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Designing an Automatic Room Temperature Control System for Smart Homes for the Elderly Using IoT

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Abstract: The elderly population in Southeast Asia currently represents 8% or approximately 142 million people, according to the World Health Organization (WHO). As individuals age, various factors require greater attention, such as physical and mental health, a healthy and regular diet, as well as safety and comfort in their living environment. Extreme room temperatures often cause discomfort among the elderly, potentially worsening their health conditions. This study proposes the design of an automatic room temperature control system for smart homes, specifically for elderly care, utilizing Internet of Things (IoT) technology. The system employs a DHT22 sensor, alongside fans and heaters, to maintain stable room temperatures. The methodology includes problem identification, system overview, requirements identification, system and device design, system testing, and evaluation. The system measures room temperature using the DHT22 sensor and automatically regulates the fans and heaters to ensure a comfortable environment for the elderly. Test results indicate that the system effectively maintains room temperature stability. Furthermore, the system can be controlled remotely via the Blynk application, providing ease of use for the elderly in managing the system from a distance. This system thus aids the elderly in consistently maintaining a comfortable room temperature tailored to their specific needs.

Keywords: Internet of Things; Blynk; Automatic Room Temperature Control System; DHT22; Elderly.

1. Introduction

The aging population in Southeast Asia has been on a steady rise, with the elderly now accounting for 8% of the total population, or approximately 142 million individuals, according to the World Health Organization (WHO). The demographic shift towards an older population is expected to accelerate, with the number of people aged 80 and above projected to triple between 2020 and 2050. Notably, by 2050, the elderly population in Indonesia is expected to surpass that of other Asian regions [1]. Physiologically, older adults tend to prefer warmer environments compared to younger individuals. Psychologically, a temperature range of 20-24°C, considered comfortable for most people, may not be adequate for the elderly. Low temperatures can adversely affect health by reducing muscle strength, sweating capacity, hydration levels, and vascular reactivity [2]. As people age, it becomes increasingly important to pay attention to various aspects of their well-being, including physical and mental health, maintaining a healthy and regular diet, as well as ensuring safety and comfort in their home environment. One critical factor in maintaining comfort at home is achieving an appropriate room temperature that meets the specific needs of the elderly. Extreme temperatures, whether too high or too low, can cause discomfort and even exacerbate health problems in the elderly. Therefore, it is essential to continuously monitor and regulate room temperature to ensure it remains within a range suitable for the elderly.

The optimal indoor environment typically involves a room temperature of approximately 18°C to 28°C and a humidity level between 40% and 60%. When the temperature exceeds 28°C, cooling devices such as fans or air conditioners (AC) are necessary to maintain comfort [3]. However, the ideal room temperature varies among individuals; for most people, it generally falls between 20°C and 25°C. For elderly individuals living in Indonesia, the ideal room temperature is slightly higher, ranging between 24°C and 26°C throughout the year, due to the tropical climate characterized by consistent heat and humidity. Several factors can influence the temperature within a room, including the building's location, design, and seasonal variations. Typically, room temperature is managed using air conditioners or fans for cooling and central heating systems for warmth. During extreme weather changes, room temperature can fluctuate significantly, often causing discomfort among the elderly when the temperature becomes unstable. Such instability in room temperature can negatively impact the health of elderly individuals. Therefore, maintaining a stable room temperature that aligns with the needs of the elderly is crucial, as improper temperature regulation can lead to various health issues.

Technological advancements have revolutionized many aspects of daily life, making them more practical and efficient. One such advancement is the development of smart home systems. These systems integrate various technologies to offer specialized functions tailored to the needs of users, enhancing the practicality and effectiveness of daily living [4]. Smart home systems often incorporate devices and systems that utilize the Internet of Things (IoT) technology, allowing connected devices to be controlled automatically based on user preferences [5]. IoT refers to a concept where specific objects can transfer data over a network without requiring human-to-human or human-to-computer interaction. Essentially, IoT connects a multitude of devices and systems worldwide, enabling them to share data and communicate with one another through the internet. These technologies typically involve sensors and software designed to facilitate communication, control, and data exchange between devices, provided they are connected to the internet and support wireless operations. IoT is closely associated with the concept of machine-to-machine (M2M) communication, which allows devices to communicate and operate autonomously. By leveraging IoT, smart home devices can be controlled remotely via smartphones, providing real-time updates on the home's condition.

The design of an automatic room temperature control system for smart homes, particularly for elderly care, aims to provide a solution that simplifies the monitoring and controlling of room conditions in real time. This system is designed to be automated, reducing the need for direct human intervention. The system will be developed using the DHT22 sensor, which can measure both temperature and humidity levels in the surrounding environment. The DHT22 sensor has a temperature measurement range of -40°C to +80°C and a humidity measurement range of 0% to 100%, with a resolution of 0.1°C and 1% Relative Humidity (RH) respectively [5]. The sensor data is processed by a microcontroller, which then determines the appropriate action for the connected devices, such as activating a fan or heater. The collected data is transmitted to the Blynk platform, which has been pre-configured with the system, enabling the monitoring and control of the room's conditions remotely through a mobile application. As long as the system remains connected to the internet, users can access and monitor the data on the Blynk server using their smartphones.

The aging population in Southeast Asia, particularly in Indonesia, presents unique challenges related to maintaining comfort and health within the home environment. The design of a smart home system that integrates IoT technology to automate room temperature control offers a practical and efficient solution for addressing these challenges. By utilizing the DHT22 sensor and leveraging the capabilities of the Blynk platform, this system enables elderly individuals to live more comfortably, with the assurance that their home environment can be monitored and adjusted to meet their specific needs, regardless of external temperature fluctuations. This not only improves the quality of life for the elderly but also enhances their safety and well-being by ensuring that their home environment is consistently maintained within a comfortable and health-promoting temperature range.

2. Research Method

This study aims to design a system capable of automatically regulating room temperature by utilizing Internet of Things (IoT) technology. The design process involves several stages, each intended to ensure that the resulting system functions effectively to create a comfortable indoor environment for the elderly. The first stage of this research is problem identification, where the researcher analyzes the issues and system requirements that need to be addressed. This stage is crucial to ensure that the developed system can effectively solve the primary problem, particularly the need for stable and suitable room temperature regulation for the elderly. The second stage is the system overview, which provides a general description of the system to be designed, including the tools and workflow involved. At this stage, the basic concept of the system is formed, outlining how the various components will interact and work together to achieve the system's objectives. The third stage is system requirements identification, which aims to determine the necessary hardware and software for designing the system. This identification process includes selecting components such as the microcontroller, temperature sensor, and software platform that will be used to operate the system.The fourth stage is system and tool design, where the tools to be used in the system are designed in detail. For instance, the NodeMCU ESP8266 is used as the microcontroller, and the DHT22 sensor is employed as the temperature measurement tool. This stage involves the integration of all components to form a coherent system that operates harmoniously. The fifth stage is system testing, which is conducted to test the functionality of the system and ensure that it operates optimally according to the specified requirements. This testing phase is critical for determining whether the designed system meets all user needs and functions without significant issues. The final stage is system evaluation, conducted after the system testing. In this stage, the researcher evaluates the system to identify any shortcomings or problems that may have arisen during testing, so they can be promptly addressed. This evaluation also aids in making decisions regarding further development of the system.

For system testing, the black box testing method is employed. This method is a software testing technique where the tester evaluates the system's functionality based on input and output without considering the internal structure or source code of the application being tested. Black box testing focuses on how the system responds to specific inputs and ensures that the software functions according to the specified requirements. This testing is also useful for identifying errors and bugs in the system, so they can be addressed before the system is fully implemented. Figure 1 illustrates the system design, which utilizes the NodeMCU ESP8266 as the microcontroller. The NodeMCU ESP8266 is responsible for storing the program code (Wijanarko & Hasanah, 2017) and processing the temperature data received from the DHT22 sensor [6][7]. After receiving the temperature data, the system determines which device to activate, such as a fan or heater, depending on the room temperature. Devices connected to the system will automatically activate based on the temperature thresholds set in the program code. For the system to function properly, the NodeMCU ESP8266 must be programmed using the Arduino IDE, a software commonly used for programming, editing, and uploading code to the appropriate microcontroller [8]. This system is also connected to the Blynk platform, allowing control of the NodeMCU via the internet [9], with two operational modes: automatic and manual. The system operates as follows: First, it connects to Wi-Fi and the Blynk server. The DHT22 sensor periodically reads the room temperature. The data is then sent to the Blynk application. If the system is in automatic mode, the fan will activate when the room temperature exceeds 27°C, and the heater will activate when the room temperature drops below 25°C. In manual mode, users can control the fan or heater through the Blynk application.

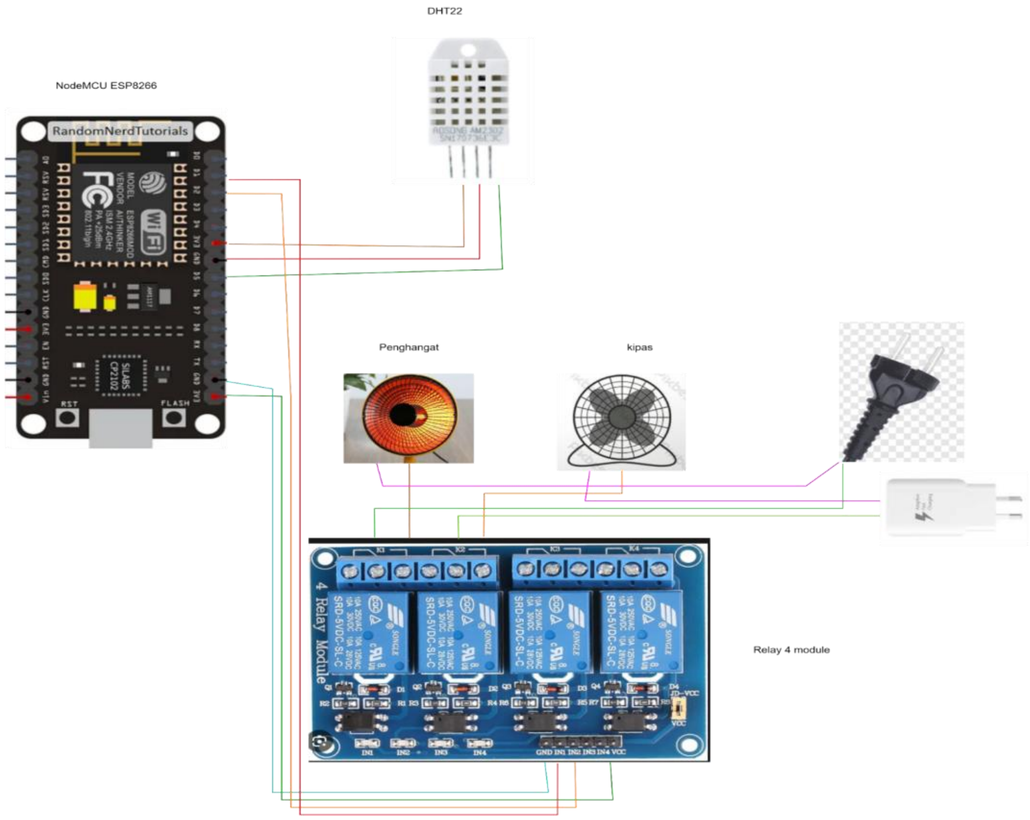

Figure 1. System Design

The system designed in this research provides an effective solution for automatic room temperature regulation, which is essential for creating a comfortable and safe environment for the elderly.

3. Result and Discussion

3.1 Results

This research resulted in the development of an IoT-based automatic room temperature control system designed for smart homes, specifically tailored for elderly users. The system's components include the NodeMCU ESP8266, DHT22 sensor, 4-module relay, fan, and heater, with the software managed through the Arduino IDE and the Blynk platform. The system underwent black box testing, which evaluates the system's functionality based on application specifications and related aspects, without analyzing the internal code or architecture [10]. Below are the results from the black box testing.

3.1.1 DHT22 Sensor Testing

Table 1 presents the comparison between the readings from the DHT22 sensor and a hygrometer. The testing was conducted in a closed room over a 24-hour period to evaluate the accuracy and stability of the DHT22 sensor.

Table 1. DHT22 Sensor Testing

Time	DHT22 (°C)	Hygrometer (°C)
02:00	22.8	22.6
04:00	23.1	23.4
06:00	24.3	24.3
08:00	25.8	25.6
10:00	26.8	26.4
12:00	27.4	27.1
14:00	27.8	28.0
16:00	27.3	27.5
18:00	27.6	27.6

20:00	27.4	27.4
22:00	25.7	25.4
24:00	24.8	24.4

As shown in Table 1, the DHT22 sensor readings are compared with those of a hygrometer. The results indicate that the DHT22 sensor exhibits good accuracy, with the temperature differences between the DHT22 sensor and the hygrometer being within ±0.4°C. This confirms the sensor's reliability in measuring room temperature under controlled conditions.

3.1.2 Automatic and Manual Control Testing

Table 2 shows the results of testing the system's automatic and manual control modes. The testing aimed to determine how the system responds under different operational modes.

Table 2. Automatic and Manual Control Testing

Time	Temperature (°C)	Fan	Heater	Conclusion
18:00	27.6	On	Off	[√] Valid
19:00	27.0	On	Off	[√] Valid
20:00	26.4	Off	Off	[√] Valid
21:00	26.3	Off	Off	[√] Valid
22:00	25.7	Off	On	[√] Valid
23:00	24.8	Off	On	[√] Valid

The results in Table 2 demonstrate that the system operates effectively in both automatic and manual modes. In automatic mode, the fan activates when the room temperature exceeds 27°C, and the heater activates when the temperature drops below 25°C. In manual mode, the system functions correctly when the fan or heater is controlled via the Blynk platform. Additional testing was conducted to measure the time required for the microcontroller to send data to the Blynk platform. The results show that data transmission takes approximately 200 milliseconds with an internet speed of 20 Mbps. Further testing aimed to identify potential issues when the system is in manual control mode. Two specific tests were performed: the first involved turning the fan and heater on and off at different times, and the second involved turning them on and off simultaneously. The results confirmed that all devices operated as intended, with the fan and heater functioning correctly whether activated separately or at the same time. The testing results confirm that the IoT-based automatic room temperature control system performs effectively. The primary advantage of this IoT-based system is its ability to allow users to monitor the room's temperature and control devices remotely, even when they are not at home.

3.2 Discussion

Figure 2 illustrates the complete hardware setup of the system, which includes several components: a) NodeMCU ESP8266, b) DHT22 Sensor, c) 4-module relay, d) Fan, e) Heater, and f) Jumper cables.

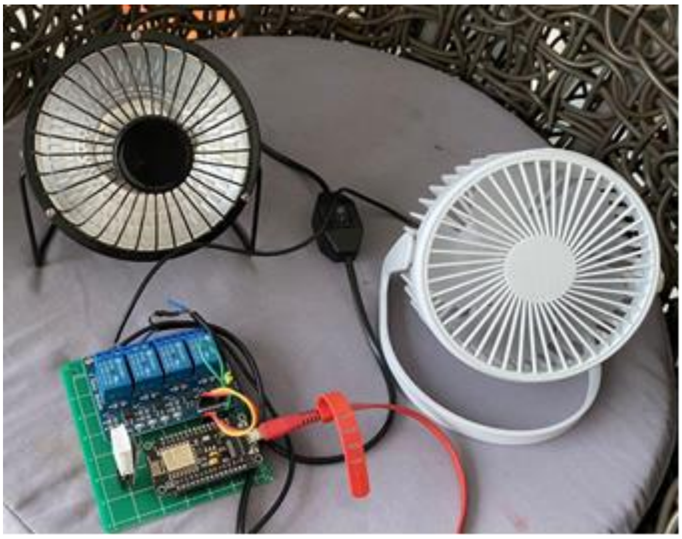

Figure 2. Tool Design

These components were assembled and connected to the Blynk platform to facilitate easy monitoring and control of the devices. The system was subjected to black box testing, focusing on the functional specifications of the system without examining the source code or internal structure [11]. The initial testing evaluated the accuracy and stability of the DHT22 sensor in reading room temperature, as shown in Table 2. For better accuracy assessment, a comparative analysis was performed [12], where the DHT22 sensor readings were compared with a hygrometer in the same room over 24 hours. The results indicate that the DHT22 sensor has a satisfactory level of accuracy, with a temperature measurement discrepancy of approximately ±0.4°C.

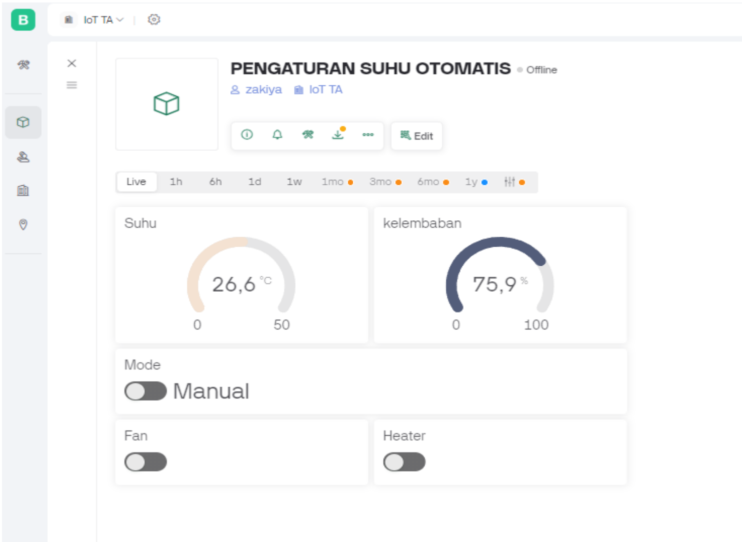

Figure 3. Blynk display

Table 2 also displays the outcomes of testing the system's automatic and manual control modes. The purpose of this testing was to assess the system's response when operating in different modes. The results show that the system functions well in automatic mode, where the fan activates at temperatures above 27°C and the heater activates at temperatures below 25°C. In manual mode, the system also operates effectively, with the fan or heater being controlled via the Blynk platform. Subsequent testing aimed to determine the time required for the microcontroller to send data to the Blynk platform. The results indicate that the transmission process takes approximately 200 milliseconds with an internet speed of 20 Mbps. Another set of tests was conducted to evaluate the system's performance when operating in manual control mode. Two specific scenarios were tested: first, turning the fan and heater on and off at different times, and second, turning them on and off simultaneously. The results confirm that all devices operated as expected, with the fan and heater functioning correctly whether activated separately or simultaneously. From all the tests conducted, it can be concluded that the IoT-based automatic room temperature control system operates effectively. The primary advantage of this system is that it allows users to monitor the room temperature and control the devices remotely, even when they are not at home. This feature enhances the convenience and safety of maintaining an appropriate room environment for elderly users.

4. Related Work

The development of IoT-based systems for environmental monitoring and control has become increasingly prominent in recent years, driven by the need for more efficient and responsive solutions in various settings. Muhammad Fadli (2022) which focuses on creating an IoT-enabled server room monitoring system. The system employs NodeMCU ESP8266 v3, DHT22 temperature sensors, and an RTCD3231 digital timer to continuously monitor temperature and humidity levels within a server room environment [6]. The primary objective of Fadli's research was to mitigate the risk of hardware damage due to adverse environmental conditions by providing real-time alerts to the server administrator. This study underscores the critical role of IoT in safeguarding sensitive electronic equipment through timely monitoring and intervention. Another notable contribution to the field is the research by Fenny Vinola and Abduk Rakhman (2020), this study explores the integration of IoT with home automation systems, employing a combination of Raspberry Pi, NodeMCU with an ESP8266 WiFi module, and a DHT22 temperature sensor, along with an ESP32 Wemos

LoLin32 Lite development board [13]. Additionally, the system incorporates Infrared LED sensors for sending commands to air conditioning units and Infrared Receivers for receiving signals from remote controls. Vinola and Rakhman's work demonstrates how IoT can enhance the ability to remotely monitor and control room temperature and air conditioning systems, thereby improving energy efficiency and user convenience. This research highlights the potential of IoT technologies in transforming traditional home environments into more intelligent and responsive spaces. Further expanding on the application of IoT in temperature management, the study by Abizar Rachman, Zainal Arifin, and Septya Maharani (2020), explores the use of IoT for controlling air conditioning systems [11]. Their research utilizes the NodeMCU ESP8266 v3 microcontroller, combined with a DHT11 temperature sensor, Infrared Receiver and emitter, and the Blynk cloud platform. The primary aim of this study was to enable users to control air conditioning units via an Android smartphone, with the ability to manage the system remotely from any location. Rachman, Arifin, and Maharani's research illustrates the growing trend towards integrating IoT with mobile applications, offering users enhanced control over their home environments and contributing to the evolution of smart home technologies. These studies collectively illustrate the growing importance of IoT in the development of advanced environmental control systems. By leveraging IoT technologies, these systems offer real-time monitoring and management capabilities, which are essential for both critical infrastructure and residential applications.

The transformative potential of the Internet of Things (IoT) has been extensively recognized across various fields, particularly in enhancing monitoring and control systems within household and institutional settings. Irianto (2023) explores this potential through the development of the Prepaid Smart Energy Meter Monitoring System (Pre-SEMMS), specifically designed for household use. This system employs IoT to enable real-time energy monitoring and management, providing users with detailed insights into their energy consumption. The system's prepaid functionality encourages efficient energy usage by allowing users to manage their consumption more effectively. This study demonstrates how IoT can innovate traditional energy systems, making them more interactive and user-friendly, especially in residential settings [14].

Similarly, the work of Putra and Budiyanto (2021) illustrates the application of IoT in the public health sector, particularly in response to the Covid-19 pandemic. Their research focuses on the development of a multi-sensor body temperature measurement system aimed at reducing the spread of the virus. By utilizing multiple sensors to accurately monitor body temperature, the system acts as a crucial tool for the early detection of potential infections. This is especially relevant in public areas where continuous health monitoring is essential for preventing disease transmission. Their study highlights the important role of IoT in enhancing public health monitoring through the provision of real-time, accurate health data that can guide timely interventions [15].

Expanding on the use of IoT in institutional settings, Usman (2016) investigates how monitoring and evaluation systems can be improved within government institutions. His thesis focuses on designing and analyzing a system for monitoring and evaluating cooperative activities at the Dinas Koperasi Kabupaten Sidoarjo. Usman's research shows how systematic data collection and analysis can enhance decision-making processes and improve operational efficiency. By integrating IoT-based monitoring systems into cooperative management, the study demonstrates how technology can streamline operations and ensure that institutional goals are met more effectively [16]. In comparison to these studies, the current research on designing automatic room temperature control systems for smart homes, particularly for elderly individuals, shares the goal of leveraging IoT to improve user experience and operational efficiency. However, this research is uniquely focused on addressing the specific needs of elderly individuals, ensuring their comfort, safety, and independence in their living environments. While Irianto (2023) emphasizes energy management and Putra and Budiyanto (2021) concentrate on health monitoring, this study integrates these elements by creating smart home systems that not only manage energy efficiently but also cater to the health and comfort needs of elderly users [14][15].

Additionally, the importance of security in IoT systems, as highlighted by Elsayed *et al.* (2021) and Mahlous (2023), is also relevant to the current research. Ensuring the security of IoT systems in smart homes is crucial, particularly for vulnerable populations like the elderly, who may be more susceptible to cyber threats. This study builds on these insights by developing systems that not only provide automatic temperature control but also incorporate robust security measures, user-friendly interfaces, and real-time monitoring features [21][22].

The use of IoT in smart homes, as discussed by Zhang, Li, and Wu (2020) and Forkan *et al.* (2019), presents significant opportunities for improving the living conditions of elderly individuals. These studies emphasize how IoT technologies can enhance the quality of life for the elderly by enabling independent living and ensuring their comfort and safety through automated environmental controls [17][18]. Furthermore, research by Moyle, Murfield, and Lion (2021) and Alshdadi (2023) underscores the effectiveness of smart home technologies in supporting health outcomes for elderly individuals, particularly those living with dementia, through personalized care and real-time monitoring [19][20]. While these studies collectively illustrate the diverse applications of IoT in enhancing monitoring and control systems, the current research stands out by focusing specifically on the needs of elderly individuals in smart homes [23]. By addressing energy management, health monitoring, and security, this research aims to develop systems that significantly improve the quality of life for the elderly, enabling them to live independently and securely in their own homes.

5. Conclusion

The system developed in this study successfully regulates room temperature automatically within the specified limits, utilizing the DHT22 sensor to accurately and responsively measure both temperature and humidity. This ensures that the system maintains a comfortable environment for users, particularly the elderly. The integration of Internet of Things (IoT) technology enhances the system's utility by enabling real-time monitoring and control of room temperature through the Blynk application, which is accessible from anywhere and at any time. This functionality allows users to activate or deactivate the fan and heater only when necessary, thereby optimizing energy usage while maintaining comfort within the room. For future development, several recommendations can be made. Firstly, the system could be enhanced by incorporating additional sensors to monitor the presence and activity of residents, which would help reduce unnecessary energy consumption when no activity is detected in the room. Secondly, future research could explore the use of more advanced mobile applications than Blynk, alongside improvements to the user interface design to make it more accessible and user-friendly for elderly individuals. Thirdly, further testing should be conducted to identify and address potential system challenges, such as resilience to power outages and internet connectivity issues. Additionally, incorporating a database to store historical data would enable better tracking and analysis of temperature trends over time. Finally, implementing notification and alarm features in the application would provide users with timely alerts regarding room temperature conditions, thereby enhancing the system's overall functionality and ensuring a safer living environment for the elderly.

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