tolerance, resource allocation, availability, and cost-effectiveness are evaluated through experiments with 50 requests. All three approaches achieve a 100% success rate, but processing times vary. The local single cluster has the longest duration, while the local multiple clusters and multiple cloud clusters perform better and offer faster processing, scalability, fault tolerance, and availability. From a cost perspective, the local single cluster and local multiple clusters incur capital and operational expenses, while the multiple cloud clusters follow a pay-as-you-go model. Overall, the local multiple clusters and multiple cloud clusters outperform the local single cluster in terms of performance, scalability, fault tolerance, resource allocation, availability, and cost-effectiveness. These findings provide valuable insights for selecting appropriate clustering strategies in cloud environments.

KEYWORDS

cloud computing, load distribution, clustering approaches, performance analysis, multiple cloud clusters, Node.js

1 INTRODUCTION

The advancements made in cloud computing have altered the way users access distant resources easier than ever before. Due to this shift in how things are done, Cloud Service Providers' (CSPs) role is becoming more vital with time as they continue providing an increasing number of innovative solutions for customers worldwide [1]. The total value of cloud computing is predicted to increase significantly, from $141 billion to $495 billion, by 2022 [2]. This significant growth has prompted studies investigating

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its effectiveness and anticipating increased integration in the future [3]. Cloud computing acts as a solution offering off-premises computing power to users wishing to access tools and retain data, all facilitated by CSPs from a location in the cloud and accessible through the internet [4]. Relatedly, CSPs provide these resources using an "X as a Service" (XaaS) model including Software (SaaS), Infrastructure (IaaS), or Platform (PaaS) [5]. Given these options, cloud services are available via public, private, or hybrid cloud models depending on user requirements. Currently, CSPs range from industry tycoons such as Amazon, Google, IBM, and Microsoft, providing numerous services tailored towards specific clients based on their needs [6].

Cloud computing has emerged as a transformative technology, enabling the utility model of computing to serve clients worldwide. IT and business resources such as servers, storage, networks, and applications can be dynamically delivered to clients across the globe. The adoption of clusters in the cloud market has significantly increased, providing an opportunity to enhance clusters' capabilities to accommodate growing client requirements on the nodes [7].

A multi-cluster system refers to a distributed architecture that comprises multiple clusters, with each cluster consisting of several nodes capable of independent computation and data storage. These systems find application in various domains such as high-performance computing, data analytics, and cloud computing [8]. Compared to traditional single-cluster systems, multi-cluster systems offer notable advantages, including enhanced scalability, reliability, and fault tolerance. Consequently, they have gained significant attention in research and development, with the potential to revolutionize large-scale computing tasks [9].

However, the adoption of clusters in the cloud environment poses several challenges. These challenges include load balancing within a single cluster, managing fluctuating service demands, evaluating the trustworthiness of new clients, and addressing scalability and performance issues [10]. Scalability, defined as the ability to allocate appropriate computing resources to clients dynamically, is crucial in cloud environments. Failing to provide flexible services and scale computing resources can result in the deficient performance of the server [11]. To effectively manage resources in the cloud market, cloud service providers must handle a growing number of client requests while ensuring optimal performance [12].

Efficient management of server requests is essential in maintaining optimal functioning, building customer trust, and seamless service delivery. In addressing this aspect, this study emphasizes enhancing server capacity as a significant factor in timely response to user requests. Therefore, it suggests adopting a novel approach by implementing server clustering as an effective means of workload distribution. Each cluster has a designated head with oversight responsibilities for its operation.

Our research endeavors are aimed at improving cluster performance by enhancing its ability to meet growing client demands. Proposed as part of this effort, is an innovative architectural environment which divides a single cluster into smaller individual clusters for optimal request processing efficiencies in nodes, and minimal delays or downtime resulting from the process itself.

The proposed approach has been successfully implemented through an experimental setup utilizing Node.js programming language. Before conducting research experiments, performance metrics were compared for which results indicated that cloud computing can facilitate clustering, thereby offering scalability and flexibility crucial for optimizing services provided to clients.

With the aim of boosting efficiency and saving time when processing servers, the study proposes dividing one large cluster into several smaller ones, each complete with its own back up-server. Consequently, improving server processing times became achievable and may lead researchers to focus their investigation on this precise aspect.

The experimental findings were meticulously reviewed to gauge how effective the proposed approach is. To do so, performance metrics were compared pre- and post-application implementation under specific consideration of time wasted during request processing. Our anticipated result is an enhancement in server scalability and efficiency achieved via cluster division, which should translate into superior overall cluster output.

To optimize resource usage while delivering excellent service quality, we conducted this research with specific objectives, which include streamlining request processing and enhancing cluster robustness through an innovative architectural approach that divides clusters strategically. We anticipate that reducing time wastage during node processing coupled with improving server performance should yield the desired results and meet the expanding demands of customers effectively. Overall, these findings should assist us in meeting clients' evolving expectations as well as maintaining superior service delivery standards.

2 RESEARCH BACKGROUND

This section presents an overview of cluster computing, single core clusters, and multi core clusters which have delivered significant enhancements in performance levels. Achieving optimal results requires a clear appreciation for application behavior patterns and trends. This section outlines distinctions between traditional single-core clusters compared with those containing multiple cores. Our research identifies specific challenges when processing requests in nodes across a multi cluster core, whilst promoting its benefits.

2.1 Cluster computing

When several computers are connected to work together seamlessly as one unit, this is referred to as cluster computing [13]. IBM introduced this concept in the 1960s as a viable alternative for interconnecting massive mainframe computers with cost-effectiveness as its core value proposition [14]. Recently, cluster computing has garnered exceptional attention following advancements such as efficient microprocessors, high-speed networks, and pivotal tools capable of improving distributed computing performance available since the '80s onwards [15].

Recent technological advancements have paved the way for cost-effective parallelization solutions such as clusters, making them increasingly popular options across all sectors of computing, including high-performance applications where high-throughput and reliability are critical [16]. A computer cluster utilizes collections of interconnected computers combined collaboratively to achieve better computational processing efficiency than traditional single device platforms [17]. A cluster is defined as a collection of nodes, each having independent control over stand-alone workloads while collaborating in real-time with others via high-speed local-area networks [18]. Clusters allow executing heavy-duty tasks that are impractical on single machines [19]. The nodes can vary in number, and they incorporate memory units alongside comprehensive operating systems dependent on what specifications best suit their intended use [20]. The main system components include individual machines interlinked via fast interconnects, in addition to software features geared towards enabling maximized performance throughput during parallel execution operations, ensuring prompt task delivery [21].

Cluster computing is an effective approach of achieving improved availability rates in addition to better performance while keeping expenses minimized,

compared with individual computers [22]. Nevertheless, several significant drawbacks need to be factored in [23]. For example, establishing a cluster entails complexities requiring multidisciplinary knowledge. Other complications include scalability limits and communication overheads which together present significant synchronization challenges that disrupt efficient operation levels, significantly compromising overall system effectiveness. Further, factors such as fault tolerance coupled with reliability must be managed carefully when configuring the cluster. Moreover, the overall purchase costs, infrastructure prerequisites, and maintenance charges are all important aspects to consider [24]. Hence, organizations need to consider these challenges against their own specific performance priorities before deciding whether to invest in cluster computing services [25].

2.2 Single-core clusters

A single-core cluster includes nodes, each equipped with a single processor and a single core. Standardization is a key characteristic of such clusters, ensuring that nodes are similar in terms of memory, cache, and server connection [26]. Further, caches, which are storage locations for active data, play a crucial role in reducing latency, improving access times, and enhancing overall efficiency [27].

In the context of a common algorithm like the Message Passing Interface (MPI), a cluster composed of single-processor nodes can execute the algorithm independently. The performance of a single-core cluster relies on the processor's frequency [28]. Theoretically, incorporating multiple single-core processors onto a single chip could double the performance. However, the average speed of each core is slower than the fastest single-core processor due to communication delays at various levels of the cluster's communication link [29].

2.3 Multi-core clusters

The development of cloud computing systems, also known as multicore clusters, has been driven by the convergence of high-performance computing technology and high-speed connections [30]. In the past, clusters utilized multiple single-core processors. However, the industry has now introduced chips with multiple processors, or multi-cores, to address the limitations of single-core clusters [31]. A comprehensive understanding of multi-core chips necessitates acknowledging that individual processor cores operate at slower speeds in comparison to single-core processors [32]. However, when multiple cores collaborate on a single chip, higher data processing rates can be achieved [33]. With each new chip generation, we can anticipate an increase in the number of cores accompanied by reduced processing time. Notably, multi-core clusters exhibit a hierarchical storage structure where cache memory is shared among processor cores [34]. This implies that processors within the same node share main memory, while those from different nodes do not. To achieve optimal efficiency, parallel programming is recommended, with task allocation based on application communication patterns and system characteristics carefully considered [35].

The demand for multi core clusters has grown significantly due to their various benefits. The numerous advantages offered by multi core clusters have contributed to their growing popularity in recent years. Firstly, multi-threaded software enables the utilization of multi core technology, which can execute many tasks simultaneously and enhance overall system performance and efficiency by freeing up resources that were

previously tied up in managing multiple processors [36]. Secondly, multi-core clusters offer simple scalability as an essential feature. Organizations can add more cores or nodes to these clusters easily for enhanced computing power requirements when needed [37]. This flexibility provides a reliable way to handle computational demands while ensuring efficient operations at all levels of usage over time with minimum room for error from additional overhead tasks such as cooling equipment required in large data centers; hence less heat generation and lower energy consumption [38].

2.4 Node.js clustering

A feature embedded within the Node.js runtime environment is its unique clustering function. Through its utilization of child processes, it streamlines incoming requests management and enables task distribution within applications. This strategy can effectively use the capabilities of numerous CPU cores in multi-core systems enhancing scalability and boosting performance for Node.js applications [39].

Node.js operates using a cluster system which involves assigning a master process to manage multiple worker processes. Every slave runs its instance of the Node.js event loop to undertake operations. While distributing incoming connections or tasks, a load-balancing algorithm is implemented by the master process. This guarantees that each CPU core shares an equal workload across all slaves and smoothly completes assigned tasks [40].

Node.js clustering offers numerous primary benefits, including better performance and increased throughput for applications. Multiple cores are utilized, effectively allowing for greater processing power and speedy handling of concurrent requests while making good use of all available system resources efficiently. Additionally, this technique enhances resilience, so that even if a slave process fails or crashes within clustered deployment setup, it will not affect overall availability negatively due to some inbuilt error management mechanisms and security features that are factored into its design and triggered to action immediately, maintaining a stable environment at unprecedented scales [41].

Complexities that arise from attempting to build scalable applications in Node.js involve managing multiple processes and load balancing. Node.js clustering provides a simple solution by removing these hurdles altogether. This functionality proves to be particularly valuable when developing high performance web servers or real time applications required to manage an extensive number of concurrent connections [42].

Typically, Node.js operates on one thread that employs just one CPU core, irrespective of whether numerous cores exist in the system or not. Nevertheless, overcoming this predicament while improving performance calls for transitioning operations towards a multi core strategy utilizing clustering instead. The clustering method involves creating multiple Node.js procedures, collectively known as worker nodes designed to work simultaneously over an identical server port caliber through Inter Process Communication (IPC). With this setup, automatic workload balancing can be achieved such that, whenever any process manages resource-centric tasks, other secondary processors proffer an additional request processing power using spare CPUs [43].

Node.js has gained popularity among developers who strive to cluster tasks efficiently due to its use of JavaScript language, which opens up possibilities for optimization [44]. This ability can be advantageously employed in intrusion detection or protection schemes for cloud markets that depend heavily on traffic data from the marketplace's various nodes. Adequate interpretation and analysis enable one to evaluate a more extensive range of judgments regarding trends in activity levels

that influence the larger picture around investments in cloud markets. Designing an effective intrusion detection scheme typically entails several phases, which include initial sensing strategies; allowing to assure the cloud environment remains secure with suitable arrangements; intrusion prevention itself by incorporating proper policies like access controls into an IT system's architecture; performing behavior analyses on network systems that allow effective prediction; and responsibility management plan that maps out how well security incidents are managed where necessary roles are evidently defined, leveraging resources effectively [45].

3 RELATED WORK

Numerous studies have delved into enhancing techniques specifically tailored for cloud environments. In this section, we provide a review of research conducted in this domain emphasizing their contributions.

A pioneering study in this domain was conducted by [46]. They put forth an approach called the single cluster methodology to handle requests in cloud environments. The primary objective of their research revolved around enhancing downtime load distribution and overall system performance. Although their local single cluster approach demonstrated a success rate of 100% in request processing, it was observed to have limitations in terms of processing time. The authors acknowledged the necessity for methodologies that could provide expedited processing times.

To overcome the limitations of the cluster method using local single cluster approach, the researchers of [47] introduced the use of multiple clusters method. Their research focused on improving performance, scalability, fault tolerance, resource allocation and availability, in cloud environments. They conducted experiments involving 50 requests and discovered that the local multiple clusters approach exhibited processing time, scalability, fault tolerance and availability compared to the local single cluster approach. However, one aspect that was not explicitly considered during the study was the cost effectiveness of the proposed method. This gap in understanding prevents us from comprehending the implications associated with the suggested approach.

There has been a growing interest in utilizing cloud clusters to enhance clustering methods. The authors of [48] conducted a comparison of clustering approaches including employing a locally single cluster, locally multiple clusters, and harnessing multiple cloud clusters. They conducted experiments involving 50 requests to evaluate performance, scalability, fault tolerance, resource allocation, availability, and cost effectiveness. The outcomes revealed that both the use of clusters locally and multiple cloud clusters surpassed the local cluster approach in terms of several metrics. Notably, the multiple cloud clusters approach offered benefits such as processing, scalability, fault tolerance, resource allocation, availability and cost effectiveness due to its pay-as-you-go model. However, the study did not delve into analyzing the limitations or weaknesses of the proposed approaches, leaving an opportunity for further exploration.

Expanding on previous research, [49] proposed a clustering approach that blends local multiple clusters with multiple cloud clusters. Their objective was to enhance performance fault tolerance and cost effectiveness while considering the effectiveness. By conducting experiments and simulations, they successfully showcased that the hybrid approach outperformed clustering methods. This hybrid approach effectively leveraged the resources of clusters and the scalability of cloud clusters leading to performance fault tolerance and cost effectiveness. However, it is worth noting that the study primarily focused on performance and cost effectiveness without delving into the impact on metrics, like resource allocation or availability.

Another study of [50] investigated the application of machine learning techniques to optimize clustering approaches in cloud environments. The researchers proposed a predictive model that utilizes historical data to dynamically allocate resources in clusters based on workload patterns. Their study showed promising results in terms of performance improvement and resource utilization optimization. However, the study primarily focused on the performance aspect and did not comprehensively evaluate other factors such as fault tolerance or cost-effectiveness.

The study presented by [51] introduced an algorithm focused on load balancing for clustering in cloud environments. Their objective was to optimize resource utilization and minimize response time by distributing workloads among clusters based on their capacities and current utilization levels. The experimental findings indicated that their algorithm successfully achieved workload balance, resulting in improved performance and reduced response time.

The authors of [52] tackled the issue of handling faults in methods in cloud environments. Their proposed algorithm aimed to enhance system reliability and availability by identifying and recovering from node failures. To achieve this, they incorporated nodes and deployed fault detection mechanisms to maintain uninterrupted operation. The experimental evaluations showcased that their fault tolerant clustering algorithm remarkably improved system reliability while minimizing downtime. Nevertheless, the study did not explore its effects on measures such as performance.

The research conducted by [53] examined the impact of methods on energy efficiency within cloud environments. The study aimed to reduce energy consumption while ensuring performance levels. The researchers introduced a clustering algorithm that incorporated energy awareness, dynamically adapting resource allocation according to workload patterns and system conditions. The experimental findings indicated energy savings without compromising performance.

Considering the cost-effectiveness aspect, [54] conducted a study that analyzed the trade-offs between performance and cost in different clustering approaches. They proposed a cost-performance model that considers factors such as processing time, scalability, and resource allocation efficiency. Through experiments and simulations, they evaluated the cost-performance trade-offs of local single clusters, local multiple clusters, and multiple cloud clusters. The findings showed that selecting the clustering method relies on the unique features of the workload and the limitations imposed by cost considerations. Nonetheless, the research did not extensively delve into factors, like fault tolerance or availability.

The cost effectiveness aspect was explored in a study conducted by [55]. They investigated the balance between performance and cost in approaches. In their research, they proposed a model that examined factors such as processing time, scalability, and resource allocation efficiency, aiming to assess the trade-offs in cost performance. Through experiments and simulations, they evaluated the cost performance trade-offs of clusters, local multiple clusters, and multiple cloud clusters. The results indicated that the choice of clustering approach should consider workload characteristics and cost limitations.

Prior research has extensively examined methods within cloud environments. These methods encompass clusters, local multiple clusters, and multiple cloud clusters. While these studies have made strides in terms of enhancing performance, scalability, fault tolerance, resource allocation, availability, and cost effectiveness, there remain drawbacks that necessitate attention. The local single cluster approach exhibits its limitations pertaining to processing time. On the hand, the local multiple clusters approach lacks an analysis of cost effectiveness. Moreover, further investigation is required to uncover weaknesses in the multiple cloud clusters approach [56, 57].

Recent research endeavors have proposed approaches that incorporate machine learning techniques to tackle these challenges [58]. However, further exploration is needed to evaluate their impact across metrics and address the limitations inherent in existing clustering approaches [59, 60].

The current research aims to improve cluster performance to meet the growing demands of clients. The motivation behind this endeavor is to enhance the efficiency of request processing in clusters while minimizing delays and downtime. The major contribution of this research lies in improving cluster performance to meet growing client demands. It proposes an innovative architectural environment that divides a single cluster into smaller ones, optimizing request processing efficiencies and minimizing delays. By dividing clusters into ones equipped with backup servers, the study effectively improves server processing times. The experimental findings successfully validate the proposed approach leading to enhanced server scalability and efficiency. Furthermore, the research prioritizes streamlining request processing, reinforcing cluster resilience and optimizing resource utilization to ensure service quality and meet the expanding demands of customers. In summary, it offers insights into optimizing cluster performance and meeting the evolving expectations of clients.

4 RESEARCH METHODS

This research aims to investigate the behavior of a cluster under a specific test scenario where the number of requests has increased. A comparison is made with the multi-cluster method to evaluate performance improvements, high availability, load balancing, and reduction in response time, allowing the system to handle a higher volume of requests.

To conduct the experiment, the researchers utilized k6, a developer-focused, open-source load-testing tool known for its productivity in performance testing. The implementation of k6 allowed for the anticipation of performance degradation and the prompt identification of problems, enabling a proactive approach in the development of resilient systems and robust applications. The user-friendly nature of k6, as well as its utilization of JavaScript, proved to be valuable for the effective implementation of tests in this study.

The conventional approach in Node.js for managing incoming client requests involves queuing them in a single thread through its Event Queue system. However, our research aimed to explore alternative methods that could potentially enhance the efficiency of adopting an event-driven architecture. By conducting extensive testing and experimentation, we investigated the feasibility of utilizing the Event Loop not only for event listening but also as an infinite loop for data processing, thereby opening up new possibilities and potential improvements in the handling of requests within the Node.js.

This study adopted an inventive technique to expedite request processing within Node.js software by eliminating I/O blocking. Our results showed that such an overhaul greatly ameliorates time efficiency in the system. To verify its efficacy, we performed comparisons between two distinct groups—one with a single thread while another utilizing worker threads based on CPU capacities—and analyzed their relative outputs thoroughly.

In this research, we utilized a system that incorporated eight cores by creating eight Node.js instances, each designed with its independent event loop. We configured the program to operate effectively on one port (PORT 3002). Our implementation necessitated that we create several worker processes; hence we relied on an intelligent strategy deployed by our master process to handle connecting incoming traffic and distributing incoming ones among our various workers evenly. We utilized a

powerful module named the Worker Threads in Node.js because of its proven ability to carry out CPU-intensive JavaScript tasks.

To assess the efficacy and efficiency of distinct clustering scenarios, our method entails carrying out two experiments. Specifically, experiment one will involve employing single clustering while experiment two will employ multi clustering. Experiment one tackles the typical means of utilizing a solo clustering configuration through clustered nodes running on only one server or computing device. Researchers endeavor to evaluate this method's efficiency and limitations by analyzing various performance metrics such as response time, throughput, and resource utilization. Table 1 summarizes the metrics used for comparison and their definitions.

Table 1. The metrics used for comparison between the two experiments

#	Metrics	Definition
1	HTTP req connecting	This refers to the process of establishing a connection between the client (usually a web browser or an application) and the server that hosts the requested resource. It involves establishing a TCP connection.
2	HTTP req duration	This is the time it takes for an HTTP request to complete, starting from the moment the request is sent to the server until the response is received.
3	Expected response true	This indicates that you are expecting a successful response from the server. In the context of load testing or automated testing.
4	HTTP req failed	This means that the HTTP request was not successful. It could be due to various reasons, such as a server error, network issue, or an invalid request.
5	HTTP req receiving	This refers to the process of the client receiving the response from the server after sending an HTTP request. It involves receiving and reading the data sent by the server.
6	HTTP req sending	This is the process of the client sending an HTTP request to the server.
7	HTTP req handshaking	Handshaking typically refers to the initial communication between the client and server to establish the parameters of the connection, such as the supported protocols and encryption methods. In the context of HTTP, it can refer to the establishment of a TCP connection.
8	HTTP req waiting	This refers to the time spent by the client waiting for a response from the server after sending an HTTP request. It could be due to various factors, including network latency, server processing time, or server-side delays.
9	Iterations	This refers to the number of times a specific action or task is repeated. In load testing, it typically represents the number of iterations or cycles of sending requests and receiving responses.
10	Iteration duration	In the context of load testing, an iteration refers to a complete cycle of sending an HTTP request and receiving the corresponding response. The iteration duration is the time it takes to complete one iteration.
11	Vus	Vus stands for "virtual users". In the context of load testing, a virtual user simulates a single user interacting with the system under test. The number of virtual users represents the concurrency or simultaneous user load applied during the test.

Using a multi-cluster strategy is the focus of our second experiment. The purpose is to determine its advantages in optimizing application performance when numerous copies are deployed on multiple computing devices or servers that form a cluster through efficient load balancing capabilities. Our goal is to evaluate whether this design results in scalable operations and improves fault tolerance when assessing performance metric outcomes in comparison with experiment one's outputs.

Our research method adheres to standardized procedures to ensure the validity and reliability of our findings regarding the behavior of clustering scenarios under various parameters. To achieve this, we establish controlled experimental environments for each scenario, where we deploy applications and simulate diverse workloads while collecting relevant data. To assess the performance of these scenarios effectively, we employ robust techniques for measuring relevant metrics. Through statistical analysis of these measurements, we can effectively compare the efficiencies, scalability, and

overall performances of different clustering scenarios. This approach enables us to generate meaningful insights and draw reliable conclusions from our research.

By conducting these experiments, valuable insights can be gained regarding the strengths and limitations of single clustering, the benefits of multi clustering, and the advantages of leveraging cloud-based multi-cluster architecture. The findings will contribute to the understanding of cluster computing and assist in making informed decisions when choosing the most suitable clustering approach for specific application requirements.

5 EXPERIMENTS AND RESULTS

5.1 Load balancing with Bluster mode

Improving operational efficiency is essential to ensure the smooth running of Node.js applications by running an optimized workflow that can be achieved through load balancing with Bluster mode using Process Manager2 (PM2). PM2 has dramatically simplified the process by offering core features such as process management and batching functions to horizontal load balancing capabilities and non-stop reload allowing for easy and seamless application control. The use of PM2's user-friendly interface ensures hassle-free starts, stops, and restarts of the system while providing a centralized management platform for users to constantly monitor resource consumption levels.

Automatic reloading during application updates or deployment with near-zero downtimes that feature in PM2's Bluster Mode allows you to maintain continuity without interruptions whilst ensuring maximum efficiency achieved through optimization efforts like status monitoring. PM2 offers various key performance indicators monitored uniformly and displayed effectively, allowing quick identification and resolution of performance-related issues such as CPU usage rate, memory consumption rates, request throughput based on how many requests are processed per second, worker status in clustered apps amongst other vital KPIs, which helps optimize your systems further. Figure 1 shows detailed metrics resulting from adopting PM2 during operations.

Furthermore, PM2 along with bluster-mode offer development teams a fast-track route towards operational excellence by improving system uptime through simplified workflows encouraging productivity growth.

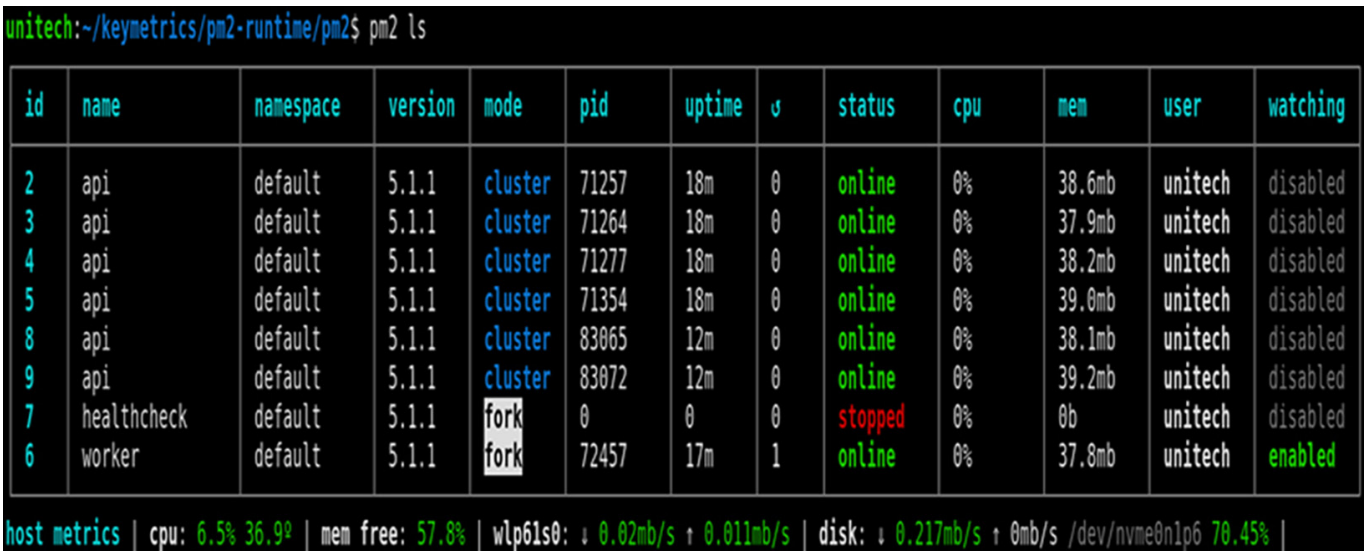

Fig. 1. Key metrics in PM2

5.2 Cluster mode: Node.js load balancing and zero downtime reload

In optimizing Node.js applications for peak performance and high availability, cluster mode is an essential feature worth exploring for efficient resource utilization. The master process manages several worker processes that balance incoming requests evenly, leading to better overall app performance. Cluster mode optimizes resource utilization, allowing applications to handle a larger volume of client requests effectively by spreading out operations evenly across processes, ensuring maximum efficiency. Another significant advantage is the zero downtime reload capability, whereby updating or reloading an application does not disrupt incoming requests due to master process management skills.

By taking advantage of the benefits of multiprocessing such as faster rebalancing of sockets if errors are not handled appropriately, developers ensure that robust applications are built with increased scalability and improved overall performance.

In cluster mode, two configurations exist: single- and multi-node configurations. Running on a solo machine per core might cause some limitations in terms of scalability due to backup constraints but running several instances on multiple machines called nodes provides better load balancing capabilities, enabling effort distribution among various tasks and leading to parallel processing advantage in multi nodes setups for maximum efficiency optimization.

For better scalability, increased performance rates along with optimal fault tolerance levels and utilizing multiple computing abilities made possible via Node.js's Cluster Mode becomes inevitable. By tactfully distributing workloads among different nodes, more power is given to the application to execute tasks seamlessly, thereby effectively handling a higher number of concurrent requests. Load balancing algorithms are then brought into play here to spread requests evenly among nodes—the aim being to optimize resource utilization while preventing any node from being overloaded. With the cluster mode already in place, recovery from any unhandled error or reloading of resources is swift and easy through faster socket rebalancing.

With the clustering arrangement, downtime rarely occurs—with other highly functional nodes continuing performance as usual in cases where there are hardware failures or resource mismanagement on a particular node. In summary, parallel processing, an ideal load balancing system, and quenched downtimes are enabled utilizing Node.js's cluster mode.

The experimental setup and procedure for the two conducted experiments are outlined as follows: Experiment 1 using single clustering and Experiment 2 using multi clustering.

5.3 Experiment 1: Local single clustering

In this scenario, the following steps were performed to evaluate the performance of single clustering on-premise:

1. Installation of Influx DB on Windows: Influx DB was installed on a Windows machine to facilitate data storage and management.
2. Installation of Grafana on Windows: Grafana was installed on the same Windows machine to provide visualization and analysis capabilities.
3. Running Grafana: The Grafana interface was accessed by opening a web browser and navigating to the designated port (http://localhost:8086/).

4. Creation of a Grafana Dashboard: A dashboard was created in Grafana to present the performance metrics obtained from the single clustering experiment.
5. Addition of Influx DB as a data source: Influx DB was configured as a data source in Grafana, establishing a connection to access the performance data. The database was set to “myk6db”.
6. Configuration of Influx DB details: Relevant details from Influx DB, such as the query “SELECT * FROM “_internal” LIMIT 10”, were set in Grafana to retrieve the required data.
7. Running Influx DB: The Influx DB service was initiated from the specified installation directory (C:\Program Files\Influx Data\influx dB).
8. Creation of the “single-clustering.js” file: A JavaScript file named “single-clustering.js” was created to implement the single clustering experiment.
9. Adding code to “single-clustering.js”: The necessary code for the single clustering experiment was added to the “single-clustering.js” file, as shown in Figure 2.

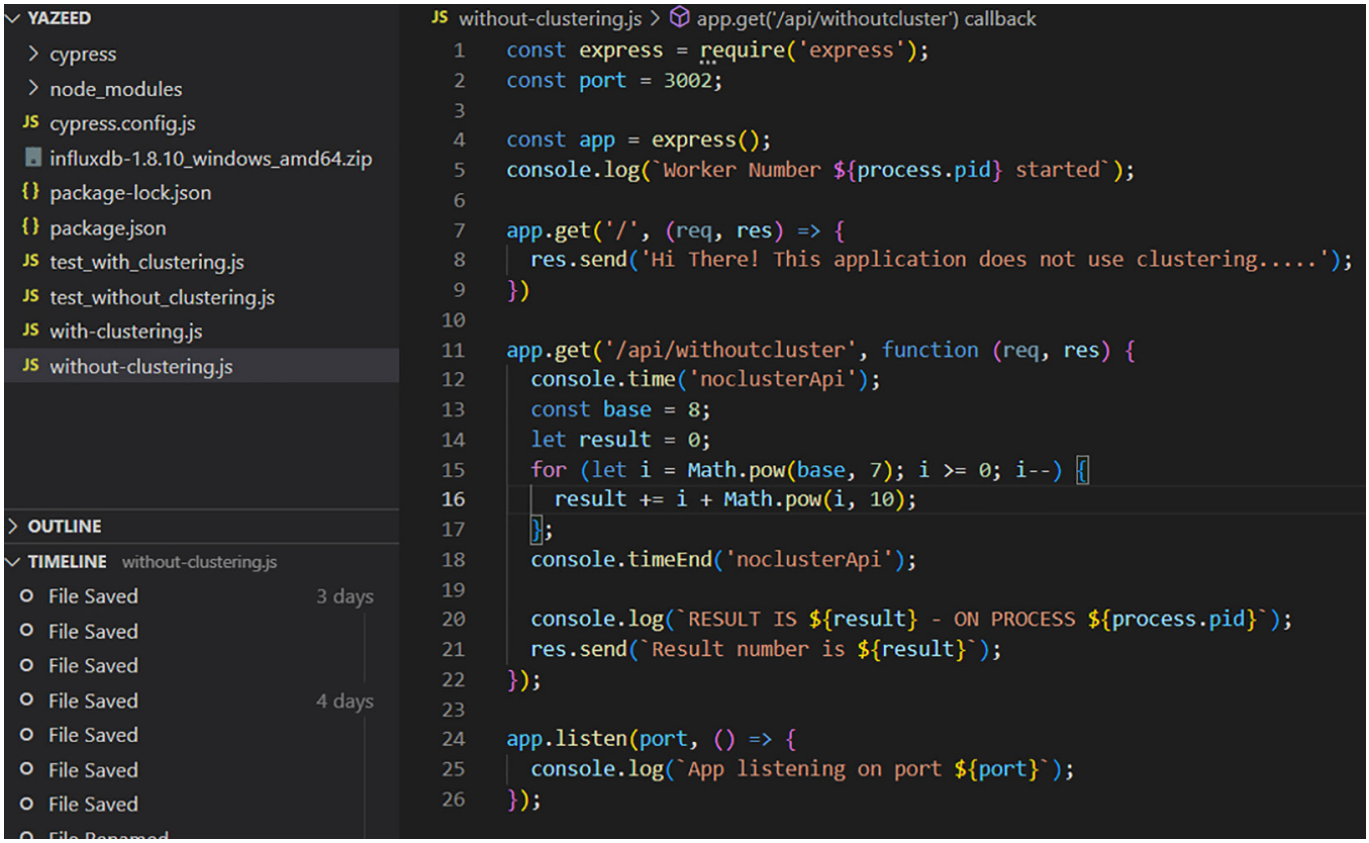

Fig. 2. Single clustering code

10. Running the Node server: The Node server was executed in the terminal, where the single clustering experiment was being performed.
11. Sending 50 requests to the single clustering setup: A total of fifty requests were sent to the single clustering configuration to evaluate its performance and measure relevant metrics. The results are shown in Figure 3.

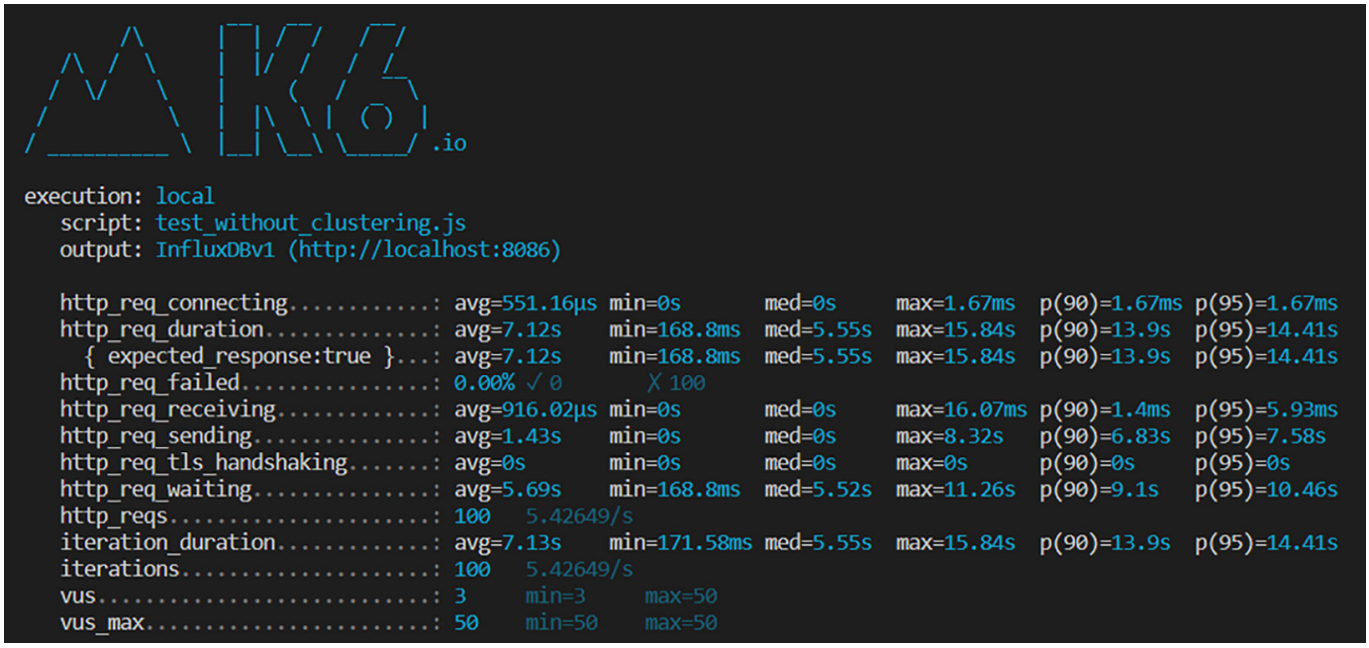

Fig. 3. The result of sending fifty requests with single clustering

12. Dashboard visualization: the dashboard provides a comprehensive overview of the single clustering process, displaying detailed information and metrics. Figure 4 shows the dashboard for the single clustering process.

Fig. 4. Dashboard for the local single clustering process

13. Analysis of the results: the outcome of sending fifty requests to the single clustering setup was recorded and analyzed to assess its performance characteristics. Table 2 below presents the outcome of sending fifty requests using the single cluster configuration:

Table 2. The results of sending fifty requests with single clusters

	Avg	Min	Mid	Max	p (90)	p (95)
HTTP req connecting	551.16 µs	0 s	0 s	1.67 ms	1.67 ms	1.67 ms
HTTP req duration	7.12 s	168.8 ms	5.55 s	15.84 s	13.9 s	14.41 s
Expected response: true	7.12 s	168.8 ms	5.55 s	15.84 s	13.9 s	14.41 s
HTTP req failed	0.00% ✓ 0	✗ 100				
HTTP req receiving	916.02 µs	0 s	0 s	16.07 ms	1.4 ms	5.93 ms
HTTP req sending	1.43 s	0 s	0 s	8.32 s	6.83 s	7.58 s
HTTP req handshaking	0 s	0 s	0 s	0 s	0 s	0 s
HTTP req waiting	5.69 s	168.8 ms	5.52 s	11.26 s	9.1 s	10.46 s
HTTP req	100	5.42649/s				
Iteration duration	7.13 s	171.58 ms	5.55 s	15.84 s	13.9 s	14.41 s
Iterations	100	5.42649/s				
Vus	3	3		50		
Vue's max	50	50		50		

5.4 Experiment 2: Local multi clustering

To evaluate the performance of multi clustering on-premise, the following steps were followed:

1. Influx DB Installation on Windows: Influx DB was installed on a Windows machine to enable efficient data storage and management.
2. Grafana Installation on Windows: Grafana was installed on the same Windows machine to provide advanced visualization and analysis features.
3. Accessing Grafana: The Grafana interface was accessed by launching a web browser and navigating to the designated port (http://localhost:8086/).
4. Dashboard Creation in Grafana: A new dashboard was created within Grafana to display relevant metrics and statistics.
5. Adding Influx DB as a Data Source: A new data source named "Influx DB" was added in Grafana to establish a connection with the Influx DB database.
6. Setting Database Configuration: The database configuration was set to "myk6db" within Grafana to ensure proper data retrieval.
7. Influx DB Details Retrieval: Details from Influx DB were obtained using the query: "SELECT * FROM "_internal". Database" LIMIT 10.
8. Running Influx DB: Influx DB was executed from the specified directory (C:\Program Files\Influx Data\influx dB).
9. Creation of "Multi clustering.js" File: A file named "Multi clustering.js" was created to contain the code for the multi clustering process.
10. Implementation of Multi Clustering Code: The necessary code for multi clustering was added to the "Multi clustering.js" file, as shown in Figure 5.

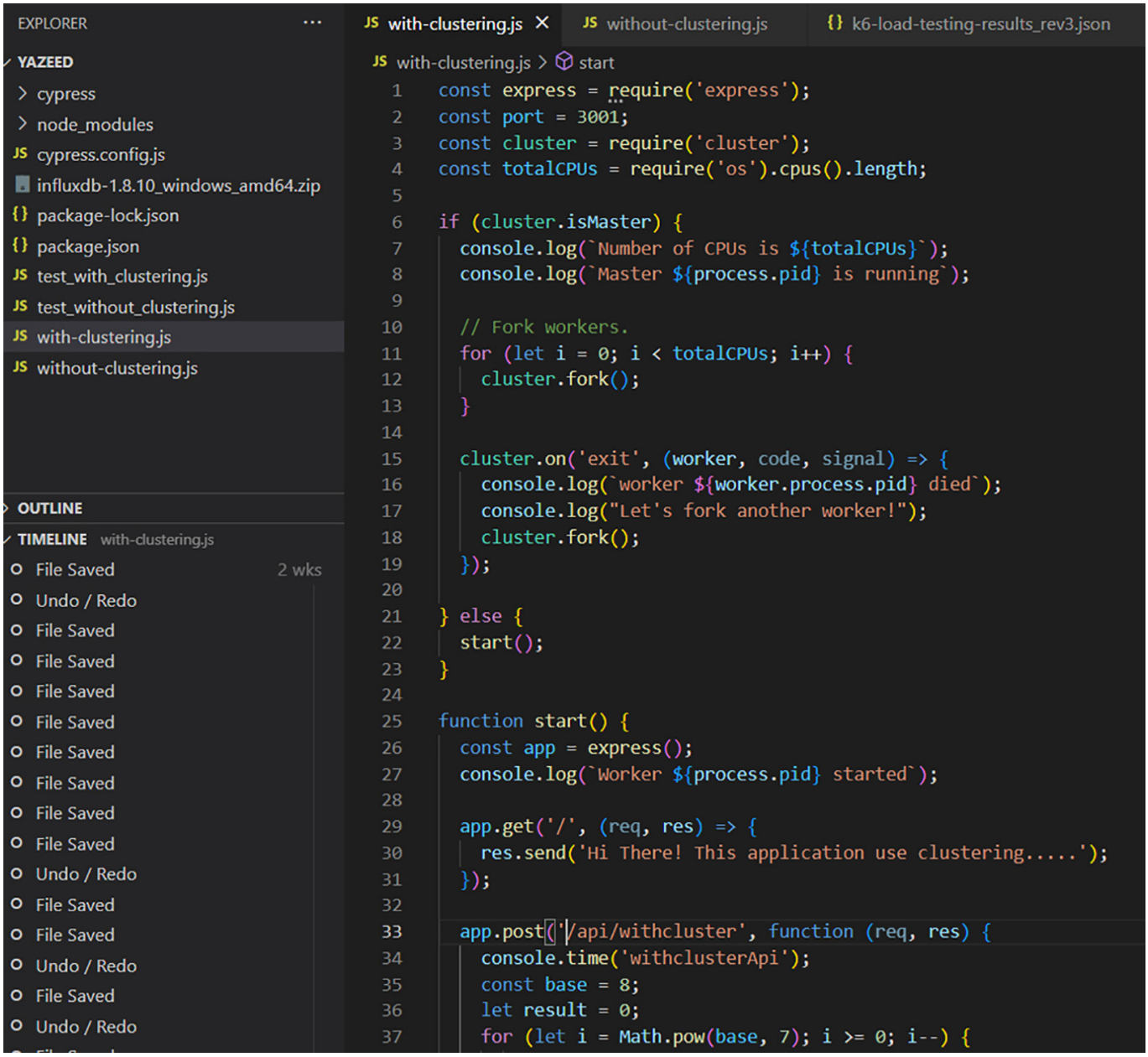

Fig. 5. Multi clustering code

14. Accessing the Node Server Terminal: The terminal where the Node server was running was accessed for further actions.
15. Sending 50 Requests to Multi Clustering: Fifty requests were sent to the multi clustering system to assess its performance. The result of sending fifty requests with multi clustering are shown in Figure 6.

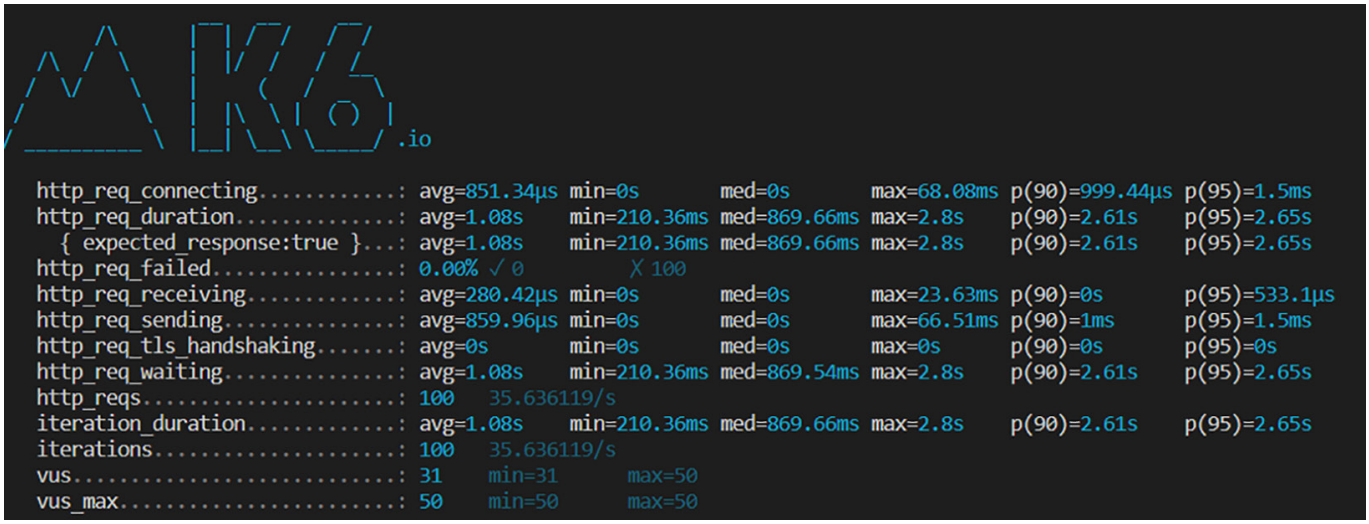

Fig. 6. The result of sending fifty requests with local multi clustering

16. Dashboard Visualization: The dashboard within Grafana displayed detailed information and visualizations related to the multi clustering process. Figure 7 shows the dashboard for the multi clustering process.

Fig. 7. Dashboard for local multi clustering process

17. Analysis of the results: the results obtained from sending fifty requests with multi clustering were analyzed to evaluate system efficiency. Table 3 illustrates the results obtained from sending fifty requests with multiple clusters.

Table 3. The results of sending fifty requests with local multiple clusters

	Avg	Min	Mid	Max	p (90)	p (95)
HTTP req blocked	.39 ms	0 s	0 s	68.08 ms	3.5 ms	.5 ms
HTTP req connecting	551.16 µs	0 s	0 s	68.08 ms	3.5 ms	1.5 ms
HTTP req duration	1.08 s	10.36 ms	869.66 ms	.8 s	.61 s	.65 s
Expected response: true	1.08 s	10.36 ms	869.66 ms	.8 s	.61 s	.65 s
HTTP req failed	0.00%					
HTTP req receiving	80	0 s	0 s	3.63 ms	0 s	533.1 µs
HTTP req sending	859.96 µs	0 s	0 s	66.51 ms	1 ms	1.5 ms
HTTP req handshaking	0 s	0 s	0 s	0 s	0 s	0 s
HTTP req waiting	1.08 s	10.36 ms	869.54 ms	.8 s	.61 s	.65 s
HTTP req	100					
Iteration duration	1.08 s	10.36 ms	869.66 ms	.8 s	.61 s	.65 s
Iterations	100					
Vus	31	31		50		
Vue's max	50	50		50		

As can be noticed from Table 3, the utilization of a multi-cluster system offers several notable advantages over the single cluster as outlined below:

1. Improved scalability: the ability to operate each cluster independently enables the addition or removal of clusters as required to accommodate specific workloads. This facilitates dynamic scaling of the system without necessitating a complete overhaul or reconfiguration.
2. Enhanced reliability: by distributing workloads and data across multiple clusters, a higher level of fault tolerance can be achieved. Even if one or more clusters experience failures, the system can continue to function, minimizing disruptions.
3. Enhanced performance: the parallelization and distribution of tasks across different clusters enable faster completion of tasks, resulting in improved overall performance.

In summary, multi-cluster systems offer significant benefits in terms of scalability, reliability, and performance. These systems find application in various domains, including high-performance computing, data analytics, and cloud computing, where their advantages are increasingly recognized and leveraged.

In addition to single and multi-clustering, we conducted a third experiment with multi-clustering on the cloud. The method of the third experiment is as follows.

5.5 Experiment 3: Multi clustering on cloud

To evaluate the performance of multi clustering system on the cloud, the following steps were followed:

1. Signing up for an Azure account on the Microsoft Azure website.
2. Creating a new Virtual Machine (VM) within a newly created resource group, providing the necessary details for the VM following the step-by-step instructions.

3. Starting the VM and downloading the Remote Desktop Protocol (RDP) or Secure Shell (SSH) version to establish remote control.
4. Executing the Influx DB on the VM.
5. Sending 50 requests to the multi clustering system to assess its performance and analyze the obtained results. Table 4 illustrates the results obtained from sending fifty requests with multiple clusters on cloud.

Table 4. The results of sending fifty requests with multiple clusters on cloud

	Avg	Min	Mid	Max	p (90)	p (95)
HTTP req connecting	370.4 µs	0 s	0 s	2.98 ms	0.98 ms	1.24 ms
HTTP req duration	420.1 µs	0 s	28.07 ms	50.08 ms	25.57 ms	35.98 ms
Expected response: true	65.1 ms	0.17 ms	25.56 ms	58.12 ms	25.18 ms	38.19 ms
HTTP req failed	0.00% ✓ 0	✗ 100				
HTTP req receiving	389.56 µs	0 s	0 s	2.07 ms	0.8 ms	1.91 ms
HTTP req sending	389.56 µs	0 s	0 s	1.58 ms	0.72 ms	1.19 ms
HTTP req handshaking	0 s	0 s	0 s	0 s	0 s	0 s
HTTP req waiting	65.1 ms	0 s	25.56 ms	58.12 ms	25.18 ms	38.19 ms
HTTP req	100					
Iteration duration	65.1 ms	0.17 ms	25.56 ms	58.12 ms	25.18 ms	38.19 ms
Iterations	100					
Vus	1	1		50		
Vue's max	50	50		50		

The performance of the three experiments; using one local cluster, multiple local clusters, and multiple cloud clusters, specifically in managing and processing a set of 50 requests was assessed. The comparative analysis is conducted using various essential metrics, including the number of successful requests, failed requests, completed requests, warned requests, as well as the time taken for request sending, request completion, and request reading per second. Table 5 shows the results of the comparison.

Table 5. Comparative analysis of performance and characteristics of three clustering approaches in handling 50 requests

	Local Single Cluster	Local Multiple Clusters	Multiple Cloud Clusters
Number of Successful Requests	50	50	50
Number of Failed Requests	0	0	0
Number of Completed Requests	50	50	50
Number of Warned Requests	0	0	0
Time Taken to Send Request (per second)	1.43 s	859.96 µs	389.56 µs
Time Taken to Complete Request (per second)	7.12 s	1.08 s	65.1 ms
Time Taken to Read Request (per second)	5.69 s	1.08 s	65.1 ms
Scalability	Limited	Higher scalability	Highly scalable
Fault Tolerance	Single point of failure	Higher fault tolerance	Higher fault tolerance

(Continued)

Table 5. Comparative analysis of performance and characteristics of three clustering approaches in handling 50 requests *(Continued)*

	Local Single Cluster	Local Multiple Clusters	Multiple Cloud Clusters
Resource Allocation	Shared resources	Dedicated resources	Flexible allocation
Performance	Limited capacity	Improved capacity	High capacity
Network Latency	Dependent on local network	Dependent on network	Dependent on network
Load Balancing	Manual	Load balancing	Automated load balancing
Availability	Dependent on local setup	Improved availability	High availability
Scalability Management	Requires hardware expansion	Cluster expansion	Automated scalability
Maintenance and Management	In-house responsibility	In-house responsibility	Managed by provider
Cost	Capital and operational	Capital and operational	Pay-as-you-go

The results from the three experiments comparing the performance of the local single cluster, local multiple clusters, and multiple cloud clusters provide valuable insights into their effectiveness in handling 50 requests. Firstly, all three approaches demonstrated 100% success in processing the requests, with no failures or warnings. However, notable differences were observed in the time taken to send, complete, and read requests. The local single cluster had the longest processing times, whereas the local multiple clusters and multiple cloud clusters exhibited significantly faster performance. This highlights the advantage of distributed setups and cloud infrastructure in improving processing speed.

Scalability and fault tolerance also varied among the approaches. The local single cluster showed limited scalability and a single point of failure, whereas both the local multiple clusters and multiple cloud clusters demonstrated higher scalability and fault tolerance. The ability to allocate dedicated resources and implement flexible resource allocation further contributed to the improved performance of the local multiple clusters and multiple cloud clusters.

Additionally, the availability and maintenance aspects differed between the approaches. The local single cluster was dependent on the local setup, while both the local multiple clusters and multiple cloud clusters offered improved availability and required in-house responsibility for maintenance. However, the multiple cloud clusters had the added advantage of being managed by the cloud provider, reducing the maintenance burden on the organization.

Cost-wise, the local single cluster and local multiple clusters incurred capital and operational expenses, whereas the multiple cloud clusters followed a pay-as-you-go model. This demonstrates the potential cost-effectiveness of cloud-based solutions, allowing organizations to optimize costs based on usage.

Overall, the results indicate that both the local multiple clusters and multiple cloud clusters outperformed the local single cluster in terms of performance, scalability, fault tolerance, resource allocation, and availability. The multiple cloud clusters, in particular, exhibited superior scalability, fault tolerance, and cost-effectiveness. However, organizations should consider their specific requirements and constraints when selecting the most suitable approach for handling requests.

The outcomes of this research offer valuable insights into the efficiency and effectiveness of each clustering approach, thus assisting decision-making processes regarding the selection and implementation of appropriate clustering strategies for diverse applications.

6 CONCLUSION

The research aimed at analyzing how different clustering techniques affect reliability along with efficiency with a keen interest in Node.js applications. Within this context, we analyzed three scenarios—local single clustering, local multi clustering, and multi clustering on cloud for the purpose of undertaking several experiments and evaluations that helped us derive relevant conclusions. We carried out tests within the "single cluster" environment after having established all necessary components such as dashboards databases, sending requests directed towards one cluster. These procedures provided in-depth insights into performance measures and potentialities achievable through singular approaches.

In addition, we further explored the feasibility of "multi clustering" comprising installations along with appropriate configurations while handling program workloads that can be distributed across multiple setups. Our findings showed numerous scalability benefits achieved via such methodology suitable primarily for programming-based network architecture.

Overall, our analytical results reveal significant insights surrounding the use of different clustering methodologies while implementing Node.js applications. The single cluster approach can provide straightforward baselines suitable for routine tasks but upgrading towards scalable optimizations inclusive on diverse networking infrastructures (i.e. cloud servers) might be more beneficial concerning developing better future-proof platforms ensuring reliability and flexibility even during peak usage periods.

7 FUTURE WORK

To advance our understanding further in clustered architectures' applications across varied industries, we must adopt an approach that focuses on investigating configuration optimizations alongside load balancing algorithms while striving for improved scalability along with performance enhancements in related system designs.

Continuing along these lines, there is a need for significantly more efficient work distribution methods that can use resources effectively while reducing content inertia across multiple groups. Moreover, given the increasing levels of cloud computing adoption today than ever before, improving the effectiveness of cloud-based environments cannot be overemphasized. Therefore, research must advance the discovery of innovative technologies and new technologies that improve resource allocation while enhancing energy efficiency in multi-cluster systems. Achieving success here will go a long way in enhancing our collective knowledge and understanding of the application of cluster environments in several different areas.

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PAPER

Low-cost Wireless Lamp Socket and Power Plug for Smart Homes and Its Comparison with Available Commercial Competitors

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ABSTRACT

Smart home manufacturers widely produce Wireless Lamp Socket and Power Plug devices, which offer various features ranging from basic on/off control to more complex functionalities such as monitoring energy consumption, power losses, and harmonics. However, these devices tend to be expensive, as indicated by market surveys. To address this issue, the current study aimed to develop low-cost wireless control nodes for smart homes that operate using relays. The two nodes consisted of lamp socket and power plug built with low-cost electronic components, including a Wi-Fi built-in Microcontroller ESP8266 (Wemos D1 mini model) as the backbone to create ESP-Mesh wireless network and to provide control ports for high/low logic, a relay module, an AC-to-DC converter module, and terminals (E27 screw for lamp socket node and C-type plug for the power plug node). This paper primarily focuses on the hardware aspects. In order to evaluate the effectiveness of the nodes, the following tests are conducted: (1) product demonstration to assess the product functions, (2) power measurement in idle and active conditions, (3) ESP-Mesh connection testing, and (4) RSSI measurement. Functional testing is done using a smartphone with the UPISmartHome version 2.0 Android application, which successfully controlled the nodes wirelessly. In idle conditions, power plug and lamp socket nodes consume 426.36 mWatt and 418.275 mWatt of power, respectively. Further, in active conditions, power plug and lamp socket nodes consume 435.704 mWatt and 440.583 mWatt of power, respectively. RSSI testing results show that both nodes can be controlled within an optimal range of 60 meters (with reference to RSSI below –85 dBm) without the Internet, utilizing the ESP-Mesh feature of ESP8266. This range is deemed reasonable for smart homes of 21, 36, or 45 square meters. Both nodes could be controlled under the ESP-Mesh network that gets build. We also present the comparison with other products of competitors in this paper.

KEYWORDS

lamp socket, power plug, smart home, low-cost, ESP8266

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1 INTRODUCTION

In the smart home environments, wireless lamp socket and power plug are among the various types of end devices that enable users to switch from conventional to modern (remote-controlled) control of household devices through smartphone-based or web-based applications. Power plugs function as switches with power socket interfaces that can be plugged into other electronic devices [1], [2], similar to an adapter [3]. On the other hand, lamp socket is a switch with threaded lamp interfaces that can be connected to standard lamps. Both lamp socket and power plug allow users to control the power flow to the devices, such as lamps or other home appliances, that are connected to the node interface and linked through a smartphone app or a specialized website. These two nodes provide a wireless technology solution for non-wireless devices, such as lamps, fans, refrigerators, etc.

In previous studies [4]–[7], we have carried out the smart home development that only focused on creating one end device, the power plug, while neglecting the potential of other devices such as lamp socket. By leveraging the same hardware configuration, other devices can be realized, leading to various efficient smart home devices that adhere to the principles of rapid development and lightweight implementation concepts [8]–[10]. However, the previous studies failed to address the issue of improving connectivity reliability using wireless network topology such as Mesh, as addressed in [11]. Adiono, et al., attempted to fill this gap by developing multiple smart home nodes on the MINDSTM platform, including power plug and lamp socket with the same hardware configuration and basic control features, such as “on” or “off” [28]. These nodes followed the standard use cases in Indonesia and were packaged considering consumer electronics aspects. However, the system architecture, hardware configuration, and wireless communication mechanism in the MINDSTM were complex. This paper is an extended version of study conducted previously [12], focusing on hardware design and technical testing.

This study contributes to enhance the functions from [8]–[10]. Lamp socket node has the following specifications: (1) it has an output node that uses a fitting for standard E27 threaded lamps, (2) it is connected to other nodes in the ESP-Mesh network, provided by ESP8266 [13], (3) it can be controlled “on” or “off” up to a distance of 60 meters without an internet network with RSSI below –85 dBm according to the capabilities of ESP8266. In addition, the power plug node has the following capabilities, such as (1) when active, its power consumption is lower than the MINDSTM products [8], [14]–[16], which is 435.704 mWatt compared to the previous (618.5 mWatt). (2) With the same control function, the block diagram of this proposed socket is simpler compared to the other platform [8], [14]–[16]. (3) The output node uses a standard terminal commonly used in Indonesia (*C*-type) to be used as a power plug. Both nodes can only be controlled through a special Android application (UPISmartHome Apps version 2.0). Although the proposed hardware was designed using a Do-It-Yourself (DIY) method, it adheres to the main principle that nodes in a smart home should be compact, easy to install in various types of houses, and comply with consumer electronics or standardized packaging aspects (not just random packaging) [9], particularly for power plug and lamp socket nodes. The firmware part of ESP8266, including ESP-Mesh implementation, and Android apps have been discussed in [12].

2 LITERATURE REVIEWS

This section provides literature reviews of existing commercial products and research-based studies. Power plug and lamp socket function as switches or relays [17], enabling wireless control e.g., through Bluetooth, which allows consumers to efficiently and easily turn ON or OFF household devices [18], [19]. Various power plug and lamp socket products are available with a range of features, including Wi-Fi connectivity that enables users to control all household devices from afar. Some manufacturers also collaborate with original equipment manufacturers (OEMs) to ensure compatibility with voice-based commands, such as HomeKit, Alexa, Google Assistant, or Siri [20]. Advanced features include setting schedules to automatically turn devices ON or OFF at specified times, remote checking of which plug is active, knowing when devices are being used, and the devices used most frequently. Some power plug products have energy usage monitoring features [21] that allow for home energy-saving efforts [22], [23]. However, as the features provided increase, the price tends to increase, leading to a trade-off in the system. Tech Advisor provides a list of various commercial power plug and lamp socket products, with prices starting at around USD 10 for standard and simple features [20].

Despite the availability of hundreds of commercial power plug and lamp socket nodes, several nodes have been developed for various reasons, such as interoperability [24], [25], operating voltage [26], operating system [27], unaccounted price factors, and incompatible interfaces for Indonesia, which uses the E27 screw standard (for lamp socket) [28], [29] and *C*-type (for power plug) [30], [31]. For example, Tekler, et al., developed an IoT-based plug device called Plug-Mate [4], a home load management system that automates load energy consumption reduction based on plug type, home, and control preferences. Plug-Mate has been evaluated for five months through field tests (achieving savings of up to 7.5%) and has received positive user feedback, with a satisfaction rate of 4.7 out of 5. Deng, et al., created Smart Plug 2.0 [5], a plug with wireless power control, monitoring, and protection against electrical short circuits, overload, arcs, and ground faults. Karanchery and Rakesh [6] modified conventional sockets to have IoT-based control functions at a minimal cost (around USD 10), using only five components, namely NodeMCU 8266, relay module, power switch, plug base, and other components such as LEDs, cables, resistors, etc. The power plug is controlled for activation and deactivation via a smartphone device with a Blynk-based application. Serano, et al., built the *N*-type socket Smart Plug, which includes two versions, namely plug adapter and wall socket [7], featuring power quality and energy analyzer capabilities at an affordable cost (total price of USD 30). The smart plug also offers automation features and can remotely turn on and off connected loads. Even though they contributed immensely, the *N*-type socket is not suitable to be implemented in Indonesia since we use *C*-type.

Based on the description above, this current study proposed a simpler hardware arrangement, wireless communication mechanism, and system architecture for power plug and lamp socket nodes compared [5]–[7] and commercially available smart home products.

3 METHODS

3.1 Hardware design and its specifications

Lamp socket node was designed to confirm to the E27 standard thread interface, which was the most commonly used in Indonesia and was also followed by other competing smart home products in the market. By following this standard, users could easily plug-and-play their regular household lamps into lamp socket products. Furthermore, its node could be plugged into any existing power outlet in the home without the need for any modification to the electrical installation, making it a practical and user-friendly product. The design of the lamp socket node was also minimalistic, utilizing minimal electronic components to keep the product compact and not bulky in appearance.

To meet the required specifications, lamp socket hardware was composed of three main modules. The first module is ESP8266 Wemos D1 mini microcontroller, which provided wireless network services and served as the controller. The second part is the relay, which acted as the switch for turning the lamp "On" or "Off". The third part is the AC-to-DC converter (Hi-Link HLK-PM01 3W), which converted the ~220V AC voltage to a 5VDC voltage to power ESP8266 and SONGLE SRD-05VDC-SL-C Relay. The hardware arrangement of the proposed system was shown in Figure 1a. ESP8266 controlled the relay to allow the 220V AC voltage to flow towards the fitting, thereby turning the lamp on or cutting off the voltage to turn the lamp off. The relay had a normally open (NO) and normally closed (NC) switch, with the output voltage from the converter (5VDC) connected to the NO switch, which was then connected to the lamp. Therefore, when the relay switch was in the NO position, the Node was active. This means that if it is connected to a lamp, the lamp would be turned on. On the contrary, when in the NC position, the connected lamp would be turned off (Node inactive). ESP8266 processed and controlled the relay status and sent it to other nodes through the mesh network.

The Node Power Plug is a wireless solution that allows existing household electronic devices to be controlled remotely, without requiring any modification. To ensure safety, only compatible devices such as rice cookers, televisions, lamps, and fans could be connected to this socket. The main power source for the device was the standard 220–240V AC voltage in Indonesia, and the output socket confirmed to the Indonesian standard (*C*-Type), making it a practical and convenient option for users.

The hardware construction for the power plug node was identical to that of the lamp socket node, as illustrated in Figure 1b. It consisted of three main components, including (1) a custom AC-to-DC converter module that produced a 5VDC voltage from ~220V AC input, (2) ESP8266, and (3) a relay. The principle behind the operation of devices was the same as the lamp socket node, with ESP8266 used to control the relay and allow the 220V AC voltage to flow to the AC terminal. Once electricity was flowing, the power plug could be used as a plug. To turn off the device connected to the power plug, the relay disconnected the electricity flow through the command from ESP8266. Compared to smart plug products on the MINDS™ platform [8], [14]–[16], the hardware arrangement in this current study was simpler and involved only three components, as shown in Figure 1. In contrast, the MINDS™ involved a self-designed AC-to-DC converter circuit, a 3.3VDC regulator for communication module power supply (Zigbee), a Zigbee module (XBee Pro), a relay, a relay driver circuit consisting of an optocoupler and transistor switch configuration, a current sensor circuit (ACS712 sensor), as well as other components such as fuse, switch, button, and LED indicators.

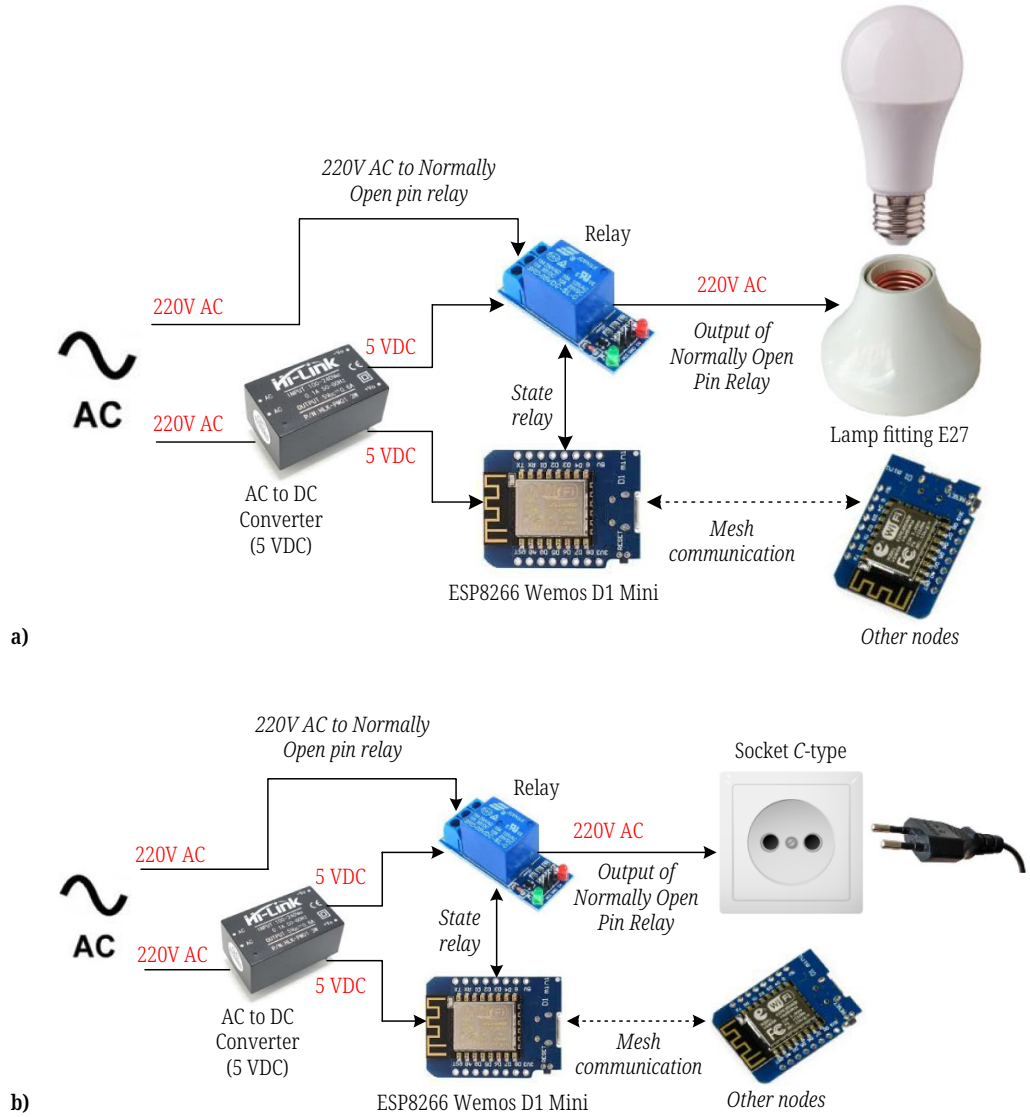

Fig. 1. Block diagram for nodes (a) lamp socket and (b) power plug, reproduced from [12] with permission

3.2 Printed Circuit Board (PCB) design

To ensure consistency in both the working principles and required electronic components for Node Power Plug and Lamp Socket, the PCB design for both nodes was made identical, as illustrated in Figure 2a. EAGLE software was used to design the PCB, which had the same dimensions for both nodes, with a length of 5.5 cm and a width of 4.9 cm. The PCB contained various components, including ESP8266 denoted as U5, AC-to-DC converter (U4), relay (U3), reset button (S1), AC power socket (P1), AC output socket (P2), 1kΩ resistors (R1 and R2), and LED indicator lights (D1 and D2). Table 1 provided a description of the electronic components used in the nodes, their respective prices, and the total cost, which was estimated at around IDR 164,000.0 or 11.09 USD per Lamp Socket or Power Plug Node, excluding the casing box, E27 fitting (IDR 10,000 or ~0.68 USD), *C*-type AC socket/plug (IDR 15,000 or ~1 USD), and the double-layer PCB printing cost (including masking) with a size of 5.5 cm × 4.9 cm.

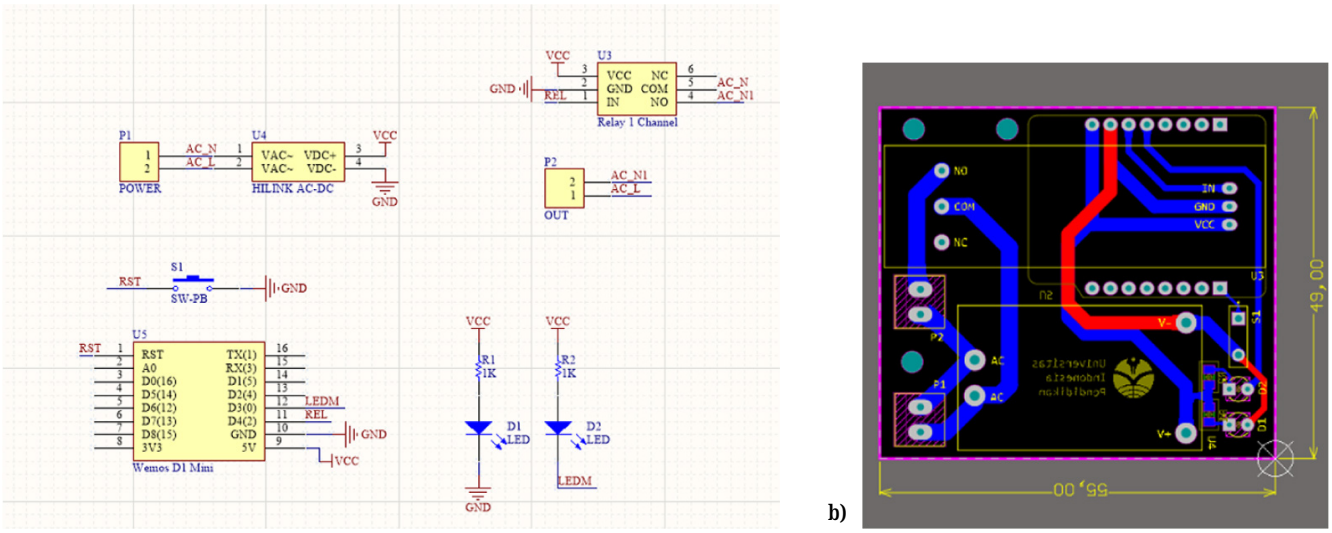

Fig. 2. Electronic circuits for lamp socket and power plug nodes including (a) circuit schematic in eagle software and (b) PCB layouts

Table 1. List of constituent electronic components and total prices (reference from national online stores)

No	Component Name	Total	Total Price	References
1	ESP8266 Wemos D1 mini	1	IDR 65,000.00	https://www.tokopedia.com/arduino-robot/d1-mini-wemos
2	AC-to-DC converter 5V 0.6A (Hi-Link HLK-PM01 3W)	1	IDR 60,000.00	https://www.tokopedia.com/indo-ware/adaptor-model-pcb-hlk-pm01-ac-dc-input-100-240vac-output-5v-0-6a-0-6a
3	Relay SONGLE SRD-05VDC-SL-C	1	IDR 25,000.00	https://www.tokopedia.com/pcmelektrobik/relay-module-12v-1-channel-with-led
4	Connector 5 mm 2 pin	2	IDR 8,600.00	https://www.tokopedia.com/eltech-online/2-2p-2pin-p-pin-5-08mm-etb-13-blue-biru-taiwan-terminal-screw-blok
5	AC power socket	1	IDR 3,500.00	https://www.tokopedia.com/rereaudio/socket-ac-power-angka-8-outlet-inlet-soket-chasis
6	1kΩ resistors	2	IDR 500.00	https://www.tokopedia.com/alfaelectro/resistor-0805-1k-ohm-10pcs
7	Red 3mm LEDs	1	IDR 200.00	https://www.tokopedia.com/putraniagabdg/led-3mm-merah-hijau-kuning-led-3-mm-kualitas-bagus-merah
8	Green 3mm LEDs	1	IDR 200.00	https://www.tokopedia.com/putraniagabdg/led-3mm-merah-hijau-kuning-led-3-mm-kualitas-bagus-merah
9	Reset button	1	IDR 1,000.00	https://www.tokopedia.com/putraniagabdg/push-button-12x12x9-tombol-push-on-pcb-4pin-tinggi-9mm
Total			IDR 164,000.00 (USD 11.09)	

3.3 Casing design and components integration

To reduce production costs, a simple casing was designed using readily available boxes and plugs from the market. Although this product utilized a generic box with perforations to accommodate the lamp fitting or AC plug, its aesthetic appeal was inferior to that of its competitors. For example, Bardi™ and Bossman™ employed unique custom-molded casings provided by the TUYA®

platform, while the MINDSTM from Bandung Institute of Technology [8], [14]–[16] used custom-designed 3D printed casings made of PLA material by the State Polytechnique Madiun [32]. The fitting and plug depicted in Figure 3a and 3b, respectively, were then connected to the box. By adopting this simple casing manufacturing approach, the main difference between power plug and lamp socket lay in the interface to home appliances, with lamp socket featuring an E27 threaded interface as shown in Figure 4a, and the Power plug using a *C*-type AC terminal according to Figure 4b. The top and bottom views of the PCB were shown in Figure 5a and 5b, respectively.

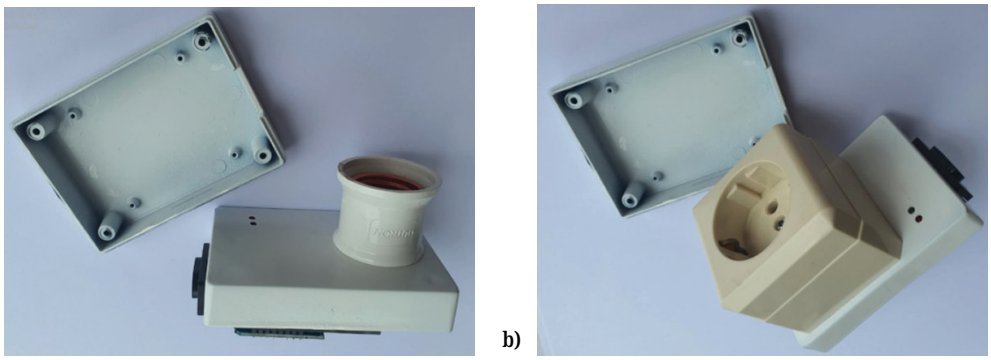

Fig. 3. A simple casing built using a generic box and standardized socket (Stecker with E27 fitting & 220V AC receptacle with *C*-type terminal) for the nodes, including (a) lamp socket and (b) power plugs

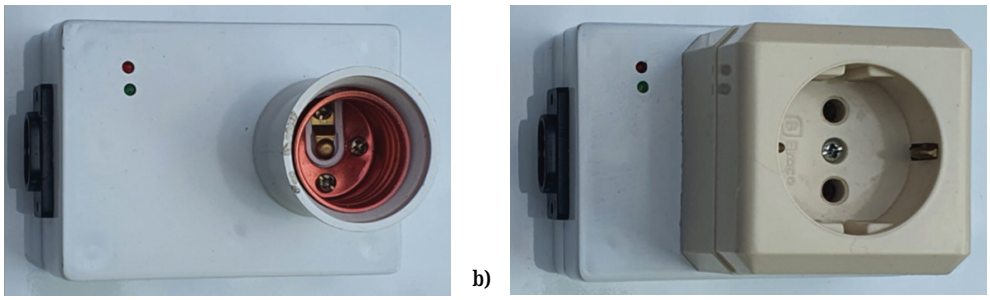

Fig. 4. Compact node-packaged (user ready) for (a) lamp socket and (b) power plug

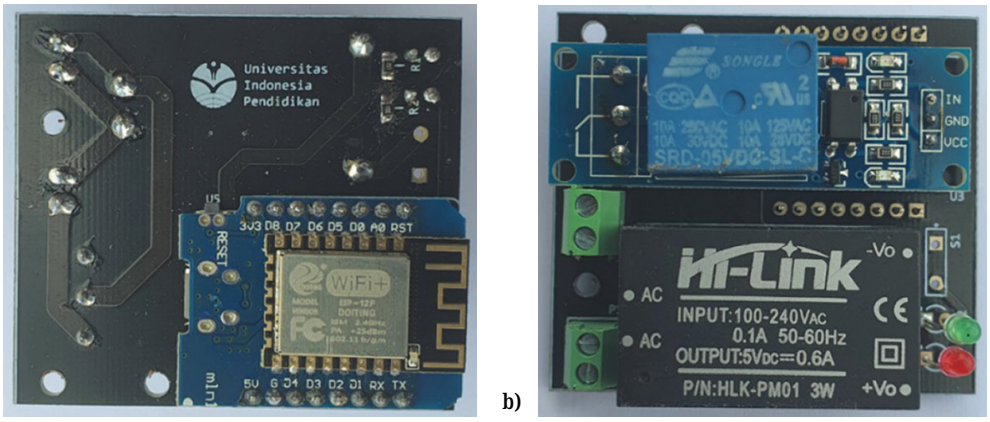

Fig. 5. A photograph of one unit PCB kit that has been assembled for lamp socket and power plug nodes, including (a) top view, installed ESP8266 Wemos D1 mini; (b) power plug, installed SONGLE SRD-05VDC-SL-C relay module, Hi-Link HLK-PM01 3W AC-to-DC converter, AC in/out voltage terminal, and 1 mm LED as power indicator (red) and connect to the network (green)

4 RESULTS AND ANALYSIS

4.1 Functional tests

Functional testing was conducted using a Samsung Galaxy TAB A T295 smartphone installed with the UPISmartHome version 2.0 Android application as the remote control. The design of the application was not discussed in this article but was well elaborated in [12]. To perform the testing, a 7 Watt lamp was installed on lamp socket node, and a 12 Watt lamp was connected to the power plug node. The nodes were further connected to a 220V AC power source via power cables. Each node has two LED indicators, one red and one green, both with 3W power. Initially, the red LED lit up to indicate that the node was connected to the 220V AC voltage. When the green LED lit up, it indicated that the node was connected to the ESP-Mesh network, and the node (lamp socket & power plug) could be controlled through the application. If only the red LED was on, it meant that the node was not connected to the application through the ESP-Mesh network. The Android application was programmed to act as a node and was designed to automatically connect to the ESP-Mesh network. When users opened the UPISmartHome version 2.0 application (without the need for a login process), both nodes could be wirelessly controlled without an internet connection. The functional performance of lamp socket and power plug nodes was presented in Figure 6a and 6b, respectively. The test results showed that both nodes functioned well and could be turned "Off" and "On" using the remote, namely, the Android application version 2.0. In this test, only two buttons, such as symbols representing a plug and a lamp, were used in the application. This testing was performed at a close range of around <30 cm to ensure the "On" or "Off" function. For further testing, the remote control's range of the nodes was evaluated through Received Signal Strength Indicator (RSSI) and distance testing. As people now enjoy the convenience of network services to manage their smart home environment [33], this study fulfilled the requirement to provide wireless control services.

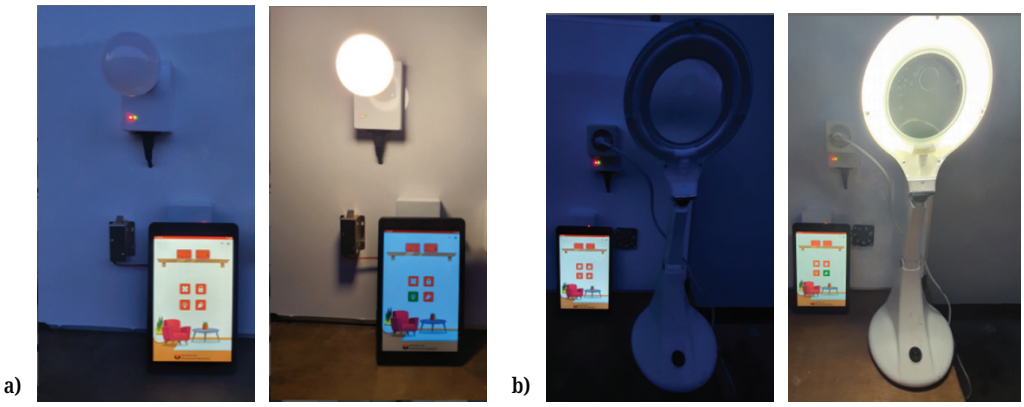

Fig. 6. Demonstration of functional testing on nodes: (a) lamp socket; (b) power plugs

4.2 Power consumption

In this study, power consumption was considered an important parameter for determining whether the node was low-power or not. To measure the power consumption of the two nodes, power testing was conducted using a digital multimeter (FLUKE model 17B+) to measure the current and voltage when the node

was in active condition (connected to ESP-Mesh network and communicating with other nodes) and idle condition (not connected to other nodes). The results of the power test showed that the measured current for the power plug node in idle and active conditions was 83.6 mA and 85.6 mA, respectively, with voltage measured at ~5.1 VDC. Regarding lamp socket node, the measured current was 82.5 mA and 86.9 mA in idle and active conditions, respectively, with the measured voltage of 5.07 VDC for both conditions. Although the active conditions led to an increase in current consumption compared to the idle, the increase was not more than 5 mA. By multiplying the measured voltage and current for both conditions, power consumption data for the two nodes were obtained. The lamp socket node had a power consumption of 418.275 mWatt and 440.583 mWatt in idle and active conditions, respectively. Meanwhile, for the power plug node, the power consumption was 426.36 mWatt and 435.704 mWatt in idle and active conditions, respectively. Table 2 shows that both nodes had lower consumption compared to the MINDS™ platform [8], [14]–[16]. In addition, the power consumption in idle conditions was higher than [8], [14]–[16], the power difference between the two conditions was lower at 9.344 mWatt, compared to 369 mWatt in [8], [14]–[16] for the power plug node.

In summary, the developed nodes exhibited different power consumption levels in the two conditions due to the RF block in ESP8266 microcontroller becoming active in active condition. The difference in power consumption levels was attributed to the RF block and AC-to-DC converter module, which, despite having the same brand and model, did not consume the same amount of power. Given that most sockets must be idle most of the time, this increase in consumption will impact the overall energy efficiency of the design. Regardless of this condition, the two nodes still contribute to energy conservation programs due to their relatively low power consumption in terms of active state. This proposed system can potentially benefit smart home applications.

4.3 RSSI testing

This study used ESP8266 as a wireless access module. According to reference [12], the Wi-Fi module had a maximum range of 70 meters with RSSI reference of –93 dBm. RSSI is an important indicator that was used to assess the received signal strength parameters on a device [34], [35], in this case, ESP8266 module. Therefore, ESP8266 module was measured to determine the maximum RSSI value that could accurately control the node. As each ESP8266 module had different network range capabilities, the modules for node power plug and lamp socket were measured and compared. The testing was conducted outdoors in a straight-line configuration without any obstacles, with the transmitted signal received directly. The nodes were placed at predetermined distances, ranging from 10 meters to 200 meters with a 10-meter interval, and the testing was performed five times for each in order to obtain the average RSSI value in dBm. Table 3 shows the measurement results of distance variation (10 to 180 meters) against RSSI values. At a distance of 10 meters, its values for lamp socket and power plug nodes were –63 dBm and –65 dBm, respectively, with the two nodes having the same value at distances of 20 and 50 meters. The difference in the value between the two nodes was approximately –1 dBm to –3 dBm. The measurement results showed that the optimum value was –93 dBm. Due to the difference in these values, such as maximum difference of around –3 dBm, the maximum distance also varied. The power

plug node could only reach a distance of 150 meters, beyond which the signal was lost. Meanwhile, lamp socket node could still be used or controlled up to a distance of 180 meters.

Since ESP8266 module have varying qualities in terms of wireless range [12], [36], both nodes had a maximum limited distance of 60 meters [37], which was the most reasonable distance based on the reference of the maximum RSSI value of –85 dBm. To reflect the results more clearly, we convert Table 3 to a line plot as visualized in Figure 7. Hence, the decrease in RSSI values as distance increases can be distinguished easily; it shows the baseline performances of a default wireless access module for comparison purpose between power plug and lamp socket.

Based on the capabilities of these two nodes, they were suitable for implementation in houses with types 21, 36, or 45. In Indonesia, developers divide house types based on the building area's size, which comprises six types: 21, 36, 45, 54, 60, and 70. Type-21 houses have a building area of $21m^2$ (ex., 3×7 meters, 5.25×4 meters, or 6×3.5 meters). Type-36 houses are built with dimensions of 6×6 meters or 9×4 meters. While type-45 is generally constructed with 6×7.5 meters dimensions. However, it is difficult to use for the above type-54 due to the dimension distance. For this reason, the Indonesian modern houses for types 21, 36, and 45 still can be covered with ESP-Mesh network of this proposed nodes.

4.4 Mesh connection testing

The ESP-Mesh testing for power plug and lamp socket Nodes required the use of a Gateway. Through this testing, empirical data on the maximum distance of both Nodes was obtained, indicating that beyond a certain distance, communication between the Nodes was lost. To carry out the ESP-Mesh testing, power plug Node, Gateway, and lamp socket Node were placed in a testing scenario, and commands were given while in Active conditions. Besides the Gateway and the two Nodes, other Nodes were included in the testing, as reported in [12]. The test devices were intentionally placed far apart from each other, to prevent them from performing self-configuration, self-healing, and self-organizing and to form an ESP-Mesh network. In other words, the wireless connection was completely disconnected. Table 4 summarized the ESP-Mesh testing results in matrix form, including Gateway to lamp socket Node (maximum 80 meters), Gateway to power plug Node (maximum 43.5 meters), and lamp socket Node to power plug Node (maximum 87 meters). The farthest distance obtained was between lamp socket Node and the power plug Node, while the shortest distance was between the Gateway and the power plug Node.

These findings showed that the ESP-Mesh connection operated as expected. The self-configuration, self-healing, and self-organizing capabilities of ESP8266 W [38], as demonstrated by the ESP-Mesh test, showed maximum distance variation, even in extreme differences, which exceeded 40 meters. However, for type 21, 36, or 45 houses, this distance could be scaled and reasonably used as a reference for implementation in the field. Besides the coverage and low power consumption, the other potential avenues for further enhancing the nodes could be automatic plug load identification, as done by [39] and automatic fault detection features as carried out by [40]. Some other features include smart building controls and building energy assessments. These advancements have a great potential to significantly contribute to the automation and digitalization of our proposed system, making it worthwhile areas for exploration in future research.

4.5 Cost analysis

This section compared the prices of power plug and lamp socket nodes that were created with those of other competitors. The reference price for these nodes was based on Table 1, which was IDR 100,000. The cost of producing the casing for the node power plug was IDR 30,000 (~2 USD), which was obtained by adding the price of the box X-type plastic (IDR 15,000 or ~1 USD) to the price of the plug (~1 USD). Similarly, the cost of producing the casing for lamp socket node was IDR 25,000 (IDR 1.06), which was accumulated from the price of the box X plastic and the E27 fitting (IDR 10,000 or ~0.68 USD). The cost of printing a double-layer PCB with a size of 5.5 cm × 4.9 cm was IDR 22,907.5 or ~1.55 USD obtained from the PCB area, which was 26.95 cm^2 × IDR 850.00. This implied that the total cost for 1 unit of lamp socket was IDR 211,907.5 or 14.33 USD and 1 unit of the power plug was IDR 216,906.5 or ~14.67 USD.

As previously explained, there were currently dozens of commercial power plug and lamp socket products available. Therefore, this section was limited to products that were available in Indonesia, and only the *C*-type terminal-based power plug node as seen in Table 5, and the E27 standard lamp socket node depicted in Table 6 were compared. The reference price was based on the most popular online marketplaces in the country, namely Shopee, Tokopedia, and Lazada. Tables 5 and 6 contained the product names, features, and prices. The comparison results showed that the nodes created were more affordable than other commercial competitors. The relay used has 10 Ampere of current output maximum and works at 220V AC. Hence, our lamp socket products have 2200 Watt (multiplication between current and AC voltage) of power maximum, which is higher than other competitors. Since we compare few aspects (i.e., the terminals type, maximum power consumption, the need of Wi-Fi connection, wireless network abilities, and prices), the other advantages of commercial products in comparison table (i.e., GALVEE, TUYA, CORUI, Bosman, Avaro, Bardi, FANTECH Smart Life, ONASSIS, Deon, IT, Acome, and Lumi Smart Home) are not elaborated at all. The whole features can be found in their original sources (official websites) including voice or gesture command services, cloud services, timers, number of users, and many more.

Even though Wi-Fi-based smart home systems (online-type) are very popular and reliable worldwide, some developing countries need help accessing them feasibly due to their serious problem: poor internet connection. A stable internet connection is highly required to ensure the Wi-Fi-based smart home system functions properly, as the device must always be connected to the internet to maintain a seamless connection to the cloud via Wi-Fi within the home. Low-quality Internet connection in developing countries, such as Indonesia, leads to difficulty in accessing the services offered by this system [41]. These circumstances also make the smart home industries hard to grow up. There are commercial products in Indonesia, as presented in Tables 5 and 6, where most cooperate with third parties (e.g., TUYA, Google, Alexa, Etc.). The offline-based smart home is a favourable solution. Through this study, the proposed product fills the gap: an offline smart home platform that provides nodes in the form of smart plugs and lamp sockets. In an offline smart home system, internet and cloud services are unnecessary, and the system architecture is less complex as they use ESP-Mesh.

Most commercial smart home systems have many advantages with a trade-off in cost. Many variations of smart home products need a unified control interface standard [42], resulting in being incompatible for different countries. Android products and applications developed in this study are permitted and do not violate smart home standard rules because there are no standards for the smart home system. Finally, it

is expected to provide low-cost smart home access because there is no need to engage third-party services, or standalone systems. The offline service can provide a quick response. This research is limited to applications for smart homes and can be applied to other areas, such as Smart Campus [43], with additional energy monitoring features.

Table 2. Power consumption comparison

Node	Previous Work [8], [14]–[16]			This Work		
	Idle	Active	Difference	Idle	Active	Difference
Power plug	249.5 mWatt	618.5 mWatt	369 mWatt	426.4 mWatt	435.7 mWatt	9.3 mWatt
Lamp socket	–	–	–	418.3 mWatt	440.5 mWatt	22.2 mWatt

Table 3. Summary of inter-node RSSI test results

Node	Distance (m)																	
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
Lamp socket	–63	–65	–68	–69	–80	–81	–82	–83	–83	–83	–85	–87	–87	–87	–90	–91	–91	–93
Power plug	–64	–65	–67	–79	–80	–83	–84	–84	–85	–86	–88	–90	–91	–92	–93	–	–	–

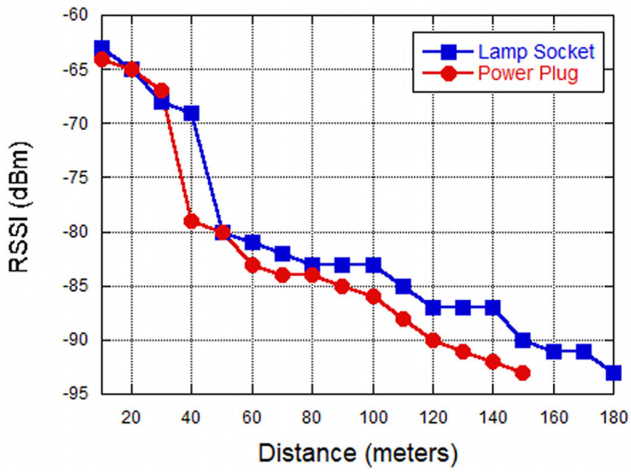

Fig. 7. Performance comparison of power plug and lamp socket in terms RSSI against distance

Table 4. Inter-node mesh connection testing

	Gateway	Lamp Socket	Power Plug
Gateway	–	80 meters	43.5 meters
Lamp socket	–	–	87 meters

Table 5. Comparison of lamp socket nodes with similar commercial competitors

No.	Brands	Links	E27 Socket	Power Max.	Need Wi-Fi?	Wireless Network	Price (IDR)
1	GALVEE	https://bardi.co.id/	Yes	200 W	Yes	No	360,000
2	TUYA	https://www.tuya.com/	Yes	40 W	Yes	No	323,000
3	CORUI	https://corui-smarthome.com/	Yes	40 W	Yes	No	242,325
4	Proposed	https://www.sh-upi.com/	Yes	2200 W	No	Yes	211,907.5

Table 6. Comparison of power plug nodes with similar commercial competitors

No.	Brands	Links	*C*-Type	Power Max.	Need Wi-Fi?	Wireless Network	Price (IDR)
1	Bosman	https://www.bosman.co.id/	Yes	2200 W	Yes	No	476,000
2	Bardi	https://bardi.co.id/	Yes	2200 W	Yes	No	452,000
3	Avaro	https://avaroindonesia.co.id/	Yes	3680 W	Yes	No	439,000
4	FANTECH Smart Life	https://fantech.id/	Yes	2200 W	Yes	No	399,000
5	ONASSIS	https://www.onassis-hardware.com/	Yes	3520 W	Yes	No	398,400
6	Deon	https://deonsmart.com/	Yes	3680 W	Yes	No	361,000
7	IT	https://ms-livewithit.eraspace.com/	Yes	2500 W	Yes	No	359,000
8	Acome	https://home.wook.cn/id	Yes	2400 W	Yes	No	329,000
9	Lumi Smart Home	https://lumismart.id/	Yes	1650 W	Yes	No	289,000
10	Proposed	https://www.sh-upi.com/	Yes	2200 W	No	Yes	216,906.5

5 CONCLUSION

This paper described two nodes that were designed for wireless-based smart home relay On/Off control, namely, the lamp socket and power plug devices. Both nodes were built using low-cost electronic components and were designed to comply with Indonesian standards, including a main power supply of 220V–240V AC, an E27 threaded interface for the lamp socket, and a *C*-type socket for the power plug. Both nodes have been compared with other similar competitors, and we won in terms of cost. The lamp socket was designed using the plug-and-play principle allowing users to install standard lamps without altering the electrical installation. Meanwhile, the power plug offered a simple solution for wireless on/off control of existing electronic devices or appliances without the need for modification. The switch function only applied to the "on" to "off" states, following the general function of controlling a conventional lamp and a terminal. Functional testing results showed that both nodes could connect to the relay and cut or connect power flow based on commands from UPISmartHome Apps version 2.0. Power consumption testing was conducted by measuring current and voltage in idle-active conditions for both nodes. Furthermore, RSSI measurement results were obtained, indicating that the nodes could be controlled up to an optimum range of 60 meters without an internet connection and were suitable for operation in houses up to type 40. Both nodes were connected to the ESP-Mesh network, which enhanced accessibility as it was scalable. Although the nodes only served basic "On" and "Off" functions, they were suitable for public use and had the potential to add more features at a cost. Features such as power and energy monitoring, automatic disconnection in case of overload, scheduling, security, and privacy access control, etc., could be added. Testing still needed to be conducted for electromagnetic compatibility (EMC), timer accuracy, and Quality of Service (QoS) testing, which included average end-to-end delivery delay, remote to ESP8266, and end-to-end throughput measurement.

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PAPER

Signature Verification Based on Dex CRC and Blake2 Algorithm to Prevent Reverse Engineering Attack in Android Application

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ABSTRACT

The rapid growth of Android applications has led to more cybercrime cases, specifically Reverse Engineering attacks, on Android apps. One of the most common cases of reverse engineering is application repackaging, where the application is downloaded via the Play Store or the official website and then repackaged with various additions or changes. One of the ways to avoid Application Repackaging attacks is to check the signature of an application. However, hackers can manipulate the application by adding a hook, i.e., replacing the original function for getting signatures with a new modified function in the application. In this research, the development of a verification method for Android applications is carried out by utilizing Dex CRC and the Blake2 algorithm, which will be written in C using the Java Native Interface (JNI). The results of this study indicate that the verification method using Dex CRC and the Blake2 algorithm can effectively protect Android applications from Application Repackaging attacks without burdening application performance.

KEYWORDS

reverse engineering, application repackaging, blake2, Android protection

1 INTRODUCTION

Android is a Linux kernel-based operating system developed by Google, which is widely used on smartphones and tablets today. Android smartphone sales are predicted to take around 68% of total smartphone sales. This causes the development of Android applications very rapidly [1]. App repackaging is a reverse engineering attack technique that is used to modify or insert various kinds of code into applications. In application development, there are always hackers who try to exploit/attack applications developed in the form of reverse engineering, including Application Repackaging, which is a common and severe threat in the world of Android

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application development. Hackers can use reverse engineering tools to disassemble an app and change, insert, modify the source code or make fake purchases [2].

Attackers can abuse the app repackaging to commit crimes such as modifying, pirating or inserting malware and then share the application through third-party market applications or websites [3]. According to [4], 80% of malware samples are implemented via app repackaging. Code obfuscation, stub Dex, VMP, and MD5 Signature verification are commonly used to protect applications from reverse engineering attacks, where the code is difficult for attackers to understand the Smali code and they can be bypassed by using some debugging tools, such as DexDump, ARM Pro, NP Manager, Ultima (used for analyzing and extracting Android applications and getting the original code and then repacking the app again) but consume a lot of time to hack. All anti reverse methods mentioned above have vulnerabilities including:

- Ad removal/addition or modification.
  In some applications such as games, there are advertisements that are sometimes annoying so that users try to disassemble the application and then delete/add/modify the existing ad providers in AndroidManifest.xml.
- Cloning.
  When hackers want to duplicate the same application on a Smartphone, this can be done by changing the application package.
- Cheating game.
  Game cheats can be inserted into the application with Reverse Engineering.

To address these vulnerabilities and enhance security measures, we propose a novel signature verification technique for applications. It involves calculating the CRC of the Dex file and encrypting it using the Blake2 algorithm to generate a hash signature [24], which is then used for integrity checks. Even the slightest change in the application will result in a different hash value. Our signature method is independent of the default Android signature, making it difficult for third-party tools to detect or manipulate the signature value. As a result, any repackaged application can be detected and appropriate actions can be taken.

2 RELATED WORK

There are many studies about the method of preventing reverse engineering in Android applications. [5] discussed obfuscation techniques to deceive and delay hacker time to reverse engineer, [6] also introduced obfuscation techniques by adding useless code and encrypting strings on dex, then [7] discussed an advanced technique, namely control flow obfuscation where the obfuscation process is made more complicated and more effective, and [8] combined obfuscation and native code to make the code more difficult to reverse. In the same year, [9][10][11][12][13][23] also improved the obfuscation technique by using similarity analysis to detect repackaged apps. [14] used an obfuscation technique in the Kotlin programming language, which is a new language in Android application development, and in 2019, [15] used an obfuscated logic bomb which will be triggered when the application has been modified.

Another technique is Stub Dex which was discussed by [16]. This technique moves classes.dex to another place in the APK then makes Stub Dex the first to be called when running the application and dynamically loads resources/classes.dex which will run. He also added a rooted/debugging environment and evasion attack.

Furthermore, there is a virtualization technique introduced by [17][18][19] where this technique secures the code by extracting the ARM instruction key and then mapping the instruction into virtual instructions which are then encoded into the SO file. [20] added mapped key protection to the virtualization process to make it difficult to restore so that the code is very difficult to crack. [2] implemented this virtualization method at the binary level making it more difficult to crack and extending the hacking time.

In addition, [1] used the Robust Feature Signature technique where this technique detects malware or applications that have been repackaged using a database of around 1260 application samples and studies the META.INF and classes. dex of each application then calculate the value of its similarity. Furthermore, [21] used the tree structure of the AndroidManifest.xml file to detect cloned Android applications.

The author in [22] compared the original signature of existing applications on the Android market with the signatures of third-party applications and then calculated the similarity values of the two signatures.

3 PROPOSED METHOD

Default Android signature verification using MD5 can be easily obtained from third-party tools and then entered into the hook function which makes the application signature appear as if it has not changed. An example of the default Android signature hook is shown in Figure 1.

```
static void c(Context context) {
    try {
        //MD5 DATA
        String data = "5F745C3E85992E6A87B38A5EE429A62C";
        DataInputStream is = new DataInputStream(data);
        final byte[][] originalSigns = new byte[is.read() & 0xFF][];
        for (int i = 0; i < originalSigns.length; i++) {
            originalSigns[i] = new byte[is.readInt()];
            is.readFully(originalSigns[i]);
        }

        Class<?> activityThreadClass = Class.forName("android.app.ActivityThread");
        Method currentActivityThreadMethod = activityThreadClass.getDeclaredMethod("currentActivityThread");
        Object currentActivityThread = currentActivityThreadMethod.invoke(null);

        Field sPackageManagerField = activityThreadClass.getDeclaredField("sPackageManager");
```

Fig. 1. Code snippet of hooking get signature function to bypass signature verification

Figure 1 shows that the default Android signature that has been obtained using third-party tools will be saved on the hook source code

String data = “5F745C3E85992E6A87B38A5EE329A62C”

and then force getSignature function to return the original signature every time the application is opened using the hook function, so that it appears that the

application has not changed. An overview of the MD5 verification bypass using hooking method (Figure 1) can be seen in Figure 2.

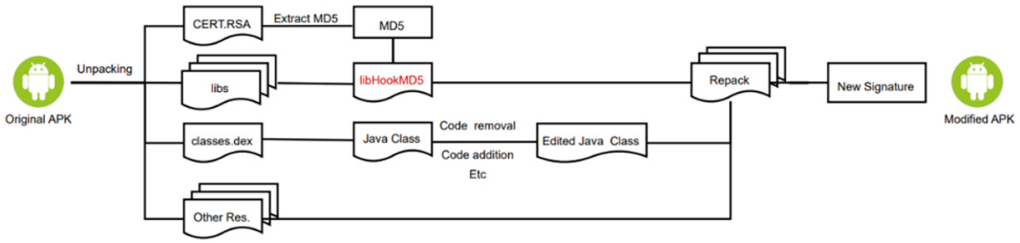


Fig. 2. MD5 verification bypass flow using hook

Hackers use third-party apps or manually bypass signature hook such as "libHookMD5". This hook will manipulate the getSignature function to always return the original md5 signature.

Therefore, we proposed a novel signature verification technique using Dex CRC and Blake2 Algorithm. This technique is written in C using the Java Native Interface (JNI) so that the source code is better preserved from decompilation and can run the blake2 algorithm effectively. This technique works by taking the CRC from classes.dex and then encrypting it using the Blake2 algorithm to get a secure signature hash, then this hash will be verified every time the application runs. If the application undergoes the slightest change, such as changing the application name, changing the package, changing the string, editing the XML layout, or editing the class.dex, the hash signature will change and will still be detectable even though a signature verification bypass has been carried out from several third-party tools. The Dex CRC signature verification architecture can be seen in Figure 3.

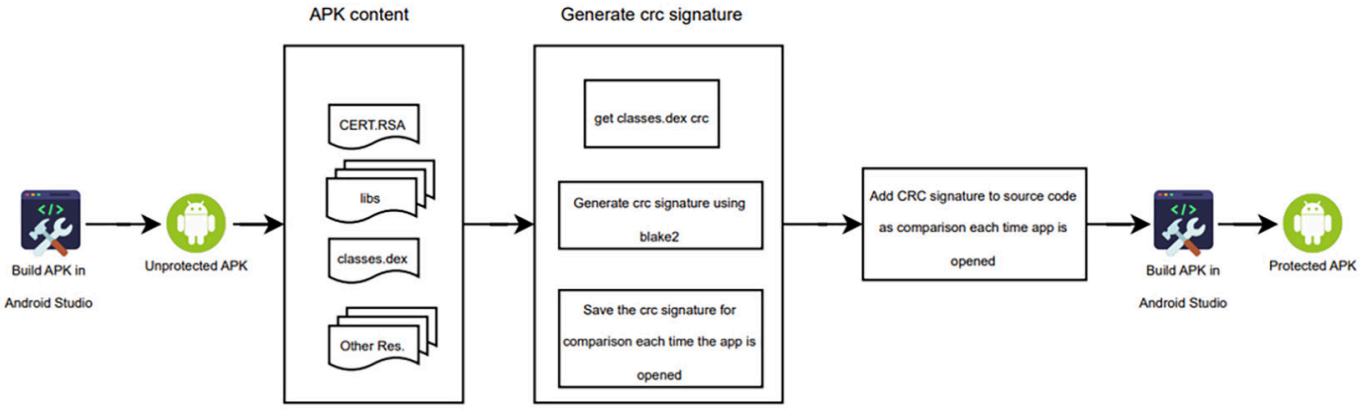


Fig. 3. Dex CRC and Blake2 Signature verification architecture

The developed signature verification method can be resistant to signature bypass attacks because it does not use the default Android signature using MD5. Unlike the method we propose, the signature is obtained from the application classes.dex and then encrypted using Blake2 with a secret key so that the hash signature cannot be obtained by even third-party tools. Hackers may find it impossible or very difficult to get Dex CRC signature to be hooked, see Figure 4.

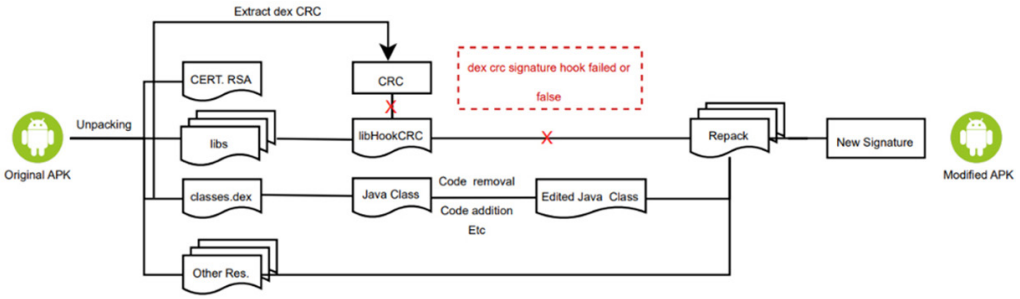


Fig. 4. Dex CRC and Blake2 signature verification cannot hooked/bypassed

Pseudocode 1: Dump/Log the Original Signature

```
1 dumpOrigHash()
2   crc_orig_hash = null
3   Crc = getCRC()
4   crc_hash = blake2(crc, "key")
5   log(crc_hash)
6 End
```

First, we run the application and generate Dex CRC and Blake2 signature using Android log and we save it into the source code as the original signature

Pseudocode 2: Check Signature Function

```
1 CheckSignature()
2   crc_orig_hash = "ABCD" // this is the hash obtained in step 1
3   crc = getCRC()
4   crc_hash = blake2(crc, "key")
5   if (crc_hash != crc_orig_hash)
6     //do some stuff
7     Exit()
8   Endif
9 End
```

After the original signature is obtained and added to the source code, now it will run every time the app is opened and compare the current running Android application signature with the saved original signature to make sure that the application is repackaged or not. If the application is detected as repackaged then the application will force close.

4 PERFORMANCE EVALUATION

We have evaluated the performance of our proposed signature verification based on Dex CRC and Blake2 algorithm to mitigate reverse engineering attacks on applications. The evaluation was carried out by performing some modification/repackaging on Android applications and performing signature bypass using third-party tools to test the robustness of the proposed signature verification. In addition, we also evaluate application performance at startup by comparing CPU, memory usage, and load time in the original application and the application that has been added by the proposed method. To carry out this evaluation, we use a private application because

the code must be added to the source code so that the evaluation is carried out on the application we have made.

In this evaluation, we used the Xiaomi 11T Pro smartphone device with Android version 13 as shown in Table 1. We used Android Studio to evaluate RAM and CPU and used the MT Manager and NP Manager tools to bypass signature verification where these two tools in total have 4 of the most frequent signature bypass methods used by hackers.

Table 1. Smartphone specification

Brand / Type	Xiaomi 11T Pro
Android Version	13
RAM	12 GB
CPU	Snapdragon 888

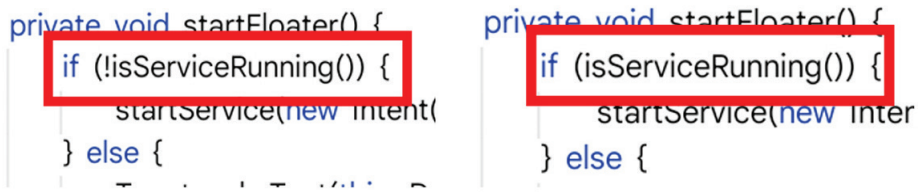
As can be seen in Table 2, we made several modifications to the application and the Dex CRC and Blake2 signature has changed, which indicates that the application is no longer original or has changes.

Table 2. Application modification attack test

No	Attack Type	Original Signature	Signature after Modifying
1	Changing Application Name	D260C66BDD686065825251732B1A...	964A182212F15628812925AC8B...
2	Changing some xml	D260C66BDD686065825251732B1A...	964A182212F15628812925AC8B...
3	Modify classes.dex	D260C66BDD686065825251732B1A...	D1ED8A27415CAF8767F23D7D...

(a) original Smali code **(b) modified Smali code**

Fig. 5. Smali code



(a) original java code **(b) java code after Smali modification**

Fig. 6. Java code

Figure 5 (a) and (b) shows the original Smali code and modified Smali code, respectively [25]. The hacker modified the conditional statement as shown in Figure 5 (b). Figure 6 (a) and (b) shows the original java code and java code after Smali modification.

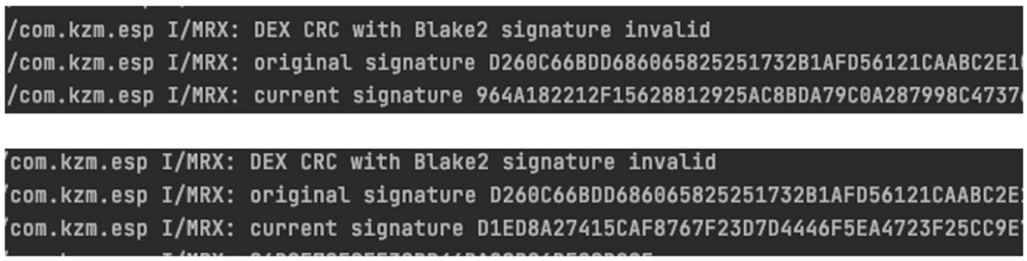


Fig. 7. Signature verification result after changing application name, xml and modifying dex file

Figure 7 shows our method detects and displays a log of signature verification results after changing the app name, XML layout, and modifying dex. In Table 3, the signature verification bypass test was carried out using four signature kill/bypass tools including NP Kill Sign., NP Kill Sign. V2, SF Kill Sign., and Modex 3 Kill Sign., where we can see the results that none of the four bypass signatures can manipulate the proposed CRC signature so that the application can still be detected as an application that is not original or has been modified/repackaged.

Table 3. Signature verification kill/bypass test

No	Attack Type	Original Signature	Signature after Modifying
1	NP Sign Killer	D260C66BDD686065825251732B1A...	DF2825FDC4A03EB45E3F11B9 ...
2	SF Sign Killer	D260C66BDD686065825251732B1A...	D7A94A1F436F46AE3D3159AA...
3	Modex 3 Sign Killer	D260C66BDD686065825251732B1A...	6C36AAA597EE268C49D57CE4...
4	NP Sign Killer v2	D260C66BDD686065825251732B1A...	FAB93CDB2653643CE4F74E5D...

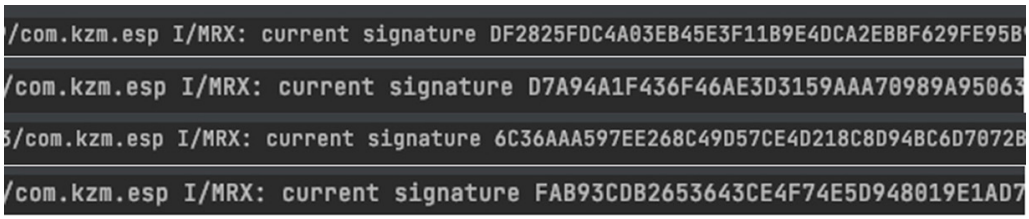


Fig. 8. Signature verification result for signature killer in Table 3

Figure 8 shows that certain logs were deleted by the signature kill tools, but the current signature verification based on Dex CRC and Blake2 remains intact and cannot be bypassed. Furthermore, Table 4 demonstrates that our proposed method has no significant impact on CPU usage, as the highest CPU usage observed in applications using MD5 verification is 29%, while applications using Dex CRC and Blake2 signature verification show a slightly lower CPU usage of 27%. The memory usage of the application where the highest RAM usage is 173 MB for applications using MD5 signature verification and 184 MB for applications using Dex CRC and Blake2 signature verification and the average difference between the two methods in RAM usage is only 3.2 MB. In terms of loading time, MD5 signature and our method (combination of Dex CRC and Blake2) take 5 seconds and 5.57 seconds to open MainActivity of the application, respectively.

Table 4. Performance test table

Attempt	Memory Usage (MB)		CPU Usage (%)		Loading Time (Second)	
	Dex CRC	MD5	Dex CRC	MD5	Dex CRC	MD5
1	168,00	160,00	26	26	4,96	4,71
2	162,00	166,70	26	26	4,54	4,47
3	166,50	161,20	26	25	4,55	4,55
4	162,90	164,30	25	25	4,83	4,84
5	163,00	160,00	25	25	5,00	4,49
6	170,50	162,00	27	26	4,68	4,37
7	167,00	164,00	26	29	4,38	4,25
8	184,20	173,00	18	17	5,57	5,40
9	167,00	162,00	26	24	4,61	5,41
10	168,00	167,40	25	26	5,11	5,19
11	166,30	159,00	25	26	5,00	4,48
12	164,20	159,70	25	25	4,92	4,93
13	162,00	167,00	26	25	4,68	4,75
14	169,50	171,20	26	25	4,67	5,21
15	170,00	165,40	25	26	5,06	5,06
16	170,10	166,50	26	25	5,08	5,08
17	168,60	166,90	26	26	5,00	4,51
18	160,00	161,40	26	24	5,00	4,56
19	170,80	161,20	26	26	4,72	5,07
20	163,70	161,00	25	26	5,54	4,79
Max	**184,20**	**173,00**	**27**	**29**	**5,57**	**5,41**
Min	**160,00**	**159,00**	**18**	**17**	**4,38**	**4,25**
Average	**167,22**	**164,00**	**25**	**25**	**4,89**	**4,81**

We also compare the other method with our proposed method in Table 5.

Table 5. Method comparison

Type of Attack	Method					
	Code Obfuscation	Stub Dex	Virtualization	Robust	Default Signature Verification	Proposed Method
Decompile App	Yes	Yes	Yes	Yes	Yes	Yes
Directly edit decompiled app	Yes	No	No	Yes	Yes	Yes
Recompile/repackage app	Yes	Yes	Yes	Yes	Yes	Yes
Recompiled app can running without signature verification bypass	Yes	Yes	Yes	Yes	No	No
Recompiled app can running after signature verification bypass	Yes	Yes	Yes	Yes	Yes	No

The evaluation shows that reversed/repackaging application using Dex CRC and Blake2 algorithm cannot be run even though hackers add the signature verification bypass as shown in Figure 4. Our proposed method has a minimal impact on application performance because of small changes to the app, unlike the obfuscate and virtualization methods requiring many changes to the code. Hence, the size of the application becomes large, which will affect the performance.

5 CONCLUSIONS & FUTURE DIRECTIONS

This paper presents a novel approach called Signature Verification Based on Dex CRC and Blake2 algorithm for ensuring the integrity of Android applications. By leveraging Dex CRC and Blake2, this method enhances the security of applications against reverse engineering attacks where the repackaged application cannot run even if it has a signature verification bypass. To the best of our knowledge, Dex CRC and the Blake2 algorithm are the first techniques employed to bolster the resilience of Android applications, addressing the vulnerabilities found in existing methods. The performance evaluation demonstrates that the proposed method effectively mitigates signature verification bypass techniques commonly used by attackers. It provides robust protection even against minor modifications, such as changes to application names or packages. Furthermore, the performance evaluation indicates that the use of Dex CRC verification has a minimal impact on application performance.

Our proposed method focused on preventing an application from running after being repackaged/reversed so that the changes made by hackers will be useless. However, hackers could still read the information contained in decompiled applications, especially in the java classes. To cover this issue, a combination of several methods is required so that the anti-reverse method can be improved.

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PAPER

An Effective Intrusion Detection in Mobile Ad-hoc Network Using Deep Belief Networks and Long Short-Term Memory

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ABSTRACT

A Mobile Ad-hoc Network (MANET) is a self-organizing collection of mobile devices communicating in a distributed fashion across numerous hops. MANETs are an appealing technology for many applications, including rescue operations, environmental monitoring, tactical operations, and so on, because they let people communicate without the usage of permanent infrastructure. This flexibility, however, creates additional security vulnerabilities. Because of its benefits and expanding demand, MANETs have attracted a lot of interest from the scientific community. They do, however, seem to be more vulnerable to numerous attacks that wreak havoc on their performance than any network. Traditional cryptography techniques cannot entirely defend MANETs in terms of fresh attacks and vulnerabilities due to the distributed architecture of MANETs; however, these issues can be overcome by using machine learning approaches-based intrusion detection systems (IDS). IDS, typically screening system processes and identifying intrusions, are commonly employed to supplement existing security methods because preventative techniques are never enough. Because MANETs are continually evolving, their highly limited nodes, and the lack of central observation stations, intrusion detection is a complex and tough process. Conventional IDSs are difficult to apply to them. Existing methodologies must be updated for MANETs or new approaches must be created. This paper aims to present a novel concept founded on deep belief networks (DBN) and long short-term memory (LSTM) for MANET attack detection. The experimental analysis was performed on the probe, root to local, user to root, and denial of service (DoS) attacks. In the first phase of this paper, particle swarm optimization was used for feature selection, and subsequently, the DBN and LSTM were used for the classification of attacks in the MANET. The experimental results gave an accuracy reaching 99.46%, a sensitivity of 99.52%, and a recall of 99.52% for DBN and LSTM accuracy reaching 99.75%, a sensitivity of 99.79%, and a recall of 99.79%.

KEYWORDS

mobile ad-hoc network, intrusion detection, deep belief network, long short-term memory, particle swarm optimization

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1 INTRODUCTION

Along with the rapid adoption of lower-cost, smaller, and more capable wireless nodes in recent years, mobile ad-hoc networks (MANETs) have garnered considerable interest, establishing them as among the most promising fields of wireless network growth [1], [2]. Ad hoc networks are widely utilized in wireless systems and are employed in a wide variety of contexts, spanning rescue operations, personal area networking, disaster relief, and a variety of business, scientific, and defense applications [3]. Due to the current proliferation of cutting-edge technology, MANETs have garnered a considerable reputation in recent years [4]. MANETs, which feature self-maintenance, self-configuration, low-cost deployment, are collections of mobile nodes that rely on one another to transport packets and extend the mobile nodes' restricted transmission ranges. The MANET doesn't require any additional infrastructure to be deployed and is extremely inexpensive to implement anywhere [5], [6].

Typically, MANETs do not rely on centralized equipment like routing backbones or fixed routers. There are no connected wires. As a result, nodes are limited to communicating with nodes in their communication range. Because MANET nodes can freely join and leave networks, network elements are unpredictable. It's worth noting that, because wireless technology utilizes open transmission means, monitoring is quite straightforward. Additionally, the absence of a coordinated and unified dubious filtering infrastructure poses significant security challenges for MANETs. As a result, MANETs are especially susceptible to assault. When a source node wishes to transfer packets of data to a destination node over a medium that is open, it employs multi-hop transmission with the assistance of a relay node. Considering the unstructured network, dynamic topology, open media, and great movement of the nodes, hostile nodes can readily infiltrate the network [7].

Malicious nodes attempt to disrupt network resources by dropping data packets, stealing critical information, or modifying data packets, all of which result in unwanted situations[8], a phenomenon referred to as a Denial of Service (DoS) attack[9]. A DoS is an occurrence that impairs or removes a network's ability to execute its intended purpose. The objective is to deprive nodes' interaction of network capacity, resulting in data packets being dropped and bandwidth being reduced, by prohibiting people from accessing resources [10].

A DoS assault is among the greatest famous kinds of network intrusion, to degrade the service offered by a particular target to other genuine customers [11], [12], [13]. There are various types of DoS attacks, including blackhole, wormholes, flooding, and gray hole [14], [15], [16], [17]. Each leverages a unique security flaw in the network and wreaking havoc on variables like connection interruption, traffic flooding, system interruption, and access blocking in the wireless link [18]. The initial three assaults outlined above alter the system's behavior of routing by fabricating and modifying routing pathways. In contrast to the other approaches, flooding attacks target specific network users by sending a large number of bogus data. According to [19], a flooding assault can reduce the packet distribution ratio by much to 84 percent. The UDP flooding assault [20] is a type of data syn flood assault in which the chosen target is overrun by a constant stream of data circulation at a higher bit rate and packet scope than normal. IDS are used to monitor and identify network infractions to recognize and respond to them [21]. As a result, it is critical to successfully implement and manage such systems to assure the integrity and availability of network services [19] [22].

The remainder of the paper is laid out as follows. The related work was described in Section 2. The recommended approach is then presented in Section 3, followed

by the evaluation data gathered through experiments and comparative studies in Section 3. Finally, in Section 4, the conclusion is offered.

2 RELATED WORK

To reveal separate sorts of DoS attacks, ref. [23] presented a cross-layer IDS. They've also used data mining and clustering methods to Figure out how often intrusive activity occurs. When compared to other existing models, this technique results in faster detection of unlawful activities.

Ref. [24] gives another intriguing paper that continues the trend of association-rule (ARM) mining for IDS in the MANET ecosystem. They've released a cross-layer ID framework that can identify malicious networks and other sorts of DoS assaults. This method uses a fixed-width clustering method to capture harmful behavior in MANETs properly. In Moradi et al., [25] the authors presented ANNs used in the MANET viewpoint. They described a neural network-based IDS in MANET for detecting DoS assaults. To capture DoS attacks, the experimental stage is carried out in a virtual MANET setting while reviewing the outcomes of ANN modeling. This set of works gives evidence that the method used can efficiently achieve a high degree of detection for DoS assault. Abdel-Fattah et al. [26] describe an application of IBL in the domain of IDS for MANET. Traditional systems have struggled to gather real-time attacks, prompting scientists to find and resolve the issue by inventing a new intrusion mechanism to reliably identify fraudulent efforts in MANET. The research shows that the unique method can detect anomalous behaviors with small positive percentages whilst attaining a greater detection rate, based on experimental results. In MANET, the authors [27] investigated the K-NN technique further. The goal of this research is to develop a novel intrusion detection model for MANET. To categorize the audit's foreknowledge for anomaly detection, this model uses the CP-KNN algorithmic approach. With the highest accuracy rates, high confidence rate, and a low false-alarm rate, the unique work indicates the accurate detection of many anomalies. Lately, a method for noticing DoS assaults in WMN was developed [28]. The algorithm's performance was tested using average packet drop rate, delay metrics, and packet delivery ratio. By including a priority system in the system, it has remained demonstrated that the projected IDS positively remove malevolent nodes and boost the packet distribution ratio while decreasing the drop of the packet. To track down fraudulent nodes in MANET, a novel tracing approach dubbed ZSBT has been suggested [29]. Before forwarding a packet, nodes insert the area ID into it with a particular frequency using the suggested algorithm. In these instances, the rogue node's identification is inaccurate. SVMs were studied in detail in [30] to detect DoS assaults. The suggested method's performance has been experimentally confirmed, demonstrating that the proposed SVM-based detection methodology provides extremely high accuracy. Ref. [31] proposes a proactive detection approach for DDoS threats with reduced processing complexity. Additionally, a thorough examination of routing assaults and their countermeasures in MANET can be discovered in [17], [14]. The articles conduct reviews of IDS and discuss their fortes and weaknesses. Other systems for dealing with DoS and DDoS assaults in MANETs have been proposed [32], [18]. The earlier suggestions are primarily based on methods that consider a single network attribute, such as hello-interval attack delay [18], or the answer is limited to a single routing algorithm [32]. Hence, the major gaps noticed in previous studies, such as improving the limiting feature selection for data collecting, must be filled. Another issue noticed in existing works is the focus on one specific assault.

Contrary to previous attempts, this paper proposed an FS approach based on PSO for feature selection as against existing studies. The DBN and LSTM models were utilized for the classification of the probe, user-to-root, root-to-local, and DoS attacks as against previous studies that focused on only the DoS attack.

2.1 Proposed DL-IDS for MANET

The proposed DL-IDS is made up of four modules; the collection of data module, a feature selection module, a detection engine module, and a response module. The data collection module feeds the PSO for feature selection operation. The FS feeds the detection engine module with the necessary network facts for specialized data analysis, and the response module acts on the detection engine module's output [33]. Each of the modules is created in stages, with the demands of the ultimate system in mind.

2.2 Collection of data module

The criterion collected in this section is determined by the type of threat to be alleviated. Each type of network interruption impacts distinct system performance factors, and different types of the user to root, probe, remote to local, DoS assaults necessitate different detection and neutralization strategies. When a misbehaving node floods the target in a MANET, it causes a substantial rise in the packets number targeted at the destination per unit of time, effectively outsourcing the target and exceeding the bandwidth boundary which leads to packet drops frequently.

2.3 Feature selection module

The method began with the acquisition of a dataset, followed by data filtering and normalization, which helps to eliminate inconsistent and outlier data. Finally, PSO was used to select the best fraction solution from the dataset, after which the data was separated into two parts: training and testing.

2.4 Detection engine module

The detection module is at the heart of the IDS system and has a significant impact on its performance. It can be created with the help of special algorithms, an ML model, or any ANN [34]. The architecture of the proposed system is given in Figure 1. Nodes (N) contribute to conventional MANET parts such as receiving and delivering data during normal operation, as shown in Figure 2. The destination base (D) collects and processes packets of data without difficulty. Figure 3 depicts a hypothetical circumstance in which the system is under attack. In this case, network nodes (N) keep functioning normally; however, the offending node (A) begins sending a large volume of useless data to its victim (D), which gradually ceases to function properly, resulting in many node failures and delayed signal arrival. The intrusive and normal data statistics are used to train the DBN and LSTM detection modules. The mean of one-second periods is used to calculate the statistics of each feature. The data is separated into test and training portions, which are then normalized and used as the system's input. Because the detection unit has been taught to learn how the network behaves under normal and attack settings, large departures from the norm are labeled as an intrusion.

The system has been tested with various nodes in the network and its performance is verified after teaching the detection module with five nodes.

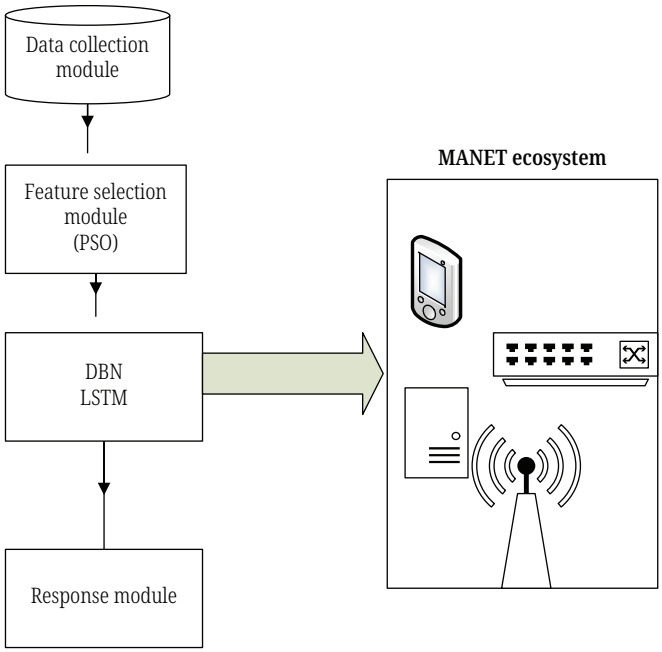

Fig. 1. The architecture of the PSO + DBN-LSTM for IDS-MANET

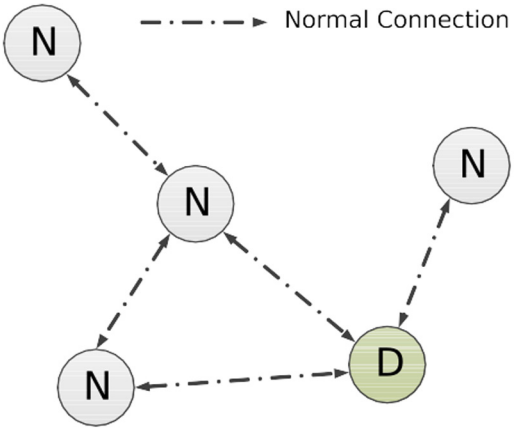

Fig. 2. An example of a MANET environment [35]

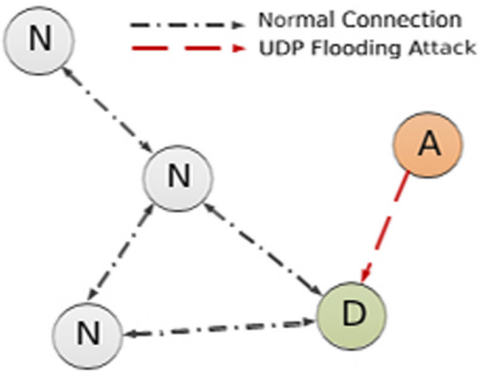

Fig. 3. A MANET amid a DoS assault using UDP flooding [35]

2.5 Response module

The detection module sends the DBN-IDS and LSTM-IDS output to the response module, which makes the ultimate decision. After processing the inputs, the final response is formed, and the relevant actions are taken. Before reacting to the detection module's output, two crucial considerations must be taken into account: the detection module's precision and the potential patterns of future DoS assaults.

2.6 Particle swarm optimization

Particle Swarm Optimization (PSO) is a swarm intelligence-based numerical optimization technique developed by social psychologist James Kennedy and electrical engineer Russell Eberhart in 1995 [36]. PSO is a metaheuristic optimization algorithm paradigm that has garnered popularity in recent years because of its ease of use in unstructured, large high-dimensional data that cannot be handled with classic algorithms [37]. PSO stands for "particle swarm optimization". A set of completely random potential solutions is used to carry out this search. A swarm is a cluster of potential solutions, and each viable solution is referred to as a particle. The search in PSO is impacted by two forms of particle learning. During the motion, each particle learns from other particles as well as from its own experience. Learning from others is referred to as social learning, whereas learning from one's own experience is referred to as cognitive learning. As a consequence of social training, the particle remembers the best solution that any particle in the swarm has visited, which we refer to as gbest [36]. As a consequence of learning skills, the particles save the best answer it has found so far in their memory, dubbed pbest. Figure 4 shows a typical geometric representation of a particle's motion in two dimensions.

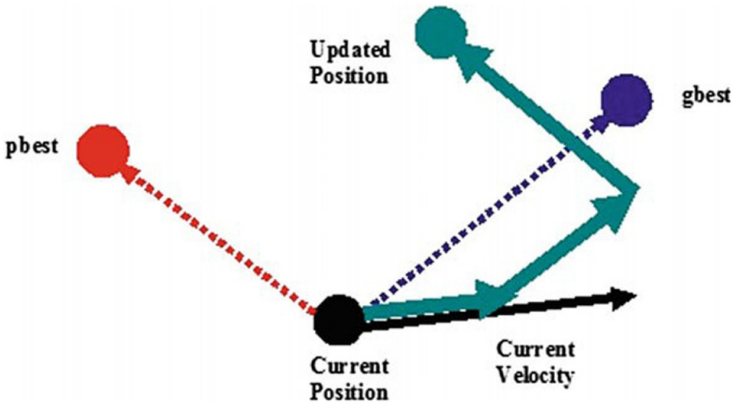

Fig. 4. Particle movement in the PSO process as a geometric illustration [36]

2.7 Deep belief network

The DBN [38], a probabilistic generative system, is a deep neural network classifier that combines RBM [39], a multilayer unsupervised learning network, and BP [39], a supervised learning network. Figure 5 depicts a multilayer generative model with symmetric unguided links in the two highest layers and directed top-down interconnections from the level above in the lower layers [40]. The recognition system is represented by the upward arrows, while the generative model is represented by the downward

arrows [41]. A graphical model of a DBN having m levels can be created. The following is the joint probability of the position as a leading u and the hidden layer i_j for $j = 1{:}m$.

$$p(u, i_1, \ldots, i_m) = p(u \mid i_1) \prod_{m=2}^{j=1} P(i_j \mid i_{j+1})\, p(i_{m-1} \mid i_m) \tag{1}$$

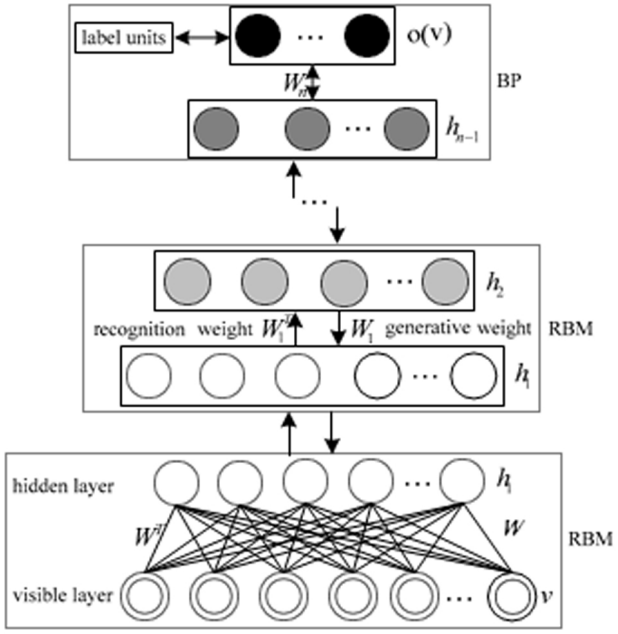

Fig. 5. A DBN and its parameters [41]

2.8 Long short-term memory

The LSTM is a type of recurrent neural network [42]. Hochreiter and Schmidhuber introduced LSTM in 1997 [43]. LSTM are recurrent neural networks (RNNs), which are neural networks with at least one cycle in their underlying structure of inter-neuronal connections. LSTM is designed primarily to understand long-term connections and can overcome the challenges that RNNs had previously [44]. An input layer, one or even more concealed units, and a production (output) layer comprise an LSTM network. The LSTM is arranged in a chain structure. The recurring module, on the other hand, has a unique structure. It features four cooperating levels with a unique form of communication, rather than a single neural network like a normal RNN [45]. Figure 6 showed the diagrammatic representation of LSTM memory cell structure.

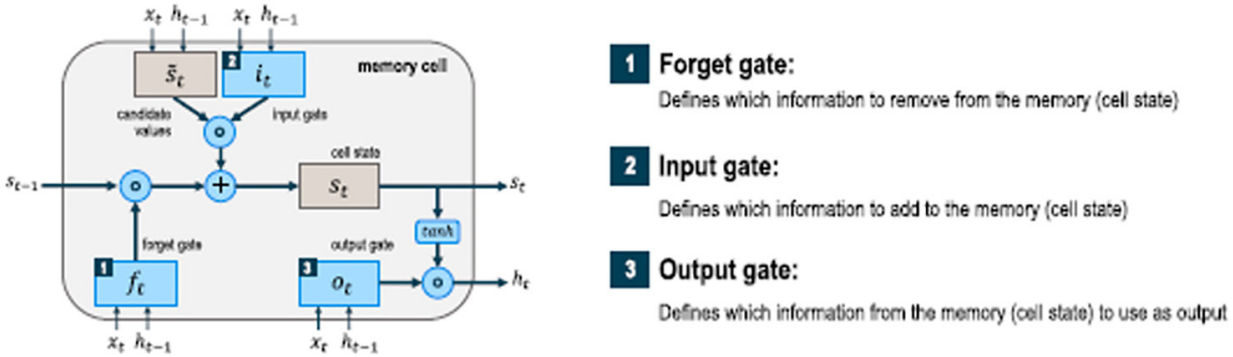

Fig. 6. The LSTM memory cell's structure [44]

3 RESULTS AND DISCUSSION

The system was created to select an efficient DL model for ID in MANET, and this section offers the analysis of the results of the DBN and LSTM methodologies utilized for the experimentation of this research. Among the DBN and LSTM, the experimental model aims to find the best DL classification approach. The training and testing set of data was split in half and passed to DBN and LSTM classifiers, respectively, at a percentage ratio of 75 percent and 25%. Machine learning statistical variables such as classification accuracy, true positive rate, false-negative rate, error rate, specificity, sensitivity, and training duration were used to analyze the outcomes.

3.1 Experimental performance of DBN classification phase

Table 1 lists the DBN classification evaluation parameters for reduced features based on the accuracy, sensitivity, f-score, specificity, recall, and error rate.

Table 1. Performance of the DBN model

Technique	Accuracy	Sensitivity	F-Score	Specificity	Recall	Error Rate
DBN	99.46	99.52	98.79	97.75	99.52	0.5399

3.2 DBN results of system computational time

The actual computing time spent training and processing the DBN for training the dataset is recorded in Table 2, and it is expressed in total seconds spent on the training process.

Table 2. Training of DBN model

Timing Results	Training Time
DBN	58.53

3.3 Experimental performance of the LSTM classification phase

Table 3 displays the LSTM classification's evaluation criteria for reduced features based on the accuracy, sensitivity, f-score, specificity, recall, and error rate.

Table 3. Performance of the LSTM model

Technique	Accuracy	Sensitivity	F-Score	Specificity	Recall	Error Rate
LSTM	99.75	99.79	99.46	99.01	99.79	0.2413

3.4 LSTM results of system computational time

The actual computing time spent training and processing the LSTM network for training the dataset is calculated in seconds. Table 4 summarizes the findings.

Table 4. LSTM training time

Timing Results	Training Time
LSTM	52.33

3.5 Comparative evaluation of DBN and LSTM models

Table 5 illustrates the f-score, specificity, sensitivity, accuracy, and error rate evaluation metrics for the DBN and LSTM models.

Table 5. Evaluation of the performance of the DBN and LSTM models

Techniques	Accuracy	Sensitivity	F-Score	Specificity	Recall	Error Rate
DBN	99.46	99.52	98.79	97.75	99.52	0.5399
LSTM	99.75	99.79	99.46	99.01	99.79	0.2413

The classification accuracy demonstrates that the LSTM network model achieved the best classification rate, implying that the LSTM performed most effectively. Figure 7 showed that the LSTM outperformed the DBN in terms of accuracy, sensitivity, F-score, specificity, and recall while the LSTM model indicates lower error as compared to the DBN network.

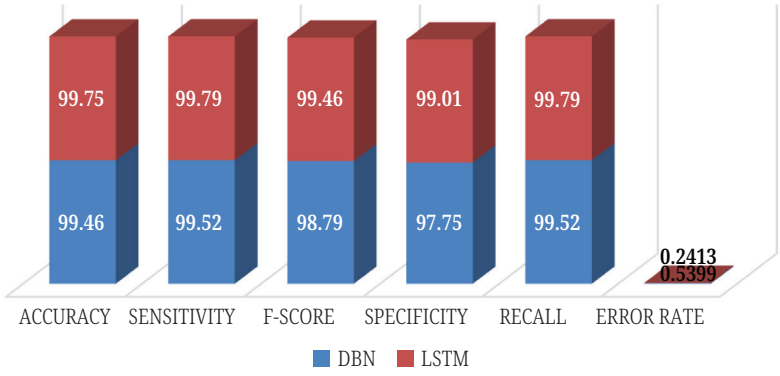

Fig. 7. Comparative evaluation of DBN and LSTM

3.6 Performance of sensitivity vs specificity

The number of right positive predictions divided by the total number of positives is used to compute Sensitivity (SN), whereas the number of correct negative predictions divided by the total number of negatives is used to determine Specificity (SP). The best sensitivity and specificity fall at 1. The obtained results show the sensitivity and the specificity rate have a value close to 1, indicating a good predictive rate. The LSTM proved better than its counterpart as its specificity and sensitivity equate to 1. Figure 8 depicts the metrics of sensitivity and specificity.

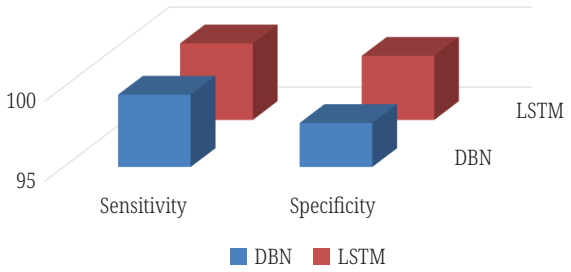

Fig. 8. Sensitivity and specificity metrics

4 CONCLUSION AND FUTURE WORK

MANETs are a far more appealing target for a multitude of different decentralized threats, which generally target the protocol stack's network and data link layers. As a result, deploying an IDS as a second line of protection in MANETs is critical. While authentication and encryption measures may safeguard in some ways, such as lowering the number of invasions, they cannot guard against unknown or unique threats. In this scenario, a deep-learning solution aids in the detection of previously undetected intrusive activity. In this research, we offer MANET detection methods based on DBN and LSTM. The PSO was used for feature selection, while the DBN and LSTM networks were used for the classification of MANET attacks. The results findings showed that the LSTM model gave an outstanding performance when compared with the DBN model. This study identified PSO-LSTM and PSO-DBN as promising AI techniques for estimating attacks in a MANET environment. Especially in the proposed PSO-LSTM model, they could predict the attacks with high reliability.

However, the field of MANET classification techniques is fairly small. When contrasted with the body of information that researchers have studied in other domains, it isn't as extensive. As a result, we recommend that this area be researched further to improve the classification-based IDS in MANET in future work. Additionally, future work may look into the aspect of addressing the classification of IDS in MANET as a multi-class problem and not as a binary problem as shown in this current study.

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PAPER

Performance Evaluation of Machine Learning Approaches in Detecting IoT-Botnet Attacks

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ABSTRACT

Botnets are today recognized as one of the most advanced vulnerability threats. Botnets control a huge percentage of network traffic and PCs. They have the ability to remotely control PCs (zombie machines) by their creator (BotMaster) via Command and Control (C&C) framework. They are the keys to a variety of Internet attacks such as spams, DDOS, and spreading malwares. This study proposes a number of machine learning techniques for detecting botnet assaults via IoT networks to help researchers in choosing the suitable ML algorithm for their applications. Using the BoT-IoT dataset, six different machine learning methods were evaluated: REPTree, RandomTree, RandomForest, J48, metaBagging, and Naive Bayes. Several measures, including accuracy, TPR, FPR, and many more, have been used to evaluate the algorithms' performance. The six algorithms were evaluated using three different testing situations. Scenario-1 tested the algorithms utilizing all of the parameters presented in the BoT-IoT dataset, scenario-2 used the IG feature reduction approach, and scenario-3 used extracted features from the attacker's received packets. The results revealed that the assessed algorithms performed well in all three cases with slight differences.

KEYWORDS

Internet of Things, botnet detection, IoT botnet attack, machine learning, network security, cyber security

1 INTRODUCTION

The Internet of Things (IoT) are physical devices connected with each other over a network; these devices are able to collect and share data with other devices [1, 2]. The IoT devices are low power consumption devices, which makes them suitable for many applications in many sectors [3]. In addition, they have the ability to be used for remotely monitoring, controlling, and managing equipment and systems, which results in enhancing efficiency and reduce costs. Smart home systems are an example of IoT home utilization, which allows the home owners to remotely monitor and

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operate their home appliances [4]. Another example is the wearable devices that can collect health and fitness information to be used later in providing users with advice in terms of nutrition and exercise [5]. Furthermore, healthcare and transportation are growing applications of the IoT. In healthcare, the IoT devices are able to monitor patients' vital signs in real-time, providing the clinicians with the latest information about the patients for suitable care and treatment [6]. In transportation, IoT devices and sensors can be used to monitor and collect data about the traffic flow for better decision making in terms of, for example, reducing traffic jams [7]. However, as the field of IoT connected devices grows, concerns about privacy, security, and data management are emerging [8]. The way IoT devices collect and share data makes these devices vulnerable to many types of cyberattacks, especially in terms of preserving privacy [9, 10]. Therefore, there is need for systems to protect and defend the IoT networks. Despite these obstacles, the potential benefits of IoT are significant, and the technology is expected to expand and improve over the next few years. As more products connect to the internet, the possible applications of IoT become limitless, and it has the ability to change the way we live, work, and interact with the world around us [11].

One of the modern threats that the IoT faces nowadays is Bot-IoT attacks, also known as IoT botnet attacks. Bot-IoT attacks have become a serious threat in recent years as a result of the rise of internet-connected devices and the lack of effective security measures. Many types of bot-IoTIoT attacks include hackers acquiring control of a large number of connected devices (called zombies) and utilizing them to launch coordinated attacks, sometimes by exploiting software defects in the devices. One of the most common uses of bot-IoTIoT attacks is DDoS attacks, in which a large number of devices are used to flood a target server or network with traffic, causing it to become overloaded and unavailable for legitimate users. In rare cases, bot-IoTIoT attacks have been used to carry out ransomware attacks, in which data on the target device is encrypted and held for ransom. Bot-IoT attacks may be harmful for both individuals and businesses. In addition to the financial consequences of cyber-attacks, such as lost revenue and system and infrastructure damage, there may be severe reputational harm [12]. For example, if a bot-IoTIoT assault disrupts a company's operations, it may result in bad news and a loss of confidence from customers and partners. Therefore, it is vital to protect internet-connected devices in order to avoid bot-IoTIoT attacks. This includes updating devices with the most recent security patches as well as using strong passwords and two-factor authentication. It is also vital to regularly monitor network traffic and device behavior for signs of bot-IoTIoT activity, such as unusual spikes in traffic or unexpected changes in device behavior. A number of industry-wide efforts are also underway to fight the bot-IoTIoT threat. Several internet service providers, for example, are striving to restrict bot-IoT traffic, and industry-wide security rules for IoT devices are being created. The bot-IoT threat poses a significant hazard to the growing number of internet-connected devices. However, with proper security measures and proactive monitoring, these risks may be reduced, and the safety and security of these devices and the networks to which they connect can be assured [13].

Machine learning is one of the most recent methods for detecting and mitigating cyberattacks including bot-IoT threats [14]. Its algorithms are trained and tested using well-known benchmarks (datasets). Furthermore, it can identify new sorts of bot-IoT assaults in real-time scenarios [15]. Although machine learning is a potent tool for detecting bot-IoT threats, training and validation utilizing related and well-known datasets is critical to the effectiveness of its algorithms.

The structure of the paper is organized as follows. Section 2 illustrates the literature review. Section 3 presents an overview of the methodology. Section 4 discusses the experiments and results discussion. Section 5 concludes our work.

2 LITERATURE REVIEW

This section will explore some of the latest machine learning techniques used to detect bot-IoT and malwares in IoT environment.

The authors of [16] proposed a hybrid intelligent deep learning approach to secure industrial IoT infrastructure against different types of bit attacks. They have evaluated the proposed approach using N-BaIoT dataset. Authors of [17] proposed a machine learning based model to detect botnet based DDoS attacks in the IoT environment. Different machine learning algorithms were used to build the proposed model such as KNN, MLP ANN. The BoT-IoT dataset was used to train and test the proposed model. A packet based botnet detection system using machine learning is proposed by [18]. Seven features were extracted from network packet and used to train and test the dataset. The authors of [19] proposed a machine learning model combined with hybrid feature selection method to detect IoT botnets. The most informative features were selected to be used by machine learning models in the training and testing stages. A machine learning algorithm based on multilayer framework is proposed by [20] to detect botnet attacks. Filter module and classification module were used for the detection purpose of C&C botnet server. In addition, a behavior based analysis was used to analyze the captured packet's header. The behavioral features of the captured packets during a period of time were used by the proposed deep learning model by [21] to detect botnet attacks. The proposed model is able to classify the detected botnets into categories. Another deep learning algorithm is proposed by [22] to detect botnet attacks in the IoT environment. The proposed algorithm is able to handle imbalanced data using Synthetic Minority Oversampling Technique (SMOTE). The bot-IoT dataset is used by the authors to train and test the proposed algorithm. A two-level deep learning framework is proposed by [23] to detect botnet attacks in IoT networks of smart cities. The framework is able to distinguish the botnet behavior from the legitimate behavior at the application layer of the DNS services. A graph features-based machine learning model is proposed by [24] to detect botnet attacks over networks. CTU-13 and IoT-23 datasets were used to evaluate the proposed model. The model showed the ability to detect the families of the botnets in addition to the ability of facing the zero-day attacks. After testing different machine learning algorithms, authors decided to use ExtraTrees classifier with Pearson's correlation features subset in their proposed model. The authors of [25] put forward an adaptive online learning strategy to detect IoT botnet attacks in real-time. In addition, authors utilized online ensemble learning alongside the proposed adaptive strategy. A real IoT traffic dataset is used to train and test the proposed model.

2.1 The general approach of Bot-IoT detection

Figure 1 illustrates the general scheme of the bot-IoT detection process explaining the steps that will be followed in general to evaluate the machine learning algorithms. Hence, in the real environment, the first step is to capture the IoT network traffic. The next step is to extract the features (parameters) from the

captured packets to be used later (i.e., by the classifier) in the detection process. Therefore, it's vital to capture packets of the IoT network traffic as much as possible to increase the collected information ratio which, as a result, will affect final detection results.

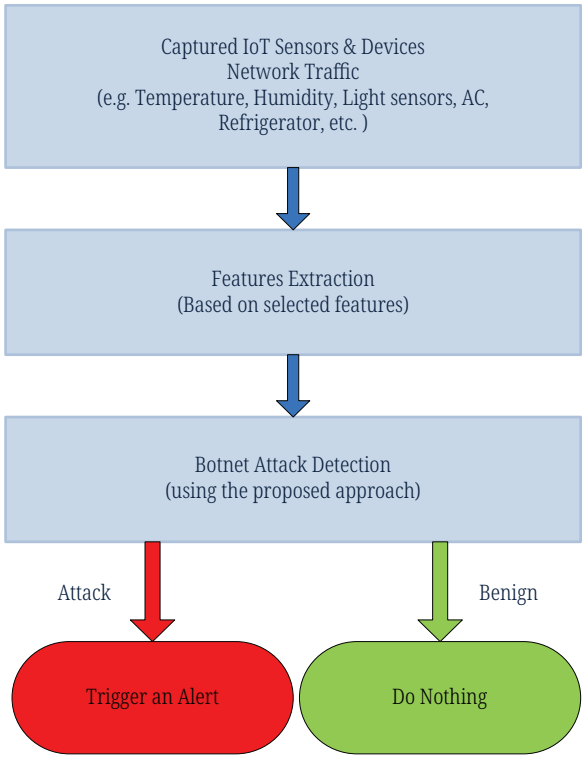

Fig. 1. General scheme of the IoT botnet detection approach

3 METHODOLOGY

3.1 Datasets

As it's difficult to setup a testbed to generate a realistic IoT traffic and simulate bot traffic, we chose to use a well-known benchmark dataset used by literature to evaluate different machine learning approaches [26]. Many researchers used the bot-IoT dataset to evaluate their proposed models. Therefore, we selected bot-IoT dataset for the evaluation purpose. The boT-IoT [27] dataset was developed in the Cyber Range Lab of the Australian Center for Cyber Security (ACCS) using the tshark tool. The collected traffic includes a mix of normal and abnormal (bot) traffic. Ostinato tool and Node-red were used to produce the simulated network traffic. The dataset contains four different types of attacks, namely DDoS, DoS, Scan (probe), and Information theft. The original dataset size is 17 GB. However 5% of the dataset is available for the evaluation of Machine Learning models [28], where reducing the number of used features in both training and testing ML models will reduce the amount of needed resources and, as a result, reduce the needed computing power [29]. Furthermore, to make it easier for the researchers and to achieve a good accuracy results of the training models, the dataset authors extracted a 5% of the original dataset with a total size of 1.07 GB and made it publicly available in CSV file format for academic research purposes [30].

Table 1. Features included in the bot-IoT dataset

Feature No.	Feature Name	Feature Description
1	pkSeqID	Row Identifier
2	proto	Protocol Name
3	saddr	Source IP address
4	sport	Source port number
5	daddr	Destination IP Address
6	dport	Destination port number
7	seq	sequence number
8	stddev	Standard deviation of aggregated records
9	N_IN_Conn_P_SrcIP	Number of inbound connections per source IP
10	min	Minimum duration of aggregated records
11	state_number	Numerical representation of feature state
12	mean	Average duration of aggregated records
13	N_IN_Conn_P_DstIP	Number of inbound connections per destination IP
14	drate	Destination-to-source packets per second
15	srate	Source-to-destination packets per second
16	max	Maximum duration of aggregated records

Table 1 shows the features (attributes) included in the bot-IoT dataset. The number of used features will differ based on the three scenarios, which will be discussed later in this paper.

3.2 Data preprocessing

To conduct the experiment, we analyzed and prepared the dataset to be suitable for the machine learning training and testing processes. Therefore, unnecessary features (i.e., attack subcategory) were taken out of the dataset and the nominal and string features have been converted to numerical values to suit the used classifiers (i.e. TCP-0, UDP-1, etc.) [31]. The 10-fold cross validation is used to evaluate the machine learning algorithms. Figure 2 illustrates the proposed framework to analyze the bot-IoT detection using different machine learning algorithms.

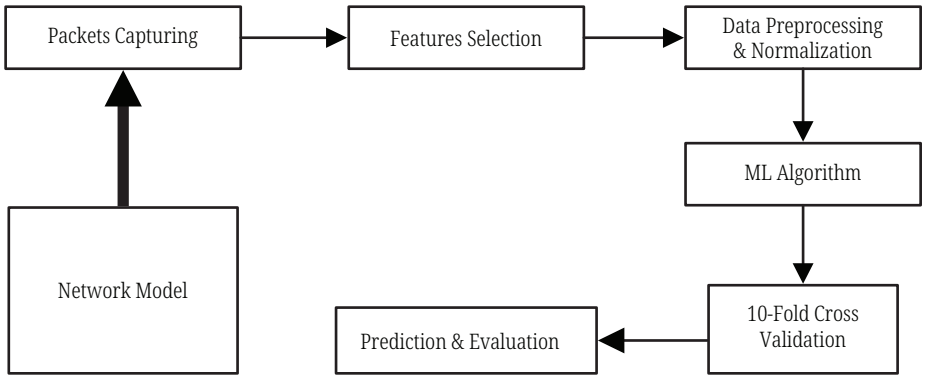

Fig. 2. The Proposed framework for bot-IoT attack detection analysis

4 EXPERIMENTS AND RESULTS DISCUSSION

Three scenarios have been used to evaluate six machine learning algorithms. The first scenario will be conducted using all dataset parameters, and in the second scenario, Information Gain algorithm is used to select the most significant parameters of the dataset. However, in the third scenario, the experiment will rely on source packet parameters. The six machine learning algorithms, namely REPTree, RandomTree, RandomForest, J48, metaBagging, and Naive Bayes, have been tested and evaluated using bot-IoT dataset. In addition, the confusion matrix is used to compare their performance.

4.1 Scenario #1: Experiment with all available parameters

In this section, the experiment will be conducted based on the extracted parameters (all parameters introduced by boT-IoT dataset) from the connection packets between attacker and the targets using six machine learning techniques. As shown in Figure 3, the results of the six classifiers are convergent with slight differences. For instance, Naive Bayes showed the least accuracy and TP rate ratios while the other five classifiers showed 100% of accuracy and TP rate. Whereas in terms of ROC Area, the RandomForest and Naive Bayes classifiers showed the best performance with ratio of 100%. Besides, with 0.2732%, Naive Bayes showed the poorest results in terms of correct instances classification.

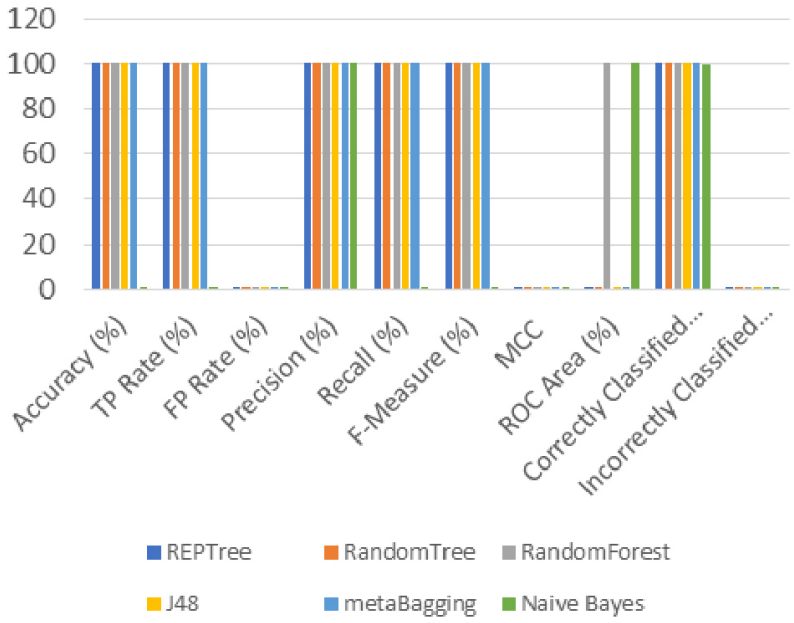

Fig. 3. Testing results using all dataset parameters

4.2 Scenario #2: Experiment with parameters reduction using information gain algorithm

Equation 1 describes the Information Gain algorithm, which is used to evaluate and reduce the number of used parameters. Table 2 illustrates the results of using

IG algorithm for the purpose of parameters reduction. Nine parameters with ranks greater than 0.0005 have been selected to be used in the classifiers testing phase.

$$\text{InfoGain(Class, Attribute)} = H(\text{Class}) - H(\text{Class} \mid \text{Attribute}) \quad (1)$$

Where:
H: represents the Entropy
Class: whether legitimate, suspicious or phishing websites
Attribute: denotes the features

Table 2. Selected features using IG algorithm

P#	P-Name
1	pkSeqID
5	daddr
6	dport
10	state_number
11	N_IN_Conn_P_DstIP
13	srate
8	N_IN_Conn_P_SrcIP
3	saddr
7	seq

Figure 4 shows the results of classifiers testing using the nine parameters selected using IG algorithm. On the first hand, the classifiers showed very good results on comparing with each other. On the other hand, Naive Bayes classifier showed the least performance compared to the other five classifiers in term of Accuracy, TP Rate, Recall, F-Measure, MCC, CCI, and ICI, with ratios 0.997%, 0.997%, 0.997%, 0.999%, 0.209%, 99.7261%, and 0.2739%, respectively. Here it showed a superior performance in terms of FP Rate, Precision, ROC area with ratios of 0.003%, 100%, 100%, respectively.

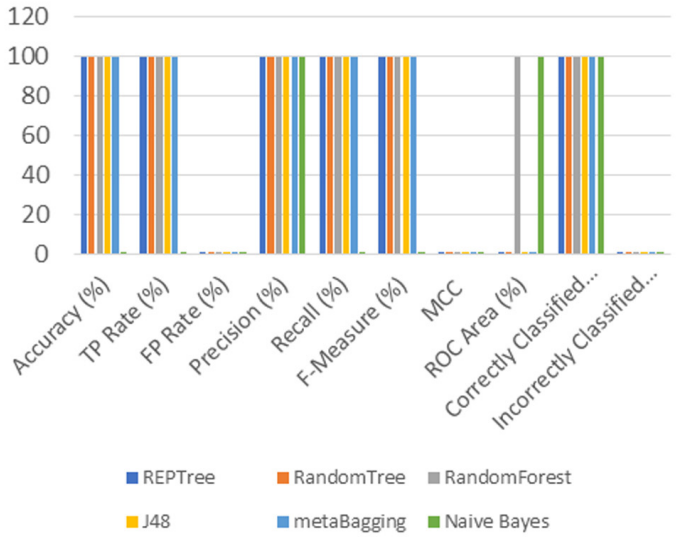

Fig. 4. Testing results using IG parameters reduction algorithm

4.3 Scenario #3: Experiment with source packets parameters

In this section, the experiment will be conducted based on the extracted parameters from the attacker source packets using six machine learning techniques. proto, saddr, sport, N_IN_Conn_P_SrcIP, srate are the five parameters that will be extracted from the attacker source packets to be used to detect the botnet attacks in the bot-IoT dataset. As illustrated in Figure 5, RandomTree classifier showed the best performance among the other five classifiers with following results; 100%, 100%, 0.23%, 100%, 100%, 100%, 0.791%, 0.838%, 99.9949%, 0.0051%, respectively. On the other hand, Naive Bayes classifier showed the least performance in terms of FP Rate, MCC, CCI, ICI with ratios of 0.776, 0.195, 99.9764, 0.0236, respectively.

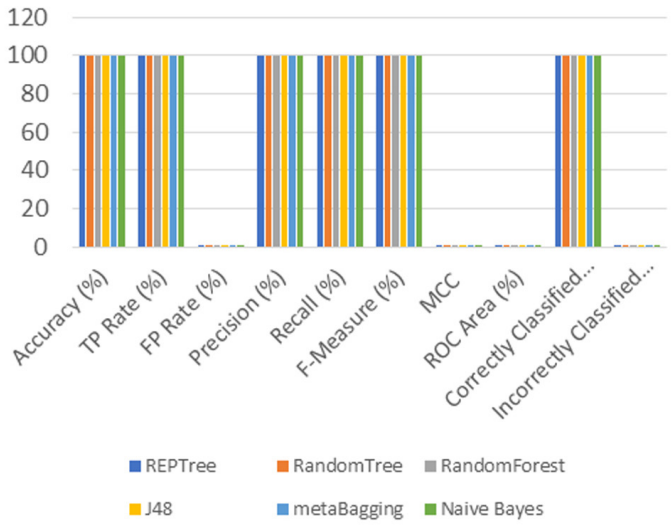

Fig. 5. Testing results using attacker source packets parameters

5 CONCLUSION

In this study, we investigated and examined six machine learning techniques for detecting Botnet attacks in the IoT context. The algorithms that have been tried include REPTree, RandomTree, RandomForest, J48, metaBagging, and Naive Bayes. The six machine learning methods are evaluated using the boT-IoT benchmark dataset, which is a well-known benchmark dataset. The results showed that the RandomForest Classifier outperformed the other examined classifiers in scenario number one. When compared to the other examined classifiers, the RandomTree classifier produced the best results in scenarios 2 and 3. Therefore, it's recommended to use the RandomTree classifier in the IoT environment to detect botnet activities. In the future, additional datasets will be explored to evaluate machine learning techniques. In addition, new machine learning classifiers will be tested in future research.

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PAPER

A Microservices-based Framework for Scalable Data Analysis in Agriculture with IoT Integration

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ABSTRACT

We propose a microservices-based framework for scalable data analysis in agriculture with IoT integration, leveraging the flexibility and modularity of microservices architecture to build a highly adaptable, maintainable, and efficient data analysis system. This framework allows for faster data processing and carry a diversity of agricultural data analysis tasks while maintaining scalability and fault tolerance. Despite the potential benefits, several challenges and obstacles need to be addressed, such as data integration and standardization, the development of agricultural-specific analytical microservices, and ensuring data security and privacy. Practical application and real-world validation are required to assess the impact of the proposed framework on the agricultural sector and inform future research directions.

KEYWORDS

microservices, data analysis, agriculture, IoT, scalable framework

1 INTRODUCTION

Microservices architecture has emerged as a popular software development paradigm due to its flexibility, scalability, and maintainability [13]. By breaking applications into smaller, autonomous services that can be coded, installed, and scaled separately, microservices enable faster development cycles and better resource utilization. In this manuscript, we suggest a framework for leveraging microservices architecture to improve data analysis processes and support diverse analytical tasks in the agricultural domain, which is increasingly reliant on data produced by Internet of Things (IoT) devices [11].

The main motivation behind this article is to address the need for an efficient and scalable framework that can leverage microservices architecture to enhance data analysis processes in the agricultural domain. With the increasing utilization of IoT devices in agriculture, there is a substantial amount of data being generated from diverse sources such as sensors, drones, and satellite imagery [1]. By applying

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advanced data analysis techniques to this vast amount of agricultural data, valuable insights can be gained, leading to improved decision-making, resource management, and overall productivity. Therefore, the development of a microservices-based framework specifically tailored to agricultural data analysis tasks becomes crucial in order to unlock the full potential of IoT in agriculture and provide practical solutions for farmers and other stakeholders.

The proposed framework consists of several microservices, each responsible for a specific data analysis task. These microservices communicate via well-defined APIs, allowing for easy integration and extensibility. Key components of the framework include data ingestion, preprocessing, storage, analytical microservices tailored to agricultural use cases, and an orchestrator to coordinate the interactions among the microservices [2].

In this project, we present the design of the proposed framework, discuss its potential benefits and challenges, and identify areas for future research. The paper is structured as follows: reviews of the relevant literature on microservices, data analysis, and IoT in agriculture; the Methods section describes the methods and components of the proposed framework; section 4 discusses the results and impact of the framework; the Discussion section explores the implications and challenges of implementing the framework; and the final section concludes the manuscript with a swift summary and directions for future research.

2 LITERATURE REVIEW

2.1 Microservices architecture

Microservices architecture is an approach to software development that involves breaking applications into smaller, autonomous services that can be developed, deployed, and scaled independently [13]. This architectural style has gained popularity due to its flexibility, scalability, and maintainability, as well as its feature to support continuous integration and delivery practices.

In [19], the authors present a comparative analysis of an IoT-based smart farming system that integrates machine learning techniques to optimize crop yield and reduce resource wastage in agriculture. The proposed architecture, comprising hardware and software components, is based on an innovative EDGE-Fog-IoT-Cloud platform. The system collects data from various sensors and utilizes machine learning algorithms for soil moisture prediction, enabling informed irrigation decisions. Results indicate the feasibility and cost-effectiveness of the implemented smart farming system in optimizing water resources for precision agriculture. However, limitations of AI techniques, such as training speed and accuracy balance, pose challenges to the integration of machine learning in smart agriculture. The authors propose future research directions, including the collection of physical farming system parameters and measurement of hardware performance at the server level.

A. Abraham et al. (2021) [11] provide a comprehensive overview of microservices architecture, discussing its key principles, benefits, and challenges. They highlight the importance of modularity, loose coupling, and well-defined interfaces in the design and implementation of microservices. Additionally, they address the challenges of data management, security, and monitoring in microservices-based systems.

2.2 Data analysis and machine learning in agriculture

The application of data analysis and machine learning techniques to agriculture has gained significant attention in recent years due to the increasing availability of data from various sources, such as IoT devices, satellite imagery, and weather data [8]. These techniques have been used to address a wide range of agricultural problems, including crop yield prediction, disease detection, and resource management.

For example, A. Abraham et al. (2021) [11] present a review of machine learning applications in agriculture, focusing on crop yield prediction, disease detection, and soil property estimation. They highlight the potential of machine learning algorithms, such as support vector machines, artificial neural networks, and decision trees, in addressing these problems and improving agricultural productivity.

Zhang C et al. (2019) [5] demonstrate the usage of deep learning for image-based cassava disease detection. Using a convolutional neural network (CNN), they achieve high accuracy in classifying cassava leaves according to their disease status. This approach has the potential to aid in early disease detection and targeted interventions, thereby reducing crop losses and improving food security.

2.3 IoT in agriculture

The Internet of Things (IoT) has emerged as a key enabler of data-driven agriculture, allowing for the collection of large volumes of data from various sources, such as sensors, drones, and satellite imagery [1]. IoT devices can provide real-time monitoring and control of agricultural processes, leading to improved decision-making, resource management, and overall productivity.

Previous research discusses the potential of IoT in agriculture, highlighting its role in precision agriculture, smart irrigation, and livestock monitoring. They also address the challenges of data management, interoperability, and security in IoT-based agricultural systems [1].

2.4 Microservices in data analysis

The use of microservices architecture in data analysis has been explored in various domains, as it offers several benefits such as scalability, flexibility, and maintainability [6]. Zaharia et al. (2016) present Apache Spark, a unified engine for big data processing that employs a microservices-based architecture [9]. The modularity and scalability of Spark make it suitable for a wide range of data analysis tasks, including machine learning, graph processing, and stream processing.

3 METHODOLOGY

3.1 Framework overview

The proposed microservices-based framework for scalable agricultural data analysis with IoT integration consists of several key components, each responsible for a specific data analysis task. These microservices communicate via well-defined

APIs, allowing for easy integration and extensibility. The main components of the framework include:

- **Data Ingestion Microservice:** This service handles the ingestion of raw data from various sources, including IoT devices, converting them into a unified format for further processing [2].
- **Data Preprocessing Microservice:** This service manages storage and retrieval of processed data, providing efficient access to the data for the analytical services.
- **Analytical Microservices:** These services implement a range of data analysis algorithms tailored to agricultural use cases, including machine learning models, statistical analyses, and visualization tools [9].
- **Orchestrator Microservice:** This service coordinates the interactions among the other microservices, ensuring efficient resource allocation and fault tolerance.

3.2 Data integration and standardization

One of the main challenges in agricultural data analysis is the integration and standardization of data from various sources, such as IoT devices, satellite imagery, and weather data [1]. The Data Ingestion Microservice addresses this challenge by converting the raw data into a unified format, which can then be used by the other microservices in the framework [2].

3.3 Agriculture-specific analytical microservices

The proposed framework includes a set of Analytical Microservices tailored to agricultural use cases. These services implement a range of data analysis algorithms, including machine learning models, statistical analyses, and visualization tools. Examples of agricultural-specific analytical microservices include:

- **Crop Yield Prediction:** This microservice utilizes machine learning algorithms, such as artificial neural networks or decision trees, to predict crop yields based on historical data and relevant input features, such as weather data and soil properties [8].
- **Disease Detection:** This microservice employs image processing and deep learning techniques, such as convolutional neural networks, to detect and classify plant diseases based on images of affected leaves [3].
- **Resource Management:** This microservice uses optimization algorithms and simulation models to support decision-making related to resource allocation, such as water, fertilizer, and pesticide application.

4 RESULTS AND IMPACT

4.1 Potential impact of the framework

The proposed microservices-based framework for scalable agricultural data analysis with IoT integration has the potential to bring several benefits to the agricultural sector, including:

- **Improved Data Processing Efficiency:** The modularity and scalability of the microservices architecture enable faster data processing, allowing the system to accommodate increasing data volumes and computational demands.
- **Enhanced Flexibility and Adaptability:** The framework's modular design allows for the addition, removal, or modification of individual microservices without impacting the entire system, facilitating rapid adaptation to evolving agricultural data analysis requirements.
- **Better Maintainability:** Separating concerns among distinct microservices simplifies the development and maintenance of individual components, reducing the complexity of the overall system.

These benefits can lead to improved decision-making, resource management, and overall productivity in the agricultural sector.

4.2 Real-world application and validation

While the proposed framework offers promising benefits, its impact on the agricultural sector can only be fully assessed through real-world application and validation. Implementing the framework in a practical setting would provide valuable insights into its effectiveness, as well as any limitations or challenges that may arise during its deployment.

This real-world validation would also serve as an opportunity to gather feedback from end-users, such as farmers and other stakeholders, to inform further development and refinement of the framework. Such feedback would be crucial for identifying areas for improvement and ensuring that the framework meets the diverse and evolving needs of the agricultural sector.

In the next page an updated UML Framework (Figure 1) that provides a more detailed component diagram of the proposed microservices-based framework for scalable agricultural data analysis with IoT integration. It includes additional components like APIs, data sources, and visualizations to help stakeholders and future practitioners better understand the architecture.

In this enhanced diagram, data sources such as Sensor Data, Weather Data, and Satellite Imagery are shown to provide input to the Data Ingestion Microservice. An API Gateway and RESTful API are included to handle communication between the Farmer and the Orchestrator Microservice. Lastly, a Visualization Dashboard component is added to display the results from the analytical microservices back to the Farmer.

This updated diagram should provide a more comprehensive overview of the software architecture, helping future stakeholders better understand and apply the framework.

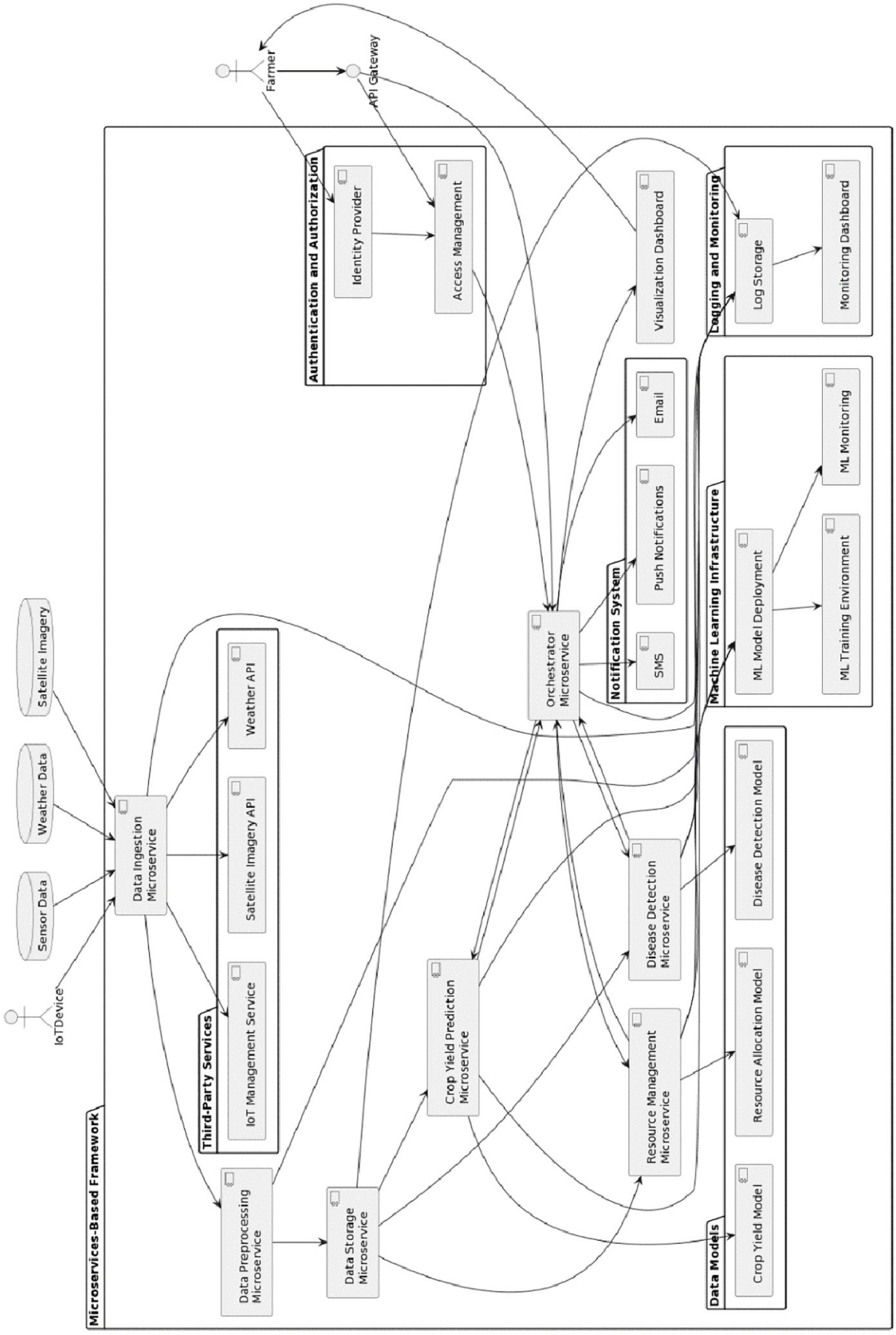

Fig. 1. Software architecture diagram

5 DISCUSSION

While the proposed framework holds significant promise for improving agricultural data analysis, there are several challenges that must be addressed during its implementation. Key challenges and strategies for overcoming them include:

- **Data Privacy and Security:** Ensuring the privacy and security of sensitive agricultural data is a critical concern, particularly when dealing with IoT devices and cloud-based storage solutions. To address this challenge, the framework should incorporate robust data encryption techniques and adhere to industry best practices for data protection.
- **Interoperability:** With a wide variety of IoT devices and data sources in use within the agricultural sector, achieving interoperability among these disparate systems is a significant challenge. The framework should leverage existing data standards and protocols to promote seamless integration with existing systems and devices.
- **Network Connectivity:** The availability and reliability of network connectivity, particularly in rural and remote agricultural areas, can pose a challenge for IoT-based data collection and analysis. To mitigate this issue, the framework should incorporate offline data processing capabilities and leverage edge computing techniques to reduce reliance on constant network connectivity.
- **Scalability:** As data volumes and computational demands grow, the framework must be able to scale to accommodate these increased requirements. The microservices architecture inherently supports scalability, but careful resource management and optimization will be necessary to ensure efficient performance.
- **User Acceptance:** Encouraging adoption of the framework among farmers and other stakeholders may be challenging, particularly if they are unfamiliar with advanced data analysis techniques and IoT technologies. To address this issue, the framework should be designed with a user-friendly interface and provide extensive documentation, training, and support to facilitate adoption.

Some potential solutions to the challenges outlined above include employing robust data encryption methods and adhering to data protection best practices to ensure data privacy and security. Moreover, leveraging existing data standards and protocols can promote interoperability among various IoT devices and data sources within the agricultural sector. To address the issue of network connectivity in rural and remote areas, incorporating offline data processing capabilities and utilizing edge computing techniques can help reduce reliance on constant network connectivity. The microservices architecture inherently supports scalability, but efficient performance can be ensured through careful resource management and optimization.

Despite the limitations, the future vision for the proposed framework involves continued development and refinement to overcome these challenges. Enhancing the framework's usability by designing a user-friendly interface and providing extensive documentation, training, and support can encourage adoption among farmers and other stakeholders. Additionally, ongoing research and collaboration with industry partners can lead to the development of novel solutions for data privacy, security, and interoperability. The framework's success and widespread adoption will depend on a combination of technical advancements, industry collaboration, and user-centered design, ultimately contributing to a more efficient, sustainable, and data-driven agricultural sector.

6 CONCLUSION

In conclusion, we have presented a microservices-based framework for scalable agricultural data analysis with IoT integration. The framework leverages the advantages of the microservices architecture to improve data processing efficiency, adaptability, and maintainability in the context of agricultural data analysis. By incorporating agriculture-specific analytical microservices and addressing the challenges associated with data integration, privacy, security, and user acceptance, the proposed framework has the potential to significantly impact the agricultural sector.

However, it is important to recognize the weaknesses of the proposed framework. The real-world impact of the framework can only be fully assessed through practical implementation and validation. Such validation would provide insights into the effectiveness of the framework, as well as any challenges that may arise during its deployment. Additionally, feedback from end-users, such as farmers and other stakeholders, is crucial for further development and refinement of the framework. This feedback will help identify areas for improvement and ensure that the framework meets the diverse and evolving needs of the agricultural sector.

Future research should focus on the practical implementation of the proposed framework, addressing the challenges outlined in the discussion section, and gathering feedback from end-users to inform ongoing development and refinement. By doing so, the framework can be further improved and tailored to the specific requirements of the agricultural sector, ultimately contributing to more efficient and effective data-driven decision-making in agriculture.

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