

DEVOLPOED WHEELCHAIR

(VOICE CONTROLLED)

**GRADUATION PROJECT SUBMITTED TO
THE BIOMEDICAL DEPARTMENT
OF
NEAR EAST UNIVERSITY**

BY

AHMED NASHWAN

MOUAIAD ASHRAFI

MUTAZ SHAHEEN

**IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS
FOR THE DEGREE OF BACHELOR OF SCIENCE
IN BIOMEDICAL ENGINEERING**

NICOSIA 2016

DEVOLPOED WHEELCHAIR

(VOICE CONTROLLED)

GRADUATION PROJECT SUBMITTED TO

THE BIOMEDICAL DEPARTMENT

OF

NEAR EAST UNIVERSITY

BY

MUTAZ SHAHIN

MOUAIAD ASHRAFI

AHMED NASHWAN

IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS

FOR THE DEGREE OF BACHELOR OF SCIENCE

IN BIOMEDICAL ENGINEERING

NICOSIA 2016

ACKNOWLEDGEMENTS

First we would like to thank our supervisor Mr. Alper YOUSOUF who has shown plenty of encouragement, patience and support. He guided us through this project as graduate students.

We are also thankful for the contributions and comments of the teaching staff of the Department of Biomedical Engineering.

We are especially grateful to Assoc.Prof.Dr. Terin ADALI for being a constant source of encouragement. She helped us gain self-confidence. Here also we would like to thank our co-advisor Msc. Ali IŞIN and Msc. Fatih NURÇİN and friends at the Department of Biomedical Engineering who helped us one way or another.

This project was generously supported by the Department of Biomedical Engineering of the Near East University.

DEDICATION

I would like to dedicate this project to my beloved parents, grandparents and family for their encouragement and support. Also to my friends, I will always appreciate all they have done.

Last but not least, I hope that peace and love find their way back to my wounded countries, Syria and Palestine.

MUTAZ SHAHIN–AHMED NASHWAN–MOUAIAD ASHRAFI

ABSTRACT

The present day society demands the people to be independent, irrespective of their natural challenges, mentally or physically. Physically impaired people have to rely on someone for fulfilling their even minor needs. The probability of them to go and interact with the outside world is very minimal, unless they are provided with modern moving tools such as a Wheel Chair. There are two possibilities of either using manual driven or electric powered driven wheel chairs. The former solution is only for the people who have disability in lower limbs and also long term usage poses further health problems. Additionally the efficiency of the manual driven wheel chairs are merely 10-20%.

This project aims to control a wheelchair by means of human voice. It enables the disabled people who can't move their hands and legs to move around independently using the voice recognition application which is interfaced with motors to make the movement easy as much as possible, using a voice recognition application which is interfaced with motors.

The prototype of the wheelchair is built using a computer software, in addition to its versatility and performance in mathematical operations and communication with other electronic devices. The system has been designed and implemented in a cost effective way so that if our project is commercialized the needy users in developing countries will benefit from it. In order to do that we applied a program carried on Arduino circuit which is connected to the voice recognition the signal operates a motor to control the movement of the chair.

In this way we have obtained a wheelchair which can be driven with using voice commands and with the possibility of avoiding obstacles and downstairs or holes detection. The wheelchair has also been developed to allow autonomous driving. The project, in which prototype has been produced, Electronic system configuration, a sensor system, a mechanical model, voice recognition and autonomous control are considered.

Keywords: voice control, intelligent wheelchair, speech recognition.

CONTENTS

ACKNOWLEDGEMENTS	III
DEDICATION	IV
ABSTRACT	V
LIST OF FIGURES	VIII
LIST OF TABLES	IX
CHAPTER 1: INTRODUCTION.....	1
1.1 INTRODUCTION.....	1
1.2 LITERATURE REVIEW	2
1.3 PROBLEM STATEMENT.....	3
1.4 SOLUTION OF THE PROBLEM	3
CHAPTER 2: SIGNAL OBTAINING AND PREPROCESSING	5
2.1 VOICE SIGNAL OBTAINING	5
2.2 MATERIALS AND METHOD.....	7
2.3 ELECTRONIC SYSTEM CONFIGURATION.....	10
CHAPTER 3: VOICESIGNALS INTERRUPTION.....	12
3.1 ARDUINO.....	12
3.2 BOARD	13
CHAPTER4: MECHANICAL DESIGN OF THE WHEELCHAIR.....	15
4.1 WHEELCHAIR DESIGN	15
CHAPTER 5 :RESULTS AND DISCUSSION.....	17
CHAPTER 6 : CONCLUSIONS AND FUTURE ADVANCES	18
REFERENCES	19
APPENDICES.....	20
Appendix A: Arduino code	20
Appendix B: wheelchair design.....	30
Appendix C: wheelchair batteries	30

Appendix D: dual H-bridge motor driver	31
Appendix E: wheel bearing	32
Appendix F: Prototype circuit	32
Appendix G: Power calculations	33

LIST OF FIGURES

Figure 1 Block diagram of wheelchair components.....	5
Figure 2 Block diagram of the electronic system of the wheelchair.....	11
Figure 3 Arduino Inputs and Outputs.....	12

LIST OF TABLES

Table 1 Command Words and Directions.....	6
---	---

CHAPTER 1: INTRODUCTION

1.1 Introduction

“Give me a wheelchair that is light and compact, that fits in a small plane when I need to fly outing the wet season. Make sure it’s comfortable, does not give me pressure sores, to make me look like a cripple straight out of hospital. It has to be easy to push because I want to get out, go crabbing in the boat and go fishing on the beach.” (Hales S 2001) This quotation describes the needs of a wheelchair user in an Aboriginal community.

The number of people who need to move around with the help of some artificial means, whether through an illness or an accident, is continually increasing. These means have to be increasingly sophisticated, taking advantage of technological evolution, in order to increase the quality of life for these people and facilitate their integration into the working world. In this way a contribution may be made to facilitating movement and to making this increasingly simple and vigorous, so that it becomes similar to that of people who do not suffer deficiencies. Systems already exist which respond too many of the needs of people with different degrees of incapacity.

Recently, the old person and the physically handicapped person who use a wheelchair are increasing. However, only two type wheelchairs by the hand-operating and operating the joystick, have come into wide use. The former type needs muscular strength for the operation and the latter type needs the skill. Therefore, there is a problem that it is difficult for the old and the handicapped person to use these interfaces.

Today In biomedical sector, a wheelchair is an important device because of the recent advancements in the industrial populations. The demand of the physically handicapped and the aged are ever rising. As Smart wheelchair will play significant role in the future welfare society.

The use of smart wheelchair inspires the view of the machine as partner rather than as an instrument. The present wheelchairs do not have combination of technologies for their working.

However, only two types of wheelchairs are available in market like hand operated and joystick operated have come into wide use.

We are trying to construct a voice controlled wheelchair; the system will recognize and follows natural language voice instructions such as “Start, Stop etc.” The objective of this project is to make wheelchair moving forward, backward, Left & Right with the help of voice commands. A wheelchair fitted with obstacle sensor to achieve some independent mobility when any obstacle is there in front of wheelchair.

The obstacle sensor will help the rider control the wheelchair by taking over some of the decision for steering and avoiding objects until user is able to handle the job. The voice command is a person dependent, the voice command we provide to the voice recognition model is person dependent. The system comprises of transmitting section and receiving section. Initially, the voice command is stored in the data base with the help of the function keys.

The voice received is processed in the voice recognition system where the feature of the voice command is extracted and matched with the existing sample in the database. The module recognizes the voice and sends control messages to the microcontroller. The proposed Speech Recognition Based Wheelchair Operation allows physically disabled person to control the wheelchair easily without the need to use hands.

The movement of the powered wheelchair depends on the motor control and drive system which consists of microcontroller and motor driving. Once the voice recognition system recognizes the voice commands in comparison to the stored memory, the respective coded digital signals would be sent to the microcontroller which then controls the wheelchair accordingly.

1.2 Literature review

A wheelchair is a wheeled mobility device in which the user sits. The device is propelled either manually (by turning the wheels by the hand) or via various automated systems,

Wheelchairs are used by people for whom walking is difficult or impossible due to illness (physiological or physical), injury, or disability, Users can find custom-made high quality ultra-light high performance wheelchairs as well as accessories that enable them to individualize their look and style.

The first wheelchair was invented, needed assistance to propel, the 20th century saw a rapid development in wheelchairs, from the first motorized wheelchair, to the first folding wheelchair, to lightweight and sports wheelchairs. Researches in the area of wheelchair control system are still going on. Many people with disabilities do not have the skill essential to control a joystick on an electrical wheelchair. This can be a great drawback for the user who is permanently unable to move any of the arms or legs. They can use their wheelchair easier only using voice commands. In the proposed design, the main idea of using voice activated technology for controlling the motion of the wheelchair is to prove that it can be an exclusive solution for severely disabled. (H. R. Singh, 1999)

1.3 Problem statement

Independent mobility is crucial for development of physical, cognitive, communicative and social skill for physically impaired people. The high price of the electric wheel chairs. This project is thus aimed at the development of more sophisticated control scheme for electric powered wheelchair.

The main problem of the wheelchair is that cannot be used by disabled person, so the type of artificial aid needed by a disabled person in order to move about depends, to a large extent, on the level of his incapacity. So no need to handles behind the seat to allow it to be pushed by another person.

1.4 Solution of the problem

In order to guide a wheelchair, various situations can be distinguished:

a) If the user is capable of controlling his head or his hands, the ideal solution is the use of a joystick.

b) Where there is a high level of incapacity, solutions are basically centered on the use of other means, such as the voice or eye movements. In this case, the presence of safety sensors is justified with the object of assisting the user to guide the chair (detection of obstacles, nearness to certain places, and the existence of stairs.)

c) Only in extreme cases it is suggested that there may be a need for the chair to cover certain distances in an autonomous manner, without the need for any intervention on the part of the user.

CHAPTER 2: SIGNAL OBTAINING AND PREPROCESSING

2.1 Voice Signal Obtaining

Figure 1 shows the system block diagram showing the interconnections between each block and module. All the modules are mounted onboard as to ease the wheelchair movement. This includes a microphone which is located nearest to the user so as to make it handy and easy to use.

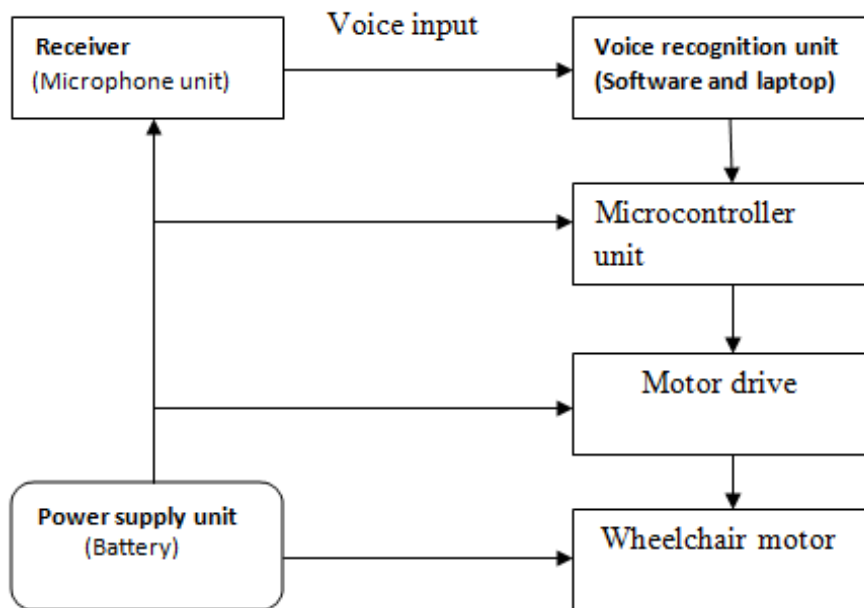


Figure 1: block diagram of wheelchair components

Generally, the input voice level affects the recognition accuracy result. For best recognition result, the microphone should be mounted or attached as closed as possible to the user's mouth. Principally, the system is triggered by the voice command word produced by the user through the use of this microphone. To keep the system as simple as possible, the words are kept short and the quantity is kept to minimum quantity, the command words are chosen and they are shown:

Command	Left motor Motor 1	Right motor Motor2
Forward along	clockwise	clockwise
Forward one meter	clockwise	clockwise
Forward 3 meters	clockwise	clockwise
Forward 10 meters	clockwise	clockwise
Backward along	counterclockwise	counterclockwise
Backward one meter	counterclockwise	counterclockwise
Turn right 45 degree	clockwise	counterclockwise
Turn right 90 degree	clockwise	counterclockwise
Turn right 180 degree	clockwise	counterclockwise
Turn left 45 degree	counterclockwise	clockwise
Turn left 90 degree	counterclockwise	clockwise
Turn left 180 degree	counterclockwise	clockwise
Exit from right	clock wise	counterclockwise
	clockwise	clockwise
	counterclockwise	clockwise
Exit from left	counterclockwise	clockwise
	clockwise	clockwise
	clockwise	counterclockwise

Table 1: commands used and directions for each motor either on clockwise or counter clockwise.

The voice from the user is picked up by a microphone and the analog output of the receiver is then fed to the voice recognition module. In this module, the signal is then compared and matched to the data previously stored in its memory to determine the corresponding output command. Then it latches data which is in binary-coded decimal to

the Arduino microcontroller. This signal is then processed by the Arduino and the output is sent to the output pin of the required motor (right or left or both of them) which is connected to the motor interface unit. These signals will drive the motors and make the wheelchair moves. (Dote, Y. 1990)

When the user speaks the word ‘forward’ to the microphone, the wheelchair moves in forward direction. The word ‘back’ means it moves in backward or reverse direction. Meanwhile the word ‘left’ causes the wheelchair to turn to the left, and ‘right’ makes the wheelchair to turn to the right direction. The wheelchair will continue moving in the direction according to the word received until the user speak out the word ‘stop’.

When the user pronounces the word “stop. Then the motors stop immediately by using the electrical braking method.

2.2 Materials and Method

To fabricate a realistic voice controlled wheelchair, various kinds of equipment are necessary. At first wheelchair is made mechanically or by the installation of mechanical equipment/parts. Secondly, electrical equipment/components are designed for using in the wheelchair and after installing these in the mechanical wheelchair, the mechanical wheelchair now is turned to an electrical wheelchair. Here some brief idea about the equipment/components used to construct the wheelchair and their installation.

Wheel: a wheel is a circular component that is intended to rotate on an axial bearing. The wheel is one of the main components of the wheel and axle which is one of the six simple machines.

Wheels, in conjunction with axles, allow heavy objects to be moved easily facilitating movement or transportation while supporting a load, or performing labor in machines.

Caster Wheel: a caster (or castor) is an unproven, single, double, or compound wheel that is designed to be mounted to the bottom of a larger object (the “vehicle”) so as to enable that object to be easily moved. They are available in various sizes, and are commonly

made of rubber, plastic, nylon, aluminum, or stainless steel. Casters are found in numerous applications, including shopping carts, office chairs, and material handling equipment. Generally, casters operate well on smooth and flat surfaces.

DC Motor: a dc motor is an electric machine that converts electrical energy into mechanical energy. The reverse conversion of mechanical energy into electrical energy is done by an electric generator. In normal motoring mode, most electric motors operate through the interaction between an electric Motor's magnetic field and winding currents to generate force within the motor. In certain applications, such as in the transportation industry with traction motors, electric motors can operate in both motoring and generating or braking modes to also produce electrical energy from mechanical energy, there are many characteristics were considered when motor had been chosen:

1. Easy to control.
2. The motor should be small and lightweight.
3. High economic efficiency.
4. Durable and easy to maintain.
5. Low noise.
6. Low cost.
7. Must be able to be used under various conditions and humidity.

Axle: an axle is a central shaft for a rotating wheel or gear. On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to the vehicle, with the wheels rotating around the axle.

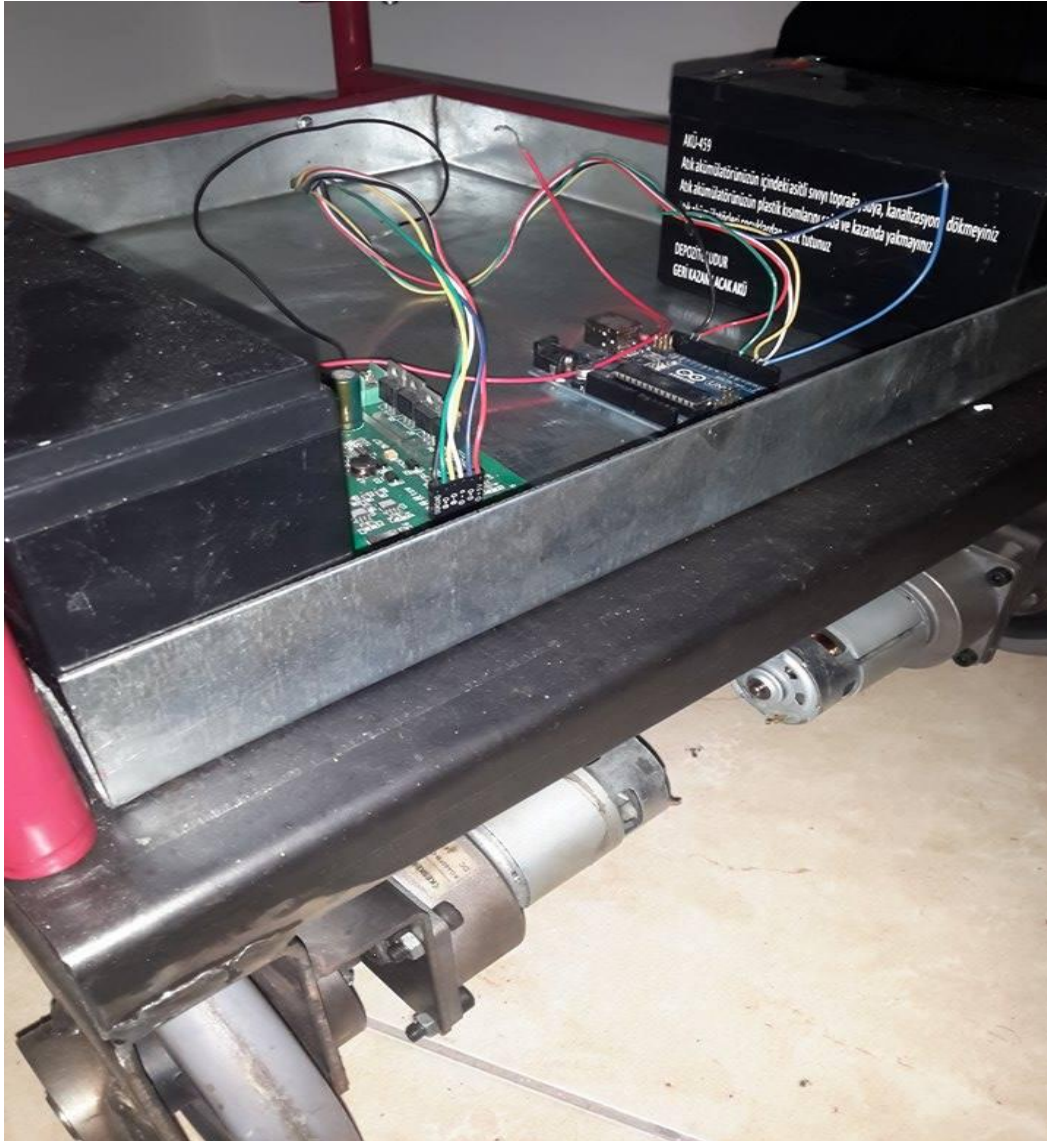
In the former case, bearings or bushings are provided at the mounting points where the axle is supported. In the latter case, a bearing or bushing sits inside a central hole in the wheel to allow the wheel or gear to rotate around the axle. Sometimes, especially on bicycles, the latter type axle is referred to as a spindle.

Bearing: a bearing is a machine element that constrains relative motion and reduces friction between moving parts to only the desired motion. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Many bearings also facilitate the desired motion as much as possible, such as by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts, a built in gear being used between the motor and the wheel.

Lead-Acid Battery: the lead–acid battery was invented in 1859 by French physicist Gaston Planet and is the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features, along with their low cost, makes it attractive for use in motor vehicles to provide the high current required by automobile starter motors.

Motor driver: A motor driver is a little current amplifier; the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor, we used (irf3205) dual motor driver.

A package under the seat between the front wheels and back ones will carry the batteries and motor driver (it is near to back wheels).



Main parts of the frame of the wheelchair: Axels and bearing

2.3 Electronic System Configuration

The block diagram of the electronic system is shown in Figure 3, it has been conceived as an open and adaptable modular system. In this way, an eventual addition could be made just by adding a board with the desired function.

The main blocks in the system are as follows:

- 1) Speed and direction control (driver circuits)

2) Power and Activation Motor Unit.

3) Speech Recognition Unit.

4) Arduino Board.

The system has a flexible configuration and is easily upgradable. More features can be added by merely changing/adding specific boards. The different blocks of the present system use 8-bit micro-controllers.

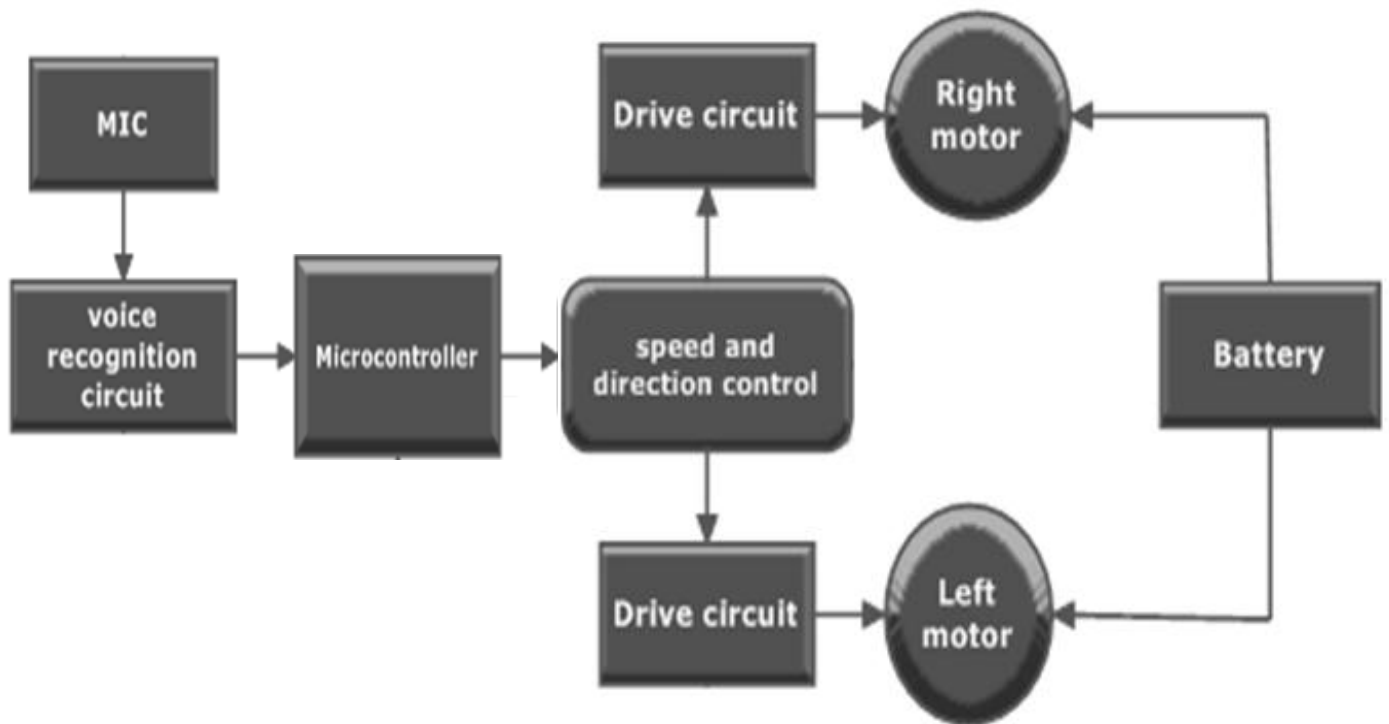


Figure 2: Block diagram of the electronic system of the wheelchair.

CHAPTER 3: VOICESIGNALS INTERRUPTION

3.1 Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware and software. We used ARDUINO as microcontroller that receives the output of the rectifier stage and interprets the impulses in order to convert them into modulated width pulse signal to control the motors. (McRoberts, M. 2013).

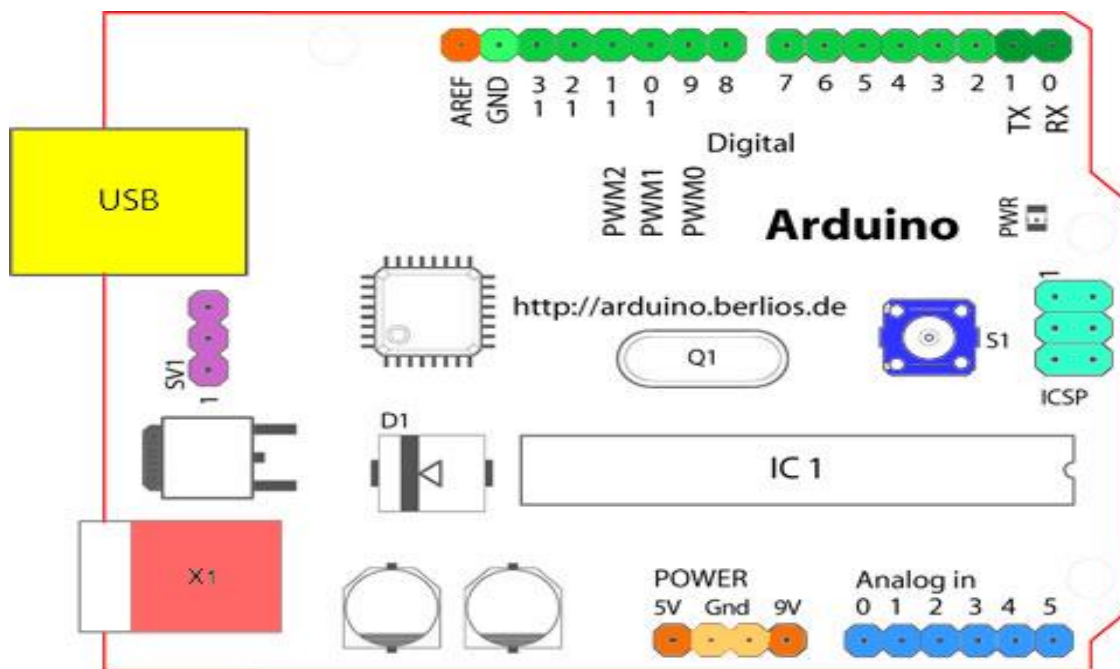


Figure 3: Arduino inputs and outputs

Pins of the Arduino, inputs and outputs

- Analog Reference pin (orange).
- Digital Ground pin (light green).
- Digital Pins 2-13 (green).
- Reset Button - S1 (dark blue).
- Analog in Pins 0-5 (light blue).
- Power and Ground Pins (power: orange, grounds: light orange).

- External Power Supply In (9-12VDC) - X1 (pink).
- USB (used for uploading sketches to the board and for serial communication between the board and the computer; can be used to power the board) (yellow).

What we used for our project:

1. Arduino Uno Board.
2. USB programming cable.
3. 9V battery or external power supply (for stand-alone operation). The board is powered by a battery rather than through the USB connection to the computer.
4. Breadboard for external circuits, and solid wire for connections.
5. PC running the Arduino development environment. One of the important features of Arduino environment is that you can easily create any code to achieve your own purpose, just download it from Arduino website and it will run automatically. After uploading the board it can be disconnected from the PC, and the program will still run from the top each time you push the reset button.

3.2 Board

The 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 quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again. (ARDUINO. (n.d.). 2014).

3.3 Software

Arduino programs divided into three main parts: structure, values (variables and constants) and functions. After writing the code, the Arduino programming environment compiles it (Purdum, 2012).

Problems:

First time that we uploaded the code some problems appeared in the bottom of the program window as syntax error in the program caused by probably a mistake in typing. Generally, staring at the error line will reveal the problem by the following steps such as:

Run the Arduino program again.

Check that the USB cable is secure at both ends.

Reboot your PC because sometimes the serial port can lock up.

If a “Serial port...already in use” error appears when uploading.

Second is how to choose proper threshold which determines the status of bionic hand (open\close). The solution was by trial and error; which is a fundamental method of solving problems. It is characterized by repeated, varied attempts which are continued until success.

CHAPTER4: MECHANICAL DESIGN OF THE WHEELCHAIR

4.1 Wheelchair design

A force is the amount one object tries to push or pull another object. The earth exerts a force on every object, pulling it towards the ground. This is known as the force due to gravity, and the center of gravity of an object is the point where it can be balanced.

Building wheelchair system basically based on mechanical studying. There are two mechanical parts have been studied in this project, the dimensions of all parameters (seat, motors, wheels, gear, batteries and drive kit), the other part was the power calculations.

Operation of the Wheelchair: in this system some advanced voice commands are designed so that the user can choose the speed. The user can select the speed in two levels, either slow or fast speed to move. For example if the user need only to move in a short distance or to approach object, he should use the slow speed. This speed selection is important for safety and extra maneuverability of the user.

The main part of the design is to control the motion of the wheelchair. The working principle of the wheel chair based on the voice recognition. There are four types of motions considered, moving forward, moving in reverse direction, moving to the left and moving to the right. For the speed, the user may use slow or fast speed. Slow speed is important as the user want to move in short distance or approaching an object. The system starts by applying the supply voltage to the speech recognition circuit. The system will be in stand by condition in which the LED on circuit recognition board will be turned on.

The direction and speed of the wheelchair depends on the user. For the forward command the wheelchair moves in forward direction. For the reverse direction the opposite movement of wheel rotation will occur. The left command will make right wheel moves forward and left wheel moves backward. The right command makes left wheel moves forward and right wheel rotate backward. In this system, by assigning the word command

stop the rotation of both motors will stop. The wheelchair system will go back to the stand by condition or end the whole system by turning off the power supply of the speech recognition board, the weight of wheelchair contains the weight of seat, wheels, motors, batteries and motor drive.

The system can be controlled in two speed conditions, fast and slow. For fast condition the system will supply higher current to the motors. If the user does not want the wheelchair to move in high speed, the slow speed can be set by applying low current supply to the motors. (G.Pacnik, 2005).

Chapter 5 :RESULTS AND DISCUSSION

After the design and development of the wheel chair with respective interfacing circuits, the technology will be tested for the motion of the wheel chair using trained voice. The proposed design was implemented using modern concept. This would be implemented for disabled people after having the smoothly furnished design of the wheel chair.

Results: The important aspect of the wheelchair system is to find its velocity. While the voice controlled wheelchair moving in a straight line, the distance and time is noted for velocity. The velocity of the wheel chair needs to be experimented under two conditions. First the velocity is observed in unloaded condition. The wheelchair was made to move in a straight line and the velocity is found 1.53ft/s. Secondly, with 15kg loads was allowed the wheelchair to carry the load and the velocity was found 1.24ft/s. Finally a person weighing 30kg was seated at the wheelchair. The voice controlled wheelchair was allowed to move in a straight line. The velocity of the wheel chair with this load is 1.21ft/s. Based on the above result, the velocity of voice controlled wheelchair is affected by the load. It is observed that the velocity of the wheelchair system will decrease proportional to the load that is carried by the system.

Discussion: This proposed system contributes to the self-dependency of physically challenged and older people. It reduces the manual effort for acquiring and distinguishing the command for controlling the motion of a wheelchair. The speed and direction of the wheelchair now can be selected using the specified commands. Thus the only thing needed to ride the wheelchair is to have a trained voice. Besides that, the development of this project is done with less cost and affordable. However this system requires some improvements to make it more reliable. This design could be improved by implementing wireless communication, using sensors to detect obstacle in the wheel chair. By improving this system, we directly enhance the life style of the disabled people in the community. Lastly, we hope that this kind of system could contribute to the evolution of the wheelchair technology.

CHAPTER 6 : CONCLUSIONS AND FUTURE ADVANCES

The social need is the independence of the physically challenged people. The mobility of the physically impaired people is made possible by the use of wheelchairs. Initially manual driven wheelchairs were used by physically handicapped people. However, the electrically driven wheelchairs are gaining popularity in the society.

The aim of the project was to design a voice controlled wheelchair for disabled people usually depend on others in their daily life especially in getting from one place to another. From the above results and discussions following conclusion can be drawn. The voice controlled wheel chair runs successfully with a speed 0.5 m/s for 40kg load.

The wheelchair responds to the voice command from its user to perform any movement functions. The basic movement functions includes forward direction, left and right turns and stop. In order to recognize the spoken words, the voice recognition processor must be trained with the word spoken out by the user who is going to operate the wheelchair. This voice operated wheel chair will assist the handicapped persons to make them self-dependent for the purpose of movement for which these people are dependent on other most of the times. A person with disabled with legs and arms can use this wheel chair efficiently if he is able to speak, the motor drive and control system of the intelligent wheelchair has been presented.

The proposed Arduino based voice operated intelligent wheelchair would bring more convenience for the disabled people. The technology can also enhance safety for users who use ordinary joystick-controlled powered wheelchairs, by preventing collisions with walls, fixed objects, furniture and other people.

A map and GPS system can be added to Arduino and by naming the places, wheelchair can go automatically to required place without commands of directions.

Ultrasonic and infrared sensors can be added to avoid obstacles in the way of the chair, and also joystick can be added to control the wheelchair manually in an emergency situation. A camera can be added to back of the wheelchair and a small LCD screen to let the user see without moving.

REFERENCES

- Furni, S. 1989. *Digital Speech Processing, Synthesis and Recognition*. Marcel Dekker.
- Dote, Y. 1990. *Servo Motor and Motion Control Using Digital SignalProcessors*
- Miller, D. and Grant, E. *Design & Testing of a Low Cost Robotic Wheelchair Prototype*.
Proceedings of CIRFSS'94.
- Colwell, John. "Design for ECE 249 car." May 22nd, 1997.
- ARDUINO. (n.d.). *ComponentLib/Servo*. Retrieved 10 14, 2014, from arduino:
<http://playground.arduino.cc/ComponentLib/Servo>.
- Carr, Joseph J. Brown, John M. (2001). *Introduction to Biomedical Equipment Technology (4th Edition)*. New Jersey: Prentice Hall.
- McRoberts, M. (2013). *Begining Arduino, 2nd Edition*. New York: Apress.
- Rory A. Cooper, "Intelligent Control of Power Wheelchairs", *IEEE Engineering Medicine and Biology*, 1995.
- G.Pacnik, "Voice Operated Intelligent Wheelchair-VOIC", *IEEE International Symposium on Industrial Electronics (ISIE)*, 2005.
- Ruei-Xi Chen, Liang-Gee Chen, Lilin Chen, "System design consideration for digital wheelchair controller", *IEEE Transactions on Industrial Electronics*, 2000.
- H. R. Singh, Abdul Mobin, Sanjeev Kumar, Sundeep Chauhan and S. S. Agrawal, "Design and Development of Voice/Joystick Operated Microcontroller Based Intelligent Motorised Wheelchair", *IEEE Tencon*,, 1999
- Bell, T., & Phillips, T. (2008, May 6). A solar flare. *Science @ NASA Podcast*. Podcast retrieved from <http://science.nasa.gov/podcast.htm>
- Simpson, R.C., Levine, S.P. *Voice control of a power wheelchair*. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*. 2002
- Curtis, KA, Dillon, DA. *Survey of wheelchair athletic injuries: common patterns and prevention*.*Paraplegia*. 1985;23:170–175.
- Nichols, P, Norman, PA, Ennis, JR. *Wheelchair user's shoulder*. *Scand J Rehabil Med*. 1979;11:29–32.

APPENDICES

Appendix A: Arduino code

```
//Import the Bitvoicer library.
#include <BitVoicer11.h>

//Initiate the BitVoicer Serial Class.
BitVoicerSerialbitVoicer = BitVoicerSerial();

int V5 = 13; //power to the motor driver circuit
int DIR1 = 2; //direction of the first motor
int DIR2 = 4; //direction of the second motor
int PWM1 = 3; //speed of fist motor
int PWM2 = 6; //speed of the second motor
int SPEED = 255;

void setup()
{
    //Starts serial communication and sets up the pinModes
    Serial.begin(9600);
    pinMode(DIR1, OUTPUT); //Set control pins to be outputs
    pinMode(DIR2, OUTPUT);
    pinMode(PWM1, OUTPUT);
    pinMode(PWM2, OUTPUT);
    pinMode(V5, OUTPUT);
}
```

```

        //to stop everything at the startup when connect the arduino to pc
digitalWrite(V5, LOW);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
digitalWrite(DIR1, 1);
digitalWrite(DIR2, 1);
}
void loop()
{
    //Retrieves data from serial buffer
bitVoicer.getData();

if (bitVoicer.strData == "")
{
    return;
}

if (bitVoicer.strData == "forward_along")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 high, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
}
}

```

```

else if (bitVoicer.strData == "forward_one_meter")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 high, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(2000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
}
else if (bitVoicer.strData == "forward_three_meters")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 high, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(6000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
}

```

```

else if (bitVoicer.strData == "forward_ten_meters")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 high, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(20000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
}

else if (bitVoicer.strData == "backward_along")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 0); //Set motor direction, 1 low, 2 low
digitalWrite(DIR2, 0);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
}

else if (bitVoicer.strData == "backward_one_meter")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 0); //Set motor direction, 1 low, 2 low
digitalWrite(DIR2, 0);

```



```

analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(2000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
}
else if (bitVoicer.strData == "turn_right_ninety_degree")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 low, 2 low
digitalWrite(DIR2, 0);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(1000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
(bitVoicer.strData = "stop");
}
else if (bitVoicer.strData == "turn_right_forty_five_degree")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 low, 2 low
digitalWrite(DIR2, 0);
analogWrite(PWM1, SPEED);

```

```

analogWrite(PWM2, SPEED);
    delay(500);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
(bitVoicer.strData = "stop");
    }
    else if (bitVoicer.strData == "turn_right_hundred_eighty_degree")
    {
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 low, 2 low
digitalWrite(DIR2, 0);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(2000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
(bitVoicer.strData = "stop");
    }
    else if (bitVoicer.strData == "turn_left_ninety_degree")

    {
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 0); //Set motor direction, 1 low, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);

```

```

analogWrite(PWM2, SPEED);
    delay(1000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
}
else if (bitVoicer.strData == "turn_left_forty_five_degree")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 0); //Set motor direction, 1 low, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(500);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
}
else if (bitVoicer.strData == "turn_left_hundred_eighty__degree")
{digitalWrite(V5, HIGH);
digitalWrite(DIR1, 0); //Set motor direction, 1 low, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(2000);

```

```

analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
}
else if (bitVoicer.strData == "exit_from_right")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 low, 2 low
digitalWrite(DIR2, 0);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(1000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
(bitVoicer.strData = "stop");
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 high, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(2000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
digitalWrite(V5, HIGH);

```

```

digitalWrite(DIR1, 0); //Set motor direction, 1 low, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(1000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
}
else if (bitVoicer.strData == "exit_from_left")
{
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 0); //Set motor direction, 1 low, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);
    delay(1000);
analogWrite(PWM1, 0);
analogWrite(PWM2, 0);
bitVoicer.strData = "stop";
digitalWrite(V5, HIGH);
digitalWrite(DIR1, 1); //Set motor direction, 1 high, 2 high
digitalWrite(DIR2, 1);
analogWrite(PWM1, SPEED);
analogWrite(PWM2, SPEED);

```

```

        delay(2000);
    analogWrite(PWM1, 0);
    analogWrite(PWM2, 0);
    bitVoicer.strData = "stop";
    digitalWrite(V5, HIGH);
    digitalWrite(DIR1, 1); //Set motor direction, 1 low, 2 low
    digitalWrite(DIR2, 0);
    analogWrite(PWM1, SPEED);
    analogWrite(PWM2, SPEED);
        delay(1000);
    analogWrite(PWM1, 0);
    analogWrite(PWM2, 0);
    (bitVoicer.strData = "stop");
    }
    else if (bitVoicer.strData == "stop")
    {
        digitalWrite(V5, LOW);
        analogWrite(PWM1, 0);
        analogWrite(PWM2, 0);
        digitalWrite(DIR1, 0); //Set motor direction, 1 low, 2 low
        digitalWrite(DIR2, 0);
    }
}

```

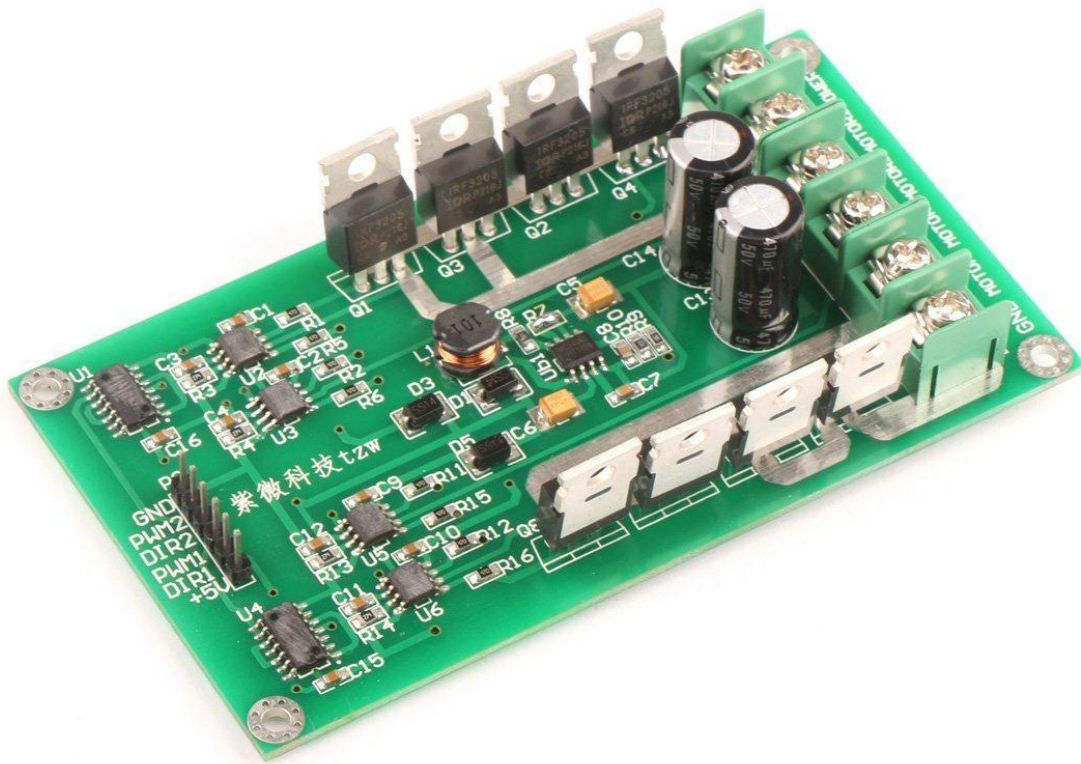
Appendix B: wheelchair design



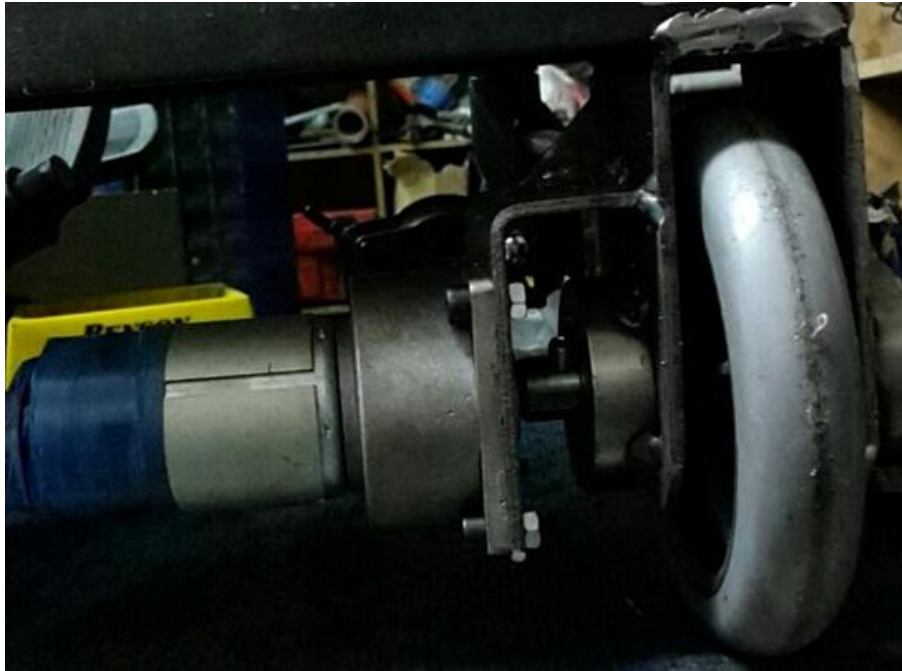
Appendix C: wheelchair batteries



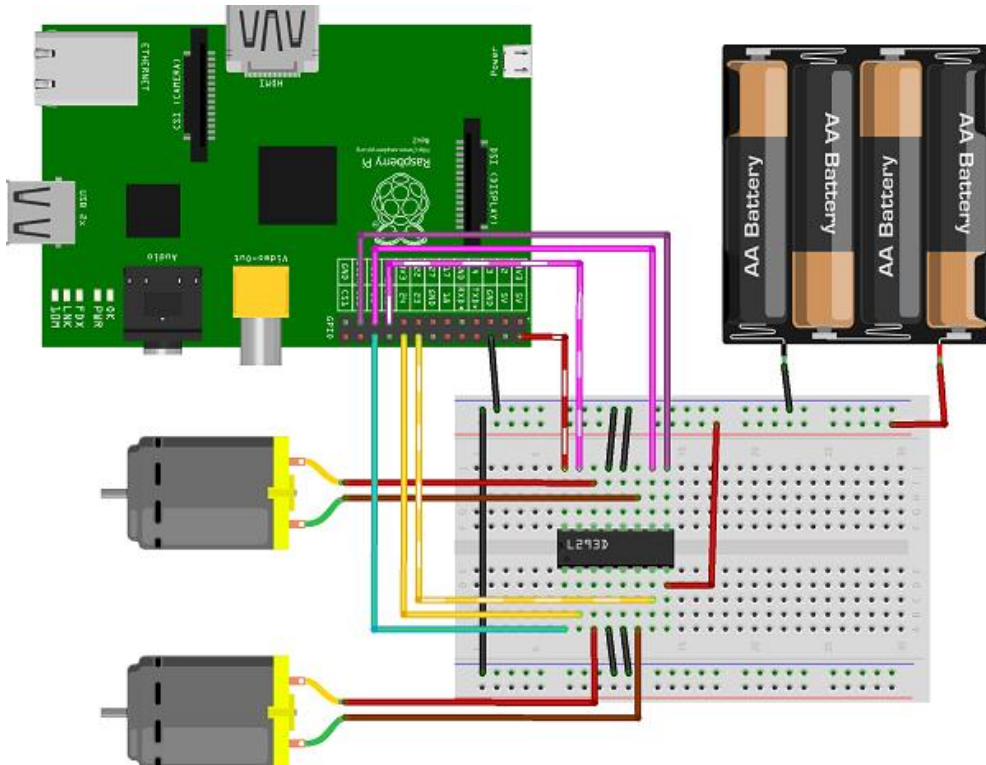
Appendix D: dual H-bridge motor driver



Appendix E: wheel bearing



Appendix F: Prototype circuit



Appendix G: Power calculations

Weight of the Wheelchair:

$$W = \text{mass} * g$$

Reaction of the incline:

$$R = W * \cos(\text{the phase})$$

Friction force

$$f_x = \mu_{\text{max}} \times R$$

Weight opposite the direction of the movement:

$$W_x = W * \sin(\text{the phase})$$

At equilibrium

$$\Sigma F_x = F - f_x - W_x = 0$$

$$F = f_x + W_x$$

Torque at the wheel

$$T = F \times r \text{ [7]}$$

Calculation of rpm:

$$V = 2\pi r \times \text{RPM} \times (60/1000) \text{ km/hr}$$

$$\omega = \text{RPM}/60$$

$$\text{POWER} = I * V$$