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Design and Implementation of Obstacle Avoidance Autonomous Robotic Car

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ABSTRACT

One of the most critical characteristics of any autonomous robotic car is to be able to avoid obstacles along its path. Autonomous mobile robot has a built-in system that could guide it whenever it encounters an obstacle along its path. By sending sonic pulses, the robot's distance to obstacle can be measured and at the same time control steering gear to realize the obstacle avoidance function. In this paper, the development of an autonomous robotic car that could avoid obstacles is presented. This was implemented by using an ultrasonic sensor for sensing obstacles and directs its movement. ATmega328 microcontroller was used to collect distance information from the ultrasonic sensor, compares the measured distance based on the embedded algorithm and used it to determine whether to move forward or change its path. Through the hardware and software systems design, the obstacle avoidance robotic car platform was built while good experimental effect was obtained. The safe distance that can be sensed by the sensor was observed to be 15 cm with 180^0 angular coverage area.

1. INTRODUCTION

Autonomous robot is a machine that is capable of moving on its own in an unstructured and unknown environment. Autonomous robot is usually equipped with software intelligence to sense its environment, detect obstacles in its path and move around an unknown environment overcoming the obstacles [1]. There are many robotic platform designs that are employed in designing of autonomous robots. These designs are usually developed by considering the physical environment in which the robot has to be deployed. The use of autonomous systems to perform relevant and delicate tasks is fast growing and their application in various fields cannot be over emphasized. There are autonomous robots like snake robots, walking robots, autonomous drones and autonomous robotic cars or rovers.

Obstacle avoidance is an important task in robotic systems development, as the autonomous robot's aim is to reach the destination without collisions [2]. One type of autonomous robot that can detect obstacles and edges, and as well takes alternative paths free of obstacles and edges, is a real-time obstacle avoiding edge detection robot. This paper proposes a robot with intelligence embedded in it, which guides it whenever an obstacle comes its way using an algorithm. The design allows the robot to navigate in an unknown environment by avoiding collisions. Obstacle avoidance in robots can bring more flexibility in varying environments and make them much more efficient, so that their continuous human monitoring will not be required.

2. LITERATURE REVIEW

Obstacle avoidance autonomous robotic cars are freely moving and can operate on their own without direct human supervision [6]. They are capable of self-decisions based on what it senses and also programmed to recognize. An obstacle detection and avoidance autonomous robot has various areas of applications. For instance, the operational technique can be implemented in cars [7]. If the control system is fast enough, it can quickly decrease the speed and avoid accidents with obstacles that occurs rapidly. With the traffic becoming more complex with new situations, there is increasing demands for the control systems and algorithms [1]. Autonomous robotic cars can also be employed in dangerous environments or in any other way that is not appropriate for humans. In [2], ultrasonic sensor module with transmitter, receiver and an ATmega16amicrocontroller were used. In their work, a short pulse of ultrasonic sound was sent to the microcontroller while the microcontroller listened to the echo. The distance was calculated by taking the time duration between the transmission and reception of pulse and echo respectively. In this paper, they designed an ATmega16 microcontroller based on range finder using ultrasonic module. This module will measure distance up to 2.5m. By employing ATmega16a and HC-SR04 ultrasonic sensor, they were able to reduce the cost and increase the efficiency. Thus, a low power, low cost and simple system for distance measurement was implemented. The ultrasonic sensor was reported to operate in millimetre range due to the effects of environmental accuracy [3]. This paper discussed the list of environmental parameters which have the major influence on the accuracy of the ultrasonic sensor. Mathematical equation was formulated for calculating the instantaneous speed of sound by considering these environmental parameters. The maximum percentage error of about 0.33 was reported when compared for temperature range of 0-50^{o}C.

3. METHODOLOGY

In order to achieve the goal of this research, the proposed obstacle detection and avoidance robotic car consists of the chassis, four geared DC motors and tyres, servo motor, power switch, Lithium Ion battery, DC-DC boost converter, buck converter, ultrasonic sensor, motor shield, screws and wires. Since the current requirements of the DC motors are often higher than what the Arduino output pins can provide, there is need to use motor shield as it is equipped with additional circuitry that could provide up to 600mA current to each of the DC motors. This shield provides power to both the DC motors and servo motor as well as the ultrasonic sensor, which makes it much easier. A switch was connected to the battery to turn the robotic car ‘on’ or ‘off’. This autonomous robotic car has 5 different modes; move forward, stop, move backward, scan right and left, and turn right or left. Since only one ultrasonic sensor is employed in this research, the ultrasonic sensor must have the capability to turn around to scan for alternative way to move. Therefore, there is need to attach the ultrasonic sensor together with servo motor. Servo motor is a simple electric motor that produces closed-loop position control [4]. The servo shaft can be turned in 180 degrees to help the ultrasonic sensor scans the obstacles around and chooses the clear path to move along. A homemade bracket was used to attach the sensor to the servo motor. The block diagram of the implemented obstacle avoidance robotic car presented in Figure 1.

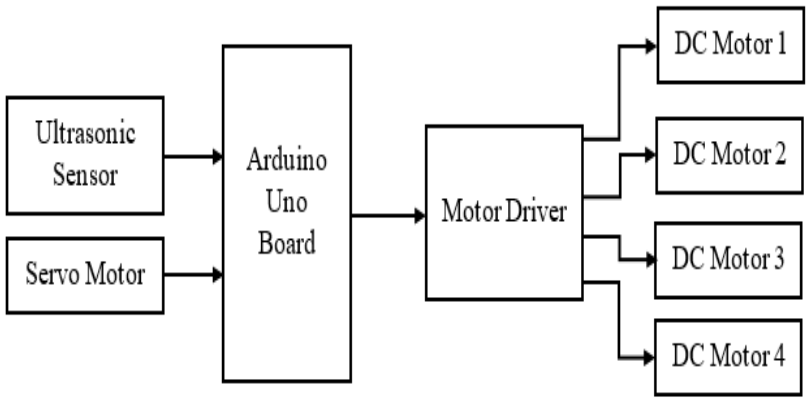

Figure 1: Block Diagram for the Autonomous Robotic Car Hardware Implementation

In the algorithm implementation, the trigger pin on the ultrasonic sensor was pulled high for a minimum of 10µs. The transmitter module on the ultrasonic sensor sent a sonic burst, which consists of 8 pulses of 40KHz. After hitting an obstacle, the signals reflected back to the receiver [5]. During this time, the Echo pin goes high to enable sending and receiving signal pulses [8]. The time between sending and receiving a sonic burst is converted to distance using appropriate calculations. As the goal of this research is to implement an obstacle avoidance robotic car by employing ultrasonic sensor and Atmega328 microcontroller. The circuit diagram implementation of the robotic car is shown in Figure 2. All the connections were made by following the wiring diagram. The implemented robotic car was put to test by connecting it to Lithium Ion battery, both the front wheel motors functioned normally while the robot was moving forward. As the robotic car moves, the ultrasonic sensor continuously sends sonic pulses while the Atmega328 microcontroller measures the distance between the robot and the reflective obstacle surface [9]. If the distance between the implemented robotic car and the obstacle is less than 15cm, the robot stops moving, then the servo motor turns the ultrasonic sensor to scan right and left directions for new distance. If the distance from the robotic car towards the left side is more than that of the right side, the robotic car then activates the left wheel motor in reversed direction before turning left. However, if the distance from the robotic car towards the right side is more than that of the left side, the robotic car then activates the right wheel motor in reversed direction and turns right.

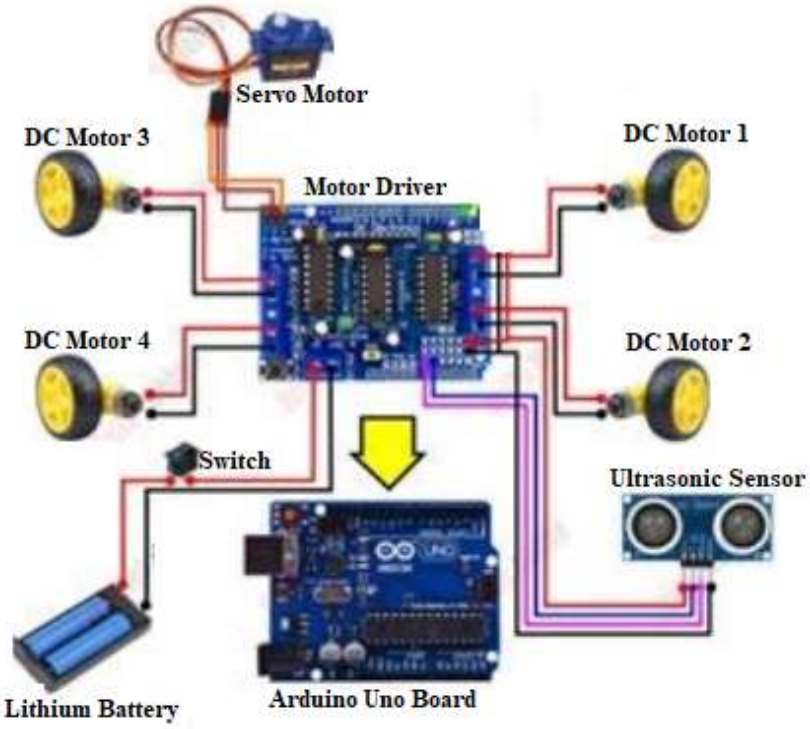

Figure 2: Circuit diagram of the obstacle-avoiding robot

This operation continues forever while the robotic car continuously navigating without colliding with any obstacle. Power supply used to operate the implemented robotic car was 7.4V with a capacity of 3500mAh. This enables the robot to operate for several hours before the battery could runs out. Also, use different battery/battery-packs for powering Arduino and the Motor-Driver module, but ensure they share a common ground. Compile the code given below in the Arduino-IDE and hit upload. Turn on the toggle switch and watch the robot avoiding obstacles [1].

The controller board is used to communicate with the PC using serial communicator (USB connection). The data is transferred between them bit by bit. An adaptor is used to supply power to the controller board and a USB programmer is used to burn the hardware program (written in Arduino IDE) into the Arduino board. The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, mac OS, Linux) that is written in the programming language Java [10]. It originated from the IDE for the languages Processing and Wiring. It includes a code editor with features such as text cutting and pasting, searching and replacing text,

automatic indenting, brace matching, and syntax highlighting, and provides simple one-click mechanisms to compile and upload programs to an Arduino board [11]. The programming for the Obstacle Detecting and Avoiding Robot is done in C Language and uses various pre-defined header file. The components for the implementation of the robotic car is shown in Figure 3 with the developed prototype presented in Figure 4.

Figure 3: Robot Components

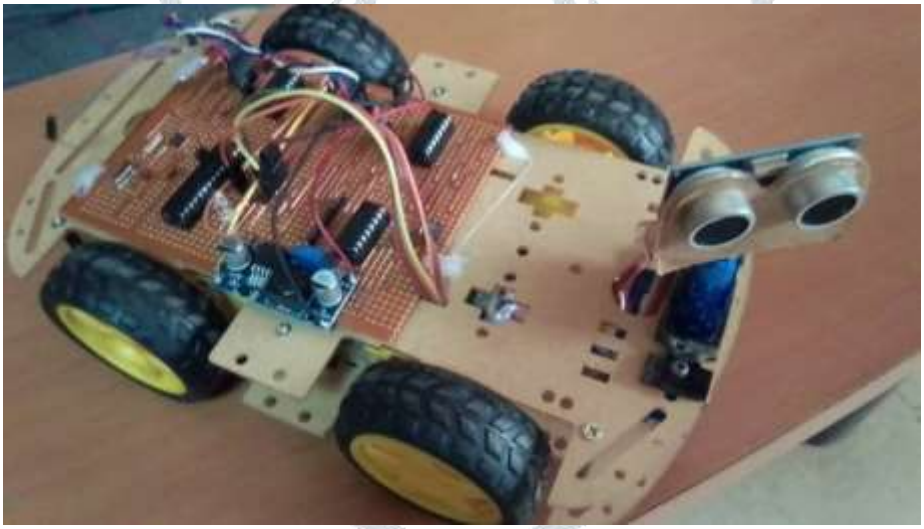

Figure 4: The Developed Prototype

4. RESULTS

The completed prototype of the obstacle detection and avoidance robotic car is shown Figure 4. The motion of the robotic car was initiated by the ultrasonic sensor as different values were sent to the DC motors due to the distance to obstacles around the robot. Adjustments were made to the robotic car algorithm until it navigated through obstacles without difficulties. Distance measurement test was carried out with the ultrasonic sensor while adjusting the algorithm. This was achieved by placing an obstacle at certain distance from the sensor, the distance was then measured with a ruler and then compared with the distance specified by the sensor. The result obtained therefore showed that the ultrasonic sensor was precise except in the case where the object was placed below the specified range by the manufacturer. According to the manufacturer's specifications, the sensor can identify a distance from 2-400 cm. The result is shown in table 1.

Table 1: Results from Test with Ultrasonic Sensor

Measured Distance (cm)	Manufacture's Sensor's Distance (cm)
0	0
1	2
5	5
10	10
15	15
20	20
25	25
30	30

Furthermore, obstacle detection test was conducted by placing different objects along its path and also around it to make sure it could turn as desired. It was observed that the implemented robotic car turned left and right when it detected an object placed to the right and left directions respectively during its movement. Another test conducted during the movement of the implemented robotic car was by placing obstacles all around it to ensure it completely stops. In addition, obstacles with different colors, shapes and sizes were also investigated by placing them in front of the implemented robotic car. This was done to investigate which objects color, shape and size the ultrasonic sensor could be able to detect along its path. The ultrasonic sensor was attached on top of the bottom plate which maintained a height difference of 6 cm between the ground and the center of the ultrasonic sensor. The result with obstacles with sizes and colors are presented in Table 2 and Table 3.

Table 2: Result for Testing Object's sizes

Object Sizes		Status
Length (cm)	Height (cm)	
12	15	Detected
12	2.5	Not Detected
6	10	Detected
6	5	Detected
6	2.5	Not Detected

This is to investigate the sensors' capability to detect low obstacles on its path. The test was carried out by placing an object with a length of 12 cm and a height of 15 cm in front of the robotic car, which was easily detected by the robotic car. Also, another object with 6 cm x 7.5 cm was placed in front of the robotic car and was again easily detected. In contrast, the robotic car was unable to detect an object with a length of 6 cm and a height of 2.5 cm when placed along its path. In order to investigate the object with the lowest detectable height, objects with a height of 3.5 cm, 4 cm and 5 cm were investigated. The result showed that the object with height 5 cm was the lowest obstacle that could easily be detected by the ultrasonic sensor.

Table 3: Result for Testing Object's with Colors

Obstacles	Distance measured (cm)	Detected distance (cm)
Wall	10	10
Wood	10	10
Colored	10	8
Metal	10	10

5. CONCLUSIONS

We are in the world of robotics nowadays. Knowingly or unknowingly, we have been using different types of robots in our daily life. The aim of this research has been achieved by investigating and manipulating different parts of the robotic car to make it autonomously navigating without colliding with any obstacles along its path. The overall end objective was to make the implemented robotic car detect and avoid obstacles along its path by programming it to use ultrasonic sensor attached to it. Different objects with various sizes and colors have been investigated and the performance of the robotic car was satisfactory. It was observed that objects size below 2 cm could not be detected as colored objects were absorbing the sonic pulses sent by ultrasonic sensor.

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