IMPLEMENTATION OF VOICE-CONTROLLED WHEELCHAIR BASED ON PULSE WIDTH MODULATION

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M.A.Sc. **MAY, 2022**

IMPLEMENTATION OF VOICE-CONTROLLED WHEELCHAIR BASED ON PULSE WIDTH MODULATION

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B.C.Sc, D.C.M

A dissertation submitted in partial fulfillment of the requirements for the degree of

MASTER OF APPLIED SCIENCE

(M.A.Sc.)

of the

UNIVERSITY OF COMPUTER STUDIES, YANGON

May 2022

ACKNOWLEDGEMENTS

First of all, I would like to thank the Ministry of Science and Technology for giving the golden opportunity to attend the Master Degree course in the University of Computer Studies, Yangon.

I respectfully would like to give my sincere thanks to Teacher Gyi Dr. Mie Mie Khin, Rector of University of Computer Studies, Yangon, for her valuable permission to submit this thesis.

I deeply thank to Dr. Htar Htar Lwin, Pro-Rector and Dean of Faculty of Computer Systems and Technologies, University of Computer Studies, Yangon, for her valuable suggestions and provisions to carry out this thesis work.

I indebted to my supervisor, Dr. Htet Thazin Tike Thein, Lecturer, Faculty of Computer Systems and Technologies, University of Computer Studies, Yangon, who renders close supervisions, detailed guidance and support. In addition, with her encouragement, keen interest, patience, direct and indirect contribution are leading the accomplishment of this thesis.

I would like to thank Daw Hnin Yee Aung, Lecturer of English Department, University of Computer Studies, Yangon, for editing this thesis from the language point of view.

I also would like to express my thanks to Dr. Amy Htun, Professor, Faculty of Computer Systems and Technologies, University of Computer Studies, Yangon and Dr. May Thu Myint, Lecturer of Information Science Department, University of Information Technology, Yangon.

I wish to express my deep gratitude to Daw Kyi Kyi Win, Associated Professor, Faculty of Computing and Dr. Kyi Lai Lai Khine, Lecturer, Faculty of Computer Software Department, University of Computer Studies, Yangon.

All in all, I am grateful to all members in board of examiners of thesis for their excellent suggestions and helpful guidance to accomplish this thesis.

Last but not least, I would like to express my profound thanks to all family members and friends for their unforgettable encouragement, support, patience, understanding and spending their precious time throughout my thesis journey.

ABSTRACT

In this thesis, the innovative and low-cost self-assistive design of wheelchair for the intended users is implemented to facilitate the control of voice commands. Moreover, the implementation of voice-controlled wheelchair focuses on Arduino, Voice recognition module and Motors in construction. The speed controller also performs by changing the average voltage sent to the motor by switching the motor supply on and off very quickly using Pulse Width Modulation (PWM) technique. The voice recognition module operates on user's voice commands and the corresponding coded data stored in the memory of the Arduino Microcontroller. Arduino Microcontroller controls all the direction accordingly.

The voice-controlled wheelchair can detect any obstacles in the way of wheelchair with the use of ultrasonic sensor. It provides more independent and easy access for the wheelchair users who cannot control their movements especially by hands. It is designed for the users to perform certain tasks using their voices. Besides, the user can easily speak their commands to the microphone making more user-friendly and independent. The movements of the voice-controlled wheelchair in environmental noise area and silent area are experimented in this thesis. According to the experimental results, the percentage of the voice commands accuracy in silent area is better than environmental noise area because the voice module can catch more commands in silent area.

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CHAPTER 1

INTRODUCTION

Nowadays, the health care sector has been continually targeting to offer the services for people in need of mobility assistance. Therefore, more and more emphasis are being directed towards the design and development of intelligent tools (e.g., such as the robotic wheelchairs) which offer a lot of functions, high stability, and safety to people in need of mobility assistance. Moreover, advanced technologies associated with robots have the potential to promote the lifestyles of people suffering from disabilities [14]. Innovative researchers have utilized robotic technologies to create robotic wheelchairs through a standard electric wheelchair, computer, and sensors. Robotic wheelchairs try to provide navigation assistance, mobility, to move the user from one place to another independently, and to socialize the individual. Related developments are often grouped under the terms Rehabilitation Technologies or Assistive Technologies. They attempt to restore human abilities that have been reduced or lost by disease, accident, or old age. Mobility is one such function. There are many reasons why a person may not be able to travel freely, including motor control problems, spinal injuries, and amputation [55].

A wheelchair is a mechanical device which effectively applies wheels and mechanical support to overcome a loss of legs or leg control. Manual wheelchairs can be operated by persons who have the use of their upper body or someone available to assist. Powered wheelchairs have been developed for when either of these cases does not apply. However, these devices typically require a high level of user control, and this is something precluded by many severe forms of disablement. People with arms and hands impairment encounter difficulties to utilize normal wheelchair. Their hands cannot move the normal wheelchair to any direction. That is why, voice-controlled wheelchair is developed to overcome the difficulties encountered by disabled persons to use the wheelchair [64]. The wheelchair will be performed through the given voice commands input. Unilateral microphone which is placed as per the user comfort offer the voice commands to the wheelchair. For voice recognition, the Voice Recognition Module is applied and the output from this module is then received by Arduino [53,16]. The operation of Arduino is that it converts the voice commands into considerable output.

According to the direction specified in the commands, the wheelchair move in smooth fashion. Arduino Uno Microcontroller circuit and DC gear motors to create the movement of the wheelchair, the motor driver(L298N)'s speed control and the DC gear motors' direction, the buzzer for alarm and Ultrasonic Sensors (HC-SR 04) to detect the obstacles between the wheelchair and the way of direction. Microcontroller is utilized for setting the speed ranges and it can be obtained by varying the duty cycles time periods in the program. Pulse Width Modulation (PWM), an electronic technique, is applied for High and Low pulses to vary the speed in the motor [54,23]. By utilizing a voice-controlled wheelchair system, people will become more and more independent as it applies voice recognition system for triggering and controlling all its movements. The wheelchair users enable the wheelchair by simply speaking to the microphone with the help of the system,

The system is implemented by applying voice commands. In the first step, these commands given by the wheelchair user are recognized as input. Once it is recognized, equivalent instructions are obtained by transforming these voice commands. Using voice recognition module, the voice recognition is performed [17]. The outcome from this module is directed to Arduino. Then, Arduino utilizes a motor driver IC to drive the motors. To facilitate the movement of wheelchair, all the modules are mounted onboard. Microphone is placed nearest to the user with the purpose of easy access. The voice of user is already trained and then stored in the recognition module. The module matches it with the existing command when the user gives the command. If the voice and the command matches, the module returns the output [7]. By applying the supply voltage to the speech recognition circuit, the intended system is started. Using PC/Laptop, all voice commands are to be recorded into the voice recognition module. The wheelchair system will return to the standby condition or end the whole system by turning on and off the power supply switch of supplying to the Arduino circuit board which acts as the main controller. In this system, there are four wheels; two main wheels and two caster wheels. The wheel which relates to the motor is considered as the main wheel. Main wheel is used for allowing heavy objects to be moved easily facilitating movement. A caster (or castor) wheel is an undriven, single, double, or compound wheel to enable that object to be easily moved. Caster wheels are available in various sizes, and are commonly made of rubber, plastic, nylon, aluminum, or stainless steel. Generally, casters operate well on smooth and flat surfaces [3].

1.1 Objectives of the Thesis

The main objective of this thesis is to intend to build the wheelchair using the voice commands of wheelchair user which are connected to the voice recognition module. The Arduino receives the output of the voice module and then controls the direction and the speed of the wheelchair with motor driver. This voice-controlled system makes the dependent wheelchair user into independent one. Many people cannot control the standard joystick interface applied in power wheelchairs [24,20]. With the help of voice-controlled wheelchair, the user can drive the wheelchair without anyone's support. Therefore, the objectives of this thesis are as follows:

- To provide easy access for the wheelchair user
- To control the wheelchair by voice commands
- To provide obstacle detection for the safe movement
- To be helpful to physically handicapped people
- To reduce human efforts and risks

1.2 Motivation of the Thesis

The motivations in this thesis are as follows:

- This system allows paralyzed person to live a life with less dependence on others for their movement as a daily need using speech recognition technology.
- Voice controlled wheelchair provides a way of human interaction with machine or tools.
- The voice of the user can manage the manual wheelchair and it can be applied as a power wheelchair [65].

1.3 Organization of the Thesis

There are five chapters in this thesis: firstly introduction, objectives, motivations, and organization of the thesis are included in Chapter 1.

In Chapter 2, the detailed explanation of the background theories for the system is presented.

The implementation design with five major devices with detailed explanations are described in Chapter 3.

In Chapter 4, the hardware implementation, the system flow, the system design and the experimentation of the proposed system are described in step-by-step fashion.

Finally, the conclusion, limitations and future works of the thesis are presented in Chapter 5.

CHAPTER 2

BACKGROUND THEORY

Nowadays, a huge difference in daily life is emerged to access with their devices, homes, cars, and so on with the use of digital assistants such as Google's Google Assistant, Apple's Siri, and Microsoft's Cortana. These kinds of technologies provide us to access a computer or device which interprets which kinds of users is saying and then respond to user questions or commands. Voice recognition refers to the ability of a specific device to receive and interpret spoken directives [18]. It can interact and respond to human's commands. Basically, voice recognition technology enables to identify what is being uttered by a speaker in text form. The utterance typically exists isolated word or sentence or sometimes even a paragraph. The algorithm for voice recognition is implemented as a computer program which converts a signal of speech to a sequence of words.

2.1 Voice Recognition

Voice recognition is one of the approaches which commonly used to control the electrical and electronic utilizations because of easily being reproduced by human. It is a key technology which can provide human interaction with machines for controlling wheelchairs. A voice can typically activate the wheelchair to make it easy for physically paralyzed persons who cannot manage their movements by hands. Patients who usually depend on other persons moving from one place to another such as cerebral palsy, quadriplegic, and multiple sclerosis have lost the freedom of mobility. To overcome these problems, that is why, voice-controlled wheelchair is required to implement [12, 37].

Typically, the wheelchair can be operated using the voice commands input through the user. These commands are given for the wheelchair using unilateral microphone by individual user's effort. The voice recognition module is intended for voice recognition process and Arduino receives the output from this module. In this study, the system is to control access to voice commands by specific user to implement a wheelchair using small words recognition system [27].

2.2 Classes of Voice Recognition

The most common approaches to voice recognition can be divided into two classes. They are:

- Template matching
- Feature analysis

2.2.1 Template Matching

Template matching is the simplest technique and has the highest accuracy, but it also suffers from the most limitations. As with any approach to voice recognition, the first step is for the user to speak a word or phrase into a microphone. The electrical signal from the microphone is digitized by an “analog-to-digital (A/D) converter” and is stored in memory. To determine the "meaning" of this voice input, the computer attempts to match the input with a digitized voice sample, or template that has a known meaning. This technique is a close analogy to the traditional command inputs from a keyboard. The program contains the input template and attempts to match this template with the actual input using a simple conditional statement.

2.2.2 Feature Analysis

Speaker-independent speech recognition has proven to be very difficult, with some of the greatest hurdles being the variety of accents and inflections used by speakers of different nationalities. Recognition accuracy for speaker-independent systems is somewhat less than for speaker-dependent systems, usually between 90 and 95 percent. Another way to differentiate between voice recognition systems is by determining if they can handle only discrete words, connected words, or continuous speech. Most voice recognition systems are discrete word systems, and these are easiest to implement. For this type of system, the speaker must pause between words. This is fine for situations where the user is required to give only one-word responses or commands but is very unnatural for multiple word inputs. In a connected word voice recognition system, the user is allowed to speak in multiple word phrases, but he or she must still be careful to articulate each word and not slur the end of one word into the beginning of the next word. Totally natural, continuous speech includes a great deal of "coarticulation", where adjacent words run together without pauses or any other apparent division between words. A speech recognition system that handles continuous speech is the most difficult to implement [1, 45].

2.3 Voice Recognition Systems

Voice recognition originated on PCs but with integration in smartphones and its rising popularity, it became more accessible within the use of home devices. Voice recognition is "the technology by which sounds, words or phrases spoken by humans are converted into electrical signals and these signals are transformed into coding patterns to which meaning has been assigned"[27]. The difficulty in using voice as an input to a computer simulation lies in the fundamental differences between human speech and the more traditional forms of computer input.

While computer programs are commonly designed to produce a precise and well-defined response upon receiving the proper (and equally precise) input, the human voice and spoken words are anything but precise. Each human voice is different, and identical words can have different meanings if spoken with different inflections or in different contexts. Several approaches have been tried, with varying degrees of success, to overcome these difficulties. Some voice recognition systems work differently to others, depending on the software used to develop them [6, 9]. Here are some examples of different voice recognition systems:

2.3.1 Speaker-Dependent System

The speaker dependent system depends on knowledge of the speaker's voice. Machine learning is a key part of this system because it analyses data and recognizes user patterns. Smart hubs can understand phrases and words that the person uses. In other words, they are trained by the user. This also means that the system is more accurate to the person's voice; it's used to hearing.

2.3.2 Speaker-Independent System

The speaker-independent system can recognize words from a wide range of contexts and understand words regardless of who is speaking. They understand a range of speech patterns, fluctuations, and tones. Most systems designed for phone calls will be speaker independent system.

2.3.3 Discrete Speech Recognition System

When it comes to discrete speech recognition, the user must be more careful about phrase sentences. They need to pause between words for the software to understand.

2.3.4 Continuous Speech Recognition System

This recognizes how user would speak normally, meaning user does not need to pause between each word for it to understand what users' saying. Tools designed for transcribing will make use of this kind of voice recognition.

2.3.5 Natural Language Voice Recognition System

A natural language voice recognition system is one that we are mostly used to. It uses natural language processing (NLP). NLP is another branch of artificial intelligence that allows computers to interpret and learn natural human language. It allows the computer to understand our natural way of talking, including fluctuations and accents. That's why our home smart hub can answer questions and conversationally respond to them.

2.4 Applications of Voice Recognition

There are a lot of applications of voice recognition in real world. The most popular applications are:

- Workplace
- Banking
- Marketing
- Healthcare
- Internet of Things (IoT)

2.4.1 Workplace

Some of the applications for voice recognition in the workplace consist of:

- Searching documents or reports in computers
- Making tables or graphs
- Printing documents on request
- Managing video conferences
- Scheduling Business Meetings
- Travel planning

2.4.2 Banking

Some of the applications for voice recognition in banking consists of:

- Fetching information related with transactions, balance and so on
- Making payments
- Receiving information about transaction history

2.4.3 Marketing

Adding a new way of marketers is required in voice systems to reach their consumers. There will be a new type of data intended for marketers to analyze along with voice recognition.

2.4.4 Healthcare

Some of the applications for voice recognition in healthcare consist of:

- Searching information quickly from medical records
- Reminding to workers by instructions or processes
- Asking queries associated with a disease from home
- Saving time for input data
- Better improved workflows

2.4.5 Internet of Things (IoT)

Some of the applications for voice recognition in healthcare consist of:

- Hands-free usage in listening messages
- Managing the Radio
- Assistance services in guidance and navigation
- Responses to voice commands

2.5 Advantages and Disadvantages of Voice Recognition

There are many advantages and disadvantages of voice recognition:

2.5.1 Advantages of Voice Recognition

- It is assisting people with disabilities to interact, type and operate with computers.
- It can capture speech much faster than user can type.
- It makes easy usage with the phone or other speaking devices.
- People enable to type text and use email with voice recognition without diverting their eyes from road. Therefore, Automobile Safety is ensured for automobile users [7].

2.5.2 Disadvantages of Voice Recognition

- **Lack of Accuracy and Misinterpretation**: It can lack of accuracy and misinterpret words if user does not speak clearly.
- **Time Costs and Productivity**: Users may suffer time consuming more than they expected in voice recognition system. Besides, users must review and edit to correct errors. Some programs which are developed to adapt user voice and speech patterns cause time consuming. These programs may slow down user workflow until the program is up to speed. Moreover, user need to learn how to utilize the system [1].

2.6 Automatic Speech Recognition (ASR)

Speech recognition is also different from voice recognition. Speech recognition refers to the ability of a machine to recognize the words that are spoken (i.e., what is said), and voice recognition involves the ability of a machine to recognize speaking style (i.e., who said something). Nowadays, Automatic speech recognition (ASR) is an independent, machine-based process of decoding and transcribing oral speech. Typically, ASR is the technology which allows human beings to apply their voices to speak with a computer interface in its most sophisticated variations, resembles normal human conversation [11]. A typical ASR system receives acoustic input from a speaker through a microphone; analyzes it using some pattern, model, or algorithm; and produces an output, usually in the form of a text. ASR means an automated process that inputs human speech and tries to find out what was said. ASR is actually very useful in speech-to-text applications, speech-controlled interfaces, search engines for large speech or video archives, and speech-to-speech translation. In recent years, automatic speech recognition technology has advanced to the point where it is used by millions of individuals to automatically create documents from dictation [2, 30].

Many ASR programs require the user to "train" the ASR program to recognize their voice so that it can more accurately convert the speech to text. It was also speaker dependent and required extensive training. Speech recognition systems can be characterized by three main dimensions: speaker dependence, speech continuity, and vocabulary size. According to the speech data in the training database, Automatic speech recognition (ASR) systems can be speaker-dependent, speaker-independent, and adaptive. ASR systems can be characterized based on the vocabulary size (i.e., small, or large vocabulary) to which they are trained [63]. The purpose of an ASR system is to transform a speech signal into a text message transcription of the spoken words independent of the speaker accurately and efficiently, environment or the device used to record the speech [28]. There are many benefits using ASR. Among them, three significant factors are:

- Accessibility for the deaf and hard of hearing
- Cost reduction through automation
- Searchable text capability

CHAPTER 3

SYSTEM DESIGN APPROACH

Many difficulties are faced by people with arms and hand impairment to utilize a normal wheelchair. In moving the normal wheelchair, their hands don't enable to operate it to any direction. Therefore, voice-controlled wheelchair is a need for such people to overcome the difficulties encountered in moving the wheelchair in smooth fashion. By applying the given input voice commands, the wheelchair will be operated in a comfort fashion. With the help of the unilateral microphone, the voice commands are given to the wheelchair by placing as individual user's comfort [44].

3.1 Overview of the System Design

A general overview of the system is shown in Figure 3.1. From the unilateral microphone, the voice commands of the wheelchair user are obtained. Voice Recognition Module is applied for voice recognition process and then the outcome from this module is then directed to the Arduino. Arduino Uno Microcontroller circuit and DC gear motors to create the movement of the wheelchair, the motor driver to control the speed and the direction of the DC gear motors, the buzzer for alarm and Ultrasonic Sensor is also mounted in front of the wheelchair to detect the obstacles in between wheelchair and the way of direction [20,49].

Voice Recognition Module v 3.1 is applied for voice recognition and the output from this module is then directed to Arduino. The Arduino then transform the voice commands into considerable output to move the wheelchair depending upon the direction specified in the commands. People will become less dependent by utilizing a wheelchair control system. The wheelchair control system is implemented by applying a voice recognition system. It intends to apply in triggering and managing all its movements. By speaking to the microphone, the wheelchair users can simply manage the wheelchair. The system uses five major devices:

- Voice Recognition Module
- Ultrasonic Sensor
- Arduino
- DC Gear Motors, Motor Driver
- Buzzer

The overview of the system design is shown in Figure 3.1. There are three main parts in this system: input voice, matching voice, and controlling.

- The commands of the wheelchair take to the unilateral microphone.
- The Voice Recognition Module is used for voice recognition.
- The module examines it with the existing command and returns the result back to the Arduino which acts as the main controller.

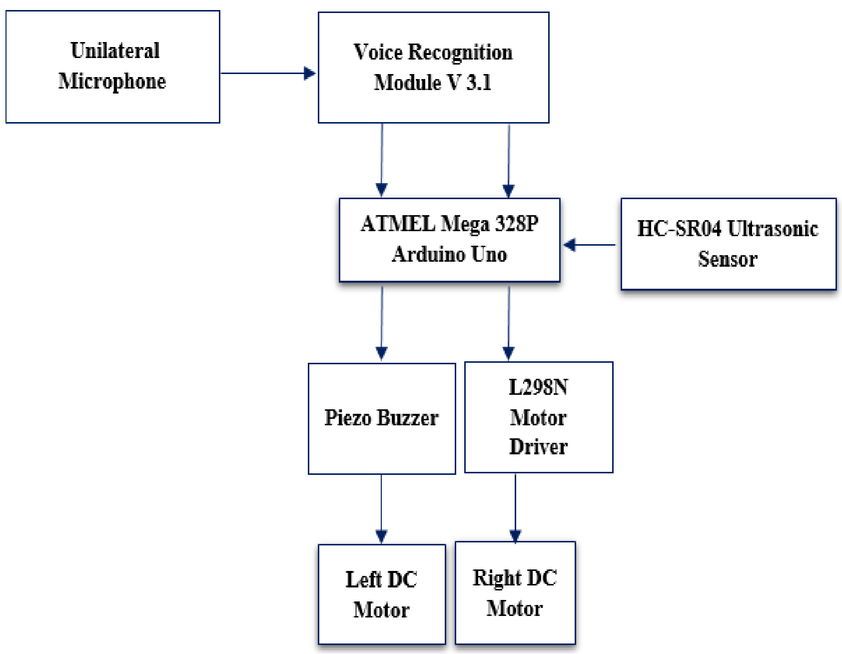


Figure 3.1 The Overview of the System Design

3.2 Voice Recognition Module V 3.1

Voice Recognition Module, compact and easily controlled recognition board, is a speaker-dependent voice recognition module. It provides to 15 voice commands in all, with each 1.5seconds. Maximum voice commands can operate at the same time. However, more than 7 commands, the user must be in a group. All sorts of sound are trained as command. Firstly, users must train the module before recognizing any voice command. There are typically two controlling ways in this board:

- Full function in Serial Port
- Part of function in General Input Pins

Several kinds of waves are generated by general Output Pins on the board while corresponding voice command was recognized. Before using this module, the user needs to record his/her voices by using Arduino IDE software so that the device can recognize the voice of the user [65, 5, 6]. This voice module v 3.1 is used to record the wheelchair user voice and recognize that voice to follow the instructions of the user. The quality of microphone also plays the important role for the performance of the wheelchair. It's better to choose a microphone with good sensitivity.

Moreover, the recording room is absolutely required to make sure noise free environment. While recording the voice commands, the user is strongly recommended not to change his or her voice tone (normal tone) for efficient voice recording. One important thing is that the distance between the microphone and the wheelchair user can achieve better results between 1 inch (2.54cm) to 2.6 inches (6.6cm). After connecting the Arduino Uno with the laptop or desktop computer, the desired program can be opened to upload the code into the Arduino by clicking on the upload button and wait for a while.

Figure 3.2 show the voice recognition module v 3.1 and its specification as follow:

- Voltage: 4.5-5.5V
- Current: <40mA
- Digital Interface: 5V TTL level UART interface
- GND - Ground
- VCC - 5 V
- RXD - Digital pin 3 of Arduino
- TXD - Digital pin 2 of Arduino

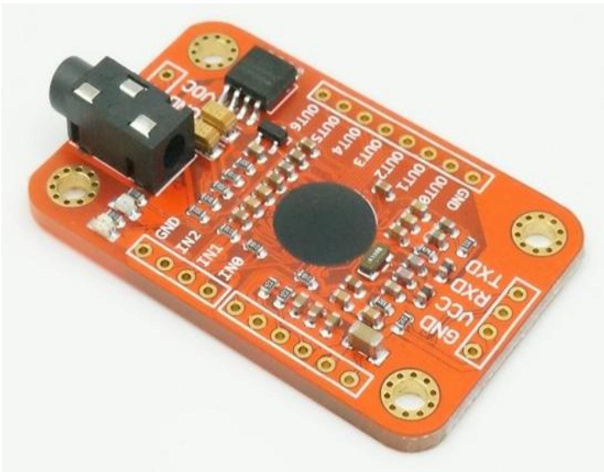


Figure 3.2 Voice Recognition Module V 3.1

3.3 ATMEL Mega 328P Arduino uno

The ATMEL Mega 328P Arduino uno has 6 analog inputs, a 16 MHz quartz crystal. Moreover, it consists of a USB connection, a power jack, 14 digital input/output pins, an ICSP header and a reset button. The voice recognition module returns the outcomes to the Arduino and then these outcomes are converted into the format accepted by the motors. Under the control of the Arduino, the motors work according to the command given [26].

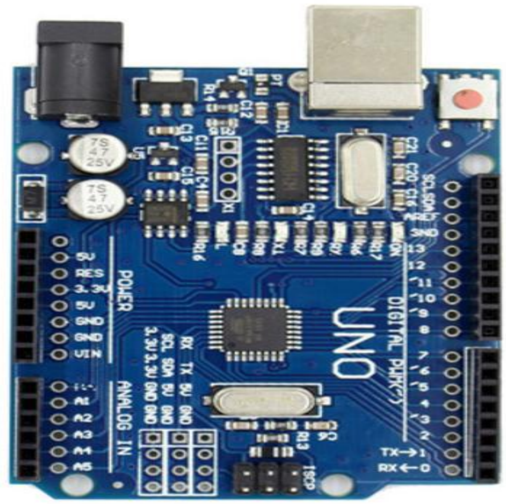


Figure 3.3 ATmega328p Arduino uno

Figure 3.3 show ATmega328p Arduino uno and its specification as follow:

- Flash Memory: 32 KB (ATmega328) of which 0.5 KB used by bootloader
- Clock Speed:16MHZ
- SRAM: 2 KB (ATmega328)
- EEPROM: 1 KB (ATmega328)
- DC Current per I/O Pin
- DC Current for 3.3V Pin

3.4 HC-SR04 Ultrasonic Sensor

HC–SR04 ultrasonic sensor is utilized to know the distance from the target object using high frequency ultrasonic sound. It consists of 4 pins, Vcc, Trigger (input), Echo (output) and Ground. It can measure transparent and dark object. Insensitive to interference like smoke, different lighting condition and water vapor. Its operation is affected by sun light or black material and use for solid object detection. It cannot detect color different. Difficult in sensing small, curved object, thin and soft material such as cloth and dust. The sensor used in the system can detect objects 80 cm (2feets and 8 inches) from the object’s position and above 3inches (7.6cm) from the ground [36, 52].

Figure 3.4 show HC–SR04 ultrasonic distance sensor and it specification as follow:

- GND: Ground

- VCC: 5 V
- Trig Pin: A0 (analog input pin) of Arduino
- Echo Pin: A1(analog input pin) of Arduino
- Operating Voltage: +5V(DC)
- Operating Current: Less than 15mA
- Operation Frequency: 40Hz
- Measuring angle covered: Not more than 15 degrees.
- Theoretical Measuring Distance: 2cm-450cm
- Practical Measuring Distance: 2cm-80cm
- Accuracy: 3mm

Figure 3.4 HC–SR04 Ultrasonic Distance Sensor

3.5 GM 25-370 -24140 DC Gear Motor (300RPM)

The system consists of two D –shaped DC gear motors are suitable for this system dues its small size, silent operation, low speed, and big torque. In this system, the user of wheelchair can also control wheelchair by some angle where user wants to rotate the left and the right movements of wheelchair by like 45˚, 60˚, 90˚ etc. The implementation of the system is intended for turning the wheelchair left and right with nearly 90˚ angle. The left command will make right wheel moves backward and left wheel moves forward. The right command makes left wheel moves backward and right wheel forward. It can also be achieved by using DC gear or stepper motor of high torques and less RPM.

Figure 3.5 DC Gear Motor

Figure 3.5 show DC Gear Motor and it specification as follow:

- Operating voltage: 12V DC
- Gear ratio: 1:20
- No-load speed: 300 RPM 0.1A
- Rated torque: 0.5Nm

The following equation of the wheelchair is the user can calculate the distance travel between one second of the wheelchair. Linear velocity is the rate of change of the position of an object that is travelling along a straight path. Because any moving object has a linear velocity, this measurement shows up very often in everyday life.

The relation between RPM to Linear Velocity formula is:

$$\mathbf{v} = \mathbf{r} \times \mathbf{RPM} \times \mathbf{0.10472} \ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

where:

v: Linear velocity, in m/s

r: Radius of the wheel, in meter

RPM: Angular velocity, in RPM (Rounds per Minute)

The basic formula for distance (d), which equals speed (velocity) and multiplied by time(t):

$$\mathbf{d = vt} \ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

3.6 L298 N Motor Driver

Motor Driver L298N is a dual H-Bridge motor driver for Arduino which allows speed and direction control of two DC motors at the same time. The module can drive DC motors that have voltages between 5 and 35 V, with a peak current up to 2A each. The driver consists of L298 IC with heat sink and 14 pins with different functions such as two screw terminals for outputs of two motors, ENA and ENB pins for PWM pins of microcontroller, 4 logic pins for any digital pin of microcontroller, 12V jumper and 3 power pins (i.e., 12V for power supply, GND and 5V power of microcontroller). The driver has LED indicating rotational direction of each motor.

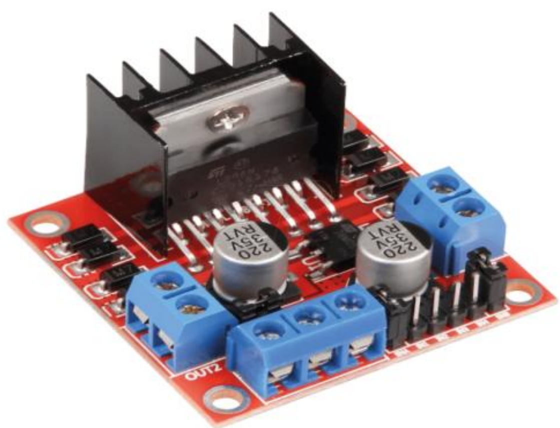


Figure 3.6 Motor Driver L298N

3.7 Buzzer

Buzzer module makes the simplest sound. Just change the frequency, the user can hear different sound (like alarm). In this system, buzzer can be alerted the guardians of the physically disabled person when buzzer makes a sound and take necessary care. If the paralyzed person needs any help, the wheelchair user speaks help command to turn on the buzzer.

Figure 3.7 Piezo Buzzer

3.8 Pulse Width Modulation (PWM)

Pulse-width modulation (PWM), a powerful technique, is intended for controlling analog circuits with a microcontroller's digital outputs. It is a commonly used technique for generally controlling DC power to an electrical device, made practical by modern electronic power switches. PWM is applied in many applications, ranging from communications to power control and conversion. Moreover, PWM is commonly used to manage the brightness of lights, the speed of electric motors, ultrasonic cleaning applications, and so on. The duration of the "ON" time can be adjusted as desired as it is basically a digital unipolar square wave signal. The microcontroller can control the power delivered to the load [17].

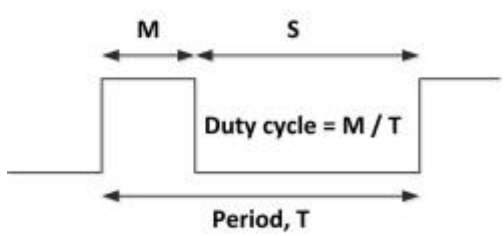


Figure 3.8 Typical PWM signal

The Figure 3.8 represents a typical PWM signal. The “ON” and the “OFF” times can be defined as the MARK (or M) and SPACE (or S) times of the signal, respectively. Signal amplitude, signal frequency (or period), and the signal duty cycle are three kinds of interested parameters for PWM. Logic “1” level of the microcontroller output which depends on the power voltage is fixed for amplitude. In this system, the output logic 1 level of the microcontroller is used which is +3.3 V. The frequency also depends on the application and PWM signal with a frequency of 40 kHz is generated. This is the frequency commonly used in most ultrasonic applications, such as distance measurement, ultrasonic cleaning, and so on [4].

3.8.1 Characteristics of PWM

There are two primary components in PWM signal's characteristics:

- **Duty cycle**: A duty cycle is the fraction of one period when a system or signal is active. It can be expressed as a ratio or percentage. A period is the time it takes for a signal to conclude a full ON-OFF cycle.
- **Frequency**: The rate at which something repeats or occurs over a particular period. Similarly, the rate at which a vibration happens that creates a wave, e.g., sound, radio, or light waves, typically calculated per second.

3.8.2 Effects of Frequency and Duty Cycle of PWM

PWM is principally suited for running inertial devices like motors, which are not as quickly affected by this distinct switching. This is also equally true for LEDs with PWM because of the linear fashion in which their input voltage affects their functionality. However, the PWM switching frequency needs to be high enough not to affect the load, yet the resulting waveform that the load perceives should also be smooth. Typically, the frequency in which the power supply must switch will vary extensively depending on the device and its application [5]. For example, the switching must be done several times a minute in an electric stove and well into the tens or hundreds of kHz for PC power supplies and audio amplifiers. One of the significant advantages of using PWM is that power loss in the switching devices is substantially low [33].

In fact, during the off phase of a switch, there is virtually no current. Also, during the on phase of a switch, there is practically no drop in voltage across the switch while transferring power to its load. Since power loss is a consequence of both voltage and current, this translates into virtually zero loss in power for PWM. Moreover, PWM is perfectly suited for digital controls, due to the nature of digital technology (i.e., 1's and 0's, or ON and OFF states) [35]. The Duty Cycle, denoted by D, is the ratio of the ON time to the period of the signal, i.e., D = M/T. It is the fraction of time in which the signal was high, and it can be varied from 0% to 100%. The power supplied to the load is controlled by varying the duty cycle. Signals with different duty cycles is shown in figure 3.9.

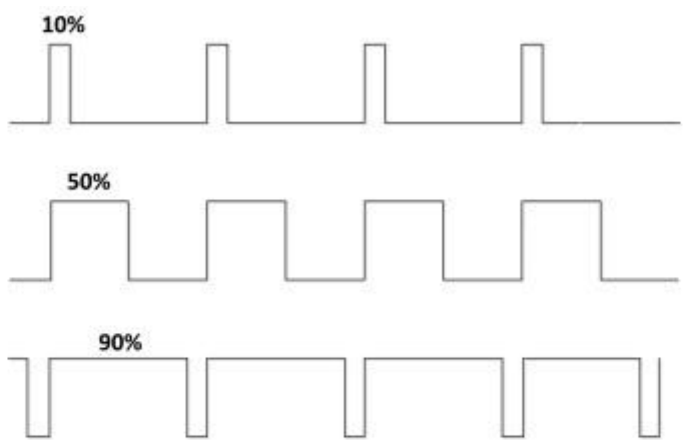


Figure 3.9 Signals with different duty cycles

The relationship between RPM to pulse width duty cycle can be obtained by the following equation is:

RPM= (predefined pulse width duty cycle /maximum pulse width duty cycle) x no load speed of the motor

If 255 PWM duty cycle equals 300 RPM (no load speed of the motor) then the simple way to model is that, for front movement, depending on the motors' speed and the prototype wheelchair's load, the pulse width duty cycle as a wheelchair user is set 100 duty cycle. This can be computed by using RPM= (predefined pulse width duty cycle /maximum pulse width duty cycle) x no load speed of the motor. In this system, predefined pulse width duty cycle is 150 for front movement, maximum pulse width duty cycle is 255, no load speed of the motor is 300 RPM and the required RPM for 150 duty cycle is nearly 177 for front movement. For left and right movements of the wheelchair, predefined pulse width duty cycle is also 150 so the required RPM for left and right movements are also nearly 177 RPM.

For rear movement, predefined pulse width duty cycle is 100 for backward movement of the wheelchair so the required PRM for rear movement is also nearly 118 RPM and slow movement of the wheelchair is set to nearly 153 RPM with 130 duty cycle. The use of PWM in this system is to manage a small motor which has the benefit of the power loss in the small switching transistor is small either fully "ON" or fully "OFF". The switching transistor, as a result, causes a much-reduced power dissipation with a linear type of control which results in better speed stability. Besides, the amplitude of the motor voltage remains constant. The result is that the motor is always at full strength and can be rotated much more slowly without it stalling.

CHAPTER 4

THE IMPLEMENTATION OF THE SYSTEM

The main purpose of the voice-controlled wheelchair for intended users utilizes Voice Recognition Module V 3.1. This module not only learns how to train it using different languages but also learns how to delete a voice command and then replace with another voice command.

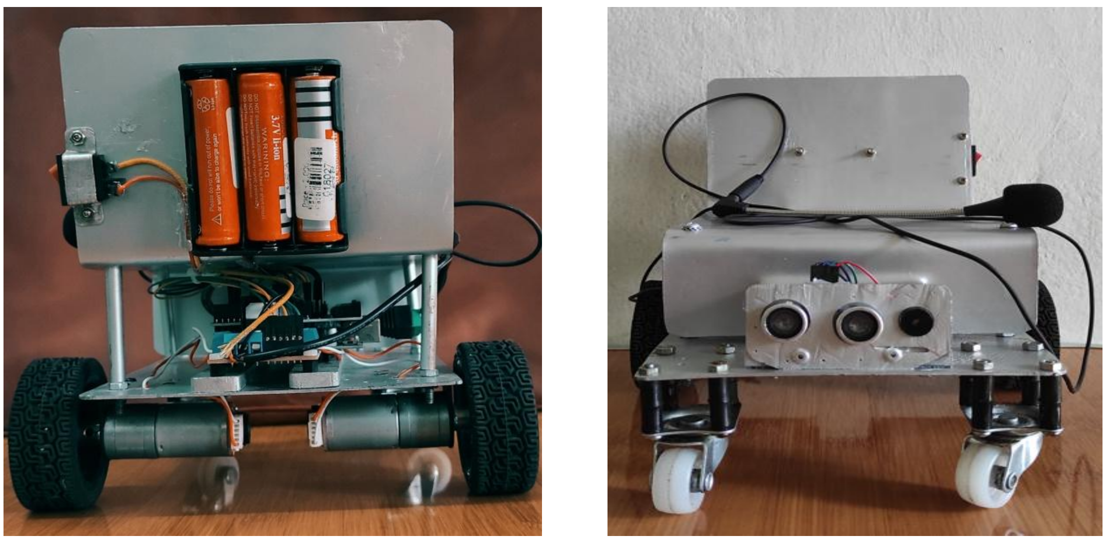
4.1 Hardware Implementation of the System

Voice recognition module v3.1 can be easily used with the Arduino to control anything user wants. To start voice recognition module, it is needed to prepare two programs to be performed. One program is used for the voice commands training and another program is used for the controlling purpose. Firstly, before the user start the program, he or she is required to make sure that downloading the necessary library for the voice recognition module has been already finished.

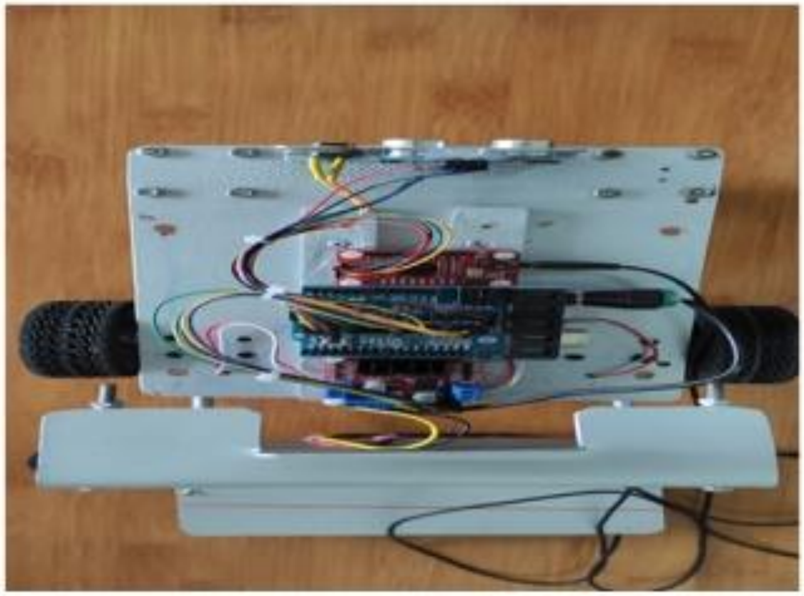
The Voice Recognition Module V 3.1 can be interfaced with the Arduino or Mega using male to female type jumper wires.

- Ground of the Voice recognition module connected with the Arduino's Ground.
- VCC of the Voice recognition module connected with the Arduino's 5v.
- RXD of the voice recognition module connected with pin 3 of the Arduino.
- TXD Pin of the voice recognition module connected with pin 2 of the Arduino.

The second step is to connect a USB cable and the Arduino with laptop or PC. After connecting the Arduino Uno with laptop or PC, it is needed to open the desired program, and upload the code into the Arduino by clicking on the upload button and then wait for a while. After the user is done with the uploading then the next step is to open the Serial Monitor, with the purpose of following the commands and start training. One important thing is that to make sure the room is noise free because the background noises can really effect the command's training and user will get errors. While recording the voice commands relax user body, try not to change user voice tone, do recording in the normal way [54, 20]. The hardware implementation of the front wheelchair part, the back wheelchair part and main part of the systems are as shown in Figure 4.1. The complete prototype of the system's wheel is described in Figure 4.2.



(a) The back part of the wheelchair **(b) The front part of the wheelchair**



(c) The main part of the wheelchair

Figure 4.1 Hardware Implementation of the System's Wheelchair

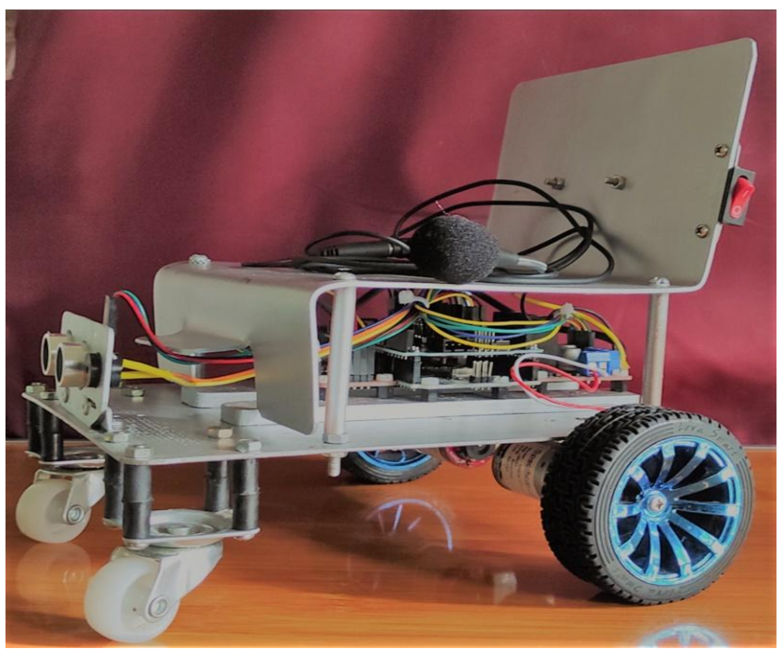


Figure 4.2 The Prototype of the System's Wheelchair

4.2 Design Implementation of the System

This system consists of voice recognition module v 3.1, ATMEL Mega 328P Arduino uno, HC-SR04 Ultrasonic Sensor, GM 25-370-24140 DC Gear Motor (300RPM), L298 N motor driver and Buzzer. The circuit diagram of the system is as shown in Figure 4.3. Voice recognition module v 3.1 is connected at 4 pins (GND, VCC, pin 2 and pin 3) of the Arduino uno board. Ultrasonic sensor is connected at 4 pins (GND, VCC, A0 and A1) of the Arduino uno board. The output of the two DC Gear motor is connected at two screw terminals of the motor driver. Motor driver is connected at 4pins (pin 8, pin9, pin10, pin11) of the Arduino uno board for direction controlled of the system and the speed controlled of the system, motor driver is also connected at 2pins (ENA and ENB) of the Arduino uno board. Alarm for the buzzer is connected at 2pins (GND and pin13) of the Arduino uno board. So this system is low cost than other type of voice controlled wheelchair system.

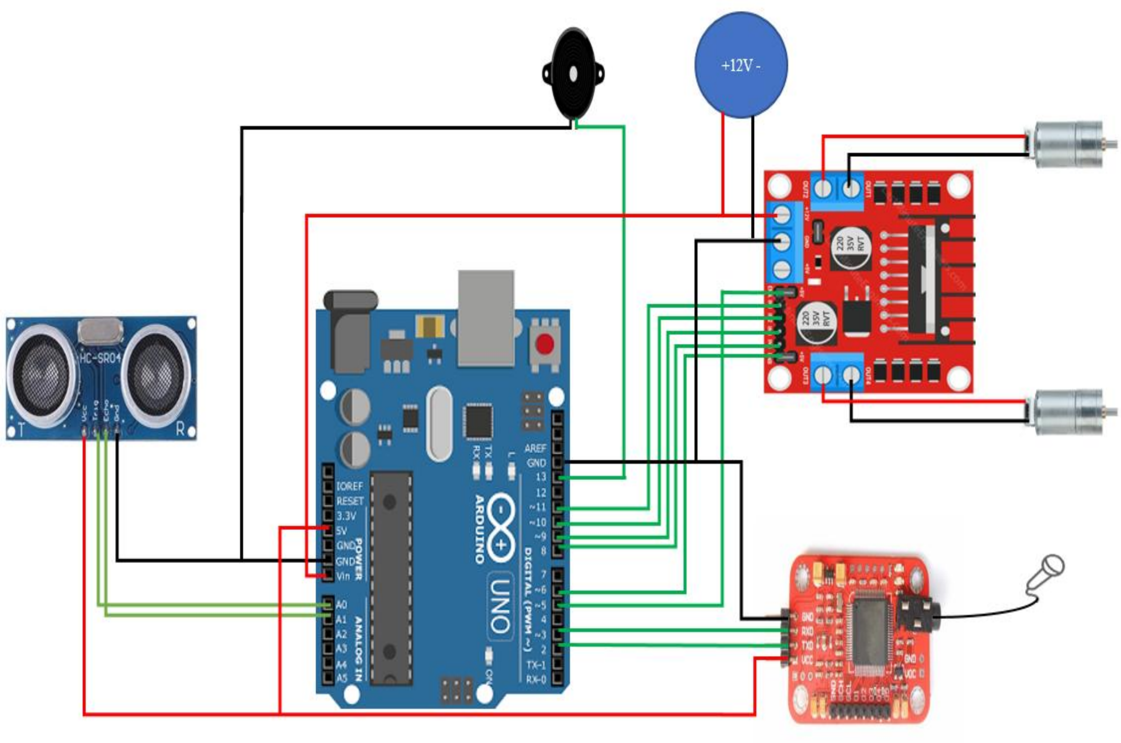


Figure 4.3 Circuit Diagram of the Wheelchair

4.3 System Flow of the System

The detailed system flow of the system is shown in Figure 4.4. It presents the voice-controlled wheelchair using Voice Recognition Module V 3.1 and Arduino Uno. Firstly, the wheelchair receives input commands from the microphone of the voice recognition module. And then, the Ultrasonic Sensor checks the obstacles. If the sensor detects any obstacle, the wheelchair will be stopped. If the sensor detects nothing, the voice module checks whether the voice command is valid or not. When the received input command is valid, the wheelchair performs with this command.

The main purpose of the system is to control all the movements of the wheelchair as per user's voice commands. The five basic movements of the wheelchair in this system are described as follows:

- Moving Forward
- Moving Backward
- Turning Left
- Turning Right
- Stop Condition

The wheelchair moves forward according to the "forward" command until the obstacle is detected. Likewise, to run the opposite movement of wheel rotation, the backward command moves the wheelchair to the backward direction. By using the right command makes left wheel move backward and right wheel forward. According to the left command, wheelchair's right wheel move backward, and wheelchair's left wheel moves forward. The rotation of both motors will stop by the stop command, Moreover, in this system, the wheelchair can be controlled by some angle where the user wishes to rotate its wheelchair by like 30˚, 45˚, 60˚ etc. [47, 22].

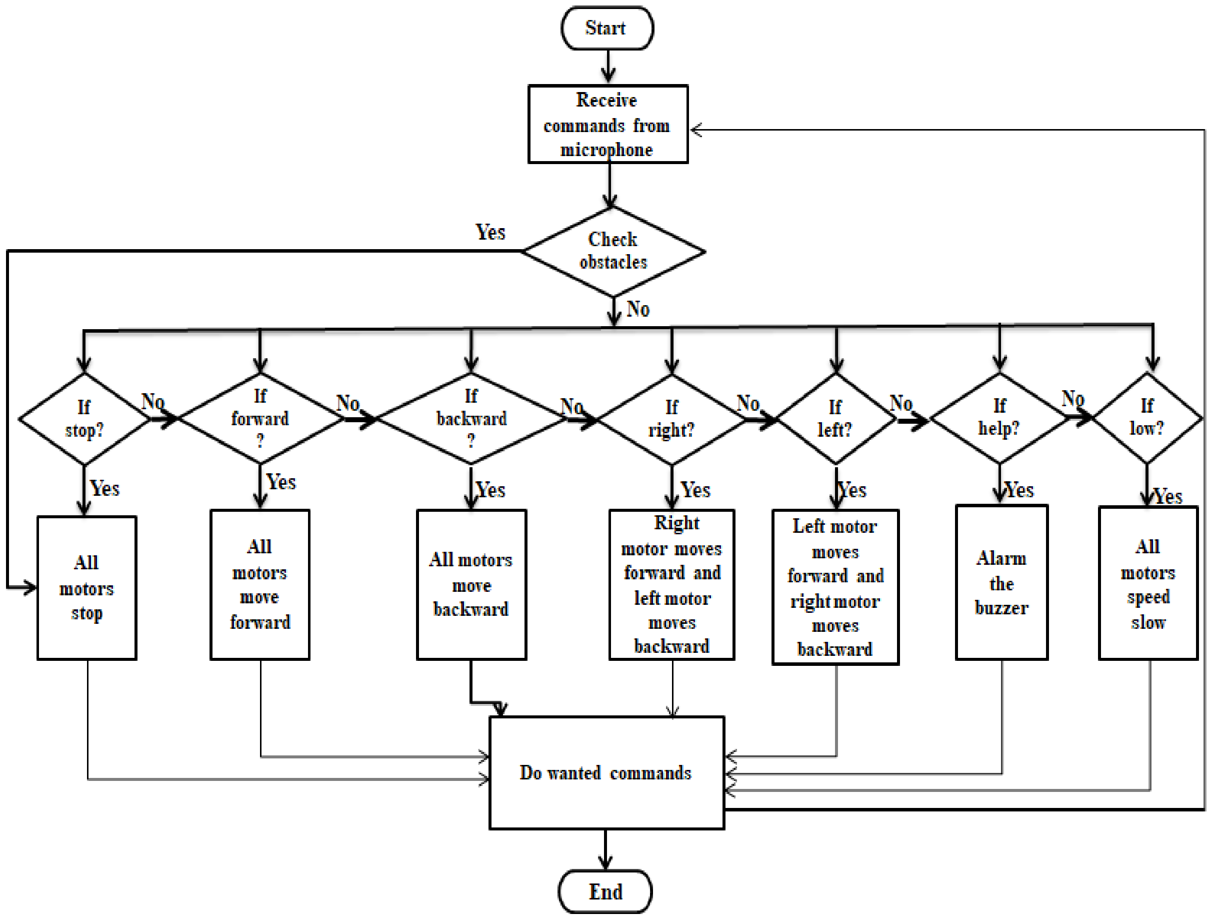


Figure 4.4 System flow of the System

4.4 Experimentation of the System

Firstly, the system performs the training process using voice recognition module with commands for the wheelchair.

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

/***************************************************************************/
/** declare print functions */
void printSeperator();
void printSignature(uint8_t *buf, int len);
void printVR(uint8_t *buf);
void printLoad(uint8_t *buf, uint8_t len);
void printTrain(uint8_t *buf, uint8_t len);
void printCheckRecognizer(uint8_t *buf);
void printUserGroup(uint8_t *buf, int len);
void printCheckRecord(uint8_t *buf, int num);
void printCheckRecordAll(uint8_t *buf, int num);
void printSigTrain(uint8_t *buf, uint8_t len);
void printSystemSettings(uint8_t *buf, int len);
void printHelp(void);

/***************************************************************************/
// command analyze part
#define CMD_BUF_LEN      64+1
#define CMD_NUM     10
typedef int (*cmd_function_t)(int, int);
uint8_t cmd[CMD_BUF_LEN];
uint8_t cmd_cnt;
uint8_t *paraAddr;
```

Figure 4.5 Training process for the wheelchair

After the wheelchair is trained with the commands, the next step is to apply these commands to control other modules. In this system, the voice-controlled wheelchair for physically disabled person is implemented using Arduino programming language based on C. When user clicks “Arduino program”, the Arduino control program for controlling speed and direction of the two motors by the motor driver , buzzer and ultrasonic sensor (the rest part of the wheelchair)will be appeared as shown in figure 4.6.

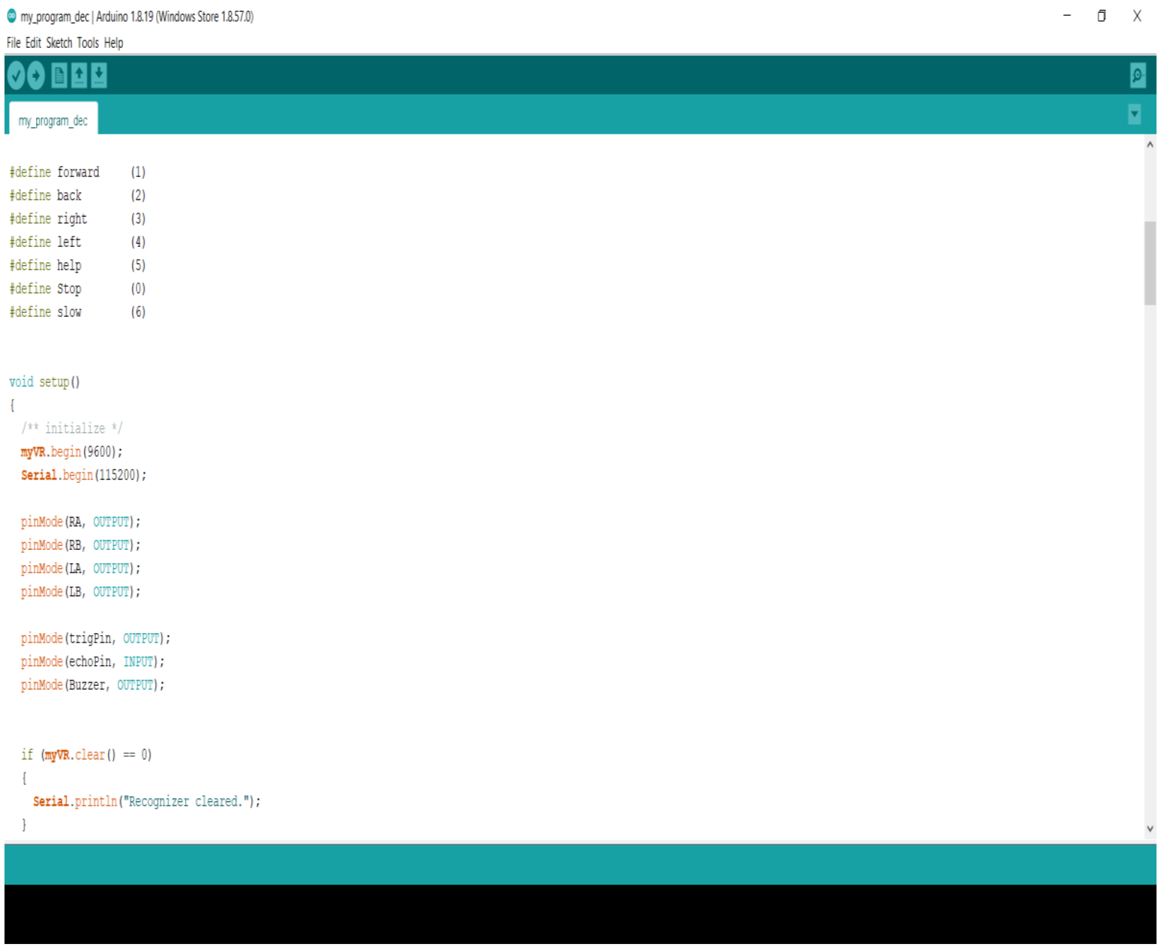


Figure 4.6 Control program page for "Arduino Program"

In Figure 4.7, when user clicks controlling Arduino program file, click Tools button, choose Board: "Arduino Uno" and select Port for Uno board. And then clicks file menu, click Examples, and choose Voice RecognitionV3-master and vr-simple-train.

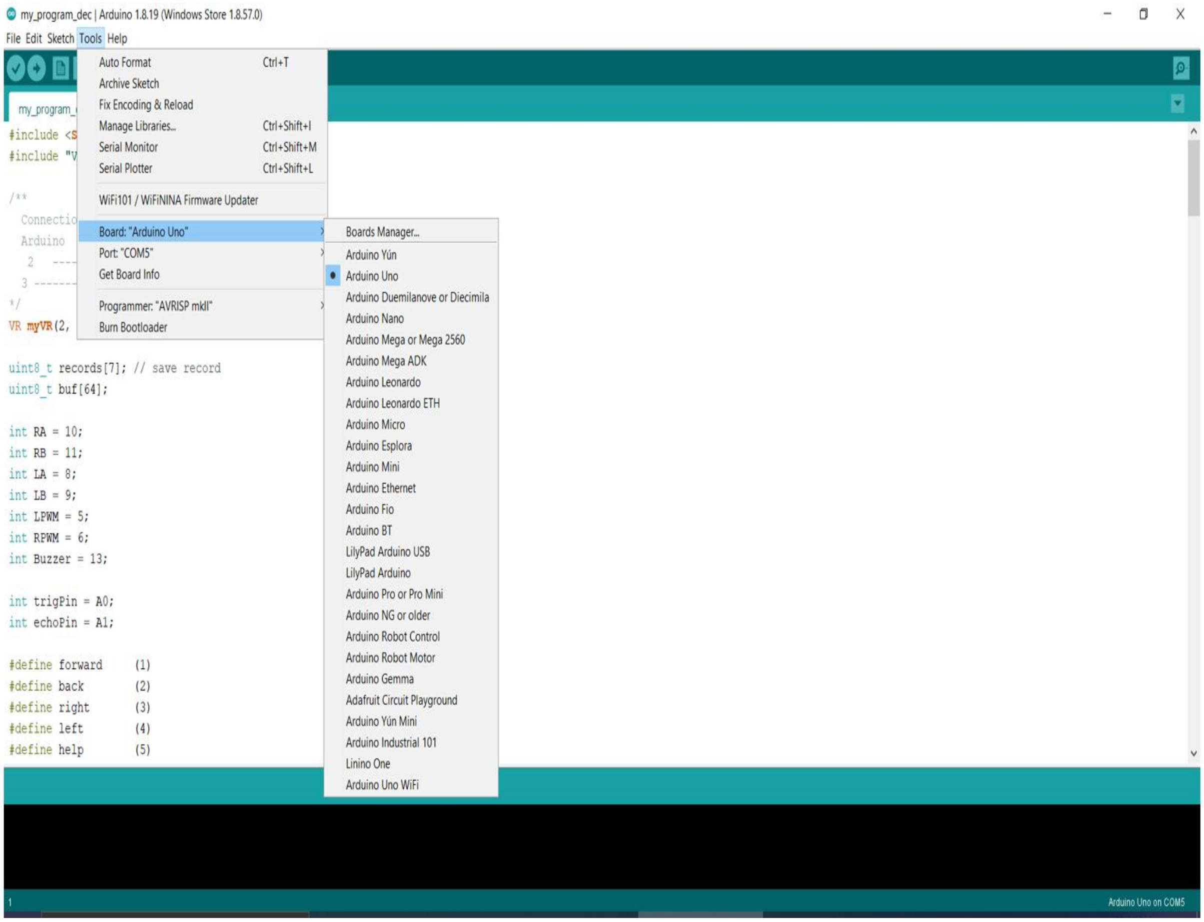


Figure 4.7 Choosing communication port and board (Step 1)

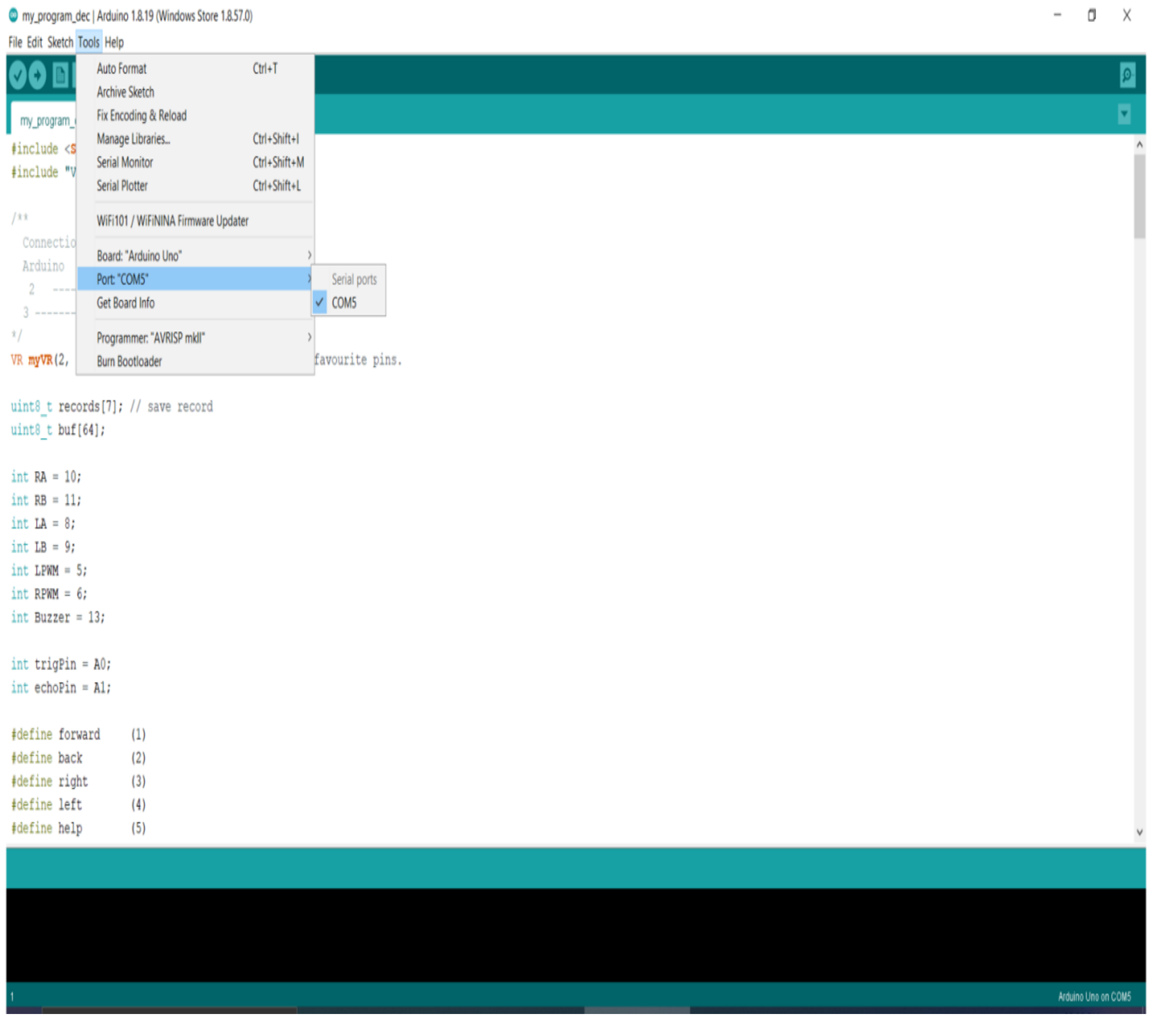


Figure 4.8 Choosing communication port and board (Step 2)

Next step is by clicking “File” button, user select “Example, VoiceRecognitionV3 and vr_sample_train” to record the required commands in the library program. It can be depicted in Figure 4.9.

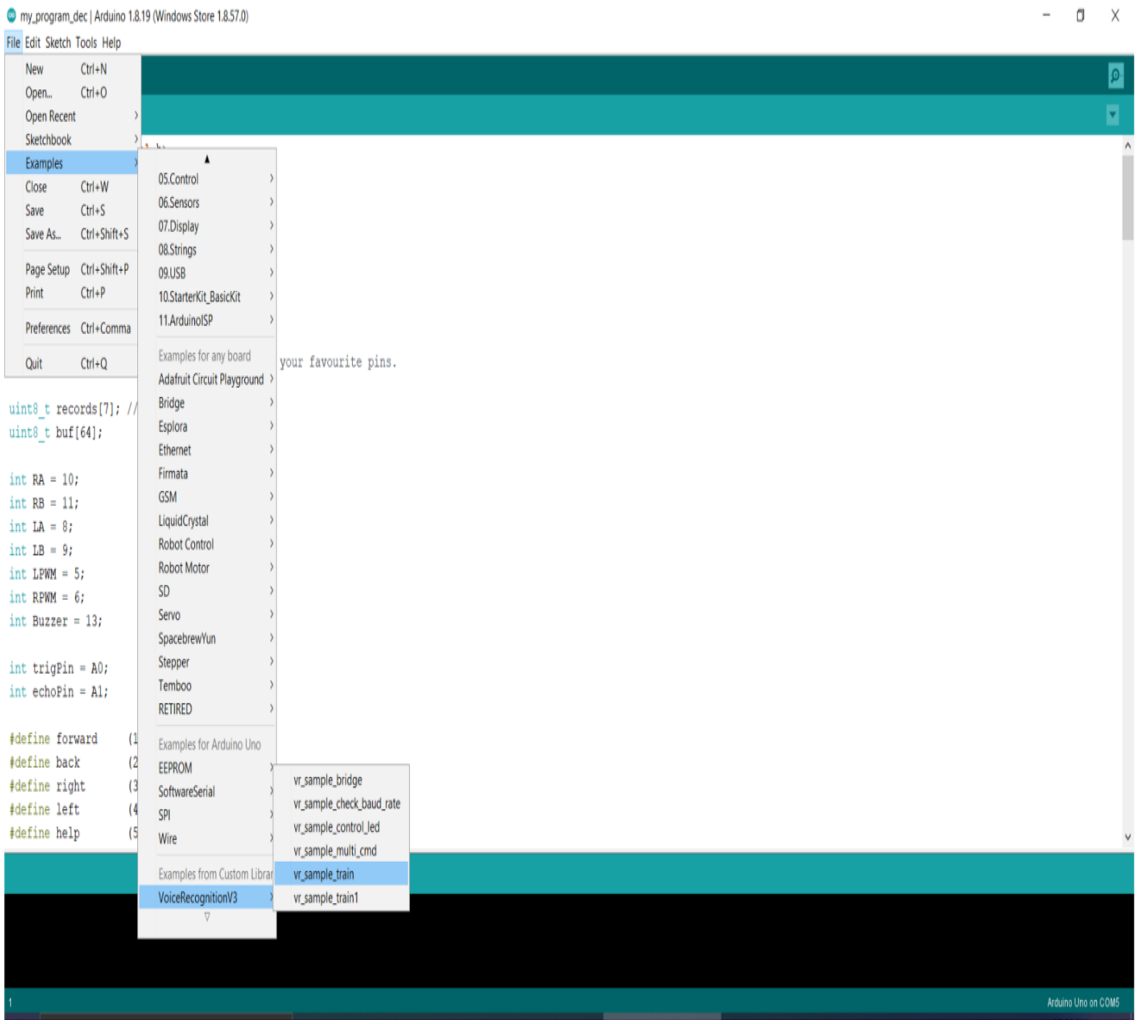


Figure 4.9 Selecting library file for training commands

In Figure 4.10, with the purpose of training the required commands in the library program, user click compiling button and wait a second.

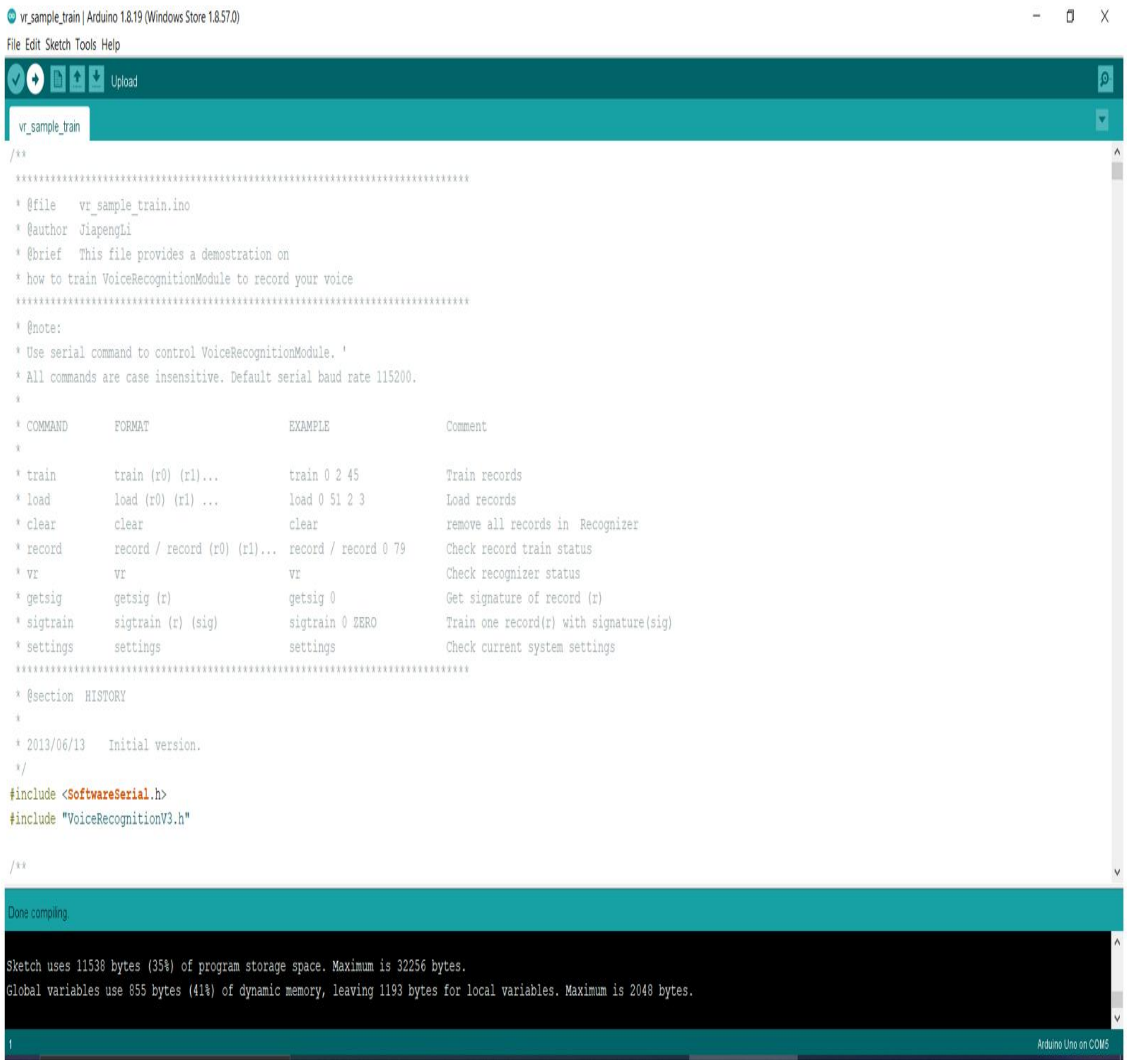


Figure 4.10 Clicking compiling button for required commands

After compiling the library program, another step to proceed is that user can click upload button and wait a second as shown in Figure 4.11. When the user clicks "upload" button, "Done uploading" message will be appeared and click again "compile" button, "Done compiling" message will be appeared after waiting for a while. By clicking "Serial motor" button, user can train voice commands by microphone.

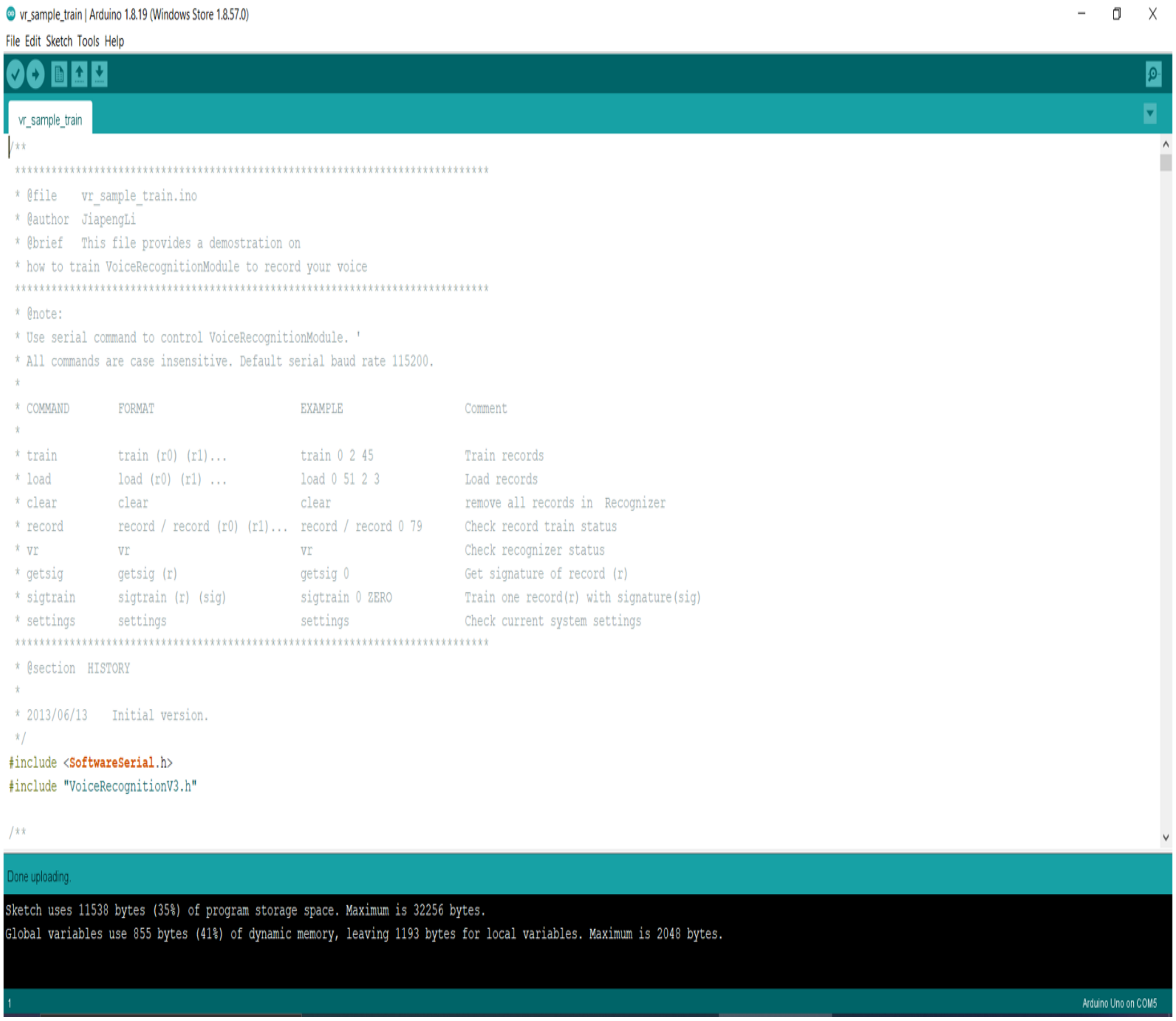


Figure 4.11 Clicking upload button

After uploading library program, user can train the required commands in serial motor. It can be shown in Figure 4.12.

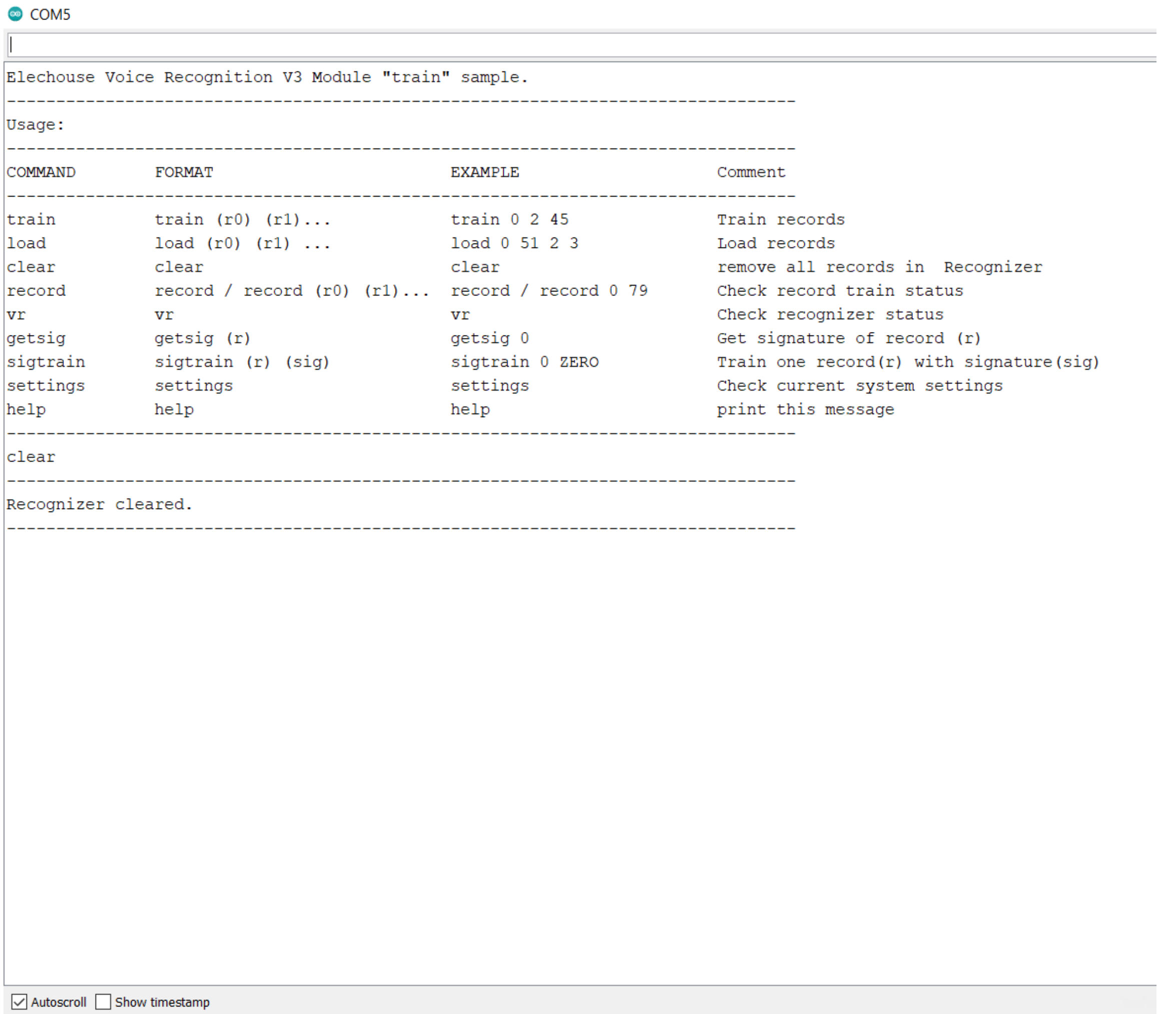


Figure 4.12 Training the required commands in serial motor (Step 1)

In the serial motor dialogue box, user type “train 0” for stop command and record for the stop command into the recognizer. And then, type train 1 to 6 to record the required commands into the recognizer until the commands are successfully recorded. It can be depicted in Figure 4.13.

```
train 1

Elechouse Voice Recognition V3 Module "train" sample.
--------------------------------------------------------------------------------
Usage:
--------------------------------------------------------------------------------
COMMAND        FORMAT                        EXAMPLE                    Comment
--------------------------------------------------------------------------------
train          train (r0) (r1)...            train 0 2 45               Train records
load           load (r0) (r1) ...            load 0 51 2 3              Load records
clear          clear                         clear                      remove all records in  Recognizer
record         record / record (r0) (r1)...  record / record 0 79       Check record train status
vr             vr                            vr                         Check recognizer status
getsig         getsig (r)                    getsig 0                   Get signature of record (r)
sigtrain       sigtrain (r) (sig)            sigtrain 0 ZERO            Train one record(r) with signature(sig)
settings       settings                      settings                   Check current system settings
help           help                          help                       print this message
--------------------------------------------------------------------------------
clear
--------------------------------------------------------------------------------
Recognizer cleared.
--------------------------------------------------------------------------------
train 0
--------------------------------------------------------------------------------
Record: 0       Speak now
Record: 0       Speak again
Record: 0       Success
Train success: 1
Record 0        Trained
--------------------------------------------------------------------------------
train 0
--------------------------------------------------------------------------------
Record: 0       Speak now
Record: 0       Speak again
Record: 0       Success
Train success: 1
Record 0        Trained
--------------------------------------------------------------------------------
train 0
--------------------------------------------------------------------------------
Record: 0       Speak now
```

Figure 4.13 Training the required commands in serial motor (Step 2)

After finishing the recording commands successfully, the user can type “load 0 1 2 3 4 5 6”in the serial motor of the library program to load recording command into the recognizer. It can be shown in Figure 4.14.

```
COM5
load 0 1 2 3 4 5 6
Record: 2        Speak now
Record: 2        Speak again
Record: 2        Success
Train success: 1
Record 2         Trained
--------------------------------------------------------------------------------
train 3
--------------------------------------------------------------------------------
Record: 3        Speak now
Record: 3        Speak again
Record: 3        Success
Train success: 1
Record 3         Trained
--------------------------------------------------------------------------------
train 4
--------------------------------------------------------------------------------
Record: 4        Speak now
Record: 4        Speak again
Record: 4        Success
Train success: 1
Record 4         Trained
--------------------------------------------------------------------------------
train 5
--------------------------------------------------------------------------------
Record: 5        Speak now
Record: 5        Speak again
Record: 5        Success
Train success: 1
Record 5         Trained
--------------------------------------------------------------------------------
train 6
--------------------------------------------------------------------------------
Record: 6        Speak now
Record: 6        Speak again
Record: 6        Success
Train success: 1
Record 6         Trained
--------------------------------------------------------------------------------
```

Figure 4.14 Load recording command into the recognizer

After testing the load command in the serial monitor of the library program, the user can return to the controlling program of the Arduino program. Then, user can click compile button and upload button and then wait a second. Finally, user can check the recording commands in the serial monitor of the Arduino program is shown in Figure 4.15.

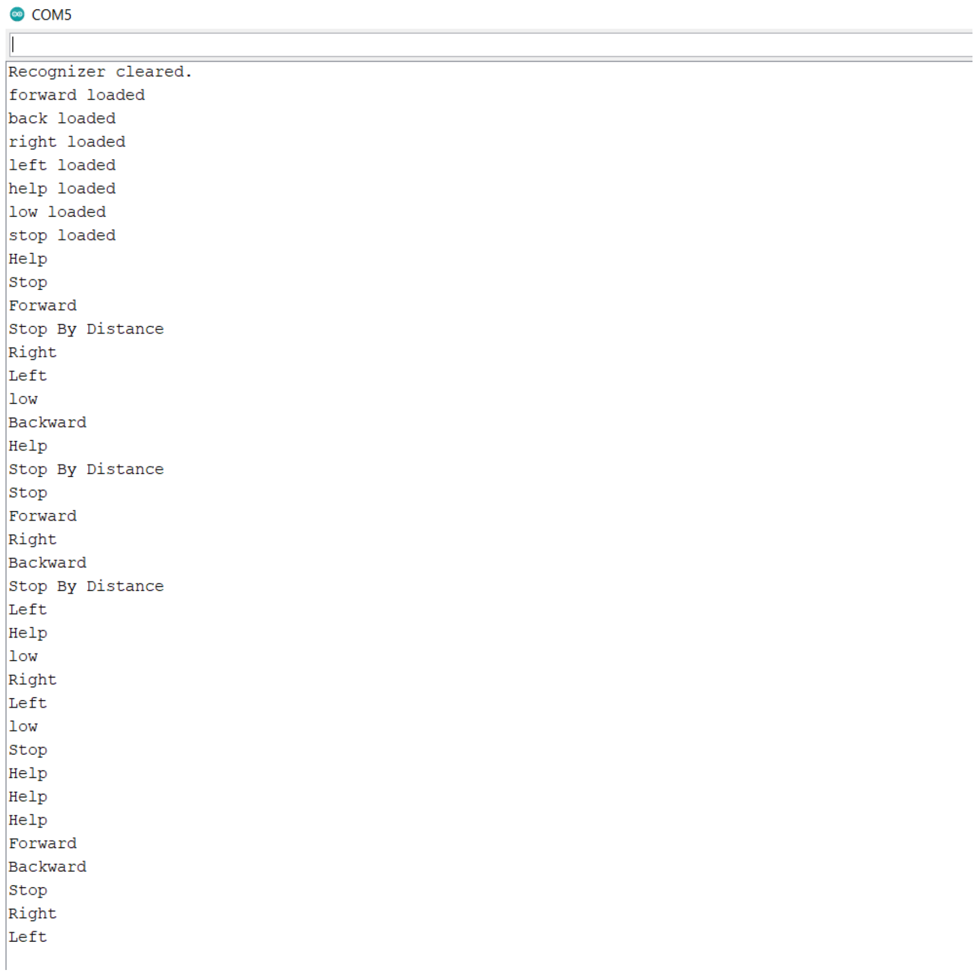


Figure 4.15 Recording commands in the serial monitor

4.5 Experimental Results

The experimental results presented in this section describes the performance of the system. By comparing the output results i.e., the environmental noise with the silent area with the purpose of calculating the accuracy of the system. It is the measurement of the difference between the environmental noise area and the silent area results. In fact, there are totally 50 samples for each command word spoken by the wheelchair user. The percentage of accuracy for each command in environmental noise area and silent area in Table 4.1.

The percentage of the accuracy of the wheelchair in environmental area is 78% (Accuracy = 350-78/350 x100%= 77.7%) and in silent area is 86% (350-49/350x100%= 86%). The percentage of accuracy can be obtained by:

accuracy = (correctly predicted class / total testing class) × 100%.......................4.1

$$\boldsymbol{accuracy = \frac{approximation - error}{approximation} * 100}\%$$......................4.2

In this system, US English is used as the command language for wheelchair. The accuracy depends on the pronunciation spoken by the wheelchair user. According to the detailed observations from the experimental result above, there are four command words that have 80% of accuracy. They are “Forward”,” Low”, “Right”, and “Stop”. This means that all of them are easy to be pronounced by the user. The hardest work to recognize by the system is “Left” which scored about 70% of accuracy in environmental area [48].

Voice commands	Result in environmental noise area		Result in silent area	
	No of correct commands	No of errors	No of correct commands	No of errors
Stop	41	9	45	5
Forward	43	7	46	4
Backward	37	13	40	10
Right	40	10	45	5
Left	35	15	40	10
Help	36	14	40	10
Low	40	10	45	5

Table 4.1 The comparison results between noise area and silent area

Table 4.2 describes the system which is recorded after replacing new jumper wires weekly and monthly testing results of 70 samples depending upon the motions of the wheelchair. The number of errors depending upon the commands of the user that cannot catch correctly by the voice module because of the quality of microphone and Arduino uno has a single hardware serial.

Commands	One week(70 trials)	One Month (70 trials)
Stop	10	9
Forward	9	9
Backward	9	8
Right	10	10
Left	9	8
Help	10	10
Low	10	9
Accuracy (%)	94.3	90

Table 4.2 The comparison results of weekly and monthly tested between noise area and silent area

The wheelchair movements are experimented in environmental noise area as shown in figure 4.16. According to the experimental results, the “Forward” command has reached the highest accuracy (83 percent). Besides, the “Stop” command, “Right” command and “Low” command offer satisfying accuracies, specifically over 80 percent. The “Backward” and “Help” commands also offer good accuracies for the system. However, the accuracy of “Left” command resulted from the experiments is the minimum in compared with other commands.

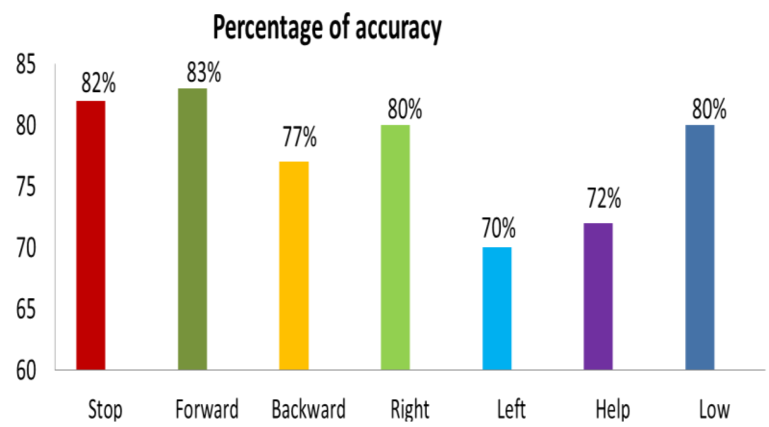


Figure 4.16 Percentage of accuracy for the wheelchair movements in environmental noise area

The wheelchair movements are experimented in silent area as shown in figure 4.17. According to the experimental results, the "Forward" command has also reached the highest accuracy (92 percent). Moreover, the "Stop" command, "Right" command and "Low" command offer the same satisfying accuracies, specifically 90 percent. The "Backward", "Left" and "Help" commands also offer good accuracies for the system over 80 percent.

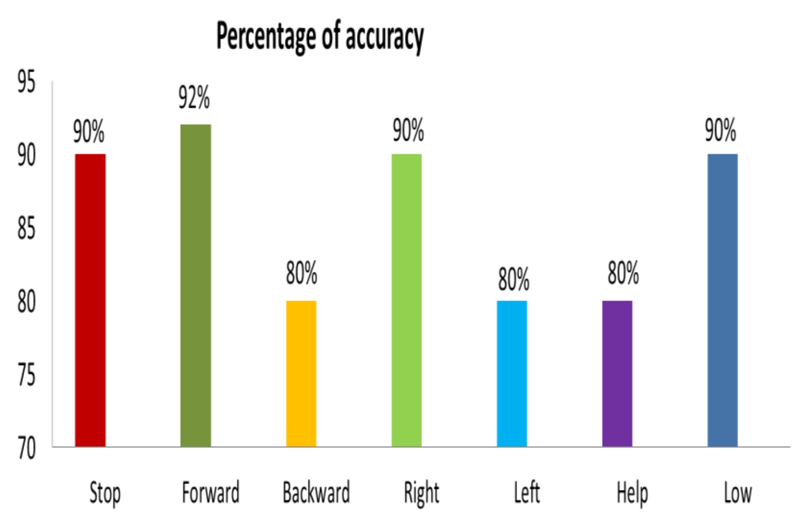


Figure 4.17 Percentage of accuracy for the wheelchair movements in silent area

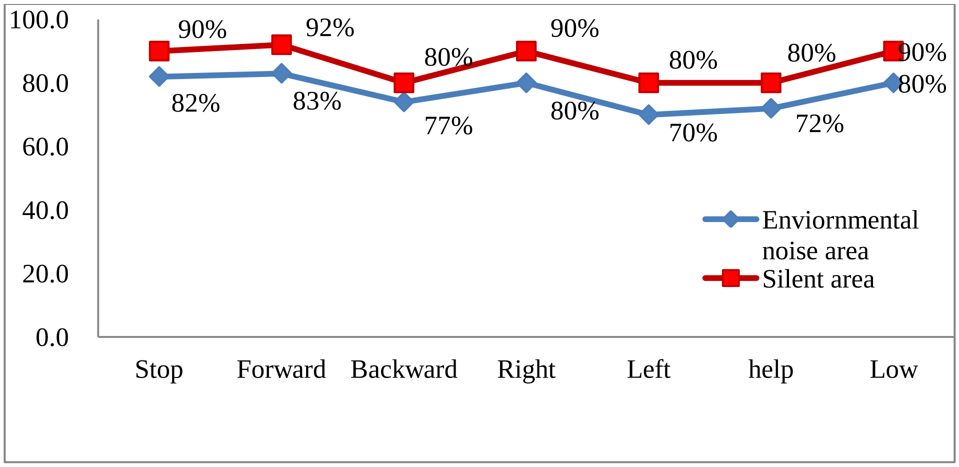


Figure 4.18 Percentage of command accuracy in environmental noise and silent area

The percentage of accuracy for the wheelchair movements in environmental noise area and silent area are shown in figure 4.16 and figure 4.17 respectively. The comparison results of percentage of command accuracy in environmental noise and silent area show in figure 4.18. According to the experimental results, the percentage of the command accuracy in silent area is better than environmental noise area because the voice module can catch more commands in silent area.

CHAPTER 5

CONCLUSION

In this system, a voice-controlled wheelchair is designed and implemented for physically disabled persons applying Voice Recognition Module and Arduino in managing the movements of a wheelchair. Voice-controlled wheelchair is implemented to enable for disabled ones to utilize the wheelchair to overcome the difficulties encountered in current time. The Voice Recognition Module is applied for voice recognition process. And then, the outcome of this module is hand overed to the Arduino. To drive the motors, Arduino applies a motor driver IC, and the microcontroller offers flexibility in controlling the speed by changing the duty cycle of the PWM pulse. The design of the wheelchair is intended not only offer great competitive with other types of electrical wheelchair but also minimize the manufacture cost.

The synthetic voice commands of the user stand one of the requirements to manage the wheelchair. This kind of technique can also improve safety for wheelchair users by preventing furniture, fixed objects, collision with walls, and other people. “Voice-controlled Wheelchair” is useful for physical handicapped people like the joystick-controlled wheelchair, and sensor can be appended to the wheelchair to stay away from crash. However, some people suffer uncomfortable access using powered wheelchairs. As these powered wheelchairs with the standard joystick interface cause unable to control them. A proposed voice-controlled wheelchair provides an alternative way for physical disabled person who cannot control their movements especially the hands with easy access. By utilizing the proposed wheelchair system, the disabled people will become more independent. By speaking to the microphone, the users can simply operate the wheelchair.

Moreover, the movements of the voice-controlled wheelchair are experimented in environmental noise area. According to the experimental results, the “Forward” command has reached the highest accuracy (83 percent). Besides, the “Stop” command, “Right” command and “Low” command offer satisfying accuracies, specifically over 80 percent. The “Backward” and “Help” commands also offer good accuracies for the system. However, the accuracy of “Left” command resulted from the experiments is the minimum in compared with other commands. Besides, the movements of the wheelchair are experimented in silent area. According to the experimental results, the “Forward” command has also reached the highest accuracy (92 percent). Moreover, the “Stop” command, “Right” command and “Low” command offer the same satisfying accuracies, specifically 90 percent. The “Backward”, “Left” and “Help” commands also offer good accuracies for the system over 80 percent. The percentage of the command accuracy in silent area is better than environmental noise area because the voice module can catch more commands in silent area according to the experimental results from the system.

5.1 Limitations of the system

While working on the system, several limitations are emerged from the system. It can pick noise signals and produces errors in response to it. Firstly, batteries and jumper wires used should be good quality products and must be kept under check. Secondly, the price of the DC gear motor should be considered as the higher price offer the better speed control performance. Finally, the ultrasonic sensor is not installed on the side of the wheelchair, so it cannot detect any objects coming from the side.

5.2 Future work of the system

As the future work, the wheelchair will transfer up or down a set of stairs. A wheelchair up and down (step) movement is very difficult, even if there is a helper. The user cannot attempt this type of transfer if helpers are not available. To overcome this problem, the stair climbing wheelchair with voice-controlled system can be used. The person using the wheelchair should be seated with their entire body fitting in the chair. A seat belt should be used to keep the user in the chair while attempting the transfer.

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