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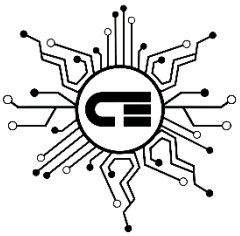
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Lost Centroid ID in CCTV Analytics for Slow Moving Object

Ulva Elviani[1], Hanavi[2], Fadhil Hidayat[3]*

[1]Universitas Pendidikan Indonesia, Indonesia
[2]Kementerian Luar Negeri Republik Indonesia, Indonesia
[3]Institut Teknologi Bandung, Indonesia
Correspondence E-mail: ulva@upi.edu

ABSTRACT

Accuracy is the most common problem experienced by traditional CCTV, especially people counting in locations where people are in the camera's field of view for a long time. This study proposes a method to address the lost centroid ID problem through a time delay mechanism in the object detection and tracking path using YOLO. This method can reduce the number of duplications and improve overall data reliability by maintaining object identities in predetermined frames, even when objects are temporarily undetected. Experiments were conducted on 100 CCTV video recording files in the Bandung train station area. The results showed that in locations in the slow-moving object category, such as waiting rooms, the accuracy increased significantly from 42% to 72% by applying a maxdisappeared threshold value of 200 frames. While at fast-moving object locations, a threshold of 40 frames increased the accuracy from 83% to 94%. This approach improves the performance of the people counting forecasting model for a more reliable surveillance system both statically and dynamically.

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1. INTRODUCTION

CCTV (Closed-Circuit Television) devices are still popular surveillance systems in public spaces. Although effective in recording and monitoring suspicious activity, CCTV, which works traditionally, only functions as a passive monitoring tool. Traditionally, this system requires officers to observe the footage and identify anomalies manually. These issues can cause delays in response and potential negligence. The analytical system embedded in CCTV or CCTV Analytics allows CCTV to monitor in real time and provide feedback to support the early warning system and decision-making process.

Computer vision and deep learning [1][2][3] enable CCTV to detect, classify accurately, and track objects [4]. The YOLO (You Only Look Once) algorithm [5] has been widely used in real-time object detection through video. This algorithm strongly detects objects with high processing speed [6]. Several studies, including those conducted by Barthélemy et al. [7] and Shakil et al. [8], have successfully detected individuals and monitored crowds in dynamic environments such as roads and pedestrian paths.

However, both studies still focus on fast-moving object environments, namely locations where individuals only cross the CCTV camera coverage area for a short time and do not stay in one spot for a long time. This problem is relatively more straightforward in the context of tracking and counting objects. In contrast, slow-moving object environments such as waiting rooms, service counters, or similar locations that require people to be in the camera's range for an extended period pose challenges in maintaining object tracking consistency [9], especially when there is temporary occlusion or stationary behaviour that causes the tracking algorithm to lose its centroid identity (ID) [10]. When the centroid ID is lost, the system assigns a new ID to the same object to be re-detected [1] so that the object is counted more than once [11]. Double-counting of objects significantly reduces the accuracy of the crowd [12] and will ultimately affect the reliability of the forecasting and decision-making models.

To overcome these problems, this study proposes an improved object detection mechanism by inserting a delay buffer to handle the loss of the centroid ID. The main idea of this study is to maintain the object identity for a specific period determined by the maxdisappeared parameter, even though the object is temporarily undetected [13]. For example, at a rate of 30 fps and a maxdisappeared threshold of 200 frames, the system will maintain the ID of a lost object for about 6.6 seconds before considering it permanently lost. The optimal delay value is determined through a trial-and-error approach based on analyzing CCTV footage at five locations in Bandung train stations. This mechanism helps prevent premature assignment of new IDs and reduces the risk of repeated object calculations.

This research's methodological basis lies in using the centroid ID as an object identity marker. Centroid tracking is a widely accepted approach in object counting systems, especially when facial recognition systems cannot be applied. Although face tracking provides more precise identification [14], its accuracy can decrease drastically when applied to conditions where the object is covered by specific attributes such as masks, head coverings, hair, or other obstacles [15]. Likewise, non-image processing [16], such as infrared sensors [17] or WiFi-based presence estimation methods [18][19][20], will experience obstacles in dense environments with overlapping objects. Therefore, this centroid tracking approach balances computational efficiency and tracking reliability.

However, the reliability of CCTV Analytics depends on the accuracy of the object-counting process. Inaccurate calculations can produce incorrect datasets, resulting in incorrect decision-making analysis. For example, overestimating or underestimating the number of

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visitors in crowd management will impact resource allocation and safety and security planning [13]. Therefore, ensuring that each individual is not double-counted is important in producing valid analytical data. Based on these challenges, this study improves the detection and tracking pipeline by inserting a lost centroid ID-solving mechanism for slow-moving object environments. This solution is expected to improve the reliability of people counting, reduce double counting, and produce a clean dataset to support subsequent forecasting models. This study also bridges the practical needs of surveillance-based data analytics, especially in static or semi-static public spaces.

2. METHODS

The method of handling a lost centroid ID is to set the pause time when the system loses the ID. The pause time is determined by trial and error based on CCTV recordings at five Bandung station locations. The length of the pause time depends on the speed at which the system is running. If the speed is 30 fps with a maxdisappeared value of 200 frames, the system maintains the lost ID for 200/30 = 6.6 seconds. The flowchart of the pause time insertion in the YOLO algorithm can be seen in **Figure 1**. The figure generally explains the YOLO v3 algorithm, but is equipped with a tracking function and a proposed method for handling lost centroid ID. The lost centroid ID function insertion is placed on the shaded chart. The detection process begins with a video input resized to 416 x 416 pixels. Using a 3 x 3 kernel, convolution is performed to produce a new image. The new image is max-pooled to reduce the video input. If the output is not the same as 13 x 13 x 25, the convolution and max pooling processes are repeated. Meanwhile, if the output has met 13 x 13 x 25, then the thresholding score calculation and non-max suppression process are carried out. This stage is general in a YOLO algorithm for object detection.

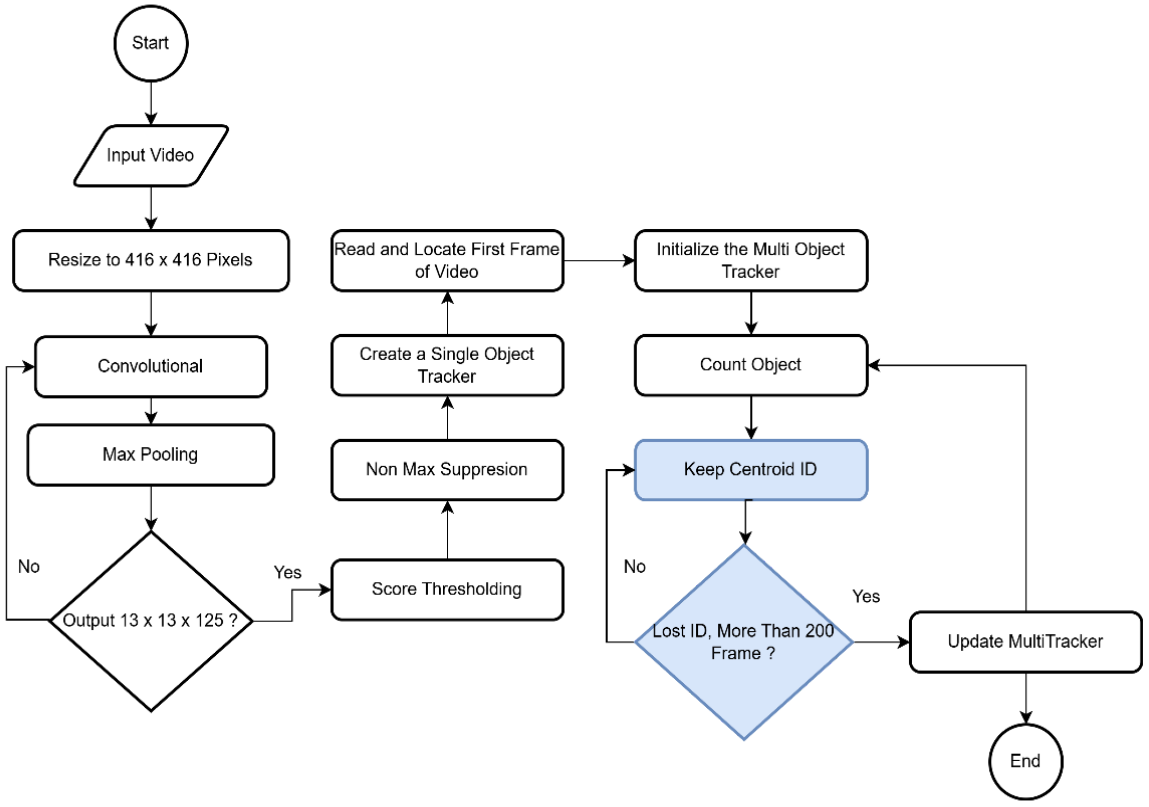


Figure 1. Lost Centroid ID solving flowchart

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Research improvements are in the shaded section. When the object has been successfully detected, tracking is carried out to determine the object's location and provide labelling as a centroid ID number. The counting process occurs every time the system produces a new ID. Therefore, when a lost ID occurs, a pause time setting function is inserted so the system does not immediately update the 17 new IDs. The system will update the new ID if 200 frames have been running, starting from when the system loses the ID.

3. RESULTS AND DISCUSSION

Lost centroid ID is when an object loses detection and simultaneously loses its centroid ID. ID numbering is used to identify each detected and counted object [9]. Therefore, if an object is in the camera's range for a long time and the lost ID occurs repeatedly [11][1], it can cause low counting accuracy [12] and interfere with forecasting results. The lost centroid handling method is demonstrated by sensing 100 video files and presenting screenshots of the detection and counting results. The data used in this demonstration comes from CCTV footage of Bandung Train Station. The description of the dataset and the things involved in the data collection process are in **Table 1**.

Table 1. Data Understanding

No	*Aspects*		*Descriptions*
1.	Describe dataset	Number of video files	100 video files
		Duration per file	± 1 Hour
		Video date	27 – 31 October 2020
		Video time	13.00 – 17.00 WIB
		Channels	5 Channels / Location
		Video format	. Dav
2.	Counting technique	Up and down	Channel 3 and Channel 5
		Stay/All object	Channel 2, Channel 4, and Channel 6
3.	Data collection	Dataset validation	CCTV Stasiun KA Bandung
		Data model	Pretrained Yolo
		Storage duration	Per 5 Seconds

This process uses trial and error to find the optimal pause time to maintain the centroid ID. The pause time is adjusted to each location based on the length of visitor interaction in a room. Locations oriented as paths (fast-moving objects) are given a maxdissappeared value of 40 frames, and locations that function as waiting rooms or services (slow-moving objects) of 200 frames. In addition, determining the pause time also considers the processing speed (fps) when the detection and counting process takes place. The list of test values to find the

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most optimal maxdissappeared value running on a system with a speed of 28 fps is shown in **Table 2**.

Table 2. Maxdissappeared Testing Value

Locations	*30*	*40*	*70*	*100*	*150*	*200*	*240*
Entrance Waiting Room							
South Gate Route							
Exit Waiting Room							
South Entrance							
North Entrance							

Based on the maxdisappeared value test in **Table 2.** The location of the north entrance waiting room, the north exit waiting room, and the north entrance are slow-moving object locations tested with maxdisappeared values of 70, 100, 150, 200, and 240. This location was not tested with values 30 and 40 because the resulting pause time is too small, which is 1.43 seconds, so there is still the potential for the same object to be counted repeatedly. The pause time is obtained by dividing the maxdisappeared value by speed.

Based on the test results at the slow-moving location adjusted to the speed and movement of the number of passengers, the most optimal maxdisappeared value is 200 frames, or equivalent to 7.14 seconds. The location of the south door path and the south entrance are fast-moving object locations tested with maxdisappeared values of 30 and 40. This location was not tested with maxdisappeared values of 70, 100, 150, 200, and 240 because this location only functions as a path, so that visitors are not long in the CCTV range. Based on the test results, the most optimal maxdisappeared was chosen at 40 frames or 1.43 seconds.

The test results prove that handling lost centroids has been proven to minimize counting the same objects repeatedly, especially in slow-moving locations such as the north entrance waiting room, the north exit waiting room, and the north entrance. The lost centroid ID handling method was evaluated at two location points: the north entrance waiting room, which represents the slow-moving location, and the south door path, which represents the fast-moving location. Ground-truth evaluation was carried out by comparing the number of manual calculations with 51 system calculations.

The number of visitors who interacted at the north waiting room location for 5 minutes based on human vision observations was 29 people. In **Figure 2,** shown results of computer vision counting before the lost centroid modification counted 68 people with an accuracy of 42%. After the lost centroid modification, computer vision managed to count 40 people with an accuracy of 72%. Thus, modifying the lost centroid ID at the slow-moving location (north waiting room entrance) increased the counting accuracy by 30.5%. The increase in counting accuracy also occurred at the fast-moving location (south entrance lane). Based on observations, the number of visitors who interacted at the south entrance lane location for 5 minutes was 99 people. Before the lost centroid modification, 120 people were counted with an accuracy of 83%. After the lost centroid modification, it became 105 people with an

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accuracy of 94%. Thus, modifying the lost centroid at the south entrance lane increased the counting accuracy by 11%.



Figure 2. Visual test results in the waiting room north of the exit

4. CONCLUSION

The proposed lost centroid ID method, which applies a delay time of up to 200 frames at the location of slow-moving objects, has proven effective in simultaneously minimizing repeated calculations of the same object. Based on the experimental results of slow-moving and fast-moving objects, accuracy is significantly increased by 30.5% in the waiting room area and by 11-11% on routes with heavy traffic levels. This approach can increase the reliability of people counting on CCTV Analytics, especially for forecasting and strategic decision-making in public spaces.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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Redesigning the User Interface of a Language Translation App to Enhance User Experience Using Design Thinking

Jaka Septiadi[1], Rizki Hikmawan[2], Jihan Nurhaliza[3], Azhar Nurulhaifa[4], Azzahra Salsabilla[5], Indy Hendiyani[6], Jasmine Nayla Hafiezh[7], Afifah Nurfadilah[8]

[1,2,3,4,5,6,7,8]Universitas Pendidikan Indonesia, Indonesia

Correspondence E-mail: jakaseptiadi@upi.edu

ABSTRACT

Language translation applications have become essential tools for supporting cross-language communication and are useful in daily and professional life. Naver Papago is a language translation mobile-based application that utilizes Artificial Intelligence technology. However, the application has a less intuitive interface, which limits users' ability to use its features effectively. The purpose of this study is to redesign the user interface of the Naver Papago mobile-based application to improve user experience. This study uses a Design Thinking approach that prioritizes user needs through five key stages: Empathize, Define, Ideate, Prototype, and Test. In the final stage, the prototype was evaluated by 13 respondents with a usability testing approach and using the Maze platform. Participants were asked to complete 10 representative tasks to assess the functionality and usability of the redesigned prototype. The Maze usability score reached 71%, placing it in the medium category.

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1. INTRODUCTION

In the era of globalization, the use of smartphones has rapidly expanded and become an inseparable part of daily life. Smartphones are not only used as tools for communication but also for various activities such as work, learning, shopping, and accessing entertainment [1]. According to Badan Pusat Statistik (BPS), the smartphone usage rate in Indonesia reached 67.29% in 2023. This phenomenon indicates that smartphones are currently an essential aspect of daily life. The massive use of smartphones in Indonesia has a major impact on daily life. One of these applications is a language translation tool, which plays an important role in facilitating a range of activities, particularly in the context of education [2].

Language translation applications are utilized as tools to assist students in improving their understanding of foreign languages [3]. According to a study [4], the use of translation applications in classroom learning can enhance students' foreign language proficiency, indicating that such applications have a positive impact on the student learning experience. In the field of education, students' learning experience is directly related to the effectiveness of instruction and their motivation to learn. In the context of using language translation applications, an intuitive user interface enables students to access the required information more easily, conduct learning activities more effectively, and improve learning efficiency [5]. A well-designed interactive experience can strengthen learners' sense of involvement and engagement, while also increasing the enjoyment and appeal of the learning process [6].

The author conducted in-depth interviews with students who often use the Naver Papago mobile-based application in their daily lives, especially in supporting the learning process, both in class and outside the classroom. The aim was to analyze the effectiveness of using the application on students' learning motivation. Based on the interview results, most respondents stated that the Naver Papago application has shortcomings in terms of user interface. Some features that are not well understood in their use are rarely used, even though they are important to use. Respondents expressed frustration with the application's lack of user friendliness.

Given these insights, the redesign of Naver Papago's UI/UX is imperative. By applying the Design Thinking approach, this study aims to address user pain points and preferences [7]. This approach ensures that the redesigned interface not only resolves current usability issues but also aligns with user expectations [8]. This study uses the results of in-depth interviews with students to thoroughly understand the challenges of UI/UX in using the Naver Papago application, especially the impact of UI/UX on increasing student learning motivation in multiple languages. This study aims to increase user satisfaction in using this application.

The outcome of this redesign process is a prototype framework that includes several page structures, features, and contents, which provides a representation of the Naver Papago mobile-based application interface design. By emphasizing the importance of a user-centered approach and addressing the specific needs of users, this study aims to provide a comfortable and engaging foreign language learning experience, thereby increasing students' motivation in the foreign language learning process.

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2. METHODS

The design thinking approach is an iterative process that focuses on understanding user perspectives, questioning assumptions, and reformulating to find innovative strategies and solutions that may not be obvious at first [9]. It combines a practical, solution-oriented mindset with a toolkit of interactive methods, offering both a way of thinking and working. Design thinking emphasizes gaining a thorough understanding of the end users for whom solutions are being crafted [10]. This approach encourages empathetic observation and insight into user needs and behaviors. It promotes a mindset of critical inquiry, challenging existing problems, assumptions, and potential outcomes [10][11]. Particularly effective for addressing complex or ambiguous issues, design thinking reframes challenges with a human-centered lens, encourages diverse idea generation through collaborative brainstorming, and embraces iterative development through prototyping and real-world testing. The process is inherently experimental, involving cycles of visualization, model-building, evaluation, and refinement of ideas.

According to the Interaction Design Foundation [9], the design thinking process consists of five stages (see **Figure 1**).

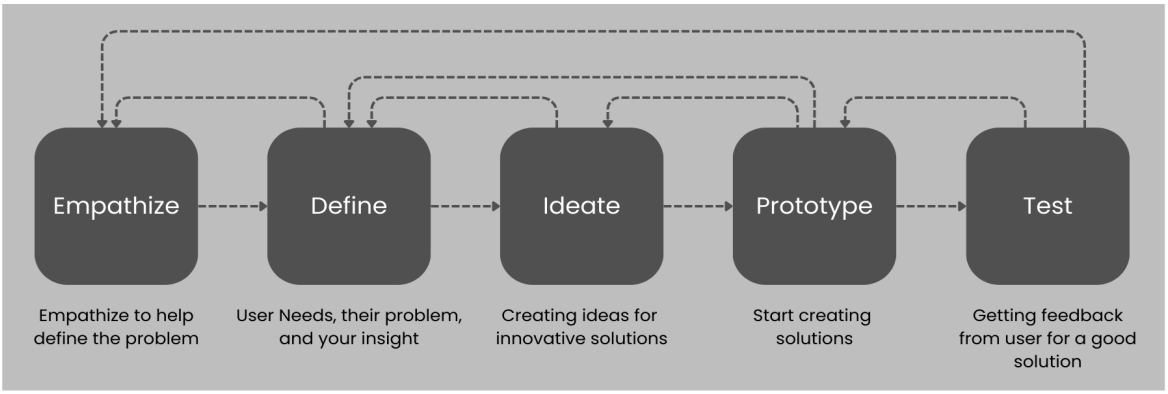


Figure 1. The Design Thinking Process Consists of Five Stages

In the first stage, Empathize is focused on emphasizing ethnographic methods to gain a deep understanding of the user's experiences, needs, and challenges [12]. This stage involves interview and observation methods. The interviews were conducted as direct interactions between the interviewer and the respondents. The interviews were carried out with thirteen college students who frequently use the Naver Papago mobile-based application. The primary goals are to gain a deep, personal understanding of the user's needs, emotions, and experiences. Furthermore, interviews help the author to identify the challenges and frustrations users face, revealing gaps or problems in their current experiences. Observation was conducted by examining how users interact with the application, including their behavior, challenges, reactions, and areas where users may experience confusion or frustration that may not be immediately obvious through verbal communication. In this stage, the author has defined the criteria for respondents, which are as follows:

- College students.
- Aged between 17 and 21 years.
- Users of the Naver Papago application.

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- The respondents are individuals who are proficient in using laptops, smartphones, and technology.

The second stage is Define, where the insights gathered during the empathize stage are analyzed and synthesized to define the core problem that needs to be solved. The objective is to uncover patterns, themes, and key insights that help understand the needs, pain points, and desires of the users. The Define process can be done by using several tools and techniques to help synthesize insights [13], such as affinity diagram [14][15], empathy map [15][16], user persona [14][15][16], how might we [17], and user journey map [18]. In this study, the empathy results are represented through user persona, empathy map, affinity diagram, and storyboard.

The third stage is the Ideate process. The focus in this stage is on generating a wide range of ideas and potential solutions to address the problem defined in the Define stage [13]. Creativity is encouraged during this stage, with an emphasis on thinking beyond conventional boundaries and considering numerous possibilities before refining and selecting the most effective solution [18].

The fourth stage is the Prototype process. The prototyping stage is principally on converting ideas into tangible or digital representations that can be tested and explored [18]. In this stage, the sketches created in the previous stage are converted into low-fidelity wireframes. The design system technique is utilized as a framework for component guidelines to create a high-fidelity wireframe.

The final stage is the Testing process, where the prototype developed in the previous stage is prepared to be evaluated through usability testing. The objective is to verify that the design aligns with user needs and preferences, ultimately enhancing the overall user experience. The usability testing was conducted with 13 participants, who were users of the Naver Papago application.

3. RESULTS AND DISCUSSION

3.1. Empathize

In the process of redesigning the Naver Papago user interface, the empathize stage was carried out to gain a comprehensive understanding of the users' perspectives and experiences, explore the needs, motivations, and challenges or problems of the user. And minimize subjective bias by directly understanding the user's experience. The data collection method at this stage uses the interview and observation method with the user. The questions asked in the interview aim to collect data on the habits, needs, and problems of users in using the Naver Papago application. While observations were conducted to see directly how users behave and react in using the application by monitoring all activities.

After conducting interviews and observations, the author processes all the findings that have been obtained into the form of an empathy map and user persona as a representation of the user's needs. The empathy map generated from the findings is presented in **Figure 2**. In addition, the author uses personas to represent the characteristics of users that reflect their goals, needs, and challenges faced in using the application. This user persona includes

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information such as background, demographics, goals, challenges, and user expectations. The representation of user personas can be seen in **Figure 3**.

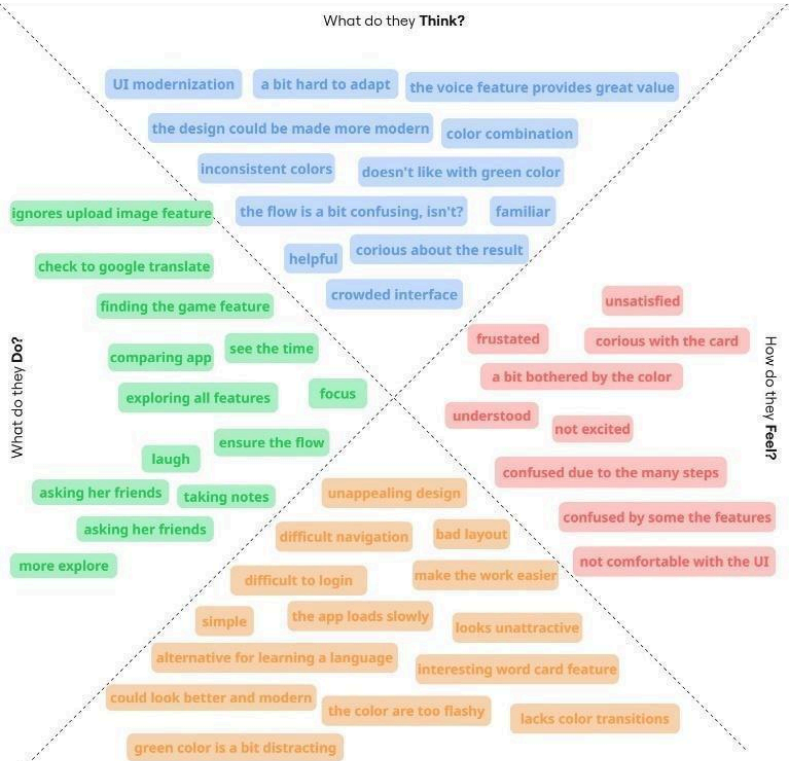


Figure 2. The Empathy Map Generated

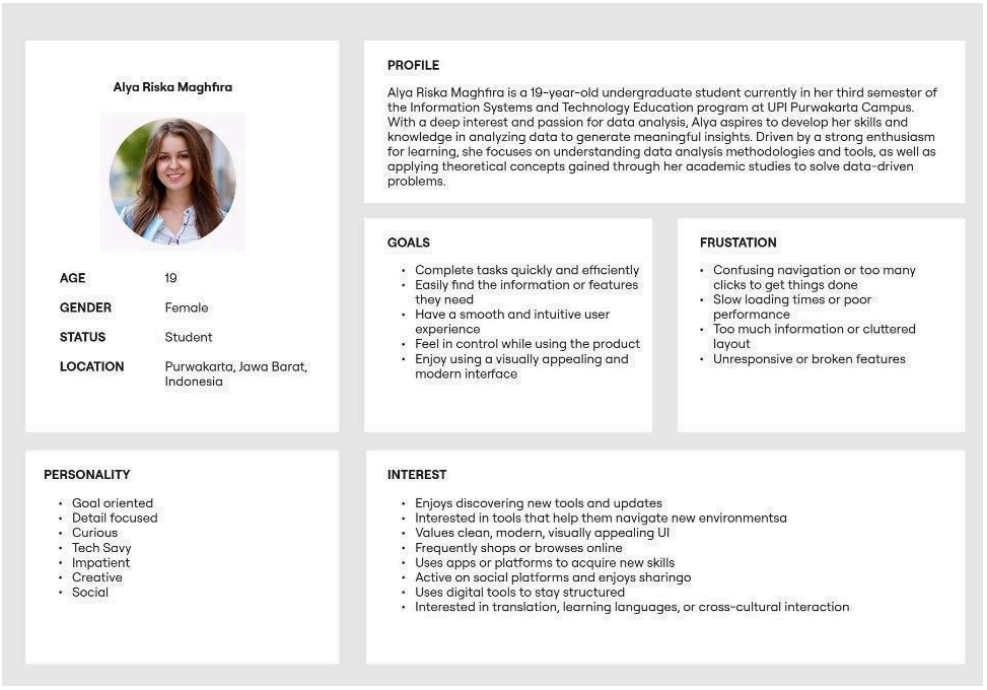


Figure 3. The Representation of User Personas

3.2. Define

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In this stage, the results in the empathize stage will be defined more clearly and will be more focused on the core of the problem. This process analyzes user problems in terms of application usage and determines the desired feature. Pain points were taken based on the interview and observation results that have been mapped into an empathy map. Pain points can be seen in **Figure 4**.



Figure 4. Pain points

Based on Figure 4, two primary aspects are the main focus in the use of the application. The first pertains to user interface concerns, including bad layout, difficult navigation, color, crowded interface, and unattractive design. The second aspect is related to the quality and features regarding duration, facilities, and system specifications. Based on the results of the pain point mapping analysis, this study uses the How Might We (HMW) method, which refers to both aspects of pain points. The HMW results are shown in **Table 1**.

Table 1. How Might We Formula.

How Might We		
Pain Point	**How**	**Possible Solutions (Might)**
Difficult Navigation	How could we simplify the navigation structure?	Redesign the menu with a more logical structure and intuitive icons.
Bad Layout	How could we redesign the layout?	Rearrange UI elements based on priority and ease of access.
Unattractive Design	How could we enhance the visual design?	Apply modern design principles, attractive illustrations, and consistent typography.
Color Combination	How could we apply more harmonious color schemes?	Use a visually pleasing and accessible color palette.
Crowded Interface	How could we remove visual clutter?	Eliminate unnecessary elements and add sufficient white space.

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Difficult to Login	How could we simplify the login process?	Add quick login options like biometrics or social media login.n
Loading Slowly	How could we optimize performance?	Optimize code and images, and implement caching strategies.
Too Many Steps in Word Cards	How could we reduce unnecessary steps?	Streamline word card interactions to one or two essential steps.
Inconsistent Colors	How could we unify the color system?	Create and follow a consistent color style guide.
Unappealing Design	How could we improve design elements?	Redesign icons, buttons, and visual components to be more engaging.
Difficult to Adapt	How could we make the app more intuitive?	Add interactive onboarding tutorials and simplify the interface.
Lacks Color Transitions	How could we introduce smooth color transitions?	Implement soft transition effects between screens.
No Facility to Translate Documents	How might we add a feature that allows users to translate documents directly within the app?	Implement a document upload feature that supports translation for formats like PDF, DOCX, or TXT.
The Colors are too Flashy.	How might we adjust the color scheme to be more visually comfortable and user-friendly?	Redesign the interface using softer, neutral tones or provide a dark mode/light mode toggle for user preference.

3.3. Ideate

Following the define stage, the process continues with the ideate stage. At this stage, the focus is on generating solution ideas for the issues identified earlier. Ideas can be gathered by assessing various existing or accomplished concepts, which will lead to the creation of a user flow and sitemap, crucial elements that serve as a foundation for the subsequent development stages [18]. Before proceeding to the user flow, it is essential to design the Information Architecture (IA). Information Architecture plays a vital role in organizing the content of the application, ensuring that users can navigate and access information efficiently. The construction of the IA not only enhances usability but also acts as a basis for information in user flow design. The IA can be seen in **Figure 5.**

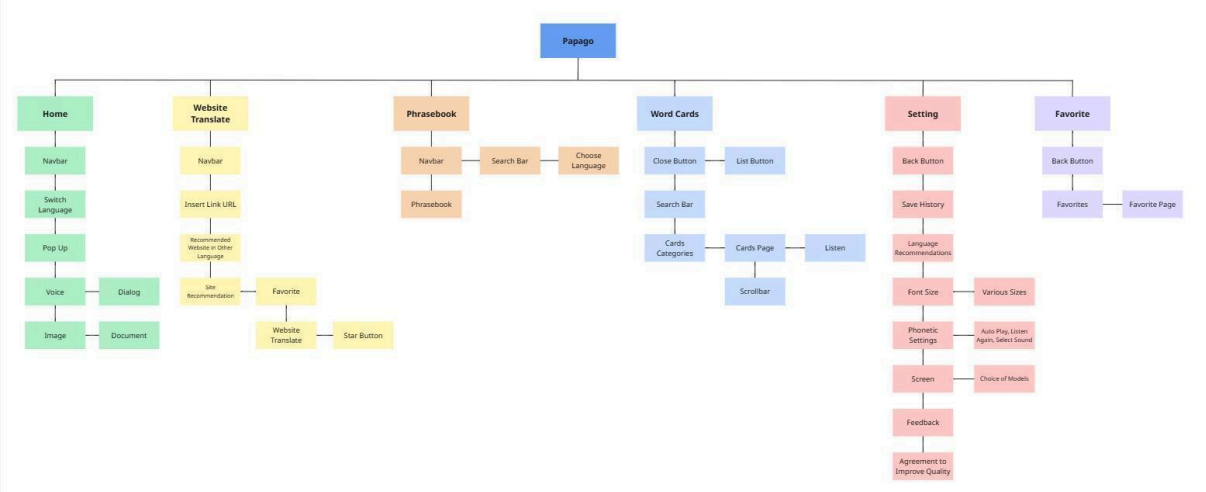


Figure 5. The construction of the IA

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After designing the Information Architecture, the next step is to design the user flow. The user flow is designed to represent the steps taken by the user to complete the main tasks in using the application, thus ensuring that the navigation created is in accordance with the IA structure. The user flow is designed hierarchically; this user flow consists of the main page (parent) and subordinate pages (child). The user flow can be seen in **Figure 6**.

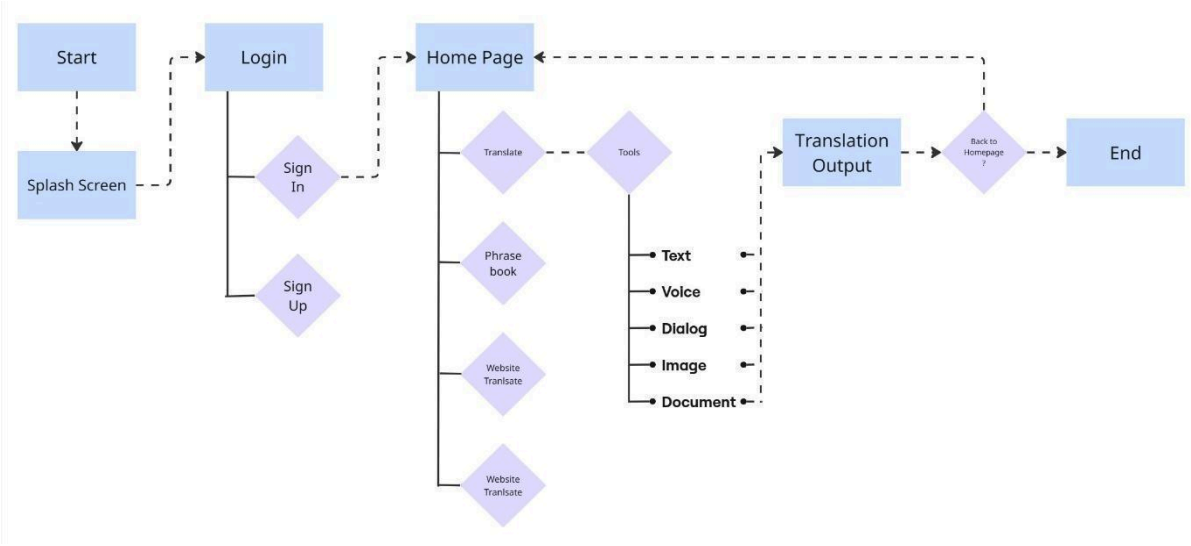


Figure 6. User Flow

3.4. Prototype

In this stage, the potential solution concepts that have been created in the previous stage are further refined into an interactive model. A prototype is a representation of a solution that has been defined in the previous stage and serves as a visual and functional representation of the user interface. This study utilizes Figma as the design tool due to its flexibility in creating prototypes. The prototyping process begins with creating a low-fidelity wireframe that places more emphasis on content layout and information structure. Low-fidelity wireframe can be seen in **Figure 7**.



Figure 7. Low-Fidelity Wireframe

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After completing the low-fidelity prototype and validating the basic structure and functionality, the design process progressed to the design system. A design system was established to ensure visual consistency and interface scalability. The design system includes a set of standardized UI components such as buttons, input fields, icons, color palettes, typography styles, and spacing rules. These elements were carefully defined based on usability principles and brand identity, allowing for a more efficient design workflow and a cohesive look across all screens.

As can be seen in **Figure 8**, in this study, the Papago brand was changed to Mamago as an effort to maintain the credibility and integrity of the original brand, as well as avoid potential violations of intellectual property rights.

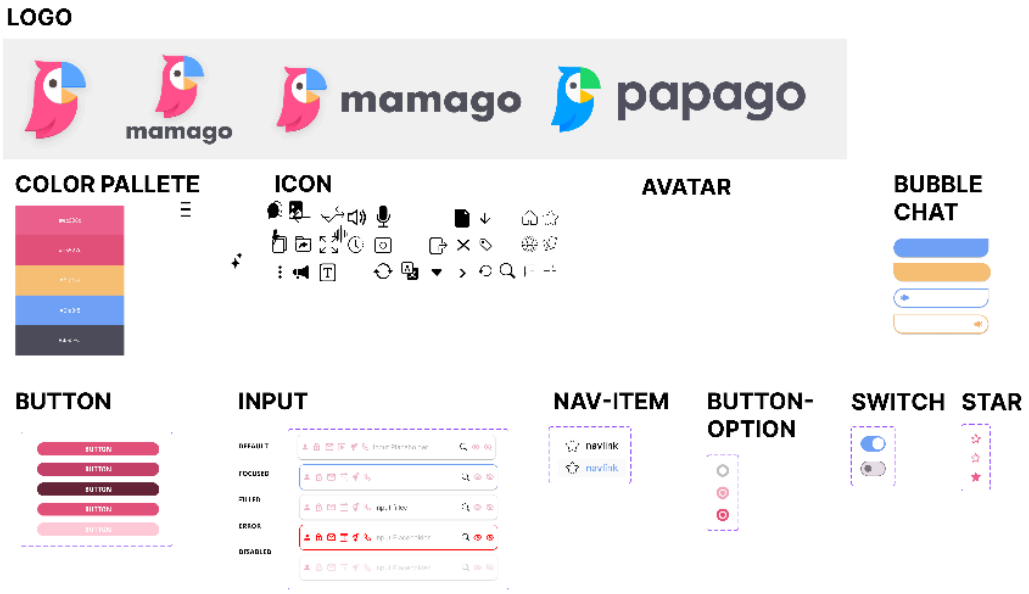


Figure 8. Papago Brand

After completing the low-fidelity prototype and design system, the design process progressed to the development of the high-fidelity prototype. The high-fidelity prototype provides a more realistic representation of the final product, allowing users to better visualize the overall experience. High fidelity wireframe can be seen in **Figure 9**.

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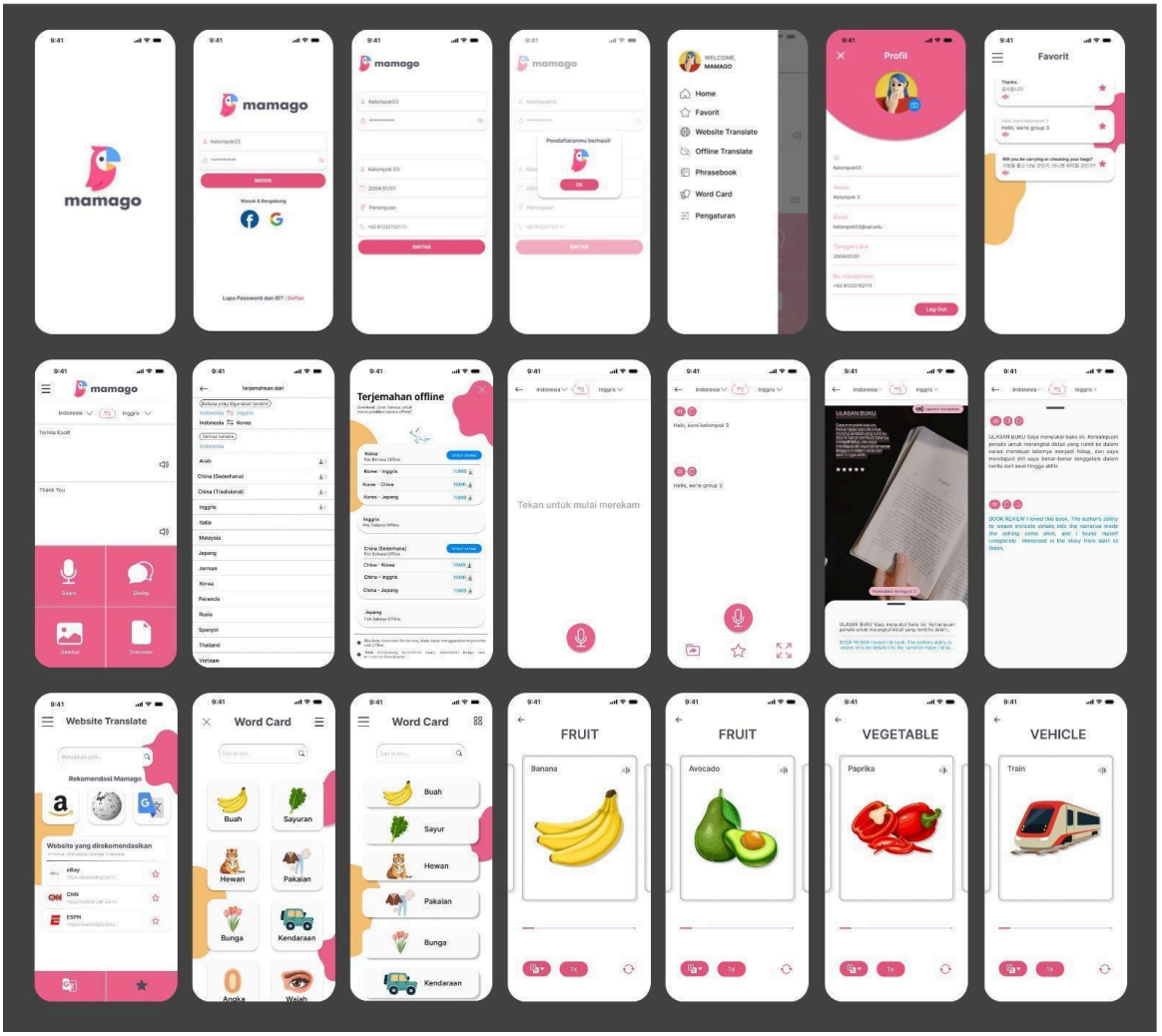


Figure 9. Papago Brand

3.5. Test

The final stage of the design thinking process is Test, which aims to evaluate the usability and effectiveness of the high-fidelity prototype. In this study, usability testing was conducted with 13 student respondents as participants, representing the target user group. In this evaluation, task scenarios were assigned during usability testing to examine the extent to which participants can perform assigned tasks while using the application in their daily lives.

To facilitate the testing process and collect both quantitative and qualitative feedback, the prototype was uploaded to the Maze platform. Maze enabled remote testing by allowing users to interact with the prototype and complete a set of predefined tasks [19]. During the evaluation, each respondent was asked to complete 10 specific tasks that reflect key user goals within the application. The functions included; 1) Registering and logging in to Papago; 2) Translating an image; 3) Translating voice input; 4) Using the conversation (dialog) feature; 5) Editing the user profile; 6) Marking a translation website as favorite; 7) Searching for a phrasebook; 8) Viewing favorite translations; 9) Searching for a word card and; 10) adjusting voice settings. The task scenario and Usability Testing Results Using Maze can be seen in **Table 2 and Table 3**.

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Table 2. Task Scenario

Task	Instruction
Registering and logging in to Papago	Register your account first before you log in.
Translating an image	Take a picture of the object you want to translate, then select all the translation results and click to view the full translation results.
Translating voice input	Record a voice to translate the language and add it to the favorites for the result.
Using the conversation (dialog) feature	Engage in a conversational dialogue to facilitate language translation, and subsequently review the recorded history of the interactions that have occurred.
Editing the user profile	Navigate to your user profile and make edits to any information you choose.
Marking a translation website as a favorite	Add the recommended website to your favorites.
Searching for a phrasebook	Search for a phrasebook in the language of your choice.
Viewing favorite translations	Locate and view your list of favorite translations.
Search for a word card	Search for word cards in the Fruit category.
Adjusting voice settings	Locate and modify the voice settings.

Table 3. Usability Testing Results Using Maze

Task Num.	Usability Score (%)	Success Rate (%)	Misclick Rate (%)	Average Duration (seconds)
T1	71	93.8	35.3	16s
T2	64	100	48.1	31.7s
T3	70	100	29.9	24.1s
T4	68	100	33.4	17.3s
T5	75	100	20	23.5s
T6	60	100	35.1	17.5s
T7	56	85.7	64.3	36.7s
T8	77	92.3	39.1	19.8s
T9	83	100	32.3	13s
T10	86	100	15.8	19.1s
Average	**71**	**97**	**35.3**	**21.8**

The results of usability testing using Maze are presented in Table 3. Scenario testing is measured based on three parameters: (1) task completed; (2) time per completed task; and (3) number of clicks [20]. Task completion time is the time required by a participant to complete a specific task while testing the application. Completed tasks refer to the level of success that includes [21][22]: (1) the task can be completed successfully, and the number of errors in the processing steps is less than or equal to the number of predetermined processing steps; (2) the task can be completed but has more errors in the work steps than the number of predetermined steps; and (3) the task cannot be completed correctly. Misclick evaluates how often participants click incorrectly while completing a task. Average

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duration refers to the time per completed task, which is the duration of participant task engagement is measured from the moment they begin the evaluation until the point at which they cease working on it.

Based on the usability testing results shown in Table 3, the average task completion rate across 10 tasks was 97%, with the overall Maze usability score was 71 71 71%. This gap suggests that although nearly all participants were able to complete the tasks, the experience was not fully intuitive for many of them. Maze usability score threshold is categorized as high (80-100), medium (50-80), and low (0-50). With a Maze Usability Score of 71%, the results of this evaluation fall into the medium category. The evaluation also recorded a misclick rate of 35.5% and an average task duration of 21.8 seconds. The relatively high misclick rate suggests that users may have encountered confusion or uncertainty when navigating the interface, leading them to click on unintended elements. Meanwhile, the average duration indicates that participants generally completed tasks within a reasonable time, although some hesitation or inefficiencies in the user journey may still be present.

4. CONCLUSION

This study successfully applied the Design Thinking approach to redesign the user interface of the Naver Papago application. Through five iterative stages- Empathize, Define, Ideate, Prototype, and Test—the research focused on understanding user needs, identifying pain points, and proposing solutions that address real usability issues.

The results of the usability test show that although the success rate of task completion is very high (97%), the user experience still needs to be improved, as reflected in the Maze usability score of 71%, which is in the medium category. The high misclick rate of 35.5% indicates that some interface elements are not fully intuitive, causing user confusion. The average task completion time of 21.8 seconds indicates that the completion time is reasonable, although there is still room to simplify the interaction flow and improve the overall efficiency of the application.

5. ACKNOWLEDGMENT

The author would like to express sincere gratitude to all participants who were involved in the user interviews and usability testing, particularly the students who provided valuable feedback throughout the design process. Special thanks are also extended to the academic advisors and stakeholders who offered guidance and support during the research. This project would not have been possible without their contributions.

6. AUTHORS' NOTE

The authors declare that there are no conflicts of interest regarding the publication of this article.

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Improving Transformer Performance for Text Summarization in Video Transcription

Rizky Dwi Putra[1], Aldy Rialdy Atmadja[2], Yana Aditia Gerhana[3]*

[1,2,3]Faculty of Science and Technology, UIN Sunan Gunung Djati Bandung, Indonesia

Correspondence E-mail: 1217050127@student.uinsgd.ac.id

ABSTRACT

In conveying information today, it can take the form of online video content. The rapid growth of online video content has created a strong need for automatic text summarization to improve information efficiency. Summarization is important because it allows audiences to quickly capture the essence of lengthy materials, reduces information overload, and ensures that key points can be accessed without going through the entire content. This study explores the use of Whisper Turbo for transcription and mT5 for summarizing Indonesian-language YouTube videos. Whisper Turbo produces accurate transcriptions, although the results vary depending on audio quality and topic complexity. The transcribed text is then summarized using mT5, which achieves strong performance with a ROUGE-1 F1 score of 54.13% and a ROUGE-L score of 49.39%. These findings indicate that mT5 outperforms the standard T5 model despite using less training data. Overall, the combination of Whisper Turbo and mT5 offers an effective solution for generating concise and reliable summaries of video content, with broad potential applications in education, journalism, and digital documentation.

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1. INTRODUCTION

The development of digital technology has brought about significant changes in various aspects of human life, including how information is produced, disseminated, and consumed. Along with the industrial revolution and digital transformation, society is faced with new challenges in managing the rapid and massive flow of information. One tangible impact of this progress is the increased use of digital media, such as video, as the primary means of conveying information [1]. Video-based media has become popular because it can present content in a visual and engaging way [2]. However, to ensure the effectiveness of information delivery, it is crucial to structure content concisely and relevantly, and avoid unnecessary information so that the main message can be clearly received by the audience [3].

Artificial intelligence (AI) and machine learning technologies offer innovative new approaches to addressing this challenge. One application is video summarization, which can efficiently filter and present the core information from long videos [4]. By generating a summary in the form of a short text, this technique not only saves users time in understanding the video content but also helps reduce data size, thereby benefiting both users and computing systems [5].

As the growth of video content on various digital platforms accelerates, the need for technology capable of quickly filtering relevant information becomes increasingly urgent. Video summarization not only offers efficiency in obtaining information but also opens up significant opportunities across various sectors, such as education, media, corporations, and public services [6]. This technology enables users to grasp the core message of a video without having to watch its entire duration. Therefore, various studies have focused on developing intelligent models capable of understanding the context of video and audio, ensuring that the summarization process is not only fast but also maintains the meaning and accuracy of the information conveyed [7].

To achieve optimal video summarization, the use of the Whisper model is one of the key components in this research. Whisper is an audio transcription model developed using the Large-Scale Weak Supervision approach, trained using large-scale data from various sources, recording backgrounds, and languages. This model uses a transformer-based encoder-decoder architecture, with parameter sizes ranging from 39 million to 1.55 billion, depending on the model version. With support for over 98 languages, Whisper offers extensive multilingual capabilities [8]. The data format used is designed to enable the model to perform various tasks flexibly and reliably. Both the encoder and decoder in this model work efficiently to support accurate audio-to-text transcription [9]. Developed by OpenAI, Whisper known as an advanced Automatic Speech Recognition (ASR) system equipped with various automatic filtering mechanisms to improve transcription accuracy. With these capabilities, Whisper can generate text from speech more accurately, which is crucial in the initial stages of summarization [10].

Subsequently, text summarization is performed using the mT5 (Multilingual Text-to-Text Transfer Transformer) model, which has proven superior through deep training and evaluated using the ROUGE metric. The mT5 model leverages strong language representations through neural network architecture, enabling it to generate high-quality summaries. By training this model on the Liputan6 dataset, the system is expected to adapt more effectively to the characteristics of the Indonesian language [11]. Testing transformer models in summarization commonly uses Rouge because Rouge calculates the overlap between the summary

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generated by the model and the reference summary through unigrams (ROUGE-1), bigrams (ROUGE-2), and longer sequences (ROUGE-L for longest common subsequence) [12].

Research on text summarization from video transcripts using transformer architectures has been widely conducted on both English and Indonesian videos. First, this study highlights how the use of Natural Language Processing (NLP) plays a crucial role in accelerating, simplifying, and enhancing the accuracy of content navigation on the YouTube platform. This study demonstrates that NLP can optimize the user experience in consuming digital content. Additionally, the study underscores the challenges and opportunities for future development of NLP-based summarization methods [13]. Additionally, the abstractive summarization approach was also tested using the BART (Bidirectional and Auto-Regressive Transformer) model with training based on the Liputan6 dataset, yielding evaluation scores of ROUGE-1 of 37.19, ROUGE-2 of 14.03, and ROUGE-L of 33.85 [14]. Previous studies that serve as references in this study utilized the T5 (Text-to-Text Transfer Transformer) model and the Whisper model for text summarization in video transcripts. This study utilized a dataset of 50,000 liputan6 transcripts, and the model was able to generate satisfactory summaries, with training evaluation scores of F1-score on the ROUGE metric at 39.23 (ROUGE-1), 13.17 (ROUGE-2), and 23.84 (ROUGEL) [15]. In that study, there was a limitation in token length to minimize chunking or segmentation of the text input, which led to suboptimal summarization results and model performance.

Referring to previous studies that have examined transformer-based automatic summarization technology and automatic speech recognition, this study improves a larger model and proposes an approach that enhances transformer performance while optimizing input token length to reduce text chunking. In addition, this study summarizes videos with a wider range of topics, thereby expanding the scope of evaluation and increasing the relevance of model results in the context of real-world applications.

2. METHODS

This research design began with the data collection stage, which involved collecting videos from YouTube as the main source. The videos were then transcribed using the Whisper model to produce transcript texts as the basis for the next process. The transcription texts will be evaluated for accuracy using the word error rate. The transcripts obtained were not used directly, but went through a preprocessing stage to organize the data into a more structured form suitable for model processing. The preprocessing used was tokenization, which divides the text into small parts such as words or sub-words.

After preprocessing, the transcript text was entered into the mT5 model, which had undergone a learning stage with an Indonesian language dataset taken from liputan6. The mT5 model is an advancement of the T5 model, where mT5 has a larger model size and broader language coverage. In Indonesian text summarization studies, mT5 excels because it is trained on a large dataset that includes Indonesian text [16]. This process produced a summary that was then tested to assess its quality and relevance. The evaluation is carried out using the ROUGE metric, which measures the level of similarity between the generated summary and the reference summary. The evaluation is carried out using the ROUGE metric, which measures the level of similarity between the generated summary and the reference summary. The ROUGE metric is commonly used to evaluate text summarization because it compares the generated summary with the reference summary, producing ROUGE-n and ROUGE-L scores [17]. The final stage of this research is to conclude the effectiveness of the

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combination of Whisper and mT5 in generating informative and accurate text summaries from YouTube videos. The method used is described in **Figure 1**.

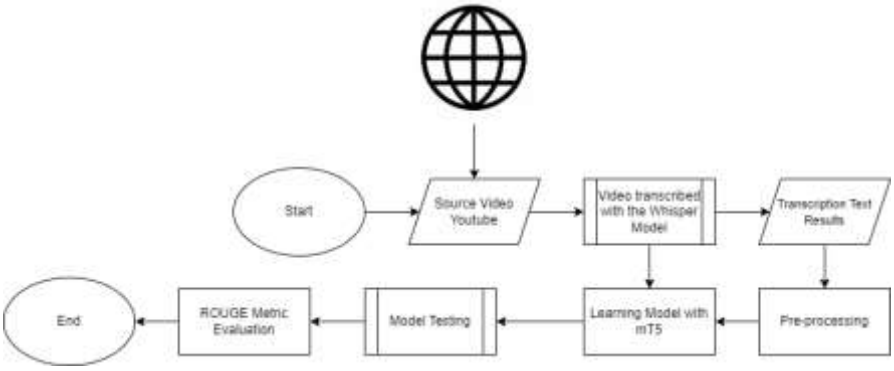


Figure 1. The method of preprocessing.

3. RESULTS AND DISCUSSION

3.1. Text Transcription with the Whisper Turbo Model

Transcription testing in this study was conducted using several YouTube videos with varying durations and topics. All videos were selectively chosen to represent variations in language structure and content length. The transcription process was carried out using the Whisper Turbo model, which is known for its high performance in terms of accuracy and processing speed [18]. Some of the videos used were already equipped with built-in transcripts from YouTube, allowing the calculation of the Word Error Rate (WER) by comparing the Whisper Turbo transcription results with the original transcripts. The WER test results are presented in **Table 1** as a basis for evaluating the effectiveness of Whisper Turbo in automatically generating text transcripts from online videos.

Table 1. Example Sentences Before Tokenization and Tokenization Results

Video Title	Duration (Minute)	Transcription Time (Seconds)	*Word Error Rate* (WER)
Different Tribes, Cultures, And Religions	5	25,09	28,37%
BPUPKI - History of the Investigating Body for Preparatory Efforts for Indonesian Independence	8	46,33	41,44%
History of the First Computer l The Discovery and Development of Computers	20	77,96	30,96%

Table 1 shows the transcription results of YouTube video content, including transcription time and word error rate (WER), which varied. The best WER result was shown in the first video because it was shorter than the other videos, and the sound in the video was clear. The lowest results are shown by the second video compared to the third video, where the second video has a shorter duration than the third video, but the third video has better

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sound and information delivery than the second video. This indicates that WER is strongly influenced by the clarity of the audio in the video [19].

3.2. mT5 Model

3.2.1. Fine-Tuning Using the Liputan6 Dataset

The mT5 model was implemented through fine-tuning on the Liputan6 dataset. This dataset was selected because it consists of Indonesian online news articles covering diverse topics and written in a factual style, making it suitable for training summarization models on long input texts. The Liputan6 dataset contains 215,827 data points categorized into canonical and extreme sets. For the fine-tuning process, 21,000 canonical data points were used. The fine-tuning scenario applied an 80%–20% split, with 80% of the data used for training and 20% for testing [20]. The configuration used for fine-tuning is the mT5 model with 3 epochs, a batch size of 1, and a learning rate of 0.0001. This configuration was chosen to maintain a balance between model accuracy and efficiency and to ensure that the model can understand and learn data patterns optimally in the division scenario used.

3.2.2. Evaluation of ROUGE Metrics on mT5 and T5 Models

In this study, the mT5 model will be compared with the T5 model to determine which performs best in summarization. The mT5 model uses the Liputan6 dataset with 21,000 data points, while the T5 model uses 25,000 data points, both with the same configuration. After the fine-tuning process is done, the model will be evaluated using the ROUGE metric to see how well it works before it's used to summarize videos. The results are shown in **Table 2**.

Table 2. Comparison of mT5 and T5 model metric evaluations with Liputan6 dataset fine-tuning

Scenario	Score	ROUGE-1	ROUGE-2	ROUGE-L
mT5 model 21.000 dataset	*Recall*	**64,45**	**29,85**	**58,99**
	Precision	**47,42**	**20,66**	**43,22**
	F1-Score	**54,13**	**24,04**	**49,39**
T5 model 25.000 dataset	*Recall*	51,05	15,08	44,53
	Precision	30,64	8,58	25,79
	F1-Score	37,78	10,85	32,25

The evaluation using the ROUGE metric, as shown in **Table 2**, presents the recall, precision, and F1-score for ROUGE-1, ROUGE-2, and ROUGE-L. The highest values are observed in ROUGE-1, indicating that the model is quite effective in extracting important words from the video text transcription. On the ROUGE-1 metric, mT5 achieved an F1 score of 54.13%, with a recall of 64.45% and a precision of 47.42%. Similar results were also seen on the ROUGE-2 metric, where mT5 achieved an F1 score of 24.04%, much higher than the T5 model. On the ROUGE-L metric, mT5 again showed its superiority with an F1 score of 49.39%, compared to the T5 model. This comparison shows that even though it uses less training data, the mT5 model is capable of producing more accurate and relevant summaries, and has better efficiency than the T5 model in Indonesian text summarization tasks. This is because the mT5 model itself is a development of the T5 model, where the mT5 model has a larger model size and more language coverage. In processing Indonesian text, mT5 is superior because it is trained with a large dataset that includes Indonesian text.

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3.2.3. Final Evaluation of Text Summarization Results from Whisper Model Transcription Using ROUGE Metrics

The final evaluation in this study was conducted on the text summarization results of 5-minute, 8-minute, and 20-minute videos that had been transcribed using the Whisper Turbo model. The transcription texts from each video were then summarized using the mT5 model, which had previously been fine-tuned with 21,000 articles from the Liputan6 dataset. In this process, the input length of each transcription was limited to 700 tokens to align with the maximum capacity that the mT5 model could process without causing context loss or the omission of important information. To assess the quality of the generated summaries, the ROUGE metric was used, which consists of ROUGE-1, ROUGE-2, and ROUGE-L. These three metrics are used to measure the extent of alignment between the model-generated summaries and the reference summaries based on the occurrence of single words, consecutive word pairs, and the longest common word sequences. The evaluation results of the text summarization from the Whisper Turbo model's transcriptions are shown in **Table 3**.

Table 3. Final Evaluation of Transcription Results Summary for Whisper Turbo Model and mT5 Model

Video Title	Duration (Minute)	Score	ROUGE-1	ROUGE-2	ROUGE-L
Different Tribes, Cultures, And Religions	5	*Recall*	44,28	10,14	27,14
		Precision	25,61	05,83	15,70
		F1-Score	32,46	07,40	19,89
BPUPKI - History of the Investigating Body for Preparatory Efforts for Indonesian Independence	8	*Recall*	**54,95**	**20,90**	**32,43**
		Precision	**37,88**	**14,37**	**22,36**
		F1-Score	**44,85**	**17,03**	**26,47**
History of the First Computer l The Discovery and Development of Computers	20	*Recall*	50,67	13,63	30,76
		Precision	22,35	06,00	13,57
		F1-Score	31,02	08,33	18,83

With the three videos tested, the second video showed the best performance in terms of summarization, discussing “BPUPKI - History of the Investigation Agency for the Preparation of Indonesian Independence.” This can be seen from the ROUGE-1 F1-Score value, which reached 44.85%, higher than the other two videos. In addition, the ROUGE-2 and ROUGE-L scores for this video were also the highest, at 17.03% and 26.47% respectively, indicating that the summary was not only relevant in terms of content but also more structured and linguistically coherent. Compared to the first and third videos, the second video has a better balance between Recall and Precision, resulting in a summary that not only covers important information but also remains concise and relevant. In this study, the good summarization results can be seen in the second video. This is because the second video is not too long (8 minutes), which minimizes the chunking process and helps preserve the information without losing it. In contrast, the third video, which has a much longer duration, produced less accurate summarization results due to excessive chunking, which caused a significant amount of information loss.

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4. CONCLUSION

This study demonstrates that combining the Whisper Turbo model for transcription with mT5 for extractive summarization yields strong results in processing Indonesian-language video content. Whisper Turbo efficiently converts audio to text, while mT5 produces relevant and well-structured summaries, particularly for longer videos. Refinement with the Liputan6 dataset consistently outperforms T5, showing that multilingual models adapt better to Indonesian linguistic structures. The approach has broad applications in education, advertising, and other sectors where video is a key medium for information delivery. Future improvements could focus on expanding the model's ability to handle a wider variety of content, thereby enhancing its generalization capability. In addition, exploring advanced models such as LongT5 and applying hybrid summarization approaches, combined with user evaluation, holds strong potential for achieving near human-level summarization quality. Furthermore, this research can be further developed by incorporating datasets from Indonesian regional languages.

5. ACKNOWLEDGMENT

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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Prototype of Blockchain-Based Diploma Transcript Authentication Method

Aprianti Nanda Sari[1], *Trisna Gelar* [2*]

[1,2]Department of Computer and Informatics Engineering, Politeknik Negeri Bandung, Indonesia
Correspondence E-mail: trisna.gelar@polban.ac.id

ABSTRACT

Each year, more than one million students receive their degrees from institutions of higher education. Some of them may make use of their diplomas and academic transcripts to apply for jobs or to pursue a career. To reduce the likelihood of diplomas being forged, the Ministry of Education and Culture of the Republic of Indonesia has implemented the Electronic Diploma Verification System (SIVIL). On the other hand, SIVIL storage is still carried out in a centralized way, which means that there is a risk that irresponsible parties could cause damage to the integration of diploma data that has been stored. The purpose of this research is to integrate blockchain theory and architecture to preserve the authenticity of diplomas, thereby resolving this issue. The identification of the problem, the review of the relevant literature, the analysis, the design, the production of the prototype, and the testing were done to accomplish this objective. According to the findings of the tests, the prototype that was developed can satisfy functional requirements and preserve the integrity of the data that is contained on diplomas and academic transcripts.

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1. INTRODUCTION

Based on the higher education data in Indonesia for the year 2020, over one million students completed their studies, and a portion of them will pursue employment in the industrial sector[1]. As part of the recruitment process, graduates are typically required to provide evidence of their academic accomplishment by submitting a copy of their diploma and academic transcript. Yet numerous issues arise, including the loss and forgery of those educational assets. Diploma forgery is a criminal offense involving the fabrication, modification, or use of a forged diploma with the purpose of obtaining employment prospects and advancing one's career[2]. This action constitutes academic fraud and violates Article 263 of the Criminal Code (KUHP). This has negative consequences for multiple stakeholders, including both the industry and institutions[3]. Given that accreditation by independent bodies like BAN-PT serves as a crucial mechanism for ensuring and standardizing the quality of higher education, the act of diploma forgery directly contradicts these efforts and erodes the trust placed in accredited qualifications.

On the other hand, blockchain, which was introduced by Satoshi Nakamoto in 2008, has had a significant impact on data storage methods in different industries[4]. Essentially, a blockchain is a collection of data blocks that are linked together through a hash value. Once a block is added, it cannot be easily changed. This makes blockchain highly resistant to data tampering [4], [5]. In the context of diploma authentication, blockchain offers an opportunity to prevent forgery by ensuring that any record (such as a student's graduation data) cannot be altered without detection. Furthermore, because each copy of the data is stored across many computers (called nodes), unauthorized changes on one computer will not affect the overall system.

Multiple related research studies implemented blockchain as a method of validating the authenticity of diplomas and transcripts. The majority of the research makes use of established blockchain platforms such as Blockcert and Ethereum [6] , [7] , [8] , [9] , [10] , [11]. Consequently, the diplomas and transcripts are maintained in the format of photographs or scanned images, demanding significant storage capacity. The diploma and transcript link in the form of a QR Code is then embedded in the original diploma and transcript document, or you can also use the client application provided. Embedding the QR Code is not in compliance with Regulation 59/2018 issued by the Minister of Research, Technology, and Higher Education of the Republic of Indonesia. This regulation specifically pertains to diplomas, competency certificates, professional certificates, degrees, and the protocols for documenting degrees in higher education institutions.

The objective of this research is to explore the implementation of blockchain technology in securing educational assets in higher education, to prevent the counterfeiting of these assets while complying with Indonesian laws, without providing additional information (such as a QR Code) on the diploma. Additionally, this research aims to identify methods that can do this while decreasing storage memory requirements.

2. METHODS

This research has eight distinct stages: problem identification, literature review, analysis, design, prototype development, and testing, as shown in **Figure 1**.

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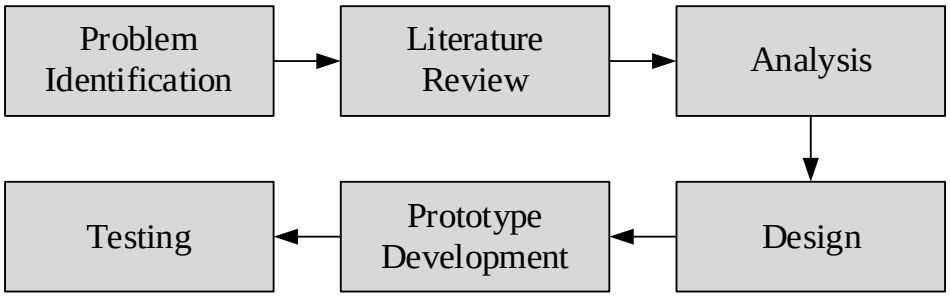


Figure 1. Research Methodology

2.1. Problem Identification

Problem Identification refers to identifying and characterizing problems or difficulties that are unique to blockchain technology and how it is used as a higher education certificate authentication method.

2.2. Literature Review

Once the problem has been identified and the underlying cause has been determined, the next step involves conducting a comprehensive review of existing literature. The objective is to acquire a fundamental theory that applies to the topic at hand. For this literary analysis, scholarly papers and other relevant sources on the subsequent subjects, i.e., hash functions, peer-to-peer networks, consensus algorithms, blockchain, and its architecture, will be consulted.

2.3. Analysis

Once the literature study is finished, the subsequent step involves doing a comprehensive analysis. This analysis encompasses examining the many components found on diplomas and transcripts, studying similar research conducted previously, and assessing the requirements of the method that is to be produced.

2.4. Design

Once the needs analysis is completed, the subsequent stage involves designing the proposed approach by developing a visual and conceptual representation. The design encompasses the creation of a blockchain architecture, the design of a process for storing and verifying educational asset data.

2.5. Prototype Development

Once the analysis and design of the system requirements are completed, a prototype will be developed. The Python programming language is utilized for prototype development.

2.6. Testing

The primary objective of this prototype testing is to obtain a profound understanding of the degree to which the prototype accomplishes the specified objectives and to identify any issues or enhancements that may be required.

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3. RESULTS AND DISCUSSION

3.1. Analysis

3.1.1. Existing Procedure

In Indonesia, the process of assigning numbers to national diplomas starts with higher education administrators correlating the diploma number with the student identification number of potential graduates. Subsequently, the identified data is reported to the validator at the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia. The National Diploma Number will be deemed valid if it can be authenticated via SIVIL and it must be incorporated in the diploma issued by the university.

Despite the use of holograms and logo stamps on paper diplomas in Indonesia, the presence of these security features does not effectively prevent the occurrence of counterfeit diplomas and transcripts. Consequently, paper-based documents remain susceptible to fraud. In 2017, the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia introduced a website-based system that allows for online verification of diplomas. The system is called "Sistem Verifikasi Ijazah Secara Elektronik" (SIVIL). However, another issue arises with the electronic storage of a diploma verification system on a centralized platform[6]. One disadvantage of centralized storage is that it increases the vulnerability of the database to hacking, as all the information is stored on a single centralized system.

3.1.2. Analysis of the components of diplomas and transcripts

As per Regulation 59/2018 issued by the Minister of Research, Technology and Higher Education of the Republic of Indonesia, diplomas in higher education consist of various essential components, which are: (a) national diploma identification number, (b) higher education institution logo, (c) higher education institution name, (d) higher education institution and/or study program accreditation decision identification number, (e) higher education program, (f) Study program name, (g) full name of the diploma holder, (h) place and date of birth of the diploma holder, (i) student ID, (j) resident registration number or passport number for international students, (k) the title given and its abbreviation, (l) graduation date (m) place and date of diploma issuing, (n) name and role of the individual in charge of a higher education institution who holds the authority to sign the diploma, (o) higher education institution stamp, (p) photo of the diploma holder.

On the other hand, an academic transcript typically includes the following components: (a) academic transcript identification number, (b) national diploma identification number, (c) higher education institution logo, (d) higher education institution name, (e) higher education program, (f) study program name, (g) full name of the academic transcript holder, (h) place and date of birth of the academic transcript holder, (i) student ID, (j) graduation date, (k) academic transcript publication date, (l) name and role of the individual in charge of a higher education institution who holds the authority to sign the academic transcript, (m) list of course taken, credits, and grades, (n) GPA and its predicate.

3.1.3. Requirement Analysis

In Indonesia, the issuance of diplomas is governed by Regulation 59 of 2018, Article 3, which stipulates that it must adhere to three fundamental principles: prudence, accuracy, and legality. **Table 1** provides a comprehensive overview of the specific principles.

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Table 1. Principles regarding the issuance of diplomas

Principle	Explanation
Prudence	Preserve the genuineness of the certificate to prevent it from being readily counterfeited.
Accuracy	Correctness of the information and facts mentioned in the diploma.
Legality	As per the stipulations of regulations and legislation.

In addition to these principles, a university has the authority to revoke a diploma if it is demonstrated that the scientific work employed to achieve the diploma is a result of plagiarism. The specific regulation governing this matter can be found in Article 32 of Regulation Number 6 of 2022, issued by the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia.

Based on these principles and regulations, and the shortcomings of the previous research, the functional requirements for the system to be constructed are subsequently outlined in **Table 2**.

Table 2. Principles regarding the issuance of diplomas

Requirement	Explanation
Data Integrity	Decentralized and unchangeable blockchain technology ensures the preservation of data integrity. This is because each block is tied to the preceding block through a hash value. Therefore, blockchain could comply with the principle of prudence and accuracy.
Non-repudiation	Once educational asset data is incorporated into the blockchain network by a university, the college will be unable to reject it since each block will be authenticated using a private key. This can satisfy the principle of accuracy.
Tracebility	Blockchain enables the ability to track the origin of stored data. It is crucial for parties seeking to verify the legitimacy of alumni diplomas to determine the current validity status of the credential in question.
Flexibility	The developed approach must possess the capability to adjust to the data format and requirements for diploma issuance that are applicable in Indonesian universities. This can satisfy the principle of legality.
Light and easy to use	The storage system has minimal memory consumption. In addition, it may be easily accessed without the need for any further installations.

3.2. Design

3.2.1. Architecture of the proposed blockchain

Blockchains have five separate layers: the application, data, consensus, network, and execution layers[12]. This research provides a detailed description of the layers as follows.

- The application layer governs the way in which users engage with the blockchain system. The prototype in this study remains a console or command-line interaction.
- The data layer is responsible for defining the data structure of a block and determining its storage mechanism. The prototype requires the form of a data block containing the specific information outlined in the section Design of the proposed method.
- The consensus layer takes charge of defining the consensus algorithm used. Consensus or agreement algorithms enable a cluster of computers to collaborate effectively, ensuring that they can continue operating even if some individual members fail. The importance lies in the engagement of multiple computers, including potential eavesdroppers, within a blockchain system. The consensus algorithm is designed to prevent eavesdroppers from disrupting the reliability of the blockchain. The prototype utilizes a Proof-of-Authority consensus mechanism, operating on the assumption that the university maintains the

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blockchain privately. Another possibility consensus could use a shared secret algorithm, such as Shamir [13], [14], [15].

- The network layer is responsible for the establishment and administration of communication between nodes or machines within a blockchain system. The prototype operates on a peer-to-peer network, allowing every unit or representation within the organization to have access to the blockchain.
- The execution layer is responsible for carrying out transactions that have been initiated by the user through the application layer. A detailed explanation regarding this process is written in the section Design of the proposed method.

3.2.2. Design of the proposed method

Generally, the suggested method consists of four phases, as seen in the **Figure. 2**. It should be noted that the numbering (i.e., 1-4) in the figure corresponds to the four phases described below.

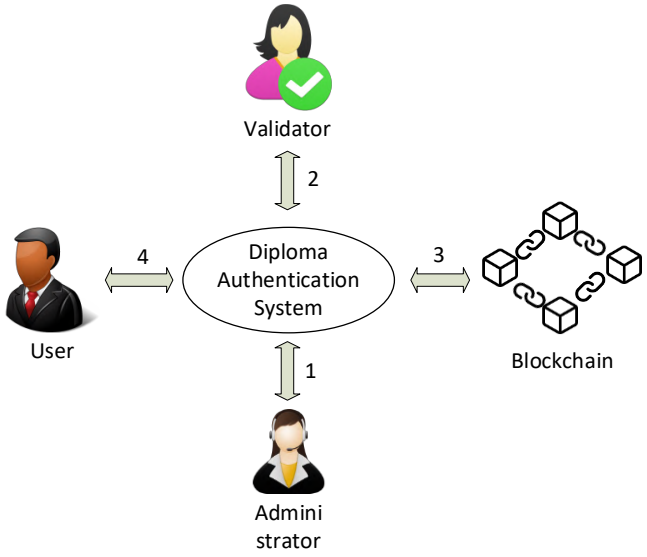


Figure 2. Proposed methods

1. Data gathering. This initial step will occur just once (with the exception that the diploma may be revised or revoked). The procedure for storing diplomas started with higher education administrators establishing a correlation between the diploma number and the student identification number of prospective graduates [16], [17].

   Let *S1* || *S2* be an operation to concatenate two strings *S1* and *S2*. The detailed procedure in this phase is described in **Figure 3**:

   - After the higher education administrator passes the authentication process to access the system, the diploma and academic transcript details are entered. This information will be kept as a string.
   - The default status of this diploma is "valid" unless the administrator opts to revoke or modify it. The system automatically stored the administrator's username and the timestamp of diploma submission. The combination of this information follows this operation *status* || *username* || *timestamp,* and it will be kept as string *b*.
   - Concatenate *a* and *b* to yield *c,* or it is denoted by *c = a || b*.
2. Data verification. The data that resulted in the first phase will be verified by the validator at the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia.

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Once the validator states that the submitted information is valid, the *information* about his username and timestamp will be added, denoted by *d = c || username || timestamp.*

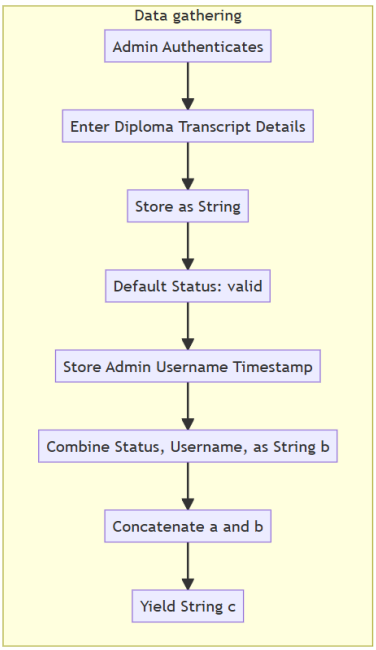


Figure 3. Data gathering workflow

3. Block generation. If the validator determines that the submitted data is valid, each diploma will be placed as a block on the blockchain that consists of three main components: index, diploma and transcript details, and previous hash as shown in Figure 3.
   Let *hash(a)* is a process to extract the hash value in a string *a* using a hash function such as MD5, SHA, etc. Let *block*[*max*] be the rightmost block in the blockchain system. The block generation is described in **Figure 4**:

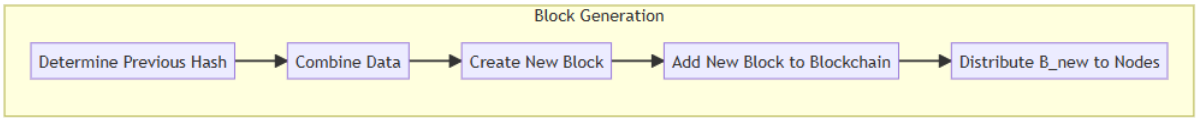


Figure 4. Block generation workflow

   - Determine the cryptographic hash value of the most recent block on the blockchain, called the previous hash $prevhash$. Or denoted by $prevhash = hash(block[max])$.
   - Combine the data from the verification phase (d) and its preceding hash to yield a new block, or it is denoted by $newblock = d||prevhash$.
   - Add the new block into the blockchain, which is denoted by $blockchain = dump(newblock)$
   - Lastly, distribute the newly created block to the nodes within the blockchain system.
4. Authentication procedure. Alumni are not required to include a duplicate of their diploma or academic transcript when seeking employment. To access the system, he simply needs to log in using his alumni credentials and retrieve the diploma number in the form, as shown in **Figure 5**. In order to verify the authenticity of the diploma, industry stakeholders just need to enter the system and scan the offered QR Code. Subsequently, the system will exhibit alumni diploma information, including transcripts and any record of credential revocation[18], [19].

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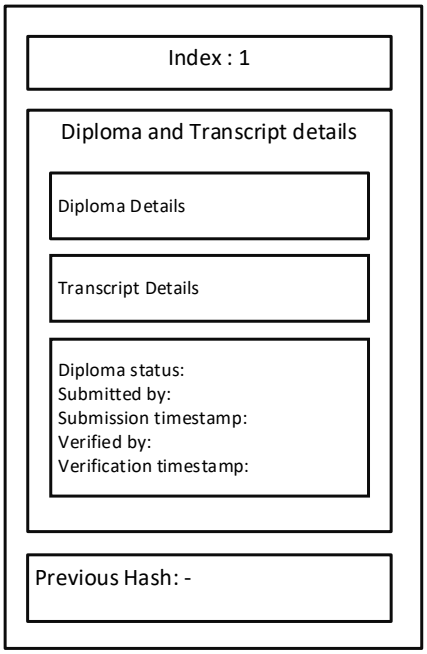


Figure 5. Illustration of the proposed block

3.3. Prototype

The Python programming language was utilized for the implementation of the prototype. Below are several prototype screenshots. Once the higher education administrators have successfully logged into the system, they are able to enter specific information regarding diplomas and transcripts [20]. Subsequently, it will generate a new block, as depicted in **Figure 6a**. To revoke a diploma, the administrator just needs to enter the corresponding diploma number. Because the blockchain is fixed, the status of a diploma cannot be revoked by simply altering the value in the "status" column. Instead, it is done by adding a block with the value "invalid" in the "status" column.

Other parties seeking to authenticate and confirm the educational credentials of potential employees or alumni just need to provide the national diploma number. Assuming the national diploma number is legitimate, the system will exhibit the educational resources of the job seeker, as shown in **Figure 6b**.

The prototype's data layer architecture is designed according to Regulation 59/2018 issued by the Minister of Research, Technology, and Higher Education of the Republic of Indonesia. This architecture enables the application of the prototype to all educational assets across universities in Indonesia. Therefore, it is possible to fulfil the flexibility requirements. Since the details of both the diploma and academic transcript are stored in a text format, the data consumption is certainly less than the image format.

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```
"id": 2,
"no_ijazah": "IJAZAH001",
"nama_pt": "Politeknik Negeri Bandung",
"no_akreditasi": "1681/SK/BAN-PT/Akred/Dipl-III/VII/2018",
"program": "Diploma-III",
"nama_prodi": "Teknik Informatika",
"nama_mhs": "Aprianti Nanda Sari",
"tempat_lahir": "Bandung",
"tgl_lahir": "12/12/1990",
"npm": "12345",
"nik": "123456789",
"gelar": "A.Md (Ahli Madya)",
"tgl_lulus": "10/10/2023",
"tempat_terbit_ijazah": "Bandung",
"tgl_terbit_ijazah": "10/12/2023",
"nama_pimpinan": "Marwansyah, Ph.D.",
"jabatan": "Direktur",
"status": "sah",
"no_transkrip": "TRANSKRIP001",
"tgl_lulus": "10/10/2023",
"tempat_terbit": "Bandung",
"tgl_terbit": "11/10/2023",
"nama_pimpinan": "Marwansyah, Ph.D",
"jabatan": "Direktur",
"ipk": "3.80",
"predikat": "Cumlaude",
"mk": [
        {
        "kode_mk": "123",
        "nama_mk": "Matematika Diskrit 1",
        "sks_mk": "3",
        "nilai_mk": "A"
        },
        {
        "kode_mk": "124",
        "nama_mk": "Matematika Diskrit 2",
        "sks_mk": "3",
        "nilai_mk": "B"
        }
    ]
"hash_transkrip": "212415ad051acf542432b3866d7063f6",
"timestamp": "2024-08-12 12:47:15.099325",
"username": "aprianti",
"previous_hash": "3299873001796b9c88e3d4e4a9e1507f"
```


Figure 6a. Newly formed block.

```
Data Ditemukan!
IJAZAH
-------------------------------------------------  ----------------------------
National diploma identification number:            IJAZAH001
Higher education name:                             Politeknik Negeri Bandung
Accreditation ID:                                  1681/SK/BAN-PT/Akred/Dipl-II
Higher education program:                          Diploma-III
Study program name:                                Teknik Informatika
Full name of the diploma holder:                   Aprianti Nanda Sari
Place of birth of the diploma holder :             Bandung
Date of birth of the diploma holder :              12/12/1990
Student ID:                                        12345
Resident registration number or passport number:   123456789
Title given and its abbreviation:                  A.Md (Ahli Madya)
Graduation date:                                   10/10/2023
Place of diploma publication:                      Bandung
Date of diploma publication:                       10/12/2023
Higher education in charge name:                   Marwansyah, Ph.D.
Higher education in charge role:                   Direktur
DIPLOMA STATUS:                                    sah
-------------------------------------------------  ----------------------------

ACADEMIC TRANSCRIPT
tidak ada
----------------------------  ----------------
No Ijazah:                    IJAZAH001
No Transkrip:                 TRANSKRIP001
Tempat Terbit Transkrip:      Bandung
Tanggal Terbit Transkrip:     10/12/2023
Nama Pimpinan Penandatangan:  Marwansyah, Ph.D
Jabatan Penandatangan:        Direktur
IPK:                          3.80
Predikat :                    Cumlaude
----------------------------  ----------------

DETAIL NILAI
 Kode Mata Kuliah   Nama Mata Kuliah       SKS  Nilai Mutu
------------------  --------------------  -----  ------------
       123          Matematika Diskrit 1      3  A
       124          Matematika Diskrit 2      3  B

Process finished with exit code 0
```

Figure 6b. Prototype displays details of diplomas and academic transcripts.

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3.4. Testing

In the context of security testing, specifically when examining the integrity of data on a diploma or academic transcript. For instance, an individual who lacks responsibility alters the graduation date to “10/12/2023. It should be noted that the system will present a notice indicating that the blockchain is invalid, as seen in **Figure 7**.

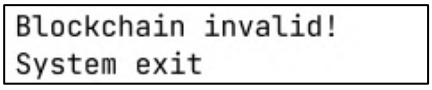


Figure 7. Prototype detects invalid blockchain

4. CONCLUSION

Based on the test findings, the prototype can fulfil the requirements of an educational asset verification and validation system. The preservation of data integrity is exemplified in the sub-chapter on security testing. The prototype is capable of presenting warning messages to users to indicate the invalidity of the blockchain. The prototype can also fulfil the need for non-repudiation and traceability since revoking a diploma involves the same procedure as adding a new block to the blockchain, but with a status of "invalid". Traceability can also be utilized to indicate the validity of a prospective worker's diploma, allowing the industry to easily determine its status.

As of now, the system remains at the prototype stage. In future research, efforts will be focused on collaborating with selected universities for pilot testing. This would involve assessing system performance in a real institutional environment and gathering structured feedback from both administrative and IT departments to evaluate usability, scalability, and integration readiness.

In general, the constructed prototype performs effectively, thereby mitigating the issue of diploma fabrication. Industry or companies conduct the verification and validation procedure transparently within the system to ensure accurate and secure educational asset information. The current prototype operates in a single-node environment. To simulate realistic deployment scenarios, future iterations will include deploying the blockchain system across multiple nodes representing various departments or units within a university. This will allow for testing fault tolerance, consensus behaviour, and data synchronization performance across distributed systems.

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6. AUTHORS’ NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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Digital Game Design for the Elderly: Implementing a User-Centered Approach to Enhance Cognitive Function

Rahbiah Winda Sari[1], Retno Widyanungrum[2], Dyah Santhi Dewi[3]

[1,2,3]Departemen of Systems and Industrial Engineering, Institut Teknologi Sepuluh Nopember, Indonesia
Correspondence E-mail: rahbiahwinda@gmail.com

ABSTRACT

Dementia is a condition marked by a decline in cognitive functions such as memory and thinking, which interferes with daily activities and has become a serious public health issue in Indonesia. This study proposes a mobile game as a medium for cognitive stimulation among older adults, employing a User Centered Design (UCD) approach that prioritizes user needs. The research involved 16 elderly participants to identify their needs, design the game interface, evaluate usability using the USE Questionnaire, and measure the impact of the game. The resulting design emphasized accessibility through a simple interface, clear icons, large buttons and text, and high color contrast. The prototype, developed iteratively with UCD principles, included three short duration games (Memori Warna, Find Pet, and Match Fruits) targeting memory and concentration skills. Usability testing showed a positive learning curve, with improved completion times after repeated trials. The overall usability score was 83.43%, with satisfaction scoring highest at 87.07%. These findings indicate that UCD based mobile games are easy to use, engaging, and hold promise as inclusive tools for supporting cognitive health in the elderly.

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1. INTRODUCTION

Dementia is a condition characterized by a decline in cognitive functions, such as difficulty remembering and thinking, which affects daily activities. If left untreated, dementia worsens with age [1][2]. According to the World Health Organization, there are currently over 55 million people living with dementia worldwide, more than 60% of whom reside in low and middle income countries. Every year, there are nearly 10 million new cases [3].

In Indonesia, the population is entering an aging period, marked by an increase in life expectancy followed by a rise in the number of elderly individuals. This is evident from the growing elderly population, which increased from 18 million (7.56%) in 2010 to 25.9 million (9.7%) in 2019, and is projected to continue rising, reaching 48.2 million (15.77%) by 2035. In 2016, there were an estimated 1.2 million people with dementia; this number is expected to rise to 2 million by 2030 and 4 million by 2050. Several factors contributing to the high cost of dementia care in Asia include a lack of understanding of the disease and insufficient resources and training for caregivers of people with dementia (PWD) [4]. To improve the quality of life for dementia patients, interventions focusing on cognitive stimulation are becoming increasingly important, as regular and serious engagement in games can influence the cognitive abilities of the elderly [5].

Games have been shown to be effective in enhancing motivation and engagement in therapy. Purposefully designed games can support the development of memory, attention, and social skills. Various types of games can be utilized in cognitive therapy for older adults, including board games, card games, and digital games. Indicates that games involving strategy and problem-solving can significantly improve executive function and working memory [6]. The goal of incorporating games into rehabilitation and intervention is to enhance motivation for continued participation in the process while keeping the brain engaged in all functions, including memory [7]. Prevention of dementia can be achieved by maintaining cognitive function in the elderly through regular physical activity [8]. The use of games in therapy can enhance the effectiveness of recovery in an enjoyable way, thereby increasing user motivation and engagement. Therefore, game design should consider rules, challenges, and an engaging interface [9]. Various studies have shown that mentally stimulating activities, such as games and mental exercises, can help slow disease progression and improve cognitive function. Additionally, social games involving interaction with others can enhance social and emotional skills in older adults [10][11]. The accessibility of mobile games and their interactive appeal present great potential as therapeutic tools. However, to design effective games, it is essential to understand the needs and preferences of users, especially the elderly [12].

In efforts to improve the quality of life for people with dementia, various therapeutic approaches have been developed, including cognitive therapy and technology based interventions. One such approach is the use of mobile games, which offer advantages in accessibility and interactivity, making them an effective means to engage dementia patients in brain stimulating activities as a tool for cognitive stimulation.

Mobile games can be an effective tool to reduce cognitive decline in the elderly. Game selection should be tailored to the needs and preferences of older adults, with a user friendly interface to ensure effectiveness and user satisfaction [13][14]. To encourage the adoption of mobile games among seniors and caregivers, the games can incorporate features for therapy based game selection. The application should not only have a good user interface and an attractive visual design, but also be able to engage the elderly by offering easy operation and well-organized buttons and colors [15].

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Given Indonesia's growing elderly population, there is a need to develop effective dementia interventions and preventive measures. This includes designing mobile games and fostering technological innovations in healthcare services. This study adopts a User Centered Design (UCD) approach to identify what elderly users desire in a game and how they interact with technology. UCD is a design approach that places the user as the main focus at every stage of the design process. This approach aims to create products that better meet the users' needs and requirements, thereby enhancing the overall user experience [16][17][18]. One of the key attributes of a good application is fulfilling usability aspects. To determine the extent to which a mobile game can be used by users to achieve specific goals effectively, efficiently, and with user satisfaction in its usage context, system testing is required. One method that can be used for application testing is the USE Questionnaire, which consists of four parameters: usefulness, ease of use, ease of learning, and satisfaction [19]. The expected outcome of this mobile game design is an application that is not only engaging and enjoyable but also effective in stimulating cognitive functions. The game aims to enhance memory, attention, and critical thinking skills while providing emotional support through positive social interactions.

2. METHODS

This study involved 16 elderly respondents aged 60–80 from both rural and urban areas, including four individuals with no prior mobile gaming experience. The sample size was determined using a balanced design approach based on the experimental variables employed. Data were collected through direct observation and interviews. Research Steps:

1. Problem Identification
   Observations and interviews were conducted in Kutai Kartanegara, East Kalimantan, to explore user needs, expectations, and challenges. Literature reviews supported the understanding of dementia, cognitive stimulation, gamification, UCD, usability, and the USE Questionnaire instrument.
2. Specify the Context of Use
   Development of user personas, identification of user needs, and preliminary solutions based on research findings.
3. Specify the User Requirements
   Creation of a sitemap, user flow, and wireframes aligned with user needs.
4. Produce Design Solutions
   Interface design and prototyping, including layout, icons, colors, and elderly friendly interaction flows.
5. Evaluate the Designs
   Usability testing was conducted through usability tests, completion time measurement, learning curve assessment USE Questionnaire with a 1–4 Likert scale.
6. Results Analysis
   Discussion of findings from all stages.
7. Conclusion and Recommendations
   Summary of results and suggestions for future research.

3. RESULTS AND DISCUSSION

This study involved 16 elderly respondents, consisting of 8 males and 8 females. The respondents came from two different geographical backgrounds rural and urban areas. Each respondent group included four individuals with no prior experience using mobile games. Subsequently, all respondents were assigned codes to facilitate the data collection process.

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The codes used consisted of the letter 'R' (standing for 'respondent') followed by numbering from 1 to 16, as shown in **Table 1** for example, R1 refers to the first observed respondent.

Table 1. Respondent Code

Code	Gender	Area	Mobile Game Experience
R1	Male	Urban	No
R2	Male	Urban	No
R3	Female	Urban	No
R4	Male	Urban	Yes
R5	Female	Urban	Yes
R6	Female	Rural	Yes
R7	Female	Urban	Yes
R8	Male	Rural	No
R9	Male	Rural	Yes
R10	Female	Rural	No
R11	Male	Rural	No
R12	Female	Rural	No
R13	Female	Rural	Yes
R14	Male	Rural	Yes
R15	Female	Urban	No
R16	Male	Urban	Yes

At this stage, the user needs identification process was conducted to determine the appropriate application design. The methods used included observation and interviews with 16 respondents. The interviews were designed to gather relevant information regarding respondents' experiences and challenges in using digital devices, as well as their preferences for game types they found appealing. Subsequently, the interview results were compiled to identify key issues faced by the respondents. The interview questions and summary of results, as shown in **Table 2**.

Table 2. Interview Questions and Summary of Results

Interview Questions	Majority Responses
Have you ever used a smartphone or tablet?	Most have, but still experience difficulties
What challenges do you face when using smartphone/ tablet applications?	Confused about app functionality, text is too small, navigation is confusing.
Are you interested in playing digital games?	Yes, if the game is easy to understand and not complicated.
What type of games do you prefer?	Simple games like picture guessing, color matching, or object matching
What features do you consider important in games for elderly users?	Large text, clear buttons, high contrast colors, and easy to understand instructions.
Would you like the game to help train your memory and thinking skills?	Yes, most believe this would be very helpful.
Would you prefer if the game could be played without internet connection?	Yes, for more practical use anytime.
What are your expectations for games specifically designed for elderly users?	Easy to use, enjoyable, not confusing, and beneficial

3.1. Specify the Context of Use

The initial stage of the user centered design process begins with understanding the context of use through observation and interviews. This step aims to explore the needs, limitations, and habits of respondents when using digital devices, which then form the

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foundation for developing user personas, identifying user needs, and formulating solutions through mobile game development.

1. User Persona

The user persona aims to represent the characteristics of the application's users, including their background, habits, needs, and challenges. Based on the user personas of 16 elderly respondents, it was found that they preferred mobile games with simple designs, easy to understand interfaces, and minimal technical instructions. However, several complaints were noted, such as difficulty understanding foreign terms, small text sizes, confusing layouts, and concerns about pressing the wrong buttons or losing data. Respondents also experienced difficulty locating the game icon, confusion during initial use, limited device storage, and a lack of usage guidance.

2. User Needs

User needs reflect the expectations, preferences, and goals of respondents in using digital products. The data was collected from respondents' answers regarding application usage and cognitive stimulation, which served as the basis for designing the mobile game. The results of the observations as shown in **Figure 1**.



Figure 1. Findings from Respondent Observations

Based on the interview results, it was found that most elderly individuals had used digital devices such as smartphones or tablets, but still experienced difficulties in operating them. The most frequently mentioned issues included small font sizes, confusing app navigation, and a lack of clear guidance. Respondents expressed interest in digital games, provided that the games were simple and easy to understand. Features considered important in games for the elderly included the use of large fonts, clear buttons, high contrast colors, and simple instructions. Most respondents also stated that they preferred games that could help maintain memory and thinking skills. Additionally, games that could be played without an internet connection were considered more practical and aligned with their needs.

3. Problem Solving Problems

Based on an analysis of the problems faced by respondents when using digital devices, several solutions can be identified to improve accessibility and user comfort. First, the application should be designed with an elderly friendly interface, including large text, wide clickable buttons, and high contrast color combinations to reduce reading and navigation difficulties. A simple and consistent layout can also reduce confusion in operating the app. To help elderly users understand how to play the game, interactive guidance in the form of visual

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tutorials such as illustrated instructions should be available and accessible at any time. These guides are particularly important when users open the application for the first time.

On the other hand, cognitive features should also be integrated into the game, including activities involving memory, concentration, or other brain stimulating exercises with gradually adjustable difficulty levels to remain challenging yet not overwhelming. Game integration can be a solution to stimulate the brain while providing enjoyment for respondents. The interface should follow simple design rules and allow flexible playing time. Considering the limited internet access for some respondents, the application should also be able to function offline to ensure they can still use it at any time without relying on a network connection. Support through socialization and assistance either through brief training or help from family members and caregivers is essential to help respondents overcome initial difficulties in using digital devices. With the implementation of these solutions, respondents are expected to use digital technology more independently and comfortably while also gaining cognitive health benefits.

3.2. Specify the User Requirements

The second stage of User Centered Design focuses on specifying user requirements. In this phase, visual representations such as the sitemap, user flow, and wireframe are created to illustrate the navigation structure, usage flow, and interface design of the game to be developed.

1. Site Map

The sitemap illustrates the relationships between pages and the main navigation paths that users will follow. This mapping helps in designing a logical and accessible navigation system that aligns with the needs of the elderly users. The sitemap as shown in **Figure 2**.

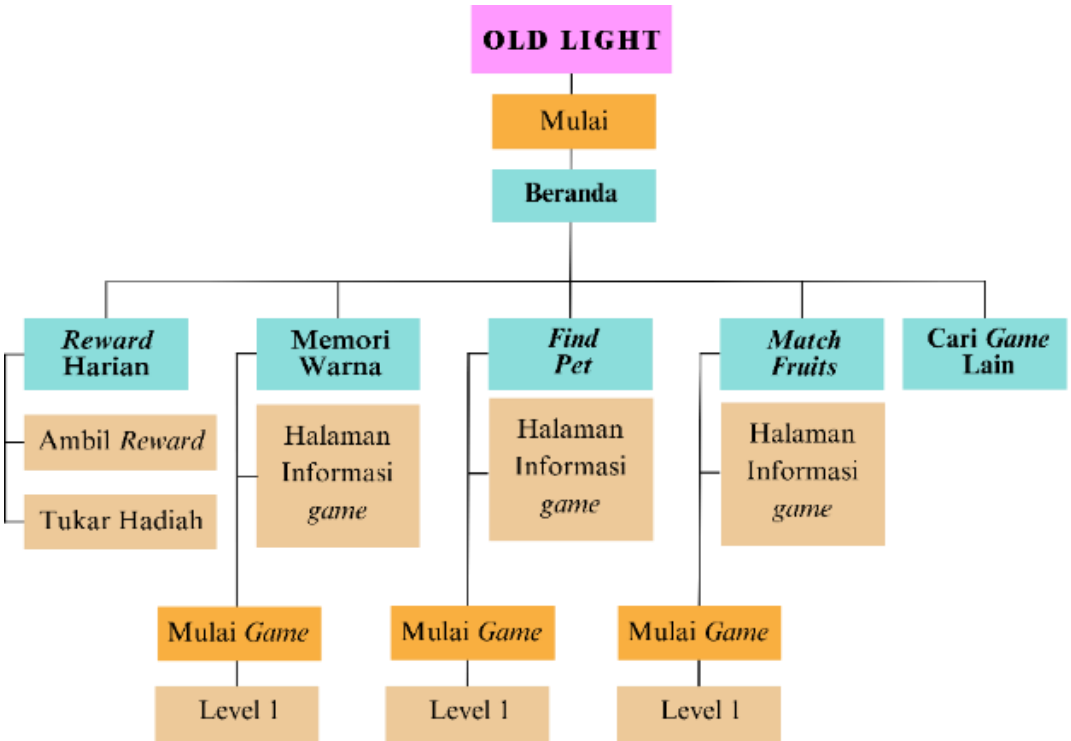


Figure 2. Site Map

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2. User Flow

The user flow illustrates the step by step path showing how users navigate from one page to another to achieve specific goals within the application. The purpose of designing the user flow is to ensure that user interactions proceed efficiently and without confusion. The user flow as shown in **Figure 3**.



Figure 3a. User Flow for Opening the Game.



Figure 3b. User Flow for Memory Color, Find Pet, Match Fruits.



Figure 3c. User Flow for Reward.

3. Low Fidelity Wireframe Design

The low fidelity wireframe is designed as an initial guide for developing the medium fidelity prototype. This design presents the layout of key elements such as buttons, text, icons, and navigation without visual details or color schemes, and is structured based on the previously identified needs of the respondents is shown in **Figure 4**.

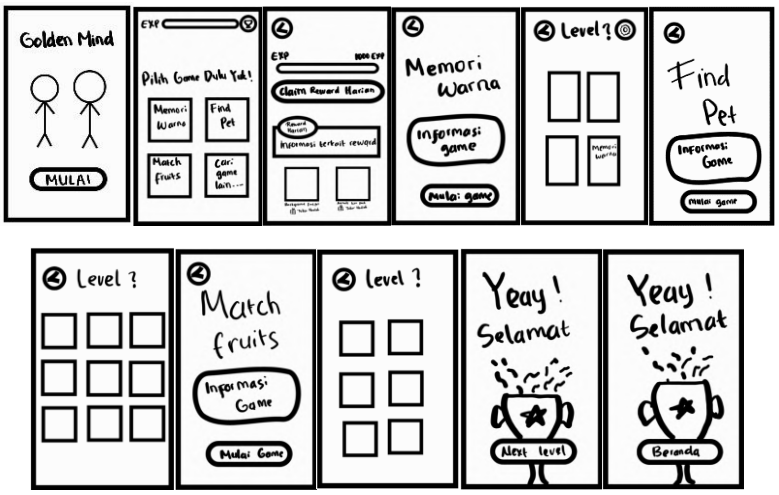


Figure 4. Wireframe Low Fidelity

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4. Medium Fidelity Wireframe Design

Before designing the medium fidelity wireframe, a design guideline was developed as a reference for interface development. This guideline focuses on design principles tailored to the needs of older adults, including clear visuals, adequate font and button sizes, simple navigation, comfortable colors, and intuitive icon usage. The game interface in this study is designed to be simple, clean, and uncluttered, making it easier for elderly users to focus on key elements. The font used is Fredoka, with font sizes of 18, 24, and 32 pt. Buttons are designed to be large enough for easy visibility and touch interaction. All text is presented with high contrast against the background to enhance readability. The navigation structure is kept simple and linear to facilitate easy movement between screens. Each navigation button is accompanied by a clear and recognizable icon and label to prevent user confusion when exploring the app interface. The color selection follows color psychology principles, serving not only an aesthetic function but also supporting the user's psychological comfort. The chosen colors avoid low contrast and overly bright tones that could cause eye strain. Instead, color gradients are used selectively to add visual variety without overwhelming the user.

Icons serve as essential visual elements that support the understanding of functions or information without relying on lengthy text, as shown in **Table 3**. In the design of this mobile game, icons are used consistently and intuitively to simplify user navigation and interaction. This design strategy is specifically tailored to accommodate the needs of older adults who may have limitations in visual and cognitive abilities.

Table 3. Use of Icons

Icon Name	Function	Usage Location
Back arrow icon	Navigates to the previous page	Top left corner
Information icon	Provides instructions or how to play	Game start page
Fruit & number icon	Main object for the game of matching fruits and numbers	*Match Fruits* page
Cute animal icon	Game object for matching animals	*Find Pet* page
Color card icon	Game object to be remembered	*Memori Warna* page
Trophy & confetti icon	Indicates success	Result page

After establishing the design guidelines, the medium fidelity stage was carried out by arranging visual elements in greater detail, as shown in **Figure 5**. This design presents the shape of buttons, icons, text sizes, and a more precise content layout, referring to the needs of older adults such as easy navigation, readability, and a simple user interface.

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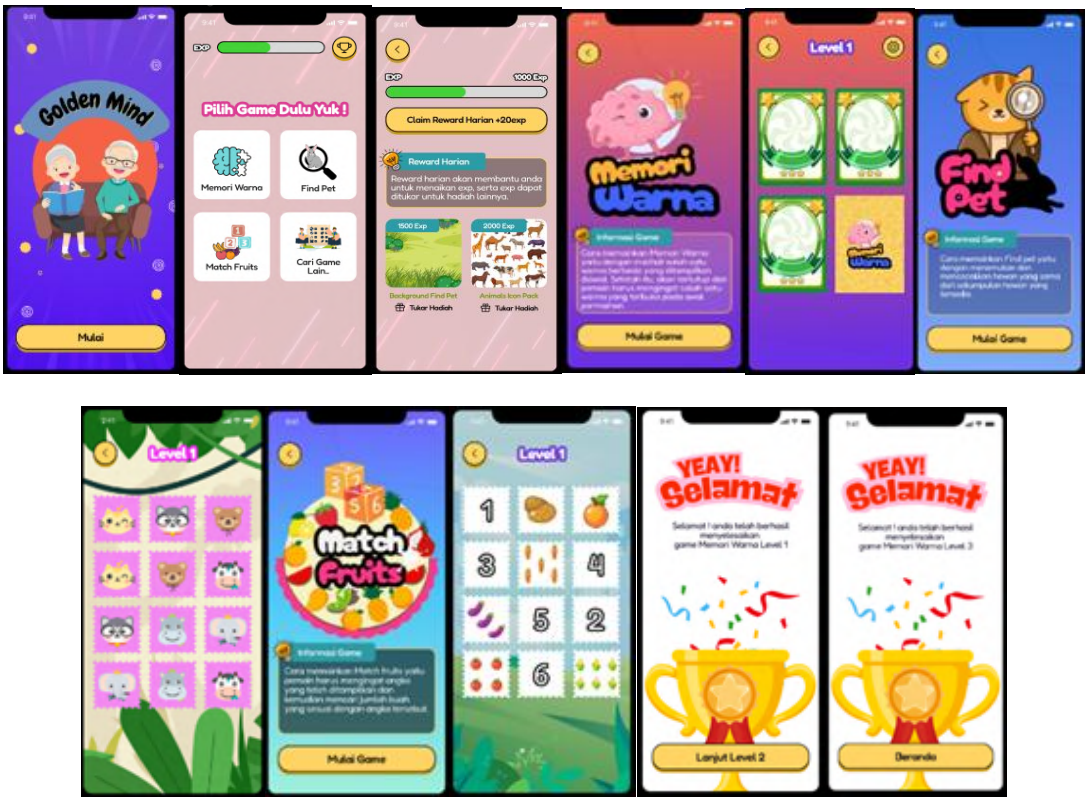


Figure 5. Wireframe Medium Fidelity

3.3. Produce Designs Solutions

The third stage in the user centered design approach is the process of generating design solutions. This stage focuses on developing solutions that meet the needs and characteristics of the identified respondents. The design solution developed is a mobile game consisting of three games Memori Warna, Find Pet, and Match Fruits. The design considers aspects such as ease of use, visual comfort, and simple interactions that suit older adult users. All game elements are designed to be easily accessible and usable, including by respondents with no prior experience in playing mobile games. This stage also includes the creation of a mobile game prototype with an engaging visual appearance.

Interface Design Development. This step involves the development of the design solution, covering the creation of the interface in visual form up to the prototype stage, as shown in **Figure 6**. The interface design process uses digital design tools, specifically Figma. Figma was chosen because it offers ease in creating responsive and collaborative designs, and it supports realistic interactive prototype visualization. The design is developed in the form of a website prototype that simulates the appearance of a mobile application to facilitate initial testing and evaluation

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Figure 6. Interface Display Prototype

3.4. Evaluate the Designs

The fourth stage of the user centered design process is evaluation through usability testing to ensure that the interface and functions meet the needs of older adults. This method observes respondents' ability to complete the game design tasks, ease of use, and level of satisfaction. The testing was conducted in two stages (before and after treatment) to optimize the design based on respondent feedback.

1. User Testing Before Treatment

The testing involved 16 elderly respondents who played the game prototype from the menu to the reward screen. The objective of this test was to evaluate the usability of the initial design. Observation results revealed three main issues insufficient color contrast making it difficult to identify important elements, non intuitive icons causing confusion, and text size being too small, making it hard to read.

The issues experienced by respondents in the initial design were classified based on visual interface aspects (color, icons, and text). The observation results were then visualized in a chart to illustrate the distribution of respondents in each aspect, as shown in **Figure 7**. Based on the chart, the “Clear Icons” category received the highest score with 16 respondents, indicating that the icons were appropriately designed and easy to understand. Additionally, 11 respondents experienced difficulty due to the text size being too small, while 5 respondents stated that the text was completely unreadable. Regarding the color aspect, 9 respondents indicated that the color contrast was sufficient and distinguishable, while 7 respondents found the color contrast to be inadequate. These findings suggest an inconsistency in color usage, which could lead to confusion.

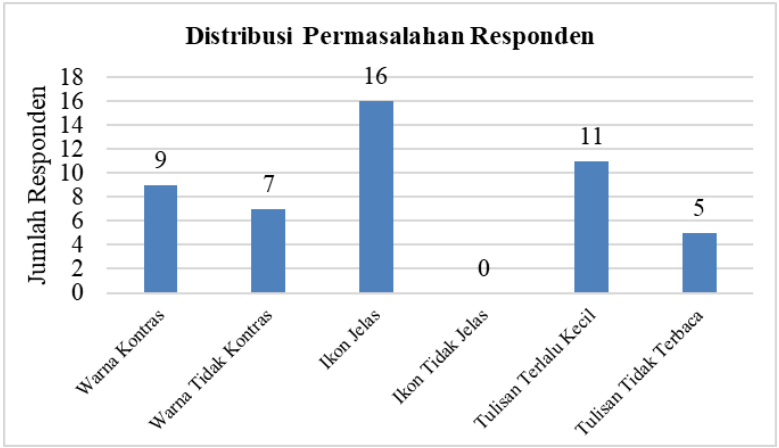
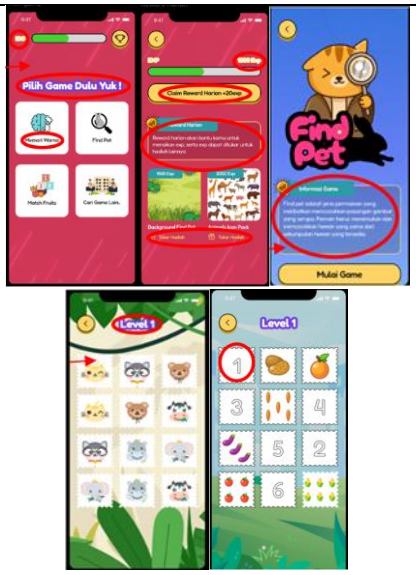
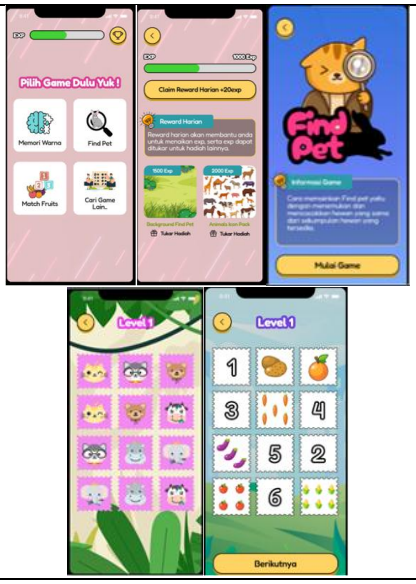


Figure 7. Respondents Based on Icon, Color, and Text Clarity in the Initial Design

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Therefore, a redesign of the interface is necessary. **Table 4** presents a comparison of the game interface before and after improvements based on the results of the usability testing conducted in the before treatment stage.

Table 4. Identification of Respondents' Visual Issues

Before Improvement	After Improvement
	

Based on the results of the user testing evaluation in the *before treatment* stage, which identified visual issues such as overly bright background colors, low color contrast, and small text size (18 pt), design improvements were made by applying a pastel pink background, increasing the text size to 32 pt, and optimizing color contrast and element thickness. These changes resulted in a more comfortable and readable interface for elderly users.

2. User Testing After Treatment

User testing after treatment was conducted to evaluate the effectiveness of the game design in providing cognitive stimulation for the elderly. The evaluation covered three aspects completion time, learning curve, and the USE Questionnaire. In the completion time test, 16 elderly respondents were asked to play three types of games (Memori Warna, Find Pet, and Match Fruits) three times each. Completion time was measured in seconds to assess respondent efficiency and the effectiveness of the interface improvements. In the Memori Warna game, the average time decreased from 65 seconds (session 1) to 40 seconds (session 3). The Find Pet game showed a reduction from 83 seconds to 46 seconds, while Match Fruits went from 81 seconds to 47 seconds. The fastest completion times were recorded in the third session: 20 seconds by Respondent 4 for Memori Warna, 22 seconds by Respondent 6 for Find Pet, and 28 seconds by Respondent 16 for Match Fruits. This decrease indicates a positive learning curve, as shown in **Figure 8**, demonstrating an improvement in the users' ability to understand gameplay flow and adapt to the interface after repeated interactions. The improvements in readability, icon clarity, and layout design have proven effective in enhancing interaction for elderly users.

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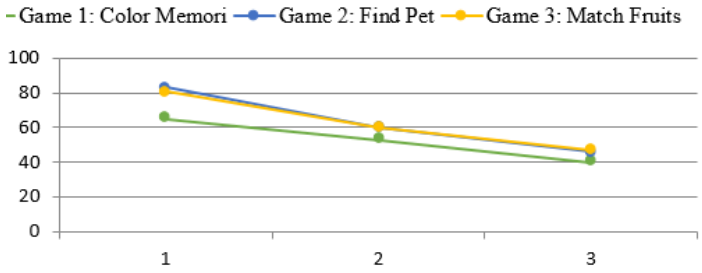


Figure 8. Average Completion Time per Trial Char

In addition to measuring time, the evaluation was also conducted through usability testing using a set of statements compiled into a questionnaire. Each respondent rated 30 statements, which were categorized into four factors: usefulness, ease of use, ease of learning, and satisfaction. The evaluation used a 4 point Likert scale, with the following categories: strongly disagree (1), disagree (2), agree (3), and strongly agree (4). The average score for each statement was calculated to assess the system's feasibility, both overall and based on each individual factor. After data were collected from all respondents, the next step was to calculate the mean score for each questionnaire item. This score was obtained by summing all respondents' scores for a particular statement and dividing it by the total number of respondents (n = 16). The recap of the assessment results as shown in **Table 5**.

Table 5. Questionnaire Recapitulation Results

Factor	No	Statement	Score
Usefulness	1	Helps with activities	3.31
	2	More active and enthusiastic	3.31
	3	Useful	3.44
	4	Organizes activities	2.94
	5	Facilitates daily activities	3.38
	6	Saves time	3.06
	7	Meets needs	3.69
	8	Meets expectations	3.38
Total *Usefulness*			26.50
Ease Of Use	9	Easy to use	3.75
	10	Simple interface	3.31
	11	Easy to understand	3.44
	12	Clear steps	3.38
	13	Customizable	2.81
	14	Requires little effort	3.25
	15	No need to read the manual	2.88
	16	Works consistently	3.31
	17	Liked by new or old users	3.25
	18	Errors easily fixable	2.88
	19	Always usable	3.38
Total *Ease of Use*			35.63

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Factor	No	Statement	Score
Ease Of Learning	20	Quick to understand	3.50
	21	Easy to learn	3.44
	22	Comfortable to learn	3.56
	23	Quickly get used to it	3.13
Total *Ease of Learning*			13.63
Satisfaction	24	Feeling satisfied	3.56
	25	Would recommend it	3.38
	26	Enjoyable	3.63
	27	Met expectations	3.31
	28	Interesting	3.38
	29	Want to keep playing	3.44
	30	Happy while playing	3.69
Total *Satisfaction*			24.38
Total Overall			100.125

The equation used to calculate the level of usability using the USE Questionnaire is as follows [1]:

$$k(\%) = \frac{s \times y \; x \; d}{s \times y \times ha} \times 100\% = \frac{usability\ score\ obtained}{maximum\ usability\ score} \times 100\% \quad (1)$$

Explanation:
Pk (%) : Usability level in percentage
S : Scale score
y : Number of statements
d : Number of respondents
ha : Maximum score

The data obtained is then converted based on the eligibility category table as shown in **Table 6** [20].

Table 6. Feasibility Category by Percentage (%)

Percentage (%)	Classification
<21	Very Infeasible
21-40	Infeasible
41-60	Fair
61-80	Feasible
81-100	Highly Feasible

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USE Questionnaire Overall Measurement

Based on the overall calculation of the USE Questionnaire, the average score obtained was 100.125 from 30 statements with 16 respondents. The usability percentage is calculated as follows [2]:

$$(PK) = \frac{100.125 \times 16}{4 \times 30 \times 16} = \frac{1602}{1920} = 83.43\% \quad (2)$$

Thus, a usability percentage score of 83.43% indicates that the product or application tested falls under the "Highly Feasible" category based on the available feasibility classification. This means that, in general, the application has met users' expectations in terms of usefulness, ease of use, and satisfaction.

USE Questionnaire Measurement on Usefulness Aspect

The usefulness aspect is used to measure the extent to which the application helps users effectively achieve their intended goals. Based on the measurement results, an average score of 26.50 was obtained from 8 statements and 16 respondents, and calculated as follows [3]:

$$(PK1) = \frac{26.50 \times 16}{4 \times 8 \times 16} = \frac{424}{512} = 82.81\% \quad (3)$$

A percentage score of 82.81% indicates that the usefulness aspect also falls under the "Highly Feasible" category, meaning the application is considered very helpful in assisting users to complete their desired tasks or objectives.

USE Questionnaire Measurement on Ease of Use Aspect

The ease of use aspect aims to assess how easily the application can be used by users, in terms of both appearance and interaction. From the calculations, an average score of 35.63 was obtained from 11 statements and 16 respondents, calculated as follows [4]:

$$(PK2) = \frac{35.63 \times 16}{4 \times 11 \times 16} = \frac{570.08}{704} = 80.97\% \quad (4)$$

Thus, the score of 80.97% indicates that this aspect also falls under the "Highly Feasible" category, meaning the application's interface and features are considered easy to understand and use by users.

USE Questionnaire Measurement on the Ease of Learning Aspect

The ease of learning aspect aims to assess how quickly users can understand and learn how to use the application. Based on the collected data, the average score for this aspect was 13.63 from 4 statements, with a total of 16 respondents, and it can be calculated as follows [5]:

$$(PK3) = \frac{13.63 \times 16}{4 \times 4 \times 16} = \frac{218.08}{256} = 85.19 \quad (5)$$

With a percentage score of 85.19%, the ease of learning aspect is categorized as "Highly Feasible." This indicates that the application is easy to learn and understand by users.

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USE Questionnaire Measurement on the Satisfaction Aspect

The satisfaction aspect is used to determine the level of user satisfaction with the application overall. The average score obtained was 24.38 from 7 statements. With a total of 16 respondents, the calculation is as follows [6]:

$$(PK4) = \frac{24.38 \times 16}{4 \times 7 \times 16} = \frac{390.08}{448} = 87.07\% \quad (6)$$

The result of 87.07% shows that the satisfaction aspect also falls into the "Highly Feasible" category, meaning users feel very satisfied with the application in terms of appearance, functionality, and overall user experience.

4. CONCLUSION

Based on the needs analysis of 16 older adults, a simple interface design with clear icons, large text, and high contrast colors emerged as key factors, supported by the role of caregivers. The prototype was developed using a User Centered Design approach, resulting in three games (Find Pet, Match Fruits, and Memori Warna) that adhered to accessibility principles. Usability testing results showed significant improvements across four aspects ease of use, satisfaction, usefulness, and ease of learning. Observations demonstrated that older adults were able to complete tasks related to memory, attention, and pattern recognition more quickly and with fewer errors, indicating cognitive stimulation potential.

Recommendations for future researchers include developing additional accessibility features, expanding field testing across diverse geographical and demographic settings, and conducting long-term studies using cognitive assessment tools to ensure user comfort, validate findings, and accurately measure the game's impact on cognitive abilities in older adults.

5. ACKNOWLEDGMENT

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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Towards an Integrated Authentication System: Single Sign-On (SSO) Architecture for Higher Education Applications

Yusza Reditya Murti [1], Fadil Al Afgani [2], Teguh Rijanandi [3]

[1] Digital Business Study Program, School of Economics & Business, Telkom University
[2] Bachelor of Software Engineering Program, School of Computing, Telkom University
[3] Master of Cybersecurity Program, School of Computing, Telkom University
Correspondence E-mail: yuszaa@telkomuniversity.ac.id

ABSTRACT

Post-COVID-19, universities face increasing demands to enhance digital services through applications like Academic Information Systems (SIAKAD) and Learning Management Systems (LMS). Multiple applications require users to manage numerous login credentials, causing "password fatigue," reduced efficiency, and security risks. This study designed a Single Sign-On (SSO) architecture integrating authentication across internal applications, third-party systems, and Wi-Fi networks. The solution leverages Keycloak as Identity Provider (IdP), utilizing OpenID protocol for application integration and EAP-PEAP for Wi-Fi authentication. Results demonstrate successful authentication process simplification and increased user satisfaction through reduced repeated logins. System Usability Scale (SUS) testing yielded an average score of 74.22, meeting acceptable standards for enhanced user experience. Performance testing showed the system handles up to 12,000 authentication sessions with manageable CPU and RAM fluctuations. This research successfully developed an effective SSO solution addressing higher education authentication challenges. The architecture improves operational efficiency, simplifies login processes, and strengthens security while ensuring seamless integration through standard protocols and user-friendly interfaces.

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1. INTRODUCTION

Post-COVID-19 pandemic, higher education institutions (universities) are faced with the demand for enhanced digital services through various operational applications, such as the Academic Information System (SIAKAD) and the Learning Management System (LMS). Adopting this technology aims to improve the efficiency of academic and administrative processes within the university environment. [1]. However, the large number of applications has created challenges for users (students, lecturers, and educational staff) who must manage multiple login credentials. [2], [3], [4]. This situation makes it difficult for users to remember passwords and requires them to log in repeatedly to various systems. Consequently, users experience "password fatigue," which drives them to use weak passwords or repeat the same password for convenience, thereby increasing system security risks [4]. Furthermore, repeated logins between applications reduce user satisfaction and increase system vulnerabilities. On the administrative side, the dynamic of user access rights (roles) changes and user management, such as account deactivation or adjusting permissions, further burdens the system's operational functions [1], [5].

To address these challenges, this research aims to design and implement a Single Sign-On (SSO) architecture for the university environment. The SSO architecture developed in this research is expected to integrate all applications used in the university. This solution not only simplifies the login process but also integrates user data into a single location (one database), reduces administrative burden, and improves security. Additionally, this research aims to design an SSO system that is easy to implement, using standard protocols that can integrate various third-party applications used in higher education environments, such as WordPress-based websites, Moodle-based LMS, Google Workspace, Microsoft Education Workspace, and Wi-Fi authentication using the Protected Extensible Authentication Protocol (EAP-PEAP).

Numerous studies have implemented SSO in higher education ecosystems using various protocol approaches, such as in the research in [2], [3], [4], and [6]. The concept of Single Sign-On (SSO) presents a strategic solution to overcome this issue, allowing users to access various resources with a single authentication process. [7], [8]. The specific implementation of SSO on Wi-Fi networks can improve security by integrating strong authentication protocols such as Protected Extensible Authentication Protocol (EAP-PEAP), which protects user credentials through an encrypted tunnel. [9], [10], [11]. The studies [3], [5], [12], and [13] Has developed SSO system architectures using various approaches. These previous findings form the theoretical foundation for the design of the solution in this study.

The solution proposed in this study is the development of an SSO architecture that integrates access for all internal applications, third-party applications, and Wi-Fi networks in a university environment. This study introduces a novel approach by integrating Single Sign-On (SSO) with Wi-Fi authentication using EAP-PEAP (Extensible Authentication Protocol-Protected EAP) in the context of Indonesian higher education. The SSO architecture in this study uses the OpenID protocol. This protocol was chosen because of its ability to easily integrate with various applications and third-party applications, such as WordPress-based websites and blogs, Moodle-based LMS, and Google Workspace. Therefore, the unique contribution of this research is not merely another SSO implementation, but a validated, scalable blueprint that bridges the gap between digital service access and physical network infrastructure within a singular, secure authentication framework for an academic environment.

Overall, this research aims to design and build a comprehensive SSO architecture that includes four main components: (a) Utilizing Keycloak as a centralized Identity Provider (IdP) connected to a directory service (LDAP) and a network authentication server (RADIUS). [7], b)

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Integrating Keycloak and EAP-PEAP for Wi-Fi authentication, (c) Developing an SSO Portal Application to facilitate user access to all services without repeated logins, and (d) Integrating user management, activity monitoring, and access control with SIAKAD. This SSO system is expected to improve operational efficiency and user convenience in higher education institutions, while strengthening security and access management aspects.

2. METHODS

This study uses the Design Science Research Methodology (DSRM) method in designing a Single Sign-On (SSO) system architecture adapted to a college or university environment. The DSRM approach was chosen because of its ability to produce technological artifacts that are solution-oriented and relevant to practical problems through a systematic and structured process. [14], [15]. This methodology includes five main stages, namely Problem Identification and Motivation, Definition of Solution Objectives, Design and Development, Demonstration, and Evaluation. Each DSRM stage in this study can be seen in **Table 1** below.

Table 1. Stages of the DSRM Method

Research Steps	Definition
Problem Identification and Motivation	Identifying challenges and requirements through literature studies and semi-structured interviews with users at three universities.
Definition of Solution Objectives	Define the solution objectives, namely designing an SSO architecture that supports system integration, improves security, reduces authentication time, and improves user experience.
Design and Development	Designing an SSO architecture, considering several important aspects such as security, interoperability, performance, and ease of use. Development was carried out using the Software Development Life Cycle (SDLC) model.
Demonstration	Implementing the designed SSO architecture in a limited environment at a college to test the system functionality.
Evaluation	Conducting performance evaluations [7], [12] and usability evaluations [16], [17] or user experience to measure the effectiveness, efficiency, and user satisfaction with the implemented system.

3. RESULTS AND DISCUSSION

3.1. Requirements Analysis

The first crucial step before designing a Single Sign-On (SSO) system architecture for higher education is to conduct a comprehensive requirements analysis. The goal is to ensure the solution truly meets the needs of users and the organization. Universities typically have complex digital ecosystems consisting of various user types, including students, lecturers, employees/staff, top management, and administrators, all requiring access to various applications and services. The primary need is a centralized authentication system that eliminates repetitive logins, improves security, and simplifies user management.

The analysis results indicate that universities need to integrate SSO with various applications, such as the Academic Information System (SIAKAD), the learning management

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system (Moodle), Google or Microsoft Workspace services, and the content management system (WordPress). To ensure all applications are seamlessly connected, support for standard protocols such as OpenID Connect and SAML is required.

Furthermore, universities have users with varying roles. Therefore, the system must be able to manage authorization levels and access rights appropriate to the needs of each role. On the other hand, user data synchronization is crucial. SSO needs to be connected to a central database and able to integrate with directory services like LDAP to ensure consistent user data across platforms.

Increasing use of mobile devices and wireless networks, network authentication integrated with SSO is also a necessity. Users must be able to access services securely across various devices, such as smartphones and laptops. Security is also a top priority. The system needs to implement strong authentication protocols, data encryption, and mechanisms to prevent unauthorized access. Furthermore, the architecture must be scalable to accommodate the growing number of users and applications, given that continuous access to educational resources is vital. Finally, user experience is crucial. An intuitive and consistent interface will accelerate adoption across the campus community. An ideal SSO Portal Application offers a seamless login process and a uniform interface across all access points.

By considering all the above aspects, the designed SSO system architecture is expected to serve as a strong and flexible foundation for an integrated authentication system in higher education environments, providing an optimal user experience while maintaining high security standards.

3.2. Logic Architecture Design

The diagram in **Figure 1** shows a Single Sign-On (SSO) architecture designed for a higher education environment. The developed SSO architecture uses Keycloak as the SSO server, which serves as the authentication center for various applications. All users, including students, lecturers, staff, top management, and administrators, can access all applications and services through the SSO Portal Application, which serves as the main gateway for all systems.

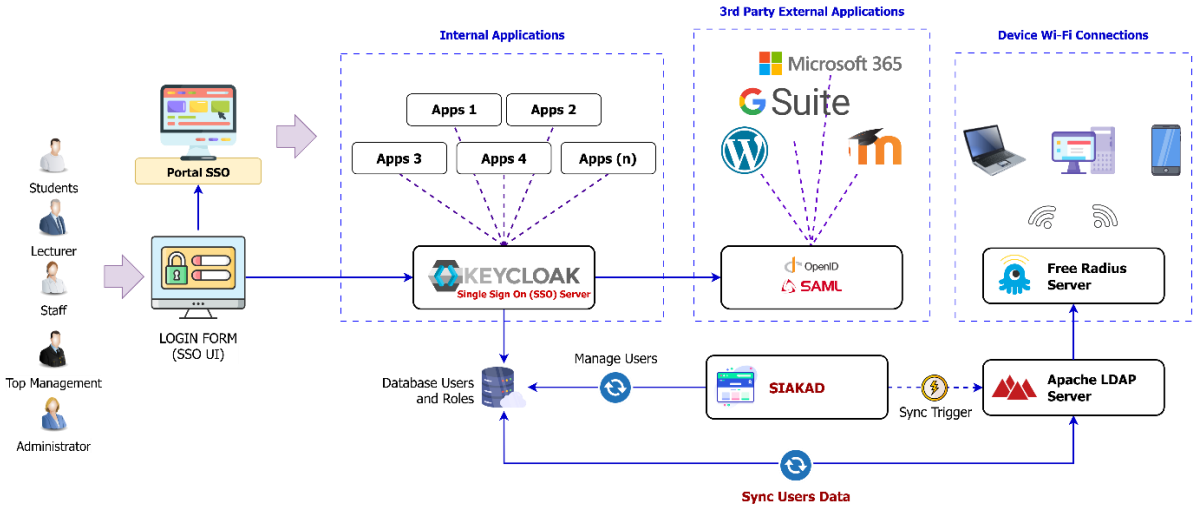


Figure 1. Logic Architecture Design SSO

SSO Architecture supports several standard protocols, including OpenID and SAML, which support various service connections, including WordPress, Google Suite, and Moodle. Keycloak serves as an identity provider that manages authentication for several different applications (Apps 1-n) through secure, token-based connections. On the data management

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side, this architecture utilizes the Academic Information System (SIAKAD) database to store user information. This database is integrated with the Apache LDAP Server for directory services, with bidirectional synchronization ensuring consistent user data across the system. Furthermore, the Free Radius Server enables network authentication for wireless access and devices.

This architecture demonstrates a well-designed identity and access management system where user credentials are verified once through Keycloak, allowing users to log in only once to access all applications and services across the university. SIAKAD functions not only as an application but also as a user management interface, triggering synchronization with an LDAP server when user data changes. Overall, this design addresses common challenges in higher education IT environments by providing secure, centralized authentication while maintaining flexibility for diverse applications and user roles. Implementation of standard protocols (OpenID, SAML) ensures interoperability with existing and future systems, ensuring the architecture remains scalable and ready to support the growth of the institution's digital ecosystem.

3.3. Wi-Fi Connection Interface

In this section, we will show several screenshots of the settings interface on an Android device when you want to connect to EAP-PEAP (Protected Extensible Authentication Protocol) based Wi-Fi. **Figure 2** illustrates the Wi-Fi connection process for EAP-PEAP. The connection process differs from a standard captive portal. With EAP-PEAP, users simply enter their SSO username and password directly into the operating system's built-in network configuration, rather than through a browser-based pop-up window that displays a landing page, as with typical captive portal technologies. Furthermore, the SSO concept for applications utilizes KeyCloak as the application's back-end authentication, which relies on the user's master database, similar to authentication on this network. An explanation of SSO for applications is outlined in the next sub-chapter on the SSO Portal Application.

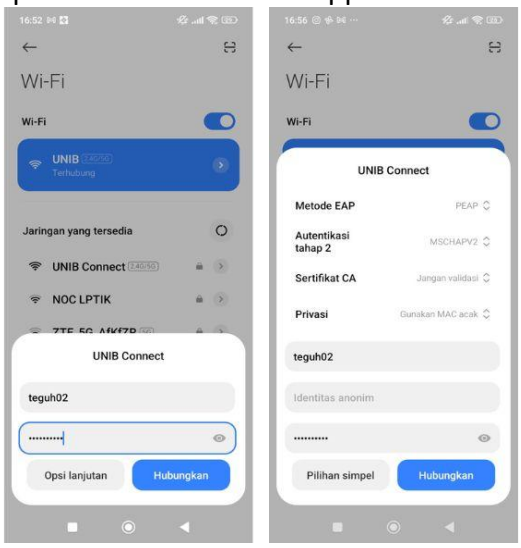


Figure 2. EAP-PEAP-based Wi-Fi connection interface on Android devices

3.4. Portal Single Sign-On (SSO)

The Single Sign-On (SSO) portal serves as the main homepage for all campus members to access digital services centrally. **Figure 3** shows the SSO portal application interface, which is designed to be concise and familiar. It includes several features, such as notifications to keep

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users informed, a search feature to help users find application features and services, a list of application services to make it easier for users to switch between applications, and a news feature to provide users with the latest information and news.

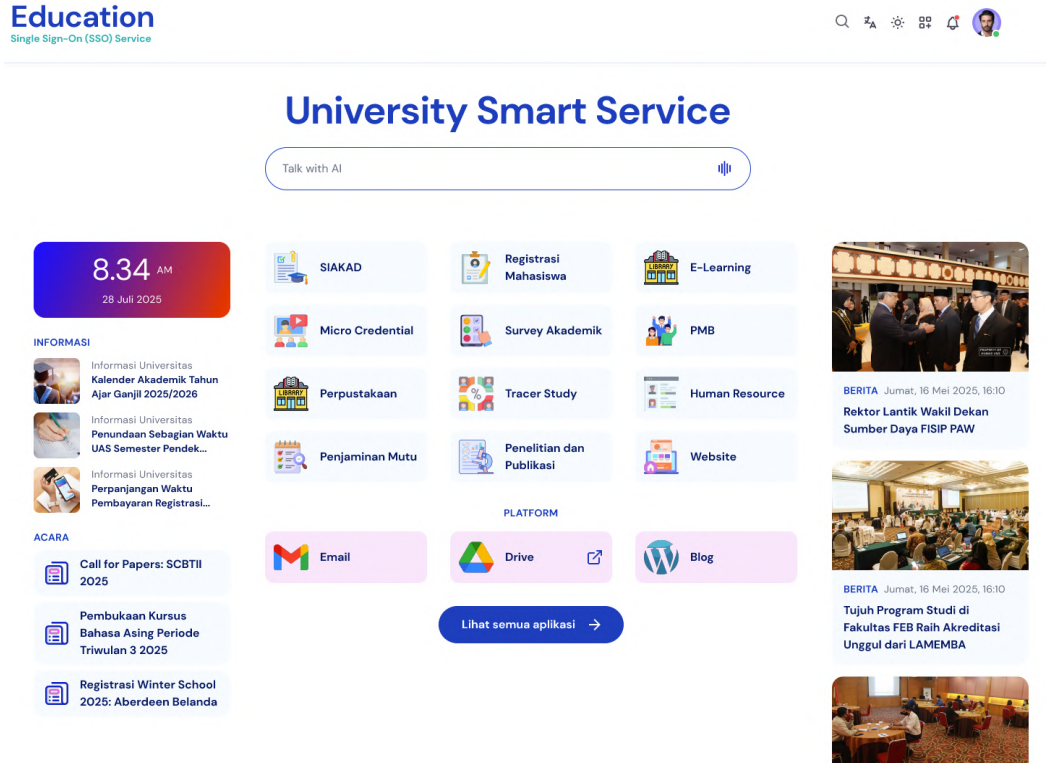


Figure 3. Interface of the SSO Portal Application

With SSO integration through Keycloak, users only need to log in once and move between applications without having to enter their credentials repeatedly. With a consistent user interface, comfortable color contrast, and typography that's readable across devices, the portal serves not only as a gateway but also as a hub for daily university activities, combining information, assignments, and applications in a simple, secure, and scalable experience tailored to the university's needs. **Figure 4** Academic Information System (SIAKAD) interface in two different display formats: the desktop view on the left and the mobile view on the right.

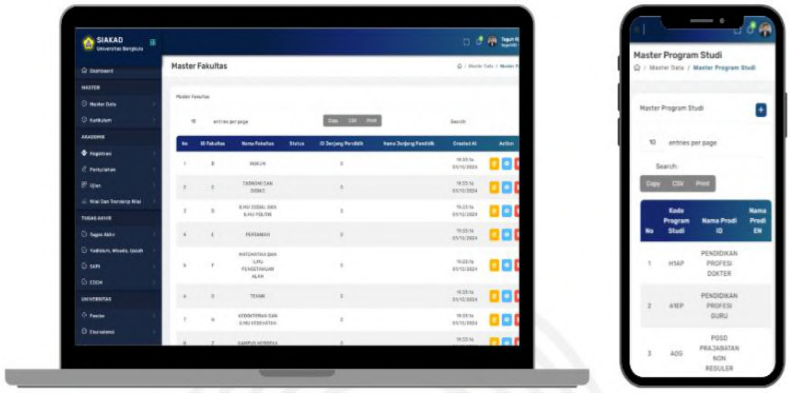


Figure 4. Academic Information System Interface (SIAKAD)

3.5. User Management and Integration

Figure 5 shows how user identities are managed and synchronized across the university's digital ecosystem. The process begins with SIAKAD (Academic Information System), which has

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a "Manage User" function to manage user data. This user data is then stored in the SIAKAD Database (Users Database). From this database, there is a "Sync Data" process that ensures user data is synchronized to the Apache LDAP Server. The Apache LDAP Server serves as a central directory that stores user authentication information.

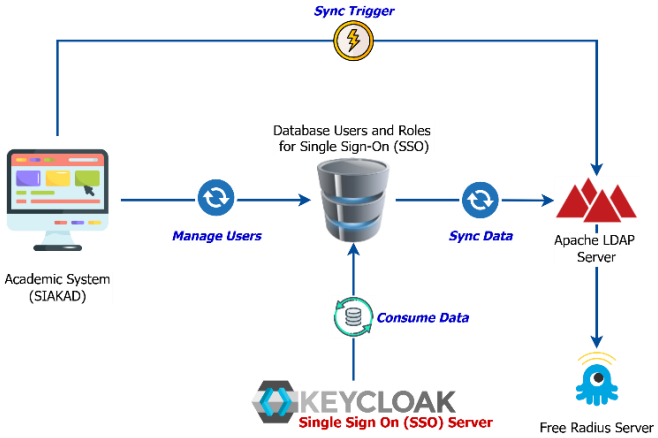


Figure 5. User Management and Integration

This server is connected to a Free Radius Server that handles device authentication, such as smartphones and laptops, via a wireless connection. With this architecture, users can access the system using the same credentials from various devices. The "Sync Trigger" flow shown from the Apache LDAP Server back to SIAKAD is used to ensure data consistency between systems. This allows changes made to the LDAP server to be forwarded back to SIAKAD to maintain data integrity. Overall, this diagram illustrates an integrated approach to user management and system integration that enables centralized identity management, Single Sign-on (SSO), and efficient data synchronization between various system components.

3.6. Deployment

The deployment section will explain the Single Sign-On (SSO) architecture concept designed in this research. A more complete explanation of the architecture is as follows. **Figure 6** illustrates several SSO components designed in this research. First, all user information is stored in a database called IAM, which is then accessed by the Keycloak server and the FreeRADIUS server, both of which serve as backends for the application and network SSO concept

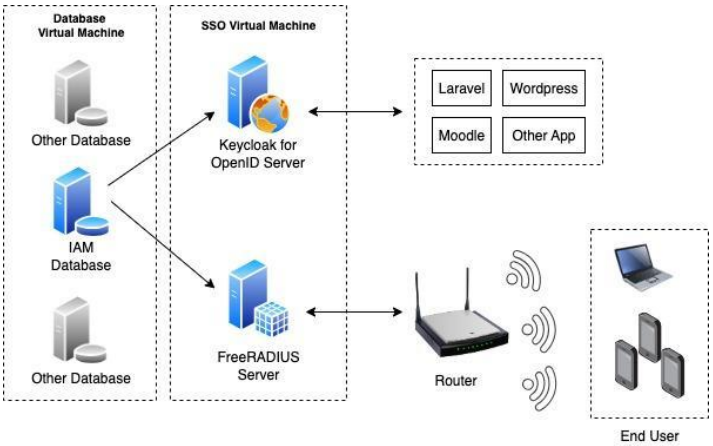


Figure 6. Single Sign-On (SSO) architecture diagram to be designed

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First, the Keycloak server, utilizing the OpenID protocol, is used as a bridge for authentication across multiple applications. Furthermore, the FreeRADIUS server serves as a bridge for authentication sent by network devices such as routers when a new user attempts to connect to the internet. Freeradius determines whether the user's username and password are valid or invalid, allowing the user to connect or not. With this single database concept, it is hoped that network and application access will require only a single access point, as proposed by the SSO concept.

3.7. Performance Testing

In this performance testing phase, we will discuss the performance of the server design, based on the deployment points outlined previously. The performance testing is explained below. Based on **Table 2** displays several user histories that were successful ("Access-Accept") or unsuccessful ("Access-Reject") in connecting to the network, and the data is displayed in the date range of July 17, 2025, to July 31, 2025. The data is generated by FreeRadius, which is stored in the IAM database

Table 2. History of session status of users who have connected to the SSO Wi-Fi network

Date	Status	Total
17/07/25	Access-Reject	898
18/07/25	Access-Accept	146
18/07/25	Access-Reject	53
21/07/25	Access-Accept	8
21/07/25	Access-Reject	6
22/07/25	Access-Accept	50
22/07/25	Access-Reject	189
23/07/25	Access-Accept	405
23/07/25	Access-Reject	475
24/07/25	Access-Reject	2064
25/07/25	Access-Accept	469
25/07/25	Access-Reject	318
26/07/25	Access-Accept	1891
26/07/25	Access-Reject	2
27/07/25	Access-Reject	273
28/07/25	Access-Accept	3044
28/07/25	Access-Reject	387
29/07/25	Access-Accept	1372
29/07/25	Access-Reject	5830
30/07/25	Access-Accept	9293
30/07/25	Access-Reject	792
31/07/25	Access-Accept	12702
31/07/25	Access-Reject	2139

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Figure 7 illustrates a diagram based on the historical data presented in **Table 2**. **Figure 7** shows differences in the number of user sessions with successful and unsuccessful statuses. The highest number of sessions was shown on July 29, 2025, for rejected statuses with 6,000 sessions, and on July 31, 2025, for successful statuses with 12,000 sessions.

Furthermore, the CPU and RAM usage history during testing, according to the session status history data described previously in **Table 2**, is as follows, as illustrated in Table 3 below.

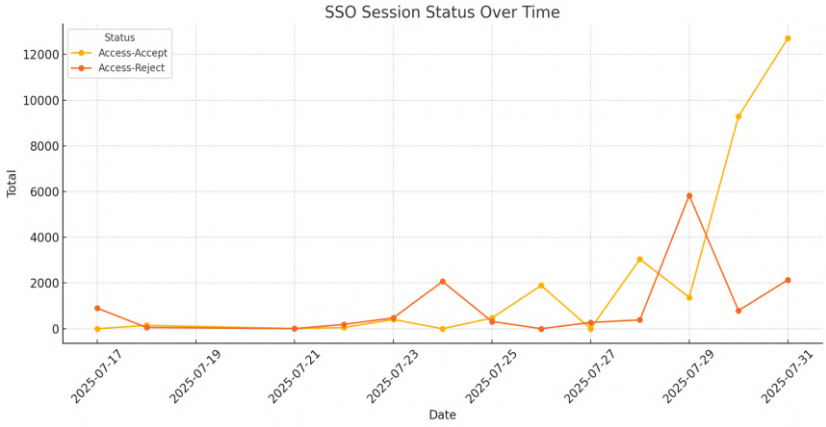


Figure 7. Total SSO session diagram

Table 3, described previously, presents the results of CPU and RAM usage collected by researchers based on the test results presented in **Table 2**. Both tables display data spanning July 17, 2025, to July 31, 2025. Table 3 shows significant changes in CPU and RAM usage on the SSO server for both Wi-Fi network authentication and application authentication. This is illustrated graphically in **Figure 8**

Table 3. History of CPU and RAM usage of the SSO *Wi-Fi* server and Application

Time	Total CPU Usage	Total RAM Usage
17/7/2025	0,03106271916	0,03266300862
18/7/2025	0,0624801238	0,06771712939
19/7/2025	0,06295687135	0,06997227645
20/7/2025	0,06343454732	0,07057634019
21/7/2025	0,06392178921	0,07418943244
22/7/2025	0,06437081225	0,07606327389
23/7/2025	0,06492218995	0,06193965521
24/7/2025	0,06528185305	0,05901939347
25/7/2025	0,06574194144	0,06649759883
26/7/2025	0,04961246821	0,05091507292
27/7/2025	0,04995151753	0,04043856865
28/7/2025	0,04999030708	0,03767043748
29/7/2025	0,05049999576	0,05111074034
30/7/2025	0,05105480152	0,05040540034
31/7/2025	0,05140933625	0,05999610294

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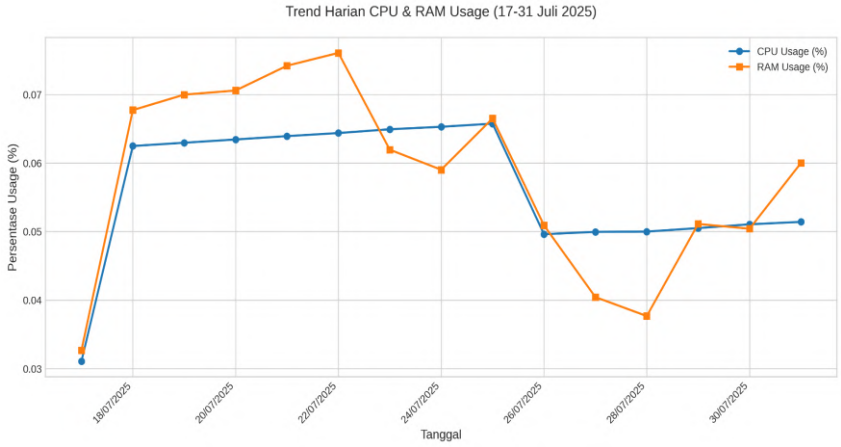


Figure 8. Diagram of RAM and CPU usage history according to the tests carried out in Table 2

As seen in **Figure 8**, CPU and RAM usage are very significant. For example, on July 22, 2025, RAM usage reached nearly 100% of its normal usage. However, on July 28, 2025, RAM usage dropped drastically to below 40%.

The performance evaluation of the proposed SSO architecture demonstrates exceptional operational efficiency and scalability. Utilizing a modest server configuration of 4 vCPUs and 8 GB RAM, the system successfully managed a peak load of 12,000 authentication sessions. Throughout this load, the resource utilization remained stable, with CPU and RAM consumption fluctuating between 40% and 80%, well below critical thresholds that would indicate performance degradation. When contextualized against established benchmarks in the literature [18], which report higher resource utilization for similar infrastructures, these results are notably superior. This favorable comparison confirms that the architected solution is not only functionally robust but also highly resource-efficient.

3.8. Usability Testing

The System Usability Scale (SUS) is a measurement instrument developed by Brooke (1996) to evaluate user perceptions of the ease of use of a system or application [16]. This measurement instrument uses ten standardized items on a five-point Likert scale, resulting in a score between 0 and 100. **Figure 9** illustrates the SUS testing process used in this study. The SUS testing in this study aimed to measure the level of system acceptance and usability of the SSO Portal Application interface design from the perspective of the academic community..

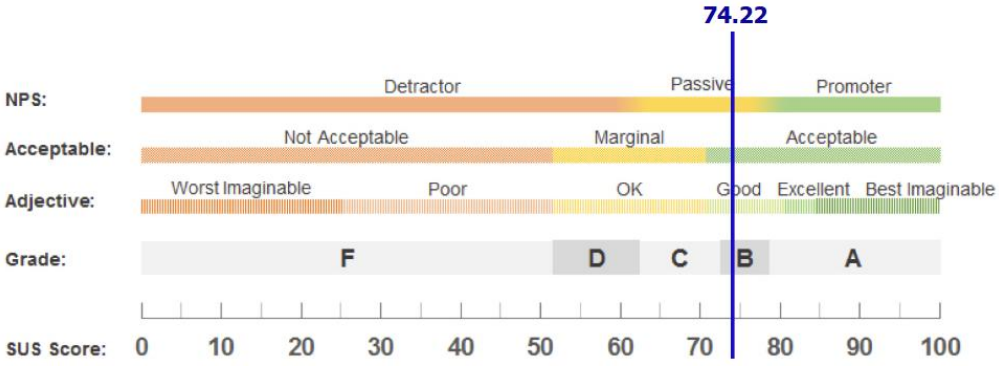


Figure 9. SUS Score Scale Result

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The survey involved 441 respondents from three universities, consisting of students, faculty, and staff. The survey results showed an average SUS score of 74.22, with scores distributed by respondent group as follows: students (72.48), staff (75.73), and faculty (74.43). The detailed results of the SUS scores are presented in **Table 4**.

Figure 9 displays the SUS Score Scale results. The average SUS score of 74.22 places the SSO Portal Application in the B category, interpreted as "Good" based on the research [16]. This result indicates that the system has met acceptable standards (Accept), as it exceeds the acceptable usability threshold of 68. The Net Promoter Score (NPS) remains in the "Passive" category [17], indicating that user satisfaction levels have not yet reached the optimal level of loyalty for recommending the system to other potential users.

Table 4. Detailed Results of the SUS Scores

User	Jumlah Responden	SUS Score	Grade	SUS Score Range	Adjective	Accepteable	NPS
Mahasiswa	282	72.48	C+	71.1–72.5	Good	Acceptable	Passive
Staf	71	75.74	B	74.1–77.1	Good	Acceptable	Passive
Dosen	88	74.43	B	74.1–77.1	Good	Acceptable	Passive
TOTAL	**441**	**74.22**	**B**	**74.1–77.1**	**Good**	**Acceptable**	**Passive**

The usability testing results, reflected in the System Usability Scale (SUS) score of 74.22, indicate a “Good” user experience, yet the system falls within the “Passive” category, suggesting room for improvement. These results indicate that the SSO Portal Application has successfully met basic user functional needs but still requires improvements in the user experience to achieve maximum satisfaction. One possible reason for this score is the relative novelty of the Single Sign-On (SSO) system, as students and Civitas academica may not yet be fully familiar with this new approach. This lack of familiarity could contribute to the system not reaching the “Promoter” level. Similar challenges were observed in the [19], where a C+ average score was recorded, highlighting that users may require time to adjust to new systems. Furthermore, recent studies have also emphasized the need for enhanced authentication efficiency and user-centered SSO design to improve scalability and user acceptance in multi-cloud environments [20].

To bridge this gap and elevate user experience from passive acceptance to active advocacy, a multifaceted strategy is proposed for future work. First, targeted UI/UX refinements will be implemented based on detailed user feedback sessions, focusing on simplifying the portal dashboard, clarifying navigation cues, and streamlining the authentication flow between services. Second, a comprehensive and ongoing socialization campaign is crucial. This will include interactive workshops, video tutorials, and clear documentation to familiarize the academic community with the system's benefits and functionality, thereby reducing hesitancy and building confidence. Third, establishing a continuous feedback loop through embedded feedback buttons and periodic surveys will allow for real-time issue resolution and iterative design improvements. The impact of these enhancements will be rigorously measured through follow-up SUS and NPS evaluations, creating a data-driven cycle of refinement. This proactive and user-centric approach is essential for transitioning the SSO system from a functional tool to a seamlessly integrated and positively perceived cornerstone of the digital campus ecosystem

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Test results indicate that the SSO Portal Architecture and Application implemented in higher education institutions have been well-received by the majority of users. However, there are differences in experience between user groups. The test results serve as the basis for further development, focusing more attention on the user interface and adjusting functionality to make the system more user-friendly.

4. CONCLUSION

This research has successfully designed and implemented a comprehensive Single Sign-On (SSO) architecture to address authentication challenges in a post-COVID-19 higher education environment. The success of the system implementation can be seen from the achievement of all established research objectives. The SSO architecture, developed using Keycloak as an Identity Provider (IdP), has proven capable of integrating various internal applications, such as SIAKAD, third-party applications like WordPress, Moodle, and Google Workspace, as well as Wi-Fi network access via the EAP-PEAP protocol, into a single, centralized, effective, and efficient platform.

The evaluation results demonstrate significant success in achieving the research objectives. Usability testing using the System Usability Scale (SUS) with 441 respondents from three universities showed an average score of 74.22, which indicates the system is in the "Good" category and has met acceptable standards by exceeding the acceptable usability threshold of 68. Although there are variations in scores between user groups with students (72.48), staff (75.74), and lecturers (74.43), these results demonstrate that the system has succeeded in meeting the basic functional needs of the entire academic community.

5. ACKNOWLEDGMENT

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6. AUTHORS' NOTE

This article has been reviewed using the plagiarism detection software iThenticate, and the results show a similarity index of 4%, which is within acceptable academic standards. The authors declare that all sources have been properly cited, and the work presented is original and free from plagiarism.

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Trajectory Tracking of a Four-Wheel Omni-Directional Mobile Robot using PID Control Method

Fizar Maulana[1] , Nundang Busaeri [2], Imam Taufiqurrahman[3]*

[123]Department of Electrical Engineering, Faculty of Engineering, Universitas Siliwangi, Indonesia
Correspondence E-mail: fizar.maulanaokta9@gmail.com

ABSTRACT

Omni-Directional Mobile Robot (OMR) offers superior mobility that allows it to move in any direction without the need to change orientation. However, for precision applications such as robotic competitions or industrial logistics, the main challenge is the ability to accurately track the trajectory. This study proposes a simulation of a Proportional-Integral-Derivative (PID) control system for OMR with a four-wheel configuration. The research methodology includes inverse kinematics modeling to translate the robot's speed into the speed of individual wheels, the design of PID controllers to minimize position errors, and its implementation in a MATLAB simulation environment. The test scenario is carried out by providing a series of reference points (waypoints) that the robot must follow. The simulation results showed that the designed PID control system was able to direct the robot to follow a specified trajectory with a high degree of accuracy. The speed analysis of each wheel also shows a dynamic response that corresponds to kinematic calculations. This study proves the feasibility of implementing PID controllers for trajectory tracking applications on four-wheel OMRs and can be the basis for development on physical platforms.

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1. INTRODUCTION

The development of robotics technology, especially mobile robots, has had a significant impact on various aspects of life. One type that attracts attention is the Omni-Directional Mobile Robot (OMR) [1][2]. OMRs utilize special omni-wheels with additional rollers [3][4], enabling them to move in any direction without changing the robot's body orientation, making them holonomic robots [5]. This superior maneuverability is beneficial in tight or complex environments [6][7]. OMRs come in configurations like three-wheel (120°) or four-wheel (90° or 45°), each affecting its kinematic model [8], [9]. This study focuses on a four-wheel configuration with an X-shaped (45°) arrangement, which offers good mechanical stability. OMR applications are diverse, ranging from industrial automation [10][11], healthcare, exploration, to robotic competitions.

In industrial applications, OMRs are used for the transport of materials within factories autonomously, while in military applications, these robots are used for reconnaissance missions to reduce risks to personnel [12][3]. In these various applications, the fundamental problems faced are communication and, most importantly, the positioning of the robot. Precisely controlling movement becomes very difficult because it has to adjust the speed of four DC motors simultaneously. The robot's ability to calculate the current position relative to the previous position, or dead reckoning, requires considerable effort [5] The determination of this position relies heavily on input from several sensors, one of which is the rotary encoder, which specifically aims to obtain the rotational speed of each wheel [14][1].

To overcome positioning problems and achieve accurate trajectory tracking, a control system is needed. Some commonly used control methods include odometry, artificial neural network (NN), fuzzy logic, and Proportional-Integral-Derivative (PID) controllers [15][16][17]. The odometry method, which estimates position changes over time using data from motion sensors such as rotary encoders, is often implemented as feedback to improve precision [8][9]

PID controllers, although conventional, are still very widely used due to their ability to produce precise and fast control. In robotic applications, PID controllers are ideal for counteracting the decrease in DC motor speed due to load, so that the rotary speed can be kept constant as desired [18][16] PID controllers work by minimizing the error values present in the system and can provide a fast response, making them ideal for controlling DC motor actuators [19][20][21].

This research focuses on the design and simulation of a PID control system for an omni-directional mobile robot (OMR), aiming for precise movement toward predefined waypoints. The study's main contribution is the integration of an accurate inverse kinematics model for a four-wheel configuration with a PID-based closed-loop control scheme to minimize position errors. The simulated OMR uses a four-wheel layout arranged at 45-degree angles, ensuring balanced motion dynamics. All modeling and analysis, including kinematic computation and controller performance evaluation, were conducted using MATLAB. The scope is limited to system design and validation within a simulation environment, serving as a preliminary step toward implementation on a physical platform.

2. METHODS

The steps that must be taken to achieve the goals of this research can be seen in **Figure 1.** below.

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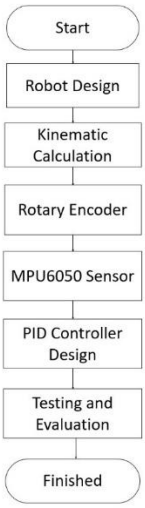


Figure 1. Research Flowchart

The research flowchart in Figure 1 illustrates the systematic stages of the robot design and development process. The research begins with defining the mechanical parameters of the mobile robot, such as wheel radius and wheelbase distance, to determine the kinematic relationships. Kinematic calculations are then performed to establish the mathematical model governing the robot's motion and trajectory control.

Next, the rotary encoder module is integrated to measure wheel rotation, generating pulse signals for displacement and speed feedback, which are essential for estimating position and velocity. The MPU6050 sensor is incorporated to provide complementary data on angular acceleration and orientation, enhancing motion estimation accuracy and stability analysis.

Subsequently, a PID (Proportional–Integral–Derivative) controller is designed and tuned to regulate the robot's motion dynamics. The controller processes feedback from the encoder and sensor data to minimize error between desired and actual trajectories, ensuring smooth movement. Finally, the system undergoes testing and evaluation to validate performance, responsiveness, and robustness.

Figure 2 shows a robot wheel that can move in any direction. An omni wheel is a wheel that is tucked between the wheels. This single wheel has a small wheel that functions to move in all directions. **Figure 2** shows the Omni wheel with 14 rollers and a width of 82 mm.



Figure 2. Omni-Wheel

Figure 3 is a schematic of a four-wheeled omni wheel. The linear speed of each wheel (V_i) is the result of the superposition of two components of motion, namely rotational motion and robotic translational motion.

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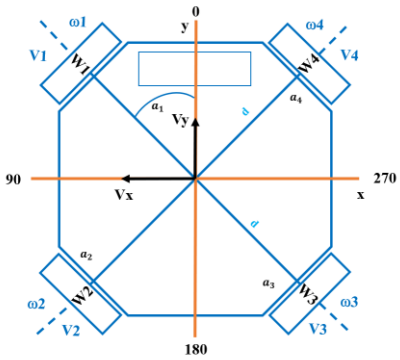


Figure 3. Schematic of the arrangement of the omni wheel with four wheels

The contribution of translational motion is obtained by projecting the velocity vector in the direction of the rotation of the wheel. Meanwhile, the contribution of rotational motion depends on the angular velocity $[x, y]$ *of the robot* θ and the distance from the center of the robot to the wheel R. This relationship is formulated with equation (1).

$$V_i = -sin(a_i)x + cos(a_i)y + R\theta \tag{1}$$

Furthermore, the linear velocity of a wheel V_i has a direct relationship with its angular velocity ω_i through the parameter r of the radius of the wheel, as shown in equation (2).

$$V_i = r\omega_i \tag{2}$$

By substituting equation (1) into equation (2), a reverse kinematics model for one wheel is obtained, as presented in equation (3).

$$\omega_i = \frac{1}{r}(-sin(a_i)x + cos(a_i)y + R\theta) \tag{3}$$

Equation (3) is arranged for each wheel with equation (4).

$$\omega_1 = \frac{1}{r}(-sin(a_1)x + cos(a_1)y + R\theta)$$

$$\omega_2 = \frac{1}{r}(-sin(a_2)x + cos(a_2)y + R\theta)$$

$$\omega_3 = \frac{1}{r}(-sin(a_3)x + cos(a_3)y + R\theta) \tag{4}$$

$$\omega_4 = \frac{1}{r}(-sin(a_4)x + cos(a_4)y + R\theta)$$

The specifications of the Omni robot are shown in **Table 1**.

Table 1. Specification of Omni Robot

No.	Symbol	Information
1	x *and* y	The coordinates of the robot's position from the global map reference.

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2	a_1, a_2, a_3, a_4	The angle that is shaped between the wheel and the axis y robot.
3	$W1, W2, W3, W4$	Symbols for the wheel in each position.
4	$d\ [meter]$	Distance (meters) between the wheel and the center of the wheel.
5	$v_1, v_2, v_3, v_4\ [^m/_s]$	Linear speed of the robot's wheels.
6	$\omega_1, \omega_2, \omega_3, \omega_4\ \left[^{rad}/_s\right]$	Wheel angle speed.
7	V_x	Speed against the robot's x-axis.
8	V_y	Speed against the robot's y axis.

To represent the system as a whole, equations (4) are arranged into the form of equation matrices (5).

$$\begin{bmatrix}\omega_1\\ \omega_2\\ \omega_3\\ \omega_4\end{bmatrix} = \frac{1}{r}\begin{bmatrix}-sin(a_1)x + cos(a_1)y + R\\ -sin(a_2)x + cos(a_2)y + R\\ -sin(a_3)x + cos(a_3)y + R\\ -sin(a_4)x + cos(a_4)y + R\end{bmatrix}\begin{bmatrix}x\\ y\\ \theta\end{bmatrix} \quad (5)$$

By substituting the specific angular values $(a_1, a_2, a_3, dan\ a_4)$ of the equation (5), the robot configuration used in this study obtained the equation (6).

$$\begin{bmatrix}\omega_1\\ \omega_2\\ \omega_3\\ \omega_4\end{bmatrix} = \frac{1}{r}\begin{bmatrix}-sin(45°)x + cos(45°)y + R\\ -sin(135°)x + cos(135°)y + R\\ -sin(225°)x + cos(225°)y + R\\ -sin(315°)x + cos(315°)y + R\end{bmatrix}\begin{bmatrix}x\\ y\\ \theta\end{bmatrix} \quad (6)$$

Equation (6) is at the heart of the motion control algorithm, which allows precise calculation of the rotational speed of the motor to achieve an accurate goal. For computational implementations, the angular value in degrees is converted into radian units in the equation (7).

$$\begin{bmatrix}\omega_1\\ \omega_2\\ \omega_3\\ \omega_4\end{bmatrix} = \frac{1}{r}\begin{bmatrix}-sin\left(\frac{\pi}{4}\right)x + cos\left(\frac{\pi}{4}\right)y + R\\ -sin\left(\frac{3\pi}{4}\right)x + cos\left(\frac{3\pi}{4}\right)y + R\\ -sin\left(\frac{5\pi}{4}\right)x + cos\left(\frac{5\pi}{4}\right)y + R\\ -sin\left(\frac{7\pi}{4}\right)x + cos\left(\frac{7\pi}{4}\right)y + R\end{bmatrix}\begin{bmatrix}x\\ y\\ \theta\end{bmatrix} \quad (7)$$

The PID controller integrates three control actions proportional, integral, and derivative which mathematically work together to reduce or eliminate errors within the control system. Equation (8) represents the PID control output signal, expressed as a Pulse Width Modulation (PWM) signal, which is used to regulate the motor's rotational speed.

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$$u = Kp(e)t + Ki\int_0^t e(t)dt + Kd\frac{de(t)}{dt} \quad (8)$$

In this system, u represents the control signal, while Kp, Ki, and Kd denote the proportional, integral, and derivative constants, respectively. The term e(t) refers to the error signal, which is obtained by comparing the desired reference value with the actual sensor readings. This approach utilizes encoder data to estimate the system's position parameters x, y, and θ allowing the controller to correct deviations and compensate for positional errors that may occur during operation.

The next step is to determine how to organize the production of the robot. Research flow chart in **Figure 4.** shows the steps involved in the manufacture of the robot.

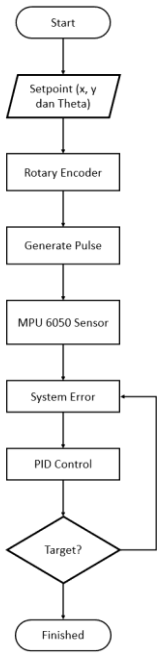


Figure 4. Study Flowchart

The set points at the x, y, and theta coordinates are the starting points of the flowchart from Figure 4. The pulse given is then made using sensor readings and the position to be traversed, so that it matches the trajectory of the drive. There is a compatibility ratio with a particular trajectory. A system error is a reading sign that has a set point. Enter the system fault into the PID controller to adjust the generator to match the desired target and make the error zero.

3. RESULTS AND DISCUSSION

In designing this robot, the next step is to create a 3D design that serves as an initial visualization before the actual design is made, when all the required dimensions have been determined. The robot's design drawings aim to know the parameters to make the programming process easier.

Figure 5. is a Robot design designed to know the size of the frame. From Figure 5, the wheelbase distance and base radius of the OMR robot can be determined.

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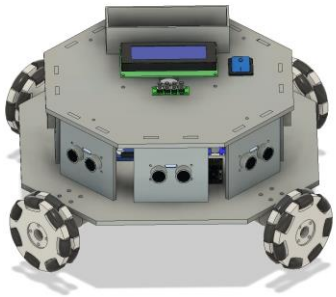


Figure 5. 3D design of mobile robots

After knowing the image, the next step is to determine the image of the stage series. The specifications of the robot frame can be seen from the **Table 2**.

Table 2. Specification of Omni Robot Frame

No.	Information	Size (mm)
1	Wheelbase to midpoint of the body	150
2	Length Diameter	300
3	Diameter Roda	82

Table 2. shows the frame specifications of the omni robot. It further describes the flow of the omni robot control system. The process starts from a reference that determines the target trajectory and this data is processed through inverse kinematics to calculate the required wheel angular speed. Furthermore, the PID Controller adjusts the speed of each motor according to the reference speed and feedback from the rotary encoder can be seen in **Figure 6**.

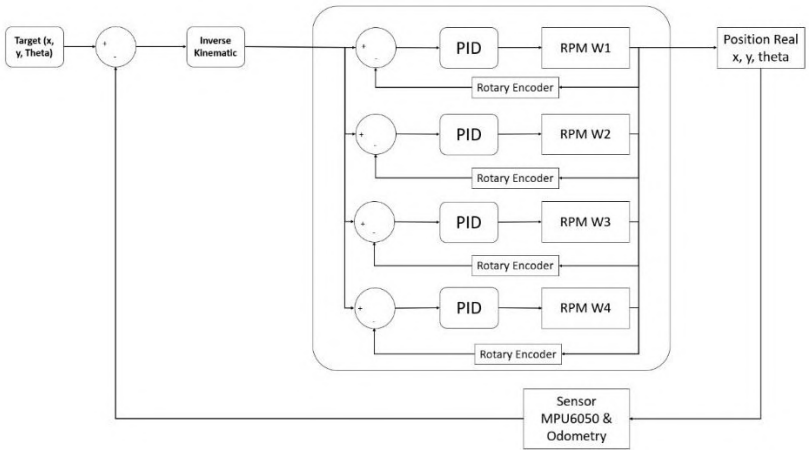


Figure 6. Diagram control

A mathematical model of a four-wheeled omni-wheel mobile robot is simulated using Simulink's MATLAB with the physical parameters shown in Table 2. These parameter values are adapted from previous research that applied PID control to omni-wheel robot systems with similar configurations to support the accuracy of track movement.

The PID controller is designed to regulate the robot's translation and rotation speed to be able to follow a predetermined reference trajectory. The simulation was carried out without

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considering external interference, as the research was focused on simulated system performance analysis. **Figure 7, Figure 8, and Figure 9** show the Simulink model of the omni-wheel robot, wheel speed calculations through inverse kinematics, as well as translational and rotational movement results that demonstrate the effectiveness of PID control in maintaining track stability and precision.

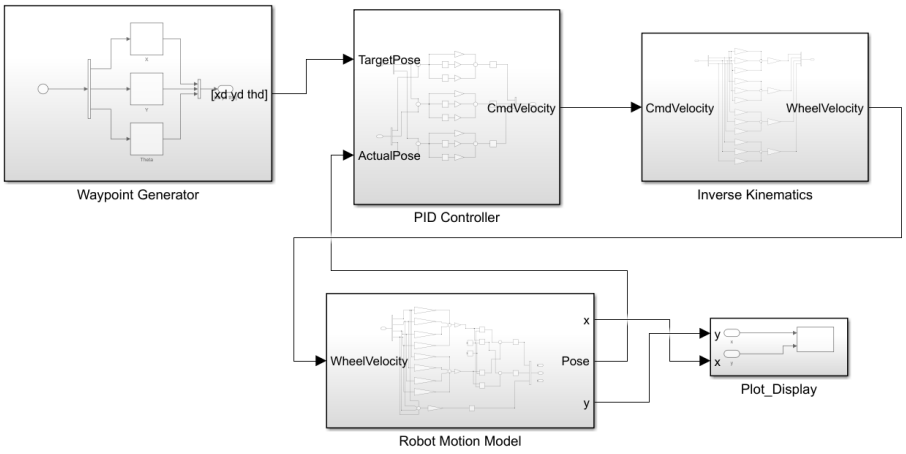


Figure 7. Block simulink model trajectory tracking robot omni-wheel

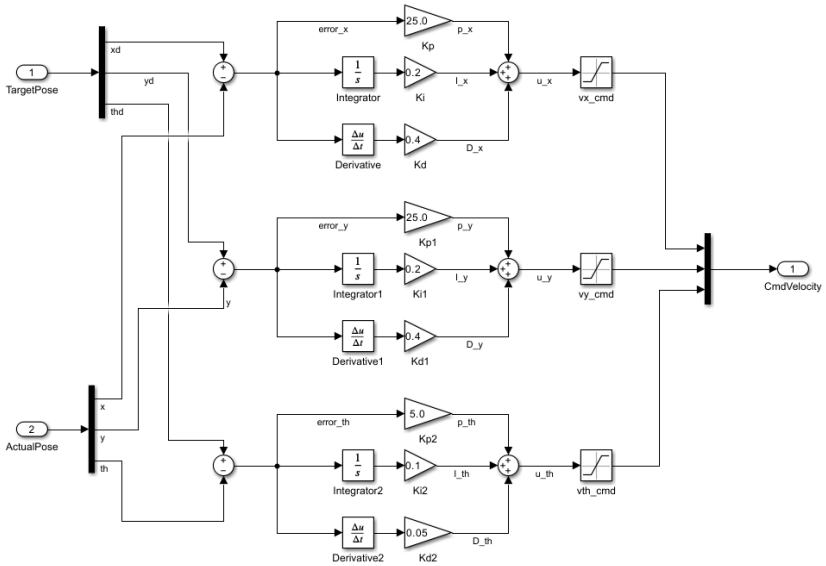


Figure 8. Block simulink control PID robot omni wheel

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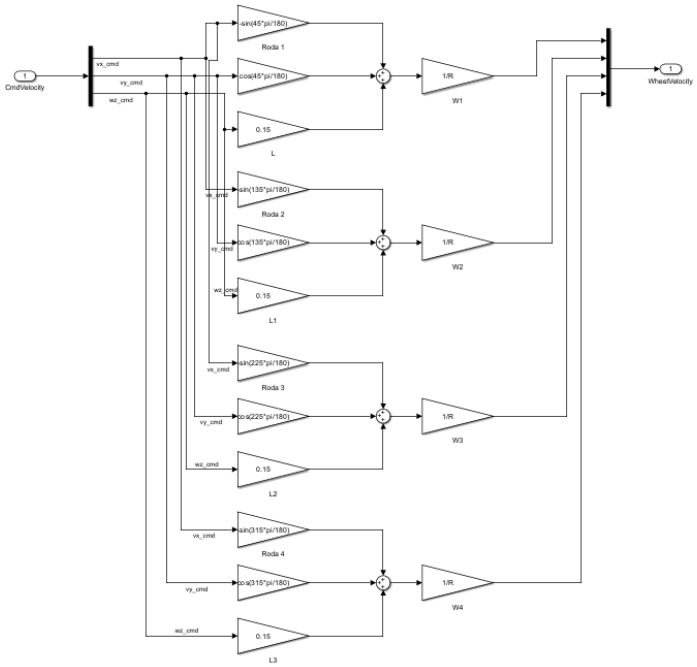


Figure 9. Block simulink inverse kinematic omni-wheel robot

The results of the program simulation using a square (or rectangle) trajectory, with multiple waypoints defined for the Omni Mobile Robot (OMR), are shown in **Figure 10**. The test is carried out by providing reference points that the robot must reach in order. The directional points are expressed in coordinates (x, y, θ) as [0, 0, 0; 3.0, 0.0, π/4; 3.0, 2.0, π/2; 0.0, 2.0, π/2] in time units [0; 3; 6; 9; 12; 15]. Figure 13 shows the results of the kinematics of the robot's movement and control response. The initial condition is represented by the first point [0, 0, 0]. The second point [3.0, 0.0, π/4] is reached in about 3 seconds, indicating the robot's smooth movement along the x-axis before turning in the y-direction. The subsequent waypoints on [3.0, 2.0, π/2] and [0.0, 2.0, π/2] depict the robot successfully following the planned square trajectory, although slight deviation may occur due to PID parameter tuning and kinematic interaction effects.

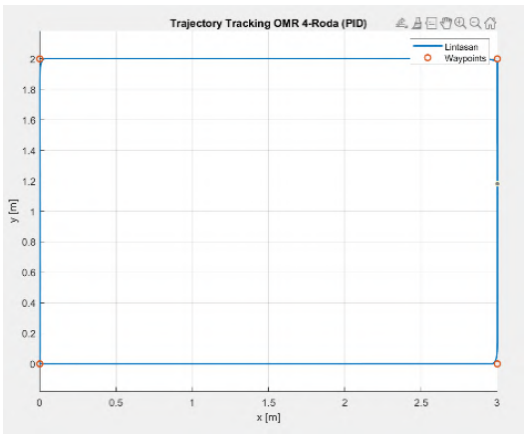


Figure 10. Trajectory Tracking on a square trajectory

Figure 11 continues the experiment from Figure 8 by changing the shape of the trajectory to a triangular path, while maintaining the same time interval [0; 3; 6; 9; 12; 15]. The waypoint points are set at position (x, y, θ) [0.0, 0.0, 0.0; 3.0, 0.0, π/4; 1.5, 2.0, π/2]. The robot starts at [0,0,0], moves along the x-axis, then turns upwards towards the y direction to complete the

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triangular trajectory. The simulation results showed that the PID controller remained stable and performed consistent track tracking across various path shapes, demonstrating good control system adaptability.

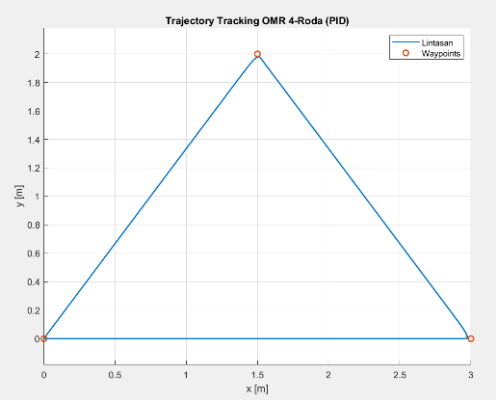


Figure 11. Trajectory Tracking on a square trajectory

Figure 12 and **Figure 13** show a comparison of the angular speed response of the omni wheel on square and triangular trajectories. Each image shows the tracking performance between the actual wheel angle speed ($\omega_1 - \omega_4$, full line) and its reference value (ω_1, ref – ω_4, ref, dotted line). The results show that the PID controller is able to create each wheel in a way that is consistent with the stability and synchronization of the system. In a square trajectory, the change in speed is sharper due to the greater weight, whereas in a triangular trajectory, the change in speed is smoother. This shows that the control algorithm can effectively adapt to different types of trajectories.

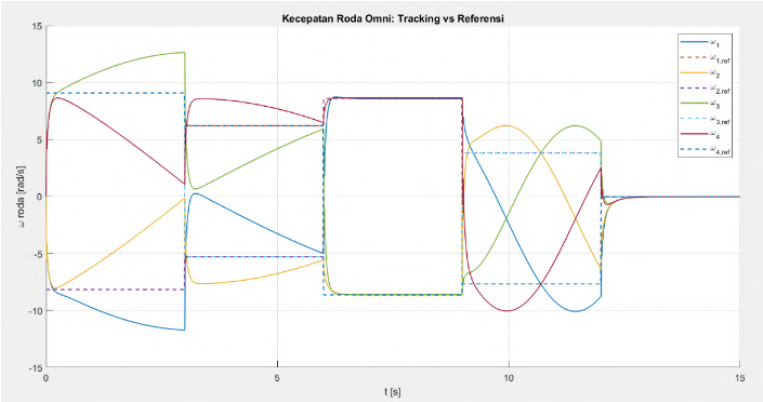


Figure 12. Wheel angular speed response on a square track

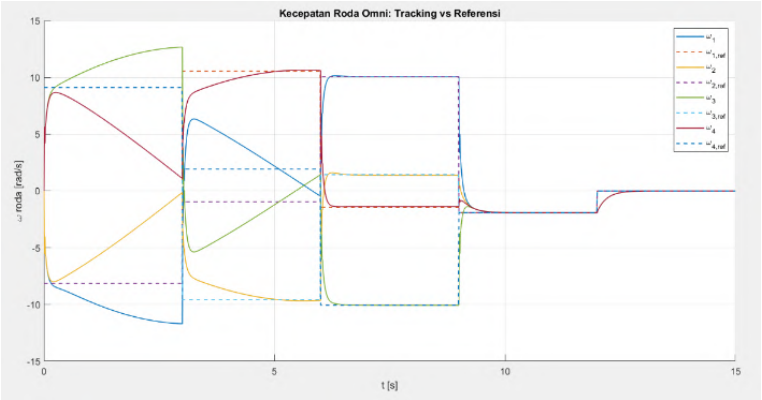


Figure 13. Wheel angular speed response on triangular trajectories

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4. CONCLUSION

This study successfully demonstrated the simulation of a four-wheeled omni-directional mobile robot (OMR) controlled using a Proportional–Integral–Derivative (PID) method. The research encompassed several stages, including mechanical design, component selection, electrical system configuration, inverse kinematics modeling, and PID controller implementation for position control. Simulation results conducted over 15 seconds with various waypoints showed that the designed PID controller effectively guided the robot to follow both square and triangular trajectories with high accuracy and stability. The OMR was able to reach each waypoint precisely while maintaining smooth rotational motion, indicating that the PID control strategy successfully minimized position errors and ensured consistent trajectory tracking. These findings confirm the feasibility of applying PID control to four-wheeled omni-directional mobile robots and provide a strong foundation for future implementation on physical platforms where environmental disturbances and sensor noise can be further analyzed.

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6. AUTHORS' NOTE

The author declares that there is no conflict of interest related to the publication of this article. The author confirms that the paper is free of plagiarism.

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Investigation of Cyber Malware Attacks On Server Networks Using SIEM Method Based On NIST 800-61

Ali Muhammad[1], Budi Jejen Zaenal Abidin[2], Yolanda Putri Yani[3], Nurul Widyastuti[4], Angge Firizkiansah[5], Miri Ardiansyah[6]*

[1,5]Departement of Informatics Engineering, Universitas Sains Indonesia, Bekasi, Indonesia
[2,3,6]Departement of Information Systems, Universitas Sains Indonesia, Bekasi, Indonesia
[4]Kementerian Agama, Indonesia
Correspondence E-mail: ali.muhammad@lecturer.sains.ac.id

ABSTRACT

The growth of cyber threats, especially malware attacks on servers, has increased significantly and is increasingly complex. These attacks can cause huge losses regarding data confidentiality, system integrity, and service availability. Slow and unstructured handling of security incidents can worsen the impact. This research aims to develop an efficient detection and response system to malware attacks, especially on servers that are the main targets of cyberattacks. This research uses a systematic and responsive approach using the NIST 800-61 Rev 2-based SIEM (Security Information and Event Management) framework in handling cyber incidents. The SIEM framework enables an investigation or digital forensics process that includes monitoring, correlating, and analyzing incidents. Meanwhile, NIST 800-61 Rev 2 aims to analyze the investigation process or digital forensics of cybercrime cases and generate digital evidence. The results of this study show that malware cyberattacks tend to be silent and do not show any anomalies on the server. Digital forensic evidence is presented to detect the veracity of a malware attack.

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1. INTRODUCTION

In an increasingly advanced digital era, server networks are one of the main foundations in managing information and operating organizational systems, both in the government, education, health, and financial sectors. The development of this technology provides many conveniences, but it also opens a gap for cybersecurity threats, especially malware attacks. Malware is malicious software designed to damage, infiltrate, or steal data from computer systems and networks. It can take the form of viruses, trojans, worms, spyware, ransomware, and adware [1][2][3][4][5]. Malware cyberattacks have increased significantly every year, both in terms of number and complexity. In Indonesia, malware-based cyberattacks have targeted various sectors, including educational institutions, hospitals, and financial and service companies [4]. Many of these attacks are not detected early due to limitations in monitoring systems as well as a lack of awareness and preparedness from network managers. Therefore, early detection of malware is a crucial aspect of maintaining digital infrastructure security.

One of the evolving methods for dealing with cybersecurity incidents is the National Institute of Standards and Technology (NIST) approach that offers a systematic framework for responding to security incidents. SIEM (Security Information and Event Management) is a technology that supports incident detection and response in real time by combining log analysis, data correlation, and system monitoring [6][7][8][9]. Meanwhile, NIST Guide 800-61 Rev 2 provides a structural approach to handling incidents such as malware attacks, which includes four main stages: preparation, detection and analysis, containment, eradication and recovery, and post-incident activity [4][10]. The application of the NIST 800-61 Rev 2 method integrated with the SIEM system is expected to detect and analyze malware attacks more effectively and efficiently. With SIEM technology, organizations can gain comprehensive visibility into network activity and proactively identify indications of attacks.

Much research has been conducted in the domain of digital forensics and network security, including malware investigations and system hacking. However, most of these studies have focused on the static analysis aspect and have not integrated the NIST incident response method thoroughly. For example, Kurniawan & Riadi examined Cerber ransomware analysis but only focused on network behavior without compiling a complete incident response flow [5]. Firmansyah's research presents forensic analysis on virtual routers using the NIST approach, but has not incorporated a SIEM-based approach to strengthen detection in real time [11][12][13]. Similarly, Ramadhan studied ARP poisoning attacks using the NFGP model, but focused on post-mortem analysis and Quality of Service measurement, rather than early detection [6][14][15][16].

Other research, such as by Azmi & Deris, uses the Deep Packet Inspection (DPI) approach to detect ransomware, but the approach is technical and has not been structured in a standard framework such as NIST. This shows that there is still a void in research that combines the NIST 800-61 Rev 2 framework with SIEM capabilities as an automated detection and response system to malware [1][16][17][18]. This research can be used as a foundation for building a malware detection and response system that is able to identify threats quickly and accurately with the support of standard frameworks and advanced technology. Given that modern malware is increasingly sophisticated in tricking traditional security systems, early detection and forensic analysis based on the NIST 800-61 Rev 2 framework is crucial. According to Amsor, digital forensics plays an important role in law enforcement in the digital

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realm, but it will only be effective if the forensic system is able to identify and secure digital evidence from the beginning of an incident [19][20][21][22].

Conventional malware detection systems often function only reactively. The addition of SIEM capabilities in incident management can help perform automated detection, log evidence collection, and in-depth data correlation [23][24][25][26]. As stated by Butarbutar, the implementation of the NIST framework has proven effective in structuring the stages of network forensics, but it needs to be optimized with a system capable of analyzing network traffic in real time [10][27]. In addition, Nofiyan's research shows that the use of NIST methods for phishing forensic analysis can help investigate attack patterns [7][28][29]. However, the approach is still manual and has not been integrated with SIEM technology. Use of SIEM This research is the main differentiating aspect that strengthens the urgency of the research, because in addition to adopting standard forensic methods, this research also addresses challenges in the effectiveness of actual malware detection.

Investigating malware cyberattacks is very important because malware is malicious software specifically designed to damage, infiltrate, or steal data and confidential information from computer systems and networks. This research aims not only to detect and analyze malware cyberattacks. But also to present forensic evidence that can be used as a reference for policy makers in securing confidential data and information, both from within computer systems and through networks.

2. METHODS

This research uses a systematic and responsive approach using the SIEM (Security Information and Event Management) framework based on NIST 800-61 Rev 2. The steps of this research are as follows, as shown in **Figure 1**:

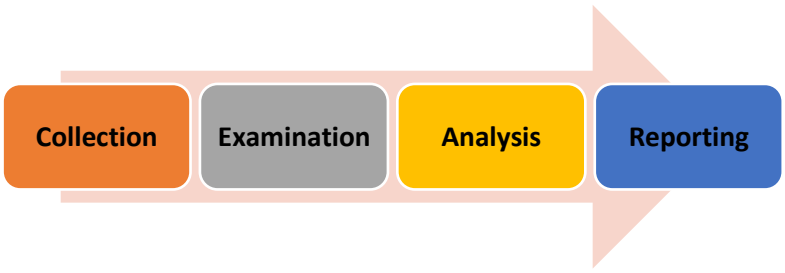


Figure 1. Research Stages Using the NIST Method

2.1. Data Collection

Collecting data on malware attacks is done by handling evidence and the digital evidence acquisition process. Evidence handling is the process of separating digital evidence on malware attacks from other attack evidence processes. In this process, malware attack data is labeled according to the standardization set in an organization/company. This labeling process is used to facilitate the forensic investigation stages that will be carried out. Next, the data will be moved to the storage location. This moving process is called the digital evidence acquisition process. The digital evidence acquisition process is carried out by moving log files or records of malware attack activity to a predetermined storage medium. The process of retrieving malware attack activity records can be done live forensically. Live forensic is a process of retrieving malware attack data that is carried out while all networks and systems are running, as shown in **Figure 2**.

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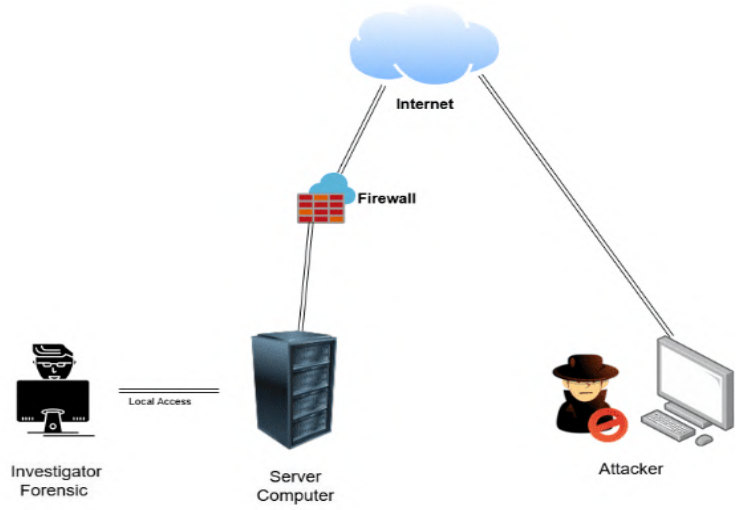


Figure 2. Network Investigation Acquisition Process

2.2. Examination

In the investigation process, forensic investigators examine log files or records of attack activity that are investigated as anomalies in malware attacks on a system or network. This investigation process can be done and identified early through the Wireshark application. In contrast to DoS (Denial of Service) attacks, which can be identified directly by the compaction of traffic or network traffic that is different from usual. Malware cyberattacks tend to be silent and require special expertise in the utilization of in-depth forensic tools.

2.3. Analysis

The analysis in this study uses SIEM or Security Information and Event Management based on NIST 800-61 Revision 2 from the National Institute of Standards and Technology. SIEM or Security Information and Event Management is a comprehensive approach to managing information security and identifying with a response to security threats. SIEM combines technology and identification processes in collecting resources, analyzing an activity log on a network, and reporting security data from various sources, including logs, network devices, software, and the use of applications or other software on both desktop, mobile, and virtual devices.

NIST 800-61 Revision 2 is the best forensic investigation guide published by the National Institute of Standards and Technology to keep an organization or company able to effectively and efficiently maintain and handle data and information leaks. Data and information leaks can result in security incidents, either from malware attacks or other cyberattacks that disrupt the course of business processes in an organization or company, as shown in **Figure 3**.

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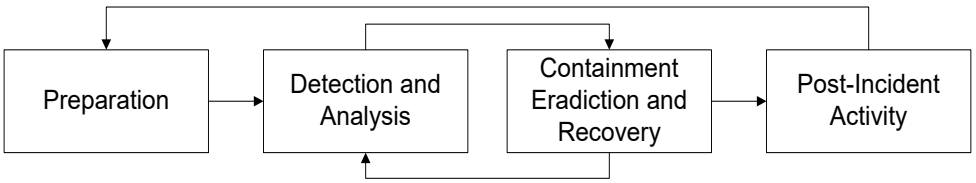


Figure 3. Stages of Network Forensic Analysis Using the SIEM Method Based on NIST 800-61 rev 2

The steps of the SIEM method based on NIST 800-61 Rev 2 are as follows:

1. Preparation

Preparation is an investigative process to identify the resources and personnel involved in responding to a data and information security incident, as well as the development of an incident response plan. The forensic investigator determines the incident response plan regarding the steps to deal with a malware attack.

2. Detection and Analysis

Detection and Analysis is a stage that involves detecting and collecting information about information security incidents that occur. Forensic investigators use a variety of forensic tools to detect malware attacks and analyze malware attacks.

3. Containment, Eradication, and Recovery

Containment, Eradication, and Recovery is the process of reacting to the detection and evaluation of malware/ransomware, which involves containment of the incident, eradication of the cause of the incident, which is malware, and recovery of information systems and data. This stage guides the forensic investigator in determining the appropriate mitigation in dealing with the attack. If at this stage no mitigation can be found, the process will return to the previous stage, namely the Detection and Analysis stage. Then continue to enter this stage again. The Detection and Analysis stage and the Containment, Eradication, and Recovery stage will continue to repeat until they find mitigation or anomalies that occur on the network.

4.Post-Incident Activity

Post-Incident Activity is the process of analyzing the incident response to identify any areas for improvement, as well as updating the incident response plan and training personnel. At this stage, the forensic investigator creates a report on the ransomware/malware attack and conducts an evaluation to safeguard the system and avoid another malware/ransomware attack.

2.4. Reporting

The reporting stage is the process of presenting the results of the analysis that has been carried out on malware cyberattack records. Findings and analysis related to evidence of malware cyberattack records in detail are attached to this reporting document.

3. RESULTS AND DISCUSSION

This research uses network investigation data released by malware traffic analysis with the code 2017-01-28. The identification results are:

3.1. Victim Computer Detection (Forensic Investigator)

The results of the identification of information on the victim's computer or the computer used by the forensic investigator are as follows described in **Table 1**:

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Table 1. Victim Computer Description

Identification Name	***Computer on Log File***
IP Address	172.16.4.193
Host Name	Stewie_PC
MAC Address	5c:26:0a:02:a8:e4
Windows User Account Name	STEWIE-PC

3.2. Network Traffic Identification

The network evaluation results in the log file code 2017-01-28 do not show any anomalies or attacks that burden the network with the presence of large-scale data or information transmission. The results of the investigation of network traffic that looks normal can be seen in **Figure 4** below.

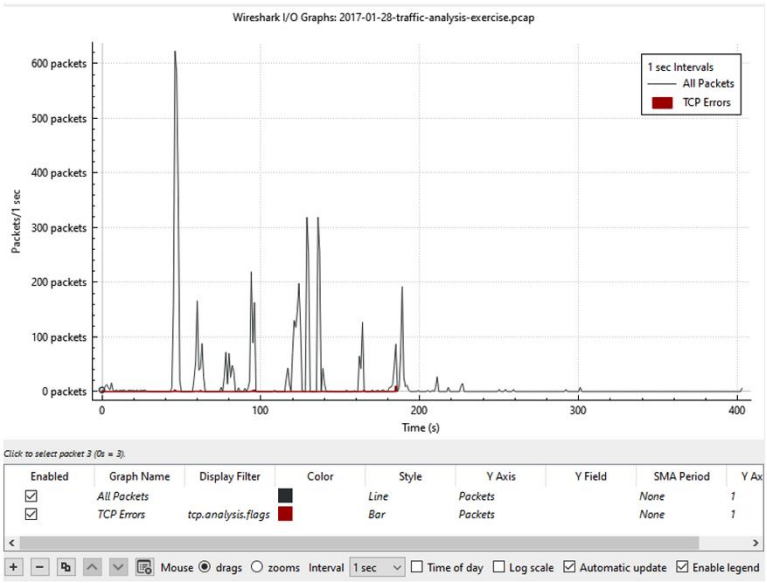


Figure 4. Network Traffic Investigation Results

3.3. Malware Identified in Wireshark Application

Malware detection can be done through the Wireshark application. Filter data using HTTP. request. Suspicious activity usually comes from domains with unusual endings, such as [dot] top. In **Figure 5**, it is explained that the anomalous data in the log file code 2017-01-28 can be p27dokhpz2n7nvgr.1jw2lx.top and several other files.

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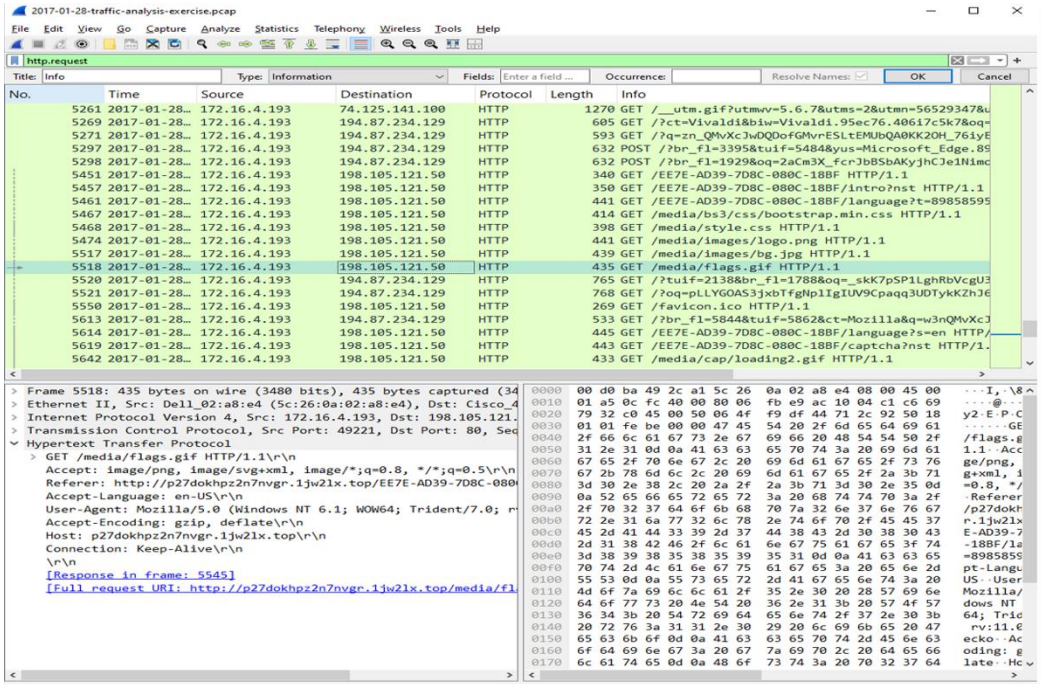


Figure 5. Anomaly Detection in Wireshark Application

3.4. Malware, Ransomware, and Trojans Identified on Any Run App

Checking using any run application obtained information that the log file code 2017-01- 28 contains the domain p27dokhpz2n7nvgr.-1jw2lx.top. This domain is a domain associated with Cerber malware, ransomware, and trojans as shown in **Figure 6**.

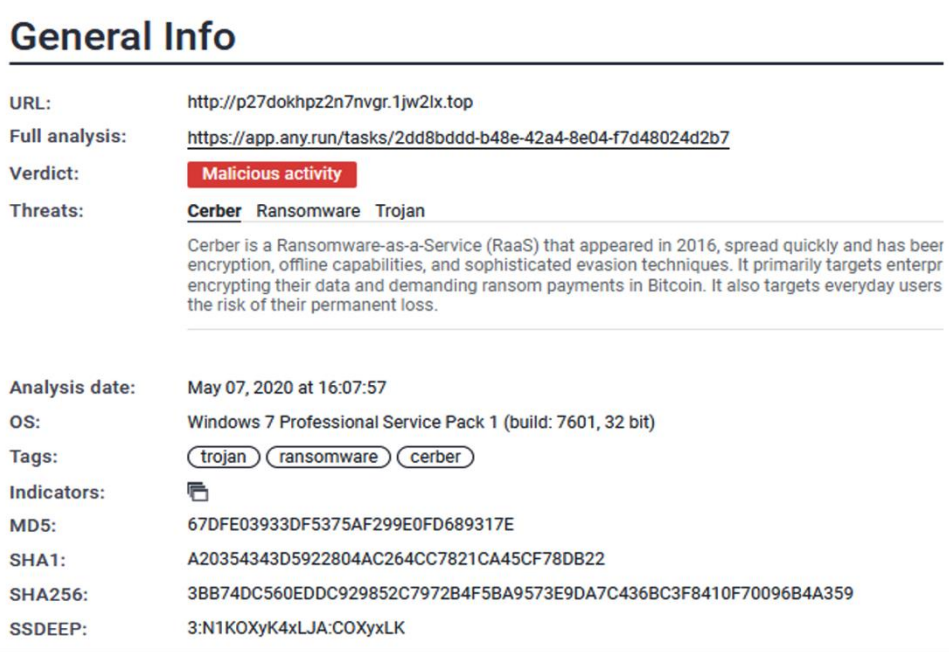


Figure 6. Any Run Application Testing Results

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3.5. Ceber Ransomware Identified in Hybrid Analysis Application

Another test on the log file code 2017-01-28 was using the hybrid analysis application. The test results show that p27dokhpz2n7nvgr.-1jw2lx.top is a domain containing Cerber and ransomware with a threat score of 100/100 and AV Detection of 30%. However, BforeAI analysis shows that the domain is clean and 0% of malware. The results of the investigation and analysis with the hybrid analysis application can be seen in **Figure 7**.

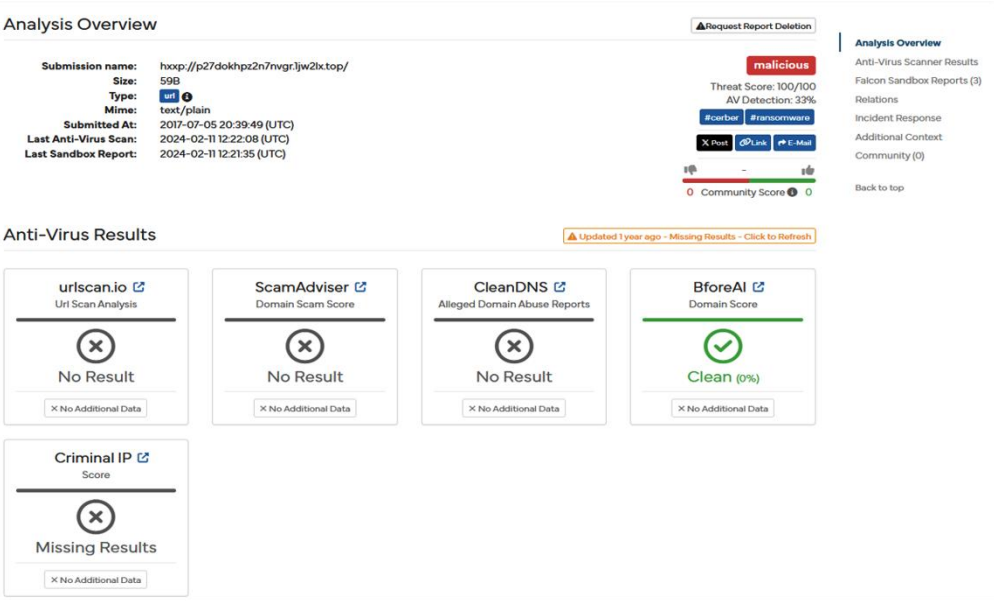


Figure 7. Results of Investigation and Analysis of Hybrid Analysis Application

But Falcon Sandbox has another report. Falcon Sandbox reports that the domain p27dokhpz2n7nvgr.-1jw2lx.top is malicious. Repot's Falcon Sandbox analysis can be seen in **Figure 8** below.

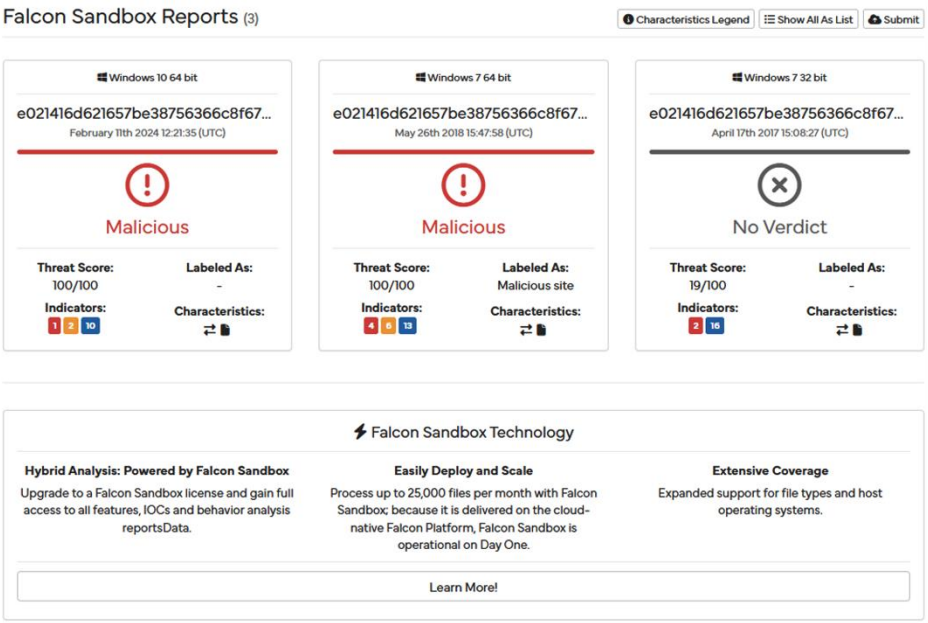


Figure 8. Falcon Sandbox Analysis Results on Hybrid Analysis Application

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3.6. Cerber Ransomware Identified in Total Virus App

The log file code 2017-01-28 was then tested using virus total. The test results show that the log file contains a ransomware-type network trojan named cerber. The results of the total virus application analysis can be seen in **Figure 9.**

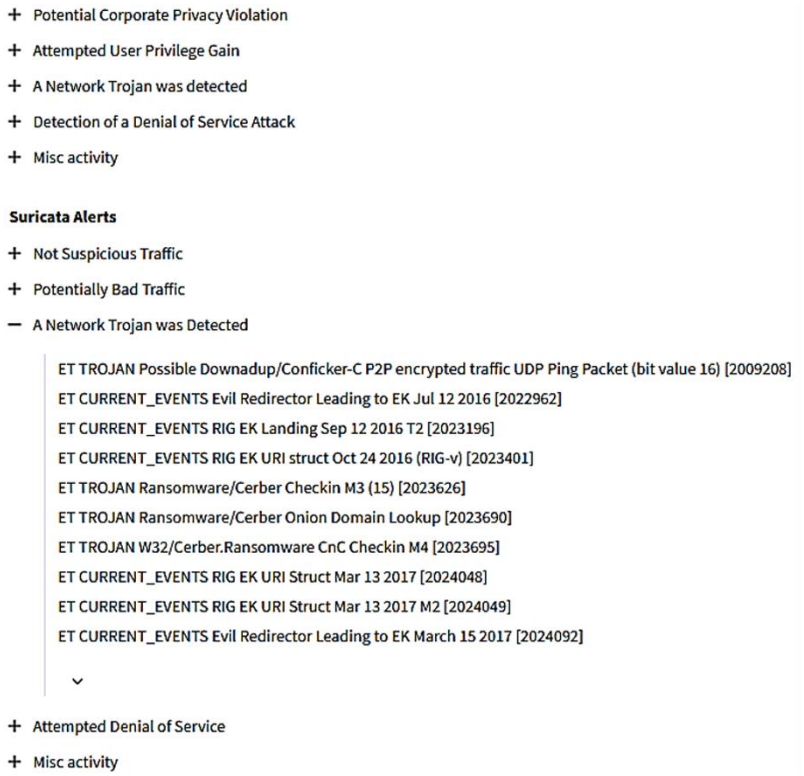


Figure 9. PCAP File Analysis With Virus Total Application

3.7. Phishing Domains Identified in Kaspersky

Malware identification was also performed using the Kaspersky application. The results of the identification and detection of the log file code 2017-01-28 were declared clean by karspersky. The results of the investigation and analysis can be seen in **Figure 10** below:

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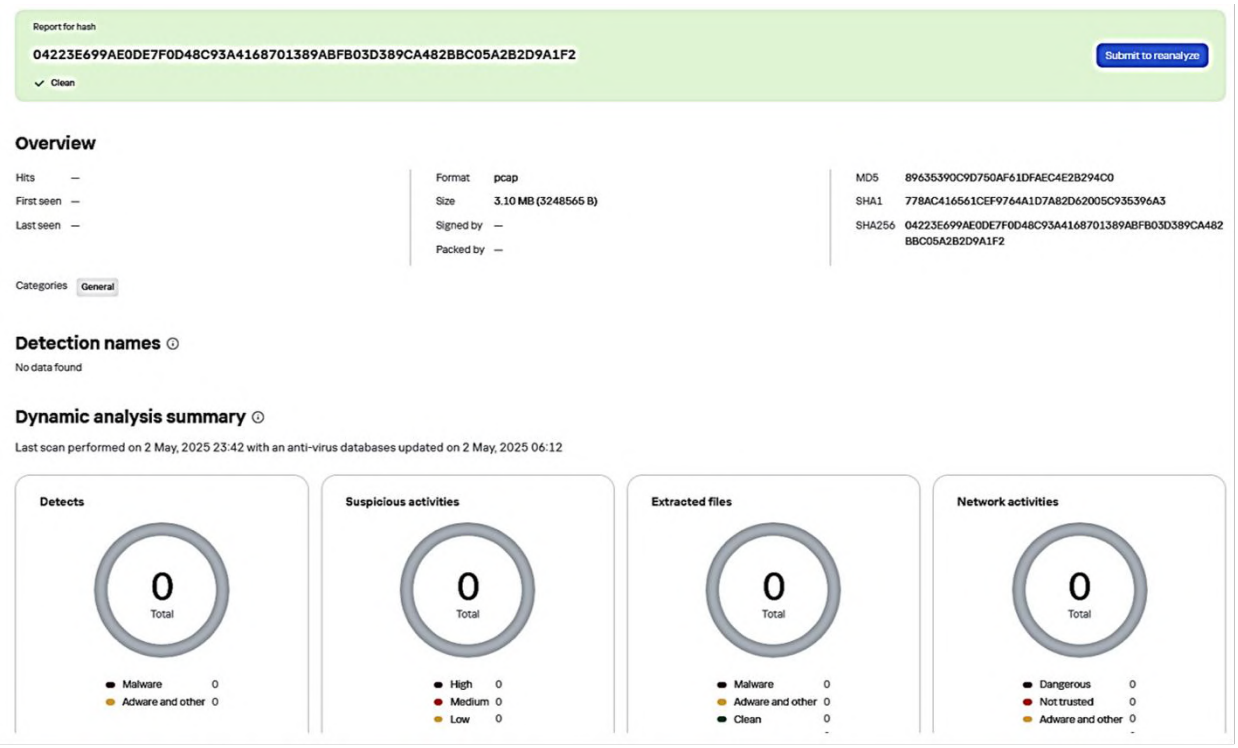


Figure 10. Results of Investigation and Detection of Malware in log files by Karspersky

However, Kaspersky warned of a web phishing attempt on the domain p27dokhpz-2n7nvgr.1jw2lx.top. The results of the analysis and investigation can be seen in **Figure 11**.

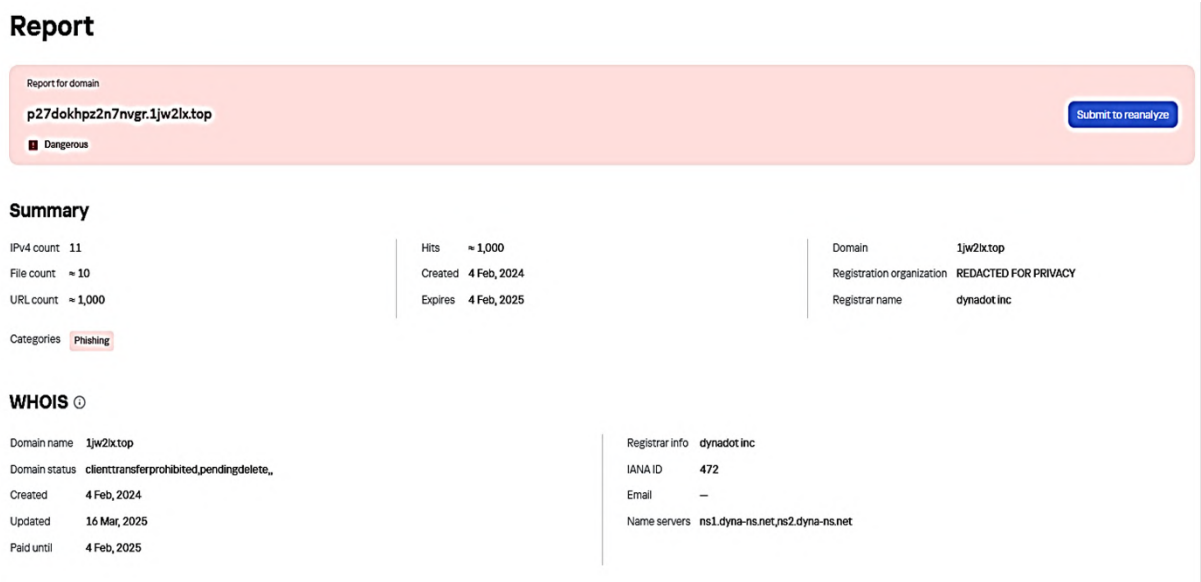


Figure 11. Investigation and Detection Results of p27dokhpz2n7nvgr.1jw2lx.top by Karspersky

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3.8. Potential and Threat of Cerber/Cerberus Malware Operation

Analysis of the mitre attack application showed that cerber/cerberus has been used in private operations for two years. This malware is a banking trojan whose use can be rented on forums and black markets. Some of the actions that can be performed by this cerber or cerberus trojan are as follows:

1. Cerberus communicates with the C2 server using HTTP.
2. Cerberus can update the malicious payload module on command.
3. Cerberus hid its icon from the app vault after its first launch.
4. Cerberus disabled Google Play Protect to prevent its future discovery and removal.
5. Cerberus can remove itself from the device on command.
6. Cerberus can record keystrokes.
7. Cerberus can generate fake notifications and launch overlay attacks against attacker-defined applications.
8. Cerberus can inject inputs to grant itself additional permissions without user interaction and to prevent app deletion.
9. Cerberus can collect the location of the device.
10. Cerberus pretends to be the Adobe Flash Player installer.
11. Cerberus communicates with C2 using HTTP requests over port 8888.
12. Cerberus uses string blurring techniques and standardized payloads.
13. Cerberus can obtain the device's contact list.
14. Cerberus can collect messages, information, or data from a device.
15. Cerberus can send messages, information, or data from the device.
16. Cerberus can obtain a list of installed applications.
17. Cerberus can collect device information, such as default apps and device locale.
18. Cerberus avoids analysis by only activating the malware after recording a certain number of steps from the accelerometer.

4. CONCLUSION

The conclusion of the research investigating malware cyberattacks on server networks using the SIEM method based on NIST 800-61 Rev 2 is as follows:

1) Malware attacks tend to be invisible in network traffic, but malware can transfer data from the target computer to the attacker's computer.
2) Some forensic investigation applications may not be able to identify malware in attack logs or log files. However, the foresight and experience of the investigator are the key milestones in conducting a malware investigation.
3) In reporting evidence data in the form of attack records or log files, evidence of analysis and detection of malware attacks can be attached.
4) Cerberus malware cyberattacks pose a more dangerous threat than Denial of Service (DOS) attacks because cerberus malware attacks are capable of stealing confidential information and data.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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