An Autonomous Vehicle Model for Automatic Lane Detection

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Abstract: This paper is all about the process to make an autonomous vehicle model for traffic observation and lane detection. This model will focus on an object on a specific part of the road and react according to the situation with the help of feed which it will get from the camera in the form of video/image and then processed with the help of image processing in Raspberry Pi4.

The effectiveness of the paper is to recognize hazards on the road in real time and tackle the traffic even without the main driver present physically inside the vehicle model.

Raspberry Pi4 is used, which itself is a portable single computer board to do all the work in hand. Raspberry Pi4 will send all the information to Arduino Uno R3 which, according to the condition, sends a signal to the DC motor driver. The Motor Driver then controls all the four wheels of the vehicle model according to the signal received which helps in rotation of the wheels of the vehicle model.

Keywords: Arduino, autonomous vehicle, lane detection, traffic, Raspberry Pi.

1. Introduction

Autonomous vehicles, predominantly designed for passenger use (though applicable to trucks, buses, and various other vehicles), operate without the need for human intervention to ensure safe driving. These vehicles integrate sensors and software for tasks such as vehicle control, navigation, and driving [1]. Referred to as Autonomous Vehicles (AVs or autos), self-driving cars, driverless cars, or robotic cars (Robo-cars), they possess the capability to sense their surroundings and navigate securely with minimal or no human assistance. The potential implications of this technology on various industries and other contexts could shape the future [2].

Rephrase"Self-driving cars combine a variety of sensors to perceive their surrounding such as radar, Lidar, Sonar, GPS, odometer and inertial measurement units. Advanced control system interprets sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage [3]. To allow self-driving vehicles to take over the streets, there is a trend by automakers to gradually add technologies that collaborate with drivers both in driving and maintaining the car itself, such as:

- Controlling the speed.
- Assistance in driving.
- Manage the braking system.
- Detecting obstacle and people in roadside.
- Alerting other vehicles.
- Adjusting speed as per road conditions.

2. Methodology

2.1. Principle of Autonomous Vehicle

This section elucidates the operational mechanism of the vehicle model, detailing its functionality in tracking lanes, observing traffic symbols, and executing appropriate responses.

The total process is explained below step-wise:

- Feed is captured from the Raspberry Pi Camera Module.
- Feed is displayed in Original named frame.
- Feed is processed with the help of OpenCV library and then displayed as bird view in the Perspective named frame of a region of interest.

- Processed image is then converted into gray scale image from RGB scale image using functions of OpenCV.
- Gray Scale image is then processed with Canny Edge Detection and along with the Histogram library of OpenCV.
- The Final result is then displayed in the Final named frame.
- Then with the help of image processing and calculations the Lane Center and Frame Center is plotted in the final named frame.
- Now, the Result is being calculated from the Lane Center and Frame Center.
- According to the Result Raspberry Pi will send instruction to the Arduino Uno for the motor controls using GPIO pins.
- After receiving the instruction from Raspberry Pi, Arduino Uno will execute the required sets of code to send signal to Motor Driver L298N Bridge.
- Motor Driver L298N Bridge will control the motion of the DC Geared Motor according to the signal received from Arduino Uno.
- The Model will start moving according to the signal received from Motor Driver L298N Bridge.

2.2. Technologies Used

2.2.1. Raspberry Pi4 Model B

The latest addition to the fourth-generation Raspberry Pi family is the 4GB version of the Raspberry Pi 4 Model B. This model stands out as a high-performance, versatile computer equipped with a quad-core 64-bit ARM Cortex-A72 CPU. Notable features include two micro-HDMI ports supporting resolutions up to 4K, USB 3.0 support, a USB-C connector for power input, genuine Gigabit Ethernet with PoE capability (requires an additional PoE HAT), and dual-band wireless networking along with Bluetooth 5.0. These combined features position this board as an excellent choice for Single Board Computer (SBC)-based IoT papers [4].

2.2.2. Raspberry Pi Camera

The Raspberry Pi 5MP camera board is a uniquely crafted camera module equipped with a flexible ribbon cable, ensuring seamless compatibility with Raspberry Pi boards. It is furnished with a fixed lens that delivers a 5-megapixel resolution. This camera module excels at capturing striking moments with a resolution of 2592 x 1944 pixels and is adept at recording high-quality videos in the 640x480p 60/90 format [5].

2.2.3. Arduino Uno R3

The Arduino Uno R3 serves as a microcontroller board, utilizing the ATmega328P as its core component. It incorporates all the necessary elements to support the microcontroller. To initiate its operation, you can effortlessly connect it to a computer using a USB cable and provide power through either an AC-DC adapter or a battery. The term "Uno," meaning "one" in Italian, was chosen to coincide with the release of Arduino's IDE 1.0 software. The R3 version of the Arduino Uno is the latest and third iteration of the board. Both the Arduino board and IDE software are regarded as reference versions for Arduino, consistently evolving with each subsequent release. The Uno board stands as the foundational model in a series of USB-Arduino boards and serves as the benchmark model for the Arduino platform.

2.2.4. Motor Driver L298 N-Bridge

The L298 is an integrated monolithic circuit available in 15-lead Multiwatt and PowerSO20 packages. Serving as a high-voltage, high-current dual full-bridge driver, it is engineered to interface with standard TTL logic levels and proficiently manage inductive loads such as relays, solenoids, DC motors, and stepping motors [6]. It is equipped with two enable inputs, allowing independent activation or deactivation, regardless of the input signals. The emitters of the lower transistors in each bridge are interconnected, and the corresponding external terminal can be employed for connecting an external sensing resistor. Furthermore, an additional supply input is incorporated to ensure the proper functioning of logic at a lower voltage.

2.2.5. DC Geared Motor

A DC Gear Motor, alternatively referred to as a DC Geared Motor or Speed Reduction Motor, combines a DC motor with a gearbox, operating on direct current power. Typically, the inclusion of a gearbox is intended to regulate the speed of the motor shaft and enhance its torque output. Widely applied in various fields, from robotics to automobiles, DC gear motors are especially prevalent in small and medium-sized motoring applications due to their versatile functionality. The construction of a DC motor involves creating a magnetic field, achieved by utilizing a magnet, which can be either an electromagnet or a permanent magnet.

The 200 RPM DC Gear Motor distinguishes itself by providing substantial torque and revolutions per minute (rpm) at lower operating voltages, presenting a significant advantage. This motor is compatible with a 69mm Diameter Wheel for Plastic Gear Motors and an 87mm Diameter Multipurpose Wheel for Plastic Gear Motors [7].

2.2.6. PCB Board

A Printed Circuit Board (PCB) is a structured assembly of conductive and insulating layers, forming a laminated sandwich configuration. PCBs fulfill two closely intertwined functions [8]. Firstly, they securely affix electronic components to designated positions on the outer layers through soldering. Secondly, they establish robust electrical connections and ensure dependable open circuits between the terminals of these components, commonly referred to as PCB design.

Each conductive layer is meticulously designed with an artwork pattern of conductors, creating a resemblance to wires on a flat surface. This design facilitates electrical connections exclusively on that particular layer. Another manufacturing process involves the incorporation of vias—small and precisely positioned holes drilled through the laminate and subsequently plated with copper. These vias act as electrical interconnections between layers that would otherwise be insulated within the

laminate structure. This configuration facilitates a controlled third-dimensional connection between conductive layers, ensuring both reliability and cost-effectiveness in the mass production of electronic products.

2.2.7. LED

A Light-Emitting Diode (LED) operates as a light source utilizing semiconductor technology, producing light when an electric current passes through it. Within the semiconductor, electrons recombine with electron holes, releasing energy in the form of photons. The color of the emitted light, corresponding to the energy of the photons, is determined by the energy required for electrons to cross the semiconductor's band gap [9]. To achieve white light, a method involving either multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device is utilized.

2.2.8. Electrolyte Capacitor

An electrolytic capacitor is defined as a polarized capacitor where the anode maintains a higher or more positive voltage compared to the cathode. As implied by its name, it is a polarized capacitor, and its operation relies on utilizing an electrolyte, ensuring that the anode maintains a higher or more positive voltage than the cathode.

2.2.9. Resistance

A resistor is a passive component with two terminals that includes electrical resistance within a circuit. Within electronic circuits, resistors serve various purposes, including diminishing current flow, adjusting signal levels, dividing voltages, biasing active elements, and terminating transmission lines.

2.2.10. Wires

The specific kinds of wires used in this work comprises of jumper and connector wires which are discussed below. Jumper wires are simple wires featuring connector pins on both ends, allowing for the establishment of connections between two points without requiring soldering. Frequently utilized with breadboards and other prototyping tools, they streamline the process of modifying circuits as needed. This represents a basic and essential element of electrical connections. Connecting wires serve as a conduit for electrical current to travel from one point to another within a circuit. Usually crafted from materials like copper or aluminum, these wires are pivotal in ensuring the smooth flow of electricity.

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2.2.11. CSI Cable

This cable enables one to exchange the default flex cable of 150mm long on a camera (the classic or 'NoIR' variant) for a cable of a varied length. The replacement process involves delicately opening the connector on the Pi and introducing the new 50mm long cable. We offer a range of cable lengths, including 50, 100, 200, and 300mm, allowing to choose a perfect fit for applicable requirements.

2.2.12. Power Source

In this work a Power Bank is used as a power source with a battery-powered device crafted for recharging the batteries of mobile phones or other electronic devices. Power banks, also referred to as portable chargers, are compact batteries equipped with circuitry to oversee both the input and output of power. Such devices may be charged using a USB and are subsequently used for charging battery-powered items like mobile phones.

3. Methodology

3.1. Schematic Diagram & Connection

3.1.1. Arduino UNO - Motor Driver L298 N-Bridge

The Arduino motor driver is employed as a motor driver, and the connection details are outlined in Table 1. Subsequently, the connection diagram for the driver is presented.

Table 1. Motor driver L298 N-Bridge PIN connection details

Arduino (Pin. No)	L298-N (Pin. No)
5(PWM)	Enable-A
7(DIGITAL)	Input –A1
6(PWM)	Input –A2
8(DIGITAL)	Input –B1
9(PWM)	Input –B2
10(PWM)	Enable-B

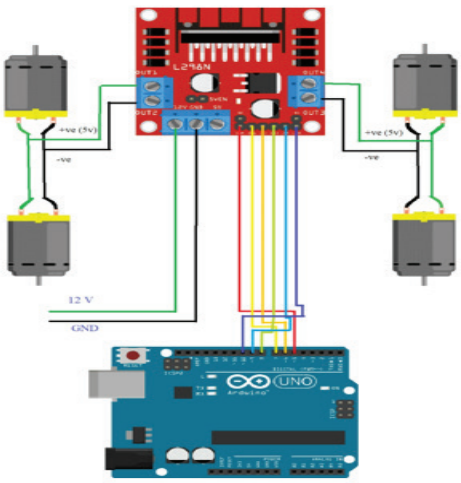


Figure 1. Arduino UNO - Motor Driver L298 N-Bridge

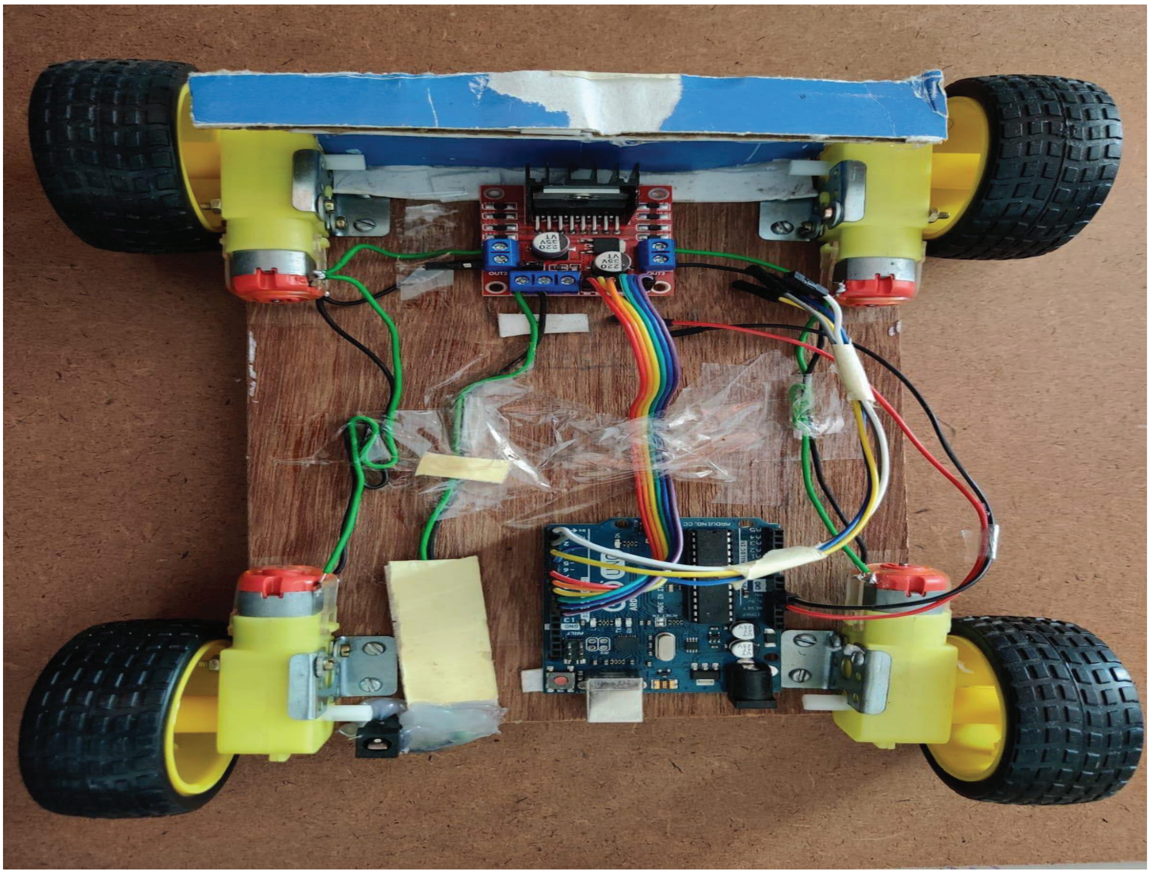


Figure 2. Lower Vehicle Model

3.2. Custom PCB

The PCB is tailored to facilitate the implementation of the autonomous vehicle. For convenient reference, the connection details specific to this paper have been illustrated in Figure 3.

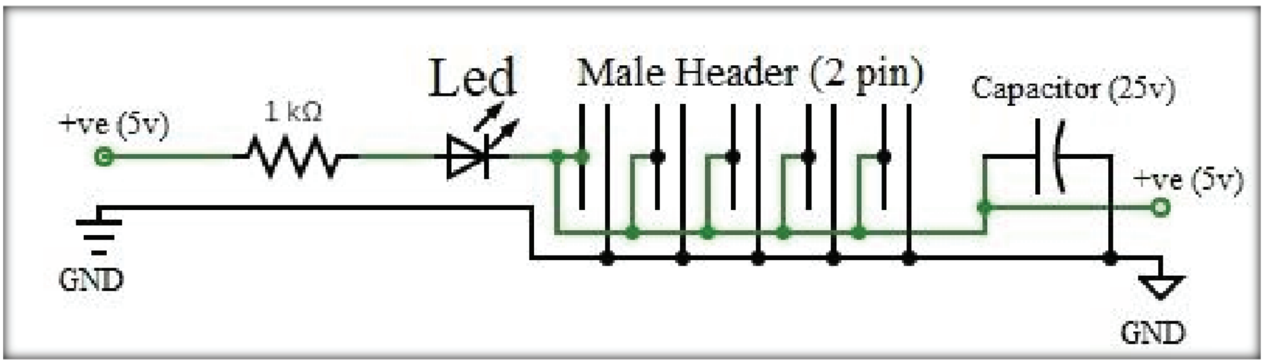


Figure 3. Connection details for PCB customization

The screenshot of the actual hardware has been provided in Figure 4.

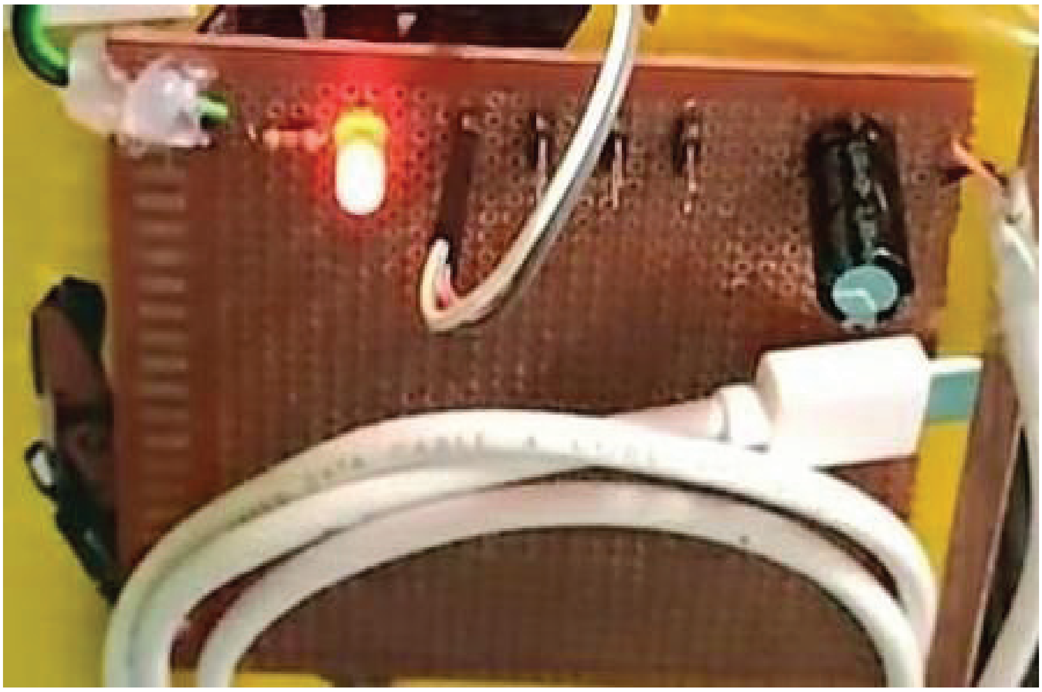


Figure 4. Snapshot of actual hardware of PCB connection

3.3. Custom PCB to Arduino UNO R3

The PCB is connected to the Arduino UNO circuit such that the two male headers of the PCB is connected to the 5V analog and ground respectively.

The circuit details have been provided in Figure 5.

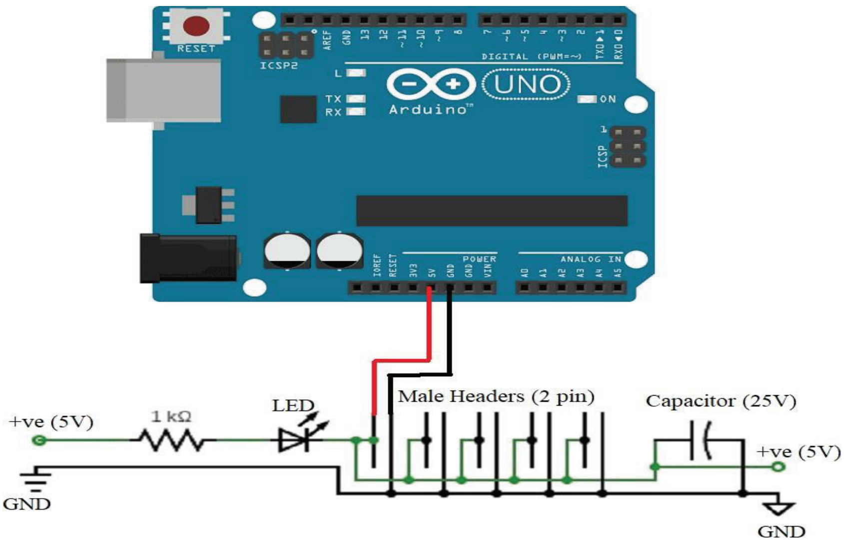


Figure 5. Circuit diagram of customized PCB with Arduino UNO 3 circuit

3.4. Arduino UNO to Raspberry Pi Connection

The ultimate stage of the model involves establishing the connection between the Arduino circuit and the Raspberry Pi. The specification of the pin connections for this stage is presented in Table 2, followed by the connection diagram depicted in Figure 6.

Table 2. Arduino UNO and Raspberry Pi Pin connection details

Arduino	**Raspberry Pi**
0(RX)	29 (GPIO-5)
1(TX)	31 (GPIO-6)
2(DIGITAL)	33(GPIO-13)
3(PWM)	35 (GPIO-19)

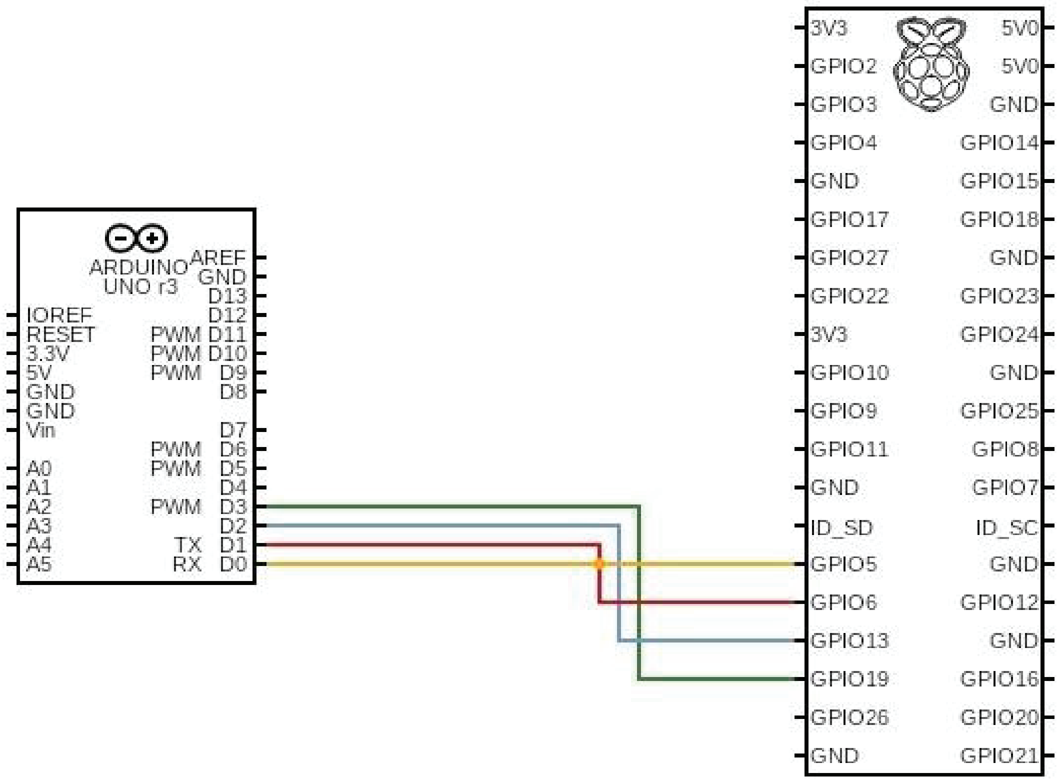


Figure 6. Arduino UNO and Raspberry Pi Pin connection diagram

4. Results and Analysis

The result section has been provided in the following manner:

- First, the vehicle models have been provided.
- Next, the result analysis has been given.

4.1. Vehicle Model

In the provided figure below, it is evident that the Raspberry Pi is powered by the power source. Additionally, the Raspberry Pi is connected to the Arduino, situated in the lower chassis of the vehicle model, using GPIO Pins.

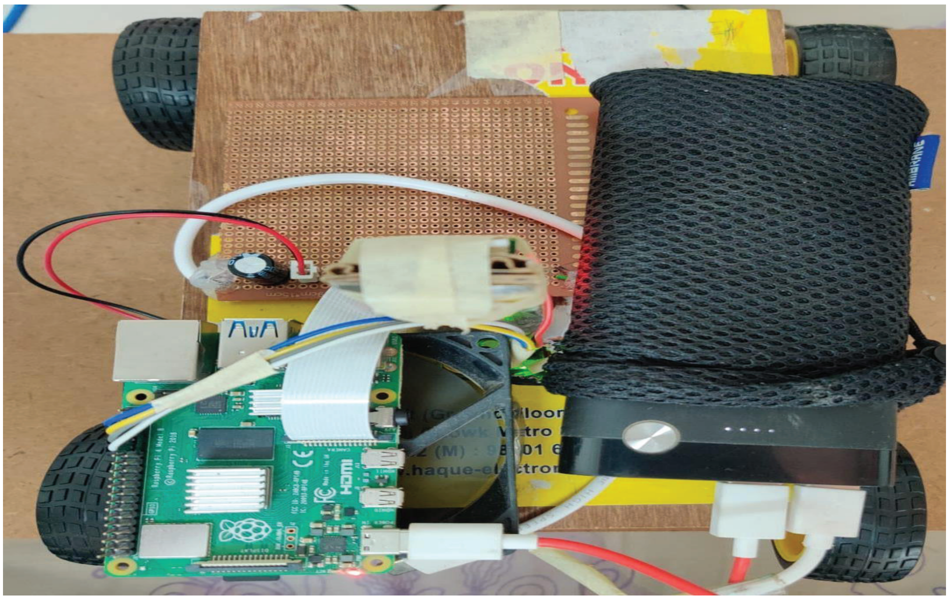


Figure 7. Vehicle Upper Model

In the presented diagram, we can see that the Arduino is linked to the Motor Driver L298-N Bridge through a combination of digital and PWM Pins. The four DC Motors are connected to the outputs of the Motor Driver L298-N Bridge. More precisely, the left two DC Motors are associated with L298-N Bridge Output 1, while the right two DC Motors are connected to L298-N Bridge Output 2.

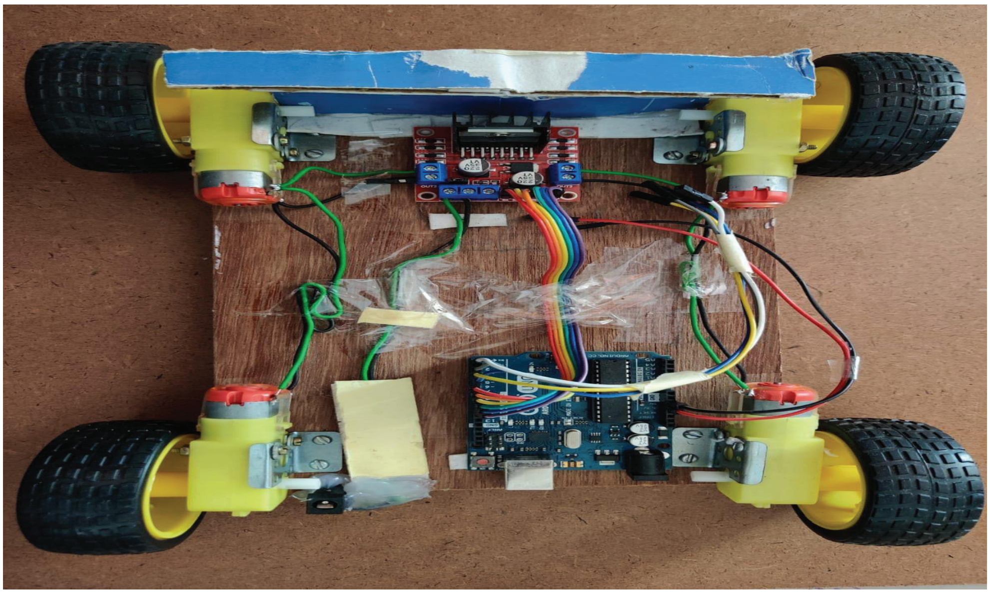
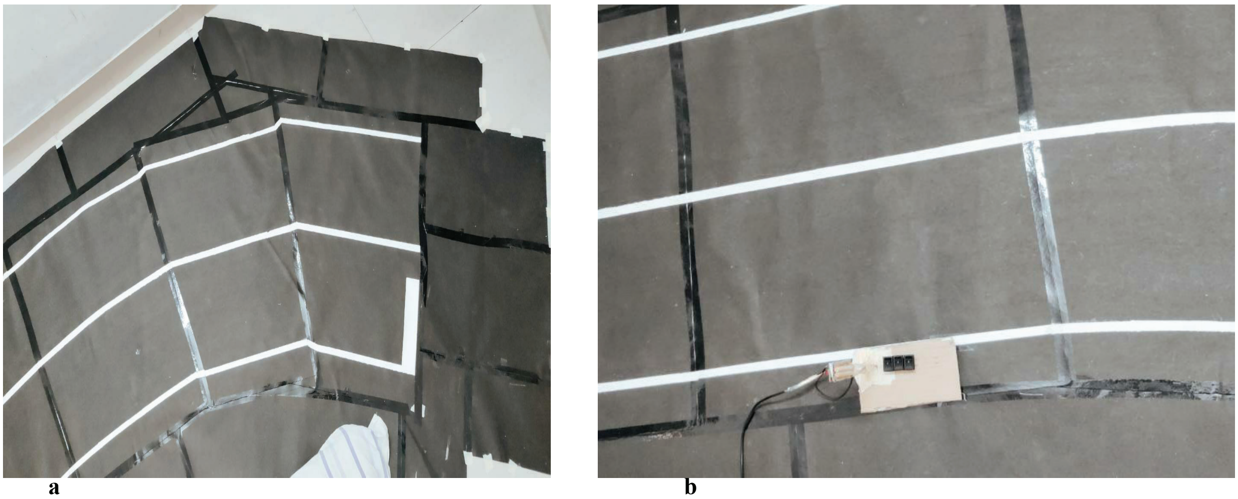


Figure 8. Lower Vehicle Model

The next module shows the signal and object (as a car) that has been used in the paper.

a **b**

Figure 9. (a) Stop signal; (b) a car as obstacle



a b

Figure 10. (a) Photo of lane created; (b) the autonomous car in lane

4.2. Base Screen

This is the base screen where we have 5-windows each displaying individual feeds. The 5-windows titled as:

- Original – Shows the actual feed from the camera.
- Perspective – Shows the region of interest in Bird/Perspective View.
- Final – Shows the final feed after all image processing and canny edge detection.
- Stop Sign – Shows the region for stop sign.
- Object Detected – Shows the region for Object Detection

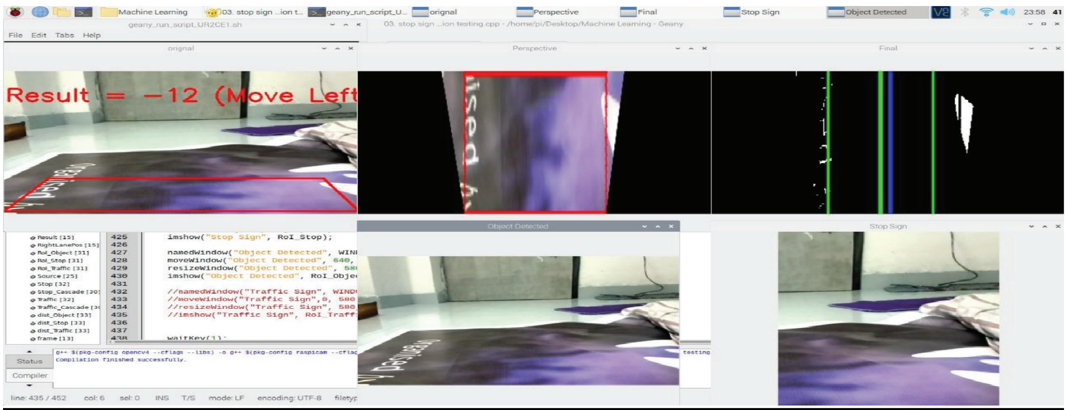


Figure 11. Screenshot showing base screen

4.3. Object Detection

Within the "Object Detected" window, a red box is presented, signifying the estimated distance of the detected object from the vehicle model within the lane. Should an object be identified and fall within the predetermined range, the vehicle will execute a lane change to navigate around the object and subsequently revert to its original lane.

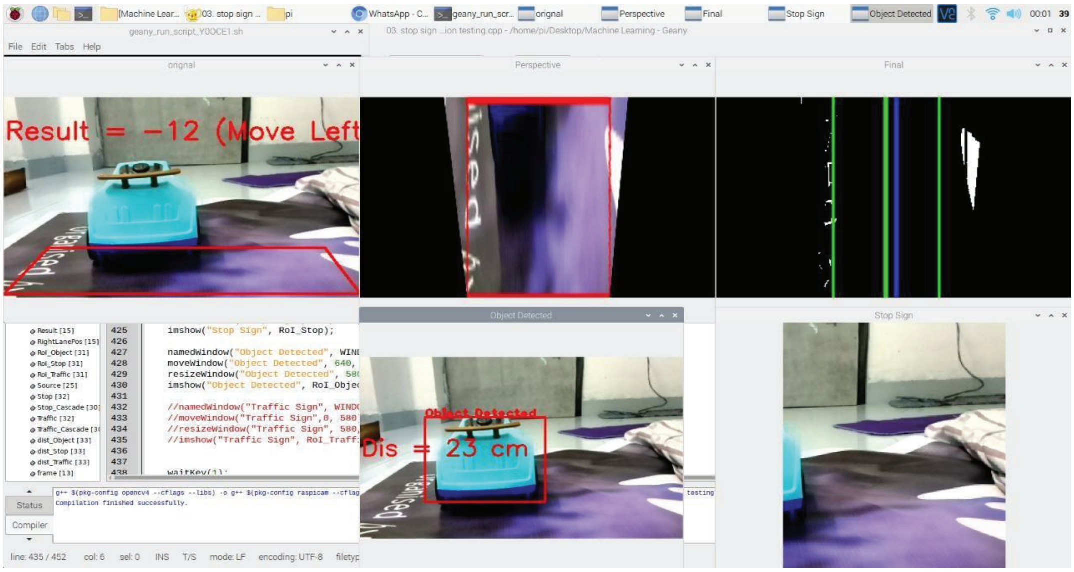


Figure 12. Screenshot showing the object detection

4.4. Stop Detection

In the "Stop Sign" window, a red box is displayed, revealing the approximate distance of the stop sign from the vehicle model when detected along the lane.

When the stop sign is identified within the predefined distance, the vehicle will come to a halt for a specified duration.

The image below illustrates the configuration for detecting a stop signal.

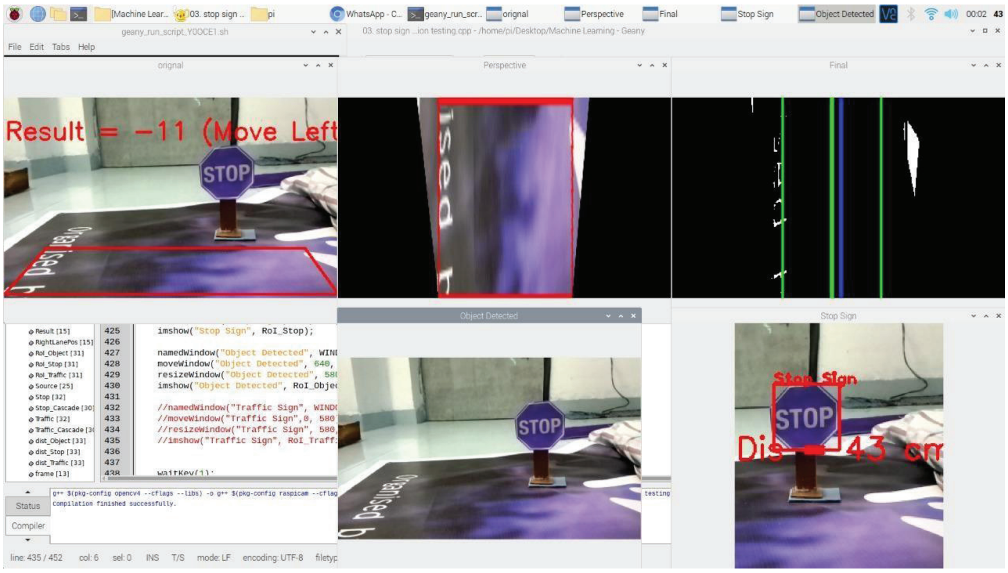


Figure 13. Screenshot showing the stop sign detection

5. Conclusion and Future Scope

Self-driving vehicles hold the promise of becoming an efficient and sustainable mode of transportation, with the potential to prevent accidents and streamline the driving experience for all. Crucial hardware elements, including the Raspberry Pi 4 Model B, Camera, and Arduino UNO R3, contribute significantly to the prominence and convenience of this model on the road.

These technological advancements are anticipated to decrease the likelihood of accidents, thereby preventing injuries. Our model effectively fulfills the objective of self-driving, ensuring the vehicle remains within the desired lane.

In the years to come, self-driving technology is expected to play a pivotal role in transforming the driving experience, shifting from the mandatory presence of a human in the driver's seat to an optional one. Our self-driving technology is meticulously designed to proficiently handle various driving aspects, swiftly averting accidents and injuries. The ongoing evolution of safety technologies lays the foundation for the development of intelligent, software-defined automated systems capable of navigating roads with minimal human intervention.

References

1. Vu Trieu Minh, Reza Moezzi, Klodian Dhoska, John Pumwa, Model Predictive Control for Autonomous Vehicle Tracking , International Journal of Innovative Technology and Interdisciplinary Sciences; Vol. 4 No. 1 (2021).

2. Salman Akhtar, Saeid Habibi, "The Interacting Multiple Model Smooth Variable Structure Filter for Trajectory Prediction", IEEE Transactions on Intelligent Transportation Systems, vol.24, no.9, pp.9217-9239, 2023.

3. Mostafa Uddin, Sarit Mukherjee, Murali Kodialam, TV Lakshman, "GLAMAR: Geo-Location Assisted Mobile Augmented Reality for Industrial Automation", 2020 IEEE/ACM Symposium on Edge Computing (SEC), pp.232-245, 2020.

4. S. Karuppuchamy, R.K. Selvakumar, "A Survey and Study on "Vehicle Tracking Algorithms in Video Surveillance System"", 2017 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), pp.1-4, 2017.

5. Pradeep Sanganna Bangari, Sanika Kuttappa K, Shivanandan N M, Sreelekshmi C, Ambily Babu, Autonomous Car using Raspberry PI, International Journal of Innovations in Engineering and Technology (IJIET), Vol-9 Issue-3 2023.

6. Husam A Almusawi, Mohammed Al-Jabali, Amro M Khaled, Korondi Péter, Husi Géza; IOP Conf. Series: Materials Science and Engineering, 2022, Vol.1256.

7. Mérida-Calvo, L.; Rodríguez, A.S.-M.; Ramos, F.; Feliu-Batlle, V. Advanced Motor Control for Improving the Trajectory Tracking Accuracy of a Low-Cost Mobile Robot. Machines 2023, 11, 14.\

8. Benjamin Vedder, Jonny Vinter, and Magnus Jonsson, A Low-Cost Model Vehicle Testbed with Accurate Positioning for Autonomous Driving, Journal of Robotics, 2018, Volume 2018, Article ID 4907536.

9. F. C. Braescu, "Basic control algorithms for vehicle platooning prototype model car," in Proceedings of the 21st International Conference on System Theory, Control and Computing, ICSTCC 2017, pp. 180–185, Sinaia, Romania, October 2017.