



Hamm-Lippstadt University of Applied Sciences



Prototyping & Systems Engineering Presentation

Group 7



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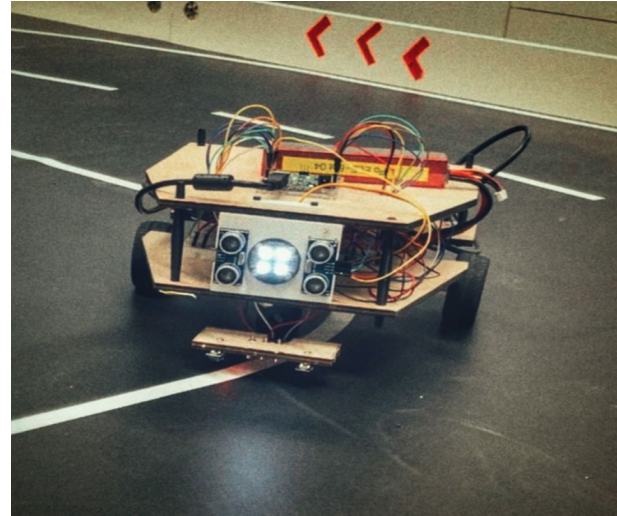
Introduction

Team Members:

- Md Sayem
- Sayed Galib Hossen Rizvi
- Ronjon Sarker
- Raphael C. G. Catchpole
- Dapsara Kapuge

Project Overview

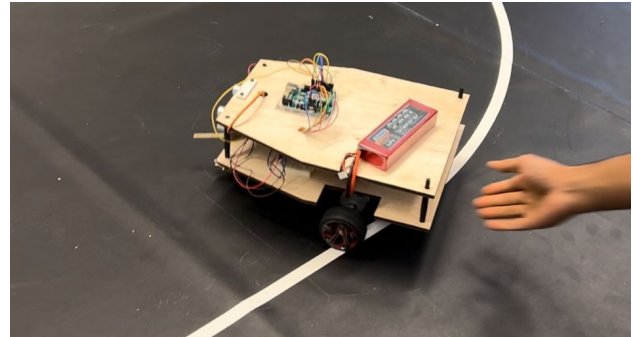
- Developing an autonomous car using Arduino.
- Integrates ultrasonic sensors for obstacle detection
- Infrared sensors for line following
- Uses color sensor for color detection
- DC motors drive the car.
- Servo motor for obstacle removal



Goals : Demonstrate advanced navigation, obstacle avoidance and removal using servo and color sensor, and adaptive behavior

Mission Statement

“Develop an Arduino-based autonomous car with advanced sensors for intelligent navigation, obstacle avoidance and removal, and environmental interaction, showcasing innovation in DIY robotics.”





Project Requirements

Functional Requirements

1. **Path Tracing:** The vehicle should be able to trace a predefined path.
2. **Sharp Turns:** The vehicle must be capable of executing sharp turns (e.g., 90° turns).
3. **Circuit Navigation:** The vehicle should be able to navigate various circuit patterns (e.g., circular or oval).
4. **Speed Adjustment:** The vehicle must be able to adjust its speed efficiently.
5. **Obstacle Detection:** The vehicle should be able to identify and avoid obstacles.
6. **Color Recognition:** The vehicle must be able to recognize different colors.
7. **Ignoring Maneuver:** The vehicle should be capable of ignoring an obstacle and get back to line again
8. **Obstacle Bypass:** The vehicle must be able to bypass obstructions.
9. **Parking:** The vehicle should be able to successfully park in designated spots.

Success Criteria

1. **Accuracy:** The vehicle successfully traces the predefined path with minimal deviation.
2. **Performance in Turns:** The vehicle executes sharp turns smoothly and accurately.
3. **Circuit Completion:** The vehicle navigates various circuit patterns without issues.
4. **Speed Optimization:** The vehicle adjusts speed efficiently based on conditions.
5. **Obstacle Handling:** The vehicle detects and avoids obstacles effectively.
6. **Color Detection:** The vehicle accurately recognizes and responds to different colors.
7. **Obstacle Ignoring:** The car can ignore obstacles and get back in the track.
8. **Obstacle Bypass Success:** The vehicle bypasses obstructions without collision.
9. **Parking Accuracy:** The vehicle parks accurately in designated spots.

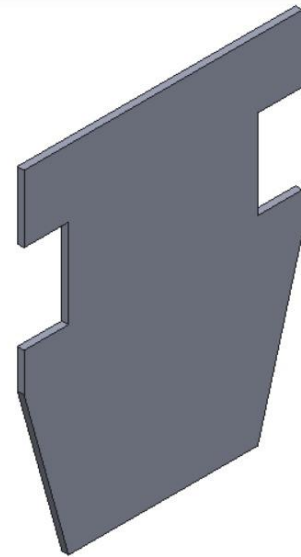
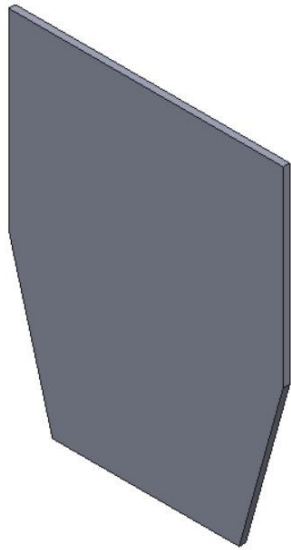


Design

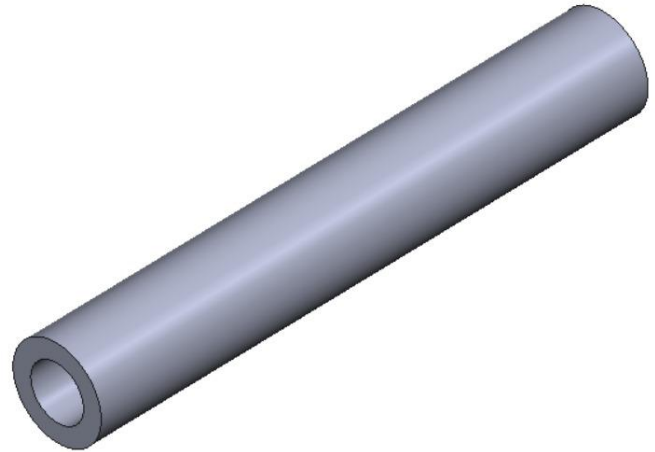
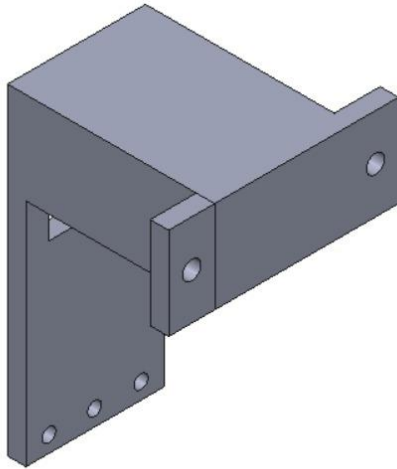
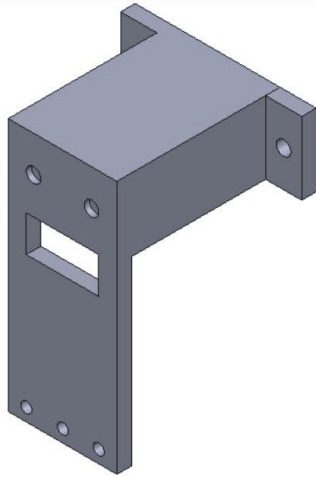


CAD Models

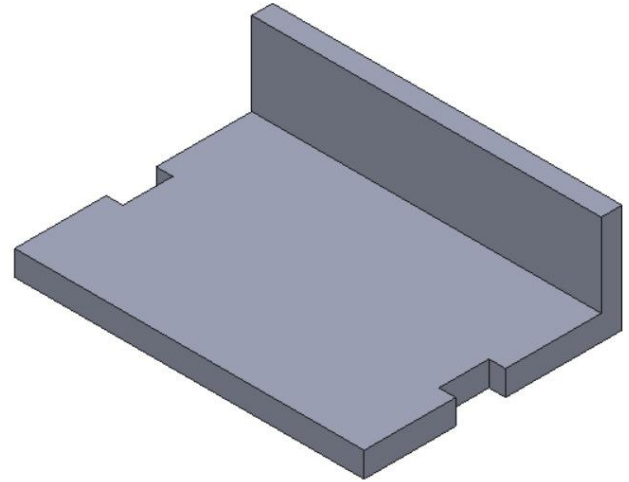
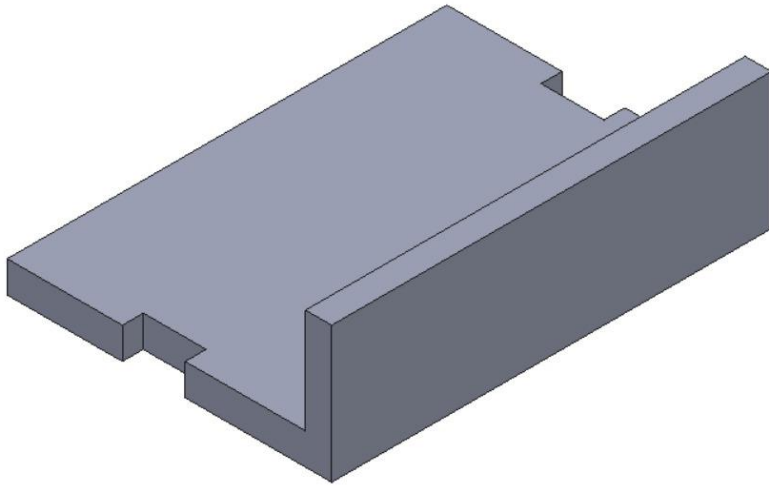
Laser Cut Parts



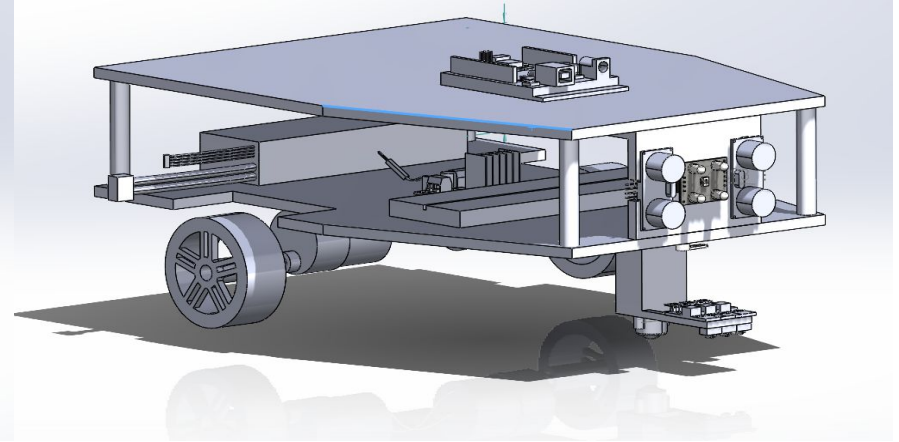
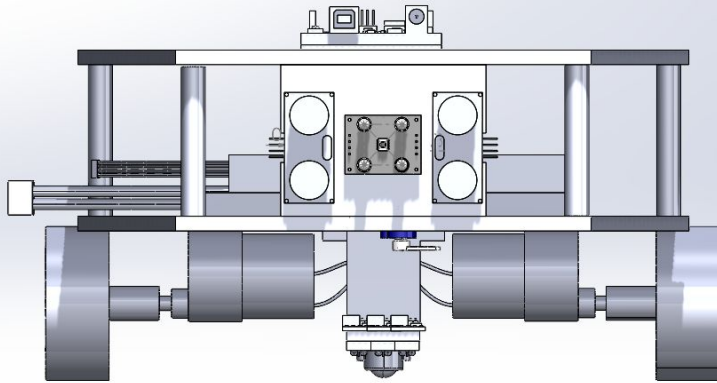
3D Printed Parts



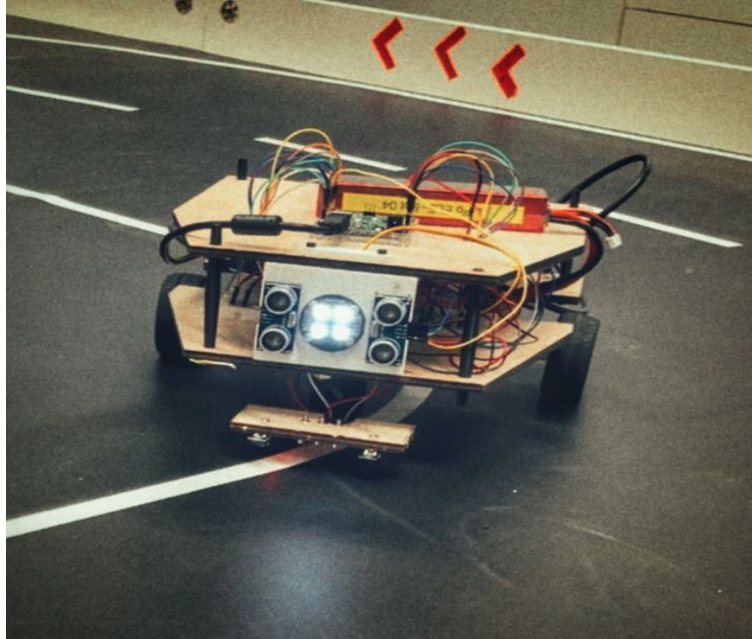
3D Printed Parts



Finished Assembly



Final Product





Hardware

Components

Microcontroller:

Arduino Uno

Sensors:

ST 1140 Line Tracking IR Sensors (2 units)

HC SR-04 Ultrasonic Sensor

TCS3200 Color Sensor

Actuators:

DC Motors (2 units)

Servo Motor

Motor Driver:

L298 Motor Driver

Power Supply:

Battery Pack

Miscellaneous:

Various connecting wires

Various screws

Breadboard



Hardware Integration

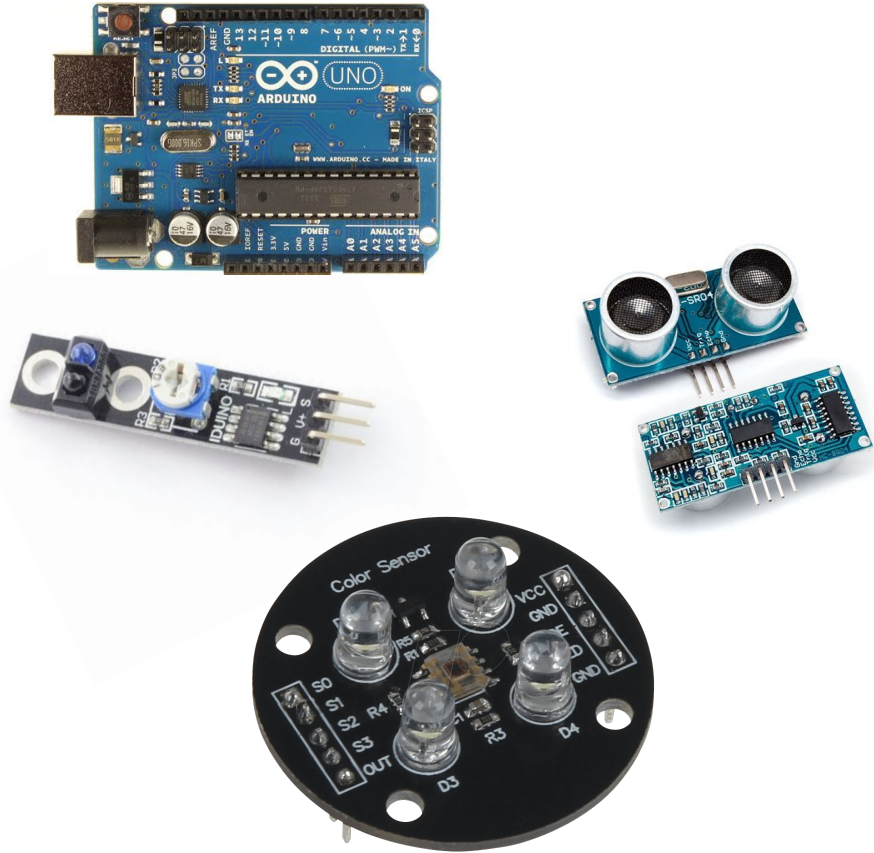
Hardware Integration

Central Controller: Arduino Uno

- Coordinates sensors and actuators

Sensors:

- **IR Sensors (ST 1140):**
 - Detect the line
 - Connected to digital input pins
- **Ultrasonic Sensor (HC-SR04):**
 - Measures distance to obstacles
 - Uses trigger and echo system
 - Connected to digital pins
- **Color Sensor (TCS3200):**
 - Detects color of objects
 - Connected to digital and analog pins



Hardware Integration

Actuators:

- **DC Motors:**
 - Controlled by L298 motor driver
 - Connected to PWM pins
- **Servo Motor:**
 - Executes color-based actions
 - Connected to digital pin

Power Supply:

- Battery pack powers the system

Integration Process:

- Test each component individually
- Program Arduino to read sensors and control actuators
- IR sensors adjust motor speeds for line-following
- Ultrasonic sensor readings trigger color sensor actions





Software

Key Algorithms and Code

Line Following Algorithm

Purpose: Keep the robot on the line using IR sensors.

Logic:

Both sensors detect line: Move forward.

Left sensor off line: Turn right.

Right sensor off line: Turn left.

```
void loop() {  
    distance_F = Ultrasonic_read();  
    Serial.print("D F="); Serial.println(distance_F);  
  
    int rightSensor = digitalRead(R_S);  
    int leftSensor = digitalRead(L_S);  
    Serial.print("Right Sensor: "); Serial.println(rightSensor);  
    Serial.print("Left Sensor: "); Serial.println(leftSensor);  
  
    if (rightSensor == 1 && leftSensor == 1) {  
        if (distance_F < Set) {  
            Stop();  
            delay(1000);  
            int color = getColor();  
            if (color == 1) {  
                IgnoreObstacle();  
            } else if (color == 2) {  
                servo.write(0);  
                delay(1000);  
                servo.write(180);  
                delay(1000);  
            } else if (color == 3) {  
                ParkCar();  
            }  
        } else {  
            forward();  
        }  
    } else if (rightSensor == 1 && leftSensor == 0) {  
        turnLeft();  
    } else if (rightSensor == 0 && leftSensor == 1) {  
        turnRight();  
    }  
}
```


Key Algorithm and code

Obstacle Detection and Avoidance

Purpose: Detect obstacles with ultrasonic sensor, act based on color.

Logic:

Measure distance. If obstacle detected, stop and check color sensor.

Red: Avoid obstacle. Green: Park. Blue: Move servo.

```
void loop() {  
    distance_F = Ultrasonic_read();  
    Serial.print("D F=");  
    Serial.println(distance_F);  
  
    int rightSensor =  
digitalRead(R_S);  
    int leftSensor =  
digitalRead(L_S);  
    Serial.print("Right Sensor: ");  
    Serial.println(rightSensor);  
    Serial.print("Left Sensor: ");  
    Serial.println(leftSensor);  
}
```

Key Algorithm and code

```
if (rightSensor == 0 && leftSensor == 0) {  
  if (distance_F < Set) {  
    Stop();  
    int color = getColor();  
    if (color == 1) {  
      IgnoreObstacle();  
    } else if (color == 2) {  
      servo.write(0);  
      delay(1000);  
      servo.write(90);  
      delay(1000);  
    } else if (color == 3) {  
      ParkCar();  
    }  
  } else {  
    forward();  
  }  
} else if (rightSensor == 1 && leftSensor == 0) {  
  turnRight();  
} else if (rightSensor == 0 && leftSensor == 1) {  
  turnLeft();  
}  
}
```

Key Algorithm and code

Ultrasonic Sensor Reading

Purpose: Measure distance to obstacle.

Logic: Send pulse, measure echo time, calculate distance.

```
long Ultrasonic_read() {  
    digitalWrite(trigger, LOW);  
    delayMicroseconds(2);  
    digitalWrite(trigger, HIGH);  
    delayMicroseconds(10);  
    long time = pulseIn(echo, HIGH);  
    return time / 29 / 2;  
}
```

Key Algorithm and code

Color Detection

Purpose: Detect object color using TCS3200 sensor.

Logic: Measure pulse widths for red, green, blue. Determine color by smallest value.

```
int getColor() {  
    int redValue, greenValue, blueValue;  
  
    digitalWrite(S2_PIN, LOW);  
    digitalWrite(S3_PIN, LOW);  
    redValue = pulseIn(OUT_PIN, LOW);  
  
    digitalWrite(S2_PIN, HIGH);  
    digitalWrite(S3_PIN, HIGH);  
    greenValue = pulseIn(OUT_PIN, LOW);  
  
    digitalWrite(S2_PIN, LOW);  
    digitalWrite(S3_PIN, HIGH);  
    blueValue = pulseIn(OUT_PIN, LOW);  
  
    Serial.print("Red: ");  
    Serial.print(redValue);  
    Serial.print("\tGreen: ");  
    Serial.print(greenValue);  
    Serial.print("\tBlue: ");  
    Serial.println(blueValue);  
}
```

Key Algorithm and code

```
if (redValue < greenValue && redValue < blueValue)
{
    Serial.println("Color: Red");
    return 1;
} else if (blueValue < redValue && blueValue <
greenValue) {
    Serial.println("Color: Blue");
    return 2;
} else if (greenValue < redValue && greenValue <
blueValue) {
    Serial.println("Color: Green");
    return 3;
} else {
    return 0;
}
}
```

Key Algorithm and code

Motor Control Functions

Purpose: Control robot movement.

Logic: Use motor driver to set direction and speed.

```
void forward() {
    Serial.println("Moving forward");
    analogWrite(enA, 117);
    analogWrite(enB, 130);
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    digitalWrite(in3, HIGH);
    digitalWrite(in4, LOW);
}

void aforward() {
    analogWrite(enA, 200);
    analogWrite(enB, 200);
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    digitalWrite(in3, HIGH);
    digitalWrite(in4, LOW);
}

void backward() {
    analogWrite(enA, 200);
    analogWrite(enB, 200);
    digitalWrite(in1, LOW);
    digitalWrite(in2, HIGH);
    digitalWrite(in3, LOW);
    digitalWrite(in4, HIGH);
}
```

Key Algorithm and code

```
void abackward() {
    analogWrite(enA, 200);
    analogWrite(enB, 200);
    digitalWrite(in1, LOW);
    digitalWrite(in2, HIGH);
    digitalWrite(in3, LOW);
    digitalWrite(in4, HIGH);
}

void turnRight() {
    Serial.println("Turning right");
    analogWrite(enA, 140);
    analogWrite(enB, 153);
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    digitalWrite(in3, LOW);
    digitalWrite(in4, HIGH);
}

void aturnRight() {
    analogWrite(enA, 200);
    analogWrite(enB, 200);
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    digitalWrite(in3, LOW);
    digitalWrite(in4, HIGH);
}
```

Key Algorithm and code

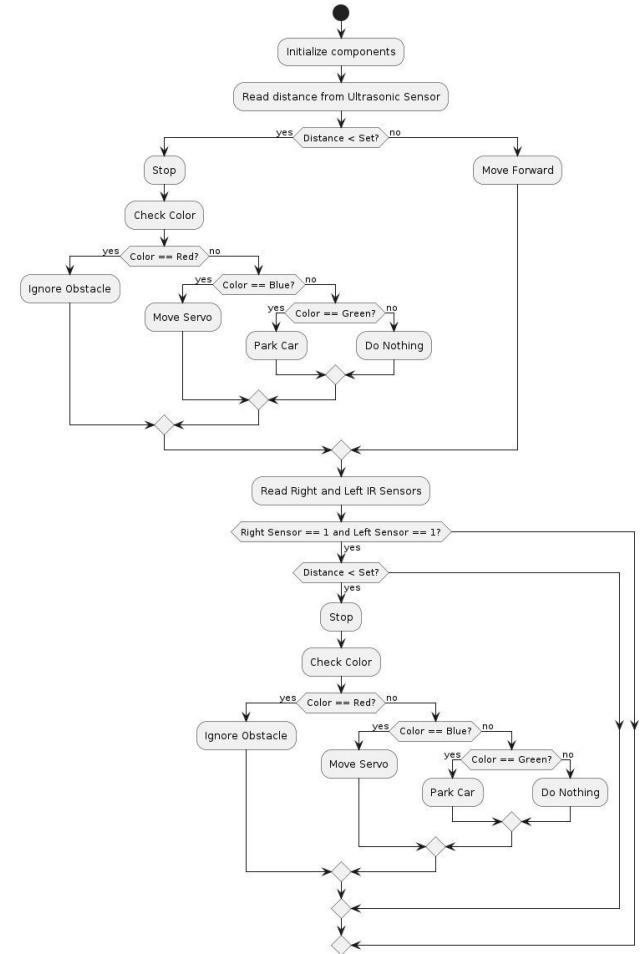
```
void turnLeft() {  
    Serial.println("Turning left");  
    analogWrite(enA, 140);  
    analogWrite(enB, 153);  
    digitalWrite(in1, LOW);  
    digitalWrite(in2, HIGH);  
    digitalWrite(in3, HIGH);  
    digitalWrite(in4, LOW);  
}
```

```
void aturnLeft() {  
    analogWrite(enA, 200);  
    analogWrite(enB, 200);  
    digitalWrite(in1, LOW);  
    digitalWrite(in2, HIGH);  
    digitalWrite(in3, HIGH);  
    digitalWrite(in4, LOW);  
}
```

```
void Stop() {  
    Serial.println("Stopping");  
    digitalWrite(in1, LOW);  
    digitalWrite(in2, LOW);  
    digitalWrite(in3, LOW);  
    digitalWrite(in4, LOW);  
}
```

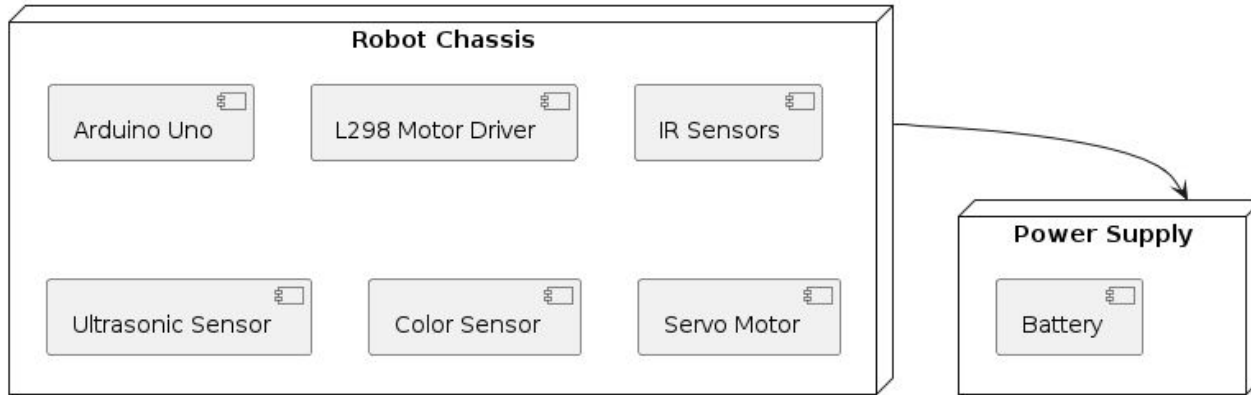
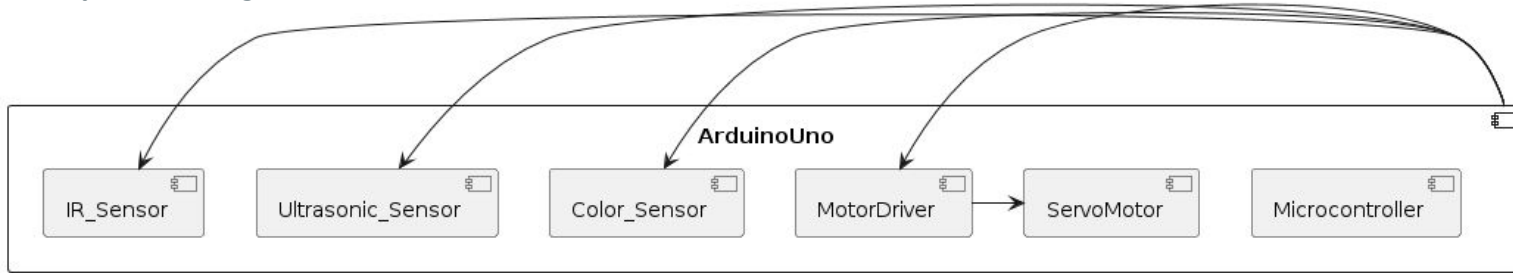

State Charts and UML Diagrams

Activity diagram



State Charts and UML Diagrams

Component Diagram



Deployment Diagram



System Integration

Actuators:

DC Motors: Controlled by L298 driver for movement.

Servo Motor: Performs actions based on colors.

Software Implementation

Arduino IDE: Writes, compiles, and uploads code.

Sensor Data Processing:

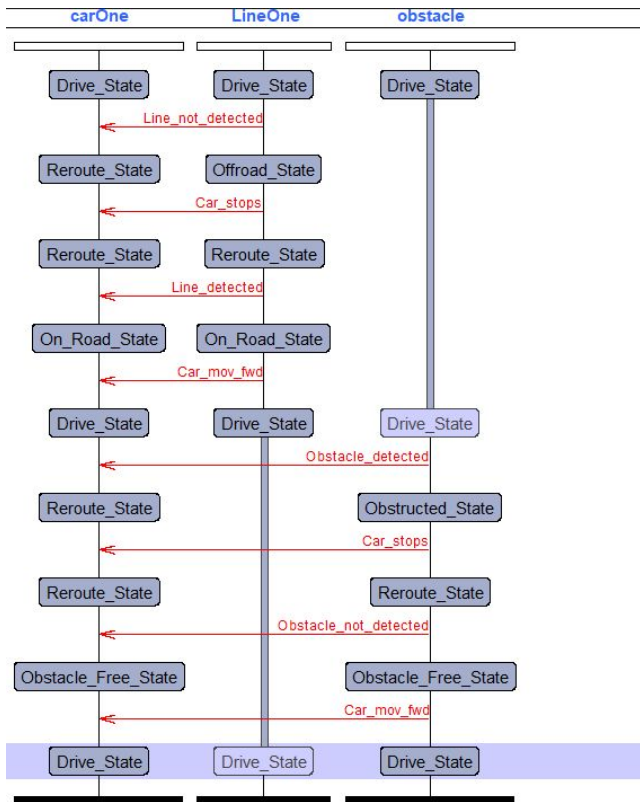
IR Sensors: `digitalRead` to follow lines.

Ultrasonic Sensor: `Ultrasonic_read` for obstacle detection.

Color Sensor: `getColor` for color detection.

Motor Control: `analogWrite` for speed, `digitalWrite` for direction.

Decision Making: `loop` function reads sensor data to control movements.



Prototyping Final Model 1.1.xml - UPPAAL

File Edit View Tools Options Help

Editor Symbolic Simulator Concrete Simulator Verifier

Enabled Transitions

- Obstacle_detected: obstacle → carOne
- Line_not_detected: LineOne → carOne

Cons

Simulation Trace

```

Car_stops: LineOne → carOne
(Reroute_State, Reroute_State, Drive_State)
Line_detected: LineOne → carOne
(On_Road_State, On_Road_State, Drive_State)
Car_mov_fwd: LineOne → carOne
(Drive_State, Drive_State, Drive_State)
Obstacle_detected: obstacle → carOne
(Reroute_State, Drive_State, Obstructed_State)
Car_stops: obstacle → carOne
(Reroute_State, Drive_State, Reroute_State)
Obstacle_not_detected: obstacle → carOne
(Obstacle_Free_State, Drive_State, Obstacle_Free_State)
Car_mov_fwd: obstacle → carOne
(Drive_State, Drive_State, Drive_State)

```

Prev Next Replay

Open Save Random

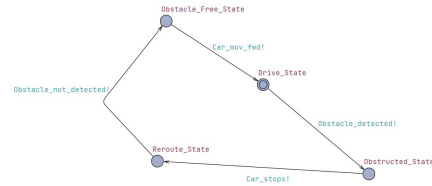
Slow Fast

1 Starker Pollenflug

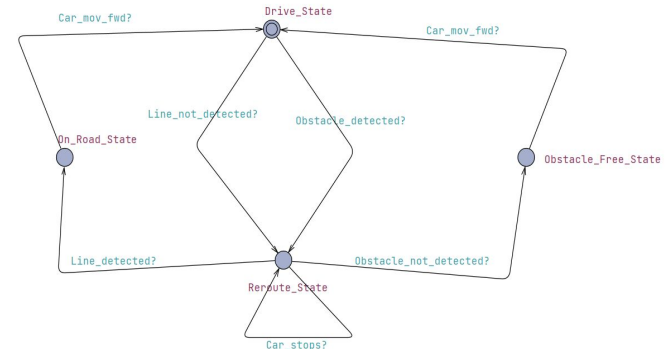
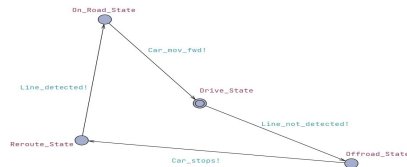
Simulation

UPPAAL Simulation

Obstacle



Line



Car



Challenges and Limitations

Limitations of the Current Prototype

R Sensors: Affected by ambient light and reflective surfaces.

Ultrasonic Sensors: Accuracy influenced by surface texture and obstacle angle.

Motor Control: Basic, with limited speed and turning adjustments.

Color Sensors: Inconsistent under varying lighting conditions.

Battery Life: High power consumption limits performance.

Scalability: Limited scope for adding new sensors or functionalities.

Surface Effectiveness: Less effective on uneven or reflective surfaces.

Processing Power: Arduino Uno's limited processing power.

Obstacle Avoidance Algorithm: Basic, lacks sophisticated pathfinding.



Future Work

Potential Improvements

- **Add More Sensors:** Incorporate additional ultrasonic sensors or use LiDAR for 360-degree obstacle detection.
- **Improve Accuracy:** Use higher-resolution sensors for more precise measurements and detection capabilities.
- **Multi-Sensor Fusion:** Combine data from multiple sensors to make more informed decisions.
- **Traffic Sign Detection:** Implement traffic sign recognition to obey road signs and signals.
- **Dynamic Adjustments:** Implement algorithms to adjust speed and direction based on real-time sensor data.

Future Development Plans


- Implement advanced algorithms like PID control for precise line following.
- Integrate GPS modules for outdoor navigation to follow predefined routes.
- Expand color sensor usage for more accurate color detection..
- Add a camera module for advanced obstacle recognition and lane detection.
- Add wireless modules (Bluetooth, Wi-Fi) for remote control and monitoring.





The End

Thank you for your Attention!





Q&A Session