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Obstacle Detection and Anti-Collision Robot Using Ultrasonic Sensor

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Abstract: Obstacle detection can be considered central and paramount in designing mobile robots. This technique enables mobile robots equipped with sensors to transverse and maneuver freely in an environment preventing damage as a result of a collision with obstacles in its path. Several systems with different approaches have been developed for the anti-collision of a robot with obstacles. The approach to Sensor selection, path planning, and navigation processes determines the operation of such a system and differs from one another. This paper presents a low-cost ultrasonic distance sensor for obstacle detection to enhance anti-collision in mobile robot navigation. The system is designed with the C/C++ programming of the Arduino software (IDE) and implemented on the ATMega 2560 Microcontroller of the Arduino board. An ultrasonic sensor detects an obstacle and sends the data collected to the controller which directs the motor driver to stop or move the robot while following a visible predefined path (blackline) embedded in the ground and detected with the help of an IR sensor placed beneath the robot. Experimental results with varied obstacle positions show a decent performance scoring 96.4% accuracy at a 50cm distance to the obstacle.

Keywords: Arduino Software, Microcontroller, Mobile Robots, Obstacle Detection, Programming.

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1. INTRODUCTION

In recent times, robotics has gained tremendous recognition in scientific research as the use of robots now plays a major role in homes, manufacturing, medical care, service delivery, entertainment, and lots more [1]. Obstacle detection is a fundamental requirement for an autonomous robot in the development of mobile robotics enabling mobile robots' capability to transverse and avoid collisions with obstacles in the environment [2]. It is required to integrate sensors of different kinds on the robot to collect information from the surrounding environment to detect and avoid collision with the obstacle. [3]. Amongst the several sensor integrations adopted to enhance obstacle detection, the ultrasonic sensor provides offers a plausible solution due to its low cost and high-ranging capability. It is an electronic device that calculates the distance of a targeted object by transmitting ultrasonic waves and converting the reflected ultrasonic waves into an electrical signal. It has two main components: the transmitter and the receiver. The transmitter transmits ultrasonic waves by using piezoelectric crystals. The study employs the use of an ultrasonic sensor to avoid the collision of the robot with an obstacle on its path. The robot follows a line-tracking mechanism to navigate to its destination.

Several successful systems have been developed for anti-collision of the robot with obstacles especially Vision systems been utilized to greatly improved robot versatility. The work of Samadi et al. [4], on obstacle avoidance robots equipped with a tilt-mounted vision system. The robot detects and avoids obstacles in its environment through the use of histograms of images obtained from a monocular camera. Anthony et al. [5] reported a smart distance measurement technique with an IR sensor. The research suffers a major drawback of IR-based sensors detecting only short distances. Magar et al. [6] implemented an anti-collision robot processor using RFID technology for avoiding static collisions and an ultrasonic sensor to avoid dynamic obstacles. Ohya et al. [7] considered the implementation of vision and ultrasonic systems on a mobile robot for obstacle avoidance. The robot gets accustomed to its surroundings using appearance-based obstacle detection for global and local avoidance. Object detection was carried out by the ultrasonic sensor while the vision camera enables its object classification. The study of Philip et al. [8] employed the use of a laser scanner sensor on a small mobile robot platform to generate a path free from collision from a grid map algorithm. Ismail et al. [9] developed an obstacle-avoiding robot with IR and PIR motion sensors using the Arduino platform. PIR sensors were more to be more sensitive compared to IR sensors in detecting human beings. However, the work suffers drawbacks of obstacle avoidance challenges. The project also uses multiple ultrasonic sensors on the robot to detect obstacles in real time and requires no path planning. This project employs the use of a single ultrasonic sensor on a blackline following robot to detect obstacles and avoid collision with the object in its path as it travels. It uses the

Arduino software which enables a C/C++ code written in the Arduino IDE and uploaded to Atmega 328P Microcontroller on the Arduino board.

2. MATERIALS AND METHODS

2.1 Design of the System

The study was implemented using Arduino Uno Microcontroller, an HC-SR04 Ultrasonic Sensor, An IR sensor to detect its black path, and a motor driver which eventually controls the robot wheels through the geared DC Motors. The robot detects the presence of any object within the specified distance by emitting an ultrasonic pulse every 300 ms which echoes from the object. Using the time of travel and speed of sound in air, the Arduino the distance to the obstacle. An object within this distance is referred to as an obstacle, the robot. To design the obstacle-detection robot, an electronic circuit was designed which represents the hardware interface and communication flow as seen in figure 1. The components assembly of the robot is shown in figure 2.

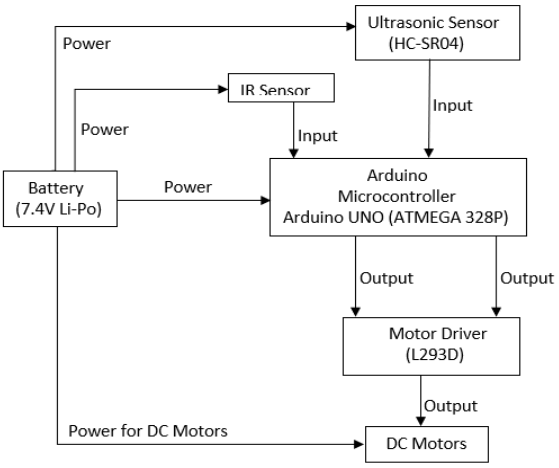

Figure 1. Design flow diagram for Hardware Interface

2.2 Working Principle

When the robot is powered on, the IR sensor beneath the robot track blackline and navigates on it, while the ultrasonic sensor calculates continuously, the robot's distance to the obstacle placed before it.

The HC-SR04 ultrasonic sensor is placed at the foremost part of the top plate of the robot to continuously emit pulses and receive reflected signals (echo) of the object placed before it. When an object is within the specified obstacle distance, the ultrasonic sensor echo pin received the signal causing ATMega 2560 Microcontroller to send a low (0V) signal to the DC motor through the L293D motor driver to stop its motion and gives a buzz alarm until an obstacle is no longer detected for the robot to move forward. Figure 4 shows the flowchart of the operating process.

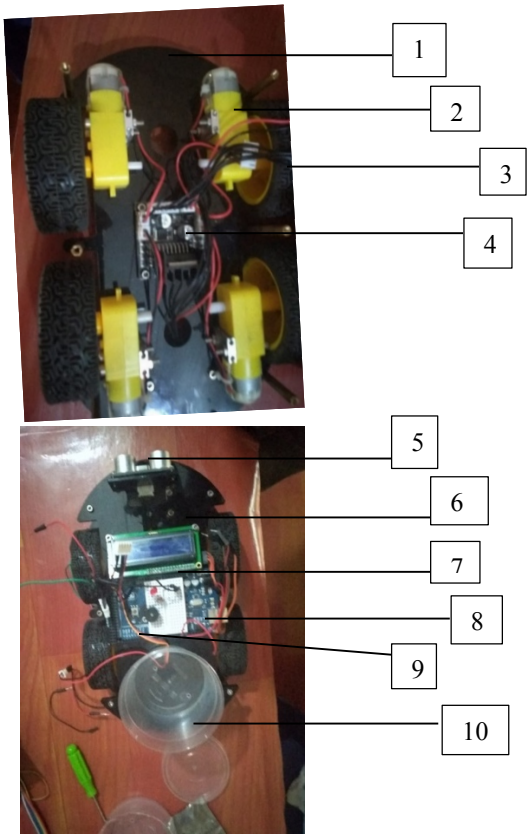

Figure 2. Component assembly of the robot

KEY

Number	Name of component
1	Robot base plate
2	Geared DC
3.	Robot wheel and tire
4.	L293D Motor Driver
5.	HC-SR04 Ultrasonic Sensor
6.	Robot top plate
7.	1602 LCD Module
8.	Arduino Mega
9.	Buzzer
10.	Item Carrier

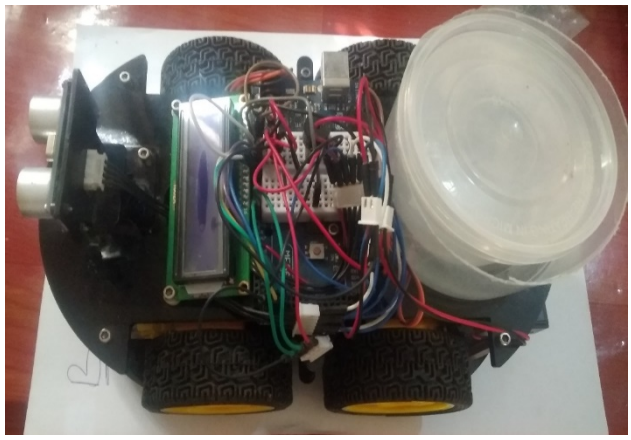

Figure 3. Complete Assembly of the robot

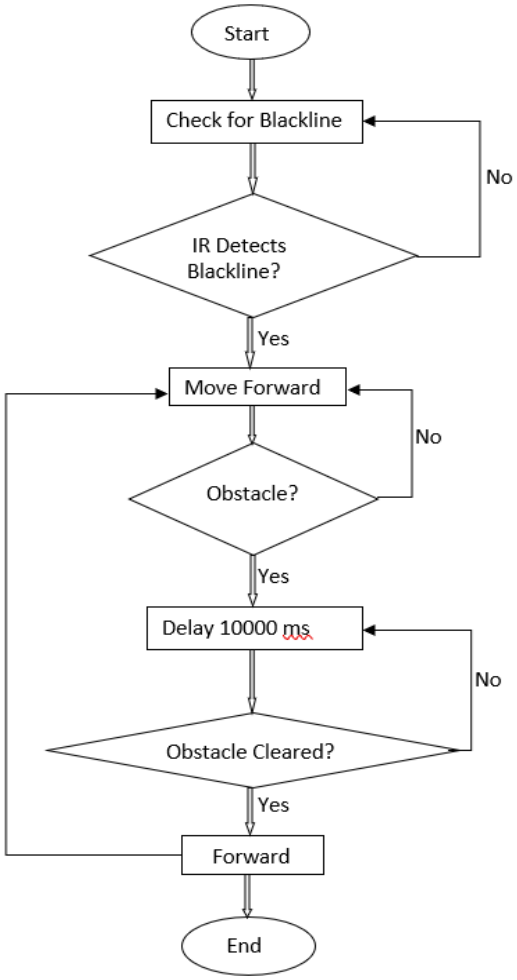

Figure 4. Flowchart of Operating process

The experimental setup is demonstrated as shown in figure 5. Whenever the robots encounter an obstacle and stop, a meter rule was used to measure the actual obstacle distance from the HC-SR04 transceiver to the obstacle (solid object). The obstacle distance measured value is compared with the programmed value for the various tests. The farther the obstacle is from the robot, the minimal the error in obstacle distance as compared to the programmed data. The result is tabulated as shown in table 1.

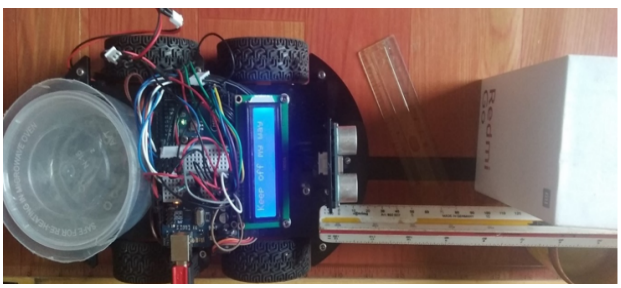

Figure 5. Experimental setup of the robot for obstacle detection

3. RESULTS AND DISCUSSION

The obstacle detection robot was developed and implemented by pacing obstacles at varied obstacle distances to measure the actual obstacle distance compared with the programmed data as tabulated in table 1. The performance of the HC-SR04 ultrasonic sensor in detecting obstacles to the robot and the ATMega 2560 microcontroller processing power in sending a low signal (0V) to stop the wheel to avoid a collision with an obstacle was evaluated and tabulated as shown in Table 1. It was observed that the robot detects the obstacle with minimal error (3.6%) at a 50cm obstacle distance to avoid collision with the obstacle.

Table 1. Obstacle Detection Test with Robot

Expected Obstacle Distance	Actual Measured Distance			Average Distance	Error	% Error
	Test 1	Test 2	Test 3			
10cm	5.6cm	5.3cm	5.4cm	5.4cm	4.5cm	45%
20cm	16.4cm	16.2cm	16.5cm	16.4cm	3.6cm	18%
30cm	26.8cm	26.6cm	27.4cm	27cm	3.0cm	10%
40cm	37.2cm	37.6cm	38.3cm	37.7cm	2.3cm	5.8%
50cm	48.2cm	48.6cm	47.8cm	48.2cm	1.8cm	3.6%

4. CONCLUSION

The paper is aimed at developing an obstacle detection and anti-collision robot that detect obstacles and avoid headlong collision with them. This was achieved using an ultrasonic sensor to detect obstacles, an IR sensor for blackline following, and DC motors for the wheels using the Arduino Microcontroller and IDE. The evaluated results from the experiment as presented were encouraging which further demonstrate the possibilities of this approach to robot obstacle detection and collision avoidance.

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