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Research Article

IoT Based Smart Home Automation System: Design and Development

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About Article

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ABSTRACT

Home Automation System (HAS) is becoming increasingly popular with the advancement of communication technology. A smart home is a better implementation of the Internet of Things (IoT), offering users the convenience of controlling home appliances on the Internet through an automated system. This paper presents a low-cost smart home automation system using Wi-Fi to support remote control and monitoring of home appliances via an Android application. The system is constructed on the basis of an Arduino UNO microcontroller equipped with a Wi-Fi module. In addition, several sensors are implemented to sense temperature, humidity, and motion inside the residence. A new system overcomes the limitations of the existing home automation systems. This is achieved by design and construction a low cost Wi-Fi-based Automation System for Smart Home prototype using Arduino microcontroller and Android-Based smartphone. An automation system is interfaced with home appliances with the help of a relay board. The proposed architecture facilitates optimal and easy control of electrical and electronic appliances with the help of Wi-Fi and a virtual mobile interface.

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1. INTRODUCTION

In this section, the researcher discusses the significance of the study, scope, problem statement, objectives, thesis and a summary.

The world is still battling with the deadly Covid-19 pandemic. Therefore, the need to develop and implement new techniques to help maintain hygiene at both the household and organizational levels (WHO, 2021). In most cases, lights, televisions, and other household appliances are operated manually. However, with the advancement in automation, this can be achieved remotely and efficiently using a smartphone (Kumar & Patel, 2020).

This project introduces a home automation system controlled through a simple Android application, allowing users to control electrical appliances within the house using touch or voice commands. All commands are transmitted via a Wi-Fi modem (ESP8266) to an Arduino UNO (Sharma *et al.*, 2019). This innovation presents a more hygienic and efficient method of interacting with household devices, eliminating the need for physical contact with switches, an important consideration in post-pandemic living.

There are numerous IoT-ready embedded systems, microcontrollers, and devices available on the market today that are cost-effective and highly capable (Ali & Singh, 2022). Among these, the ESP8266 stands out for its affordability, versatility, and compatibility with a wide range of sensors and actuators. It also benefits from a strong developer community and documentation support (Chen & Lee, 2021).

Consequently, with such a system in place, the need to switch electrical devices on/off when away from home is increasing both convenience and hygiene (Ramesh & Prasad, 2020).

1.1. Motivation and significance of the study

Home automation is a new technology that allows a house to perform some tasks automatically. It is becoming increasingly popular, not only for the sake of enhancing home conditions but also within business and industrial setups. The technology is always in motion, becoming more interactive by adding newer features to support greater needs from users. Home automation installation does not need very complex procedures. It begins with the identification of the automation need. For instance, if the primary need is the enhancement of home security, all the parts needed will be selected and outlined before the system is automated. Similarly, if high-energy lighting systems are installed, home automation can be employed to conserve unnecessary energy usage, resulting in enhanced comfort, security, and efficiency. Home automation is advancing very rapidly, with its use growing in different industries. The project herein is on automating a home setup. In a demonstration, one room with significant appliances is used to demonstrate the automation system.

1.2. Scope of study.

Examine the already available information about HAS in books, etc and focus on addressing the limitations and adding further fascinating features so that we improve people's lives worldwide.

In other words, this project is full of hands-on activities ranging from literature and practical research.

1.3. Problem statement

Installation of the room automation systems in the existing residential houses requires a massive and expensive makeover since the planning of the room space and gadgets is non-compliant with automation. This implies that it is normally not feasible to install an appropriate home automation system. Theft, however, is one of the fundamental challenges facing most homeowners in the country. Certain homes in Zambia are without a security system. Also, incidents of fires caused by negligence are increasing at a high rate. Therefore, buildings are at risk of such acts of theft and other accidents. Zambia highly depends on one form of energy consumption by the local market, also in the last decade, other than physical switches and door handles, which may be the root cause of the spread of the COVID-19 virus, so the project is concentrating on designing and implementing an IoT-based home automation system.

1.4. Project objectives

1.4.1. Main objective

To design and implement Automation system for Smart Home Internet of Things (IoT).

1.4.2. Specific objectives

i. To design a circuit for an IoT based Automation system for smart.

ii. To write a code that will be uploaded in a microcontroller.

iii. To determine the effectiveness of the system.

1.5. Research questions

i. How do you design a circuit for an IoT-based Automation system?

ii. How do you write code that will control the microcontroller?

iii. How do you determine the effectiveness of the system?

1.6. Summary

This section discussed the Background of the study, purpose and importance of the research, boundaries and limitations, identified problem and study goals, structure of the thesis, and an overview of the part.

2. LITERATURE REVIEW

2.1. Background of connected home technology.

Home automation, or smart home technology, is a key aspect of the Internet of Things (IoT). All the devices in the system are assigned a unique IP address so that it can be remotely accessed and controlled from anywhere, anytime (Al-Fuqaha *et al.*, 2015). It refers to a system where Home appliances and equipment are interconnected for centralized, efficient management, enhancing user convenience and operational efficiency (Miorandi *et al.*, 2012).

Historically, home automation systems were limited to basic lighting and simple appliance controls. However, with the advancement in wireless communication and embedded systems, the concept has evolved to offer full remote control of home environments through mobile applications, cloud platforms, and AI integration (Zhang & Cook, 2016). This advancement has made the vision of an interconnected, responsive home environment a reality.

Modern home automation systems allow users to define how devices should behave, why, and when they should react to specific conditions. This brings not only convenience but also control, energy efficiency, and cost savings (Gubbi *et al.*, 2013). These systems can also send alerts in case of emergencies such as water leaks, gas leaks, fires, or unauthorized access, thereby increasing the security of smart homes (Sicari *et al.*, 2015).

Moreover, at any time, users can reconfigure automation settings based on their preferences using an Android application or any other compatible control interface. This adaptability further enhances the user experience and supports personalized energy management strategies (Patel & Doshi, 2018).

Kuantan (2013) It has been argued that various steps have been undertaken to develop energy-efficient solutions for the domestic setup in light of growing demand for electricity. One effective way involves the inclusion of energy forecasting systems in smart homes. This approach relies on the utilization of sensors and actuators to track home energy consumption on a round-the-clock basis in real time.

The design of Kuantan, for example, takes instantaneous data from domestic environments using a sensor network. The data is then analyzed with predictive models such as Multi-Layer Perceptron (MLP) and K-Nearest Neighbor (K-NN) algorithms to provide estimates of energy consumption. These forecasting functionalities not only provide real-time insights into energy consumption but also predict future energy consumption trends, enabling residents to make informed and proactive energy-saving decisions (Kuantan, 2013).

In addition to that, energy consumption forecasting has been explored by using Long Short-Term Memory (LSTM) networks, which are a form of recurrent neural network. Experimental results from actual data reveal that MLP performs significantly better compared to the K-NN model in prediction accuracy with RMSE values of 1.62 and 1.80 respectively. In addition, LSTM performs best with an RMSE value of 0.07.

According to Algoiare (2014), Smart Home (SH) has the potential to allow the user to sense home states, Home Automation Systems can also keep track of environmental variables such as humidity, temperature, and light levels, and operate HVAC systems with minimal human intervention. There has been a lot of contribution from researchers as well as developers in translating this concept into a practical reality.

For instance, Song *et al.* (2017) suggested a resource-aware smart home system management using a domain-object hierarchical model for home context capture. They used Web Services Description Language (WSDL) and Simple Object Access Protocol (SOAP) for remote access to home data via mobile devices.

In order to enhance the energy efficiency, Han *et al.* suggested a Smart Home Energy Management System (SHEMS) based on IEEE 802.15.4 and ZigBee technology. Their system comprised a multi-sensor and lighting control application with an overall energy consumption reduction.

Referring to user-oriented interaction within smart homes, Wu *et al.* proposed a model for explaining the interaction among services, physical spaces, and individuals. Deriving from the framework, they developed two context-aware applications, i.e., "Media Follow Me (MFM)" and "Ubiquitous Skype."

To forecast user behavior, presented an algorithm named SPEED (Sequence Prediction through Enhanced Episode Discovery). The technique predicts human activity by partitioning behavior into episodes—a collection of interdependent actions—and utilizes a finite-order Markov model and the Partial Matching (PPM) algorithm to enhance prediction precision.

Chen *et al.* (2021) presented a knowledge-based system for long-term, real-time activity detection based on multi-modal sensor information. The system features context modeling, situation analysis, and a multilayered framework for activity interpretation—ranging from low-level sensor readings to high-level behavioral knowledge. The contextual information was stored and queried using Semantic Web technologies, and reasoning was supplied by the Euler inference engine.

These research studies emphasize the key intelligent home aspects of context sensitivity, power efficiency, friendly user interaction, and efficient activity detection.

Based on these ideas, this article suggests a smart home solution that combines the strengths of the Internet of Things (IoT) and cloud computing. IoT introduces sense-making to household appliances, allowing users to monitor and respond to environmental change remotely. Cloud computing, however, offers scalable computing and storage capacity to enable home services deployment and management. Cloud computing also enables the users to control and access home systems from anywhere and at any time.

Jabbar *et al.* (2018) echoes that Internet of Things (IoT) is an emerging technology that surrounds ordinary things, from industrial devices to consumer products, in order to exchange information and accomplish tasks while occupied with other events. An IoT-based smart home automation system is a system that uses PCs, mobiles, or remote devices to control basic functions for the home automatically from any point on the earth through the internet. The proposed intelligent home automation system is unique compared to the other systems as it gives the freedom to the user to operate the system from any location in the world through an internet connection, and also possesses intelligent nodes with the ability to make decisions according to the environmental factors. A home automation system was developed on the basis of sensor nodes directly interfaced with Arduino microcontrollers. The microcontroller is programmed in a manner that can perform some basic operations depending on sensor values. e.g., fan operation depending on the reading of the temperature, and light operation depending on whether there is motion in the room, etc. Apart from this, the Arduino board is connected to the internet through a Wi-Fi module. Another feature provided by this system is to monitor the power consumption of different household appliances. The suggested system provides the user with remote control of different appliances both inside and outside the home. The suggested system is extendable, i.e., multiple devices can be controlled. The goal of the proposed system is to provide an effective and low-budget solution for a home automation system based on IoT. Results show that the proposed system is able to handle all the controlling and monitoring of the house.

Acharjya *et al.* (2018) emphasizes on The home automation system can be employed in various applications such as home security, lighting control, fire detection, smart heating, motion

sensing, and door automation. It is designed to give homeowners constant comfort, safety, energy efficiency (through reduced operation costs), and convenience. The Internet of Things (IoT) will drive the delivery of multi-faceted smart home services, each offering different automation solutions based on the requirements of a household.

This study proposes the development of an automated home monitoring system using Raspberry Pi that can provide a cost-efficient and a versatile platform for smart home devices. The system is developed and deployed with the use of sensors and actuators that communicate with each other through a gateway that utilizes Wi-Fi. Raspberry Pi and Arduino Uno are the backbone of the project that serve as the connection between the networked sensors and actuators that provide smart home control and monitoring (Acharjya, 2018).

2.2. Limitations of the existing HAS

The research review that one of the main issues in most existing HAS is their implementation and maintenance cost which is not affordable for most users. Consequently this paper propose a new system to overcome the limitations of the existing home automation systems. This has been achieved by design and construct a low cost Wi-Fi-based Automation System for Smart Home prototype using Arduino microcontroller and Android-Based smartphone. The system is developed to control all the electrical appliances at home easily and efficiently and enable the remote control by supporting the IoT concept.

3. METHODOLOGY

3.1. Introduction

This section gives the detail of methodology with regard to baseline study, system design, and each major component used in this project with reference to system design requirements, types, and operational conditions of each component (Patel & Rathod, 2020).

3.2. Baseline study

This part outlines the research methodology and conceptual framework used in this study, the logical research stages, and the specific implementation details of the proposed system. It also outlines the key components of the system and how they function together to meet the objectives of the study. The flow chart in the figure illustrates the research activities carried out in this study and the sequence in which they were executed.

system design (Sharma *et al.*, 2019).

The design of the smart home automation system uses Arduino UNO and ESP8266 Wi-Fi module in combination with RemoteXY platform to create a mobile-controlled switching system. The system provides remote ON/OFF control for lights and appliances within a house. The code ensures proper communication between hardware and app interface (Abdullah *et al.*, 2021).

3.3. System design

Figure 1 shows the layout design of the home prototype. The next step is the modeling phase, in which all the tools and materials required are assembled to construct the smart home prototype (Saini & Saini, 2020).

Figure 1. Layout design of the home prototype.
Source: Author

The prototype is constructed using plywood, as indicated in Figure 2 The hardware and wiring installation are then carried out. The programming stage is then carried out using the Arduino IDE. In an attempt to develop and improve the design, any issues encountered in the development process are realized and addressed during the testing process (Sirohi & Maheshwari, 2021). Corrections are made so that the same errors do not recur. Lastly, the final design of the project is closely examined.
3.3 Main Components of Home Automation System

3.4. Arduino

Arduino UNO, as shown in Figure 2 is used as the main controller in this project due to its simplicity, low cost, open-source nature, and wide community support. It allows easy connection with various sensors and actuators (Kaur & Kaur, 2018). The Arduino board reads input data from sensors and sends control signals to the output devices

Figure 2. The Arduino UNO microcontroller

The ESP8266 Wi-Fi module, as shown in Figure 3 is used to enable internet connectivity. It supports 3.3V logic level and communicates with Arduino via UART protocol. This module is preferred for IoT applications because of its low cost, built-in TCP/IP stack, and good compatibility with cloud platforms (Ali *et al.*, 2017). IoT applications.

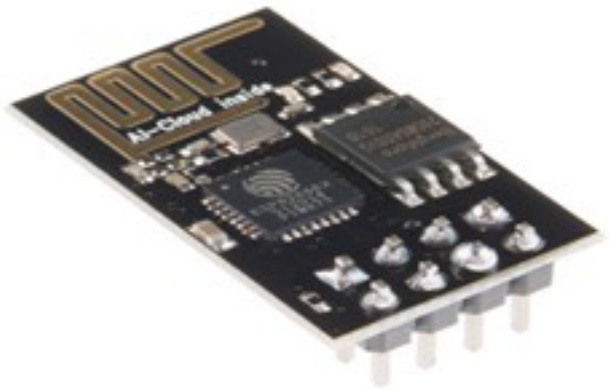

Figure 3. Wi-Fi Module

3.5. Virtual mobile application

In this project, the mobile application created using RemoteXY serves as an electronic switch. It can be operated from anywhere globally if both the mobile device and the Arduino system are connected to the internet. The application transmits commands through Wi-Fi to control appliances such as lights and LEDs (Ahamed & Ahamed, 2020).

Figure 4 shows two switches and a push button used to control two bulbs and an LED respectively. This app-based control ensures safety and convenience, particularly useful during health-sensitive periods such as pandemics.

Figure 4. Switches and a push button used to control two bulbs
Source: Author

The diagram above illustrates the importance of the code in the Arduino and the predefined credentials in the Virtual App. These form part of the security features which can be used independently by a Smart Home and will not interfere to another Smart Home anywhere in the world. They can never be a time a user can operate the neighbor's device regardless of distance involved.

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3.6. Relay board

The relay module used in this project (Figure 5) acts as a switching device, providing a safe interface between the low-voltage Arduino signals and high-voltage appliances like light bulbs. Relays are preferred in such applications due to their robustness and ability to handle high current loads reliably (Patil & Kulkarni, 2016).

Figure 5. A relay board
Source: Relay module schematic.

3.6. Schematic diagram for relay

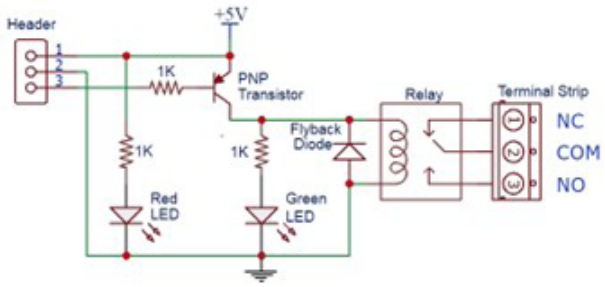

Figure 6. Schematic diagram for relay
Source: 5v signal channel relay module.

4. RESULTS AND DISCUSSION

In addition to these components, several other sensors and devices are included in the system for enhanced functionality. These include temperature and humidity sensors, PIR motion sensors, voltage regulators, and home appliance replicas such as televisions and decoders (Gupta *et al.*, 2019).

The design of the system is divided into three parts:

i. Electronics Operation: Connections of relays, Arduino board and module

ii. Electrical Operation: Connection of bulbs to the mains and the circuit through the relays

iii. Wireless Operation: Programming the Arduino in order for the Wi-Fi module to be able to communicate with a smartphone without traditional wires.

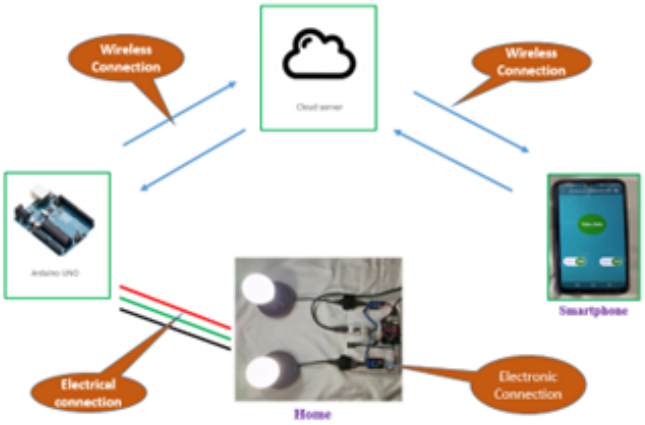

Figure 6. Technical operational principles.
Source: Author

5. CONCLUSION

The research project propose, design and made-up a low cost Wi-Fi based Automation System for Smart Home prototype using Arduino and Android smartphone. It enables the control all the electrical appliances such as the bulb and fan at home easily and efficiently via Wi-Fi. The sensor can monitor the motion, humidity and temperature of the house. Timer will be ON when there is a motion detected in the house. The Smart Home Automation System provide a comfortable, intelligence, good security and improve the quality of life. By using this smart home system, electric bill can be reduced because the user can control the electrical appliances anytime without using human energy.

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