Hand Gesture Based Robotic Controlled Vehicle

By

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BS Thesis

In

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DEDICATION

I dedicate our project work to my Almighty ALLAH, the Holy Prophet Muhammad (S.A.W), and my country Pakistan.

I dedicate this thesis to our loving family, whose unwavering support, encouragement, and belief in our abilities have been the foundation of our academic journey. To our parents, whose sacrifices and love have been a constant source of motivation, we are forever grateful.

I extend our heartfelt appreciation to our esteemed thesis supervisor, **Dr. Zahid Mehmood Jehangiri**, for their invaluable guidance, mentorship, and expertise. Their unwavering belief in the potential of this research has inspired us to strive for excellence.

Lastly, I express our sincere thanks to the readers and reviewers of this thesis. Your insightful feedback and constructive critique have helped shape and refine this work.

To all those who have played a part, no matter how big or small, in shaping this thesis and our academic journey, we extend our deepest gratitude. This accomplishment is as much yours as it is ours, and we are forever grateful for your presence in our life.

ACKNOWLEDGEMENTS

SHUKAR ALHAMDULLILLAH First, I are thankful to Allah who gave us the power and chance to complete our thesis work. I are thankful to our parents and our teachers for their constant inspiration and prayers during the progress of this project.

I would like to express our heartfelt gratitude and appreciation to all those who have contributed to the completion of this thesis. First and foremost, I extend our thanks to our thesis supervisor, **Dr. Zahid Mehmood** and Co-Supervisor **Dr.Yasir Ali Shah** for their support, guidance, and invaluable feedback throughout the process. Their mentorship has been instrumental in shaping the direction and quality of this work.

I would like to express our appreciation to all the people who have helped us in accomplishing this dissertation.

Muhammad Ahmed FA19-BCE-020/ATD

ABSTRACT

A Hand Gesture Based Robotic Controlled Vehicle

Human vehicle interface is the interaction between human and robot. The space between the physical and the digital world is brought closer by the introduction of gesture concept. This technology of gesture recognition can be defined by the interaction between the computer and the body language of human beings. The purpose of robotics in commercial& residential intention has come to be quite essential for executing challenging work in a more conveniently simple way. The primary objective of the project is to make a robotic vehicle which can be controlled by hand gestures. In this project we are using hand gestures to control the robotic vehicle using the Arduino interface. We introduce a hand- gesture- based control interface for navigating a car-robot.

A 3-axis accelerometer is adopted to record a user's hand trajectories. It commands the carby using accelerometer sensors that are connected to a hand glove. The trajectory data is transmitted wirelessly via an RF transmitter. The received trajectories are then classified to one of five control commands for navigating a car-robot. This will allow the user to regulate actions, i.e., forward, backward, leftward, and rightward movements,

While using an equivalent accelerometer sensor to regulate the throttle of the car. It also has a great change for handicapped people.

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ABBREVIATIONS

PHRI	Physical Human Robot Interaction
HCI	Human-Computer Interaction
RGB	Red, Green, Blue
MMI	Man-Machine Interface
CNN	Convolutional Neural Network
RF	Radio Frequency
IC	Integrated Circuit
DC	Direct Current
IDE	Integrated Development Environment

Chapter 1

Introduction

1.1 Introduction

Robots are key in the automation process. Robotics is currently one of the most modern technological fields. A robot is usually an electromechanical device with automatic capabilities to perform tasks. Some robots need guidance, which can be provided by a computer interface or remote control. Robots can be fully or partially autonomous. In recent years robotshave played a great role in automations across all sectors like construction, military, medical, manufacturing, etc.

A Gesture Controlled robot is a kind of robot which can be controlled by your hand gestures not by buttons. You just need to wear a small transmitting device in your hand which contains an accelerometer. By transmitting the appropriate gesture, the robot will be controlled under the desired command.

A gesture-controlled robot is controlled using the hand, without using other methods like buttons or joystick. Here a person only needs to move their hand to operate the robot. A transmitting device is placed in the user's hand, which contains the RF Transmitter and MPU6050 which is a combination of a gyroscope and accelerometer to transmit a command to the robot so that it can perform the specified task of moving forward, back, turning left, right and stop. These commands will be identified using hand gestures.

1.2 Gesture Recognition

Gesture Recognition means defined as any physical movement, large or small, that can be interpreted by a motion sensor. Gesture recognition is a thriving field of computer science, with an international convention committed to gesture and facial recognition. As the field continues to grow, so will the way for it to be utilized. Gesture recognition processes are designed to intensify human-computer interaction, and can occur in multipleways, such as using touch screens, a camera, or other devices.

1.2.1 Hand Gesture Controlled Robot

A Gesture Controlled robot is a bot which can be controlled by your hand gestures. You just needto have a small transmitting device in your hand, which includes an acceleration meter to transmit an appropriate command to the robot so that it follow whatever command we give.

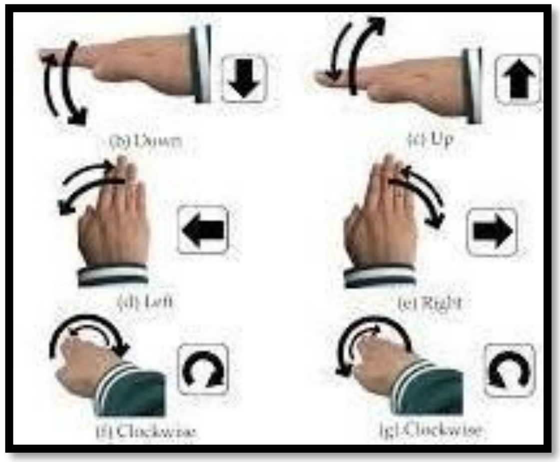

Figure-1.1: Hand Gestures [1]

1.2.2 Robotic Vehicle

A robot is an automatic machine that is capable of locomotion. Mobile robotics is mostly considered as a subfield of robotics and information engineering. Autonomous robot vehicles are vehicles capable of intelligent motion and action without requiring eithera guide or tele operator control.

Mobile robots have the capability to move around in their environment and are not fixed to one physical location. Mobile robots can be "autonomous" which means they can navigate an uncontrolled environment without the need for physical or electro- mechanical guidance devices. Alternatively, mobile robots can rely on guidance devices that allow them to travel a pre-defined navigation route in relatively controlled space.

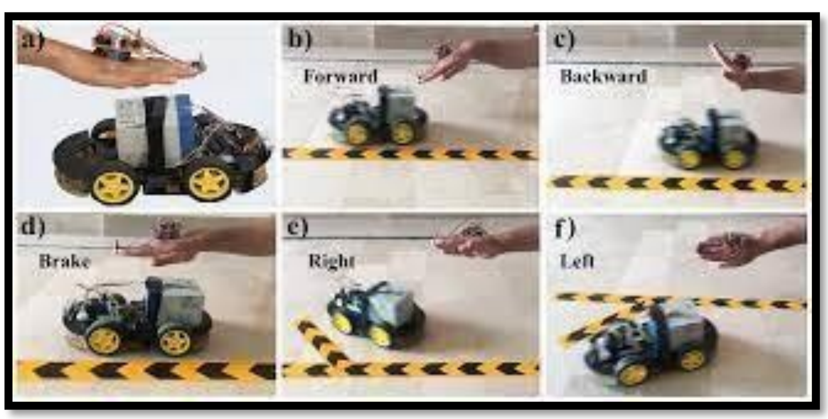

Figure-1.2: Hand Gestures Recognition [2]

1.3 Motivation

- This prototype does not need any expert. We can easily operate in a short interval which will finally reduce time and energy loss.
- It provides a more schematic way of controlling the robot.
- Also provides better living conditions for people with disabilities.
- A single equipment that can handle multiple applications.
- Less power consumption and more efficiency are also a motive behind this project.

1.4 Objectives

The aim of the project is to develop a human machine interface used to control robotic vehicle. Our objective is to make this device simple as well as cheaper, so it can be used for several purposes. This project is aimed to build a car that can be controlled by hand gestures (wirelessly). In this project, the user can control motions of the car by wearing controller glove and performing predefined gestures. This can be also used in many applications such as wireless controller car racing etc.

Chapter 2

Literature Review

2.1 Literature Review

This chapter covers the overview and standard methods on which the results were tested and, the review of the Hand gesture methods.

2.1.1 Glove based Approach

Different technologies have been implemented for hand gesture-based recognition systems. The goal is to control certain systems using different techniques. One of the most common approaches is glove based approach. In this approach there are sensors attached to glove which acquire the gestures and the signals generated by sensors are processed and corresponding instructions are performed. [3].

Figure-2.1: Glove based Gesture Recognition [3]

2.1.2 Vision based Hand Gesture Recognition

The goal of this project is to use hand gestures to operate a robot. The recorded hand pictures are processed to determine the appropriate targets. Then, to regulate the robot's motion, control signals are supplied to the receiver unit [4].

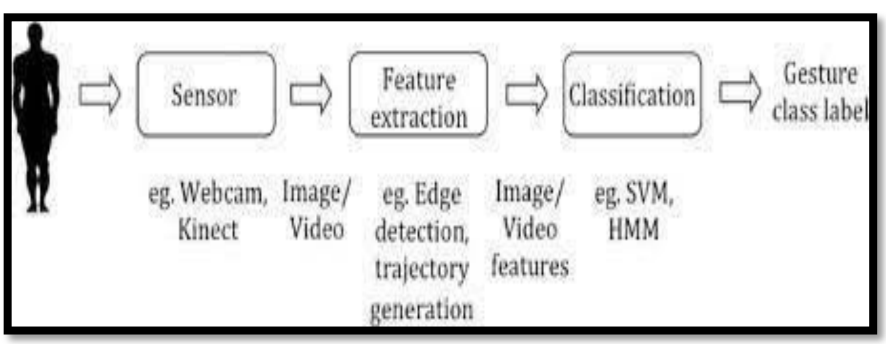

Figure-2.2: Camera based Gesture Recognition [5]

2.1.3 Sensor based Hand Gesture Recognition

This describes how humans can communicate with robots using basic hand gestures. This can be done using a Leap motion sensor. We suppose that the robot is capable of emotional interaction in this scenario. This study helps us to understand how humans can interact with a robot using effective hand gestures [6].

Figure-2.3: Sensor based Hand Gesture Recognition [6]

2.1.4 Accelerometer based Hand Gesture Recognition

A three-axis accelerometer records the user's hand motions. Any form of connection is used to provide data wirelessly to a microcontroller. Accelerometers are attached to the gloves as sensors to convert positional changes of the hand into signals which are then interpreted by the controller to perform the instructions.

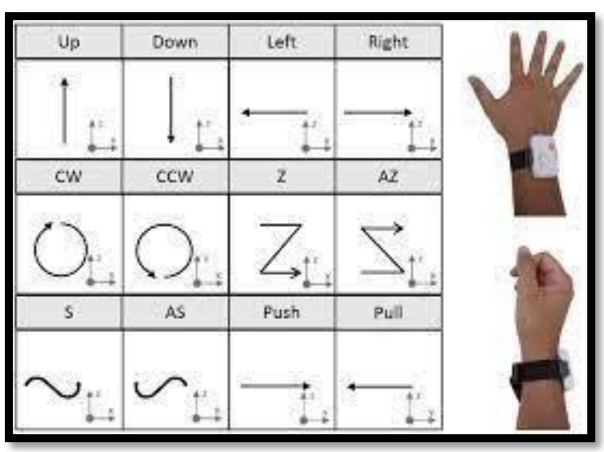

Figure-2.4: Axis based Hand Gesture Recognition [7]

The received signals are then converted into one of five car-robot navigational control commands. The user's gesture directs the movement of the robot. This model consists of transmitter unit with Microcontroller for recognition of gestures. The instructions will be followed by the receiver unit [8].

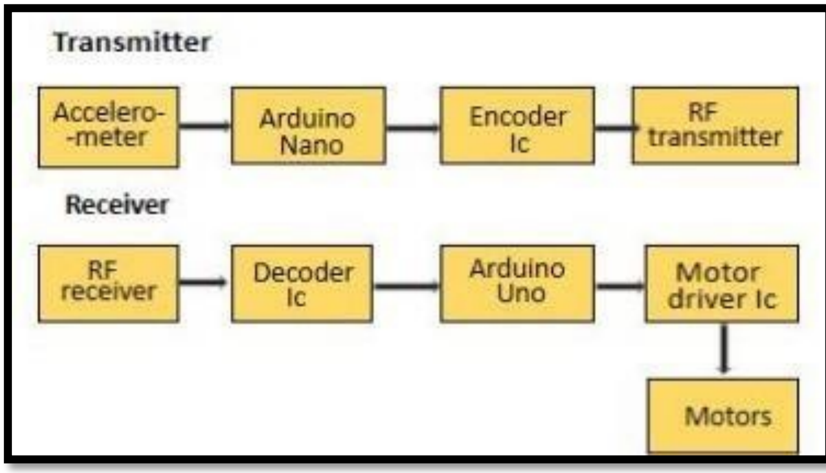

Figure-2.5: Block diagram [9]

2.1.5 Hand Gesture Based Wireless Robotic Arm Control for Agricultural Applications

As the robotics industry is still in budding phase, there is a lot of scope for out of the box research to use robotics and automation for agricultural purposes in specific countries suiting the countries climate and agricultural practices. The basic idea is to exploit the latest advances in robotics and automation field and use for agricultural applications. The user wears the glove fixed with various sensors and can control the robot remotely. The robot with the robotic arm and camera roams over the field or the orchard and beams the images/video of the fruits to the user and harvested fruit can be collected in basket attached to the rove

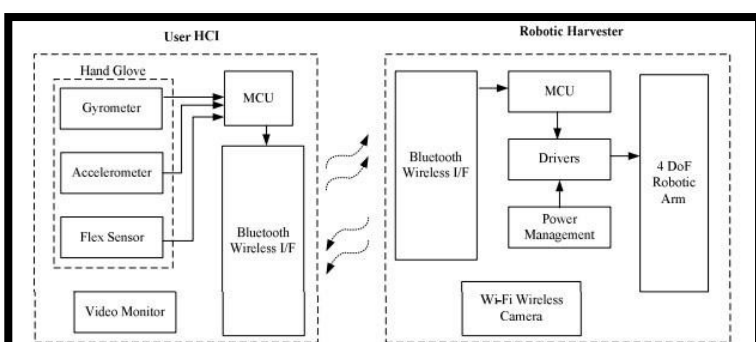

Figure-2.6: Architectural Diagram of the Proposed HCI and Harvest

The user HCI is the transmitter, and the robotic harvester is the receiver. The transmitter block contains all the sensors, Bluetooth and an MCU, integrated into a wearable device.The wearable device transmits real time joint angles of the users arm to the robotic arm [10].

2.1.6 Laser Based Tracking System through HCI

It is a finger gesture recognition system based on an active tracking mechanism. The simplicity of this tracking system is such that it would be possible to in-titrate the whole system on a chip, making it an interesting input interface for portable computing devices. Recognition of gestural characters allows information to be input in a naturalway. The recognition of three-dimensional gestures is also studied, opening the way to a more complex interaction mode and to other kinds of applications [11].

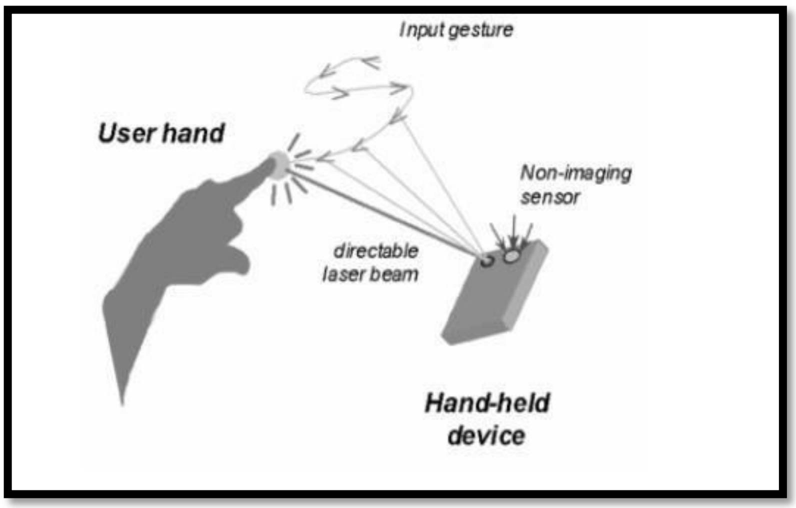

Figure-2.7: The propose system as a MMI for portable devices [11]

2.1.7 A Gesture-Based Teleoperation System for Compliant Robot Motion

In gesture-based tele-operation system for compliant robot motion, using the left hand as the commander and the right hand as a positioner, different operation modes and scaling ratios can be tuned on-the-fly to meet the accuracy and efficiency requirements. Moreover, to provide the operator with a telepresence capability a vibration-based force feedback system was developed. The pick-and-place and peg-in-hole tasks were used to test the effectiveness of the tele-operation system we developed [12]

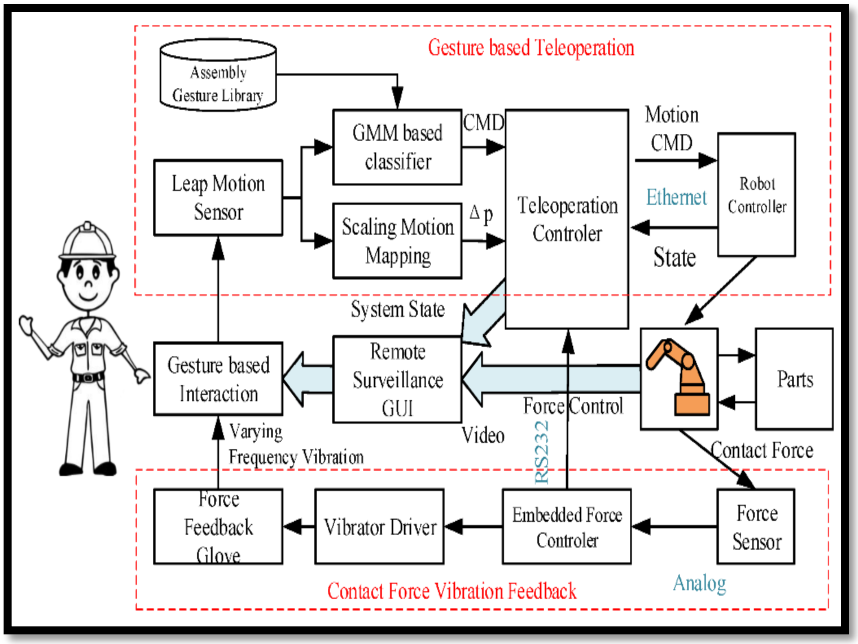

Figure-2.8: Proposed plot of gesture-based teleoperation system for robot motions [12]

Teleoperation means the operator can remotely control the robot. Usually, a physical human-robot interaction (PHRI) device is used to provide the motion commands, and such devices can be dissected into joysticks and motion-tracking (motion capture) devices. The joystick is usually a better control device because it can reflect forces that are experienced at the remote site [12].

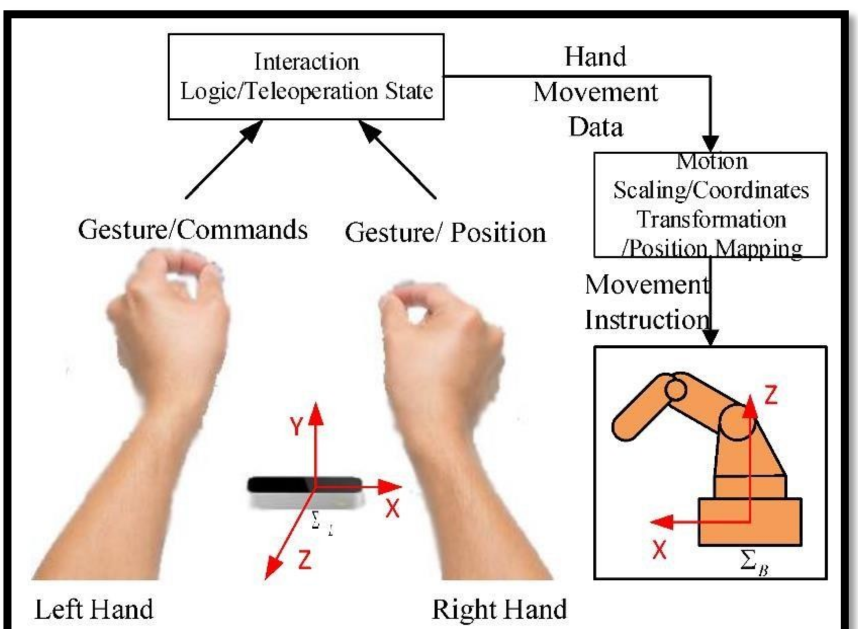

Figure-2.9: Interaction logic for the gesture-based teleoperation system [12]

2.1.8 Gesture Based Vehicle Control Using Sixth Sense Technology

The robotic vehicle is intended in this process by defining the users real-time motion instructions that are implement using image processing algorithms and integrated methods. An inbuilt webcam of the system is used to capture the real time video of gestures. Color markers are used to interpret the gesture movements. To transmit the gesture commands wirelessly ZigBee series s2 module is used [9]. ZigBee coordinator is connected to the serial port of the system through USB Explorer board. ZigBee router is mounted on the voltage regulator to regulate the voltage to 3.3V. To control the robotic vehicle ATMEL89c51 microcontroller is used [13].

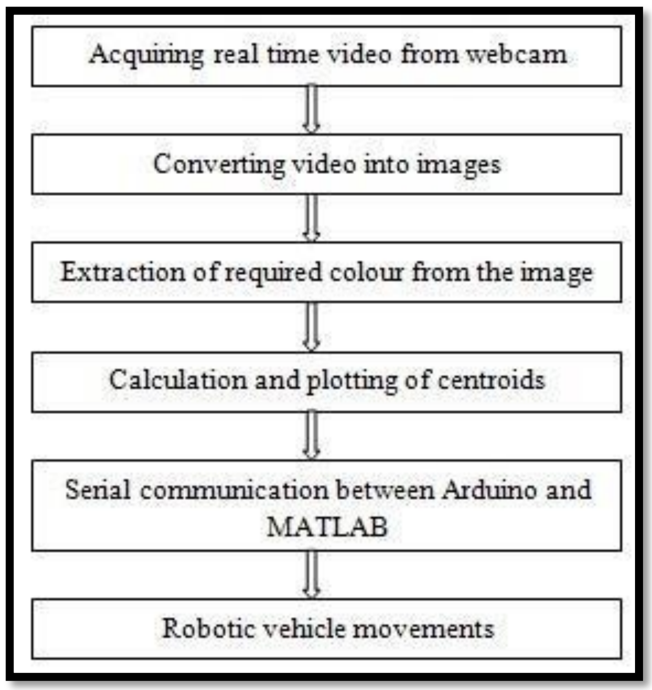

Figure-2.10: Basic flow of the system [13]

2.1.9 Real-Time Hand Gesture Spotting and Recognition Using RGB-D Camera and 3D Convolutional Neural Network

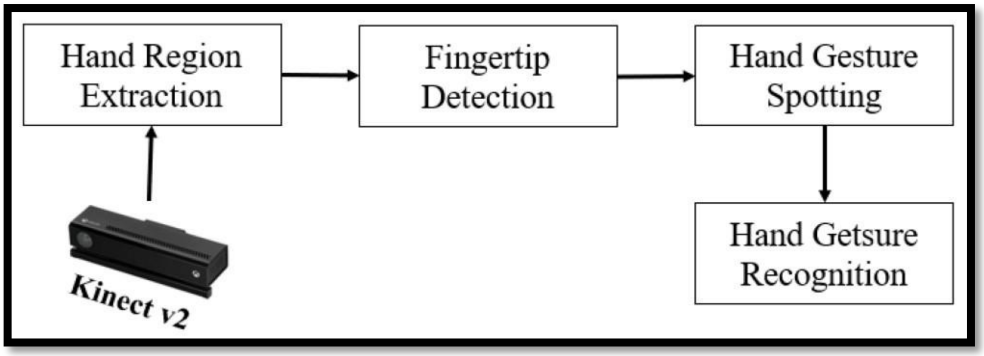

Figure-2.11: Algorithm pipeline [14]

This is a method for fingertip detection and hand gesture recognition in real-time using an RGB-D camera and a 3D convolution neural network (3DCNN). This system can accurately and robustly extract fingertip locations and recognize gestures in real-time.

The hand region of interest is first extracted using in-depth skeleton-joint information images from a Microsoft Kinect Sensor version 2, and the contours of the hands are extracted and described using a border-tracing algorithm. The K-cosine algorithm is used to detect the fingertip location based on the hand-contour coordinates model, and the result of fingertip detection is transformed into the gesture initialization in order to spot hand gestures. Finally, a gesture is recognized based on the 3D convolutional neural network [14].

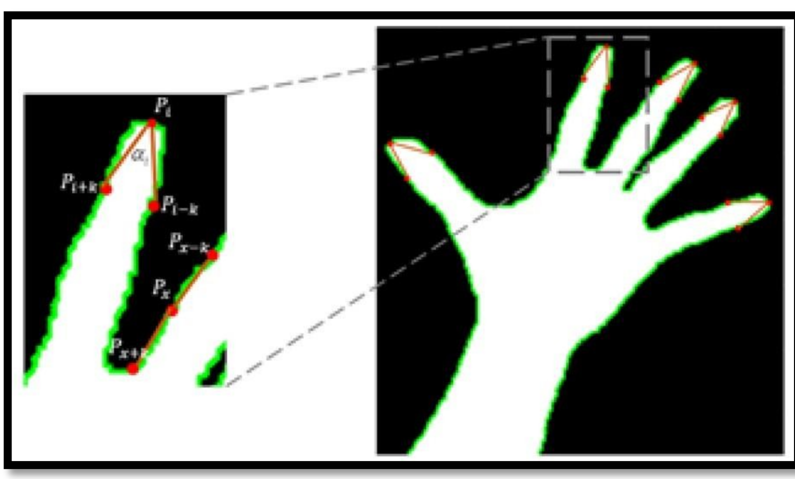

Figure-2.12: Fingertip detection using the K-cosine algorithm [15]

Chapter 3
Proposed Methodology

3.1 Proposed Methodology

The approach which we used to operate robotic vehicle is MPU6050 based approach.

3.1.1 MPU6050

The **MPU6050 module** is a Micro Electro-Mechanical Systems (**MEMS**) which consists of a **3-axis Accelerometer and 3-axis Gyroscope** inside it. This helps us to measure acceleration, velocity, orientation, displacement and many other motions related to parameters of a system or object.

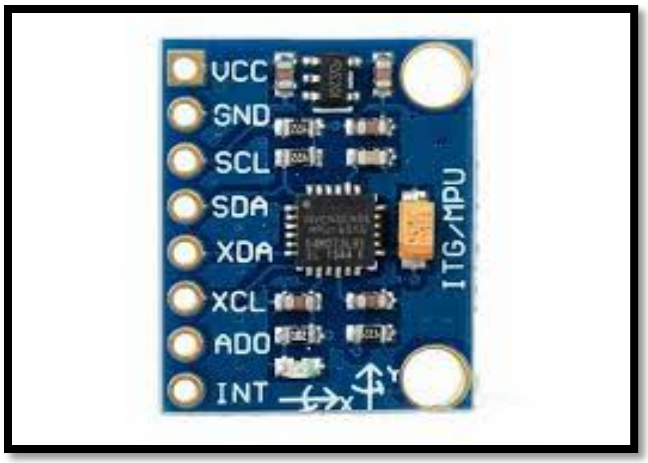

Figure-3.1: MPU6050 Module

Measuring Acceleration

The MPU6050 has an on-chip accelerometer that can measure acceleration over four programmable full-scale ranges of ±2g, ±4g, ±8g, and ±16g.

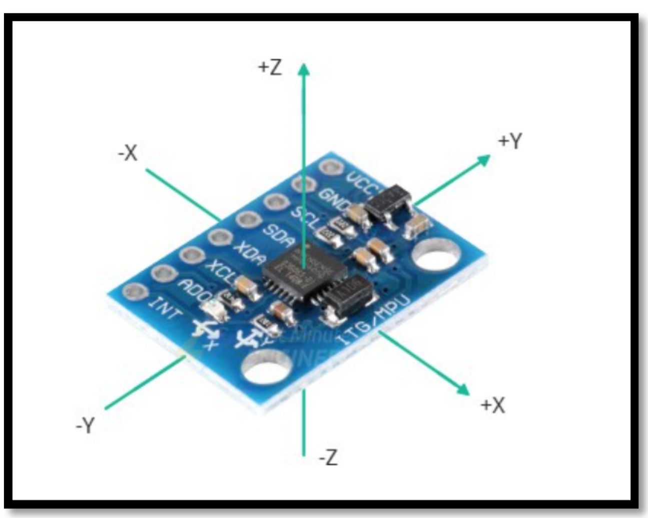

Figure-3.2: Axis Measurement

The MPU6050 is equipped with three 16-bit analog-to-digital converters that simultaneously sample the three axes of movement (along the X, Y, and Z axes). [18]

Working of Accelerometer

In order to understand the working of accelerometer consider a ball inside a 3D cube.

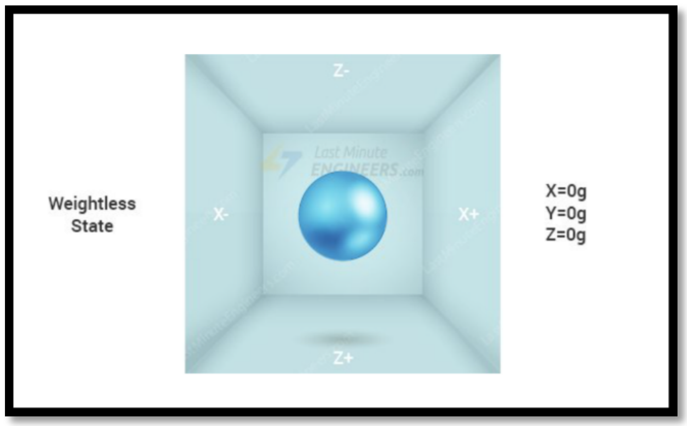

Figure-3.3: Weightless state [18]

Assuming that the cube is in outer space, where everything is weightless, and the ball will simply float in the center of the cube.

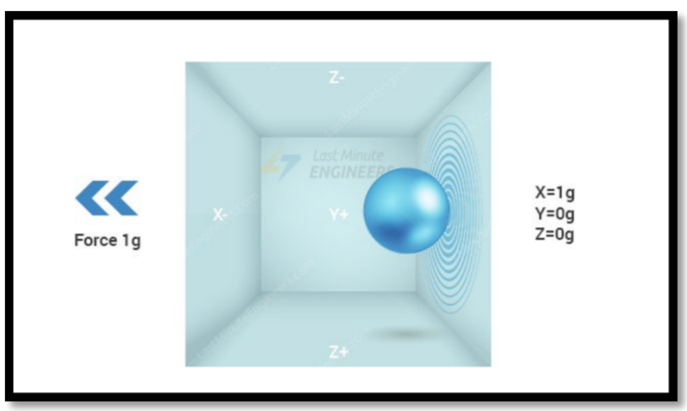

Figure-3.4: Apply force of 1g [18]

Assume that each wall represents a specific axis. If we suddenly move the box to the left with acceleration 1g (1g is equivalent to gravitational acceleration 9.8 m/s^2), the ball will hit the wall X. If we measure the force the ball exerts on wall X, we can obtain an output value of 1g along the X axis.

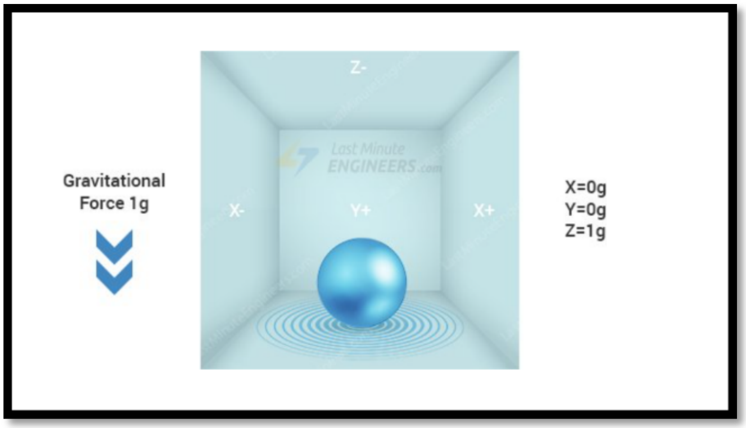

Figure-3.5: gravitational force [18]

If we place that cube on Earth. The ball will simply fall on the wall Z, exerting a force of 1g. The box isn't moving, but we still get a 1g reading on the Z axis. This is because gravity is pulling the ball downward with a force of 1g.

A MEMS Accelerometer

A MEMS (Micro-Electro-Mechanical System) accelerometer is a micro-machined structure built on top of a silicon wafer.

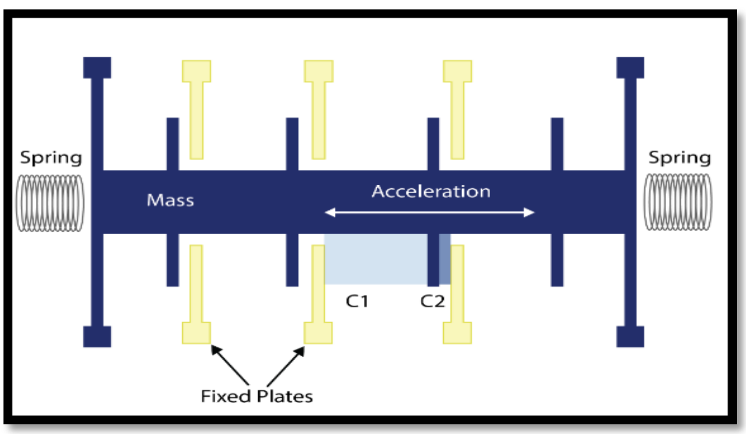

Figure-3.6: MEMS accelerometer [19]

The structure is suspended by polysilicon springs. It allows the structure to deflect when accelerated along the X, Y, and/or Z axes. As a result of deflection, the capacitance between fixed plates and plates attached to the suspended structure changes. This change in capacitance is proportional to the acceleration along that axis.

Measuring Rotation

The MPU6050 has an on-chip gyroscope that can measure angular rotation over four programmable full-scale ranges of ±250°/s, ±500°/s, ±1000°/s, and ±2000°/s.

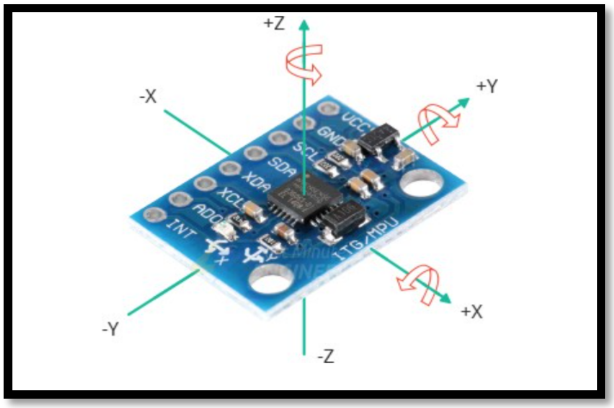

Figure-3.7: Angle measurement

The MPU6050 is equipped with three more 16-bit analog-to-digital converters that simultaneously sample the three axes of rotation (along the X, Y, and Z axes).

Working of Gyroscope

Gyroscope works by generating the Coriolis Effect.

Coriolis Effect

The Coriolis Effect states that when a mass (m) moves in a specific direction with a velocity (v) and an external angular rate (Ω) is applied, the Coriolis Effect generates a force that causes the mass to move perpendicularly. The value of this displacement is directly related to the angular rate applied.

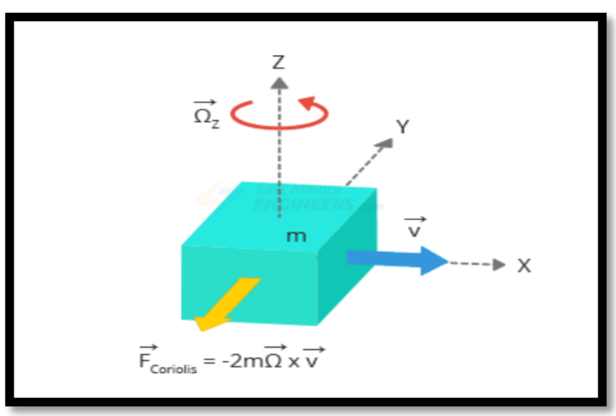

Figure-3.8: Coriolis Effect [18]

A MEMS Gyroscope

The MEMS gyroscope sensor consists of a mass (consisting of four parts M1, M2, M3, and M4) that is maintained in a continuous oscillating movement so that it can respond to the Coriolis Effect. They simultaneously move inward and outward in the horizontal plane.

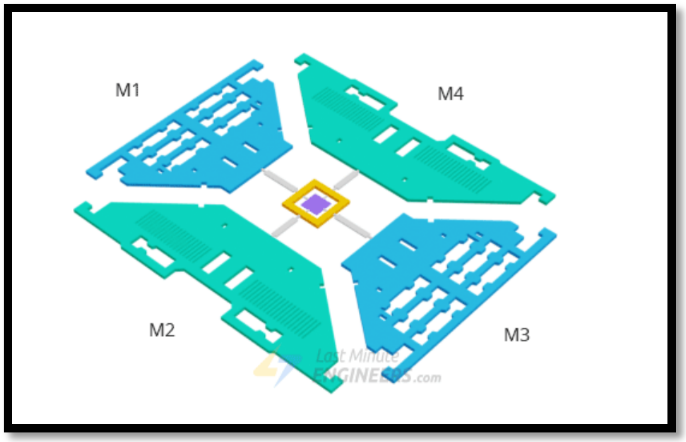

Figure-3.9: Representation of MEMS gyroscope [18]

There are three modes along which the angular rotation is applied.

Roll Mode

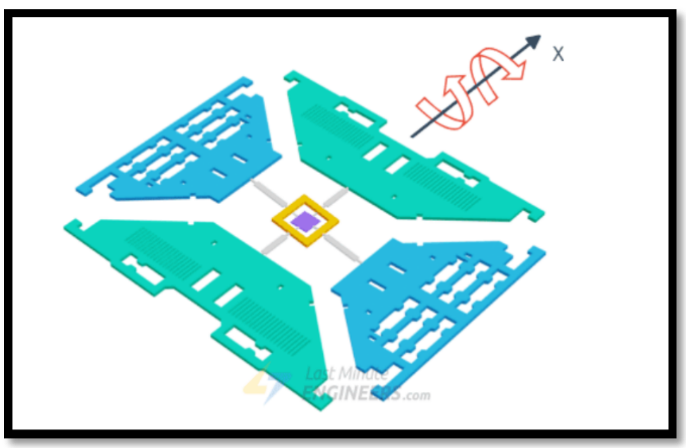

Figure-3.10: Roll mode in gyroscope [18]

When an angular rate is applied along X axis, M1 and M3 will move up and down due to Coriolis Effect. This causes a change in the roll angle.

Pitch Mode

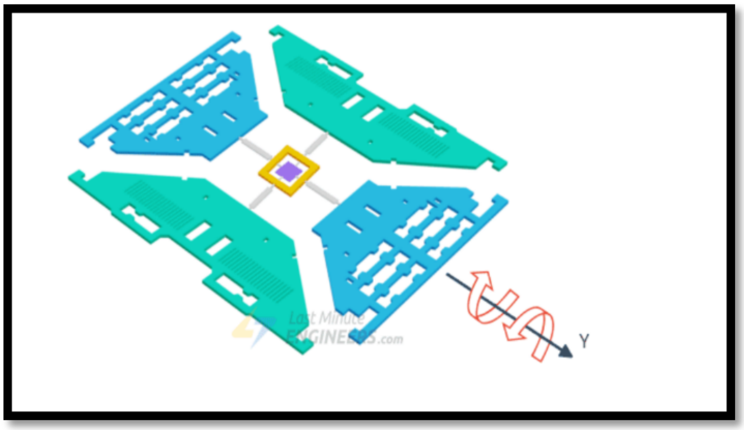

Figure-3.11: Pitch mode in gyroscope [18]

When an angular rate is applied along the Y axis, M2 and M4 will move up and down due to Coriolis Effect. This causes a change in the pitch angle.

Yaw Mode

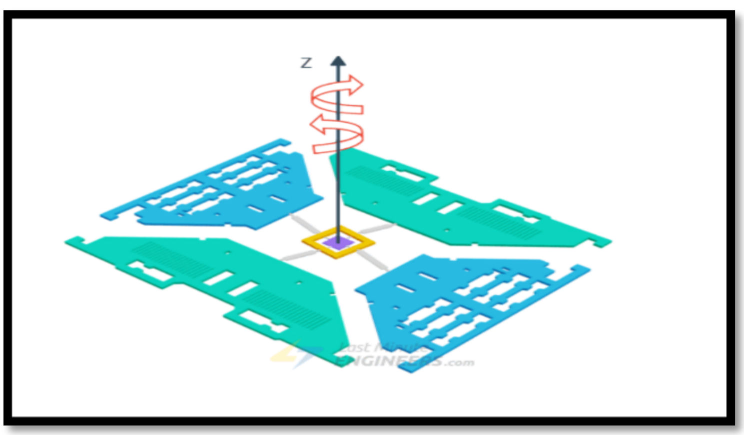

Figure-3.12: Yaw mode in gyroscope [18]

When an angular rate is applied along the Z-axis, M2 and M4 will move horizontally in opposite directions. This causes a change in the yaw angle.

3.1.2 MPU6050 Module Pin Configuration

The MPU6050 module has a total of 8 pins. In which we used 4 pins for interfacing.

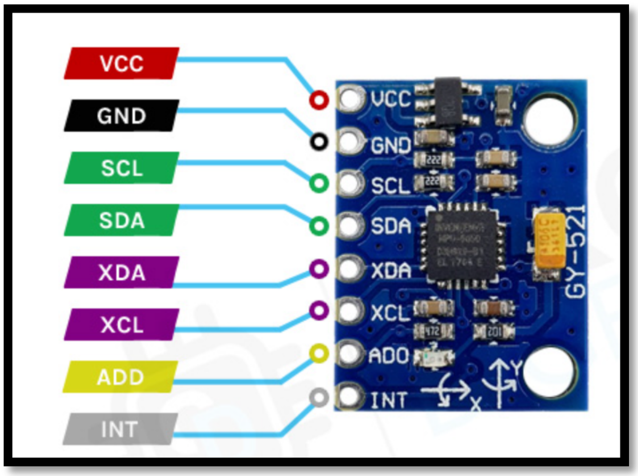

Figure-3.13: Pin configuration of MPU6050 [18]

VCC: Provides power for the module, Connect to the 5V pin of the Arduino.
GND: Ground Connected to Ground pin of the Arduino.
SCL: Serial Clock Used for providing clock pulse for I2C Communication.
SDA: Serial Data Used for transferring Data through I2C communication.

3.2 Proposed Method

The gesture-controlled robot consists of two parts:

1. Hardware part
2. Software part

3.2.1 Hardware Part

Hardware contains two parts:

i. Transmitter
ii. Receiver

3.2.1.1 Transmitter

The transmitter contains the following components:

Components Specifications

i. **MPU6050 module** is a combination of accelerometer and gyroscope which transmits commands. The MPU6050 works by detecting changes in acceleration and rotation in three dimensions (X, Y and Z axis)

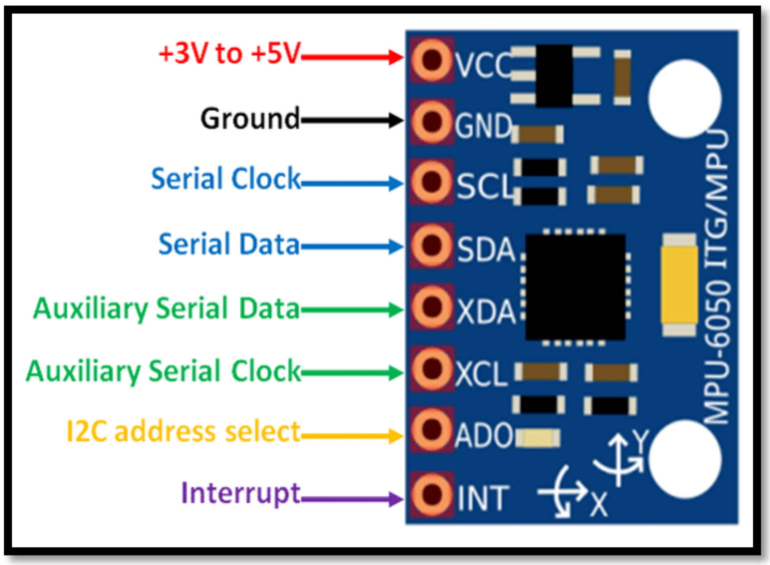

Figure-3.14: MPU6050 module

Specifications

Interface	I2C
Max Operating Temperature	85 °C
Max Supply Voltage	3.6 V
Min Operating Temperature	-40 °C
Min Supply Voltage	2.5 V
Output Type	Digital
Packaging	Tape and Reel
Power Rating	100 mW
Resistance	5.6 kΩ
Tolerance	1 %
Voltage Rating	75 V

Table 3.1. MPU6050 Specifications

ii. **A microcontroller (Arduino Uno)** which receives input from MPU6050 and provides output. Arduino Uno is a microcontroller board which is based on the ATmega328.

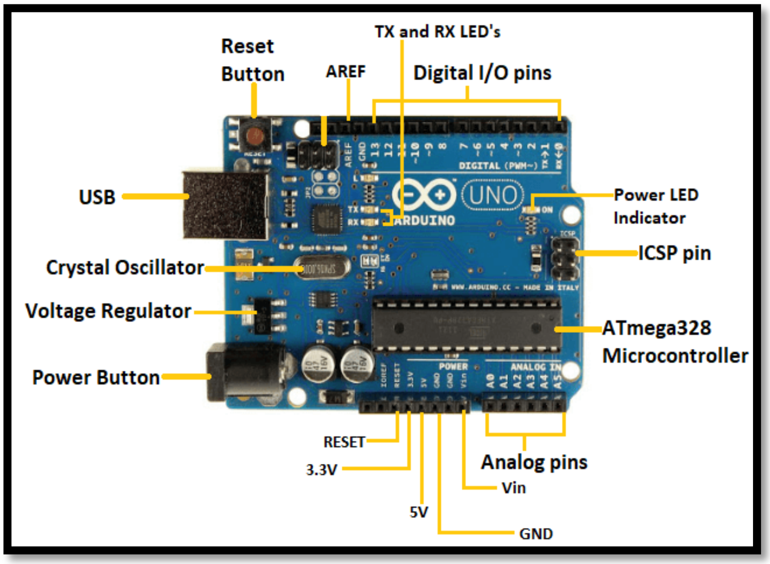

Figure-3.15: Arduino Uno module

Specifications

Microcontroller	ATmega328P
Operating Voltage	5 V.
Input Voltage (nominal)	7-12 V
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
EEPROM	1 KB
Clock Speed	16 MHz
SRAM	2 KB

Table 3.2. Arduino Uno Specifications

Working principle of Arduino Uno

Arduino works in a very simple way. It uses three main things to do its job:
Inputs: Sensors and switches are connected to the controller to give it information. These are called inputs, and they can be nearly anything from on/off signals, variable voltage* signals, or communication from another controller. [20]

iii. **RF Transmitter** module transfers data to the receiver with the help of antenna. It is used for wireless communication. The wireless data transmission is done using 434 MHz Radio Frequency signals.

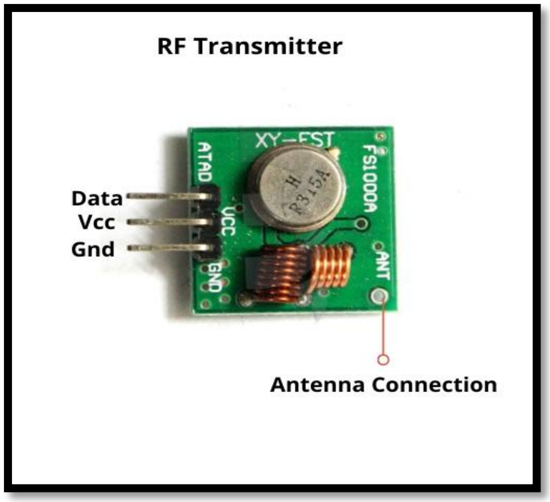

Figure-3.16: RF transmitter module

Specifications

Model Name	FS 1000a
Operating Voltage	5V
Operating Current	9 mA to 40 mA
Operating frequency	433 MHz
Transmission Distance	3 meters (without antenna) to 100 meters (maximum)
Modulating Technique	ASK (Amplitude shift keying)
Data Transmission speed:	10 kbps
Circuit type	Saw resonator

Table 3.3. RF Transmitter Specifications

RF Transmitter Working Principle

The main part of the transmitter module is the SAW resonator which is tuned for 433.xx MHz operation. Moreover, there is also a switching transistor and a few other passive components. [20]

Transmitter Interfacing

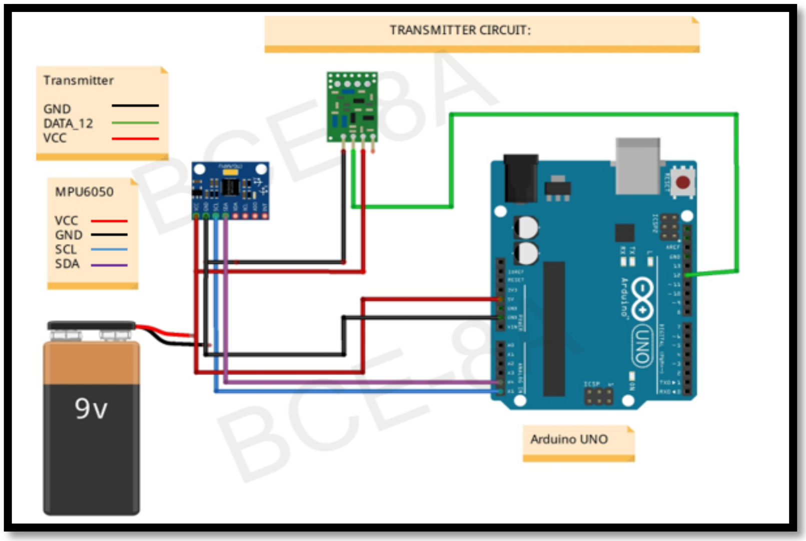

Figure-3.17: Circuit diagram of transmitter

Proposed Methodology of Transmitter

In the transmitter end there is a hand glove on which the circuit is mounted on. The circuit contains the components i.e., MPU6050, RF transmitter and Arduino controller. According to the tilt of human hand the actions will be performed.

MPU6050 Sensor will generate different random values on three axis i.e. X, Y and Z. We will monitor those values and make a logic to get a physical value on each axis.

Equation to get values

$$\boldsymbol{For\ x\ axis = \left(\frac{Raw\ data\ on\ x_{axis}}{16384}\right) g}$$

$$\boldsymbol{For\ y\ axis = \left(\frac{Raw\ data\ on\ y_{axis}}{16384}\right) g}$$

$$\boldsymbol{For\ z\ axis = (\frac{Raw\ data\ on\ z\_axis}{16384}) g}$$

The sensitivity scale factor value of 16384 for the accelerometer of the MPU6050 sensor represents the number of least significant bits (LSB) per unit of acceleration. For every 16384 units of raw data from the accelerometer, there is a change of 1g in acceleration. By dividing the raw accelerometer values by this scale factor, we can obtain the acceleration in units of g.

We will apply 5 checks (conditions)

- Two for x axis (right/left movement)
- Two for y axis (forward/backward movement)
- One for all other values on x and y axis, except these values (stop position).
- For each movement, 3-bit data will be transmitted through RF module to the receiver end.

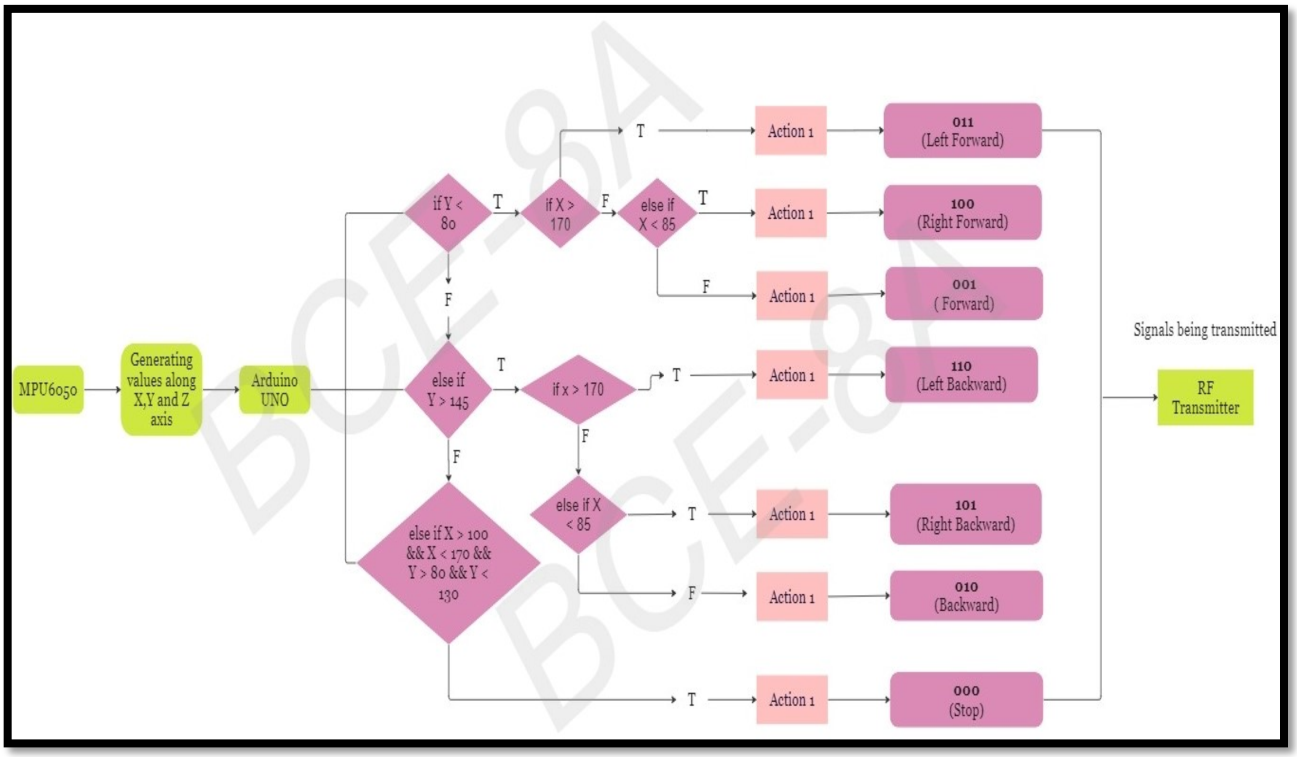

Figure-3.18: Transmission flow chart

Based on movement of the human hand and its acceleration calculated using MPU6050 the values are then passed to the Arduino and respective actions are formed. Then the signals are transmitted to the receiving block of the robotic car.

3.2.1.2 Receiver

The receiver contains the following components:

Components Specifications

i. **RF receiver** which receives the data with the help of antenna.
The wireless data transmission is done using 434 MHz Radio Frequency signals.

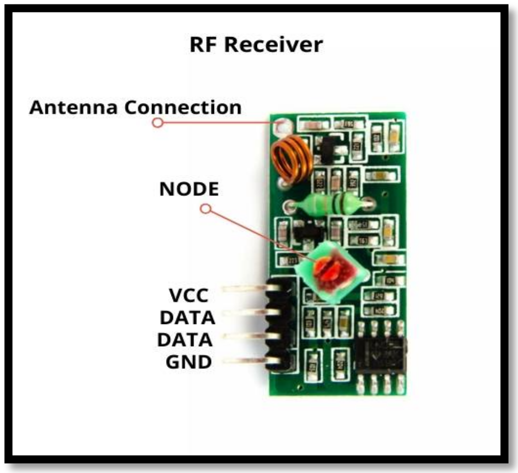

Figure-3.19: RF receiver module

Specifications

Model Name	XY-MK-5V
Operating Voltage	5V
Receiving Sensitivity	105 DB
Operating frequency	433 MHz
Current Consumption in Standby	4 mA
Modulating Technique	OOK

Table 3.4. RF Receiver Specifications

RF Receiver Working Principle

The receiver module is a little complex, consists of an RF tuned circuit and some operational amplifiers to amplify the received carrier wave coming from the transmitter. It then provided the coming amplified signal to a phase lock loop (PLL) which permits the decoder to lock onto a stream of digital bits which allows better-decoded output.

When a logic HIGH is given to the DATA input, the oscillator produces a constant RF output carrier wave at the frequency of 433 MHz and, when the DATA input is drawn to logic LOW, the oscillator stops. This technique is known as Amplitude Shift Keying

(ASK). [20].

ii. **DC motors** that convert electrical energy into mechanical energy.

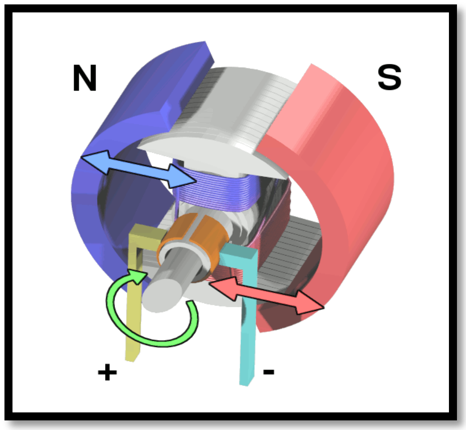

Figure-3.20: DC motor

Voltage Equation of Dc Motor

$$V = E_b + I_a R_a \qquad \text{Equation (1)}$$

Power Equation of Dc Motor

$$VIa = Eb\ Ia + Ia2\ Ra \qquad \text{Equation (2)}$$

Frequency Equation of Dc Motor

$$\text{Frequency} = \frac{(\text{Number of Poles}*\text{Motor Speed})/120f}{(n*N)/120} \qquad \text{Equation (3)}$$

Specifications

Operating Temperature	4.5 V to 9 V
Rated Voltage	6 V
Rated Load	10g*cm
Current at No load	70mA (max)
No-load Speed	9100 ±1800 rpm
Loaded current	250 mA max
Weight	27.5mm x 20mm x 15mm
Motor Size	17 grams

Table 3.5. DC Motor Specifications

DC Motor Working Principle

A DC motor is an electrical machine which converts electrical energy into mechanical energy. The basic working principle of the DC motor is that whenever a current carrying conductor places in the magnetic field, it experiences a mechanical force. Fleming's left-hand rule and its magnitude decide the direction of this force. [22]

iii. **Motor Driver L293D** is a Motor Driver IC which allows DC motor to drive in desired direction. L293D is a 16-pin IC which can control DC motors in any direction.

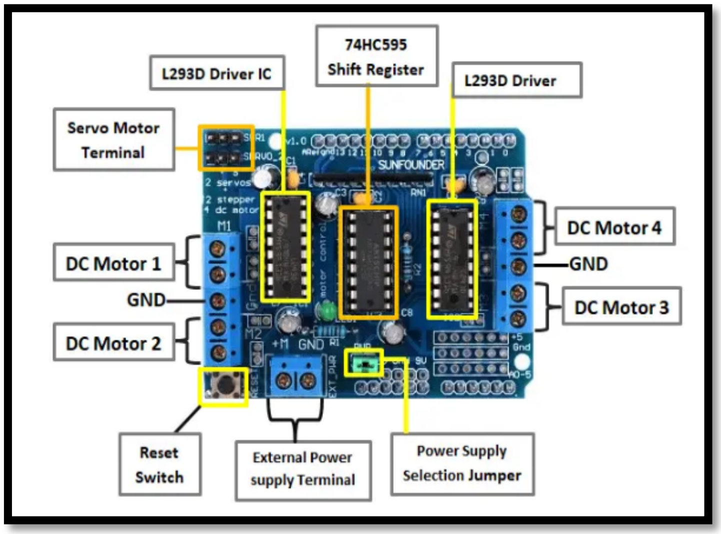

Figure-3.21: L293D motor-driver

Working Principle of L293D Motor Driver:

This L293D IC works on the basic principle of H-bridge, this motor control circuit allows the voltage to be flowing in any direction. As we know that the voltage must be change the direction of being able to rotate the DC motor in both the directions. [23]

Specifications

Model	L293D
Shield	Motor Driver Shield
Motor	Can run motors on 4.5 VDC to 25VDC
Peak Output Current	1.2 A per channel
H bridge	0.6 A per bridge

Table 3.6. Motor Driver L293D Specifications

iv. **Rain Sensor** which contains a sensing pad with uncovered copper traces, together acts as a variable resistor whose resistance varies according to the amount of water on its surface. This resistance has an inverse relation to the amount of water.

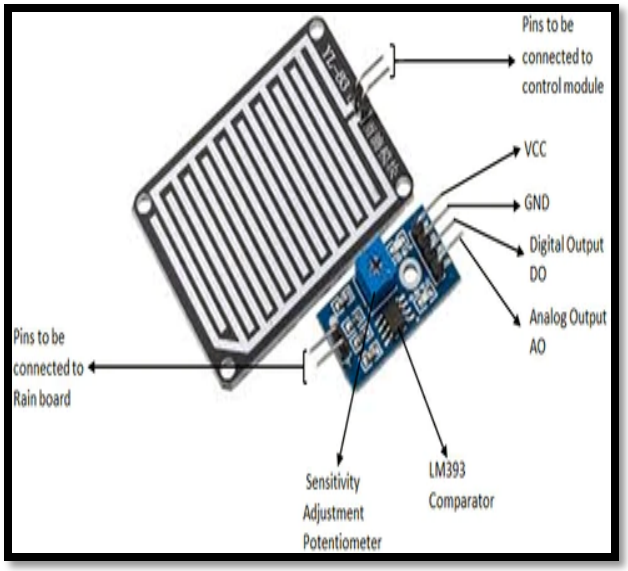

Figure-3.22: Rain sensor

Working Principle of Rain Sensor

It works on the principle of resistance. The raindrop sensor measures the moisture via analog output pins and it provides a digital output when a threshold of moisture exceeds. The module is based on the LM393 op amp. It consists of an electronics module and a printed circuit board that “collects” the rain drops. [25]

Specifications

Operating Voltage	3.3v to 5V
Operating Current	15 mA
Sensitivity	Adjustable via Trim pot
Comparator Chip	LM 393
Sensing Pad	5cm x 4 cm nickel plate on one side.

Table 3.7.Rain Sensor Specifications

v. **Servo Motor** consists of a circuit that controls and provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision.

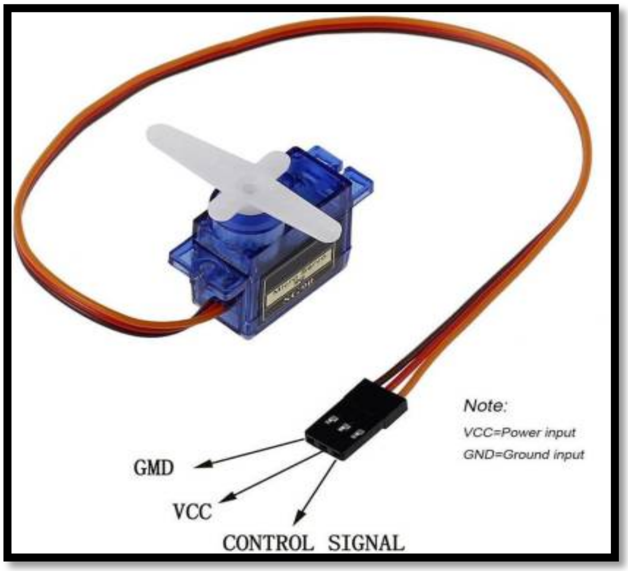

Figure-3.23: Servo motor

Specifications

Operating Voltage	5 V
Operating Speed	0.1s/60°.
Weight of motor	9 g
Torque	2.5kg/cm

Table 3.8 Servo Motor Specifications

Voltage Equation of Servo Motor

$$V = iaRa + KeVm \qquad \text{equation (1)}$$

Torque of Servo Motor

$$iaKT = J\alpha \qquad \text{equation (2)}$$

Working principle of Servo Motor

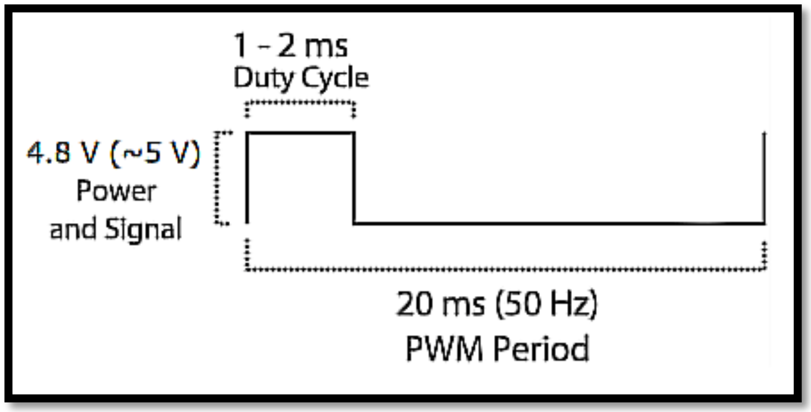

Figure-3.24: Servo motor wave graph [20]

From the graph we can understand that the PWM signal produced should have a frequency of 50Hz that is the PWM period should be 20ms. Out of which the On-Time can vary from 1ms to 2ms. So when the on-time is 1ms the motor will be in 0° and when 1.5ms the motor will be 90°, similarly when it is 2ms it will be 180°. So, by varying the on-time from 1ms to 2ms the motor can be controlled from 0° to 180°. [26]

vi. **Ultrasonic sensor** which detects objects that are some distance away from the robot. Ultrasonic sensors are based on the ultrasonic signal. They produce high-frequency sound waves which reflect on an object.

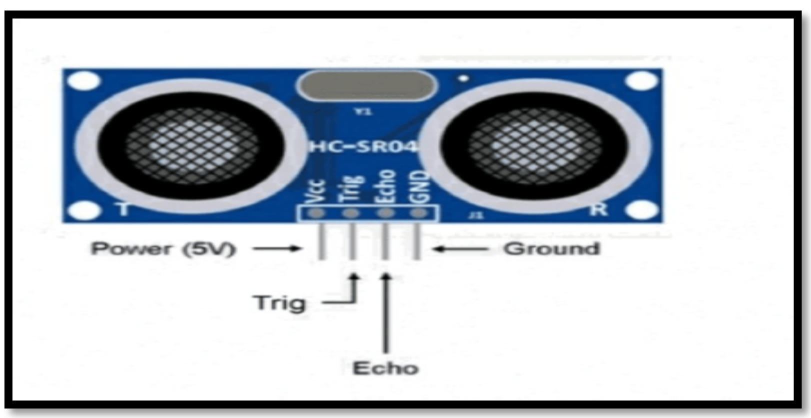

Figure-3.25: Ultrasonic sensor

Distance measurement

$$L = 1/2 \times T \times C.$$

Specifications

Operating Voltage	5 V
Operating Current	15 mA
Operating Frequency	40 kHz
Maximum Range	4 m
Minimum Range	2 cm
Input Trigger Signal	10us TTL pulse
Output Echo Signal	Output TTL level signal, proportional with range
Measuring Angle	15 degree

Table 3.9 Ultrasonic sensor Specifications

The ultrasonic sensor works when the trigger input supplied with 10us. After that 8 cycle burst of ultrasound (40Hz) will be emitted from the module. Once an object is detected, ultrasound will bounce back to echo to be received with the time taken for the ultrasound to reach echo. With the time taken, distance can be calculated. Figure 5.5.2 shows how ultrasonic sensor works. [27]

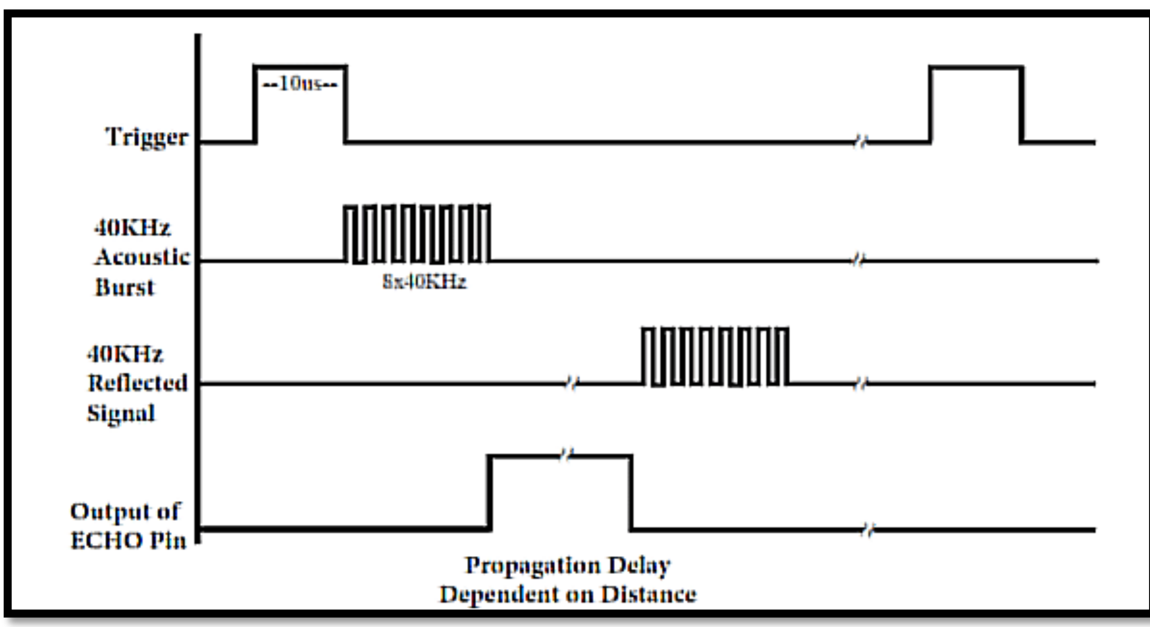

Figure-3.26: Ultrasonic sensor Timing Diagram [27]

Receiver Interfacing

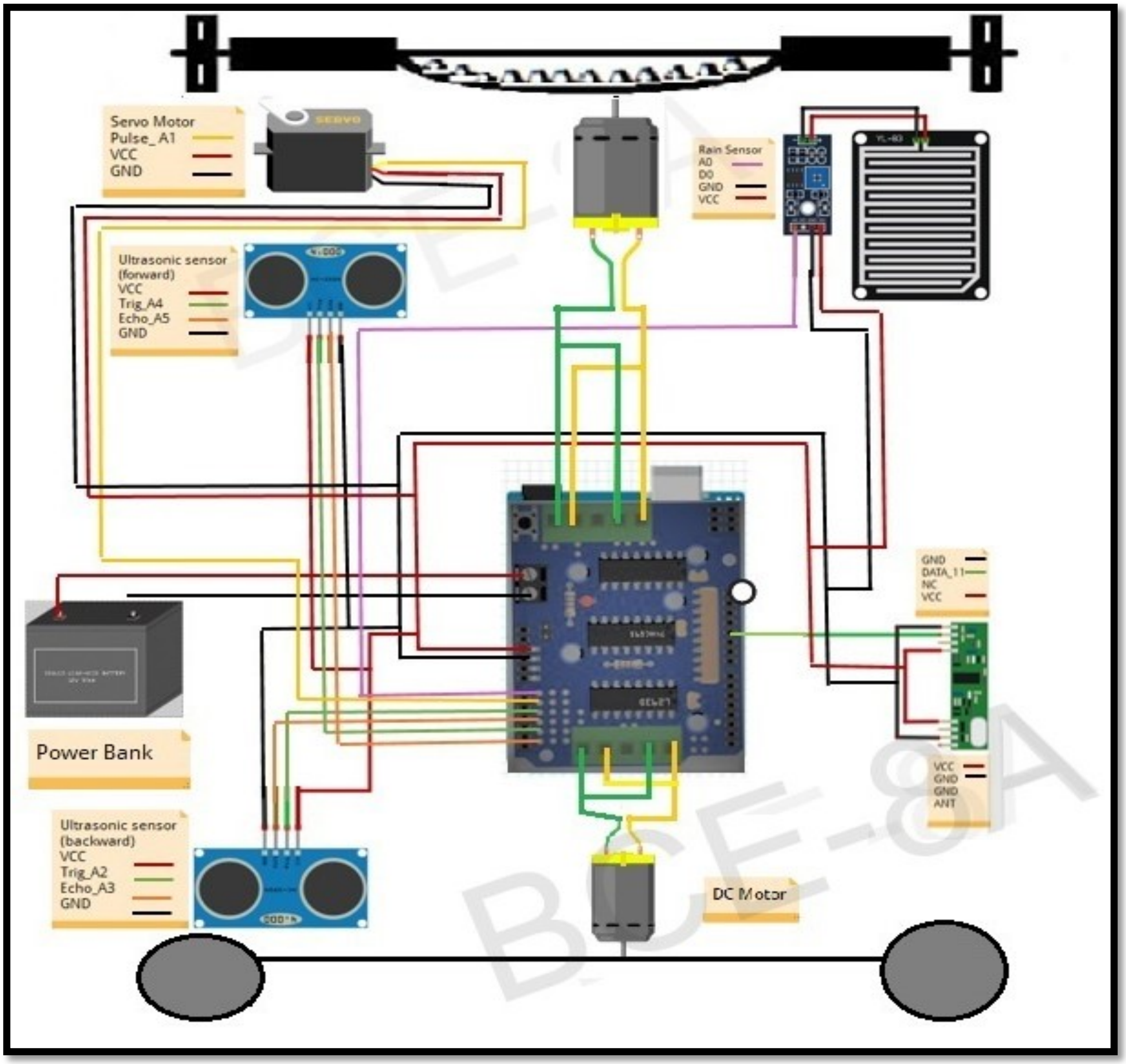

Figure-3.27: Circuit diagram of receiver

Proposed Methodology of Receiver

The signals that are transmitted by the transmitter are then received by the RF receiver. RF receiver receives the serial data and then send it to the microcontroller.

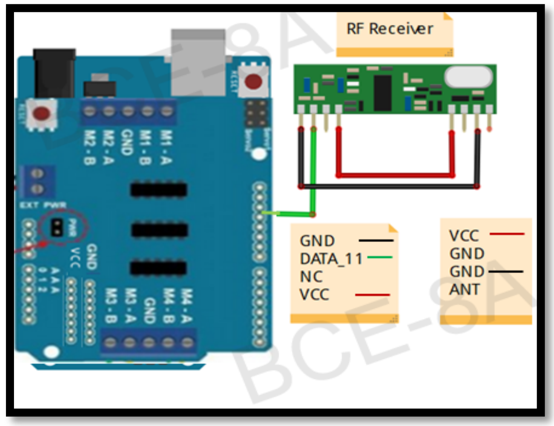

Figure-3.28: Circuit diagram of receiver connected with Arduino Uno

The result of motion of the hand signals from Arduino is given to the motor driver IC for respective movement of the DC motors for movement of car in a desired direction of the hand gesture i.e., forward, backward, right, left or to stop.

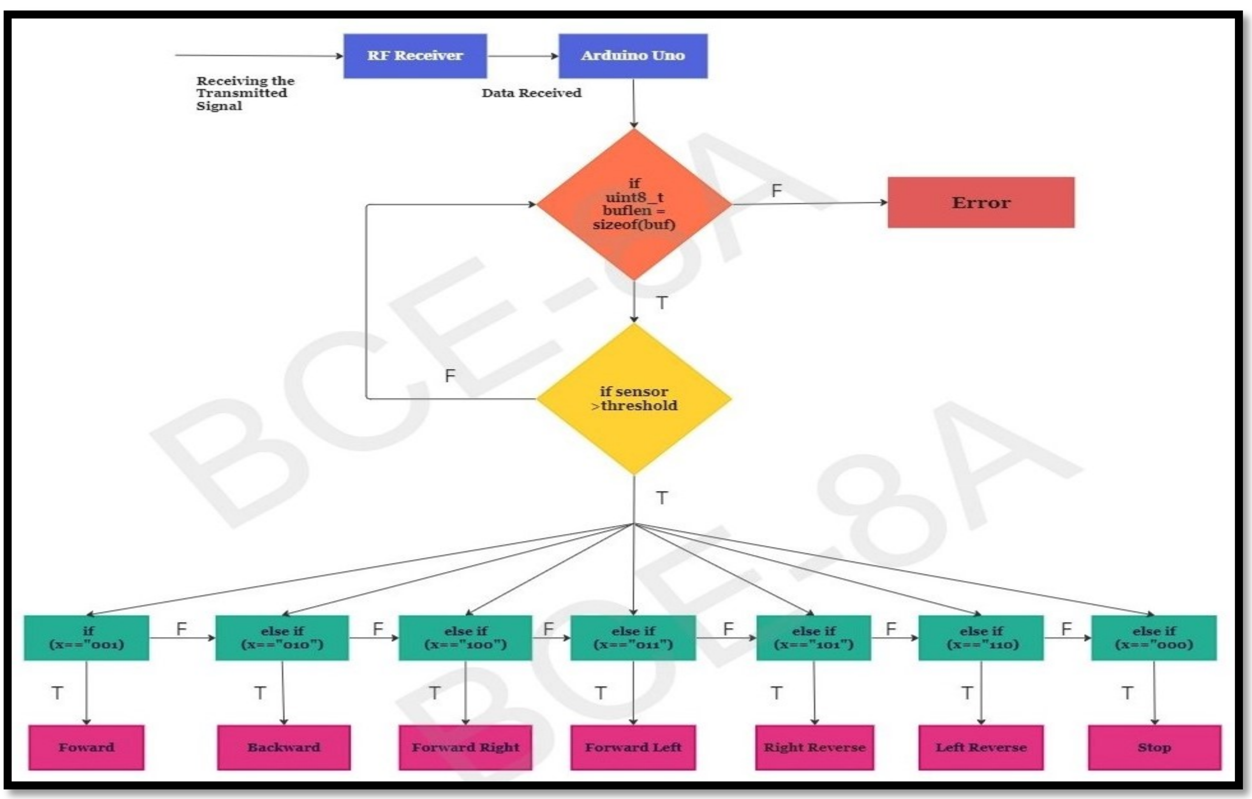

Figure-3.29: Receiver flow chart

For object detection, we use ultrasonic sensor that monitors the distance of the car from any other object coming in its way.

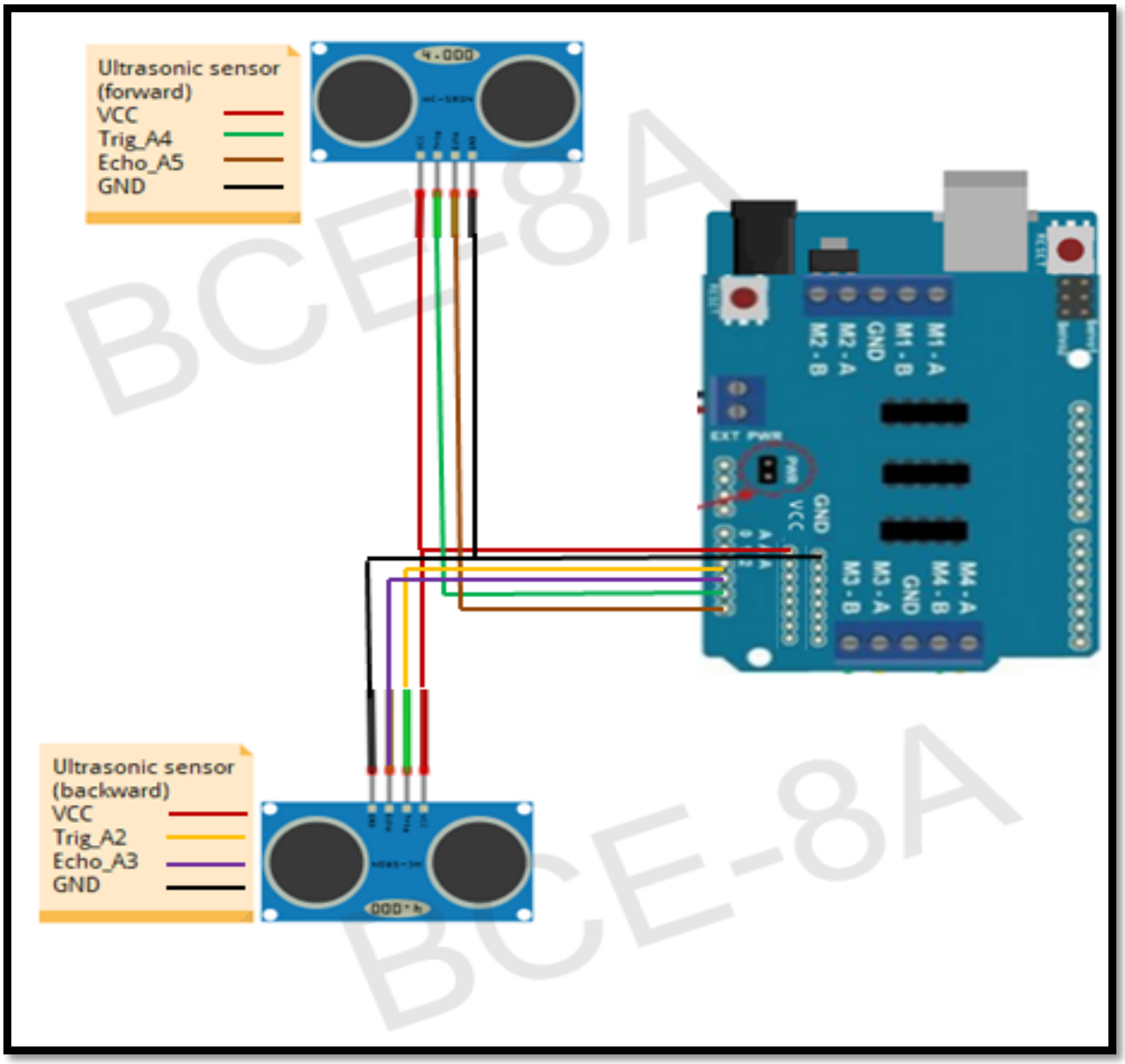

Figure-3.30: Ultrasonic sensors used for object detection

It will start measuring distance (threshold value 70 cm (2 feet (approx.)) continuously. The Ultrasonic sensor emits high frequency sound waves. The waves fall on the object and get reflected. The sensor emits waves of frequency about 40KHz.

We'll compare the receiving bits with the transmitted bits. When the bits match with one from all others, the car will move in that direction. e.g., if **001** is transmitted from transmitter and it received as it is **001**, the car will move in forward direction, until the other signal is received.
If the distance of the object becomes less than the threshold value (which is 70 cm) the car will apply breaks.

For the movement of wipers, if any water drops fall on the windshield, it detects the water with the help of water detection sensor (rain sensor) and the wipers will start moving with the help of servo motor and they will wipe out the water.

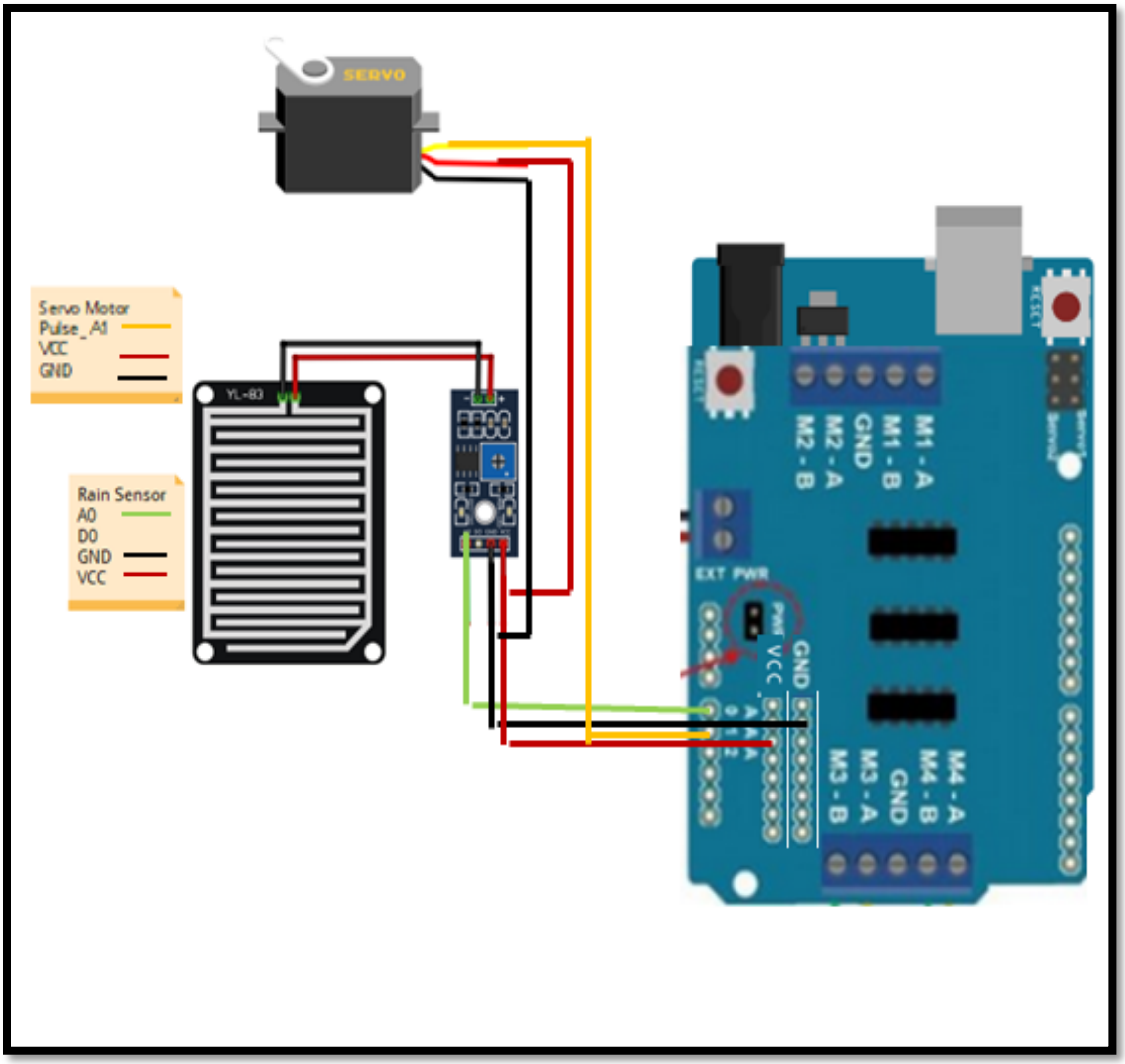

Figure-3.31: Servo motor for the wiper motion and rain sensor for water

The more water on the surface means better conductivity and will result in a lower resistance.

The rain sensor contains a sensing pad with series of exposed copper traces that is placed out in the open, possibly over the roof or where it can be affected by water.

3.2.2 Software Part

Arduino Uno:

The software that we used to write program is Arduino Integrated Development Environment (IDE) and connected to the Arduino hardware in order to upload programs. Before uploading the program there is a need to select appropriate Microcontroller so, "Arduino Uno" is selected and then for communication with computer and Arduino Uno boards there is a need to select COM port from the Tool menu.

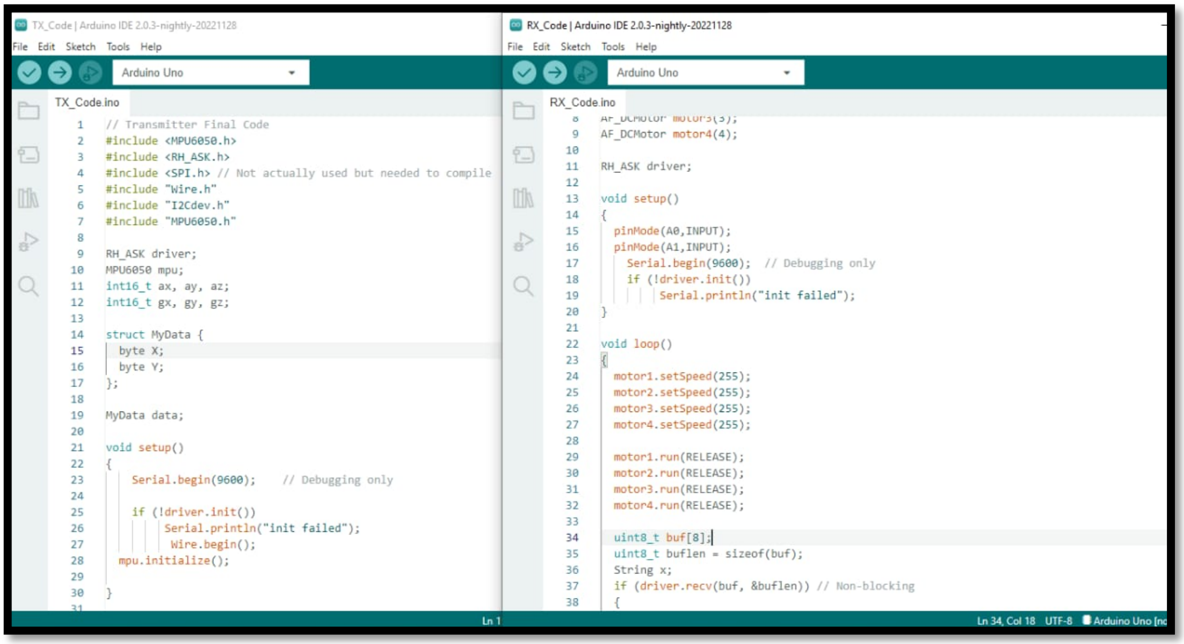

Figure-3.32: Arduino IDE

Pseudo Code:

i. Transmitter Pseudo Code:

```
Import libraries:
    - Import MPU6050 library for gyro and accelerometer data
    - Import RH_ASK library for RF communication
    - Import Wire library for I2C communication

Initialize variables and instances:
    - Initialize RH_ASK driver instance named "driver"
    - Declare variables for accelerometer and gyro data (ax, ay, az, gx, gy, gz)

Define data structure:
    - Define a struct named "MyData" with fields X and Y
```

Setup:
- Begin serial communication for debugging
- Initialize RH_ASK driver
- Start I2C communication
- Initialize MPU6050 sensor

Main Loop (loop function):
- Define control messages for different gestures
- Read accelerometer and gyro data from MPU6050 sensor
- Map raw accelerometer data from X and Y axes to range 0-255

Gesture Detection and Command Sending:
- If Y axis data < 80 (downward gesture):
    - If X axis data > 170 (right-forward gesture):
        - Send "011" command over RF
    - Else if X axis data < 85 (left-forward gesture):
        - Send "100" command over RF
    - Else:
        - Send "001" command over RF

- If Y axis data > 145 (upward gesture):
    - If X axis data > 170 (right-backward gesture):
        - Send "110" command over RF
    - Else if X axis data < 85 (left-backward gesture):
        - Send "101" command over RF
    - Else:
        - Send "010" command over RF

- If X axis data between 100 and 170 and Y axis data between 80 and 130 (little bit downward gesture):
    - Send "000" command over RF

Wait and Debugging:
- Wait for RF packet to be sent
- Print mapped X and Y axis data and raw gyro data for debugging

End of Loop:
- Repeat loop to continuously detect gestures, send control commands over RF, and monitor sensor data

ii. Receiver Pseudo Code:

```
//Import libraries

Include RH_ASK library
Include SPI library
Include AFMotor library
Include ServoTimer2 library

// Define constants
Rain Sensor:
   Set rainSensorPin = A0
   Set servoYawPin = A1
   Set sensorThreshold = 800

Ultrasonic Sensor:
   Set TRIG_PIN = A2
   Set ECHO_PIN = A3
   Set DISTANCE_THRESHOLD = 80

Motor Control:
   Define motor1, motor2, motor3, motor4

RF Receiver:
   Set LED_PIN = A5
   Initialize RF driver

// Setup function
Setup:
   Initialize Serial communication
   Attach servoYaw to servoYawPin
   Set pinMode for LED_PIN, TRIG_PIN, and ECHO_PIN
   If RF driver initialization fails, print error message

// Function to increment servo pulse
Function incPulse(val, inc):
   If val + inc > 3000:
      Return 800
   Else:
      Return val + inc
```

```
// Function to stop motors
Function stopMotors:
   Set motor speeds to 250
   Release all motors
   Turn on LED

// Main loop
Loop:
   Read rain sensor value into sensorValue
   If sensorValue < sensorThreshold:
      Calculate new servo position using incPulse function
      Move servoYaw to new position
   Else:
      Set servoYaw to minimum position

   Generate ultrasonic pulse
   Measure pulse duration
   Calculate distance

   If distance < DISTANCE_THRESHOLD:
      Call stopMotors function
      Turn on LED
      Delay for 1 second
   Else:
      Turn off LED

   If RF message received:
      Interpret RF message
      Perform corresponding action:
          "001": Move vehicle forward for 5 seconds
          "010": Move vehicle backward for 1 second
          "100": Turn vehicle right for 1 second
          "011": Turn vehicle left for 1 second
          "101": Move vehicle diagonally left backward for 1 second
          "110": Move vehicle diagonally right backward for 1 second
          "000": Stop all motors for 1 second

End of loop:
     - Repeat loop to continuously detect received gestures/commands from RF module, ultrasonic and rains sensors and operate accordingly.
```

Chapter 4

Simulation and Results

4.1 Simulation

Because of transmitter device wearing on hand and receiver on the robot-car, the robot-car starts moving according to the movement of hand gestures. In this paper, we have explained about the 5 different hand gesture or movement positions i.e. stop condition, forward movement, backward movement, moves towards right and moves towards left and with some additional systems like rain sensor connected to servo motor and an ultrasonic sensor.

4.1.1 Stop Condition

The robot-car can be stopped by making the accelerometer parallel to the horizontal plane; this makes all the output pins of motor drivers set to (0000).

4.1.2 Forward Movement

The robot-car starts moving in forward direction, by making accelerometer tilted to forward direction, this condition sets the two-output pin of motor driver 1 (00) to low and set high on the other two output pin of motor driver 2 (10).

4.1.3 Backward Movement

The robot-car starts moving in forward direction, by making accelerometer tilted to forward direction (upwards), this condition sets the two-output pin of motor driver 1 (00) to high and set low on the other two output pin of motor driver 2 (01).

4.1.4 Moves towards Forward Right

The robot-car starts move towards right side by tilting the accelerometer towards right direction while moving Forward making an angle turn of 45 degree, and this makes the two-output pin of motor driver 1 (10) low and other two output pin of motor driver 2 (10) high.

4.1.5 Moves towards Forward Left

The robot-car starts move towards left side by tilting the accelerometer towards left direction while moving Forward making an angle turn of 45 degree, and this makes the two-output pin of motor driver 1 (01) high and other two output pin of motor driver 2 (10) low.

4.1.6 Moves towards Reverse Right

The robot-car starts move towards right side by tilting the accelerometer towards right direction while moving Backward making an angle turn of 45 degree, and this makes the two-output pin of motor driver 1 (10) low and other two output pin of motor driver 2 (01) high.

4.1.7 Moves towards Reverse Left

The robot-car starts move towards left side by tilting the accelerometer towards left direction while moving Backward making an angle turn of 45 degree, and this makes the two-output pin of motor driver 1 (01) high and other two output pin of motor driver 2 (01) low. [16]

The accelerometer MPU6050 obtains the angular wrist rotation in 3-4xis, i.e. in x, y, and 2 directions.

The data is fed to the Arduino UNO. The pin (12) function as a data pin. Two Vcc pins and two ground pins are present on-board, all the remaining pins are general purpose 3 V pins. The python code uploaded in the micro-controller sets or resets the voltage levels of 3 bits demonstrated in the given table.

From Table 4.1 we get to see the threshold values of the accelerometer and the logic (the movement in a particular direction) is fed to the micro-controller. According to the direction inferred from Table 4.1, the 3-bit logic is set to reset following Table 4.2 as indicated below.

S.No	**Conditions**	**Comments**
1	100 < X < 170 && 80 < Y < 130	Stop
2	Y < 80	Forward direction
3	Y > 145	Backward direction
4	X < 85	Forward Right direction
5	X > 170	Forward Left direction
6	X < 85	Backward Right direction
7	X > 170	Backward Left direction

Table 4.1. Decision from 3-axis data

Table 4.2 provides the movement of the robot-car from the receiver end, the data pins are pins of the L293D motor driver, they are provided with the above logic, hence the motors rotate according to the logic of the data pin, and finally we can observe the movement of the robot-car. [17]

Transmitted bit	**Motor 1**		**Motor 2**		**Comments**
	Pin1	Pin2	Pin3	Pin4	
001	0	0	1	0	Forward
010	0	0	0	1	Reverse
000	0	0	0	0	Stop
100	1	0	1	0	Forward Right
101	1	0	0	1	Reverse Right
011	0	1	1	0	Forward Left
110	0	1	0	1	Reverse Left

Table 4.2. Data pins logic

4.1.8 Rain Sensor

The FC-37 Rain Sensor is set up by two pieces: the electronic board and the collector board that collects the water drops, upon collecting the water drops the servo motor connected to it will move with wipers on the wind screen of our robot-car.

4.1.9 Ultrasonic Sensor

The Ultrasonic Sensors are connected at the front and back of our robot-car. Initially, it sends an ultrasonic pulse out at 40 kHz which travels through the air and when there is an obstacle or object, it bounces back to the sensor cautioning the driver about the obstacle/object.

4.2 Results

The coordinates after the movement of the accelerometer are provided to the micro-controller, which is eventually sent to the motor driver through the transmitter receiver section. The values which the data pin (11) of the motor driver gets in equivalent to 9 V and 0 V according to the accelerometer movement in (1 and 0) is shown in Table 4.3. The car movement and the orientation of the wheels along with the data in the data pin (11) of the motor controller are shown Table 4.4.

Accelerometer orientation	**Transmitted bits**	**Motor 1**		**Motor 2**		**Comments**
		Pin 1	Pin 2	Pin 3	Pin 4	
+y	001	-	-	1	0	Forward
-y	010	-	-	0	1	Reverse
-x,+y	011	0	1	1	0	Left/ Forward
+x, +y	100	1	0	1	0	Right/Forward
+x, -y	101	1	0	0	1	Right/Reverse
-x, -y	110	0	1	0	1	Left/Reverse

Table 4.3. Motion induced by the accelerometer orientation.

Car Movements	**wheel movement**
Forward	Motor 2 moves Clockwise
Backward	Motor 2 moves Anti-clockwise
Forward Right	Motor 2 will move clockwise but motor 1 will make angle turn of 45 degree on the right side using gears of motor 1 or using servo motor.
Reverse Right	Motor 2 will move anti-clockwise but motor 1 will make angle turn of 45 degree on the right side using gears of motor 1 or using servo motor.
Forward Left	Motor 2 will move clockwise but motor 1 will make angle turn of 45 degree on the left side using gears of motor 1 or using servo motor
Reverse Left	Motor 2 will move anti-clockwise but motor 1 will make angle turn of 45 degree on the left side using gears of motor 1 or using servo motor.

Tabe 4.4. Direction of motion induced by accelerometer orientation.

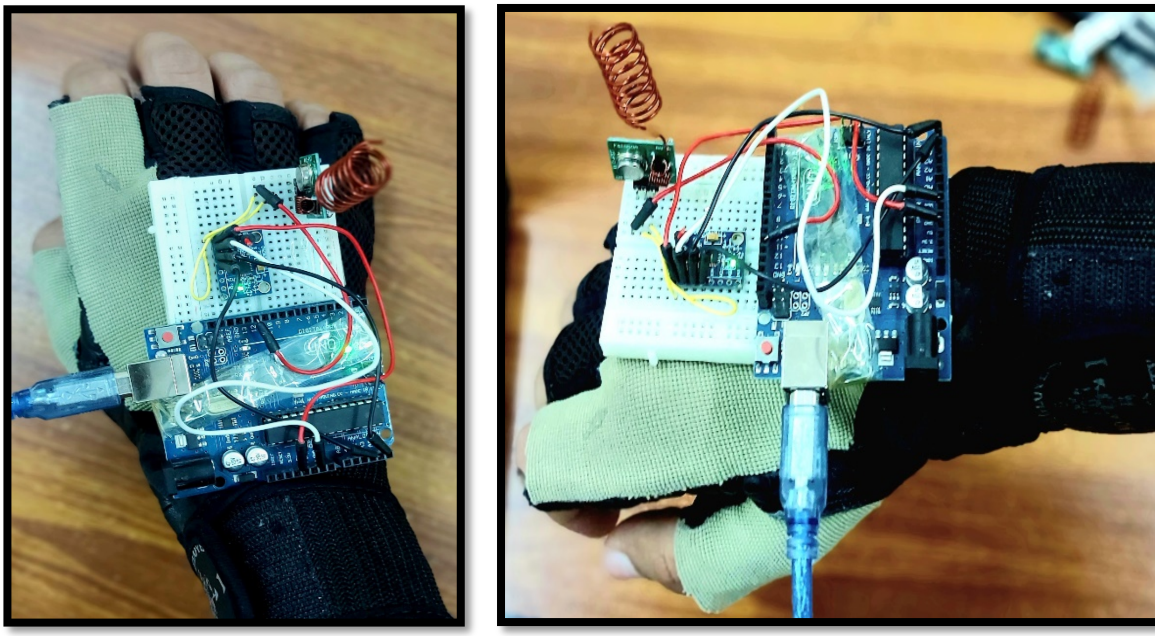

Figure-4.1: Final Hardware, Hand Glove

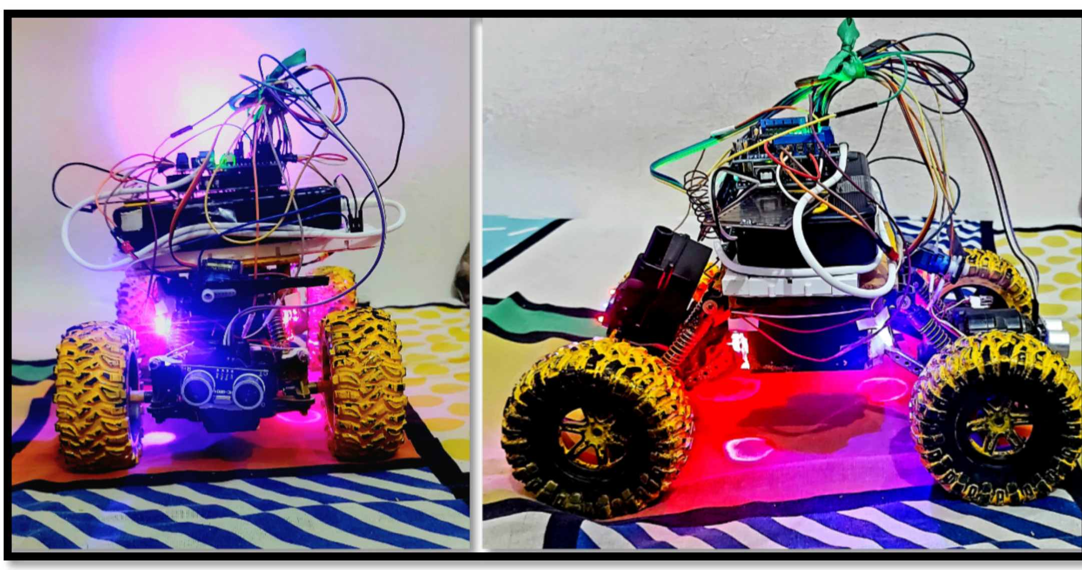

Figure-4.2: Final Hardware, Robotic Car

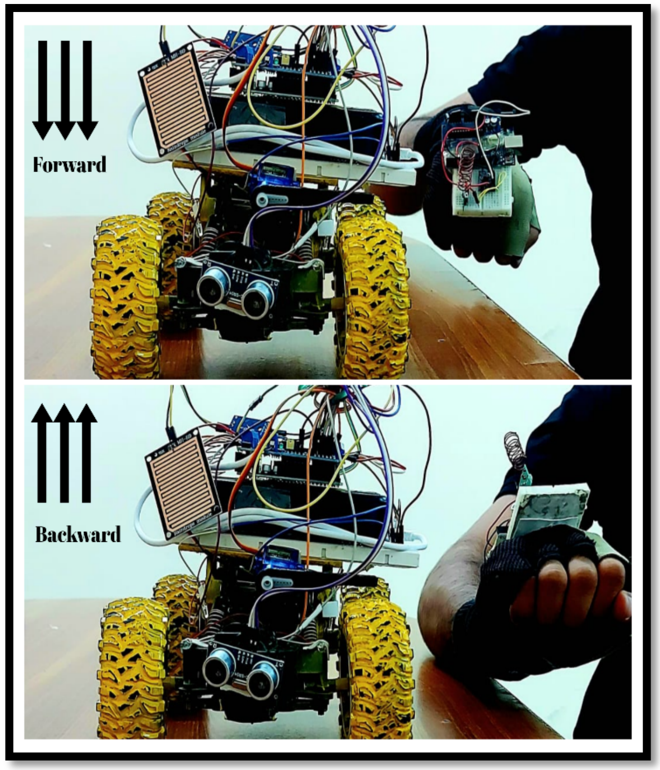

Figure-4.3: Hand gestures for forward and backward movements

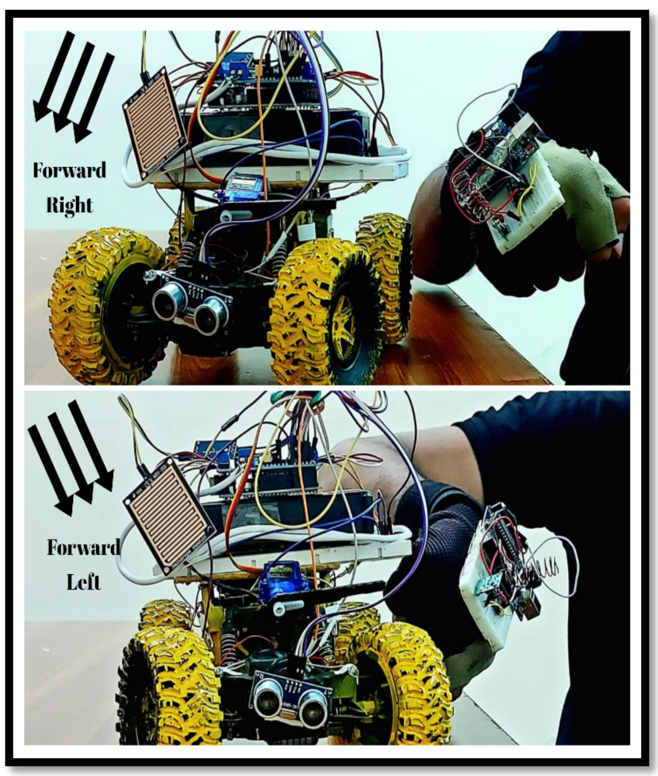

Figure-4.4: Hand gestures for forward right and left movements

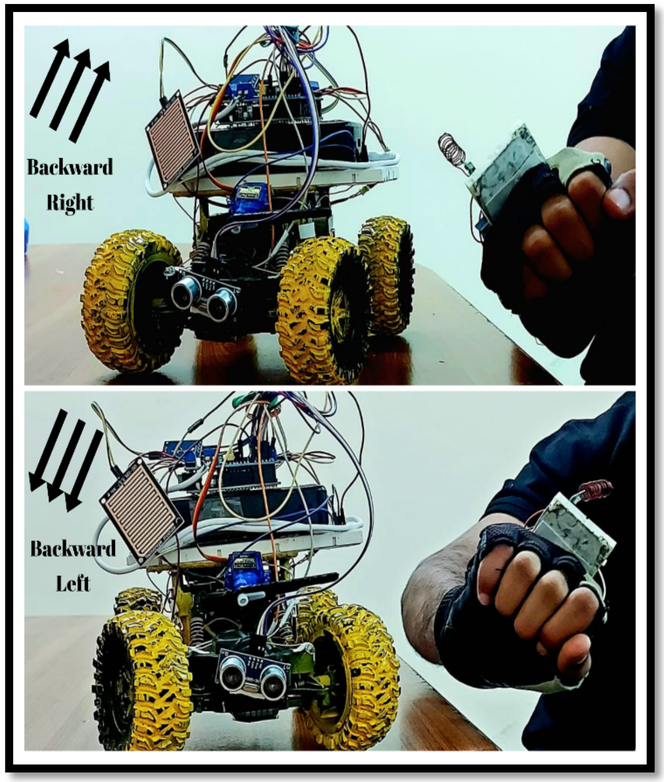

Figure-4.5: Hand gestures for backward right and left movements

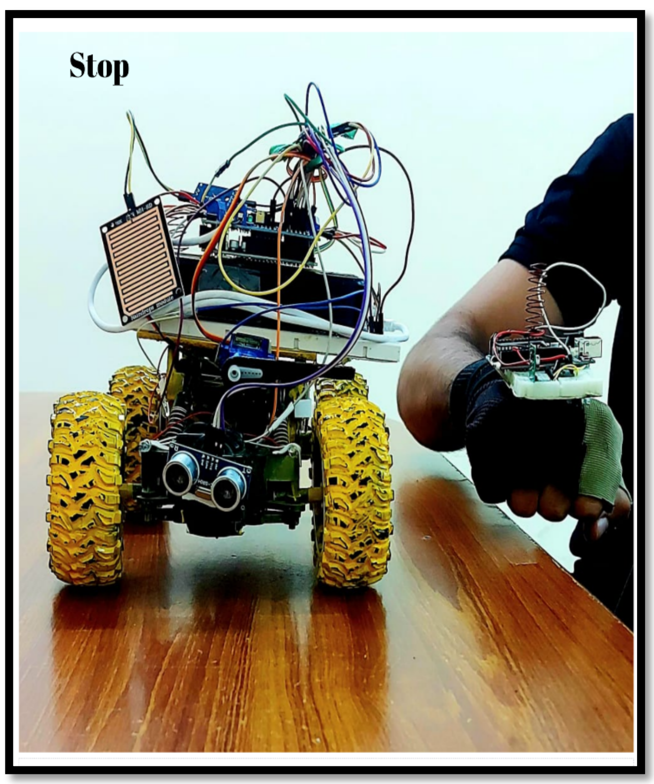

Figure-4.6: Hand gesture for halting the vehicle

Chapter 5
Conclusion and Future Work

5.1 Conclusion

This project successfully explored the realm of hand gesture-based robotic controlled vehicles, opening up exciting possibilities for intuitive and efficient human-robot interactions.

In this project, a hand gesture controlled robotic vehicle has been developed. An unmanned ground car capable to move based on hand gestures. The robot is to be controlled wirelessly. The project is divided into two parts the robotic vehicle and the wireless transmission device mounted on the hand. Using the RF transmitters and receivers the whole design will automate. Its basic features implanted are five that is moving forward, backward, left, right and to stop. Further features included are sharp angle turns, rain sensors, automated wipers, object detectors and automatic breaks. The sensors are intended to replace the remote control that is generally used to run the car.

The hardware part was implemented using the Atmega microcontroller, specifically Arduino Uno. The software part was implemented by using the Arduino software (C language was used).
Our method achieved improved performance in case of Efficiency, Specificity and Sensitivity.

By developing a robust and accurate gesture recognition system, we have empowered users to effortlessly maneuver the robotic vehicle with simple hand movements, eliminating the need for traditional controllers.

As the technology continues to mature, hand gesture-based robotic controlled vehicles have the potential to revolutionize the way we interact with machines and pave the way for a more intuitive and accessible future.
It is our hope that this research will inspire further investigations and applications, ultimately contributing to the advancement of robotics and human-robot interactions.

5.2 Future Work

In future, there is a chance for progress of the results as well and the following study can be enhanced by performing the following:

a. This system can be used in many fields, i.e., in military operations, agriculture or medical field.
b. The involvement of Computer vision and Image processing can also make a bigger impact on the project.
c. Voice recognition can also be done.
d. By installing Wi-Fi and Bluetooth options, the progress may vary in a good way.
e. Explore the incorporation of additional sensors, such as depth cameras or infrared sensors, to enhance the perception capabilities of the robotic vehicle.

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