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Real-Time Location Monitoring and Routine Reminders Based on Internet of Things Integrated with Mobile for Dementia Disorder

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Abstract

The increasing number of dementia sufferers worldwide demands a new approach to monitoring daily activities and locations to reduce the risk of getting lost. This study develops a real-time location monitoring and routine reminder system based on the Internet of Things (IoT), integrated with a mobile application. The system is designed to assist individuals with dementia, particularly elderly and younger adults with cognitive impairments, in performing daily routines independently, while providing a sense of security for families and caregivers through real-time location tracking features. This technology utilizes GPS for accurate location monitoring, daily activity reminders, and automatic notifications for caregivers in case of deviations from usual routes. The system development includes prototype creation that consists of a mobile application and IoT tools such as the ESP32 WROOM microcontroller, Ublox Neo6M V2 GPS module, and SIM800L V2 GSM module. Functionality testing and impact evaluation were conducted to assess its effectiveness in improving the quality of life for dementia sufferers and facilitating monitoring for caregivers. With features such as daily reminders, emergency contacts, and real-time data integration, this system is intended not only for dementia patients but also for families and caregivers seeking tools to ensure the safety and comfort of the sufferers. It is expected that this research will enhance the independence of dementia patients in performing daily activities and provide innovative solutions through IoT technology to improve well-being across different age groups.

Keywords: dementia; Global Positioning System (GPS); Internet of Things (IoT); real-time monitoring; reminder application

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1. Introduction

The clinical condition of a person experiences significant loss of cognitive abilities and memory, causing difficulties in daily living, which is one of the biggest problems for people in the world. Dementia is increasingly becoming a problem in the health context. The prevalence rate of this disease tends to increase with age [1]. Due to the increase in the elderly population, diseases such as dementia are also increasing year by year [2]. Negative impact on the quality of life of sufferers, resulting in higher levels of depression, anxiety, and psychosis compared to non-sufferers. People 65 years of age or older with Alzheimer's disease are susceptible to dementia, a prevalent condition. Of them, over 70% are 75 years of age or older. Of the 55 million persons with dementia globally, 60% to 70% are thought to have Alzheimer's disease [3]. Therefore, it is very interesting to develop technology research for dementia sufferers. The Internet of Things (IoT) technology is a solution that can provide efficient health services remotely [4].

It is possible to use the Internet of Things technology to develop ideas and developments related to more user-friendly smartphones. Control devices process sensor input from the surrounding environment and then output, such as movement. The Internet of Things (IoT) is an invention that can solve problems by combining technology and social effects [5]. The IoT technology has a layered architecture. One layer functions as data sensing, the second layer has the ability to structure and process data, and the third layer controls various high-end protocols and interface logic that helps transmit data [6]. Using geofencing, the boundaries of a location are determined virtually using Global Positioning

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System (GPS) technology. Geofencing is a hypothetical fence that covers a specific location. A GPS tracking system typically consists of three basic parts: a server that records movement data about the target, a terminal that is mounted on the target, and software or apps that are suitable for tracking [7]. The use of GPS on IoT devices connects device locations and uploads location coordinates to a real-time database [8]. The use of real-time makes the IoT device security system which is still not widely implemented and is currently developing, as well as expanding the variety of wireless connectivity that connects IoT transmission devices to users running applications for both sufferers and their families [9]. The application of this security system can be applied in developing IoT applications based on geofencing technology using verification to enter the application system.

The number of mobile applications in the healthcare industry including those targeted at individuals with dementia has increased as a result of the growing use of smartphones. The primary goals of these applications are to sustain social engagement and enhance the patient's cognitive functioning [10]. Mobile apps that support the management of health issues and enable user involvement with attributes such as internet connectivity, portability, functionality, and timely access [11]. According to the study, smartphone reminder apps are developed using neuropsychological models of functional impairment. This laboratory-based pilot study assessed the app's viability, efficacy, and subjective utility in people with mild cognitive impairment or mild dementia who were able to do their daily activities with the help of a reminder app using a within-participant, balanced, cross-sectional design. [12]. IoT-based monitoring can be used to collect and store health data and save the lives of patients, especially those with certain disorders. Therefore, the addition of features such as emergency contacts is very useful in complementing the features of the application [13]. There are IoT tools that can be developed together with mobile applications for routine reminders and the addition of emergency contact features that can be easily accessed in one application so that they have a good impact on dementia sufferers.

Based on data from the Ministry of Health published on the Kemkes.go.id website, it is recorded that Alzheimer's dementia sufferers reach 27.9% of the population, with 4.2 million of Indonesia's population at risk of uncertain age. Many scholars have discussed various issues associated with the use of electronic tracking devices in health care practice, including the possibility that they harm people with dementia by making them more isolated and losing contact with their loved ones [14]. A recent systematic review of the use of GPS systems in dementia care concluded that the implementation of GPS systems in dementia care promises more safety for users, less burden for caregivers and more activity and better health for both. However, there is no evidence to show corroborating results from the application of this method [15].

2. Research Methods

In this section, we present some related work, research into system architecture models, and explain the methods used.

2.1 Related Work

GPS is now widely used in wearable technology like smartwatches and portable consumer electronics like smartphones and navigation systems. Wearable devices are defined as " objects that are operated by software and electrical components that are integrated into garments or worn as accessories." The majority of mobility outcomes derived from the first work based on these devices were the average amount of time spent outside the home and the average number of places visited by users [16]. Innovative solutions powered by the internet of things (IoT) have been created to enable live and continuous health tracking and provision of comprehensive information to patients and healthcare providers.

Electronic devices that have the right sensors can now monitor most health factors such as body temperature, respiratory rate, blood pressure, spo2, electrocardiogram (EKG), heart rate, and blood sugar [17]. For data transfer, the wearable device must have wireless connectivity. For Internet of Things applications, there are many microcontrollers to choose from based on specific needs and standards. Arduino is one of the most popular and newest microcontrollers used to connect automation systems to remotely controlled devices. Innovative solutions that can offer remote solutions in real time are urgently needed. health monitors like all over the world [17]. Instructions on how to operate the gadget and download the GPS application on their mobile will be sent to the victims or their families. The aforementioned programs have demonstrated their efficacy as a lone worker tool for monitoring [15]. The system sends the position when the user moves away from the specified area [18]. For sufferers, this application can be used as a routine reminder which can be set by the description and also the clock manually in the application by the sufferer. Sufferers can also make calls to emergency contacts added to the application with just one tap, this aims to ease the brain's ability to memorize when something undesirable happens outside of control.

The main goal of this research is to create practical, easy-to-access and intuitive-to-use technological solutions, which aim to improve the quality of life for people with dementia. With this IoT-based application, sufferers are expected to be able to carry out daily activities more independently and comfortably, without feeling constrained by physical or memory limitations. This technology will give sufferers freedom in their activities, but still maintain their security through a sophisticated monitoring system. On the other hand,

families who care for people with dementia will also feel great benefit from this application, because they can carry out real-time monitoring anytime and anywhere, thus providing a sense of calm and reassurance. This application will also help reduce family concerns about the sufferer's safety, as well as allow them to focus more on other aspects of care that can improve overall well-being.

It is hoped that the results of this research can be the first step in developing IoT-based technology that supports mental health and social well-being, especially in terms of caring for people with dementia. Apart from that, it is also hoped that this research will pave the way for the development of similar applications that can be applied to other health conditions that require intensive monitoring.

2.2 Research framework and data

As a framework for this research, it is based on initial conditions where there were no tools for monitoring location, routine reminders and calling emergency contacts that could be easily accessed and integrated directly with mobile applications for dementia sufferers. As a result, there are many cases of people with dementia disappearing from family monitoring and the memory of dementia sufferers is also reduced because there are no reminders that can be used automatically every day for their daily routines.

This research aims to develop an application based on IoT technology integrated with a GPS device, specifically designed to facilitate family monitoring of dementia sufferers. Dementia sufferers often struggle with memory, especially regarding locations and daily activities, requiring continuous attention and supervision. The application, connected to a GPS device, allows families to track the sufferer's movements and activities in real time, providing a sense of safety and security for both the sufferers and their families. Additionally, this application will be equipped with user-friendly features such as customizable notifications, location alerts, and detailed activity logs for more efficient monitoring.

The data collection procedure in this research was carried out through several stages. First, location data is obtained using a GPS module connected to the ESP32 microcontroller. This GPS module functions to determine the user's geographic coordinates, which are then sent to the ESP32 for further processing. After the GPS module reads the location data, the data is sent to the ESP32. On the ESP32, the received data is processed to determine the user's longitude and latitude coordinates. Apart from that, the processed data is also uploaded to the hosted database and also Firebase to store user data. The hosted database is used as a storage medium and real-time data management which is then forwarded to the mobile application that has been developed for this research.

2.3. Model architecture

The architectural model discussion will be explained starting from the database model to accommodate real-time GPS data as shown in Table 1.

Table 1. GPS database models

User	Requirements
Unique_id	As a Unique Identifier or unique identifier for scraping data on mobile apps
Latitude	Stores the Latitude of the IoT device response
Longitude	Storing Longitude of IoT Device Response
Update_date	Saves the last updated data

Modelling a database model to accommodate users is carried out with data that will be filled in when the user registers into the application whose features can be seen by the user in the application by the provisions in Table 2.

Table 2. User models

User	Requirements	Feature
User_UID	As a Unique Identifier or unique identifier for each user to differentiate one user from another user	-
Name	Save user name	View Edit
Email	Stores the user's email address, which is often used as a form of authentication for logging in	View Edit
Password	Stores user passwords used for authentication at login	View Edit
Phone_number	Saves the user's phone number for emergency contact	View Add Edit Delete
Profile_images	Saves a URL or reference to a user's profile picture	View Add Edit Delete

Supporting software for creating mobile applications is used to carry out programming to create an application that runs well, starting from coding for applications, and IoT tools to databases to store data. The Kotlin programming language and Android Studio were used to create the smartphone application that aids in the remote tracking of sufferers. An Integrated Development Environment (IDE) is this software. [19]. Using Firebase, it is hoped that there will be a feature in the service that has verification. If the user has not verified after registering the application, the user is not allowed to enter the system. This aims to ensure user data security does not use dummy data or unofficial data, so it asks users to verify using the personal email they enter. Users can make interactive electronic devices with Arduino, an open-source electronic prototyping platform. They make single-board microcontrollers and microcontroller kits, which make applications more accessible and easy to understand [6]. It can be seen in Table 3 and Figure 1 display the

sequence flow diagram for user verification sent via Firebase service authentication.

Hardware is used to develop IoT devices by assembling and connecting modules to their respective pins. The ESP32WROOM microcontroller is used as the brain of the tool which was developed by coding using Arduino IDE software by installing several libraries to push data into the API database which holds latitude and longitude with a unique code defined on the microcontroller. To retrieve latitude and longitude data, a Ublox Neo6M V2 GPS module is needed to communicate with satellites using the network generated by the internet provider. Therefore, this module is very suitable for battery-operated mobile devices as these are cheap and low-power devices. Calculating the distances of the various satellites is the receiver's job. It is pre-programmed to know the position of the satellite at any given time. The earth receives radio signals containing information about the satellite's position and the current time, and the module receives these signals and can find its own position by calculating the time difference [19]. One of the devices has GSM technology because this technology can work on 2G slowly and has a distance of up to several meters. Family and personal data will be stored in this application's database. It also includes an alert system that informs nurses about the medications that should be given to sufferers [20]. So this tool requires the GSM module SIM800l V2 to recognize the card provider and get internet access to support the creation of IoT tools as shown in Figure 2. Details are in Table 4.

Table 3. Supporting software

No	Tools	Tools Name
1.	Apps Framework	Android Studio IDE
2.	IoT	Arduino IDE
3.	Hosted Database	MySQL
4.	User Database	Firebase

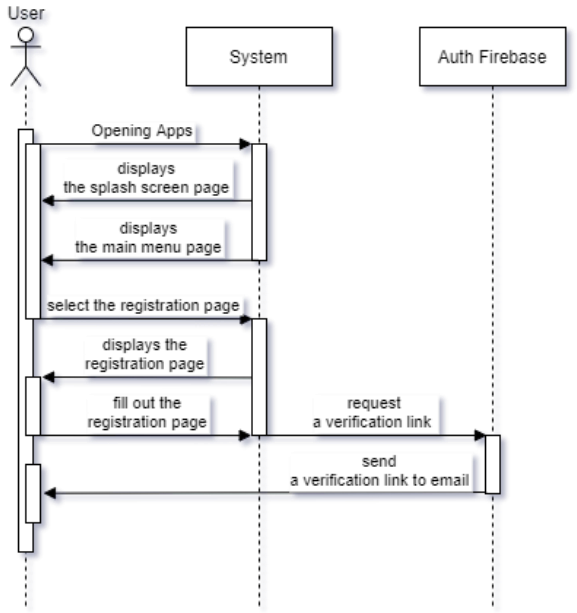

Figure 1. Sequence diagram request verification link

Table 4. Supporting hardware

No	Tools	Tools Name
1.	Microcontroller	ESP32 WROOM
2.	GPS Module	Ublox Neo6M V2
3.	GSM Module	Sim800l V2
4.	SIM Card	GSM IoT Card

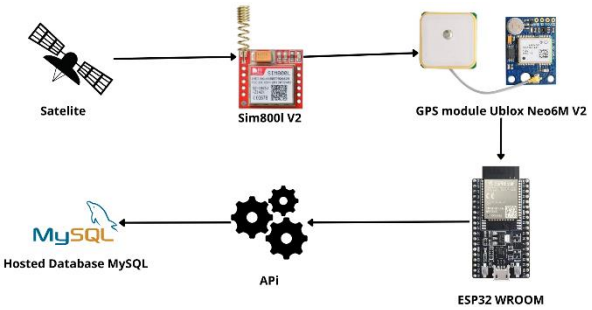

Figure 2. IoT tool architecture

The working system flow is divided into two, where there is a flow for IoT tools to work as well as applications so that they can be synchronized with an Application Programming Interface (API) As shown in Figure 3. With IoT tools activated, the components work according to their respective uses and functions to obtain latitude and longitude. Then, the microcontroller forwards it to the database via API which will fetch the data in real-time using a cloud database service.

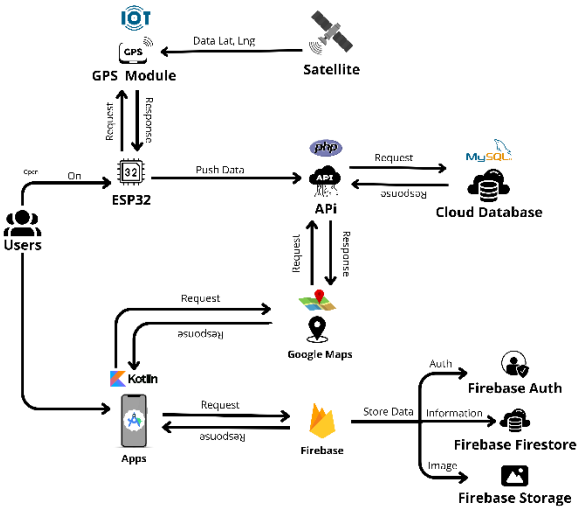

Figure 3. Flow architecture

On the application side, after the user has an account, the application will work to display maps which will fetch latitude and longitude data from the IoT tool and will update the location points in the maps, which means it will always synchronize with the cloud database in real-time (provided that the IoT tool must always active and has an internet signal). These maps take information generated by the GPS/GSM module embedded in the tricycle. This information includes the position of the tricycle operator based on longitude and latitude, the speed of the tricycle, the distance of the tricycle, and the condition of the tricycle. To get the location/position of the tricycle, the latitude and longitude are displayed in the application [21]. On the

other hand, user data will be stored in a different database, namely Firebase, to maximize database performance specifically for IoT tools and to avoid data collisions and database speed.

3. Results and Discussions

At this stage, IoT applications and tools are developed, measured and evaluated. Testing is carried out to provide performance on IoT tool functions, databases, application design and application performance.

3.1 Results

Discussion of the results of the application implementation shows that this application is able to run well when the IoT tool is operated. The use of the ESP32 WROOM microcontroller and UBLOX NEO6M V2 GPS module proved effective in sending real-time location data to the hosted database via API. This application can display location information with high accuracy and without interruption, thanks to the reliability of hardware components and internet connection stability regulated by the ESP32 WROOM. System testing shows that all features, including routine reminders and location monitoring, function optimally and make it easy for users to monitor positions accurately.

These results confirm that the integration between the mobile application and IoT devices has been successful so that this application can provide the support needed for users with dementia. According to the original idea, using a minimalist interface design also makes it easier for consumers to utilize the application. All things considered, this application can satisfy user requirements and offer a practical way to handle regular reminders and monitoring, enhancing the quality of life for its users. Details of the IoT tool's work results are in Table 5 and Figure 4.

Testing features that have been implemented, such as the routine reminder feature, is important to put more focus on the accuracy of the data in the reminder database to prevent possible errors in the timing or activity descriptions. This is because when the application is running, any setting errors will be very visible, disrupting the user experience of the application. Testing was carried out using the black box method as explained in Table 6 to Table 12.

Table 5. GPS database data

Unique_id	Latitude	Longitude	Update_date
S54LXX	-7.748000	110.355202	2024-10-04 08:45:50
S12JXX	-7.755000	110.375202	2024-10-04 08:45:52
S45LXX	-7.728000	110.395202	2024-10-04 08:45:56

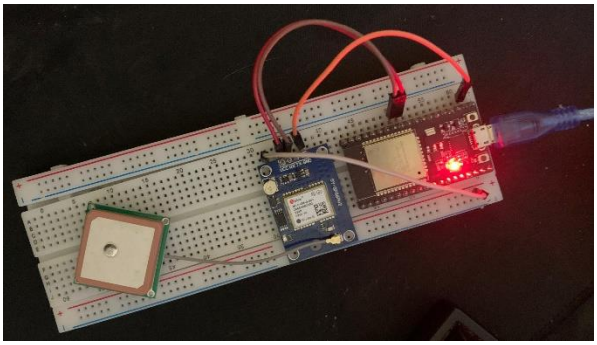

Figure 4. IoT testing

Apart from IoT tools and applications, User Interface (UI) design is the core of application development, where a UI that looks simple and easy to understand will be very useful for dementia sufferers who are the main focus of this research. Figure 5 illustrates the application usage flow, starting with the Splashscreen, followed by the Welcome Page, and leading users through the registration or login process, account verification, and finally to the Home Page. Additionally, the flow includes features for resetting forgotten passwords. This clear and structured design ensures that users can interact with the application with ease while maintaining security for their account data.

Table 6. Test register application

Test Case	Description	Initial Conditions	Scenario
Register	Users register an account in the system to enter the application	The user does not have an account	Users enter the data necessary for needs register a new account to the application.
Expected	Observation		Conclusion
Displays message or response if data entered is not by the which are expected and sends authentication to verify if it is correct	The user is successful in getting the verification link when he enters the data correctly and it doesn't work if it doesn't match		Success

Table 7. Test login application

Test Case	Description	Initial Conditions	Scenario
Login	The user tries to enter the application system	Users have registered an account and verified it	User enter email and the password in accordance with the when do account registration
Expected	Observation		Conclusion
The system will display a message or response when the wrong user enters an email or password and will go to the main page if succeed	The system can display responses according to the user's condition when entering email and password		Success

Table 8. Test reset password application

Test Case	Description	Initial Conditions	Scenario
Reset password	Reset the password if the user forgets the current password	The user forgot his current password	Users do forget simulation passwords and enter that email related.
Expected	Observation		Conclusion
The system sends a message to reset the password to the user's email a add a new password	The system successfully sent the password reset link		Success

Table 9. Test add reminder application

Test Case	Description	Initial Conditions	Scenario
Add reminder	Add reminders to daily routines	The user has successfully logged into the system	User fills in name, description and hours reminder of new routine for added.
Expected	Observation		Conclusion
The system displays data which is input and moves on to push notifications	The system successfully displays the data which is input and displays a reminder notification when it's time		Success

Table 10. Test add IoT application

Test Case	Description	Initial Conditions	Scenario
Add IoT	Synchronize IoT tools with applications	The user clicks the Add IoT button	The user activates the IoT tool and enters a unique code into the application
Expected	Observation		Conclusion
The slicing system response is “OK” and displays real-time monitoring of available maps in the application	The system successfully sent a response and displayed the location according to latitude and longitude in the database		Success

Table 11. Test emergency contact application

Test Case	Description	Initial Conditions	Scenario
Add emergency contact	Add and can make calls with emergency contacts	The user has not added an emergency contact	Users enter emergency contact on the menu on the page arrangement.
Expected	Observation		Conclusion
The system sends data into Firebase and applications display contact fragment emergency	The fragment has been successfully created and can make direct calls when clicked		Success

Table 12. Test manage account application

Test Case	Description	Initial Conditions	Scenario
Manage account	Users can manage accounts such as viewing, editing and deleting data	The user wants to make changes to the data	The user enters new data test changes passwords and deletes the account
Expected	Observation		Conclusion
The system sends a response and sends an authentication SMS to do a data change	The system sent successfully response and Users can make changes to the data		Success

The UI design regarding adding routine reminders is also made very easy to understand which users can access by inputting the routine name, and description and selecting the appropriate time. With this, application users can immediately enjoy the routine reminder service at the selected time and if there is an error after saving the reminder, users can also edit the time and description and can even delete it without waiting for the routine time to arrive. Apart from that, emergency contacts can be accessed in the settings menu. Users can access this menu to add emergency contacts for their closest family which will be stored in the Firebase database and can also edit or delete inappropriate contacts.

In an attractive application UI, of course, security for entering the system must be implemented to protect user account data so that it cannot be misused, one way is to carry out verification after the user registers their account, as can be seen in the application usage flow in Figure 7. Aware of the Internet of Things technology for locating dementia patients, these individuals may roam freely without worrying about getting lost thanks to this technology, which always knows where they are.

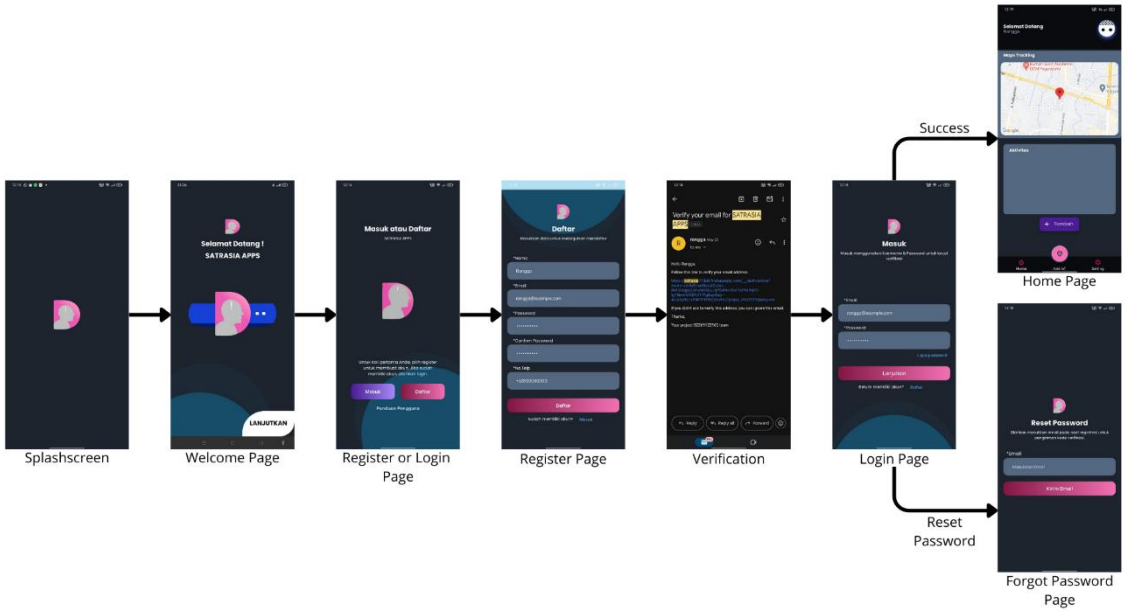

Figure 5. Flow registration and login application

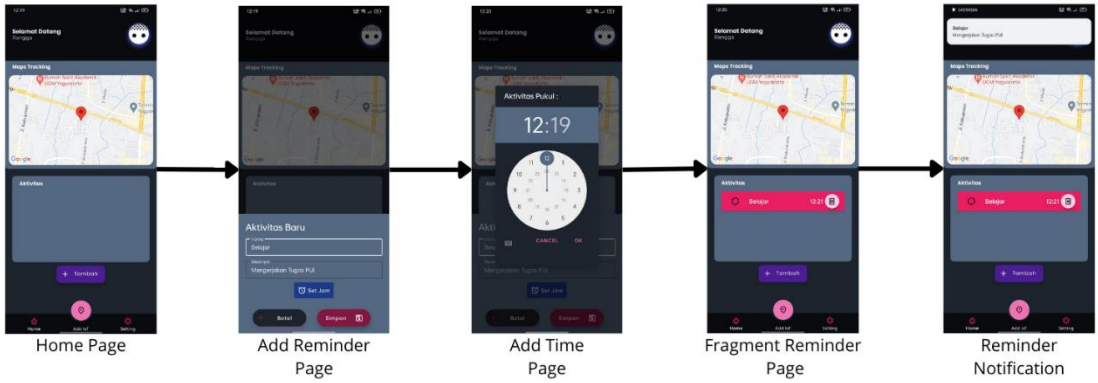

Figure 6. Flow add reminder application

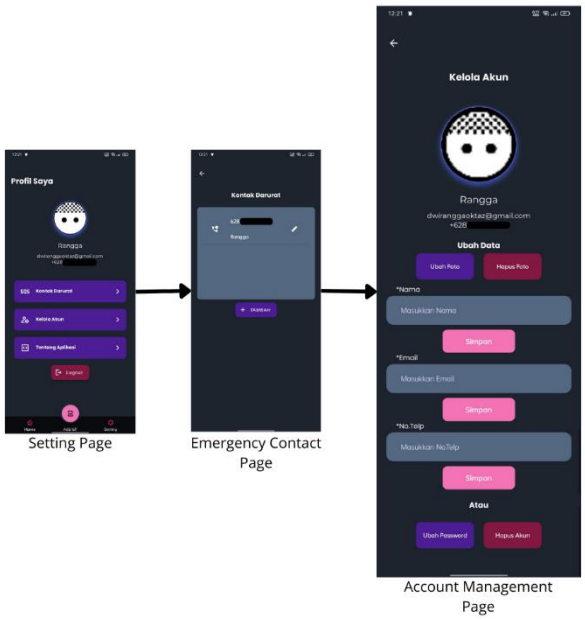

Figure 7. Flow manage account application

With straightforward and easy-to-use capabilities, victims can be freely located and monitored using any Android smartphone. As long as they have an Internet connection, application users may also determine their exact location on a map, as well as their speed and direction [22].

3.2 Discussions

The development of this research must be carefully considered to ensure the application functions optimally and provides a reliable and user-friendly experience. The development focus will include feature improvements, enhancing database completeness for accurate tracking, and refining the mobile front-end interface for better usability. In designing the tools, it is essential to focus on creating something intuitive, comfortable, and easy to remember, minimizing the chance of users forgetting how to navigate it. Adding several modules will improve the tool's functionality, ensuring that sufferers and their families can use the services confidently without fear of potential issues or malfunctions. Furthermore, increasing native account security should be considered to reduce reliance on third-party applications, allowing the application to operate within its own environment with robust security measures tailored to the specific needs of the research

focus, ensuring user data is protected while maintaining ease of access and use.

4. Conclusions

Based on the research that has been carried out and discussed in detail in the previous sub-chapter, several conclusions can be drawn regarding the design of IoT applications and tools in this research, namely that this system is a digital solution for monitoring the routine and location of people with dementia. This application was developed using Android Studio tools with the Kotlin programming language for the mobile side, while for authentication and user data storage, Firebase was used, as well as a MySQL database for data from IoT devices. Features in the application include routine reminders, location monitoring, emergency contacts, and account management. Each feature is designed and implemented according to the initial design, ensuringEoptimal functionality and a good user experience. The application interface design is made as minimal as possible to make it easier for users to navigate the application. Every page, from the splashscreen to the app's about page, is created with comfort and ease of use in mind. The use of IoT technology in the application, by utilizing the ESP32WROOM microcontroller and UBLOX NEO6M V2 GPS module, allows sending real-time location data to a hosted database via API. The implementation of this tool runs smoothly and supports the application as a whole. This application was tested successfully, showing that the integration between the mobile application and IoT devices works without problems. This provides assurance that users can monitor and manage the activities and location of people with dementia effectively increasing safety and comfort for people with dementia and their monitors.

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