

Smart Home Automation Systems: AI Approaches for Monitoring and Reducing Power Consumption

Deepender^{1,*}, Sanju², Kanwal Preet Kaur³

Abstract

This study comprehends a Bluetooth controlled home automation system that users can control remotely through a specific Android platform. Technology advancements lead to homes that acquire greater intelligence. Remote-controlled switches continue replacing standard wall switches because they operate as part of system-wide central control gear in contemporary homes. Today's users must operate wall-mounted manual switches in every room of the house. Members of both these populations face an additional obstacle for home automation usage. The modern advancements of remote home automation work effectively through smartphone technology. The smartphone application uses this system to send receiver commands which operate the load connected to the device. The receiver features an Arduino board connected to a HC-05 module. Through this technology, users can use specific features of the GUI application to activate device control from any location. The system provides an economical solution which permits users to manage multiple devices simultaneously. Devices under home control need password protection to authorize users for access.

Keywords: Smart automation system, relays, smart home, security, Arduino board

INTRODUCTION

The integration of technology into household operations under the term home automation allows users to enhance safety while gaining control over their systems for increased comfort and better power usage. PoS simplifies controlled operation of home appliances along with security systems and house lighting from smart technologies that incorporate mobile devices and voice assistant programs. Users achieve easy home control through automated systems which operate from the comfort of their location whether in the house or somewhere remote. Home automation presents a system composed of hardware networks connected by communication protocols with electronic interfaces [1]. The modern smart home system uses its network components to achieve stealth communication between devices by employing Bluetooth, Wi-Fi, and other wireless protocols. The networked elements provide users with the ability to control multiple functions from a single point. Through embedded system methodology, home automation provides users with easy systems while ensuring swift deployment and increased protective features which enhances both accessibility and efficiency of smart home technology. The essential features which home automation systems offer include:

- *Appliance Management:* lets users command home appliances to optimize energy efficiency and gain more convenience.
- *Safety Enhancement:* happens through two methods: surveillance camera and alarm system and smart lock administration [2]. The system monitors power consumption in order to reduce wastage and decrease electricity expenses. Through smart locks and authentication systems house residents can allow or block entry into distinct house areas.

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Received Date: May 27, 2025

Accepted Date: June 15, 2025

Published Date: August 26, 2025

Citation: Deepender, Sanju, Kanwal Preet Kaur. Smart Home Automation Systems: AI Approaches for Monitoring and Reducing Power Consumption. Journal of Power Electronics & Power Systems. 2025; 15(3): 10–17p.

Home automation systems have progressed past their original remote control capabilities by integrating two advanced elements: data-based system management and automatic tracking of devices [3]. The "Advanced Home Automation System" provides users with control features and effectively manages data storage for performance enhancement analysis. The system provides users with insights about their energy usage patterns that leads to better efficiency through time. The standout capability of this system enables the assignment of exclusive ID tags to every connected device. Connected devices establish automatic reconnections when they pair together with no need for repeated configuration. A search capability within the system allows users to check current device usage through name or unique ID searches. The increasing intelligence and user-compatibility of smart home technology makes home automation systems better and fitting for users through ongoing progress. The system creates comfortable living conditions while simultaneously helping users save energy and enhance security and better functionality throughout their homes. Home automation technology sets the foundation for molding how people will live in modern society throughout the evolution of technology.

LITERATURE REVIEW

Modern technological advancements enable the automation of domestic daily chores, as homes today contain several programs and appliances [3]. Each addition of digital devices to our houses makes establishing interconnections between them more necessary. Home automation finds its implementation at this point [4]. A study explains that the advantages of all systems include comfort, security and efficiency, yet the challenge stems from customizable features. Home automation devices are transitioning from expensive to affordable products while providing researchers an excellent chance to explore smart homes through this technological advancement [5]. The fundamental physiological need of shelter also scores as a necessary safety measure according to Maslow's hierarchy of needs because survival depends on both shelter and safety. Trustworthy security combined with control is the primary benefit which wireless technology provides for home automation systems according to Yuneela and Sharma [6]. Home automation systems have generated multiple effects which start with basic control and security and progress to advanced applications such as building management and health monitoring [7]. The simplicity of this method matches its description perfectly and the Internet of Things created the technical possibility (IoT).

METHODOLOGY

Home Automation management system software features an interface that users can operate without difficulty. The whole programming process and component installation takes place at home and in the laboratory before testing is performed. A large number of wires together with components formed the basis for constructing the system. This system follows the minimum cost approach for its completion [8]. The technology possesses adjustable features which users can customize. The device needs to have the appropriate application active for changing any element of its setups. All system components went through automated testing along with security precaution assessment until they passed the checks for correct device matching [6]. A mobile device together with Bluetooth functionality is needed to operate this system. This project contains two essential stages known as hardware implementation and software implementation which direct the designed home automation system prototype toward testing on real hardware. Figure 1 shows the circuit diagram of the system.

Through an application, users can gain easy access to manage electronic devices and household appliances with this home automation system. Users can handle and observe their home situations with ease through smartphone and tablet applications. The automation system works through a mobile application providing users with remote control access to different home appliances. A smartphone delivers control signals to the home automation system via Bluetooth for the purpose of device control operations [9]. Users access efficient home operation management through this wireless system without necessary manual interaction with appliances. The application presents a friendly interface that allows users easy access to carry out commands without complex procedures. The Bluetooth-based control system integrates into the system to create a dependable and effective link between mobile devices and

household equipment. The local communication system provides security advantages because it restricts device access to people operating inside a particular distance range [10]. The system maintains an integrative feature that allows users to incorporate various connectivity protocols such as Wi-Fi and IoT-enabled protocols which create expanded remote access together with automation capabilities. Systems controlling the house are evolving with modern smart technology developments that enable voice command interfaces and scheduling features and utility meter tracking. The enhancements implemented in home automation systems enhance usability while improving efficiency and security thus establishing itself as an essential aspect of present-day household living standards.

Hardware Architecture

The physical computing platform of Arduino functions through its combination of a microcontroller board along with an integrated development environment (IDE) (Figure 2). Through its position as open-source hardware, the technology has become widely popular to build both home automation products and robotics and develop interactive electronic projects. Through Arduino, users build specific solutions which integrate sensor input for data processing followed by output control that operates motors and lights and alternative connected devices. The device serves as an excellent platform for automated operations because it enables users to activate lights and motors along with other responses from sensor data. Users achieve Arduino programming by sending instructions to the microcontroller which determines what jobs it must execute [11]. Arduino IDE provides a software environment which helps users simplify coding procedures along with compilation and code transfer operations directed to the board. Among all Arduino devices the Arduino Uno serves as a popular platform derived from Wiring and utilizes Processing to power its interface. The unified system consists of these components that simplify the entire process from project development to deployment. A fundamental benefit from Arduino comes from its support for multiple operating systems. Users from any operating environment can install and use the Arduino IDE because it supports Windows, macOS and Linux platforms [12]. Thanks to its open-source makeup, Arduino welcomes user collaboration for designing and sharing code and applications with other users. Arduino has achieved its position as a leader in prototyping and education because of its user-friendly interface and widespread community backing together with its adaptable nature.

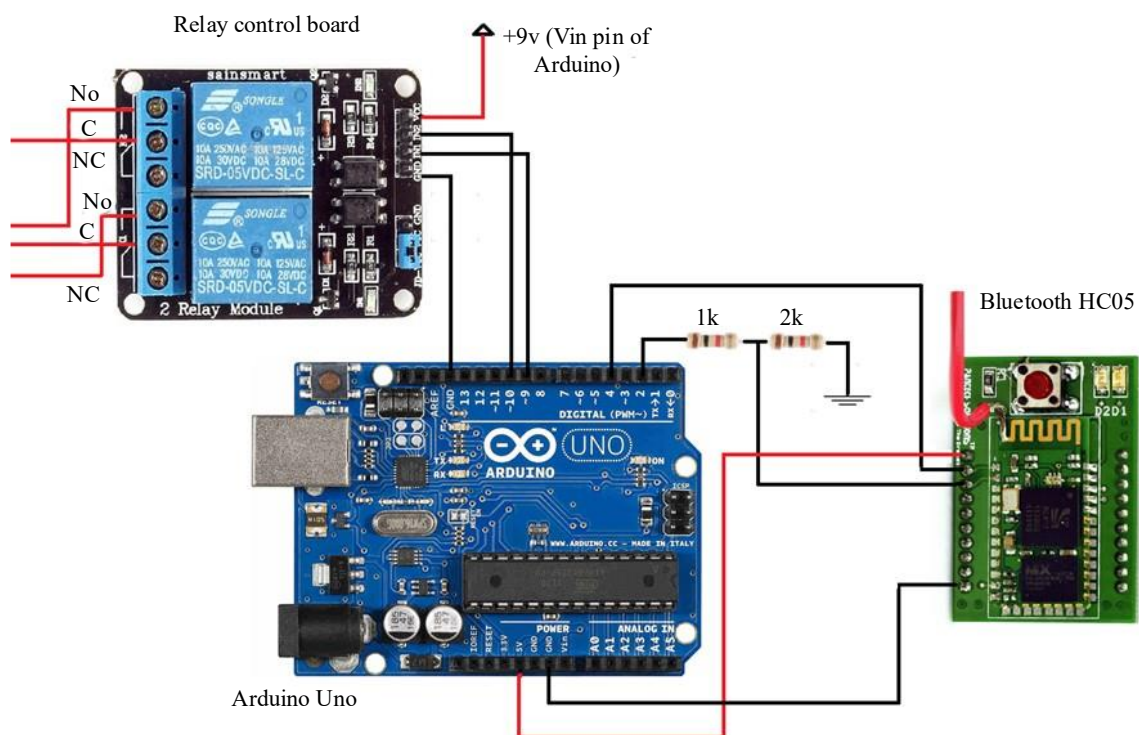


Figure 1. Circuit diagram for the system.

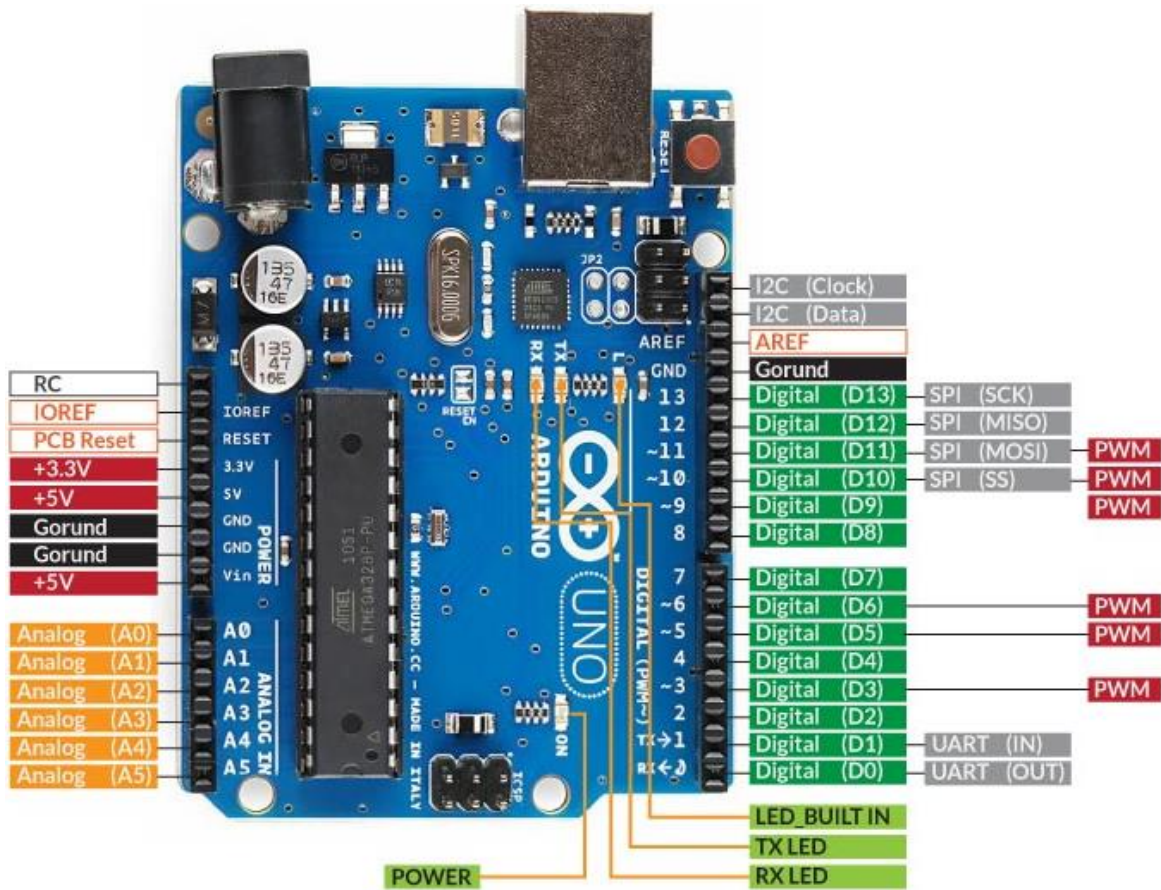


Figure 2. Arduino Uno.

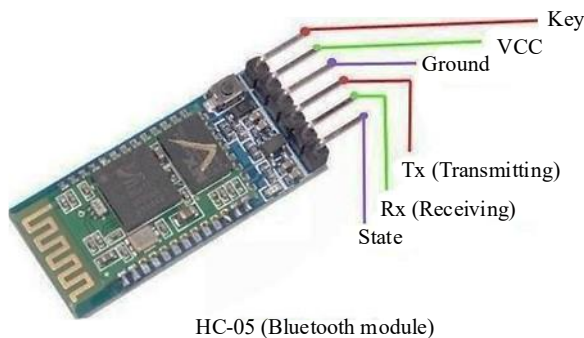


Figure 3. Bluetooth module.

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The system components connect to each other through the relay to perform its role as the central control unit (Figure 4). The activation of all triggering sensors as well as modules that reach an active state activates the relay to power up connected devices or systems. After the fingerprint sensor matches with the stored fingerprint, it triggers the relay to activate which operates the servo motor to unlock or open the device. The smooth automated operation results from the successful integration of sensors and relays with actuation units. The system includes a feature which provides users with instant alerts in real-time [15]. The system has a feature that allows any activated sensor to start the relay mechanism which sends instant feedback messages to the user through texting to their phone. The electrically operated switches known as relays find extensive application within consumer electronics along with automation systems because they enable control of high-power devices by using low-power signals. The integration of GSM modules enables relay control from any distance and allows users to operate house appliances or curtain systems through actuators. The components connect through an established wiring diagram to achieve correct integration between all parts and intended functionality. The system requires proper interconnection of sensors together with relay modules and actuators including servo motors while utilizing communication modules which include GSM. The wiring diagram produces an operation that is both reliable and efficient which allows the system to work effectively across home automation and security system applications. Such systems that link relays with GSM technology demonstrate great adaptability for building smart connected environments.

SOFTWARE ARCHITECTURE

The Data Flow Diagram (DFD) stands as one of the primary process models used for system analysis (Figure 5). A DFD serves as a visual representation tool that displays data movements between processes and data stores and external system components. A DFD presents structured visual information about system activities and operational sequences which serves as an indispensable tool for system development projects and current system evaluation. DFDs split complicated systems into smaller parts to enable developers and analysts to comprehend their current status while finding ways to optimize existing systems. The Home Automation System demonstrates its operational flow effectively through the use of a data flow diagram. The diagram shows how user input travels through the system processing until device execution completes the desired functions [3–6].



Figure 4. Relay Module.

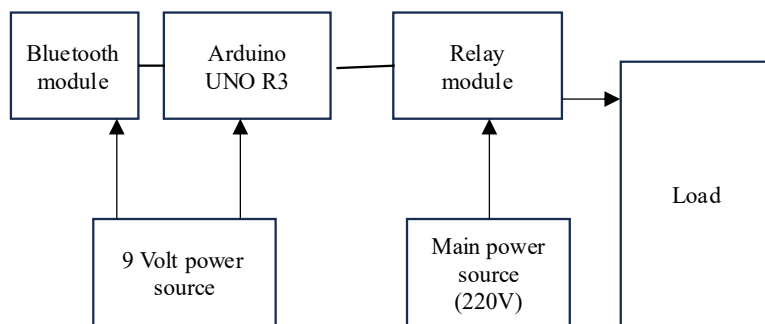


Figure 5. Data Flow Diagram.

The flow of a user command for lighting and thermostat control starts at the interface then goes through the processing unit to achieve output device actions according to the DFD. The diagram showcases important system operations including data verification together with decision-making steps and sensor and actuator communication processes during its path. Through a DFD, the system's components interconnect as shown while representing data storage retrieval and transformation processes. The DFD delivers important value to home automation systems through its ability to provide complete system functionality understanding which helps engineers design systems and debug them and improve their performance. The design model enables complete process assessment to confirm system efficiency together with reliability which satisfies user expectations.

Embedding effective functionality into this system requires two main software components which are Arduino Integrated Development Environment (IDE) and Bluetooth terminal application. Programmers can develop code through the user-oriented Arduino Integrated Development Environment for uploading it to Arduino microcontroller boards through compilation. This interface enables developers who are beginners as well as experienced users to connect through a streamlined interface to program and debug while performing tests successfully. The IDE brings compatibility with various Arduino boards to its users and adds features for syntax highlighting and auto-formatting and provides a serial monitor tool for live board communication. Within this system the Arduino IDE enables users to develop firmware that supports hardware control and data processing as well as device connectivity. The Bluetooth terminal application, on the other hand, serves as a communication interface between the user and the system [7–9].

The application operates from mobile phones, tablets and computers to manage wireless Bluetooth data exchange with users. The system uses this software interface to grant users easy access for device control functions and sensor data tracking and system setting adjustments from a remote location. The Bluetooth terminal application functions together with Arduino-based hardware to create a wireless system that executes user commands without data transmission errors. The system relies upon these two software programs to function as its fundamental operating components. The system functions through the Arduino IDE which manages hardware operations and low-level programming whereas the Bluetooth terminal application enables wireless user interface access. Both software components give users powerful functionality and friendly interfaces which makes the system appropriate for household automation through industrial process control.

RESULTS AND RELATED WORK

The proposed system offers a transformative solution to enhance the mobility and independence of individuals with disabilities. By enabling remote control of various home appliances, such as lights, fans, air conditioners, and other electronic devices, the system allows users to switch these devices on or off based on inputs received from their end. This functionality is particularly beneficial for individuals with limited physical mobility, as it eliminates the need for manual interaction with appliances, thereby improving their quality of life and reducing dependency on others. One of the standout features of this system is its ability to manage and optimize power consumption [16, 17].

Through a dedicated application, users can monitor and control the energy usage of their home appliances, ensuring efficient operation and reducing unnecessary power wastage. This not only contributes to cost savings but also promotes sustainable energy practices, aligning with modern environmental concerns. The home automation system represents a significant advancement in smart technology, providing users with a convenient and modern way to control their devices remotely. By integrating user-friendly interfaces, such as mobile applications or voice commands, the system ensures ease of use and accessibility for all users, regardless of their technical expertise [18, 19, 6]. This aligns with the growing trend of smart homes, where technology is leveraged to create more comfortable, secure, and energy-efficient living environments. In terms of related work, this system builds upon existing research and developments in the field of home automation and assistive technologies. Previous studies have demonstrated the effectiveness of IoT-based systems in improving the lives of individuals with disabilities, as well as the potential of smart home technologies to enhance energy management and user convenience. However, this system distinguishes itself by combining affordability, ease of implementation, and a focus on accessibility, making it a practical solution for a wide range of users. Overall, the results of this system highlight its potential to revolutionize home automation, particularly for individuals with disabilities, while also contributing to energy efficiency and modern technological advancements. Its successful implementation paves the way for further innovations in the field, encouraging the development of more inclusive and sustainable smart home solutions.

CONCLUSION

The home automation system provides users with distinctive features including an advanced interface that looks great and offers better functionalities and user experience than traditional solutions. The automation system functions exactly as described in its name because it unites mobile technology with home automation controls that let users operate appliances from anywhere. The system adopts modern communication technologies for a unique approach that amalgamates a Bluetooth module with an Arduino microcontroller and a relay circuit to establish an efficient automation system architecture. This system provides ease of understanding to complex home automation terminology along with technical aspects. The straightforward contemporary presentation of the technology enables advanced automation systems to reach users who were previously out of reach. The system requires fundamental simplification especially when used with mobile devices because their limited screen size demands an interface that provides full functionality yet avoids user overload. The proposed system combines three essential characteristics as a low-cost security-focused solution that implements automatic configuration through remote control features to direct home appliance management. The study presents a unique remote control management process which effectively accomplishes user device oversight from afar. The Bluetooth-enabled method surpasses past approaches because it provides efficient and safe and expandable technology that suits contemporary smart residences. Additionally, the system doubles user convenience while delivering enhanced home security features that address important issues in modern society. The system demonstrates practicality through its ability to fulfill necessary goals for home automation solutions while showing effectiveness in operation. This home automation system makes a major advancement in the evolution of smart home technology. Using affordable technology combined with secure design alternatives the system provides intuitive controls for distant home appliance management. This system proved successful in demonstrating its potential to change daily life which leads to new developments in home automation technology.

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