OBSTACLE AVOIDING ROBOT WITH PULSE WIDTH MODULATION MOTOR CONTROL

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INTRODUCTION

The project presents the design and implementation of an analog obstacle-avoiding and fire-detection robot. The robot is built on a four-wheel car chassis and incorporates ultrasonic sensors for real-time obstacle detection, as well as dedicated sensors for fire detection. Motor speed and direction are controlled via a PWM (Pulse Width Modulation) signal generated by analog circuits, enabling smooth maneuvering and efficient speed control without the use of microcontrollers. By combining sensor-based environmental awareness and analog PWM control, this robot is capable of autonomously navigating around obstacles and identifying fire hazards, demonstrating a practical approach to analog-based robotics for safety and automation tasks.

THEORY

Analog circuits process signals that vary continuously over time. In robotics, analog electronics are essential for real-time sensing and control because many physical phenomena—such as distance, light, heat, or sound—are naturally analog.

- **Sensors as Analog Signal Sources:**

  Sensors like ultrasonic modules that was used in the robot for obstacle detection powered by an Arduino Uno microcontroller. The sensor consists of a transmitter that continuously emits high frequency waves which is then received back by the receiver. These waves are analysed to check for any echoes from nearby obstacles. This data is then used to control the actuators. This data is then transmitted to the Servo motors for their functioning.

- **PWM Generation in Analog Circuits:**

- Pulse Width Modulation (PWM) is a technique used to precisely control analog outcomes, such as motor speed, by rapidly switching a voltage or current source ON and OFF at high frequency. The most important parameter is the duty cycle, defined as the proportion of ON time to total cycle time:

- Duty Cycle $= \frac{T_{\text{on}}}{T_{\text{on}}+T_{\text{off}}}$

- By adjusting the duty cycle, the average power delivered to a load can be smoothly and efficiently controlled. PWM signals are square waves where the effective output, averaged over time, varies from 0% (completely off) to 100% (fully on). This allows for efficient, intermediate power control without significant energy loss.

- For this project, a 555 timer IC was used to generate PWM signals. In “astable” mode, the 555 timer acts as an oscillator and outputs a continuous square wave, with frequency and duty cycle set by external resistor and capacitor values. Changing these values or using a control voltage allows modulation of the pulse width, enabling precise motor speed control in analog robotics.

- **Motor Driver Integration:**

  An IC like the L293N acts as an interface between low-power control signals and high-power motors. Analog PWM signals applied to the motor driver enable proportional control of the robot's wheels, allowing for gentle acceleration, turning, and obstacle avoidance.

METHODOLOGY

COMPONENTS REQUIRED:

S. NO	SECTION	COMPONENTS
1.	MECHANICAL PARTS	4-wheel robot car chasis 4* Dc motors 4* wheels
2.	MICROCONTROLLERS AND CONTROL UNITS	Arduino Uno L298N motor driver module
3.	SENSORS AND MOTION CONTROL	Ultrasonic sensors (HC-SR04) Servo motors (SG90)
4.	PWM SPEED CONTROL CIRCUIT	555 timer IC Potentiometer (10k) Resistors (1k, 10k) Capacitors (0.01uF, 0.1uF, 10uF)
5.	POWER SUPPLY	Li- ion batteries 18650

1. SYSTEM DESIGN AND PLANNING

The system was designed around an Arduino Uno microcontroller, which served as the primary control unit for processing sensor data and executing motion commands. An HC-SR04 ultrasonic sensor was employed for obstacle detection, as it provides reliable distance measurements using the time-of-flight principle of ultrasonic pulses. The sensor was mounted on a servo motor, enabling dynamic scanning of the environment across a defined angular range to detect obstacles in multiple directions.

A L298N dual H-bridge motor driver was selected to interface the Arduino with the two DC motors that power the robot's wheels. This driver allows independent bidirectional control of each motor and supports both logic-level direction control and PWM-based speed regulation. To provide smooth analog control of motor speed independent of the Arduino's digital PWM output, a 555 timer IC circuit was designed separately to generate the required PWM signals.

2. PWM CIRCUIT DEVELOPEMENT

The 555 timer circuit was configured in astable mode to generate a continuous PWM waveform that controls the motor speed via the ENA and ENB pins of the L298N motor driver. A potentiometer replaced one of the fixed resistors to allow real-time adjustment of the duty cycle, effectively controlling the motor speed. The PWM output voltage from the 555 timer oscillated between 0 V and 5 V, making it directly compatible with the motor driver's enable pins.

By adjusting the potentiometer, the average voltage applied to the motors could be smoothly varied, allowing gradual acceleration or deceleration rather than abrupt changes. This analog PWM control was particularly useful for fine-tuning motor performance during testing and calibration. The 555 timer circuit was first simulated and then verified on a breadboard before being soldered to the main chassis.

3. SENSOR INTEGRATION AND CONTROL

For environmental sensing, an HC-SR04 ultrasonic sensor was integrated with the system to detect obstacles by measuring the time delay between transmitted and received ultrasonic pulses. The sensor was mounted on a servo motor controlled by the Arduino to perform horizontal scanning across approximately 0°–180°.

The Arduino continuously triggered the ultrasonic sensor and captured distance readings. The sensor data were compared to a predefined threshold distance (typically 20 cm) to determine the proximity of obstacles. Based on this feedback, the Arduino executed decision-making logic to control the robot's motion:

- If no obstacle was detected within the threshold, the robot moved forward.

- If an obstacle was detected ahead, the servo scanned left and right to identify a clearer path.
- Depending on which side offered more free space, the robot executed a left or right turn.

This closed-loop control allowed real-time obstacle detection and avoidance, effectively combining mechanical scanning and distance measurement for better navigation.

4. MOTOR DRIVER INTERFACE

The L298N motor driver acted as a crucial interface between the low-power control circuitry and the higher-current DC motors. Each of the two channels of the driver was connected to one motor, with the IN1–IN4 control pins receiving digital logic signals from the Arduino to determine rotation direction. The ENA and ENB pins were connected to the PWM outputs generated by the 555 timer circuit, enabling analog control over the motor speed.

The driver was powered through an external battery pack to ensure sufficient current delivery without overloading the Arduino. Flyback diodes within the driver protected the circuit from voltage spikes caused by motor inductance. The entire setup ensured safe, stable, and efficient motor operation, translating control logic into smooth mechanical motion.

5. ASSEMBLY AND HARDWARE IMPLEMENTATION

Once individual components and circuits were tested separately, the entire system was assembled on the robot chassis. The Arduino Uno, 555 timer PWM module, L298N motor driver, and sensor assembly were securely mounted to ensure stability during motion. Wiring was carefully organized to minimize electromagnetic interference and voltage drops, with common ground connections maintained between all modules.

Power was supplied from a rechargeable DC battery source capable of delivering sufficient current for both the control and drive circuits. The chassis was designed to balance the weight distribution of all components, allowing for stable motion and efficient turning. All modules were labeled and connected through male–female jumper wires for easy replacement or troubleshooting. The final assembly underwent continuity testing before being powered up.

6. TESTING AND CALIBERATION

The final stage involved extensive testing and fine-tuning of both the hardware and software components. The robot was tested in controlled environments with varying obstacle distances and arrangements to evaluate its obstacle-avoidance efficiency. The PWM duty cycle was gradually adjusted using the potentiometer on the 555 timer circuit to achieve optimal speed control without motor stalling.

Additionally, the servo rotation angles were calibrated so that the ultrasonic sensor could accurately cover the desired scanning range without hitting mechanical limits. The threshold distance for obstacle detection was also optimized to balance reaction time and smooth navigation.

Observations during testing were recorded to identify inconsistencies in sensor readings or motor behavior. Minor software modifications and hardware adjustments were made accordingly to improve responsiveness and reliability. The successful calibration confirmed that the robot could autonomously detect and avoid obstacles in real time while maintaining stable motion.

BLOCK DIAGRAM

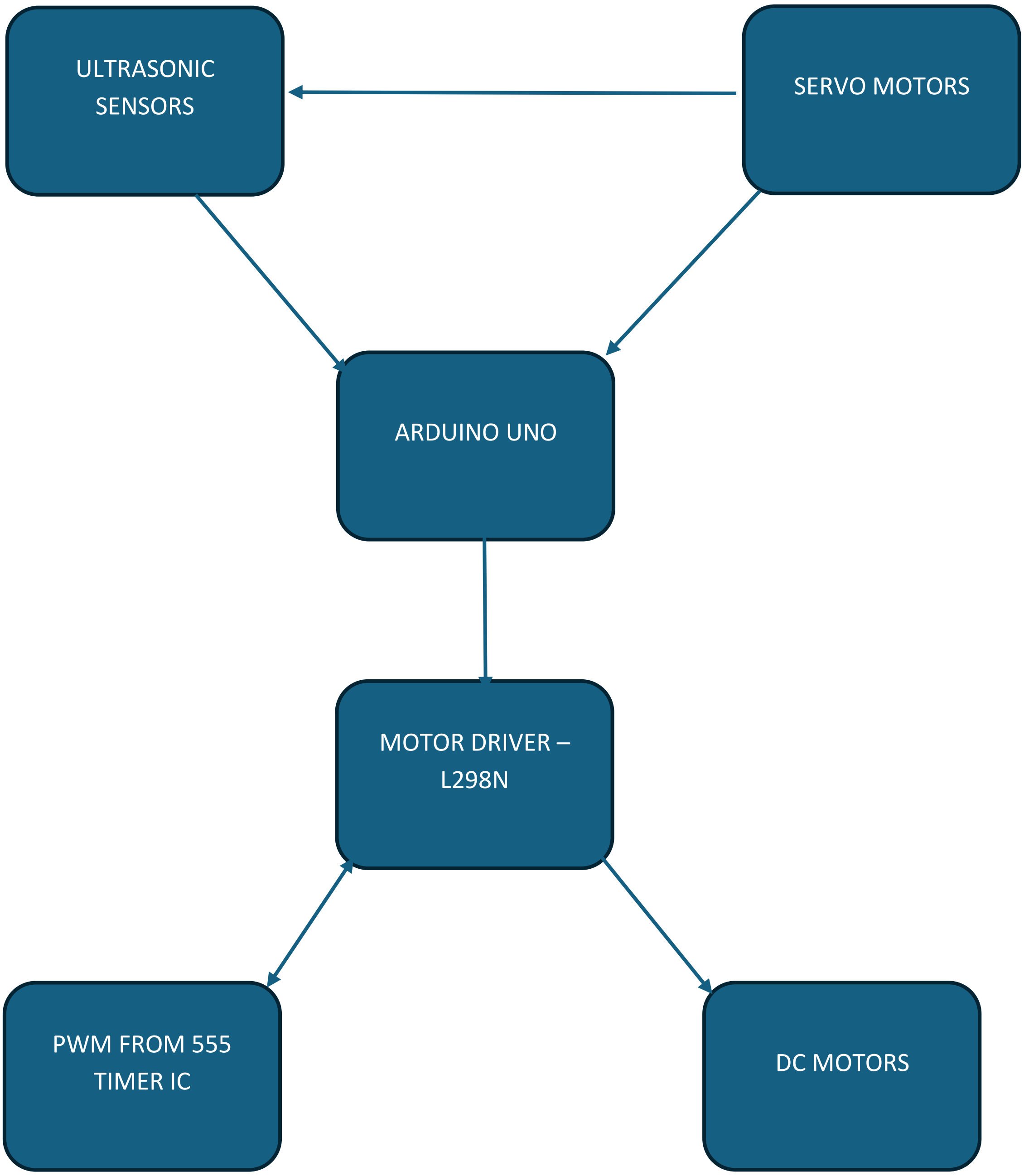
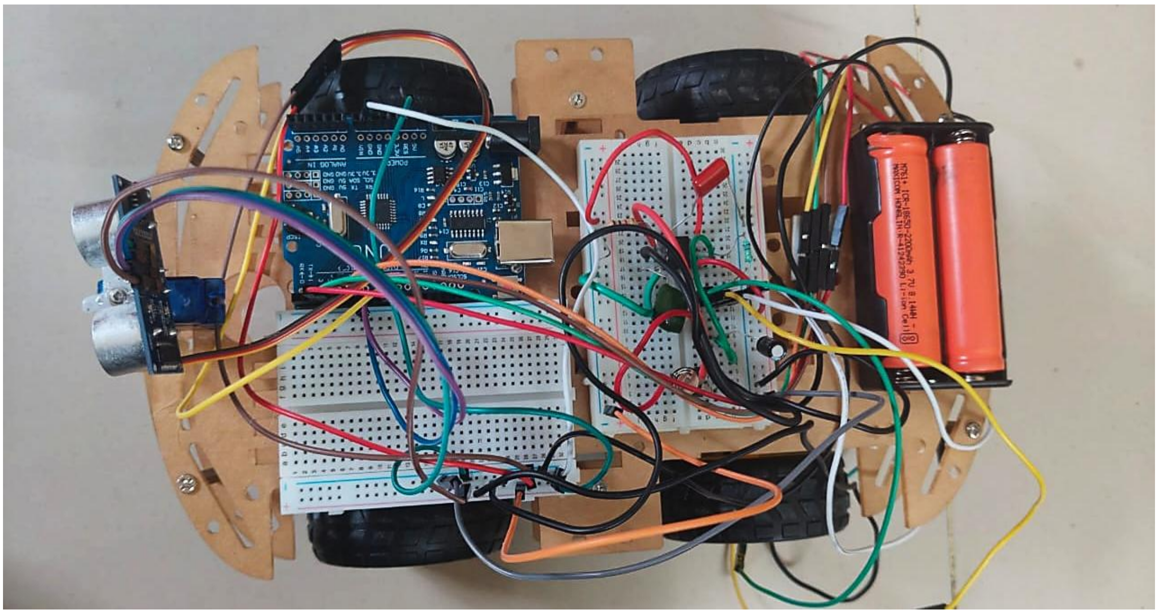
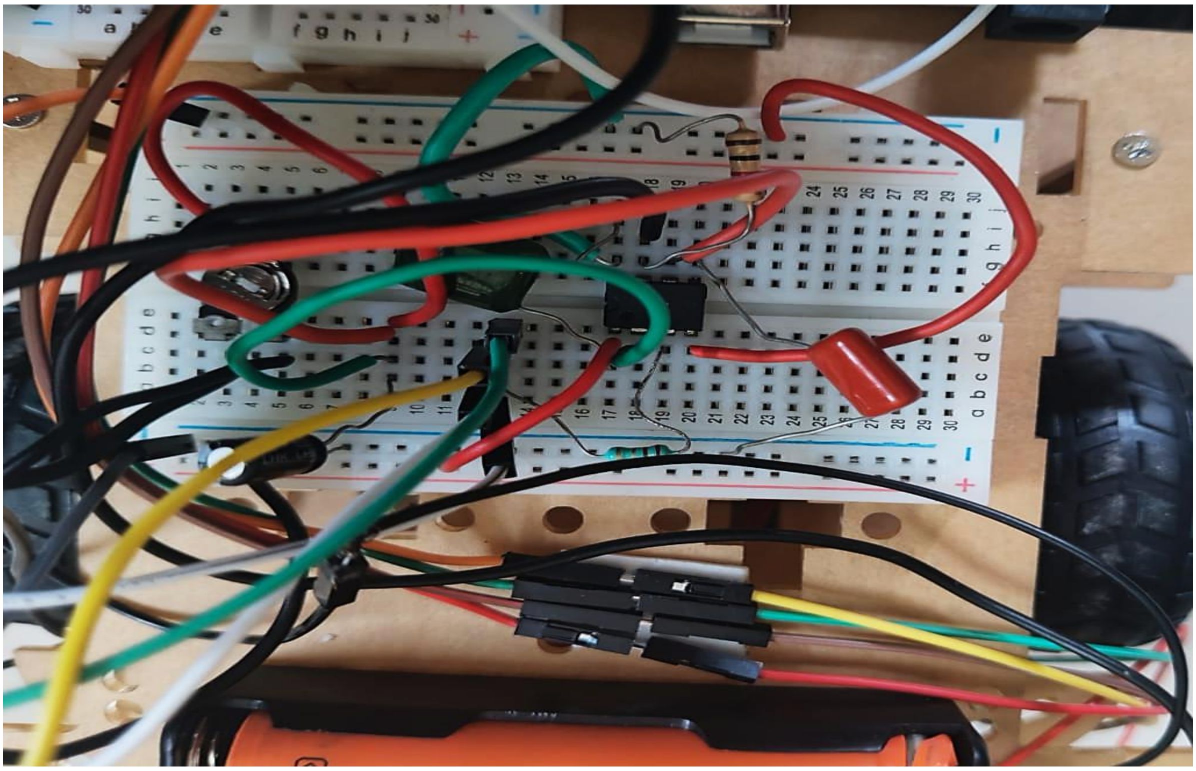


PHOTO GALLERY

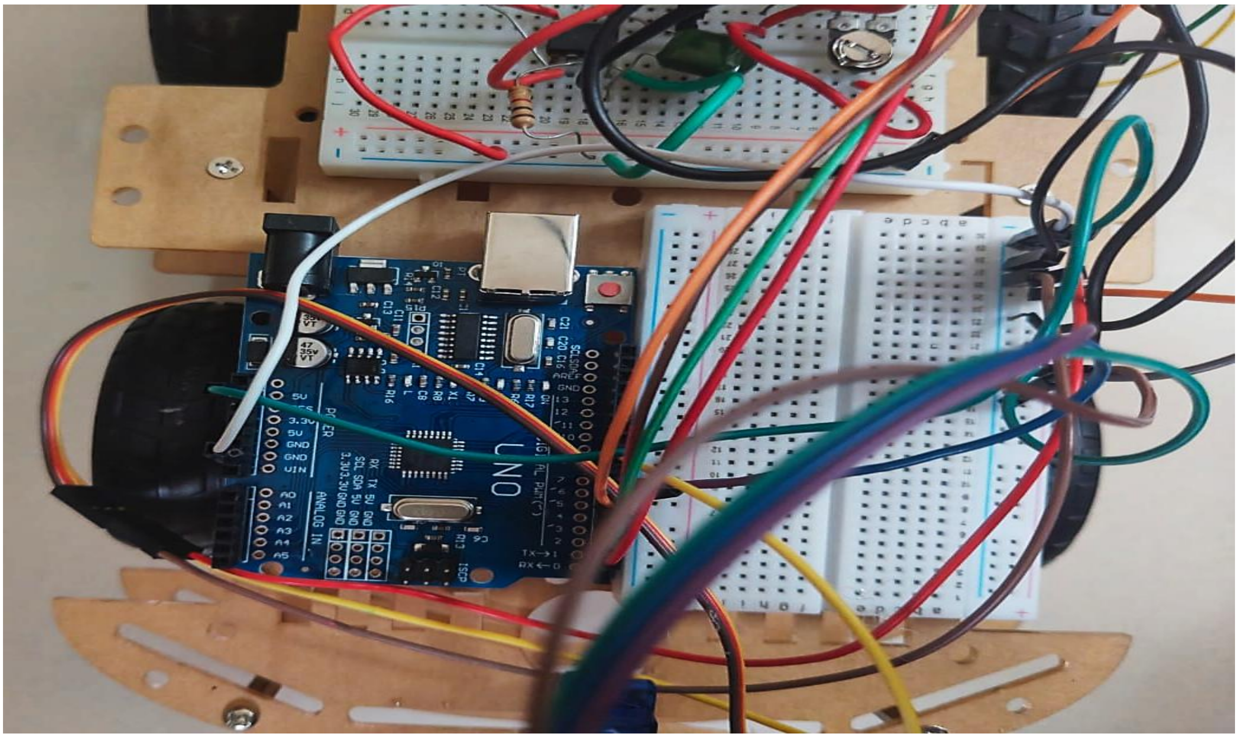
Top-View:



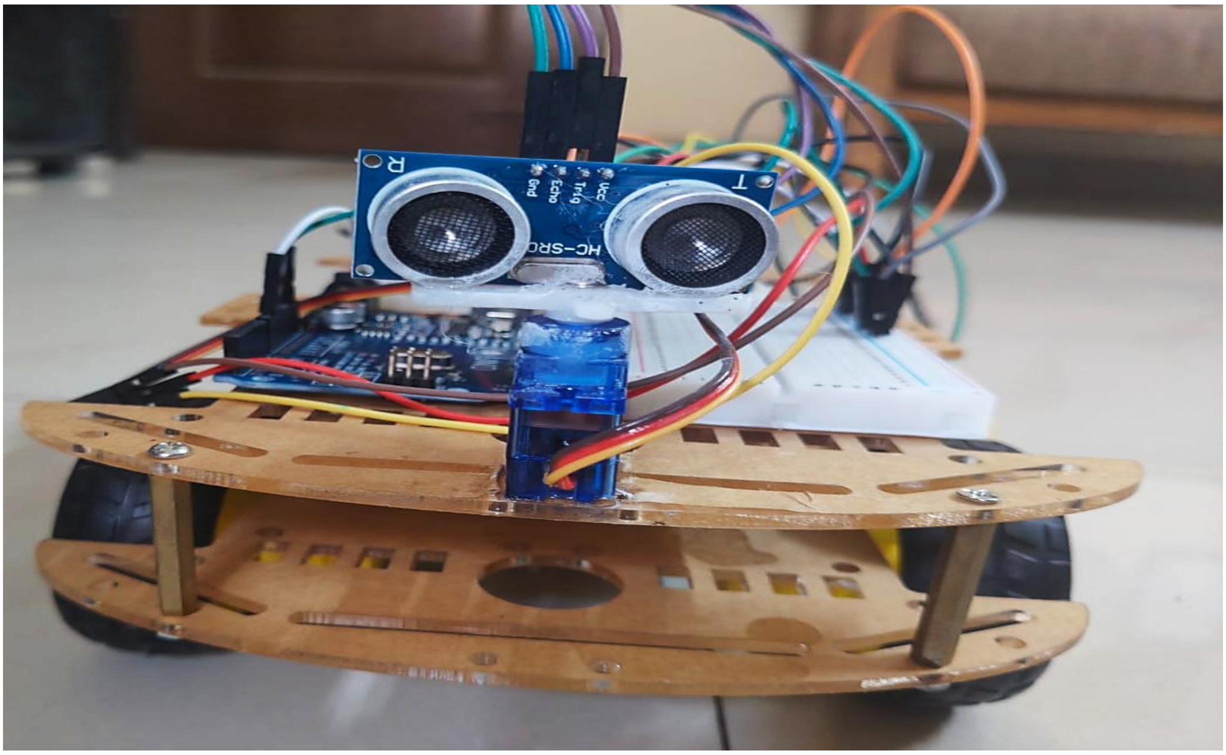
PWM Control Circuit:



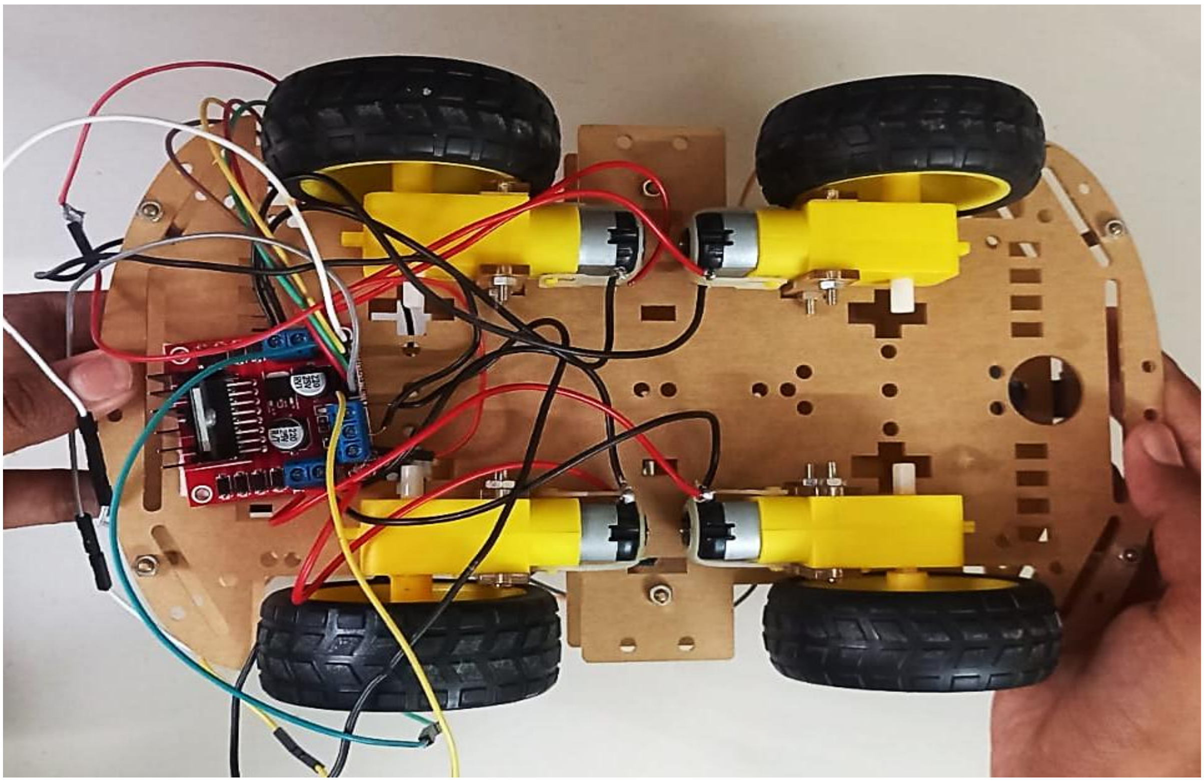
Arduino Connections:



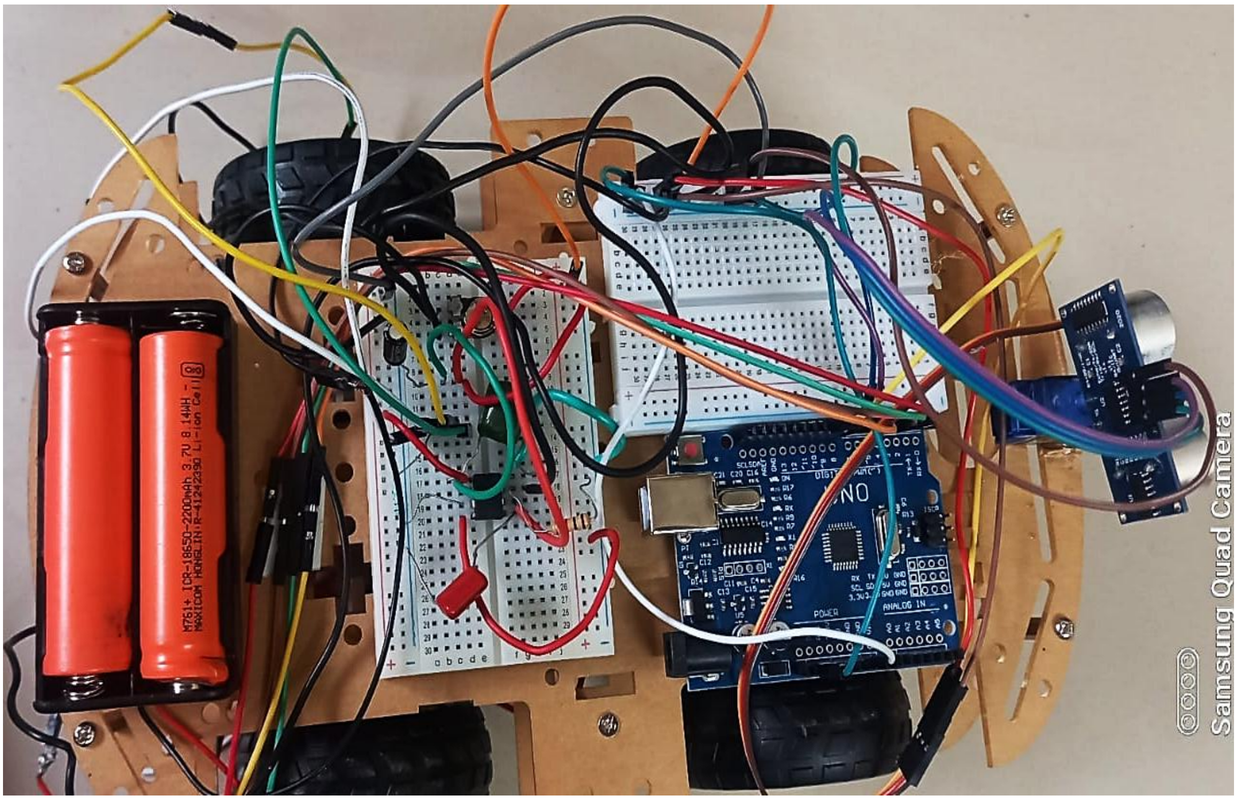
Ultrasonic Sensor:



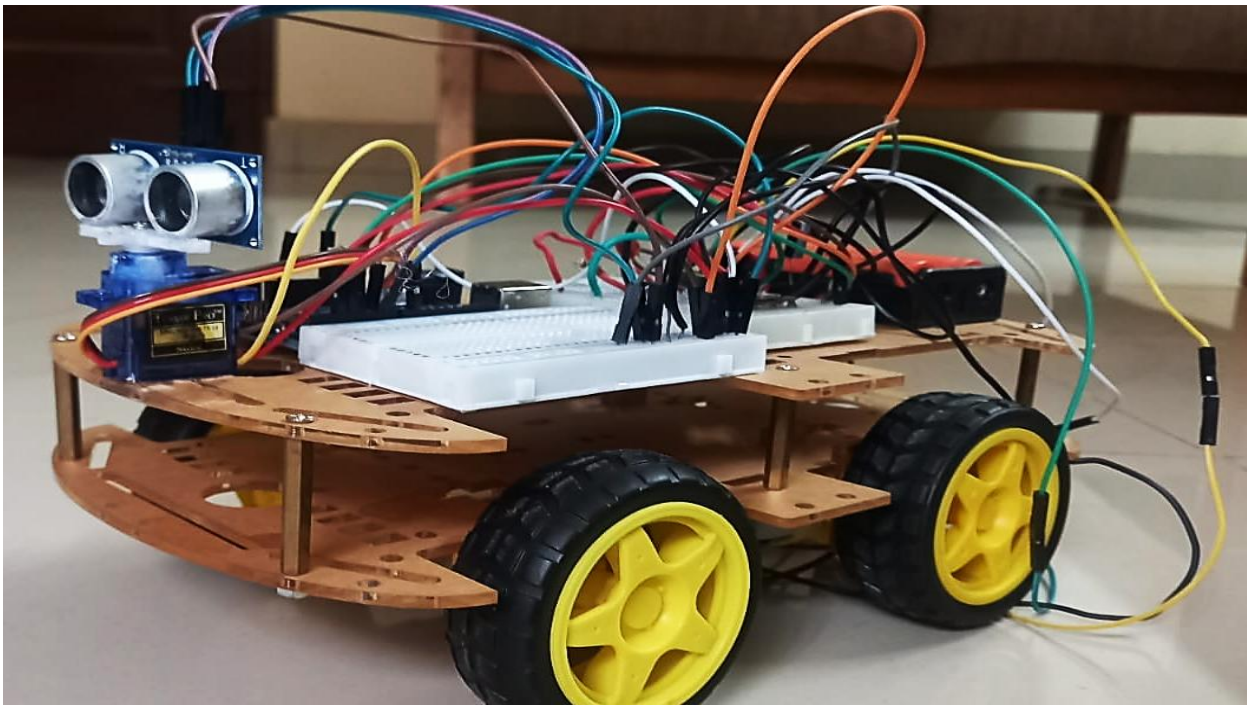
DC Motor Connections:

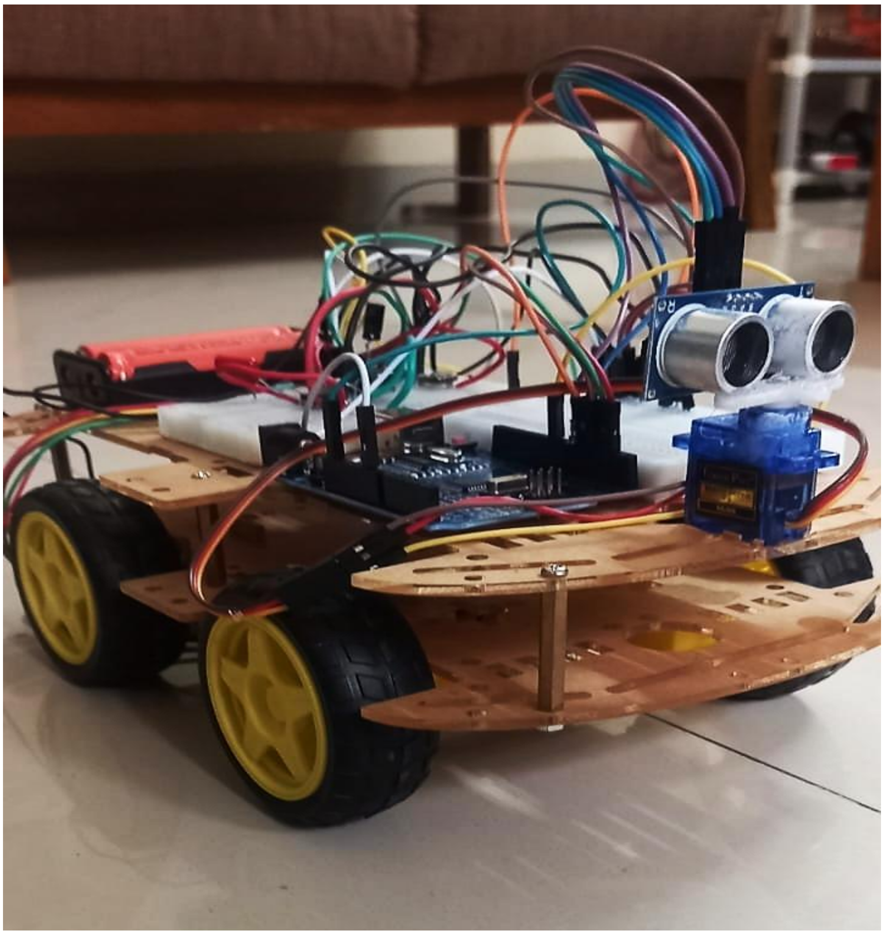


Robot Connections:



Obstacle Avoiding Robot with PWM Controlled motor speed





RESULTS AND DISCUSSION

This project on Obstacle avoiding robot with PWM controlled motor speed was a great way to integrate a basic analog concept of pulse width modulation to a widely used and implemented robot. With this robot analog PWM control circuit was executed and effectively used to vary motor speed in response to sensor inputs. Using the Ultra sonic sensors installed, the robot consistently detected obstacles and adjusted direction or stopped without collisions during testing. PWM signals provided smooth, energy-efficient motor operation throughout all trials, and the L293N motor driver performed reliably with the four-wheel chassis.

FUTURE SCOPE

This project has a great scope for future developments and subsequent scaling. This can be made more efficient moving forward by the incorporation of flame and temperature sensors to develop a comprehensive fire detection and safety unit. By combining real-time obstacle avoidance with multi-sensor fire hazard monitoring, the robot can serve as an intelligent first responder for building safety, industrial automation, and emergency preparedness.

With additional integration with camera modules live monitoring from remote regions, environmental surveillance, automatic alert generation, and integration with wireless communication protocols or building management systems, extending the robot's utility to smart infrastructure and proactive hazard mitigation applications can be made possible.

CONCLUSION

The project successfully demonstrated the use of analog electronics and PWM for effective motor speed control in a mobile robot platform. By integrating ultrasonic sensors for obstacle detection and utilizing a 555 timer IC for PWM generation, the robot was able to navigate and respond to its environment in real time. The results highlight the efficiency and reliability of analog PWM control for robotic motion and open avenues for expanding functionality with additional safety and sensing features in future work.

REFERENCES

1. https://howtomechatronics.com/how-it-works/electronics/555-timer-ic-working-principle-block-diagram-circuit-schematics
2. https://www.youtube.com/watch?v=2XjqS1clY_E&t=157s
3. https://www.youtube.com/watch?v=A_3Gx2CpEXo
4. https://www.electronics-tutorials.ws/blog/pulse-width-modulation.html