Navigation Control of a Four-Wheeled Robot, based on Hand Motion of a Tele-operator

Exploratory Project Report

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CERTIFICATE

This is to certify that the Exploratory Project entitled "**Navigation Control of a Four-Wheeled robot, based on Hand Motion of a Tele-operator**" submitted by **Ayush Kumar (22095019), Harsh Chawra (22095041), Mitul Agarwal (22095064) and Rajat Kumar (22095087)**, to the Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University) Varanasi, in partial fulfilment of the requirements for the award of the degree "Bachelor of Technology" in Electronics Engineering is an authentic work carried out at Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University) Varanasi under my supervision and guidance on the concept vide project grant as acknowledged.

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DECLARATION

I hereby declare that the work presented in this project titled "**Navigation Control of a Four-Wheeled robot, based on Hand Motion of a Tele-operator**" is an authentic record of our own work carried out at the Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi as requirement for the award of degree of Bachelors of Technology in Electronics Engineering, submitted in the Indian Institute of Technology (Banaras Hindu University) Varanasi under the supervision of **Dr. Thanjai L. Oppili Prasad**, Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University) Varanasi. It does not contain any part of the work, which has been submitted for the award of any degree either in this Institute or in other University/Deemed University without proper citation.

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ABSTRACT

The primary aim of this project is to engineer a robot car that can be effortlessly controlled using hand gestures, utilizing an Arduino Uno microcontroller, an MPU6050 gyro sensor, and an ultrasonic sensor for detecting obstacles. By harnessing a combination of gyro and accelerometer sensors, the system aptly captures and interprets hand gestures, allowing the Arduino Uno to translate this data into precise commands for the robot car's navigation. The overarching goal is to streamline robot control processes, alleviate the cognitive burden on operators, and ensure responsiveness suitable for a wide array of applications, spanning industrial automation, healthcare, entertainment, and beyond.

Results indicate that the system effectively controls the robot car based on simple hand gestures. This approach offers a natural and intuitive alternative to traditional control interfaces, reducing the learning curve for users and enabling broader adoption of robotic systems. The system's ability to reliably translate human motion into robot commands demonstrates significant potential for applications in telerobotics, logistics, warehouse operations, entertainment, and educational contexts. The project's idea contributes to the advancement of user-friendly interfaces for human-robot interaction, laying the groundwork for future developments in this area.

Furthermore, the project's modular design and open-source nature encourage innovation and customization within the robotics community. By providing a framework for integrating gesture control with robotics, the project invites collaboration and experimentation across various disciplines. This fosters the exploration of novel applications and functionalities, potentially leading to breakthroughs in fields such as assistive technology, rehabilitation robotics, and interactive exhibits.

Contents

Chapter 1

INTRODUCTION

1.1 Motivation

The motivation for a hand-controlled robot is to improve the mobility and independence of individuals with chair-ridden physical disabilities. Traditional wheelchair controls, like joysticks, can be cumbersome and difficult for those with limited dexterity. A gesture-based system offers a more intuitive and accessible solution, reducing physical strain and increasing safety. This approach empowers users with a more natural way to interact with their environment, enhancing their autonomy and reducing reliance on caregivers. By enabling greater freedom of movement, this innovative control system aims to improve the quality of life for wheelchair users and broaden their participation in everyday activities.

1.2 Existing Technologies and Challenges

Existing technologies for robot control, such as joysticks, keyboards, and button-based interfaces, often require significant training and dexterity, presenting a steep learning curve for new users. Gesture-based controls, like Microsoft Kinect and Leap Motion, offer more intuitive interaction but face challenges with accuracy and environmental constraints. Wearable devices also provide gesture recognition but can lack precision. The main challenges are complexity, physical limitations, reliability, and safety. This project aims to address these issues by developing a simple, reliable gesture-controlled robot system using Arduino Uno and MPU6050 gyro sensor technology.

1.3 Problem Statement

The objective of this project is to design and implement a user-friendly and interactive robotic platform controlled entirely by hand gestures. The platform will utilize a microcontroller as its brain, interpreting signals from sensors mounted on a glove, such as accelerometers detecting tilt or flex sensors measuring hand position, to translate the user's intuitive hand movements into control commands. These commands will enable basic movements like forward, backward, left, right, and stop. Additionally, an ultrasonic sensor will be integrated to enable obstacle avoidance functionality, autonomously adjusting the robot's trajectory upon detecting obstacles. The project aims to create a seamless and intuitive user experience where the robot becomes an extension of the user's hand movements, enhancing safety and usability in various environments.

1.4 Proposed Solution

The proposed Hand Gesture Controller robot Car(see Figure 1) using Arduino aims to offer a user-friendly and natural method for controlling robot cars through hand gestures. The proposed system combines the use of sensors, wireless communication, and Arduino programming for hand gesture recognition and robot control. Here are the key features of the proposed system:

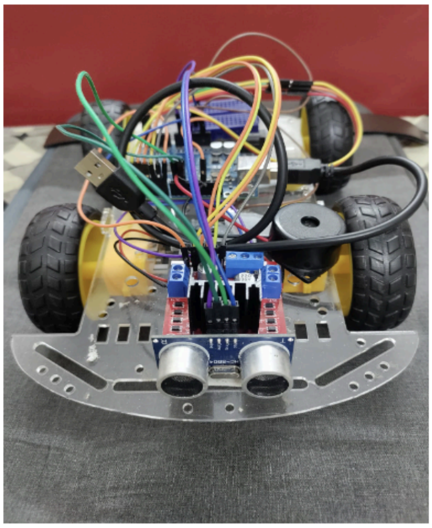


Fig 1.1- The 4 wheeled robot

● Hand Gesture Controller: The hand gesture controller consists of a flex sensor and an accelerometer to capture hand movements. The flex sensor is used to detect finger movements, while the accelerometer detects hand orientation.

● Robot Car: The robot car is equipped with a motor driver for processing the data and sending commands to the motors to drive the wheels.

● Arduino Programming: The Arduino board is programmed to receive the hand control data, process it, and send commands to the motors to control the robot car's movement.

● Hand Motion Algorithm: The proposed system uses a hand motion algorithm to recognize different hand gestures and translate them into specific commands for the robot car

● Ultrasound-Based Object Avoidance: Additionally, the proposed system incorporates an ultrasound sensor to enable obstacle detection and avoidance. This feature enhances the safety and autonomy of the robot car by allowing it to detect obstacles in its path and navigate around them, further enhancing the user-friendly and intuitive nature of the control system.

Block Diagram & Components Required :

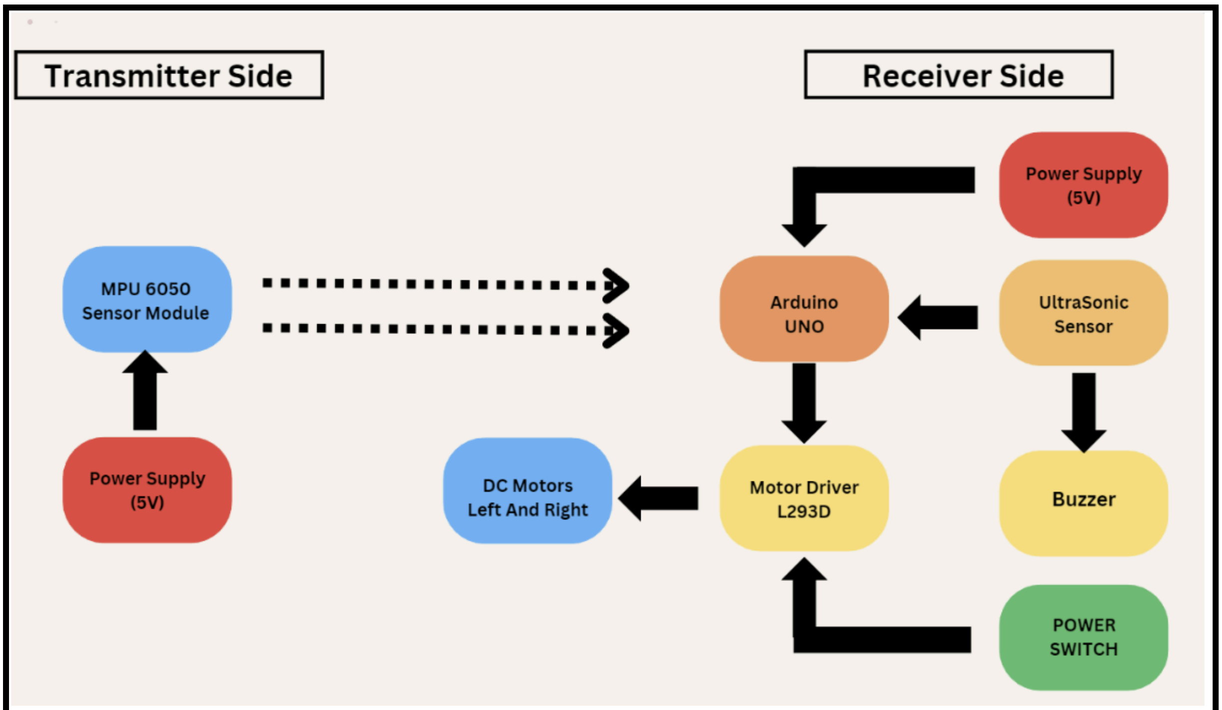


Fig 1.2: Block Diagram of the proposed solution

- **MPU6050 (gyroscope and accelerometer):-** The MPU-6050 sensor enables precise motion tracking, pivotal for responsive hand gesture control in the car.
- **Arduino Uno (receives data & controls motors):-**Arduino Uno receives data and precisely controls motors for seamless functionality.
- **Motor driver (controls motor speed/direction):-**L293D motor driver precisely controls motor speed and direction.
- **Robot car chassis (wheels, motors):-**robot car chassis comprises wheels and motors for locomotion.
- **Ultrasonic Sensor:-**The ultrasonic sensor utilizes high-frequency sound waves to measure distances accurately, providing crucial environmental awareness for obstacle detection and navigation in robotics applications.

Chapter 2

RESULT AND DISCUSSION

2.1 Circuit Implementation:

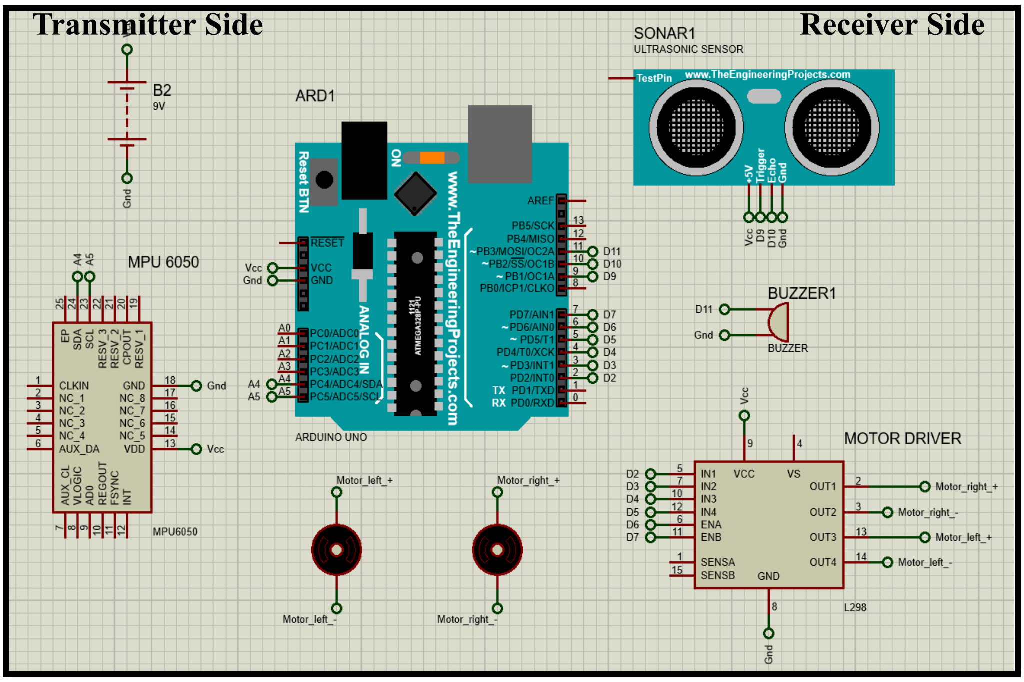


Fig 2.1: Circuit Diagram

Here's a detailed explanation of the connections and data flow among the components in the setup:

1. **MPU6050 Sensor Connection (Gyro Sensor):**

- The SDA (Serial Data) and SCL (Serial Clock) pins of the MPU6050 sensor are connected to the A4 and A5 pins of the Arduino, respectively.
- Through these connections, the Arduino communicates with the MPU6050 sensor using the I2C (Inter-Integrated Circuit) protocol.
- The MPU6050 sensor continuously sends data regarding the orientation and movement of the robot car to the Arduino.

2. Motor Driver Connection:

- The IN1, IN2, IN3, and IN4 pins of the motor driver are connected to digital pins D5, D4, D3, and D2 of the Arduino, respectively.
- This connection allows the Arduino to control the motor driver, regulating the rotation and direction of the motors.
- By sending appropriate signals to these pins, the Arduino can command the motor driver to adjust the speed and direction of the robot car's movement.

3. Motor Connection:

- The output terminals (out1 and out2) of the motor driver are connected to the respective wheels of the robot car.
- These connections ensure that the motor's movements are translated into motion effectively, allowing the robot car to move according to the commands received from the Arduino.

4. Ultrasonic Sensor Connection:

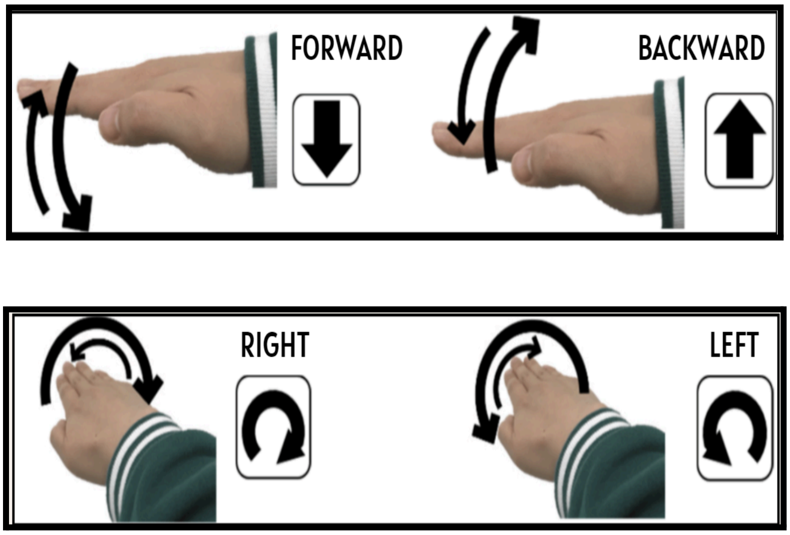
- The trig (transmitter) pin of the ultrasonic sensor is connected to digital pin D6, while the echo (receiver) pin is connected to digital pin D7 of the Arduino.
- This setup enables the Arduino to trigger ultrasonic pulses by sending a signal to the trig pin.
- The ultrasonic sensor then emits ultrasonic waves, which bounce off obstacles in the environment and return to the sensor.
- The Arduino measures the time it takes for the echoes to return to the sensor, using the echo pin.
- Based on this time measurement, the Arduino calculates the distance to the obstacle and adjusts the robot car's movement to avoid collisions effectively during operation.

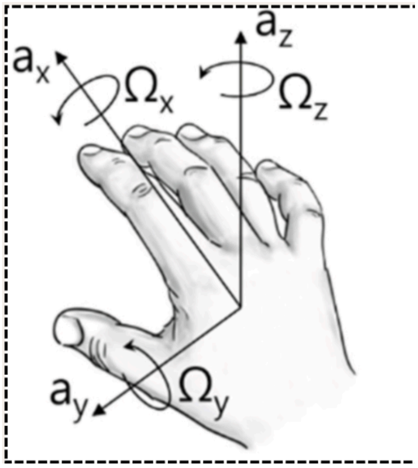
5. Buzzer Connection:

- A buzzer is connected to the Digital pin of the Arduino D11.
- This connection enables the Arduino to control the buzzer by toggling the pin high and low.

2.2 Results :-

Hand Control Instructions:-





Motor Driver Response:-

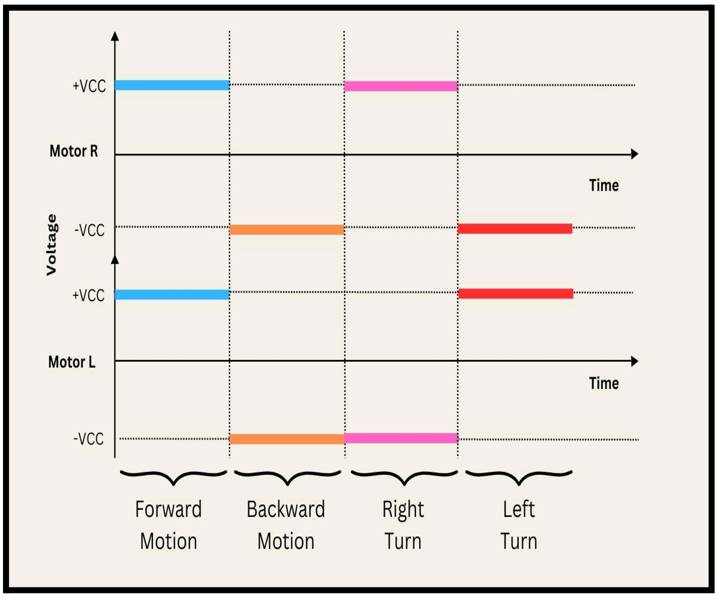


Fig 2.2: Motion response

In a four-wheeled robot, movement is achieved by controlling the voltage supplied to the wheels.

- **Forward:** Apply equal voltage (+VCC) across both sets of wheels to move forward.
- **Backward:** Reverse the polarity of the voltage (-VCC) across both sets of wheels to move backward.
- **Left Turn:** Apply voltage as (+VCC) to the left set of wheels and as (-VCC) to the right set of wheels to execute a left turn.
- **Right Turn:** Apply voltage as (+VCC) to the right set of wheels and as (-VCC) to the left set of wheels to execute a right turn.

By varying the voltage supplied to each wheel, different directions and movements can be achieved, allowing the robot to navigate effectively.

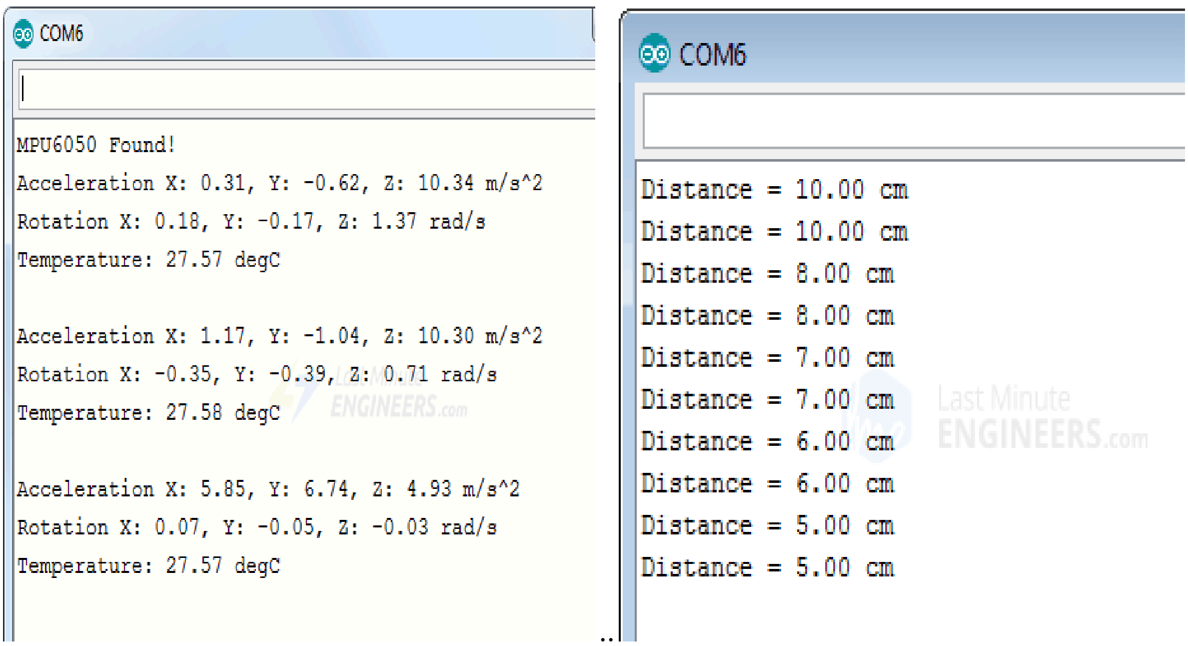
MPU 6050 Response:-

The MPU-6050 consists of a 3 axis gyroscope which can detect rotational velocity along the x,y,z. It has both 3-Axis accelerometer and 3-Axis gyroscope integrated on a single chip. The gyroscope measures rotational velocity, along the X, Y and Z axis. It measures acceleration by measuring gravitational acceleration along the 3 axes.

UltraSonic Sensor Response:-

An ultrasonic sensor is an instrument that measures the distance to an object using ultrasonic sound waves. It uses a transducer to send and receive ultrasonic pulses that relay back information about an object’s proximity. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse.

Fig 2.1: Readings obtained from Ultrasonic sensor(Right) and MPU 6050 sensor(Left)



Test Video Links:-

Youtube G-Drive

Chapter 3

CHALLENGES , CONCLUSION AND FUTURE SCOPES

3.1 Challenges

Accuracy and Sensitivity: Ensuring precise translation of hand gestures into desired movements.

Range of Motion: Defining comfortable and user-friendly hand movements for each command.

Wireless Reliability: Maintaining consistent and reliable communication between the controller and the robot car.

3.2 Conclusions

The Hand Gesture Controller robot Car using microcontroller offers an innovative way to control a robot car via hand gestures. This wireless system is simple to use and can be applied in education, entertainment, and accessibility contexts. Despite some limitations like limited range, fewer gesture options, and calibration needs, it has shown promise for hands-free, intuitive control of robots. Further research could explore its capabilities, address its constraints, and improve overall performance and usability.

3.3 Future Scopes

Gesture Recognition Expansion: Expand the range and complexity of recognized gestures, allowing for more nuanced and diverse robot control.

Improved Accuracy and Calibration: Develop more robust calibration techniques to reduce errors and improve system reliability in various environments.

Longer Communication Range: Extend the wireless communication range for broader usability in outdoor or large-area settings.

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Appendix

Program Code:-

```
// Module: Setup
setup():
   initialize_pins(), serial(), i2c(),
mpu6050()
// Module: Loop
loop():
   read_mpu6050_data(&ax, &ay, &az,
&gx, &gy, &gz)
   // Function:
ultrasonic_distance_measurement
ultrasonic_distance_measurement(&distan
ce)set_motor_speeds(255)
   if distance <= 20.00:
      obstacle_avoidance()
   else:
process_motion_command(Received_Com
mand, Speed_index)
// Function: process_accelerometer_data
process_accelerometer_data(&Tx_comma
nd,  ay):
// Function: obstacle_avoidance
obstacle_avoidance():
   activate_obstacle_indicator()
   stop_motors()
   delay(500)
   move_forward()
   delay(500)
// Function: process_motion_command
process_motion_command(Received_Com
mand, Speed_index):
   manage_run_stop_mode(Speed_index)
   if Run_Stop_Mode == 1:
execute_motion_command(Received_Co
mmand)
// Helper Functions
calculate_speed_index(&Speed_index,
value)
ax_or_ay_exceeds_threshold(ax, ay)
determine_motion_command(&Tx_comm
and, ax, ay)
trigger_ultrasonic_pulse()
calculate_distance_from_pulse()
activate_obstacle_indicator()
stop_motors()
move_forward()
execute_motion_command(Receive_Cmd)
manage_run_stop_mode(Speed_index)
```

Datasheet Specifications:

Arduino UNO:

Arduino Uno is a popular microcontroller development board based on 8-bit ATmega328P microcontroller. Along with ATmega328P MCU IC, it consists other components such as crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller.

MPU6050 Sensor

- MEMS 3-aixs accelerometer and 3-axis gyroscope values combined
- Power Supply: 3-5V
- Communication : I2C protocol
- Built-in 16-bit ADC provides high accuracy
- Built-in DMP provides high computational power

Motor Driver(L298) Sensor

- Operating voltage range: +5 to +46V
- Maximum supply voltage:50V
- Maximum Input and Enable Voltage:+7V

Ultrasonic Sensor:

- Operating voltage: +5V
- Theoretical Measuring Distance: 2cm to 450cm
- Practical Measuring Distance: 2cm to 80cm
- Accuracy: 3mm
- Measuring angle covered: <15°
- Operating Current: <15mA
- Operating Frequency: 40Hz

Buzzer:

- Rated Voltage: 6V DC
- Operating Voltage: 4-8V DC
- Rated current: <30mA
- Sound Type: Continuous Beep