Chapter 4

Hardware Components

4.1 Introduction

In order to achieve the best results and a complete representation, the project utilized the finest hardware tools available. This includes high-resolution cameras or imaging devices to capture detailed images, ensuring the model's accuracy and intricacies are faithfully reproduced. Additionally, professional-grade equipment may have been used for precise measurements, ensuring the proportions of the model are accurate.

4.2 Hardware Module

The structure as shown in **Figure 4.1** provides a general overview of how the various components of the project are interconnected.

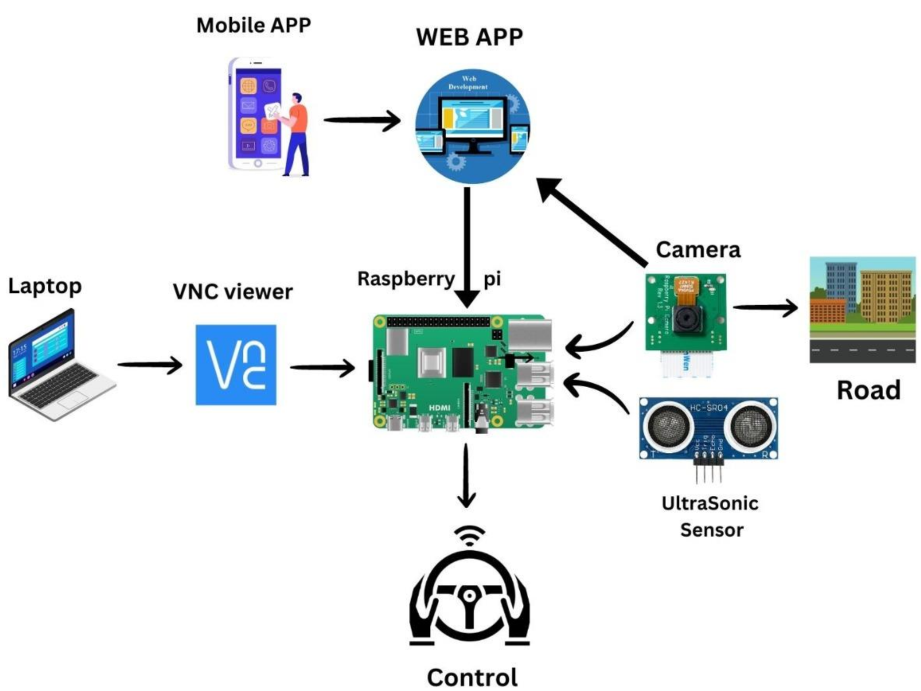

Fig. 4.1: System Structure

To execute the project, we needed the electronic components shown in **Figure 4.2** to assist us in operating this connection and achieving the desired efficiency, as follows:

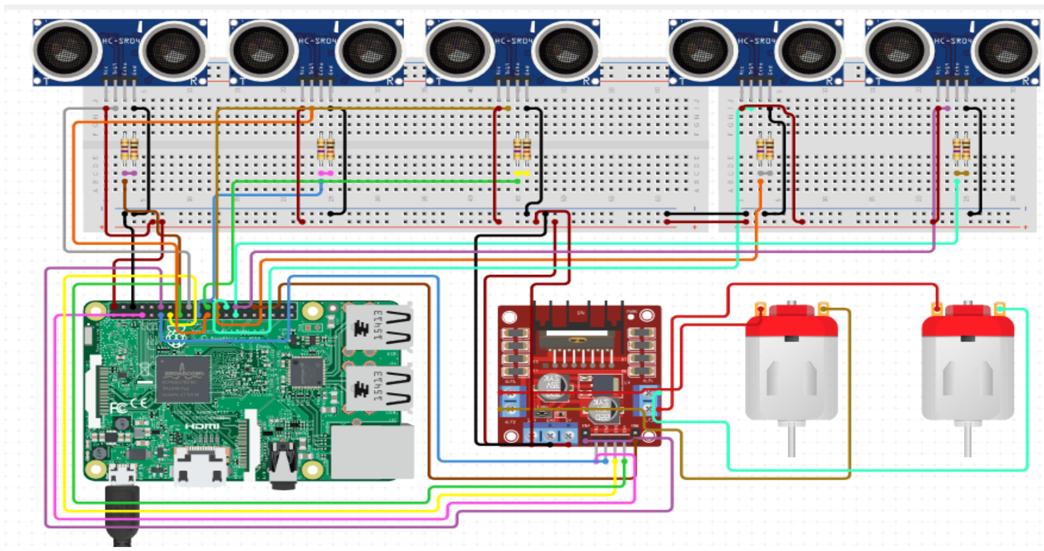

Fig. 4.2: System Hardware Connection

1- **Raspberry Pi:** The central and essential part of the system, as it coordinates and connects all the components, converting signals and data between them to achieve full control over the car.

2- **Raspberry Pi Camera:** It records video and transmits it live for controlling the car through a web page. If there is a malfunction in the camera, the user may not be able to see the live video, which can affect the control through the web page.

3- **Ultrasonic Sensor:** It is installed on the sides of the car and is used to detect the presence of other cars or nearby obstacles. When the ultrasonic sensor encounters a shock wave, it sends an alert signal to warn of the presence of a nearby car.

4- **GPS (Global Positioning System):** It is responsible for determining the car's location. In case of any issues or if the car gets lost, the GPS can be used to determine its location.

5- **Motor Driver:** It controls the movement of the wheel and steers it in the desired direction. This component contributes to achieving the car's motion and navigation in the specified directions.

4.2.1 Working Mechanism

There is a 12-volt battery that is connected to a switch to control the power supply to the car. Another separate switch is connected to the Raspberry Pi. We take a connection from the battery to what is called a voltage regulator, which is powered by 12 volts and outputs 5 volts for a circuit that controls the ultrasonic sensors. These sensors are connected to the Raspberry Pi. There are also 2 motor drivers connected to the Raspberry Pi through 6 pins responsible for the wheel directions. Each motor driver has 4 wires, and each pair of wires in each motor driver controls the rear and front wheels. There is also a button for alerting the driver in case of a problem. The actual components can be found in Figure 4.3, illustrating the connections between them. There are two power sources: the battery, which powers the entire system, and the power supply, which independently powers the Raspberry Pi to avoid any issues. Additionally, each wheel of the car has a motor connected to the motor driver.

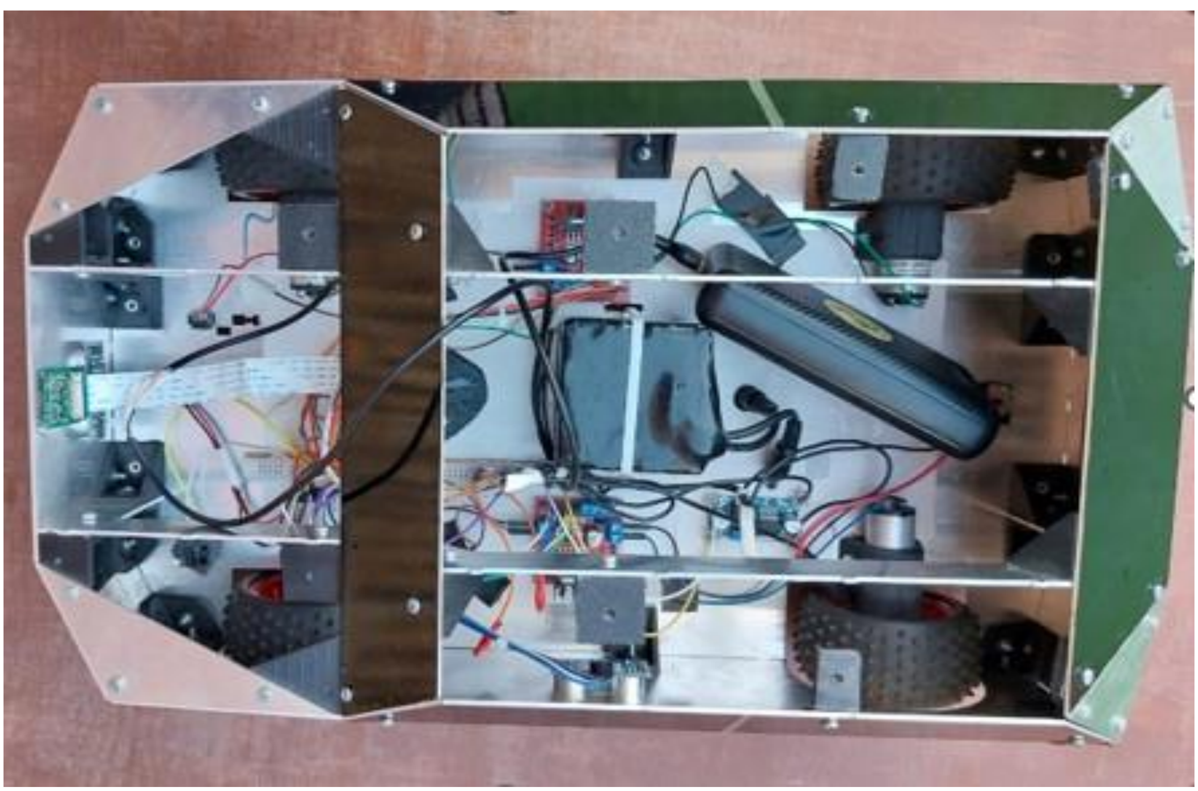

Fig. 4.3: Internal Structure

4.2.1.1 Bins Number

A specific pin mapping for the motor drivers connected to the Raspberry Pi as shown in Table 4.1 shows the numbers of the pins responsible for the wheel directions, whether it is for forward or reverse.

Table 4.1: Number of Bins

Motor Driver	Ultrasonic
Right Motor Driver • Motor1 (forward) right pins: EN → 3 Front → 5 Back → 7 • Motor 2 (back) right pins: EN → 19 Front → 21 Back → 23	***Ultrasonic Front*** Trig → 35 Echo → 37 ***Ultrasonic Left*** Trig → 16 Echo → 18 ***Ultrasonic Right*** Trig → 22 Echo → 24
Left Motor Driver • Motor 3 (forward) left pins: EN → 11 Front →13 Back → 15 • Motor 4 (back) left pins: EN → 29 Front → 31 Back → 33	

So, the previous table illustrates the number of pins used in motor driver and ultrasonic through the hardware connections.

4.2.2 Design

The shape is streamlined, and great care was taken in selecting both the form and the materials to ensure that the size of the model is proportionate to its movement. The design of the model is carefully crafted to optimize its aerodynamics and reduce any unnecessary drag as shown in Figure 4.4. Additionally, the materials used are chosen to be lightweight yet strong, allowing for smooth and efficient movement of the model. This attention to detail ensures that the size of the model is well-suited for its intended motion.

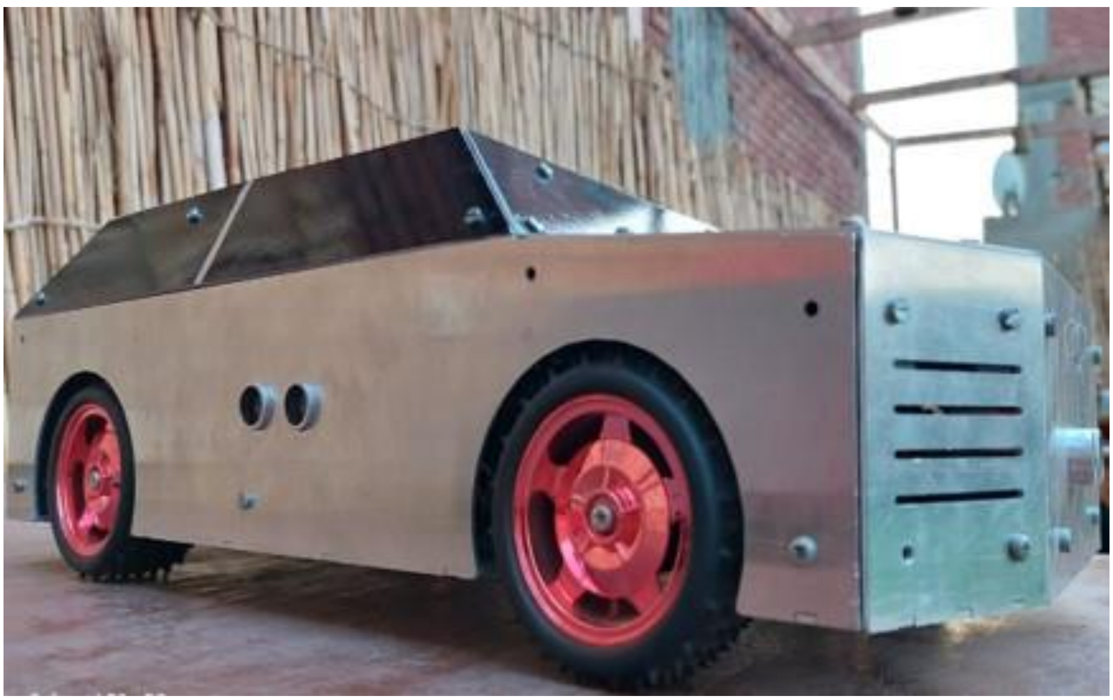

Fig. 4.4: Car Design

We used a combination of metal and 3D printing in creating the model. The metal component was chosen for its durability and structural integrity, while the 3D printing technology allowed us to precisely fabricate intricate and detailed parts of the model. This combination ensured that the model had the necessary strength and accuracy while also allowing for customization and flexibility in design.

4.2.3 Tools

The system requires computing ability with camera vision and motor driving in addition to some sensors and this will be implemented like shown in Figure 4.5 This section explains the hardware used to satisfy the system requirements.

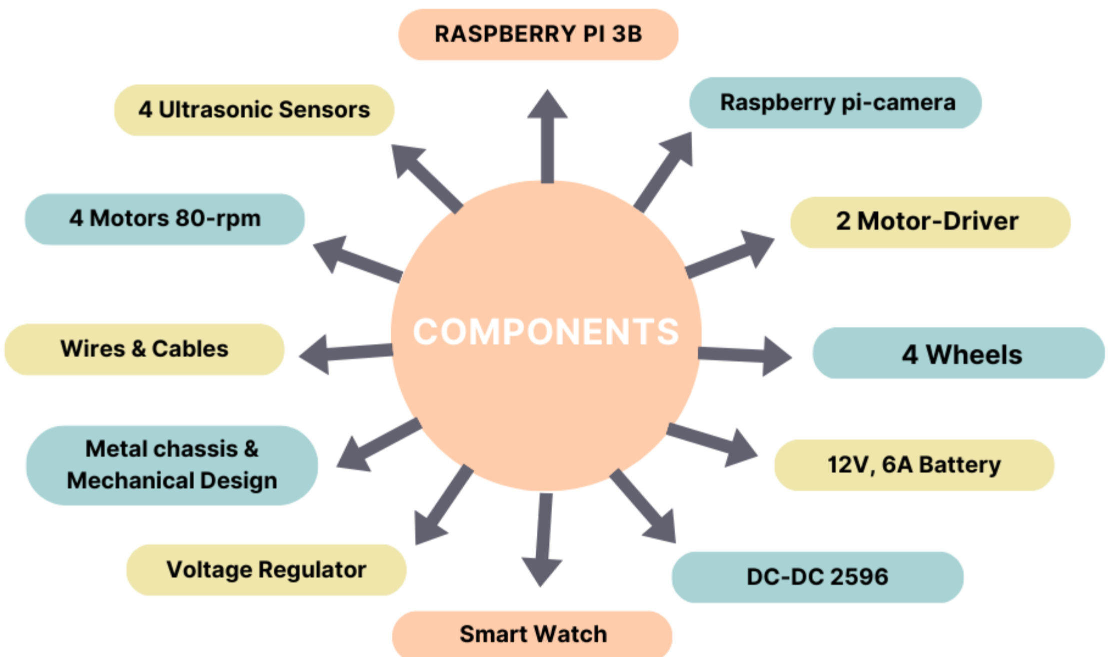

Fig.4.5: Hardware Tools

A. Raspberry pi 3 model B

The Raspberry Pi is a credit card-sized computer with an ARM processor that can run Linux. This item is the Raspberry Pi 3 Model B, which has 1 GB of RAM, Wi-Fi, Bluetooth 4.1, Bluetooth Low Energy (BLE), an Ethernet port, HDMI output, audio output, RCA composite video output (through the 3.5 mm jack), four USB ports, and 0.1″-spaced pins that shown in **Figure 4.6** that provides access to general purpose inputs and outputs (GPIO). The Raspberry Pi requires a microSD card with an operating system on it (not included). The Raspberry Pi is very popular, with lots of example projects and information available online. [7]

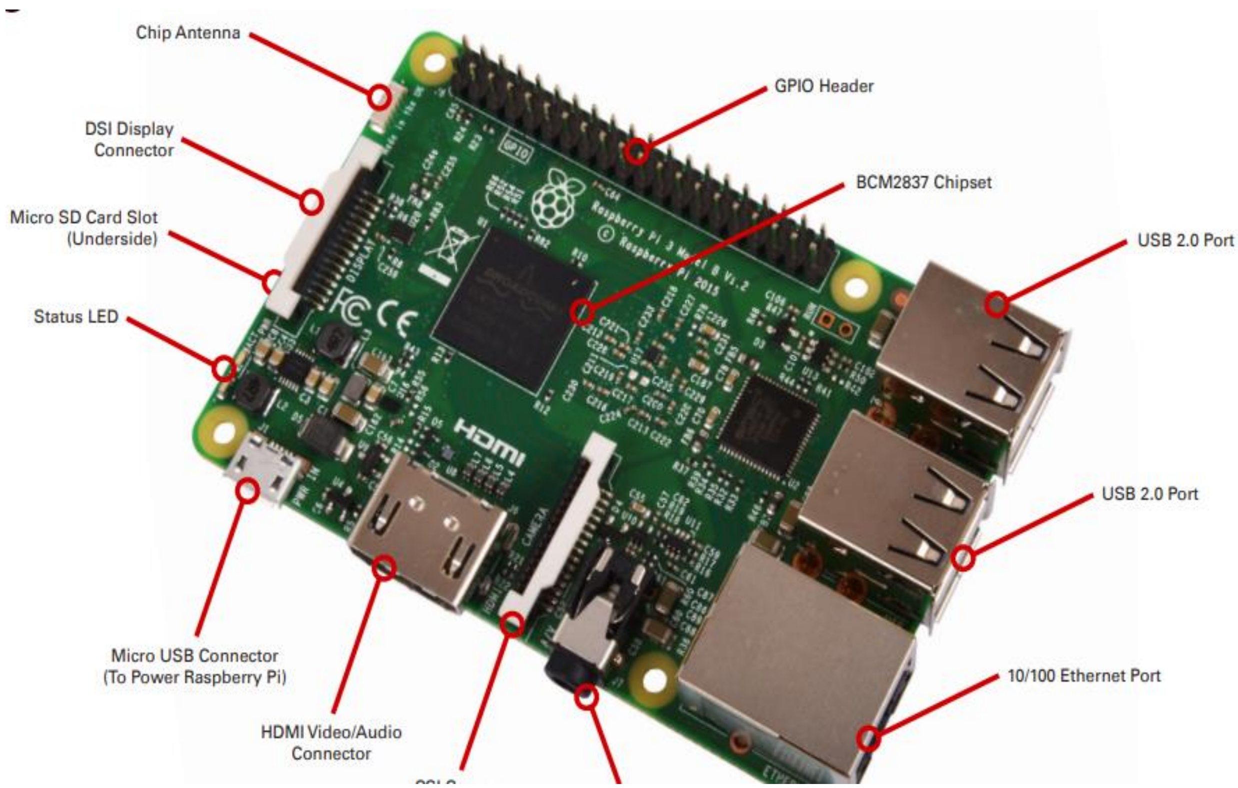

Fig. 4.6: Raspberry Pi 3 Specifications

- **Function**

  Raspberry is used as follows:

  1. It controls the movement of the robot, as it is responsible for the voltage and signal that reach the motor drivers to operate the motors by moving the wheels forward, backward, right, or left.
  2. It has a web-based code controller, which is a web page for controlling the robot. It contains a live feed and buttons for moving the robot forward, backward, right, or left.
  3. There is code that is used to determine the boundaries of the road, and based on this, decisions are made for the direction of the car.
  4. It is connected to ultrasonic sensors that are used in the self-driving code to calculate distances between objects and receive all the data from the ultrasonic sensors, as well as video streaming from the camera, and based on that, necessary decisions are made.

- **Datasheet**

  As shown in 4.7, there are specific information and specifications regarding the connectors and the proper way to connect them in the correct locations.

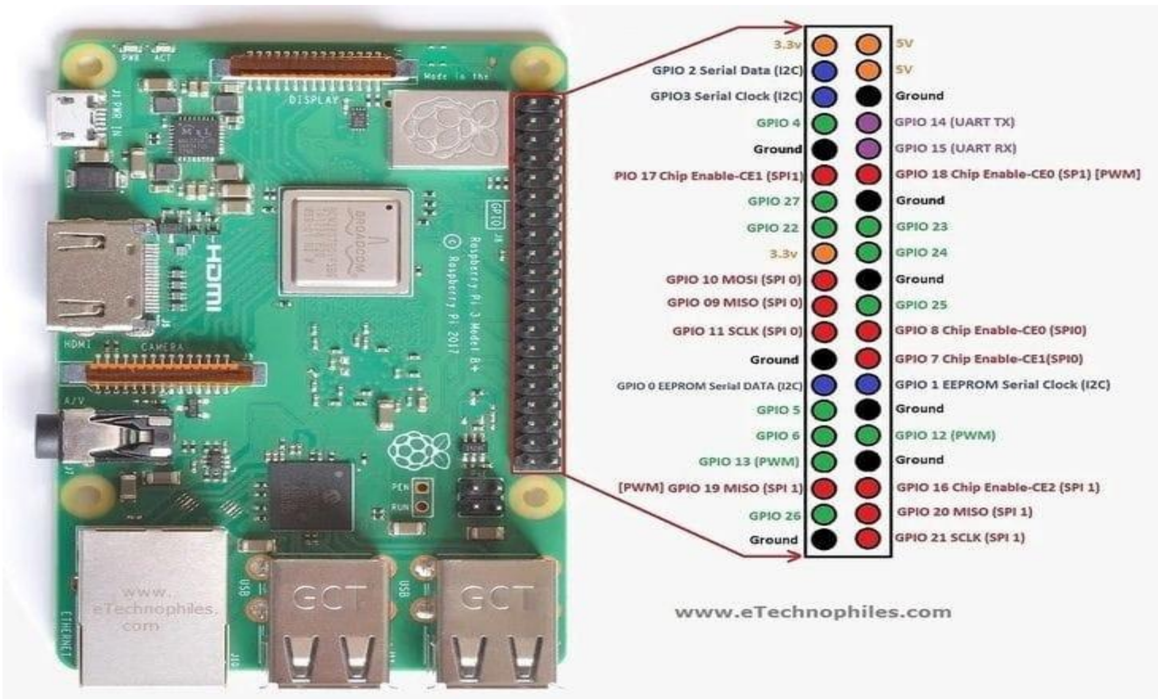

Fig.4.7: Raspberry Pi 3 Datasheet

As previously understood, we understood the data sheet specific to Raspberry Pi. The data sheet for Raspberry Pi.

B. Raspberry Pi Camera

This 5mp camera module is capable of 1080p video and still images and connects directly to your Raspberry Pi. **Figure 4.8** shows the camera of Raspberry Pi which is only capable of taking pictures and video, not sound.

Fig.4.8: Raspberry Pi 3 Camera

Connect the included ribbon cable to the CSI (Camera Serial Interface) port on your Raspberry Pi, boot up the latest version of Raspbian and you are good to go. The camera is capable of 2592 x 1944 pixels static images, and also supports 1080p @ 30fps, 720p @ 60fps and 640x480p 60/90 video [8]

C. Ultrasonic Sensors

Ultrasound, or *ultrasonography* shown in **Figure 4.9**, works on the principle that sound is reflected at different speeds by tissues or substances of different densities. Ultrasound technology has been used medically since the 1940s. *Sonograms*, the pictures produced by ultrasound, can reveal heart defects, tumors, and gallstones; since low-power ultrasonic waves don't present any risks to a body, they're most often used to display fetuses during pregnancy in order to make sure they're healthy.

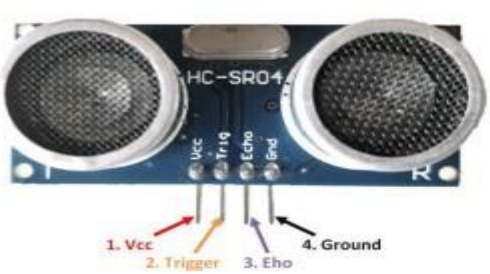

Fig.4.9: Ultrasonic Sensor

Ultrasonics like has many other uses, including underwater *sonar* sensing. High-power ultrasonics are so intense that they're actually used for drilling and welding. shows the ultrasonic sensors. [9]

D. Motor Driver

From the name, a motor driver means a device that drives motors. However, motor driver chips can't go an engine without a microcontroller. A motor driver as shown in **Figure 4.10** show cases itself as an interface between the motor and the microcontroller. The reason is that the microcontroller and the motor work on different ranges of voltages. The engine will use up a higher current level than the microcontroller.

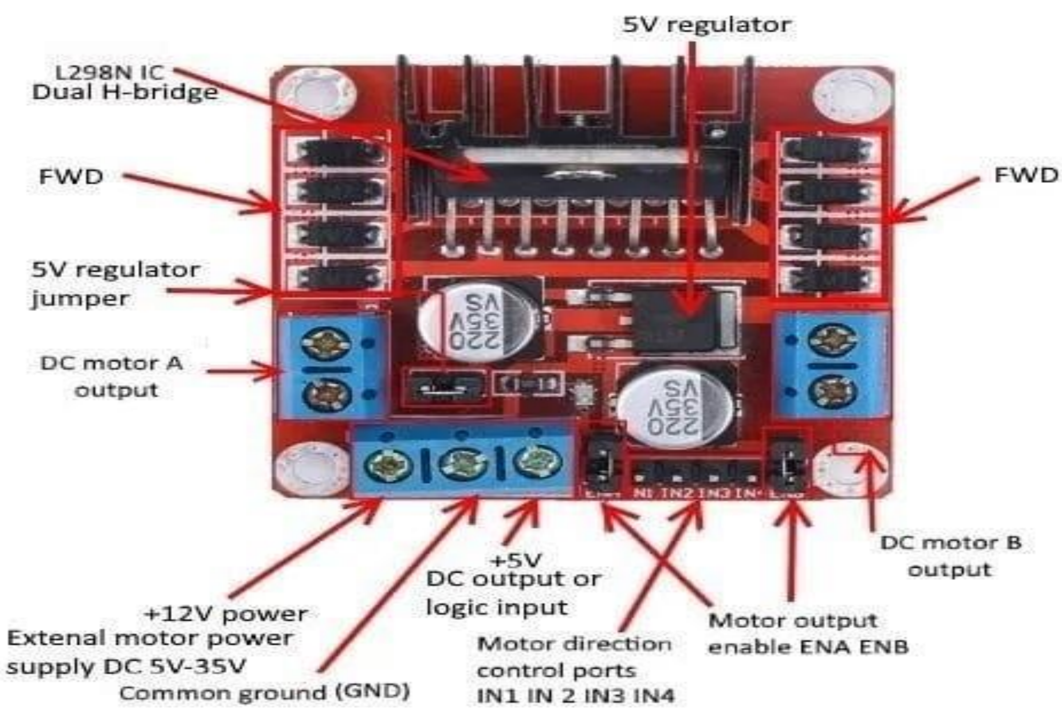

Fig.4.10: DC Motor Driver

We require a motor driver module when connecting two devices that operate under different current levels to a power supply voltage. In this case, a motor acts as a third device that steps up or steps down the voltage supply.

- **Function**

Motor driver operates through three inputs in1, in2 and enable, which are present on each motor. To move the wheels forward, an input signal should be applied to in1, while to move the wheels backward, a signal should be applied to in2. The enable input is used to turn the wheels on or off and is activated by applying a high signal to it, as long as the circuit is turned on.

E. DC-DC 2596 Voltage Regulator

A DC-DC voltage regulator is a type of voltage regulator that converts a higher DC voltage to a lower DC voltage. The function of a DC-DC voltage regulator shown in **Figure 4.11** is to provide a stable output voltage that is lower than the input voltage. This is achieved by using an inductor, capacitor, and a switching transistor that turns on and off at a high frequency.

Fig.4.11: DC-DC 2596 Regulator

When the transistor is on, the inductor stores energy from the input voltage, and when the transistor is off, the inductor releases the stored energy to the output capacitor, which filters the output voltage.

- **Function**

A dc-dc voltage regulator is used to reduce voltage from 12 volts to 5 volts, where the 5 volts is input to the Raspberry Pi and a wire is connected from the battery to the voltage regulator, which outputs 5 volts to be fed into the ultrasonic sensors. However, currently, the Raspberry Pi is disconnected as there is no 12 volts input from the battery. Instead, the voltage is directly input to the Raspberry Pi through a power bank, while the rest of the circuit is powered by the 12-volt battery. Therefore, this module reduces the voltage from 12 to 5 to power all the ultrasonic sensors with 5 volts.

Other hardware components are; **DC motors 80 rpm, Batteries, Wheels, Metal Chassis**

4.2.4. Hardware and User Control Module

The function of self-driving car, also known as an autonomous car or driverless car, is to navigate and operate a vehicle without human intervention. The goal of self-driving cars is to provide a safe and efficient mode of transportation while reducing the reliance on human drivers.

Here are some key functions and capabilities of self-driving cars:

1- Sensing and Perception: Self-driving cars use a variety of sensors such as cameras, radar, lidar (light detection and ranging), and ultrasonic sensors to perceive their surroundings. These sensors continuously collect data about the environment, including other vehicles, pedestrians, road markings, and traffic signs.

2- Mapping and Localization: Self-driving cars rely on highly detailed maps to understand their position and navigate the road network. They use GPS, odometry, and other localization techniques to determine their precise location within the mapped environment.

3- Decision-Making and Planning: Based on the sensor data and the current environment, self-driving cars employ advanced algorithms and artificial intelligence to make real-time decisions. They analyze the data, predict the behavior of other road users, and plan their trajectory accordingly. This includes tasks such as lane changing, merging, turning, and overtaking.

4- Control and Execution: Self-driving cars have sophisticated control systems that translate the planned trajectory into vehicle movements. These systems manage the acceleration, braking, steering, and other control inputs to ensure safe and smooth driving.

5- Real-Time Monitoring and Redundancy: Self-driving cars continuously monitor their own performance, the state of their sensors, and the overall system health. They are designed with redundant systems and fail-safe mechanisms to handle unexpected situations or failures and ensure the safety of the passengers and other road users.

The ultimate goal of self-driving cars is to provide safer, more efficient, and more convenient transportation options. By removing the potential for human error, self-driving cars have the potential to reduce accidents, improve traffic flow, and enhance mobility for people who are unable to drive themselves. In our project, we relied on a set of these operations to achieve maximum efficiency in self-driving cars. For example, we utilized Sensing and Perception. Although we could have used the Lidar x360 sensor, we opted for a set of ultrasonic sensors, fully aware that it would affect our efficiency and the range of vision. While the Lidar can read distances of tens of meters, the ultrasonic sensors only read short distances. We also implemented Decision-Making and Planning, allowing the car to make appropriate and optimal decisions based on the Raspberry Pi's input. Additionally, we incorporated Control and Execution by creating a backup system in case the self-driving car fails. This backup system is controlled through a website where a live stream of the road is uploaded, allowing manual control of the car. We find that our system operates with a significant combination of these functions, making it more distinctive and accurate compared to other systems that rely on a single function only.

Summary

In this chapter, the hardware connections are discussed through a structure that illustrates it. Components of project work together in an integrated manner and the importance of Raspberry Pi in the project. The car's design is reviewed and the reason for choosing its shape. All the hardware tools, mentioning their definitions and functions are covered. The control unit, which was explained to us through codes on how to connect and control it, whether through autonomous driving or a web page.