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A Prototype of Obstacle Avoidance for Autonomous Vehicle

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Abstract

Obstacle avoidance is one of the major tasks needed to be carefully focused by the autonomous system designers. In this digital era, most industries are moving towards autonomous systems. Obstacle avoidance is considered as a primary concern for any autonomous system. In this paper, a prototype of an autonomous vehicle is presented, which is capable of obstacle avoidance using an ultrasonic sensor for its movement and avoidance. An Arduino microcontroller is used to achieve the desired operation. In order to achieve the desired task of the proposed system, a proper methodology is followed which combines appropriate selection of hardware components as well as logic design of actions for obstacle avoidance. The proposed system can easily detect an obstacle, and move accordingly towards the safe path, by first detecting and then verifying the safe path. This can be very useful if implemented in real life. It can ultimately reduce the chances of accidents of trains and road vehicles which will save lots of lives. It can also detect broken roads and train tracks, which may result in reducing the chances of accidents to some extent. The accuracy of the autonomous vehicle depends on the output received by the ultrasonic sensor; therefore, it is not affected by the lighting environment. The prototype has been tested in various experimental settings and achieves appropriate results.

Keywords: Arduino, ultrasonic sensor, autonomous vehicle, obstacle avoidance

Introduction

Obstacle avoidance is one of key concerns of any autonomous vehicle. The autonomous obstacle avoidance vehicle is designed to provide safety mechanism for such vehicles that are on track or road by preventing collisions [1]. It costs many lives in case of collisions. The autonomous vehicle can easily detect an obstacle and avoid colliding with that obstacle, no matter if the environment is already known or not. This can work in any environment with any problem which guarantees road safety. Although many such systems are developed reports are published on road safety [2], however, these cannot ensure the safety of people's lives.

There are several navigational robots with famous methods like Wall-following[3], Edge Detection [4], and Color following[5]. Some commonly used methods[3-5] for obstacle avoidance are based on edge detection, therefore robots need to be stopped to acquire desire accuracy. A few of the detection methods[3-5] make use of complex algorithms that enable the robot to work. These systems are not convenient because they just look in front, with no capability to detect surroundings left and right.

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In this paper, an obstacle avoidance autonomous vehicle is presented that is equipped with an ultrasonic sensor[6], Arduino microcontroller[7], and servo motor [8]. Arduino is an open-source software and hardware kit for creating electronic projects. Whenever the vehicle starts moving, the obstacle detection and avoidance system are activated. The ultrasonic sensor continuously generates sound waves, when these waves strike the obstacle if any, the waves are reflected in the ultrasonic sensor. The distance between the vehicle and obstacle is calculated by using Eq. (1). Information regarding the distance between vehicle and obstacle is sent to the Arduino microcontroller through signals. Depending on the input signals, received by the Arduino controller, it decides to stop the vehicle and checks for an obstacle on the left and right sides of the vehicle, if any of the paths are clear it moves forward in that direction. Hence, it detects and avoids the obstacle and crosses by obstacle safely.

The rest of the paper is organized as follows: Section 2 discusses literature review, while Section 3 elaborates methodology followed for the design of proposed system. Section 4 presents proposed system whereas testing and experiments along with the limitations of this research is presented in Section 5. Finally, the paper is concluded in Section 6.

1. Literature Review

In terms of road accidents and loss of lives of loved ones, many researchers have contributed and attempted to provide solutions for a safe journey. In this section, we discuss a few of studies in this regard.

Obstacle Avoidance Robot [9] is an autonomous robotic vehicle, which detects obstacles present on its path through the sensors, avoids them, and takes the decision based on internal code set in it.

Obstacle avoidance on roadways using range data [10] is an autonomous vehicle that detects and locates obstacles present in the road environment for navigation of a robotic vehicle equipped with an active laser-based range sensor.

Valsalan and Surendran[11] proposes a line follower and obstacle avoidance system, which moves on a specific path determined by the user and detects the obstacle that comes in its way.

A Real-Time Obstacle Avoidance Method [12] detects obstacles and calculates the likelihood of collision with them.

Modi et al.[13] compares three different methods for obstacle detection and avoidance. The methods used for comparison include a laser scanner, a rotating sonar sensor, and fixed mounting of sonar sensors.

Kim et al. [14] proposes an algorithm that is capable of avoiding obstacle collision for a mobile robot. The vision system approach, as well as the edge detection approach, are used in the system.

Most of the systems observed in the literature[10-14], needed the accuracy for the desired output. While having complex algorithm in concern which are time-consuming because they stop the vehicle in front of an obstacle and decide where to go and with no functionality of looking in surroundings for a better outcome. In the proposed system vehicle is optimized in detecting an obstacle, without stopping vehicle while slowing it down and deciding where to go, it takes less time just like a human driver on driving seat. The proposed system is discussed in the following section in detail.

2. Methodology

In this section, design methodology of the proposed system is discussed systematically. Autonomous systems are developed using combination of hardware and software components. Major parts of the hardware components include circuits and sensors while software component includes the programming of circuit and design/logic of actions in response to sensor inputs. Careful selection of appropriate hardware components and logic design of software components is of utmost importance. The design of the proposed system is

based on the methodology illustrated in Figure 1. First step is to define the domain of the autonomous system followed by determining the environment of the system in which autonomous system will be used. Next all the necessary functions of the systems need to be defined after that hardware components are determined. Later, real time actions are determined, and logic is designed for the actions of the autonomous system. Finally, the system is implemented and tested against various actions and environmental settings. If during experimentation any modification is realized, then changes are made at appropriate stage.

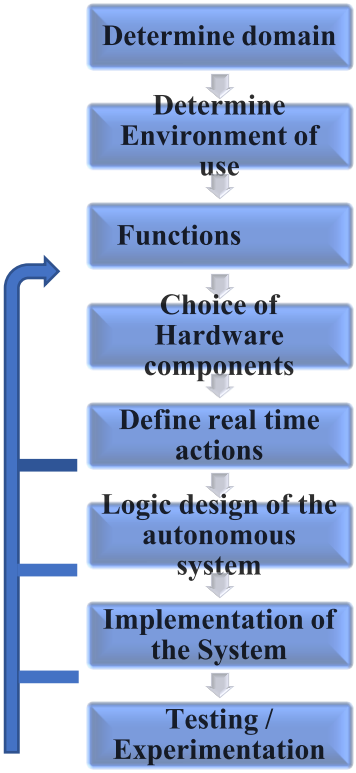


Figure 1-Methodology of obstacle avoidance for autonomous vehicle

3. Proposed system

The proposed system is an intelligent autonomous vehicle which is developed using the methodology described in Section 3. The system makes use of combination of sensors and computational logic. This system is embedded with an ultrasonic sensor for measuring distance and detecting depth of road for a safe journey. Distance readings are taken by the ultrasonic sensor and sent to Arduino microcontroller that analyses readings received from ultrasonic sensor to control the movement of motors through motor driver Integrated Circuit (IC), which in turn helps the vehicle to move left and right and go forward smoothly. Figure 2, illustrates the workflow of the proposed system. Step by step description is given below for a better understating of the proposed system.

- Whenever the vehicle starts moving, obstacle detection and avoidance system are initiated.
- While running, the sensor simultaneously detects any obstacle that comes on its way.
- As an obstacle is detected in the predefined distance limit, the sensor will send the distance value to the Arduino controller.
- Then Arduino analyses the readings and checks its surroundings by moving the ultrasonic sensor left and right with the help of a servo motor.

- While checking all conditions wherever the obstacle is, the vehicle will avoid that obstacle and will move to its destination, without any collision and the system work fine with fast detection.

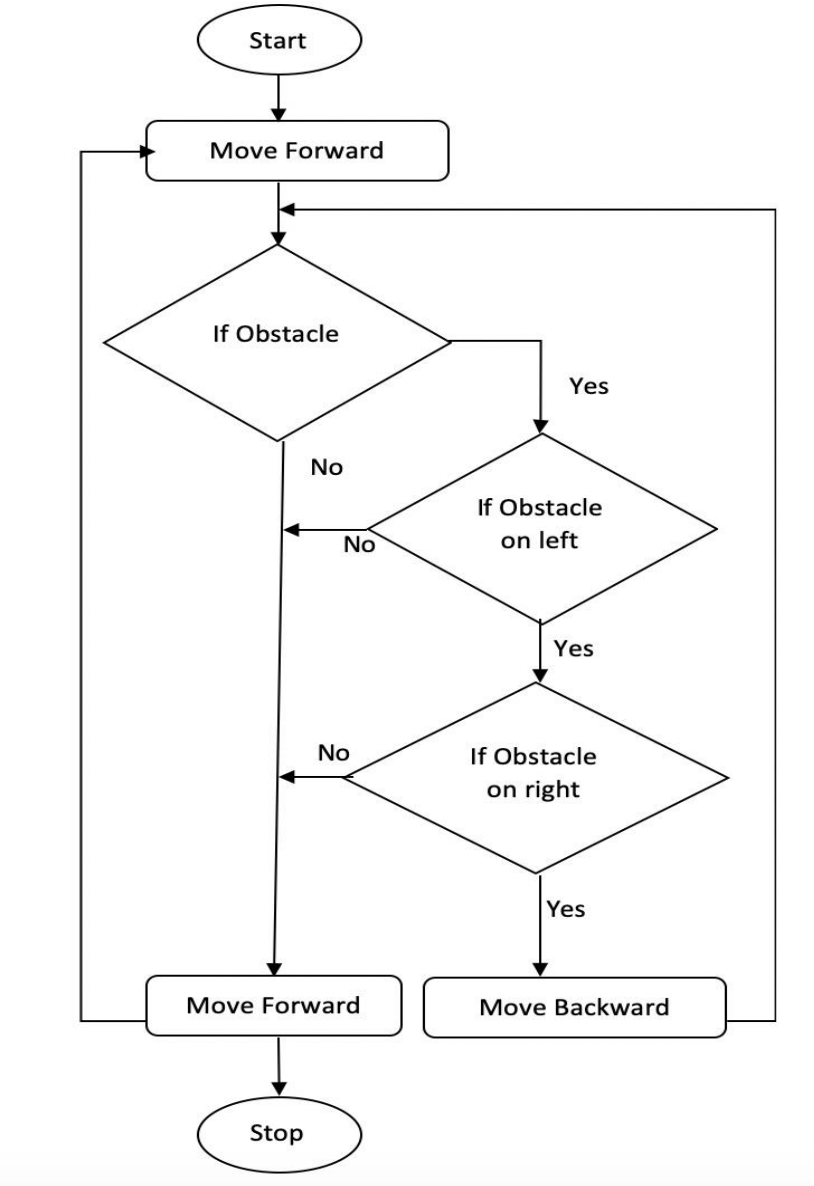


Figure 2-The working mechanism of the proposed system

A. Basic Design of Autonomous Vehicle

This system is built using an Arduino development board with an embedded microcontroller. Arduino is connected with DC motors through motor driver IC, which provides power to actuators that help motors to turn left, right, forward and backward. Table 1 gives more understanding regarding the movement of motors in an autonomous vehicle.

Table 1- Movement of motor

Output Motor 1	Output Motor 1	Output Motor 2	Output Motor 2	Motor's output		Movement
				Right	Left	
0	VSS	VSS	0	Straight	Straight	Straight
0	VSS	0	0	Straight	No movement	Left turn
0	0	VSS	0	No movement	Straight	Right turn
0	VSS	0	VSS	Straight	Reverse	Sharp left
VSS	0	VSS	0	Reverse	Straight	Sharp right
VSS	0	0	VSS	Reverse	Reverse	Backward

Table 1 shows that motors are moved in forward and backward direction for changing route of the vehicle. The motor movement is based on the output received from the ultrasonic sensor, which gives values in distance. To change the direction, different output in voltages is given to motor pins, as shown in Table 1. The voltage is given HIGH on one terminal and LOW on the other terminal of each of the motors to move the vehicle forward and backward. This complete task is achieved programmatically using Algorithm 1.

```
Algorithm 1
Movement (Distance)
While (Status = ON) { //Status is vehicle status
If(Distance <= TH) //Check minimum distance

{                          //threshold

Slowdown();
        DistanceR =LookRight();
        DistanceL = LookLeft();
        If(DistanceR > Distance L){
        TurnRight();
        StopTurningRight();
}Else {
TurnLeft();
StopTurningLeft();
}
}
}Else{
        MoveForward();
}
        Distance = ReadDistance();
End
```

B. Working of Ultrasonic Distance Sensor

There are varieties of sensors available for the detection of obstacles [15], which include infrared sensors, ultrasonic sensors, cameras, and sonar. These all can be used to measure distance in their field of work.

In the proposed system, we have used an ultrasonic sensor for obstacle avoidance and detection [15]. The working mechanism of the ultrasonic sensors is instigated by generating sound waves of very high frequency, which can't be heard by the human ear. These sound waves pass through the air at the speed of sound which is approximately 343 m/s[16]. Once an obstacle is witnessed ahead of the sensor, the sound waves are reflected and received by the sensor. The time duration from the discharge of the waves and echoing back to the sensor is used to compute the distance.

Figure 3(a), illustrates, how sound waves are initiated and returned to the sensor which echoes the waves. This distance is calculated using Eq. (1), in which the speed is the speed of sound.

$$\boldsymbol{Distance = Speed \times Time} \quad (\mathbf{1})$$

Where Speed used in Eq. (1), is the speed of sound waves that are triggered and returned after reflection from any obstacle and *Time* is the time taken by a sound wave from trigger to echo. The approximate speed of the sound is measured as 343 m/s or 0.034 cm/µs at 20 degrees centigrade. When the speed of sound is multiplied by the time, yields the distance traveled by the sound waves. The distance is calculated using Eq. (1), which is double the actual distance because it is calculated twice, i.e., the distance from the sensor to obstacle and from obstacle to the sensor. Therefore, the actual distance is obtained by dividing the measured distance by two as given in Eq. (2).

$$Distance(cm) = Speed\left(\frac{cm}{\mu s}\right) \times \frac{Time(\mu s)}{2} \quad (2)$$

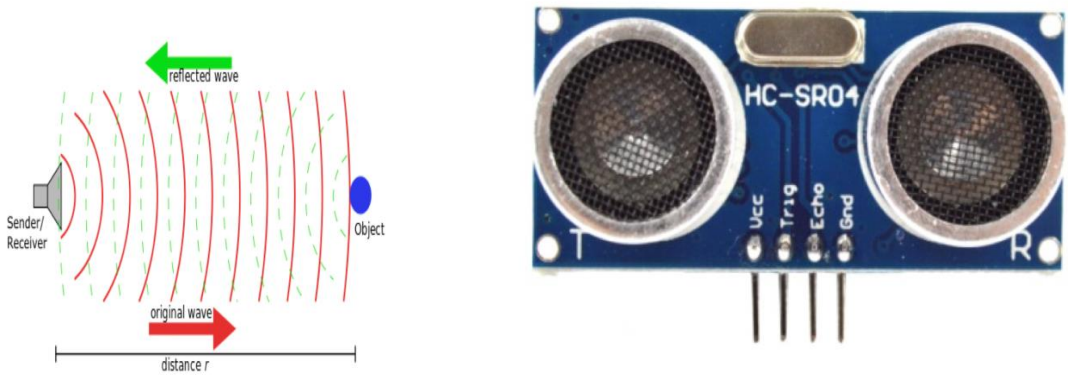
Where cm refers to centimeter and µs refers to the microsecond. To get the one-sided distance covered by the sound waves and converted in centimeters, Eq. (2) is used. For purpose of understanding, an example is given in Eq. (3), which converts 2000 in centimeters.

$$Distance(cm) = 0.0343\left(\frac{cm}{\mu s}\right) \times \frac{2000(\mu s)}{2} = 34.3cm \quad (3)$$

We have used HC-SR04 [15] ultrasonic sensor, which contains 4 pins Trig, Echo, VCC, and GND as shown in Figure 3(b). Features of the ultrasonic sensor are given in Table 2.

Table 2- Features of the ultrasonic sensor

Feature
Working Current: 15 mA
Effectual Angle: <15 degree
Ranging Distance: 2cm – 400 cm/1''- 13ft
Resolution: 0.3cm
Measuring Angle: 30 degree
Input pulse width: 10 uS



(a) **(b)**

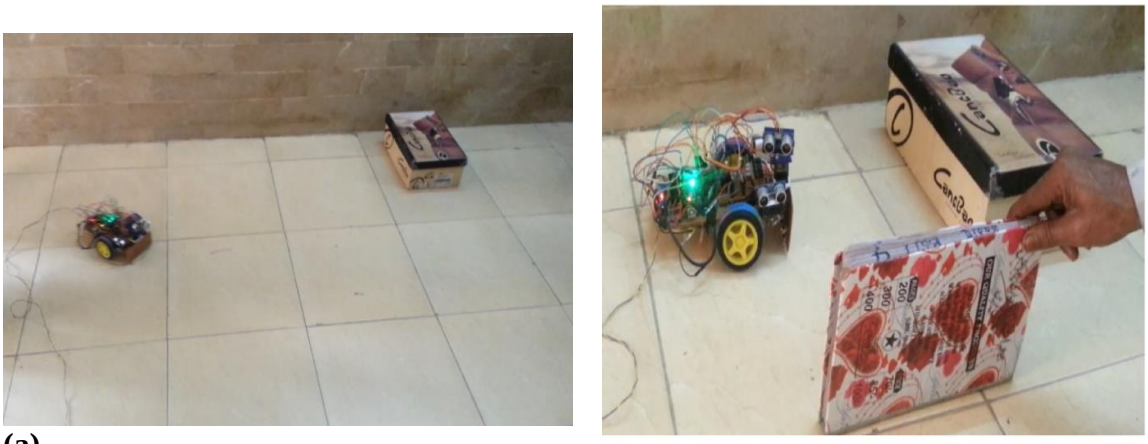
Figure 3-This figure depicts the ultrasonic sensor (a) the working mechanism of ultrasonic sensor [17] (b) Ultrasonic sensor

4. Testing and experiment

Obstacle avoidance autonomous vehicle is tested in various environments and different conditions. If the path is clear with no obstacle, then the vehicle runs forward smoothly without any interruption as shown in Figure 4(a)

If the autonomous vehicle detects any obstacle it slows down and checks if there is a path available in left or right to move ahead then it proceeds towards the free path.

It is also tested in the complex path if there is not any path available in any direction, then it just checks the surroundings by looking left, right, and front and then move backward or turn back to the free path available to go as shown in Figure 4(b).



(a) **(b)**

Figure 4-This figure depicts the working of a vehicle based on a given path (a) free move without any obstacle (b) complex situation with a closed path

During the testing and experimentation phase, few limitations are observed. A few times the depth of road is miss-interpreted by the system. To avoid this limitation, multiple sensors can be added at different positions. Through this, accuracy will be maintained and enhanced. Another limitation is the delay in response time when an obstacle is detected and then removed.

5. Conclusion and Recommendations

In this paper, we presented a prototype of an obstacle avoidance autonomous vehicle. A brief review of literature is also presented related to the proposed system. The system is designed by following a methodology, which is also systematically described. The system is designed by keeping in mind increasing road accidents all over the world[1], which has become a very serious issue to be addressed. In the proposed system, the focus has been given to avoid collision regardless of any lighting condition or environment. The ultrasonic sensor continuously detects the path to avoid any unwanted collision and the movement of motors is controlled automatically with the simple algorithm of obstacle avoidance. It is an attempt to provide safety on roads to some extent. As of future work, the vehicle size dimensions will be implemented to reduce the chances of an accident. Moreover, a target navigational system will be implemented for autonomous vehicles.

Disclosure and conflict of interest

The authors declare that they have no conflicts of interest.

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