DESIGN AND MODELLING OF SMART HOME TECHNOLOGIES FOR THE AGED PERSONS

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CERTIFICATION

This is to certify that this work titled **DESIGN AND MODELLING OF SMART HOME TECHNOLOGIES FOR THE AGED PERSONS** was carried out by **OKORAFOR GODFREY NWAJI (20114855388)** in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy (PhD) in Computer Engineering, Department of Electrical and Electronics Engineering, Federal University of Technology, Owerri, Imo State, Nigeria.

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DEDICATION

This research is dedicated to the God Almighty, whose grace enabled the accomplishment of this my Ph.D program, and to my wife (Okorafor Nneka Chima) and our children (Okorafor Ihuomachukwu Prince, Okorafor Somtochukwu Praise, Okorafor Oziomachukwu Promice, and Okorafor Chinazaekpere Princess).

I love you all with all my heart.

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LIST OF ABBREVIATIONS

1. .Net Framework – provides a comprehensive and consistent programming model for building applications that have visually stunning user experiences and seamless and secure communication.
2. .wav Files – (Waveform Audio File Format) is a Microsoft and IBM audio file format standard for storing an audio bit stream on PCs.
3. AC Power – the rate of flow of energy past a given point of the circuit in an alternating current circuit.
4. C programming language – a general-purpose computer programming language designed for implementing system software but also widely used for application software.
5. Dead Home here is defined as a home with closed curtains, carpet, an air-conditioner, and other leaving home appliances switched off.
6. GND – a common return path for electric current
7. Group -- help to manage records, each group 7 records. System group and user group are supported.
8. Home Control – simplified way of managing home appliances.
9. I/O Pins – input/output pins from the module and microcontroller, where signals pass through.
10. LED Indicators – light emitting diodes that will light when some functions are called.
11. Live Home here is defined as a home with opened curtains, carpet, an air-conditioner, television, and other leaving home appliances, switched on, and with background music or noise from a stereo people.
12. Load -- copy trained voice to recognizer
13. Main Controller – the part of the prototype that contains the voice module, which controls the signals when voice commands are recognized.

14. Microcontroller – a small computer on a single IC, which can be programmed to be use in automatically, controlled products and devices. It is an open source physical computing platform based on a simple input/output (I/O) board and a development environment that implements the Processing language.
15. Microsoft Visual C# - is a programming language that is designed for building a variety of applications that run on the .NET Framework. C# is simple, powerful, type-safe, and object-oriented.
16. PC Interfaced Controller – a device that sends control signals and is controlled by a PC.
17. PC interfacing – allows a computer and other hardware component to function independently while using interfaces to communicate with other components via an input/output system.
18. Recognizer -- a container where acting voice commands (max 7) were loaded. It is core part of voice recognition module. For example, it works like “playing balls”. You have 80 players in your team. But you could not let them all play on the court together. The rule only allows 7 players playing on the court. Here the Recognizer is the list which contains names of players working on the court.
19. Recognizer index -- max 7 voice commands could be supported in the recognizer. The recognizer has 7 regions for each voice command. One index corresponds to one region: 0~6
20. Relay – an electrically operated switch.
21. Relay Driver – a circuit that manages the relay operation and secures the coil part of the relay.
22. Signature -- text comment for record
23. Train -- the process of recording voice commands
24. Transistor – a semiconductor device used to amplify and switch electronic signals and power.

25. USB – (Universal Serial Bus) is an industry standard cables, connectors and protocols used in a bus for connection, communication and power supply between computers and electronic devices.

26. Vcc – common collector voltage supply of the system.

27. Voice Activated – systems that can be activated through voice commands.

28. Voice Command Record -- the trained voice command store in flash, number from 0 to 79

29. Voice module – refers to the VoiceGP module

30. Voice Recognition – is the process of taking spoken words as an input to a computer program. Voice recognition recognizes spoken words with any type of voice. The spoken words are converted into electrical signal from which, are transformed into coding patterns of assigned meaning.

31. Voice Synthesizer – interpreter of voice commands.

32. VoiceGP Dev Kit Software – a software uses to program the VoiceGP Module.

33. VoiceGP DK-T2SI – a module, which includes all of the hardware and software, that are necessary to quickly and easily develop voice recognition capabilities in some desired applications.

ABSTRACT

Smart home technology for the aged persons here is a wireless sensor-based home system that provide the aged persons a safe, sound and secure home environment, while enabling them to live independently in their own homes as long as possible. The aged persons here are that population within the ages of 65 years and above. Nowadays, the rapid increase in the number of aged persons, including those with disabilities, the decrease in the number of family care-givers as a result of youths` migration to cities in search of white-collar jobs, and inability of government to provide adequate infrastructural needs to these aged persons has resulted in a miss-match on the caring facilities in Nigeria. These have contributed to the problem of these aged persons, since neither families nor government are able to meet their needs, especially in Africa due to high level of mass poverty, illiteracy and corruption in governance. Therefore, the task of this proposed system here is to design and model a voice-activated home control system that will utilize the natural voice of the aged home occupants, to provide a more convenient, easier to install and use, user friendly home technologies for the aged persons. This will enable them maneuver assistive wheelchair, and manage home appliances through voice commands. This assistive wheelchair developed is embedded with collision detection and avoidance. The tools used to realize this proposed system are; The Personal Computer (PC), HC-SR04 ultrasonic sensor, and Voice Recognition (VR) module in a PC used for voice processing and recognition, Microphone for voice signal acquisition, C-language with the help of C# for coding. Bluetooth and Radio Frequency (RF) transceivers wirelessly link the input module to the controller module (microcontroller) which selects the appliances/assistive device to be controlled according to the input voice command. Proteus Virtual System Modelling (VSM) was used for developing smart home technology system schematic model and carried out the animated simulation to validate the system`s performance within the home. The designed system was tested on Dead Home (a home with closed curtains, carpet, an air-conditioner, and other leaving home appliances switched off) and Live Home (a home with opened curtains, carpet, an air-conditioner, television, and other leaving home appliances, switched on, and with background music or noise from a stereo people) conditions, and the effective result was 92.93% for dead home and 75.85% for live home respectively. This showed that the realized system controlled the devices with voice, though, the level of this system response is higher in dead home than in a live home, hence, the level of the system performance is lower in a noisy environment.

Keywords: Voice Recognition, Proteus VSM, Voice Activated, Microcontroller, voice Command.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The notion of smart home was first introduced in the early 1980s when the concept of “intelligent building” was first used (Lynggaard, 2013). In the concept, a proposed intelligent implementation of electrical devices, security devices, and consumer electronic devices for domestic tasks automation, human-friendly control, and easy communication, as well as safety, was made. The implementation of these homes however, focused on building a smart home environment for able-bodied and young persons with the simple aim of enhancing their home comfort, energy saving, and security as shown in Figure 1.1.

Presently, the number of elderly persons with physical challenges that require external help to perform their everyday movement tasks and other activities of daily living have been on the rapid increase. Therefore, the problem of caring for this group of people has become a serious issue as many of them are always seen clustered at city roundabouts, church gates, event centers begging for arms. More so, this problem of the aged persons will be more serious in the near future, if nothing is done to solve it now especially in Africa due to mass migration of abled bodied care-giver youths to the cities for greener pastures. Therefore, this has motivated this designed home technologies (smart home technologies) research work titled design and modeling of smart home technologies, that will meet the increasing needs of this group of persons in their home environments. It is obvious that the solutions to the problems of aged persons cannot be solved by increasing the number of care-givers, rather, it can significantly be reduced by the deployment of various modern assistive technologies, through building of smart homes. Hence, this research tends to use the available advanced technological devices to design smart home technologies for the aged persons to meet their special needs. The background diagram of smart home network and the disabled aged persons are shown in Figure 1.1.

Figure 1.1: The Background of Study Diagram

Also, the decline in mortality rate due to improved health care services and living condition has equally led to the increasing population of this aged persons. The aged persons are that percentage population of persons in a given population with ages 65 years and above. The world`s aged person's population has grown at an accelerated pace, and 2009 projections gave an estimated 737 million persons were aged 60 years and above, which nearly two thirds of whom lived in developing nations. This number is projected to increase to 2 billion in 2050 (World Health Organization. 2011). However, this continuous rise in the population of the aged persons has resulted to rapid increase in the cost of caring for them, hence, worsening the problem of caring for the aged persons due a miss-match on the caring facilities. The high population of the aged persons involved in arm-begging, showed the level of neglect this group of persons are suffering from the society and the societies` leaders. Although, few of these persons can be found in their family homes, nursing homes, hospitals, and so on, the costs of their maintenance in these places are very expensive. Hence, they are not adequately taken care of either by their families or care-givers, and their talents are allowed to waste just because they are old. In finding a solution to the problem of these persons, (Graafman, 1998; Wang & Liu, 2018), studied the merger between gerontology and technology known as Gerontechnology, which utilizes technological advancements to improve the health, mobility, communication, and environment of the aged persons. Gerontology in the other hand is the study of ageing persons, and the social, psychological and biological aspects of the ageing process itself. Technically, a smart home technology may be described as a home integrated with technological devices to perceive the state of the home occupant through sensors and intelligently acts upon the home environment through controllers. Smart Home Technologies (SHT) emanated as a result of intelligent home automation and ubiquitous computing. Currently, the home automation area offers remote and timer control of systems and embedded devices such as light, heating, ventilation, entertainment systems, appliances, and so on, to improve comfort, convenience, energy efficiency, and security. However, this is where this proposed smart home technologies for the aged persons comes into play because of the need to make the home system behave autonomously.

Actually, Smart living is an intelligent process that involves the remote control of consumer devices and media sharing. This work utilized the recent trends in Information and Communication Technology (ICT) which have given support to ubiquitous access, for the networking of automated electrical gadgets in the home using mobile devices. The development of computer systems network that monitors and controls the physical world through the use of sensors, has made the entire world a global village, and thus enabling the occupant of this smart home access and control their environment through the use of mobile devices. Hence, SHTs are good home alternatives for the independent life of aged persons because these home environments are embedded with various intelligent devices, which provide residents with both movement assistance and home monitoring and control. These numerous modern home-embedded systems will be able to perform their functions without disturbing and without causing any pain, inconvenience, like movement restriction to the user, instead, they provide users a level of comfort.

However, the architectural design of this proposed SHT is based on distributed smart multi-agent architectures to overcome the technological challenges such as huge network, central server processing load and embedded resource usage experienced in the currently existing homes. Therefore, these homes for people with special needs will be designed to overcome these problems, while their control algorithms are based on commands relevant to the specifics of the user's requirements. This is because the level of installed technology in this home for the aged persons varies from person to person, depending on the degree of physical impairment, life habits, and desired safety conditions. This smart home technology system will enable full integration of this group of citizens to the society by providing them the opportunity to show-case their talents in sports, economy building, in exercising their franchise and contributing their own quota to the development of the nations at large.

1.2 PROBLEM STATEMENT

Nowadays, there have been rapid population increases in the number of aged persons all over the world and more so, most of these aged persons suffer from impairments that prohibit them from going about their normal life. These disability conditions may have been caused by accident, traditional delivery practices in developing countries, poliomyelitis, stroke, tribal wars, and act of terrorism or due to physical or mental trauma thereby rendering them incapacitated. Some of these persons are pictured in Figure 1.2.

More so, the decrease in the number of care-givers as result of youths` migration to cities in search of white corner jobs has contributed to the problem of the aged persons, and no solution to this now, especially in African due to high level of mass poverty and illiteracy. Also, the current advancements on new technologies and developed user interfaces such as cell phones and household appliances have not made the lives, wellbeing and comfort of these targeted persons shown in Figure 1.2 easier because of high level of illiteracy. Also, rising population of this group of persons has resulted to an increase in the cost of caring for them, therefore neither families nor government is able to meet their needs. This inability of government to provide adequate infrastructural needs to these aged persons have worsen the caring problem situation for the aged persons and has created a miss-match on the caring facilities.

Figure 1.2: The problem of the disabled aged persons and the smart home solution

Sequel to these problems, many researchers have contributed immensely in providing solution to the problems of this group through design and development of face recognition technology, eye tracking technology, head tracking technology, finger sign recognition, tongue rolling pattern recognition, and so on. Despite these research solution contributions, none has totally met the general need of these aged persons. Therefore, the task of this proposed system here is to design and model a voice-activated home control system as depicted in Figure 1.2 that will utilize the natural voice of the aged home occupant to provide a more convenient, easier to install and use technologically user-friendly home technologies for the aged persons in Ugwulangwu community, Ebonyi State Nigeria.

1.3 OBJECTIVES OF THE STUDY

The main objective of this research is to design and model smart home technologies for the aged persons, in a Nigerian community based setting. This main objective will be achieved by embarking on the following specific objectives.

1. Design of voice activated device control system that is wireless sensor based for the aged persons.
2. Develop an embedded prototype system model that would allow the aged persons to control all electro-mechanical appliances through voice in a smart home.
3. Development of software that will drive the system.
4. Validation of the modelled design for accuracy and efficiency.

1.4 JUSTIFICATION

In the light of population increases in the number of the aged persons who want to live independently in their homes without a care-giver, so the need for Smart Home Technologies (SHTs) requirements increases. Therefore, the possible solution to the challenges of the aged persons proposed in this work is smart home technology development for the overall goal of improving the Quality of Life (QoL) of the aged persons. As the size of this group of people keep on rising, there is need to develop smart home technologies, which will assist this group of people with movement impairments to move un-obstructively in their home, thereby enabling them to continue living at home in safety and independence.

Therefore, the need to provide voice activated wireless home network (smart home technology), that will enable the aged persons to continue living alone at home by enabling them to:

1. Perform civic Activities of Daily Living (ADL).
2. Control household electrical, electronic, and mechanical devices.
3. Have access to smart home devices and so on, that will enhance their life longevity.

Hence, this SHT will assist the aged persons to control their environment, move and communicate effectively. In other words, it will increase the quality of life, and life expectancy of the aged persons, and increase their self-esteem.

1.5 SCOPE OF THE STUDY

This work was restricted to the development of models that the aged persons who suffer impairments that restrict them from an unaided movement in their home environments will use, which involves, the hardware and software designs of multiple; interface control system. These was done through the implementation of, the electrical control system module, the voice activated system module, and the robotic wheelchair system module, and:

1. The voice recognition system can be activated or deactivated depending on the user’s preference
2. The system will only allow the user to turn on/off the fan, and light using speech recognition through an AC socket control.
3. The system allows the user to open/close the doors and the windows.
4. It allows the user to maneuver the assistive motorized wheelchair through a voice command.
5. The interfaces for the aged blind and dumb persons were not considered.

CHAPTER TWO

LITERATURE REVIEW

2.1. Review of Related Technology

Here, a review of technological advanced developments that brought about the emergence of smart homes are presented.

2.1.1 HC-05–Bluetooth

The standard feature for cellular phones is a Bluetooth technology which can be used in wireless connection for cellular phones and home appliances. The Bluetooth technology gives an efficient method for controlling home automation. It is a low cost and a secured technology.

The Arduino Bluetooth board is used in the system. The system operates on over 2.4 GHz ISM band frequency, covering a distance range of 10 m, with data transmission rate of 1 Mbps speed, (Prashant & Aarti, 2015; Kavitha, 2018). This module HC-05 shown in Figure 2.1 transmits and receives data wireless in serial format; it is used to provide a connection between Micro-Controller Unit (MCU) and Personal Computer (PC) for the data transferring purpose.

Figure 2.1: HC-05 Bluetooth Module (source Bhavik et al., 2016)

The I/O ports of the Bluetooth board and relays are used to connect the devices to be controlled. The Bluetooth simply is password protected. A Bluetooth device has the ability to scan and detect other devices easily. It has the ability of checking whether devices are working properly or not (Palaniappan et al, 2015).

2.1.2 Arduino

Arduino UNO shown in Figure 2.2 is a single board computer, and is an open-source physical computing platform based on a simple input/output (I/O) board. The type of the Arduino board used by this author is ATMega328P Arduino Uno Microcontroller having 2KB static RAM, 32KB flash memory, 8-bit CPU, 6 Analog I/O pins and 14 Digital I/O pins (Sonali et al, 2015). The language used to program the Arduino microcontroller is C/C++. Programs are created in the Arduino development environment for the program compilation and linking source codes are downloaded to the Arduino board, where they can be ran (Boxall., 2013).

The Arduino Uno is a microcontroller board based on the ATmega328p. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button Bramhankar, A. Y., & Sapana. 2015. It contains everything needed to support the microcontroller. The Arduino Uno, can either be connected to a computer using a USB cable or power it with an AC-to-DC adapter. The Arduino circuit acts as an interface between the software part and the hardware part of the project (El-Latif & Ahmed, 2014). An (Bramhankar, A. Y., & Sapana. 2015) consists of an Atmel 8-, 16- or 32-bit AVR microcontroller with complementary components which helps in programming and other circuit incorporation. This board has a 5volt linear regulator and a 16 MHz crystal oscillator.

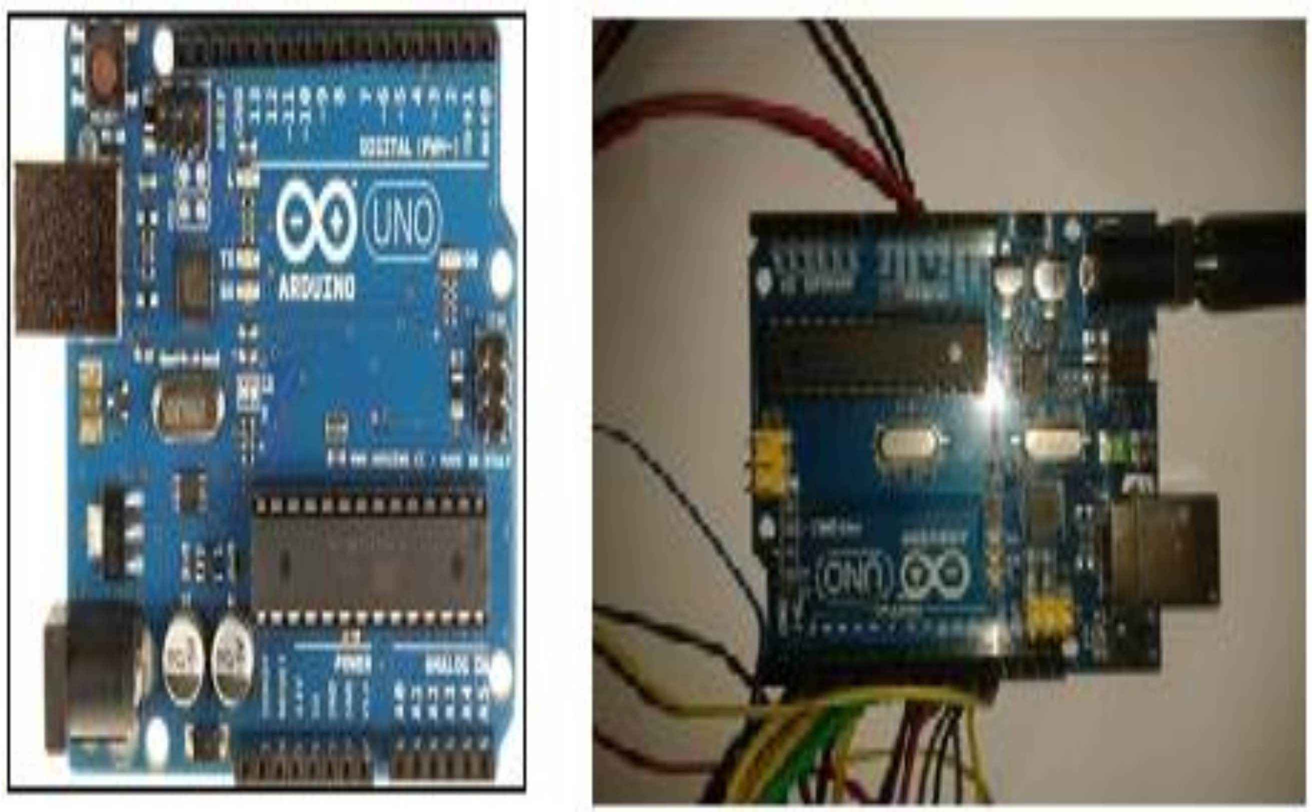


Figure 2.2: The Arduino Uno board Bramhankar, A. Y., & Sapana. 2015

2.1.3 Android Based Phone

Android is a mobile operating system (OS) based on the Linux kernel and currently developed by Google. With a user interface based on direct manipulation, the OS uses touch inputs that loosely correspond to real-world actions, like swiping, tapping, pinching, and reverse pinching to manipulate on-screen objects, and a virtual keyboard. The Android platform was used because of its huge market globally and it’s easy to use user interface (Yan & Shi, 2013). Applications on the Android phones extend the functionality of devices and are written primarily in the Java programming language using the Android software development kit (SDK).

Android operating system is primarily designed for smart phones and tablets. Android applications are written in Java programming language using the Android software development kit (SDK) and run-in virtual machines (Sonali et al, 2015). The ATMega328P Microcontroller is connected by HC-05 Bluetooth Module using wireless technique to the Bluetooth Controller Android application, and the Input/output ports of the embedded system board are connected to home appliances. Android is the base of the application software, which has the largest base of Smartphone. The Smartphone screen of Android application is shown in Figure 2.3.

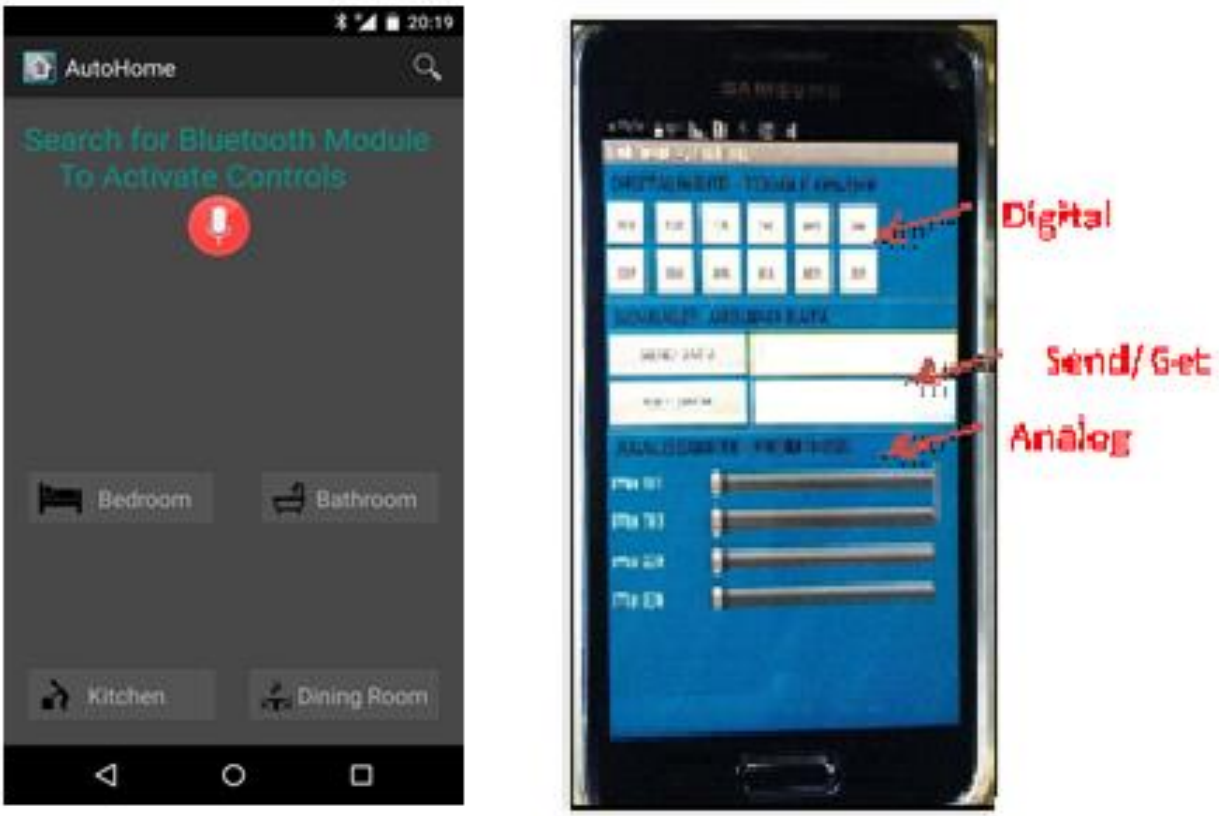


Figure 2.3: Smartphone screen of Android application (Riadh et al, 2018)

2.1.4 Bluetooth Wireless Technology

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices, and building personal area networks (PANs) (Chakradhar et al., 2013). Bluetooth is designed as a short range, low energy, low-cost wireless connectivity that uses radio technology.

Bluetooth devices work with 2.4 GHz frequency. A channel hoping technique is used to divide the 2.4 GHz band into 79 channels. In this technique the data is separated into smaller pieces called packets. The data packets are exchanged between the transmitter and receiver at one frequency, and then at another frequency the transmitter and receiver exchange another packet. This process continued repeatedly until all data are transmitted. The channels change every 625 microseconds. Usually, it performs 1600 times per second BWT devices use seventy-nine 1-megahertz frequencies in the ISM band as shown in Figure 2.4. The ISM frequency bands, having a range of 2.4 GHz and 2.483 GHz in the radio spectrum, has been reserved for industrial, scientific and medical purposes (Chadha, et al., 2013).

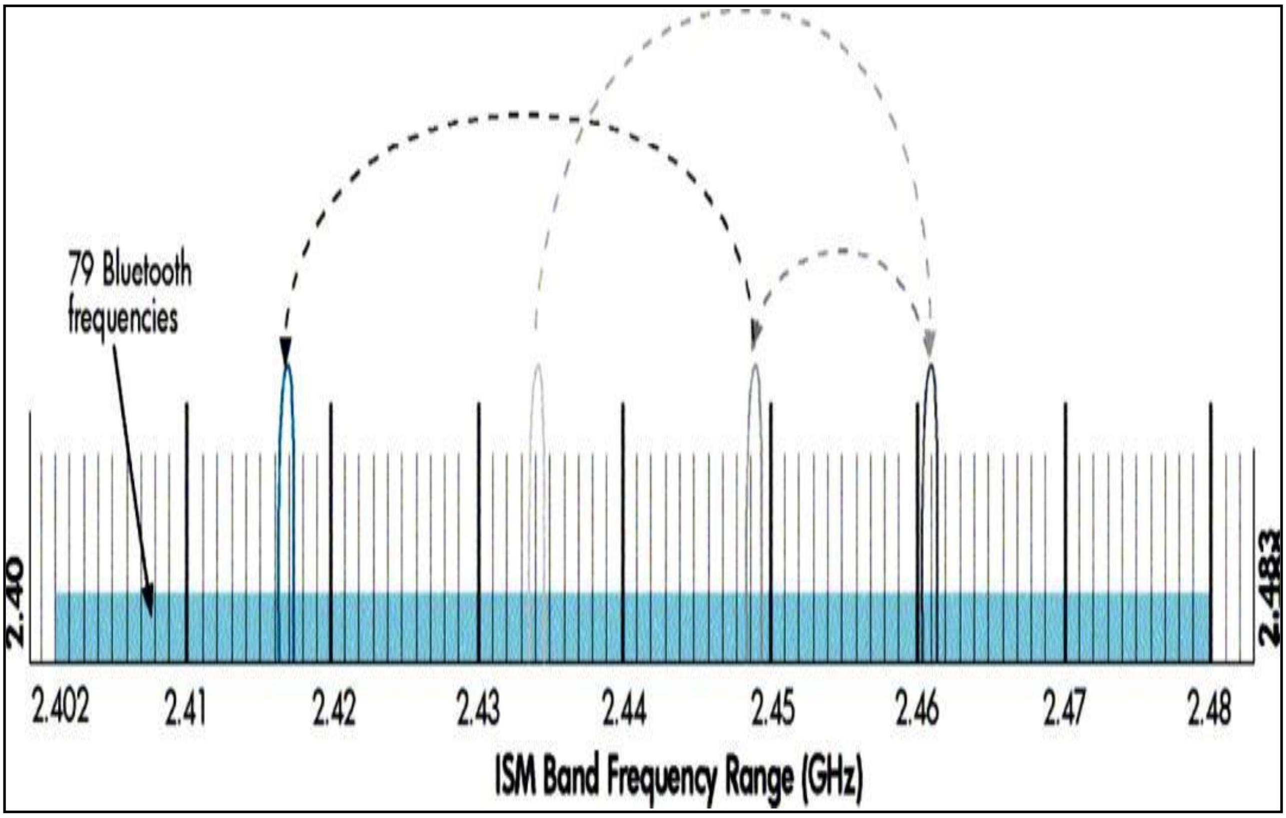


Figure 2.4: BWT devices frequencies hop up to 1600 times per second. (Riadh et al, 2018)

2.1.5 PWM on an Arduino, (**Riadh et al, 2018**)

Pulse Width Modulation (PWM) is a technique used to change the pulse width of signal, which in turn, changes the duty cycle to control the effective voltage level to the attached component. Figure 2.5 shows a voltage signal with pulses of duration τ_o that repeat every τ_c units of time. If this signal with a response time larger than τ_c is supplied to a device, then the device will test the signal as a DC input with an effective voltage V_{eff} of (Peddapelli, 2017).

$$V_{eff} = V_s \frac{\tau_o}{\tau_c} \qquad (2.1)$$

Where $\frac{\tau_o}{\tau_c}$ is the duty cycle ratio of the square wave pulses.

By adjusting the duty cycle (Figure 2.5) of signal, the effective DC output voltage is controlled. PWM of digital input/output pins either a High (5V) or Low (0V) depending on coding it. The I/O pins is controlled with the programming of pin Mode, digital Write and digital Read functions.

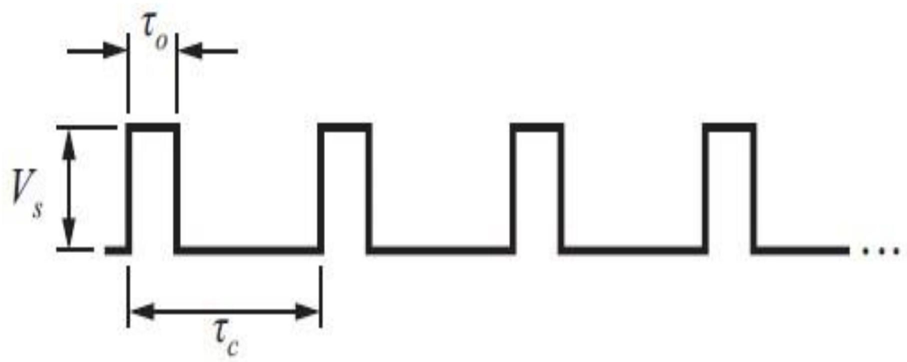


Figure 2.5: PWM duty cycle. (Riadh et al, 2018)

Analog Write function generates a square wave that can be varied in the function. It is 8-bit value that corresponds to voltage range between 0 and 5 volts for the values varying between 0 and 255. A value 0 gives a duty cycle of 0% and a value 255 gives a duty cycle of 100%. The analog Write value can be calculated as shown below:

Analog Write value= Duty cycle * 255

The PWM output level is particular with the analog Write. Figure 2.6 describes the scaling relationships between the parameters of PWM outputs. The quantities are linearly related. Thus,

$$PWM_{out\ level} = 255 \times \frac{\tau_o}{\tau_c} = 255 \times \frac{V_{eff}}{V_s} \qquad \textbf{(2.2)}$$

Since V_s = 5V, the formula became:

$$PWM_{out\ level} = \frac{255}{5} \times V_{eff} \qquad (2.3)$$

Therefore, an effective voltage of 3V can be calculated as follows:

$$PWM_{out\ level} = \frac{255}{5} \times 3 = 153$$

2.1.6 H-Bridge

A D.C. Motor requires a voltage difference between its terminals to rotate in which, the direction is depended on the side connected to the negative or positive terminals. Swapping the terminals will change the rotation of the motor in the opposite direction. The H-bridge enables the DC motor to rotate in forward and reverse directions and also provides enough current for the motor to run. It is named H-Bridge according to its shape of connection as shown in Figure 2.6. An H-Bridge is basically a set of 4 switches which leads to different motions or actions if it is combined with an Arduino. A couple simple digital output signals, can be used to open or close these switches. When the switch A1 and switch A2 are closed, the motor rotates clockwise. When the switch B1 and switch B2 are closed, the motor rotates anti-clockwise (Cooney et al, 2004).

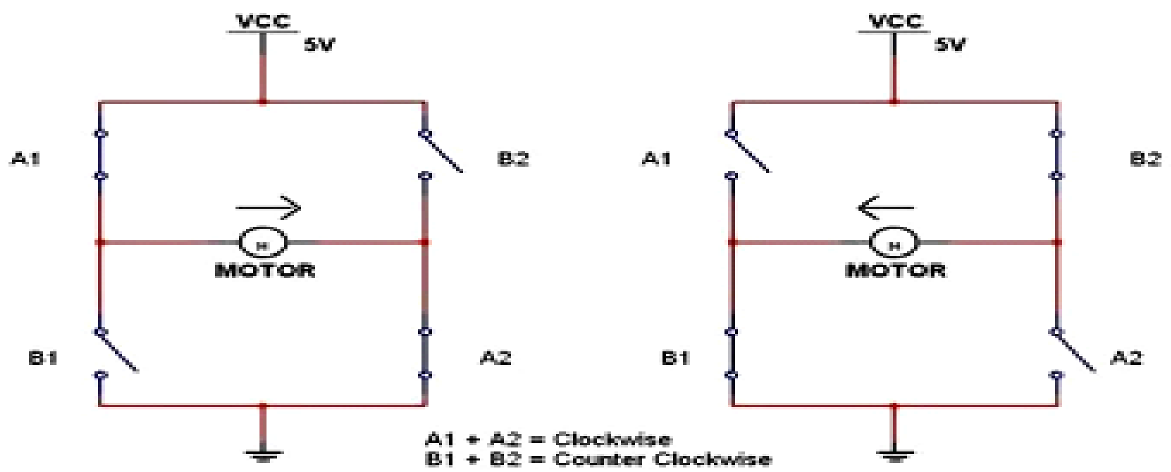


Figure 2.6: H-bridge theory (Riadh et al, 2018)

The SN754410 Quadruple Half-H Driver Integrated Circuit (IC) is used to control the direction of a DC motor. Figure 2.7 shows the pin configuration of the IC, and Table 2.1 is the function of its working, the scaling relationships for PWM parameters is shown in Figure 2.8.

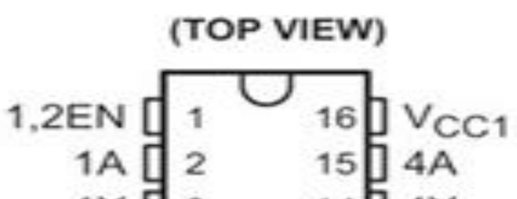


Figure 2.7: Pin configuration of SN754410 Quadruple Half-H Driver IC (Riadh et al, 2018)

Table 2.1: Function Table

INPUT		OUTPUT
A	**EN**	**Y**
H	H	H
L	H	L
X	L	Z

H=High Level, L=Low Level, X=irrelevant, Z=high impedance (off)

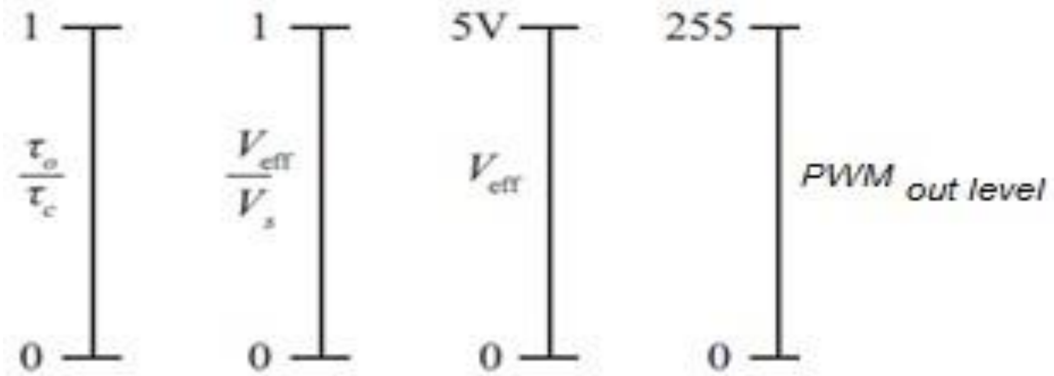


Figure 2.8: Scaling relationships for PWM parameters (Riadh et al, 2018)

2.1.7 The Voice Recognition Board

This board is a compact and an easy-control speech recognition board, and a speaker-dependent voice recognition that can supports up to 80 voice commands, with each voice 1500ms (one or two words spoken). It can only allow for maximum of 7 voice commands to effectively work at the same time. The 8051 microcontroller libraries, and Easy Control combine with the voice recognition board has 2 controlling ways (Figure 2.9): Universal Asynchronous Receiver and Transmitter/ General Pins Input Output (UART/GPIO) the controlled Serial Port (full function), and User-control General Pin Input Output GPIO (part of function). The module needs to train users before it recognizes any voice command. General Output Pins generate several kinds of waves while corresponding voice command was recognized (Hassan, 2019).

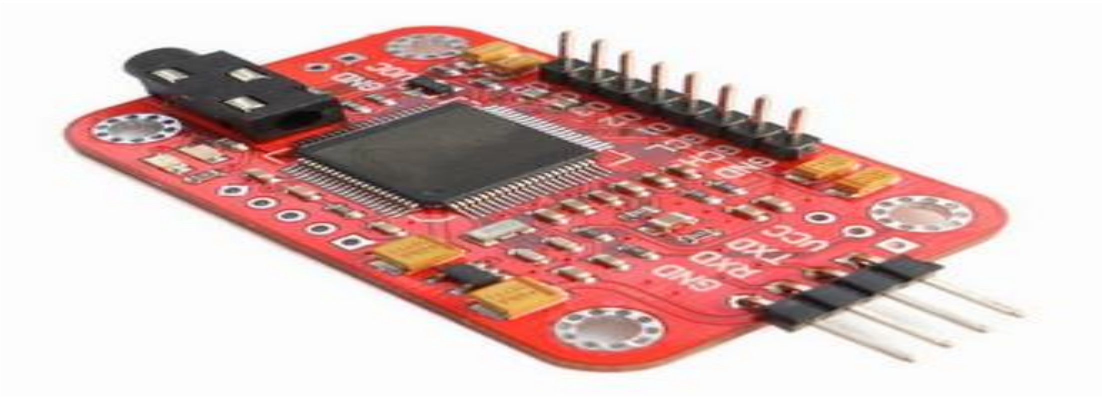


Figure 2.9 Voice recognition module (Hassan, 2019)

2.1.8 The Joystick

The joystick provides signal to the microcontroller which is transmitted to the smart wheelchair through the wireless RF. The joystick has two axes: X and Y axis, these axes are made up of both positive and negative (that is X= X_{+ve}, X_{-ve}; Y = Y_{+ve}, Y_{-ve}) axes to provide signal control for four directional controls of forward, backward, left and right movement of the smart wheelchair (Figure 2.10) (Hassan, 2019).

Figure 2.10: The Diagram of Joystick Control (Hassan, 2019)

The setup was completed by attaching four switches example S1, S2, S3 & S4 respectively, which are used for rotating the smart wheelchair to any desired direction. With these switches (S1, S2, S3 & S4), smart wheelchair can be moved in any direction of choice such as left, right, forward or backward by just pressing a respective single button. During forward motion both motor runs in forward direction, and the binary switch condition for forward movement are: S1 = 0, S2 = 1, S3 = 0, & S4 = 1; and during reverse motion both motors run in reverse direction, and the binary switch condition for reverse movement are: S1 = 1, S2 = 0, S3 = 1, & S4 = 0. For right movement, one motor runs in forward direction and the other motor runs in reverse direction, and the binary switch condition for right movement are: S1 = 1, S2 = 0, S3 = 0, & S4 = 1; and left movement, one motor runs in reverse direction and the other motor runs in forward direction, and the binary switch condition for left movement are: S1 = 0, S2 = 1, S3 = 1, & S4 = 0. These are summarized below:

S1	S2	S3	S4	Output Resultant Effect
1	0	0	1	Motor moves Right
0	1	1	0	Motor moves Left
0	0	0	0	Motor Halt
0	1	0	1	Motor moves Up
1	0	1	0	Motor moves Down

The high-power motor controller has four ports. Two ports are OUT A and OUT B, and these are connected with the motor positive and negative terminals. The other two ports are VIN and GND, these are connected with batteries. There are two motor used in this system, one controller is connected with one motor and other controller is connected with other motor (Hassan, 2019).

2.1.9 Microcontrollers

The Microcontroller (89C51/89S52 series) from ATMEL are the micro controller Chips that will be considered for implementation in this Research proposal “smart home for the aged persons”. In the work of Nishigandha et al., 2018, microcontroller integrated to utilize output of the activities of the voice recognition module, the joystick and the RF module. It receives and process signals and data coming from the modules interfaced to it and sends the corresponding results through the RF module to the receive system (Nishigandha et al., 2018).

This microcontroller is of an eight-bit class of CMOS microcomputer, that requires 3 capacitors, resistors and 5-volt power supply during operation. It comes with both Random-Access Memory (RAM) Read Only Memory (ROM), parallel and serial port (Universal Asynchronous Receiver/ Transmitter), and so on. All these are in one single chip with Flash Erasable Programmable Read Only Memory (EPROM) in micro control chip, the advantages of this micro control chip are it makes design cheap, easier, and it can be reused for many times. Flash EPROM is loaded with programs include the instructions that will be compiled by the micro controller (Nishigandha et al., 2018).

This microcontroller has 40 pins, 32 pins for parallel port as shown in Figure 2.11. One port includes 8 pins, so 32 pins formed 4 parallel ports, each of them is recognized as port 0, port 1, port 2 and port 3. Number of each pin of parallel port starts from 0 through 7, first pin of port 0 is named P0.0 and the last pin of port 3 is named P3.7. It is a USB based microcontroller, and has the capability of being used to develop standalone system which can communicate to the software on the computer.

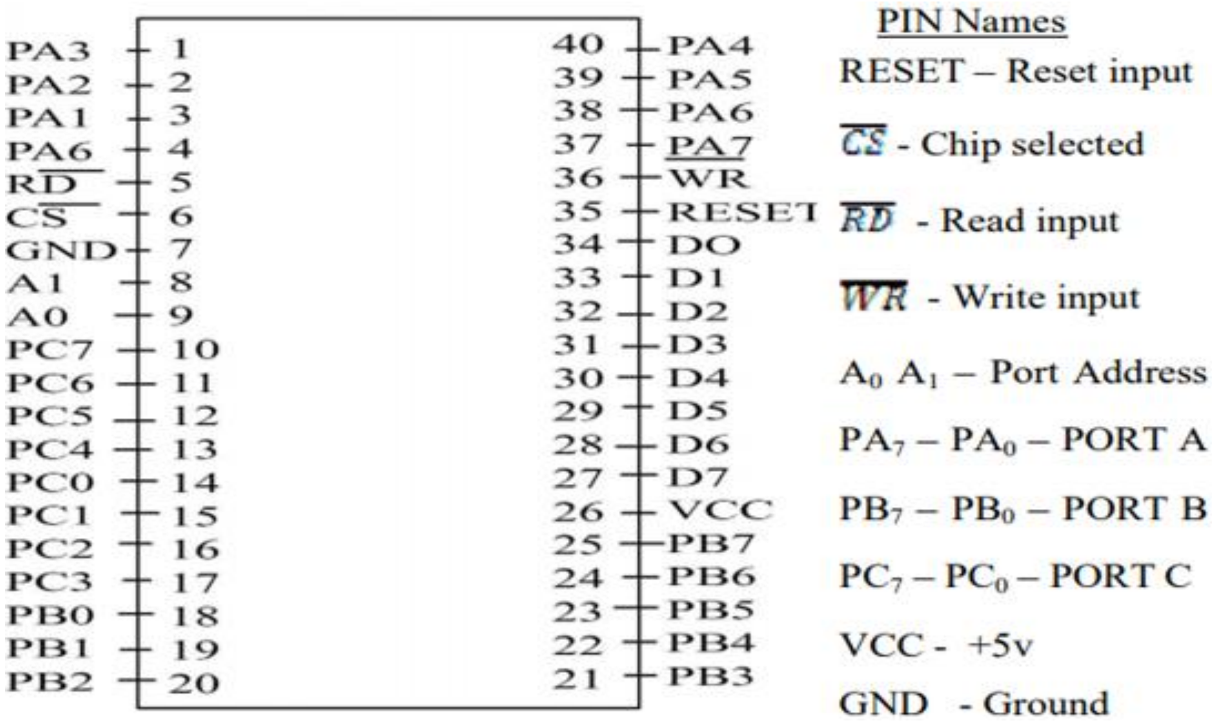


Figure 2.11: The Microcontroller Pin illustration

It has a built-in USB connection that is used by the IDE to upload source code into the processor. The connection is established in the programs, to send data back to the computer or to receive commands in serial fashion from the computer. The serial object contains all the code that was needed to send and receive data (Nishigandha et al., 2018)

Arduino UNO is a multi-purpose microcontroller board based on the ATmega328P. It has 14 digital input/output pins and 6 analog inputs as shown in Figure 2.30. Each of the 14 digital pins on the Uno can be used as an input or output. An Arduino Uno board can either be powered via USB connection or with an external power supply (AC-to-DC adapter or battery). Leads from a battery can also be inserted in the Gnd and Vin pin headers of the power connector. The board can operate on an external supply of 6 to 20 volts (Galadima, 2014; Kioumars & Tang, 2011). In the journal of title "Improved Authentication Using Arduino Based Voice & Iris Recognition Technology", a voice recognition system is proposed to build as security function.

2.1.10 The RF Module

RF Modules transfer data wirelessly, and this makes them most suitable for remote control applications, where there is need to control devices or robots without getting in touch with them (due to various reasons like convenience, safety, handicapped, and so on). Now short-range RF module wireless control applications such as, an ASK RF Transmitter-Receiver Module of frequency 433 MHz, were chosen for this application because, they are quite compact and cheap (Fahmida et al., 2016).

A general RF communication block diagram is shown in Figure 2.13, and the encoders/decoders/microcontrollers are TTL compatible, the user inputs will be given in TTL logic level. This TTL inputs data from the user are sent serially using an encoder or a microcontroller, and this serial data can be directly read using the RF Transmitter, then performs Amplitude Shift Keying (ASK) (or Frequency Shift Keying (FSK) in some cases) modulation on it and transmit the data through the antenna (Fahmida et al., 2016).

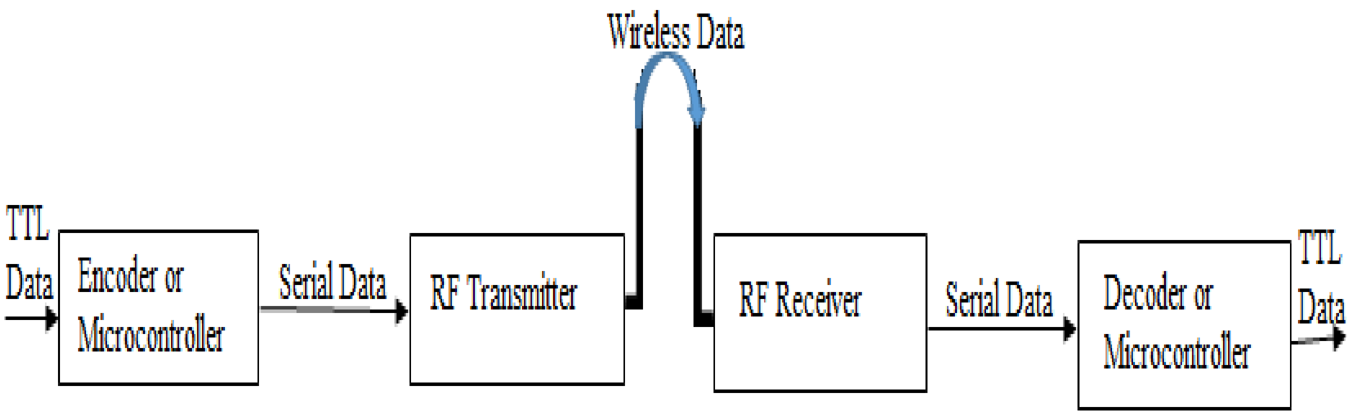


Figure 2.12: RF Communication Block Diagram

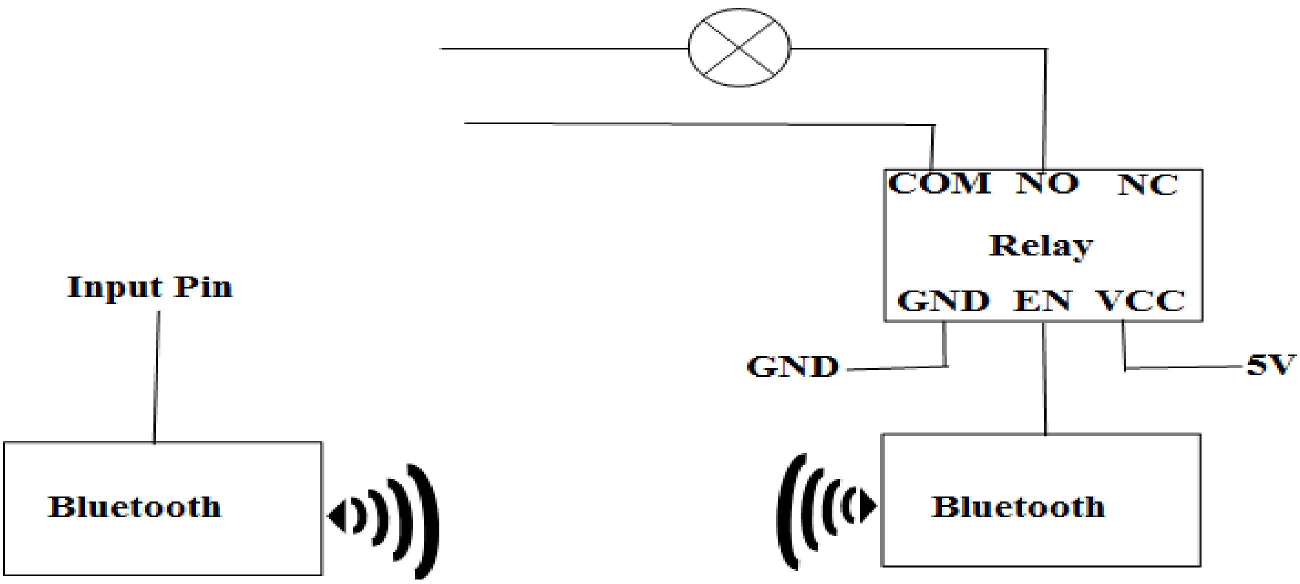
In the receiver side, the RF Receiver receives the modulated signal through the antenna, performs all kinds of processing, filtering, demodulation, and so on, and gives out a serial data. This serial data is then converted to a TTL level logic data, which is the same data that the user has input. The RF receiver module, receives data from the remote transmitter and compares the received data with the already store data in the microcontroller end of the receiver (Fahmida et al., 2016). The functions of the transmission ports are illustrated in Table 2.2.

Table 2.2: RF Transmitter and Receiver Functional Ports.

RF Transmitter			RF Receiver		
Pin No.	Name	Function	Pin No.	Name	Function
1	GND	Ground (0V)	1, 6, & 7	GND	Ground (0V)
2	Data	Serial Data Input	2	Data	Serial Data Input
3	Vcc	Supply Voltage	3	NC	Node
4	ANT	Antenna	4, & 5	Vcc	Supply Voltage (5V)
			8	ANT	Antenna Output

2.1.11 The Bluetooth Module

The Bluetooth module is connected through the serial port of the microcontroller (pin10 and pin11) as shown in Figure 2.14. The Bluetooth receives data from the android phone to control the doors and window.



The Figure 2.13: The Block Diagram of the System Bluetooth Module. (Rommer et al, 2011)

The proposed system is composed of two major units; the remote system transmitter control unit and the remote system receiver control unit. The remote system transmitter control unit comprises of the input recognition devices modules such as voice input module, joystick module and push button module. The remote system receiver control unit however is comprised of the electrical and electromechanical units which are the bulb units, the TV unit, the fan unit, the fridge unit, the door and window unit, the vehicular wheelchair unit, and the emergency call unit (Rommer et al, 2011).

2.1.12 **Relay Driver** (Syafaruddin & Miyauchi, 2014).

A relay is an electromagnetic switch that is activated when a current is applied to it, and a relay is normally used in a circuit as a type of switch as shown in Figure 2.15 below. There are different types of relays and they operate at different voltages. When a circuit is built the voltage that will trigger it has to be considered. In their project, Rommer et al, 2011 built a relay circuit that is used to turn appliances on/off using high or low voltage. The high/low signal is supplied from the Arduino Uno microcontroller. In their work, when a low voltage is supply to the relay of an appliance, it is turned off and when a high voltage is supply to the relay of an appliance, it is turned on. The relay circuit that drives four appliances in the Voice operated Android and Arduino Home automation system is shown Figure 2.15 (Rommer et al, 2011). The number of appliances can be modified according to the user's requirements.

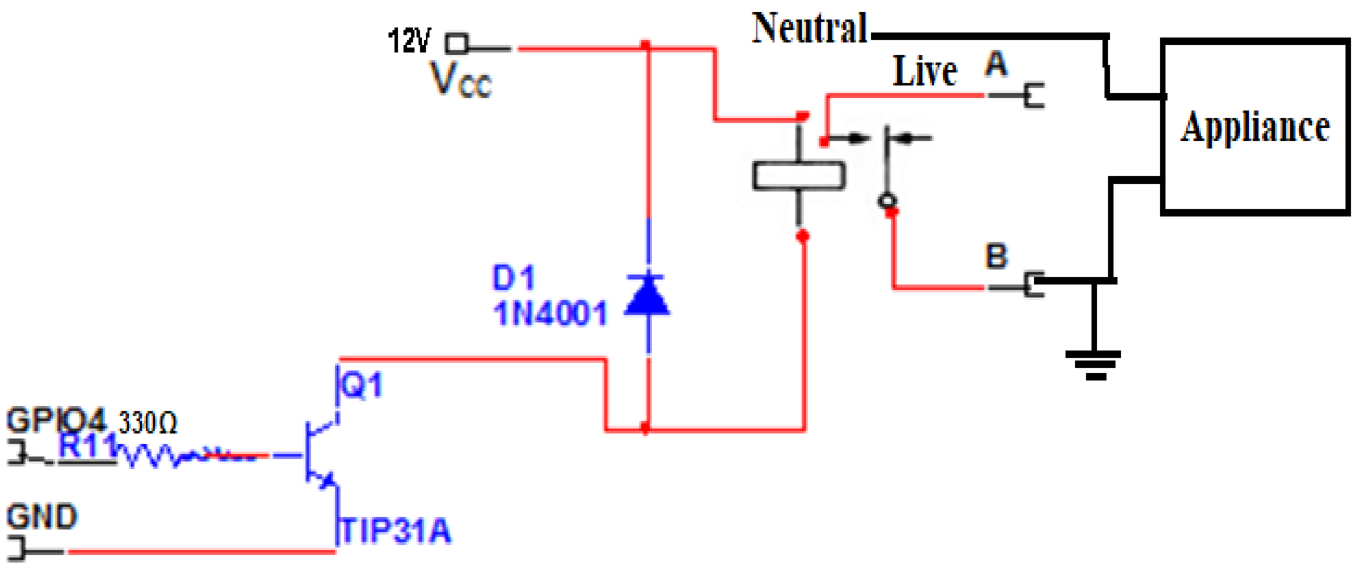


Figure 2.14: Relay Driver Circuit (Syafaruddin & Miyauchi, 2014)

The relay driver is a mechanism that controls a switch by means of a low voltage control signal as shown in Figure 2.16. In the design, it consists of a 12-V relay, 330Ω Resistor, 1N4001 diode, and a TIP31 NPN transistor. The resistor is connected to the positive signal coming from a GPIO pin of the VoiceGP module. The other end of the resistor is connected to the base pin of TIP31 which serve as the triggering signal for the transistor. The emitter pin of TIP31 is connected to the GND because TIP31 NPN-transistor, and the pin of the VoiceGP module was also grounded (Rommer et al, 2011).

As a low voltage signal, coming from the GPIO pin, flow and pass through the 330Ω resistor up to the Base-Emitter junction of the transistor, the TIP31 will be in saturation state which will enable connection between the collector and emitter junctions. When TIP31 transistor goes into the saturation state, the relay will have a successful 12-V supply on its pins, particularly the inductor part of the relay. When the relay is supplied with a 12-V, the switch part will be closed. The switch part serves as a bridge connection between the 220-V power and the AC socket (where the specific appliance was plugged). As the switch closes, it establishes complete connection of the appliance and the 220-V which then energizes the electronic appliance (Syafaruddin & Miyauchi, 2014). Initially, the switch part of the TIP31 transistor is open. It is open when there is no low voltage signal supplied to the base pin. When the transistor switch part is open (cut-off state), the 12-V supply on the relay will not be complete because the collector pin, where the other end of the inductor part of relay is connected, is not connected to the emitter where the ground was connected. As the transistor is in cut-off state, the switch part of the relay will not close and will forbid 220-V power to the appliance. Thus, the electronic appliance is not energized. The 1N4001 Diode serves as a suppressor diode in the relay driver. The suppressor diode prevents voltage spike arising at the inductor as voltage across was reduced or removed (Rommer et al, 2011).

2.1.13 The SIM900A

The GSM shield connected to the microcontroller is used to send/ receive messages and make/receive calls just like a mobile phone by using a SIM card from a network provider. This can be done by plugging the GSM shield into the microcontroller board and then plugging in a SIM card from an operator that offers GPRS coverage. The shield employs the use of a radio modem by SIMComm. Communication can easily be done with the shield by using the AT commands. The GSM library contains different methods of communicating with the GSM shield. This GSM Modem works with any GSM network operator SIM card just like a mobile phone with its own unique phone number. The advantage of using this modem is that its RS232 port can be used to communicate and develop embedded applications. Applications like SMS Control, data transfer, remote control and logging can be developed easily using this (Yoo & Shaik, 2016).

The modem can either be connected to a PC serial port directly or to any microcontroller through MAX232. It can be used to send/receive SMS and make/receive voice calls, also, used in GPRS mode to connect to internet and run many applications for data logging and control. In GPRS mode, it can connect to any remote FTP server and upload files for data logging. This GSM modem is a highly flexible plug and play quad band SIM900A GSM modem for direct and easy integration to RS232 applications. It Supports features like Voice, SMS, Data/Fax, GPRS and integrated TCP/IP stack. To be connected to a cellular network, the shield requires a SIM card provided by a network provider. Most recent revision of the board makes the connection of the shield with the microcontroller board by connecting its TX to pin 0 of microcontroller and pin 1 of microcontroller to RX of shield. Different components of the GSM shield, consulted are shown in Figure 2.16.

Figure 2.15: The components of GSM shield (Yoo & Shaik, 2016).

This is an ultra-compact and reliable wireless module; it is a complete Dual-band GSM/GPRS solution in a SMT module which can be embedded in the customer applications allowing benefit from small dimensions and cost-effective solutions. Featuring an industry-standard interface, the SIM900A delivers GSM/GPRS 900/1800MHz performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption. With a tiny configuration of 24 mm x 24 mm x 3 mm, SIM900A can fit in almost all the space requirements of applications, especially for slim and compact demand of design (Yoo & Shaik, 2016).

2.1.14 L293D Motor Driver

L293D is a quadruple H- bridge motor driver, as the name suggests it is used to drive the DC motors. This IC works are based on the concept of H- Bridge. H-bridge is a circuit which allows the voltage in either direction to control the motor direction. There are 4 input pins for L293D. Motor's directions depends on the logic inputs applied at these pins (Asyali et al, 2011). EN1 and EN2 must be high to drive the 2 DC motors as shown in Figure 2.17.

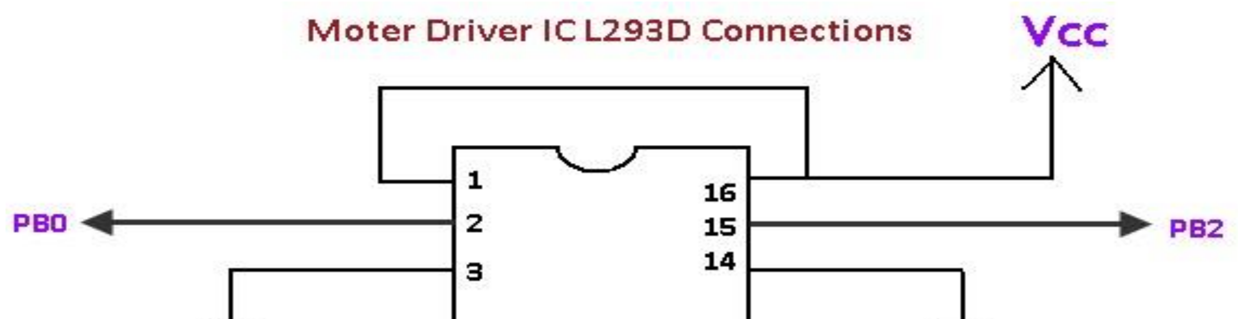


Figure 2.16: The Motor Driver IC L293D Connections. (Asyali et al, 2011)

In the circuit of figure 2.18, R1, S1 and C3 form a debouncing reset circuitry, while C1, C2 and X1 are related to the oscillator. Port pins P1.0 and P1.1 are connected to the corresponding input pins of the L293 motor driver. The motor is connected across output pins 3 and 6 of the L293. The software is so written that the logic combinations of P1.0 and P1.1 controls the direction of the motor. Initially when power is switched ON, P1.0 will be high and P1.1 will be low. This condition is maintained for a preset amount of time (around 1S) and for this time the motor will be running in the clockwise direction (refer the function table of L293). Then the logic of P1.0 and P1.1 are swapped and this condition is also maintained for the same duration. This makes the motor to run in the anti-clockwise direction for the same duration and the entire cycle is repeated. The Microcontroller (8051 chip by ATMLE Corp.), L293DNE (16 pin motor driver), DC motor (here, a geared motor is used), 9V battery, 7805 Voltage regulator, Crystal 11.0592 MHz are the components in this circuit.

L293D is a motor driver. As its name suggests it can drive a motor (normally DC motors up-to certain range). Since the output voltage of 8051 is limited to 5V only thus motors with higher required voltage need some drivers to provide them their desired input voltage. What L293D does is, it takes the TTL (0/5v) input from the output pins of microcontroller and forwards the output through itself of higher voltage (required by DC motors). Connecting a DC motor directly to the pins of 8051 would not work. It may even damage the microcontroller (Asyali et al, 2011).

L293D is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It means that two DC motor can be controlled with a single L293D IC. The L293D can drive small and big motors as well. It works on the concept of H-bridge. H-bridge is a circuit which allows the voltage to be flown in either direction. Notice that voltage need to change its direction to be able to rotate the motor in clockwise or anticlockwise direction, Hence H-bridge IC are ideal for driving a DC motor (Asyali et al, 2011)

There are two Enable pins on L293d. Pin 1 and pin 9, for the motor to be to driven, the pin 1 and 9 need must set high. To drive the motor with left H-bridge, pin 1 need to be enabled to high. And to achieve right H-Bridge the pin 9 must be made high, but if either pin1 or pin 9 goes low, then the motor in the corresponding section suspends working. It's like a switch. There are 4 input pins for this L293D, pin 2, 7 on the left and pin 15,10 on the right. Left input pins will regulate the rotation of motor connected across left side and right input for motor on the right-hand side. The motors are rotated on the basis of the inputs provided across the input pins as LOGIC 0 or LOGIC 1. Simply, there is need to provide Logic 0 or 1 across the input pins for the motor rotation. Let's consider a Motor connected on left side output pins (pin 3, 6). For rotating the motor in clockwise direction, the input pins have to be provided with Logic 1 and Logic 0 (Asyali et al, 2011).

• Pin 2 = Logic 1 and Pin 7 = Logic 0 | Clockwise Direction

• Pin 2 = Logic 0 and Pin 7 = Logic 1 | Anticlockwise Direction

• Pin 2 = Logic 0 and Pin 7 = Logic 0 | Idle [No rotation] [Hi-Impedance state]

• Pin 2 = Logic 1 and Pin 7 = Logic 1 | Idle [No rotation]

In a very similar way, the motor can also operate across input pins 15, 10 for the motor on the right-hand side. VCC is the voltage that it needs for its own internal operation 5v; L293D will not use this voltage for driving the motor.

For driving the motor, it has a separate provision to provide motor supply VSS. L293d will use this to drive the motor. It means if a motor is to be operated at 9V then there is need to provide a Supply of 9V across VSS Motor supply. The maximum voltage for VSS motor supply is 36V. It can supply a max current of 600mA per channel. Since it can drive motors Up to 36v, the use of L293D will enable it drive big motors. VCC pin 16 is the voltage (in this case 5V) for its own internal Operation (Asyali et al, 2011).

2.1.15 H-Bridge Circuit

The name "H-Bridge" is derived from the actual shape of the switching circuit which control the motion of the motor through the motor driver (L293D). It is the circuit in which l293d IC shown in figure 2.17 is mounted. It is also known as "Full Bridge". Basically, there are four switching elements in the H-Bridge as shown in Figure 2.18. The H-bridge is connected to p1.0 and p1.1 of the 8051 microcontrollers, if p1.0 is low and p1.1 is high, the transistors Q2 and Q4 will be biased and allow the flow of current from the Vcc through Q4 to Q2 and then to ground, there by rotating the motor in the anticlockwise direction (Asyali et al, 2011).

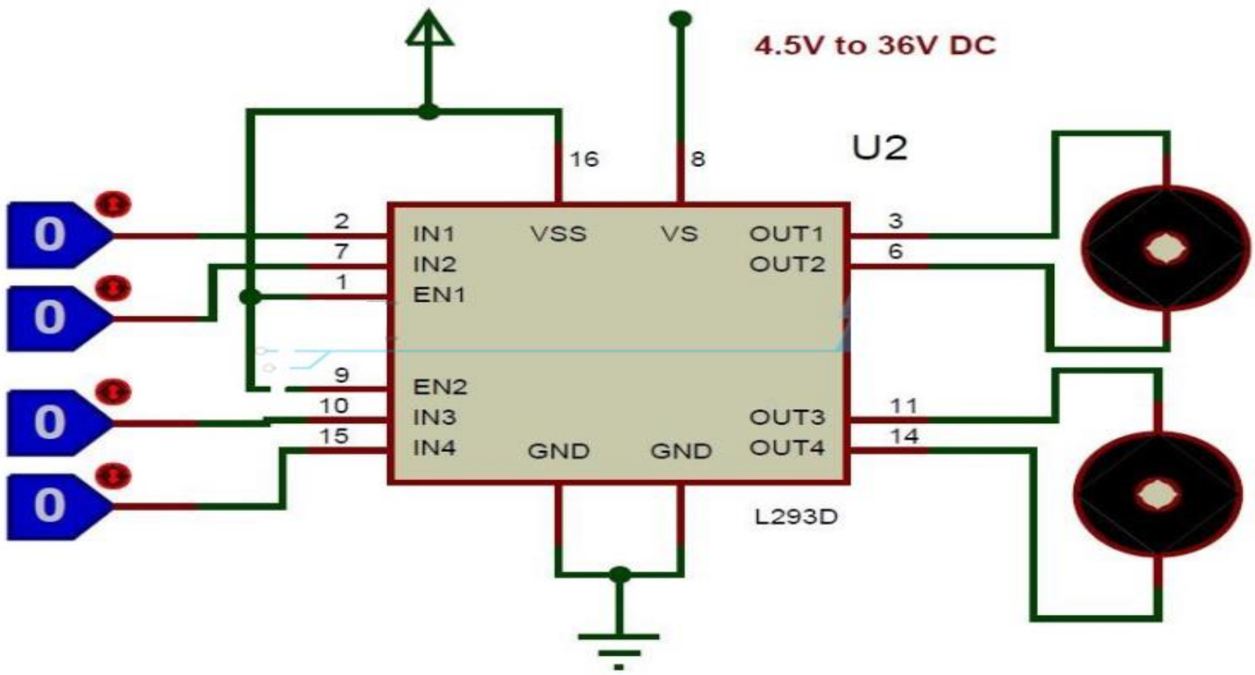


Figure 2.17: Modified H-bridge Circuit (Asyali et al, 2011)

If p1.0 is high and p1.1 is low will be bias, Q1 and Q3, thus allowing the collector current to flows from the Vcc through Q1 to Q3 and then to ground, there by rotating the motor in clockwise direction as shown in the diagram below. The above H-bridge circuit is applicable only when the dc motor voltage is only 5v, however in the situation where by the dc motor voltage is greater than 5v, the above H-bridge circuit is modified (Figure 2.18).

The above circuit is also made up of four transistor H-bridge. To run the motor in one direction, Q5 and Q8 are turned ON and Q6 and Q7 are OFF, the left side of the motor is at 12v and the right side is at ground. And hence the motor will rotate clockwise direction. To reverse the direction of rotation of the motor, Q5 and Q8 are OFF and Q6 and Q7 are ON, this will rotate the motor in anti-clockwise direction (Asyali et al, 2011).

2.1.16 Microsoft Visual Studio 2010

The Microsoft Visual Studio 2010 is an Integrated Development Environment (IDE) that is used to create software applications that may vary from windows forms, up to web services. It includes a code editor where the program code was created, debugged, compiled, and run. In the software program used in the system, the source code was written in Visual C# Language (Rommer et al, 2011).

2.1.17 C# Program

The C# program is object-oriented software that can be used for serial interfacing. The PC Software at the SHRAC unit is a C# program. It provides the overall logic of the software utility, manages the serial data between the PC and the Microcontroller, and allocates control signals.

A C# program can be used as windows applications, web applications, web services, business-type applications, mobile apps, games, and other software utilities. It uses the full capability of .Net Framework Class Library which consists of pre-built components (Rommer et al, 2011).

2.1.18 .Net Framework 4.0

The .Net Framework class library comprises of thousands of pre-built functionalities that can be used in software applications. Some of its features may include but not limited to ADO.NET for database applications, Windows Forms for desktop user interfaces, and Web Services for web applications. The .Net Framework is a pre-requisite for the SH Software Utility Program in the SHAC unit of the system design (Rommer et al, 2011).

2.1.19 8051 Microcontroller Development Environment (Sitompul & Sihombing, 2018).

The Arduino Development Environment is the software used for developing sketches (Microcontroller programs) and their compilation and upload to the Microcontroller hardware. This development environment has a text editor for writing source codes, a text console for simulation testing, message area for serial data output, and different tools with several functions. The codes supported by this environment are written in C language.

2.1.20 VoiceGP DK-T2SI

This is a Software Development Package for VoiceGP Modules. It includes all the software tools needed to develop voice recognition capabilities on some applications. This development package includes the VoiceGP IDE, FluentChip Technology Library, QuickSynthesis, and Sensory's QuickT2SI Lite. The VoiceGP IDE is used to develop the program logic of the VoiceGP module and involves all functions, decisions, and operations of the VoiceGP module. The FluentChip Library consists of important files in VoiceGP software development. The QuickSynthesis involves synthesizing audio for integrating them in the VoiceGP program. In the design, the .wav files (voice responses) are processed in the QuickSynthesis tool in order to use them in the program. The QuickT2SI Lite software, on the other hand, is used to integrate easy speech recognition commands to the VoiceGP module. QuickT2SI (Text-to-Speech-Independent) allows the user to program customized speech commands, with its corresponding stresses and sounds, and create resource files that can be used in VoiceGP IDE (Rommer et al, 2011).

2.1.21 Sketches

The software written by 8051 development software is called a sketch. A sketch provides the logic of the program embedded in the Microcontroller. Written in C language, it dictates the overall flow of the system, distributes decisions and controls, and manages the data resources (Rommer et al, 2011).

2.2 Review of Related Works

This section presents a review of various research works done in the area of smart homes and the related areas. In the related works, areas of knowledge and recognition models are summarized, while principal focus is on the application of such models to human behavior and especially to the accurate monitoring of activities of daily living in smart homes.

2.2.1 Home Automation

Home Automation (HA) is achieved from Building Automation (BA). BA has been a research field for the many decades and has contributed with many standards, theories and technologies, which have been published and commercialized (Mohamed & Ahmed, 2014). Throughout the years building automation has developed from performing simple controlled functions such as regulating the heating, ventilation, and air conditioning to handling the changing needs throughout its lifecycle (Sauter et al, 2011). BA covers an umbrella of network and computerized technologies that are integrated into commonly available building management systems (Mohamed & Ahmed, 2014; Sagi et al, 2012).

In this Information and Communication Technology (ICT) era, the home automation systems have developed in a pragmatic point of view as a residential expansion of the building automation area (Turner, 2011). The purpose of home automation is to ease life for its occupants by controlling mundane functions such as light, ventilation, heat and appliances to improve comfort, convenience, and energy efficiency in the automated homes. This is performed in a non-autonomous way by adding simple remote controlled, timer based and pre-programmable functions (Lynggaard, 2013).

Examples of remotely controllable domestic activities could be heating, lighting, houseplants, entertainment systems, pet feeding, yard watering, and controlling different kinds of domestic robots such as vacuum cleaners. This is a research area in focus today where researchers look into optimizing and maturing the technologies for bringing them into general use (Sagi et al, 2012; Liutkevičius et al., 2011).

The smart home area emerges from the technologies researched and developed in the home automation area and the building automation areas (Alam, et al, 2012; Martirano & Mitolo, 2020; Sagi et al, 2012). Thus, smart home is considered an extension of these (the home automation area and the building automation) areas where more advanced control features and autonomous behavior are added in the form of intelligence. In addition, it is stimulated by the Internet of Things (IoT) research area (Bandyopadhyay & Sen, 2011). The Internet of Things (IoT) research area provides context awareness, processing capabilities, and communication possibilities to physical things in general. Whereas the smart homes area is a subset of this dealing with homes only; however, the technologies and functionalities are developed in the IoT area. Currently, many drivers are fueling this area, especially consumer, Ambient Assisted Living (AAL), entertainment industry, and green technologies (Alam, et al, 2012; Martirano & Mitolo, 2020; Apperley et al, 2011).

With rapid economic growth, living standard are also rising day by day. The modern society wants safe, economic, comfortable and convenient life which is ideal for every family. "Home automation is a very promising area. Its main benefits range from increased comfort and greater safety and security, to a more rational use of energy and other resources, allowing for significant savings. It also offers powerful means for helping and supporting the special needs of people with disabilities and, in particular, the elderly. This application domain is very important and will steadily increase in the future (Renato & Jose, 2000). HA refers to a residence that integrates technology and services through home networking to improve the quality of living. It is not a new term for the science society, but has been around for a significant time. Home automation includes mainly centralized control of lighting, temperature, appliances, and other systems to provide improved comfort, convenience, efficiency and security. For disabled and elderly persons home automation can be the substitute for institutional care.

(Maqsood, 2014) implemented techniques and provided a viable solution to realize home automation system which constitutes Bluetooth control via Android app development for in-house control and Global System for Mobile (GSM) Communication technology for mobile control using Arduino. (Cubukcu et al., 2015) has implemented speech recognition-based remote control of home devices (Adriansyah & Dani, 2014) designed a system able to monitor and control lights, room temperature, alarms and other household appliances. The hardware part mainly consists of a digital computer, an Arduino Uno board, Light Detecting Resistors, Temperature sensor (LM35), Liquefied Petroleum Gas (LPG) and Smoke sensor (MQ2), Temperature and Humidity sensor (DHT11), Webcam, and DC Motor, which are being discussed along with their specific functions.
Home automation allows the control of home appliances like door, light, fan, oven and so on. It also provides emergency system and home security. It enables the occupant to have more control of his home, and is facilitated by home automation that reduces human efforts and time saving (Naresh et al, 2013). Sadeque Reza Khan and Farzana Sultana Dristy presented an Android based control system which can maintain the security of home main entrance and also the car door lock (Reza et al, 2015). Aniket Yeole and co, represented the implementation and design of a secure RTOS based home automation system using ATMEGA where the important features like electrical appliances and sensors were connected to the board through the Input/output ports (Bramhankar &, Sapana, 2015). The Authors, B. Murali Krishna and co, presented a home automation system using Android Smart Phone to control an application. A Bluetooth module is connected to FPGA board to control the home appliances (Krishna et al, 2015). Home automation via remote access and its good features were offered by Satish Palaniappan, and co (Palaniappan et al, 2015). They specified GSM network as the candidate for this purpose. The system is available from all over the world to a user in real

time. The design and implementation of a low cost, tangible, flexible based device automation system depending on secure cell phone was done in (Nupur et al., 2014).

Lia Kamelia, and et al, proposed and produced a prototyped system called door locks automation system using Bluetooth-based Android Smartphone. (Kamelia et al., 2014). D.Jaya Sree and M.Jhansi Lakshmi presented the design of Home Automation System that replaced the existing electrical switches which status is synchronized in all the control system with low voltage activating method that provides more safety control (Jaya & Jhansi, 2014). A voice-controlled home automation system that uses an Arduino Uno microcontroller with smart phones for the operation was done in (Albakhait et al, 2019). Here, different design and home appliances such as different electric applications, which are controlled using Arduino UNO Microcontroller Based Home Automation System are presented. The system performs its function by controlling the DC motor speed and its direction, bulb, fan and heater using a smart phone application with Bluetooth wireless technology.

2.2.2 Smart Home System

Here, the authors (Ghazal & Al-Khatib, 2015) in their work stated that smart home automation system is increasingly used due to the wide manufacturer brands and various available technologies. From a social point of view, residents are admitted to smart homes for comfort, luxury, improving quality of life, and for providing security against intrusion and burglars. Secondly, home automation is achieved using a single controller, for monitoring and controlling of interconnected appliances such as lights, power plugs, HVAC system, humidity and temperature sensors, gas, smoke and fire detectors, audio, video and home theater as well as security and emergency systems. Smart homes are cheap, low-power, cost effective, efficient, and realize the automation of a variety of domestic appliances using a user-friendly interface as remote control or any other handheld device. Elderly, handicapped patients, and people with disabilities who have locomotion difficulty can benefit from this smart home to totally operate, with high performance, all appliances and devices from anywhere in the house. When a resident is living alone, the ubiquitous access becomes very important and it is realized by using XBee transceivers that maintain RF wireless communication between the remote control and the master control panel board

In their study, they designed a smart home that was intended in particularly to the elderly, handicapped, decrepit, cripple and disable people. It enabled these kinds of residents to control and operate an assortment of appliances. These attempts offered suitable system that provided solutions to be applied to impaired individuals.

The proposed system is specialized for pre-existing houses despite of its eligibility to be extended to new houses. The main idea is that the target persons, particularly the elderly, are living at home most of the time. Since the end users are constantly residing in their dwelling, the web server mode and the GSM mode aren't efficient while the conventional Bluetooth system that operates at 10 m may not cover all the domicile area. The concept of this suggested project is to use wireless communication using XBee transceivers (Krishna & Nagendram, 2012) that achieves the total control between the remote-control tool and the master main board. The latter is based on microcontroller commanding relays that toggle the current states of the appliances` switches.

Various technologies are offered by the e-home community and presented by the manufacturers starting from peculiar software installed on Laptops to dedicated applications on phone mobiles, android devices, and i-devices; from touch screen, keypad to apparatus supported by buttons and switches. In fact, the disabled people could find devices with touch screen control panel confusing and difficult to use. Therefore, they need a simpler remote control such as laser-engraved backlit buttons, some switches, and equipped with a LCD screen to display necessary notifications. To each command button is associated a warning LED light that visualizes the situation status of the corresponding appliance. All operations are governed by a microcontroller where the EEPROM memory gives the opportunity to lock the remote by means of pass code stored in its memory.

As previously mentioned, the proposed home is assumed to have pre-existing wiring which allows the user to use one master control board. Nevertheless, multiple master boards could be configured in order to group the variety of appliances according to location or types. However, the master control board is based on a microcontroller interfaced with an XBee transceiver module to ensure full communication between the remote control and its base. The microcontroller pins are connected to relays and sensors where the configurations of the On/Off functionality of the demanded appliances are performed according to conditions specified by input sensors.

The XBee transceiver module, Series 2, allows creating complex mesh networks based on Zig-Bee firmware. It allows a very reliable and simple communication between microcontrollers through serial port data transfer. The XBee features (2mW output, 120 m range, built-in antenna, 250 kbps max data rate, and 8 digital IO pins) are convenient for their purpose. Moreover, XBee is supported by point-to-point communication adequate for using one master board and corroborative also by multi-point network compatible for using multiple master boards. The configuration of XBee is simpler, if the remote control the connection to the XBee runs as a server, whereas that linked to master board runs in host mode. The XBee characteristics give immunity against interference from neighboring systems and avoid the interaction of closer systems which averts the interruption in their services.

The realized prototype is designed to control eight different appliances: home lights, garden lights, Heating, Ventilation, and Air Conditioning (HVAC) system, entrance lock door, security system, emergency system, heater, and houseplant watering. However, the system can be extended for larger number of operations. The relays (Figure 2.18) are considerably adopted to let the low power control signal generated by the microcontroller operate high power devices. The diode connected in reverse bias mode protects the transistor against inductive loads that can damage it due to their back electromotive force. Moreover, relays can be replaced by triac that can be suitably applied to control AC power elements such as motor speed control, light dimmers, and temperature control.

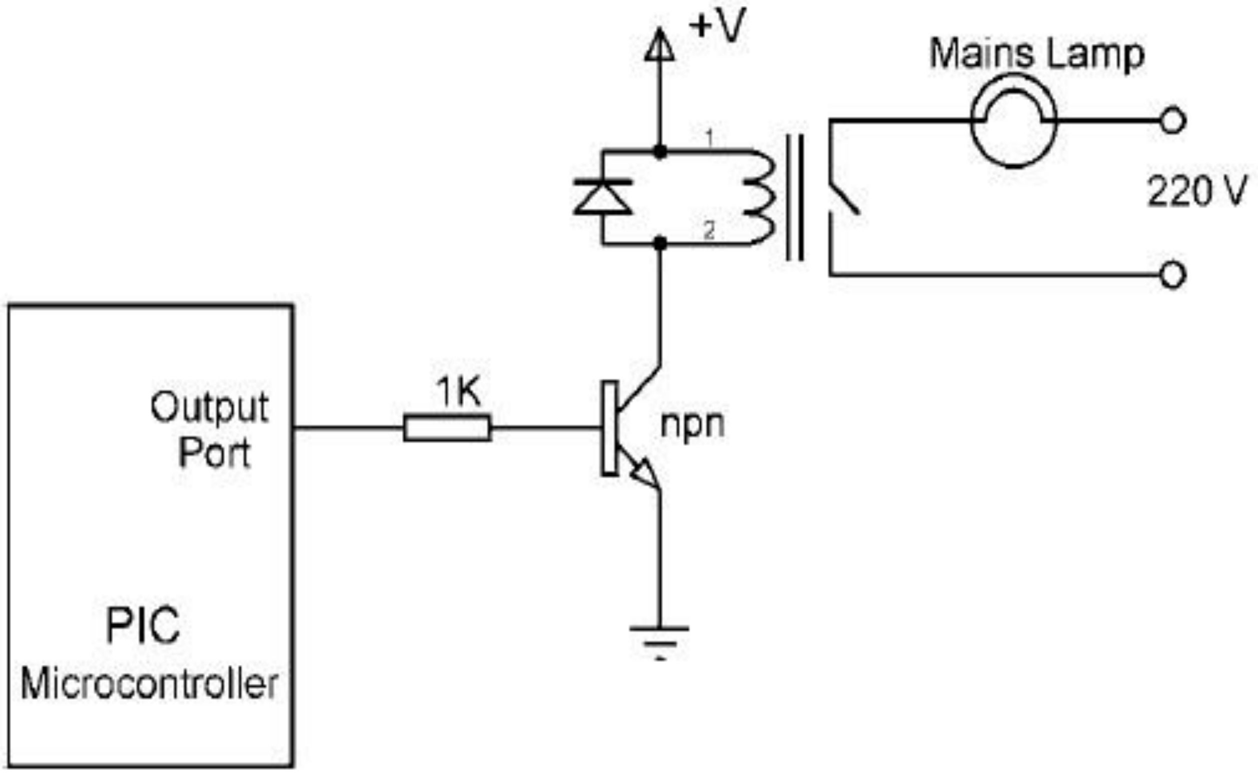


Figure 2.18. An Appliance On/Off Commanding Orders Using Relay (Ghazal & Al-Khatib, 2015)

The designed system is conceived by means of a remote-control device that sends orders wirelessly using XBee transceivers and by the master board that receives these command signals and activates appliances by triggering the associated electronic relays to achieve the ON/OFF functionality. The remote control consists of an LCD display for notification messages, many indication LEDs and eight command buttons for the different appliances, where each button corresponds to a specific appliance. Based on a social point of view, buttons are suitable for the categories of people that are intended to employ this system. Nevertheless, buttons could be replaced by touch screen devices for individuals that have an increase knowledge and familiarity with similar visual display screens. Whereas the master board is placed into a wall position in such a way that it will have the capability to reach the target appliances. Indeed, the remote control and the master board are intercommunicating to exchange information concerning which appliances are selected to be commutated ON or OFF, as well as the status of the selected appliances sent backward from master board to the remote control in the form of text messages. The XBee transceivers are picked out to ensure secure data exchange without interference and to be protected against intruders and hackers. In fact, the XBee configuration phase required the knowledge of some specific id code that realizes certain security levels.

The procedure of functionality of the home automation system specialized for elders and people with disabilities can be summarized by the following steps. When a button particular to a specified appliance is pressed, an alert LED assigned to this appliance is illumined and an alert message is shown on LCD. Moreover, the remote control sends RF command signals to the master board to be processed stored as new commands. Then, the master board processes the received signal, and the complete treatment will acquaint the microcontroller about the corresponding appliance and the associated pin ports from which the trigger signal should be initiated. When the switching circuit is activated by the microcontroller signal, it turns ON or OFF the appliance according to its previous status. Finally, the master board will periodically broadcast the elapsed time, the situation and the position of the appliances being worked upon and display them on the LCD of the remote controller.

The entire system was completely built by the authors using wooden home prototype and the home appliances were modeled by small fan and a group of lights. They tested the software to ensure that the program code does not include bug errors and produce unexpected results. However, the demo and the implementation of the system hardware realized validates their system design, and this shows that the complete operations are executed correctly. Home automation systems had progressively developed as an important field of control systems. The implementation of such systems continuously increased especially with the tendency to standardize their processes. In fact, one of the major importance of standardization is to make different kinds of devices produced from various manufacturers, capable to cooperate, communicate and function with high levels of harmony. More so, the standardized advanced processes and numerous techniques that were presented here, tend to reduce the prices of smart home, make integrated system simple, easy to handled, and to achieve permanent degrees of security (Ghazal & Al-Khatib, 2015).

Their proposed home automation system was dedicated to the elderly, people with disabilities, handicapped persons and others. It consists of remote control supported by command buttons and provided by alert LEDs and LCDs for showing messages. The unique master board toggles the ON/OFF switches of the appliances by means of relays. The remote control and its base communicate with RF signals realized by XBee transceivers.

Despite the authors designed a system for individuals that required less efforts to move, the system can as well be configured to accommodate other users by integrating multiple functions to various system models. However, it can also be adopted in hospitals, and health care centers. Besides the secure communications achieved by the XBee transceivers, another advantage of this technology resides in the characteristics of putting the system in sleep mode when it is unused for a period and then awaking it when commands are induced. This feature is of great interest since it ascertains an energy saving option and low power consumption. (Ghazal & Al-Khatib, 2015).

The authors in **(**Manisha et al., 2017), designed Home Automation System (HAS) to assist and provide support in order to fulfil the needs of elderly and disabled people at home. It has been designed for mobile phones having android platform, to automate Bluetooth interfaced microcontroller which controls home appliances like lights, fans. It presents the automated approach of controlling the devices in a household that could ease the task of using the traditional method of the switch. The most famous and efficient technology for short range wireless Communication-Bluetooth, is used here to automate the system has been around for more than a decade. In this project, a voice controlled wireless smart home system has been presented for elderly and disabled people. The proposed system consists of two components namely: voice recognition system, and wireless system. Android application has been used for voice recognition system. On the other hand, Bluetooth wireless modules have been used to implement the remote control.

Figure 2.20 illustrates the overall control function of the Home Automation System (HAS). This system was installed directly into the wall. A Bluetooth device helps to connect the device (Smart Phone) with the Graphical User Interface (GUI) wirelessly. An Android app is created to send the commands to Renesas Microcontroller through Bluetooth device. Input of the commands is voice based. Google text speech is used to give the voice input. Upon receiving the command, the microcontroller drives the motor driver to change the state of led or fan. An emergency switch is provided, if its state is changed, voice output will be played on the android device saying "It's an Emergency... Please Help!!" LCD displays the commands being executed by the microcontroller.

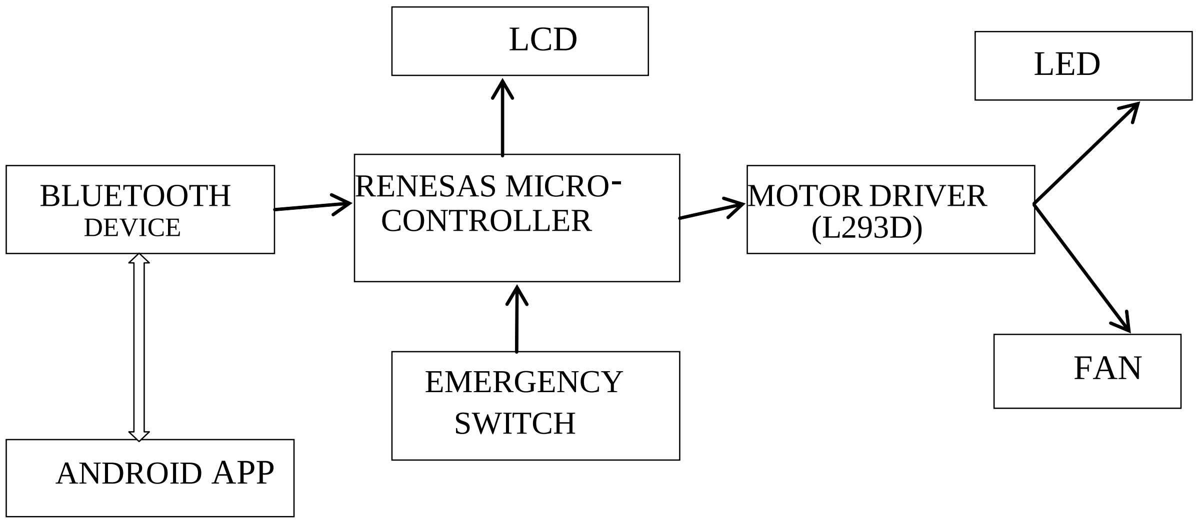


Figure 2.19: Block Diagram of Home Automation system (source Manisha et al., 2017)

This section discusses about the hardware construction of HAS. Figure 2.20 shows the circuit connection of Home automation system. The main control unit here is Renesas Micro-controller, R5F100LE which is used because it has serial interface features to establish Bluetooth connectivity. Renesas microcontroller auto generates codes for the chosen ports also, which is useful in coding. Renesas Microcontroller operates at 32MHz, and it is a 16-bit microcontroller, with Random Access

Memory (RAM) capacity of 4kb and input voltage of 12V, but for this microcontroller 5V is enough so a voltage regulator is used to cut down the voltage to the microcontroller required 5V level. It is a 64-pin microcontroller but the authors used only 58 pins, while the remaining other 6 pins were reserved.

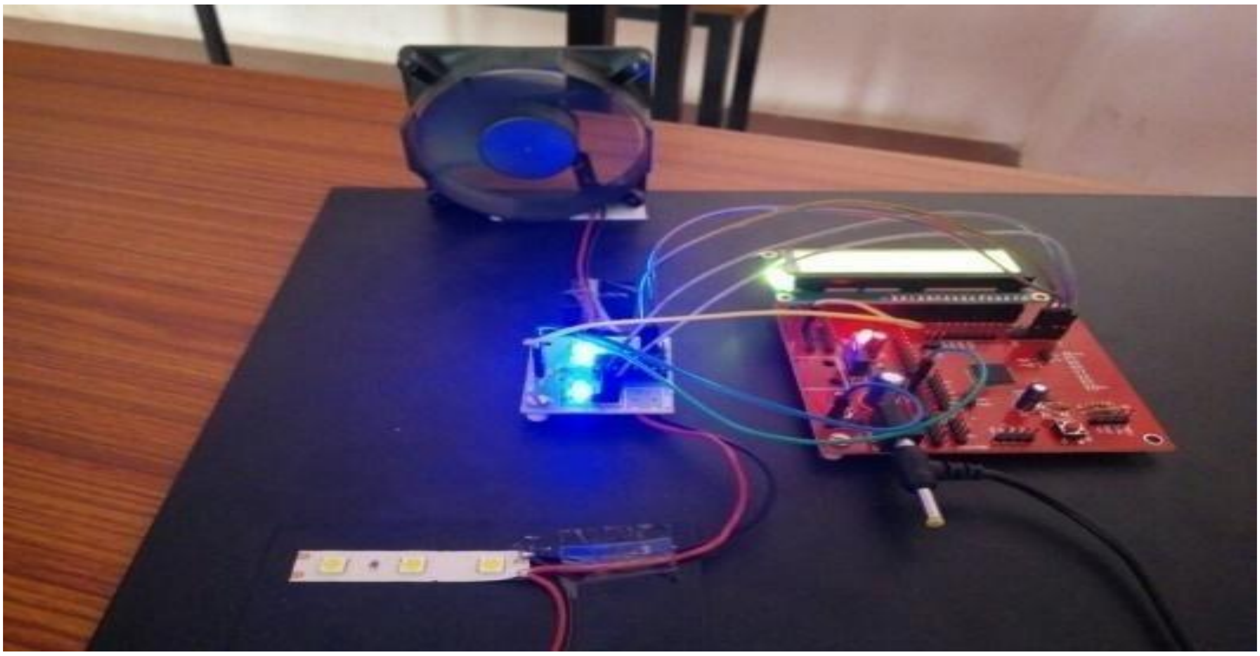


Figure 2.20: Circuitry for Home automation system (source Manisha et al., 2017)

For Bluetooth module HC-05 serial Bluetooth Module is used to establish connectivity between main control board and GUI. The Motor Driver (L293D) is an integrated circuit used to drive the fan and led light. It is used to vary the speed of the fan and control the brightness of the led light. It requires 12V and 5V power supply. It is a dual channel which controls two motors i.e., fan and led light with a single Integrated Circuit (IC). It uses 10 logics that is, if it is 1(high), fan and led light is enabled, if it is 0 (low), fans and Light Emitting Diode (LED) light are disabled. Liquid Crystal Display (LCD) is used to display the commands executed by the controller.

Light Emitting Diode (LED) is a semiconductor light source. This is used as a prototype for the lights present at homes. Using this one can control the brightness of the LED light through the commands. Central Processing Unit (CPU) fan is basically used for cooling down the CPU system.

In this regard, a prototype for the fans that were present at homes was made use of. When current is passed through the coil it creates magnetic field and the coil rotates which in turn rotates the fan. Emergency switch has three connections, for voltage, ground and to port. The initial value of the switch will be zero. If the switch state is changed to 1, a command is sent to the android app through Bluetooth which will give a voice output on the android app saying “It’s an emergency…please help”

The software design section includes the main functions of the system designed in the microcontroller and the GUI (Android). (Figure 2.21) The android app provides a login page which can be accessed by a particular user. After the login is successful Android Main Page appears (Figure 2.22). If Bluetooth is not enabled, a pop-up message will appear to enable the Bluetooth. After this, the Bluetooth module in the circuit is paired with the device Bluetooth and is connected. When input voice command is given, it is sent to the micro controller, which executes the command.

Figure 2.21: Android Login Page (source Manisha et al., 2017)

Renesas microcontroller is programmed through Cubesuite+ software. Ports are chosen accordingly and using the registers or buffers available, the program is coded. The program is compiled. After compilation a .hex extension file is generated, which is dumped onto the microcontroller. Upon receiving the command through Bluetooth, the functions written into the microcontroller are executed.

To dump the code onto the microcontroller NAND Flash was used through a software Flash programmer. NAND flash is a type of non-volatile storage that does not require power to retain the data. It can be electrically erased and reprogrammed. The advantage of NAND flash is faster to program and erase time.

Figure 2.22: Android Main Page (source Manisha et al., 2017)

Due to tremendous growth in technology and advancement in wireless communication, smart way of living has turned out to be a major part in the present era of human life. Design and implementation of home automation system using android for mobile phone has been discussed. The remote-controlled function by the smart phone provides help and assistance specially to disabled and elderly people. This proposed system has two main components namely a voice recognition system, and a wireless system. The Android application was used for voice recognition system. On the other hand, Bluetooth wireless modules have been used to implement the wireless system. Home automation application system was tested on various android mobile phones to ensure it error free. The Home Automation System furnishes a good paradigm for any automation system based on android mobile phone and Bluetooth, (Manisha et al., 2017). The system architectural block diagram is shown in Figure 2.23.

However, Sonali in (Sonali et al, 2015) observed in his research on an intelligent home system, that automation is a trending topic in the 21st century making it play an important role in daily lives. That the main attraction of the automated system is reducing human labour, effort, time and errors due to human negligence. With the development of modern technology, smart phones have become a necessity for every person as applications are being developed on Android systems that are useful to everyone in various ways (Sonali et al, 2015). Another upcoming technology is natural language processing which enables us to command and control things with voice. Combining all of these in this paper, a micro controller-based voice-controlled home automation system using smartphones was presented. Such a system will enable users to have control over every appliance in the home with their voice. All that the user needs are an Android smartphone, which is present in almost everybody's hand nowadays, and a control circuit. In his design, the control circuit consists of an Arduino Uno microcontroller, which processes the user commands and controls the switching of devices. The connection between the microcontroller and the smartphone is established via Bluetooth, a widespread wireless technology used for sharing data (Sonali et al, 2015).

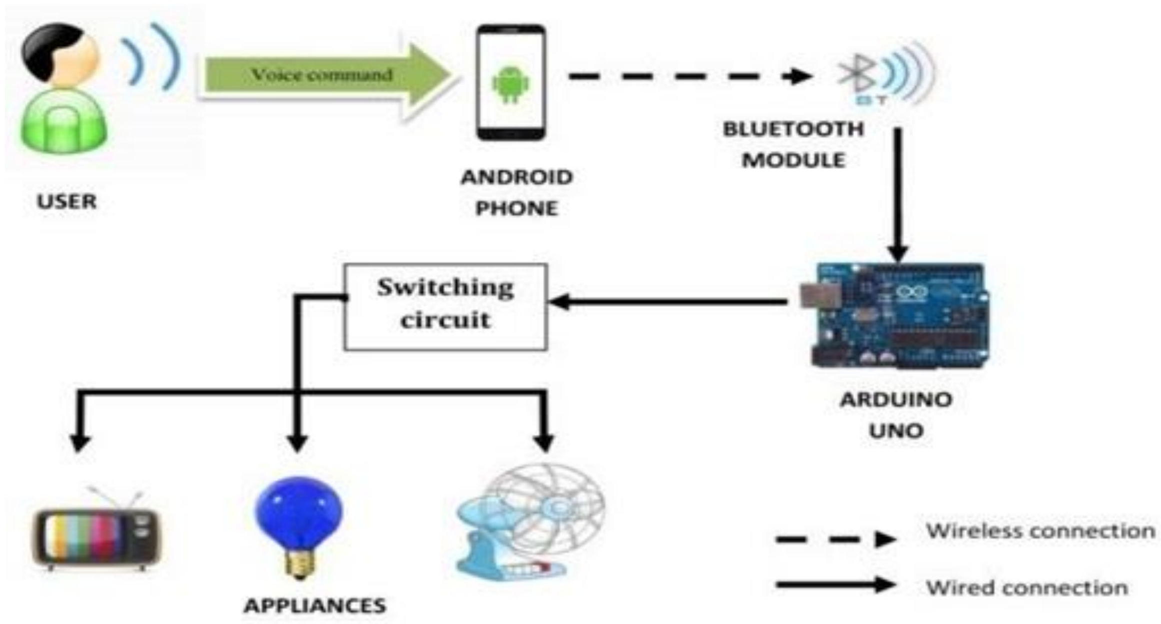


Figure 2.23: Block Diagram of the System (Sonali et al, 2015)

Android is a mobile operating system (OS) based on the Linux kernel and currently developed by Google. With a user interface based on direct manipulation, the OS uses touch inputs that loosely correspond to real-world actions, like swiping, tapping, pinching, and reverse pinching to manipulate on-screen objects, and a virtual keyboard. The Android platform was used because of its huge market globally and it's easy to use user interface (Yan & Shi, 2013). Applications on the Android phones extend the functionality of devices and are written primarily in the Java programming language using the Android software development kit (SDK). The voice recognizer which is an in-built feature of Android phones is used to build an application which the user can operate to automate the appliances in the house (Sonali et al, 2015). The user interface of the application is shown in Figure 2.24.

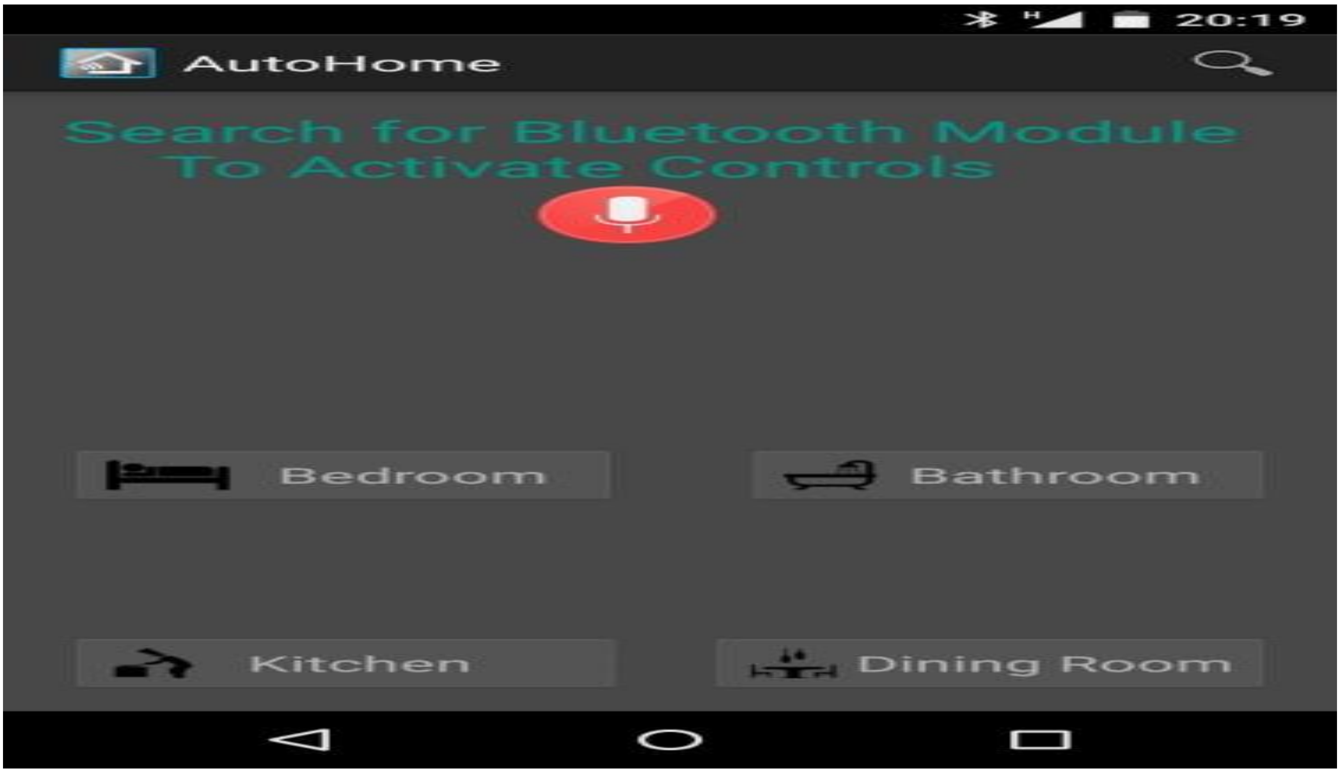


Figure 2.24: Interface for the Voice Control Application (Sonali et al, 2015)

The microphone button is tapped and the voice command is given to switch the corresponding device on/off. The voice recognizer listens and converts what is said to the nearest matching words or text. The Bluetooth adapter present in the phone is configured to send this text to the Bluetooth module on the Arduino Uno board that would in turn control the electrical appliances through the relay boards (Sonali et al, 2015). Using the above-mentioned components, the author implemented the proposed system on a breadboard. The microcontroller device with the Bluetooth module and relay circuit needs were attached with the switch board, and they then launched the android based application- “AutoHome” on their Smartphone. Through the application, the microcontroller is instructed to switch on/off an appliance. After getting the instruction through the Bluetooth module the microcontroller gives the signal to the relay board.

The application first searches for the Bluetooth device, and if it is available, then it launches the voice recognizer (Sonali et al, 2015). It reads the voice and converts the audio signal into a string. It produces a value for each appliance which will be given to the microcontroller device. The microcontroller uses the port in serial mode. After reading the data microcontroller device decodes the input value and sends a signal via Bluetooth module to the parallel port through which the relay circuit will be activated. In this work, a GSM module can also be attached to the work to enable the use of the applications anywhere mobile network is available. (Sonali et al, 2015) some images to illustrate the working of the system have been given in Figures 2.25 and 2.26, while the system operational flowchart is shown in Figure 2.27 below.

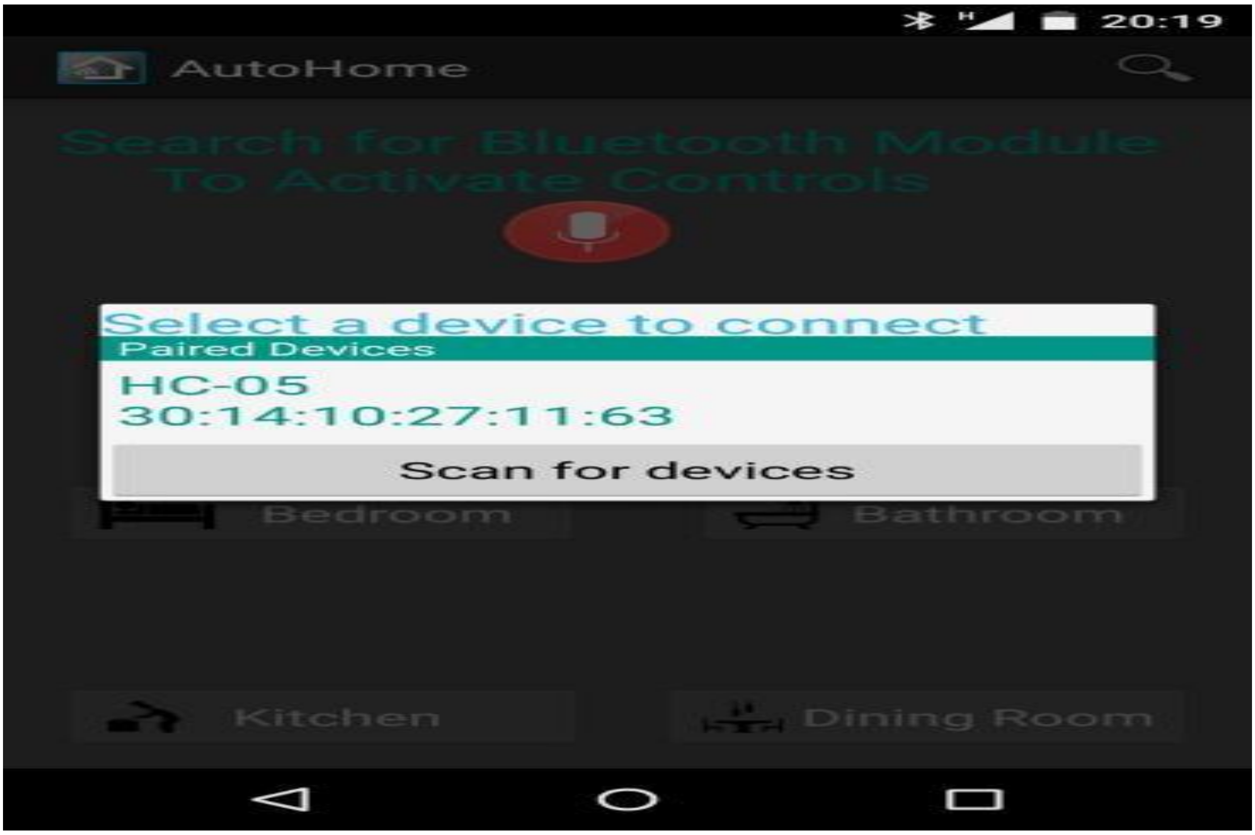


Figure 2.25: Application connecting to the Bluetooth device (Sonali et al, 2015).

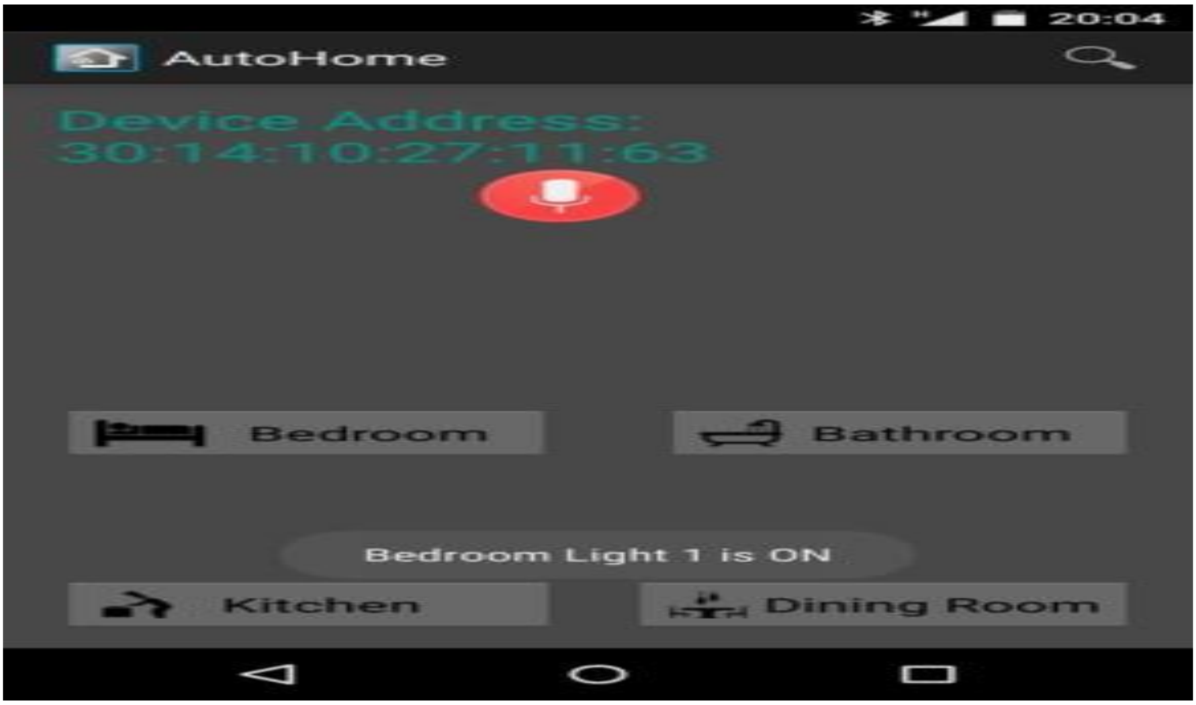


Figure 2.26: Turning ON Bedroom Light 1 (Sonali et al, 2015).

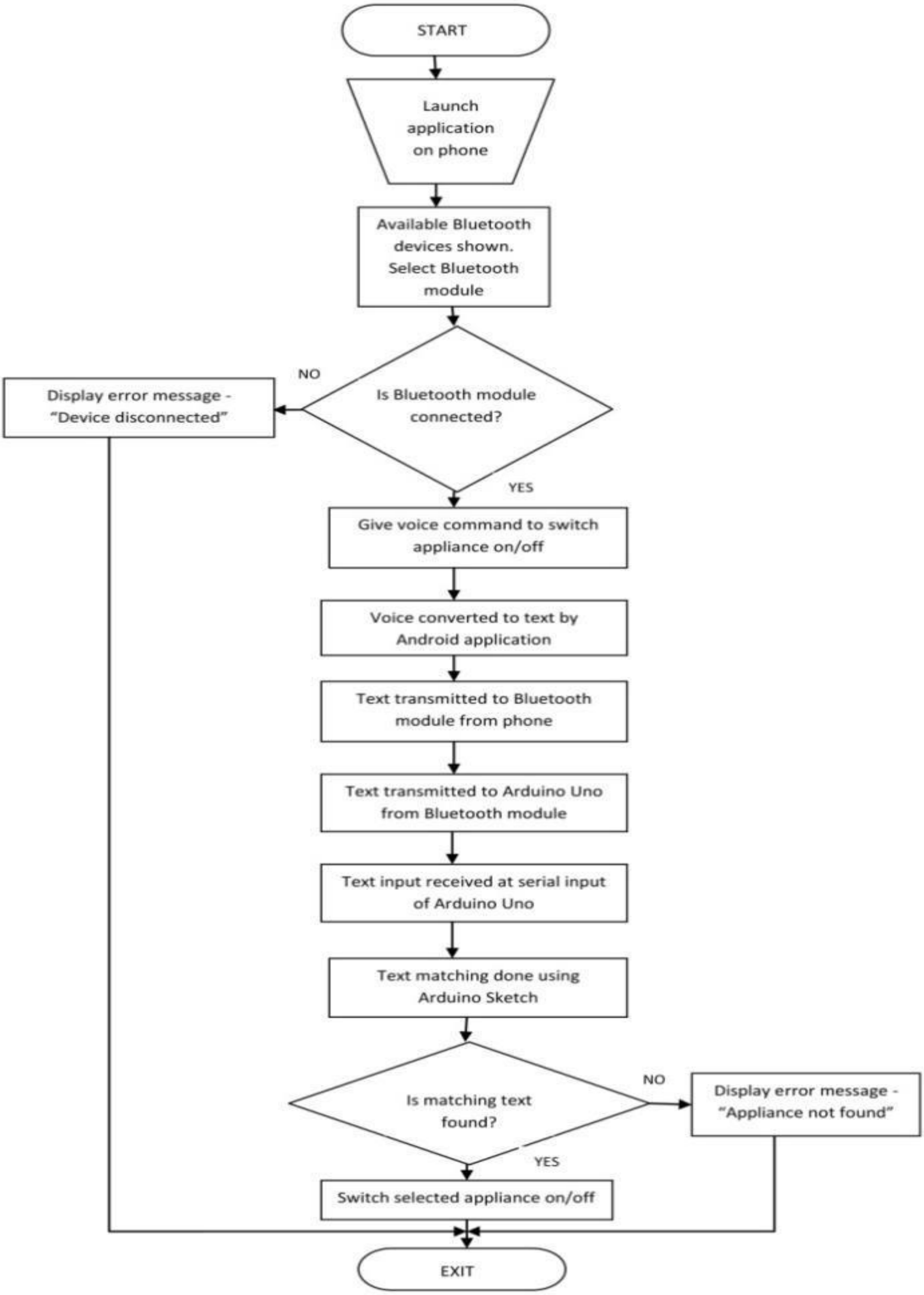


Figure 2.27: Flowchart of the entire system (Sonali et al, 2015)

The proposed project undertaken is a viable solution to the need of automation at the basic level in the homes. The project enables bringing of every appliance at home under control from a single point without having to get up and manually switch on or off the appliance (Sonali et al, 2015). The use of a Bluetooth module assists the use of this system from various locations in the house. The system is further simplified by allowing appliances to be controlled by the user`s voice. The user need not have to have to immense knowledge over the language of English. Just by saying the appliance name and the corresponding number assigned to that particular appliance, and telling it to switch on or off will enable the user to have complete control over any appliance without any effort (Sonali et al, 2015).

Android applications are very simple and user friendly allowing the user to understand its functionalities in very little time. Hence, the use of android applications in this system allows a user to easily learn the process and get accustomed to the functions. Moreover, the entire system is very flexible and scalable. Any number of appliances can be added as and when required. Hence, the systems find use not only in houses but also in many offices where appliances such as fans or lights on multiple floors can be controlled by a person on any of the floors, saving manual labour and human effort to switch on or off the electronic appliances, thereby saving time. This system, though primarily aimed to reduce human effort, will be of much importance to old aged people and physically handicapped people. It will enable them to control their home devices with ease, without going through much pressure or stress of moving about (Sonali et al, 2015).

Due to the inexpensive materials used in the construction and further cost optimization if the device is taken to the market, it finds application in a wide area. Scalability of the project would be considerably easier as the device can be used in every building using electrical appliances and devices (Sonali et al, 2015).

In addition, there have been many advertisements broadcasted are promoting awareness to switch off household appliances when not in use and thus save electricity. Hence, such a project would assist the initiatives taken by the government, as most people forget to switch off home appliances and are too lazy to return and switch it off, (Sonali et al, 2015).

2.2.3 Voice Recognition

Voice control method offers a more user interactive approach in delivering control commands (Ningqing et al., 2013). By applying speech recognition system, a system can be developed to help user control devices remotely. The voice control system for ZigBee based home automation has been introduced in journal of “ZigBee based voice Controlled Wireless Smart Home System”. Speaker independent automatic speech recognition technique has been used. In this system ZigBee network receives voice command as input to an ARM9 controller, which converts the data into a required format to be used in the microcontroller. Finally, the system generates some control characters to switch ON/OFF the home appliances (Obaid et al., 2014; Muthuselvi & Saravanan, 2014).

There are two types of speech recognition systems – speaker dependent and speaker independent systems. Speaker–dependent system is designed for a specific speaker that works by learning the unique characteristics of a single person's voice (Prabhakar & Sahu, 2013). It is also known as voice recognition. New users must first "train" the software by speaking to it, so the computer will analyze how the person talks. This system is useful as the security system. Speaker-independent systems on the other hand, require no training phase with data of users, and are desirable to many applications where training is difficult to conduct (McLoughlin, 2009).

The Microcontroller (Arduino) played an important role to integrate with Easy Voice Recognition (VR) Shield (Rani, 2014). The proposed system is using a speaker-dependent system to train the password command. In this project also using the password command rolled as the security of the system. Therefore, the usage of both boards can be used to develop a speech recognition system. The model of the system in Easy VR Module is Hidden Markov-based Model (HMM) Model.

Several models have been proposed in the literature to perform an efficient recognition of human behavior. The probabilistic theory was a widely used approach in dealing with the uncertainty of data collected from sensors. It provides a mathematical representation for degrees of belief. For example, (Yu et al., 2018) developed a Hidden Markov-based model to provide an automatic system for the detection of falls. The Hidden Markov-based model is used to detect falls based on data collection by motion sensors. The work highlighted the benefits of the proposed model based on the accuracy rate of detection. In order to build a pervasive environment, the recognition of Activities of Daily Living (ADL) is a key task. (Kabir et al., 2016) proposed a two-layer HMM to design an ADL monitoring system. The results showed that the two layers reach an effective recognition performance if compared to the conventional model. In (Liu et al., 2017), a hierarchical model was proposed to accurately detect the complex walking activities based on decision trees, random forest and HMM. The decision tree is used to detect the coarse-grained distinction of the human motion mode. The random forest is used to perform the motion mode of the fine-grained distinction. The HMM is used to obtain a robust walking recognition. The results confirmed the accuracy of HMM which performed 93,8% of accuracy. (Wang et al., 2016) proposed a new model named Sliding Window-based HMM (SW-HMM) in order to recognize the activities of daily living. First, a sequence of activities is divided into several fixed size, then, each sub-sequence is evaluated using HMM. The results showed that the performance of SW-HMM is better than the conventional model. (Kim et al., 2016) proposed a new model based on HMM, named HMM Ensemble (HMME), in order to recognize the humans' activities. The recognition of the human activities of daily living was achieved using smartphone sensors. If compared with traditional recognition activities models, the results showed the best performance of HMME regarding the recognition. The work discussed in (Liu et al., 2017) further stated a new model called Hierarchical Continuous Hidden Markov Model (HCHMM). The results showed that the hierarchical structure increases the performance of the activity recognition with a better performance regarding the accuracy with 93,18%.

Further recent techniques were discussed in support of independent living and ADL recognition (Yahaya et al, 2019; Elbayoudi et al, 2019). The approaches identify abnormalities activities by detecting any significant deviation from usual routines. The ability to adjust normality scores makes the proposed system more flexible (Yahaya et al, 2019). In a multi-sensor space, measuring the progressive trends in the person's behavior allows providing relevant indicators to health stakeholders (Elbayoudi et al, 2019).

2.2.4 Assistive Device Projects

The wheelchair project brings together researches into autonomous wheelchairs as well as from the area of dialogue management. Wheelchairs are rich and promising platform for intelligent agents and are being explored by many groups as a way to assist the aged individuals. Some of the significant researches that have been conducted in this area includes (Simpson, 2005; Sukerkar, et al, 2018) which addresses the application of techniques from robots to autonomous wheelchair navigation. The (Pires & Nunes, 2002), that dealt with autonomous wheelchair which uses a multilayer architecture with capability of navigation as well as obstacle avoidance. "This project addressed issues such as mapping, which includes equipping the environment with Infra-Red (IR) beacons to aid navigation and localization". The Sharioto wheelchair (Nuttin et al., 2001) focused its research on the robotic control of the wheelchair. The user directs the wheelchair via the joystick. The guidance system then attempts to infer the intention of the user using a Bayesian estimation approach to combine the environment information with the user input, and selects an action such as obstacle avoidance, passing through a doorway, or approaching a table. The Mihailidis (Mihailidis et al, 2007) used sensors to prevent a user from colliding with obstacles and issues voice prompts when potentially dangerous situations are detected. The Hephestus (Simpson et al., 2002); (Simpson et al., 2004) wheelchair project sought to develop a set of components to aid with obstacle avoidance and navigation on electric wheelchairs. The main goal was to develop these components in a way such that they could be applied to standard commercial wheelchairs with little or no modification to the chair itself, to allow a wider adoption of such system. Though, a wheelchair can be treated as a robot, it is necessary to take the human into account. The motion representation work with humans (Gulati & Kuipers, 2008) developed a smooth path for the wheelchair that is comfortable for the user. The results showed smooth motion in areas with tight clearance that might cause the robot to slow considerably or move sharply. The work (Taha et al., 2008) addressed the issue of the use of Partially Observable Markov Decision Processes (POMDPs) for robot navigation and user intention. In that work, POMDPs were used to construct a model of the environment and path planning. As the user provides input via the joystick, the system attempts to determine the destination of the user, and help navigate towards it. This system also estimates parts of the model through each individual user's experience. The Voice control motion system (Suryawanshi et al, 2013), early work on a speech-controlled wheelchair, was able to recognize only simple directional commands. However, this wheelchair provided no assistance with the navigation. The (Cesta et al, 2005) allowed the user to provide input directions via the joystick or a speech recognition. A combined user's directions with obstacle avoidance and wall following behaviors were achieved through a behavior-based approach. In their work (Demeester et al., 2006) introduced Bayesian estimation methods in their attempt to infer the intended path of the user. An attempt to estimate the user's desired goal based on the command issued and sensed environment, and the system attempts to account for the uncertainty in the user's input. The authors in (Mandel et al., 2005) directed their research on sensor fusion and landmark identification for mapping and navigation. Users here were able to control the assistive device through the standard joystick or the speech recognition. The speech interface used a semantic grammar to analyze syntactically by assigning a constituent structure to a sentence, that would however, resulted in a policy of mapping to actions and did not utilize a full dialogue model. In Aware Chair (Davis et al., 2003), the authors focused on capturing the user's context. The Aware chair attempted to predict the direction of the conversation to help determine the user's intention through examining the state of the environment, as well as the commands from the user. A POMDP interface was presented for wheelchair control (Doshi-Velez, et al, 2012), to bring together dialogue management, with wheelchair control.

(Vairavel & Nevetha, 2020) Hand gesture wheelchair system is trending nowadays for disabled peoples, hence, Vairavel and Nevetha in their paper, designed a hand gesture wheelchair system for a disabled person using the raspberry. This was useful for disabled persons who face difficulty in moving from one place to another in daily life. Normally wheelchairs are driven by the help of other persons or by one self. Various types of wheelchairs are constructed like the joystick control, eye control and head control systems. And in their proposed system, they used hand gesture for movement of a wheelchair by capturing hand gesture using a web camera, the wheelchair moves according to the numbers of fingers captured. The camera which is the input device to this system, captures the fingers of the user, and send image to the system, which processes and recognizes the number of fingers, and move the wheelchair to the required direction. That is, when one finger is captured, wheelchair moves left side, two fingers move right side, three-finger moves front side and four-finger it move backside (Vairavel & Nevetha, 2020). The main aim of their work was to implement an automatic wheelchair-using hand gesture reorganization.

However, (Jha & Khurana, 2016) also proposed hand gestures-controlled wheelchair. In their project, they developed a wheelchair system used for disabled peoples with hand gesture or movement of hand recognition by using MEMS technology. Embedded C programming was used to program this system. Microcontroller provides easy communication to receiver and transmitter, that tends to control the wheelchair by using MEMS technology. MEMS is used for detecting the tilt and it is also cost-effective system.

(Tatigutla, 2017) introduced a wheelchair robot using Raspberry Pi in their work the data are collected from the MEMS sensor or the android app. Here they also attached the touch screen and voice playback module to the wheelchair system. For any emergency, the user touches the touch screen in a specific area, then the voice playback module will play the voice message via the speaker. GSM module is interfaced to system enable the mobile device communicate to the controller. Here the obstacles are detected by the ultrasonic sensor and if any obstacles found it stops the wheelchair automatically.

(Sharath & Anusha, 2015) proposed gesture-controlled wheelchair normally wheelchair is not controlled by ourselves it is controlled by other persons. Here the wheelchair is controlled by hand gestures either by using head movement. The head gesture uses the accelerometer and for hand gestures touchpad is used. By using switch-mode operation the user can use both gestures. Based on the input the accelerometer senses the angular movement of head. The wheelchair movement is controlled by either using touchpad or accelerometer.

(Ilyas Malik et al, 2017) in his work on voice-controlled wheelchair system the main advantage of this paper is to control the wheelchair using the voice recognition sensor module. The user can control wheelchair movement by using their voice no other person needs help. The wheelchair movement is controlled by the dc motor and arduino controller and the obstacles are detected by the ultrasonic sensor, while the wheelchair is in motion, if any obstacle is found, the system will automatically stop the wheelchair. And the main aim of this system is to control the wheelchair using users voice recognition.

(Selvaganapathy et al, 2017) introduced Wheelchair for physically disabled people with voice & eye control in this system they used voice control and eye recognition for movement of wheelchair. The eye movement is recognized by the head camera and the wheelchair movement controlled by the dc motors. IR sensor is used to avoid obstacles while the wheelchair is in movement. Locomotor disabilities peoples can use this project.

(Tsui & Yanco, 2007) explored a visual interface for the manipulation of a robotic arm attached to a wheelchair. The LCD in front of the wheelchair display the current areas to enable the user select an object which is then gripped by the robotic arm. This interface was discovered to be faster and more comfortable than a menu-based system, and reduced the complexity of object recognition by allowing the user to narrow in on the object. Also (Felzer & Freisleben, 2002) used Electromyography (EMG) signals to control wheelchairs. Here, sensors were deployed to detect muscle contraction, then mapped into set of basic commands such as "left," "right," "straight," and "halt" after training with the subject. This interface is found to be ideal for users who cannot operate a joystick or speak. (Sharath & Anusha, 2015) developed as a gesture-based interface for input into a system. This is a text input system that relied on gross gestures, and the allowing users who lack fine motor control to input text by utilizing the advantage of touchpad edges. Experiments conducted on users, found this interface to be a comfortable input system for text entry and designating commands to the wheelchair.

2.2.5 Knowledge methods

A great effort has been devoted to identify techniques to effectively model human behavior in smart environments. Many techniques based on machine learning and pervasive computing were used to achieve a better prediction of human activities and scenarios. (Thanh et al, 2018) and (Abdelrahman and Wang, 2019) proposed a key-value modeling. This type of knowledge modeling is based on the simplest data structure to describe a given activity based on flexible units which represent sensor data. However, the capture of sophisticated context dimensions remains limited to capacities. To overcome the problems of the key-value methods, (Gargiulo., 2019) proposed the exploitation and integration of hierarchical structures into multi-label classification systems with the form of a Hierarchical Deep Neural Network (HDNN). On the other hand, other approaches used graphical modeling in the design step (Khattak et al, 2014; Laurenza et al, 2018). Unfortunately, such techniques are flat information models that are limited concerning interoperability in contextual systems.

Object-oriented modeling is another method used to represent context information by using programming principles such as abstraction, inheritance, and aggregation (Bidhandi et al, 2015). Despite the good performances of such techniques, they remain limited in regarding the interoperability issues. Logic based modeling is used to provide a clear and elegant semantics in the description of contextual information but it has yet to represent uncertain context and inflexibility regarding the user habits (Sanjari et al., 2017; Ferilli, 2014). (Hossain et al., 2017) proposed a cluster-based learning model for activity recognition in smart homes. They claimed that the model is better than the traditional active learning approaches in the discovery of new activities with optimal accuracy.

(Bae, 2014) used a model based on reasoning with an ontology for activities to design a knowledge base about the environment, and hence create a flexible recognition model.

To facilitate the recognition and tracking of human activities, (Liu et al., 2016) focused on human actions by using a classification of activities through temporal patterns. The work demonstrated the accuracy of the proposed model regarding complex activity recognition.

Wen and (Wang et al., 2016) built a general activity model with labeled data that suggests an online prediction by combining Ad-boost with graphical models such as Conditional Random Fields (CRF) to smooth out the outliers. Compared to supervised and semi-supervised models, higher recognition accuracy was demonstrated with a low amount of labeled data. An integration of a probabilistic model with ontologies was proposed in (Gayathri et al., 2017). Using the probabilistic reasoning, uncertainty of data was tackled. The proposed system showed an increase in the recognition of the activities through a Markov Logic Network model. A fuzzy logic model was combined with ontologies to overcome the challenges of classical ontologies-based approaches and in particular the uncertainty of data captured by a defecting sensor system (Bobillo and Straccia, 2016; Noor et al, 2020). To provide accurate recognition with a reasonable level of confidentiality, a fusion of collected data was applied in the context-aware reasoning for sensor-based applications.

2.2.6 An Able Old Population

The world's population is now ageing at an unprecedented rate according to (Bureau et al, 2009), especially in the developed countries of the world. This trend is observed worldwide. A report published by the U.S. Census Bureau in 2009 states that, in fewer than 10 years' time, the population of older people (aged 65 and over) will surpass that of children for the first time in history (Bureau et al, 2009). This report also states that the world's population aged 80 and over is projected to increase by 233 percent between 2008 and 2040, compared with 160 percent for the population aged 65 and over and 33 percent for the total population of all ages (Bureau et al, 2009). This report also claimed that the number of people over 65 will be 1.3 billion by 2040, 14 percent of the world's total population.

In comparison to other major world regions, Europe has the highest number of people over 65 years, with 14.5 percent of the population in Eastern Europe and 17.8 percent of the population in Western Europe aged over 65 years (Bureau et al, 2009). Records for 2008 show that Japan (21.6 percent), Germany and Italy (20 percent) are the countries with the highest percentages aged over 65 years (Bureau et al, 2009). The ageing population brings its own challenges to society as a whole, not least, financial. For example, solutions must be found that will reduce pressure on the health-care services by finding ways to assist older adults maintain independent living for longer period (Russo et al, 2004). Older adults are being encouraged to extend their working lives, thus reducing the cost of pensions. This is evidenced by recent government discussion of changes to the retirement age.

The demographics of the post-war (1939-45) period are currently impacting upon today's societies as the `baby-boomers' of this period reach retirement age (Mulvenna et al., 2009). This sustained increase in the numbers of older adults' places increasing economic, social and health-care pressures on existing services.

2.2.7 The Effects of Able Old People

The ageing process can affect an individual in various ways, some to a greater extent than others. It is common to observe declines in physical ability as well as cognitive declines. Cognitive decline is an inherent part of the natural ageing process ensuring that the number of cases increases steadily as the older population grows. Cognitive decline varies among individuals, affecting abilities such as perception, memory and planning. The most common physical declines occur in vision, hearing and motor control. As age progresses, the eye loses its ability to focus on close objects, caused by reduction in the elasticity in the lens. In addition to this, the lens of an eye thickens and yellows with increased age, thus affecting an older person's color perception. There is also a noticeable decrease in light sensitivity, which in turn affects adaptation to changes in light levels. Older people also are subject to an increased sensitivity to glare from light reflected into the eye. A reduction in depth perception which causes problems with judging distances can also occur (Becker & Webbe, 2006). Research conducted by (Fozard, 1990), concludes that age affects both the inner and outer ear thus affecting an older person's ability to hear sounds. A loss of sensitivity for high-frequency sounds is particularly common. According to (Fozard, 1990), the ageing process causes a reduction in the ability to differentiate between similar sounds occurring at different intensities or frequencies. (Howarth & Shone, 2006) found that older adults increasingly report difficulties with low frequency sounds and object localization. Older adults experience a reduction in motor coordination (Becker and Webbe, 2006). In general, older people take significantly more time than younger people when completing a movement (Chadwick-Dias et al., 2002).

2.2.8 Computer Interaction

In parallel with the increase in numbers of older people, is the increase in computing technology in all aspects of life. Many older adults are not adopting, and are not fully utilizing such technologies (Selwyn, 2004). Problems have been identified with usability and general engagement with computer technologies, and these are often exacerbated by the natural physical and cognitive declines experienced. Results have shown that older adults aged 70 and over tend to either `resist' new technologies or remain `hesitant' in its us-age. Older adults aged 60-69 tend to be more `pragmatic' about interaction with new technologies and are less likely to `resist'. They tend to use it

if they see a purpose in its use. Older adults differ significantly in their tendencies to adopt new computer technologies. Often older people don't engage with new technologies simply because they don't want to, some have a fear of technology, but often it is due to problems encountered with usability (Czaja & Lee, 2007; Eisma et al., 2003; Czaja et al, 2019; Zajicek, 2001). Eisma and the others conducted a study with 353 participants aged 50 and over to investigate their attitudes towards and usage of everyday technology. Questionnaires were used and the results found significant declines in the use of technologies with age, with the exception of telephones and televisions.
In their work, the authors in (Anghel et al, 2020) are of the view that the world is facing major societal challenges because of an aging population that is putting increasing pressure on the sustainability of care. While demand for care and social services is steadily increasing, the supply is constrained by the decreasing workforce. The development of smart, physical, social and age-friendly environments is identified by World Health Organization (WHO) as a key intervention point for enabling older adults, enabling them to remain as much as possible in their residences, delay institutionalization, and ultimately, improve quality of life (Anghel et al, 2020). In this study, they surveyed smart environments, machine learning and robot assistive technologies that can offer support for the independent living of older adults and provide age-friendly care services. They describe two examples of integrated care services that are using assistive technologies in innovative ways to access and deliver timely interventions for polypharmacy management and for social and cognitive activity support in older adults. they describe the architectural views of these services, focusing on details about technology usage, end-user interaction flows and data models that are developed or enhanced to achieve the envisioned objective of healthier, safer, more independent and socially connected older people. (Anghel et al, 2020)

Research conducted by (Selwyn, 2004) also supports the view that older people tend to be more willing to interact with computer technologies if they have a meaningful purpose to them. (Selwyn, 2004) states that older peoples' ambivalence toward computer technologies is often due to their perception of its limited relevance to their daily lives. The author encourages further work in this area to combat this. Gerontology is the study of ageing people and of the social, psychological and biological aspects of the ageing process itself.

Research has been conducted into understanding why technology is often unaccepted by target users. A study conducted by (Lee et al., 2003) examined Technology Acceptance Model (TAM) performance history and limitations and predicts its future trajectory. (Venkatesh et al., 2003) examined all existing TAM models and developed a new model. This new model was called the Unified Theory of Acceptance and Use of Technology (UTAUT) model and included demographic factors such as age and gender that had been omitted from previous TAM models. In a later study, (Arning and Zieffe, 2007) investigated users' attitudes and performance as they interacted with a computer simulated PDA device. This study included participants' ages, gender, their previous computer experience and their perceived technical confidence. The results found significant associations between the users' performance and the TAM model.

Research conducted by (Hanson, 2010) discusses a wave in the increase in digital products and services and highlights how those who do not use current technologies, particularly older people, could easily become excluded. (Hawthorn, 2007) state that this is largely due to two factors: a disinterest in such technologies by older people, and the fact that many technologies are simply not designed and built to accommodate the strengths and weaknesses of older people. (Hanson, 2010) conclude that these are problems that will not simply `go away' with the next generation of older adults, since the problems associated with age will still be apparent, as will the increase in newer technologies which must be `learnt', and those unable to engage with such technologies will quickly become excluded. (Hanson, 2010) recommends that further work be conducted which focuses on the strengths rather than the weaknesses of older adults, and remarks that if the needs of today's older adults cannot be met, then evidently, the needs of tomorrow's older adults certainly will not be met.

2.2.9 Designing for Older People

Smart homes are those built with automation to control appliances and monitor activities. One of the primary goals for smart homes is to guarantee comfort, control, and safety for the home residents, so smart homes accustom to user behaviour. To improve the safety of the elderly their daily behaviour is collected using IoT sensors and then modelled to detect any abnormal behaviour (Paudel et al., 2018).

Anomaly Detection System is a system that identifies both network and computer interruptions and abuse by observing the system's regular behaviour and comparing the data obtain from observations and then decides if the change in the other behaviour is ordinary or typical (Aran et al., 2016). Internet of Things (IoT) is the expansion of Internet network into physical regular devices. These devices are connected with each other over the Internet, and they can be controlled and monitored remotely. IoT is often also referred to as cyber-physical systems.

The basic architecture of IoT devices-based anomaly detection system consists of four layers: Perception Layer, Network Layer, Processing Layer and Application Layer. Perception layer comprises of different sensors, for example, infrared, RFID, and QR code for collecting data about the environment such ad pressure, humidity, and temperature (Ara et. al., 2015). These sensors collect the data to send it to the next level, while actuators receive control commands to perform specific actions. Network layer comprises of network communication software which is in charge of transmitting data procured from the sensors to different layers. The processing layer, called middleware layer, breaks down, stores and processes a tremendous amount of data. Numerous advances like cloud computing and big data processing work in the processing layer. These are the edge of IT systems. All needed pre-processing and analytics before entering the data center is done here. It’s the stage of analysis, management, and storage of data. Lastly, application layer gives the services to the user according to his necessity.

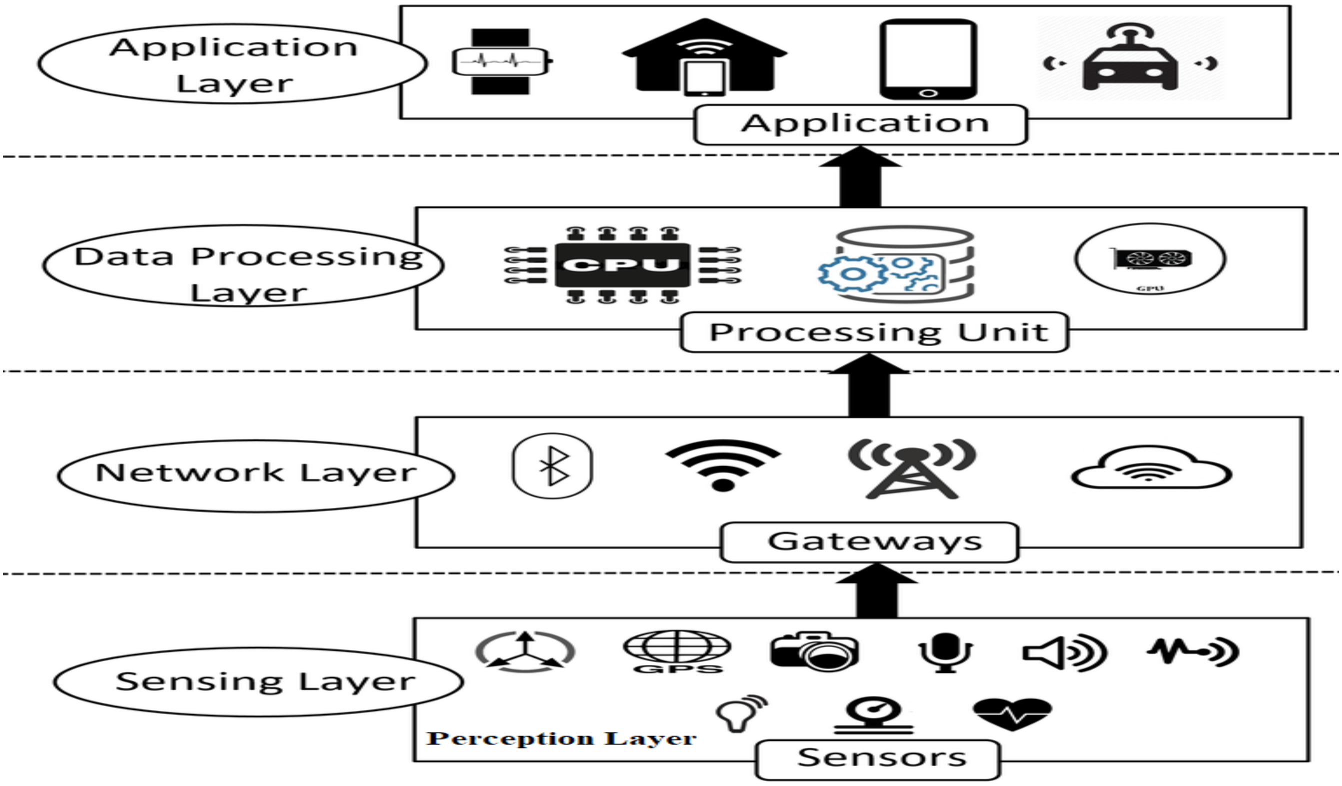


Figure 2.28: The basic architecture of IoT

However, each of these layers is prone to a set of potential attacks. For instance, one approach to monitor activities in order to find out the temporal, spatial, or behavioural anomalies is graph-based. A network graph shows the activities and their durations for a person and stores it for comparisons. If unusual trends occur, such as when a resident forgets the appropriate pattern of activities, doctors can guess whether a person is at the stage of forming cognitive disabilities (Paudel et al., 2018). Although advances in wireless sensor systems have empowered the observing of day-by-day activities of elderly people, many cyber-security attacks are expected as a result for these IoT systems being connected to the Internet (Hoque et al., 2015). From having the stored data disclosed to being hijacked and controlled remotely, these anomaly detection systems are not very reliable considering the multitude of possible security breaches they are exposed to.

In (Aran et al., 2016), the authors described how smart homes can promote elderly people with better health-care and social support services. They found that elderly people have a positive attitude towards the smart homes' implementations (Hsu et al., 2017). Moreover, elderly people were interested in the health monitoring system which can lead them to live independently. However, at the same time, they were having some concerns about the privacy of their data and the security provided by the smart homes (Pal et al., 2017). The researchers in (Pal et al., 2017) concentrated on answering the question whether the smart homes really have an influence on the elderly quality of life. Smart homes have helped elderly people to reduce the feeling of loneliness, helped them remembering their medicines and daily tasks, such as brushing their teeth and drinking water. On the other hand, Lê and Barnett in (Lê et al., 2012) said that elderly people shouldn't live in smart homes because of financial accessibility, acceptance and technical accessibility. Moreover, smart homes require a lot of technologies which are costly. Also, elderly people have a limited experience in dealing with advanced technologies. Boyanov & Minchev (Boyanov & Zlatogor, 2014) supported Lê and Barnett (Lê et al., 2012), they stated that although smart homes have many advantages, reliability of sensors, surveillance systems and misuse of personal or confidential information should be taken into account. Moreover, data could be modified in communication media by the attacker and sent to the cloud. Also, sensors are vulnerable to have attacks which can phase out the entire system. Finally, the attacker could read the data which is against the privacy.

In (Paudel et al., 2018) the authors explained how they will use a graph-based approach using the GBAD tool to detect anomalies of elderly patients living in smart homes without interfering with residents' daily activity, and to reduce the cost of healthcare associated with such situations (Paudel et al., 2018). The authors defined the anomalous behaviours to be the temporal, spatial, and behavioural anomalies. They proposed two hypotheses which claim that a graph-based approach can be reliable enough to detect anomalies of elderly patients in smart homes and discovered anomalies are possible syndrome of impairment in their cognitive abilities (Paudel et al., 2018). However, the aim of these anomaly detection systems is to help the patients' caregivers and clinicians monitor elderly people and raise the patient's' independence to be able to perform the daily tasks and routine safely. These systems are set up by installing sensors all over the home to gather data about the patients' activities without interfering with their routines. The authors' methodology was to collect data, convert it into graphs with nodes and edges to display temporal and spatial information about the patients, and finally use these graphs or patterns to clearly analyze their situations and discover anomalies. They concluded to the result of detecting anomalies from three participants who mostly had a temporal anomaly. Temporal anomaly is when someone takes longer or shorter time to carry out a specific task than the usual duration. Moreover, these may be potential indicators for having a decline in cognitive health (Paudel et al., 2018).

According to Aziz & Haq in (Aziz & Haq, 2018) IoT is widely functional to public activity appliances like smart homes. User security ought to be guaranteed by preventing illegal access since when an IoT layer is compromised, attackers can without a lot of effort get access to the whole system through that compromised node (Aziz & Haq, 2018) In addition, viruses, malicious software, and attackers can interfere with data and information integrity leading to risk for the whole IoT environment. In practical applications such as emergency, rapid response and traffic control, information collection must be fast and accurate. The research identifies the potential threats that may occur in all IoT layers. Perception layer attacks include Forged node insertion, malevolent code insertion, and Hardware

Jamming. Some security Challenges in the Network Layer are Denial-of-Service (DoS) attack, Sinkhole attack, and Man-in-Middle attack. Attacks on the processing layer include Primary infrastructure security, Data security in cloud computing, Threat to shared resources, and Attack on Virtual Machines. Engineers attempt to build up an application safe however its security stays under threat because of lower layers of IoT which is likewise the responsibility of the provider of the service (Aziz & Haq, 2018) In Application layer, attacks are malevolent code assaults, Software defenselessness, and Phishing attacks.

Arwa et al in (Aziz & Haq, 2018) discussed how fog computing is a promising technology for distributed computing providing many services to the edge network, yet faces lots of security and privacy problems in devices. Since IoT devices have limited resources regarding storage, battery, and processing capabilities, fog computing is new service that will provide a new solution for handling these real-time requirements which are not completely achieved by cloud computing (Sultana et al., 2014). The authors in (Aziz & Haq, 2018) explained how fog computing could also address many security and privacy issues as in the cloud computing. Because of the fog's service of filling the gap between the resource-constrained devices and the clouds or remote data centers, and due to its characteristics like supporting mobility, decreasing latency, location awareness, heterogeneity, and large scalability, many security issues could be introduced. The researchers summarized the major challenges of security and privacy in IoT environments such as encryption, trust, red node detection, confidentiality, access control, intrusion detection, data protection, and others (Aziz & Haq, 2018) Authentication is affected in IoT devices because of the lack of processing and storage capabilities in end devices. Such expensive computations and cryptographic operations are hard to be accomplished in IoT devices. However, trust is a critical challenge in the IoT devices due to the integration of sensors and actuators. Furthermore, some malicious nodes in the IoT environment could pretend to be a legitimate one and may misuse collected data or send wrong data for malicious purposes. Also, privacy is an inevitable challenge on remotely accessed devices. Regarding the IoT devices' inability to perform cryptographic operations on data before transmission, users' location and usage information is all vulnerable to attackers.

Another privacy issue is when attackers are able to expose and extract data that are meaningful when analyzed. Pattern-of-usage analysis violates the users' privacy when information generated by IoT devices is accessible by adversaries (Lin & Bergmann, 2016). Furthermore, access control is an important technique to ensure no malicious access can perform or generate malicious commands to any of the interconnected and resource-constrained devices. Intrusion detection on the other hand, is another challenge in widely interconnected mobile environments. IoT environment makes it hard to discover the misbehaviour or misuse of data. Moreover, data protection is a challenge in limited resource devices since data cannot be analyzed or processed in such a level. Data in IoT devices is sent to the cloud level for further analysis and hence, should be protected before and after the processing in the cloud. In order to improve their security, a new certificate revocation scheme is proposed in IoT built on fog computing (Aziz & Haq, 2018).

The authors in (Aziz & Haq, 2018) compared the most common methods for transmitting revocation data that is the Certificate Revocation List (CRL) with the OCSP (Online Certificate Status Protocol). CRL contains the black-listed certificates' serial numbers (Aziz & Haq, 2018). So, a client must download the list to know whether an intended certificate is in the list to be trusted or not. Similarly, the OCSP is a protocol that is used to get information about any digital certificate status. A client needs to submit the certificate's serial number to get a confirmation about the certificate if it has no issues. However, the authors proposed a solution to an efficient distribution of the certificate revocation information. The proposed scheme consists of the Certificate Authority (CA), back-end cloud, fog nodes, and IoT devices. The scheme uses a bloom filter in the fog nodes that stores the authorized certificates' serial numbers confirmed by a CA. After receiving a signed and updated CRL from the CA, the clouds forward them to the specific fog nodes. Then, a bloom filter that maps revocation information is created by the fog nodes, and then distributed to the intended IoT devices to verify the signature and store the information. To use it, an IoT device checks the bloom filter before any communication happens. If the certificate of the indented node to communicate with is not in the filter, the communication may begin. Security enhancement is provided by keeping the filter up-to-date, to avoid the risk of malicious use (Aziz & Haq, 2018).

In the recent years, smart homes have seen a tremendous rise due to the technology addiction. Smart homes were invented to improve the quality of life for all people, especially ordinary nondisabled people. The idea of smart homes is to save energy, control the lights, control heating and air condition, door locks and coffee makers while people are comfortable. However, people with disabilities will not be able to enjoy the benefits of smart homes devices. Controlling devices while sitting-down using smart technology is a good benefit for people who are physically disabled and older persons. To solve the problem of disabled people, the researchers in (Mtshali & Khubisa, 2019) discussed a control system based on smart home appliance for physically disabled people. In this paper (Mtshali & Khubisa, 2019), researchers presented a system that uses smart plugs, smart cameras and digital assistant, such as Google Assistant, Google Home, Amazon Alexa, or Apple Siri to take the orders by capturing the physical disabilities person's voice. Many manufactures have invented products that can interact with digital assistant, the proposed system in (Mtshali & Khubisa, 2019) will program those devices to let them act based on the voice commands.

Additionally, in (Karimi & Krit, 2019) the researchers studied threats, security requirements and open research challenges of smart home-smartphone systems. Smart homes become so popular in many people' life. Controlling the home with a click on a smartphone becomes an aim to a lot of people. However, data confidentiality, privacy and financial loss are the main concern. Existing smart homes have much vulnerability and many attacks have occurred on these systems. Therefore, these systems' security is a major problem that needs to be analyzed and solved. The researchers in (Karimi & Krit, 2019) have addressed threats that the systems have. Threats have been categorized into two: the first category is internal system threats, such as failure of home devices, power and internet malfunction, software failure and confidential data leakage. External system threats are the second category, it has denial of service, malicious injection, eavesdropping and man in the middle as threats. With the existing of all these threats, some security requirements have been suggested to increase the security level and minimize the threats exposure. Data encryption, network monitoring, user authentication could reduce the exposure of external threats while devices availability, physical protecting and devices authentication will play a major factor in decreasing internal threats.

The impact of technology on older people has been widely researched (Charness and Schaie, 2003); (Czaja & Lee, 2007) and a large body of literature has been gathered which offers guidance in the development of computer systems for older people (Czaja et al, 2019; Alm et al., 2004; Zajicek, 2001). (Zajicek, 2006) states that developing technologies for older adults is an exacting science, often varying from established Human Computer Interaction (HCI) research processes. (Zajicek, 2006) identifies certain areas in which this type of research differs significantly from other research disciplines. The requirements of older users are habitually disparate and researchers increasingly strive to find new methods of designing in this field. It is widely recognized that older adults who regularly use computers maintain an enhanced overall satisfaction with life and are generally more self-confident (Karavidas et al., 2005).

(Eisma et al., 2003) highlighted the advantages made by early involvement of older users in the design process. The authors describe some of the difficulties encountered when working with older people, and introduced the concept of mutual inspiration. Mutual inspiration is a mutually beneficial `exchange of information' between the older user and younger designer. Often, older people are unaware of the value of their own expertise and just how valuable their contribution is to the design process. The authors suggest that mutual inspiration will support and encourage the active involvement of older people in the development process thus producing more effective results (Eisma et al., 2003). (Hawthorn, 2007) echoes this sentiment, stating that new ways need to be found to accommodate older users. (Hawthorn, 2007) identifies two major issues: the distinct differences between the target users and the designer, and the difficulties older people encounter when interacting with `low-fidelity prototypes', and suggests that procuring useful design suggestions from older users would help to combat these difficulties. (Goodman & Eisma, 2003) stress the importance of investigating this user group so that they might be included effectively.

Further research, supported by the UK Research Councils as part of their `Digital Economy programs, is the `Social Inclusion through the Digital Economy' (SiDE) project (Gaye et al., 2010). SiDE began in 2009 and aims to create a centre of excellence in `Social Inclusion' which will focus on how technologies can be used to transform the lives of the `digitally disengaged'. SiDE is developing a 3000 strong panel of volunteers from people in a variety of age groups and with various disabilities which represent the many diverse types of target users. The panel includes many older adults, and also volunteers with various disabilities in vision, hearing, mobility, and cognitive or literacy issues which inhibit them in their interaction with current technologies. This panel will be involved in the design of research strategies and the evaluations of output to ensure that target users' needs are met by the research (Gaye et al., 2010).

(Elsaid et al, 2019) Internet of Things (IoT) technology is used to enhance the safety of the elderly living in smart home environments and to help their caregivers. The daily behaviour of the elderly people is collected using IoT sensors and then evaluated to detect any abnormal behaviour. In this research paper, they analyzed smart home-based anomaly detection system from a security perspective, to answer the question whether it is reliable and secure enough to leave elderly people alone in their smart homes. In this direction, they carried out comparative analysis of literature to identify the potential security breaches on all layers of an IoT device. Further, their proposed secure smart home model, was built using Cisco Packet Tracer to simulate a network of IoT devices in a smart home environment. Consequently, a list of security countermeasures is proposed to protect the IoT devices from the identified attacks (Elsaid et al, 2019).

Research by (Maciuszek et al., 2005) aims to contribute to assisting frail older people maintain independent living for longer, allowing them to `age in place'. The authors highlight that a better understanding of the design of Electronic Assistive Technology (EAT) applications by both target users and designers is necessary. To move towards this goal, (Maciuszek et al., 2005) conducted a field study into the settings of the daily lives of caregivers and the elderly to establish their needs and patterns. The findings of this study led to the construction of a design space which provides EAT designers with a tool for selecting and developing meaningful and useful EAT applications (Maciuszek et al., 2005)

2.2.10 Assisting Older People

Much research conducted into older people and computers tends to focus on assistive technologies and applications which help older adults with the activities of daily living, supporting health-care and independent living. Usability research involving older people has tended to focus on specific applications such as the Internet and email (Hanson et al., 2005).

2.2.11 Usability

Many assistive Internet based technologies exist which support and encourage the use of technology by older people. The Diadem project, which uses an expert system to monitor the interaction of users when attempting to interact with online forms and provides assistance with form access, completion and submission if required (Hanson et al., 2005). Also, Dickinson and co focused on the development of an email service specifically targeted at introducing adults aged 60 and over to the Internet (Dickinson et al., 2005). IBM developed `Web Adaptation Technology' as part of the `accessibility Works' project. This technology allows a user to adapt a website to suit personal preferences by magnifying the content of the website, and adapting the mouse and keyboard settings (Hanson et al., 2005). Changes made by the user are reflected on all websites accessed until the user specifies otherwise. The computer, called SimplicITy has a simple interface called `Square One' with just six buttons to access basic tasks such as email, file storage, web browsing and chat. The SimplicITy computer is built using Linux, is made-to order, comes equipped with 17 video tutorials, and can be ordered by post. The University of Dundee houses an interactive `User Centre', an environment where researchers and older adults meet for mutual learning (Forbes et al., 2009). This set-up is beneficial for both, supplying an opportunity to gain computer skills for older adults, while providing the researcher with a ready-made source of user feedback. The User Centre provides access to computers, laptops (Macs and PCs), printers, scanners, televisions and a Nintendo Wii with a Wii Fit board (Forbes et al., 2009).

2.2.12 Physical Assistance

Assistive technologies have been developed to support older people with household duties. The Smart Wave system was developed by (Russo et al., 2004) at the University of Florida. Smart Wave is a microwave-based cooking system which supports the older user in the preparation of hot, nutritious meals without the need to read cooking instructions or interact with the microwave buttons. Flo was used as a research platform to test various ideas for assisting older people such as intelligent reminding, data collection and surveillance. (Cest et al., 2005) conducted a RoboCare project in which they re-created a home environment equipped with sensors on mobile robots, and they utilized a PDA for user interaction in terms of a robot `remote control'. The robots responded to the users' requests for physical assistance and also acted as personal reminder agents. Living labs' are communal spaces where companies, councils, organizations and com-munities meet to mutually work together to develop innovative, assistive technologies. In 2006, a living lab called TRAIL was established in the University of Ulster to investigate the health issues of rural older people (Galbraith et al., 2008). The objective of TRAIL was to conduct studies to determine the health-related issues experienced by older people as they age in rural areas of Northern Ireland, and provide solutions to these issues to enable such individuals to maintain an independent existence in their communities for as long as possible (Galbraith et al., 2008). One TRAIL project uses Brain Computer Interfaces (BCIs) to act as tools to assist individuals with reduced communication abilities, resulting from injury or illness, interact with technologies. Another TRAIL project, called Night Optimized Care Technology for UseRs Needing Assisted Lifestyles (NOCTURNAL) supports older people in the early stages of dementia at night time by using light and spoken instructions to facilitate their independence at home (Galbraith et al., 2008).

2.2.13 Bluetooth Based Smart Home Automation System, ((Abdul, 2017)).

There are different methods in wireless technology such as Bluetooth, WIFI, and GSM. In this paper, new design and different home appliances are presented. Bluetooth Based Home Automation System using Arduino UNO Microcontroller is design and implemented. PWM technique on

Arduino is used to control the DC motor speed depending on the width of the Pulses and H-Bridge driver circuit is used to control the direction of the motor. The home automation applications that have been presented in this paper has the ability to control the DC motor speed and its direction, bulb, fan and heater using a smart phone application with Bluetooth wireless technology. The relays are used to connect these appliances to the input/ output ports of the board. The design is a low cost, flexible and using a modern technology and devices for this application. Application of wireless Bluetooth connection in control board enables a simplified way to system installation. The system has been built and operated successfully. Figure 2.29 shows the block diagram for the proposed system with some of home appliances.

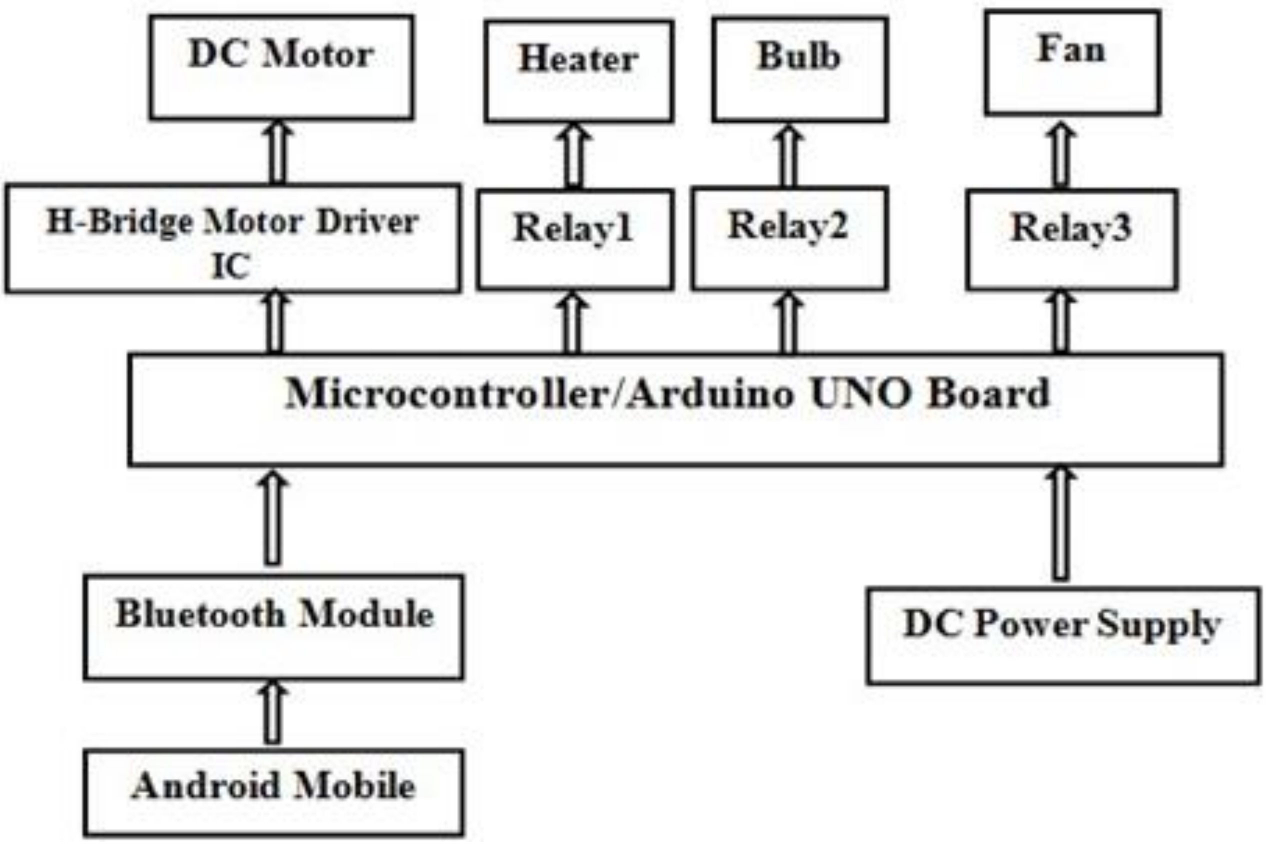


Figure 2.29: The Bock Diagram of the System (Abdul, 2017)

The H- Bridge motor driver IC (SN754410) allow controlling the direction of a DC motor with only one PWM output for controlling the speed. Relays (1, 2, and 3) is used to control the work of Heater, Bullb and Fan. Figure 2.30 shows the connections of Arduino board between these appliances and Bluetooth module. The Bluetooth simply is password protected, and by using Bluetooth wireless connection, the system is established on serial data transmission in order to facilitate on wireless communication. It also supports convey Android makes the mobile phone capable of offering system connection and control facilities.

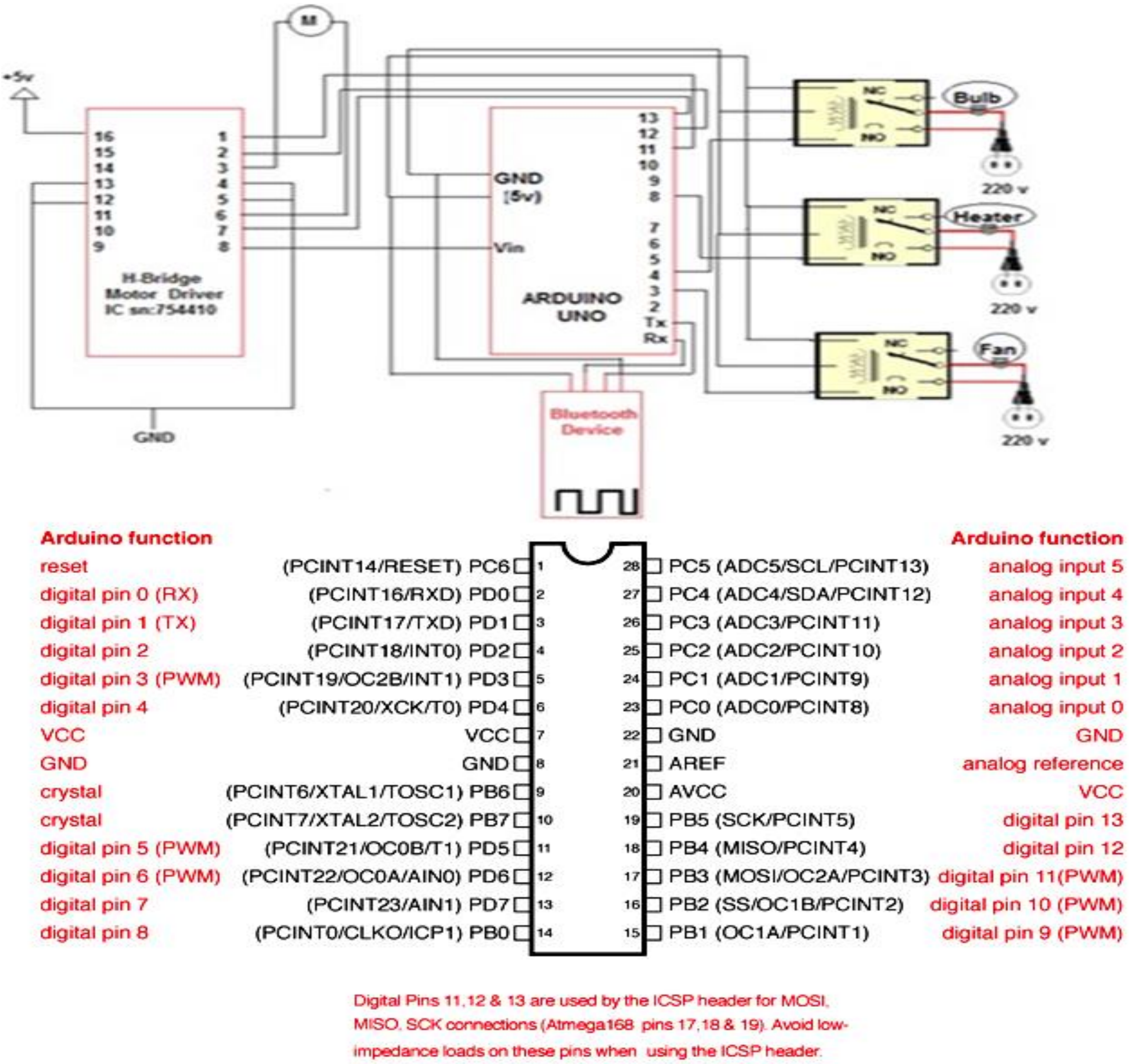


Figure 2.30: The Circuit Diagram with the anotations.

The system is integrated using Arduino Uno board, a HC-05 Bluetooth module, relays modules, an android device, and other electronic components. Figure 2.31 shows the system architecture of the proposed system which indicates the connection between the Arduino card and the peripheral devices which is Fan, Bulb, Heater and DC Motor. A connection between the Arduino Uno and the

Bluetooth module is required in order to enable the android to control the Arduino Uno. The VCC and GND pins of the Bluetooth module are connected to the VCC and GND port in the Arduino-Uno board respectively. Then connect the receiver of the Bluetooth module to the transmitter of the Arduino-Uno board and the transmitter of the Bluetooth module to the receiver of the Arduino-Uno board.

Using wires and connector blocks connect the positive end of the home appliance (e.g. Heater) to the normally open port in the relay module and the negative end of the appliance to a power source. Then connect the other port of the same relay module to the wanted Arduino-Uno port Apply the same for the other appliances only use different relays and different Arduino Uno Ports.

The SN754410 Quadruple Half-H Driver is an Integrated Circuit (IC) that allows the control of the direction of a DC motor. Pins 1, 2 and 7 from IC is connected to pins 11, 12 and 13 in Arduino, pins 3 and 6 in Arduino is connected to motor.

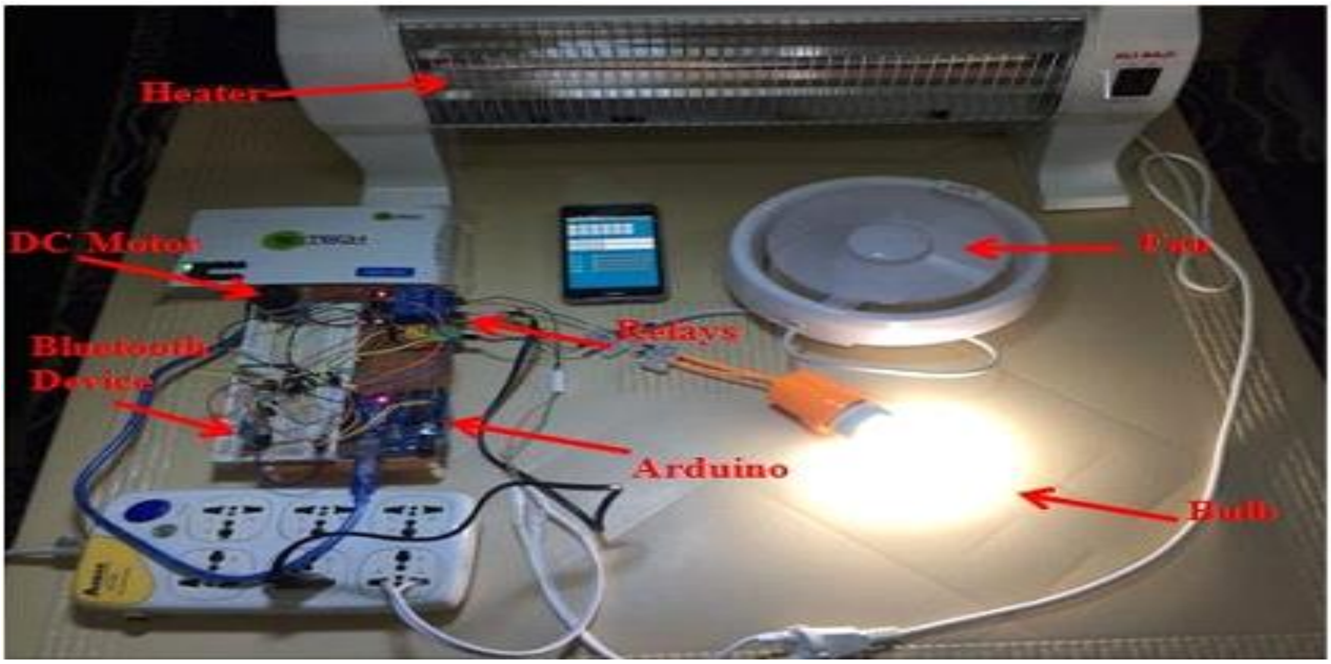


Figure: 2.31: System Architecture (Abdul, 2017).

The software is written in C-language for android applications and the flowchart as shown in Figure 2.32. At first checks if Bluetooth is already enabled on the phone, then the device will run. The software will check the devices stored in the phone's memory, also it stores the addresses of all the controller modules connected to Arduino, then the home appliance is chosen for the application. At last the signal sends to Arduino to connect it.

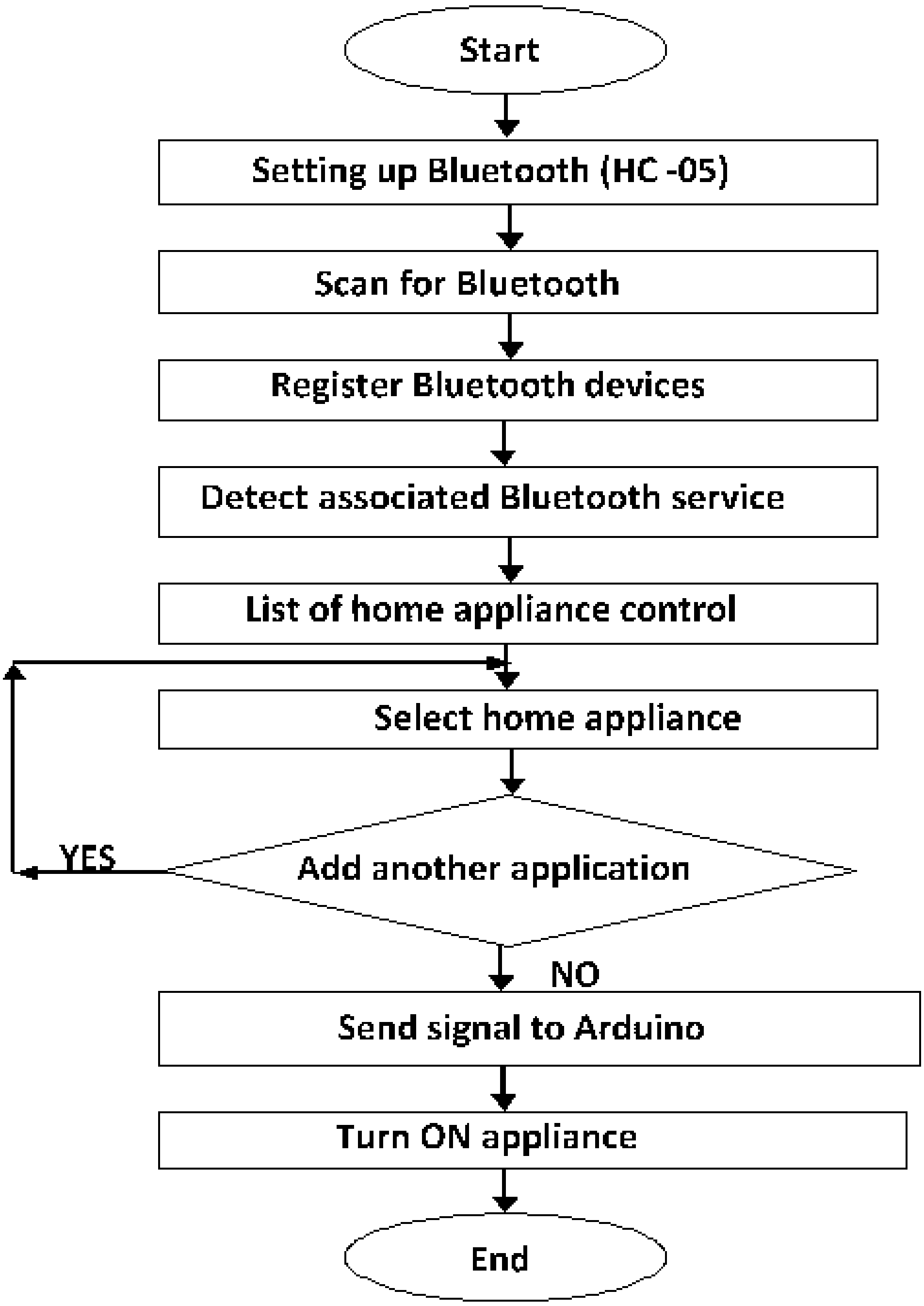


Figure 2.32: Program Flow Chart (source Abdul, 2017).

It can be concluded that Home Automation System using Arduino has been successfully designed and prototyped. This system consists of an Arduino Uno board, a Bluetooth Module, an Android phone, home appliances and an android Application. Bluetooth (HC-05) Based Smart Home Automation System was presented in this paper. The system. PWM technique is used to control the

DC motor speed, and H-Bridge driver circuit is used to control the direction of the motor. Also the system is used to control switching ON/OFF the bulb, fan and heater using a smart phone application. It provides easy control of the home appliances; it helps the people who have locomotion difficulty. Moreover, implementation of wireless Bluetooth connection gives a simple way of system installation. (Abdul, 2017).

2.2.14 Voice Recognition Smart Home Automation, (Dhawan & Thakur, 2013)

As seen in recent year's home automation is gaining importance due to use of various wireless technologies. Home automation provides security and comfort mainly for old age people and physically handicapped humans. This paper combines various technologies for home automation such as voice controlled, Android, Bluetooth and ZIGBEE, which makes it more user friendly. The low-cost Bluetooth technology follows IEEE 802.15.1 standard protocol which is open standard technology for implementation of short-range wireless communication. Android is a Linux based core open-source operating system mainly used in portable devices. ZIGBEE is an IEEE 802.15.4 standard device for applications that require low data rate, long battery life and secure networking. This section consists various technologies used for developing voice controlled smart home automation using ZIGBEE. The Voice controlled application presented in this paper is based on the following technologies: ZIGBEE, Android, and Bluetooth. Android is an emerging platform used for developing and organizing android-based applications on mobile devices supporting it. Bluetooth has its own level/standard for wireless communication technologies for short range communication provide a facility to create Android based mobile applications. ZIGBEE is a technology based on wireless standards which was developed by ZIGBEE Alliance in 1990s and it is an open global standard technology to address the distinctive needs of low power, low cost, wireless networks. The complete system is divided into two sections: the transmitter section and the receiver section

*Transmitter section relies upon +12V of supply which is used to control all the circuit elements of this section. The main signal received by this section are from an android application named "Android Meets Robot" which is directly connected to the HC-*06 Bluetooth module via serial *communication. As soon as the module receives the signal it transfers the data to the microcontroller Atmega 328P.The microcontroller checks for the appropriate input as required and forwards the signal to the ZIGBEE. The main purpose of ZIGBEE is to transmit the signals received from microcontroller. The implemented transmitter and receiver sections are shown in Figure 2.33.*

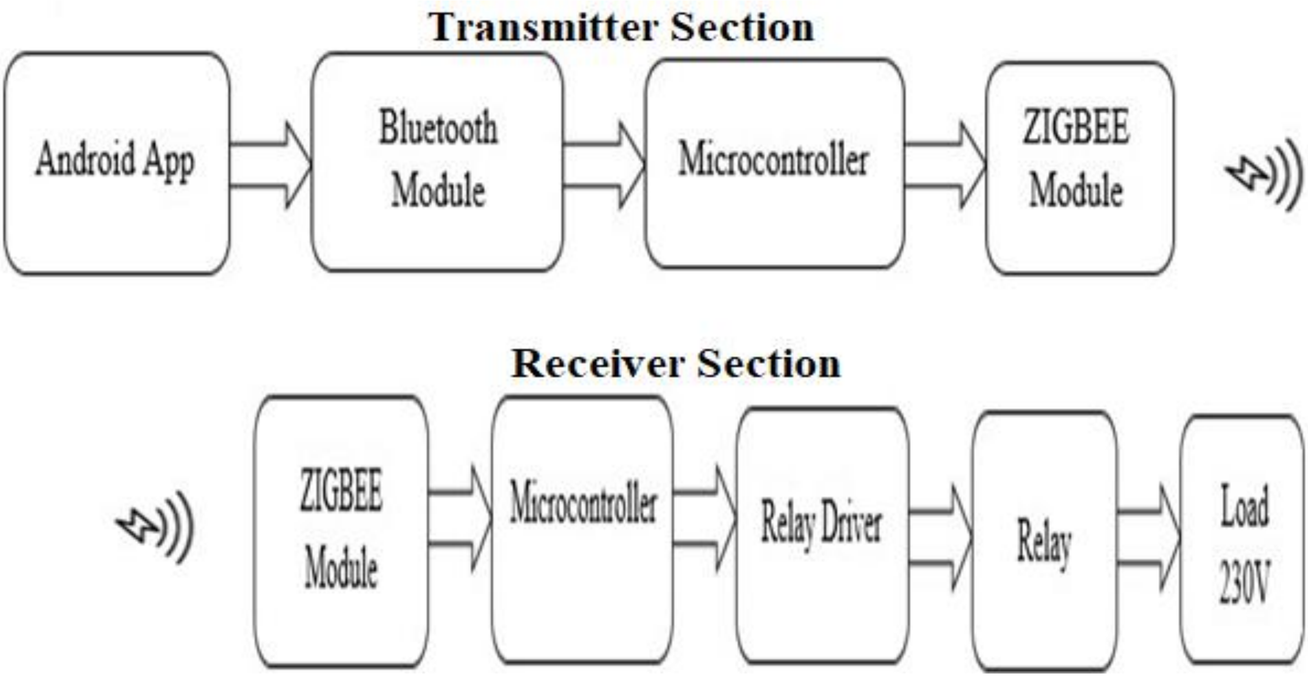


Figure 2.33: Implemented Transmitter and Receiver Sections (Dhawan & Thakur, 2013)

The receiver section consists of a +12V power supply, ZIGBEE, microcontroller, relay driver, a few relays & 16X2 LCD. As soon as the ZIGBEE receives signals, it delivers the same to the microcontroller. Microcontroller processes the signal, through which it controls the relay driver and the LCD. The microcontroller compares the alphabets spoken and accordingly provides the output which is then received by the driver IC and the same command is displayed on LCD. The driver IC controls the relay operation as per the inputs from the controller and simultaneously displays the output, that is, controls the 230V loads connected to the relays. The flow diagram of the implemented system is shown in Figure 2.34.

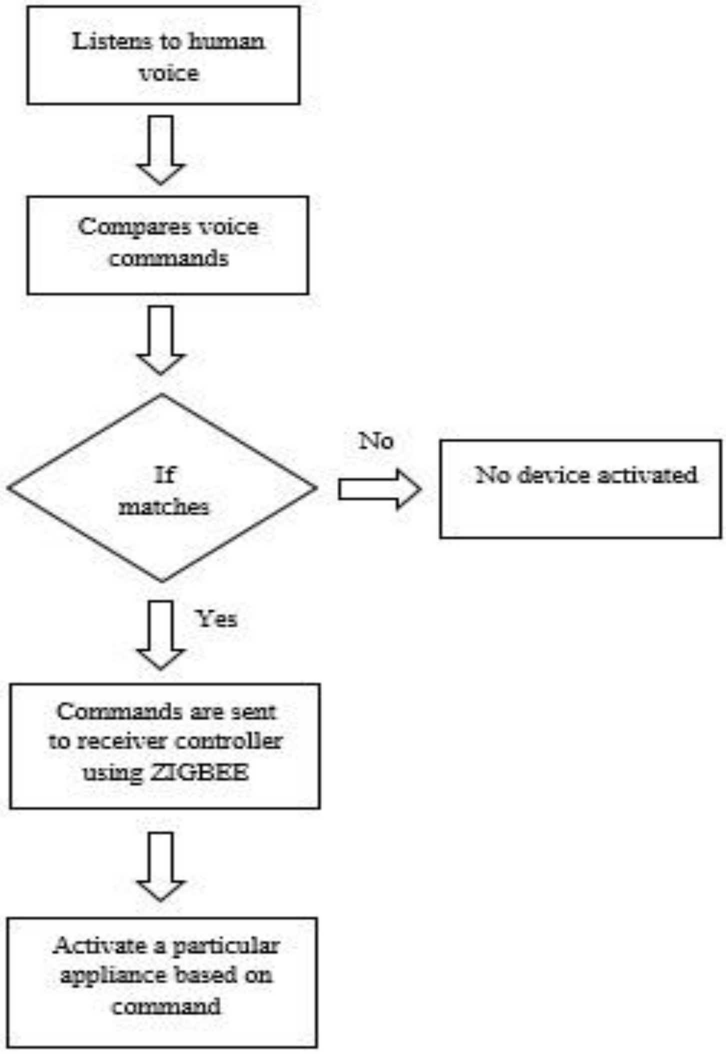


Figure 2.34: Data Flow for the Proposed System (Dhawan & Thakur, 2013)

Voice commands are the basic input for the system to work. These commands are provided to the system using an android application. The android application forwards the command to the Bluetooth module using serial communication. This command is then forwarded to the receiver section using ZIGBEE module. As per the command the microcontroller activates the relay driver and so are the appliances controlled. This system will provide user friendliness as well as long distance communication. By the use of android application, the user can operate devices without moving from his place and can operate devices in the range of approximate 300m because of the use of ZIGBEE. This project will act as a personal robot for the basic activities of handicap and old peoples. (Dhawan & Thakur, 2013).

2.3 Research Gaps

In summary, many researchers have contributed immensely in providing solution to the problems of the aged persons through design and development smart support technology systems. Despite these research solution contributions from different researchers, the findings showed that none of their work has totally met the general need of these aged persons, hence has the following general limitations that formed the research gap of this proposed work:

1. The reviewed works showed that there is no single interface that can control both relay driven appliances and motor driven devices, such as bulb, fan, door, wheelchair, etc.
2. Also, none of the reviewed work is modularized to allow plug and play capability, hence, adding of new smart devices require re-design of the entire system architecture.

Chapter 3

MATERIALS AND METHOD

This chapter presents the materials and the methods required to achieve the set objectives, and discusses these tools and the step-by-step procedures used and followed in achieving the set objectives. The materials deal with the tools, while the methods consist of the procedures employed in the system realization.

3.1 MATERIALS

The materials used in the implementation of this smart home technology system design are grouped into hardware tools and software tools. The hardware tools used includes:

3.1.1 Hardware Tools

1. Voice Recognizer
2. Headset Microphone
3. RF Module
4. push buttons
5. LAPTOP
6. DC motors
7. H-Bridge Circuit
8. Relay Drivers
9. Bluetooth Device
10. Driver Circuits

The Voice Recognizer used in this project is VoiceGP module, which is a development platform for speech synthesis and voice recognition applications, and is based on Sensory RSC-4128 mixed signal processor. Factory programmed with upgradeable Virtual Machine firmware, it enables easy and low-cost development for a wide variety of applications, with focus on speech and voice recognition.

A wireless highly sensitive miniaturized microphone is used to input voice signals to the computer simulation. It receives natural analogue voice signal, and converts the signal to an electrical signal, and sends the converted voice signal to be processed. A headset microphone is less prone to making mistakes because it is positioned at a consistent distance from the mouth as the user talks, and it also works well in a consistent and calm surrounding, without a lot of external noise that the microphone might pick up.

RF Modules use wireless techniques to transfer data, and this makes them most suitable for remote control applications, as in where there is need to control some devices or robots without getting in touch with them (due to various reasons like convenience, safety, handicapped, and so on). Now short-range RF module wireless control applications were chosen for this application such as, an ASK RF Transmitter-Receiver Module of frequency 433 MHz. They are quite compact and cheap.

The handset which serves as the microcontroller GSM shield is used to send/ receive messages and make/receive calls just like a mobile phone by using a SIM card from a network provider. This can be done by plugging the GSM shield into the microcontroller board and then plugging in a SIM card from an operator that offers GPRS coverage. The shield employs the use of a radio modem by SIMComm. Communication can easily be done with the shield by using the AT commands. The GSM library contains many methods of communication with the shield. This GSM Modem can work with any GSM network operator SIM card just like a mobile phone with its own unique phone number. Advantage of using this modem will be that its RS232 port can be used to communicate and develop embedded applications. Applications like SMS Control, data transfer, remote control and logging can be developed easily using this.

The modem can either be connected through Universal Serial Bus (USB) to the PC serial port directly or to any microcontroller through MAX232. It can be used to send/receive SMS and make/receive voice calls, also, used in GPRS mode to connect to internet and run many applications for data logging and control. In GPRS mode, it can connect to any remote FTP server and upload files for data logging. This GSM modem is a highly flexible plug and play quad band SIM900A GSM modem for direct and easy integration to RS232 applications. It Supports features like Voice, SMS, Data/Fax, GPRS and integrated TCP/IP stack. To be connected to a cellular network, the shield requires a SIM card provided by a network provider. Most recent revision of the board makes the connection of the shield with the microcontroller board by connecting its TX to pin 0 of microcontroller and pin 1 of microcontroller to RX of shield

A push button switch is turned on when it is depressed and turned off when it is undepressed for a release, and is used to make and break emergency call connection between the GSM circuit and the voltage supply.

The joystick provides signal to the microcontroller which is transmitted to the smart wheelchair through the wireless RF. The joystick has two axes: X and Y axis that provides signal for forward, backward, left and right movement of the smart wheelchair.

The laptop is the main control of this system, because the voice recognition takes place here. The recognized command is sent through Universal Asynchronous Receive and Transmit (UART) to the microcontroller which then controls the home appliances and the direction of the motors. An open-source grammar-based recognition parser called "Julian" (which is a variant of Julius) is used for voice recognition, and it is a large vocabulary open-source search engine capable of recognizing written grammar. it performs voice recognition function by searching for the most highly probable sequence of words fed in its given grammar for a particular activity. The features of this laptop are: Operating System: Windows CE 6.0; NAND Flash Storage: 2GB; Earphone Jack and Internal Speaker; Touchpad; Microphone Jack for voice recording; WIFI High Speed for LAN wireless connection; 1X SD Card Support, Video Format Support: AVI, MP4, 3GP, ASF; Music Format Support: MP3, WMA, AAC, AAC+, CAT, max up to 48 KHz at 320kbps; and Built in 1800mA/H Li-on and 9V adaptor.

The setup was completed by attaching four switches which are used for rotating the smart wheelchair to any desired direction. The smart wheelchair can be moved in any direction of choice that is left, right, forward or backward by just pressing a respective single button. During forward motion each motor runs in forward direction and during reverse motion both motors run in reverse direction. For movement of right and left one motor runs in forward direction and one motor runs in reverse direction. The high-power motor controller has four ports. Two ports are OUT A and OUT B, and these are connected with the motor positive and negative terminals. The other two ports are VIN and GND, these are connected with batteries. There are two motor used in this system, one controller is connected with one motor and other controller is connected with other motor.

The Driver circuits are typically circuits or components used to control or activate another circuit/component such as a Relay, a DC motor, etc. The current supplied by a digital logic output pin is usually tens of mA (milliAmps) which will not be enough to drive external devices requiring larger amount of current. Hence, a driver circuit is mostly used to drive such high current demanding devices such as the Relay or the DC motor. Typical drivers include discrete components like Transistors (BJT, MOSFET, Darlington pairs, etc) and driver ICs like the popular L293D or the ULN2003. These take in control signals from the digital logic output pin to activate the external devices connected to it.

The name "H-Bridge" is derived from the actual shape of the switching circuit which control the motion of the motor. It is also known as "Full Bridge". Basically, there are four switching elements in the H-Bridge. The H-bridge is connected to p1.0 and p1.1 of the 8051 microcontrollers, if p1.0 is low and p1.1 is high, the transistors Q2 and Q4 will be biased and allow the flow of current from the Vcc through Q4 to Q2 and then to ground, there by rotating the motor in the anticlockwise direction.

To run the motor in one direction, Q5 and Q8 are turned ON and Q6 and Q7 are OFF, the left side of the motor is at 12v and the right side is at ground. And hence the motor will rotate clockwise direction. To reverse the direction of rotation of the motor, Q5 and Q8 are OFF and Q6 and Q7 are ON, this will rotate the motor in anti-clockwise direction.

The Bluetooth module is connected through the serial port of the microcontroller (pin10 and pin11). The Bluetooth receives data from the android phone to control the doors and window.

The proposed system is composed of two major units; the remote system transmitter controller unit and the remote system receiver controller unit. The remote system transmitter controller unit comprises of the input recognition devices modules such as voice input module, joystick module and push button module. The remote system receiver controller unit however is made up of the electrical and electromechanical units which are the bulb units, the TV unit, the fan unit, the fridge unit, the door and window unit, the vehicular wheelchair, and the emergency call.

3.1.2 Software Tools

The software tools used includes:

1. Proteus simulation software
2. Microcontroller Development Environment
3. MySQL
4. Microsoft Visual Studio 2010
5. C# Program
6. .Net Framework 4.0

The Proteus simulation software is the software tool used primarily for electronic design automation. It is used in this work to make simulations of the various subsystems in order to make proper decisions for the prototype development.

The Microcontroller Development Environment used in the computer simulation is the Arduino Platform. The Arduino is an open-source prototyping platform that comprises a hardware component which is the microcontroller board, and a software component which is the Integrated Development Environment (IDE) used to program the hardware. The Arduino is simulated using the Proteus Simulation software to make proper design choices.

MATLAB described as a strong programming language, also provides an environment for numerical computing. It is used for plotting any function or data, it is a very strong tool for matrix manipulation, and it is the best program language for algorithmic implementation, which provides several toolboxes such as voice acquisition and database toolboxes.

MySQL is a database workbench made by Microsoft Company to help the programmer to build a different type of databases using and link it to a different application softwares using different types of programming languages. It can be linked to PHP programing language, Visual basic, C#, and MATLAB. In this project, the MySQL database is linked to MATLAB, Visual Basic and C#.

The Microsoft Visual Studio 2010 is an Integrated Development Environment (IDE) that is used to create software applications that may vary from windows forms, up to web services. It includes a code editor where the program code was created, debugged, compiled, and run. In the software program used in the system, the source code was written in Visual C# Language. The software program for collecting the voice input was written in C#. C# (pronounced “C Sharp”) is a simple, modern, object-oriented, and type-safe programming language.

The C# program is an object-oriented software that can be used for serial interfacing. It provides the overall logic of the software utility, manages the serial data between the PC and the Microcontroller simulation in the Proteus software, and allocates control signals. A C# program can be used as windows applications, web applications, web services, business-type applications, mobile apps, games, and other software utilities. It uses the full capability of .Net Framework Class Library which consists of pre-built components.

The version 4.0 of the .Net Framework is used in this paper because its class library comprises of thousands of pre-built functionalities that can be used in software applications. Some of its features may include:

a. ADO.NET for database applications,

b. Windows forms for desktop user interfaces, and

c. Web Services for web applications, etc.

3.2 METHOD

This section discussed the step-by-step processes used to achieve the design and the implementation of smart home system comprising the system hardware, software, and the prototype implementation models that form the overall design and implementation of this smart home system for the disabled aged persons. The design and modelling of the system results from the utilization of a top-down design approach and the subsequent modularization of the components of the system. The method of analysis included design, modelling, simulation, calculations and analysis of the simulation test results employing the computer software. These design methods include the step-by-step implementation of smart home functional architectural designs and modelling presentations. To develop a smart home system for the aged persons, enormous research and design considerations must be done to find a suitable system capable of meeting the requirements of the project.

3.2.1 The Wireless Sensor Based Voice-Activated Smart home System Architectural Block Diagram System for the Disabled Aged Persons

The block diagram of the proposed smart home technology systems` hardware architecture to be implemented is shown in Figure 3.1. This hardware architecture block diagram shows the interactions and operations together with the component units on a detailed description, and is related to the conceptual diagram.

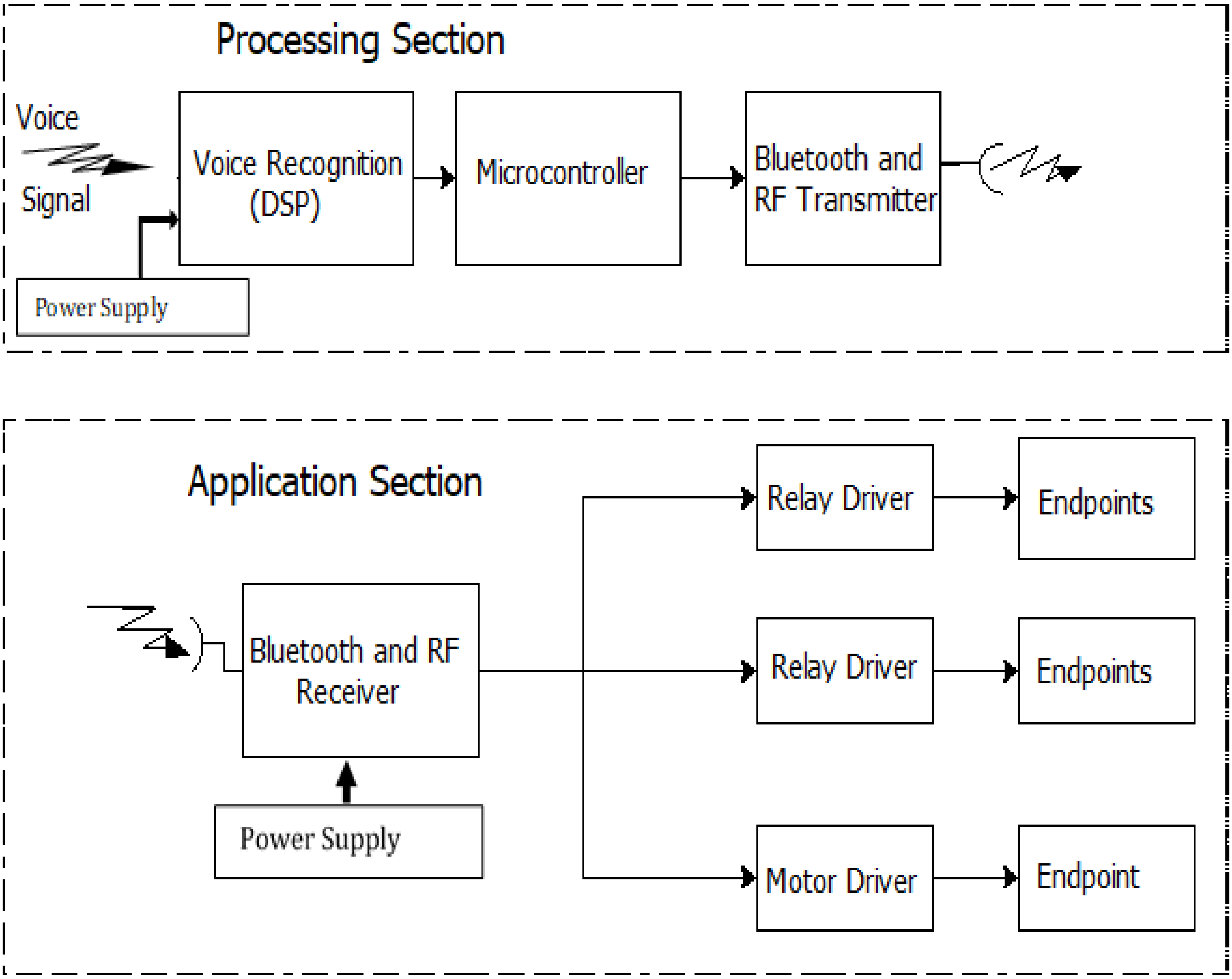


Figure 3.1: The Detailed Block Diagram of the Entire System

The system hardware architectural peripherals are realized with the following components: Microphone, Resistors, Capacitors, Transistors, Diodes, Quart Crystal, Relays, Motor Driver, Microcontroller, Voice Recognizer, Drivers, Rectifier, and so on. These components are used to implement the various system block units shown in the detailed system block diagram shown in Figure 3.1.

The conceptual (functional) diagram formulated from the system architectural block diagram is shown in Figure 3.2. This system conceptual diagram presents the overall functional ideas of the smart home system, and the system`s various interactions and operations on a high-level description basis.

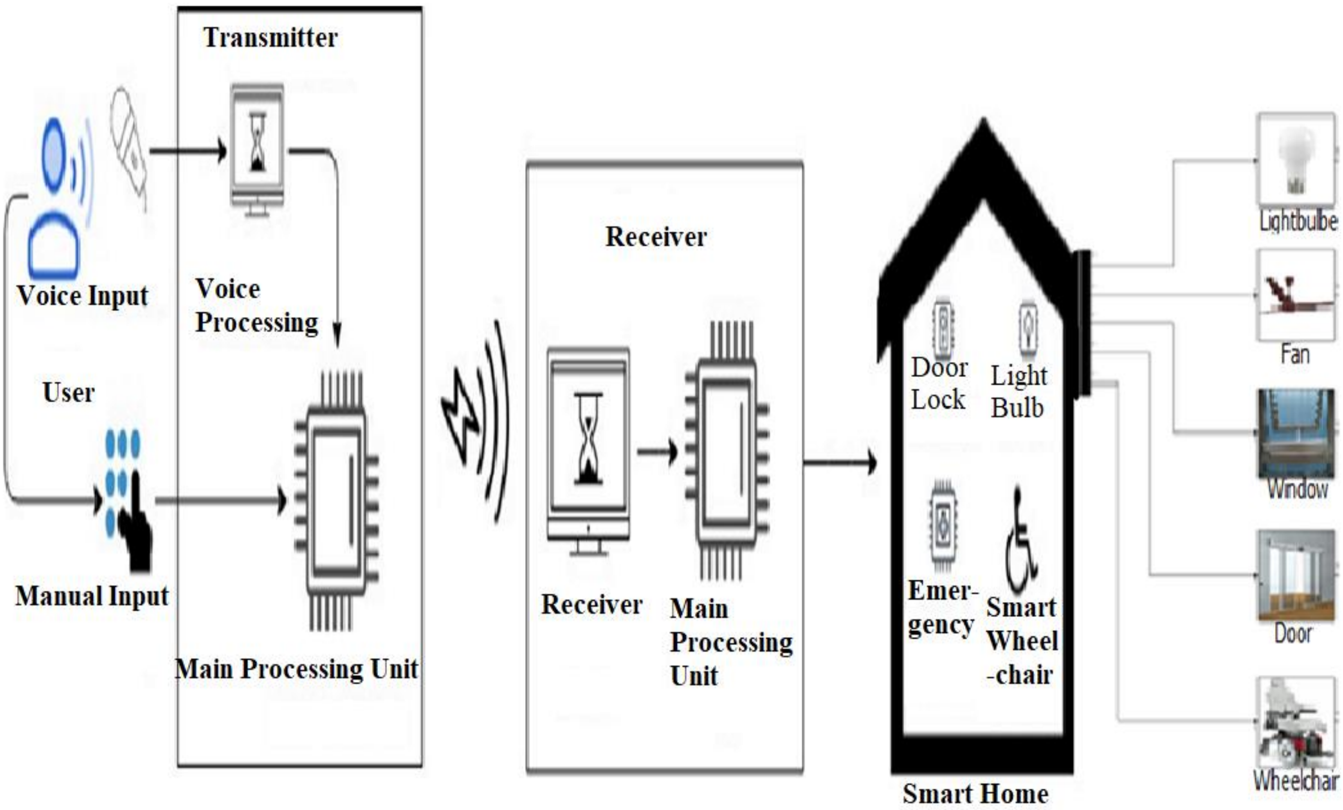


Figure 3.2: The Conceptual Diagram of a Smart Home Technology.

3.2.2 The Design Specifications

Good requirements are objective and testable. Design Specifications include; specific inputs, including data types that are entered into the system. calculations/code used to accomplish defined requirements, outputs generated from the system, explaining technical measures to ensure system security, and identify how the system meets applicable regulatory requirements. This section describes the principles and strategies used as guidelines during system design and implementation.

3.2.2.1 Material specification

The material requirements and their specifications as used in this project are stated in Table 3.1. below

Table 3.1: Material Specifications.

A	**HARDWARE SPECIFICATION**	
1	Voice Recognizer	VoiceGP DK-T2SI
2	Headset Microphone	Wireless Ominidirectional Microphone
3	Wireless Systems	RF Module (ASK RF Transmitter-Receiver Module of frequency 433 MHz) and Bluetooth Device (HC-05)
4	Microcontroller	ATMEL- 89C51
6	Switches	Push Buttons
8	Motor Driver IC	L293D motor driver (IC housed by H-Bridge Circuit)
9	Motor	DC motors
10	Motor Driver Circuits	H-Bridge Circuit (the L293D motor driver socket).
11	Relay Drivers	SPDT Relay, Form C Relay
B	**SOFTWARE SPECIFICATION**	
1	Proteus simulation software	Proteus 8 professional Suite
2	Development Environment	Microcontroller Development Environment
3	Database Workbench	MySQL
4	Integrated Development Environment (IDE)	Microsoft Visual Studio 2010
5	Programming Language	MATLAB (program language for algorithmic implementation, which provides number of toolboxes such as

		voice acquisition and database toolboxes), C# Program and C language
6	.Net Framework	.Net Framework 4.0

3.2.3 Overall System Design and Description

The system architectural block diagram of this wireless sensor-based voice activated smart home technologies for the disabled aged persons shown in Figure 3.1, is composed of modular sub units, and it is related to the functional diagram of Figure 3.2. These modular subunits were made up of two prominent modular sections, which form the two basic design blocks namely:

1. System Processing Section (SPS) and
2. System Application Section (SAS).

The entire system design will be carried-out by design execution of the two basic blocks: system processing section and system application section. Figure 3.1 represents the system processing and system application sections, and together they represent the design flow of the entire system, and explain the way in which it works.

3.2.3.1 System Processing Section (SPS)

The SPS encompasses the system power supply unit, the input unit, the processing unit, the controller unit and the wireless transmission media (transceivers) as shown in Figure 3.1.

For easy design implementation, this section is further split into the following segment units: voice input unit, manual training unit, signal processing unit, controller unit, storage units, display unit, coding and decoding unit and transmission unit, which formed the section`s design flow shown in Figure 3.3.

The voice as an input signal is fed into the system through the voice input unit, as the name implies. This input unit comprises of an input device: Microphone sensor, to receive the voice as an analog input signal to the system. The received analog input signal is then passed onto the Digital Signal

Processor (DSP) responsible for receiving and processing the analog voice input signal into digital signal.

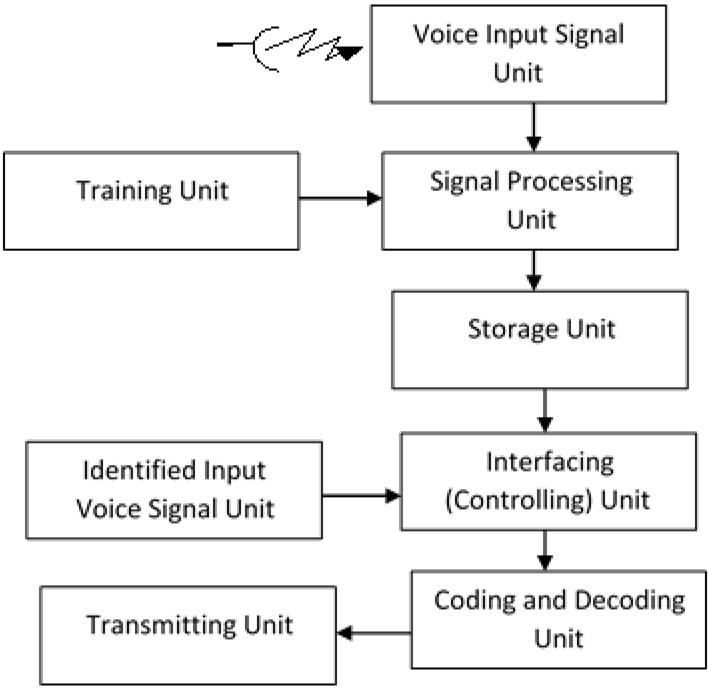


Figure 3.3: The Design Flow of the System Processing Section

The digital signal processor receives the analog voice input signal, and converts it into a digital signal to make it compatible with the system. This unit also stores the voice commands, which will be used as the preset command words, through the unit training process according to human voice vocabulary, and it matches and recognizes voice commands, relating to the function it is expected to perform.

The DSP unit is trained by the manual training unit for the needed preset command words to be set, to be used to match input signals and initiate the required tasks of device control.

After signal processing unit training with the manual training unit, the predefined command words are retained storage units as addresses in the memory. Later, the spoken voice commands are matched with the predefined commands to perform a function. In this unit, predefined commands are first saved, and later they are used for matching with the voice input to perform a predefined task.

The controller unit made up of the microcontroller with the wireless transceivers, interfaced SPS with the rest of the circuitry. This unit handles the process of choosing the appliance, which supposed to be operated.

The display unit included to make the system more users friendly and easily accessible, visually displays the spoken voice command, and the function that is going to perform, and help the users avoid errors.

The coding and decoding unit is encompassed of the signal encoder for data coding, to interface the upper part of circuit with the transmitting unit, and a signal decoder for data decoding, and to interface receiver with the rest of the circuit.

The transmission unit comprised of the transceivers as media for data transfer from SPS to SAS using suitable transmission technology.

3.2.3.2 System Application Section (SAS)

The system application section comprises of the receiving unit, the power supply unit, the switching (actuating) unit, and the endpoint (application) unit as shown in Figure 3.1.

The SAS is further split into the following segment units: switching unit, receiving unit, the power supply unit, the switching (actuating) unit, and the endpoint (application) unit, which formed the section`s design flow for easy design implementation as shown in Figure 3.4.

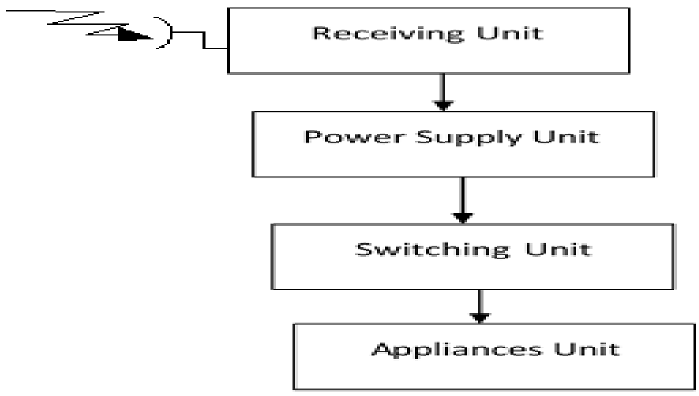


Figure3.4: The Design Flow of the System Application Section

This SAS receives data serially from one point to the other. The switching unit is composed of the actuators (relay drivers and motor drivers), which decide the device to be switched ON or OFF, OPEN or CLOSE, TURN LEFT, RIGHT, UP, DOWN or HALT based on the signal received by the controlling circuit. The appliances unit consist of the appliances to be operated upon. The safety unit is made up of the power supply to the system circuit, to protect the system against damage by back EMF, physical connections or high voltage and so on. This block is responsible for a no-physical-connection route towards the rest of the circuit, preventing damage due to physical connections.

Based on this research objective, the multimodal smart home system was realized. The various sub-technological systems that made up the smart home are shown in Figure 3.5, which is the detailed block diagram of the realized system - voice-activated smart home system for the disabled aged persons, and is composed of three major sub-units: the voice-activated subsystem, the control unit, and the end point units. The input unit that interacts with users is connected with the voice-activated subsystem, the control unit is the part of the system that interacts with the system end points, by manipulating the endpoints to the desired state using recognized command from the VAS. The endpoints comprised of the doors and windows, electrical loads and appliances, and robotic wheelchair. All these units interact together every time the home occupants issue commands to the system.

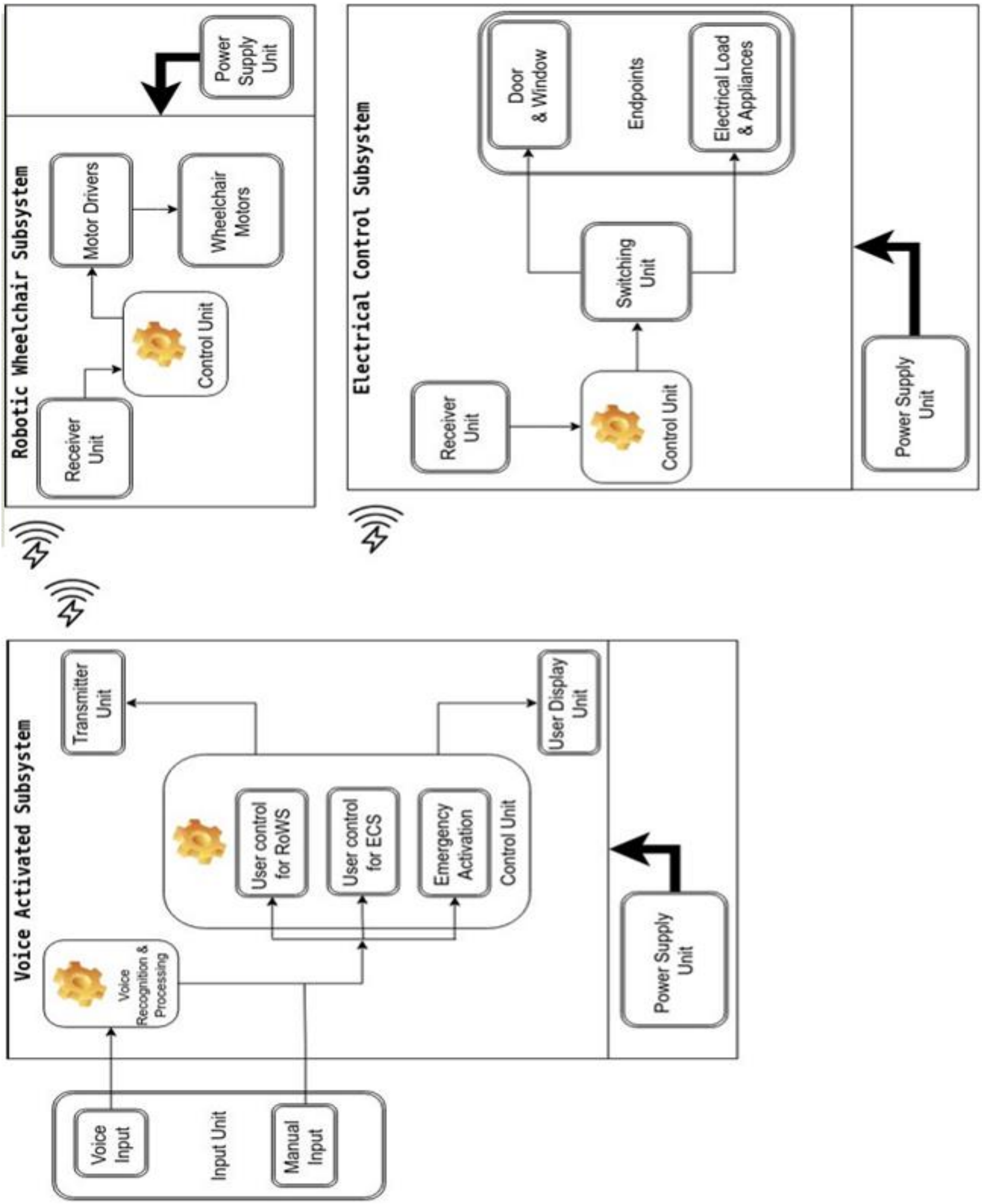


Figure 3.5: The Detailed Block Diagram of the Entire System

The Voice-activated subsystem (VAS) comprises the input unit, the control unit, and the transmitter unit. Like the name suggests, the main source of input is through *Voice*, however, there is an alternative manual source of input for robustness. Hence, the input unit consists of two input methods - voice and manual input. This input unit provides commands for controlling the endpoints, the robotic wheelchair or for emergency contact; this is done through voice or the manual input. In the control unit, the processing of the input signals takes place, which is coordinated by a microcontroller. Here, the voice signals are processed for recognition by a Digital Signal Processor (DSP) and then sent to the microcontroller for transmission. The VAS is responsible for transmitting the processed signals, now in the form of commands, to the ECS or the RoWS.

Finally, on overall system model and description, the most fundamental form, voice sensing and recognition are at the core of this smart home system. Voice requires a form of processing and analysis, after which the necessary communication to the home appliances for actuation would occur. It is with this in mind that the system was modelled. This smart home system is a controllable type, where some sort of remote control is needed to operate the system. This system sees the use of voice as the method of control due to the restrictions of the user considered.

The control of the system comes with the use of voice and an optional manual input, which on input are processed to be mapped to the appropriate command. After the processing and mapping to appropriate commands, the endpoints of the system are controlled via a wireless link within the range of the link used. This system can be expanded to fit more users and more appliances such that at the user end, a defined set of users' inputs can be allowed, and at the more endpoints (endpoints are the appliances to be controlled, such as bulb, fan, etc.) can be added where possible. The Figure 3.6 shows the model used in designing the system.

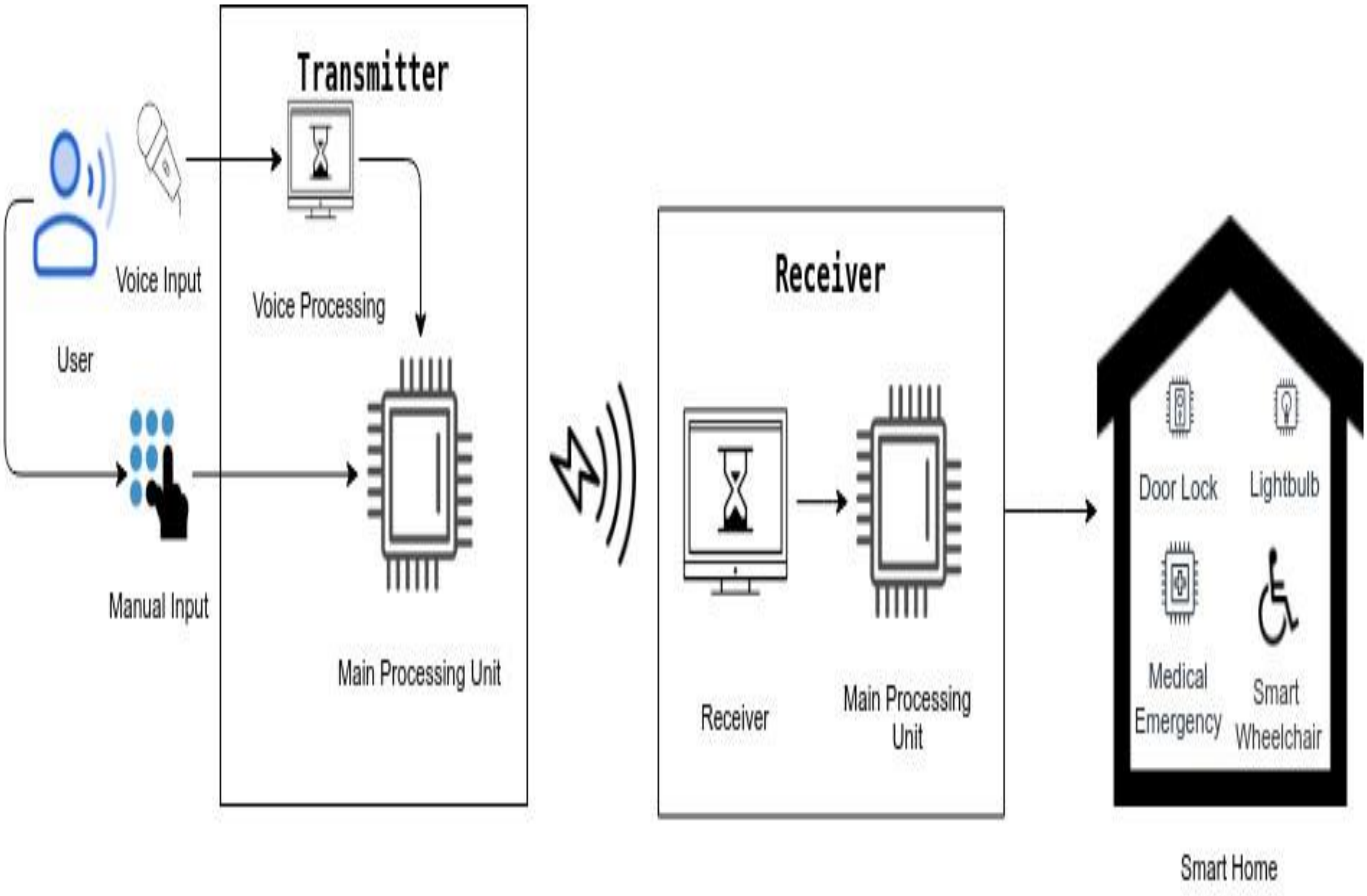


Figure 3.6: Design model for the Smart home Technologies` System

3.2.4 The System Design Model

Considering the model in Figure 3.6, the breakdown of the system model into components would see it divided through the wireless link into two main components:

1. The Voice-activated Subsystem (VAS) and,
2. The Electrical Control Subsystem (ECS).

This breakdown is synonymous to a Transmitter-Receiver structure as seen in the Figure 3.6. The transmitting section consists primarily of an input - whether voice or manual - to the system, a form of processing where the input is recognized and mapped appropriately to a command, and then sent out via a wireless link to the Receiving section. Hence, it is dubbed the Voice-activated subsystem. The receiving section consists of a wireless link for the reception of transmitted commands, a processing unit for verifying and acting upon the received commands to activate the selected electrical endpoint, hence, the name, Electrical Control subsystem.

A third subsystem according to the earlier stated requirements is also considered. It is:

3. The Robotic Wheelchair Subsystem (RoWS).

It holds the Voice-activated system since the user utilizes it for easy navigation.

Considering the system model, the system is further designed for its hardware and software constituents.

3.2.4.1 Hardware Design

The system modular design is represented by the architectural block diagram shown in Figure 3.7. This architectural block diagram gives a more detailed interaction of the components of the entire system. This block diagram has been sectioned into three main modules - The Voice-activated subsystem (VAS), the Electrical Control subsystem (ECS) and the Robotic Wheelchair Subsystem. As emphasized previously, the VAS can be seen as a transmitting unit, while the ECS and the Robotic Wheelchair Subsystem (RoWS) are considered as the receiving unit. Hence, the components include:

a) The Voice-activated subsystem (VAS).

b) The Electrical Control subsystem (ECS).

c) The Robotic Wheelchair subsystem (RoWS).

The Voice-activated subsystem (VAS) comprises the input unit, the control unit, and the transmitter unit. Like the name of the subsystem suggests, the main source of input is through *Voice*, however, there is an alternative manual source of input for robustness. Hence, the input unit consists of two input methods - voice and manual input. This input unit provides commands for controlling the endpoints, the robotic wheelchair or for emergency contact; this is done through voice or the manual input. In the control unit, the processing of the input signals takes place, which is coordinated by a microcontroller. Here, the voice signals are processed for recognition by a Digital Signal Processor

(DSP) and then sent to the microcontroller for transmission. The VAS is responsible for transmitting the processed signals, now in the form of commands, to the ECS or the RoWS.

The Electrical Control Subsystem (ECS) comprises the receiver unit, the control unit, the switching unit, and the endpoints. The receiver unit is responsible for the reception of the transmitted signals from the VCS. The control unit comprises microcontroller at the heart of the subsystem, creating a connection between the received input with the switching unit and coordinating the entire subsystem. It handles endpoint selection through the switching unit by mapping the received command to the appropriate endpoint. The switching unit responds to activation from the control unit. It mainly consists of switching devices responsible for controlling endpoints - home appliances/parts of the house - to the desired state.

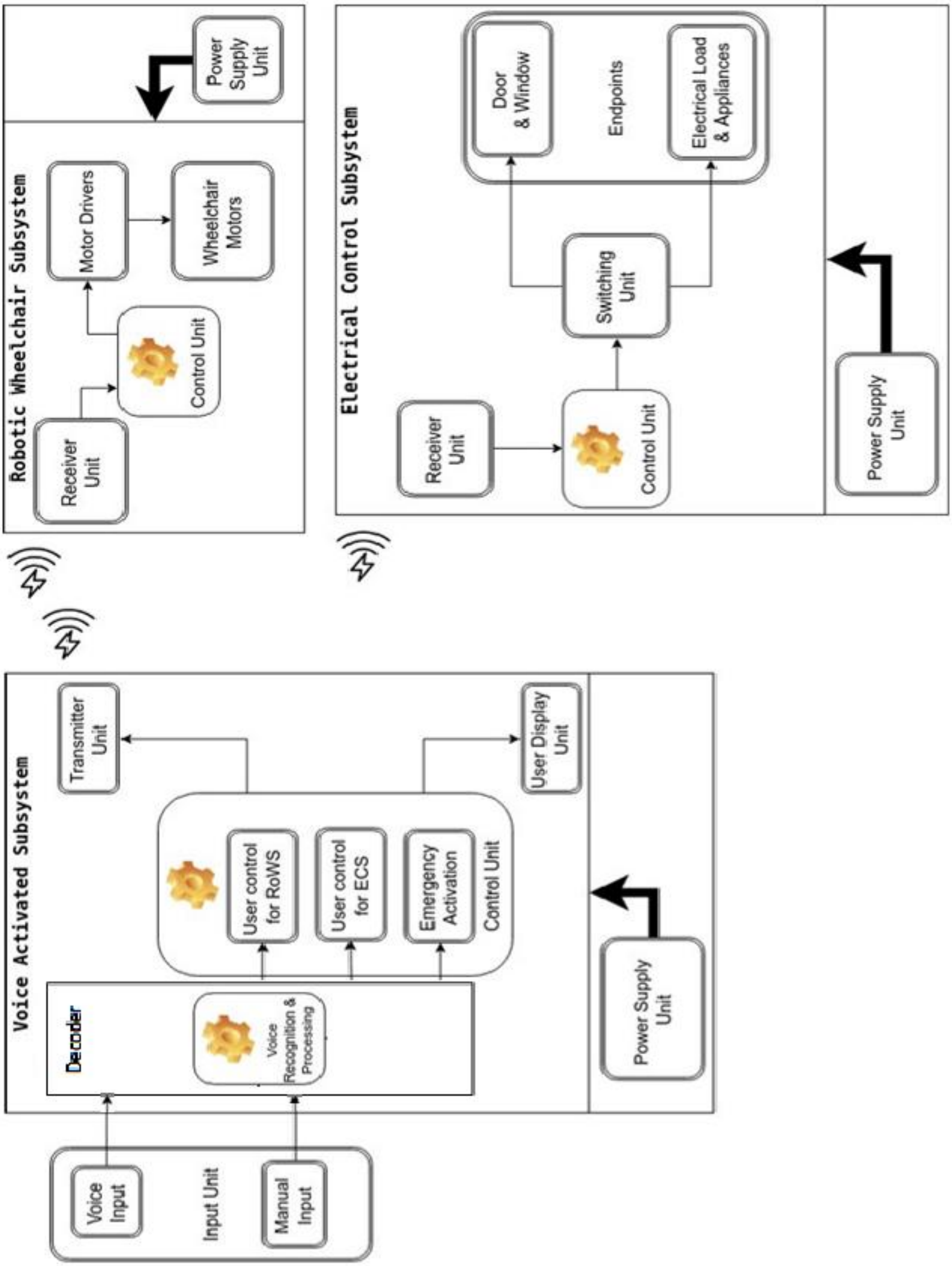


Figure 3.7: The Architectural Block Diagram of the System Hardware.

The Robotic Wheelchair Subsystem (RoWS) is similar in structure and operation to the ECS; however, its endpoints are the electric motors of the robotic wheelchair for navigation. It responds to the commands of its control unit having received commands from the VAS.

The entire smart home system can be further analyzed separately according to their subsystems.

3.2.4.2.(a) The Voice-activated subsystem (VAS)

Further analysis of the VAS will see it broken down into still smaller units as illustrated in Figure 3.7. Hence, the VAS comprises:

1. The Power Supply unit
2. The Voice-processing unit
3. The Manual input unit
4. The Control unit
5. The Output display unit
6. The Communication unit

The Power Supply Unit (PSU): The power supply unit is responsible for feeding power to the entire VCS. The VCS is a low-power system that utilizes 3.3V or 5V input voltages, hence, all units of the subsystem are reliant on low DC voltages. Since this subsystem is mobile, it is only logical to utilize a suitable battery and a regulated circuitry to supply the needed voltage levels needed by the subsystem.

The Figure 3.8 shows an illustration of this unit. The battery supplies the needed voltage and the voltage regulation circuit regulates and supplies the appropriate voltage to other units.

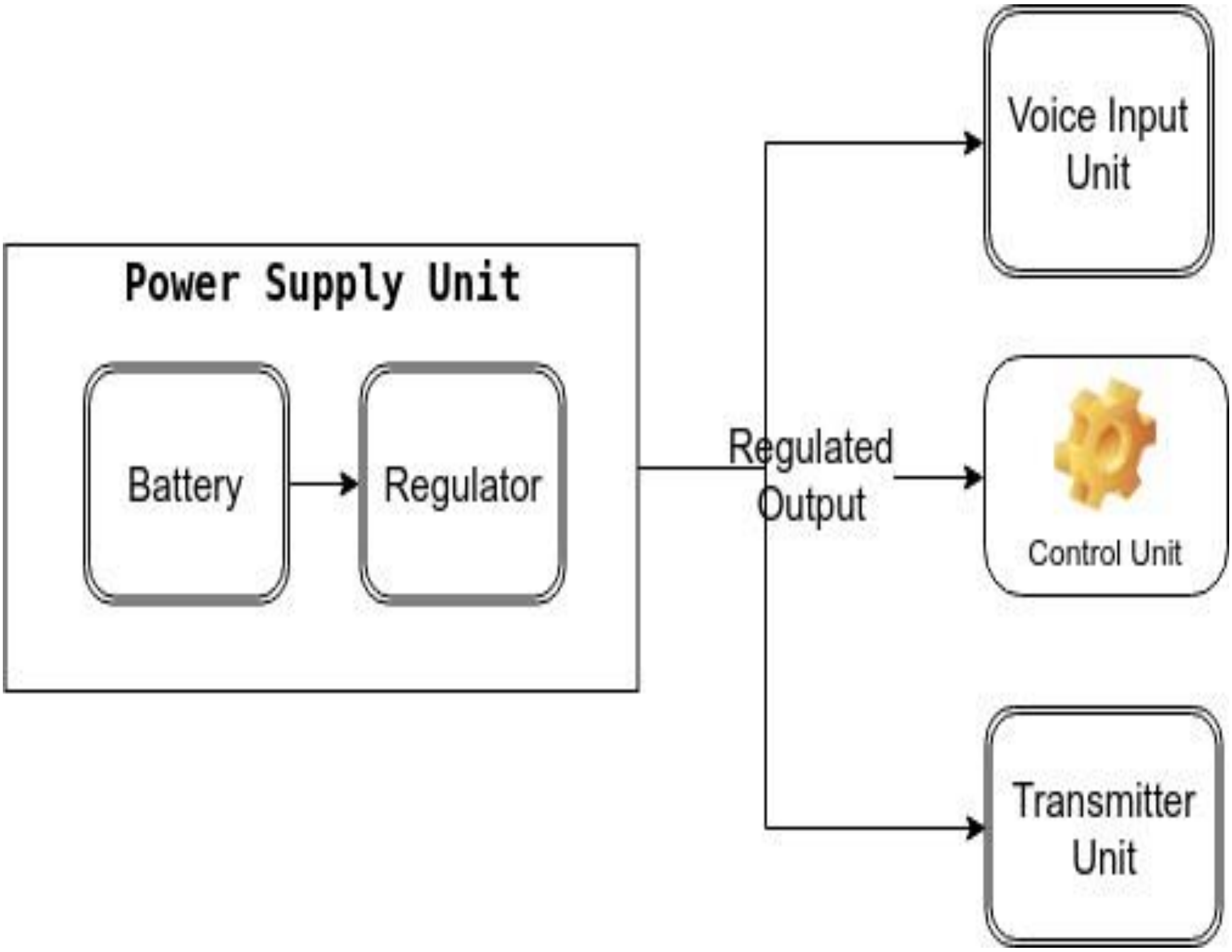


Figure 3.8: Block Diagram of the Power Supply Unit of the VAS

The Voice-Processing Unit: The voice-processing unit is the main source of input to the VAS. It mainly comprises of a microphone for collecting voice input from the user, and a voice recognition module for processing the voice input signal as shown in Figure 3.9. It is responsible for providing input for controlling the endpoints and the robotic wheelchair, and for activating an emergency response.

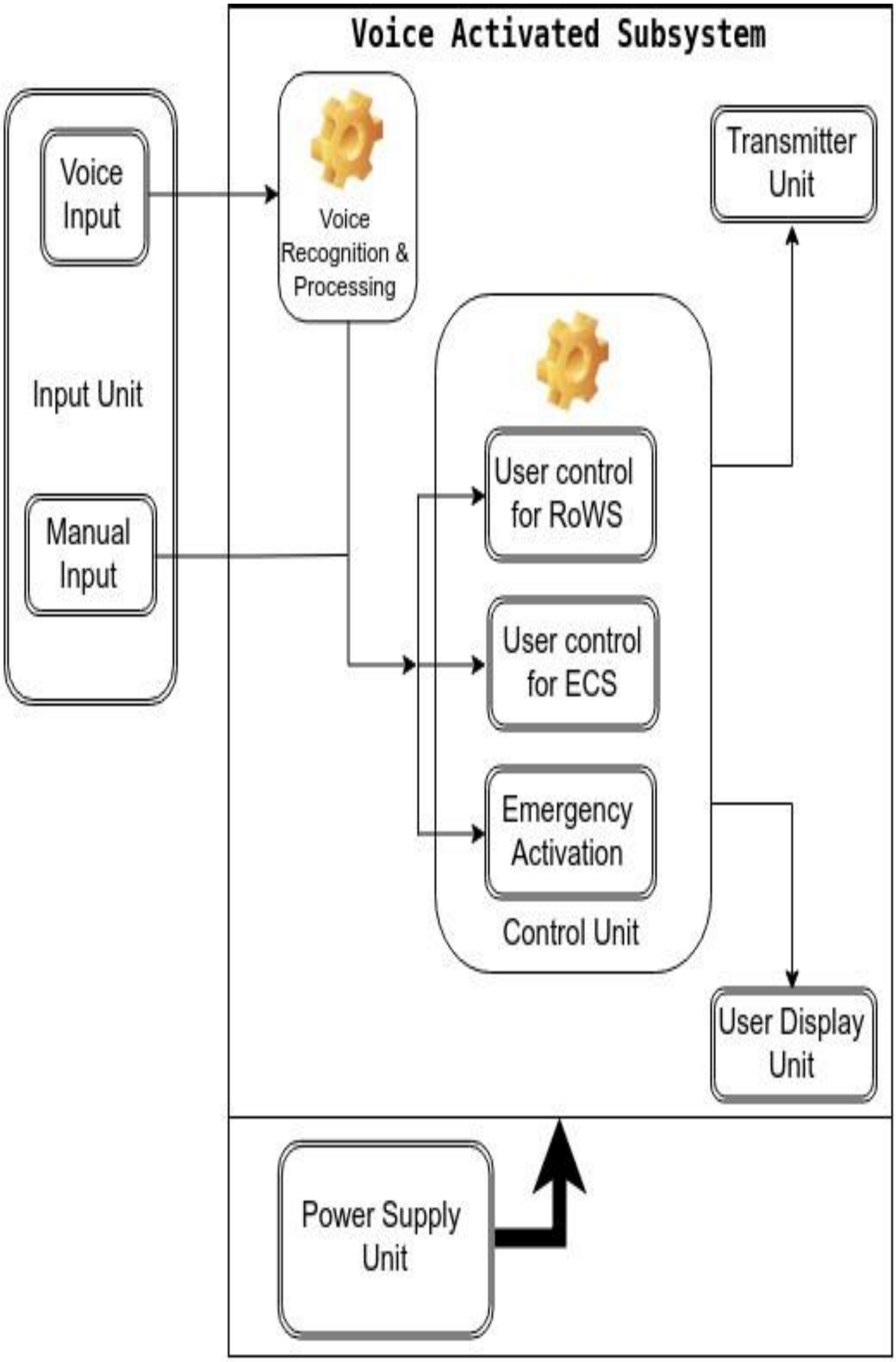


Figure 3.9: Block Diagram of the Voice-activated subsystem

The voice-processing unit receives an analogue voice signal via the microphone sensor and sends this signal to the voice recognition sub-unit which mainly comprises a Digital Signal Processor (DSP) for the analysis of the voice signal. This DSP is responsible for converting the input analogue voice signal to a set of digital signals. These digital signals are further processed into commands that can be mapped to a certain action - control of the endpoints, robotic wheelchair control, or emergency alert activation by the control unit. After the analysis of the voice signals by the DSP, and the processing of the commands by the control unit, the selected command is then transmitted via the wireless link.

The Manual Input Unit: The manual input unit is the alternative source of input to the system. It is necessary for cases of failure of the voice-processing unit serving as a form of input override to allow the user to give commands manually. It consists of input selection for controlling the endpoints of the smart home, for navigating the wheelchair, and for activating an emergency alert similar to the voice processing unit as shown in Figure 3.10.

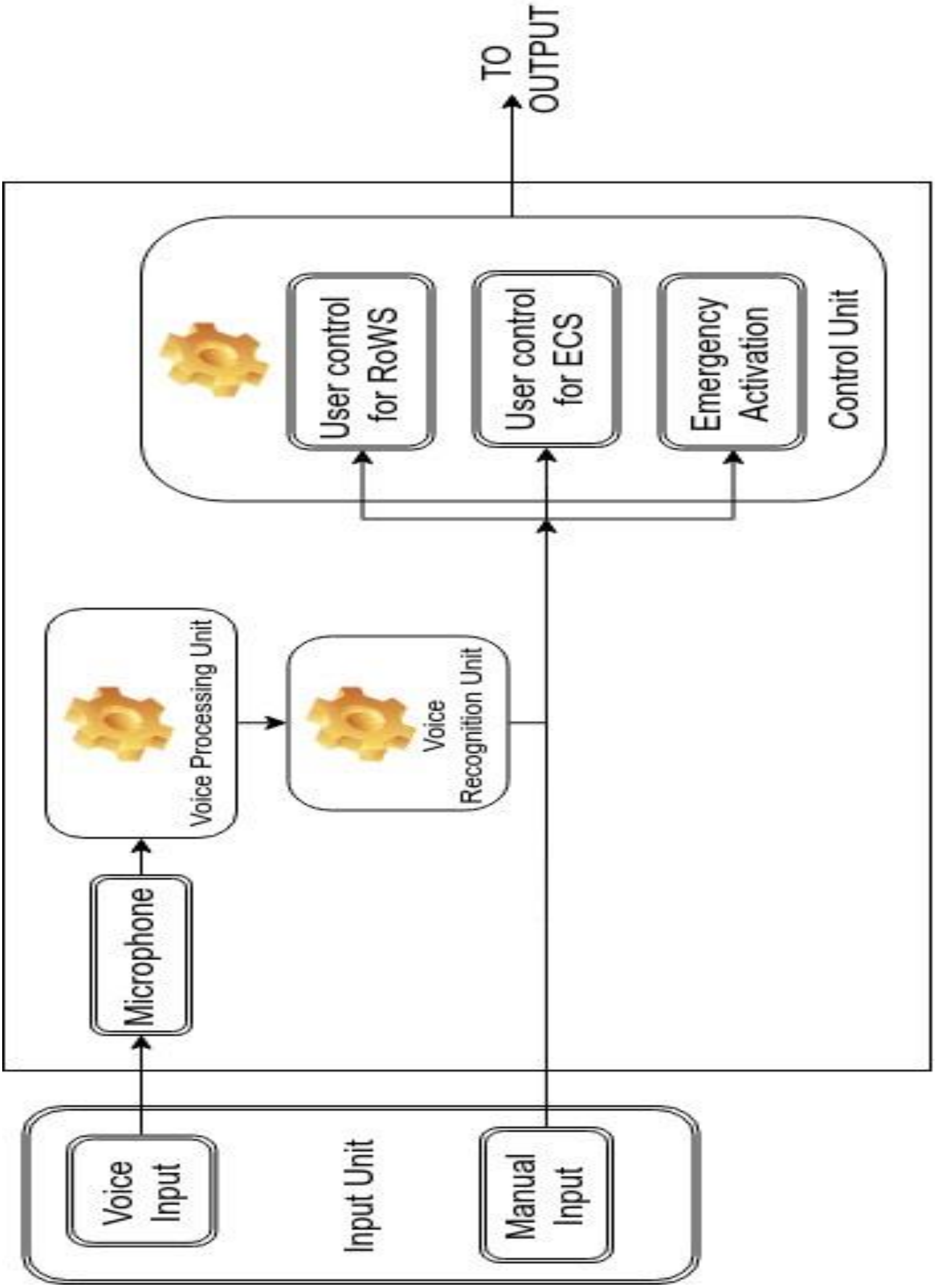


Figure 3.10: Block Diagram of the VAS as an input section.

The manual input unit sends its inputs to the control unit for verification and matching of input commands after which a certain action is performed based on the input selected.

The Control Unit: The Control Unit is the brain of the VCS. It controls and coordinates every unit in the VCS. It usually consists of a microcontroller to provide the necessary interfacing to all units of the VCS. The control unit receives voice or manual inputs, verifies and matches the inputs to appropriate commands and sends via the wireless link for an action to be taken. It also sends data to the display unit.

The Output Display Unit: The Output Display Unit is a visual output unit. It is responsible for showing the current state of the smart home system. It provides the user with the current state of the endpoints of the ECS. It receives data from the control unit and displays system recognized command appropriately as required. It is shown in Figure 3.11.

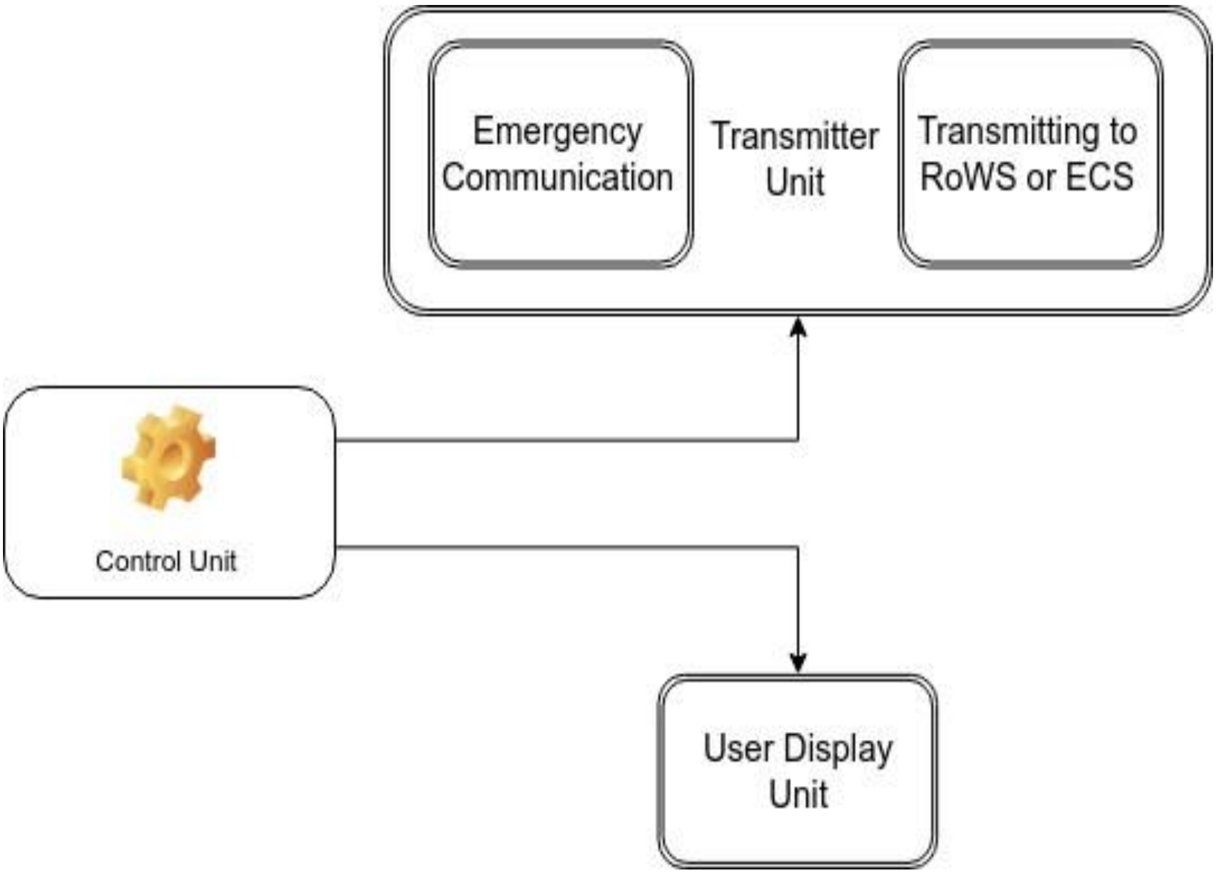


Figure 3.11: Block Diagram of the output section of the VAS

The Communication Unit: The communication unit is the link to the rest of the smart home system. It provides a wireless means of communication to other subsystems. It comprises of two modes of communication, one for controlling the endpoints or the robotic wheelchair, and the other for reaching out to an emergency contact. It is illustrated in Figure 3.11.

The communication unit receives commands from the control unit for control or emergency alert. It is responsible for encoding and sending the user command via a wireless medium.

3.2.4.2. (b) The Electrical Control subsystem (ECS)

The Electrical Control subsystem (ECS) is the controller of the electrical AC and DC endpoints in the smart home. It receives commands from the VCS and responds to the command by acting such as turning on/off an electrical point and is illustrated in Figure 3.12.

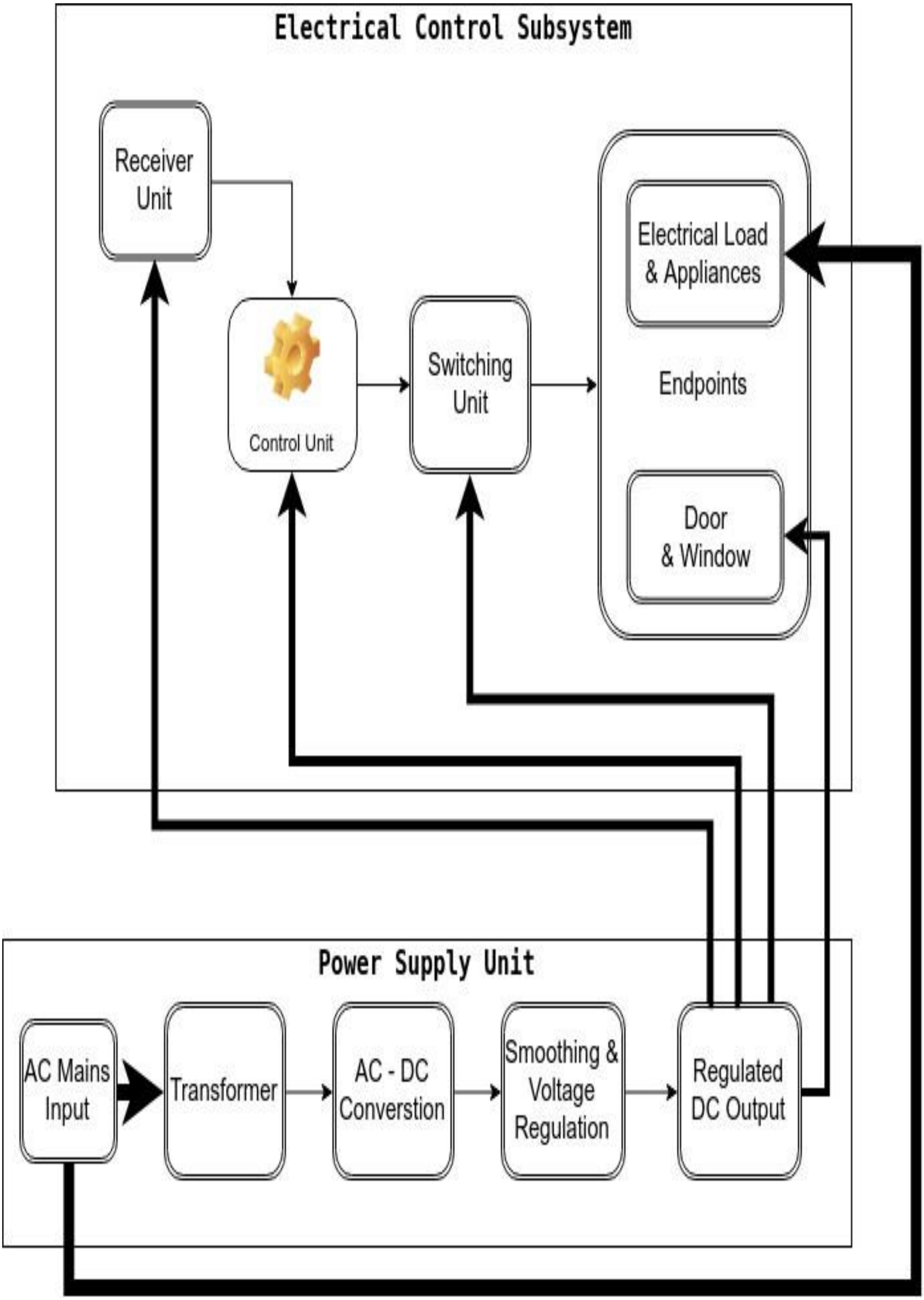


Figure 3.12: The block diagram of the ECS

It consists:

a) The power supply unit

b) The communication unit

c) The control unit

d) The switching unit

e) The endpoints

The Power Supply Unit (PSU): The PSU of the ECS is a combination of Direct Current (DC) and Alternating Current (AC) outputs. This is illustrated in Figure 3.12. It receives the 50Hz, 220/240V AC mains voltage supply and converts the AC supply to DC supply, thereby providing both voltage types as outputs to the ECS. It consists of a transformer, a rectification unit, and a smoothing and regulation unit. The AC voltage output from the PSU powers the AC electrical endpoints of the ECS whereas the DC voltage output powers the DC electrical endpoints.

The Communication Unit: The communication unit of the ECS is a receiver linked to the communication unit of the VAS and is capable of data reception for control of the smart home system. It receives commands sent from the VAS wirelessly and sends to the control unit of the ECS for processing. From Figure 3.12, it can be seen that this unit receives power from the PSU for operation, and communicates the received commands to the control unit. Hence, in this ECS, the communication unit sends commands received commands to the control unit for control of the endpoints.

The Control Unit: Similar to that of the VAS, the control unit of the ECS controls and coordinates the ECS. It receives commands from the communication unit and translates the received commands to its corresponding action. This is seen in Figure 3.12.

The Switching Unit: The switching unit switches the appropriate endpoint in response to the control unit. It consists of AC and DC electrical switches for controlling an endpoint. It is designed to meet the electrical requirements of the endpoints. It is illustrated in Figure 3.13

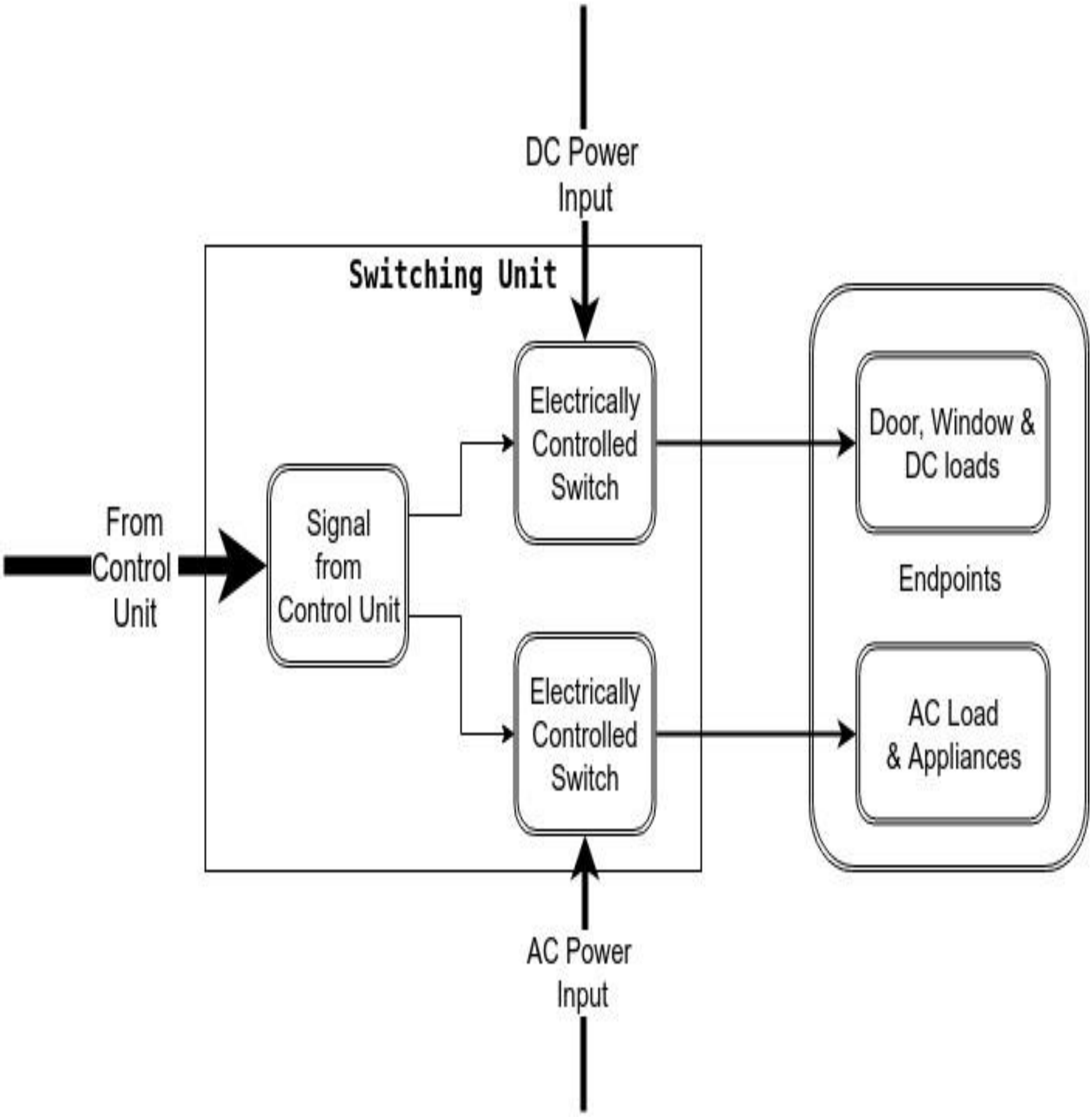


Figure 3.13: The block diagram of the switching unit of the ECS

The Endpoints: The endpoints are the termination points of the smart home system. They act in response to the voice command or the manual input of the user. The endpoints can be an AC load such as light bulbs, or a DC load such as the DC motor used in controlling the doors or the windows.

3.2.4.2. (c) The Robotic Wheelchair subsystem (RoWS)

The Robotic Wheelchair subsystem (RoWS) is another receiving subsystem in this smart home system. It is needed to aid the movement of the user since a disabled user is being considered. An illustration is shown in Figure 3.14.

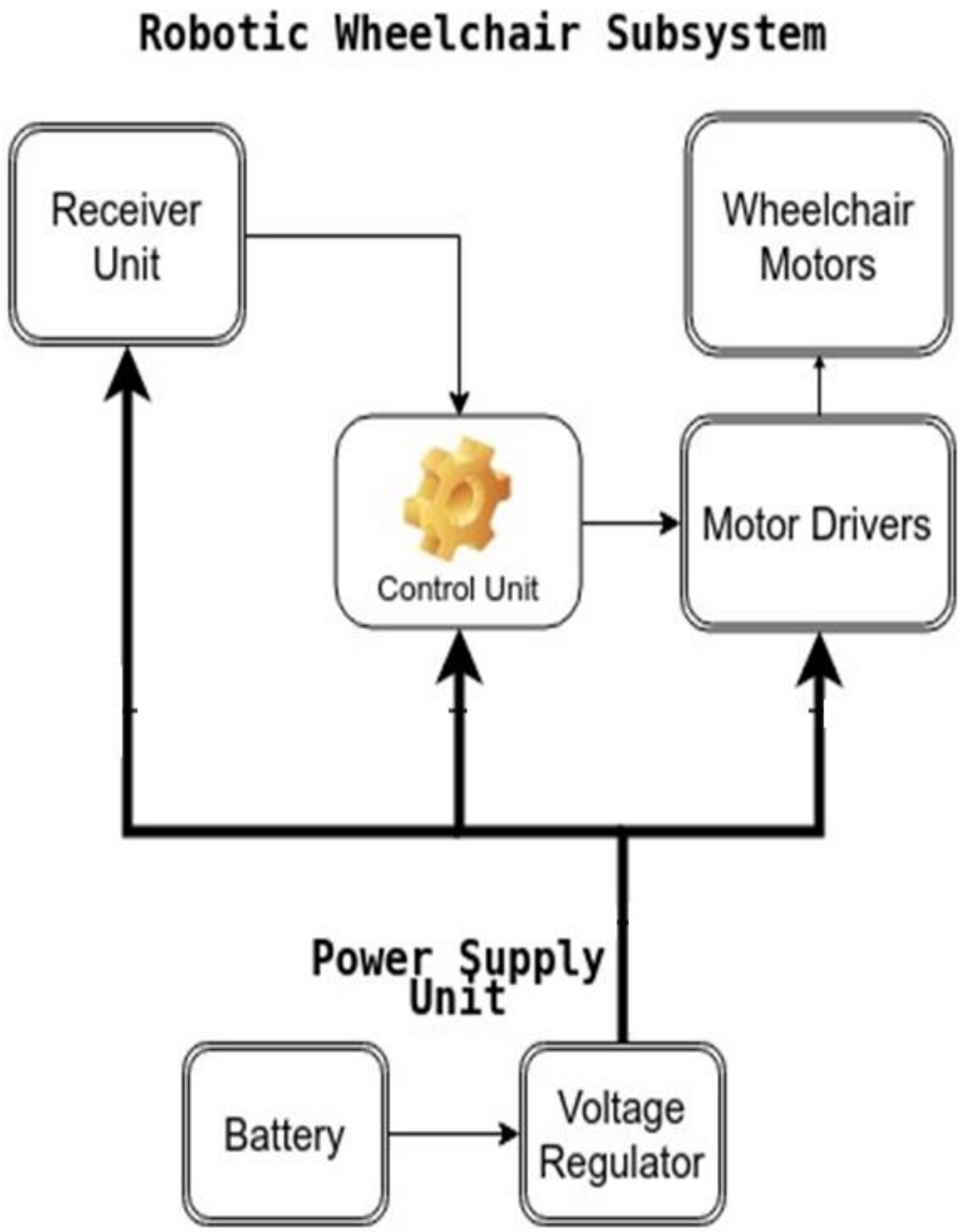


Figure 3.14: The block diagram of the RoWS

It consists of the followings:

1. The Power supply unit
2. The Communication unit
3. The Control unit
4. The Actuating unit

The Power Supply Unit: This is the same as the Power Supply Unit in the VAS. There are two options for this unit. It can either share power with the VAS or have a standalone battery for its power that would be charged when low.

The Communication Unit: This is similar in operation to the communication in the ECS. In this unit, commands for the navigation of the robotic wheelchair are received from the VAS and then sent to the control unit for the appropriate action to be taken.

The Control Unit: This unit acts similarly to the control unit of the ECS. It takes received commands from the communication unit and drives the actuating unit of the RoWS.

The Actuating Unit: This is the termination point of the RoWS. It consists actuators for moving the robotic wheelchair in reaction to received commands from the VAS.

3.2.4.3 The Robotic Wheelchair Navigation Interface

The need to create interface systems that allow a more natural interaction with a wheelchair has led to developing this proposed voice control interface smart home assistive device, that can perform a simple command control with the basic moves to drive the wheelchair using a microphone. Primarily, the Voice Activated Subsystem (VAS) consists of two parts: the first section is a vocabulary training that builds a reference voice commands model and the second is a voice recognition section that uses this reference model to compare the input commands with the model that was built. The command signals are received from the user through magneto-resistive sensor modules and microphone, and are sent to the microcontroller system. The voice commands that were used to control the voice interface can be seen in the following Table 3.2.

Table 3.2: Voice Commands for the Voice Interface

Commands	Actions	Commands	Actions
One	Power on the system	Left	Turn to the left
Up	Move forward	Right	Turn to the right
Down	Move back	Halt	Shut Down (Stops also engines)

3.2.4.4 Smart Wheelchair Obstacle Avoidance Embedded System

This work focuses on creating a smart wheelchair that provides collision avoidance at a low cost with minimal modifications to the environment or current wheelchair, so specifically for this system, and will be realized using ultrasonic sensors (e.g., HC-SR04 ultrasonic sensor, because it is the most accessible on the market). This smart wheelchair used a combination of different types of sensors, such as IR sensors, sonars, bumpers, and stereoscopic cameras, and these sensors play the role of perceiving the surroundings of the wheelchair system. The major challenge of achieving wheelchair obstacle avoidance is finding the correct sensors combinations that will properly cover the wheelchair surrounding areas. The sensors to be selected must possess the main features: need to be light in weight, small, low power consumption, inexpensive, accurate, and be robust, and resistance to every environmental condition. There is no single sensor that have been found to meet all of these features, hence the reason for the combination of different types of sensors to obtain more information around the wheelchair environment. According to the above features, this wheelchair obstacle avoidance system was developed as an embedded device, due to an embedded system can be easily mounted on the wheelchair, it does not modify the structure of the wheelchair, system programming can be performed in different operating systems, and obstacle avoidance system was distributed in modules.

Subsystem Sensors Location and Distribution: Sensors were placed in created modules with a different number of sensors in each module, to cover the largest possible environmental area as seen in Figure 3. 15, these modules are placed as follows: two of these sensor modules, which contain four sensors and cover sixty degrees, were placed at the front and the rear side of the smart wheelchair. But another set of four modules each containing three sensors placed at different angles to detect obstacles and specific floor irregularities such as holes, stairs or changes above the floor, covering 45 degrees per module, were placed at the upper left, upper right, lower left, lower right corners of the wheelchair. Similarly, in the sides of the wheelchair, four sensors each covering 15 degrees per sensor and are separated from each other, were placed per side.

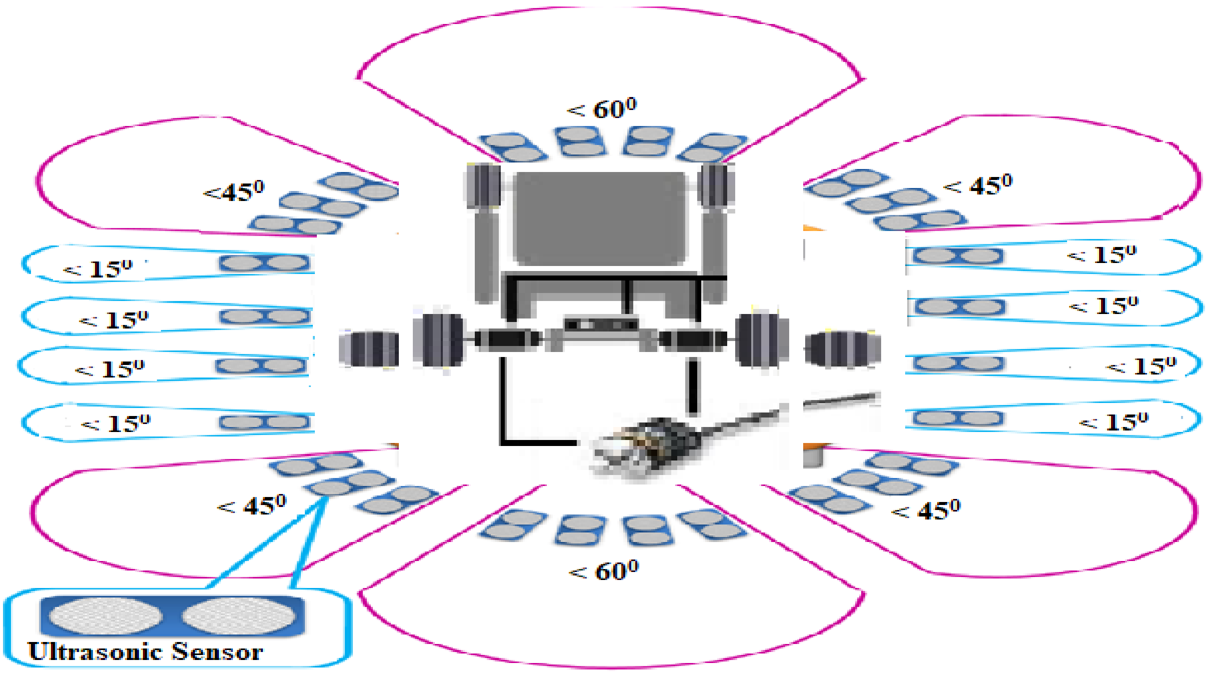


Figure 3. 15: The Distribution of Ultrasonic Sensors, for Obstacle Detection and Avoidance on Smart Wheelchair System.

Here, to enable this wheelchair prototype detect and avoid collisions, it was designed to cover a total of 300 degrees with the modules that are on the front and the rear of the wheelchair, while on the other hand, three sensors were placed on the sides of the chair to detect obstacles if it is moving sideways.

Finally, a total of twenty-six ultrasonic sensors were used on this prototype as show in Figure 3.15

The collision avoidance smart wheelchair system was designed to fit nicely into the multimodal smart home interface, and the system works by using different input commands, and it utilized most of the inputs and outputs of the microcontroller. The system structure allows constant communication with the sensor, which monitor the environment for potential obstacles, and sends the information received by sensors to the microcontroller. Primarily, this developed wheelchair has four possible methods of control that works, and are only interrupted by the presence of an obstacle, and the actions performed by this wheelchair were programmed into the system microcontroller in the circuit board. Finally, the system sensing and wiring diagram of the complete smart wheelchair system is shown (in Figures 3. 16 & 3.17), and it includes input devices, which provide signals to drive the wheelchair, and the connections of the twenty-eight ultrasonic sensors that were used as well as the battery and gearboxes engines coupled to the microcontroller circuit.

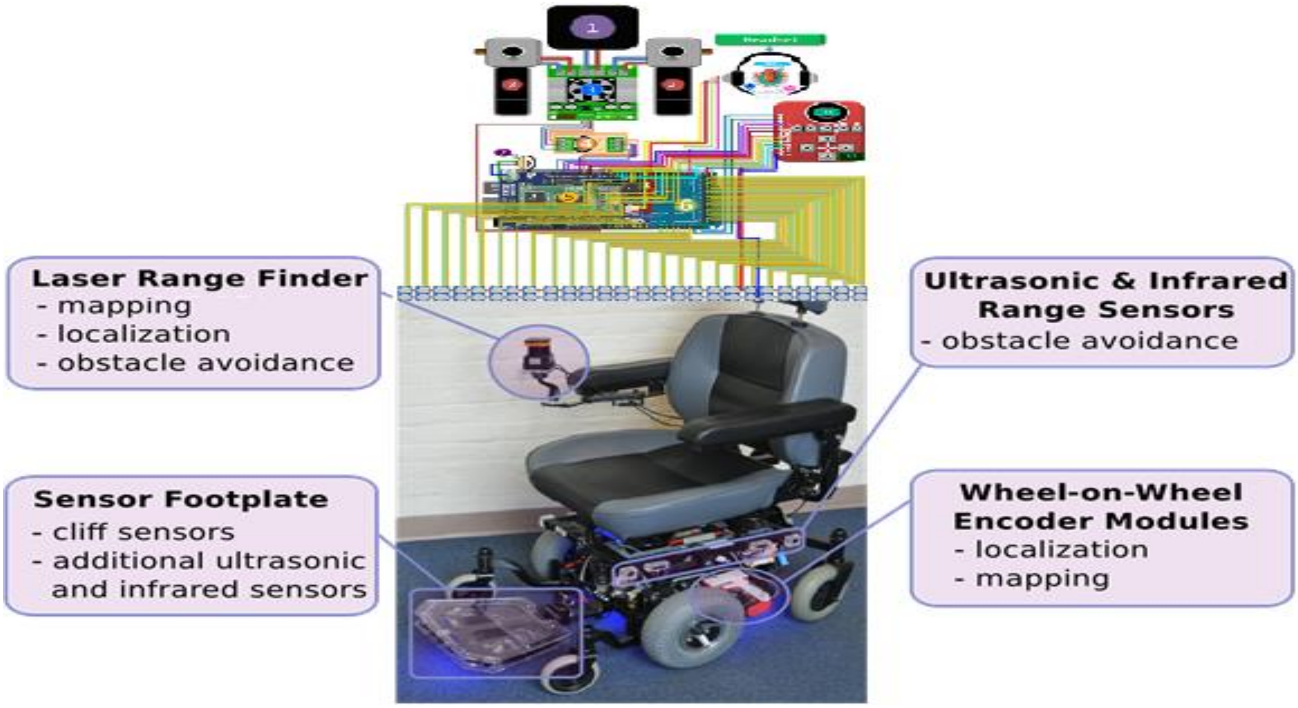


Figure 3. 16: The Smart Wheelchair Sensing Hardware Diagram

The entire subsystem architecture is shown on Figure 3.17, observe from the steering control paradigm that this system accepts velocity commands from a user interface and ultimately outputs desired velocities for the low-level motor controller. The system *Assistive Drive* Block (ADB) in between, modifies, the given velocity commands to enable obstacle avoidance, that is made possible by the costmap that holds the latest information about all the detected obstacles, and the Cliff detector in addition constantly monitors cliff sensor data to detect a possible increase in the detected range which would mean a cliff or a staircase being right under the robot footplate. This makes the system to send an interrupt stop command to the motor controller, thus preventing the wheelchair from a tipping over. On the diagram of Figure 3.17, the autonomous navigation block that is not used for steering control is shown faded. The movement task of smart wheelchair system was simulated with a graphical user interface (GUI), using actual wheelchair speed as a variable and computer for multimodal interface (hardware), in order to teach users how to use the system properly and intuitively. The programming environment that was used for the graphical interface is an open-source programming language named “Processing”, used for creating animations and interactions.

Another reason why it was decided to develop a software simulation, it is because the programming environment "Arduino" is based on processing

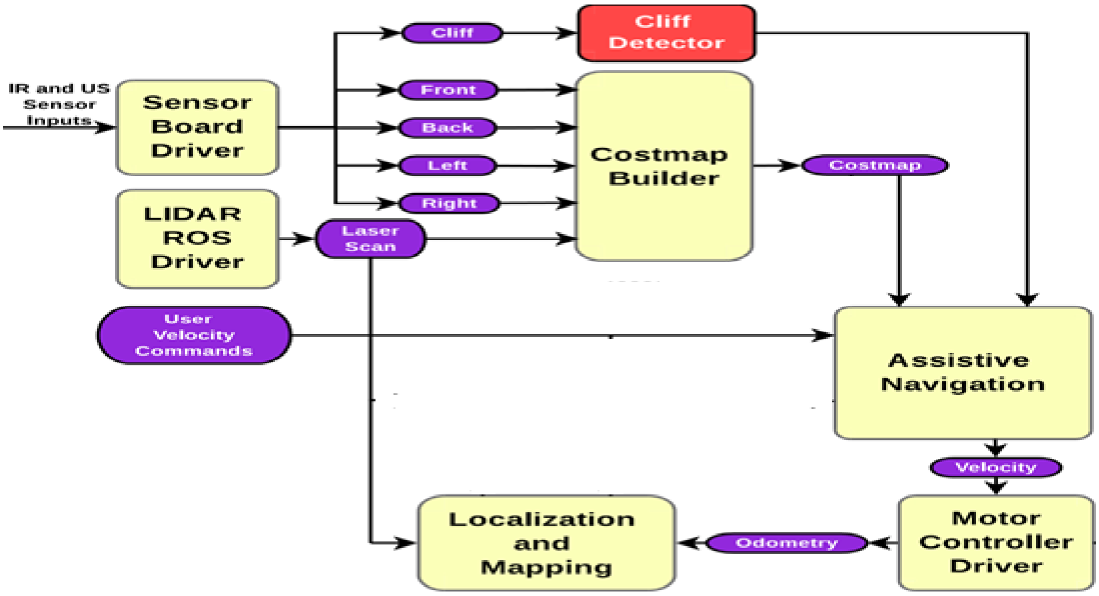


Figure 3.17: The Simulated Tasks of Obstacle Avoidance System

Furthermore, the programming of the tasks of obstacle avoidance system that was simulated works as follows.

1. When the ultrasonic sensors perceive an obstruction, the microcontroller disables commands and directions that are leading to the obstacle, but kept enabled only commands in which the sensors have not detected obstacle.

2. When the sensors detect several obstacles, the microcontroller acts in the same way as above, but when an obstacle sensed is too close, the microcontroller in addition triggers alarm to alert the user.

When the obstacle detected is within a close range of about 3 cm from the sensors, the microcontroller sends a signal to activate an alarm, indicating that there was an obstacle. Figure 3.18 shows the algorithmic flowchart of the obstacle detection and collision avoidance, while the digital robotic wheelchair collision avoidance movements are shown in table 3.2.

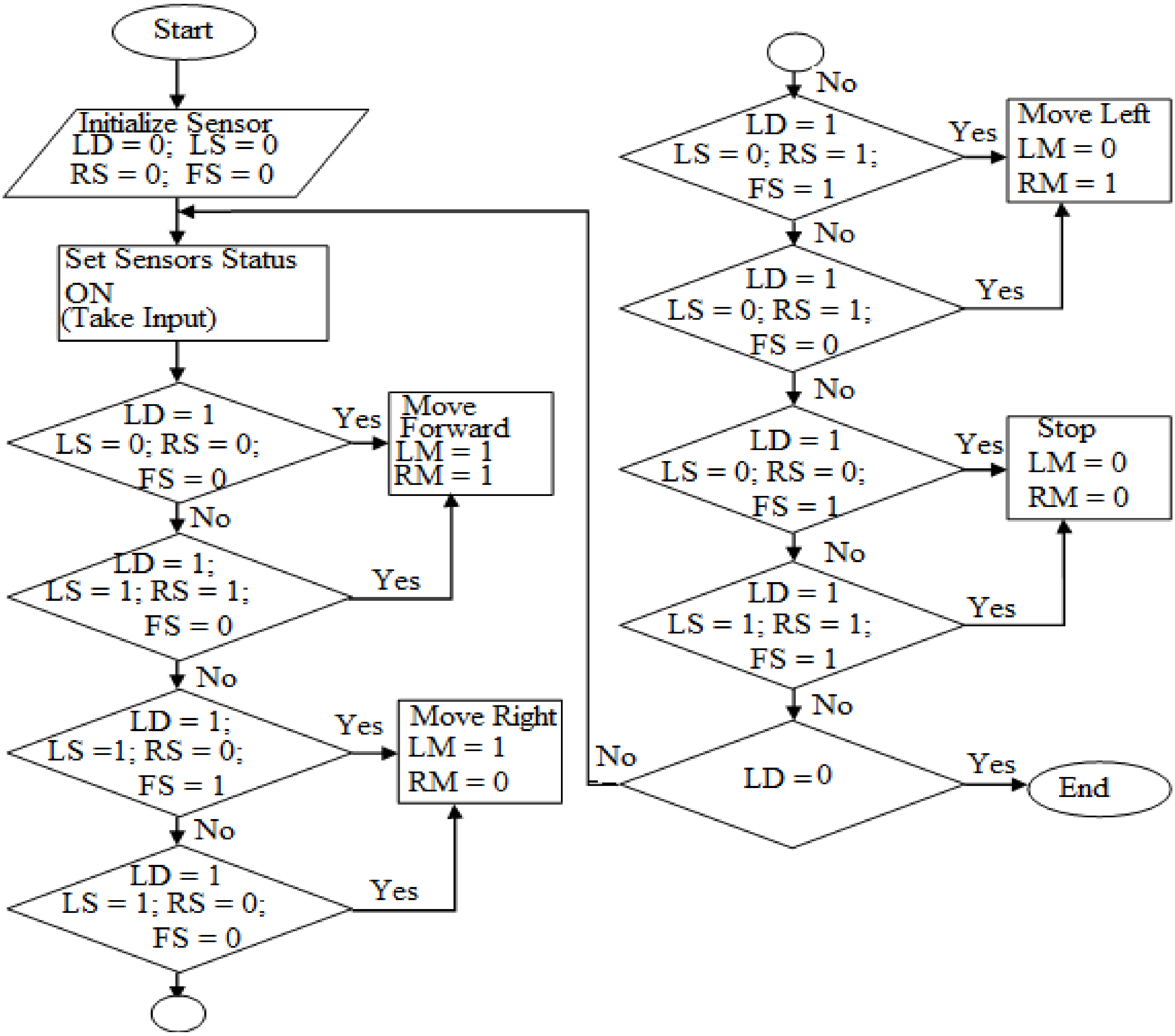


Figure 3.18: The Robotic Wheelchair Collision Detection and Avoidance Flowchart

Table 3.3: The Digitalized Robotic Wheelchair Collision Avoidance Truth Table

LD (Enable)	LS	RS	FS	LM	RM	Description
1	0	0	0	1	1	Moves Forward
1	1	1	0	1	1	
1	1	0	1	1	0	Moves Right
1	1	0	0	1	0	
1	0	1	0	0	1	Moves Left
1	0	1	1	0	1	
1	0	0	1	0	0	Stop

1	1	1	1	0	0	

3.2.4.5 Software Design

The software required for running the smart home system is designed in this section. The waterfall software development approach was used for design, programming, and modelling. The flowchart diagrams used in this design present the step-by-step procedures for the implementation of software programs used in both system design and program implementation achieved by converting the system specifications into executable software.

3.2.4.6 The System Software Architecture

The software design consists of a step-by-step design of the subsystems of the software system architecture shown in the architectural block diagram of Figure 3.19.

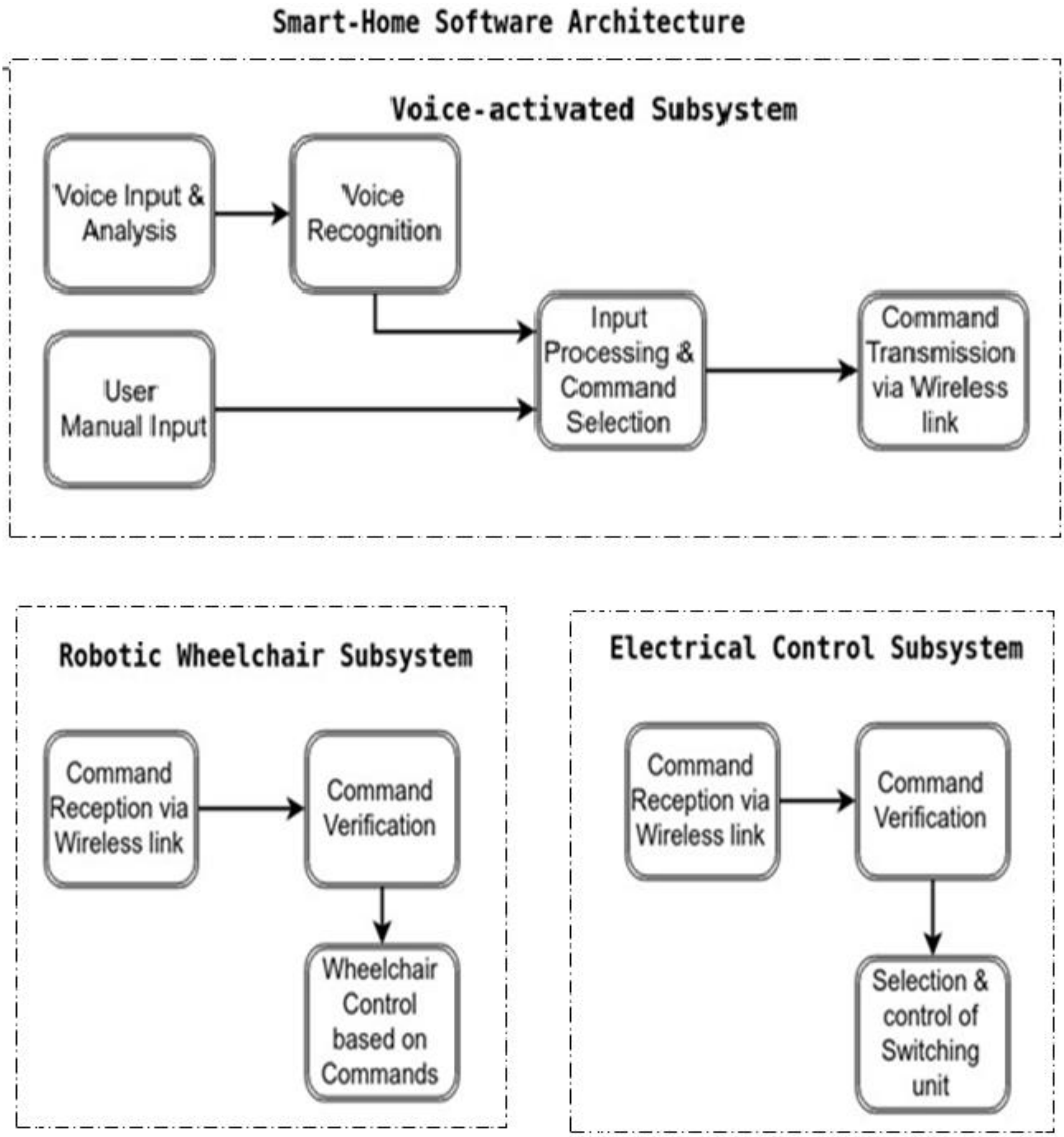


Figure 3.19: The software architecture of the smart home

Each subsystem is linked only through a physical wireless connection as described in the hardware design, and an illustration of the design flow is seen in Figure 3.19. The flow of data goes through the wireless link between the subsystems. The software in the VAS collects and processes the raw voice analogue input as digital data which is sent out to either of the ECS or the RoWS dependent on the active system. The software for the ECS receives input data, processes it and performs a corresponding action that actuates an AC or a DC appliance. Similarly, the software for the RoWS receives input data, processes it and performs a navigation action that corresponding to its input.

3.2.4.7 The System Software Design Requirements

In addition to the overall system requirements, the system software is required to meet the following criteria:

a) The software should ensure data reception from voice recognition.

b) The software should analyze the data received to communicate with the application devices.

c) The software must be able to perform accurately.

d) The software should further process the commands and map them to an output.

e) The software should execute the corresponding operations assigned to each event.

3.2.4.8 Software Design of the subsystems

3.2.4.8.(a) The Voice-activated subsystem

An effective voice recognition requires the system to detect and allow commands from the specific user designed for. This requires training the VAS adequately to detect only the voice of the user. Hence, the VAS is capable of operating in two modes the training mode and the normal mode, this is seen in Figure 3.20.

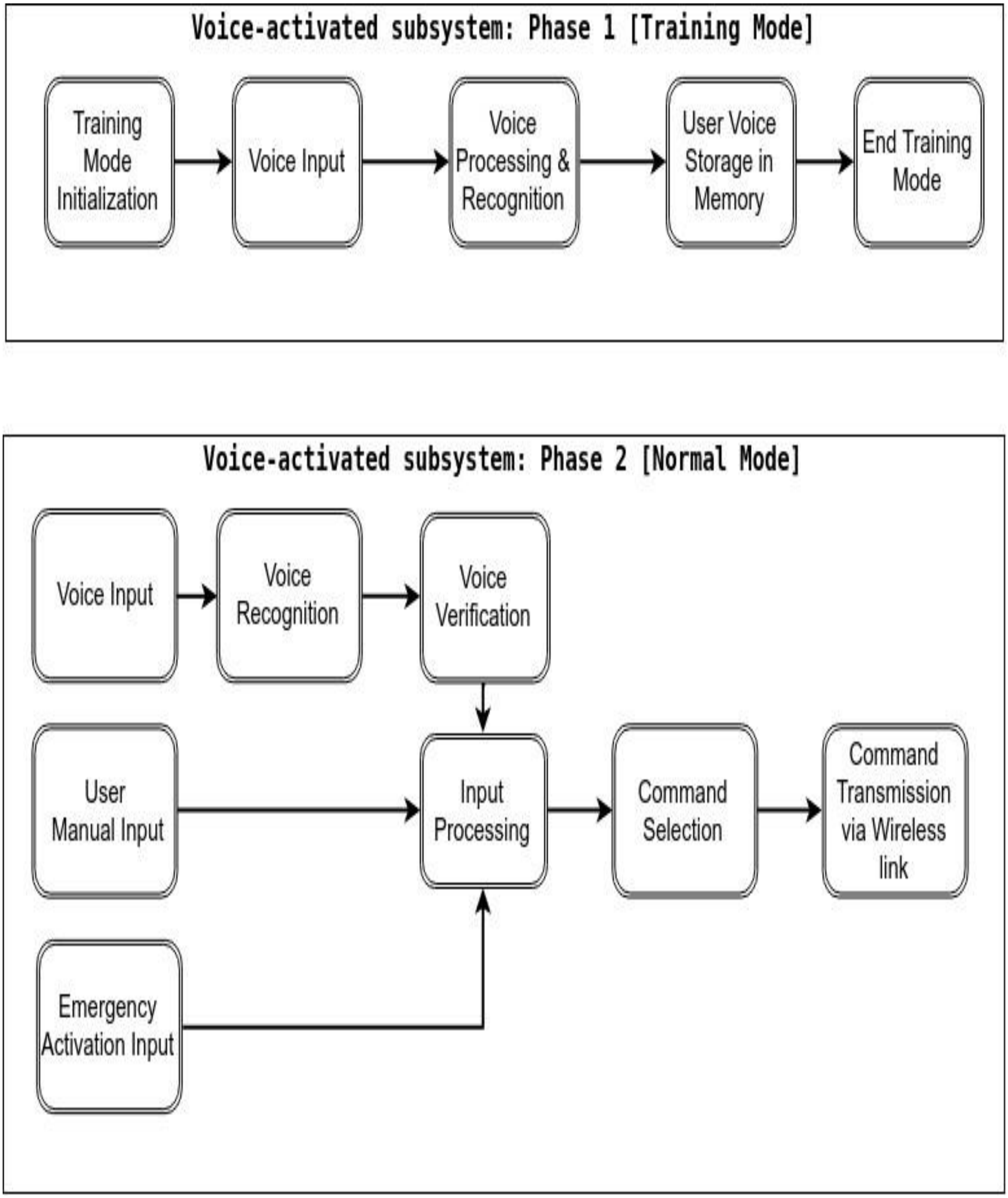


Figure 3.20: The software architecture of the VAS

The two modes of the VAS is seen in Figure 3.20. The training mode of the VAS is necessary for the system to operate as intended. It takes in the analogue voice input from the user, extracts and converts it to digital format to be stored using quantization method, and the digitally processed signals known as command words, are stored, and these command words then form the preset commands of the smart home system during normal operation. Here, the training files are prepared by the user, and the voice files are recorded from the microphone and the MFCC features are extracted from the input file, and are then stored. The collection of these training files is called database. The user then trains the system using the files in the database, and it is called training phase or pre-processing. Figure 3.21 shows the flow chart of the step of training phase.

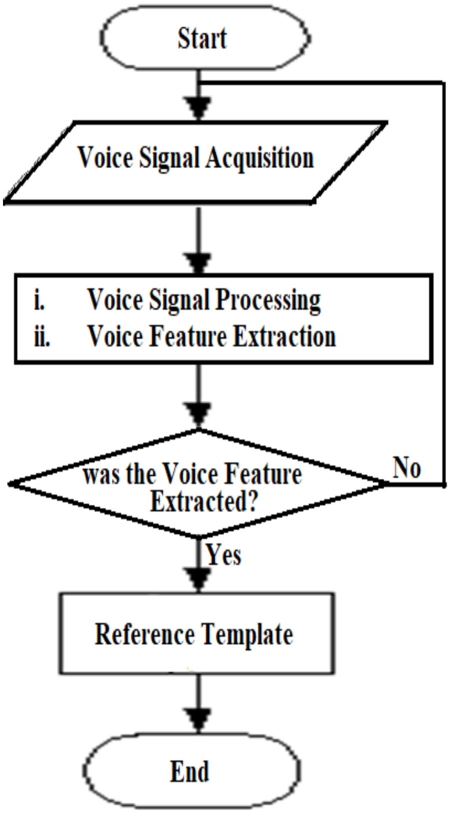


Figure 3.21: Flow Chart of the step of Training Phase

The normal mode of the VAS operates such that there are reception and verification of the voice signals with the stored voice commands of the user. When the VAS has been trained and is in normal mode, analogue voice input is sent into the VAS and converted to a format that can be verified with the predefined voice input stored during training. Once verification is successful, the commands that map to the predefined voice input are selected to enable the system to perform a particular function. This process of testing phase is illustrated by the flowchart in figure 3.22.

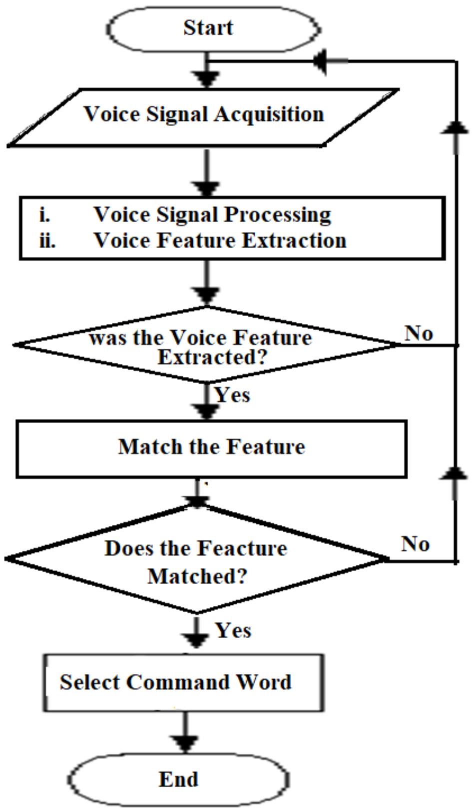


Figure 3.22: Flowchart of the step of Testing Phase

Microsoft Access Database are two databases designed using Microsoft Access 2007, and they "userId" and "homeDB". The "userId" database stores registered users` information, which, is used by the administration to identify and manipulating smart home information. Also, the "homeDB" stores all home command words related data, and it comprises of "tagId", "Username" and "dateReg" tables, which act as temporary data storage, which are essential to the program flow. The database has a login password which allows access. Figures 3.23 & 3.24 are the flow diagrams of the "userId" database and "homeDB" database.

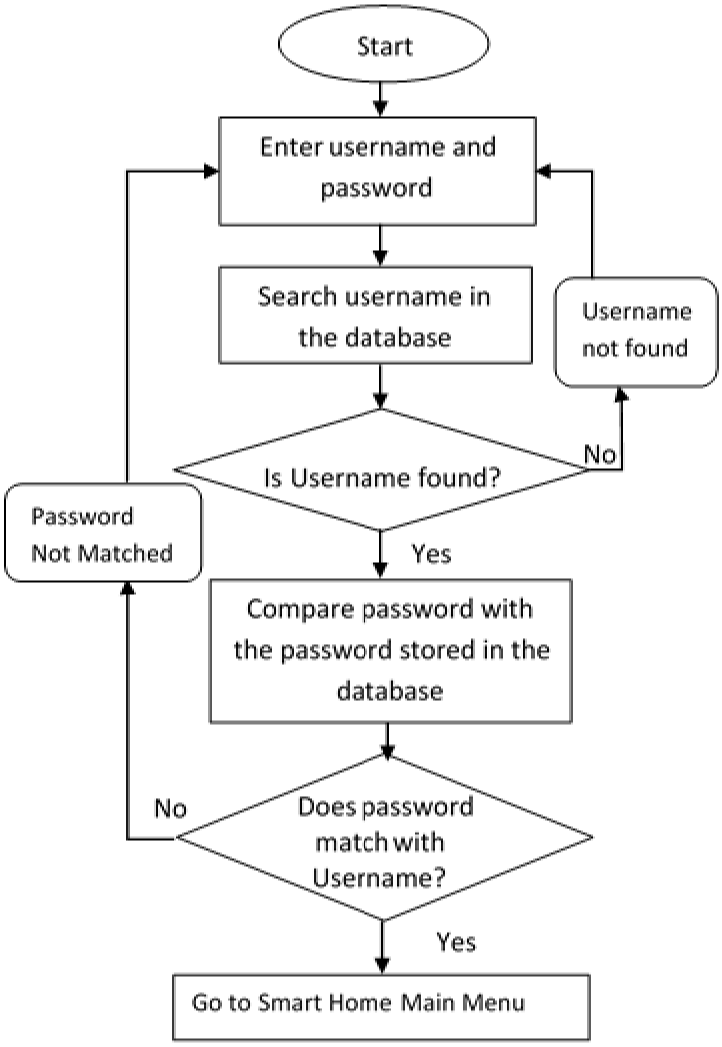


Figure 3.23 userId database

The smart home system interface is made up of the login part, to make the system more secure as users have to login first before having access to the main interface, and the main interface part. The folder of the design project is named “SMART HOME SYSTEM”, and the output of the compilation is in “Debug” folder within the project folder. Figure 3.24 is the flow chart for the login transaction

Programming the software for the VAS would require following the flowchart in Figure 3.25. The program flow is implemented by the control unit of the VAS.

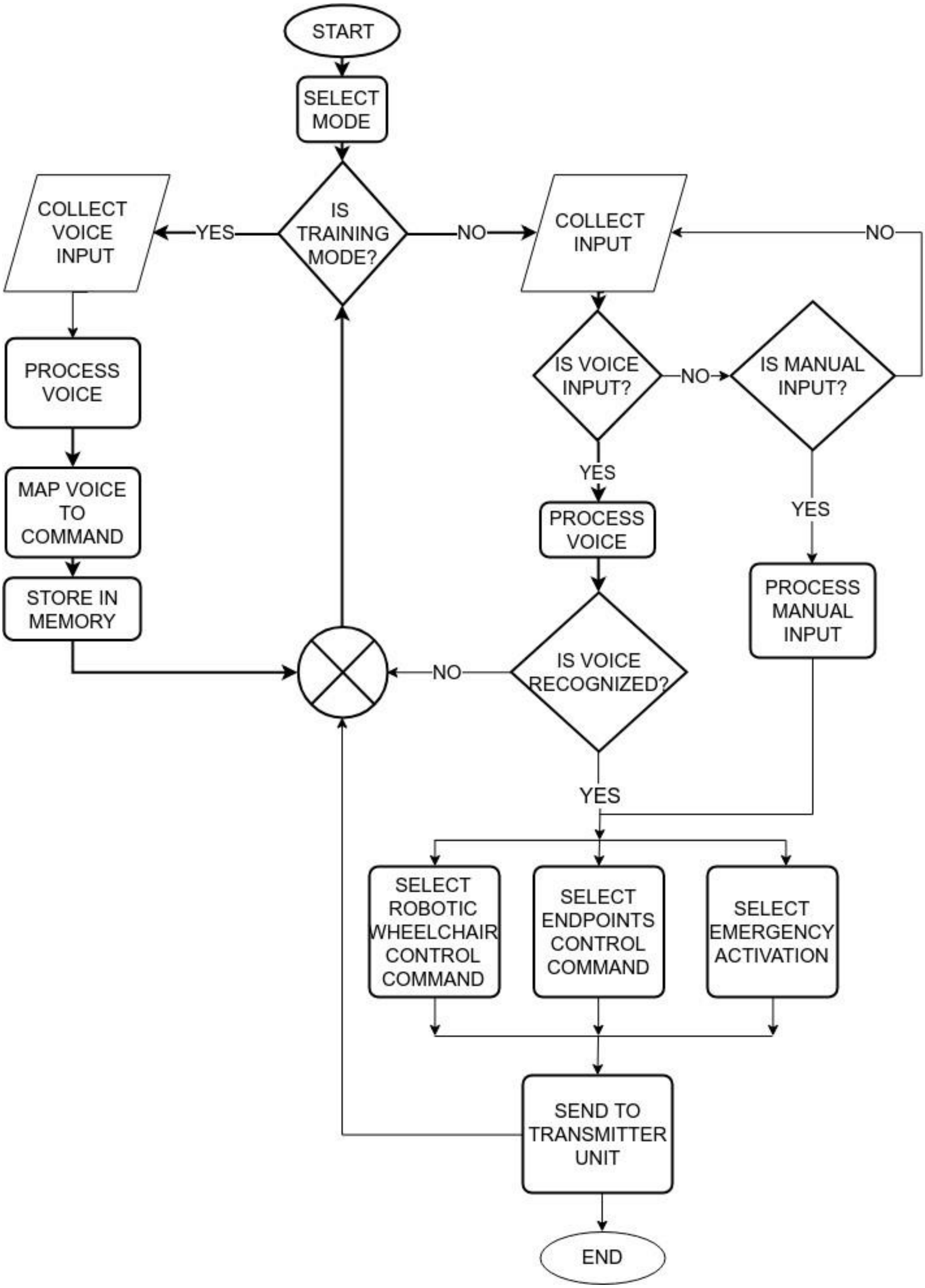


Figure 3.24: The flowchart diagram of the VAS

3.2.4.8. (b) The Electrical Control Subsystem

The control unit of the ECU holds the software for the working of this subsystem. It controls the flow of data into the subsystem and activates any action corresponding to the input received. As seen in Figure 3.25, the ECU processes data through Data Reception, Command Verification, and Command implementation.

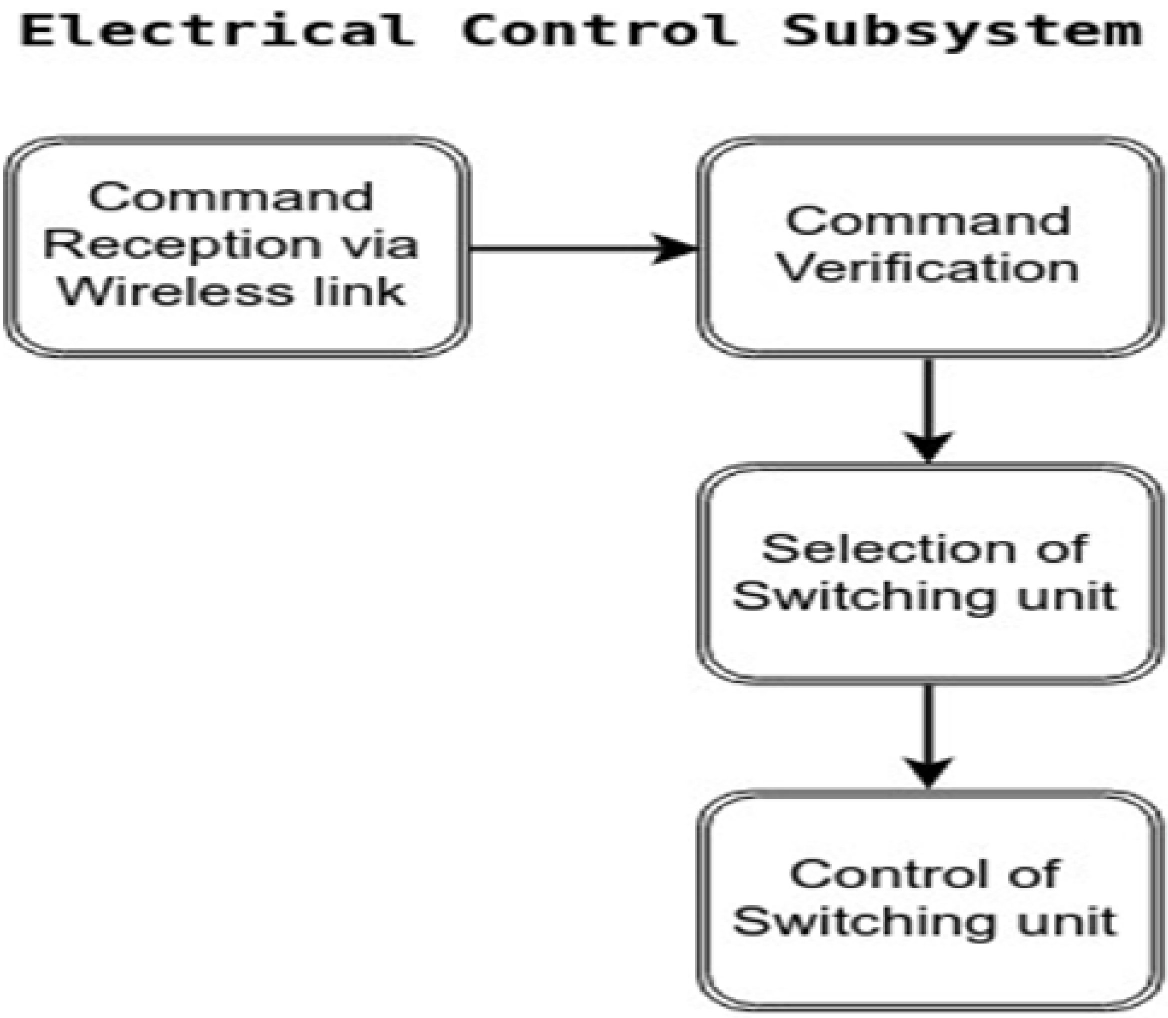


Figure 3.25: The software architecture diagram of the ECU

The ECU receives incoming data through its wireless link with the VAS. Its control unit manages the flow of data into the subsystem through the device used for communication. On reception, the input data is decoded and is passed to the control unit for verification. Its software verifies the input data from the wireless link and activates a corresponding action. If an invalid data is sent, then no action is performed. Since the control unit interfaces the communication unit with the rest of the circuitry - switching block and the endpoints, it handles all processes and the selection of the endpoint to be activated. Its software directs the flow of data between the interfaced units, hence the flowchart diagram in Figure 3.26.

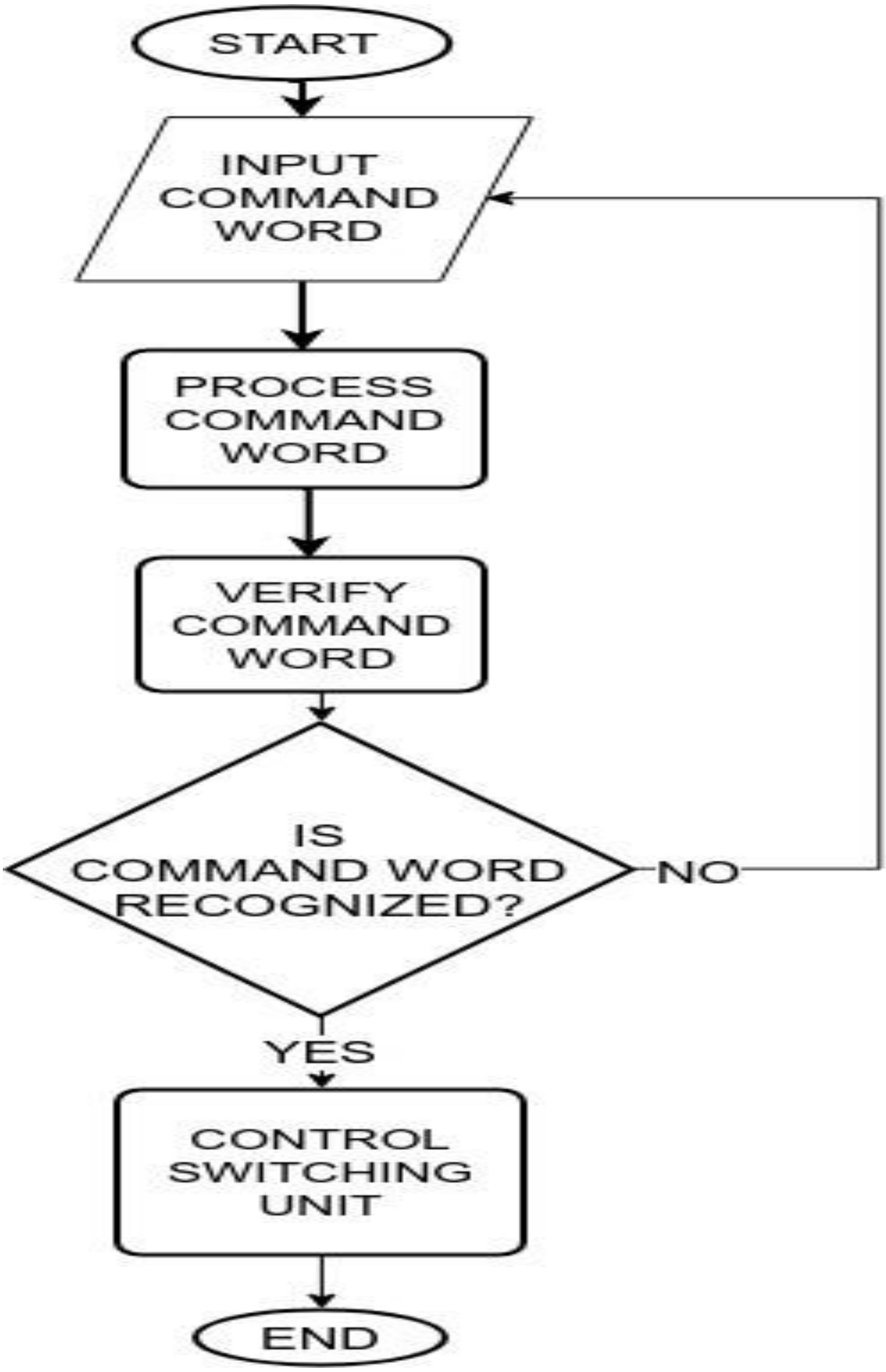


Figure 3.26: The flowchart diagram of the ECU

3.2.4.8. (c) The Robotic Wheelchair Subsystem

The software for the RoWS works similarly to that of the ECU. The control unit of the RoWS also manages the flow of data into the subsystem and activates any action corresponding to the input received. It also processes data through Data Reception, Command Verification, and Command implementation as seen in the software architecture of the smart home system shown in Figure 3.27.

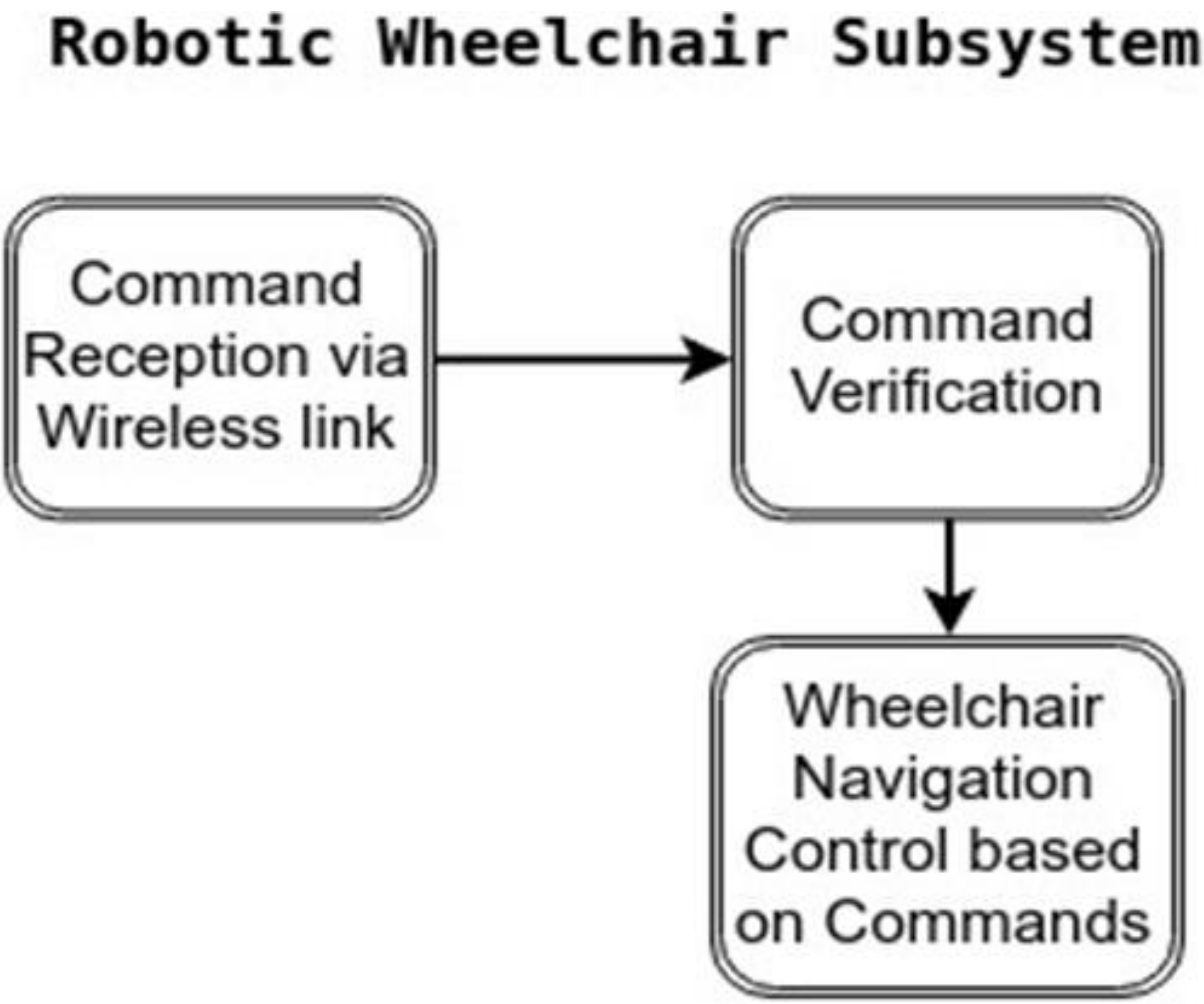


Figure 3.27: The flowchart diagram of the RoWS

The RoWS receives incoming data through its wireless link with the VAS. Its control unit manages the flow of data into the subsystem through the device used for communication. On reception, the input data is decoded and is passed to the control unit for verification. Its software verifies the input data from the wireless link and activates a corresponding action for navigating the wheelchair. Since the control unit interfaces the communication unit with the rest of the circuitry - the drive-train for the wheelchair, it coordinates the movement of the wheelchair. Its software directs the flow of data between the interfaced units, hence the flowchart diagram shown in Figure 3.28.

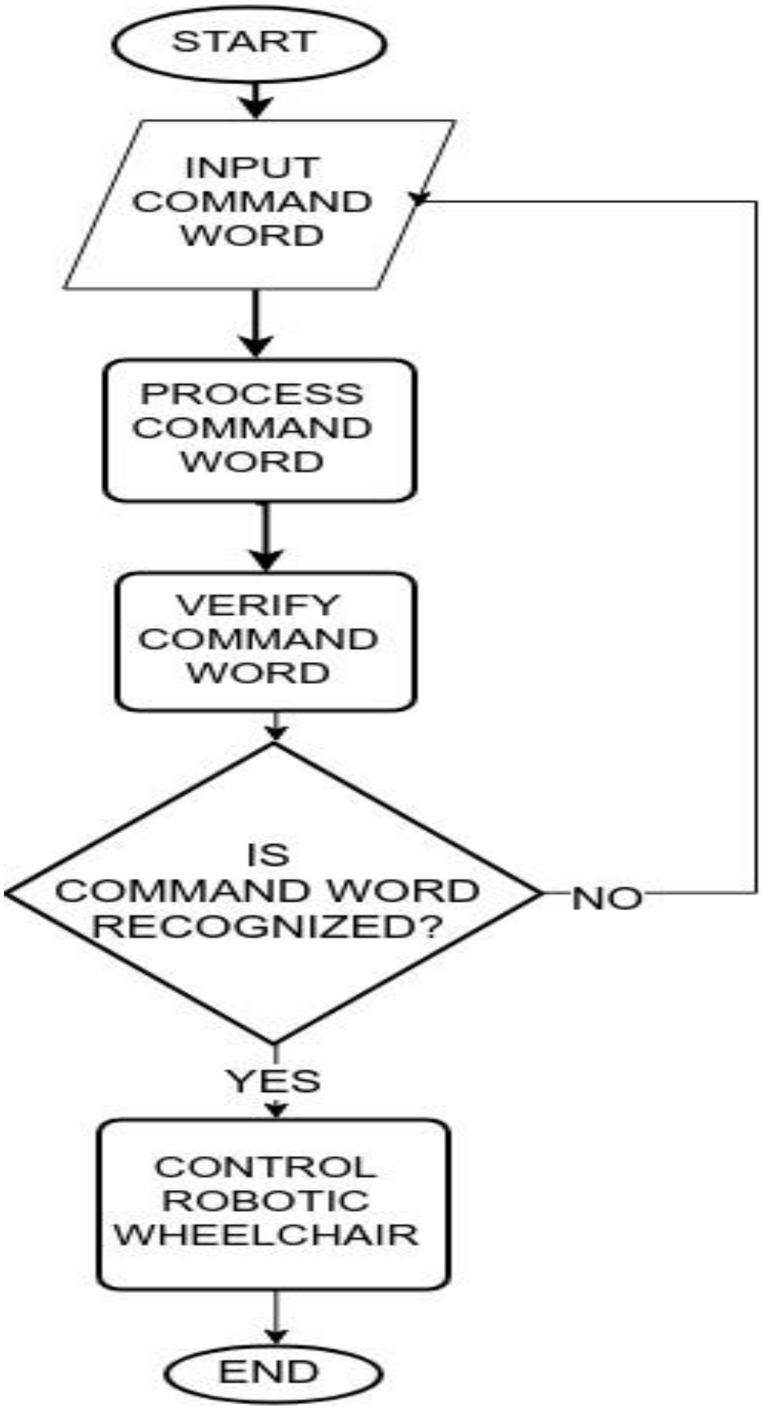


Figure 3.28: The flowchart diagram of the RoWS

3.2.5 Design Analysis

The schematic diagram shows the low-level description of the design wherein complete details about the unit components and their integrational connections are presented. The Figure 3.29 shows the schematic design of the multimodal input control smart home technologies for the aged persons Voice Control System. This schematic diagram is separated based on its two major units which are Smart Home Transmission unit and Smart Home Receiving unit. The Transmission unit is a system that allows system interactions such as data input, recognition, interpretation and sending of control signal to the remote output, while Receiving unit, interprets the received control signal and use it to switch smart home appliances. The schematic diagram of the Transmission unit and the Receiving unit are illustrated by Figure 3. 29. The smart home remote input controller is composed of the following sub-diagrams for data inputs namely the voice recognition input module, the joystick input module and the push button GSM input module. The control activities of transmission system are done by the Microcontroller Unit. However, the smart home remote application controller is composed of the following sub-diagrams for smart home output application control devices such as the window unit, the door unit, the fan unit, the electrical appliances unit, and the smart wheelchair unit. Receiving unit uses both wireless Bluetooth and RF transmission as the medium of communicating with these output devices.

The Main-controller Unit consists of a VoiceGP module, an electrets microphone, and led-indicators for voice-recognition. The VoiceGP module is an off-the-shelf voice-module and microcontroller, which is responsible for voice command recognition and control signal distribution. It acts as the heart of the voice-activated home Control System Design. Every time the VoiceGP module recognizes a certain voice command, it performs certain actions such as playing .wav files and sending signals to its IO ports.

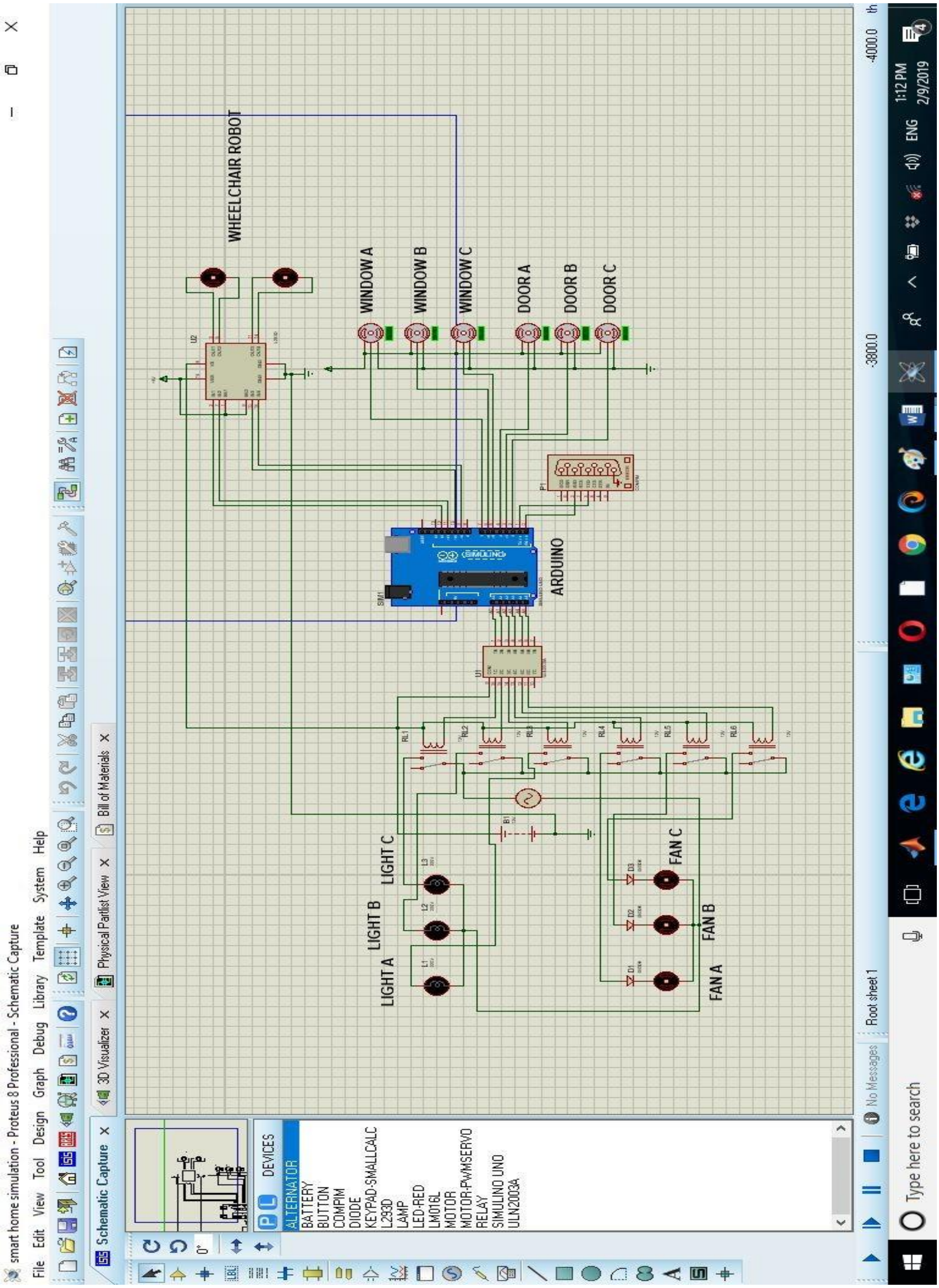


Figure 3.29: The System Schematic Diagram

The electret condenser microphone connected to the VoiceGP (refer to Figure 3.30) serves as the input for the voice command. The gain resistor in series with the positive pin of the electret microphone has a computed value of 1.237 kΩ for far mic distance of 3 meters.

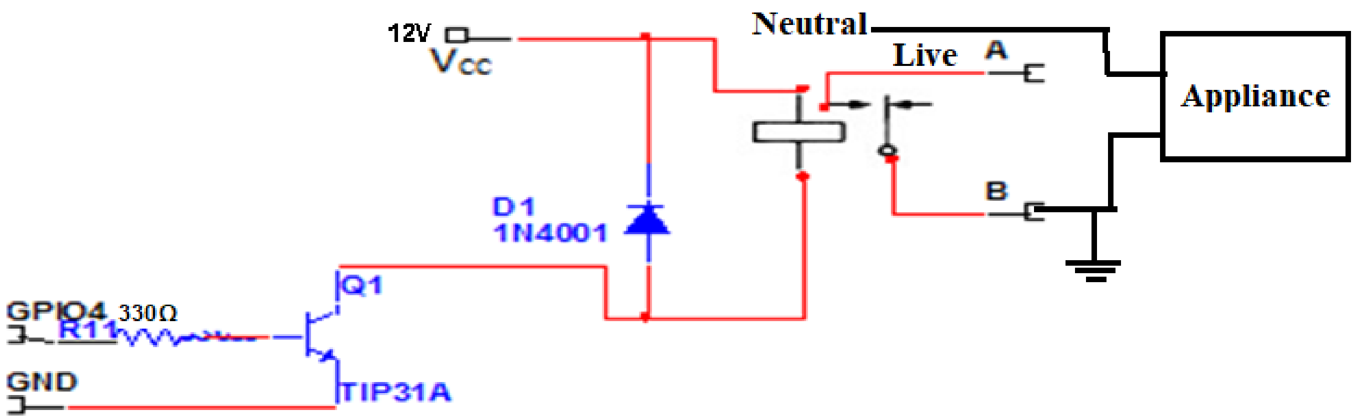


Figure 3.30: Relay Driver Circuit (Rommer et al, 2011)

The formula for gain resistance was obtained from the VoiceGP datasheet. The formula and computations are shown below:

$$R_s = 1 \text{ x } 10^{G\text{-sensitivity}/20} \qquad (3.1)$$

Where: G = overall system gain

Sensitivity = sensitivity rating of the microphone in terms of –dB.

I = impedance rating of the microphone

R_s = microphone source resistor

The Light-emitting Diodes (LED) connected to the IO ports of the VoiceGP module (LED1, LED2, and LED3) pertains to the led indicators for voice command recognition. These led indicators are lighted and represents a specific operation of the module. LED1 signifies that the voice module is ready and waiting for the trigger word to be uttered. LED2 signifies that voice module accepts the trigger word and is waiting for the specific voice command to be uttered. LED3 signifies that the voice command was rejected.

Both Lights and Fan units contain relay drivers for controlling the AC power used by the Lights, Fan, and Fridge. The relay driver circuit shown in Figure 3.30, consists of a TIP31 NPN-transistor, 330Ω resistor, 12V relay and 1N4001 diode. The 330Ω resistor serves as a circuit that allows small current pass through the base-emitter junction. The transistor serves as a circuit that controls the state of the relay. The diode serves as a protection for the relay and the relay controls the flow of AC power in the AC sockets which in turn control the Lights and Fan.

When a 3.3V positive volt was applied at the base of the transistor, the collector-emitter junction connects together. Thus, the 12V power flows through the inductor part of the relay which then energizes the switch inside the relay. The state of the switch determines if the AC power flow to the AC socket. The reverse-biased diode serves as a voltage protection for the inductor part of the relay such that no current will pass through when the transistor is not active. If ever no positive voltage is applied to the base of the transistor, the transistor will not be in active state and the AC power is disconnected to the AC socket.

The Led Indicators Unit under the Smart Home Assistive Controller unit consists of three LEDs (LED4, LED5, and LED6) which correspond to the home services provisions (wheelchair control services, door/window control services, and emergency call services) respectively. When a specific service was invoked by the user, the led indicator will be lighted indicating that, that particular service was launched. When a service was accepted, by means of PC-interface, the led indicator will be unlighted indicating that the service was already recognized.

Every microcontroller is taken to be a terminal of its own and must be matched to one access terminal. The IN4001 diodes used in this work are all signal diodes, and are used for directing signals. The resistor used in biasing these diodes is 1K$_\Omega$, because the ATEL80C51 microcontroller has a maximum allowable pin current of 5mA standard.

So V = IR (3.2)

where V = required input voltage, I = Pin current, and R = biasing Resistor

But V = 5V, and I = 5mA

Therefore, R = V / I (3.3)

R = 5 / 0.005,

1000Ω = 1K Ω.

A pull-up packed resistor is connected to the port 0 of each of the microcontroller to make the port 0 which, initially is actively low to be actively high to enable the microcontroller to be used. It takes each microcontroller a default maximum time of 2mS to set up for operation from power-up known as a reset time that enable microcontroller set for internal operation. The RC circuit also known as reset circuit, is connected to pin 9 of each microcontroller, and this RC circuit generates the reset time, T for the microcontroller, and this reset circuit is shown in Figure 3.31.

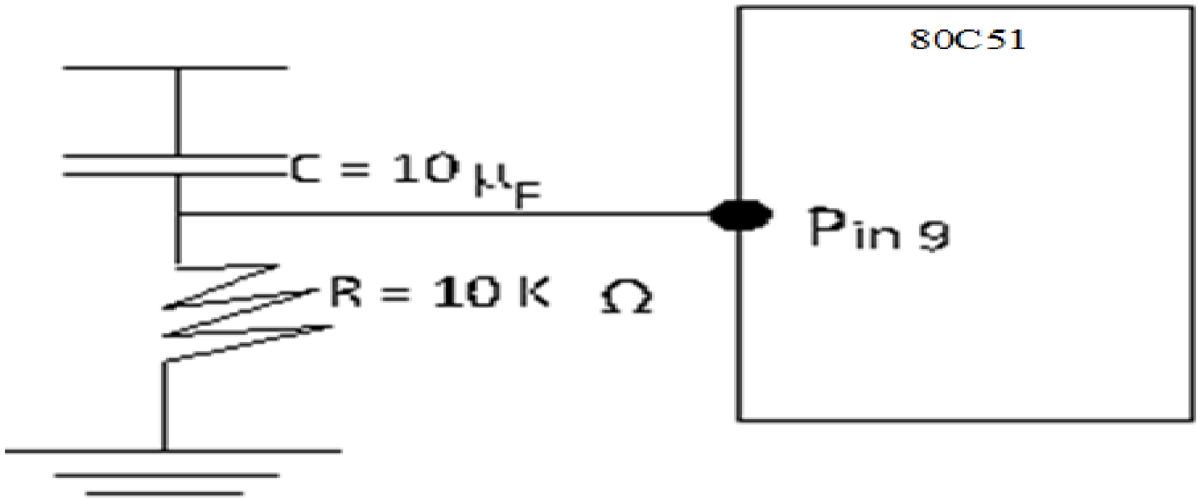


Figure 3.31: Reset circuit connection

The reset pin 9 of this microcontroller 80C51 has a capacitor, C and a resistor, R. where C = 10µF and R = 10KΩ as shown in Figure 3.31.

The reset time known as the period, T = 1.1 RC, then T = 1.1 x 0.00001 x 10000 = 1.1mS. So, these values of R and C are accepted, but since the value of T is less than 2mS, the AT80C51 on-chip oscillator requires external clock to run it. The essence of using crystal oscillator is connected to pin 19 (inputs XTAL 1) and pin 18 (XTAL 2) of the microcontroller is to control the speed of the microcontroller refers to as the maximum oscillator frequency connected in between XTAL 1 and XTAL 2, and a crystal oscillator with 12MHz frequency is used.

At the robotic wheelchair side, an H-bridge is designed with four switches such that when the switches Sw1 and Sw4 are closed, and Sw2 and Sw3 are open a positive voltage will be applied across the motor. By opening S1 and S4 switches and closing Sw2 and Sw3 switches, this voltage is reversed, allowing reverse operation of the motor. The robotic wheelchair is operated with DC motor and drivers with the H-Bridge switching conditions. Two H-Bridge is needed, and each of the H-Bridge has four transistors for motor operation switch is shown in Figure 3.32. The four conditions on which the motor movements based are shown in Table 3.4, while the wheelchair direction that is based on the direction of the motors are shown in Table 3.5

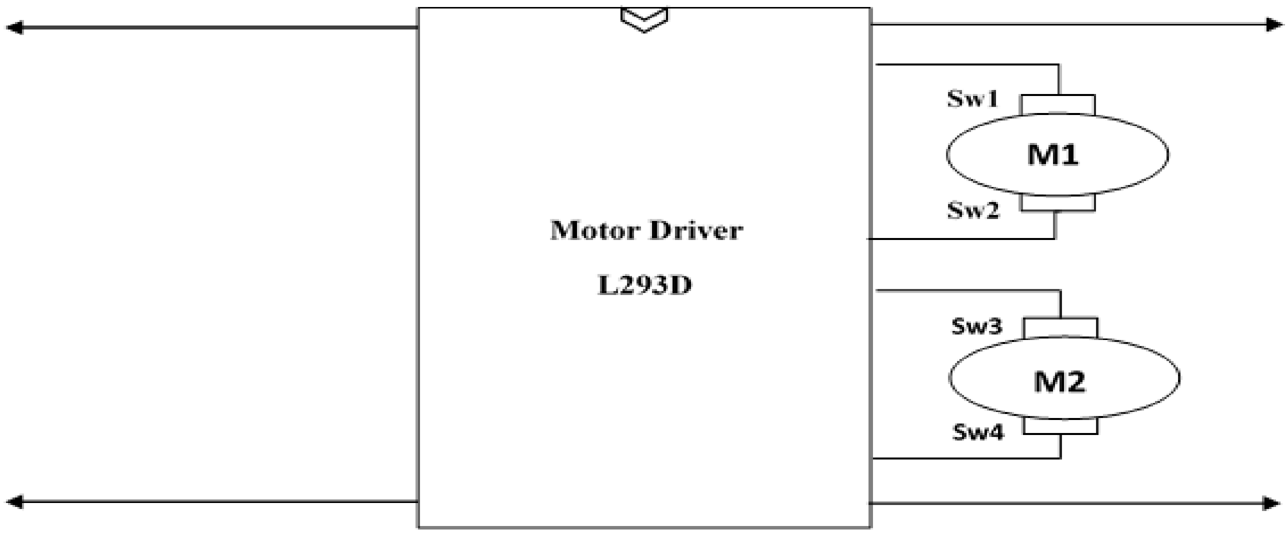


Figure 3.32: The H-Bridge Motor Operation Switch

Table 3.4: Switching Binary Conditions

S1	S2	S3	S4	Output Resultant Effect
1	0	0	1	Motor moves Right
0	1	1	0	Motor moves Left
0	0	0	0	Motor Halt
0	1	0	1	Motor moves Up
1	0	1	0	Motor moves Down

The method for binary signals generation, which has two signal periods (high and low) is known as Pulse width modulation (PWM) in which the width (W) of each pulse varies between 0 and the period (T). The power control principle here is by varying the duty cycle, whereby the conduction time to the motor is controlled, by varying t_{on} or T of the duty cycle from 0 to 1 as shown in Figure 3.33. By controlling the duty cycle results to change in the average output voltage V_{avr} between 0 and V_{in}, thus, controlling the power flow. Hence, the various logic states of the motor switches due to the duty cycle variations are shown in table 3. 5, while the motor direction in each of this variation are shown in Table 3.6

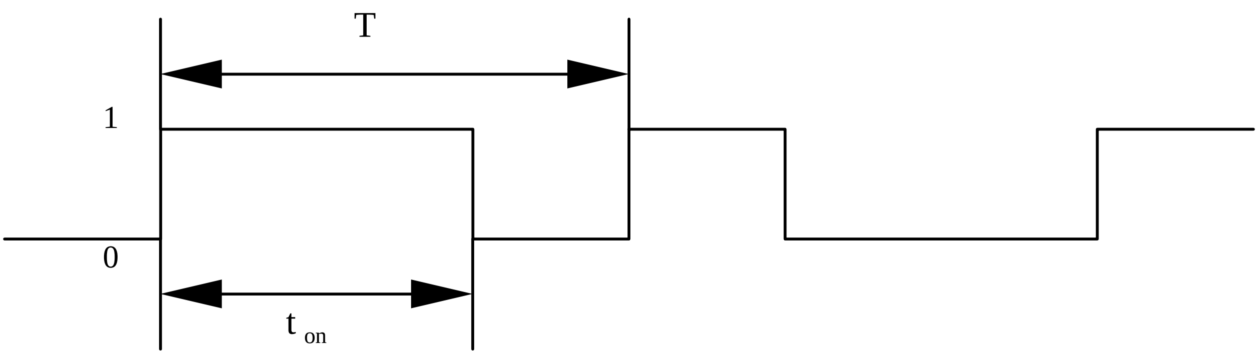


Figure 3.33: The Binary Signals Generation

Table 3.5: The Logical States of the Switches

Switch Combinations	Logic States of the Switches				Output	Output Effect
	Sw1	Sw2	Sw3	Sw4		
Sw1, Sw2	1	1	0	0	1100	Right Movement
Sw1, Sw3	1	0	1	0	1010	Up Movement
Sw1, Sw4	1	0	0	1	1001	Halt
Sw2, Sw3	0	1	1	0	0110	Halt
Sw2, Sw4	0	1	0	1	0101	Down Movement
Sw3, Sw4	0	0	1	1	0011	Left Movement

Table 3.6: The Wheelchair Direction with Respect to that of Motors

Direction	**Motor1**	**Motor2**
Forward	Up	Up
Backward	Down	Down
Left	Down	Up
Right	Up	Down

The system command words are shown in Table 3.7.

Table 3.7: The System Command Words

Command Words	**Output String values**	**Description**
	Digital	
Light on	0 0 0 1	switch on the bulb
Light off	1 1 1 0	switch off the bulb
Fan on	0 0 1 0	switch on the fan

Fan off	1 1 0 1	switch off the fan
Door open	0 1 0 0	open the door
Door close	1 0 1 1	close the door
Window open	0 1 1 1	open the window
Window close	1 0 0 0	close the window
Robot left	0 0 1 1	robot moves in left direction.
Robot right	1 1 0 0	robot moves in right direction.
Robot up	1 0 1 0	robot moves in forward direction
Robot down	0 1 0 1	robot moves in backward direction
Robot halt	0 1 1 0	robotic wheelchair stops its movement.

3.2.5.1 Smart home technology system programme and algorithms

The smart home technologies operational programs are shown in Figure 3.34

```
Commands =[Light ON, Light OFF, Fan ON, Fan OFF, Door OPEN, Door CLOSE, Window OPEN, Window
          CLOSE, Robot LEFT, Robot RIGHT, Robot FORWARD, Robot BACKWARD, Robot STOP]

c = 0

d = input(`Enter a command number:`);

Responses={Turning light on', 'Turning light off', 'Turning fan on', 'Turning fan off`, `Opening door`, . . .
`Closing door`, `Opening window', 'Close window`, `Turning robot left`, `Turning robot right`, . . .
`Moving robot forward`, `Moving robot backward`, `Stop robot`}

for i =1: length (commands)

if d = =commands (i)

     c = d;

implement(Responses (i))

  end

end

if c= = 0

implement (`INVALID COMMAND`)

end
```

Keys:

Light on = 1	switch on the bulb
Light off = 3	switch off the bulb
Fan on = 5	switch on the fan
Fan off = 7	switch off the fan
Door open = 8	open the door
Door close = 10	close the door
Window open =12	open the window
Window close =14	close the window
Robot left = 16	robotic wheelchair turns and move in left direction.
Robot right = 18	robotic wheelchair turns and move in right direction.
Robot forward = 20	robot moves in forward direction
Robot backward = 30	robot moves in backward direction
Robot stop = 40	robot halts its movement.

Figure 3. 34: The Smart home Operational Programme

3.2.6 Design Implementation of the Smart home system Technologies

As discussed in the preceding sections, the smart home system designed and subsequently implemented is a controllable smart home system where a control input is used to activated different equipment in the house. The system hardware and software design processes involving the system architecture with detailed interactions of different sub-peripheral hardware and software components were implemented. The VAS was implemented following the proposed design with the control unit being primarily one that reacts to the voice of the user. The RoWS was implemented with a prototype of a robotic car with voice commands from the VAS controlling the movement adequately. The ECU was implemented to turn on/off endpoints on the reception of voice input. The endpoints consisted of DC loads such as electrical motors for controlling the opening and closing windows and doors, and AC loads for turning on/off light points, etc.

The implemented prototype is shown in Figure 3.35. The voice input, which is converted into digital signals, are sent to the robotic car and the ECS to decide whether to trigger an alert, perform an action or otherwise.

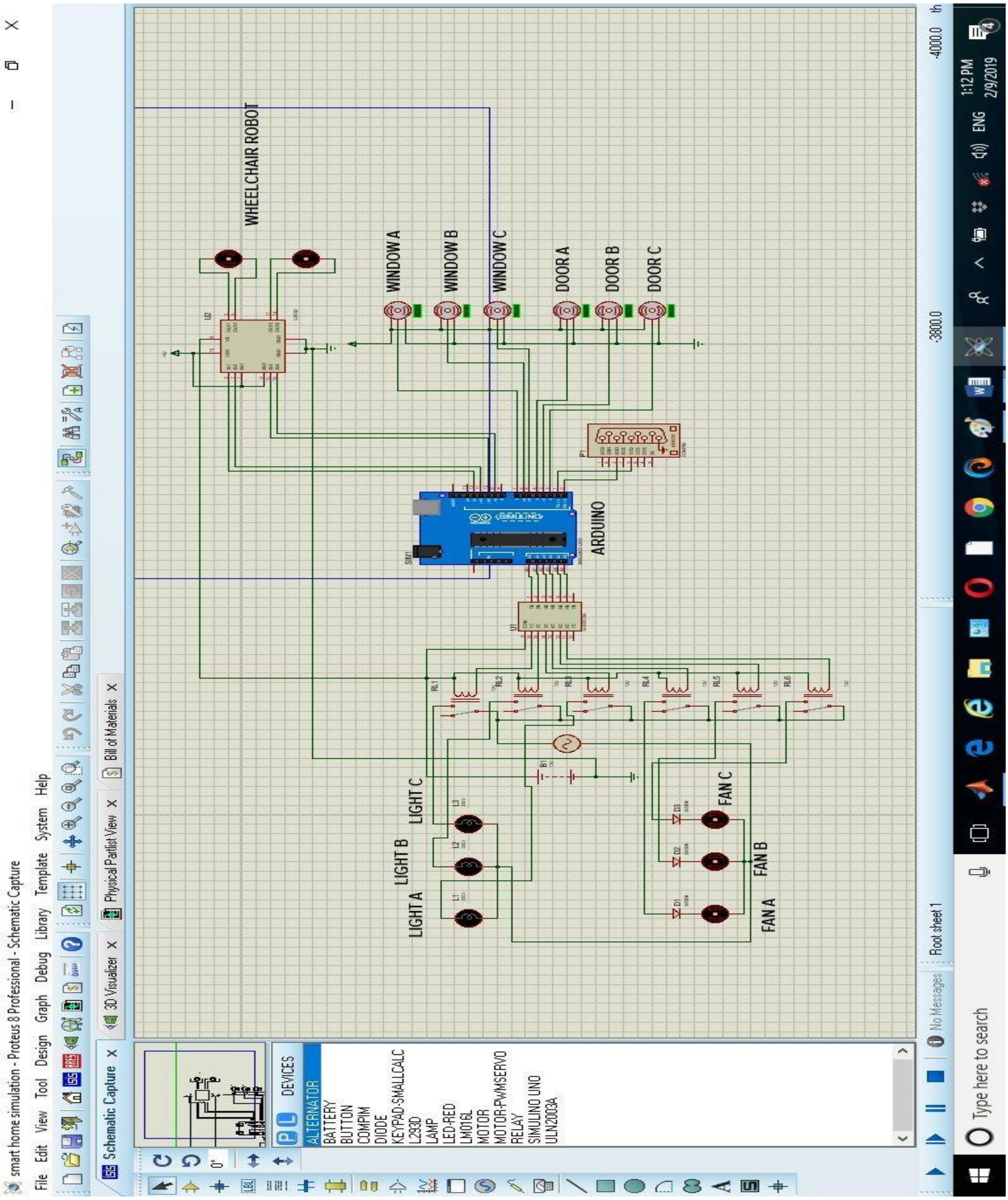


Figure 3.35: The full smart home system showing the VAS, ECU and the RoWS.

3.2.6.1 Design Implementation Choices

Developing a prototype for the smart home system required making appropriate design choices for the system while considering factors such as cost and functionality. The following choices were made for the smart home system:

Voice input device: The voice input device selected for the prototype development is the popular Voice Recognition Module V3 made by Elechouse. It is a compact and easy-control speaking recognition board. This product is a speaker-dependent voice recognition module. It supports up to eighty (80) voice commands in all with a maximum of seven (7) commands working at the same time. The module has to be trained to recognize the voice of the user before normal operation. Just about any sound could be trained as a command. The module offers two means of control: Serial Port (full function) and General Input Pins (part of function). Hence, it suits the needs of our design implementation as it could connect serially to the control unit to send data and has an accuracy of 99% under ideal conditions.

The device works at an input voltage range of $4.5-5V$ and will draw a current less than $40mA$. The choice of microphone and the noise in the environment plays a vital role in affecting the performance of the module. It is better to choose a microphone with good sensitivity and try to reduce the noise in the background while giving commands to get the maximum performance out of the module.

Control device: The Intel 8051 microcontroller (MCU) is the controller of choice for the control unit of each subsystem due to its robustness and ease of programming. It is an 8-bit microcontroller, built with 40 pins DIP (dual inline package), 4KB of ROM storage and 128 bytes of RAM storage, two 16-bit timers. It consists of four parallel 8-bit ports, which are programmable as well as addressable as per the requirement, a bit as well as byte-addressable RAM area of 16 bytes, four 8-bit ports, 16bit program counter and data pointer. An on-chip crystal oscillator is integrated with the microcontroller having a crystal frequency of 12 MHz. A pin-out diagram of this device is seen in appendix A. It sits at the heart of the control unit in each subsystem of the smart home system.

Power: The selection of a suitable power supply for the components of the smart home system is paramount for proper operation of the system. A suitable power has to be selected for each subsystem and this selection depends majorly on the mobility of the subsystem.

The VAS is a mobile subsystem of the smart home system. It is required to be as close to the user as possible, hence, the need to utilise a battery as its power source. It is combined with a suitable voltage regulator (LM7805) for better performance. The RoWS is also mobile; hence, it also needs a battery as its source. This battery source should be of a rating suitable enough to power the drive the motors of the RoWS. The ECS is immobile, hence, it can source its power from an AC source, since it also requires AC supply. A suitable power supply unit for conversion to DC can be implemented as shown in Figure 3.36.

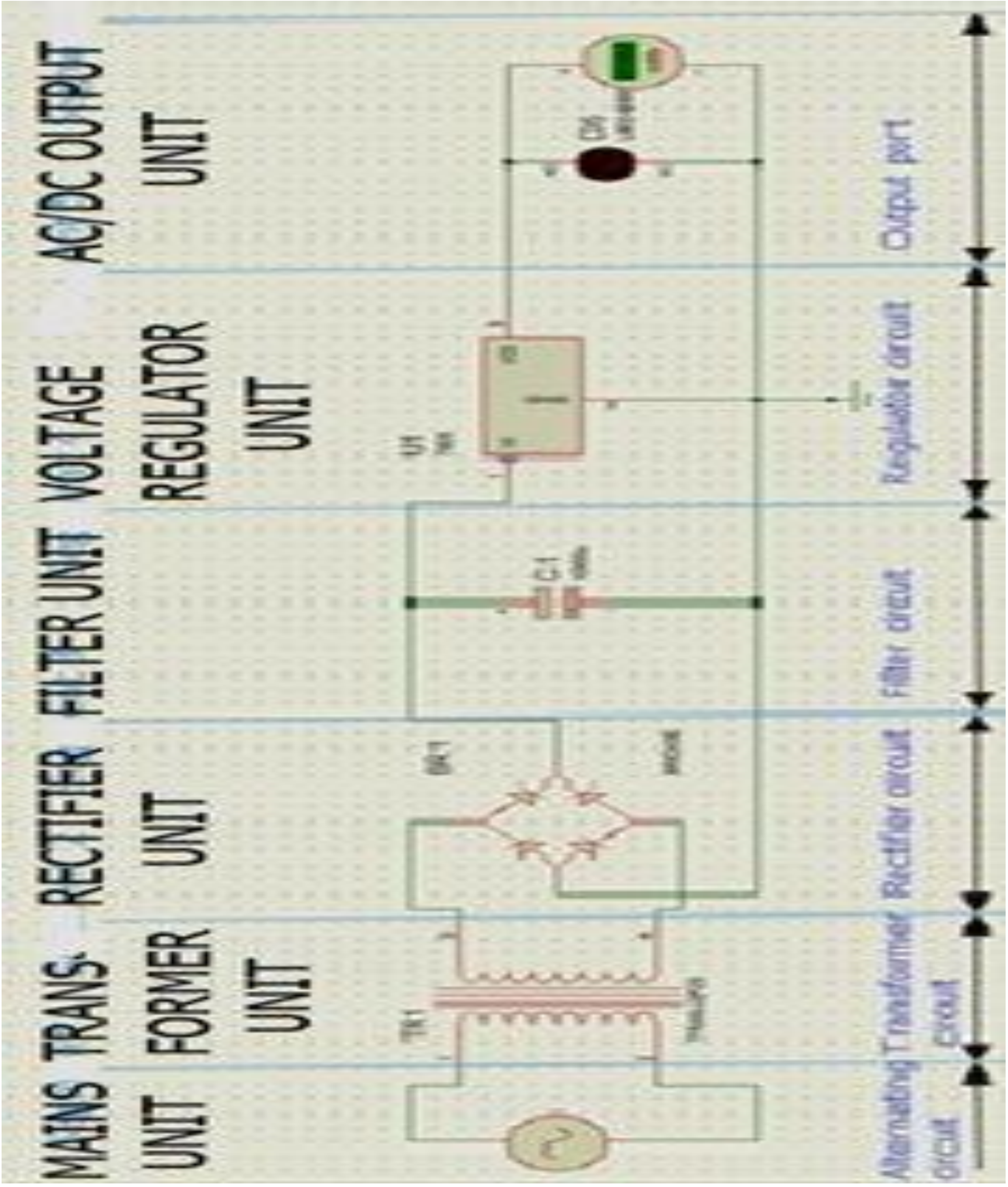


Figure 3.36: Power supply conversion for the ECS

Drivers:

a) Relay Driver: The relay driver is a mechanism that controls a switch using a low voltage control signal. In this design, a 12-V relay, 330Ω Resistor, 1N4001 diode, and a TIP31 NPN transistor is used. The resistor is connected to the positive signal coming from a GPIO pin of the 8051

MCU. The other end of the resistor is connected to the base pin of TIP31 which serve as the triggering signal for the transistor. The emitter pin of TIP31 is connected to the GND pin.

b) DC Motor Driver: The L293D is a quadruple H- bridge motor driver, as the name suggests it used to drive the DC motors. This IC works based on the concept of H- Bridge, which is a circuit that allows the voltage in either direction to control the motor direction. There are four input pins for L293D, but Motors directions depend on the logic inputs applied at these pins and making sure that EN1 and EN2 are made high to drive the two DC motors.

Communication: Three communication modules were selected for this prototype implementation for a specific function. The communication modules are Bluetooth, RF, and GSM modules for the VAS-to-RoWS, VAS-to-ECS and VAS-to-Emergency.

a) VAS-to-RoWS: A Bluetooth Module was best suited for this interface. This is due to the necessity of closeness between the VAS and the RoWS as the VAS is designed such that it is on the RoWS. The HC-05 Bluetooth module was chosen for this prototype implementation.

b) VAS-to-ECS: RF Modules are most suitable for remote control applications where distance and locality is required. It allows the user to control the appliances without getting in touch with them (due to various reasons like convenience, safety, handicapped, and so on). Now short-range RF module wireless control applications were chosen for this application such as an ASK RF Transmitter-Receiver Module of frequency 433 MHz. They are quite compact and cheap.

c) VAS-to-Emergency: The GSM Module was best suited for this communication due to the need to reach an emergency contact in such cases. It allows a variety of communication - Text messaging, voice call and internet connectivity. It serves as the gateway to the outside world in cases of emergency. The SIM900 GSM Module was chosen for this prototype implementation.

3.2.6.2 Subsystems Implementation.

The prototype implementation for this voice-controlled smart home system has two main sections; the remote hand-held microphone embedded part - the VAS - and the relay embedded endpoint control part - the ECS. Based on the user requirements, the system needs to be designed and implemented to make the system a workable system, therefore, this section describes the prototype implementation phase of the system.

3.2.6.2.(a) Voice-activated subsystem

As described in the Hardware Design section, the VAS consists: the Power Supply Unit, the Voice-processing unit, the Manual input unit, the Output display unit, the control unit and the Communication unit. Each unit was implemented according to the design requirements.

The power supply unit consists of a 12V Lithium Polymer battery connected through a voltage regulator to supply the required voltage level for the subsystem. The voltage regulator used is the LM7805 used in common applications for regulating voltages to 5V. It receives supply from the battery source and provides regulated output to the Transmitter, Control, Voice input module, and other parts of the circuitry. It is capable of supplying up to 1.5*A* to the VAS.

The voice processing unit was implemented using the Voice Recognition Module V3 shown in Figure 3.33. It comprises a microphone, the HM2007 IC which is the heart of the module and other interfaces for control and it is responsible for voice analysis and recognition. The module is first trained to receive and recognize voice input from the user through voice matching - where the voice input is received and verified. On normal operation, it communicates with the control unit via serial interface - UART - for command selection.

For manual input, a series of buttons were used to initiate control for each output point - ECS, RoWS and the Emergency activation. The emergency activation required the use of a dedicated button for activation and dedicated communication through a GSM module. The communication to other subsystems was implemented using Bluetooth and radio technology for the RoWS and ECS respectively.

The control unit was implemented using the Intel 8051 microcontroller. Its serial interfaces allow it to link with other units of the VAS for controlling and allocating resources where necessary. The code is written in C using a Microcontroller Development Environment and following the flowchart illustrated for the VAS in Figure 3.24.

The schematic design for the VAS was carried out using the Schematic designer in the Proteus Software suite. Figure 3.37 shows voice activated subsystem and electrical control subsystem extensive design.

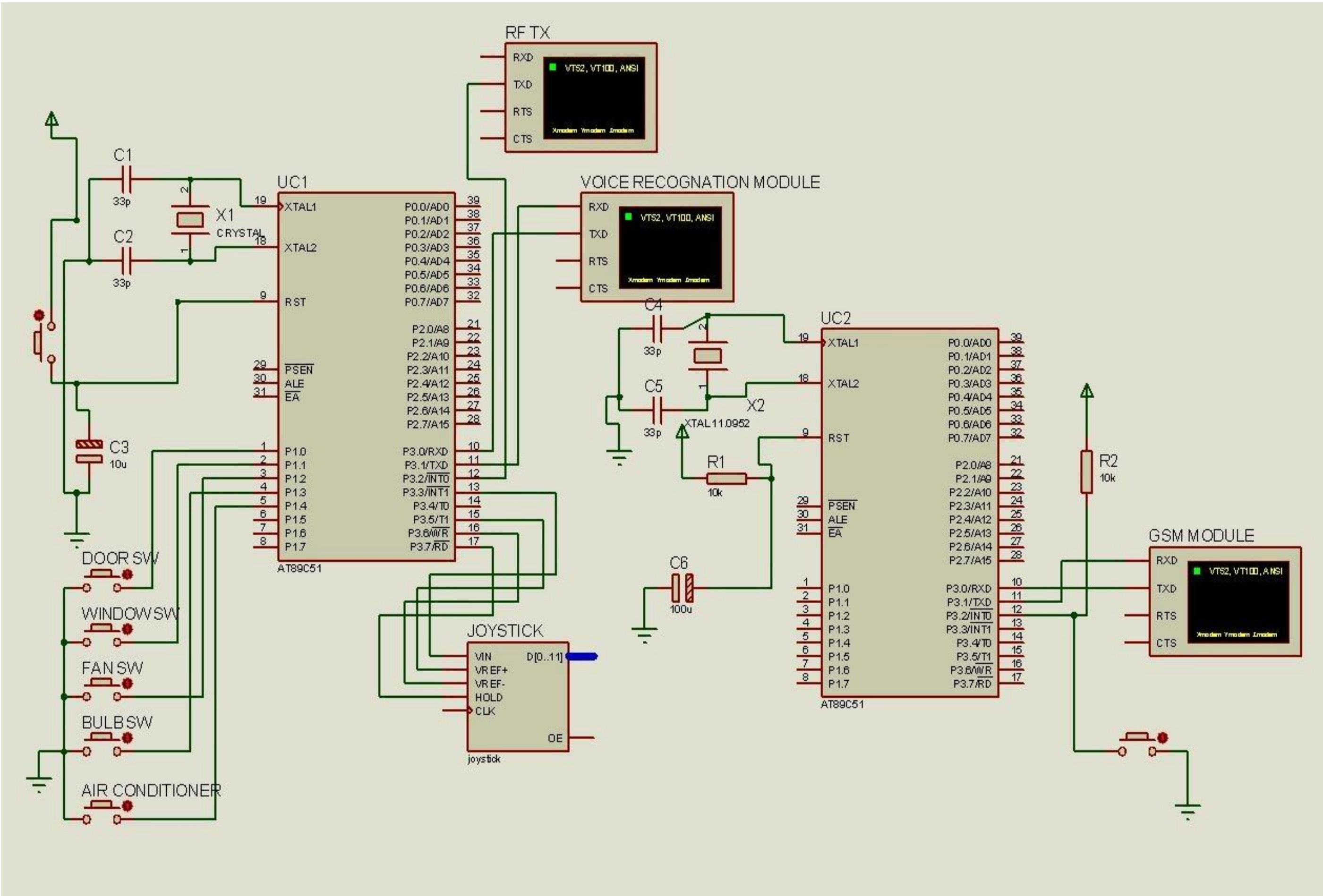


Figure 3.37: The schematic design of the VAS and ECS

This diagram represents the schematic modules of voice activated subsystem and electrical control subsystem. The unused pins of the microcontroller here, will be utilized during the integration of new appliances in the home.

3.2.6.2.(b) Robotic Wheelchair subsystem

According to the hardware design section, the RoWS has the power supply unit, the receiver unit, the control unit, and the actuating unit. This subsystem was implemented as a mini robotic car controllable through the voice input from the VAS. The power supply unit was implemented using a similar approach as the VAS, however, the voltage outputs were $5V$ &$12V$ for the receiver and control units and the actuating unit respectively. The receiver unit was implemented using a Bluetooth link via the HC-O5 Bluetooth module. The control unit was also implemented using the 8051 microcontrollers with its program written according to the flowchart in Figure 3.26. The actuating unit required using two L293D motor driver and four DC motors to drive the wheels. Each motor driver drives a pair of DC motors. The motor drivers were driven by the commands from the VAS having been translated by the 8051 microcontrollers.

The schematic design for the RoWS was carried in the Proteus Software suite. Figure 3.38 shows this design extensively.

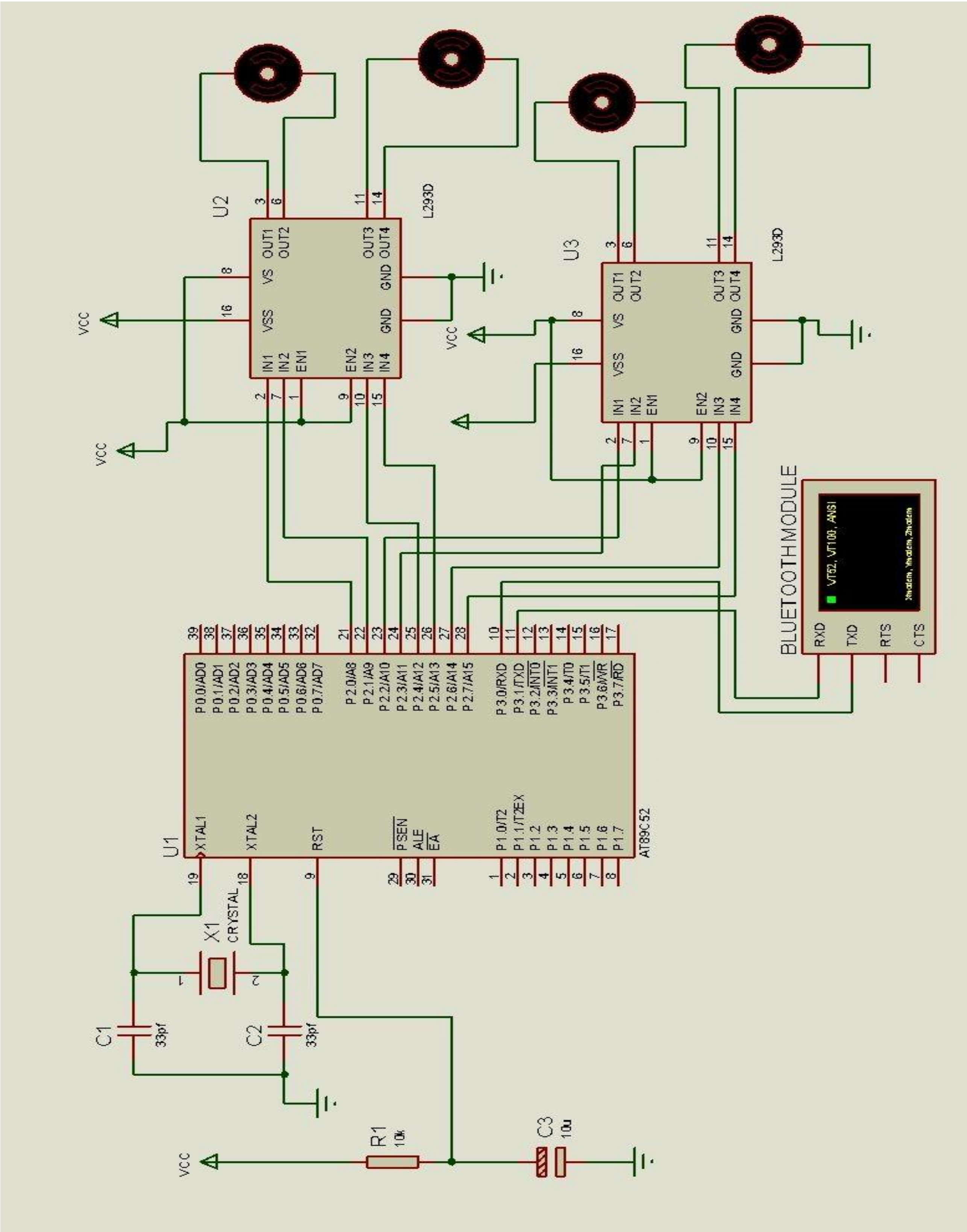


Figure 3.38: The schematic design of the RoWS

3.2.6.2.(c) Electrical Control Subsystem

The ECS comprises the power supply unit, the communication unit, the control unit, the switching unit, and the endpoints. The prototype for the subsystem was implemented according to the hardware and software design for its units with a model for a door and window used as DC endpoints and AC light bulbs used as AC endpoints.

The power supply unit for the ECS is the most complicated of the entire system. It is responsible for supplying AC and DC power output to other units of the ECS. AC power was linked directly to AC endpoints through the switching unit, and DC power was obtained having been converted through the regulated power supply circuit.

The control unit was implemented using the 8051 microcontrollers with its program written according to the flowchart in Figure 3.28. The microcontroller interfaces with the switching unit, sending commands that actuate an endpoint. It verifies the received commands from the communication unit and sends to the switching unit.

The communication and switching unit served as the input and the output of the control unit - the 8051 MCU. To cover a wide range, the communication unit was implemented using Radio Frequency (RF) Module. This allowed the ECS to be placed at any location within the range of the RF module. The switching unit comprises relays and drivers for controlling the switching of the appliances and the opening and closing of the doors and windows through connected motors.

The endpoints comprise DC and AC endpoints. To emulate a house, a prototype for the door and window were constructed. These are opening and closing mechanical system driven by DC motors to emulate the opening and closing of a door and a window. Two DC motors were used for each of the outputs and were driven by commands from the 8051 MCU through motor drivers. AC Light bulbs were used as AC endpoints for the system. They are connected and controlled by the switching unit through relays.

The schematic design for the ECS was carried out using the Schematic designer in the Proteus Software suite. Figure 3.39 shows this design extensively.

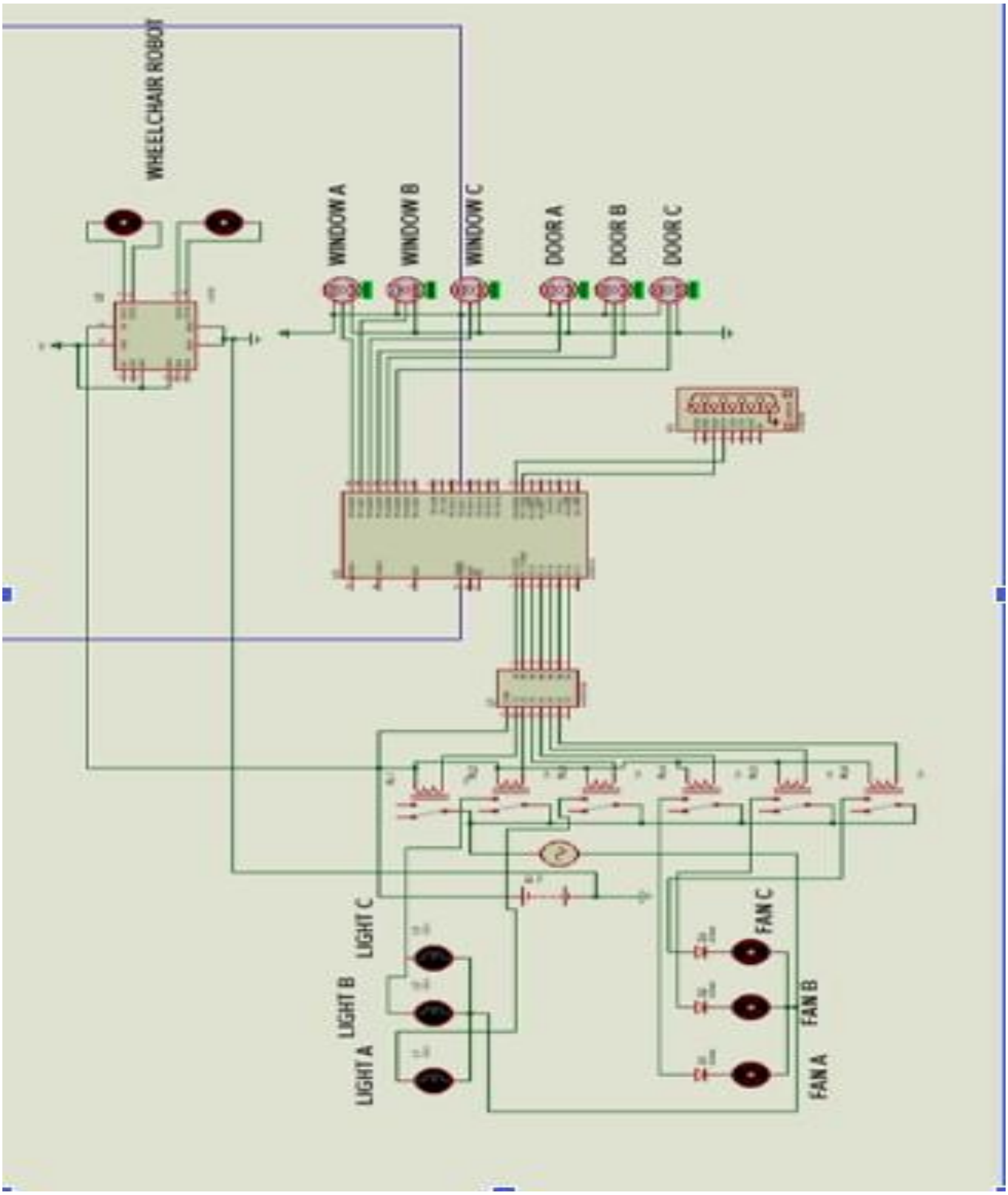


Figure 3.39: The schematic design of the ECS

3.2.6.3 Computer Simulation of the smart home system

The computer simulation of the smart home system is shown in this section. It was carried out with software tools on a Laptop computer. The simulation saw an implementation of the hardware and software design carried out in the previous section. The VAS comprises the inbuilt microphone of the computer (or a headset microphone for better reception), a computer program for processing the voice input that is linked to an Electronic Design Automation (EDA) software where the ECS and the RoWS are designed for simulation.

3.2.6.4 Simulation of the smart home system

For the transmission section, otherwise known as the VAS, Proteus 8 Professional software was used to build the voice processing and recognition, with the incorporation of C#, which is a programming language written in the Microsoft visual studio Integrated Development Environment (IDE)) coding. After recognition, the corresponding control characters are sent through the RF transceivers to the control unit in Proteus. The microcontroller in the control unit will select and communicate through the Bluetooth transceiver to the required device according to the input voice command. Also, a GSM module for emergency services is associated with the control unit. Figure 3.29 shows the simulation on Proteus

When commands are given through voice inputs to the microphone, the C# program listens for command reception. On reception, it validates the command and notifies the user on its interface, and then sends the command via a serial UART port to the control unit - the Arduino MCU in the Proteus simulation software - which carries out an action based on the given command as shown in Figure 3.40.

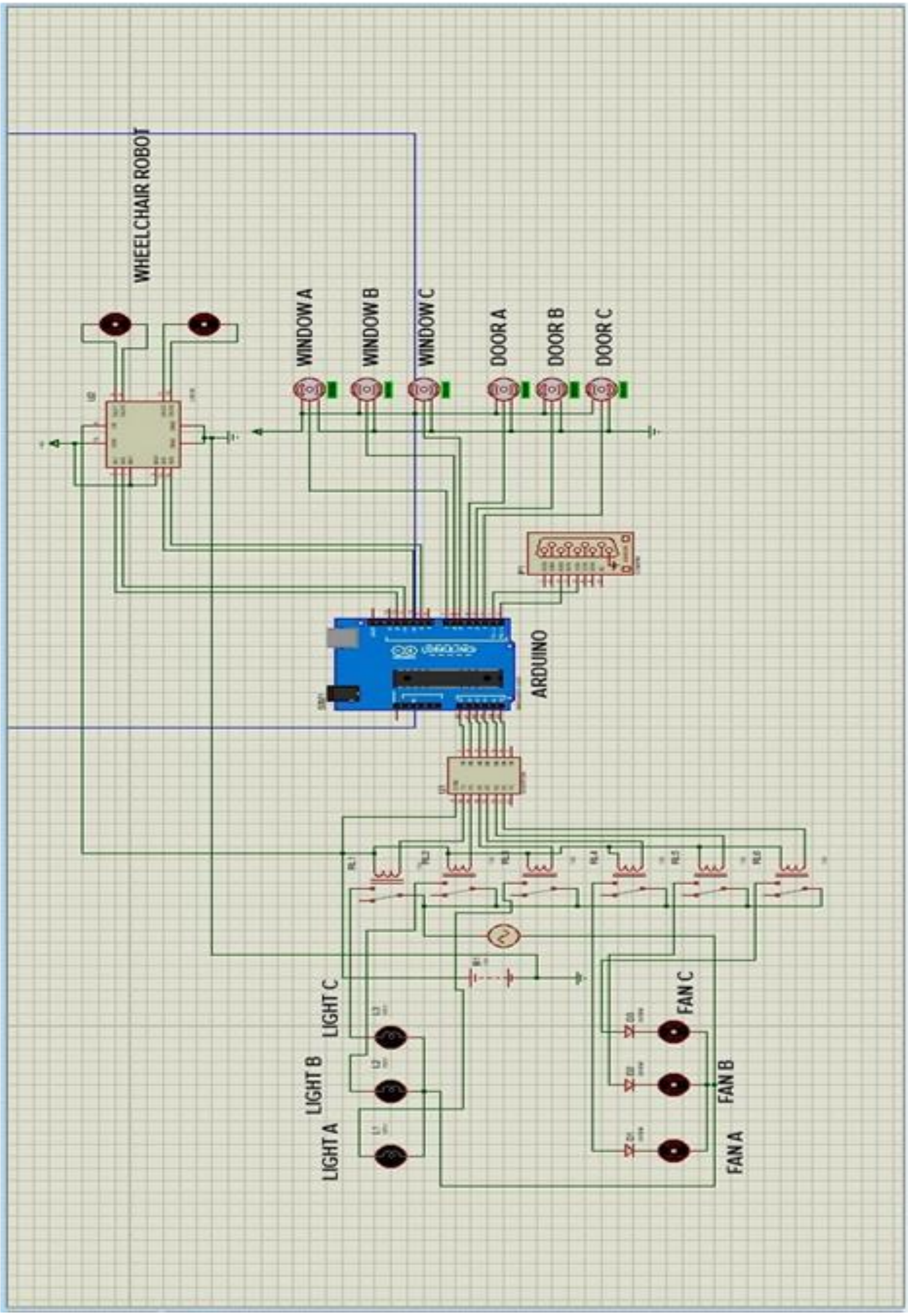


Figure 3.40: Computer Simulation of the smart home system on Proteus

3.2.7 System Operational Testing

The smart home technologies system was setup in a four 2-bedroom flats of one – story building, at Ugwulangwu in Ohaozara, Ebonyi State, Nigeria. The two first floor flats with 2-bedroom apartments with two environments were used, one is a dead home apartment, and the other is a live home apartment. The dead home apartment here is defined as a home apartment with heavy closed curtains, carpet, an air-conditioner, and the usual appliances of a living home. while a live home apartment is the same as the dead home apartment but with television on, people talking with background music coming from a stereo, and the curtains are open so external noise outside can somehow affect the testing. The tests carried out were to ascertain the level of systems operational effectiveness were carried out. The system setup is shown in screenshot of Figure 3.41, and the training and testing phase screenshot is shown in Figure 3.42.

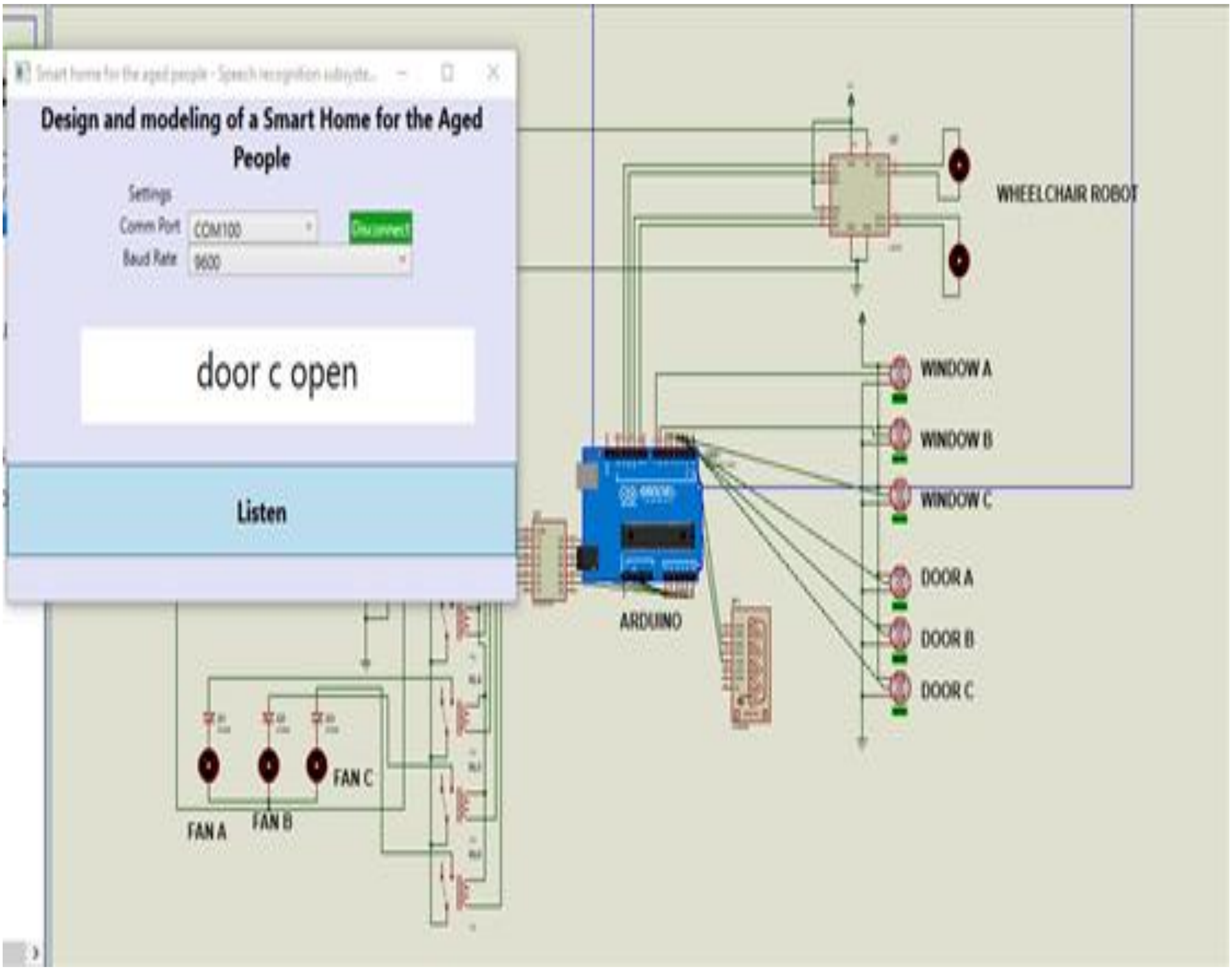


Figure 3.41: C# Software for the VAS for taking voice input

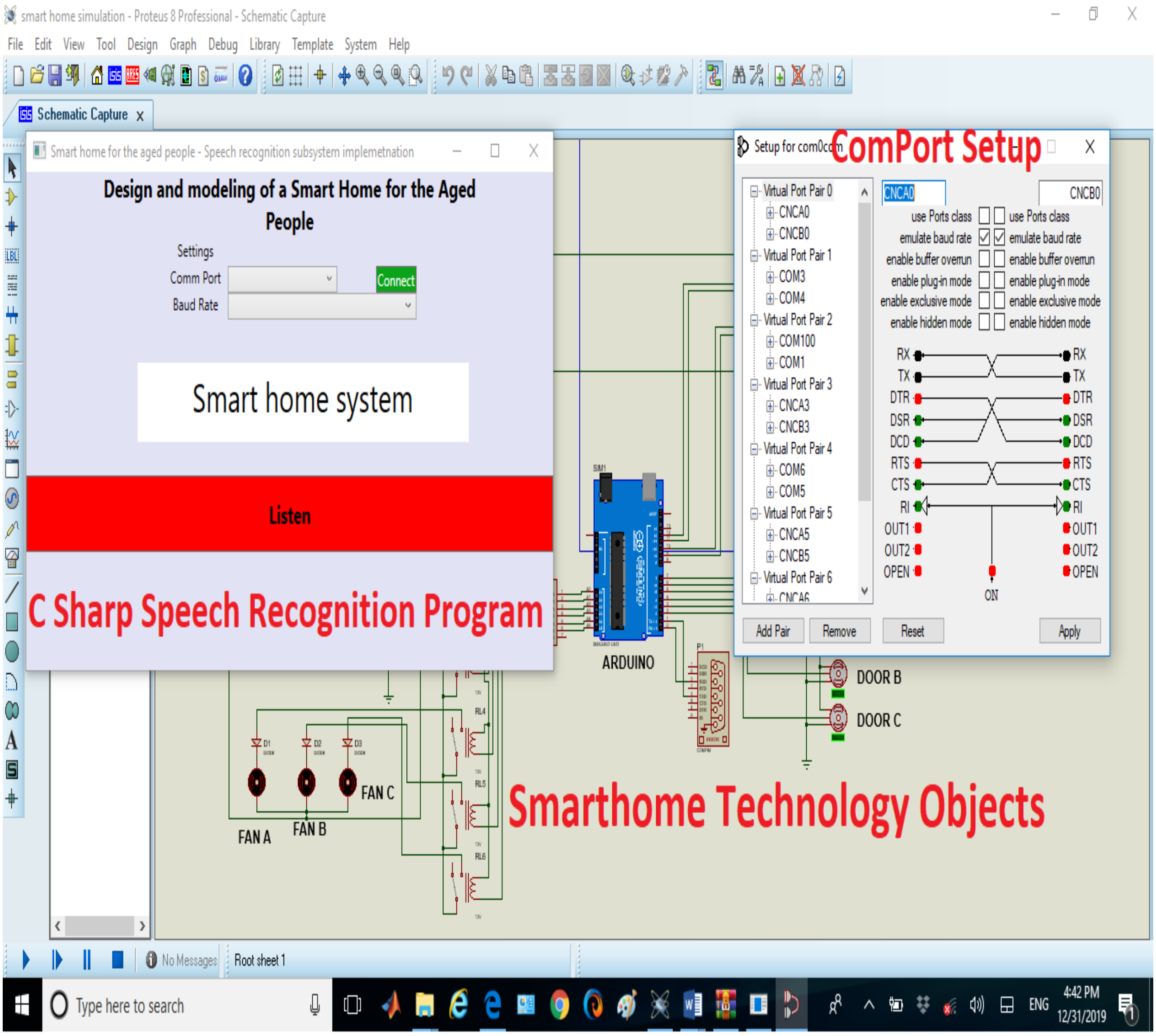


Figure 3.42: Screenshot for Training phase

There are two ways of testing, namely: real time and offline, but in this system, voice signal is tested in real time, in which the speech signal is recorded from microphone when C# record button is connected, after the settings of Comm Port and Baud Rate of COM100 and 9600 respectively were done as shown in Figure 3. 42. In the ComPort Setup, the virtual Port Pair of COM100 and COM1, with emulate baud rate selected as shown in Figure 3.43 is setup.

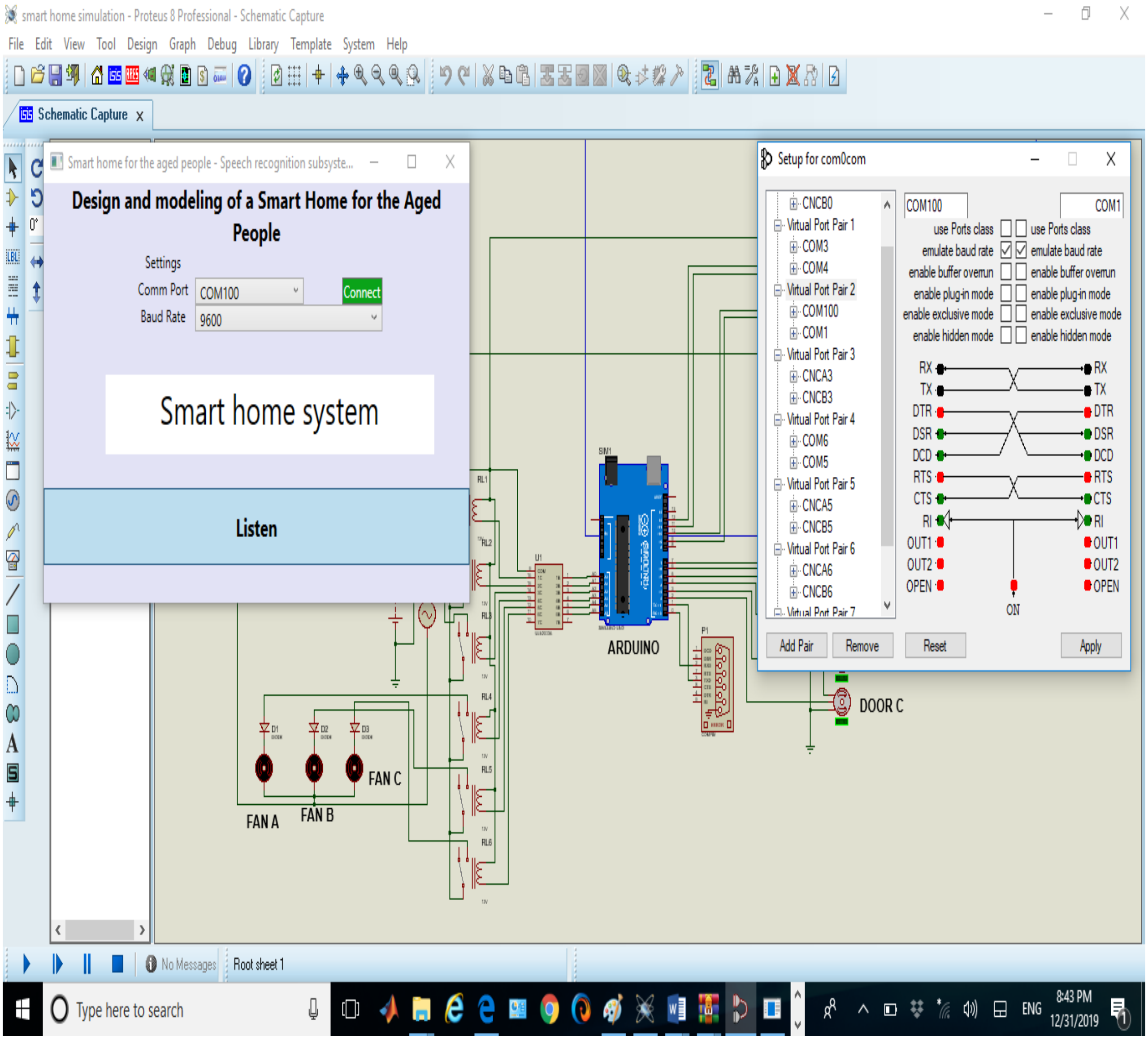


Figure 3.43: Screenshot for Testing Phase

This section discussed the various experimental tests conducted during the course of achieving the objective of this research. The experimental test commenced immediately after the voice commands of the aged beneficiaries were encoded into the system through the processes known as System Training. The tests that were carried out after the system training were to:

a) Test to determine the distance of the voice input device effectiveness from the user that is the input device (Microphone) sensitivity test;

b) Test to find the level of response and accuracy of this designed smart home system;

c) Test to determine the performance evaluation of the system by calculating the average response time of the system; and

d) Test to evaluate the system performance by calculating the error percentage of the system, to determine whether the command transmitted is the command executed, within the elapsed system response time.

The first test was executed on four aged persons (aged 60 years and above), 2 males and 2 females with different voice pitches and two of these aged persons (a male and a female) are smart wheelchair users. Furthermore, the test was carried out in a flat of a two-bedroom apartment. Here, two home environment areas were used for the test: a dead home and a live home. A dead home here is a home environment with heavy curtains closed, smoothly tared-floor, an assisted motorized wheelchair, an air-conditioner, and the usual electronic gadgets (light bulbs, fans, fridges, doors and windows) of a home. A live home, on the other hand, has just the same content as the dead room, but with a television on, people talking with background music coming from a stereo. Curtains were open and external noise outside the home were experienced during the test period.

3.2.7.1 Voice Input Device (Microphone) Distance Sensitivity Test

The purpose of this test is to determine the effective distance in which the response of the systems microphone module is most effective. The test requirements and procedures followed in conducting this test are as follows:

- Four aged persons of 60 years and above were selected (two males and two females), with different voice pitches and two of them (a man and a woman) are smart wheelchair user, to execute the test, each tester had four trials respectively.

- The first experiment was done in a dead home, but the second experiment was done in a live home which is more preferable because, this design is intended for live home.
- Set up the device and necessary equipment needed in testing the design.
- A meter tape was used to measure the distances between each interval.
- The distances used were (0.25,0.5,1,1.5,2.0,2.5,3.0,3.5,4.0,4.5, *and* 5.0) meters
- The first tester was placed at the farthest point from the system microphone sensor.
- The tester uttered trigger command word ―SMART four times, representing four trials.
- For every system (VoiceGP) response, letter P was recorded on the table for the Voice Command Detected.
- For the system non response, letter X was recorded on the table for Voice Command Not Detected.
- The same tester was positioned on each of the required distances and steps 5 to 7 were repeated respectively.
- The Ps were recorded on the table for each distance that the voice commands were detected and Xs were recorded for each distance that the voice commands were Not Detected, for all trials from all testers.
- The analysis based on the results was done and the distance in which the module is most responsive was used for the ―Speech Recognition Test.

NOTE: When two distances were of the same total number of voice detected, the one of the longer distance was used.

The keys used are as follows:

P - Voice Command Detected; X - Voice Command Not Detected; T1 –Trial 1; T2 - Trial 2; T3 - Trial 3; T4 - Trial 4

3.2.7.2 Voice Command Recognition Test

The objective of this test is to check whether the VoiceGP module will respond correctly according to the voice command spoken by the user. This test was used in both the dead and live room so as to compare their results. The Table 3.6 shows the set of commands acceptable by the system.

The steps in conducting the test are as follows:

a) Four aged persons of 60 years and above were selected (two males and two females), with different voice pitches and two of them (a man and a woman) are smart wheelchair user, to execute the test, each tester had four trials respectively.

b) The first experiment was down in a dead home, but the second experiment was down in a live home which is more preferable because, this design is intended for live home.

c) Using Microphone Distance Sensitivity Test result, the distance wherein the microphone is most sensitive for the module to response was selected would be used, in this case the 1.5-meter range used.

d) The tester was positioned 1.5 meter from the device.

e) The first tester utters each command five times representing the five trials, the system correct or incorrect response were recorded.

f) The rest of the testers were then tested respectively, and steps 4 and5 were repeated.

g) The results of tests were tabulated, and the percent error of each trial was computed, using the formula (Rommer et al, 2011):

$$\%\ Error = abs\left(\frac{T-P}{T}\right)\cdot 100\% \qquad (3.4)$$

Where, P is the accepted value, in this case it is nine (9) since there are 9 commands to be considered; V is the experimental value which is the result from the test conducted. It is the number of commands where the system responded correctly (Rommer et al, 2011). There should be a 20% error, all in all.

8. After getting the percent error of each trial from each tester, next is to compute for their average per tester using the formula (Okorafor Godfrey Nwaji, et al 2018):

$$\frac{T_1 + T_2 + T_3 + T_4}{4} \tag{3.5}$$

where T_1, T_2, T_3, *and* T_4 are percent errors obtained from the previous step.

9. Four average percent error must be obtained, then compute for the effectiveness of the system for that environment using the formula (Okorafor Godfrey Nwaji, et al 2018) :

$$100 - \left(\frac{Ave_1 + Ave_2 + Ave_3 + Ave_4}{4}\right) \tag{3.6}$$

10. Tally all the results in a table.

11. Repeat steps 4 to 10, but this time around use a live room.

12. When results have been gathered from both dead and live room, analysis and comparison were carried out.

13. Make conclusions based on the results obtained from the tests conducted.

KEYS for Tables 3 and 4: P - The system responded correctly; X - The system responded incorrectly

T1 - Trial 1; T2 -Trial 2; T3 -Trial 3; T4 -Trial 4; T5 -Trial 5

3.2.7.3 Test Summary

The various tests are summarized in Table 3.8.

Table 3.8: Test Summary

TESTING METHODS	TESTING FACTORS	DEVICE RESPONSE
AMPLITUDE OF VOICE	Normal conversation 60dB Whisper 35dB	Device responds 3 out of 4 times Device responds 1 out of 4 times
NUMBER OF WORDS	Minimum 3 words Maximum 4 words	Device responds accurately 3 out of 3 times Device responds accurately 2 out of 4 times
DISTANCE FROM MICROPHONE	Lesser distance 0.25m Greater Distance 5m	Accurate response 4 out of 4 times Accurate response 2 out of 4 times
ENVIRONMENTS	Quite Noise	Accurate response 3 out of 4 times Accurate response 1 out of 4 times
MULTIPLE SPEAKERS	Multiple speakers Individual speaker	Device responds accurately 2 out of 4 times Device responds accurately 3 out of 4 times
ROOM SIZE	Dead Rooms Live Rooms	Accurate response 3 out of 4 times Accurate response 2 out of 4 times

3.2.8 The System Evaluation

3.2.8.1 The System Performance Evaluation

This is done to determine the performance evaluation of the system by calculating the average response time of the system. The essence of this test is to calculate the response time of the system, which is the time elapsed once the control signal has been activated and the corresponding operation has been executed.

This text records the time difference between the control signal being sent and the corresponding operation being executed. It records the response time for 4 sets of all 5 commands (20 commands) sent to the smart wheelchair and calculates the average response time of the system. The response time remains the same for all applications since it is the system that delays the control and not the application. The smart wheelchair application is being used to calculate the response time since it is visually possible to record the response time of commands forward, backward, left, right or halt.

Steps Carried Out: The following are the steps of execution to calculate the average response time of the system:

a) Setup the system for the smart wheelchair Navigation program and keep a millisecond stopwatch unit beside.
b) Activate any command by moving the joystick and start the stopwatch simultaneously.
c) Stop the stopwatch once the command takes action.
d) Repeat Step 2-3 for 16 different commands.
e) Tabulate the individual response time and plot the results to calculate the average response time of the system.

The commands sent in this experiment are as shown below:

Forward - F Backward - B Right - R Left - L Stop - H

3.2.8.2 Evaluate the System Performance by Calculating the Error Percentage of the System

This is to evaluate the system performance by calculating the error percentage of the system. Here, determines whether the command transmitted is the command executed, within the elapsed system response time.

The test transmits 25 commands consecutively which are recorded as the transmitted commands and after the response time elapses, the command sent is cross checked with the command executed. If they are the same then no error is registered and if the command executed is not same as the sent command, then the system registers an error. Thus, the error for 25 commands is recorded in order to determine the average system error percentage.

The following are the sequential steps carried out to calculate the average error percentage of the system:

a. Setup the system for the smart wheelchair Navigation program and keep a millisecond stopwatch unit beside.

b. Activate any command by moving the joystick and start the stopwatch simultaneously.

c. Note the command executed after the system response time has elapsed.

d. Reset the stopwatch and repeat Step 2-3 for 25 different commands.

e. Tabulate the individual error and plot the results to calculate the error percentage of the system.

When the user speaks “Light ON” in real time, the execution time is 0.05509s. When speaking “Light ON”, command “Light ON” is shown in the massage box (Figure 3.44).

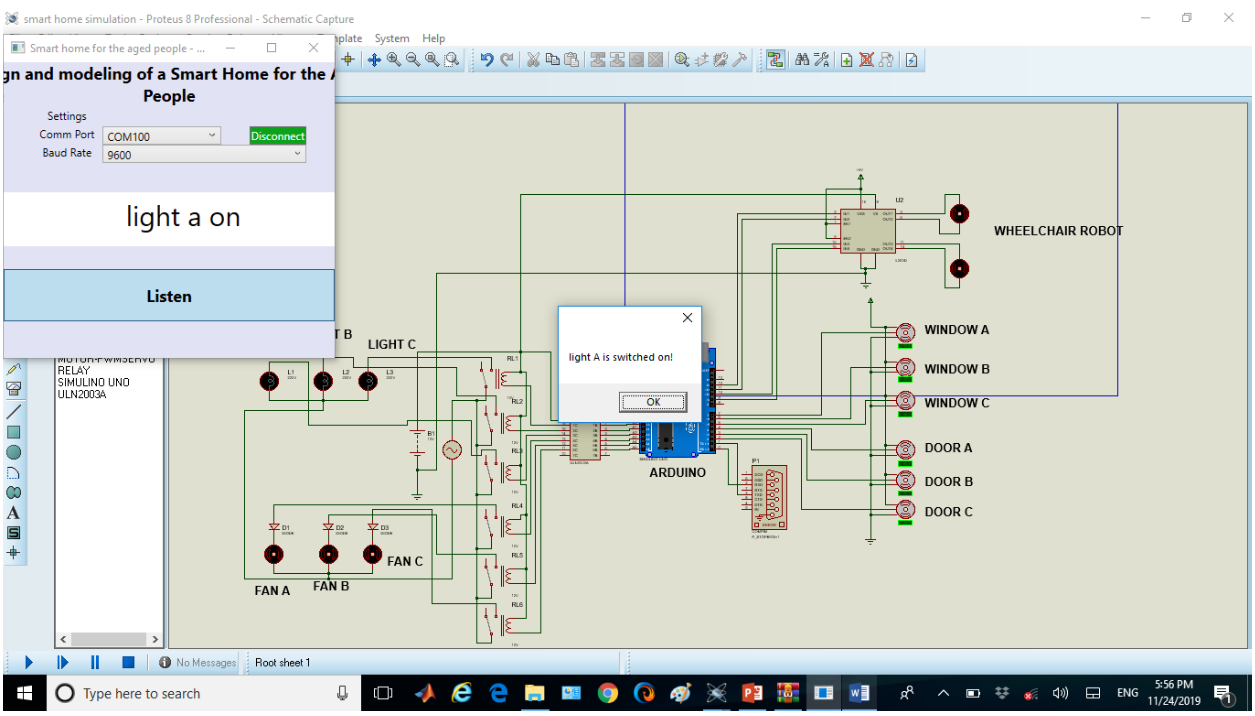


Figure 3.44: Screenshot Result when command word is "Light ON" in real time

When the user speaks "Light OFF" in real time, the execution time is 0.07041s. When speaking "Light OFF", command "Light OFF" is shown in the massage box (Figure 3.45).

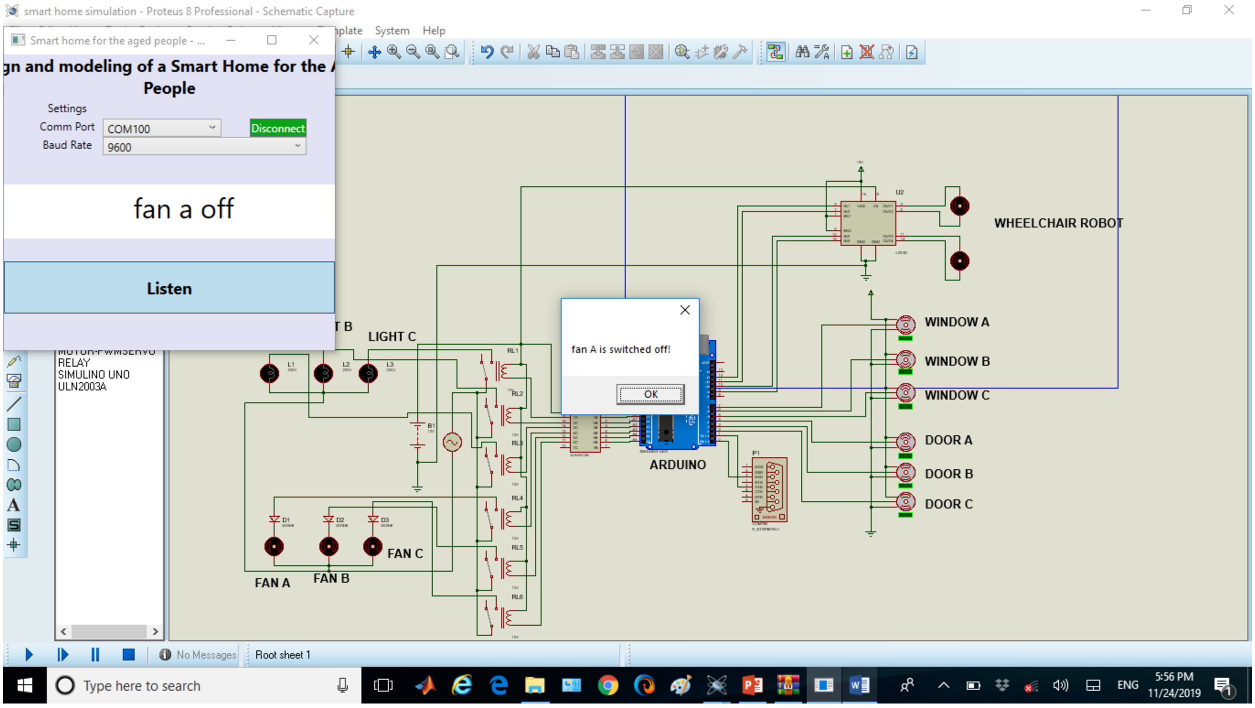


Figure 3.45: Screenshot Result when command word is "Light OFF" in real time

When the user speaks "Fan ON" in real time, the execution time is 0.06303s. When speaking "Fan ON", command "Fan ON" is shown in the massage box (Figure 3.46).

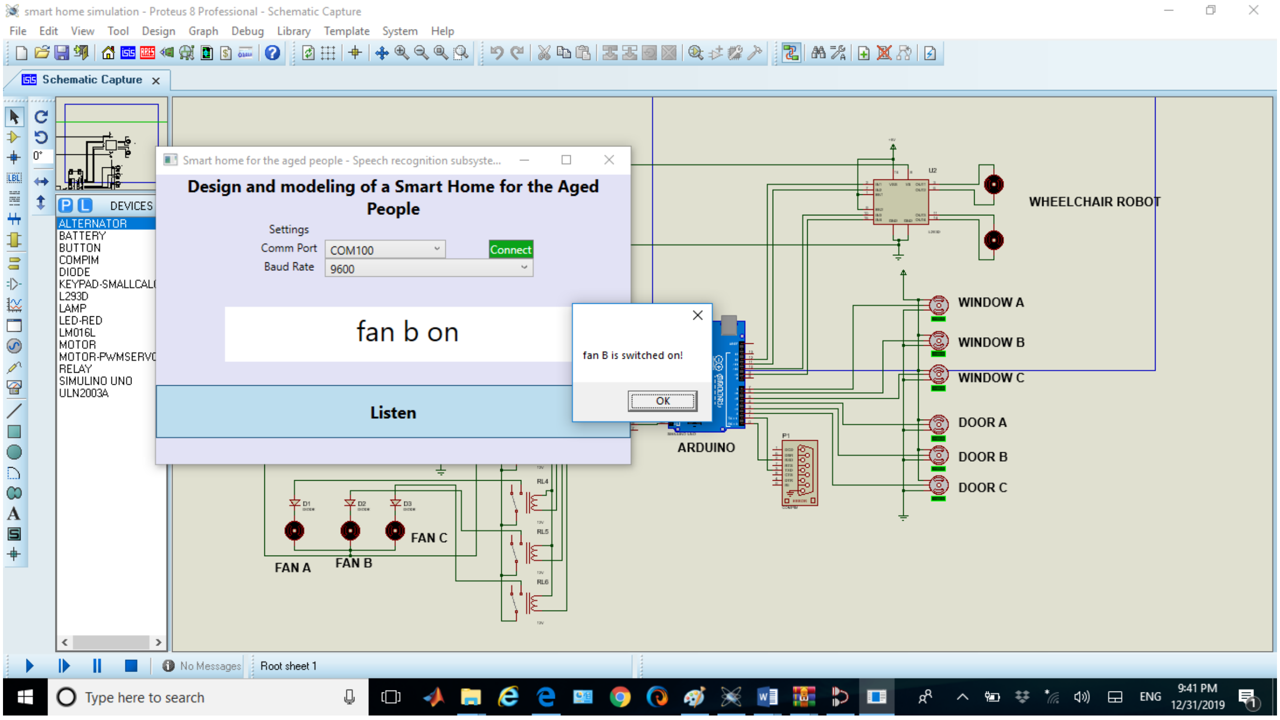


Figure 3.46: Screenshot Result when command word is "Fan ON" in real time

When the user speaks "Fan OFF" in real time, the execution time is 0.06173s. When speaking "Fan OFF", command "Fan OFF" is shown in the massage box (Figure 3.47).

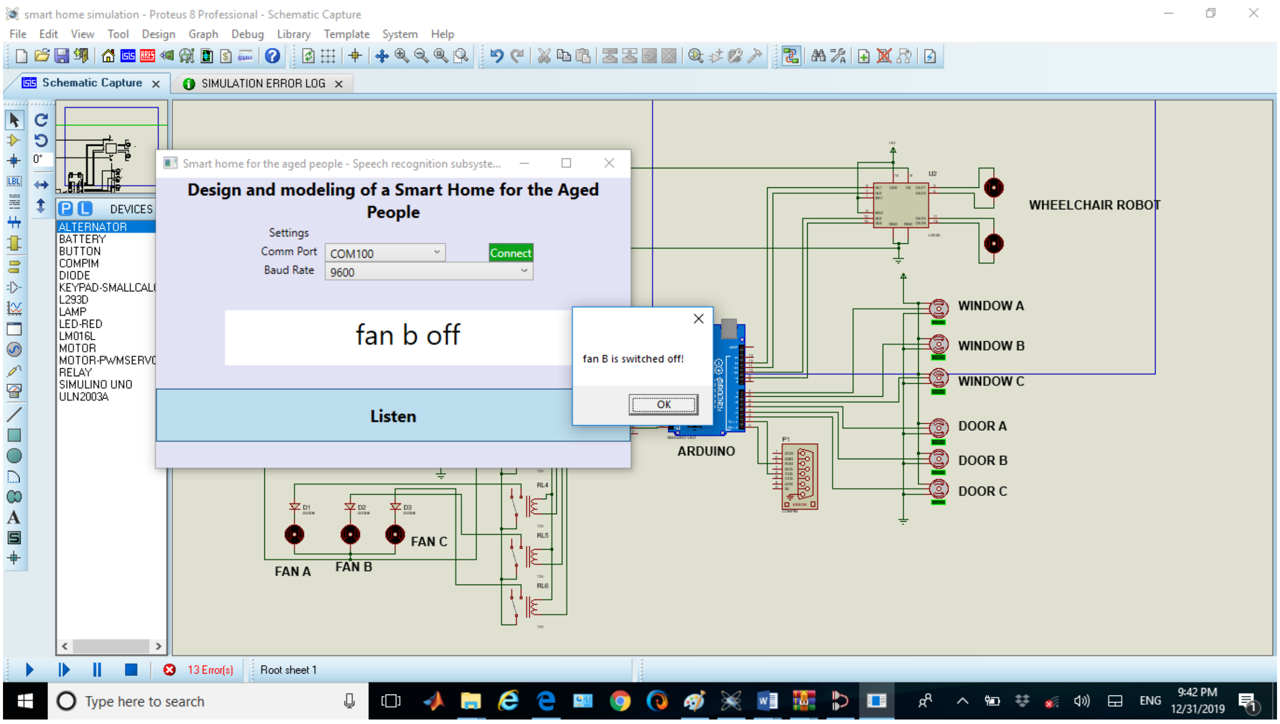


Figure 3.47: Screenshot Result when command word is "Fan OFF" in real time

When the user speaks “Door OPEN” in real time, the execution time is 0.04424s. When speaking “Door OPEN”, command “Door OPEN” is shown in the massage box (Figure 3.48).

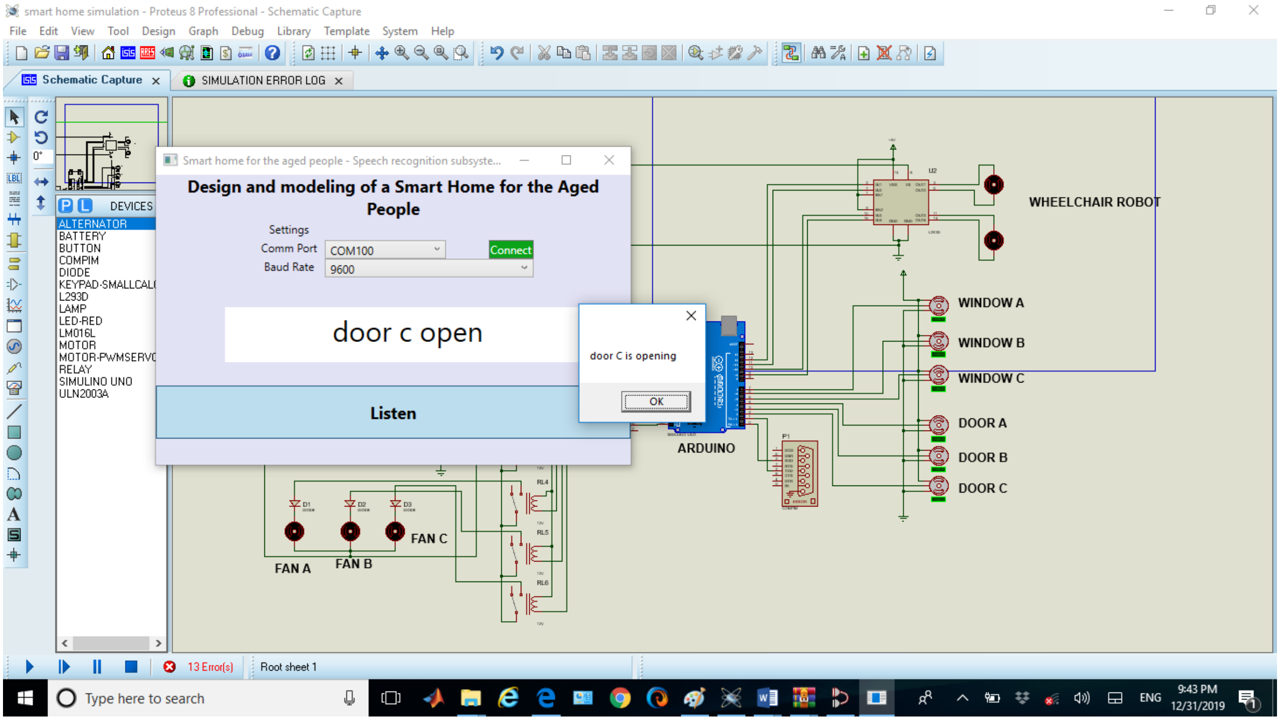


Figure 3.48: Screenshot Result when command word is “Door OPEN” in real time

When the user speaks “Door CLOSE” in real time, the execution time is 0.05861s. When speaking “Door CLOSE”, command “Door CLOSE” is shown in the massage box (Figure 3.49).

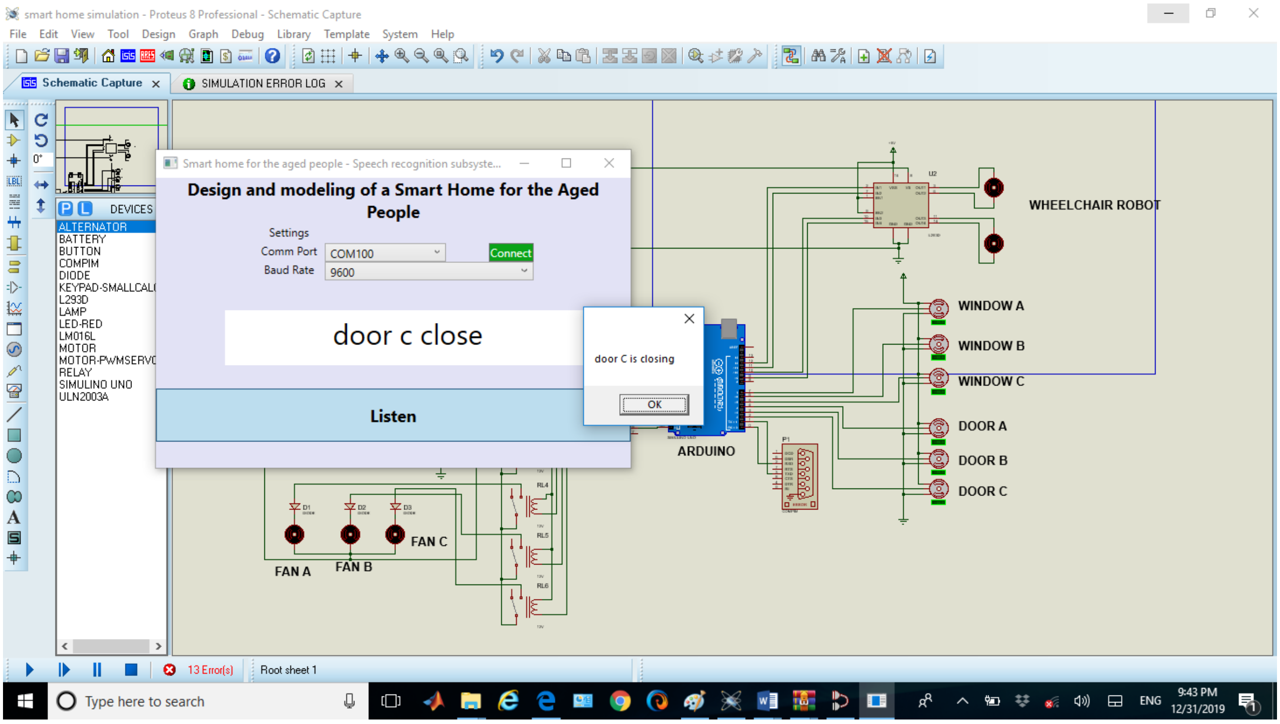


Figure 3.49: Screenshot Result when command is “Door CLOSE” in real time

When the user speaks “Window OPEN” in real time, the execution time is 0.05868s. When speaking “Window OPEN”, command “Window OPEN” is shown in the massage box (Figure 3.50).

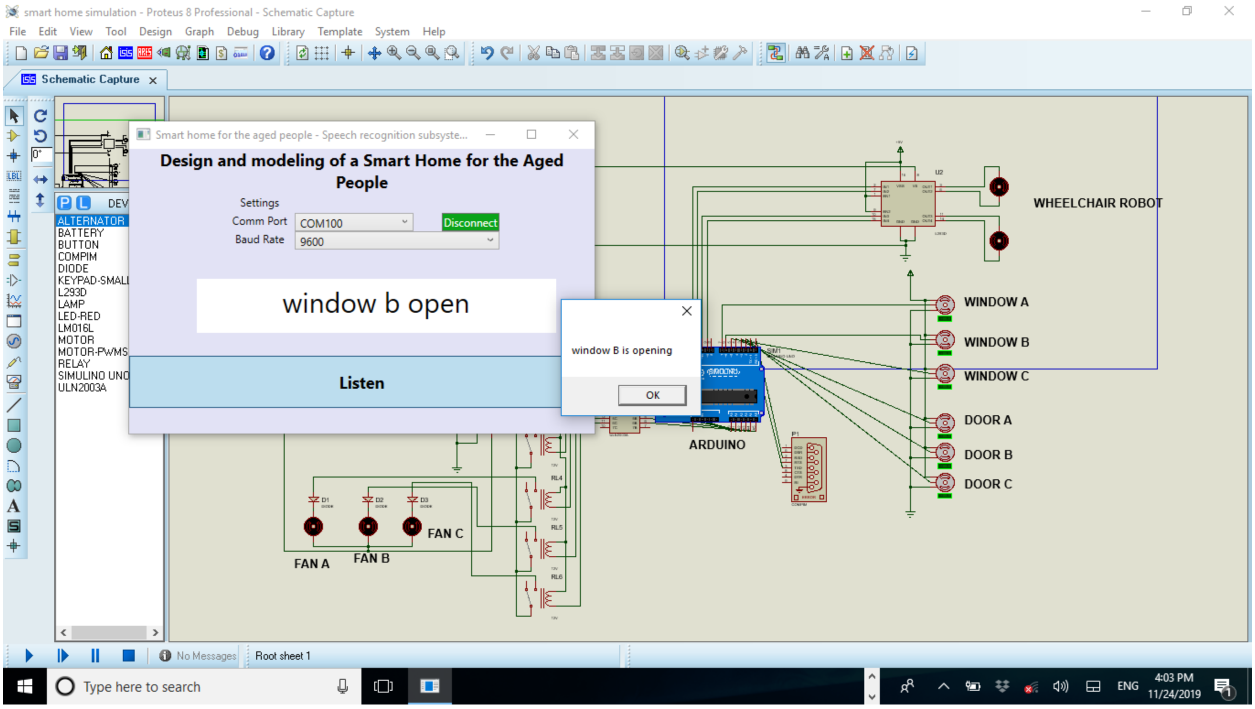


Figure 3.50: Screenshot Result when command word is “Window OPEN” in real time

When the user speaks “Window CLOSE” in real time, the execution time is 0.07837s. When speaking “Window CLOSE”, command “Window CLOSE” is shown in the massage box (Figure 3.51).

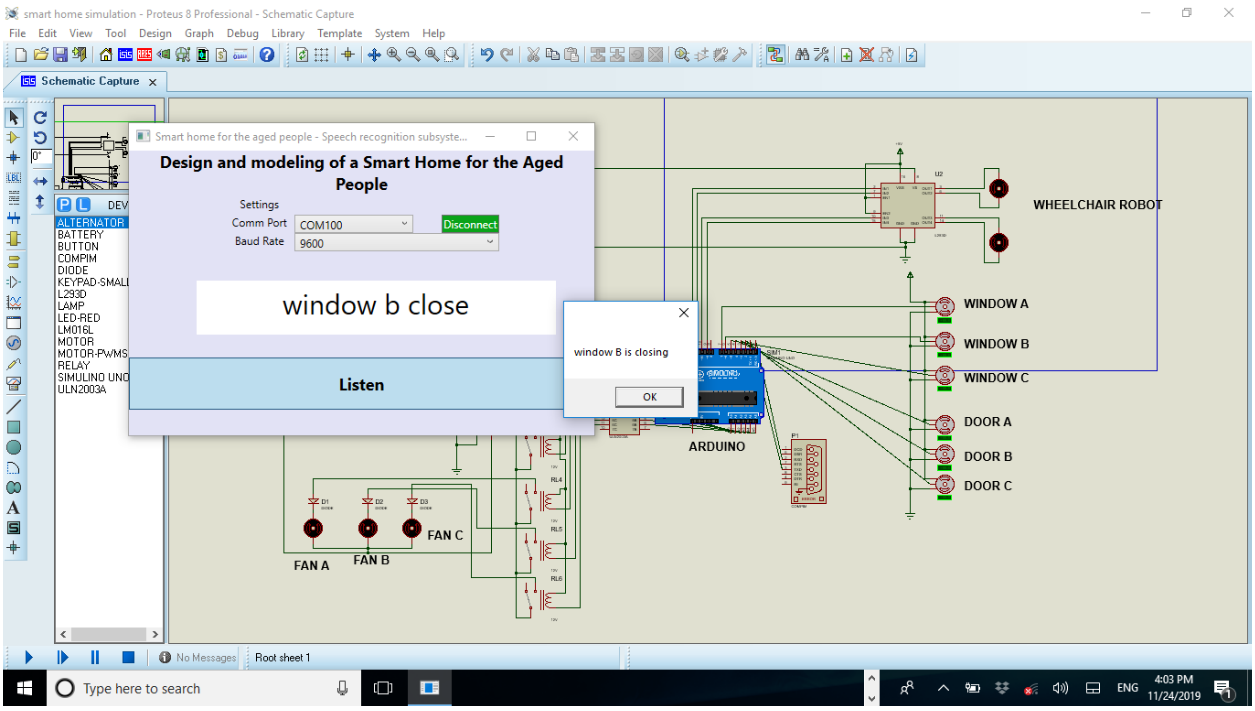


Figure 3.51: Screenshot Result when command word is “Window CLOSE” in real time

When the user speaks “Robot UP” in real time, the execution time is 0.06506s. When speaking “Robot UP”, command “Robot UP” is shown in the massage box (Figure 3.52).

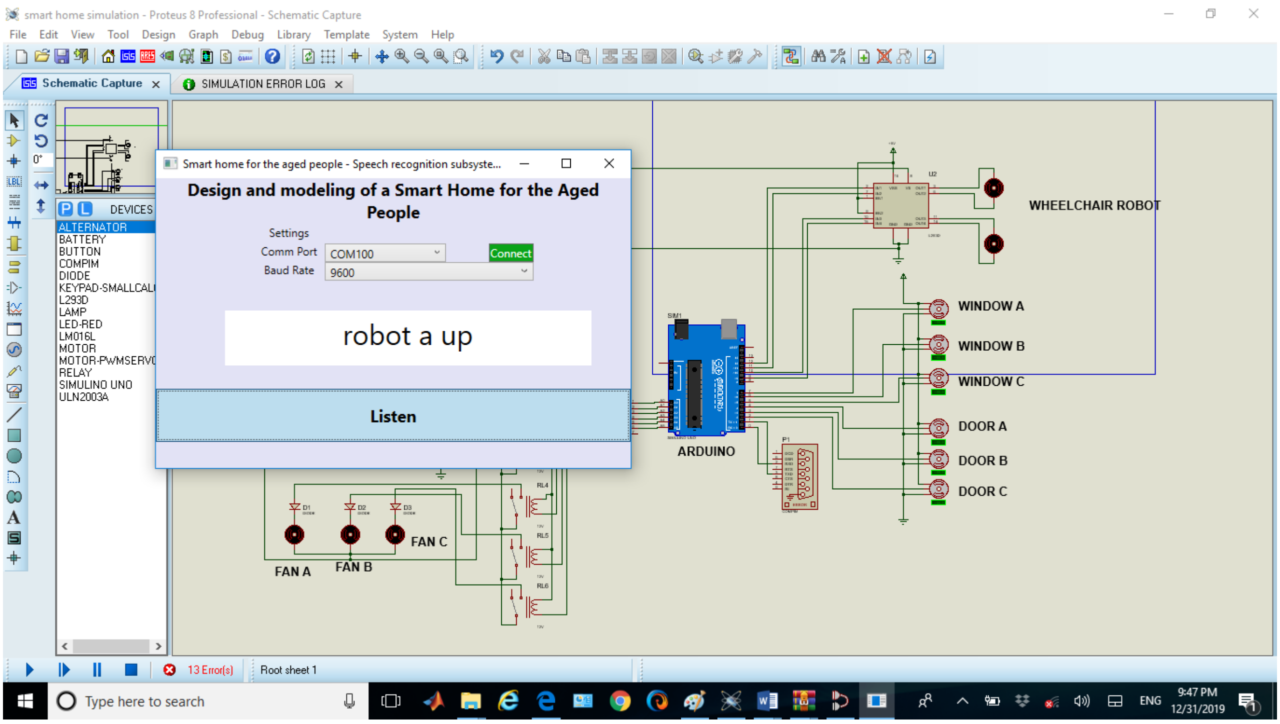


Figure 3.52: Screenshot Result when command word is “Robot UP” in real time

When the user speaks “Robot DOWN” in real time, the execution time is 0.06483s. When speaking “Robot DOWN”, command “Robot DOWN” is shown in the massage box (Figure 3.53).

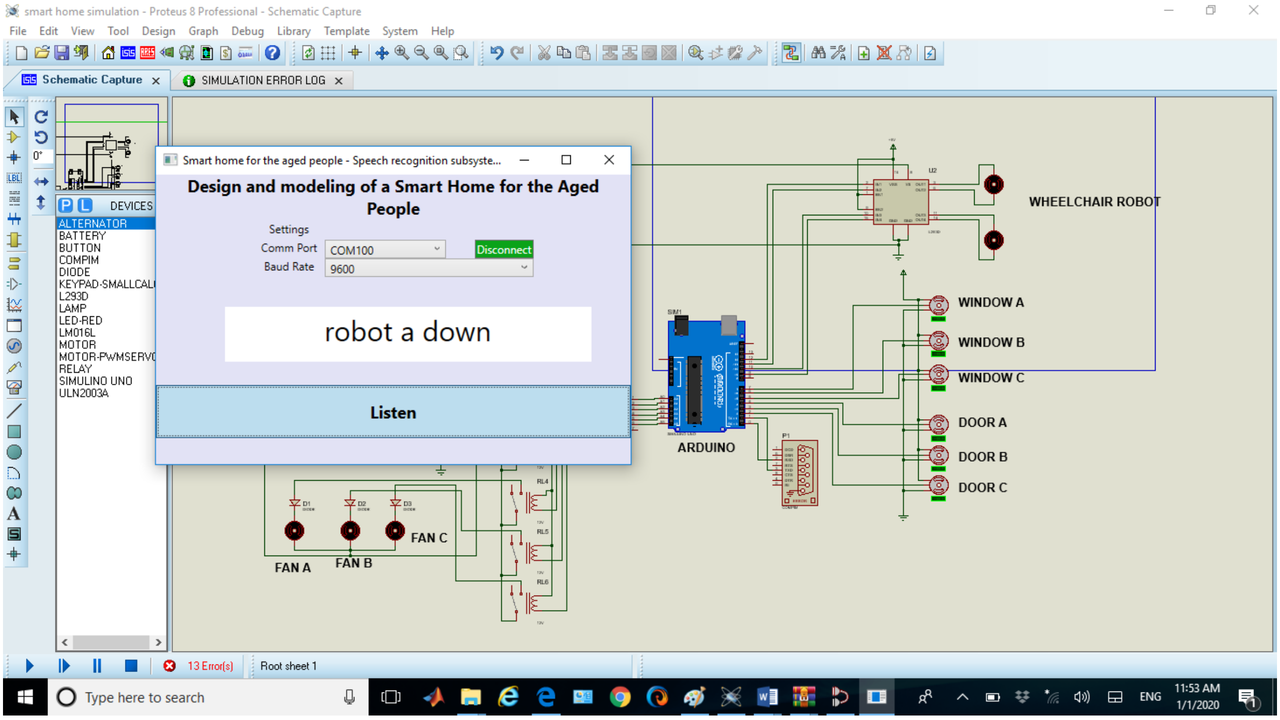


Figure 3.53: Screenshot Result when command word is "Robot DOWN" in real time

When the user speaks "Robot RIGHT" in real time, the execution time is 0.05564s. When speaking "Robot RIGHT", command "Robot RIGHT" is shown in the massage box (Figure 3.54).

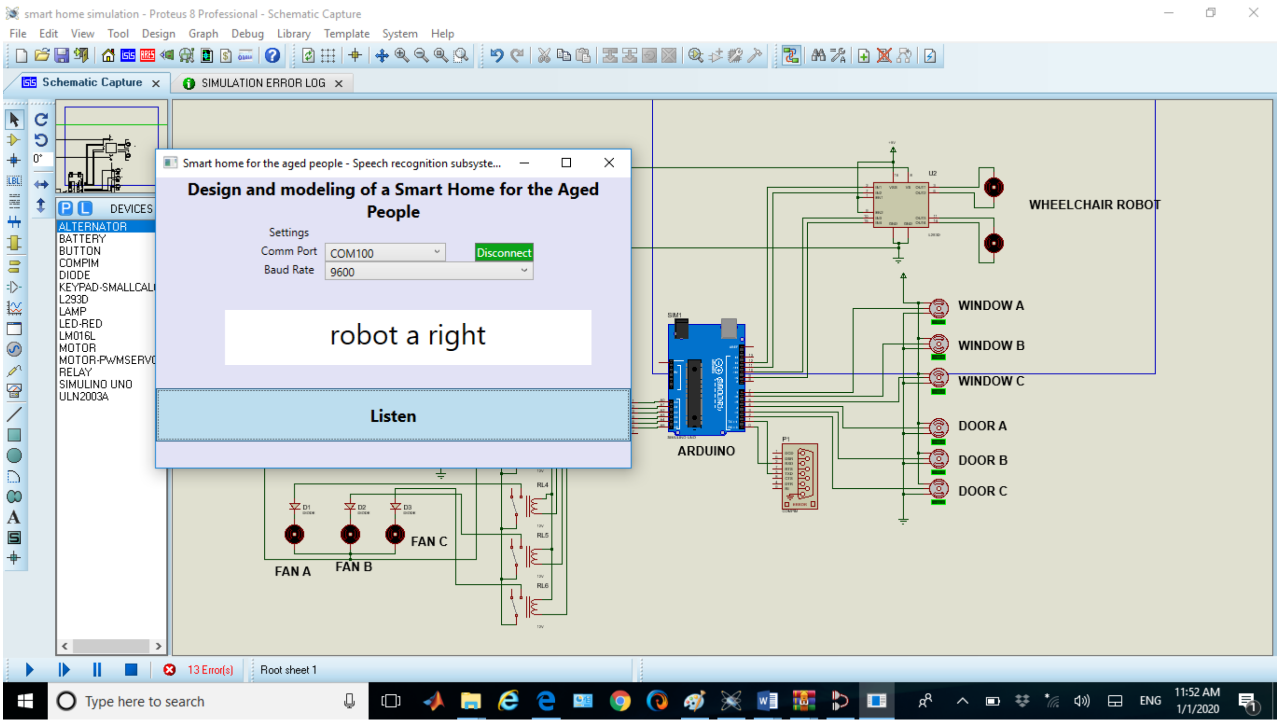


Figure 3.54: Screenshot Result when command word is "Robot RIGHT" in real time

When the user speaks “Robot LEFT” in real time, execution time is 0.46474s. When speaking “Robot LEFT”, command “Robot LEFT” is shown in the massage box (Figure 3.55).

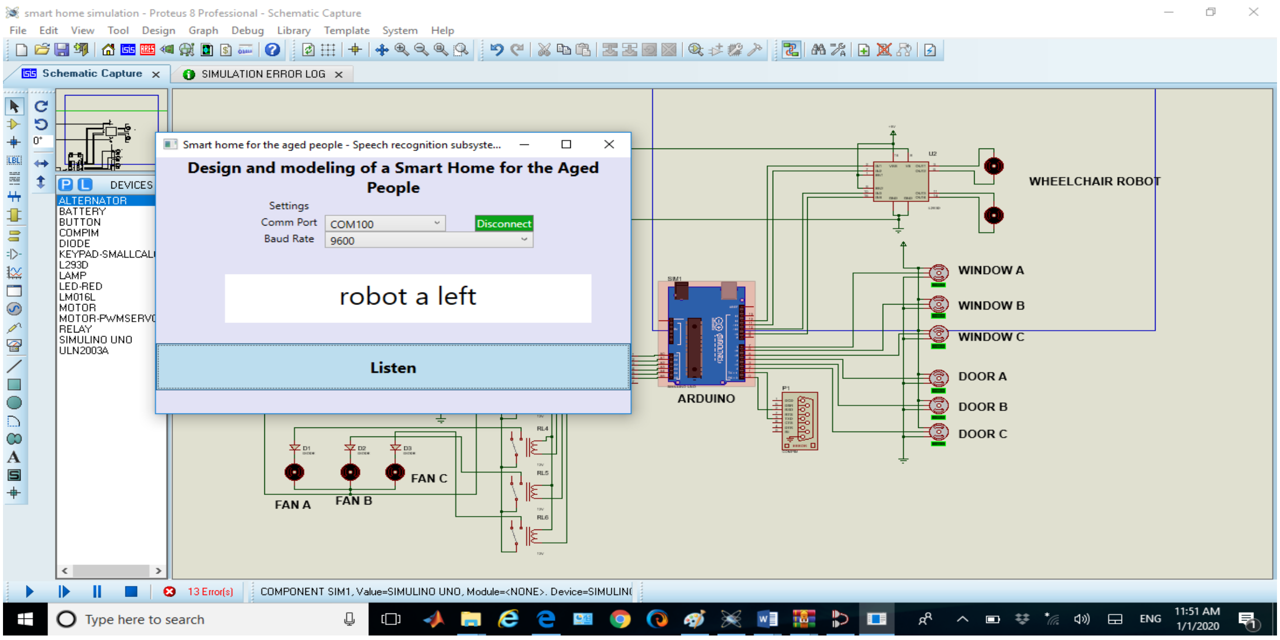


Figure 3.55: Screenshot Result when command is “Robot LEFT” in real time

When the user speaks “Robot HALT” in real time, the execution time is 0.06486s. When speaking “Robot HALT”, command “Robot HALT” is shown in the massage box (Figure 3.56).

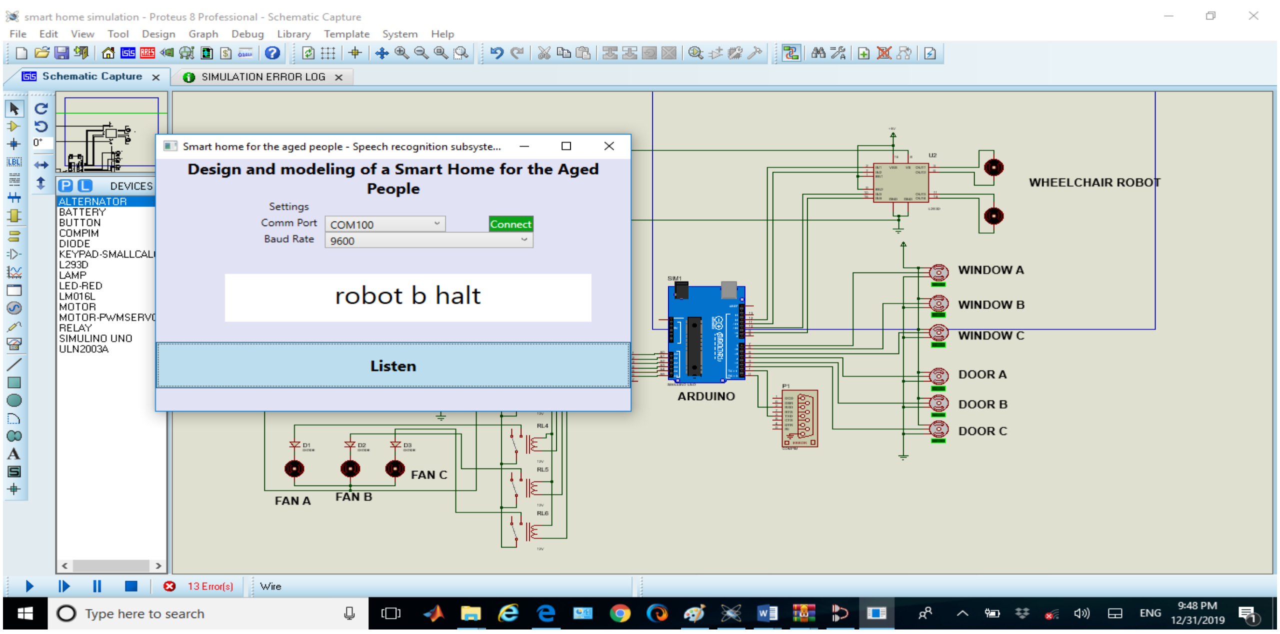


Figure 3.56: Screenshot Result when command is “Robot HALT” in real time

3.2.9 Material Cost

The detailed units and total material costs of the smart home system for the disabled aged persons are given in Table 3.9.

Table 3.9: Detailed cost of material

Materials	**Quantities (Units)**	**Unit price 000 (in Naira)**	**Cost 000 (in Naira)**
VoiceGP DK-T2SI	1	3.4	3.4
Proteus 8 Professional	1	4.5	4.5
MATLAB	1	4.5	4.5
MYSQL	1	1.2	1.2
Microsoft Visual Studio 2010	1	1.2	1.2
C# Program	1	1.2	1.2
.Net Framework 4.0	1	1.1	1.1
TOTAL			17.1

Chapter 4

RESULTS AND DISCUSSIONS

This chapter presents the results of various experimental tests conducted during the course of achieving the objective of this research and the discussions are based on the interpretations of the results obtained from the tests.

4.1 Test Results Presentations

The followings are the results obtained from various experimental tests carried the out in the course of implementing the objectives of this work:

1. Microphone Sensitivity Result – The outcome of the process of determining the effective distance of voice input device (Microphone) from the user.

2. The System Level of Response and Accuracy Result – The result obtained from the process of evaluate the designed smart home system level of response and accuracy.

3. The System Performance Evaluation Result – this is the results gotten by calculating the average response time of the system, and the system error percentage.

4.1.1 Voice input device (Microphone) Distance Sensitivity Test Results

The results obtained from voice input device (microphone) distance sensitivity tests are shown in Table 4.1 for a live home environment, and Table 4.2 for a dead home environment respectively.

Table 4.1: Voice input device (Microphone) Distance Sensitivity Test Results in a Live Home Environment.

DISTANCE (Meter)		0.25	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Male 1	T_1	P	P	P	P	P	P	P	P	P	X	X
	T_2	P	P	P	P	P	P	P	P	P	P	X
	T_3	P	P	P	P	P	P	P	P	X	P	P
	T_4	P	P	P	P	P	X	P	P	P	X	X
Male 2	T_1	P	P	P	P	P	P	P	X	X	X	P
	T_2	P	P	P	P	P	P	X	P	X	P	P
	T_3	P	P	P	P	P	P	P	P	P	P	X
	T_4	P	P	P	P	P	X	X	P	P	X	P
Female 3	T_1	P	P	P	P	P	P	X	P	X	P	X
	T_2	P	P	P	P	P	P	P	X	P	P	P
	T_3	P	P	P	P	X	P	P	P	X	P	P
	T_4	P	P	P	P	X	P	X	P	X	X	X
Female 4	T_1	P	P	P	P	P	P	P	P	P	P	P
	T_2	P	P	P	P	P	P	P	X	P	X	X
	T_3	P	P	X	P	P	X	X	P	P	P	P
	T_4	P	P	P	P	X	P	P	X	X	X	X
Total Voice Command Detected		**16**	**16**	**15**	**16**	**13**	**13**	**11**	**12**	**9**	**9**	**8**

Table 4.2: Voice input device (Microphone) Distance Sensitivity Test Results in a Dead Home Environment.

DISTANCE (Meter)		0.25	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Male 1	T_1	P	P	P	P	P	P	P	P	P	X	P
	T_2	P	P	P	P	P	P	P	P	P	P	X
	T_3	P	P	P	P	P	P	P	P	P	P	P
	T_4	P	P	P	P	P	P	P	P	P	P	X
Male 2	T_1	P	P	P	P	P	P	P	P	P	X	P
	T_2	P	P	P	P	P	P	P	P	X	P	P
	T_3	P	P	P	P	P	P	P	P	P	P	X
	T_4	P	P	P	P	P	P	P	P	P	X	P
Female 3	T_1	P	P	P	P	P	P	P	P	X	P	X
	T_2	P	P	P	P	P	P	P	X	P	P	P
	T_3	P	P	P	P	P	P	P	P	P	P	P
	T_4	P	P	P	P	P	P	P	P	P	X	X
Female 4	T_1	P	P	P	P	P	P	P	P	P	P	P
	T_2	P	P	P	P	P	P	P	P	P	X	X
	T_3	P	P	P	P	P	P	P	P	P	P	P
	T_4	P	P	P	P	P	P	P	P	X	P	X
Total Voice Command Detected		16	16	16	16	16	16	16	15	13	11	10

4.1.2 The System Level of Response and Accuracy Result

The tables below are the respective results portraying the level of system responsiveness and accuracy to the users spoken voice command. This result was obtained from both the dead home (Table 4.3) and live home (Table 4.4) and the overall effectiveness results is shown in Table 4.5 and the result comparison is shown in Figure 4.1.

Table 4.3: The System Voice Recognition Commands Response in a Dead Home

DEAD HOME ENVIRONMENT																
COMMANDS	MALE 1				MALE 2				FEMALE 3				FEMALE 4			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_6	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
SMART ACTIVATE	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
WHEEL RIGHT	P	P	P	P	P	P	P	P	P	P	P	P	P	X	P	P
WHEEL LEFT	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
WHEEL FORWARD	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
WHEEL BACKWARD	P	P	P	P	X	P	P	P	P	P	P	P	P	P	P	P
WHEEL END	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
SMART DOOR OPEN	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
DOOR CLOSE	P	P	P	P	P	P	P	P	P	X	P	P	P	P	P	P
WINDOW OPEN	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
WINDOW	P	P	P	P	P	X	P	P	P	P	P	P	P	P	P	P

TABLE 4.4: The System response in a Live home

LIVE HOME ENVIRONMENT																
COMMANDS	MALE 1				MALE 2				FEMALE 3				FEMALE 4			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
SMART ACTIVATE	P	P	P	P	X	P	P	P	P	P	P	P	P	P	P	P
WHEEL RIGHT	P	P	P	P	P	P	P	P	P	P	X	P	P	X	P	P
WHEEL LEFT	P	X	P	P	P	P	X	P	P	P	P	P	P	P	P	P
WHEEL FWD	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
WHEEL BWD	P	P	P	X	P	P	X	P	X	P	P	P	P	P	X	P
WHEEL END	P	P	P	P	P	P	P	P	P	P	P	X	P	P	P	P
DOOR OPEN	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
DOOR CLOSE	P	P	P	P	P	P	P	P	P	P	P	P	P	P	X	P
WIN OPEN	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
WIN CLOSE	X	P	P	P	P	P	P	P	P	X	P	P	P	P	P	P
LIGHT ON	P	P	P	P	P	P	P	P	P	P	P	X	P	P	P	X
LIGHT OFF	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
FAN ON	P	P	P	P	X	P	P	P	P	P	P	P	P	P	P	P
FAN OFF	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
FREEZER ON	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
FREEZER OFF	P	P	P	P	P	P	P	X	P	P	P	P	P	P	P	P
	15	15	16	15	14	16	14	15	15	15	15	14	16	15	14	15

Table 4.5: The Result of the Overall Effectiveness of the System.

TESTERS	DEAD HOME			LIVE HOM E		
	% ERROR		AVERAGE % ERROR	% ERROR		AVERAGE % RROR
Male 1	T_1	0%	1.04%	T_1	6.25%	6.25%
	T_2	0%		T_2	6.25%	
	T_3	0%		T_3	18.75%	
	T_4	1.23%		T_4	0%	
Male 2	T_1	0%	2.29%	T_1	1.23%	3.52%
	T_2	0%		T_2	0%	
	T_3	0%		T_3	1.23%	
	T_4	6.25%		T_4	6.25%	
Female 1	T_1	0%	2.29%	T_1	6.25%	3.96%
	T_4	1.23%		T_4	1.23%	
	T_5	0%		T_5	3.75%	
	T_6	0%		T_6	0%	
Female 2	T_1	0%	1.45%	T_1	0%	10.42%
	T_2	1.23%		T_2	6.25%	
	T_3	0%		T_3	0%	
	T_4	1.23%		T_4	6.25%	
OVERALL FFECTIVENESS			92.93%			75.85%

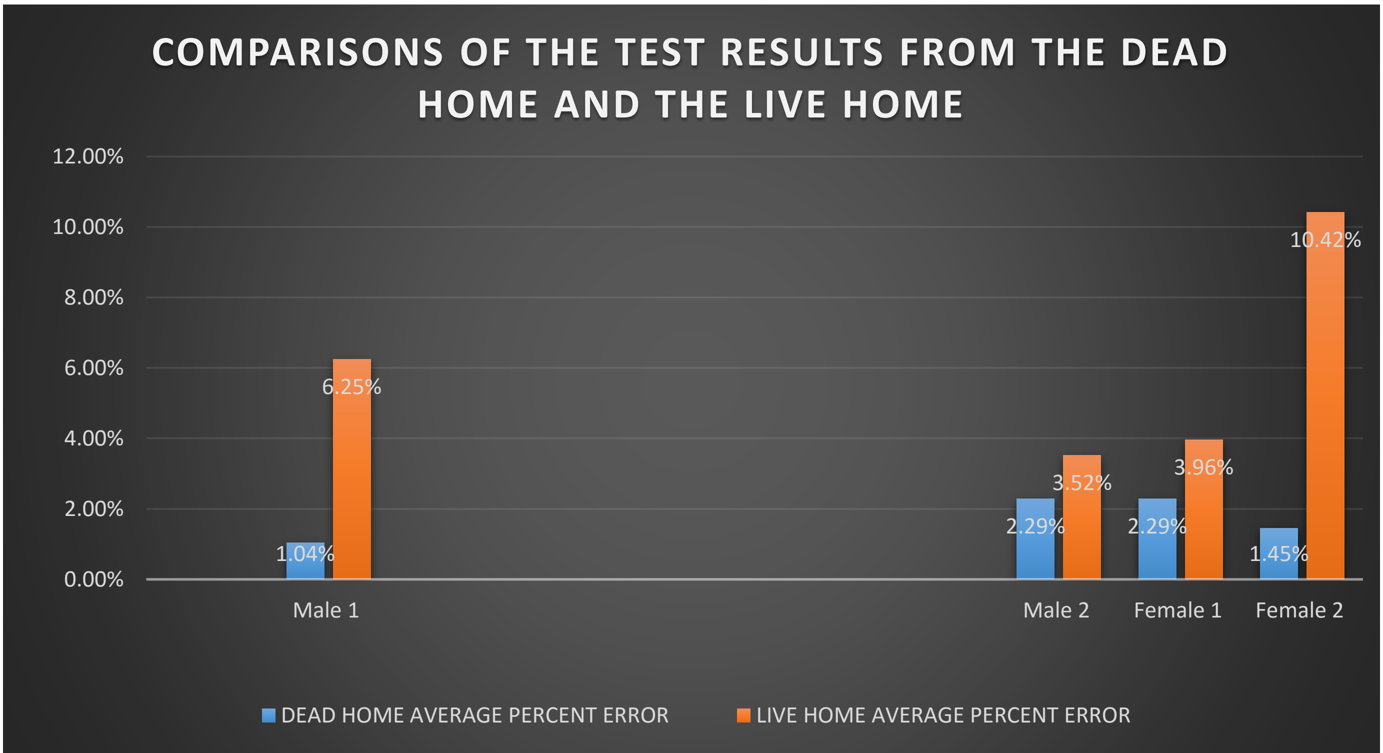


Figure 4.1 Comparisons of the System Performance in a Dead Home and a Live Home Environment.

4.1.3 The System Performance Evaluation Result Using the Elapsed Time

This is the result obtained from calculating the system response time, which is the time that elapsed once the control signal has been activated and the corresponding operation was executed. This result showed the records of the time difference between the period the control signal was sent and the period in which the corresponding operation was executed. The time response results for four sets of all five wheelchair control commands (20 commands) sent to the smart wheelchair are tabulated in Table 4.6 and the result is represented in Figure 4.2

Table 4.6: Readings of the response time for individual commands

S/No.	Command	Response Time
1	Forward	3.5
2	Forward	4.3
3	Forward	3.4
4	Forward	2.8
5	Backward	3.4
6	Backward	3.2
7	Backward	3.6
8	Backward	2.3
9	Right	2.8
10	Right	3.5
11	Right	1.3
12	Right	0.9
13	Left	3.4
14	Left	0.9
15	Left	1.3
16	Left	0.9
17	Halt	3.4
18	Halt	3.6
19	Halt	3.5
20	Halt	4.2

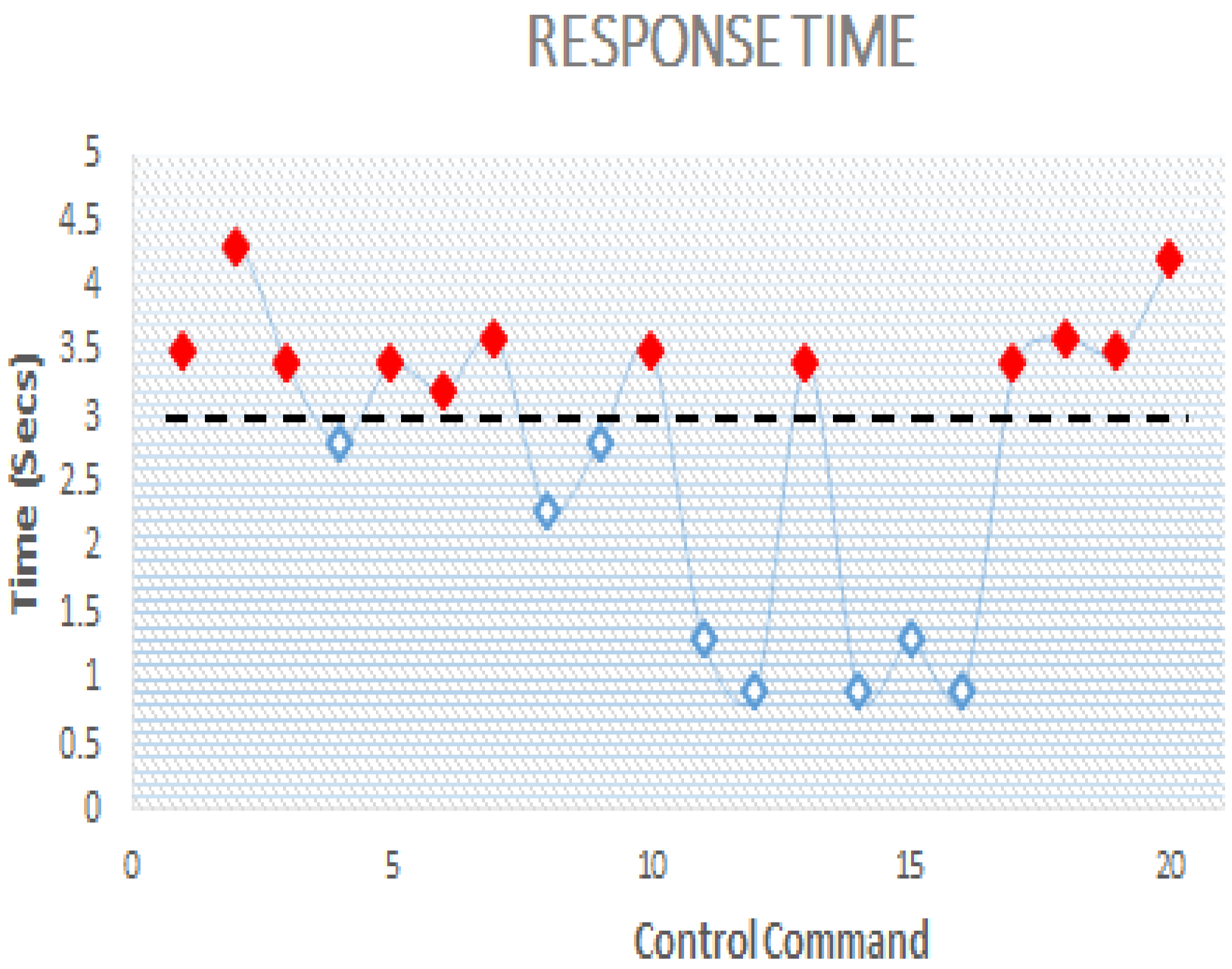


Figure 4.2: System Response Time Plot for 20 different commands

The red points above the thick black line in Figure 4.2 are commands prone to error since they are above the average response time and may not execute as the next command may overwrite the previous command, and this may prove to be inefficient.

Average Response Time = Total Response of All Readings/Number of Trials = 58.2/20 Average System Response Time = 2.91 (seconds)

4.1.4 The System Performance Evaluation Result Using the Percentage Error

This is the result obtained by calculating the systems` percentage error to evaluate the system performance, through determining whether the command transmitted is the command executed within the elapsed system response period. Hence, the results on Table 4.7 shows the system errors for 20 commands recorded and it is used to determine the average system percentage error, where an error and no error is entered as 1 and 0.

Table 4.7: Readings of the system error for individual commands

S/N	COMMAND TRANSMITTED	COMMAND EXECUTED	SYSTEM ERROR
1	Forward	Forward	0
2	Backward	Backward	0
3	Right	Forward	1
4	Left	Left	0
5	Halt	Left	0
6	Forward	Forward	0
7	Backward	Backward	1
8	Right	Right	0
9	Left	Left	0
10	Halt	Backward	1
11	Forward	Forward	0
12	Backward	Forward	1
13	Right	Right	0
14	Left	Left	0
15	Halt	Halt	0
16	Forward	Halt	1
17	Backward	Backward	0
18	Right	Right	0
19	Left	Left	0
20	Halt	Forward	1

Error Percentage = (Number of Errors/Total Number of Trials) *100

= (6/20) *100 System Percentage Error = 30%

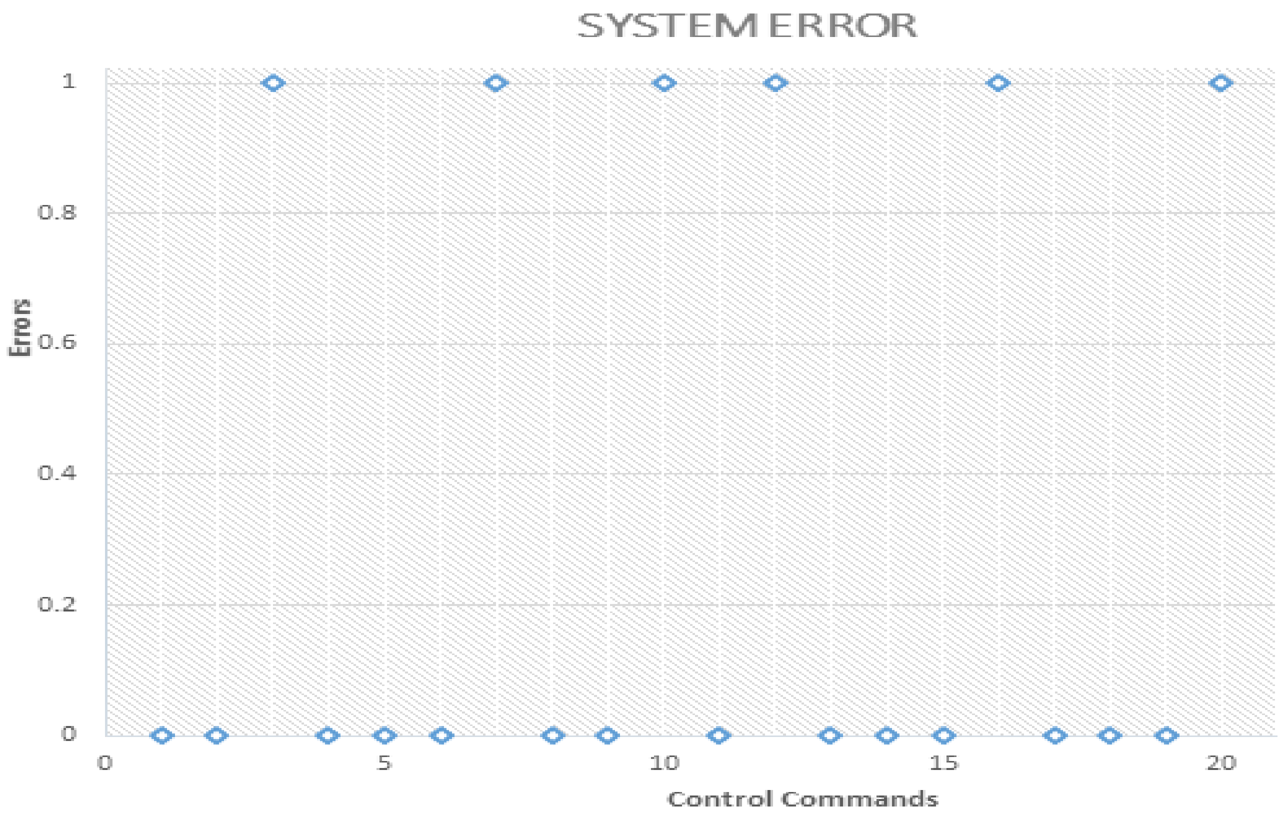


Figure 4.3: System Error Plot for a variation of consecutive commands

In this test four, the average response time of the system is high and the system can be prone to errors if the user wishes to make quick consecutive changes in navigation

4.1.5 The System Test Results Summary

The various system test results are summarized in Table 4.8.

Table 4.8: Test Results Summary

TESTING METHODS	TESTING FACTORS	DEVICE RESPONSE	OUTPUT RESUL ACCURACY
AMPLITUDE OF VOICE	Normal conversation 60dB	Device responds 3 out of 4 times	75%
	Whisper 35dB	Device responds 1 out of 4 times	25%
NUMBER OF WORDS	Minimum 3 words	Device responds accurately 3 out of 3 times	100%
	Maximum 4 words	Device responds accurately 2 out of 4 times	50%
DISTANCE FROM MICROPHONE	Lesser distance 0.25m	Accurate response 4 out of 4 times	100%
	Greater Distance 5m	Accurate response 2 out of 4 times	50%
ENVIRONMENTS	Quite	Accurate response 3 out of 4 times	75%
	Noise	Accurate response 1 out of 4 times	25%
MULTIPLE SPEAKERS	Multiple speakers	Device responds accurately 2 out of 4 times	50%
	Individual speaker	Device responds accurately 3 out of 4 times	75%
ROOM SIZE	Dead Rooms	Accurate response 3 out of 4 times	75%
	Live Rooms	Accurate response 2 out of 4 times	50%

The result of various experimental tests conducted during the course of achieving the objective of this research and the analysis are based on the interpretations of the results obtained from the tests.

The results portraying the level of system responsiveness and accuracy to the users spoken voice command, which are obtained from both the dead home and live home, and the overall effectiveness performance results is shown in Table 4.9 and the result analysis is shown in Figure 4.4.

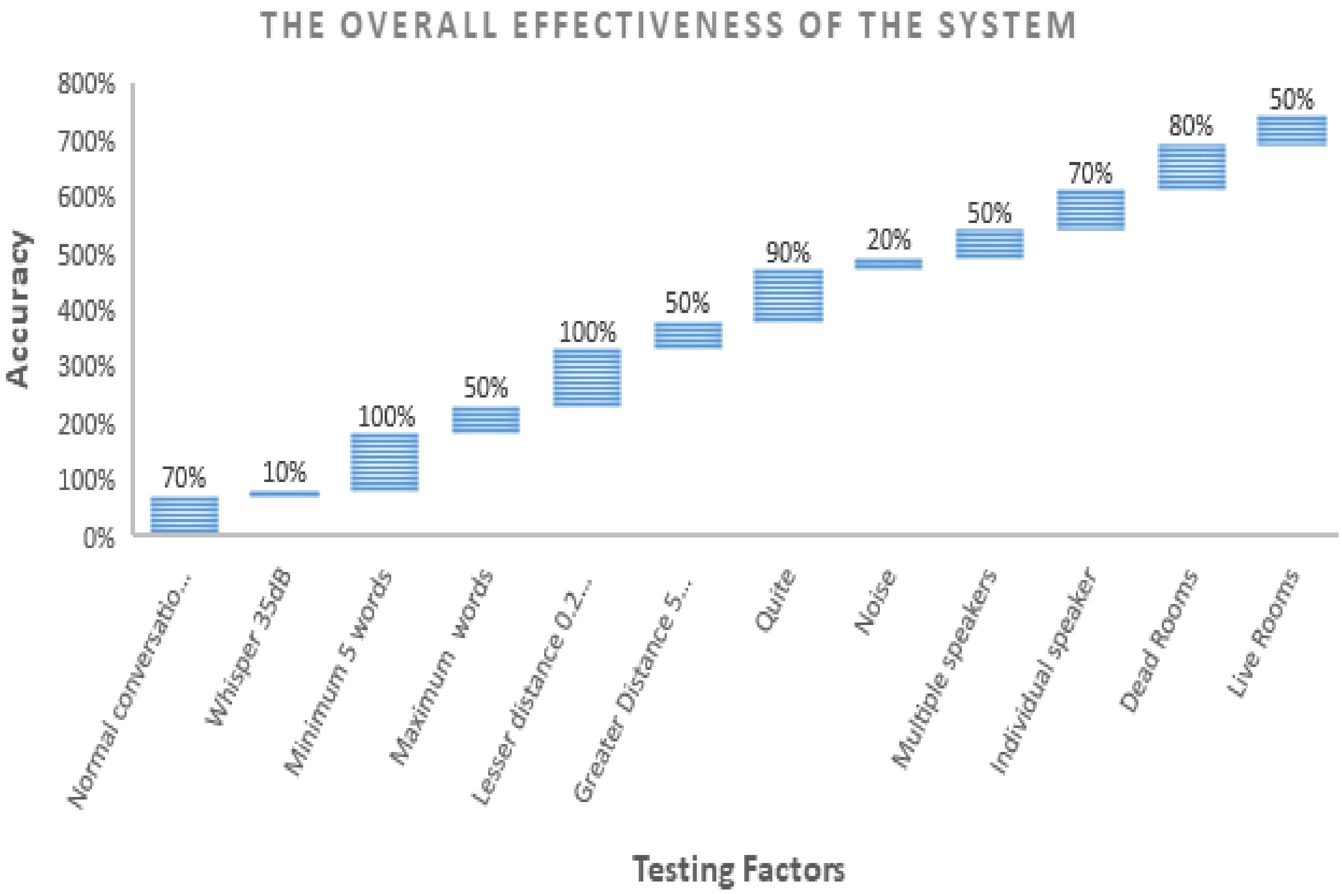


Figure 4.4: The System Overall Effectiveness Result.

4.2 Discussions

4.2.1 Voice input device (Microphone) Distance Sensitivity Test Results

The results in Tables 4.1 and 4.2 shows the Microphones response in both live home and dead home respectively. Here, the system is very much responsive in live home between the ranges 0.25 to 1.5 meters, which means that the sensitivity of the input microphone is highly responsive and very effective at close range in live home. Whereas, a distance ranges from 2.0 to 5.0 meters though at some point the module responded, it still did not give a consistent responsiveness. Despite that the result showed that from 0.5 to 1-meter distances, the microphone is very much sensitive to voice command and it responded according to the command that is uttered, the kind of voice command uttered also affected the results of the test here; that was the reason it was possible at some point, to detect some testers' voice commands even at farthest point.

4.2.2 The System Level of Response and Accuracy Result

The result on Table 4.3 shows the system's response to voice command in a dead home, the many check marks showed that this system tend to respond more correctly when used in a quiet home environment. Though, the existing cross marks implied that the system still has a certain percentage error and the result varies from the user's voice. The result in Table 4.4 showed the system's response in a live home, and existence of the many cross marks, which evidence that though the system still functions correctly, it was not performing as accurate and effective as when used in a dead home.

The overall effectiveness of the results on Table 4.5 demonstrates that all trials in dead home almost achieved zero percentage error, and even at average, dead home still has a very lower percent error. But, when the home environment of test was in a live home, a very higher percentage error occurred because of the surrounding environmental noise thus, the average percentage error for the live home is larger. Therefore, it can be seen that the design is much more effective in a dead home with 92.93%, while in a live home it is only 75.85%, and based on these results it can be deduced that the system works better on a less noisy environment area as depicted on Figure 4.2.

Finally, the interpretation of various results showed:

1. That from the voice command recognition test results, the effectiveness of the system is affected by the system's environmental noise.

2. That from system performance evaluation test result, due to high system average response time, the system is prone to errors when system user wishes to make quick consecutive changes in navigation.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

a. Conclusion

Smart home for the aged persons is a wireless sensor-based home network that provide the aged persons a safe, sound and secure home environment, and enabling them to live independently in their own homes as long as possible. The aim of this project is to design and develop a voice activated control home system that can manage and maneuver assistive wheelchair and home appliance control through voice commands for the aged, is implemented in Proteus environment. Based on the objectives of the design, the smart home technologies system has two major components: voice recognition and smart home appliances and assistive device electronic control systems. A Personal Computer (PC) was used for voice processing and recognition, and the output signal of the PC is sent wirelessly through the Bluetooth transceivers, to the control section, where a microcontroller selects the required device according to the input voice command. This process involves both feature extraction done with mel frequency cepstral coefficients, and feature matching carried out by using clustering algorithm and applying vector quantization approach.

After voice input and recognition (voice recognition module), the control signal of the recognized command is transmitted using Radio Frequency (RF)/Bluetooth transceivers from PC to the microcontroller wirelessly. The microcontroller which is connected to driver circuit for relay and motor, uses this signal to control home appliances/assistive device respectively.

The smart home technologies system designed for three room apartments was modelled, simulated and tested, and so far achieved is the control of the smart home appliance and assistive device at the same time in three different rooms, example: The system was able to turn ON & OFF Light, and Fan.

The system was able to turn OPEN & CLOSE Door, and Window.

The system used voice commands to navigate the users` motorized wheelchair.

The system performance test result showed that the level of system response is higher in dead home than in a live home, hence, the level of the system performance is lower in a noisy environment and the accents of un-trained aged persons are not supported by it. Also, the system responds precisely more effectively with a male voice than female voice.

5.2 Recommendation

For this smart home Technology system, the following is recommended to improve its functionality and usability:

1. Implementing smart home technology system that supports both foreign and local accents (English and Nigerian) languages, since most of the occupants in a smart home are mostly fluent with their local languages.
2. Implementing multimodal input smart home technology system that will enable more than one aged persons with different disabilities live independently together in the same apartment.

5.3 Contributions of this Research to Knowledge

This dissertation has made the following contribution to knowledge through:

- ❖ Designed smart home technologies system that use voice signals from the microphone sensor as input parameter to control both the relay driven appliances, and motor driven devices in a smart home.
- ❖ Developed a modularized user-friendly interface smart home technologies system with plug and play capability, which allow new smart devices to be added with ease.

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APPENDICES

Appendix A

```
/**
          Code for voice module
  ******************************************************************************
  * @file    vr_sample_multi_cmd.ino
  * @author  engr Godfrey (NCB Electronics)
  * @brief   This file provides a fullprogram on
          how to implement a multi voice command project (exceed 7 voice command)
          by using VoiceRecognitionModule
  ******************************************************************************
  * @note:
      voice control led
  ******************************************************************************
  * @section  HISTORY

    2017/10/17    .
  */
```

```
#include <SoftwareSerial.h>
#include "VoiceRecognitionV3.h"

/**
  Connection
  Arduino    VoiceRecognitionModule
   4   ------->     TX
   5   ------->     RX
*/
VR myVR(2,3);    // 2:RX 3:TX, can choose your favourite pins.

uint8_t record[7]; // save record
uint8_t buf[64];

int led = 13;
int pin1 = 4;
int pin2 = 5;
int pin3 = 6;
int pin4 = 7;
int pin5 = 8;
int group = 0;

#define robot                 (0)

#define window                (1)
#define door                  (2)
#define open2                 (3)
#define close2                (4)
#define light                 (5)
#define fan                   (6)

#define device       (7)
#define forward      (8)
#define back       (9)
#define right       (10)
#define light      (11)
#define stop2       (12)


void setup()
{
  /** initialize */
  myVR.begin(9600);

  Serial.begin(115200);
  Serial.println("Elechouse Voice Recognition V3 Module\r\nMulti Commands sample");

  pinMode(led, OUTPUT);
    pinMode (pin1, OUTPUT);
   pinMode (pin2, OUTPUT);
     pinMode (pin3, OUTPUT);
    pinMode (pin4, OUTPUT);
     pinMode (pin5, OUTPUT);
  if(myVR.clear() == 0){
```

```
    Serial.println("Recognizer cleared.");
  }
Else
{
    Serial.println("Not find VoiceRecognitionModule.");
    Serial.println("Please check connection and restart Arduino.");
    while(1);
  }

  record[0] = robot;
  record[2] = window;
  record[3] = door;
  record[4] = open2;
  record[5] = close2;
  record[6] = light;
  record[7] = fan;
  group = 0;
  if(myVR.load(record, 7) >= 0)
{
    printRecord(record, 7);
    Serial.println(F("loaded."));
  }

}

void loop()
{
  int ret;
  ret = myVR.recognize(buf, 50);
  if(ret>0){
    switch(buf[1]){
      case robot:
        /** turn on LED */
        if(digitalRead(led) == HIGH){
          digitalWrite(led, LOW);
        }else{
          digitalWrite(led, HIGH);
        }
        if(group == 0)
                        {
          }
        }
        break;
      default:
        break;
    }
    /** voice recognized */
    printVR(buf);
  }
}

/**
  @brief   Print signature, if the character is invisible,
           print hexible value instead.
```

```
  @param   buf     --> command length
           len     --> number of parameters
*/
void printSignature(uint8_t *buf, int len)
{
  int i;
  for(i=0; i<len; i++){
    if(buf[i]>0x19 && buf[i]<0x7F){
      Serial.write(buf[i]);
    }
    else{
      Serial.print("[");
      Serial.print(buf[i], HEX);
      Serial.print("]");
    }
  }
}

/**
  @brief   Print signature, if the character is invisible,
           print hexible value instead.
  @param   buf  -->  VR module return value when voice is recognized.
             buf[0]  -->  Group mode(FF: None Group, 0x8n: User, 0x0n:System
             buf[1]  -->  number of record which is recognized.
             buf[2]  -->  Recognizer index(position) value of the recognized record.
             buf[3]  -->  Signature length
             buf[4]~buf[n] --> Signature
*/
void printVR(uint8_t *buf)
{
  Serial.println("VR Index\tGroup\tRecordNum\tSignature");

  Serial.print(buf[2], DEC);
  Serial.print("\t\t");

  if(buf[0] == 0xFF){
    Serial.print("NONE");
}

void printRecord(uint8_t *buf, uint8_t len)
{
  Serial.print(F("Record: "));
  for(int i=0; i<len; i++){
    Serial.print(buf[i], DEC);
    Serial.print(", ");
  }
}
```

Appendix B

CODE FOR ROBOTIC WHEELCHAIR

```
org 0000h

MOV P2, #0FFH
MOV P1, #0FFH
;MOV p2, #11110111B
START:
JNB P2.4, $
MOV A, P2
MOV B, #11110111B; FORWARD

 CJNE A, B, NEXT

SETB P1.0
```

```
SETB P1.2
CLR P1.1
CLR P1.3
SJMP START

 NEXT:

 MOV B, #11111000B; BACK
 CJNE A, B, NEXT1

 CLR P1.0
CLR P1.2
SETB P1.1
SETB P1.3
SJMP START

 NEXT1:

 MOV B, #11111001B ; RIGHT
 CJNE A, B, NEXT2
  CLR P1.0
SETB P1.2
CLR P1.1
CLR P1.3



SJMP START
 NEXT2:
 MOV B, #11111010B ; LIFT
 CJNE A, B, NEXT3
 SETB P1.0
CLR P1.2
CLR P1.1
CLR P1.3
SJMP START
 NEXT3:
  MOV B, #11111011B
  CJNE A, B, START;  STOP

 CLR P1.0
CLR P1.2
CLR P1.1
CLR P1.3
SJMP START
  END
```

Appendix C

CODE FOR EMERGANCE REPORTING

```
org 00h
start:
MOV P1, #0FFH
                MOV R2, #5
        GO:     ACALL DELAY
                ACALL DELAY
                DJNZ R2, GO
SYSYEM_TEST:        ACALL GSM_SETUP
                ;ACALL NUMBER_1
                ACALL DELAY
                ACALL DELAY
```

```
        ACALL DELAY
        ACALL TEST_MESSAGE
        ACALL DELAY
        ;ACALL CMGD
        ACALL DELAY

        SJMP BEGGIN
; SETTING UP GSM AND SENDING TEXT MESSAGE TO CHECK IF GSM MODULE IS READY
    BEGGIN:

        ACALL check_key
            SJMP BEGGIN
GSM_SETUP:
        ACALL serial_port

        ;ACALL DELAY
        ACALL DELAY_1
        ACALL AT_0
        SETB P1.0
        ;ACALL DELAY
        ACALL DELAY_1
        ACALL ATE
        CLR P1.0
        ;ACALL DELAY
        ACALL DELAY_1

        ACALL CMGF
        SETB P1.0
        ;ACALL DELAY
        ACALL DELAY_1

        ACALL IPR
        CLR P1.0
        ;ACALL DELAY
        ACALL DELAY_1
        ACALL CSMS
        SETB P1.0
        ;ACALL DELAY
        ACALL DELAY_1
        ACALL CPMS
        CLR P1.0
        ;ACALL DELAY
        ACALL DELAY_1
        ;ACALL CNMI_READ
        ;ACALL DELAY

        RET


check_key:
        ;ACALL DELAY
        SETB P1.0
        ACALL DELAY
```

```
                ACALL DELAY
                JB P1.2,NEXT_KEY
                CLR P1.0
                ;ACALL DELAY
                ACALL DELAY_1
                ;ACALL DELAY_1
        arrm:   ACALL ARM_ROB


NEXT_KEY_2:             ;ACALL DELAY

                CLR P1.0
                ;ACALL DELAY

                ACALL DELAY_1
                SJMP CHECK_KEY


FIRE:           ;ACALL DELAY_30S
                ;ACALL CLEAR_SCREEN
                ACALL GSM_SETUP
                ACALL NUMBER_FIR
                MOV DPTR, #REPORT_FIRE
                D_5: CLR A
                MOVC A, @A+DPTR
                JZ TEST_3
                ACALL SEND
                ACALL DELAY_30S
                INC DPTR
                SJMP D_5

TEST_3: RET



HEALTH:                 ;ACALL DELAY_30S
                ;ACALL CLEAR_SCREEN
                ACALL GSM_SETUP
                ACALL NUMBER_HEALTH
                MOV DPTR, #HEAL
                D_4: CLR A
                MOVC A, @A+DPTR
                JZ TEST_2
                ACALL SEND
                ACALL DELAY_30S
                INC DPTR
                SJMP D_4
        TEST_2: RET

ARM_ROB:        ;ACALL DELAY_30S
                ;ACALL CLEAR_SCREEN
                ACALL GSM_SETUP
                ACALL NUMBER_ARM
                MOV DPTR, #ARM
```

```
        D_3: CLR A
        MOVC A, @A+DPTR
        JZ TEST_1
        ACALL SEND
        ACALL DELAY_30S
        INC DPTR
        SJMP D_3
    TEST_1: RET


CMGF:
        MOV DPTR, #MSG0
        DD: CLR A
        MOVC A,@A+DPTR
        JZ SELF
        ACALL SEND
        ACALL DELAY_30S
        INC DPTR
        SJMP DD
        SELF: RET

CSMS:   MOV DPTR, #MSG5
        NO_1: CLR A
        MOVC A,@A+DPTR
        JZ NO_0
        ACALL SEND
        ACALL DELAY_30S
        INC DPTR
        SJMP NO_1
        NO_0: RET
NUMBER_1:
        MOV DPTR, #MSG2
        NO: CLR A
        MOVC A,@A+DPTR
        JZ NOO
        ACALL SEND
        ACALL DELAY_30S
        INC DPTR
        SJMP NO
        NOO: RET
NUMBER_HEALTH:
        MOV DPTR, #HEALT
        NO_HEALT: CLR A
        MOVC A,@A+DPTR
        JZ NOO_HEALT
        ACALL SEND
        ACALL DELAY_30S
        INC DPTR
        SJMP NO_HEALT
        NOO_HEALT: RET
NUMBER_FIR:
        MOV DPTR, #FIR
        NO_FIR: CLR A
        MOVC A,@A+DPTR
```

```
                JZ NOO_FIR
                ACALL SEND
                ACALL DELAY_30S
                INC DPTR
                SJMP NO_FIR
NOO_FIR:        RET

NUMBER_ARM:
                MOV DPTR, #FIR
                NO_ARM: CLR A
                MOVC A,@A+DPTR
                JZ NOO_ARM
                ACALL SEND
                ACALL DELAY_30S
                INC DPTR
                SJMP NO_ARM
serial_port:    MOV TMOD, #20H          ;SERIAL PORT INITIALIZATION
                MOV TH1, #-3                    ;9600 BUADRATE (-3)
                MOV SCON, #50H
                SETB TR1

                RET



        CNMI:
                MOV DPTR, #MSG3
                CNMI_1: CLR A
                MOVC A, @A+DPTR
                JZ CNMI_2
                ACALL SEND
                ACALL DELAY_30S
                INC DPTR
                SJMP CNMI_1
                CNMI_2: RET
CMGL_ALL:
                MOV DPTR, #TABLE7
                AT_7: CLR A
                MOVC A, @A+DPTR
                JZ AT_3
                ACALL SEND
                ACALL DELAY_30S
                INC DPTR
                SJMP AT_7
        AT_3:   RET



ATE:
                MOV DPTR, #MSG1
                DD_1: CLR A
                MOVC A, @A+DPTR
                JZ ZONE
                ACALL SEND
```

```
                ACALL DELAY_30S
                INC DPTR
                SJMP DD_1
                ZONE: RET


SEND:                   MOV SBUF, A
HERE:           JNB TI, HERE
                CLR TI
                RET


TEST_MESSAGE:   ;ACALL  CLEAR_SCREEN
                ACALL NUMBER_1
                MOV DPTR, #TESTMODULE
                D_7:    CLR A
                MOVC A,@A+DPTR
                JZ OK
                ACALL SEND
                ;ACALL DATAWRT
                INC DPTR
                ACALL DELAY_30S
                SJMP D_7
        OK:     RET

DELAY_1:MOV R0,#250
HERE1:          MOV R1, #250
        DJNZ R1,$
        JB P1.2, HERE5
        AJMP arrm
HERE5:          JB P1.3, HERE4
        AJMP HEART
HERE4:          JB P1.4, HERE2
        AJMP FIREE
HERE2:          DJNZ R0, HERE1
        RET
DELAY: MOV R6, #5
MORE:

        ACALL DELAY_1
        ACALL DELAY_1
        DJNZ R6, MORE
        RET
DELAY_30S: MOV R2, #55
AGAIN:            MOV R3, #15
HERE3:            MOV R4, #10
BEG:            DJNZ R4, BEG
                DJNZ R3, HERE3
                DJNZ R2, AGAIN
                RET


;LCDINIT: DB           "WELCOME", 0
;INITGSM: DB           "TESTING GSM DEVICE", 0
```

```
TESTMODULE: DB  "SYSTEM IS READY",01AH
TABLE7:   DB           "AT+CMGL=","'ALL'"
REPORT_FIRE:        DB 'MEDICAL HELP IS NEEDED @ FLAT 2, NO 10 CLIFFORD RD ABA ' ,01AH
                ;DB 'COMPUTER ENGINEERING DEPARTMENT, MOUAU '
                ;DB 'GPS COORDINATE LONG:5.477098, LAT:7.539832'
HEAL:DB         'YOUR ATTENTION IS NEEDED @ FLAT 2, NO 10 CLIFFORD RD ABA ' ,01AH
                ;DB
                ;DB 'GPS COORDINATE LONG:5.477098, LAT:7.539832',01AH
ARM:            DB 'THERE IS POSSIBLE ARM ROBBERY ATTACK GOING ON @ FLAT 2,'
                DB 'NO 10 CLIFFORD RD ABA',01AH
                ;DB 'GPS COORDINATE LONG:5.477098, LAT:7.539832',
END
```

Appendix D

```
#include <Servo.h>


Servo myservowina;  // create servo object to control a servo
Servo myservowinb;  // create servo object to control a servo
Servo myservowinc;  // create servo object to control a servo


Servo myservodoora;  // create servo object to control a servo
Servo myservodoorb;  // create servo object to control a servo
Servo myservodoorc;  // create servo object to control a servo


// Definitions Arduino pins connected to input H Bridge
int IN1 = 12;
int IN2 = 11;


int IN3 = 10;
int IN4 = 9;


int lighta = A2;
int lightb = A1;
int lightc = A0;


int fana = A3;
int fanb = A4;
int fanc = A5;



// twelve servo objects can be created on most boards
int x; // blink rate determined by this variable
```

```
char strValue[6]; // must be big enough to hold all the digits and the
// 0 that terminates the string
int index = 0; // the index into the array storing the received digits



void setup() {
//  myservo.attach(9);  // attaches the servo on pin 9 to the servo object

   myservowina.attach(7);  // create servo object to control a servo
 myservowinb.attach(6);  // create servo object to control a servo
 myservowinc.attach(5);  // create servo object to control a servo

 myservodoora.attach(4);  // create servo object to control a servo
 myservodoorb.attach(3);  // create servo object to control a servo
 myservodoorc.attach(2);  // create servo object to control a servo

  myservodoora.write(0);
  myservodoorb.write(0);
  myservodoorc.write(0);
   myservowina.write(0);
  myservowinb.write(0);
  myservowinc.write(0);

pinMode(IN1, OUTPUT);
pinMode(IN2, OUTPUT);
pinMode(IN3, OUTPUT);
pinMode(IN4, OUTPUT);

pinMode(lighta, OUTPUT);
```

```
pinMode(lightb, OUTPUT);
pinMode(lightc, OUTPUT);

pinMode(fana, OUTPUT);
pinMode(fanb, OUTPUT);
pinMode(fanc, OUTPUT);



  // initialize serial communications at 9600 bps:
  Serial.begin(9600);
}



void loop()
{
  if( Serial.available())
  {
    char ch = Serial.read();

    switch(ch)
    {
      case 'a':
              // MessageBox.Show("door A is opening");
              myservodoora.write(90);
      break;
      case 'b':
//              MessageBox.Show("door B is opening");
           myservodoorb.write(90);
      break;
```

```
    case 'c':
//      MessageBox.Show("door C is opening");
            myservodoorc.write(90);
    break;
    case 'd':
    //      MessageBox.Show("window A is opening");
            myservowina.write(90);
    break;
    case 'e':
//      MessageBox.Show("window B is opening");
            myservowinb.write(90);
    break;
    case 'f':
//      MessageBox.Show("window C is opening");

          myservowinc.write(90);
    break;
    case 'g':
    digitalWrite(fana, HIGH);   //      MessageBox.Show("fan A is switched on!");

    break;
    case 'h':
//      MessageBox.Show("fan B is switched on!");
            digitalWrite(fanb, HIGH);
    break;
    case 'i':
//      MessageBox.Show("fan C is switched on!");
            digitalWrite(fanc, HIGH);
    break;
```

```
case 'j':
//      MessageBox.Show("light A is switched on!");
        digitalWrite(lighta, HIGH);
break;
case 'k':
//MessageBox.Show("light B is switched on!");
        digitalWrite(lightb, HIGH);
break;
case 'l':
//      MessageBox.Show("light C is switched on!");
        digitalWrite(lightc, HIGH);
break;
case 'm':
//      MessageBox.Show("door A is closing");
          myservodoora.write(0);


break;
case 'n':
//      MessageBox.Show("door B is closing");
      myservodoorb.write(0);
break;
case 'o':
  //      MessageBox.Show("door C is closing");
        myservodoorc.write(0);
break;
case 'p':
//      MessageBox.Show("window A is closing");
        myservowina.write(0);
break;
```

```
case 'q':
//      MessageBox.Show("window B is closing");
        myservowinb.write(0);
break;
case 'r':
//      MessageBox.Show("window C is closing");
      myservowinc.write(0);
break;
case 's':
//      MessageBox.Show("fan A is switched off!");
        digitalWrite(fana, LOW);
break;
case 't':
    //      MessageBox.Show("fan B is switched off!");
        digitalWrite(fanb, LOW);
break;
case 'u':
//      MessageBox.Show("fan C is switched off!");
        digitalWrite(fanc, LOW);


break;
case 'v':
          //      MessageBox.Show("light A is switched off!");
        digitalWrite(lighta, LOW);
break;
case 'w':


//      MessageBox.Show("light B is switched off!");
        digitalWrite(lightb, LOW);
```

```
    break;
    case 'x':
//      MessageBox.Show("light C is switched off!");
        digitalWrite(lightc, LOW);
    break;
    case 'y':
//      MessageBox.Show("wheelchair is moving forward!");
          digitalWrite(IN1, HIGH);
          digitalWrite(IN2, LOW);
          digitalWrite(IN3, HIGH);
          digitalWrite(IN4, LOW);
          delay(500);
    break;
    case 'z':
//      MessageBox.Show("wheelchair is moving backward!");
          digitalWrite(IN1, LOW);
          digitalWrite(IN2, HIGH);
          digitalWrite(IN3, LOW);
          digitalWrite(IN4, HIGH);
          delay(500);
    break;
    case 'A':
//      MessageBox.Show("wheelchair is turning left!");
          digitalWrite(IN1, HIGH);
          digitalWrite(IN2, LOW);
          digitalWrite(IN3, LOW);
          digitalWrite(IN4, HIGH);
          delay(500);
    break;
```

```
    case 'B':
//      MessageBox.Show("wheelchair is turning right!");
            digitalWrite(IN1, LOW);
            digitalWrite(IN2, HIGH);
            digitalWrite(IN3, HIGH);
            digitalWrite(IN4, LOW);
            delay(500);
    break;
    case 'C':
//      MessageBox.Show("wheelchair is halted!");
            digitalWrite(IN1, LOW);
            digitalWrite(IN2, LOW);
            digitalWrite(IN3, LOW);
            digitalWrite(IN4, LOW);
            delay(500);
    break;
    case 'D':

    break;
    case 'E':

    break;
    case 'F':

    break;

   }

//
```

```
//    strValue[index++] = ch; // add the ASCII character to the string;
//    if(ch=='0')
//    {
//      strValue[index] = 0; // terminate the string with a 0
////      x = atoi(strValue); // use atoi to convert the string to an int
//      index = 0;
//    }

//    if(index < 5 && isDigit(ch) ){
//    strValue[index++] = ch; // add the ASCII character to the string;
//    }
//    else
//    {
//      // here when buffer full or on the first non digit
//      strValue[index] = 0; // terminate the string with a 0
//      x = atoi(strValue); // use atoi to convert the string to an int
//      index = 0;
//    }
  }
//  blink();
}
void blink()
{
//     myservo.write(x);              // tell servo to go to position in variable 'pos'
//       Serial.print(x);
//       delay(15);
}

void command(String str)
```

```
{
//     myservo.write(x);              // tell servo to go to position in variable 'pos'
//       Serial.print(x);
//       delay(15);
// str.indexOf("j");


}
```

Appendix E

C# CODES

```
using System;
using System.IO;
using System.IO.Ports;
using System.Collections;
using System.Threading;

namespace SpeechRec
{
   /// <summary> CommPort class creates a singleton instance
   /// of SerialPort (System.IO.Ports) </summary>
   /// <remarks> When ready, open the port.
   ///   <code>
```

```
///   CommPort com = CommPort.Instance;
///   com.StatusChanged += OnStatusChanged;
///   com.DataReceived += OnDataReceived;
///   com.Open();
///   </code>
///   Notice that delegates are used to handle status and data events.
///   When settings are changed, close and reopen the port.
///   <code>
///   CommPort com = CommPort.Instance;
///   com.Close();
///   com.PortName = "COM4";
///   com.Open();
///   </code>
/// </remarks>
    public sealed class CommPort
{
    SerialPort _serialPort;
                Thread _readThread;
                volatile bool _keepReading;

    //begin Singleton pattern
    static readonly CommPort instance = new CommPort();

                // Explicit static constructor to tell C# compiler
    // not to mark type as beforefieldinit
    static CommPort()
    {
    }

    CommPort()
    {
                        _serialPort = new SerialPort();
                        _readThread = null;
                        _keepReading = false;
                }

                public static CommPort Instance
    {
        get
        {
            return instance;
        }
    }
    //end Singleton pattern

                //begin Observer pattern
    public delegate void EventHandler(string param);
    public EventHandler StatusChanged;
    public EventHandler DataReceived;
    //end Observer pattern

                private void StartReading()
                {
                        if (!_keepReading)
```

```
            {
                _keepReading = true;
                _readThread = new Thread(ReadPort);
                _readThread.Start();
            }
        }

        private void StopReading()
        {
            if (_keepReading)
            {
                _keepReading = false;
                _readThread.Join();    //block until exits
                _readThread = null;
            }
        }

        /// <summary> Get the data and pass it on. </summary>
        private void ReadPort()
        {
            while (_keepReading)
            {
                if (_serialPort.IsOpen)
                {
                    byte[] readBuffer = new byte[_serialPort.ReadBufferSize + 1];
                    try
                    {
                        // If there are bytes available on the serial port,
                        // Read returns up to "count" bytes, but will not block (wait)
                        // for the remaining bytes. If there are no bytes available
                        // on the serial port, Read will block until at least one byte
                        // is available on the port, up until the ReadTimeout
milliseconds
                        // have elapsed, at which time a TimeoutException will be
thrown.
                        int count = _serialPort.Read(readBuffer, 0,
_serialPort.ReadBufferSize);
                        String SerialIn =
System.Text.Encoding.ASCII.GetString(readBuffer,0,count);
                        DataReceived(SerialIn);
                    }
                    catch (TimeoutException) { }
                }
                else
                {
                    TimeSpan waitTime = new TimeSpan(0, 0, 0, 0, 50);
                    Thread.Sleep(waitTime);
                }
            }
        }

        /// <summary> Open the serial port with current settings. </summary>
    public void Open()
    {
```

```
                    Close();

   try
   {
      _serialPort.PortName = Settings.Port.PortName;
      _serialPort.BaudRate = Settings.Port.BaudRate;
      _serialPort.Parity = Settings.Port.Parity;
      _serialPort.DataBits = Settings.Port.DataBits;
      _serialPort.StopBits = Settings.Port.StopBits;
      _serialPort.Handshake = Settings.Port.Handshake;

                              // Set the read/write timeouts
                              _serialPort.ReadTimeout = 50;
                              _serialPort.WriteTimeout = 50;

                              _serialPort.Open();
                              StartReading();
                    }
   catch (IOException)
   {
      StatusChanged(String.Format("{0} does not exist", Settings.Port.PortName));
   }
   catch (UnauthorizedAccessException)
   {
      StatusChanged(String.Format("{0} already in use", Settings.Port.PortName));
   }
   catch (Exception ex)
   {
      StatusChanged(String.Format("{0}", ex.ToString()));
   }

   // Update the status
   if (_serialPort.IsOpen)
   {
      string p = _serialPort.Parity.ToString().Substring(0, 1);   //First char
      string h = _serialPort.Handshake.ToString();
      if (_serialPort.Handshake == Handshake.None)
         h = "no handshake"; // more descriptive than "None"

      StatusChanged(String.Format("{0}: {1} bps, {2}{3}{4}, {5}",
         _serialPort.PortName, _serialPort.BaudRate,
         _serialPort.DataBits, p, (int)_serialPort.StopBits, h));
   }
   else
   {
      StatusChanged(String.Format("{0} already in use", Settings.Port.PortName));
   }
}

/// <summary> Close the serial port. </summary>
public void Close()
{
                    StopReading();
                    _serialPort.Close();
```

```
            StatusChanged("connection closed");
        }

        /// <summary> Get the status of the serial port. </summary>
        public bool IsOpen
        {
            get
            {
                return _serialPort.IsOpen;
            }
        }
        /// <summary> Get a list of the available ports. Already opened ports
        /// are not returend. </summary>
        public string[] GetAvailablePorts()
        {
            return SerialPort.GetPortNames();
        }
        /// <summary>Send data to the serial port after appending line ending. </summary>
        /// <param name="data">An string containing the data to send. </param>
        public void Send(string data)
        {
            if (IsOpen)
            {
                string lineEnding = "";
                switch (Settings.Option.AppendToSend)
                {
                    case Settings.Option.AppendType.AppendCR:
                        lineEnding = "\r"; break;
                    case Settings.Option.AppendType.AppendLF:
                        lineEnding = "\n"; break;
                    case Settings.Option.AppendType.AppendCRLF:
                        lineEnding = "\r\n"; break;
                }
                _serialPort.Write(data + lineEnding);
            }
        }
    }
}
using System;
using System.Text;
using System.Runtime.InteropServices;

/// <summary>
/// Read/Write values to an ini file
/// </summary>
namespace SpeechRec
{
    public class IniFile
    {
        public string path;
        [DllImport("kernel32")]
        private static extern long WritePrivateProfileString(string section,
            string key,string val,string filePath);
        [DllImport("kernel32")]
```

```
        private static extern int GetPrivateProfileString(string section,
           string key,string def, StringBuilder retVal, int size,string filePath);

        public IniFile(string INIPath){
           path = INIPath;
        }

        public void WriteValue(string Section, string Key, string Value) {
           WritePrivateProfileString(Section, Key, Value, this.path);
        }

        public string ReadValue(string Section, string Key, string Default) {
           StringBuilder buffer = new StringBuilder(255);
           GetPrivateProfileString(Section, Key, Default, buffer, 255, this.path);

           return buffer.ToString();
        }

        public void WriteValue(string Section, string Key, int Value)
        {
           WritePrivateProfileString(Section, Key, Value.ToString(), this.path);
        }

        public int ReadValue(string Section, string Key, int Default)
        {
           StringBuilder buffer = new StringBuilder(255);
           GetPrivateProfileString(Section, Key, Default.ToString(), buffer, 255, this.path);

           return int.Parse(buffer.ToString());
        }
    }
}


using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Windows;
using System.Windows.Controls;
using System.Windows.Data;
using System.Windows.Documents;
using System.Windows.Input;
using System.Windows.Media;
using System.Windows.Media.Imaging;
using System.Windows.Navigation;
using System.Windows.Shapes;
using System.Speech.Recognition;
using System.Globalization;
using System.IO.Ports;
using System.Threading;
using System.Windows.Threading;

namespace SpeechRec
```

```
{
    /// <summary>
    /// Interaction logic for MainWindow.xaml
    /// </summary>
    public partial class MainWindow : Window
    {
        private SpeechRecognitionEngine speechRecognizer = new SpeechRecognitionEngine();
        #region variables
        //Richtextbox
        FlowDocument mcFlowDoc = new FlowDocument();
        Paragraph para = new Paragraph();
        //Serial
        SerialPort serial = new SerialPort();
        string recieved_data;
        #endregion
        public MainWindow()
        {
            InitializeComponent();
            //SpeechRecognizer speechRecognizer = new SpeechRecognizer();
            InitializeComponent();
            Connect_btn.Content = "Connect";
            btnToggleListening.Background = new SolidColorBrush(Colors.Red);
            speechRecognizer.SpeechRecognized += speechRecognizer_SpeechRecognized;
            GrammarBuilder grammarBuilder = new GrammarBuilder();
            Choices commandChoices = new Choices("door", "window", "fan", "light", "robot");
            grammarBuilder.Append(commandChoices);
            Choices valueChoices = new Choices();
            valueChoices.Add("a", "b", "c");
            valueChoices.Add("command");
            //valueChoices.Add("small", "medium", "large");
            //valueChoices.Add("a", "b", "c");
            grammarBuilder.Append(valueChoices);

            Choices stateChoices = new Choices();
            stateChoices.Add("on", "off");
            stateChoices.Add("open", "close");
            stateChoices.Add("up", "down", "left", "right", "halt");
            grammarBuilder.Append(stateChoices);

            speechRecognizer.LoadGrammar(new Grammar(grammarBuilder));
            speechRecognizer.SetInputToDefaultAudioDevice();

        }

private void btnToggleListening_Click(object sender, RoutedEventArgs e)
{

    if (btnToggleListening.IsChecked == true)
    {

        btnToggleListening.Background = new SolidColorBrush(Colors.Green);
        speechRecognizer.RecognizeAsync(RecognizeMode.Multiple);
    }
    else
```

```
    {

        btnToggleListening.Background = new SolidColorBrush(Colors.Red);
        speechRecognizer.RecognizeAsyncStop();

    }
}

private void Connect_Comms(object sender, RoutedEventArgs e)
{
    if (Connect_btn.Content == "Connect")
    {
        //Sets up serial port
        serial.PortName = Comm_Port_Names.Text;
        serial.BaudRate = Convert.ToInt32(Baud_Rates.Text);
        serial.Handshake = System.IO.Ports.Handshake.None;
        serial.Parity = Parity.None;
        serial.DataBits = 8;
        serial.StopBits = StopBits.One;
        serial.ReadTimeout = 200;
        serial.WriteTimeout = 50;
        serial.Open();
        //Sets button State and Creates function call on data recieved
        Connect_btn.Content = "Disconnect";
        serial.DataReceived += new System.IO.Ports.SerialDataReceivedEventHandler(Recieve);

    }
    else
    {
        try // just in case serial port is not open could also be acheved using if(serial.IsOpen)
        {
            serial.Close();
            Connect_btn.Content = "Connect";
        }
        catch
        {
        }
    }
}
#region Recieving
private delegate void UpdateUiTextDelegate(string text);
private void Recieve(object sender, System.IO.Ports.SerialDataReceivedEventArgs e)
{
    // Collecting the characters received to the 'buffer' (string).
    recieved_data = serial.ReadExisting();
    Dispatcher.Invoke(DispatcherPriority.Send, new UpdateUiTextDelegate(WriteData), recieved_data);
}
private void WriteData(string text)
{
    // Assign the value of the recieved_data to the RichTextBox.
    para.Inlines.Add(text);
    mcFlowDoc.Blocks.Add(para);
    Commdata.Document = mcFlowDoc;
}
```

```
#endregion
#region Sending
private void Send_Data(object sender, RoutedEventArgs e)
{
   SerialCmdSend(SerialData.Text);
   SerialData.Text = "";
   SerialData.Focus();
}
public void SerialCmdSend(string data)
{
   if (serial.IsOpen)
   {
      try
      {
         // Send the binary data out the port
         byte[] hexstring = Encoding.ASCII.GetBytes(data);
         //There is a intermitant problem that I came across
         //If I write more than one byte in succesion without a
         //delay the PIC i'm communicating with will Crash
         //I expect this id due to PC timing issues ad they are
         //not directley connected to the COM port the solution
         //Is a ver small 1 millisecound delay between chracters
         foreach (byte hexval in hexstring)
         {
            byte[] _hexval = new byte[] { hexval }; // need to convert byte to byte[] to write
            serial.Write(_hexval, 0, 1);
            Thread.Sleep(1);
         }
      }
      catch (Exception ex)
      {
         para.Inlines.Add("Failed to SEND" + data + "\n" + ex + "\n");
         mcFlowDoc.Blocks.Add(para);
         Commdata.Document = mcFlowDoc;
      }
   }
   else
   {
   }
}
#endregion
private void speechRecognizer_SpeechRecognized(object sender,SpeechRecognizedEventArgs e)
    {
      lblDemo.Content = e.Result.Text;
      if(e.Result.Words.Count == 3)
      {
         string commandtx = "0";
         string command = e.Result.Words[0].Text.ToLower();
         string value = e.Result.Words[1].Text.ToLower();
         string state = e.Result.Words[2].Text.ToLower();
      try
      {
         switch(command)
         {
```

```
case "door":
//FontWeightConverter weightConverter = new
//FontWeightConverter();
//lblDemo.FontWeight =(FontWeight)weightConverter.ConvertFromString(value);
   switch (value)
   {
      case "a":
         //lblDemo.FontSize = 12;
         switch (state)
         {
            case "open":
               SerialCmdSend("a");
               MessageBox.Show("door A is opening");
            break;
            case "close":
            SerialCmdSend("m");
            MessageBox.Show("door A is closing");
            break;
         }
         break;
      case "b":
         //lblDemo.FontSize = 24;
         switch (state)
         {
            case "open":
               SerialCmdSend("b");
               MessageBox.Show("door B is opening");
               break;
            case "close":
               SerialCmdSend("n");
               MessageBox.Show("door B is closing");
               break;
         }
         break;
      case "c":
         //lblDemo.FontSize = 48;
         switch (state)
         {
            case "open":
               SerialCmdSend("c");
               MessageBox.Show("door C is opening");
               break;
            case "close":
               SerialCmdSend("o");
               MessageBox.Show("door C is closing");
               break;
         }
         break;
   }
break;
case "window":
//lblDemo.Foreground = new SolidColorBrush((Color)ColorConverter.ConvertFromString(value));
switch (value)
{
```

```
    case "a":
        //lblDemo.FontSize = 12;
        switch (state)
        {
            case "open":
                SerialCmdSend("d");
                MessageBox.Show("window A is opening");
                break;
            case "close":
                SerialCmdSend("p");
                MessageBox.Show("window A is closing");
                break;
        }
        break;
    case "b":
        //lblDemo.FontSize = 24;
        switch (state)
        {
            case "open":
                SerialCmdSend("e");
                MessageBox.Show("window B is opening");
                break;
            case "close":
                SerialCmdSend("q");
                MessageBox.Show("window B is closing");
                break;
        }
        break;
    case "c":
        //lblDemo.FontSize = 48;
        switch (state)
        {
            case "open":
                SerialCmdSend("f");
                MessageBox.Show("window C is opening");
                break;
            case "close":
                SerialCmdSend("r");
                MessageBox.Show("window C is closing");
                break;
        }
        break;
}
break;
case "fan":
switch (value)
{
    case "a":
        //lblDemo.FontSize = 12;
        switch (state)
        {
            case "on":
                SerialCmdSend("g");
                MessageBox.Show("fan A is switched on!");
```

```
            break;
          case "off":
            SerialCmdSend("s");
            MessageBox.Show("fan A is switched off!");
            break;
        }
        break;
      case "b":
        //lblDemo.FontSize = 24;
        switch (state)
        {
           case "on":
            SerialCmdSend("h");
            MessageBox.Show("fan B is switched on!");
            break;
          case "off":
            SerialCmdSend("t");
            MessageBox.Show("fan B is switched off!");
            break;
        }
        break;
      case "c":
        //lblDemo.FontSize = 48;
        switch (state)
          {
             case "on":
              SerialCmdSend("i");
              MessageBox.Show("fan C is switched on!");
              break;
            case "off":
              SerialCmdSend("u");
              MessageBox.Show("fan C is switched off!");
              break;
          }
        break;
    }
      break;
    case "light":
      switch (value)
      {
        case "a":
          //lblDemo.FontSize = 12;
          switch (state)
          {
            case "on":
              SerialCmdSend("j");
            MessageBox.Show("light A is switched on!");
            break;
            case "off":
            SerialCmdSend("v");
            MessageBox.Show("light A is switched off!");
            break;
          }
          break;
```

```
        case "b":
          //lblDemo.FontSize = 24;
          switch (state)
          {
            case "on":
              SerialCmdSend("k");
              MessageBox.Show("light B is switched on!");
              break;
            case "off":
              SerialCmdSend("w");
              MessageBox.Show("light B is switched off!");
              break;
          }
          break;
        case "c":
          //lblDemo.FontSize = 48;
          switch (state)
          {
            case "on":
              SerialCmdSend("l");
              MessageBox.Show("light C is switched on!");
              break;
            case "off":
              SerialCmdSend("x");
              MessageBox.Show("light C is switched off!");
              break;
          }
          break;
      }
    break;
    case "robot":
    //FontWeightConverter weightConverter = new
    //FontWeightConverter();
    //lblDemo.FontWeight =(FontWeight)weightConverter.ConvertFromString(value);
    if (value == "command")
    {
      switch (state)
      {
        case "up":
          //lblDemo.FontSize = 12;
          SerialCmdSend("y");
          MessageBox.Show("wheelchair is moving forward!");
          break;
        case "down":
          //lblDemo.FontSize = 24;
          SerialCmdSend("z");
          MessageBox.Show("wheelchair is moving backward!");
          break;
        case "left":
          //lblDemo.FontSize = 48;
          SerialCmdSend("A");
          MessageBox.Show("wheelchair is turning left!");
          break;
        case "right":
```

```
                    //lblDemo.FontSize = 48;
                    SerialCmdSend("B");
                    MessageBox.Show("wheelchair is turning right!");
                    break;
                case "halt":
                    //lblDemo.FontSize = 48;
                    SerialCmdSend("C");
                    MessageBox.Show("wheelchair is halted!");
                    break;
              }
            }
            break;

            }
          }
          catch (Exception ex)
          {
            MessageBox.Show(ex.Message);
          }

            }
          }

    private void Window_Loaded(object sender, RoutedEventArgs e)
    {
      //DateTime date1 = new DateTime(2018, 12, 22, 14, 0, 0);
      //DateTime date2 = new DateTime(2018, 12, 22, 16, 0, 0);
      //if (!(DateTime.Now > date1 && DateTime.Now < date2))
      //{
      //    //MessageBox.Show("This Program is for testing purpose only, pls contact Olive on 08138564840 ");
      //    MessageBox.Show(" ");
      //    Application.Current.Shutdown();
      //}
    }

      }
    }
```