DAYANANDA SAGAR COLLEGE OF ENGINEERING

Shavige Malleshwara Hills, Kumaraswamy Layout, Bangalore-560078

(An Autonomous Institute affiliated to VTU, Accredited by NAAC with 'A' Grade, UGC & ISO 9001:2008 Certified)

VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"Jnana Sangama", Belagavi-18, Karnataka, India.

A Mini Project Report

on

"LINE FOLLOWING AND OBSTACLE DETECTION BOT"

Mini Project Submitted in partial fulfillment of the requirement for the degree of

Bachelor of Engineering

In

Electronics & Telecommunication Engineering

By

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DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION ENGINEERING
Accredited by National Board of Accreditation Council (NBA)

CERTIFICATE

This is to certify that the Mini Project work entitled **"LINE FOLLOWING AND OBSTACLE DETECTION BOT"** is a bonafide work carried out by **PRANAV (1DS24ET073), KUSHAL (1DS24ET053), QUSAI (1DS24ET078), VAISHNAVI (1DS24ET119)** students of 2^{nd} semester, Dept. of Electronics & Telecommunication Engineering, DSCE in partial fulfillment for award of degree of **Bachelor of Engineering** in **Electronics & Telecommunication Engineering,** under the **Visvesvaraya Technological University, Belagavi** during the year **2024-25**. The Mini Project has been approved as it satisfies the academic requirements in respect of Mini Project work prescribed for the Bachelor of Engineering degree.

Signature of Guide	Signature of HOD
Ambika Naik	**Dr. Vinod.B.Durdi**
Assistant professor	Assoc.Professor & Head
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DSCE, Bangalore	DSCE, Bangalore

Name of the Examiners	**Signature with date**
1.	....
2.	....

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ABSTRACT

This Mini Project report presents the design and development of an autonomous line-following and obstacle-detection robotic vehicle using a modular and cost-effective approach. The primary aim of this project is to build a beginner-friendly, microcontroller-based mobile robot capable of navigating a predefined path and intelligently responding to obstacles. Key components used in the system include an Arduino Uno, L298N motor driver, IR sensors, and an HC-SR04 sensor.

Unlike advanced robotic platforms that rely on complex vision systems or machine learning algorithms, this project simplifies the implementation using basic sensor modules and logical motor control. The IR sensors are calibrated to follow a white surface and detect black lines that guide the robot's path. Based on the sensor feedback, the robot adjusts its direction by selectively stopping one side of the motor pair to steer accurately. Two DC motors on each side are connected in parallel and powered via the L298N driver to ensure smooth and responsive movement.

For obstacle detection, the ultrasonic sensor monitors the forward path and halts the robot if an object is detected within a preset range, thereby preventing collisions. Powered by a 3-cell LiPo battery (≈11.1V), the robot demonstrates reliable switching between line tracking and obstacle detection modes in real time. This design serves as a foundational project for students and hobbyists interested in embedded systems, autonomous navigation, and robotic control systems.

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List of Abbreviations

IR sensor	Infrared sensor
Arduino UNO	Microcontroller
DC motor	Direct Current motors
L298N	Dual H-Bridge Motor Driver IC
HC-SR04	Ultrasonic Distance Sensor Module
LiPo	Lithium Polymer (Battery)
PWM	Pulse Width Modulation
PID	Proportional–Integral–Derivative
IN1–IN4	Input Pins (on L298N Motor Driver)
ENA / ENB	Enable Pins (Motor Driver Speed Control)

CHAPTER 1

1. INTRODUCTION:

1.1 Overview

Autonomous mobile robots play an important role in modern automation, especially in areas like warehouse management, delivery systems, and smart navigation. A common approach to robot navigation is line following, where the robot uses sensors to trace a visible path. In dynamic environments, it also becomes essential for robots to detect the obstacles in real time. This project focuses on the design and development of a low-cost, Arduino-based robot capable of both line following and obstacle detection using modular components such as IR sensors, an ultrasonic sensor, and an L298N motor driver.

1.2 Problem Statement

Conventional robotic navigation systems often rely on expensive components or complex algorithms, making them less accessible to beginners and students. Moreover, many basic models lack the ability to dynamically avoid obstacles, limiting their real-world use. There is a need for a simple, beginner-friendly robot that combines basic line-following capability with intelligent obstacle detection using affordable, easy-to-program components like the Arduino Uno and commonly available sensors.

1.3 Objectives

- Design an autonomous mobile robot using Arduino Uno.
- Implement line-following using IR sensors.
- Integrate ultrasonic-based obstacle detection.
- Control motors using L298N motor driver.
- Provide a scalable and educational prototype.
- To develop logic for switching between line-following and obstacle-detection modes.

1.4 Motivation

With the growing demand for automation in industries, logistics, and education, there is an increasing need for low-cost, intelligent robotic systems that can navigate autonomously with minimal human intervention. Traditional manual transport systems are time-consuming and prone to errors, especially in repetitive tasks. The motivation behind this project is to develop a simple yet functional robotic platform that demonstrates both line-following and obstacle-detecting capabilities-making it ideal for learning, prototyping, and real-world applications in resource-constrained environments.

CHAPTER 2

2. LITERATURE SURVEY:

2.1 Related Works

A relevant study, “Design and Development of Line Following Robot Using PID Control Systems” by Atharv Baluja [1], explores the use of PID control for achieving smooth line tracking using IR sensors. It helped us understand sensor-based navigation logic for path correction.

Another work, “Warehouse Automation Using Line Follower Robot” by Ayush Sharma [2], demonstrated how line-following robots can aid material transport in industrial setups. The integration of computer vision techniques in this paper highlighted the potential for advanced path planning in complex layouts.

We referred to “Design and Implementation of Line Follower Robot” by Shervin Shirmohammadi and Fahimeh Baghbani [3] for selecting the core components such as the Arduino Uno, L298N motor driver, and IR sensors. This helped us finalize our hardware configuration.

In addition, the paper “Obstacle Avoiding Robot Using Arduino Uno” by Supriya Ala [4] informed our approach toward using ultrasonic sensors for obstacle detection. The sensor configuration and decision-making flow were modeled based on the principles discussed in this work.

2.2 Summary

From the reviewed literature, it is evident that line-following and obstacle-avoiding robots are widely explored in both academic and industrial contexts. Studies on PID control systems enhanced our understanding of accurate path tracking using sensor feedback, while works on warehouse automation highlighted real-world applications and the role of advanced path planning. Research on hardware configuration, including the use of Arduino Uno, L298N motor driver, and IR sensors, guided our component selection and system design. Finally, papers focused on obstacle detection emphasized the importance of sensor accuracy and decision-making logic for real-time collision avoidance.

These insights helped shape our approach by combining simplicity with functionality, enabling the development of a low-cost, autonomous robot with both line-following and obstacle-detection capabilities.

CHAPTER 3

3. OBJECTIVES:

- **To design and construct a functional autonomous mobile robot using an Arduino Uno microcontroller.**
  This serves as the central control unit, managing sensor data and motor control logic efficiently.

- **To implement line-following functionality using two calibrated IR sensors.** These sensors allow the robot to detect and follow a predefined path, making it suitable for applications like guided transport or floor navigation.

- **To integrate an ultrasonic sensor for real-time obstacle detection and avoidance.** The ultrasonic sensor enhances the robot's autonomy by allowing it to respond dynamically to obstacles in its path, improving safety and reliability.

- **To control the movement of four DC motors using an L298N motor driver module.** This driver enables smooth and independent control of the robot's wheels, providing stable and accurate motion.

- **To develop control logic for automatic switching between line-following and obstacle avoidance modes.**
  This logic ensures the robot can adapt to changing environments and continue functioning autonomously without manual intervention.

- **To create a compact, cost-effective, and scalable platform for educational and prototype development.**
  The system is designed to be accessible and replicable, making it ideal for students, hobbyists, and small-scale automation projects.

CHAPTER 4

4. METHODOLOGY:

4.1 Component Selection

The selection of components was carried out after comparing available options based on a Figure of Merit (FOM) analysis, where different parameters relevant to each component were rated on a scale of 1 to 5. This helped us evaluate and choose components that best suited the requirements of our robot.

To construct the robot's body, we designed and cut the base manually using a **foam board**, selected for its lightweight, affordable, and easy-to-shape nature. This material provided a sturdy platform to mount all components securely while keeping the robot agile and portable.

Criteria	Arduino Uno	Arduino Nano	ESP32	NodeMCU (ESP8266)
Cost	5	5	4	5
Ease of Use	5	5	3	4
I/O Pins	5	4	5	3
Community Support	5	5	4	4
Compatibility	4	4	5	5
Total Score (/25)	**24**	23	21	21

Table 4.1: FOM for microcontroller

Criteria	HC-SR04	IR Proximity	LIDAR (VL53L0X)
Range	5	3	5
Accuracy	5	3	5
Ease of Use	5	5	3
Power Consumption	4	5	3
Cost	5	5	2
Total Score (/25)	**24**	21	18

Table 4.2: FOM for Obstacle Detection Sensor

Criteria	IR Sensor Module	LDR + LED Pair	TCRT5000
Accuracy	4	2	5
Response Time	5	3	4
Ease of Integration	5	3	3
Cost	5	5	4
Reliability	5	3	4
Total Score (/25)	**24**	16	20

Table 4.3: FOM for Line Following Sensor

Criteria	L298N	L293D	BTS7960
Voltage Range	5	3	5
Current Support	4	3	5
Ease of Use	5	5	4
Cost	5	5	3
Compatibility	5	4	4
Total Score (/25)	**24**	20	21

Table 4.4 FOM for Motor Driver

Figure 4.1: Arduino UNO

Figure 4.2: HC-SR04 Ultrasonic Sensor

Figure 4.3: IR Sensor

Figure 4.4: L298N Motor Driver

Figure 4.5: Battery

Figure 4.6: DC motor

Figure 4.7: Wheels

Component Name	Function in Project	Key Merits (Reasons for Selection)	Quantity
Arduino Uno	Central microcontroller; processes sensor inputs and controls motor output.	Easy to program- Large support community- Sufficient I/O pins- Affordable and beginner-friendly	1
IR Sensors (x2)	Detect black line on white surface to guide robot along the path.	Low-cost and accurate- Easy to interface with Arduino- Quick response time	2
HC-SR04 Ultrasonic Sensor	Detects obstacles in front of the robot using echo reflection.	Long range and high accuracy- Easy to code and calibrate- Cost-effective	1
L298N Motor Driver	Controls the direction and speed of DC motors based on Arduino signals.	Dual H-Bridge output- Drives two pairs of DC motors- Can handle higher voltages	1
DC Motors (x4)	Drive the wheels for robot movement. Motors on each side are connected in parallel.	Easily available- Sufficient torque for small robots- Compatible with L298N driver	4
Foam Board	Base platform of the robot, manually cut to desired shape.	Lightweight and easy to work with- Inexpensive and widely available- Customizable for mounting components	1
LiPo Battery (11.1V)	Powers the Arduino, sensors, and motors.	High energy density- Rechargeable- Compact and suitable for mobile systems	1
Breadboard & Jumper Wires	For testing circuit connections and prototyping.	Solderless assembly- Easy to modify circuits- Reusable	As needed

Table 4.5: Parts and Purpose

4.2 Functional Overview

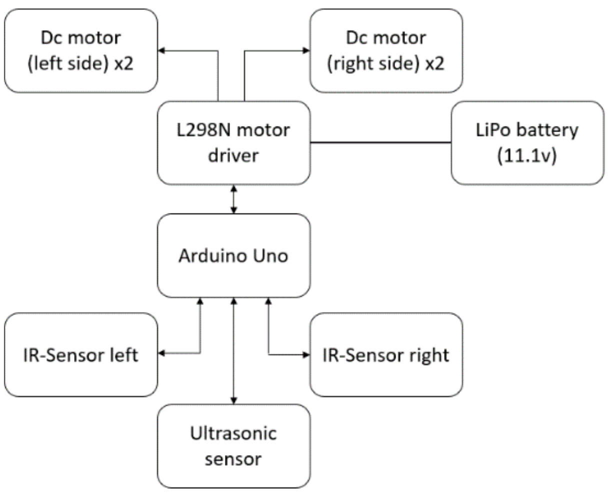

Figure 4.8: Block diagram

- **IR Line Tracking:**
Two IR sensors (IR_L and IR_R) detect the path by sensing the contrast between black and white surfaces. The robot adjusts its direction based on which sensor detects the black line.
- **Obstacle Detection:**
An HC-SR04 ultrasonic sensor detects obstacles ahead. If an object is within a preset range, the robot halts until the path is clear.
- **Motor Control:**
An L298N motor driver controls two pairs of DC motors (left and right), based on inputs from the Arduino Uno. Motors are connected in parallel for balanced movement.

- **Power Supply:**
  A 3-cell (11.1V) LiPo battery powers the Arduino, sensors, and motors.

4.3 Working Principle

- **Line Detection & Navigation:**
  IR sensors send digital signals to the Arduino. If one sensor detects black, the Arduino stops the motor on that side to steer the robot back to the path.
- **Obstacle Handling:**
  The ultrasonic sensor measures distance using echo timing. If an obstacle is detected ahead, the robot stops until the path is clear.
- **Control Switching:**
  If both IR sensors detect black (e.g., at a junction/end of a line), the robot enters obstacle detection mode, and the bot comes to a halt.
- **Power Management:**
  The LiPo battery supplies regulated power to all components, ensuring reliable operation.

4.4 Software Design

The operational core of this project is the software, which was written in C++ within the Arduino IDE. The IDE provided the essential tools to compile this code and transfer it to the Arduino UNO, enabling the robot to function as intended in real-world scenarios.

Figure 4.9: Arduino IDE

4.5 System Workflow

The below Figure 3.2 shows the circuit diagram implemented for our project. The data and control flow of the system operate as follows. The two IR sensors are connected to the Arduino Uno's digital input pins and are used to detect the contrast between the black line and the white surface. Based on the sensor input, the Arduino processes the direction logic and sends corresponding control signals to the L298N motor driver. The motor driver is responsible for driving four DC motors, with two motors connected in parallel on each side of the robot to ensure balanced motion. Additionally, an HC-SR04 ultrasonic sensor is mounted on the front and connected to the Arduino through its digital pins (trigger and echo). This sensor detects any obstacle in the robot's path. When an obstacle is detected within a present range, the Arduino halts the robot by disabling the motor outputs. The system is powered using a 3S (11.1V) LiPo battery, which supplies power to the motor driver and Arduino, enabling smooth and uninterrupted operation.

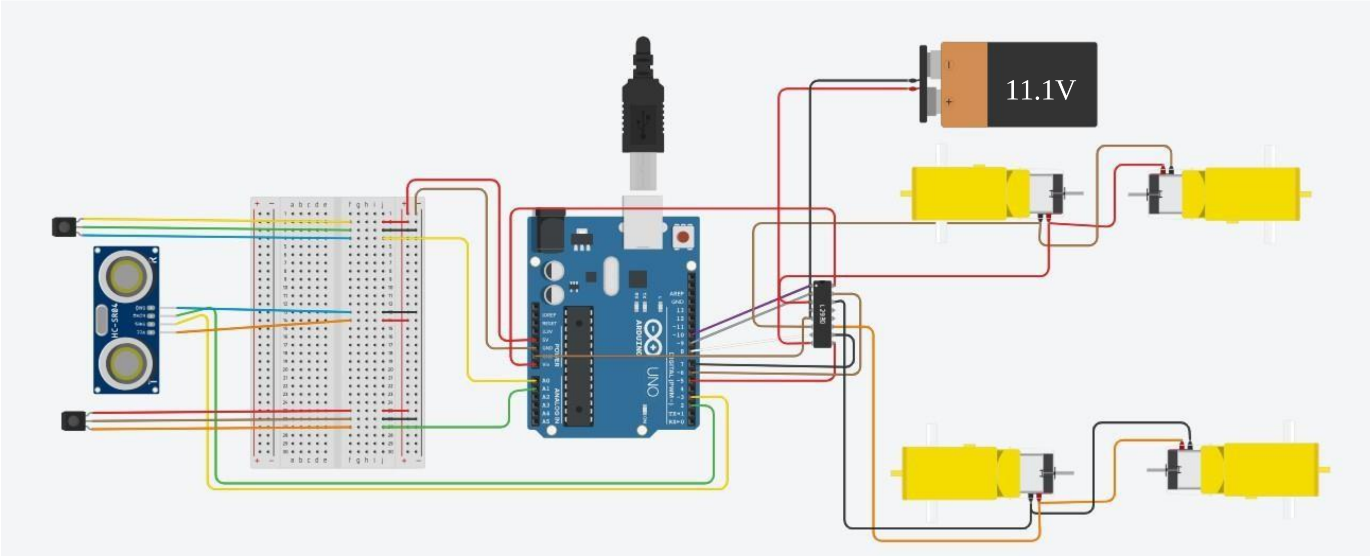

Figure 4.10: Circuit Diagram

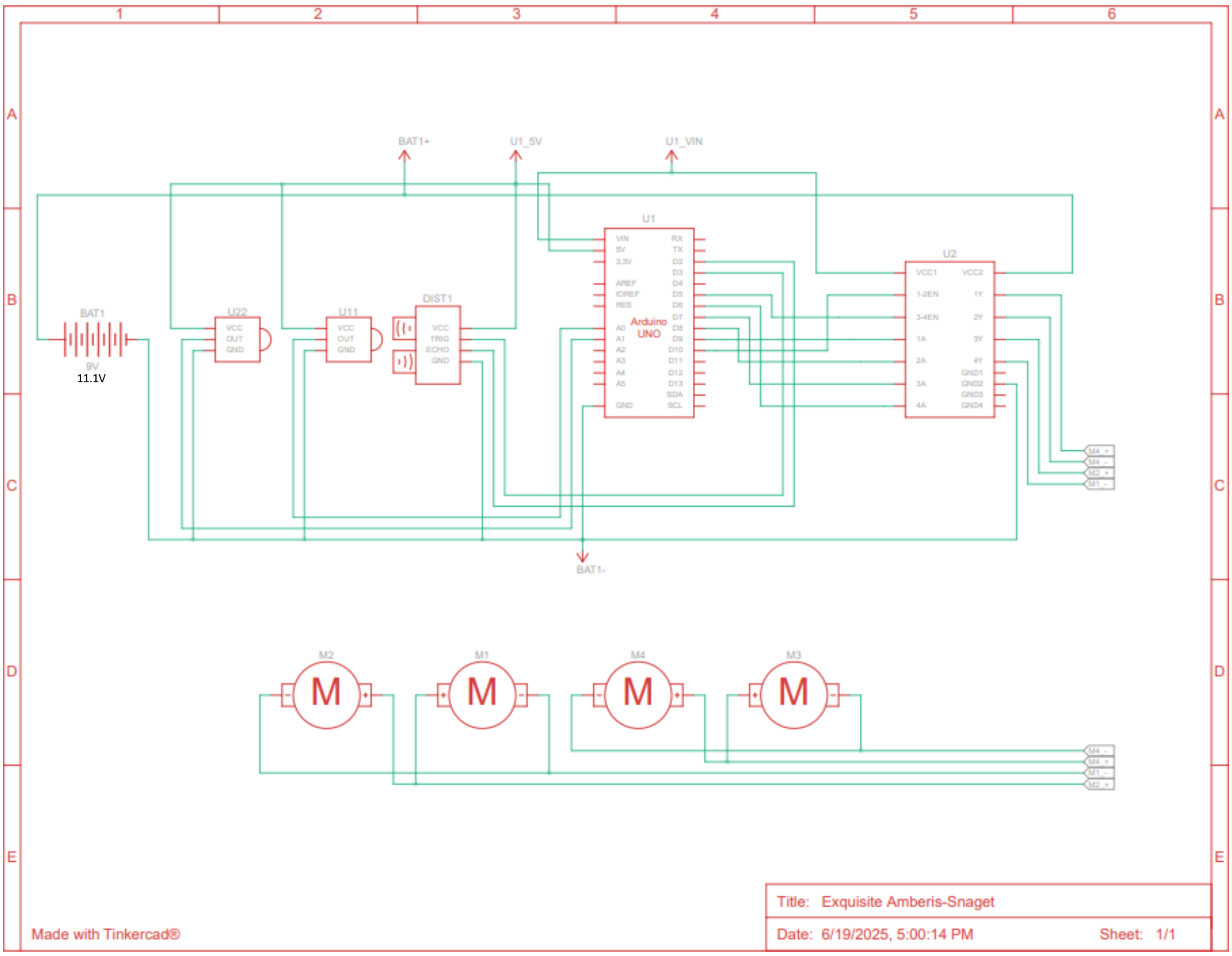

Figure 4.11: Schematic Diagram

CHAPTER 5

5. FLOW CHART & ALGORITHM:

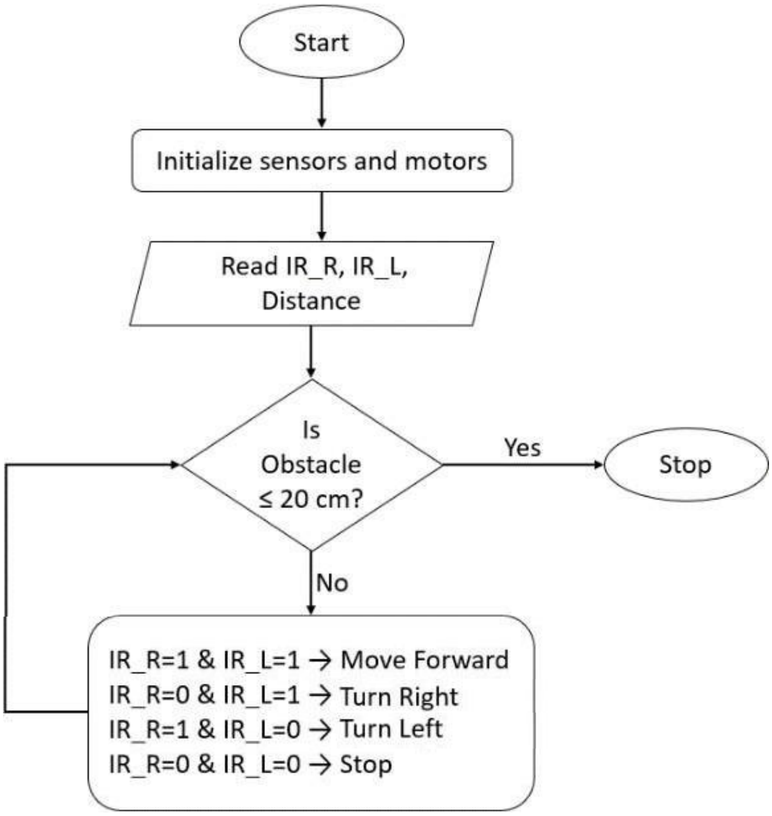

Figure 5.1: Flow Chart

ALGORITHM

Step 1: Start
Step 2: Initialize all sensors and motor pins
Step 3: Continuously read values from:

- IR Right sensor (`IR_R`)
- IR Left sensor (`IR_L`)
- Ultrasonic sensor (`distance`)

Step 4: Check if an obstacle is detected (`distance<=20 cm`)
→ If yes:
• Stop motors
• Wait until the path is clear
→ If no:
• Continue line-following logic:

- If `IR_R == 1` and `IR_L == 1`:
  • Bot Move's Forward
- If `IR_R == 0` and `IR_L == 1`:
  • Bot Turn's Right
- If `IR_R == 1` and `IR_L == 0`:
  • Bot Turn's Left
- If `IR_R == 0` and `IR_L == 0`:
  • Bot Stop's (line lost)

Step 5: Repeat the loop

CHAPTER 6

6. ADVANTAGES AND APPLICATIONS

Advantages

1. **Autonomous Navigation**
   Capable of operating without human intervention, ideal for automation.
2. **Obstacle Detection**
   Uses ultrasonic sensors to prevent collisions, enhancing safety and reliability.
3. **Low Cost & Easy to Build**
   Built using affordable, widely available components like Arduino Uno and IR sensors.
4. **Modular Design**
   Components can be upgraded (e.g., adding Bluetooth or AI vision) for future enhancements.
5. **Energy Efficient**
   Operates using lightweight materials and low-power electronics.
6. **Educational Value**
   Great for learning about embedded systems, sensor interfacing, and real-time control.
7. **Compact & Lightweight**
   Can be deployed in small, narrow pathways or tight workspaces.

Applications (with Minor Modifications)

1. **Warehouse Automation:**
   With slight enhancements in load handling and path complexity, this robot can transport small items in a warehouse or factory setup by following predefined tracks.
2. **Hospital Delivery Bots:**
   Adding a payload platform and improving navigation control can allow the robot to deliver medicines or files within a hospital.
3. **Autonomous Shopping Cart:**
   Modifying the chassis and control logic can turn this into a self-navigating cart that follows a customer or predefined paths in large stores.
4. **Smart Floor Cleaning Robot:**
   By integrating a cleaning mechanism and mapping logic, the robot can be adapted into a basic smart cleaning bot.
5. **Educational Kits:**
   This robot serves as an excellent educational tool for teaching beginners about robotics, embedded systems, and automation principles.
6. **Agricultural Monitoring (Miniature Scale):**
   With environmental sensors and solar panels, the robot can navigate along furrows or fixed paths to monitor crop health.
7. **Surveillance and Patrolling**
   Can be modified to carry sensors/cameras for security applications.
8. **Line-Guided Public Transport Prototypes**
   Concept basis for metro systems or factory conveyor trolleys.

CHAPTER 7

7.1 RESULTS

Tested Feature	Description	Status
Line Following Accuracy	Successfully follows black line on white surface using calibrated IR sensors	✓
Obstacle Detection	Ultrasonic sensor detects objects within 20 cm and halts robot	✓
Real-Time Mode Switching	Seamless transition between line-following and obstacle-avoidance modes	✓
Motor Driver Performance	L298N handled 4 DC motors smoothly; direction and speed control worked well	✓
Power Supply Stability	11.1V LiPo battery powered the robot for 15–20 minutes per session	✓
Compact Design	Lightweight foam board chassis supported modular, portable assembly	✓

7.2 CONCLUSION

The mini-project successfully demonstrated the development of a low-cost, autonomous robotic vehicle capable of following a line and avoiding obstacles using an Arduino Uno, IR sensors, and an ultrasonic sensor. The robot effectively navigated predefined paths and responded to real-time environmental changes, showcasing accurate control and sensor integration.

The implementation of the L298N motor driver provided stable motion control, and the logic for switching between line-following and obstacle-avoidance modes worked seamlessly during testing. The robot's modular and compact design makes it ideal for educational purposes, rapid prototyping, and further development.

Overall, the project served as a strong foundation for understanding the principles of embedded systems, autonomous navigation, and real-world robotics applications.

7.3 REFERENCES

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Appendix A: Source Code

```
#include <Ultrasonic.h>

// Motor pins
#define enA 10
#define in1 9
#define in2 8
#define in3 7
#define in4 6
#define enB 5

// IR sensor pins
#define IR_R A0
#define IR_L A1

// Ultrasonic pins
#define trigPin 3 //D3
#define echoPin 2 //D2

Ultrasonic ultrasonic(trigPin, echoPin);

void setup() {
  Serial.begin(9600);

  pinMode(IR_R, INPUT);
  pinMode(IR_L, INPUT);

  pinMode(enA, OUTPUT);
  pinMode(in1, OUTPUT);
```

```
  pinMode(in2, OUTPUT);
  pinMode(in3, OUTPUT);
  pinMode(in4, OUTPUT);
  pinMode(enB, OUTPUT);
}

void loop() {
  int IRR = digitalRead(IR_R);
  int IRL = digitalRead(IR_L);
  int distance = ultrasonic.read();

  Serial.print("Distance in CM: ");
  Serial.println(distance);
  Serial.print("IR R: ");
  Serial.println(IRR);
  Serial.print("IR L: ");
  Serial.println(IRL);

  if (distance <= 20) {
    stopMotors();   // Stop if obstacle is too close
  }
  else if (IRR == 1 && IRL == 1) {
    moveForward();
  }
  else if (IRR == 0 && IRL == 1) {
    turnRight();
  }
  else if (IRR == 1 && IRL == 0) {
    turnLeft();
  }
  else if (IRR == 0 && IRL == 0) {
    stopMotors();  // Line lost
  }
}
```

```
//Motor Control Functions

void moveForward() {
  analogWrite(enA, 80); //speed (0-100%)(0-255)
  analogWrite(enB, 80);
  digitalWrite(in1, LOW);
  digitalWrite(in2, HIGH);
  digitalWrite(in3, HIGH);
  digitalWrite(in4, LOW);
}

void turnLeft() {
  analogWrite(enA, 0);
  analogWrite(enB, 80);
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
  digitalWrite(in3, HIGH);
  digitalWrite(in4, LOW);
}

void turnRight() {
  analogWrite(enA, 80);
  analogWrite(enB, 0);
  digitalWrite(in1, LOW);
  digitalWrite(in2, HIGH);
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);
}

void stopMotors() {
  analogWrite(enA, 0);
  analogWrite(enB, 0);
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);
}
```

Appendix B: Final Visuals