

DESIGN AND FABRICATION OF HEAD GESTURE CONTROLLED WHEELCHAIR

FINAL YEAR PROJECT REPORT



This report is presented as part of Degree of
Bachelors of Science in Avionics Engineering

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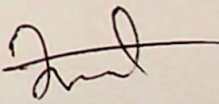
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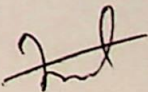
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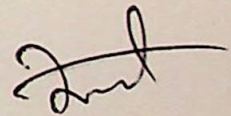
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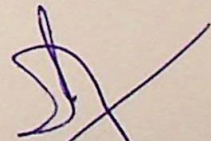
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APPROVAL

The Department of Avionics Engineering of The Superior College, Lahore has approved this work; entitled "**Design and Fabrication of Head Gesture Controlled Wheelchair**" for fulfillment of the requirements for the degree of "**Bachelors of Science in Avionics Engineering**"



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ABSTRACT

Head movement electronic wheelchair is a basic wheelchair which is modified to work through the motion of the head. This type of wheelchair is made for the patients who're not able to transport their body and are dependent on the other person for their movement. So, our projects solve the problem to some extent. The head set has an accelerometer which sends the position of the head to the microcontroller Arduino mega 2560. The controller then follows a control algorithm and sends the commands to the motor driver H-bridge circuit to drive the motors accordingly. Old homes, hospitals and bed ridden soldiers are the application of this type of wheelchair.

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CHAPTER 1: INTRODUCTION

Most precious thing in the world is life. Paralysis is one the biggest problems in the world in which a person loses the ability to move its body part. Paralyzes is caused by many reasons. In most cases of paralysis, people cannot use their legs nor their arms. Or they are born with this disability. They also lose their body parts in accidents. So, for their mobility, paralyzed person uses a wheelchair. Either he uses it manually by his hands or is dependent to other person for his mobility. For his independent movement he requires an electronic wheel chair which is very expensive and is not affordable by every paralyzed person. This wheelchair is specially made for those patients who are unable to move their body except their head. This wheelchair works by detecting the motion of the head. We used accelerometer, one of the components of the inertial measurement unit (IMU). Accelerometer detects the direction of the head and send signals to the micro-controller which is Arduino mega 2560.

The Layout we proposed is price powerful and easy. No unique calibration is needed earlier than use. The most important purpose is to convert an ordinary wheelchair available in market into a digital wheelchair managed by the head which is not being produced in Pakistan commercially.

1.1 Block Diagram

The Block diagram represents the main additives and primary functioning of our undertaking.

The inertial measurement unit is installed on the headset. The headset includes 4 main parts including a pressure sensor, a 3-axis gyroscope, a tri-axis accelerometer, and three-axis magnetic subject. We are best the use of the accelerometer in our undertaking.

The accelerometer detects the orientation of the top and sends uncooked value alerts to the microcontroller that's Arduino mega 2560. It presents ten diplomas of freedom to the person for the measurement of a body. Arduino system the information in accordance with to govern

a set of rules we proposed. The processed records are ship to the H-bridge to drive the cars for that reason. If the person moves head toward right the wheelchair right wheel stop and left wheel commenced to move therefore wheelchair movements in the proper path. If the man or woman's actions head toward left the wheelchair left wheel prevent and the right wheel started out to move hence wheelchair movements within the left path. If the individual holds his head immediately wheelchair each wheel halts and as a result, it stops. If the character bends his head forward both wheels started out to transport and as a result, wheelchair started out to transport in ahead course.

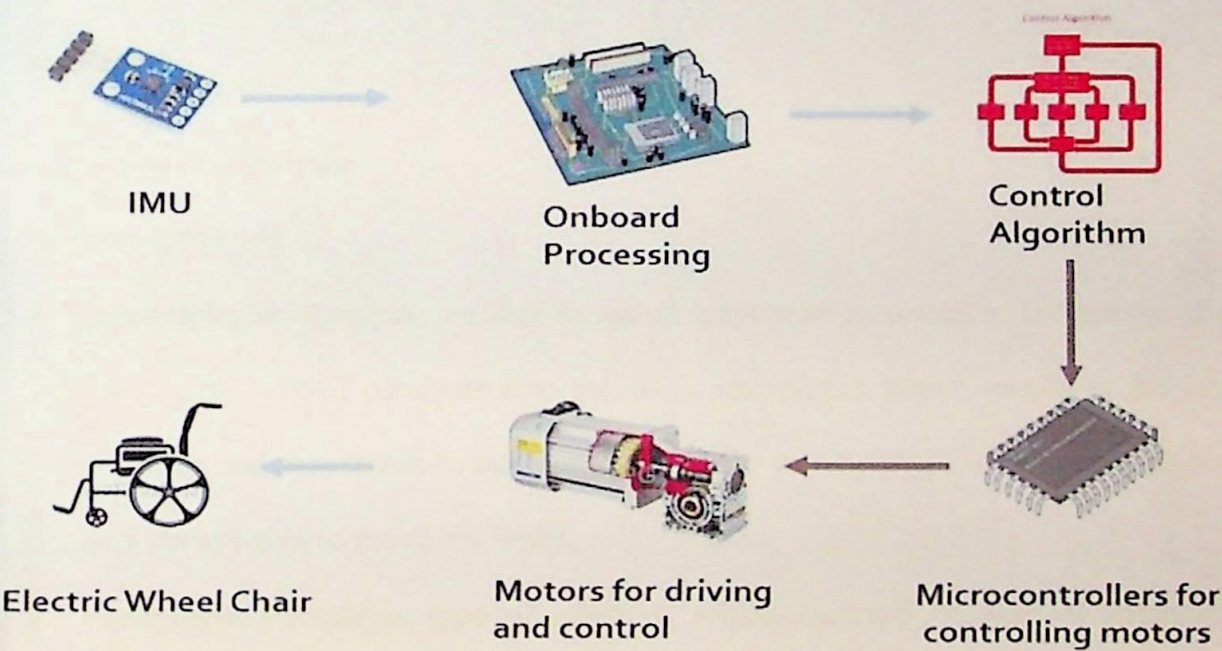


Figure 1 Block Diagram

CHAPTER 2: LITERATURE REVIEW

After advent, now we observe the development that has been made in era associated with fitness region. Design of different forms of wheelchairs have been developed for the sufferer to offer a few options for their independence in motion. Manual managed by hand, voice based, head motion and eyeball movement managed wheelchairs have been evolved for the sufferers.

2.1 Stages of paralysis

Following are the reasons for paralysis

- Accidents
- Injuries on spinal cord
- Stokes

2.2 Types of paralysis

Paralysis types are:

- **Quadriplegia:** Paralysis are due to spinal harm that outcomes in incapacity of all 4 limbs. This sort of paralysis also results in tetraplegia, which results in the lack of sensation and movement in three limbs. This the worst case in which paralysis patient isn't always able to move his limbs.
- **Paraplegia:** Paraplegia type of paralysis which incurred because of harm in the thoracic vertebra causing lack of movement in both legs.
- **Monoplegia:** Monoplegia is kind of paralysis incurred because of injury in spinal which affects the simplest one of the limbs and additionally affect apprehensive
- **Diplegia:** Diplegia is type of paralysis which affects most effective symmetrical parts of the body, generally each of the face or facets of the hands or legs.
- **Hemiplegia:** Hemiplegia is type of paralysis which leads to lack of best one side of the body. Above mentioned paralysis is triggered because of brain stroke, clots in precise

components of mind. Due to improved avenue accidents peoples are getting intense sufferer of spinal wire injuries. Soldiers get injured in struggle or from frost bites results in loss of each palms and legs.

2.3 History

Following wheelchairs have been developed for human disability

- Wheelchairs managed manually
- Wheelchairs controlled electrically
- Wheelchairs controlled by hand gestures
- Wheelchairs controlled by voice recognition
- Wheelchairs controlled by eyeball

2.3.1 Wheelchairs Managed Manually

The most inexpensive of all wheelchairs to be had for the sufferers, who're not able to transport their decrease limb or cannot walk nicely with none assistance or manual. These types of wheelchairs are used by sufferers having lowest or first diploma of paralysis.

2.3.2 Wheelchairs Controlled Electrically

These kinds of wheelchairs are made for the one's patients who're not able to transport wheelchair manually. These electronic wheelchairs are driven through cars and are powered through batteries.

This wheelchair is design for physically disable people who depends on other for their mobility even with the wheelchair. This wheelchair is designed with the user recognition voice, ultrasonic and infrared sensor systems and avoiding obstacle system has also included in this wheelchair. So, this wheelchair moves with user voice recognition and with the minimum avoidance obstacle. [1]

2.3.3 Wheelchairs Controlled by Eyeball

To control the wheelchair movement eyeball sensing is used. Camera is attached to check the eye movement. If the eye moves towards right the wheelchair moves right. If the eye moves towards left the wheelchair collectively moves towards left. Same happens for forward and backward. Software based sequence check the images taken by camera to compare with previously stored data stored in the base.[2]

2.3.4 Wheelchairs Controlled by Hand Gestures

The Hand Gesture Wheelchair is designed for the people which are disabled from both legs and hands those totally depend on other person for their mobility. However, the acceleration technology has become so advanced but still they are not so successful to made the electronic Wheelchair price constant so that every disable person can use it. This wheelchair works with the user hand gesture movements. The movements made are then interpret by the motion made by hand and then wheelchair moves according to that motion of hand. For that acceleration sensor is used in this wheelchair.[3]

2.3.5 Wheelchairs Controlled by Voice Recognition

Advancement in research and technology has shown that new sensors radar and ultrasonic technologies are major components of Electronics Travelling Aids (ETAs). These devices are majorly used by blind and physical challenged people. So by using these technology this wheelchair has been made. Any person can operate this wheelchair except those whose cannot move their neck position. Four commands are given to user start stop left and right.360 degree rotation is been placed in this wheelchair. [4]

Using high definition camera lips patterns are detected to analyze the desired required movement. It is similar to our project in recognizing the head gestures but due to complex face patterns it is hard to distinguish between the patterns.[5]

Another method to control the movement of robot is by recognizing the spatio-temporal hand gestures. This method uses two data bases. One stores predefined gestures to compare with given gesture. The success rate of correct recognition is 91.2 percent [7]

A special wheelchair for SCI (spinal cord injury) patients was developed using GPAD which uses IR sensors to recognize the hand gestures. The patient slightly moves his hand on the GPAD in four directions to move in forward, backward, left and right.[8]

Voice recognitions are widely used in smart projects and wheelchairs but so far they are not commercialized due the limited bandwidth of voice. This can be eliminated by using combination of smart obstacle avoidance with the voice-based commands to improve the results and also to commercialize these kinds of wheelchairs. [9]

There are many researchers and developers that are working or had worked on s smart wheelchair with different goals and different designs. Which is resulting in different outputs. So it necessarily means that all the products can not be the same as they use different design methods and components.[10]

Our goal is to change a normal hand managed wheelchair into an electric powered wheelchair. But from a design perspective indoor usage wheelchair are normally narrow and compact to turn easily [11]

Another entire different mechanism to control the direction of robotic wheelchair is by using flex sensors. Wheelchair direction is controlled by two fingers while speed can be automatic or can by controlled by third finger. [12]

What really makes the wheelchairs different from each-other in design perspective and operation are the components used in developing for example IR sensors, ultrasonic, cameras and gyroscope. [13]

CHAPTER 3: PROJECT DESIGN

3.1 Standard Wheelchair



Figure 2 Manual Wheelchair

The first-class of our undertaking layout is that any standard wheelchair to be had inside the marketplace can be turned into an electronic wheelchair. In our mission, we bought a trendy mild weight wheelchair from the marketplace. We attached a metal plate behind the wheelchair in order that cars can be connected on this metal plate. Also, a metal plate within the front backside is welded to the region the digital components, and batteries. After attaching these plates, the function to fold of the wheelchair have been decreased to some extent.

After this welding procedure, the frame of the wheelchair became misaligned and it required enough effort and time to realign the body and keep the stableness. We repainted the wheelchair to cowl the welded components and steel plates.

3.2 Specifications of Motors

We did research and carry out calculations regarding the motor specification for use in our undertaking. We provide you with a selection that everlasting DC car's windshield wipers motors having 12V 14W and five-ampere score and RPM 45 need to be used. The motive at the back of selecting excessive power rating is because we want our wheelchair to move easily on rough floors or terrains. Gear ratio 1:6 is used providing us sufficient torque to transport the wheelchair smoothly from stationary function without jerks. Furthermore, a good way to have clean motion and lesser noise we use helical gears instead of spur gears.

3.3 Electrical Components

Two lead-acid batteries linked in series to make overall of 24 voltage, which is the requirement of our design. These two batteries have a specification of 12 V four.2 Ah with a beginning present-day about 4A. Motors attached to these batteries drive the wheelchair consistent with the enter command. These batteries also provide the energy to electronic components which incorporates Arduino Mega 2560 controller and the Motor driving force circuit (H-bridge circuits).

The function of the H- Bridge is to pressure the cars in both clockwise and anticlockwise path. As to move the wheelchair in ahead direction each the cars must run in the same forward direction, and to move the wheelchair in right route the left motor ought to rotate anticlockwise and right motor clockwise. In this way the couple could be supplied to the wheelchair and it'll

turn in the direction of the left. So, to transport the wheelchair properly, the left motor should rotate clockwise and right motor anticlockwise.

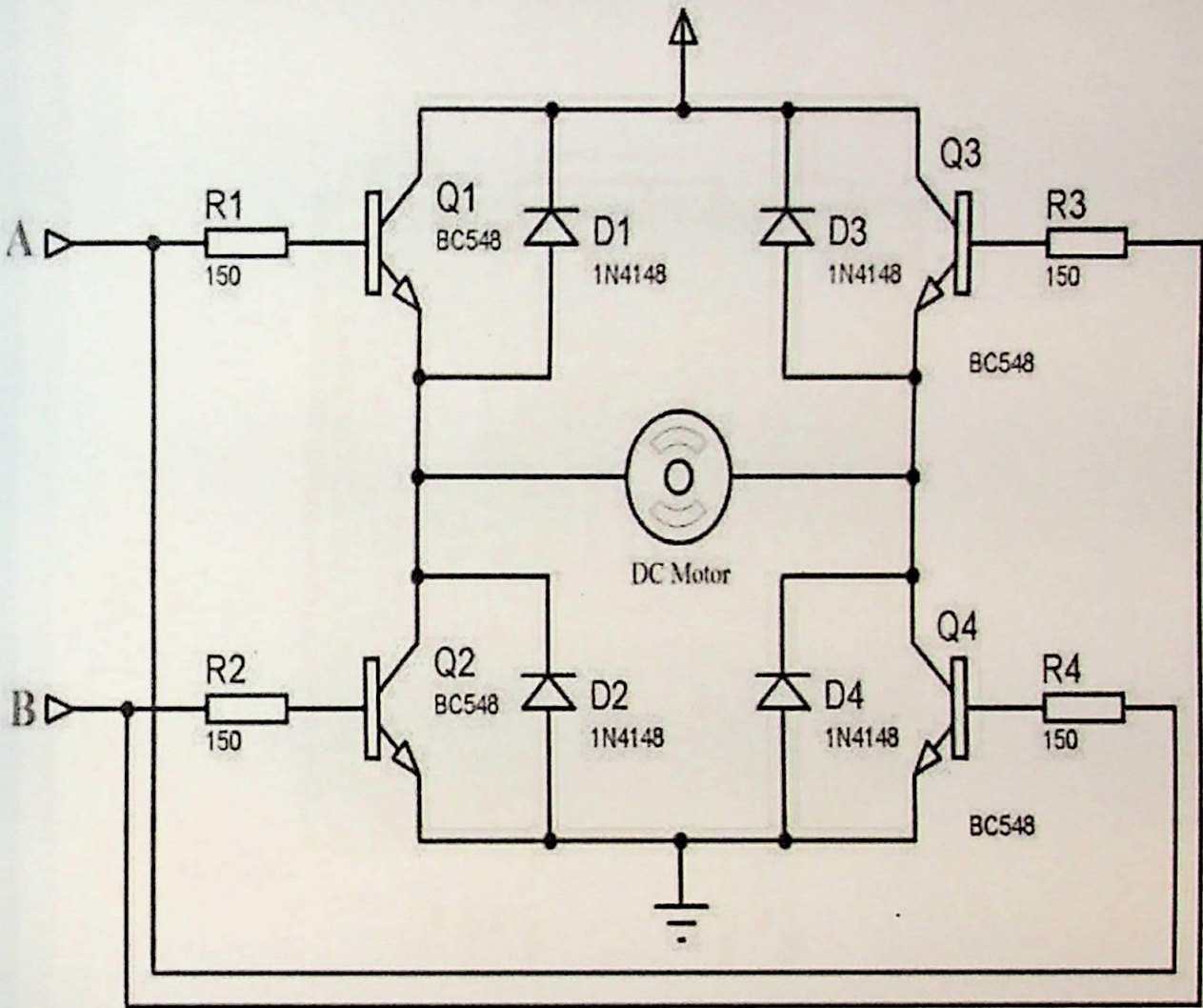


Figure 3 Motor Drive Module

The H-bridge we used is Dual channel – dual motor driving force module. This motor driving force works with a single-channel max 50A load capability. So the advantage of the use of this motor driving force module is that it's going to now not burn out effortlessly because

turn in the direction of the left. So, to transport the wheelchair properly, the
 rotate clockwise and right motor anticlockwise.

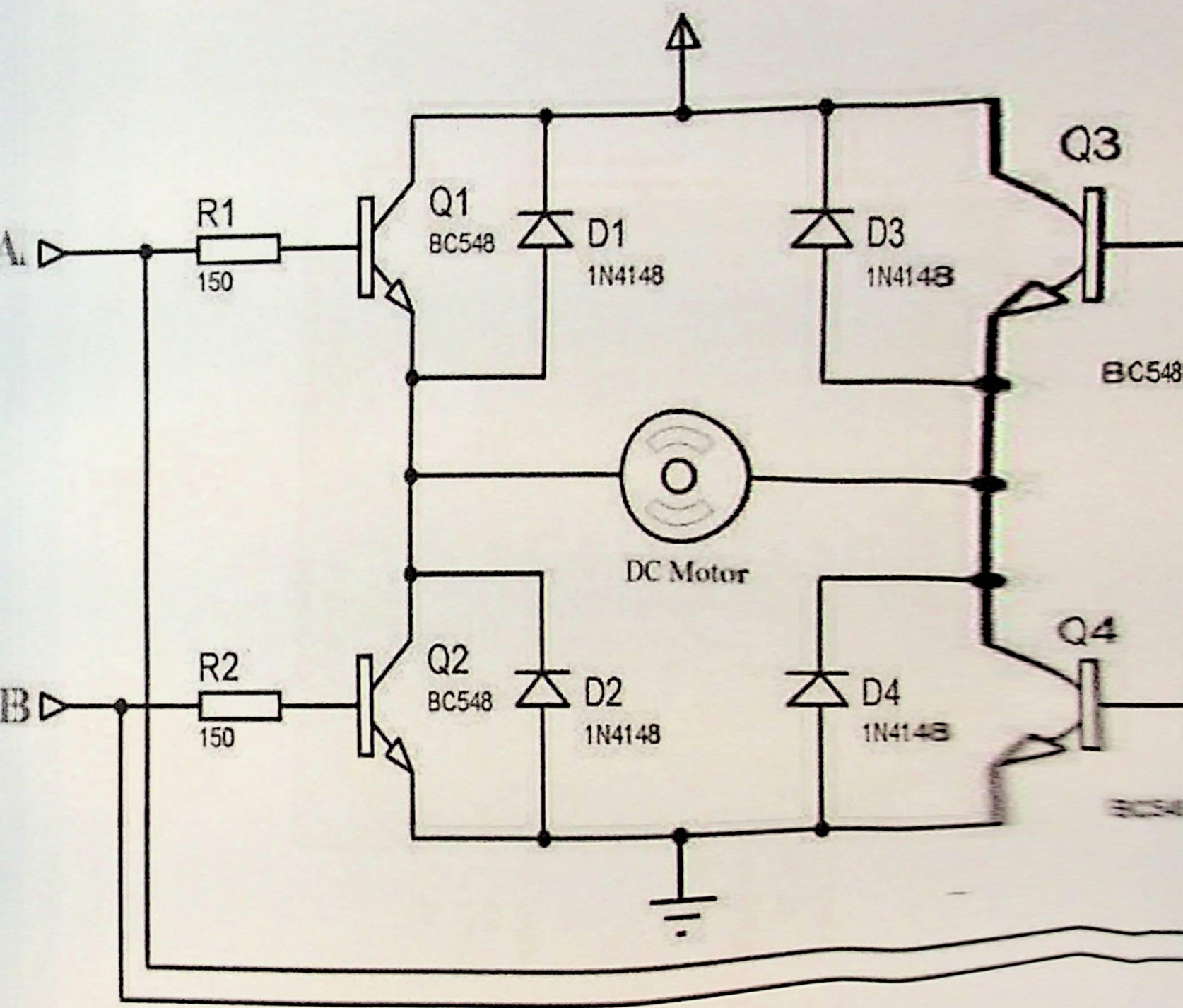


Figure 3 Motor Drive Module

The H-bridge we used is Dual channel - dual motor driving module. This driving force works with a single-channel max 50A load capability. So the use of this motor driving force module is that it's going to now not only

of its better specs and as opposed to the usage of two h-bridges, our paintings are being executed by best one module, as each the automobiles are being managed by way of.

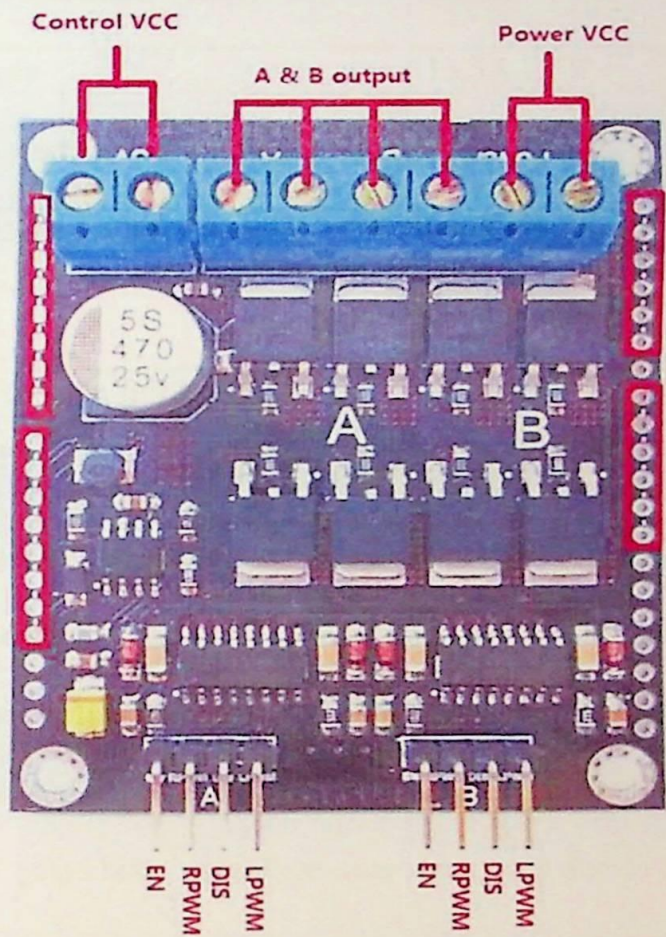


Figure 4 50 A Dual H-Bridge

A and B are the two outputs for the two motors. The power vcc pins are attached to battery where 24 V are provided to the H-bridge, which are being transferred to the motors. The control vcc is connected to Arduino, from where the signal or command is transferred to the h-bridge to control the motors accordingly. To move the motors in forward direction the LPWM pins are set HIGH and if we want to move the motors in reverse direction RPWM pins are set HIGH.

1	Weight Capacity	20kg
2	Maximum Speed	10 m/s
3	Diameter of Wheelchair Wheel	0.6 m
4	Battery Charger	15.5A 12 V
5	Battery for motors	12 V 9 A
6	Battery for electronic components	9 V 15.5 Ah
7	Motor	2 car Windshield Wiper motors
8	Batteries run time on full load	3 hours

Table 1 Technical specs

3.4 Mechanical Assembly of Motor

Two types of gears most extensively available and utilized in Pakistan are spur and helical gears. Gears having immediately tooth are known as spur gears and that they can be fabricated without problems. Teeth of the helical gears are at an angle and are tough to make in assessment to spur gears. Helical gears have advantage over spur gears due to the reality that they make less noise.

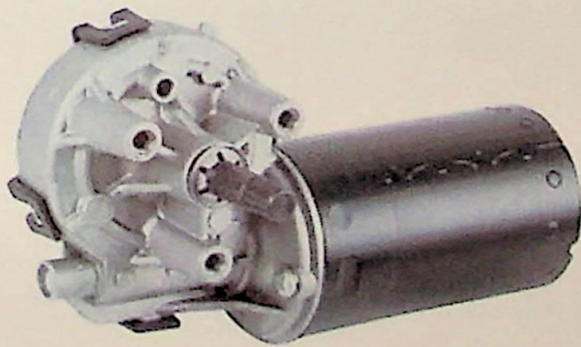


Figure 5 windshield wipers motor

Helical gears tooth interacts easily and step by step however they are much less green than spur gears. Helical gears are more long-lasting and run easily on excessive loads. Friction is greater in spur gears and because of this, they put on out speedy compared to helical gears. Considering those facts helical gears are chosen in our mechanical layout. The gear ratio was set 1:6 approach riding equipment has one third the tooth because of the driven gear. So basically, gears are being used to lessen the revolutions of the motor which turned into 180 revolutions in step with minute, which changed into too much for the wheelchair to move without delay with the vehicles without the use of gears. This equipment ratio changed into selected retaining in thoughts the safety function in conjunction with the required speed. Considering the weight of the wheelchair accompanied by electrical and mechanical components and weight of the character equipment ratio became set to obtain torque in step with our requirement.

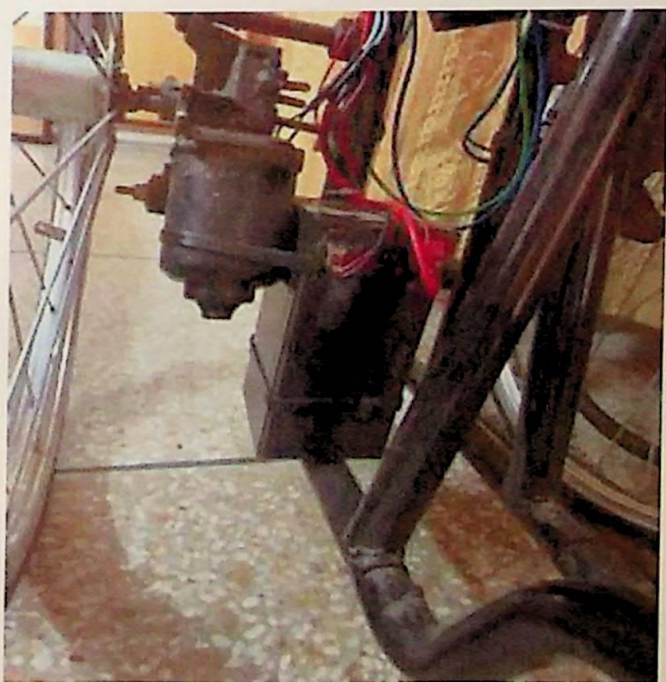


Figure 6 Motor Assembly

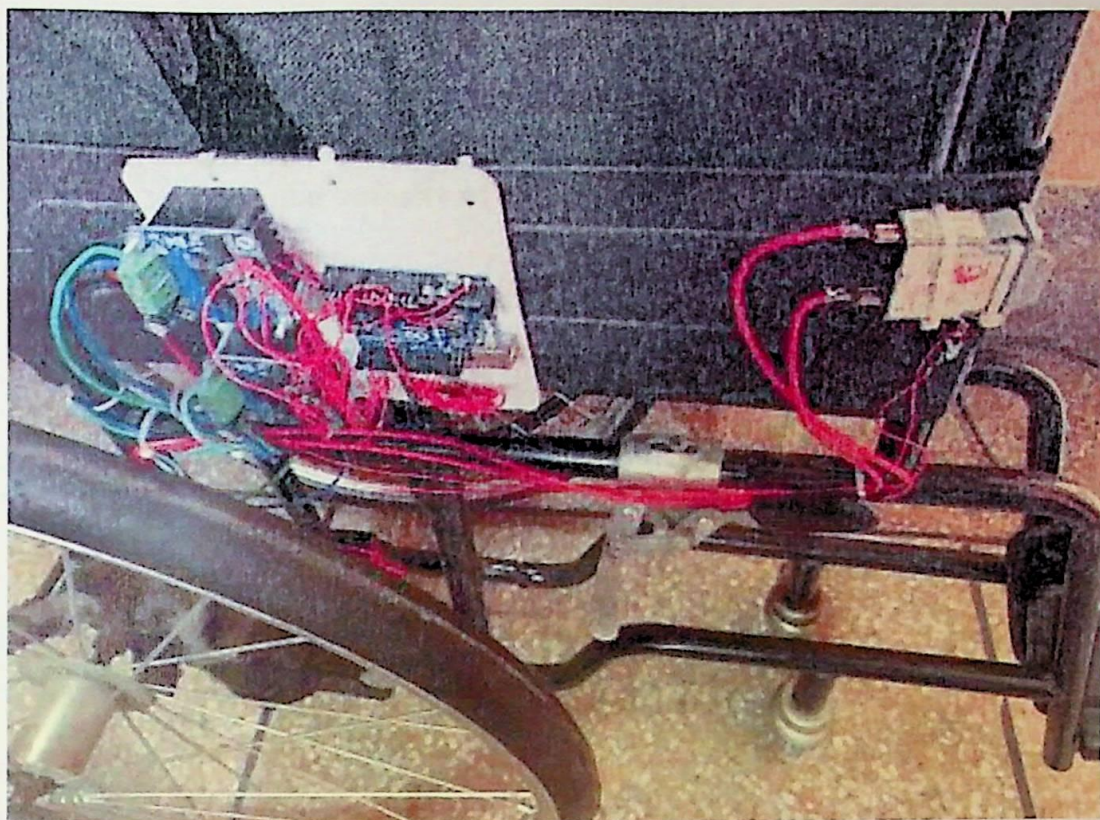


Figure 7 Complete Mechanical Design

This has been done by attaching both motors on both tires attached to the main frame of the wheelchair and bolt is used to lose or tighten the wheel.

3.5 Gear ratio

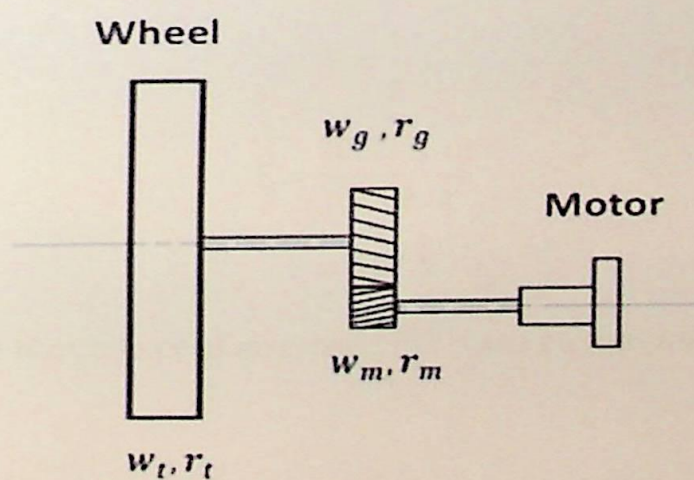


Figure 8 Gear Assembly

$$\text{RPM of motor} = 45 \text{ rpm} = 4.712 \text{ rad/sec}$$

Required wheel velocity = 1.2 m/s

Radius of wheel = 0.250 m

Angular velocity of the wheel = $v_t/r_t = 2.4$ rad/sec

$$\omega_t/\omega_g = 2.4 \text{ rad/sec}$$

$$r_g \omega_g = r_m \omega_m$$

$$r_g/r_m = \omega_m/\omega_g = 4.712/2.4$$

$$= 1.96 \approx 2$$

So approximately the gear ratio is 1:2

3.6 Torque

$$\tau = \frac{P}{\omega}$$

$$\tau = \frac{50 \text{ W}}{2.4 \text{ rad/s}}$$

$$\tau = 20.83 \text{ N.m}$$

The electric motor provides a torque of 36.36 N.m at 3.3 rad/s to each wheel of the wheelchair.

3.7 Force

$$F = \frac{\tau}{r}$$

$$F = \frac{20.83 \text{ N.m}}{0.204 \text{ m}}$$

$$F = 102 \text{ N}$$

For a torque of 20.83 N.m, a force of magnitude 102 N acts on each wheel of the wheelchair.

3.8 Inertial Measurement Unit (IMU)

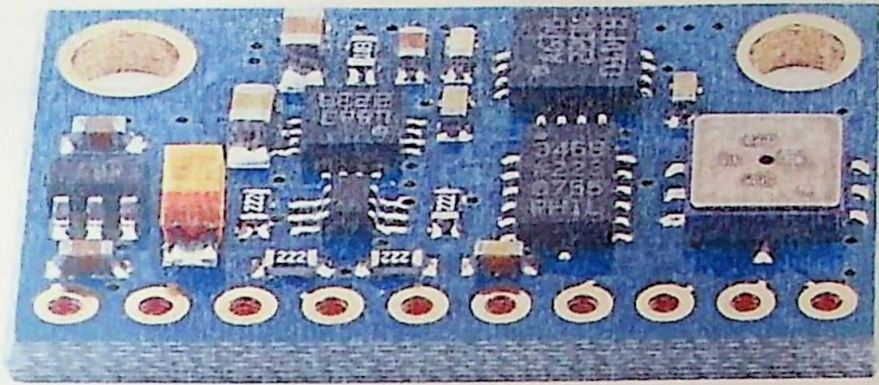


Figure 9 IMU Sensor

The IMU became located on a headset. The module became constant on the headset by way of the usage of double tape at the hair band. A photograph is represented as:

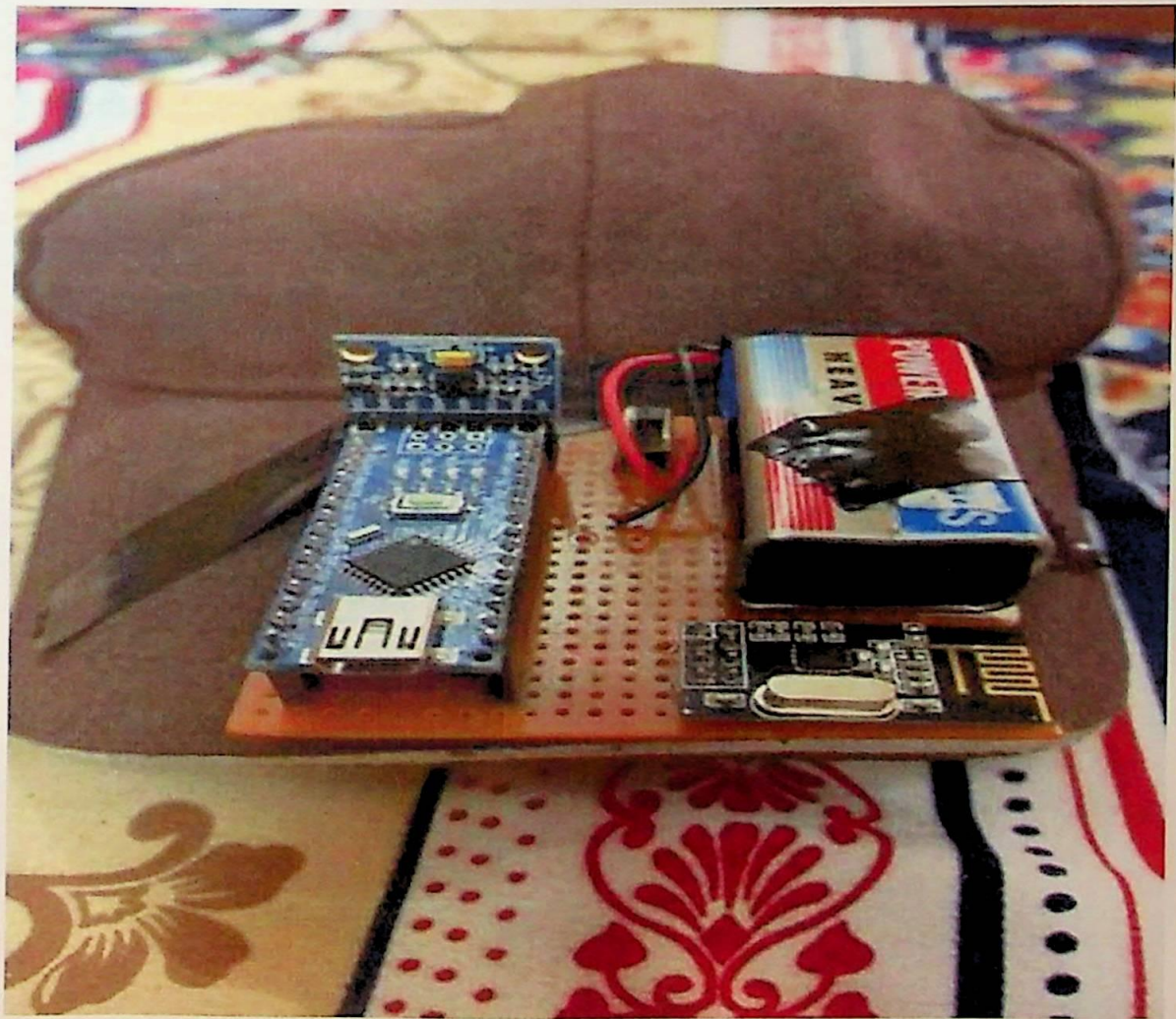


Figure 10 Headset Assembly

The sensor that we've got used for the orientation of the head is an IMU GY-eighty. It consists of an accelerometer, a gyroscope, a magnetometer, and a barometer. In our challenge, we're using a 3-axis accelerometer (ADXL345).

So, there are 3 axis x, y, and z. The ahead motion is due to x-axis acceleration and the proper and left movement is accomplished through the y-axis in which the z-axis is used as a reference acceleration. When the accelerometer is tilted to some angle it gives us some raw acceleration value. While it is tilted downwards, x-axis acceleration is compared with the gravitational acceleration to present us raw values of acceleration in the x-axis, in addition, is the case for the y-axis

These uncooked values of x and y-axis accelerations are transformed into ranges on the subject of z-axis using arc tan formula given as:

$$\tan^{-1} \frac{a_y}{a_t} = \phi \quad \text{For forward and stop motion}$$

$$\tan^{-1} \frac{a_x}{a_u} = \phi \quad \text{For left and right motion}$$

3.9 Microcontroller interface

The specifications of microcontroller Arduino Mega (2560) we use in our project are as follows:

Width of Data Bus	8 bit
Architecture	RISC
No. of Instructions	125
General Purpose Working Registers	32 x 8
Throughput	16 MIPS at 16 MHz
Non-volatile memory	32 KB
Data retention	20 years at 85 °C/ 100 years at 25 °C
EEPROM	1024 Bytes
Write/Erase Cycles	10,000 Flash/ 100,000 EEPROM
8-bit Timer/Counter	1
16-bit Timer/Counter	1
ADC Resolution	10 bit
Serial USART	1
Master/Slave SPI	1
PC	1
I/O Lines	22
Pin Package	QFN32 (5x5mm) / TQFP32 packages

Table 2 Microcontroller specs

If we want to trail the head movement, we constantly gain the readings from the sensor to produce the motion commands to the automobiles. The controller right here gets these readings from the IMU sensor and then translate them the usage of the manipulate set of rules to decide the motion commands.

CHAPTER 4: WORKING OF PROJECT

4.1 Working Principle

Now we appearance the working principle of our challenge via the use of little by little method. The IMU sensor attached on the headset offers the movement commands by using detecting the orientation of the head.

Following are the commanding options available for patient.

- Forward command

By tilting his head in forward direction at the angle of 20 degrees

- Stop Command

By keeping the head in straight position

- Right Command

By tilting his head towards right at the angle of 20 degrees

- Left Command

By tilting his head towards left at the angle of 20 degrees

When the user is sitting in the wheelchair with an instantly head function, the stop condition is being met and wheelchair shows no reaction. Now if the consumer needs to transport in ahead direction, he has to tilt the top 20 ranges downward. As lengthy as the user's head orientation is extra than 20 levels downward, the wheelchair will maintain to move forward until consumer return the top to less than 20 levels, where prevent circumstance units proper. Similarly, is the case for the left and right situations. The microcontroller, Arduino Mega 2560, receives new values from the accelerometer after each 100ms. So if the forward command is true, the H-bridge allows both the motors to power up at the same instant and hence wheelchair moves Forward. When ahead loop is accomplished the LPWM pin of H-bridge of each the left and proper vehicles is set to HIGH therefore each wheel start to circulate in ahead direction. When the Stop loop is carried out the ENABLE pins for both vehicles are set to LOW for this

reason both wheels stop. When the Right loop is performed the LPWM pin for left motor is about to HIGH and RPWM pin for Right motor is ready to HIGH, hence wheelchair turns in the direction of right. When the Left loop is executed the LPWM pin for Right motor is set to HIGH and RPWM for left motor is set to HIGH. Hence wheelchair turns toward Left.

Arduino is likewise powered with the aid of the 24 V batteries source. As the microcontroller Arduino Mega 2560 operates on low voltage and modern, so a circuit become had to decrease the voltage coming from the battery to strength the controller. This changed into completed by using regulator IC which converts down the voltage from 24 V to nine V.

Another function of moving the wheelchair backward isn't brought inside the project preserving in account the protection functions of the patient as he's unable to look again.

4.2 Control Algorithm

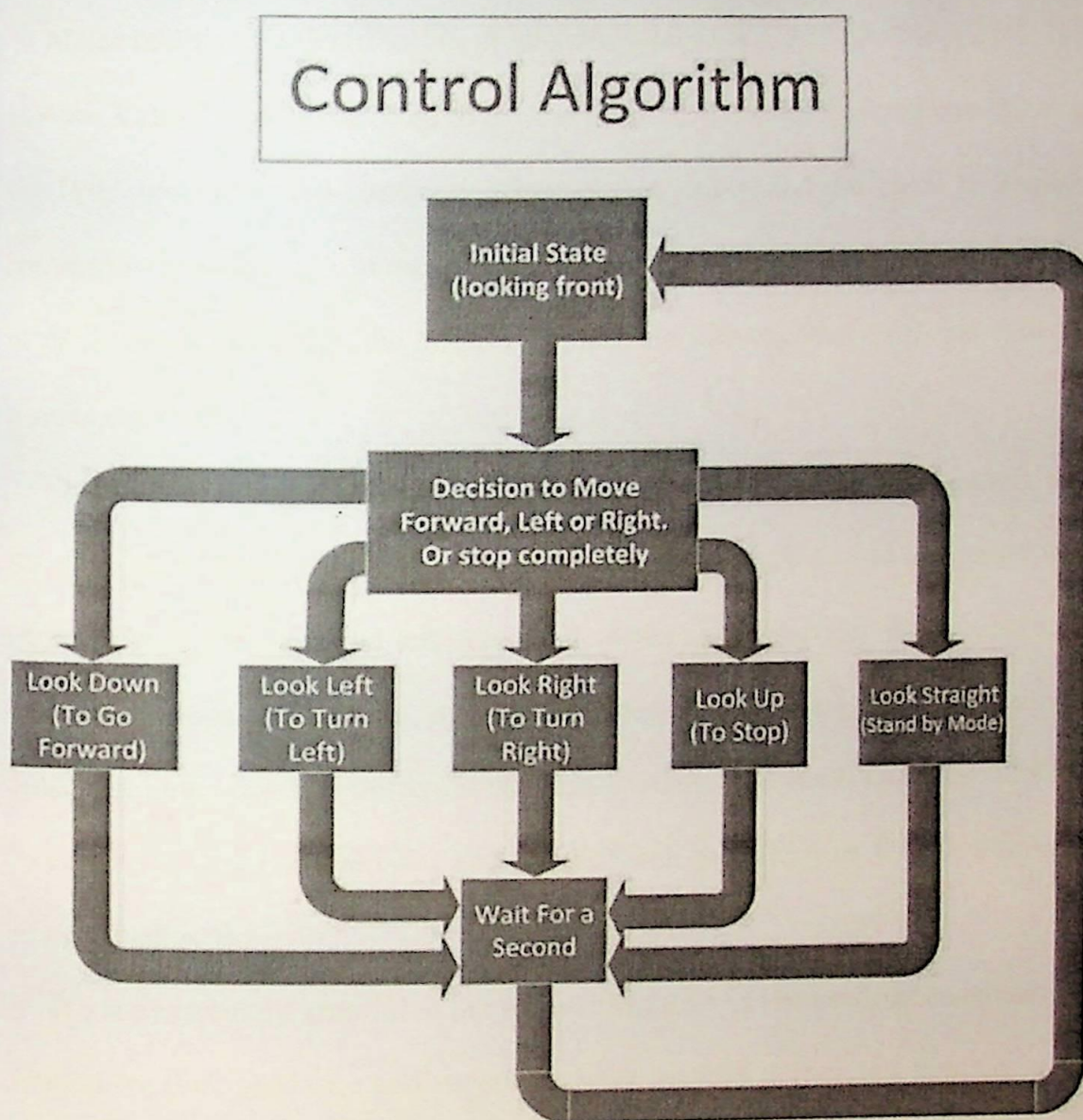


Figure 11 Movement Commands

Head moved forward $> 20^\circ$	Wheelchair moves forward
Head moved backward $< 20^\circ$	Wheelchair stops
Head moved right $> 20^\circ$	Wheelchair rotates right
Head moved left $< -20^\circ$	Wheelchair rotates left

CHAPTER 5: CONCLUSION AND FUTURE WORK

5.1 Conclusion

Major additives utilized in our project are IMU sensor, Arduino Mega 2560, H-bridge and motors. Values from the motion of head is given by means of the accelerometer established on the IMU sensor, micro-controller receives that values and processed it. These processed commands are then ship to the h-bridge to operate the automobiles consequently. Processing of the instructions within the micro-controller are accomplished consistent with our designed control algorithm.

Four commanding action can be accomplished by using patient; ahead, proper, left, forestall. By tilting his head in the direction of forward wheelchair actions in forward direction and identical goes for right and left command. When man or woman maintain his head instantly wheelchair stops. In addition, by means of absolutely unscrew the bolt at the motor plate in order that gears can be indifferent user can operated wheelchair manually. This product may be commercialized in Pakistan and sufferers can get gain from it and we've taken steps to commercialize it.

We are extremely grateful to our advisor Mr. Ahmad Hammad and co-advisor Eng. Khizer Ahmad for their guidance and support through the final year project from the very beginning to the completion.

5.2 Future Works

5.2.1 Obstacle Detection System

Currently there may be no such mechanism for obstacle detection, however a gadget may be introduced in one of these ways that if a few impediments are detected the wheelchair should stop to avoid any collision or incident.

5.2.2 Health Monitor

A fitness tracking system need to be brought within the wheelchair such that it can degree simple facts about health, together with temperature, blood strain and pulse and so forth. Upper and decrease degrees must be described and straight away emergency indication should be furnished to the care taker on crossing those stages.

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APPENDIX

/*

CONNECTIONS: nRF24L01 Modules See:

1 - GND

2 - VCC 3.3V !!! NOT 5V

3 - CE to Arduino pin 7

4 - CSN to Arduino pin 8

5 - SCK to Arduino pin 13

6 - MOSI to Arduino pin 11

7 - MISO to Arduino pin 12

8 - UNUSED

*/.

#include <SPI.h>

#include <nRF24L01.h>

#include <RF24.h>

/*--0---(Declare Constants and Pin Numbers)-----*/

#define CE_PIN 9

#define CSN_PIN 10

// NOTE: the "LL" at the end of the constant is "LongLong" type

const uint64_t pipe = 0xE8E8F0F0E1LL; // Define the transmit pipe

```

#define speed_pin1 6

//#define speed_pin2 10

#define IN_1 2 // L298N #2 in 1 motor Front Left
#define IN_2 3 // L298N #2 in 2 motor back Left
#define IN_3 4 // L298N #2 in 3 motor Back Right
#define IN_4 5 // L298N #2 in 4 motor Front Right

/*-----( Declare objects )-----*/
RF24 radio(CE_PIN, CSN_PIN); // Create a Radio

/*-----( Declare Variables )-----*/
int joystick[2]; // 6 element array holding Joystick readings
int speed = 0;
int xAxis, yAxis;

// the four button variables from joystick

long dis_f=0;
int state,run;

void setup(){
pinMode(IN_1, OUTPUT);
pinMode(IN_2, OUTPUT);
pinMode(IN_3, OUTPUT);
pinMode(IN_4, OUTPUT);

```

```

pinMode(speed_pin1, OUTPUT);
//pinMode(speed_pin2, OUTPUT);
Serial.begin(9600);
Serial.println("Nrf24L01 Receiver Starting");
radio.begin();
radio.openReadingPipe(1,pipe);
radio.startListening();
}

void loop(){
if (radio.available()>0){
radio.read( joystick, sizeof(joystick) );
xAxis = joystick[0];
yAxis = joystick[1];

if(yAxis < 470){forward();
speed = map(yAxis, 470, 0, 0, 255);}
}

if(yAxis > 550){backward();
speed = map(yAxis, 550, 1023, 0, 255);
}

if (xAxis < 470 && yAxis > 470 && yAxis < 550) {right();
speed = map(xAxis, 470, 0, 0, 255);
}
}

```

```
}
```

```
if (xAxis > 550 && yAxis > 470 && yAxis < 550) {left();
```

```
speed = map(xAxis, 550, 1023, 0, 255);
```

```
}
```

```
if (xAxis > 470 && xAxis < 550 && yAxis > 470 && yAxis < 550) {
```

```
stop();
```

```
}
```

```
Serial.print("S = ");
```

```
Serial.print(speed);
```

```
Serial.print(" ");
```

```
Serial.print("X = ");
```

```
Serial.print(xAxis);
```

```
Serial.print(" Y = ");
```

```
Serial.println(yAxis);
```

```
analogWrite(speed_pin1, speed);
```

```
//analogWrite(speed_pin2, speed);
```

```
}
```

```
void forward(){
```

```
digitalWrite(IN_1, LOW);
```

```
digitalWrite(IN_2, HIGH);
```

```
digitalWrite(IN_3, HIGH);
```

```
digitalWrite(IN_4, LOW);  
}
```

```
void backward(){  
    digitalWrite(IN_1, HIGH);  
    digitalWrite(IN_2, LOW);  
    digitalWrite(IN_3, LOW);  
    digitalWrite(IN_4, HIGH);  
}
```

```
void right(){  
    digitalWrite(IN_1, HIGH);  
    digitalWrite(IN_2, LOW);  
    digitalWrite(IN_3, HIGH);  
    digitalWrite(IN_4, LOW);  
}
```

```
void left(){  
    digitalWrite(IN_1, LOW);  
    digitalWrite(IN_2, HIGH);  
    digitalWrite(IN_3, LOW);  
    digitalWrite(IN_4, HIGH);  
}
```

```
void stop(){  
    digitalWrite(IN_1, LOW);  
    digitalWrite(IN_2, LOW);  
    digitalWrite(IN_3, LOW);digitalWrite(IN_4, LOW);} 
```