Autonomous Line following Vehicle

*Note: A university prototyping project

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***Abstract*—In this paper we will discuss an autonomous robot car with multiple uses that has been designed and developed using Arduino. The autonomous car comes with motor driver that is what accelerates it and other features such as the ultrasonic sensor, infrared (IR) sensors, and a color sensor in order to enable it avoid obstacles, follow tracks and capture colors. In relation to the movements of the robot, the motor driver allows it to be moved in various directions namely forward, backward, left or right. To ensure that this device navigates its environment correctly without colliding with objects on its path as well as any other obstacles, ultrasonic sensor measures distance. These IR sensors are applied in line following so that the robot can autonomously follow a given path. A color sensor also helps identify specific colors for decision making by the robot concerning object colors around it. Being cost effective, efficiency and scalability solutions for education and prototyping have been achieved through Arduino programming which brings together all these sensors and actuators. Furthermore, this paper goes into hardware setup details including software algorithms alongside experimental results showing how effectively complex tasks can be performed by an autonomous robot car under a wide range of conditions. Developers will benefit from this paper because of its usability when one needs to build different navigation and sensing techniques that are self-reliant.**

I. Introduction

Autonomous robotics is a relatively young intensively developing branch of engineering, computer science, and artificial intelligence fields, which implies the creation of equipment capable of performing work without any human intervention. This kind of robots has the capacity to transform sectors including production, supply chain, healthcare, and education in terms of productivity, accuracy, and security thus, an autonomous robot car becomes an effective educational objective and a basis for constructing more intricate forms of robotics.

This paper describes the development and construction of a self-operated robot car with features of a multi functional car with an Arduino control unit. The project integrates several key components: motor driver, ultrasonic sensor, infrared (IR) sensors, and a colour sensor. All contribute to the fact that the robot is able to move around, avoid obstacles, follow bi-colored lines (black and white) lines as well as identify the color of the objects.

Motor driver unit controls the movement of the robot which has the options of forward, backward, and right or left turns. Distance reader is controlled by ultrasonic sensor which gives distances, and they allow the robot to react to the obstacles in real time. The IR sensors are used for line following which makes the robot to have an ability to follow certain paths without the need of any external control. Also there is the colour sensor and this locates a particular colour, and therefore, helps the robot in making more evolved decisions vis a vis the colour of the objects on its path.

The paper will also discuss the future possibilities of this project which includes integrating Internet of things (IOT) to achieve solutions for modern problems,

Therefore, the main goal of this work is to design an open-sourced, low cost and multi-functional system that could be used as an educational and prototyping tool in autonomous robotics. The connections of a number of individual sensors and actuators with Arduino programming provides a fully fledged teaching along with experimentation facility to the students and hobbyists. Also, this compensation allows for fine-tuning of different algorithms and technologies associated with autonomous navigation and sensor fusion on this fabrication platform.

II. Structure

This paper is structured as follows: Section III describes the items of the hardware and their Corresponding Diagrams.

Section IV with regard to software implementation at the control algorithms and the signal conditioning for the sensors.

Section V, Using CAD and other 3D designing methods to create 3D printed object to complete the prototype frame.

In the last section, Section VI concludes with the summary of the findings and improvements for the robot in the future.

With this work, we would like to advance the discourse on robotics by showing an example of an efficient autonomous robot car and stressing on the numerous uses in these sort of systems.

III. Hardware and their corresponding Diagrams

A. Hardware

The prototype combines several electronic components, each serving specific functions and processing distinct properties. Here is a summary of the components:

- Arduino Uno WiFi Rev 2.
- 2 Infrared Sensors

- Ultrasonic Sensor (HCSR04)
- Color Sensor (TCS3200
- Motor Driver (L298N)
- 2 DC Motors.
- Battery

The description of each component is as followed:

- Arduino Uno WiFi Rev 2
  For this prototype, the Arduino Uno wifi rev 2 is the prototype's primary microcontroller; it is responsible for data acquisition of the sensors and the execution of operations involving the application of the actuators to initiate the right functioning for navigation. This development board integrates a microchip from Atmel AVR family which is called **ATmega4809** that has 8-bit RISC CPU core and is fulfilled with 6KB RAM, 48KB flash memory. The board includes total of 14 digital GPIO pins among which 6 come with PWM output and 6 of which are the analogue input pins, A0 to A5. The USB connection is used to establish the connection channel between PC and the device.

Fig. 1. Arduino

- Infrared Sensors IR sensors are used at the front side of the car with the help of which it locates and follows the line. At the bottom of the automobile, there are IR sensors that illuminate the exterior through the emission of infrared light. Subsequently, through observing two states, good and bad, they are capable of perceiving the reflection of the light. The location of the car can then be ascertained by the IR sensor either on the line or not on the line. It mostly remains in the queue due to these sensors. Digital pins 7 and 8 of the microcontroller are interfaced with the signal pins of the IR sensors concerned.
- Ultrasonic Sensor (HCSR04) An ultrasonic sensor has been installed to help the car feel the environment in front of the car to avoid obstruction. It produces sound waves and measures the time interval for the waves reflected by the object to get back to the device. This is made possible by the use of the ultrasonic sensor close to the car; thus, the distance measured in terms of; the overall travel time will enable the identification of an obstruction. As for the connections of the sensor, its Trigger and Eco pins are assigned to pins 2 and 3 of the board.

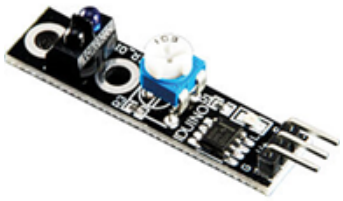

Fig. 2. Infrared Sensors

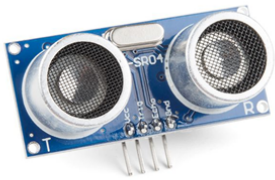

Fig. 3. Ultrasonic Sensor (HCSR04)

- Color Sensor (TCS3200) To measure the color of the obstacles on the track a color sensor (TCS3200=color sensor) was employed. Depending on the color of the car, it would knock the object out of the track or bypass the object and go around it. The TCS3200 has white LEDs as the light source used to illuminate the surface of the object whose color needs to be measured. Their reflectance or the amount of light that bounces back from the object is determined. The converter produces a frequency proportional to the intensity which the microcontroller employs to estimate the object color.

Fig. 4. Color Sensor (TCS3200)

- Motor Driver (L298N) A motor driver, L298N, also applied a for the purpose of both controlling and powering

our vehicle's geared motors. A driver IC is needed to drive the Motors. After getting signals from the Arduino Uno, the driver IC works as a switch. Provided high is the signal, the driver IC drives the switch, hence providing the motor with the required voltage to make it rotate. With the L298N motor driver, there exist two enable inputs that allow a device to be enabled on or off when needed.

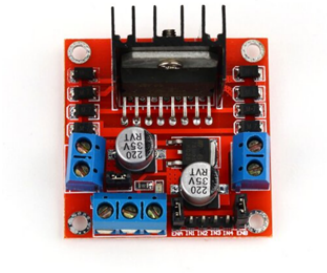

Fig. 5. Motor Driver (L298N)

- DC Motors. It is also integrated with 2 DC Motor in the front side for the incorporation of the car wheels. The Modelcraft RB 35 gearbox with a motor can apply a considerable rotational force with its torque that is at 1:30. It may also bring down speed at the exact rate that the torque is and, therefore, when torque advances, the speed of the motor will also decrease at a proportionate rate, hence giving a well-balanced and efficient performance.

Fig. 6. DC Motor

- Battery The car runs on a polymer Li-Ion battery that can be recharged. This specific battery gives the Arduino board, the motors, and the sensors the power they require.

B. Diagrams

- Block Diagram
  The block diagram (III-B) indicates the architecture for a system of an autonomous robot car, indicating the main components, controlled using an Arduino Uno microcontroller board. At the very center is an Arduino Uno, representing the central system for control. Using

Fig. 7. Battery

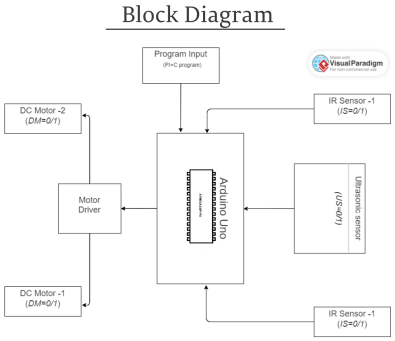

Fig. 8. Block diagram

C language as program Input, making it take a number of inputs from the different sensors and drive outputs to control the motors. On the right-hand side of the diagram, there are two different sensors attached to the Arduino Uno board: an Ultrasonic sensor and two IR sensors, denoted as IR Sensor -1 and IR Sensor -2. This ultrasonic sensor gives the distance measurement from the nearby obstacles; hence, it helps the robot navigate without collision. IR sensors detect lines or obstacles on the path and generate binary signals to the Arduino so that line following or obstacle avoidance functionality could be possible. On the left is one of the motor drivers connected into the Arduino Uno, which drives two DC motors. These are what give motion to the robot as forward, backwards, and turning. The motor driver interprets control signals from the Arduino and adjusts accordingly the speed and direction of the motors. Basically, the block diagram shows a system integrated with IR and ultrasonic sensor inputs, processed by the Arduino Uno controlling a motor driver for the control of the robot car. In clear terms, this setup will thus make the robot car trace its way around the environment in an automatic way, following lines or avoiding obstacles with instructions pre-programmed on the Arduino.

- State Machine Diagram The state machine diagram (9)

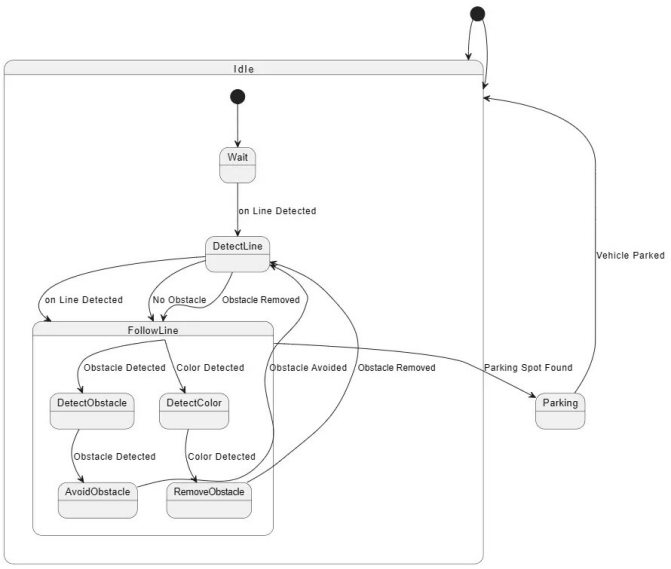

Fig. 9. State Machine Diagram

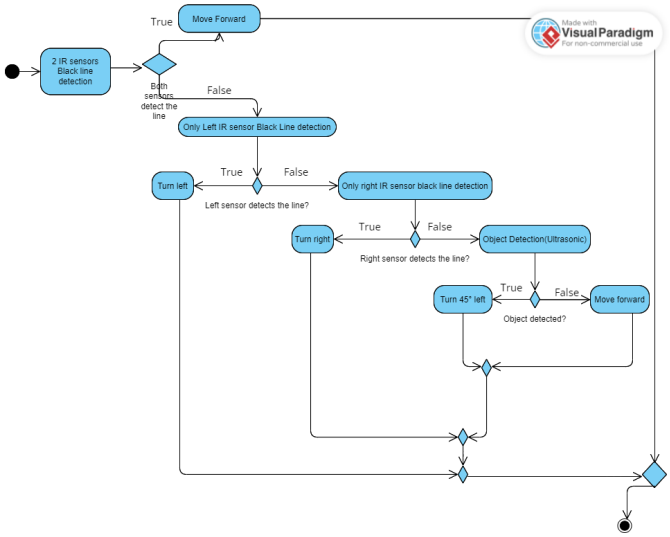

Fig. 10. Activity Diagram

shows the runtime logic of an Arduino-controlled lane-identifying vehicle with integrated color detection capabilities. The system runs in three distinct states, ”Waiting”, ”Lane Follow”, and ”Collision Detected”. When in the ”Waiting” state, the vehicle stays until both left and right sensors detect the lane markers, after which transition to the ”Lane Follow” state occurs. At this stage, the vehicle follows the lane with motor control based on continuous infrared sensor feedback. A transition back to ”Waiting” will be made when either sensor loses track of the lane resulting in bringing the car back towards the lane. The state Collision Detected is activated in case of detecting an obstacle that is too near, distance ¡ 20, while seeing a red color simultaneously, ColorSensor() == 0, this is defined in he functions in sections of Arduino code In this state, the vehicle performs avoidance actions, for example, turning left or right, then goes back to its route once the obstacle no longer poses difficulties for the vehicle's movements. It is used in this way for behavior in a structured context to keep the vehicle running autonomously, following the line, due to dynamic reactions to environmental conditions, thus promoting its efficiency and safety within specific practical applications.

- Activity Diagram

  The activity diagram (10) illustrates the decision-making process involving the vehicle when it is on the track. The process initiates right from when the IR sensors start sensing that the black line is present or is being chased. When both Sensors are in contact with the line, the car moves forward. Therefore, in case only the left IR sensor has detected this line, the vehicle moves to the left. On the other hand, if only the right IR sensor detects the line then it turns right.

  In any case of failure to detect both the IR sensors help the ultrasonic sensors to detect the obstacles. When an obstacle is identified, the vehicle steers by 45 degrees towards left avoiding the obstacle. The vehicle moves forward when there are no obstacles found in the path of the vehicle or the path is clear.

  It enables the car to stay on course; this decision-making loop can plot its own path around an object in its path with help from real-time input from sensors. They include its ability for track and obstacle detection on the track that will make the required autonomous movement safely.

  It is the diagram of vision for the logical sequences of sensors and the control mechanism of the vehicle to make it an autonomous car.

- Requirement Diagram

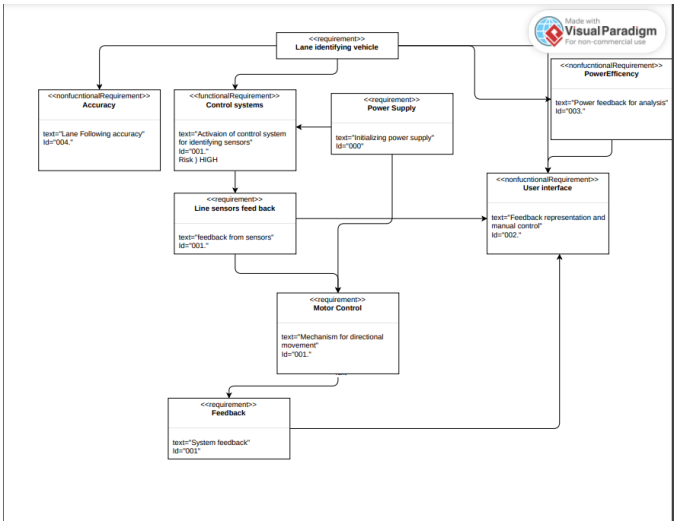

Fig. 11. Requirement Diagram

The requirement diagram (11) indicates detailed require-

ments with respect to a vehicular autonomous vehicle system that identifies lanes. It has a primary requirement at the center labeled as Lane identifying vehicle(autonomous vehicle) anchoring many functional and non-functional features. Relating to one of the categories, it incorporates the functionality of the control systems' requirements, featuring the activation of control systems for identifying sensors with a risk level noted to be high. Other critically important functional requirements will include the power supply, involving the initialization of the vehicle's power supply. The line sensors will prove critical in providing feedback since it implies giving the critical environmental data to the system. Another will be the motor control, defining mechanisms for movement of the vehicle in the directional aspects so as to ensure a following of lanes with precision. All the way to the end, there will be a continuous feedback of systems to upgrade the status of the vehicle to ensure accuracy in its operation. On the other hand, the nonfunctional requirements would be concerned with the performance of the system and how the user will relate to it. The accuracy required, especially lane following, is that the vehicle hold its path correctly. One critical requirement is that of power efficiency and requires power feedback for analysis to address how best the system will suitably use energy. Finally, there is a user interface requirement intended to represent feedback and allow manual control. This shall ensure that there is good presentation of the outputs from this system to the users, as well as allowing manual override if need be. The detailed breakdown of the requirements followed clearly reiterates the complexity and retroactions between different system components required to be in place for a dependable lane-identifying autonomous vehicle to become realized.

IV. Arduino Code

Motor Driver

The motor driver facilitates precise control over the movement of the car. It utilizes digital output pins (in1Pin, in2Pin, in3Pin, in4Pin) for controlling the direction of rotation and PWM pins (enA, enB) for adjusting the speed of motors A and B.

```
// Define pins for motor driver
const int in1Pin = 11;
const int in2Pin = 10;
const int in3Pin = 13;
const int in4Pin = 12;
const int enA = 5;
const int enB = 6;
```

Listing 1. C Language

Ultrasonic Sensor

An ultrasonic sensor is employed for distance measurement and obstacle detection. It consists of a trigger pin (trigPin) to emit ultrasonic signals and an echo pin (echoPin) to receive and calculate distances based on signal reflections.

```
// Define pins for ultrasonic sensor
const int trigPin = 2;
const int echoPin = 3;
```

Listing 2. C Language

IR Sensors

Infrared (IR) sensors are utilized for line detection and navigation. Digital input pins (leftsensorPin, rightsensorPin) detect variations in reflected IR light, enabling the car to follow predefined paths.

```
// Define pins for IR sensors
const int leftsensorPin = 8;
const int rightsensorPin = 7;
```

Listing 3. C Language

Color Sensor

A color sensor enhances the car's functionality by detecting and identifying colors of encountered objects. Control pins (s0, s1, s2, s3) configure the sensor's operational mode, while an output pin (out) provides RGB values for color analysis

```
#define s0 A0       // Analog pins for color sensor
    control
#define s1 A1
#define s2 A2
#define s3 A3
#define out A4
```

Listing 4. C Language

Functions and Operation

Motor Control Functions

These functions regulate the movement of the car, including forward motion, turning, and stopping.

```
void forward() {
    digitalWrite(in1Pin, LOW);
    digitalWrite(in2Pin, HIGH);
    digitalWrite(in3Pin, LOW);
    digitalWrite(in4Pin, HIGH);
}

void left() {
    analogWrite(enA, motorSpeed);
    analogWrite(enB, motorSpeed);
    digitalWrite(in1Pin, LOW);
    digitalWrite(in2Pin, HIGH);
    digitalWrite(in3Pin, HIGH);
    digitalWrite(in4Pin, LOW);
}

void right() {
    analogWrite(enA, motorSpeed);
    analogWrite(enB, motorSpeed);
    digitalWrite(in1Pin, HIGH);
    digitalWrite(in2Pin, LOW);
    digitalWrite(in3Pin, LOW);
    digitalWrite(in4Pin, HIGH);
}

void stop() {
    digitalWrite(in1Pin, LOW);
    digitalWrite(in2Pin, LOW);
    digitalWrite(in3Pin, LOW);
    digitalWrite(in4Pin, LOW);
}
```

Listing 5. C Language

Color Sensor Functions

These functions interact with the color sensor to capture RGB values and analyze colors of encountered objects.

```
void GetColors() {
    digitalWrite(s2, LOW);
    digitalWrite(s3, LOW);
    Red = pulseIn(out, digitalRead(out) == HIGH ?
    LOW : HIGH);
    delay(20);
    digitalWrite(s3, HIGH);
    Blue = pulseIn(out, digitalRead(out) == HIGH ?
    LOW : HIGH);
    delay(20);
    digitalWrite(s2, HIGH);
    Green = pulseIn(out, digitalRead(out) == HIGH ?
    LOW : HIGH);
    delay(20);
}

int ColorSensor() {
    // Determine color based on RGB values
    // Return color index or code
}
```

Listing 6. C Language

Ultrasonic Sensor Functionality

This function manages distance measurement using the ultrasonic sensor and adjusts the car's behavior based on detected obstacles.

```
void measureDistance() {
    digitalWrite(trigPin, LOW);
    delayMicroseconds(2);
    digitalWrite(trigPin, HIGH);
    delayMicroseconds(10);
    digitalWrite(trigPin, LOW);
    duration = pulseIn(echoPin, HIGH);
    distance = duration * 0.034 / 2;
}
```

Listing 7. C Language

Setup and Initialization

Initialising Pins

```
void setup() {
    // Initialize serial communication for debugging
    Serial.begin(9600);

    // Initialize motor driver pins
    pinMode(in1Pin, OUTPUT);
    pinMode(in2Pin, OUTPUT);
    pinMode(in3Pin, OUTPUT);
    pinMode(in4Pin, OUTPUT);
    pinMode(enA, OUTPUT);
    pinMode(enB, OUTPUT);

    // Initialize ultrasonic sensor pins
    pinMode(trigPin, OUTPUT);
    pinMode(echoPin, INPUT);

    // Initialize IR sensor pins
    pinMode(leftsensorPin, INPUT);
    pinMode(rightsensorPin, INPUT);

    // Initialize color sensor pins
    pinMode(s0, OUTPUT);
    pinMode(s1, OUTPUT);
    pinMode(s2, OUTPUT);
    pinMode(s3, OUTPUT);
    pinMode(out, INPUT);

    // Set initial motor speed
    analogWrite(enA, motorSpeed);
    analogWrite(enB, motorSpeed);
}
```

Listing 8. C Language

Main Control Loop

A color sensor enhances the car's functionality by detecting and identifying colors of encountered objects. Control pins (s0, s1, s2, s3) configure the sensor's operational mode, while an output pin (out) provides RGB values for color analysis

```
void loop() {
    // Read IR sensor inputs
    int leftsensorValue = digitalRead(leftsensorPin)
    ;
    int rightsensorValue = digitalRead(
    rightsensorPin);

    // Perform line following based on IR sensor
    readings
    if (leftsensorValue == 1 && rightsensorValue ==
    1) {
        forward();
    } else if (leftsensorValue == 0 &&
    rightsensorValue == 1) {
        right();
    } else if (leftsensorValue == 1 &&
    rightsensorValue == 0) {
        left();
    }

    // Perform color sensing and obstacle avoidance
    tasks
    GetColors();     // Read RGB values from the
    color sensor
    ColorSensor();     // Determine the detected
    color
    measureDistance();      // Measure distance
    using the ultrasonic sensor

    // Implement logic for obstacle avoidance and
    color-based decisions
    // Adjust car's trajectory and behavior based on
     sensor inputs


    delay(100);
}
```

Listing 9. C Language

V. Designing

A. Laser cutting

For this prototype lase cutting technique on plywood was to used to create the chassis 12 of the vehicle. Two similar sheets were cut with same dimension, first being the chassis with 1 central hole to place the ball bearing as we were using front wheel drive to maneuver the vehicle. Similarly screw points were later created by hand drill to create mounted hole for brackets The chassis is with the dimensions as followed.

B. Ultra sonic Mount

An ultra sonic mount was 3D printed and designed on solid works with ,stl file format. This prototype uses this mount to stabilise the ultrasonic sensor to receive a more precise reading. This mount also enable us to join a servo motor with

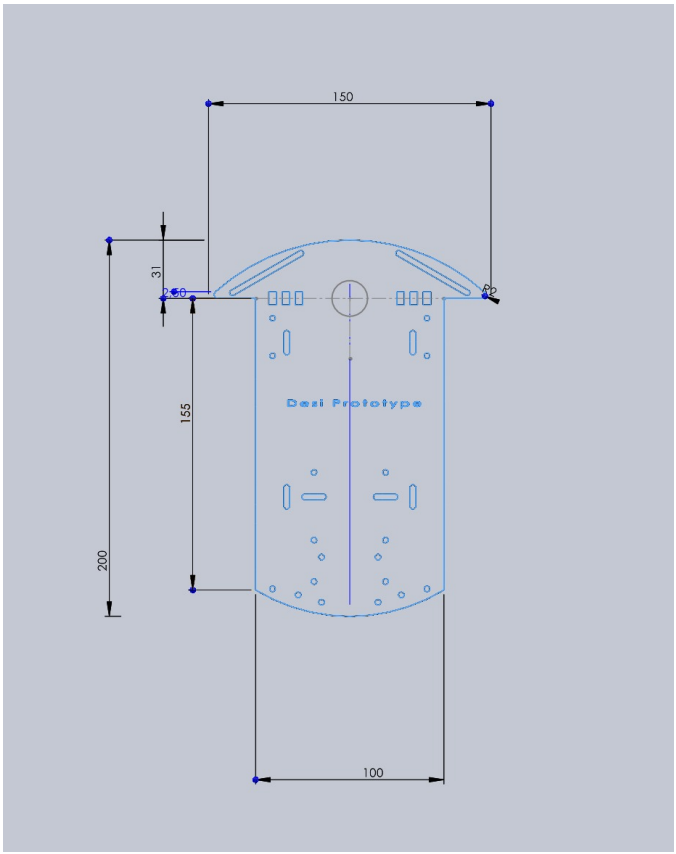

Fig. 12. Chassis

the ultrasonic sensor so the ultrasonic sensor can be used with 180 degrees rotation so it can detect objects left and the right side of the car.

Fig. 13. USmount

C. Couping nut

A coupling nut was also designed and 3D with the same techniques as the ultrasound mount. The coupling nut was used to stabilize and connect both the upper plywood sheet and the chassis together for stable and precise drive, This technique also helped lower the vehicles center of gravity which provides higher stability allowing the vehicle to go faster.

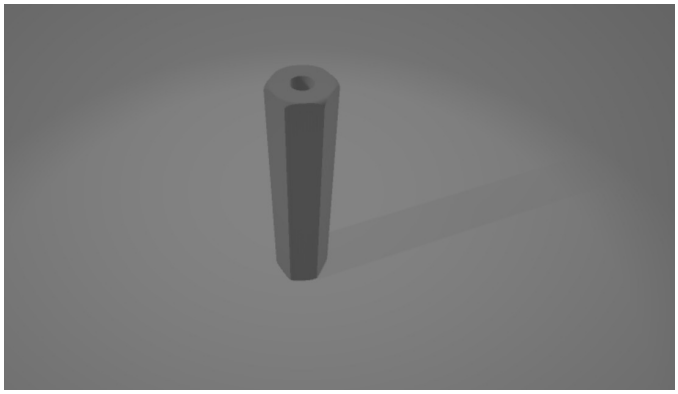

Fig. 14. Coupling Nut

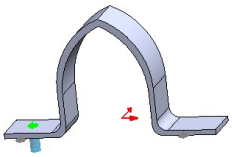

Fig. 15. Motor Clamp

D. Motor mounting Clamp

This figure shows a 3D motor mounting clamp that is used to mount DC motors to the chassis of the car for more stable connection and torque production for the drive of the car.

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ACKNOWLEDGMENT

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