5th African International Conference on Industrial Engineering and Operations Management, Johannesburg/Pretoria, South Africa, April 23 - 25, 2024
Publisher: IEOM Society International, USA
Published: April 23, 2024 DOI: 10.46254/AF05.20240151

Arduino-Based Home Automation System

Nduduzo Wiseman Langa and Oluwafemi Emmanuel Oni
Department of Electrical Engineering
University of Zululand
Richards Bay Campus
wisemanlanga4@gmail.com, OniO@unizulu.ac.za

Kayode Timothy Akindeji
Smart Grid Research Centre, Department of Electrical Power Engineering
Durban University of Technology
Durban, South Africa.
kayodea@dut.ac.za

Abstract

As technology advances, so do homes. Modern homes are gradually transitioning from traditional switches to centralized control systems using remote-controlled switches. Traditional wall switches, which are now placed in various parts of the home, make it difficult for users to access and operate them. Operating the switch is even more difficult for the elderly and people with disabilities. Therefore, in this paper, a home automation system using an Arduino board with Bluetooth that can be remotely controlled from an Android OS smartphone was developed. Remote home automation systems offer the most modern solutions using smartphones. The performance of the proposed model system has been tested on PROTEUS software package, and it is very reliable and user-friendly to the occupant for easy control of the home or office appliances via the Bluetooth of the smartphone when the user is in a remote area. Moreover, the power consumption was mitigated during the operation of the devices. The final prototype was developed and upgraded with a high security lock interface.

Keywords

Automation, keypad lock, android interface, Arduino board, Bluetooth.

1. Introduction

The term home automation describes how home appliances work in a way that minimizes human interaction (Jacobsson, Boldt, and Carlsson, 2016; Ko and Eshraghi, 2023; Perni, Suneetha, Kantamneni, and Revalamadugu, 2023; Sayeduzzaman, Hasan, Nasser, and Negi, 2024; Tzafestas, 2018). Eliminating human intervention in such mechanisms replaces them with programmed systems and applications to control devices. Home automation has grown rapidly in popularity in recent years. It is expected to continue to grow over the next few years and capture a vast consumer market. A report by (Adoghe, Owuama, Oguntosin, and Morawo, 2022) shows that the home automation industry will account for $114 billion by 2025. We have developed a new system that is very cost-effective and allows users to control any electronic device without having to issue a remote control. This project helps users to control all their electronic devices with their smartphones. Today, traditional wall switches located in various parts of the home make it difficult for users to access and operate. The switches are even more difficult for the elderly people with disabilities to operate (Pradhan, Mehta, and Findlater, 2018; Ramlee, Tang, and Ismail, 2012; Unaldi, Yalcin, and Elci, 2023). Remote-controlled home automation systems offer cutting-edge solutions using smartphones (Kirola, Rawat, Sharma, and Sinha, 2019).

Furthermore, traditional wall switches require many components, resulting in unnecessary costs (Mukherjee et al., 2024). This paper tends to promote the use of home automation systems in all households through the advanced usage of different semiconductor devices. The system is easy to use, has low power consumption, and is low cost. It ultimately provides a more reliable and energy-efficient method of using electrical appliances in a household environment, especially for elderly and disadvantaged people. Furthermore, the design project provides a very user-friendly automated security feature.

A system using an Arduino-based GSM module is proposed in reference (Onukwugha and Asagba, 2013). Arduino is responsible for managing the software side of embedded applications. Additionally, this reduces component size and increases reliability. GSM is a customized messaging system that communicates with smart homes or electrical devices through SIM cards. A prototype of the system was successfully implemented. Multiple devices were controlled simultaneously. It is suggested to use an android application to simulate a smart home (Nisar and Ibrahim, 2018). To interact with the intelligent model and android phone, the house model uses a ZigBee module. Due to the external ZigBee transceiver, it has been determined that ZigBee is not a reliable medium for communication. As a result, the system became complex and wasted energy. A low-cost Bluetooth-based home automation system employing an Android phone was described in (Hisham, Ishak, Teik, Mohamed, and Idris, 2014). Relays and an Arduino Mega 2560-R3 board were used to connect the household appliances as the board's input and output ports, and Bluetooth was utilized to create wireless communication between them. In addition, references in (Kumar and Tongbram, 2023; Latha, LAKSHMI, POOJA, INDU, and CHANDRIKA, 2023; Malunao, Fernando, and Tejada, 2023; Mishra, Gupta, Batra, and Kaur, 2024; Okomba, Adebimpe, OMODUNBI, SOBOWALE, and ADANIGBO, 2023) describe how an Android app with a Bluetooth module and Arduino UNO board was developed and used for home automation. Users can interface with the Android phone and use the Arduino UNO to control other embedded devices or sensors by sending control signals. Similar voice instructions were used by reference (Srinivasan, Sumanthkumar, Vardhan, and Chaitanya, 2023) to control household appliances using Arduino and Android OS. In their paper titled "Programmable Infrared Accessory Light Switch," (Hariharaputhran, 2022; Jubadi and Zulkifli, 2007; Ramachandrarao, 2022) proposed how to use a television (TV) remote control to operate room lighting and other appliances. The frequency of the existing remote was programmed into an Infrared (IR) remote and one IR receiver, which could then be used to directly control appliances. The downside to all these studies is the lack of high security interface which is implemented in this study.

Therefore, a home automated system is designed, tested and the final prototype is built. Coding and interface were carried out using an Arduino board for the design and implementation. Bluetooth module and an android based smartphone were used to control the desired electronic devices and to also provide feedback for the alarm systems during unauthorize login or breaches. The system final prototype is reliable and scalable to set up for a real home security system.

2. Design Model

Proposed model design, of this project consists of two main parts, the software programs interface, and the hardware for different applications. The software program interface is the program and the way of connections between the hardware parts and the Arduino. The hardware parts include computer, Arduino, PCB, LED, Sensors, Relays, and wires, which will be further explained on the System hardware section. The program of the home automation system for the microcontroller is written in C and compiled using the Arduino IDE (integrated system development) area to generate hex code. The generated hex code is burnt into the microcontroller using an mC Flash+ programmer. The microcontroller port pins are defined using '*sbit*' function for interfacing with the surrounding peripherals. By selecting device from list menu of the Home Automation Application program, which is developed using Android application installed on mobile device, will transmit ASCII characters serially through Bluetooth and on the receiving side microcontroller receives data through serial Bluetooth module on serial port of microcontroller AT89C51. 'SBUF register' will read this ASCII characters as equivalent HEX values which will be ported to Port 0, 1, and 2's pins of ATMEGA328. The flowchart of the microcontroller program control for the whole system is shown in Figure 1.

3. System Hardware

3.1 Arduino Microcontroller

The Arduino microcontroller is the processing brain behind the work of this home automation, and it was used to interface the entire system together. The Arduino plays an essential role in implementing an automated household control system. The most well-known microcontroller, Atmaga328P, is integrated with an Arduino board, as shown

in Figure 2, has a feature that makes Arduino more attractive and easier to program. Some other features include 14 digital I/O pins (6 of which can be used as PWM outputs), 6 analogue inputs, a 16MHz ceramic resonator, a USB connector, power jack, ICSP header, and reset button. The Arduino can be powered in two ways, plug it into the computer with a USB cable or power it up with an AC-DC power supply. In powering the Arduino, an external power supply is used.

3.2 Bluetooth Module

The HC-05 is a class 2 slave Bluetooth module for transparent wireless serial communication. Its operation becomes transparent to the user once it is associated with a master Bluetooth device such as a PC, smartphone, or tablet. The Bluetooth module used in this design project is HC-05, as shown in Figure 3. It receives the command and passes it onto the Arduino microcontroller. The microcontroller reads the command through a serial port; therefore, the Arduino microcontroller compares the command from the android phone to the code written on the Arduino Uno. If it matches the command, the corresponding output pin goes high. The relay driver receives the signal from the microcontroller and activates the corresponding appliance/device (load). The HC-05 works with a supply voltage of 3.6VDC to 6VDC. However, the logic level of RXD pin is 3.3 V and is not 5 V tolerant.

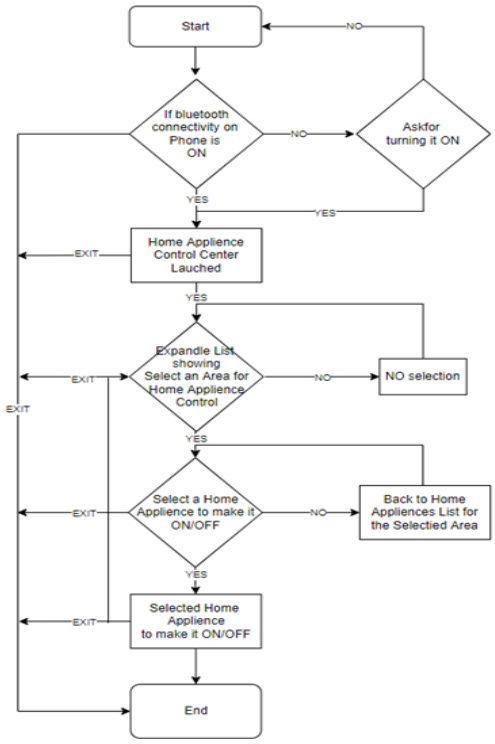

Figure 1. Proposed solution operational flow diagram

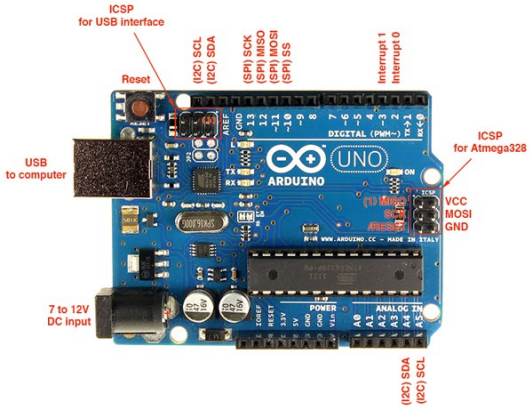

Figure 2. Layout diagram of the Arduino Uno R3.

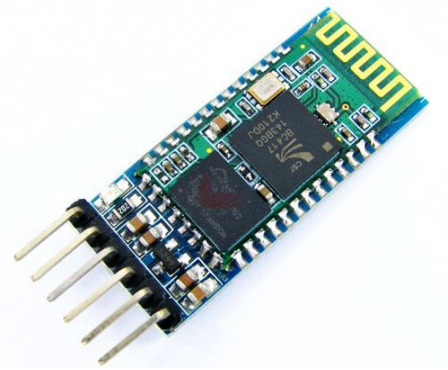

Figure 3. HC-05 Bluetooth module (Amoran, Oluwole, Fagorola, and Diarah, 2021)

3.3 Power Supply

There are multiple methods can be used to power an Arduino, the commonly used method to power supply the Arduino's is by using the external power source supplying regulated voltages required by Arduino specifications. The power supply consists of different stages that help to process the conversion voltage from AC to DC. Figure 4 presents a 240 VAC converted to a (DC) form with an output voltage of 5V (Van Nguyen, Lee, Seol, Yu, and Choi, 2007).
If a minimum of 7V as the input to the voltage regulator is used for designing the power supply, then condition (II) will not be satisfied. It was decided to design the power supply such that 10.5 V will be supplied to the input of the voltage regulator. This results in a voltage ripple of

$$\Delta V_0 = V_{0(pk)} - V_{min}$$
$$10.18 - 8.78 = 1.4\,V$$

The calculations for determining required value for the smoothing capacitor is given by,

$$C_{min} = \frac{I_{max} \times T_{discharge}}{1.44V}$$
$$\frac{1A \times 0.01s}{1.44} = 459.20\mu F$$

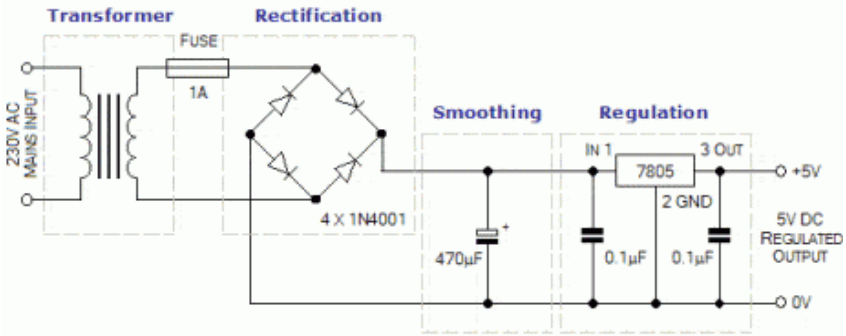

Figure 4. External power supply circuit (Amoran et al., 2021).

3.4 Relays

A relay is a type of electromechanical switch. When current flows through the relay's control pin, the control pin activates an electromagnet that pulls on the movable lever to actuate the switch. Because the control pin and the switch are electrically isolated, a relay can be used to control a large current with a small current (Warren et al., 2011). This means that an input from an Arduino that outputs about 40mA can be used as a switch to control high power loads such as AC/DC lighting or electronics. So, in this project the relay can be activated by a low current signal on his

Arduino, making it perfect as a switch for electronics. Figure 5 represents the type of relay or relay package that will be suitable for this design specifications.

4. Proposed system

The layout diagram of the design model is shown in Figure 6. It thoroughly explains the proposed system for this design. Two types of communication are involved in this design: wired and wireless. The communication between the Bluetooth module, or HC-05, and the Android-based mobile phone will help connect to the controller wirelessly. In contrast, wired communication uses a cable to interconnect the controller and the appliances.

Figure 5. 4-channel 5V relay control board proposed (Latha et al., 2023).

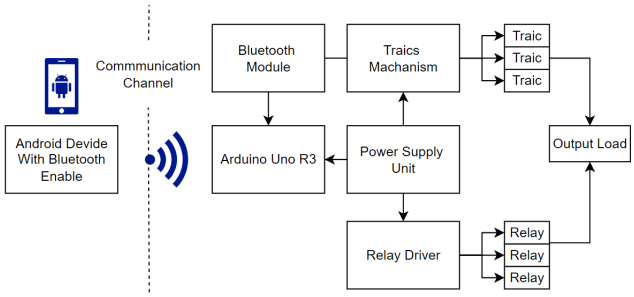

Figure 6. Block diagram of the proposed system

The design simulation is carried out on Proteus Software using Arduino integrated development environment (IDE) Application to write the code in C++/C language. For a demonstration of the automation control, the following appliances are to be used: DC fan, DC bulb, and other appliances. The Power supply is used to activate the power on the system. For the case when there are security systems involved, Triacs blocks are used to provide a rotational/motion in the load connected.

5. Software design and communication

The schematic design of the final prototype as model on proteus is shown in Figure 7. The circuit was designed using Proteus Professional 8 software. The schematic design the microcontroller, relays, Bluetooth module HC-05, and other peripheral components were discussed in the hardware section of this paper.

The control unit comprises of the following components listed below which are the major components for the control unit of the design.

- Arduino UNO 3
- Relays
- Bluetooth HC-06
- Keypads
- Motion and light Sensors for the security
- LCD display

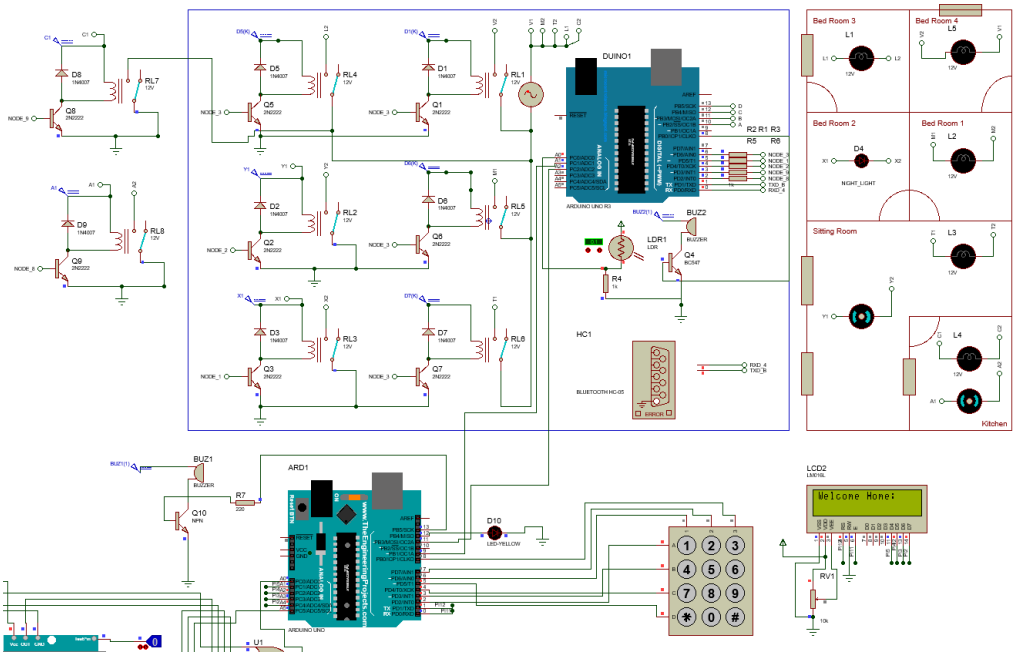

Figure 7. The design control unit on Proteus.

6. Results

The Arduino microcontroller was configured using IDE Arduino software which included the following steps:

- USART to receive the signal from the Bluetooth of the smartphone.
- Configure the Ports for the Output cases which depend on the number received from the smart phone.
- When the configuration processes done the microcontroller connecting as the follows:
- Connect HC-06 Bluetooth module Rx to Tx of the microcontroller and Tx of HC-06 Bluetooth module to Rx of the microcontroller than complete VCC to VCC and GND to GND.
- PortB.1 for example to Relay
- Relay to AC device
- After the power up of Bluetooth device turn on the Bluetooth in android phone
- Search for the devices. HC-06 is found.

Figure 8 Shows the location of the appliances for demonstration of the system operation on software design.

Press the terminal key as shown in Table of results below and print the number used in the microcontroller configuration, for example, number 1 to turn on the light and number 2 to turn off the light. Then with using this proposed system it is easy to control all devices in the office or room by the smartphone and use this smart phone to communicate through the cellular network. The benefit of using the proposed system is to reduce the power consumption by easily controlling the home or office appliances. The cost evaluation of this proposed system will be reasonable respectively and illustrated by the estimated power consumption section of the house appliances.

The following illustrates the operation of the Android app with the proposed design system, showing household appliances being operated remotely from the app.

- The following four scenarios will be used to demonstrate the functionality of the software design on Proteus:
- Turn all devices ON (simultaneously)
- Sitting Room Fan ON
- Kitchen Light only ON
- Turn ON only a few devices (represented four lights controlled simultaneously)
- Turn all devices ON (simultaneously) (a) Mobile Device Button
- Turn all devices in the house ON (simultaneously)
- Sitting Room Fan Button ON (simultaneously)
- Sitting Room Fan Button ON

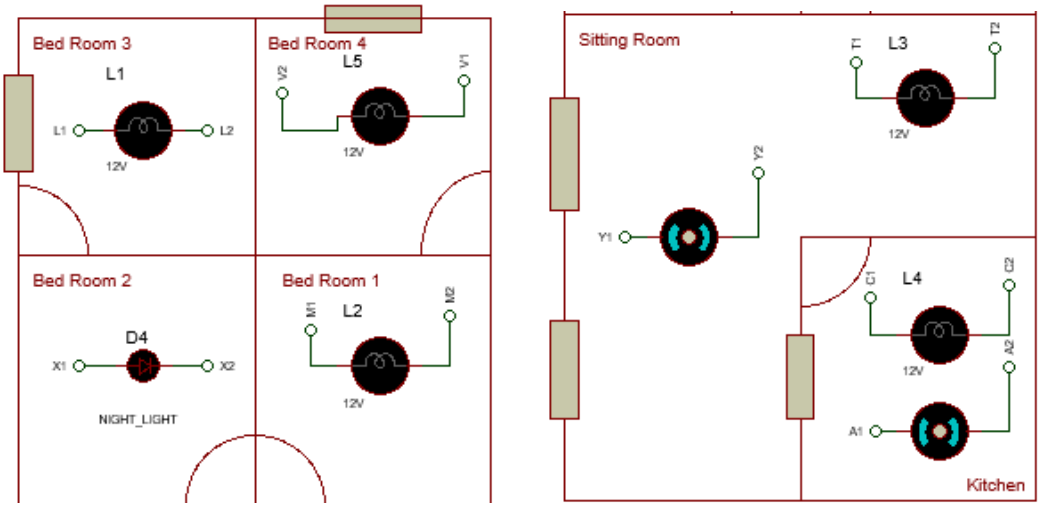

Figure 8. Location of each device in the house.

The implemented security system consists of the following components respectively. PIR Motion Detectors (Sensors) with Buzzer- Provide the alarm signal. Automated door lock system with Keypad access shown on an LCD.
The working principle of the security system shown in Figure 9 is based on the monitoring PIR sensors, the automated door lock system with keypad and the alarm notification on Android App designed. When the system is on, we monitor the sensors if there are any unauthorized movements detected if yes, we call the function that we activate the alarm and ring the buzzer. The alarm notification is then sent to the Android app controlled by the Arduino microcontroller via Bluetooth interface, then there are two ways of deactivating the alarm if one chooses to deactivate it using the Android app button that will deactivate the alarm and after deactivating the alarm successfully using the app, we go back on monitoring to check the unauthorized entry or movements again. The second way to deactivate the alarm is to use the keypad and the LCD, where you will be prompted to enter the secret password to deactivate the alarm, if the password is incorrect the alarm will continue ringing until the correct password is entered. The second way to deactivate the alarm is to use the keypad and the LCD, where you will be prompted to enter the secret password to deactivate the alarm, if the password is incorrect the alarm will continue ringing until the correct password is entered. As illustrated in Figure 10, 11 and 12, The LCD homepage will display message of “Welcome Home:” where you will then press enter which is configured as the star button, and another prompt would ask you to “Enter password:” if the password entered is incorrect it will display Access denied as illustrated or access granted. Furthermore, if the password entering attempts fails more than 2 times it will ring the alarm which means the Buzzers will be activated and will ring the noise and an immediate “ALARM” notification will be displayed on the App as shown in Figure 13 below. The keypad access security system works in two ways, it acts as access control into the house and also acts as a means of security for activating /deactivating the alarm system also interfaced with the buzzers and can also deactivate the motion detectors in the house.

Security System showing 6 PIR motion detectors, Buzzer and Keypad access system. illustrates the security system model on Proteus software package, showing 6 PIR motion detectors connected to the Arduino. Each of these sensors will be located on different rooms of the house as illustrated by the Prototype design and implementation. The user will be able to have the high-quality security advantage since there will be sensors in each and every room detecting any unauthorized movements when the alarm system is activated.

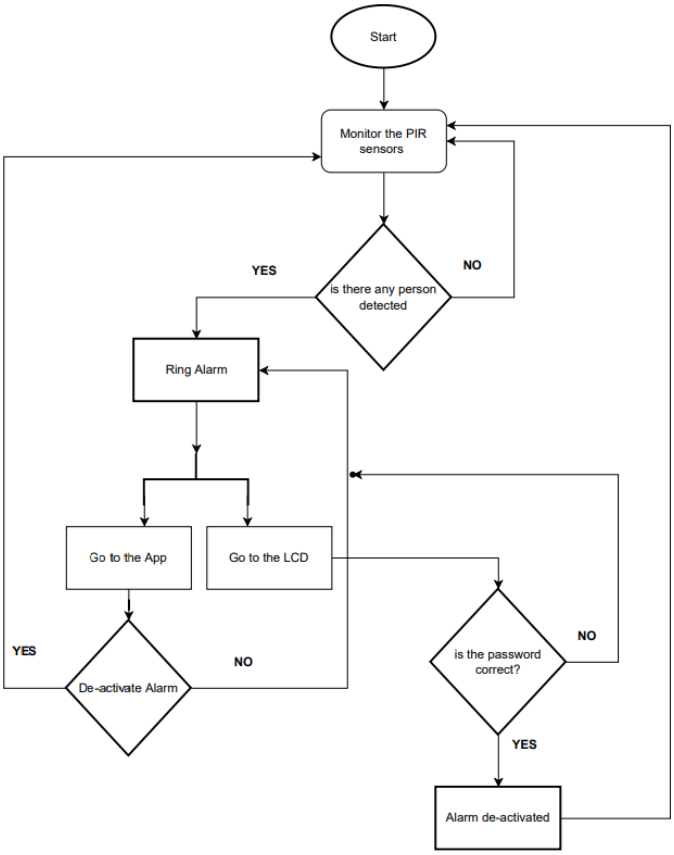

Figure 9. The working principle of the security system.

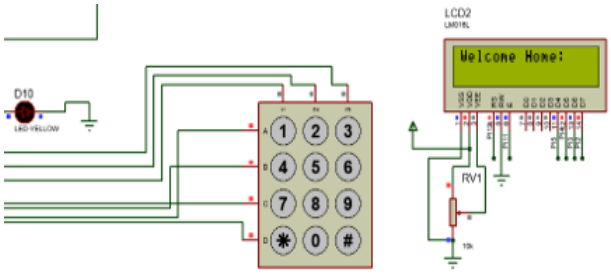

Figure 10. Shows the keypad access security system.

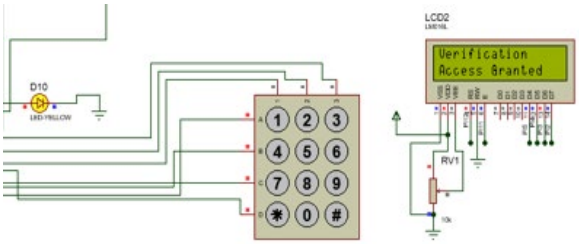

Figure 11. Shows the keypad access security system.

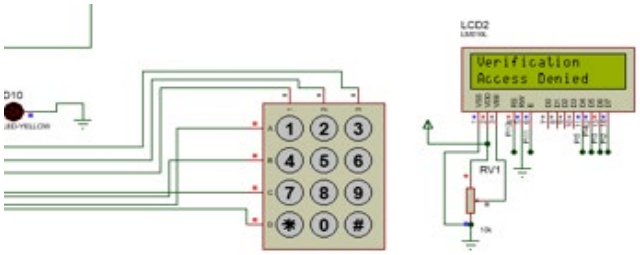

Figure 12. Shows the keypad access security system.

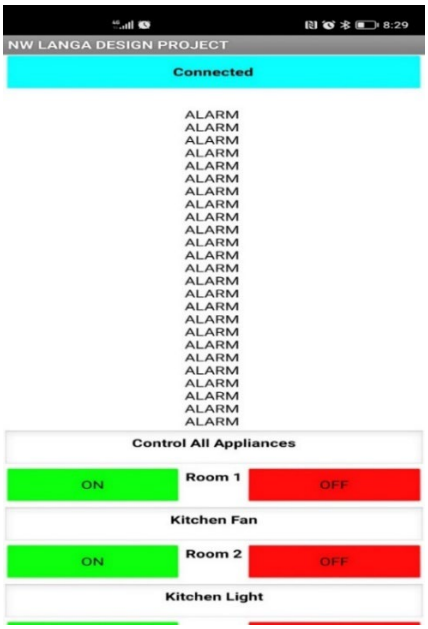

Figure 13. The android App Alarm notification

6.1 Power consumption of the house

Based on the usage of energy efficient devices, the power consumption of all devices is 1 kW, 1 unit, running for 24 hours in a day for the entire month. The power consumption is represented by Table 1 below. Wattage-1 kW. Operational Hours-8 hours, the manually switching time of the device depends on the user. Assuming the user does not turn of the lights off after being used. The automation switch turns off the appliance immediately after the device is used, and the delay is set to turn the e. Hence, the operational hours are reduced.

Table 1. Appliances power consumption (24 hours duration)

Location	Devices	Power Consumption (Manual Switch)	Power Consumption (Automatic Control)
Bedroom 1	Ligh 1	20 W x 8 hrs	20 W x 3 hrs
Bedroom 2	Light 2	20 W x 8 hrs	20 W x 2 hrs
Bedroom 3	Light 3	20 W x 8 hrs	20 W x 6 hrs
Bedroom 4	Light 4	20 W x 8 hrs	20 W x 1 hrs
Sitting Room	Fan	100 W x 8 hrs	100 W x 1 hrs
Outdoor	Alarm	10 W x 2 hrs	10 W x 0.5 hrs
Total Energy		1.46 kWh	0.345 kWh

6.2 Financial Feasibility

The financial feasibility study was conducted, and the prices of the various hardware and software components required to achieve the project specifications are illustrated in Table 2. It is further shown that the cost of implementing the small scale of this study will require an estimated budget of about R1598. Therefore, it can be concluded that the implementation of this study is feasible.

6.3 Prototype Design Implementation

Figures 14 – 20 show the demonstration of the home automation control using the smart phone to control every appliance in the house. The communication is done via Bluetooth. As seen from the figure, the light in each room turns ON and OFF when the button is pressed. Other devices such as fan and PIR sensor successfully implemented and tested. The main objective of the project is achieved, and validation of results was discussed in this section. Utilizing the suggested method has the advantages of reducing energy consumption through simple control of office

or home appliances, as well as fair cost evaluation, as shown by the estimated power consumption section of the home appliances.

Table 2 Shows the cost analysis of building the design project**.**

Component	Quantity	Price (R)
Arduino Uno board	2	R500
Android mobile phone	1	-
Light bulbs	4	R120
Fans	2	R120
Bluetooth Module HC-05	1	R118
Relay Circuit Pack	1	R109
Diodes	4	R35
Resistors	10	R28
Transistor (IGBT)	3	R18
PIR Sensor Detector Module	8	R260
Active Buzzer Module	2	R40
Others		R250
Total		R1598

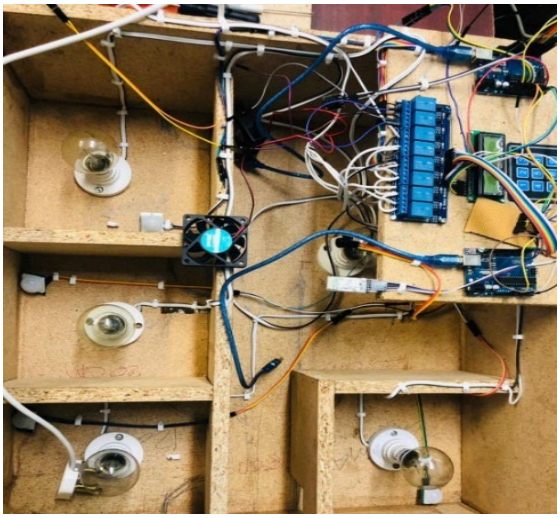

Figure 14. Top view of the final prototype

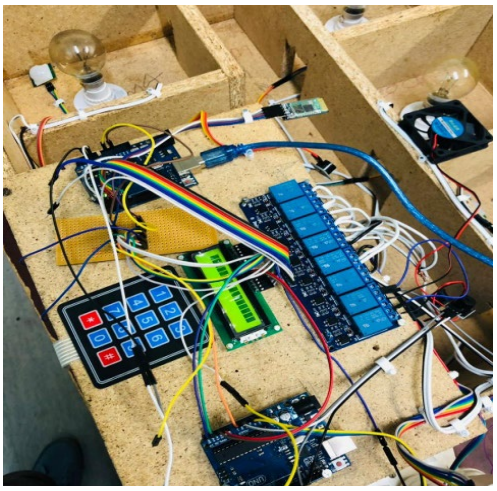

Figure 15. Final view of the design prototype

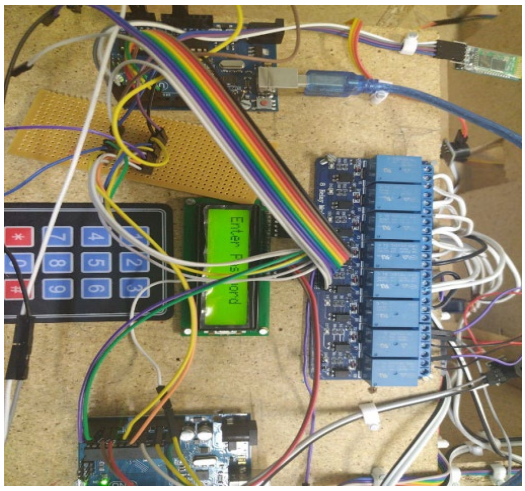

Figure 16. Authorizing user to enter Password

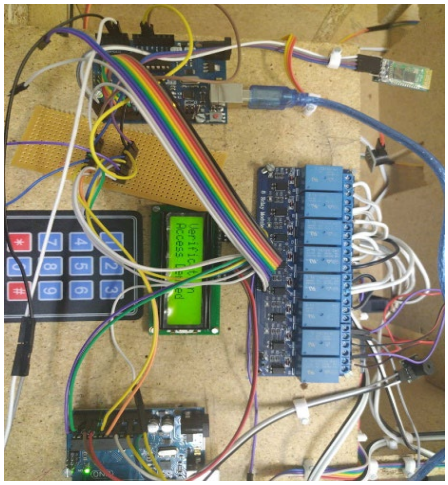

Figure 17. Access denied due wrong password

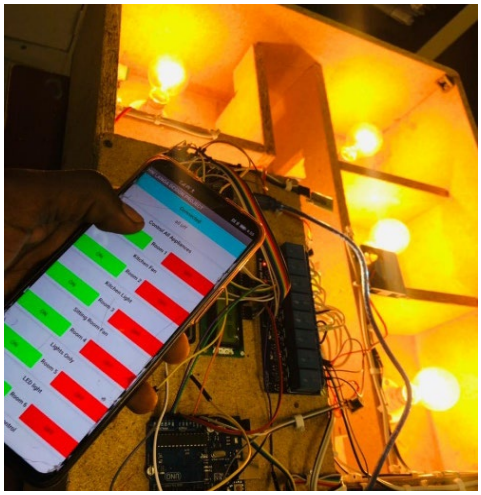

Figure 18. Test on all lights-to be ON

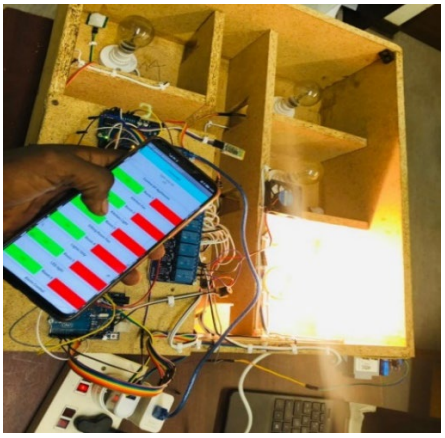

Figure 19. Test on single light Kitchen (Room 1)

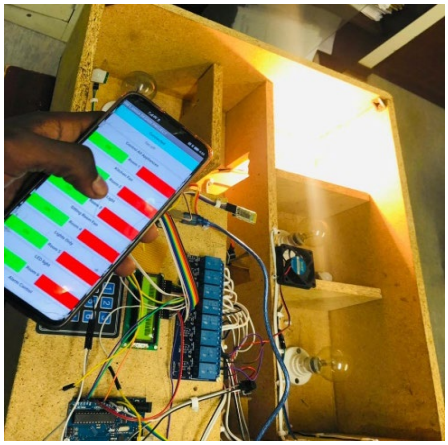

Figure 20. Test on another light (Room 2)

7. Conclusion

In this paper, an automated home system with enhanced security is proposed, designed and implemented using Arduino Uno board. The proposed system has been designed using an Arduino microcontroller and communication is via Bluetooth of a smartphone using Arduino control Application (Apk) software. The performance of the proposed model system has been tested on Proteus, and it is very reliable and user-friendly to the occupant for easy control of the home or office appliances via the Bluetooth of the smartphone when the user is in a remote area. This concludes that the required goals and objectives of home automation systems have been achieved. The system design and architecture were discussed, and the prototype presents the basic level of home appliance control and remote monitoring. Furthermore, the proposed system is enhanced with high security alarm systems and keypad. Unauthorize access at third input of wrong key code immediately triggered an alarm system which is directly related to the users. This feature is one of the major contributions of this design. This proposed final protype is equipped with a high-quality security features like automated door locks, motion detectors, buzzers, and an automated gate security system. Future work can focus on the implementation of voice recognition and control, thumbprint or pattern recognition can also be used for switching. Distance and range barriers of using Bluetooth can be accomplished with the use of Zigbee or using home Wi-Fi module via virtual private network (VPN).

References

Adoghe, A. U., Owuama, E. C., Oguntosin, V., and Morawo, B., Design and Implementation of a Low-Cost Cloud-Powered Home Automation System *Journal of Engineering Science and Technology Review, 15*(3), 177-192. 2022.

Amoran, A. E., Oluwole, A. S., Fagorola, E. O., and Diarah, R., Home automated system using Bluetooth and an android application. *Scientific African, 11*, e00711. 2021.

Hariharaputhran, V. N., Mobile And Voice Controlled Smart Switch for Home Automation Using Arduino. 2022.

Hisham, A. B., Ishak, M. I., Teik, C., Mohamed, Z., and Idris, N., Bluetooth-based home automation system using an android phone. *Jurnal Teknologi (Sciences and Engineering), 70*(3), 57-61. 2014.

Jacobsson, A., Boldt, M., and Carlsson, B., A risk analysis of a smart home automation system. *Future Generation Computer Systems, 56*, 719-733. 2016.

Jubadi, W. M., and Zulkifli, N., *Programmable infrared accessory light switch.* Paper presented at the 2007 International Conference on Intelligent and Advanced Systems, 2007.

Kirola, M., Rawat, A., Sharma, N., and Sinha, A. K., *Smart Home Automation Using Google Assistant.* Paper presented at the International Conference on Advances in Engineering Science Management & Technology (ICAESMT)-2019, Uttaranchal University, Dehradun, India, 2019)

Ko, H. S., and Eshraghi, S., Automation in Home Appliances. In *Springer Handbook of Automation* (pp. 1311-1330): Springer, 2023.

Kumar, M., and Tongbram, S., *Development of IoT Based Home Automation System Using Smartphone.* Paper presented at the 2023 5th International Conference on Energy, Power and Environment: Towards Flexible Green Energy Technologies (ICEPE), (2023).

Latha, M. K. H., LAKSHMI, S. V. S. S., POOJA, V., INDU, K., and CHANDRIKA, T., BLUETOOTH BASED WIRELES HOME AUTOMATION SYSTEM USING FPGA. 2023.

Malunao, D. C., Fernando, G. J. O., and Tejada, R. R., *GSM Based Home Automation Smart Controlled Power Outlet using Android Phone.* Paper presented at the 2023 2nd International Conference for Innovation in Technology (INOCON), (2023).

Mishra, R., Gupta, T., Batra, V., and Kaur, I., Design of Home Automation System with Emergency Control. *Journal of Scientific Research, 16*(1). 2024.

Mukherjee, S., Das, A., Saha, A., Sengupta, R., Das, D., and Chatterjee, A., Accessible Home: Empowering Disability with Smart Home Automation. *AJSE*. 2024.

Nisar, K., and Ibrahim, A. A. A., *A smart home model using android application.* Paper presented at the Proceedings of the 7th International Conference on Kansei Engineering and Emotion Research 2018: KEER 2018, 19-22 March 2018, Kuching, Sarawak, Malaysia, 2018.

Okomba, N., Adebimpe, E., OMODUNBI, B., SOBOWALE, A., and ADANIGBO, O., Development of an Android Based Home Automation System. *ABUAD Journal of Engineering Research and Development, 6*(1), 51-58. 2023.

Onukwugha, C., and Asagba, P., Remote control of home appliances using mobile phone: A polymorphous based system. *African Journal of Computing & ICT, 6*(5), 81-90. 2013.

Perni, D. D. S., Suneetha, M., Kantamneni, M., and Revalamadugu, R. V., *Mobile based Automation of Electrical Appliances.* Paper presented at the 2023 7th International Conference on Computing Methodologies and Communication (ICCMC), 2023.

Pradhan, A., Mehta, K., and Findlater, L., *" Accessibility Came by Accident" Use of Voice-Controlled Intelligent Personal Assistants by People with Disabilities.* Paper presented at the Proceedings of the 2018 CHI Conference on human factors in computing systems, (2018).

Ramachandrarao, M., MOBILE AND VOICE CONTROLLED SMART SWITCH FOR HOME AUTOMATION. *Turkish Journal of Computer and Mathematics Education (TURCOMAT), 13*(03), 920-927. 2022.

Ramlee, R., Tang, D., and Ismail, M., *Smart home system for disabled people via wireless bluetooth.* Paper presented at the 2012 International Conference on System Engineering and Technology (ICSET), 2012.

Sayeduzzaman, M., Hasan, T., Nasser, A. A., and Negi, A., An Internet of Things-Integrated Home Automation with Smart Security System. *Automated Secure Computing for Next-Generation Systems*, 243-273. 2024.

Srinivasan, C., Sumanthkumar, C., Vardhan, C. H., and Chaitanya, C. S., *Home Automation using Arduino through Voice Control.* Paper presented at the 2023 5th International Conference on Smart Systems and Inventive Technology (ICSSIT), 2023.

Tzafestas, S. G., Synergy of IoT and AI in modern society: The robotics and automation case. *Robot. Autom. Eng. J, 31*, 1-15. 2018.

Unaldi, S., Yalcin, N., and Elci, E., An IoT-based Smart Home Application with Barrier-Free Stairs for Disabled/Elderly People. *Elektronika ir Elektrotechnika, 29*(1), 15-20. 2023.

Van Nguyen, T., Lee, D. G., Seol, Y. H., Yu, M. H., and Choi, D., *Ubiquitous access to home appliance control system using infrared ray and power line communication.* Paper presented at the 2007 3rd IEEE/IFIP International Conference in Central Asia on Internet, 2007.

Warren, J.-D., Adams, J., Molle, H., Warren, J.-D., Adams, J., and Molle, H., *Arduino for robotics*: Springer, 2011.

Biographies

Nduduzo Wiseman Langa is currently pursuing a master's degree at the Durban University of Technology in the department of Electrical Power Engineering. He earned his Bachelor of Engineering degree at the University of KwaZulu Natal, South Africa. He specializes in the sector of Renewable Energy Technology (Solar PV Systems). He holds a student professional membership with the South African Institute of Electrical Engineers (SAIEE). Nduduzo, is also an active member of various community outreach programs from Nongoma district situated in the province of KwaZulu-Natal, that assist Matriculants with career guidance and support.

Oluwafemi Emmanuel Oni is currently a senior lecturer at the University of Zululand, South Africa. He received his BSc (Honours) Degree in Electrical and Electronic Engineering from Ekiti State University, Ado Ekiti, Nigeria, in 2013 and his MSc and PhD in 2017 and 2021 respectively at the University of Kwa-Zulu Natal, South Africa. He was a system and maintenance engineer at Egbin Power Thermal Plant, Lagos, Nigeria, in 2012 and at Omotosho Power Plant, Ore, Nigeria, in 2013/2014. He also a research fellow at the University of Johannesburg. His research includes power systems stability analysis using High Voltage Direct Current transmission scheme, integration of renewable energy into the grid using a multi-terminal HVDC scheme, and smart grid systems using FACTs.

Kayode Timothy Akindeji is currently a Senior Lecturer at the Department of Electrical Power Engineering, Durban University of Technology (DUT), Durban, South Africa where he is also the Administrative Leader for the Smart Grid Research Centre. He received his B.Sc. degree in Electronic and Electrical Engineering and the M.Sc. degree in Electronic and Electrical Engineering from Obafemi Awolowo University, Ile - Ife, Nigeria in 2001 and 2010 respectively. He obtained his Ph.D. degree in electrical engineering from the University of Kwa-Zulu Natal (UKZN), Durban, South Africa in 2022. He is registered as Professional Engineering Technologist with the Engineering Council of South Africa (ECSA) and a member of the Southern Africa Energy Efficiency Confederation (SAEEC). He is also a Member of IEEE. His research interests include smart grids, renewable energy, distributed generation, energy efficiency and micro-grid.