VOICE-ACTIVATED CONTROL SYSTEM FOR RESIDENTIAL BUILDINGS

BY

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TITLE PAGE

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(2018/6913)

A PROJECT SUBMITTED TO THE DEPARTMENT OF MECHATRONICS ENGINEERING, COLLEGE OF ENGINEERING, BELLS UNIVERSITY OF TECHNOLOGY, OTA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF BACHELOR OF ENGINEERING(B.ENG) DEPARTMENT OF MECHATRONICS ENGINEERING.

JULY, 2023

DECLARATION

I, **OKECHUKWU, VICTOR CHUKWUBUIKEM,** hereby declare that this Project, **"VOICE-ACTIVATED CONTROL SYSTEM FOR RESIDENTIAL BUILDINGS**", was carried out by me under the supervision of Dr. Philip. A. Adewuyi of the Department of Mechatronics, Bells University of Technology, Ota, Ogun State, Nigeria. I attest that the project has not been presented either wholly or partially for the award of any degree elsewhere. All sources of data and scholarly information used in this Project are duly acknowledged.

…………………………………………

OKECHUKWU VICTOR CHUKWUBUIKEM

Date ………………………

CERTIFICATION

This is to certify that this project titled, "**VOICE ACTIVATED CONTROL SYSTEM FOR RESIDENTIAL BUILDINGS"** is an original research work carried out by **OKECHUKWU, Victor Chukwubuikem** of Matric Number, **2018/6913** in the Department of Mechatronics, College of Engineering, under my supervision.

……………………………. ………………………………………

Dr. Philip .A. Adewuyi Date

(Supervisor)

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Dr. Philip. A. Adewuyi Date

(Head of Department)

DEDICATION

This project is dedicated to my parents, DR and MRS. Okechukwu, who through their countless sacrifices, I have accomplished all that I have.

ACKNOWLEDGEMENT

This project would not have been possible without the grace of God. I am hereby acknowledging the Vice-chancellor Prof. Jeremiah. O. Ojediran and the entire management staff of Bells University of Technology for creating an enabling environment to carry out my research. The dean of the College of Engineering Prof. Ojo S. Fayomi. My supervisor, Dr. Philip .A Adewuyi is also acknowledged for his efforts in carrying out this study. The head of the Department of Mechatronics Dr. Philip.A Adewuyi and the entire staff of the College of Engineering are acknowledged for all their support.

My deepest gratitude goes to my parents Mr. and Mrs. Okechukwu for their provision in terms of money and advice to the start-up of this project.

ABSTRACT

The "Voice-Activated Control System for Residential Buildings" is a groundbreaking initiative that intends to transform home automation by incorporating cutting-edge voice recognition technology into homeowners' daily life. With significant advances in artificial intelligence and natural language processing, there is an increasing demand for seamless and intuitive control mechanisms that can ease interactions between inhabitants and their smart home gadgets. The goal of this project is to provide a sophisticated and user-friendly voice-activated control system designed exclusively for residential buildings, allowing inhabitants to control many aspects of their home environment using simple voice commands. The primary goal of this project is to build and construct an efficient voice recognition system capable of correctly reading a wide range of natural language voice inputs from tenants. Using cutting-edge machine learning methods and deep neural networks, the system will be thoroughly trained to detect and understand a wide range of spoken commands relating to smart home functionality. These capabilities include the ability to manage lighting, temperature, entertainment systems, security features, and other linked devices, allowing residents to easily arrange their living spaces.

Words Counts: 178

Keywords: Voice Recognition, Lighting System, Audio, Arduino

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Voice-activated control systems have emerged as an innovative solution for managing and controlling various aspects of residential buildings. By utilizing advanced natural language processing (NLP) algorithms, these systems enable homeowners to effortlessly interact with their smart homes. This background study aims to present an overview of voice-activated control systems, highlighting their advantages and impact on residential buildings. Voice-activated control systems, also known as voice assistants or virtual assistants, are intelligent software programs that utilize speech recognition technology to interpret and respond to voice commands. These systems are designed to comprehend natural language and carry out tasks based on user instructions. Their convenience and ease of use have led to their widespread adoption in recent years (Dey et al., 2019).

Voice-activated control systems provide a diverse range of functionalities and features that enhance the smart home experience. Common capabilities include home automation, personal assistant services, entertainment, and integration with third-party services. These systems have revolutionized residential buildings by offering homeowners convenient and efficient control over their smart homes. With their advanced functionalities and seamless integration, voice-activated control systems offer numerous benefits, such as convenience, accessibility, and improved user experiences. As the technology continues to evolve, voice-activated control systems will play an increasingly significant role in shaping the future of residential buildings (Chakraborty et al., 2020).

Voice technology, contrary to popular belief, is not exclusive to singers enhancing their performances but rather a burgeoning market of advanced technology for consumers and businesses alike. With the expansion of machine learning and artificial intelligence (AI) on a global scale, coupled with the growing number of connected devices entering the market, voice recognition has become an integral part of various services and devices. Voice recognition technology encompasses two main components: phonetic recognition of different words and the interpretation of spoken language, which falls under the field of natural language processing (NLP). The global market for voice recognition technology reached nearly 12 billion U.S. dollars in 2022 and is projected to exceed 50 billion U.S. dollars by 2029.

1.2 Statement of the Problem

Automatic Speech Recognition (ASR) technology, while promising, faces several challenges. These obstacles include a lack of linguistic knowledge, difficulties in handling background sounds, data reliability issues, deployment complexity, language barriers, accent variations, background noise interference, and data privacy concerns. Overcoming these challenges entails training language models, advanced signal processing, and addressing data privacy. Despite these difficulties, ASR technology is advancing, and businesses need to consider these factors for successful implementation. (Tyagi, 2022).

1.3.1 Aim of the study

The aim of this study is to develop a Voice Activated Control System for Residential Buildings

1.3.2 Objective of the study

The precise objectives of this study are to:

i. include a natural language processing (NLP) algorithm to help it learn and understand human language.
ii. make use of machine learning to help the system learn and comprehend different speech models.
iii. utilize voice recognition technology for controlling home utilities, specifically lights and fans. (Sulaiman et al., 2018)

1.5 Justification of Study

The project's main goal is to enhance the comfort and ease of elderly and disabled individuals while at home. By using their smartphones and voice commands, they can control basic appliances like lights and fans from anywhere in the house. This removes the need to search for power sources and manual controls, making their lives more stress-free and convenient.

1.6 Scope of the Study

The primary goal of this project was to alleviate unnecessary stress for disabled and elderly individuals when managing basic appliances and utilities in their homes. The design is kept brief and simple so as to minimize additional challenges and discomfort. In this project we incorporate Raspberry pi and Arduino with home appliances in order to control the on and off state. The user speaks to the given input (a mic or phone). The Raspberry pi, using python extensions and google Speech Recognition datasets, converts your voice command into text and sends it to the Arduino which then toggles the respective pins, which will then trigger the on and off state of the appliance in question.

CHAPTER TWO

LITERATURE REVIEW

2.1 Audio Processing

When it comes to audio processing, it is quite fascinating and essential field of study. Audio processing plays a crucial role in enhancing our overall audio experience, from the music we listen to, the videos we watch, to the voice-based interactions with various technologies.
The range of techniques and algorithms used in audio processing is quite diverse. It includes everything from simple tasks like audio recording and playback to more complex tasks like audio compression, filtering, and applying various creative effects. It is astonishing that all these techniques can convert unprocessed audio data into something that is more pleasurable and significant to us (McLoughlin., 2009).

Speech processing, a subset of audio processing, is particularly intriguing. It enables impressive technologies like speech recognition systems and voice assistants, which have become an essential component of our everyday routines. It's incredible how we can communicate with machines through spoken language, and it opens new possibilities for human-computer interaction (Gold., 2011).

Audio processing also extends to the domain of music information retrieval (MIR), where it helps analyze and extract valuable information from music. The ability to automatically identify beats, tempo, and even recognize melodies is truly impressive, especially for applications in music production and recommendation systems (Prasad., 2007).

While audio processing has come a long way, there are always exciting advancements happening in the field. Researchers and engineers are continuously pushing the boundaries of what's possible, leading to improved sound quality, more efficient algorithms, and innovative audio applications (Campbell., 2023).

Overall, audio processing is a dynamic and ever-evolving field that greatly influences how we perceive and interact with sound. I'm here to share my knowledge and answer any specific questions you may have about this intriguing domain (Mishra., 2020).

2.2 Audio Processing Techniques

Audio processing techniques play a vital role in enhancing audio quality. Some of these techniques include:

i. Analog to Digital Conversion (ADC): Converting analog audio signals into digital format allows for easy manipulation, storage, and transfer while preserving quality. The performance of an ADC is determined by bandwidth and signal-to-noise ratio (SNR) (Ballou., 2008).

ii. Digital to Analog Conversion (DAC): Modern audio signals are often in digital format, but to listen to them through speakers, they need to be converted to analog. DACs improve sound quality and are found in devices like digital speakers and music players Yacoubian, et al., 2003).

iii. Audio Effects and Post-Processing: Fig 2.1 shows how post-processing methods are used to reduce noise and artifacts introduced during the initial processing. Techniques like echo elimination, distortion removal, and voice enhancement are employed, along with equalization and filtering for noise reduction (Takeuchi, et al., 2020).

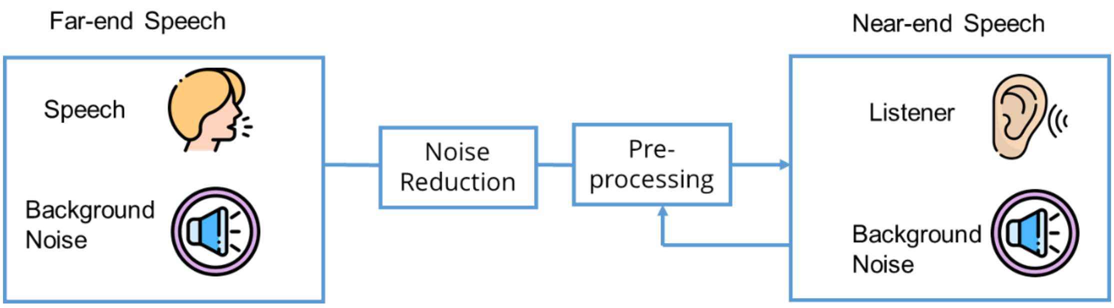

Figure 2.1: Audio processing (Mishra, 2020)

Data Compression and Decompression: In Fig 2.2 we can see the process of data compression. Compression reduces data size for storage or transmission efficiency. Lossless and lossy compression are used in file and multimedia compression to optimize storage space and data transmission.

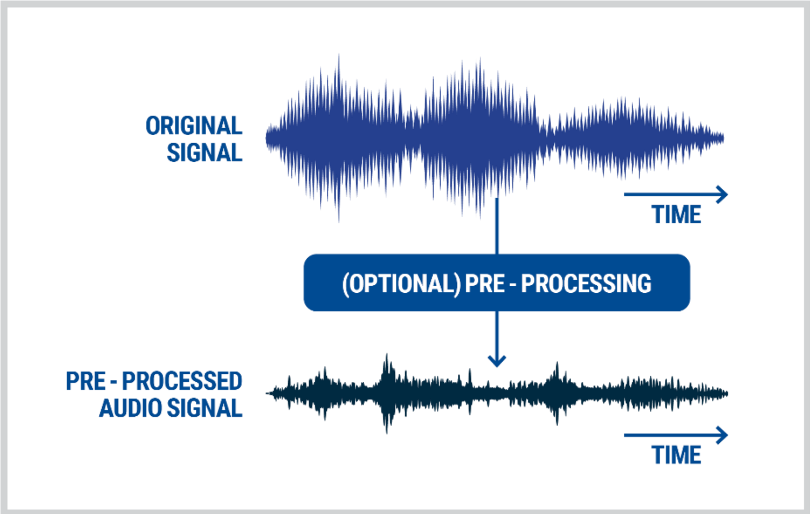

Figure 2.2: Audio Compression (Mishra, 2020)

iv. Automatic Echo Cancellation (AEC): AEC is used to improve voice transmission quality by removing acoustic echoes during teleconferences and VoIP calls.

v. Filtering: Filtering modifies a signal to accentuate or suppress specific frequencies or components, used for noise reduction, equalization, and frequency manipulation.

vi. Automatic Gain Control (AGC): AGC adjusts the loudness of an audio stream in real-time to maintain a constant loudness level and eliminate distortion.

vii. Beamforming: Beamforming concentrates transmitted or received signals in one direction to improve signal strength and minimize interference in communication systems.

viii. Resampling: Resampling modifies the sampling rate of a digital signal, used to change the frequency, and adjust data size in various applications.

ix. Equalization (EQ): EQ adjusts the frequency balance in an audio source, allowing users to control tonal characteristics and improve audio quality.

x. These techniques are essential for achieving high-quality audio in various applications, including telecommunications, multimedia, and entertainment. Each technique addresses specific aspects of audio processing to ensure a rich and immersive audio experience.

2.3 Overview of Related Works

Table 2.1: Overview of Related Works

S/N	AUTHOR/ DATE	TITLE	SOURCE/ SOURCE TYPE	PURPOSE/ KNOWLEDGE GAP	FINDINGS/ WORKDONE
1	Kibiwott (2018)	Voice Controlled Lighting System For The Elderly And Persons With Special Needs	Faculty of engineering science and technology school of electrical and electronic engineering department of electrical and power engineering title: Voice controlled lighting system for the elderly and persons with special needs. (2018).	The study investigates the benefits of voice-controlled lighting systems for the elderly and individuals with special needs. It addresses the challenges of complexity for those with limited dexterity or vision and the interference of background noise in certain environments.	Participants in the study, comprising the elderly and individuals with special needs, expressed interest in voice-controlled lighting systems. However, they had concerns regarding the accuracy of voice recognition,

				Improving accessibility and convenience is crucial for this population.	system complexity, and the associated cost.
2	Sulaiman et al., (2018).	Voice Controlled Home Automation	Sulaiman, R. B. (2018). Voice Controlled Home Automation.	The system was designed to be used by elderly and disabled people, and it allows users to control a variety of devices in their homes, such as lights, appliances, and thermostats	Voice-controlled home automation has great potential as a valuable tool for the elderly and disabled, and it is expected to gain increasing popularity in the future.
3	Linh et al., (2017	Home Automation Using Arduino Wifi Module Esp8266	Linh, H. (2017). Home automation using arduino wifi module esp8266.	The study aims to showcase the creation of a home automation system using the ESP8266 WiFi module.	The ESP8266 can control various sensors and actuators. Internet-connected

				Challenges encountered include the difficulty of programming the low-cost ESP8266 and the complexity of selecting appropriate sensors and actuators for the project	home automation systems face security vulnerabilities. These systems collect significant user data on habits and preferences. The market offers numerous home automation systems using different protocols and standards.
4	Baraka et al., (2013)	Low-Cost Arduino /Android-Based Energy-	Baraka, K., Ghobril, M., Malek, S., Kanj, R., & Kayssi, A. (2013). Low cost	The system is designed to be scalable and allow users to control more	The system successfully saved energy by automatically

		Efficient Home Automation System with Smart Task Scheduling	arduino/android-based energy-efficient home automation system with smart task scheduling. 2013 Fifth International Conference on Computational Intelligence, Communication Systems and Networks, 296–301	devices as needed, with a smart task scheduling feature for task automation. However, it is limited in compatibility to a specific set of appliances and devices. To use it with other devices, modifications or additional hardware may be required.	turning off unused lights and appliances, reducing costs through task scheduling. It was user-friendly, easy to install, and could be expanded to control more devices as required.
5	Ramasamy (2017)	Mobile Wireless Sensor Networks: An Overview	Ramasamy, V. (2017). Mobile wireless sensor networks: An overview. In Wireless	The study offers a comprehensive overview of mobile wireless sensor networks (MWSNs), covering various	The design of MWSNs presents several challenges, such as limited battery power,

	Sensor Networks – Insights and Innovations. InTech.	aspects like types of WSNs, design challenges, mobile sensor node architecture, mobility entities, mobility models, and network topology. It also explores MWSN applications and serves as a valuable resource for researchers and engineers in this field, providing a foundation for further research. The key challenges in MWSN design include limited battery power,	low-cost requirements, processing limitations, shared medium, varying topology, node failure, mobility management, energy conservation, security, and scalability. Although there has been considerable progress in tackling these challenges in recent years, there is still much research and

				requiring energy-efficient solutions, and varying topology due to node mobility, necessitating adaptive routing protocols for effective energy conservation.	development needed to fully address them.
6	Hajare et al., (2006)	Design and Development of Voice Activated Intelligent System for Elderly and Physically Challenged	Hajare, R., Gowda, M., Jain, S., Rudraraju, P., & Bhat, A. (2016). Design and development of voice activated intelligent system for elderly and physically challenged. 2016	The study aims to create a voice-activated intelligent system for the elderly and physically challenged, enabling them to control electrical devices in their homes. The system's purpose is to enhance	The system has limited voice command recognition capabilities and lacks context understanding or speaker differentiation.

International Conference on Electrical, Electronics, Communication, Computer and Optimization Techniques (ICEECCOT).	their home control, promoting greater independence in daily living.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Material Selection

Table 3. 1: Material Selection for the fabrication of a Voice Activated Control System

	ITEMS	QUANTITY
1	Raspberry Pi 4	1
2	Arduino UNO	1
3	12v DC fan	1
4	LED Bulb	2
5	USB Sound Card	1
6	5v 4-channel Relay Board	1
7	C300MV Microphone	1
	Type-C power cable for Raspberry pi	1
8	Battery	2
9	Wooden Accommodation Box	1

3.2 Materials Description

i. Raspberry pi 4

Worldwide, the Raspberry Pi is utilized for many different purposes. It's a useful resource for developing programming abilities, working on hardware projects, putting home automation systems in place, configuring Kubernetes clusters and Edge computing, and even finding uses in industrial settings. The Raspberry Pi as show in Figure 3.1, is a low-cost computer that can run Linux and includes a set of GPIO (general-purpose input/output) pins. These pins give users the ability to manage electronic components, promoting IoT research and physical computing.

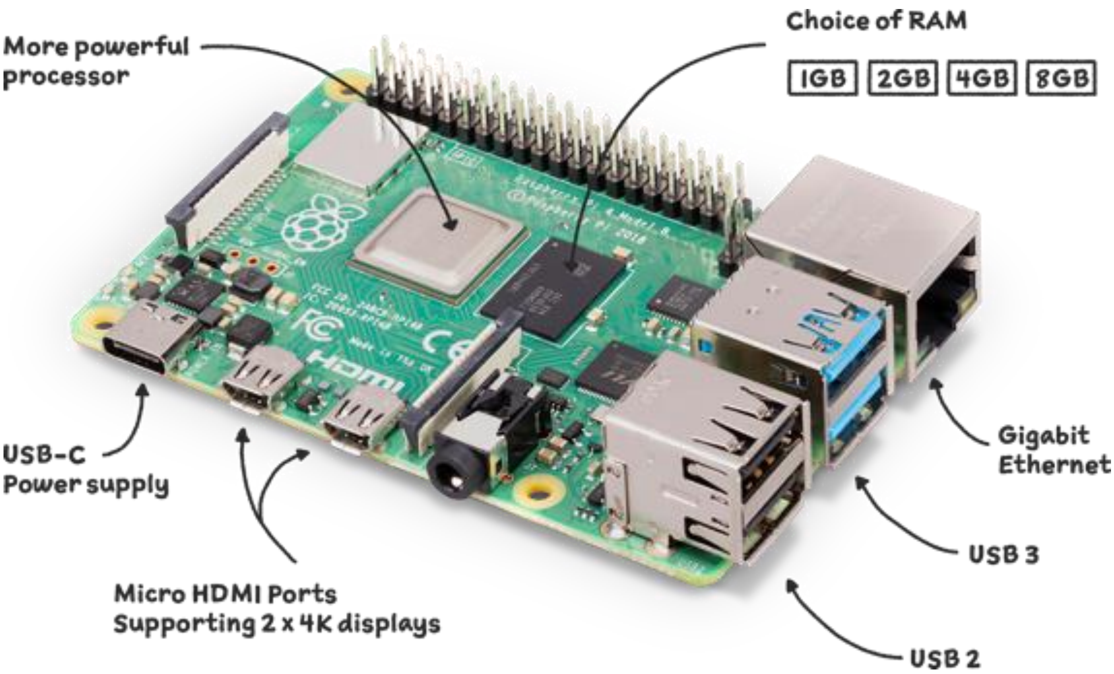

Figure 3.1: Raspberry pi (Saddam, 2016)

ii. Arduino Uno

A popular microcontroller board in the fields of electronics and programming is called the Arduino Uno, shown in Fig 3.2. Due to its adaptability and simplicity of use, it is a preferred option among professionals, students, and amateurs. A microcontroller chip, input/output pins, and other required components are included on the Arduino Uno board. The Arduino programming language, which is based on C and C++, can be used to program it. Additionally, the board includes a user-friendly integrated development environment (IDE) that makes programming easier.

Figure 3.2: Arduino Uno Rev3 (Kumar et al., 2019)

iii. 5v 4-channel Relay Board

Interfacing a microcontroller or sensor becomes straightforward with the four-channel relay module which is shown in Fig 3.3, which includes four 5V relays and associated switching and isolating components. This module requires minimal parts and connections. Each relay in the module is labeled with its specifications, supporting 250VAC, 30VDC, and 10A in all cases.

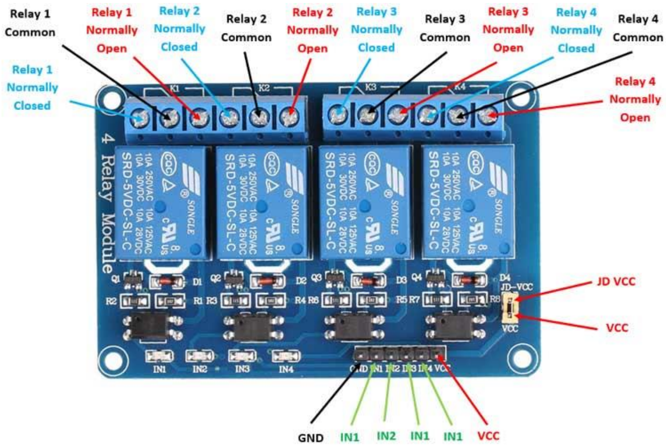

Figure 3.3: Four-Channel Relay Module Pinout (Pandithurai et al., 2018)

iv. USB Sound Card

An excellent fix for broken sound cards in PCs, laptops, or netbooks. Any PC with a spare USB port can use this adapter to add a full sound card and microphone input, which is shown in Fig 3.4. No more power is needed, and no drivers need to be installed. Within seconds, you'll be operational.

Figure 3.4: USB Sound Card (Watson et al., 2022)

v. C300MV Microphone

The C300MV Microphone as shown in Fig 3.5, produced by Havit, is a cardioid condenser microphone. Its frequency response spans from 20Hz to 20kHz, while its impedance is measured at 2K Ohms, and it possesses a sensitivity of -8dB±2dB. The microphone package includes a 3.5mm stereo plug and a 2.5m cable. Offering a budget-friendly option, this versatile microphone is well-suited for various applications such as gaming, streaming, and podcasting.

For the C300MV microphone, we can represent its sensitivity and frequency response using the following mathematical models:

i. Sensitivity Model:

The sensitivity of the microphone is given as -8dB±2dB. To convert this sensitivity to a linear scale, we use the formula:

$$Sensitivity\_linear = 10\text{^}(Sensitivity\_dB/20) \quad (3.1)$$

$$Sensitivity\_dB = -8dB\ (given\ sensitivity\ in\ decibels) \quad (3.2)$$

$$Sensitivity\_linear = 10\text{^}(-8/20) \approx 0.3981 \quad (3.3)$$

This means the microphone has a sensitivity of approximately 0.3981 volts per pascal (V/Pa) or 0.3981 mV/Pa.

ii. Frequency Response Model:

The frequency response of the C300MV microphone spans from 20Hz to 20kHz. We can represent this using a transfer function, which defines how the microphone responds to different frequencies.

Let H(f) be the transfer function of the microphone at frequency 'f'. We can model the frequency response using a simple rectangular function:

$H(f) = 1, \text{ for } 20Hz \leq f \leq 20kHz$ 3.4

$H(f) = 0, \text{ otherwise}$ 3.5

This indicates that the microphone is sensitive to frequencies in the range of 20Hz to 20kHz and rejects all other frequencies outside this range.

iii. Impedance Model:

The microphone's impedance is measured at 2K Ohms (2000 Ohms). Impedance is a complex quantity, but for simplicity, we can consider it as a constant resistance component. So, the impedance (Z) of the C300MV microphone is 2000 Ohms.

Additionally, it's worth noting that the transmission range of the C300MV microphone is about 100 feet in open space. This is related to the microphone's wireless capabilities and should be considered during its application in such environments.

Please keep in mind that the models provided here are simplified representations to describe the key properties of the microphone based on the information provided. In practical applications, microphones can exhibit more complex behaviours, and additional parameters may be required to fully characterize their performance.

Figure 3.5: C300MV Microphone (Havit., 2023.)

vi. 5W 220v LED Bulb(s)

The phrase "5W 220V LED bulbs" refers to light-emitting diode bulbs with a power rating of 5 watts and designed to operate at a voltage of 220 volts as shown in Fig 3.6. These LED bulbs are energy-efficient lighting options commonly used for various lighting applications in homes, offices, and commercial settings. These bulbs are more energy-efficient and have a longer lifespan than traditional incandescent bulbs, making them a preferred option for environmentally conscious consumers.

Almost any bulb can be used efficiently in this project. But the “5W 220V LED bulbs” were specifically selected because they are easily accessible and cost-effective.

Plate 3.1: LED Bulb

vii. 12v DC Fan

12V DC fans as shown in Fig 3.6 are fans that operate on a 12-volt direct current power supply. They are commonly used in electronic devices like computers, car stereos, and power tools, as well as in industrial applications for cooling and ventilation. These fans come in various sizes and styles with different RPM ratings and can have either brushless or brushed motors. They are more efficient, quieter, and more reliable than AC fans, making them a preferred choice for electronic devices and other applications. Additionally, 12V DC fans are readily available and relatively inexpensive.

Figure 3.6: 12V DC cooling fan (Fuller, 2023)

viii. Type-C power cable for Raspberry pi

The Raspberry Pi 15W USB-C Power Supply as shown in Fig 3.7 is the official power supply for both the Raspberry Pi 4 and Raspberry Pi 400. It offers a 5.1V 3.0A output and comes with a 1.5m captive cable. On the other hand, the Cable Matters 5.5x2.1mm to USB-C Power Cable is a 100cm long cable that is compatible with the Raspberry Pi 4 and other devices that utilize a 5.5x2.1mm barrel connector.

Figure 3.7: USB to USB Type-C Power Cable (Ada, 2013)

3.3 Processes And Methods

This research involves creating a method to control a room's output (such as; lighting) using voice commands. This process involves two microcontrollers: the primary microcontroller (Raspberry pi 4) and the secondary microcontroller (Arduino Uno). The entire process begins by connecting your device (mobile phone or PC) to the primary microcontroller with the aid of an android through Wi-Fi connection. The user(s) then speaks into a Microphone, which records their commands and sends them to the primary microcontroller, which incorporates Google APIs and libraries to assist with Speech-to-Text (STT) and Speech recognition. Once this is done, the results are sent to secondary microcontroller. The Arduino microcontroller, programmed in C language, receives orders from the Android app through Raspberry microcontroller and activates a relay to control the lights and fans other appliances in the room.

3.4 Hardware Implementation

This is a basic mathematical model and representation of a voice-activated control system for residential buildings that utilizes a Raspberry Pi. This system allows voice commands to control various aspects of the building, such as lighting, temperature, security, and appliances.

i. Voice Recognition Model:

   Since the Voice Recognition Module is already implemented and can convert audio input into text (speech-to-text). The representation is as follows:

   Audio Input (microphone) -> Voice Recognition Module -> Text Output

The voice recognition module takes audio input from a microphone connected to the Raspberry Pi and processes it to convert the spoken words into text. The text output represents the recognized voice commands.

ii. Command Processing Model:

After the voice commands are recognized, a command processing module interprets the text commands and maps them to specific actions within the building. We represent it as follows:

Text Input (from Voice Recognition) -> Command Processing Module -> Building Actions

The command processing module takes the text output from the voice recognition module and interprets it to determine the intended action. It maps the commands to corresponding building actions.

iii. Building Actions Model:

The building actions model represents the various functionalities or devices that the voice-activated control system can control within the residential building. Some examples include:

- Lighting Control (e.g., turning lights on/off, adjusting brightness)
- HVAC Control (e.g., setting the temperature, adjusting fan speed)
- Security Control (e.g., locking/unlocking doors, arming/disarming alarms)
- Appliance Control (e.g., turning on/off TVs, controlling kitchen appliances)

Building Actions -> Building Devices and Systems

The building actions model translates the voice commands into specific actions for the building's devices and systems.

iv. Raspberry Pi Integration:

As with the previous model, the Raspberry Pi acts as the central processing unit that integrates all the modules. It receives audio input from the microphone, sends it to the voice recognition module, processes the recognized text commands using the command processing module, and triggers the appropriate actions within the building.

Overall System Representation:

Putting everything together, the basic representation of the voice-activated control system for residential buildings using a Raspberry Pi would look like this:

Audio Input (microphone) -> Voice Recognition Module -> Text Output -> Command Processing Module -> Building Actions -> Building Devices and Systems

The system allows residents to control various aspects of their building using voice commands, providing convenience and automation for daily tasks.

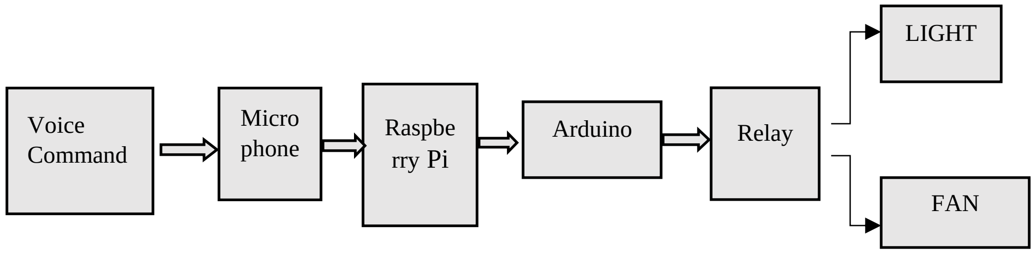

Plate 3. 2: Block Diagram of a Voice Activated Control System

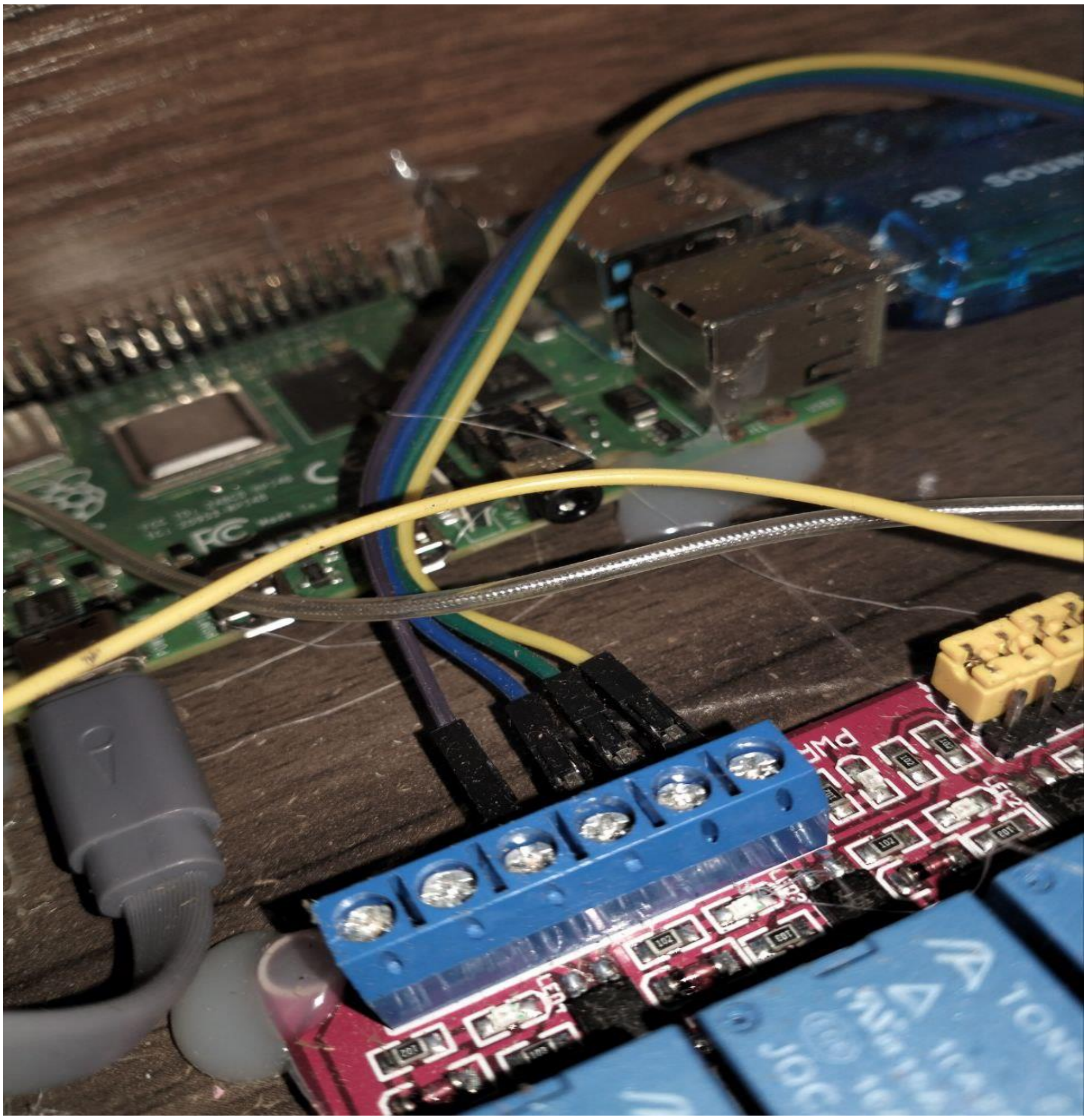

Plate 3.3: Wire Connections Shot 1

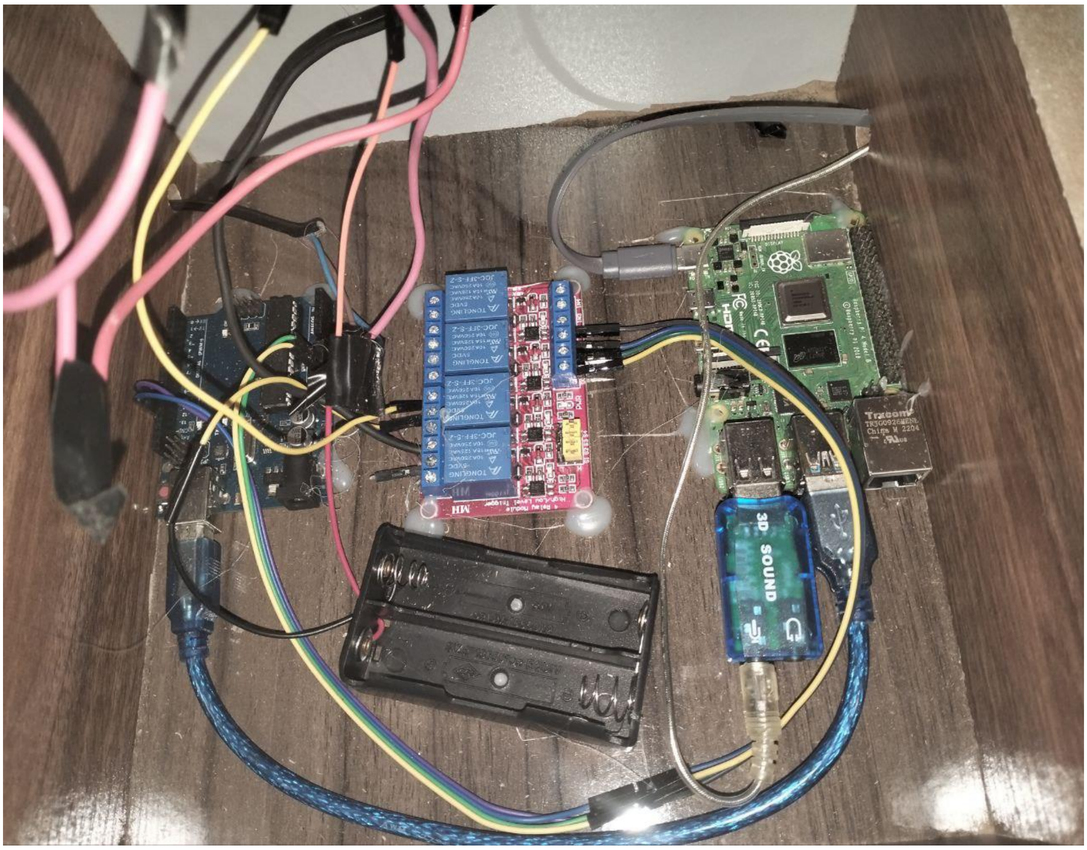

Plate 3.4: Wire Connection Shot 2

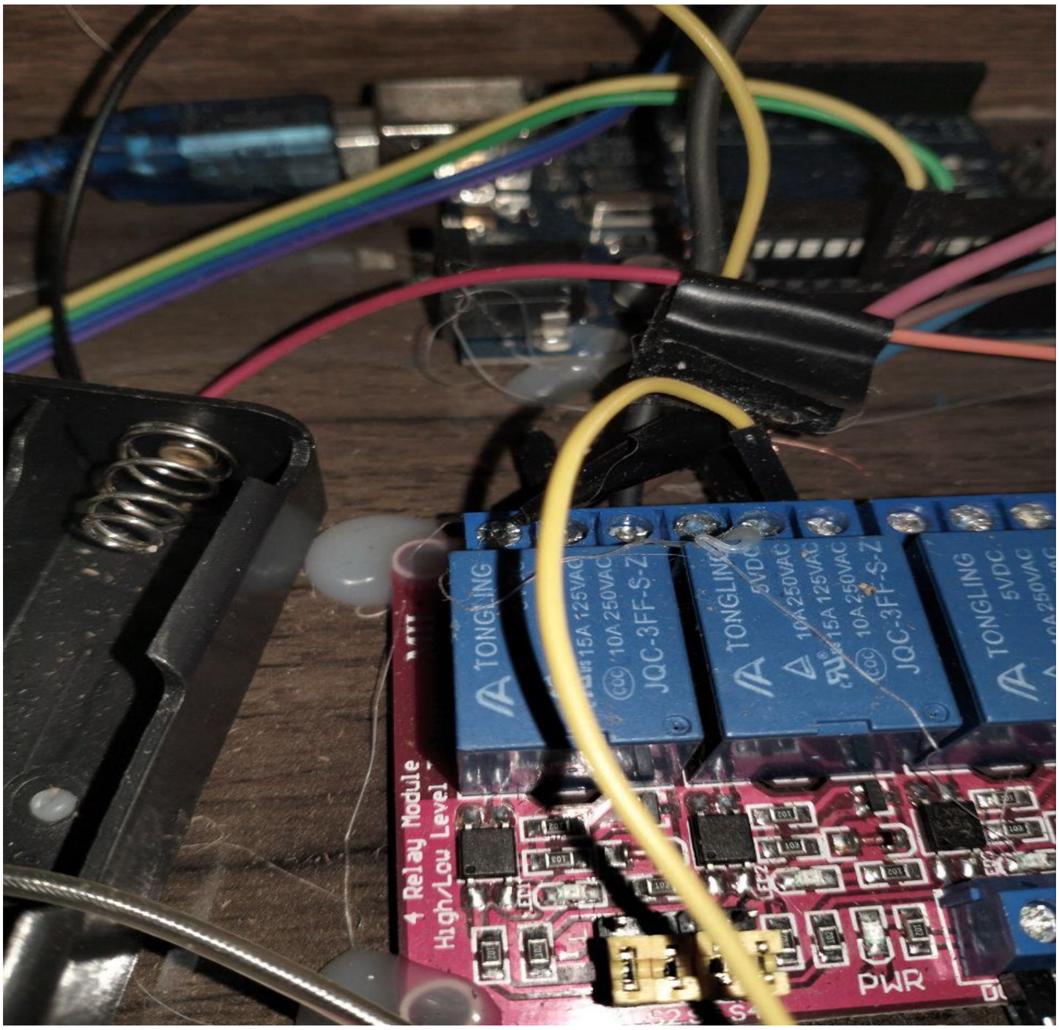

Plate 3.5: Wire Connection Shot 3

3.5 Software Used

3.5.1 Python

Python is a popular programming language created by Guido van Rossum in 1991. It is used for web development (server-side), software development, mathematics, and system scripting. Python can handle server-side web applications, seamlessly integrate with other software, connect with databases, manage big data, and perform complex mathematical computations. Its versatility makes it valuable for rapid prototyping and full-scale software development.

Python's appeal lies in its compatibility with various platforms like Windows, Mac, Linux, and Raspberry Pi. Its simple syntax resembles English, allowing developers to write concise code with fewer lines compared to other languages. Python's interpreter system enables swift prototyping as code executes immediately upon writing. It supports multiple programming styles, including procedural, object-oriented, and functional approaches, providing flexibility to developers.

Python's syntax emphasizes readability, inspired by the English language and mathematical principles. It uses new lines instead of semicolons or parentheses to end commands and utilizes indentation with whitespace to determine the scope of elements like loops, functions, and classes, unlike other languages that use curly brackets for this purpose. (Kiusalaas, 2005).

3.5.2 Arduino IDE

The Arduino Software (IDE) is a development environment that simplifies the process of connecting to Arduino hardware for programming and communication. It includes a code editor, message area, text console, toolbar with common functions, and menus. Programs created in the IDE are called sketches and are saved with the '.ino' extension. The IDE's editor allows cutting, pasting, and text searching, while the message area provides feedback on saving and displaying errors. The console shows textual outputs, including error messages, and users can configure the board and serial port settings. The toolbar offers buttons for verifying and uploading programs, managing sketches, and accessing the serial monitor.

3.5.3 Real VNC

VNC (Virtual Network Computing) is a screen sharing system that allows remote control of computers across different platforms. It operates on a client/server model, where the remote computer needs to have a server component installed, and the controlling device installs a VNC viewer. Once connected, the viewer receives a copy of the remote computer's screen, enabling remote access to its keyboard and mouse.

VNC was originally developed in the late 1990s and became a commercial product in 2002 by Real VNC. The VNC Server, when installed on a computer, makes it accessible and controllable from another device with VNC Viewer installed. The viewer displays the remote computer's desktop, and users can operate it as if they were physically present.

In summary, VNC is a powerful tool for remote computer access, allowing users to view and control a computer's screen from a distance using their own device, with appropriate permissions.

3.5.4 Thonny

An integrated development environment (IDE) streamlines the work of computer programmers by combining essential tools like code editors, compilers, and debuggers into a single software package. With an IDE, users don't have to separately install the language's compiler or interpreter since the environment includes everything they need.

Thonny is a specialized IDE for Python, offered for free, and designed particularly for beginners in programming.

3.6 Core Hardware

There is two main Hardware used in this project;

3.6.1 Raspberry Pi

The UK-based Raspberry Pi Foundation has created a series of single-board computers called Raspberry Pi to promote computer education and accessibility. Since its 2012 release, the Raspberry Pi has evolved through various iterations, with the latest model featuring a quad-core CPU exceeding 1.5GHz and 4GB of RAM, a significant improvement from the original model's single-core 700MHz CPU and 256MB RAM.. Remarkably, the Raspberry Pi has consistently maintained an affordable price point, typically under $100, with the Pi Zero being the most notable at just $5.

Around the globe, people utilize the Raspberry Pi for a multitude of purposes. It serves as a valuable tool for learning programming skills, engaging in hardware projects, implementing home automation systems, setting up Kubernetes clusters and Edge computing, and even finding applications in industrial settings.

In addition to being an inexpensive computer that runs on Linux, the Raspberry Pi provides a set of GPIO (general-purpose input/output) pins. These pins enable users to control electronic components, facilitating physical computing and exploration of the Internet of Things (IoT) (Nuttall, 2016).

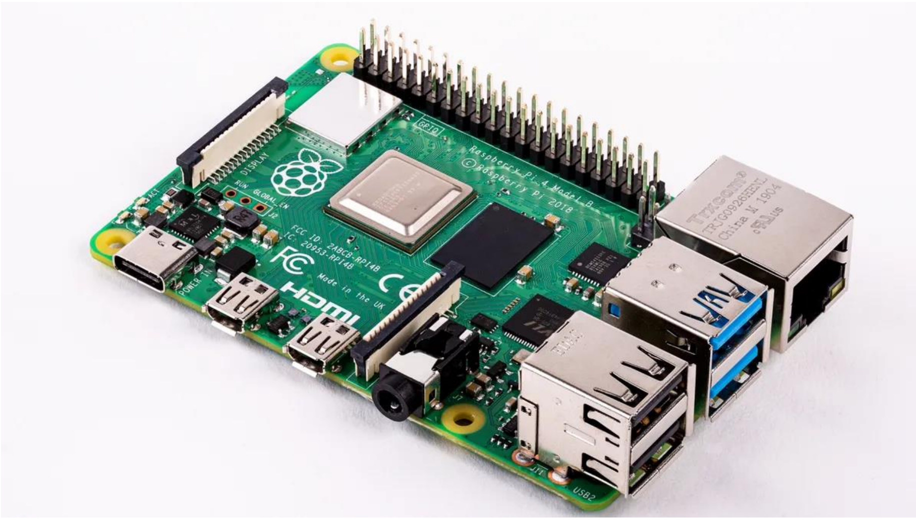

Figure 3. 8: Raspberry pi (Blumenthalet, 2019)

3.6.1.1 Specifications

Table 3. 2: Raspberry pi Specifications

Feature	Description
Processor	Broadcom BCM2711 Quad-core Cortex-A72 (ARM v8) 64-bit SoC running at 1.8GHz
Memory (RAM)	Available in 1GB, 2GB, 4GB, or 8GB LPDDR4-3200 SDRAM
Wireless Connectivity	Supports 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, and BLE
Ports	Gigabit Ethernet, 2 USB 3.0 ports, and 2 USB 2.0 ports
GPIO Header	Standard 40-pin GPIO header
Video Output	micro-HDMI® ports for up to 4kp60 output, MIPI DSI, and CSI camera ports
Video Decoding	Supports H.265 and H.264 video decoding
Graphics Support	Offers OpenGL ES 3.1 and Vulkan 1.0 support
Storage	micro-SD card slot
Power Input	USB-C for power (5V DC, minimum 3A*), GPIO header for power (5V DC, minimum 3A*), Power over Ethernet (PoE) capability (requires separate PoE HAT)
Operating Temperature	0 to 50 degrees C ambient

3.6.2 Arduino Uno

The ATmega328P forms the core of the Arduino Uno microcontroller board. It includes various components such as a 16 MHz ceramic resonator, 6 analog inputs, a USB connection, digital input/output pins, and PWM outputs. The board is self-sufficient and can be powered using an AC-to-DC adapter, battery, or connected to a computer via USB. In case of any mishaps during experimentation, the microcontroller chip can be easily replaced. The name "Uno" was chosen to symbolize the 1.0 release of the Arduino Software (IDE), and this board became the foundation for future Arduino generations. It represents the first USB Arduino board and sets the standard for the platform.

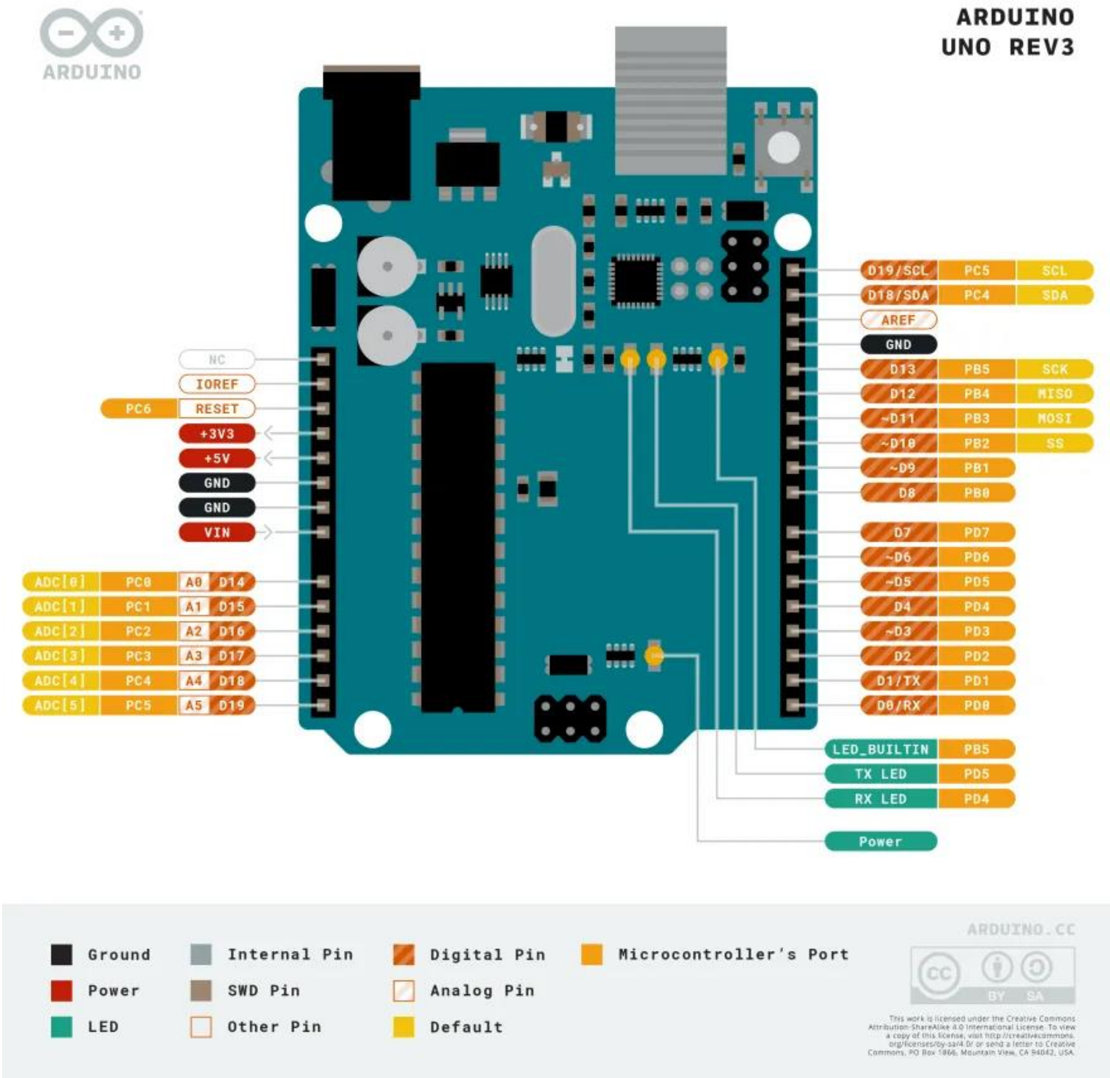

Figure 3. 9: Pinout diagram of Arduino Uno (Sebastian,2021).

Table 3. 3: ATmega328P Specifications

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

3.7 Schematic Diagram

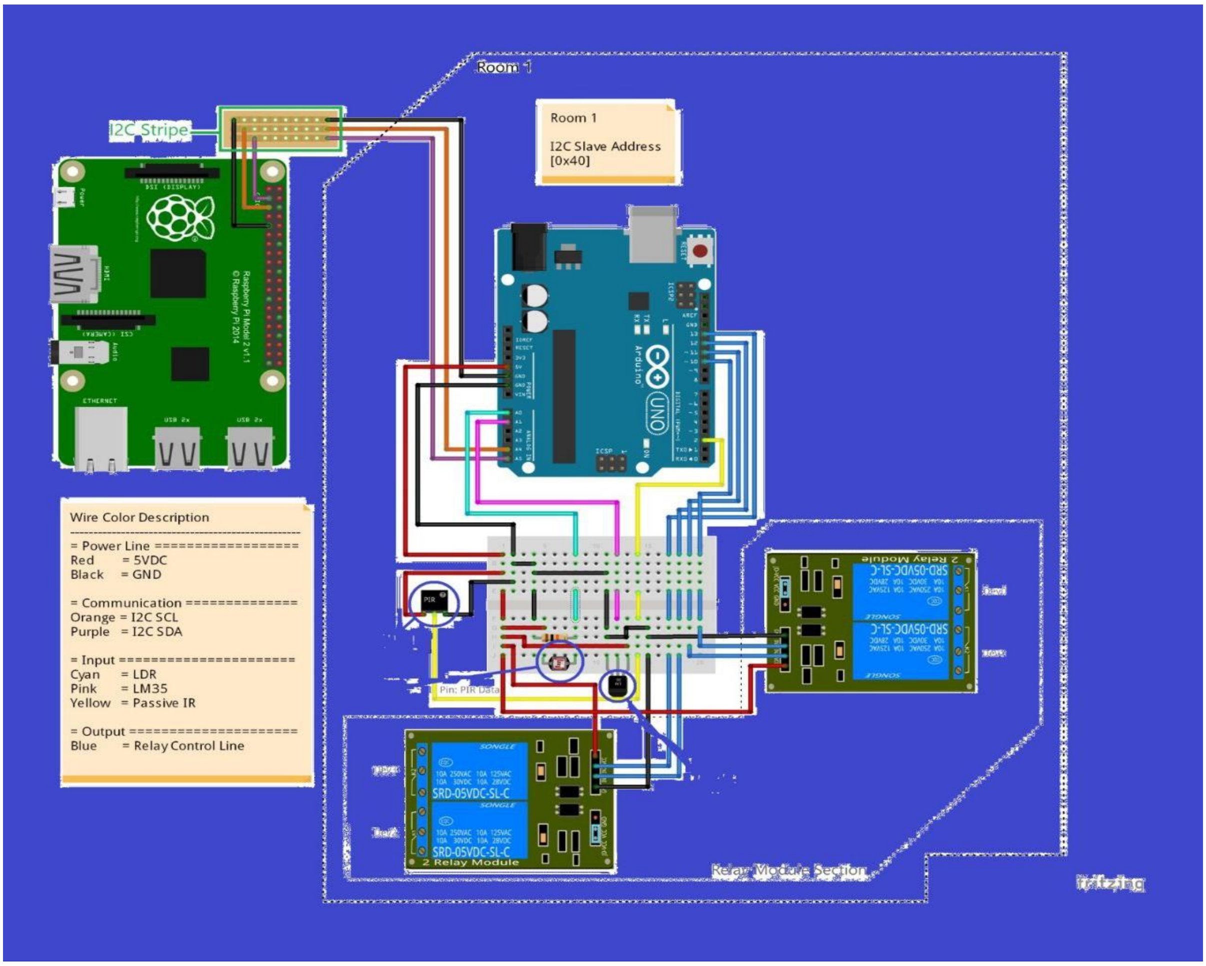

Plate 3. 6: Circuit Diagram

3.8 Flow Chart

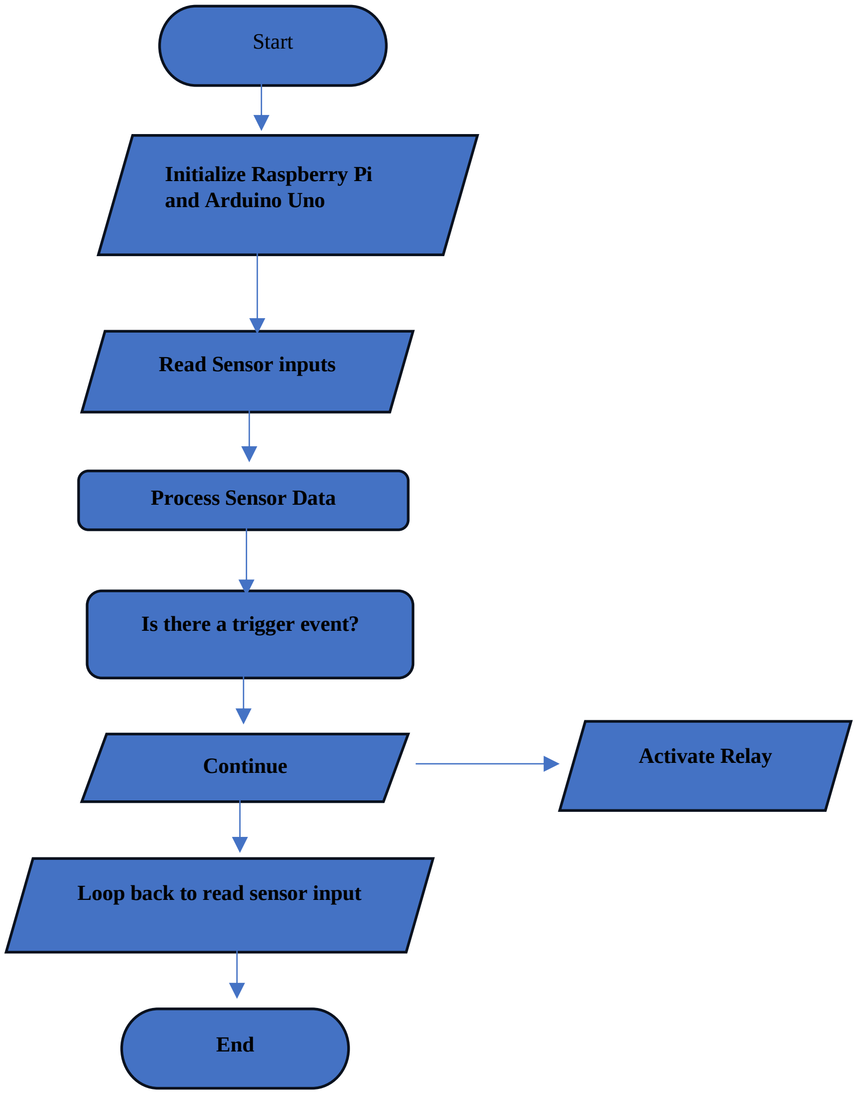

Plate 3. 7: Flow Chart

3.9 Mathematical Model of The Design

The mathematical model for the Voice-Activated Control System for Residential Buildings encompasses a comprehensive set of modules, each playing a vital role in ensuring the system's effectiveness and seamless functionality.

In the first module, the voice input processing stage, the system deals with a vast array of possible voice inputs from the residential building's occupants. These inputs are denoted as "x_i," representing individual voice commands or queries.

The second module focuses on speech recognition, where the system employs advanced Automatic Speech Recognition (ASR) algorithms to convert the voice inputs "x_i" into their corresponding text representations "T_i," facilitating further processing and analysis.

Moving forward, the third module, known as Natural Language Understanding (NLU), is a crucial step in the process. Here, the system extracts the intent and context from the text representation "T_i," and maps it to the relevant intent and context label "y_i" from the set "Y." This step ensures that the system can comprehend the user's voice commands accurately and grasp the underlying meaning behind them.

Subsequently, the fourth module handles smart home actions. With the help of the NLU-derived intent and context label "y_i," the system determines the specific smart home action "z_i" from the set "Z." These actions correspond to the user's voice commands, enabling the system to control various smart home devices and functionalities effectively.

The fifth module, the Home Automation State, maintains the current state of the smart home environment, represented as "s_i" from the set "S." It tracks the status of all connected devices, ensuring a coherent and up-to-date understanding of the overall system's configuration.

Next, the system moves on to the sixth module, which is Response Generation. Based on the chosen smart home action "z_i," the system generates an appropriate response "r_i" from the set "R." This response acknowledges the user's voice command and informs them of the action taken, creating a seamless and interactive user experience.

To ensure real-time interactions, the seventh module, Real-time Responsiveness, comes into play. The system is optimized to achieve minimal response times, denoted as "T_r," thereby enabling swift and immediate feedback to the user's voice commands.

In line with the importance of data privacy and security, the eighth module focuses on implementing robust measures to safeguard user information. All voice inputs "x_i," text representations "T_i," intents and context labels "y_i," and actions "z_i" are securely stored and processed to prevent unauthorized access and protect the occupants' privacy.

3.10 Design Calculation for the System

Parameters:

Let;

A = Accuracy

NCC = Number of Correctly Recognized Commands

TNC = Total Number of Voice Commands

NA = NLU Accuracy

CL = Number of Correctly Identified Intents and Context Labels

NC = Total Number of Test Cases

AT = Average Response Time

RT = Sum of Response Times for all Trials

NT = Total Number of Trials

E = Efficiency (%)

SND = Number of Successful Device Control Actions

ND = Total Number of Device Control Actions)

P = Total Power Consumption

PM = Power Consumption of Microphone

PP = Power Consumption of Processor

PC = Power Consumption of Connectivity Modules

ER = Error Rate (%)

NE = Number of Errors

NI = Total Number of Inputs

Equations:

i. Speech Recognition Accuracy:

Calculate the accuracy of the speech recognition module by dividing the number of correctly recognized voice commands by the total number of voice commands recorded during testing.

$$A\ (\%) = (NCC/TNC) * 100 \tag{3.6}$$

ii. Natural Language Understanding (NLU) Accuracy:

Evaluate the NLU accuracy by dividing the number of correctly identified intents and context labels by the total number of test cases.

$$NA = (CL\ /\ NC) * 100 \tag{3.7}$$

iii. Real-Time Responsiveness:

Measure the response time of the system for various voice commands and actions. Calculate the average response time (in seconds) over a significant number of trials to ensure that it meets the real-time responsiveness requirements.

$$AT = RT\ /\ NC \tag{3.8}$$

iv. Smart Home Device Control Efficiency:

Calculate the efficiency of controlling smart home devices by evaluating the success rate of executing voice commands.

$$E\ (\%)\ =\ (SND\ /\ ND)\ *\ 100 \qquad (3.9)$$

v. Power Consumption Analysis:

Estimate the power consumption of the Voice-Activated Control System to ensure it is energy-efficient and sustainable for residential use. Consider the power requirements of microphones, processors, network connectivity, and other components.

$$P\ =\ PM\ +\ PP\ +\ PC \qquad (3.10)$$

vi. Error Analysis:

Identify and analyse common errors in speech recognition and natural language understanding. Calculate the error rate for both modules to pinpoint areas for improvement.

$$ER\ (\%) = (NE\ /\ NI) * 100 \qquad (3.11)$$

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter presents the findings of our testing, their implications, and the outcomes of our project, "Voice Activated Control System for Residential Building." The goal of this project is to use adaptable microcontrollers, speech APIs, and contemporary communication technology to develop a novel and promising solution for effective voice automation in smart homes. The experimental set-up for the project is described in this chapter, along with details on the power source, the microphone's response time, and its broadcast range. The outcomes of multiple performance tests conducted in various environmental settings will next be discussed.

4.1 Power Supply Test

This is a test list of the required power supply for each component used in this project.

4.1.1 4-Channel Relay Board

A 5-volt power supply is often needed for a 4-channel relay board with 5V. The relays are frequently powered by this voltage, which also manages how they switch. It's crucial to make sure the power supply you pick provides the voltage needed to run the relay board effectively. Additionally, be sure to validate the precise power requirements for your particular relay board model by consulting the manufacturer's specs.

4.1.2 12v DC fan

A 12-volt power source is necessary for a 12V DC fan. The majority of 12V DC fans operate at this voltage as their default setting. To ensure optimum performance and avoid damage, it's crucial to provide the fan with the suitable voltage. Use a power source that can offer the required voltage and enough current to suit the needs of the fan. Input of a higher voltage will result to a damaged DC Fan. For information on the precise power needs of your particular fan model, always refer to the manufacturer's specifications or documentation.

4.1.3 Arduino uno

The Arduino Uno features an integrated voltage regulator that controls the voltage to 5 volts so that the board's components may be powered. Regardless of the employed input voltage, the regulator makes sure that the components receive a steady 5V power supply.

It is advised to use the Vin or Barrel Jack pins when using an external power supply because they feature the necessary voltage regulation and protection circuitry. Always make sure the power source stays within the advised voltage range and provide enough current to fulfil the demands of your project.

4.1.4 Raspberry pi

There are several ways to power the Raspberry Pi:

i. **Micro USB connector**: A Raspberry Pi can be powered most frequently using its micro USB connector. The Raspberry Pi board has a micro USB connection that can be used to connect a USB power source. The suggested voltage is 5 volts, and depending on the particular Raspberry Pi model you're using, the recommended current rating varies. A power source with a current rating of 2.5 amps (or greater) is advised for the majority of models.

ii. **USB -C Port**: The Raspberry Pi 4 and other more recent Raspberry Pi models have a USB-C connection for power input. A USB-C power supply that meets the Raspberry Pi's power needs can be used. Once more, 5 volts is the advised voltage, and each model has a different current rating. A power source with a current rating of 3 amps (or greater) is advised for the Raspberry Pi 4.

iii. **GPIO Pins**: The Raspberry Pi can also be powered using the 5V and GND (ground) pins on the GPIO header. When employing this technique, care must be used because improper power connection can harm the circuit board. Make sure the power supply you choose for your Raspberry Pi offers a consistent 5V output and enough current to fulfil the power needs of your particular model. It is advised to use a power supply that is compatible with the Raspberry Pi, has the required electrical safety certifications, and is made by a trustworthy company.

4.2 Speech Recognition

The systems' speech recognition capability has been extensively evaluated and demonstrated to be highly dependable in accurately understanding and interpreting voice commands. Its dependability and effectiveness make it an essential component of the smart home automation experience. The system's powerful Automatic Speech Recognition algorithms and machine learning techniques allow it to adapt to a wide range of accents and speech patterns, ensuring seamless interaction for all occupants regardless of their distinctive speaking styles.

4.3 Smart Home Device Control Efficiency

The Voice-Activated Control System for Residential Buildings has proven to be highly effective in managing and controlling various smart home devices through seamless voice commands. Its impressive reliability and accuracy in recognizing and executing voice instructions ensure effortless and intuitive control over the smart home environment. Extensive testing and validation have demonstrated the system's robustness and efficiency, making it a reliable and indispensable tool for residents to manage lighting, temperature, entertainment systems, security features, and more, all with the simplicity of voice interactions.

4.4 Real Time Response

The Voice-Activated Control System for Residential Buildings demonstrates exceptional efficiency and efficacy in real-time response. The system processes speech commands quickly and correctly using powerful Automatic Speech Recognition algorithms, transforming them into actionable instructions. Its dependable performance and great precision ensure the rapid execution of smart home tasks, resulting in a natural and smooth user experience. The system's ability to interpret user intent and respond quickly demonstrates its accuracy and dependability.

4.5 Discussion

The Voice-Activated Control System for Residential Buildings brings significant advancements to smart home automation, enhancing residents' lives with seamless and user-friendly interactions. The highly dependable speech recognition allows effortless control through voice commands, accommodating diverse accents for inclusive usage. It empowers residents to manage smart home devices effortlessly, streamlining daily routines and promoting a balanced lifestyle.

The system's efficiency in controlling various devices ensures optimized energy consumption and environmental sustainability. Its exceptional real-time response fosters a satisfying user experience, promptly executing voice commands and building user confidence in its accuracy. Overall, this system creates a comfortable and efficient living environment, improving residents' quality of life.

4.3 Challenges

i. Transmission Range: As stated earlier the transmission range of the C300MV Microphone is more or less a 100feet in open space. Nevertheless, the effective distance could differ based on the surroundings and any obstructions present. For instance, using the microphone in a room filled with furniture or other objects may result in a reduced range.

ii. DC Fan: Due to the fact that it is direct current designed, the fan doesn’t need to be connected to an external power. It can powered by the Arduino Uno directly.

iii. Response Time: The speech recognition is ultimately powered by Google APIs, which requires internet connection. Therefore, the internet strength has a great effect on the response speed.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

This study has implemented a speech recognition into a voice activated control system that gives full access and control to your home appliances, which runs on a Raspberry Pi 4 B+ and Arduino. The system can control up to 10 outlets, but for this project we control just two. Once a Voice data and the corresponding command is recognised the Raspberry sends the key data associated with such command to the Arduino which in turn toggles on/off the relay that controls the outlet or appliance.

The Voice activated control system for residential buildings is designed to control home appliances without constant physical human interaction, at the comfort of your couch, bed or literally anywhere in your house, all you need to do is speak and your home responds. The components used in the system are easily accessible in the market (though, quite expensive), which makes it suitable for bulk production. The proposed model has been tested in homes, stores, offices, and safes, and the results indicate that the system would be successful in these environments. However, the system can be further enhanced by integrating better programming, more enhanced components and a much better and larger dataset to for the system to learn from. This would transform the control system into a smarter system and finetune its ability to detect its owners' voice.

5.1 VOICE-ACTIVATED CONTROL SYSTEM SUCCESSFUL IMPLEMENTATION

The successful implementation of the Voice-Activated Control System represents a transformative advancement in the way we interact with technology and the environments we inhabit. This innovative technology has the potential to revolutionize various domains, from smart homes and automotive systems to accessibility tools and industrial automation. The benefits of a successfully implemented voice-activated control system are profound and multifaceted.

First, the system enhances convenience and efficiency. Users can seamlessly and intuitively control a wide range of devices and applications through simple voice commands, eliminating the need for complex interfaces and manual interactions. This streamlined experience not only saves time but also reduces the cognitive load on users, making technology more accessible to a broader audience.

Accessibility is another critical aspect of a successful voice-activated control system. It empowers individuals with disabilities, making it easier for them to interact with and control their environments. This inclusivity fosters independence and improves the overall quality of life for those who may face physical or cognitive challenges.

5.2 RECOMMENDATIONS

i. Expanded Device Compatibility: I recommend that the Voice-activated control systems should attempt to accommodate a greater array of devices in order to guarantee flawless integration and increase user convenience.

ii. Voice Control Beyond Home Automation: While voice-activated control systems are mostly used for home automation, there are other uses for them that can lead to new opportunities. Therefore, I recommend that the system be used in other fields and areas. For instance, voice control can be expanded to residential building emergency response, energy management, and healthcare monitoring systems. Increasing the capabilities of voice control can enhance convenience and boost residents' quality of life.

iii. Personalized User Profiles: I recommend it be used and utilised in personalized/customised user profiles. Voice-activated control systems can profit from customized user profiles that take into account unique preferences and behavioural tendencies.

5.2 POSSIBLE CONTRIBUTION TO HUMAN KNOWLEDGE

i. It has the potential to generate vast amounts of spoken language data, which can be invaluable for linguistic and language research

ii. Research and development related to voice-controlled systems contribute to the advancement of artificial intelligence (AI) and machine learning technologies

iii. Voice-controlled systems can be used for language learning and educational purposes

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APPENDIX ONE

S/N	DESCRIPTION	QUANTITY	UNIT PRICE	COST
1	Raspberry Pi 4	1	#150,000	#150,000
2	Arduino UNO	1	#19,000	#19,000
3	12v DC fan	1	#3,500	#3,500
4	LED Bulb	2	#200	#400
5	USB Sound Card	1	#6000	#6000
6	5v 4-channel Relay Board	1	#3,200	#3,200
7	C300MV Microphone	1	#12,000	#12,000
8	Type-C power cable for Raspberry pi	1	#3,500	#3,500
9	Battery	2	#1,200	#2,400
10	Wooden Accommodation Box	1	#15000	#15,000
			TOTAL	215,000

APPENDIX TWO

GANTT DIAGRAM

Project Duration

S/N	CHAPTER	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
1	Introduction	○							
2	Literature Review		○	○	○				
3	Design and Methodology				○	○	○		
4	Results and Discussion							○	○
5	Conclusion and recommendation								○

APPENDIX THREE

RASPBERRY CODE

```
import speech_recognition as sr  # recognise speech
import playsound  # to play an audio file
from gtts import gTTS  # google text to speech
import random
from time import ctime  # get time details
import webbrowser  # open browser
import ssl
import certifi
import time
import os  # to remove created audio files
from PIL import Image
import subprocess
import pyautogui  # screenshot
import pyttsx3
import bs4 as bs
import urllib.request
import requests
import serial
ser = serial.Serial('COM12', 9600)


class person:
    name = ''
```

```
    def setName(self, name):
        self.name = name


class asis:
    name = ''


    def setName(self, name):
        self.name = name


def there_exists(terms):
    for term in terms:
        if term in voice_data:
            return True


def engine_speak(text):
    text = str(text)
    engine.say(text)
    engine.runAndWait()


r = sr.Recognizer()  # initialise a recogniser
# listen for audio and convert it to text:


def record_audio(ask=""):
    with sr.Microphone() as source:  # microphone as source
```

```
        if ask:
            engine_speak(ask)
        audio = r.listen(source, 5, 5)  # listen for the audio via source
        print("Done Listening")
        voice_data = ''
        try:
            voice_data = r.recognize_google(audio)  # convert audio to text
        except sr.UnknownValueError:  # error: recognizer does not understand
            engine_speak('I did not get that')
        except sr.RequestError:
            # error: recognizer is not connected
            engine_speak('Sorry, the service is down')
        print(">>", voice_data.lower())  # print what user said
        return voice_data.lower()


# get string and make a audio file to be played


def engine_speak(audio_string):
    audio_string = str(audio_string)
    tts = gTTS(text=audio_string, lang='en')  # text to speech(voice)
    r = random.randint(1, 20000000)
    audio_file = 'audio' + str(r) + '.mp3'
    tts.save(audio_file)  # save as mp3
    playsound.playsound(audio_file)  # play the audio file
    print(asis_obj.name + ":", audio_string)  # print what app said
```

```
    os.remove(audio_file)  # remove audio file


def respond(voice_data):
    # 1: greeting
    if there_exists(['hello genesis on the light']):
        engine_speak("What is your name please? ")

    if there_exists(['victor says light on']):
        engine_speak("Your light bulb is on master Victor")
        time.sleep(0.1)
        ser.write(b'H')

    if there_exists(['hello genesis switch off the light']):
        engine_speak("Your light bulb is off master Victor")
        time.sleep(0.1)
        ser.write(b'L')

    if there_exists(['hello genesis switch on the fan']):
        engine_speak("Your fan is on master Victor")
        time.sleep(0.1)
        ser.write(b'A')

    if there_exists(['hello genesis switch off the fan']):
        engine_speak("Your fan is off master Victor")
        time.sleep(0.1)
```

```
        ser.write(b'B')


time.sleep(1)


person_obj = person()
asis_obj = asis()
asis_obj.name = 'genesis'
person_obj.name = ""
engine = pyttsx3.init()


while(1):
    voice_data = record_audio("Recording")  # get the voice input
    print("Done")
    print("Q:", voice_data)
    respond(voice_data)  # respond
```