

Solution for Autonomous Driving on the Highway

Vasile Madălin Moise
Engineer, Continental Romania
Sibiu, România
madamadalin01@gmail.com

Vlad Andrei Zamfirică
Faculty of Electronics, Communications and
Computers; University of Pitești
Pitești, România
zamfirica.vlad@gmail.com

Abstract – In this paper the behavior of an autonomous car is analyzed. Because it is forbidden to drive a car without a driver in our country we need to use a mobile robot to demonstrate the algorithm developed. In the paper we will refer to the robot as a car. The analyses are focused on the behaviors of the robot according to certain parameters.

Keywords - autonomous car; ultrasonic; Bluetooth; infrared; microcontroller;

I. INTRODUCTION

For a car to be autonomous, it should be capable to analyze what is going on around and to drive without human administration. In 2017, none of the car that can drive on roads were fully autonomous. All of the cars are driven by humans, even if that car has autonomous functionalities.

This project proposes a design for an autonomous car that can be driven via Bluetooth and once the autonomous driving is enabled and destination is set the car will drive without human input with help from the integrated sensors.

Autonomous cars need to use some technologies to interpret the environment like radar, GPS, laser light, computer vision and control systems that are able to analyze and to recognize vehicles on the road. Also, that control systems can have the job to detect road signs and humans.

II. THE MOBILE PLATFORM

The mobile platform is hand built, has three wheels, two of which are drive wheels that use each a DC motor, situated in front, with a diameter of 65 cm and the smaller one in the back used in direction. On the bigger wheels two optical encoders are used to determine the speed and traveled distance.

The robot is a small size platform (Figure 1), equipped with 3 sonar sensors, one in front and one on each side, two infrared sensors located in front, one on each side, a Bluetooth module and a LCD 16x2 used to display basic information from sensors.

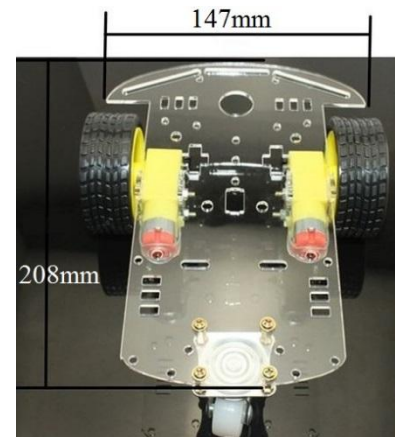


Figure 1. Chassis dimensions

For safety reasons, as the vehicle will be driven on highway at high speed, the data must be collected and processed in real time and the decisions must be taken fast. For example, if an obstacle (another car driving at low speed or stopped) will appear in front of the car, the vehicle will have to overcome the obstacle if there is no blocking (car) on the left side, to maintain a safe distance, or to go to a complete stop if the obstacle is stationary.

Because of this, the board will have integrated two microcontrollers. The first microcontroller will collect data from the ultrasonic sensors and the IR sensors. This data is transmitted via I2C communication protocol to the second microcontroller. The last one takes decisions, based on the data it receives, whether to turn right/left/go forward or stop and will display the received data on the LCD. The Bluetooth module is also connected to the second microcontroller. This will be used to send and receive data from outside the board.

III. HOW IT WORKS

A. Ultrasonic sensor

This project uses HC-SR04 (Figure 2) ultrasonic module to detect the distance from the vehicle to nearest object. It can give a distance between 2cm and 400cm, and measuring precision is around 3mm. The module is composed of ultrasonic transmitters, receiver and control circuit.

The HC-SR04 that we used in the project has four pins: GND, VCC, Tring and Echo. GND is connected

to the ground and VCC is connected to the 5 volts. Trig is connected to a digital pin on the microcontroller. Echo is like Trig, also connected to a digital pin on the microcontroller.



Figure 2. Ultrasonic sensor HC-SR04

An ultrasound is triggered by the ultrasonic module. If it will be returned to the module, it means that there is an object on its way. The distance between the obstacle and the sensor is calculated by taking in consideration the speed of sound and the time passed until the ultrasound is received.

The way of operation is like this: the microcontroller will switch the trigger pin to the high logic state, the module will automatically send 8 cycles with the 40 KHz frequency and will detect the existence of a pulse that is reflected. As long as there is a received pulse, the Echo pin will go into a high logic state. This is the time in microseconds from sending the pulses to their reception (Figure 3).

$$\text{Test distance} = \frac{\text{high level time} \times \text{velocity of sounds}}{2}$$

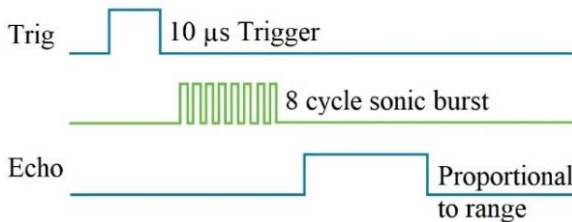


Figure 3. Ultrasonic sensor response

In the following picture (Figure 4) we have exposed an example of use for ultrasonic model HC-SR04. The distance between the sensor and the object is 10 cm. Sound speed is 340 m/s (0.034 cm/µs). Because of this data, the wave needs to travel about 294 µs. We will get the double of this value, because the wave must return to the Echo pin. To determine the distance in cm, we have the following formula: the value received by the Echo pin multiply by 0.034 µs and divide it by 2.

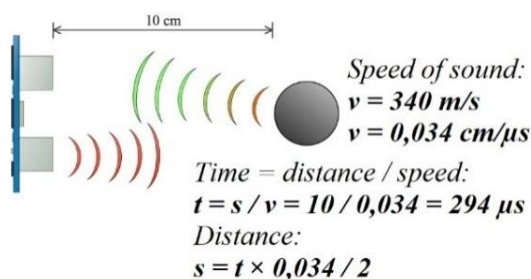


Figure 2. Ultrasonic distance detection

B. Infrared sensor

The line detector is built of an array of infrared sensors. This array can distinguish a dark line on a light surface. With this detector we can estimate whether the car has changed the lane successfully or we are driving correctly between the two white lines.

The IR sensor is composed by IR LEDs and IR photodiodes. If the surface is reflective, the IR light emanated by the LED will be thrown back to the IR photodiode. The photodiode returns a value of voltage. If that value is high, this means the surface is lighted. On the other hand, if the value is low, the surface is darker (Figure 5). For any case, the value is measured by the diffuse reflectance of the area.

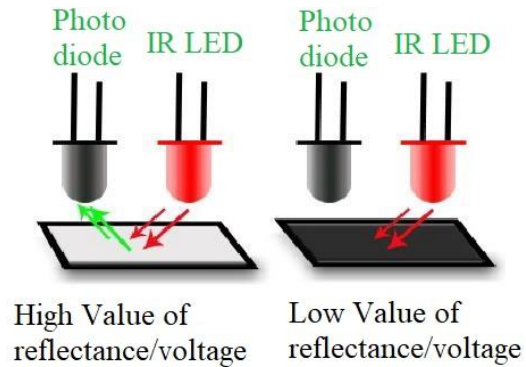


Figure 3. IR obstacle detection

This project will use 2 modules, each of them having three IR LED and three IR phototransistors. The LEDs are arranged in line to reduce the current consumption. For saving energy or for additional detection, the circuit has a MOSFET that drives the LEDs to be turned off. Each sensor gives a value of the voltage. Each phototransistor is connected to a pull-up resistor that divide the voltage between 0 V and 5 V according to reflected light.

The LED has a current limit at 5 V with resistors that allow to shift the operation to 3.3 V. For one LED, the current consumed is approximately 20-25 mA. This makes the consumption of the circuit to be maximum 100 mA.

C. Bluetooth

The vehicle will use HC-05 sub-model (Figure 6). This Bluetooth terminal can be use in two ways: master or slave.

Bluetooth is a wireless technology for transferring data on short distances (approximately 10 meters).

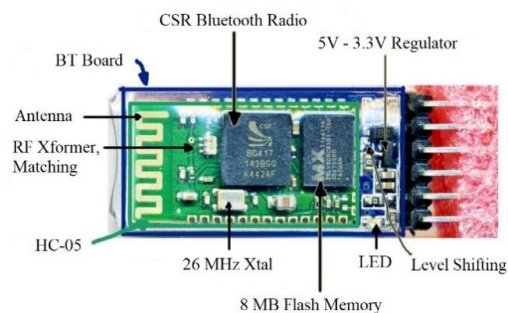


Figure 6. HC-05 Bluetooth module

This Bluetooth has two ways of work: "Command Mode" and "Data Mode". The first one can send AT commands. The second one is used to transmits and receives data to another Bluetooth module. For this project, we will use the "Data Mode" so we can send information to an Android or a Windows terminal.

HC-05 is a Bluetooth terminal that uses six pins (Figure 7): KEY (it can start AT Command mode), VCC, GND, TXD (transmit serial data), RXD (receive serial data) and STATE.



Figure 7. HC-05 Bluetooth pins

D. Microcontrollers

This project proposes a design for an autonomous car that once it will set up its destination via Bluetooth directions and it will be able to navigate by itself with the help of sensors.

As said before, for safety reasons, as the vehicle will be driven on highway at high speed, the data must be collected and processed in real time and the decisions must be taken fast. For example, if an obstacle (another car driving at low speed or stopped) will appear in front of the car, the vehicle will have to overcome the obstacle if there is no blocking (car) on the left side, to maintain a safe distance, or to go to a complete stop if the obstacle is stationary.

Because of this, the board will contain two microcontrollers. The first microcontroller will collect data from the ultrasonic sensors and the IR sensors. This data is transmitted via I2C communication protocol to the second microcontroller. The last one takes decisions, based on the data it receives, whether to turn right/left/go forward or stop. The Bluetooth module is also connected to the second microcontroller; this will be used to send data outside the board.

E. Encoders

From a historical point of view, several potentiometers have been interconnected with a rod, due to simple construction and inherent output (also called string ships). The problem with the potentiometer occurs when the contactor element inside of them is worn, thus reducing the life span. Another problem is the susceptibility to electrical noise interference, the potentiometer being an analog device.

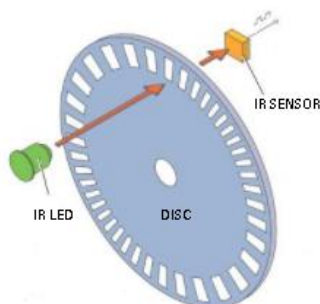


Figure 8. Rotary encoder

The rotary incremental encoder monitor (Figure 8) is used to measure linear distance by calculating the number of pulses compared to the known number of pulses per arc length.

The disc is mounted directly on the wheel shaft for more accuracy. As the wheel rotates, the rotary encoder generates pulses. As the diameter of the wheel is constant, we need to calculate the number of pulses for 1 millimeter of wheel rotation, which is the pulses per revolution divided by the diameter of the wheel:

$$PPM = \frac{PPR}{2\pi R}$$

To calculate the distance, we need to take the counted number of pulses divided by the pulses per millimeter.

$$Length = \frac{Number\ of\ pulses}{PPM}$$

In our case:

$$PPI = \frac{20}{65} = 0.30$$

E.g. 5 pulses →

$$Length = \frac{5}{0.30} = 16\ mm$$

IV. ALGORITHM

The vehicle starts to drive on the road and goes forward. The central ultrasonic sensor reads the value of the distance up to the car in front, if the car exists. If it does not exist, the vehicle keeps the lane.

In case there is a car in front, the central ultrasonic sensor will read again the value of the distance. If the values from the two cases are different, the car in front is stopped and this will cause the vehicle behind to stop. If the values from the two cases are the same, the left ultrasonic sensor will read a value to determine if a car exists or not on the left side. If there is a car on the left side, the vehicle keeps the lane and goes forward. On the other hand, if there is nothing in left side, the vehicle can start the overtake.

In the next part of the algorithm, there are two available cases:

1. The overtake can happen only if the lanes are separated by discontinuous line. In this case, the vehicle will change the lane and will go forward until the central ultrasonic sensor detects a car in front. In that moment, the central ultrasonic sensor will read again the distance. If the values from the two cases are different, the car in front is stopped and this will cause the vehicle behind to stop. If the values from the two cases are the same, the vehicle keeps the distance up to the car in front and the algorithm starts from the (*). If there's nothing in front, the right ultrasonic sensor will determine if a car exists or not in the right side: in case it exists, the algorithm starts again from the (*); in case it does not exist, the vehicle will change the lane and the algorithm starts again from the beginning;

2. If the lanes are separated by continuous line, the vehicle keeps the distance up to the car in front and the algorithm starts from the beginning.

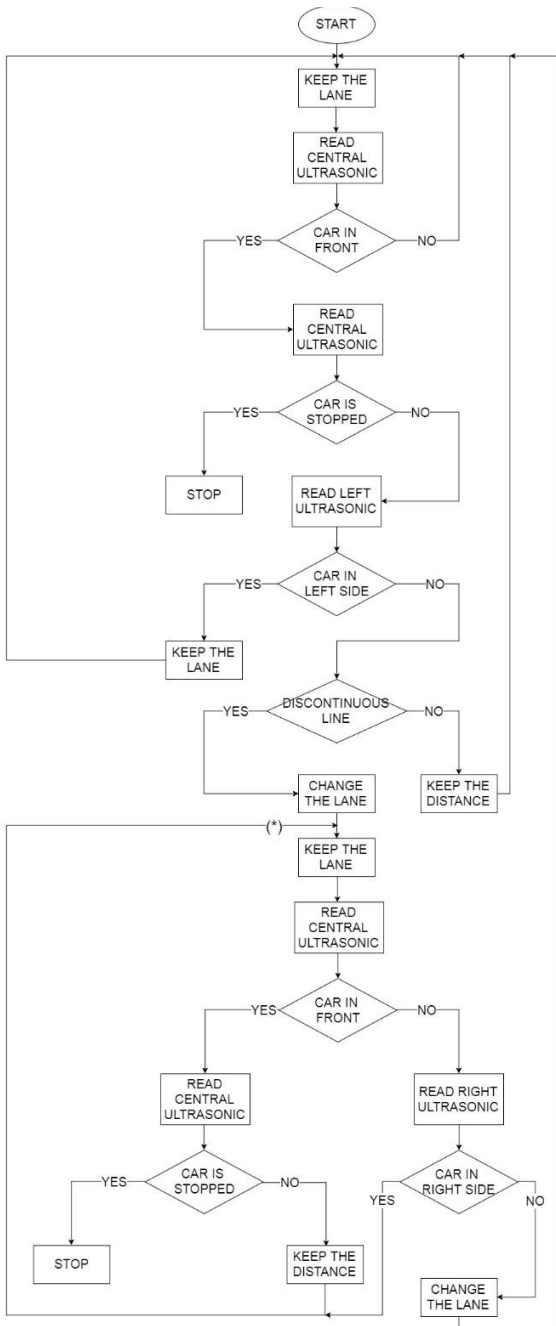


Figure 9. Algorithm structure

V. CONCLUSION

In this paper, the behavior of the car in a custom environment (a map with lanes and obstacles) has been analyzed and its behavior as autonomous car based on ultrasonic sensors and IR sensors has been simulated and tested.

The algorithms have been developed by using Arduino IDE environment with various libraries.

The results of the tests have demonstrated that an autonomous car can drive by itself on the highway and the algorithm can be implemented for a real car. Additionally, the results of the tests are useful to identify bugs and errors.

REFERENCES

- [1] https://en.wikipedia.org/wiki/Autonomous_car
- [2] <http://howtomechatronics.com/tutorials/arduino/ultrasonic-sensor-hc-sr04/>
- [3] <http://www.electronicshub.org/ir-sensor/>
- [4] <https://arduino-info.wikispaces.com/BlueTooth-HC05-HC06-Modules-How-To>
- [5] <https://www.slideshare.net/sangbuiquang3/rotary-encoder-training-material>
- [6] <http://www.machinedesign.com/sensors/basics-rotary-encoders-overview-and-new-technologies-0>