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Design and Construction of Voice-Controlled Home Automation using Arduino

Usman Isah IBRAHIM[1], Henry OHIZE[1], Usman Aaze UMAR[1], Yusuf ALIYU[2]

[1]*Department of Electrical and Electronics Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna, Niger State Nigeria*
ibrahim.m1601620@st.futminna.edu.ng/henryohize@futminna.edu.ng/
umar.m1601597@st.futminna.edu.ng

[2]*Department of Mechanical Engineering, School of Infrastructure, Process Engineering, and Technology, Federal University of Technology Minna, Niger State, Nigeria*
aliyu.m1702870@st.futminna.edu.ng

Corresponding Author: Ibrahim.m1601620@st.futminna.edu.ng, +2347030149213
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Abstract: *System automation has been widely researched in the twenty-first century due to its essential role in daily life. The fundamental advantage of an automated system is its ability to reduce human stress and minimize errors. Over the past few years, there has been a swift shift from traditional switches to switches equipped with remote controls. Currently, the presence of conventional wall switches distributed around the house poses challenges in terms of use, especially for individuals who are elderly or have physical disabilities. Due to technological advancements, mobile smartphones are now affordable for all individuals. Android devices are becoming equipped with applications that aid in multiple ways. Another new technology is the Google speech recognition APIs, which enable voice-based system command and control. This study demonstrates the implementation of voice-controlled home automation using the Arduino Uno microcontroller. Users of this system will be able to exercise full authority over every domestic device through spoken commands. The control circuit consists of an Arduino Uno microcontroller that receives and interprets voice commands from an Android smartphone equipped with the corresponding application. While the Bluetooth module shares signal data after establishing a wireless link between the microcontroller and the smartphone, the relay regulates device switching.*

Keywords: *Arduino Uno, HC-06 Bluetooth Module, Home Automation, Smartphone, Voice Control.*

1. INTRODUCTION

System automation is an extensively studied issue in the twenty-first century due to its vital role in our daily lives. The primary advantage of an automated system is its capacity to reduce human stress and eliminate errors. Over the past few years, there has been a quick change from standard switches to switches fitted with remote controls. Currently, the existence of conventional wall switches scattered around the house causes issues in terms of use, specifically for persons who are elderly, have physical movement limitations and frequent movement to on/off the switches resulting in discomfort for the able persons. Due to technological improvements, mobile devices are now affordable for all individuals. Android devices are becoming loaded with applications that provide support in numerous ways. Another new technology is the Google speech recognition APIs, which enable voice-based system command and control. This study adopted the construction of voice-controlled home automation using the Arduino microcontroller. Utilizers of this system will possess the potential to exercise full authority over any home device through voiced orders. The control circuit comprises of an Arduino microcontroller that receives and interprets voice commands from an Android smartphone equipped with the relevant application. While the Bluetooth Module shares signal data after establishing a wireless link between the microcontroller and the smartphone, the relay governs device switching [1,11].

Thus, this is particularly most reliable for people with disabilities, because they cannot use ordinary electrical switches due to discomfort in movement, they must continue to rely on their family members or caregivers to perform these obligations. Recent years have seen much research focused on producing assistive technologies to get over this restriction of differently-abled persons in controlling their living environment [2]. These persons can converse adequately despite not executing the necessary limb movements to control the switches. Therefore, the effort has centered on developing voice-based control systems to replace the physical actions essential for switching operations [3]. Communication technology has improved substantially over the past few decades, making it practical and economical for an individual to own a mobile phone. Numerous Android-compatible apps are available on Google Play Store.

Additionally, Google fosters the production of apps that can be made available on Google Play Store so people can access and utilize them. In order to make app creation more approachable for the general public, Google and the Massachusetts Institute of Technology (MIT) worked together in 2009 to develop an open-source tool that can translate the complex language of text-based coding into visual, drag-and-drop building blocks. Voice-controlled home automation, which allows one to handle numerous electric appliances effortlessly using one's voice, is in demand in today's diverse home surroundings. Voice-controlled home automation was initially designed for those wishing lavish and sophisticated homes [4]. However, for people with specific needs, it has always been essential to construct voice-controlled home automation. Around 785 million people aged 15 and older live with a disability, according to research published by the WHO; of these, 110 million individuals, according to the World Health Survey, have substantial functional problems.

Automation technologies incorporate voice-controlled or voice-recognition systems to help people with special needs [5,12]. The project's primary purpose is to provide individuals with the right level of convenience in their living spaces and, in doing so, to enable engagement with the environment of their homes. Accordingly, those with disabilities find it challenging to transverse the property to turn on the numerous lighting switches. The purpose of the design is to modify the mode of managing appliances in the home to match the mood of the people who live with impairments. This research specifically focuses on developing a solution in a native Africa context, easy to use, low-cost, and overall reliable. The smartphones used are not selective of the phone’s android version, making it accessible with simple instructions on any smartphone.

2. RELATED WORK

Albert [6] researched work focused on the 'Voice-controlled lighting system for the elderly and anyone with special needs.' The device employs speech recognition technology and the English language to control the lighting in a given space. It offers an automated strategy for regulating the lights in a home that might make switching on the lights using the standard method easier. Therefore, it uses the speech recognition Google APIs to detect the speaker's voice and effectively produce the command that would allow it to handle the home's lighting system. The Google Application Program Interfaces (APIs) and libraries were incorporated into the project's final design while extensively relying on the Arduino mega programming tool. Bluetooth module, a prominent wireless technology used for data transport, is applied to connect the microcontroller to the Android application. The vocabulary template comprising particular words and phonemes is a vital component.

Kubilay *et al.* [7] employed an EasyVR (a multi-purpose speech recognition module) microphone to provide audio-controlled home automation. Sounds are detected using the card/module, and the EasyVR commander is tasked with writing the program. The comparison's findings influence the Arduino Uno's decision on which relay card switching should be performed, providing the appropriate control. As a result, the project's performance and efficiency are altering. In order to conserve money and space for the gadget, a more portable and affordable microcontroller, such as the Arduino Nano, may have been employed. Direct connectivity with the gadget through various means has also been questioned.

Akbour [8] investigated the application of mobile voice recognition for smart home automation control via Android smartphones. This research aimed to develop a voice-based system offering user convenience and improved accessibility. The proposed system leverages Android's built-in voice recognition capabilities for secure appliance control with user identification. A prototype demonstrated remote control of lights, doors, and subwoofers, highlighting the system's potential for users with disabilities.

Kundu *et al.* [9] built a smart Home Automation system with IoT. This study developed a case for home automation, monitoring, and security systems that would have been implemented via the Internet of Things (IoT). The study focuses on the home to produce an innovative wireless home security system that tells the homeowner by email and a picture if anybody trespasses into the premises and sounds an alert if a fire breaks out. It also provides remote monitoring and control of all household appliances and temperature, humidity, and flame status. In addition, the system requires only 3 seconds to update data. A worried person can then act immediately to resolve their problem. The Internet, mobile devices, voice commands, and electrical switches are just a few ways one can operate the system.

Amin [10] focused his research work on an innovative home automation system for patient support. This low-cost, low-power device operates with verbal commands and minimum physical movement. An IoT-based portable automation system prototype is shown here for implementation. There are alternative voice control programs, including Blink and Google Assistant. The light was controlled during the system's demonstration. For elderly adults and young children in particular, this technique is accessible and user-friendly. The ESP32 Microcontroller, which comes with a built-in Wi-Fi module, is used in the hardware design. The Wi-Fi connection makes it possible to control the system from a distance.

Okomba *et al.* [13] presents a portable home automation system with an Android-based mobile application for remote control, integrating an ESP8266 microcontroller and MIT App Inventor platform. However, it overlooks a critical weakness: the absence of discussion on security vulnerabilities inherent in wireless wi-fi technology. Failing to address potential security risks like data breaches could compromise the system's integrity and user privacy. A comprehensive analysis of security measures and vulnerabilities would bolster the system's robustness.

3. RESEARCH METHODOLOGY

The goal of this research is to contribute to the shift from the use of traditional wall switches within homes to a more conventional voice-automated device, for comfort and easy accessibility to control home devices, while providing people with disabilities flexibility in controlling the home appliances with less effort.

In this study, the hardware and software components of the design of voice-controlled home automation using Arduino Uno were categorized into two groups. The whole physical makeup of the design prototype was included in the hardware section of the device. The programs are uploaded into the processing component of the design to make up the software section of the design, and the software simplifies how the entire gadget operates.

3.1 The Hardware Component

These hardware components consist of the following physical components:

i. Arduino Uno
ii. Bluetooth Module
iii. Relay Module 1 channel
iv. Transformer (220v/12v)
v. Jumper wire (set)
vi. Diode and Resistors.

The mains AC voltage was transformed into a controlled DC voltage using the power supply. A 220/12 V step-down transformer is required to convert 220 V AC to 12 V AC. A bridge rectifier was utilized to convert AC electricity to DC. Bridge rectifiers were manufactured from four 1N007-type diodes linked in a bridge-like configuration; however, the DC power was reported to contain ripple or pulses. Through the employment of a capacitor-filter circuit, voltage ripples are eliminated from the regulator's input. A voltage regulator lowers the pure DC voltage to the desired values. A 1000 F capacitor and an IC7805 voltage regulator are incorporated into our design.

The Arduino Uno must be connected to the Bluetooth module to control it. The Arduino Uno board's VCC port was connected to the VCC pin of the Bluetooth module (HC-06). The Arduino Uno's GND port is linked to the GND pin of the Bluetooth module (HC-06). The Bluetooth module receiver and Arduino Uno transmitter are also connected. The Arduino is connected with the home appliances. While the opposing end of the appliance is joined to the power supply, the positive end is connected to the normally open and standard relay. Finally, using a Bluetooth-connected Android phone, the entire home's connectivity to the system. The block diagram in Figure 1 explains how the hardware parts are connected.

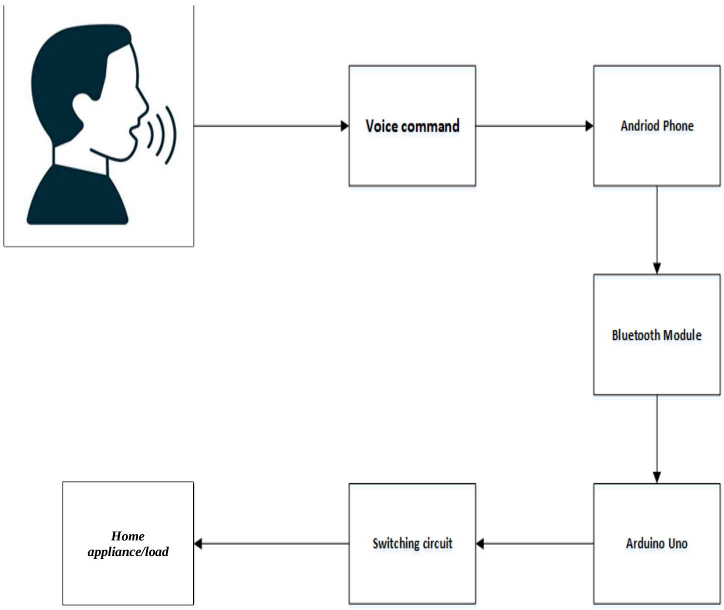

Figure 1: Block diagram of the system

3.2 Mathematical Analysis of Power Rectification System

A power supply circuit's mathematical analysis can be applied to exactly aid in designing the system's power supply, as seen in the circuit diagram in Figure 3. Equations are typically employed in this analysis to account for variables such as the peak voltage, the voltage drop across the diode, and the required value of the capacitor for the rectification circuit.

First, to design a rectification circuit, a step-down transformer is necessary. The equivalent output voltage and the maximum current is provided by Equation 1 and 2.

$$V_p = V_{rms} \times \sqrt{2} \tag{1}$$

$$I_P = I_{rms} \times \sqrt{2} \tag{2}$$

Vrms is the rms value of the transformer's output voltage, Vp is the peak voltage, Irms is the rms value of the current, and the Ip is the peak current. The DC value of the rectified voltage is given by

$$V_{dc} = \frac{2}{\pi} V_P \tag{3}$$

$$I_{dc} = \frac{2}{\pi} I_P \tag{4}$$

The shunt capacitor filter is obtained from:

$$\mathrm{V_r} = \frac{1}{4\sqrt{3}\mathrm{fcRl}} \tag{5}$$

Where C is the capacitance of the capacitor in farad, f is the frequency in Hertz, R_L is the load resistance in ohms, and Vr is the ripple voltage in volts. Therefore, we resolve eqn. 3.5 to obtain the value of C; thus,

$$C = \frac{1}{4\sqrt{3fVrRl}} \tag{6}$$

The efficiency of a rectification system can be calculated using the equation:

$$\eta = \frac{power\ output}{power\ input} \times 100\% \tag{7}$$

3.3 The Software Component

The system's software components are a collection of operational rules and applications used to govern the hardware part of the design and carry out the required task. Three functional pieces make up this component: Android application software, the Arduino IDE programming environment, and the Proteus simulation software. The Android app has a graphical user interface enables users to communicate with the meter, monitor, and adjust the load. This mobile application with a graphical user interface was built using MIT Lab Innovator. The programming tool (Arduino IDE) was used to construct the codes that supply instructions for the microcontroller's functionality. The circuit of the proposed meter was simulated using the Proteus simulation software to determine the system's workability.

3.4 The Design Algorithm

The mobile application was launched from the smartphone; it then searches for and picks the HC-06 from among the accessible Bluetooth devices. The system checks to determine if the Bluetooth (HC-06) connection was successful. If the Bluetooth device is connected, the user is prompted to deliver a voice command to turn selected appliances ON or OFF; otherwise, the error message "device disconnected" is displayed. The Android application transforms the spoken instruction into text before delivering it to the Bluetooth module and finally to the Arduino Uno. The Arduino Uno's serial input is utilized to receive the text, which is then verified to determine if it matches any previously stored content. "Application not found" is flashed on the mobile app screen if the matching text cannot be located. On the other hand, if the matching text is located, the command will determine whether the appliances are switched ON or OFF. This whole process is as indicated in Figure 2.

3.5 The System Prototype

The system prototype was produced through simulation and design implementation. The simulation was undertaken using Proteus software and provided a clear view of the arrangement of rating components to arrive at a fully functional model. The simulation was carried out on the different components separately and on the system as a whole. The simulation aided in defining the specific components and their rating and arrangement to arrive at this utterly functional model. The resulting circuit diagram of the final simulation is illustrated in Figure 3. The components were patched according to the circuit diagram on a breadboard to get the first physical prototype of the metering system. The system communications module was mounted on the breadboard as indicated in the Figure 4, enabling flexibility, especially in packaging.

4. RESULT AND DISCUSSION

4.1 Result

In order to evaluate the effectiveness of the voice (speech) recognition program and the switching mechanism, five people with varying accents were employed in both noisy and non-noisy settings. Each individual uttered the command to turn the corresponding appliance ON or OFF. The outcome of the test run on the voice-controlled system in place is shown in Tables 1 and 3 correspondingly. The spoken instructions coded to function with the speech recognition system are noted in Tables 2 and 4. The orders are matched to the numerous appliances that can be voice-activated ON or OFF.

As soon as the words "turn on" or "turn off" are pronounced, the appliance is called to send the instruction to turn the item on or off. For instance, "turn on the security light". This is clear from the style used to write the items (voice commands) under the "command" column. The other columns, A, B, C, D, and E, track how many times out of five the connected appliance under control replied (by switching on or off).

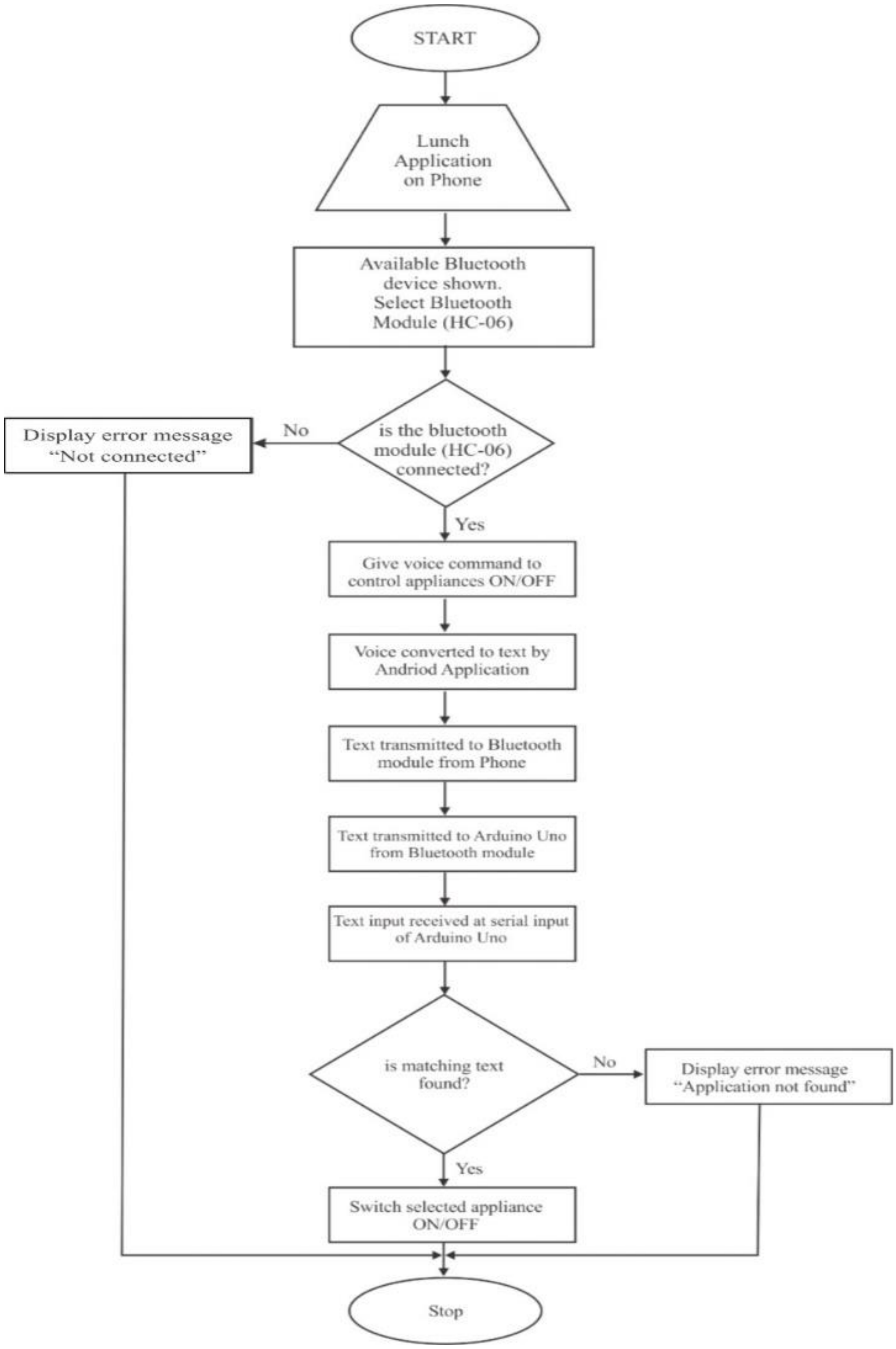

Figure 2: Flowchart of the design system

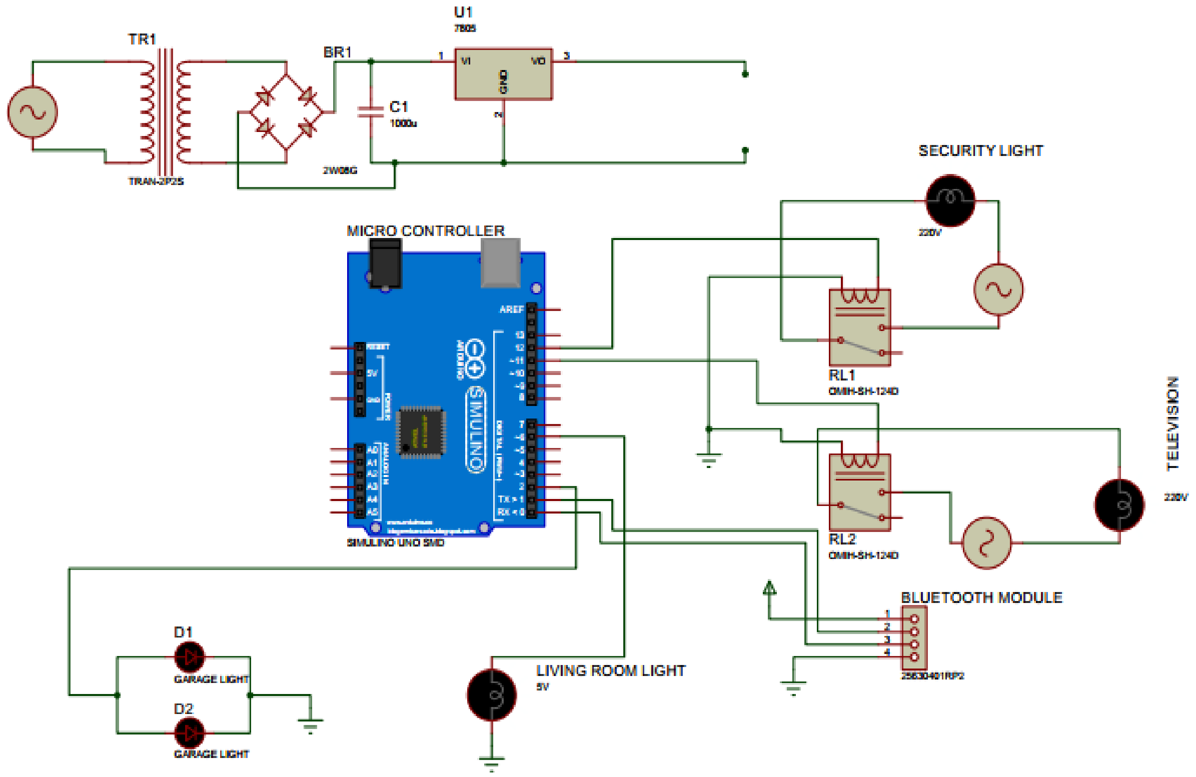

Figure 3: Circuit diagram of the system

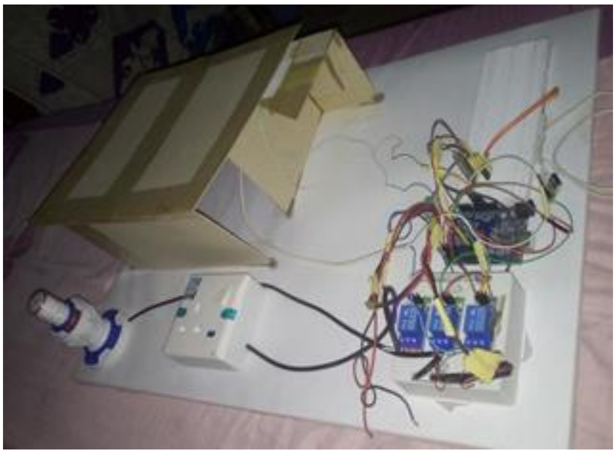

Figure 4: Bread board model of the system

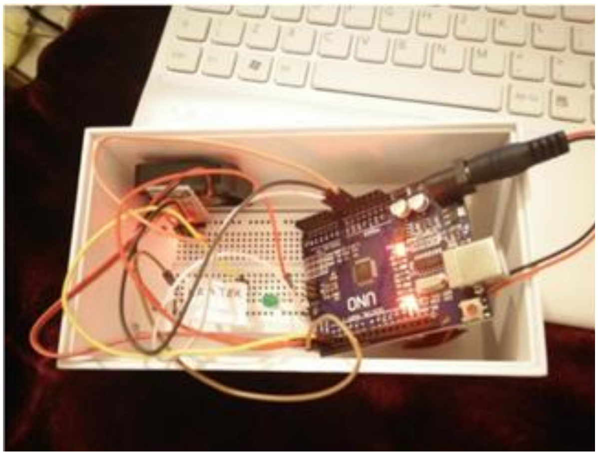

Figure 5: Testing functionality of the system

Table 1: Test result for switching each appliance for a non-noisy environment

Command	**Number of Test Persons (out of five)**				
	A	B	C	D	E
Turn on/off the living room	5	4	5	4	4
Turn on/off the Security light	4	5	4	4	4
Turn on/off the television	4	4	5	4	3
Turn on/off the garage light	5	4	5	4	4

Table 2: Overview of the test result in a non-noisy environment

Appliances	On response	Off response	Total response	Total trials	No. of Failure
Living room	11	12	23	25	2
Security light	11	10	21	25	4
Television	12	10	20	25	5
Garage light	10	12	22	25	3

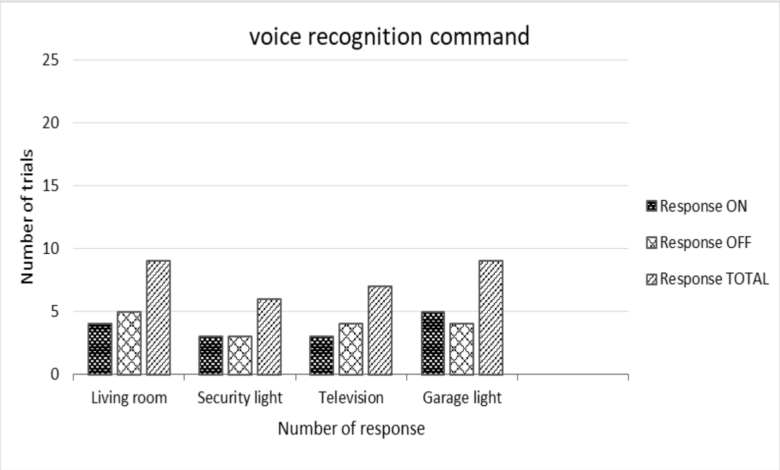

Figure 6: A bar chart showing the relationship between the number of trials and the number of responses in a non-noisy environment

Table 1: Test result for switching system in a noisy environment

Command	Number of Test Persons (out of five)				
	A	B	C	D	E
Turn on/off the living room	1	2	2	2	2
Turn on/off the Security light	2	2	1	1	1
Turn on/off the television	2	1	2	1	1
Turn on/off the garage light	2	2	2	2	1

Table 4: Overview of the test result for a noisy environment

Appliances	On Response	Off response	Total response	Total Trials	No. of Failure
Living room	4	5	9	25	16
Security light	3	3	6	25	19
Television	3	4	7	25	18
Garage light	5	4	9	25	16

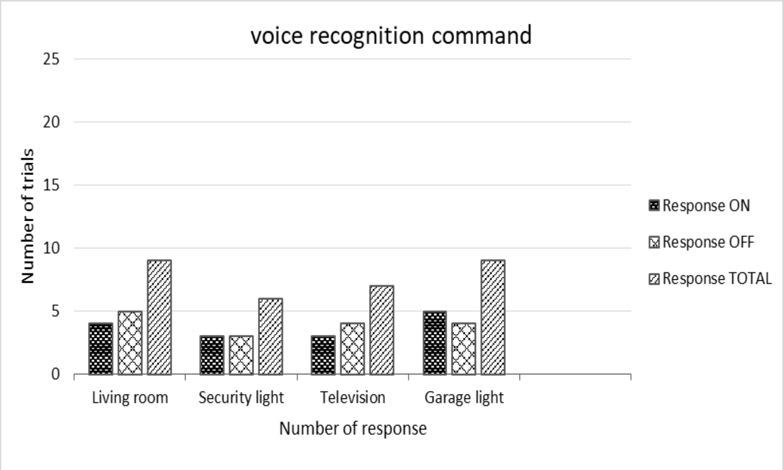

Figure 7: A bar chart showing the relationship between the number of trials and the number of responses in a noisy environment.

4.2 Discussion

The study's design and testing were successful. Tables 1 and 3 of the results reflect the number of times controlling voice commands were successfully recognized. The testing involved five persons with five distinct accents (A, B, C, D, and E) in noisy and non-noisy surroundings. These individuals were recruited to test the program to determine how efficiently it handles and reacts to accents and noise when receiving voice commands. The Bluetooth connection's range is around 30 feet (10 meters). However, the maximum communication range will differ depending on the electromagnetic environment or barriers (people, metal, walls, and others).

Overall, 86% of tries were successful in non-noisy settings. This result was produced by converting the number of successful responses into a proportion of the number of trials given to all test participants. Then, a percentage was employed to denote this ratio. There were also a few situations where the user's voice was not audible. Only 31% of tries were effective in noisy settings. Nevertheless, the system exceeded expectations by exhibiting adequate adaptability in adjusting to varied settings and ascents while correctly reacting to the user's voice questions.

The above result demonstrates that the system is dependable in a non-noisy environment but unreliable in a noisy environment.

The system's mobile app interface is displayed in Figure 8, while the actual prototype of the home automation system is represented in Figure 9. It was constructed by assembling the components on a Vero board in line with the circuit design, providing versatility, notably in packing.

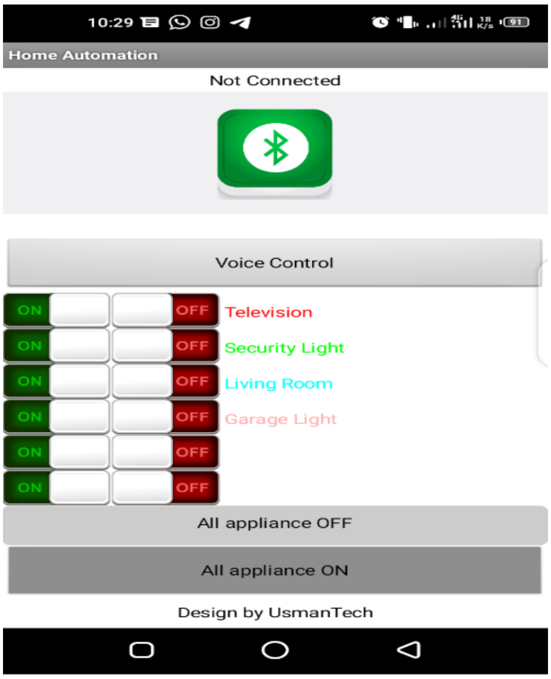

Figure 8: The android application interface

Figure 9: The final prototype of the system

With the successful completion of this research work, the following further research suggestions were proposed;

i. In order to foster inclusion among the native population of Nigeria, it is advised that the Android application provides explicit libraries that support local languages such as Hausa, Yoruba, Igbo, and others. This would improve the diversification and efficacy of the system.
ii. Further study might be undertaken to examine boosting the range of the signal to identify a means to enhance it range from the Bluetooth module.

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