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Vehicle Autonomous Driving System

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Abstract: Autonomous vehicles or self-driving cars industry and technology have played an important role in research industry and automotive industry. Autonomous cars are those vehicles have the ability to sense there surrounding and navigate and drive themselves on roads through traffic without human interventions. In other words, they can move from one location to another one without human interaction. In this paper, an autonomous vehicle system prototype is proposed. The vehicle is able to sense its surrounding and keep going on the road on its own through traffic and other barriers such as people and traffic lights. That is, the vehicles are able to drive and detect the road signals and take decision accordingly, whether to continue or to make a turn. The proposed system uses raspberry pi microcontroller and ultrasonic sensors to detect any object, obstacle, or pedestrians in front of the vehicle and to measure the distance. In addition, a raspberry pi camera is connected to the raspberry pi to continuously take pictures of the road. These pictures will be analyzed by the raspberry pi microcontroller. The vehicle is able to reach its destination safely. A self-driving car prototype has been designed and implemented. The porotype autonomous vehicle system was tested and performed as expected.

Keywords: Self-driving car, Raspberry Pi, Ultrasonic sensor, Signal detection, Raspberry Pi camera

Introduction

As technology is moving fast, manufacturing is also moving toward automation. Vehicle automation in contrast is in fact changing the conception of industry (Al-Smadi & Msallam, 2022). Autonomous vehicles or self-driving cars industry and technology have played an important role in research and automotive industry. Autonomous cars are those cars have the ability to sense there surrounding, navigate, and drive themselves on roads through traffic without human interventions (Szikora & Madarász, 2017; Pawar et al., 2021). In other words, autonomous cars are those cars that can move from one location to another without human interaction. With the number of vehicles rapidly increasing in every country, the number of traffic accidents is increasing on the roads day by day. Many of these accidents are due to human errors. Some of the common causes of these accidents are the use of mobile phones while driving, in addition to several in-car entertainment equipment's. According to the study (Ondruša et al., 2020), it is expected due to autonomous vehicles that accidents will decrease to 80% by the year of 2040. The reason of this expectation is because autonomous vehicle would make it possible to reduce traffic collision and controlling speed limits. Currently, autonomous vehicles are already implemented in several countries without any human input (Shetty et al., 2019). Tesla Motors Inc.

headquartered in Texas –United States of America successfully manufactured self-driving car, Tesla X in the year of 2015. Several companies such as Nissan Waymo and Tesla Motors Inc. are involved in manufacturing self-driving cars (Manikandan et al., 2020).

Banerjee (2020) presented a review survey about the autonomous vehicles. His paper presents a brief description of the various elements and components that are essential in making up a self-driving car system. Some of these components are sensors, global positioning system (GPS), image processing units. Thadeshwar et al. (2020) proposed an autonomous car model that consists of Monocular vision algorithm, CNN, Raspberry Pi, camera, Arduino, Haar cascade classifier, and an Ultrasonic sensor. The instructions' commands will reach the vehicle through the Arduino microcontroller which is connected to the RC vehicle. The car will operate based on convolutional neural network predictions and some hardware coded commands. Nandhini et al. (2020) described a self-driving car model using a PIC microcontroller, raspberry pi processor, speed sensor, color sensor, and ultrasonic sensor. These components were integrated to build an autonomous car. Shirke et al. (2020) proposed a self-driving car using Arduino uno, raspberry pi, ultrasonic sensors, a dc motor, and a camera. The prototype model was built with a toy car with two motors. One motor to move the toy car straight forward and backward, while the second motor is to turn the toy car left or right.

In this paper, a self-driving vehicle model is proposed. The vehicle can sense its surrounding and move on the road on its own through traffic and other obstacles such as pedestrians and traffic lights. That is, the self-driving can drive and detect the road signals and take decision accordingly, whether to continue or to make a turn. The proposed system uses raspberry pi microcontroller and ultrasonic sensors to detect any obstacle, or pedestrians in front of the vehicle and to calculate the distance. In addition, the raspberry pi camera is connected to the raspberry pi to continuously take pictures of the road. These pictures will be analyzed by the raspberry pi microcontroller. The vehicle can reach its destination safely. A self-driving car prototype has been designed and implemented. The porotype autonomous vehicle system was tested and performed as expected.

Proposed System

As the world population grows, the number of vehicles on the roads are continuously increasing. Hence, the number of traffic accidents are increasing which result in death and injuries of people. Traffic congestion is another problem the world will be facing with the increasing number of automobiles which is fuel and time costly. In this paper, we propose a self-driving car system that is able to sense and drive without any human intervention. The system includes ultrasonic sensors, raspberry pi, Dc motors, H-Bridge, raspberry pi camera, and a power supply. The ultrasonic sensors are mainly used to calculate the distance in front of the car, while the raspberry pi camera selects the correct road and the Dc motor move the car. Figure 1 shows the block diagram of the proposed module. The main components of the proposed vehicle automated driving system are described as follows.

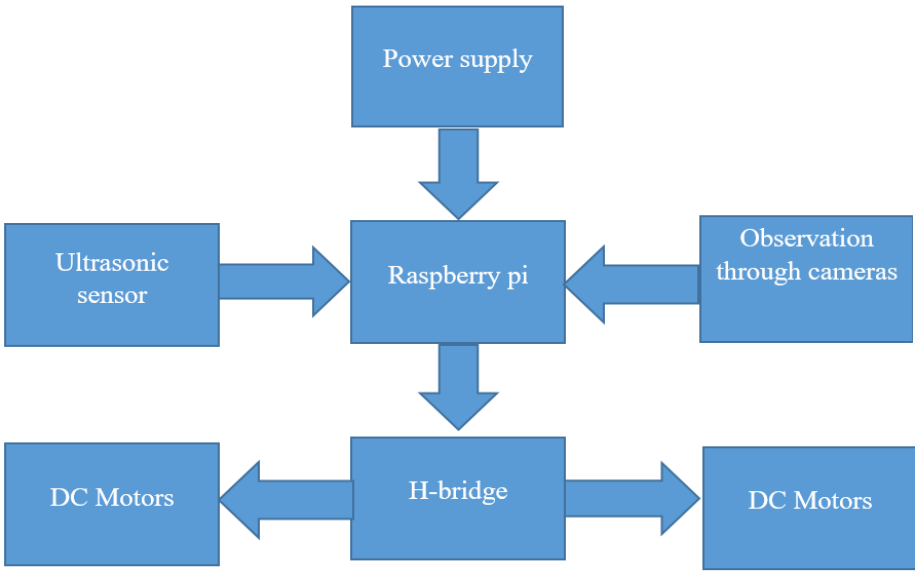

Figure 1. Block diagram of the proposed vehicle automated driving module

Raspberry Pi 3 Processor

Raspberry pi processor is a small computer board has a size of a credit card developed in 2009 by the raspberry pi foundation which is registered in England and Wales. The development of the raspberry pi was intended for teaching basic computer science and its related areas. Currently, there are five types of the raspberry pi available in the market (Nandhini et al., 2020; Al-Smadi et al., 2023). Raspberry pi microcontroller uses Python language; hence the name raspberry pi comes from the raspberry fruit and pi for python. The raspberry pi processor has been widely used to build school projects. It can be used as any desktop computer if it is connected to all peripherals such as keyboard, mouse, and monitor. Raspberry pi processor is shown in Figure 2.

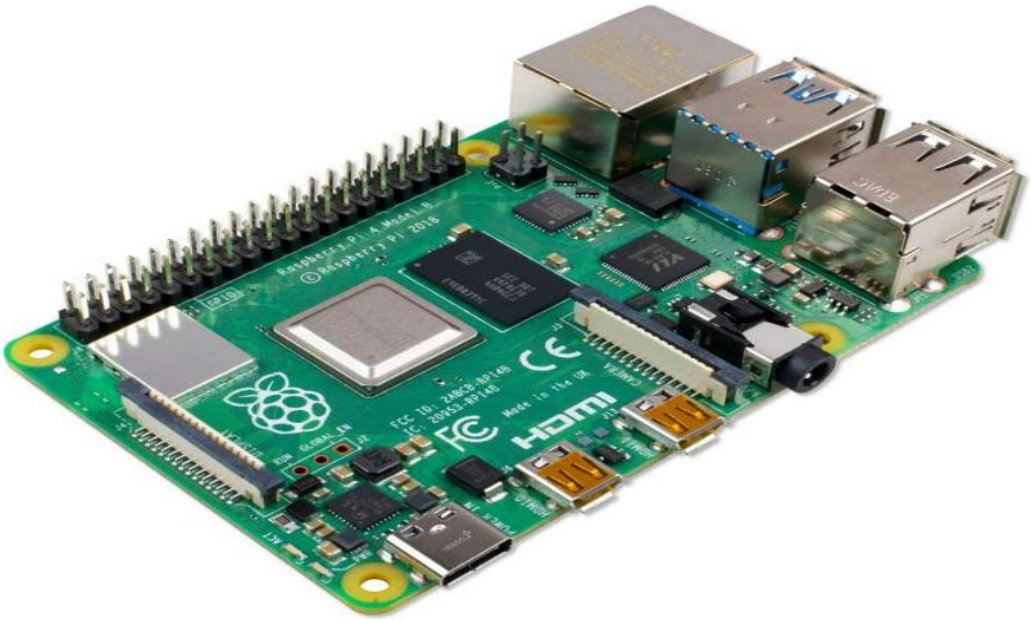

Figure 2. Raspberry Pi 3 processor (Al-Smadi et al., 2023)

Raspberry Pi 3 Camera

The Raspberry Pi camera module 2 (v2) has an 8-megapixel image sensor. The camera can take high definition video in addition to photographs. It can be used online for time-lapse, and slow-motion videos. It is connected to the camera serial interface (CSI) port on the raspberry pi with a 15 cm ribbon cable. The CSI connectors consist of two smaller interfaces which establish the communication bus. The first interface transfers data and clock signals from the camera to the processor in one direction only. The other interface is bidirectional control link (Upton & Halfacree, 2012).

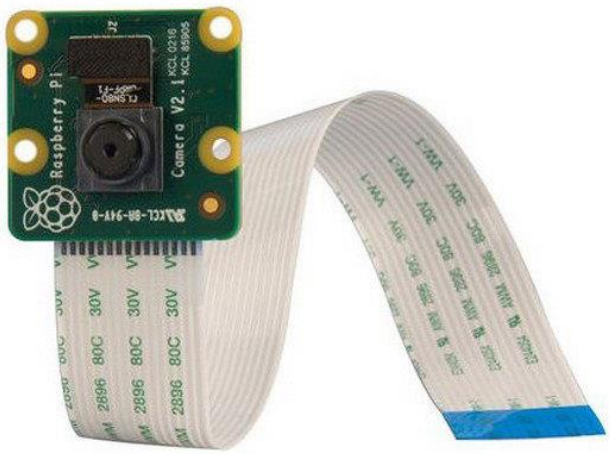

Figure 3. Raspberry Pi camera (Pawar et al., 2021)

Ultrasonic Sensor

An ultrasonic (US) sensor is an electronic sensor that can perform as a transmitter and a receiver. The transmitter converts electrical signal into ultrasonic wave. It emits ultrasonic wave at frequency of 40K Hz that travels in the air. The ultrasonic receiver waits for the ultrasonic wave to return after it gets reflected by an object and converts the sound wave into electrical and sends it back to the sensor. Figure 4 shows HC-SR04 ultrasonic sensor module. This module HC-SR04 is provided with 2cm-400cm measurement with an accuracy of about 3mm. As the pins of the HC-SR04 sensor indicates, pin 1 (Trigger) is the input pin. Pin 3 (Echo) is the output pin. The sensor uses the ultrasonic sound wave to measure the distance to the object (Al-Smadi et al., 2023).

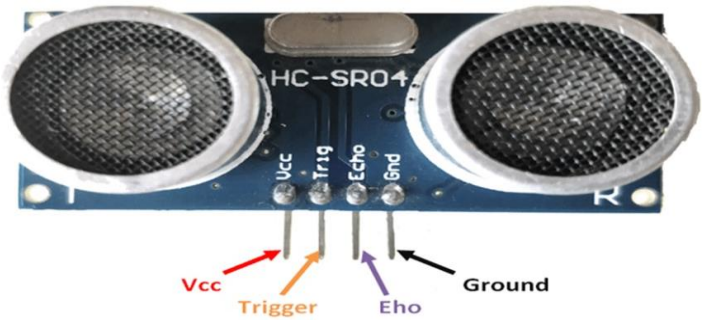

Figure 4. Ultrasonic Sensor HC-SR04 module ((Al-Smadi & Msallam, 2022)

H-Bridge

An H-bridge or a motor driver is an electronic drive circuit consists of transistors that allow the motor to change its direction as well as its speed. It is called H-bridge because it resembles the letter H. H-bridge circuit can be easily interfaced to control the DC motor rotation. It is used to drive the motor counterclockwise and clockwise by switching the polarity of the applied voltage (Al-Smadi et al. 2020). As shown in Figure 5, the H-bridge driver has four switches that allow controlling the applied source across the load in both directions. These switches are normally made with MOSTFETs or pnp and npn transistors. The H-bridge makes the motor move forward and backward by activating two switches together. For example, activating S_2 and S_3 at the same time while keeping S_1 and S_4 open will apply appositive voltage across the motor. On the other hand, activating S_1 and S_4 at the same time while keeping S_2 and S_3 open will reverse the applied voltage across the motor. This allows reserve rotation of the motor. Figure 6 shows the L298N twin H-bridge motor driver. This device permits to control speed and direction of two DC motors at the same time.

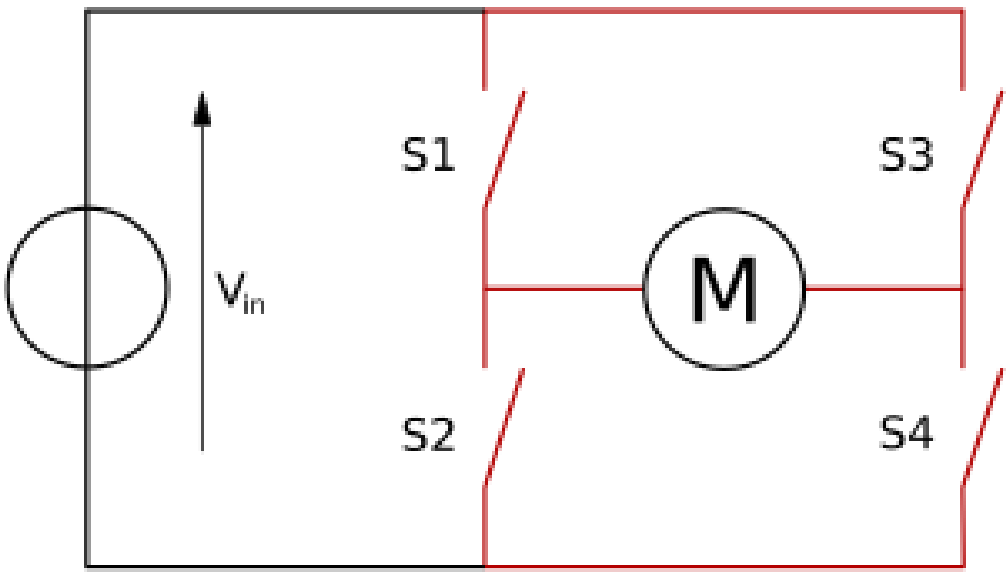

Figure 5. H-bridge motor driver circuit

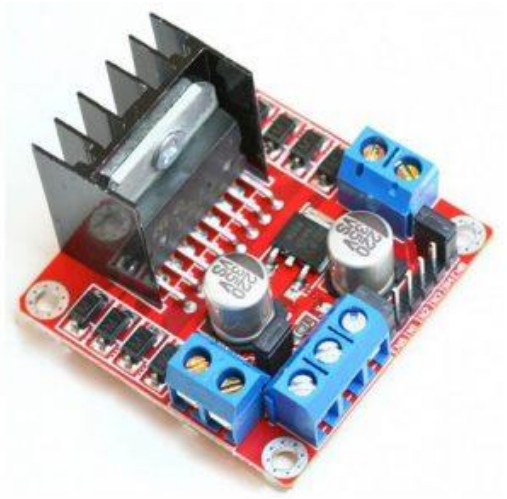

Figure 6. L298N H-bridge motor driver (Al-Smadi et al., 2020)

Python Language

Python language is a popular dynamic type, object oriented, and high-level programing language. It was developed by Guido Van Rossum in the 1980s. It is a general-purpose language which may be used for many applications such as in website developing, machine language, automating repetitive tasks, desktop applications, and many other fields (Stewart, 2019).

System Implementation

The block diagram of the proposed self-driving car prototype model is shown in Figure 1. The circuit diagram is presented in Figure 7. The main component of the proposed module is the Raspberry pi microcontroller which is considered to be the brain of the system. All other components of the system are connected to the raspberry pi. In the circuit diagram of Figure 7 the ultrasonic sensor connected to the raspberry pi. As the vehicle moves, the ultrasonic sensor will measure the distance between the front of the vehicle (where the sensor is placed) and any object on the road. The distance is calculated by measuring the amount of time required to send ultrasonic wave from the Trig pin of the sensor and waiting for the ultrasonic wave to be received back to the Echo pin of the sensor. Hence, the distance is

$$\text{Distance} = \text{Speed X Time}/2 \tag{1}$$

The universal speed of ultrasonic wave is 330 meter/second. The time in Equation (1) is divided by 2 because it is the time from sending trigger and receiving echo signals. The raspberry pi camera, which is interfaced with the raspberry pi controller through 15-pin ribbon cable is activated as long as the car is moving to keep the car at the center of the road. If the distance from the observed object is more than 20 cm, the camera will continuously take pictures of the road. These pictures will be analyzed by the raspberry pi microcontroller. The first step, the colors of the pictures will be changed to black and white using library functions imported in the code. The second step, the contours of the road will be detected by the contour function. There is another function to detect whether the road is at the center of the picture or not. This function, called the moment function, works by transforming the pixels into matrix. This matrix contains zeros and ones. The moment function also calculates the final value of the matrix which is referred to as “cx”. This value is the number of the column with entries of ones which determines whether the car should veer to the left, to the right, or keep moving straight. It was determined experimentally that the movements of the car are governed as follows.

$$\begin{aligned} cx < 160 &\quad \text{Move to the right} \\ 160 < cx < 480 &\quad \text{Keep going straight} \\ cx > 480 &\quad \text{Move to the left} \end{aligned} \tag{2}$$

These processes are shown in the flow chart of Figure 8. According to the results, the raspberry pi generates the necessary signal for the H-bridge driver motor to move in the correct direction at the proper speed. The right two wheels are connected to one DC motor, while the left two wheels are connected to the second DC motor. Therefore, when both motors rotate in the same direction, the vehicle will move forward. Table 1 shows the directions of the motors and the vehicle. In the table, clockwise means positive current, while counterclockwise negative current. If the distance is less than 20 cm, then the car will stop till the obstacle is removed. The camera will start processing and veer the car to left or to the right and the process will continue as previously described. All the components in the block diagram of Figure 1 and the circuit diagram of Figure 7 interact with each other's by taking orders from the raspberry pi microcontroller through the python code.

Table 1. The directions of the motors and vehicle

Motor 1 (Right Motor)	Motor 2 (Left Motor)	Vehicle
clockwise	clockwise	Forward
counterclockwise	counterclockwise	Backward
clockwise	counterclockwise	Left
counterclockwise	clockwise	Right
No current	No current	Stop

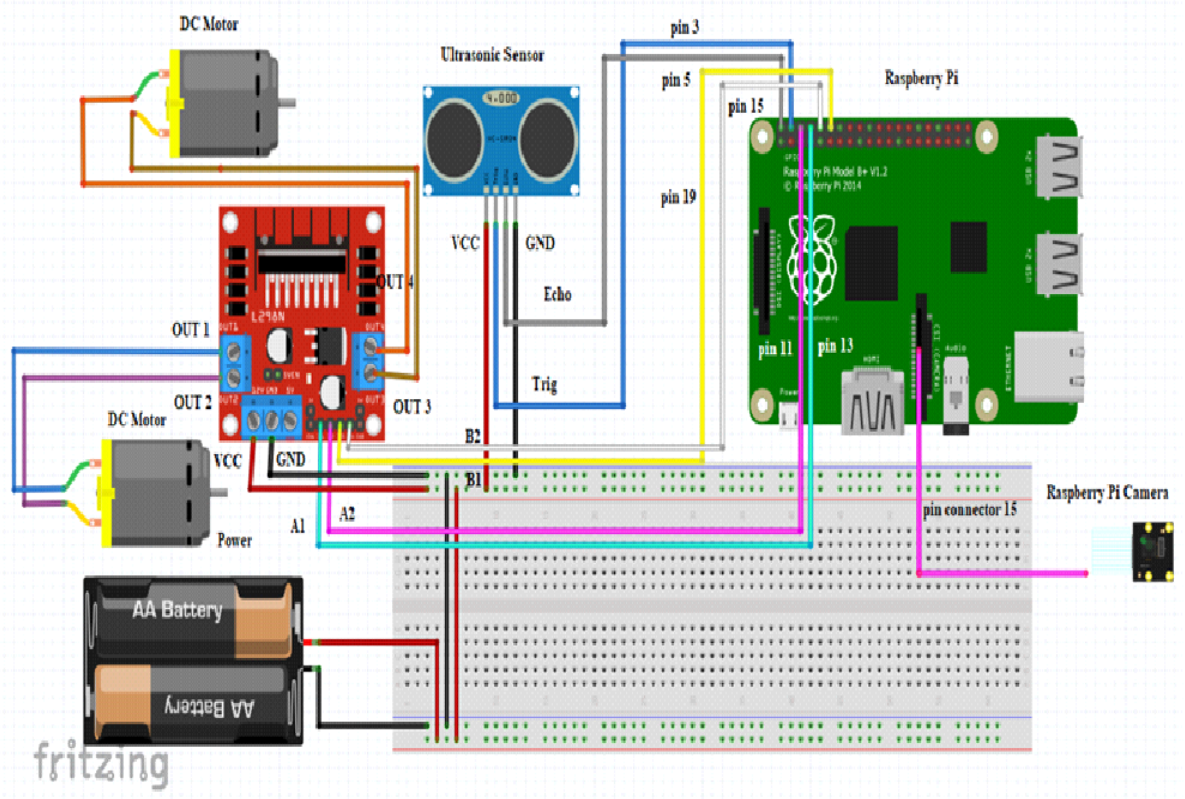

Figure 7. The circuit diagram for the proposed model

Results and Discussion

After implementing the devices in Figure 7, a prototype vehicle of the system was built and activated to start moving. Several photos were taken using the raspberry pi camera. Figure 9 shows the road is at the center of the processed picture, which means that the value of "cx" is between (160, 480). Therefore, the car will keep going straight. Figure 10 shows the road swerves to the right side, which means that the value of "cx" is less than 160. Therefore, the car will turn to the right side of the road and keep going in the correct path. Figure 11 shows the road swerves to the left side, which means that the value of "cx" is greater than 480. Therefore, the car will turn to the left side of the road and keep going in the correct path. The final prototype model for the self-driving vehicle is shown in Figure 12.

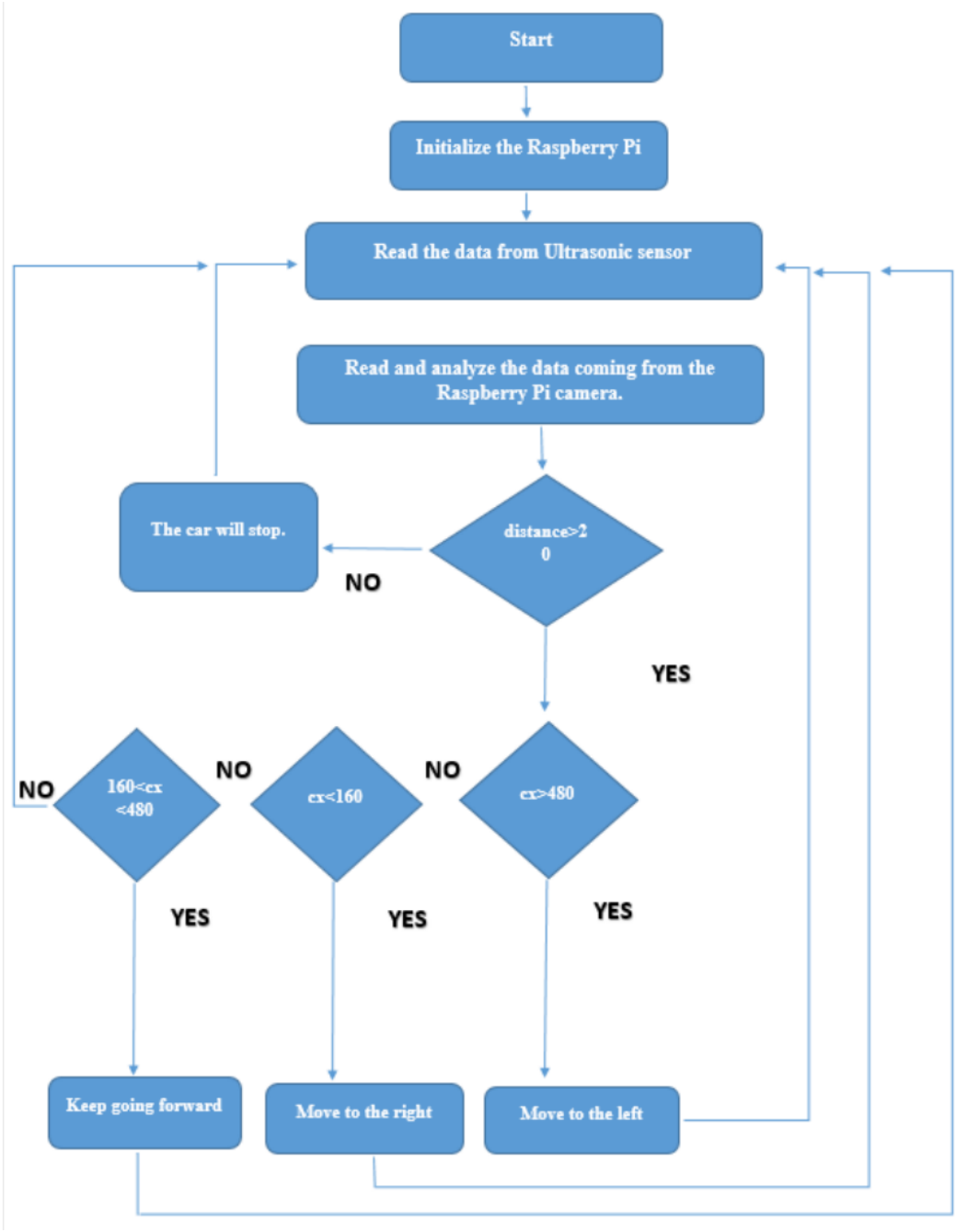

Figure 8. The flow chart of the proposed system

Figure 9. the road is at the center of the picture

Figure 10. The road veers to the right

Figure 11. The road veers to the left

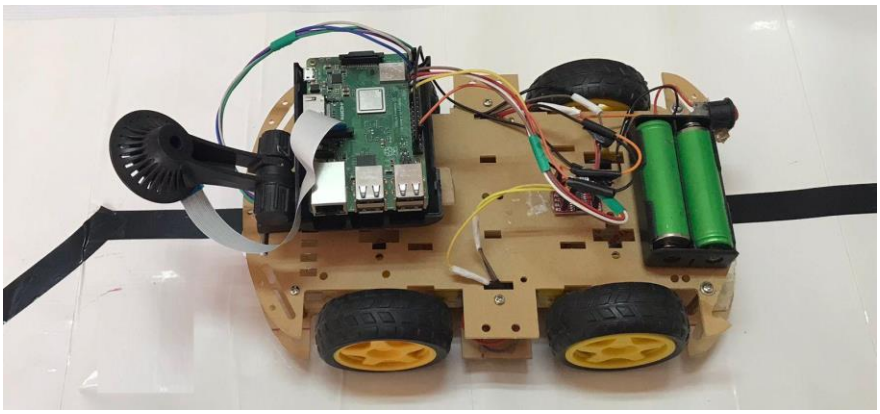

Figure 12. A prototype for the self-driving vehicle

Conclusion

This paper presented a self-driving vehicle that has the ability to move in the correct path without any human intervention. The system uses raspberry pi, ultrasonic sensors, and raspberry pi camera. Python language was used to write the code for the raspberry pi microcontroller. A prototype model for the self-driving vehicle system was built and tested. It performed as expected.

Scientific Ethics Declaration

The author(s) declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author(s).

Acknowledgements or Notes

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