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Smart Home Electrical Appliances Control with Security Automation Using Arduino for Modern Residential Applications

Najmiah Radiah Mohamad[1*], Azahari Salleh[1], Nur Alisa Ali[1], Hafez Sarkawi[1], Nik MohdZarifie Hashim[1], MohdKhanapiah Nor[1], NizaMohd Idris[1], MohdAzlishah Othman[1], SitiAmaniahMohd Chachuli[1], Siti Asma Che Aziz[1]

[1]FakultiTeknologi dan KejuruteraanElektronik dan Komputer (FTKEK),
UniversitiTeknikal Malaysia Melaka (UTeM), Melaka, Malaysia.
**Corresponding Author*

ABSTRACT: *Smart home automation systems have emerged as a critical solution for modern residential management, yet existing systems often lack integrated security features and comprehensive remote control capabilities. This paper presents the development and implementation of an Arduino-based smart home system that combines electrical appliance control with security automation through Internet of Things (IoT) technology. The system incorporates real-time monitoring and control through the Blynk mobile application, featuring LED lighting control, temperature management, and intrusion detection using infrared (IR) sensors. Experimental results demonstrate the reliability in remote operation, with good response times for device control and immediate intrusion alerts. The implemented system can reduce energy consumption compared to traditional manual controls. This research contributes to the field of home automation by providing a cost-effective, scalable solution that integrates both convenience and security features for modern residential applications. Future enhancements, such as expanded device integration and advanced security protocols, are proposed to further optimize the system's robustness and applicability. These improvements aim to transform contemporary smart home systems, making them more user-friendly and secure.*

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I. INTRODUCTION

The rapid advancement of technology in recent years has led to the emergence of smart home systems that enhance convenience, energy efficiency, and security in residential environments. As urbanization continues to increase, the demand for intelligent living solutions has become more prominent, driving the development of home automation systems that allow users to control electrical appliances remotely. Mobile and IoT technology has transformed how homeowners control and manage their living spaces [1].

Smart homes use IoT technologies to connect devices and appliances while enabling users to control them remotely through smartphones and tablets. Studies have shown that IoT implementation can lead to a 20% reduction in energy consumption [2]. Furthermore, smart homes integrate wireless communication [3] and sensor technologies, enabling remote monitoring and control of appliances through mobile devices and voice assistants [4]. IoT-based systems, utilizing components like ESP8266 Wi-Fi and Arduino controllers, can efficiently manage power consumption and reduce fire outbreak risks [5]. This connectivity allows users to monitor and manage their home environments in real-time, facilitating greater energy efficiency and improved security. For instance, homeowners can turn off lights, adjust thermostats, or monitor security cameras from virtually anywhere in the world. This level of control enhances modern living comfort while promoting energy conservation through effective consumption management.

One of the significant components of a smart home system is the ability to control the lights remotely [6]. In many households, lights are frequently left on unintentionally, leading to unnecessary energy waste. Traditional light switches require physical interaction, often resulting in forgetfulness when homeowners leave their residences. By utilizing mobile applications, users can remotely switch their lights on and off, ensuring that energy is conserved even when they are not at home. This capability is particularly advantageous for busy individuals or those who travel frequently, as it allows them to maintain control over their home environment regardless of location.

In addition to controlling electrical appliances, modern smart home systems incorporate security features that address growing concerns about home safety. Intrusion detection is a critical aspect of home security, with statistics indicating that a significant percentage of burglaries occur through main entry points such as doors and windows. The integration of security automation, including infrared (IR) sensors and alarm systems, enhances the safety of residential properties by providing immediate alerts to homeowners when potential threats are detected. The use of an Arduino microcontroller [7] allows for seamless integration of various sensors and devices, creating a comprehensive security solution that complements the appliance control features.

This paper aims to demonstrate the feasibility and effectiveness of a mobile-based smart home electrical appliances control system with security automation using Arduino. By showcasing the design, implementation, and testing of the prototype, this study contributes to the growing body of knowledge in the field of home automation. This paper emphasizes integrating remote-control capabilities and robust security features using Arduino technology. The findings underscore the importance of integrating convenience and security features in modern residential applications, paving the way for future advancements in smart home technology. By employing an IR obstacle sensor for intrusion detection and a mobile application for remote management, the system enhances both usability and safety for residents. As consumers increasingly seek solutions that enhance their quality of life while promoting sustainability, the development of such systems will become ever more critical in shaping the future of residential living.

II. SYSTEM DESIGN

The smart home automation and security system presented in this paper utilizes an Arduino microcontroller as the central hub, interfacing with various sensors and actuators to create a functional and responsive home automation system. The system integrates components such as LED lights and a cooling fan through the Blynk mobile application. The methodology involves four main steps: system design, hardware implementation, software integration, and testing.

The physical prototype developed for this project is illustrated in Figure 1. Figure 2 presents the top view of the model house, providing a comprehensive view of the spatial arrangement. The design was deliberately conceptualized to reflect contemporary residential architecture. The layout configuration is crucial as it dictates the strategic placement of components, particularly the IR Obstacle Sensor. The IR obstacle sensor provides a detection range of 10- 30 cm. As shown in Figure 1, the structure comprises three primary spaces: a living room flanked by Room 1 and Room 2 at the rear. Each room is equipped with an LED fixture that simulates a typical household lighting system. Room 1 features an additional cooling fan that represents an air conditioning unit. The LED fixtures are centrally mounted in each room to ensure optimal illumination distribution. The cooling fan is strategically positioned at the room's terminus to facilitate direct, uniform airflow distribution.

Fig. 1 The structural design of the model house

III. HARDWARE IMPLEMENTATION

This proposed smart home system architecture is designed around a central control unit comprising an Arduino Uno R3 equipped with an ATmega328P microcontroller. Wireless connectivity and Internet of Things (IoT) functionality are implemented through an ESP8266 module [8] supporting 802.11 b/g/n protocols, enabling seamless integration with the home network infrastructure and remote-control capabilities via the

Blynk mobile application [9-10] in Figure 3. The hardware integration is accomplished using a breadboard interface, where various sensors and actuators are systematically connected to appropriate pins on the microcontroller, as detailed in Table 1.

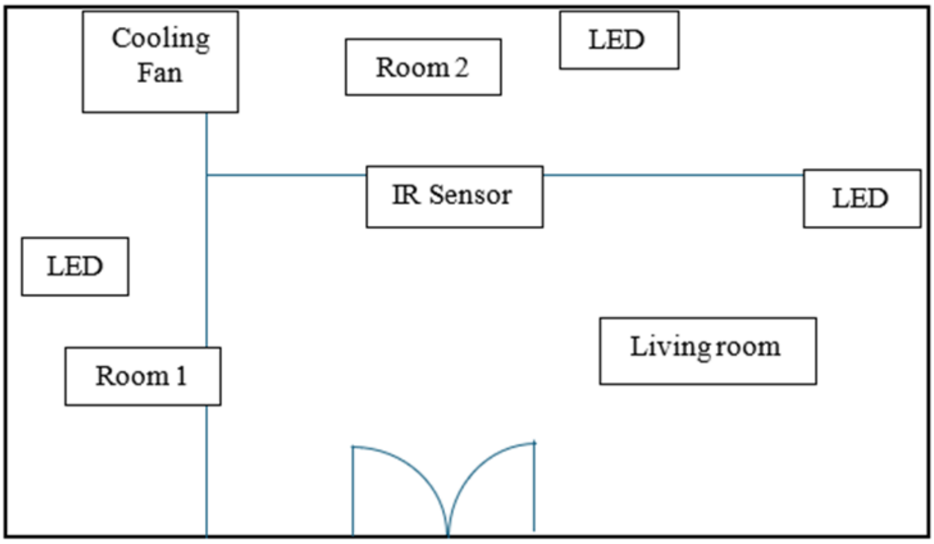


Fig. 2 Top view of the model house

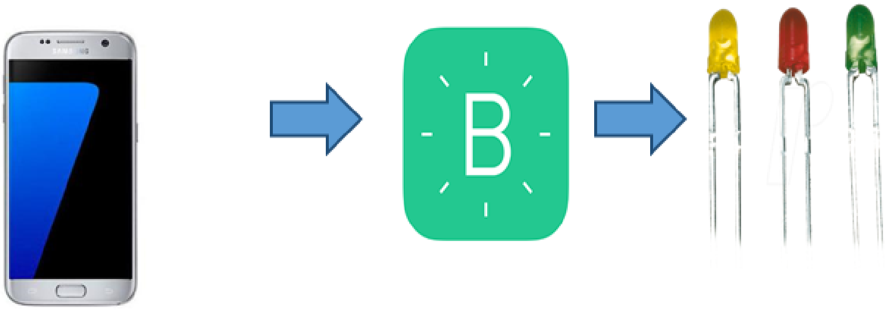


Fig. 3 Remote Appliance Control Architecture Using Blynk Mobile Interface

Table 1: Connection of each pin

Pins	Connections
GND	Ground
5V	5V power supply from Arduino board
D12	Cooling fan
D8	LED 1
D9	LED 2
D10	LED 3
D4	Buzzer
D7	Active High Input from Sensor
D2	TX of ESP8266
D3	RX of ESP8266

The security implementation shown in Figure 4 uses an infrared (IR) sensor with a 10 – 30 centimeters detection range to enable reliable intrusion detection. The ambient lighting control system utilizes LED modules operating at 5V DC with a current draw of 20 mA, providing efficient room illumination under IoT control. Environmental regulation is achieved through a 12V DC cooling fan drawing 0.15A, which modulates temperature conditions based on both sensor inputs and user commands through the mobile interface. This integrated hardware configuration enables comprehensive automation and real-time monitoring of essential home environmental parameters, with all components receiving appropriate power supply and control signals through the Arduino platform.

Fig. 4 Home security automation technical design

IV. SOFTWARE INTEGRATION

The software component of the system is crucial for enabling remote control through the Blynk mobile application. The Arduino is programmed using the Arduino (Integrated Development Environment) IDE in Figure 5, where code is written to manage the interactions between the sensors, actuators, and mobile applications. The Blynk application interface enables users to switch devices on or off while monitoring the overall system status. Users receive immediate notifications through the interface when the IR sensor detects potential intrusions. The coding was developed for the sensor and buzzer by integrating them into the looping and selection processes. Below is the segment from the IDE software.

V. TESTING AND VALIDATION

The system was thoroughly tested under different scenarios to validate its functionality. This involved leaving the lights on while exiting the home and using the Blynk application to turn them off remotely. The cooling fan’s responsiveness was also tested in Room 1, ensuring it could be controlled independently. Finally, the IR obstacle sensor was tested to confirm its ability to detect motion at the entrance and send appropriate alerts through the mobile application. The system’s remote control capabilities and the integration of real-time security monitoring were confirmed to function as intended. Testing and validation were critical to ensuring the system operated as intended. The prototype was subjected to various scenarios to evaluate its performance, including remote control of lights and detection of intrusions. Feedback from these tests was used to refine the system, enhancing its reliability and effectiveness in real-world applications.

VI. RESULT AND DISCUSSION

The system's electrical integration was implemented with careful attention to both functionality and aesthetics. The Arduino microcontroller and associated control components are fully embedded within the model's infrastructure, mirroring real-world residential electrical installations in Figure 6. To ensure system longevity and reliability, the control components are housed in a protective enclosure that provides defense against environmental factors such as moisture infiltration and insect intrusion. This protective measure aligns with standard practices in residential automation systems and significantly reduces vulnerability to tampering or unauthorized access.

Figure 7 presents the application's user interface layout, which incorporates control elements for three LED fixtures and a cooling fan. This system relies on Wi-Fi connectivity to communicate between the Arduino microcontroller and the mobile application. The Blynk application sends commands to the Arduino, which processes the inputs and triggers the appropriate actions (e.g., turning off lights or activating the fan). Figure 7 a) displays the system's initial state with all components in the deactivated (OFF) position. Upon user interaction, the interface provides visual feedback through colour-state changes, corresponding to the physical activation of components in the model house. Figure 7 b) demonstrates the application interface during active component states (ON). Therefore, if the lights are left on when leaving the home, they can be remotely switched off using a smartphone, regardless of the user's distance from the house.

In operational conditions, the Arduino microcontroller responds to user inputs by activating or deactivating the selected components. This implementation enables selective control of individual elements, allowing users to manage each component's operational state independently. The system fulfills its primary objective by enabling remote management of household appliances, particularly for energy conservation through the deactivation of unused devices.The intuitive interface facilitates straightforward user interaction through binary (ON/OFF) toggle controls for each component, exemplified by the independent control mechanisms for both the cooling fan and LED fixtures.

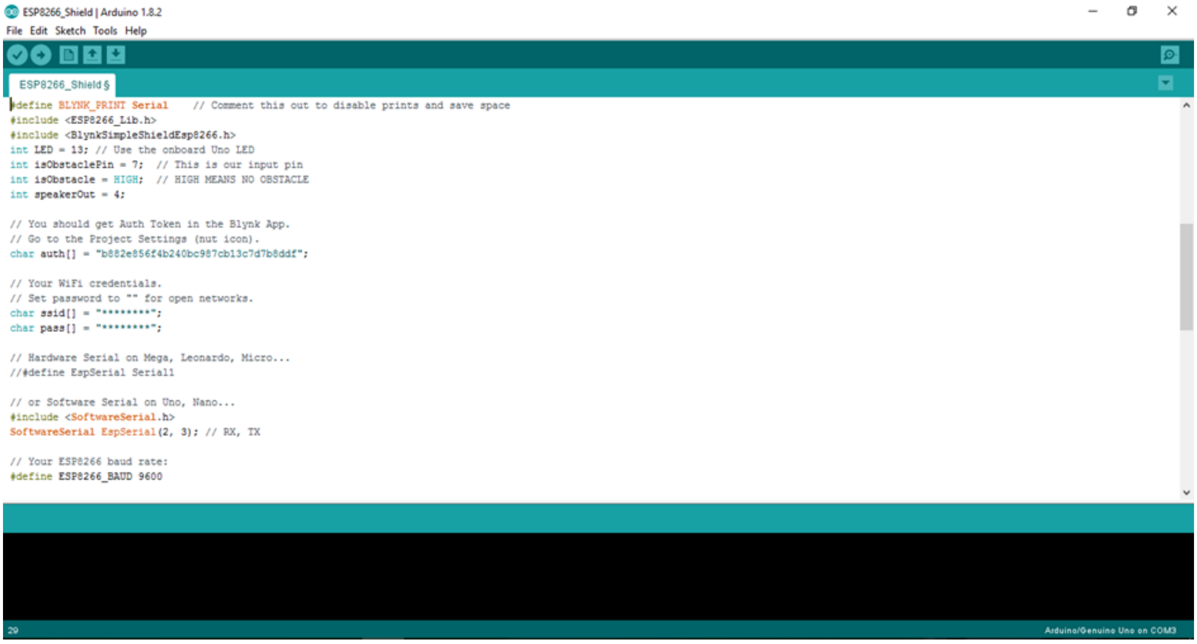


Fig. 5 Arduino IDE Configuration and Programming

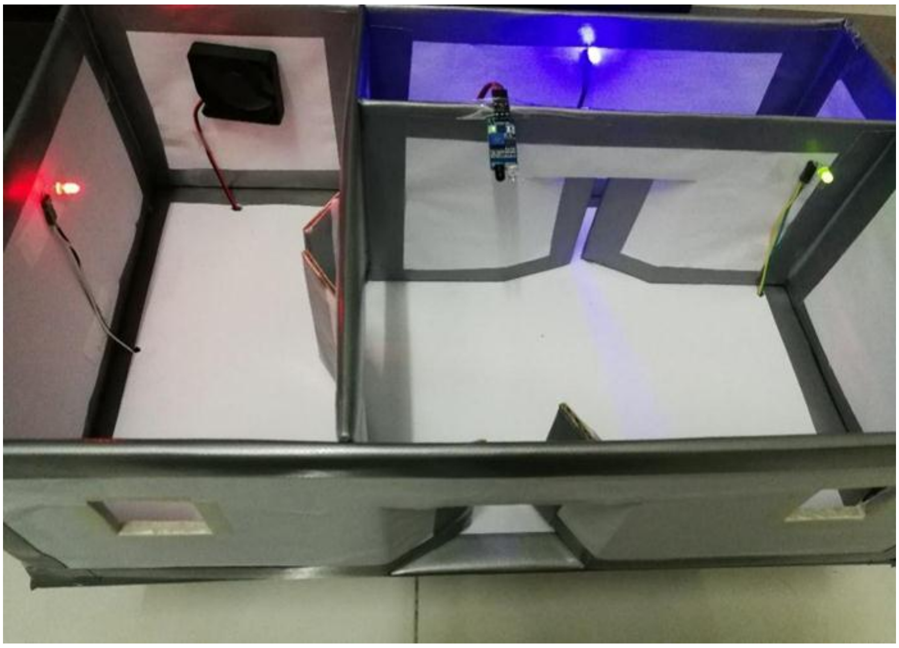
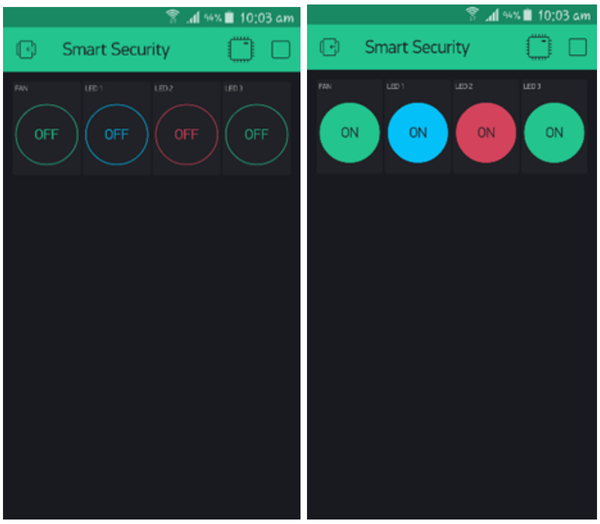


Fig. 6 All components are in active state (ON)

The IR Obstacle Sensor's detection capabilities are coupled with dual feedback systems: an auditory alert via a piezoelectric buzzer and visual notification through serial communication.When the sensor detects an object within its detection threshold, it initiates two simultaneous responses through the Arduino microcontroller:

a) activation of the auditory alarm system
b) generation of a serial output message for system monitoring



a) b)

Fig. 7 The Blynk app when all components switched a) OFF and b) ON

Figure 8 illustrates the system's binary response states:

a) "CLEAR" status: Indicates normal operating conditions with no detected obstacles
b) "OBSTACLE!! OBSTACLE!!" status: Signifies the detection of an object within the sensor's predetermined detection range.

The serial monitor output serves as a diagnostic tool, providing real-time system status verification and potential data logging capabilities. This dual-feedback approach enhances the system's utility by providing both immediate local alerts and documented detection events.

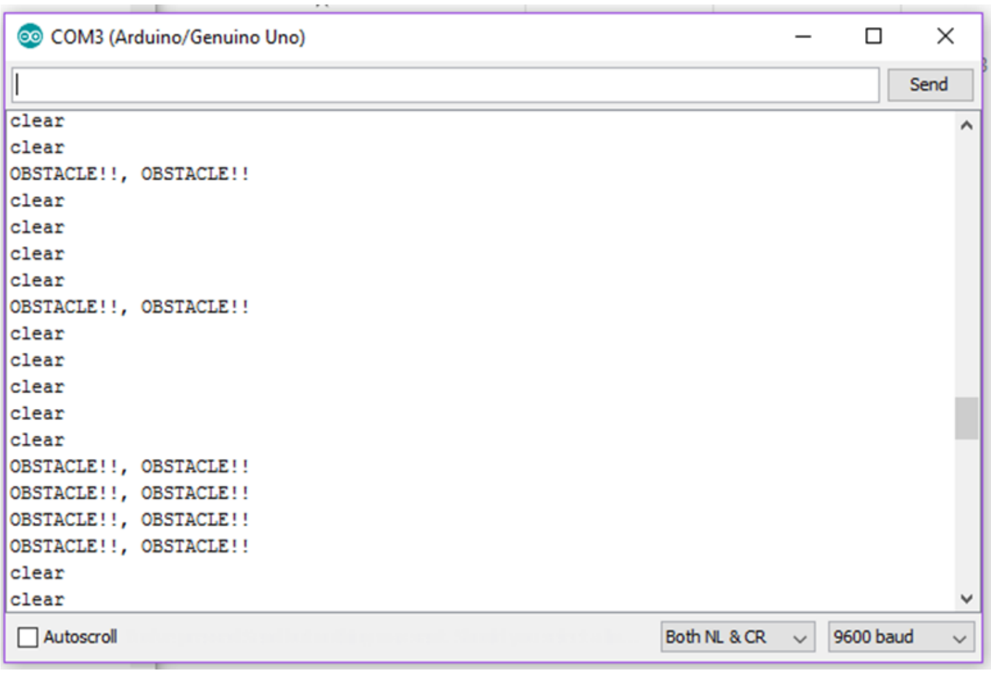


Fig. 8 Serial Monitor Visualization of IR Sensor Response States

VII. CONCLUSION AND FUTURE WORK

In conclusion, this project successfully demonstrated the implementation of a smartphone-controlled home automation and security system utilizing Arduino technology. The primary objectives were achieved through the development of a system that enables remote control of household functions such as fan and lighting control while incorporating security features through obstacle detection and alarm mechanisms.This implementation demonstrates the feasibility of developing sophisticated home automation solutions using cost-effective components while maintaining reliability and scalability.

A notable achievement of this implementation is its accessibility features, particularly beneficial for elderly or mobility-impaired users, who can manage household functions through a centralized smartphone interface. The system's core architecture, built around the Arduino Uno R3 microcontroller, successfully integrates with Wi-Fi connectivity and the Blynk mobile platform, enabling efficient command and control of connected devices. This functionality enhances convenience and energy efficiency by allowing control of household appliances from any location.In addition, the IR obstacle detection system provides real-time security monitoring through immediate alert generation upon human presence detection.

However, several potential enhancements are proposed for future research to further advance the system's functionality and applicability in modern residential environments. One area of improvement is expanded device integration, which could include incorporating additional household appliances such as washing machines, television sets, and air conditioning units, as well as the implementation of smart kitchen appliance controls like coffee makers and automated cooking systems. Enhanced security features could be realized by enabling smartphone-controlled IR sensor activation, integrating biometric access control systems, and incorporating networked surveillance cameras with mobile monitoring capabilities and advanced motion detection systems. Furthermore, as technology continues to evolve, the integration of artificial intelligence and machine learning [11] into smart home systems could further enhance their capabilities, allowing for predictive analytics and personalized user experiences.

In terms of safety, the addition of gas leak detection systems, smoke detection mechanisms, automated garage access control, and environmental monitoring systems would greatly improve the system's preventive measures. Furthermore, enhancing system robustness through advanced network security protocols, improved system redundancy, advanced error handling mechanisms, and expanded remote monitoring capabilities would ensure higher reliability and long-term performance. Collectively, these improvements would significantly enhance the system’s utility, security, and overall effectiveness in smart home applications.

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REFRENCES

[1]. Adhikary, A., Halder, S., Bose, R., Panja, S., Halder, S., Pratihar, J., & Dey, A. [2024] "Design and Implementation of an IoT-based smart home automation system in real-world scenario" EAI Endorsed Transactions on Internet of Things, Vol. 10.

[2]. Jordan, Y. A. [2023, June] "Impact of Internet of Things (IoT) on home automation and energy management" International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), Vol. 3, Issue 1. Mohamad, N. R., Wakiran, A. A., Iswandi, M. F., Salleh, A., Yunus, S. A. M. J., Sallehuddin, F., Azmi, N. F., Chach, S. A. M. (2013). Development of optical wireless audio system using infrared light communications. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), 8(6), 65-69.

[3]. Mohamad, N. R., Wakiran, A. A., Iswandi, M. F., Salleh, A., Yunus, S. A. M. J., Sallehuddin, F., & Azmi, N. F. [2013] "Development of optical wireless audio system using infrared light communications" IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), Vol. 8, Issue 6: pp. 65–69.

[4]. Netinant, P., Utsanok, T., Rukhiran, M., &Klongdee, S. [2024] "Development and assessment of Internet of Things-driven smart home security and automation with voice commands" IoT, Vol. 5, Issue 1: pp. 79–99.

[5]. Bature, U. I., Tahir, N. M., Abubakar, A. K., &Makama, A. [2021] "Internet of Things-based home automation, energy management, and smart security system" International Journal of Robotics and Automation, Vol. 2722, Issue 2586: pp. 2586.

[6]. Efendi, A., Siswanto, A., &Sudarman, A. [2018, October] "Application control and monitoring of light usage in smart home environment" 2018 Third International Conference on Informatics and Computing (ICIC): pp. 1–5. IEEE.

[7]. Hadi, N. A. A., Hasan, M. H. C., Hashim, N. M. Z., Mohamad, N. R., Rahimi, A. S., &Annuar, K. A. M. [2015] "Temperature monitoring system for infant incubator using Arduino" International Journal for Advance Research in Engineering and Technology, Vol. 3, Issue 6: pp. 8–11.

[8]. Azhuan, N. A. N., James, B., Samsudin, A., Hussin, N. H., Said, R. M., Anuar, S. H. H. H., & Abd Aziz, M. S. [2024] "Development Home Automation and Safety Circuit Breaker with Esp8266 Microcontroller" Journal of Advanced Research in Applied Mechanics, Vol. 120, Issue 1: pp. 85–98.

[9]. Ismail, S. I., Ismail, N., MohdZaki, A. H., Omar, S., & Mohamed, S. [2024] "Smart distance alert system with Blynk integration for safer gadget use" Indonesian Journal of Electrical Engineering and Computer Science, Vol. 35, Issue 1: pp. 70–77.

[10]. Salleh, A., Hashim, N. M. Z., & Mohamad, N. [2022] "Realization of IoT Water Monitoring System using Node MCU ESP8266 Microcontroller and Blynk Application" Vol. X: pp. 209–213.

[11]. Javed, A., Ehtsham, A., Jawad, M., Awais, M. N., Qureshi, A. U. H., & Larijani, H. [2024] "Implementation of Lightweight Machine Learning-Based Intrusion Detection System on IoT Devices of Smart Homes" Future Internet, Vol. 16, Issue 6: pp. 200.