An-Najah National University

Faculty of Engineering & Information Technology

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Bachelor degree in Computer Engineering

Graduation project 2

Self-driving Car

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Disclaimer

Abstract

The major goal of development the self-driving cars has been driven by the desire to improve road safety, reduce traffic congestion, and provide mobility to those who are unable to drive. Self-driving cars rely heavily on image processing to perceive and understand the driving environment. Image processing involves collecting data from cameras and other sensors installed on the car, and then analyzing that data to extract information about the surroundings. This information is then used by the car to make driving decisions. Pictures will be taken sequentially by a Raspberry Pi camera connected with Raspberry Pi 4, and then these images will be processed by the OpenCV library and machine learning and used Arduino UNO to control the motor driver(H-bridge).

The car was able to recognize road lines, drive between these lines, and recognize some traffic signs such as stop signs, green and red traffic lights. Also, the car will be able to detect and overcome obstacles.

Contents

List of Figures

Chapter 1

Introduction

Autonomous vehicles, commonly referred to as self-driving cars, that emerged as a transformative technology in the field of transportation. These vehicles are built to function autonomously, utilizing a combination of cutting-edge sensors, artificial intelligence, and complex algorithms to sense their environment and make decisions while driving. The creation and use of self-driving vehicles present a wide range of opportunities and difficulties, altering how we travel and influencing the direction of transportation in the future.

The inherent restrictions and dangers of human driving are the issue that self-driving cars seek to solve. Despite tremendous improvements in automotive safety technologies, human error continuous to be a major factor in car accidents. Self-driving cars have the potential to drastically reduce accidents and raise overall road safety.

The scope of self-driving automobiles includes a variety of topics, such as sensor technologies, machine learning, regulatory frameworks, and software and hardware development. Developing a complete and trustworthy autonomous driving system involves integrating several fields, including computer science, engineering, and transportation planning. It's crucial to remember that the use of self-driving cars may be constrained by legal and regulatory requirements, And not violate laws such as traffic lights, wrong overtaking, and exceeding the legal speed.

A safer, more effective, and universally accessible transportation system is the main goal of self-driving cars. Self-driving cars use cutting-edge technology to minimize congestion, improve traffic flow, and do away with human error. and these vehicles have cutting-edge sensors and technology that can recognize possible dangers and act immediately to reduce risks. For elderly or disabled passengers, self-driving cars can increase their sense of security and assist prevent accidents.

The significance of self-driving cars lies in their potential to revolutionize transportation and address several societal challenges. First, self-driving cars can save lives and greatly increase road safety by minimizing accidents brought on by human mistakes. Additionally, autonomous cars have the potential to improve transportation system effectiveness, hence reducing traffic congestion. They can also provide accessibility and independence for people who are unable to drive, giving them greater mobility.

This report is organized into several sections to provide a comprehensive understanding of self-driving cars. Subsequent sections will delve into the technology behind self-driving vehicles, including the key components and sensors used to operate them. We will also explore the challenges and opportunities associated with self-driving cars, and discuss their impact on road safety, transportation infrastructure, and society at large. In addition, the report will examine the current situation for the development and deployment of self-driving cars, highlighting the outstanding achievements and ongoing research efforts, as well as presenting the challenges we faced in building a model for a self-driving car and mentioning proposed solutions for it, and finally, we will explain our findings.

Chapter 2

Constraints Limitations and Earlier Coursework

2.1 Constraints Limitations

2.1.1 Lack of Resources

It was not easy to find all the required components in the electronics stores near us, which took us some time to order them from far away. Also, learning how to deal with these components took some time

2.1.2 Machine Learning

We faced a problem in training the system to recognize traffic lights, and we tried to use several systems based on artificial intelligence, such as Google teachable machine and cascade classifier, but their results were inaccurate, and in the end, we turned to library tensor flow lite model maker, which gave us acceptable and its accuracy is very good, and we improved the accuracy of training By increasing the data entered and increasing the number of training epochs.

2.1.3 Financial Budget

The project contains multiple components, and each of these components cost money, which made us dispense with some features such as high-quality cameras, so we resorted to a camera of acceptable quality and an acceptable price.

2.1.4 Lane Detection

We have faced many challenges in recognizing the sides of the road, such as the intensity of lighting that is constantly changing, so we tried to mitigate the impact of this problem by changing some parameters such as thresholding.

2.1.5 Car Movement

The movement of the car was not smooth because we could not find a model of a car that had a steering wheel (direction control via the front wheels), so we resorted to using what was available in electronic stores at the time, which is controlling the direction by all wheels.

2.2 Earlier Coursework

we gained knowledge of hardware design in the computer engineering department from all the courses we took like microcontroller, microcontroller lab, computer networking, electrical circuits, and digital design. We gained knowledge in research work and scholarly reports from critical thinking research. Other knowledge gained by participating in some online courses and we have used the Internet and YouTube to find solutions to the problems we encountered.

2.3 Standards and Protocols

2.3.1 Serial Communication

Serial communication between Raspberry Pi and Arduino is a popular way to exchange data between these two devices. This type of communication allows for a simple and reliable way to transfer data over a wired connection. This is achieved through the use of a UART (Universal Asynchronous Receiver/Transmitter) interface on both devices.

2.3.2 TensorFlow

TensorFlow is an open-source machine learning library developed by Google Brain Team. It is designed to provide an easy-to-use platform for building and deploying machine learning models, particularly those that involve neural networks. TensorFlow supports a range of platforms, including desktops, servers, and mobile devices.

2.3.3 OpenCV

OpenCV (Open Source Computer Vision Library) is an open-source computer vision and machine learning library. It was initially developed by Intel in 1999 and is now maintained by the OpenCV team. OpenCV is written in C++ and provides interfaces for several programming languages such as Python. and OpenCV provides a wide range of functions and algorithms for image and video processing, including image filtering, feature detection, object recognition, and tracking. It also includes tools for camera calibration

Chapter 3

Literature Review

Recent studies have demonstrated that driver autonomy or self-assistance can lessen accidents or crashes brought on by human mistake (Filiz, 2020), (Zhang et al., 2019,p.6). so self-driving cars must be able to recognize the lanes of the road it is traveling on. The "Hough Transformation" is one of the methods used to find the lanes (Aziz et al., 2017,p.144-148). It uses several feature extraction algorithms as well as machine learning algorithms that can be applied to lines, edges, and the region of interest. The same research could produce results with great precision given the current processing power and how different light intensities can affect a system. (Satzoda et al., 2010,p.23-26) claim that by enhancing the lane-detecting Hough Transformation algorithm, the same system's accuracy has risen.(Daigavane and Bajaj, 2010,p.76-80) The Hough transform and Canny Edge detection can be used to implement the lane detection algorithm.

To further secure the safety of the vehicle, An ultrasonic distance sensor is used in building a system to execute obstacle detection and alerting. The system detects the obstacle within a certain distance threshold. This system can be integrated into cars to avoid collision(Harish Kumar et al., 2017). And also to achieve safety the embedded system (Raspberry Pi 4) processes a stream of images originating from the MIPI CSI-2 camera (Doshi et al., 2019) and sends them to the microcontroller (Arduino UNO) (Ciganovic et al., 2018,p.7),(Cicolani and Cicolani, 2018). To operate the DC motors, the Arduino UNO provides output signals to the motor driver. There are various techniques to control the speed and direction of DC motors, which operate according to Faraday's law of electromagnetic. PWM (Pulse-width modulation) is used to control the speed of the motor. The direction of rotation of DC motors can be changed by switching their polarity, and an H-bridge is employed in this situation(Edition, 2006).

Chapter 4

Methodology

4.1 Components

4.1.1 Raspberry Pi 4

Raspberry Pi 4 is the fourth generation of Raspberry Pi single-board computers. It was released in June 2019 and is the most powerful Raspberry Pi model to date. Raspberry Pi 4 is based on the Broadcom BCM2711 SoC (system-on-chip), which includes a quad-core ARM Cortex-A72 CPU clocked at 1.5 GHz, up to 8 GB of RAM, and support for 4K video output.

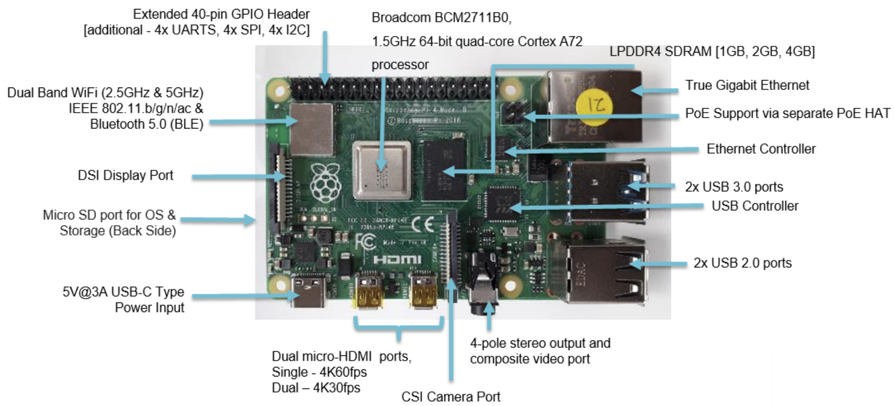

Figure 4.1: Raspberry Pi 4.

4.1.2 Arduino UNO

Arduino Uno is a microcontroller board based on the ATmega328P microcontroller. One of the key features of Arduino Uno is its simplicity. It includes a USB interface for programming and power and a set of headers for connecting external components such as sensors and motors. Arduino Uno also includes a range of built-in hardware, such as digital and analog input/output pins, PWM pins, and a serial communication interface. Arduino Uno is programmed using the Arduino Integrated Development Environment (IDE).

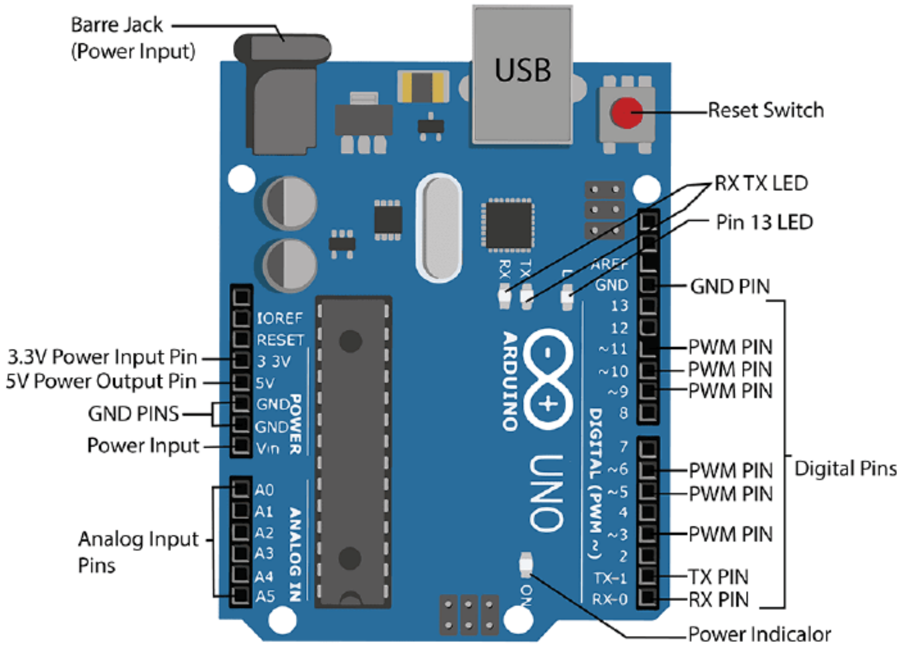

Figure 4.2: Arduino UNO.

4.1.3 Camera Module with Color for Raspberry Pi

The Camera Module with Color CMOS QSXGA for Raspberry Pi is an add-on board that allows users to capture high-quality images and videos with their Raspberry Pi.

Figure 4.3: Camera Module.

4.1.4 DC Gear Motor and Plastic Tire Wheel

We have used four DC motors with four wheels to move the car, these DC motors with gears, single axis, with DC 3-6V operating voltage and an RPM of 100R / minute.

Figure 4.4: DC Gear Motor and Plastic Tire Wheel.

4.1.5 H-bridge

An H-bridge is an electronic circuit that is used to control the direction of a DC motor, And it can output a constant voltage of 5V.

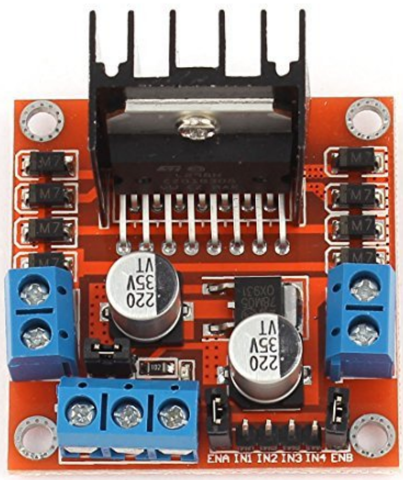

Figure 4.5: H-bridge.

4.1.6 Servo Motor

A DC motor, a gearbox, and a control circuit make up a servo motor. A potentiometer in the control circuit measures the motor's position, and a feedback loop compares the measured position to the desired position and modifies the motor as necessary.

Figure 4.6: Servo Motor.

4.1.7 Ultrasonic

Obstacles in front of the car can be detected with the help of an ultrasonic sensor. It calculates the distance from the car to the immediate object.

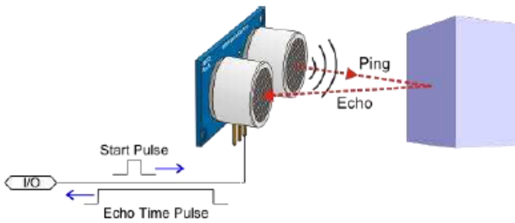

Figure 4.7: Ultrasonic.

4.1.8 Serial Cable

We used the serial cable to transmit data between Raspberry Pi and Arduino Uno, and we also used this cable to power the Arduino.

Figure 4.8: Serial Cable.

4.1.9 Power Bank and LI-ION Battery

We used the serial cable to transmit data between Raspberry Pi and Arduino Uno, and we also used this cable to power the Arduino.

Figure 4.9: Power Bank and LI-ION Battery

4.2 Setup Car

We have connected the left wheels together and connected them with the first connector on h-bridge as well as the left wheels together and connected them with the second connector on h-bridge as shown in the figure 4.10, and connected the h-bridge with Arduino and installed the Arduino and raspberry pi on the car model and connected the camera with the raspberry pi. We installed the raspberry pi OS and set up VNC on both windows and raspberry pi.

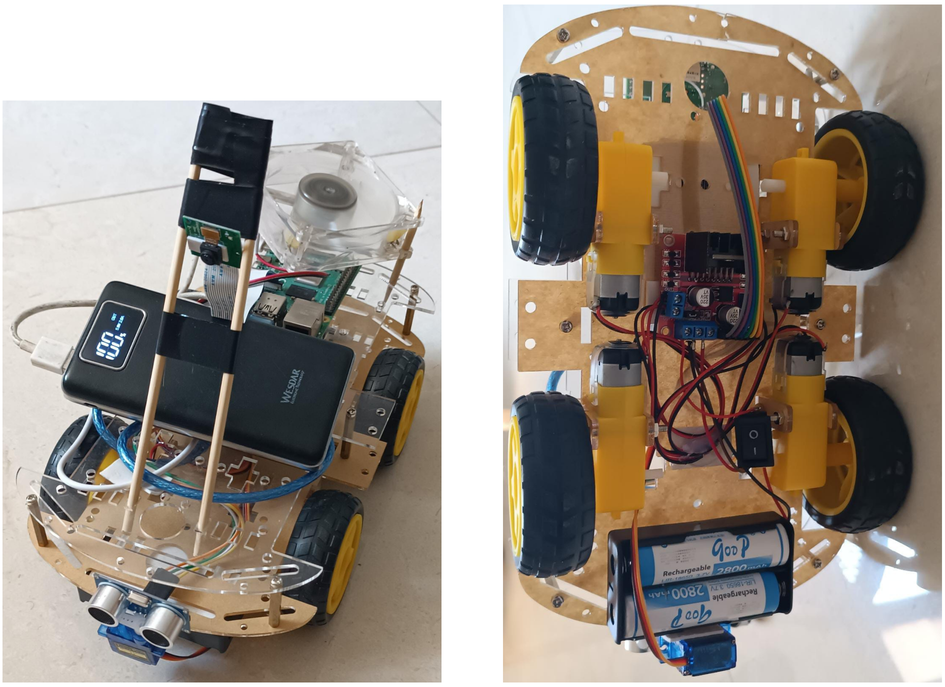

Figure 4.10: Power Bank and LI-ION Battery

4.3 Strategies

4.3.1 Lane Detection

After we installed the OpenCV library and Numpy, we have taken an image from the camera, then applied a mask (the region of interest), then convert the image to gray-scale, then applied thresholding to the image to detect black lines only, then applied the canny function to find the edges on the road, and then applied houghLinesP to draw the lines on edges detected by canny function. The detected lines are separated into vertical lines and horizontal lines based on specific thresholds as shown in Fig 4.11, and in these vertical lines, we find their intersection points with a horizontal line to determine the distance of the road edges from the middle of the car. this distance will be passed to Arduino to move the car left or right depending on the sign value. when we detect one line in the track we conclude that the car is in a curve so Arduino will know the direction of the curve by the line slope.

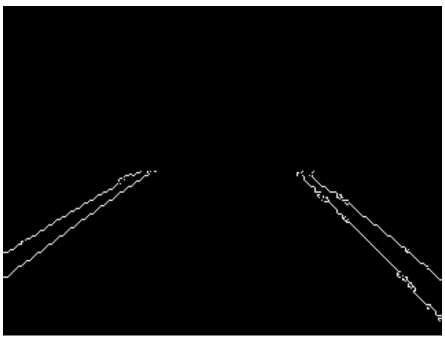

Figure 4.11: Lane Detection.

4.3.2 Traffic sign detection

After installing the tflite-model-maker and TensorFlow library, we captured many images of the stop signal and the light signals, then we determined the region of the traffic sign on each captured image, and then create XML files for each image. These files are passed to the tflite-model-maker library. After determining the number of epochs as shown in the figure 4.12, this library will train a model using machine learning, the output of training is a single file with an extension of (.tflite) then the program will use this file at a running time to detect traffic signs.

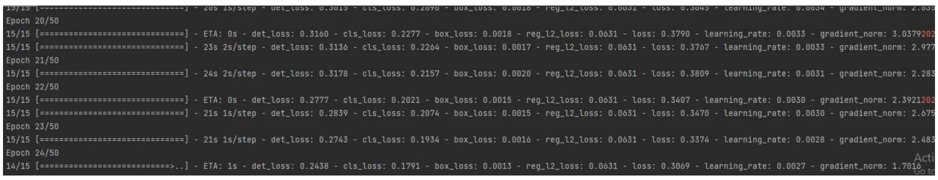

Figure 4.12: Training.

4.3.3 Obstacle Detection

We stabilize the ultrasound on a servo motor and then connect it to the Arduino. We set the maximum distance to detect an obstacle, which is 30 cm. If an obstacle is detected within this distance, the car will stop, then the servo motor will move to the left side, to make sure there is no other obstacle. On the left, move the car to be parallel to the obstacle, and then we will move the servo motor to the side of the obstacle (right side), when passing the obstacle, the car will go back to its lane.

Chapter 5

Results and Analysis

By applying the principles mentioned previously for the connection of the hardware units and the software methods which are image processing and machine learning algorithms using OpenCV and TensorFlow, the lane could be detected as shown in Figure 5.1, by the program as well as the traffic signs well be detected (Stop Sign, green Traffic Light, red Traffic Light) as shown in Figure 5.2. Furthermore, the car was kept safe by stopping at the end of the track, and by using the ultrasonic sensor to make the car stop at a safe distance from obstacles.
The result of detected traffic signs and obstacles:

1. The car will stop if it detects an obstacle and then try to pass the obstacle and return to its lane.
2. The car will stop for three seconds if it detects a stop sign and then continues its movement.
3. The car will stop if it detects a red traffic light and continues driving if it is green.

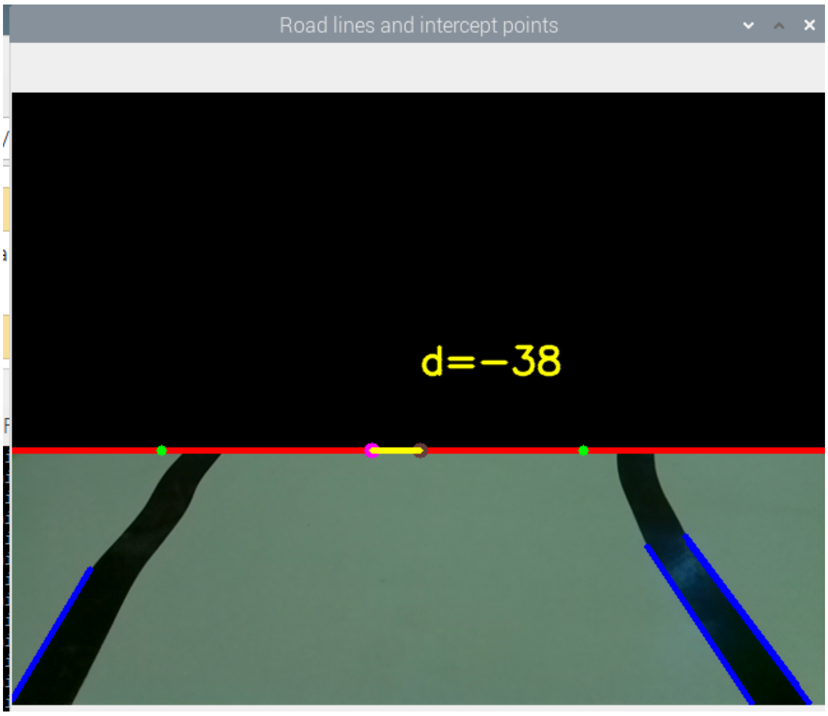

Figure 5.1: Lane detection.

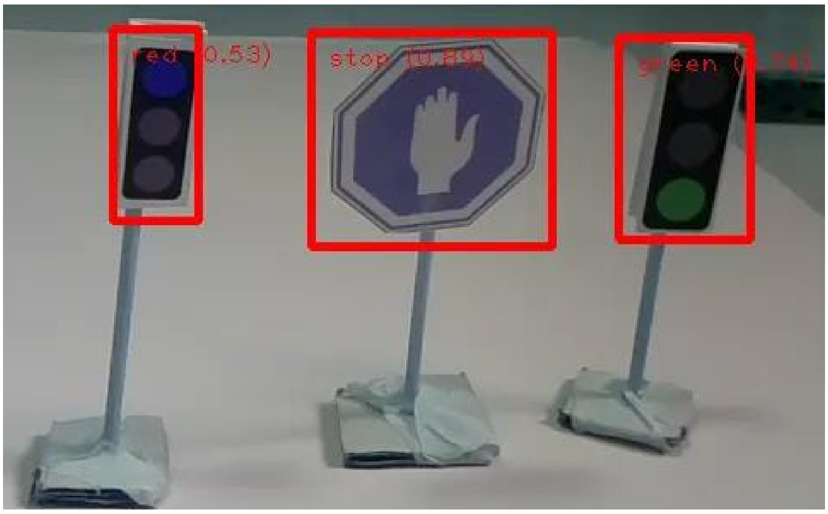

Figure 5.2: Detect traffic signs.

Chapter 6

Conclusion

The project aimed to create a fully self-driving car that can detect lanes and detect certain traffic lights. The goals were achieved by using Raspberry Pi for image processing and machine learning. The system can detect lanes and respond to a change in Route direction, detect traffic lights, and give responses accordingly. The responses are sent to the Arduino UNO. And give a result from the ultrasonic sensor to deliver the final output to the motor driver. However, the system has some limitations, such as the whole process is easily affected by the intensity of light, which leads to errors in image processing, and suggested solution to solve this problem is to use modern and advanced cameras can be used to ensure that the intensity of lighting does not affect the quality of the image.

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