Nat. Volatiles & Essent. Oils, 2021; 8(5): 3412 - 3421

NVEO
Natural Volatiles & Essential Oils

Obstacle Avoidance Robotic Vehicle

[1]Vishwa Priya V, [2]Gokul S, [3]Jeevanandham M B, [4]Sanjay Johnson W, [5]Sri Ram R T, [6]Surya Prakash L

[1]Robotics and Automation Engineering
PSG College of Technology
Coimbatore, India
vvp.rae@psgtech.ac.in

[2]Robotics and Automation Engineering
PSG College of Technology
Coimbatore, India
msgokul136@gmail.com

[3]Robotics and Automation Engineering
PSG College of Technology
Coimbatore, India
jeevakartik@gmail.com

[4]Robotics and Automation Engineering
PSG College of Technology
Coimbatore, India
sanjayjohnson.sporty@gmail.com

[5]Robotics and Automation Engineering
PSG College of Technology
Coimbatore, India
fazersriram0008@gmail.com

[6]Robotics and Automation Engineering
PSG College of Technology
Coimbatore, India

Abstract

In today's world the use of the robots in industries and in enormous technological applications has seen to be highly impactful. The use of the autonomous systems and their good performance in dangerous tasks is greatly helpful for human beings. Obstacle detection is considered as the primary requirement for an autonomous robot. The obstacle avoidance is an autonomous robot which is used for detecting the presence of an object or an obstacle and avoiding the collision that makes both the robot and the environment safe. To develop an obstacle avoidance robot, it requires desired sensors and motors according to the task. This paper is about developing a robot system which detects the obstacle and avoids the collision. This system consists of an ultrasonic sensor, Arduino Uno microcontroller, and 4 DC motors that make the robot move in an unknown environment. The ultrasonic sensor which is mounted in front of the robot is used to sense the obstacle's presence

and send the detected information to the microcontroller. Based on the information received by the controller, the robot will move forward, backward, right and left. An Arduino microcontroller is mainly used to control the vehicle and to achieve the desired detection and avoidance operation.

Keywords—*Arduino Uno, Ultrasonic sensor, servo motor, DC motor, motor driver module.*

I. INTRODUCTION

The advancement in technologies and artificial intelligence makes the robotics field much more interesting and a fast-growing research area. Robotics technology deals with design, manufacture, and working of robots. Due to their good performance and repetitive work, robots are widely used in many industrial applications. The development of mobile and autonomous robots has been receiving much attention from global manufacturing industries and researchers worldwide. Autonomous mobile robots are multi-task robots that execute different functions using controllers and sense the surrounding information using related sensors. It is mostly used in highly riskier and deeper environments where humans cannot be able to easily access the jobs. In recent years, many obstacle avoidance robots have been developed for warehouse and industry applications, and military applications. This project includes design, development and testing of the obstacle avoidance robot by placing different obstacles. The design process consists of robot construction, customizing the chassis, choosing the suitable microcontroller, selection of sensors based on their efficiency, choosing the rotating parts and interface module. The development process of the robot includes attaching the sensors with servo motors, attaching the microcontroller and rotating parts, and writing codes for the motor rotation and the whole robot operation procedure.

II. LITERATURE SURVEY

Mohammad Nasucha proposed a smart way to develop an obstacle avoidance robot using proximity sensors. The robot is constructed to look small enough with light-weight material. The sensor is placed in a lower position. So that the robot can sense the smaller obstacles in an efficient way. To sense the obstacle, three proximity sensors are used. Generally, a proximity sensor senses or detects the presence of the obstacle by emitting the electromagnetic radiation and it will get reflected back from the obstacle to the receiver. Based on this, the distance will be calculated. The robot is designed with two DC motors at the rear end and a ball-shaped bearing is placed in the front. Based on the force produced by the motorized wheels, the robot will move. Then the ATmega328P microcontroller is used for the robot controller. This system uses two lithium-ion batteries of 4.2V. And the code for the motor rotation and the whole robot operation procedure is written in the C++ language with Arduino compiler [1]. The design of the robot can also be developed by using Subsumption based architecture, a reactive control system for real time obstacle avoidance vehicles. Generally, the reactive robot is designed to explore the unknown environment [2]. Based on the sensor feedback, the robot can move in an unknown environment. Direct detection and avoidance methods include proximity sensor, tilt sensor, gyroscope, accelerometer which gives the response when the robot is in contact with obstacles. Indirect detection and avoidance method is a common method for obstacle detection and avoidance robots because of the range of detection. Sensors like proximity, infra-red sensor, ultrasonic sensors are used for this method [3]. Obstacle detection and avoidance is possible by either autonomous or remote control. By using an android application, the robot can be remotely controlled. The data will be sent from the application and it will be received by the Arduino with the Bluetooth module [4]. For the obstacle avoidance robot, the controller is an important module. For multi-

purposes like pick and place, obstacle detection and avoidance and higher end applications, ARM microcontroller can be used [5]. To sense the presence of the obstacles, IR and PIR sensors are also used but there is a limitation to use these sensors [6]. Obstacle avoidance vehicles have been very helpful for handicapped people. The vehicle can be controlled through voice-command input which is stored in the application. By interfacing the bluetooth module with the controller,this process works [7]. Suppose, if the obstacle robots are used in military applications, the robot does not know which direction to navigate. By using a digital compass and sending the information to the controller, the robot can make movement in the correct direction [8]. In real-time the obstacle detection and avoidance is a serious issue. By using “The Bug algorithm”, the robot can be able to find the smallest distance to reach the destination [9].

III. DESIGN

A. Rotating parts

The robot is designed to use 4 motors (2 wheels at front, 2 at back) which is shown in Fig. 1. The two wheels which are presented on the right side of the robot are connected to the motor drive. Likewise, left side motors are also connected to other output pins of the motor drive. Motor drive makes the robot move in the desired direction based on the sensor output information. A 12V DC motor is used in this project. This motor provides a rotation speed of about 8000rpm. For a smooth operation of the robot, the vibration has to be kept minimum. Silicon based rubber is the most suitable for wheels.

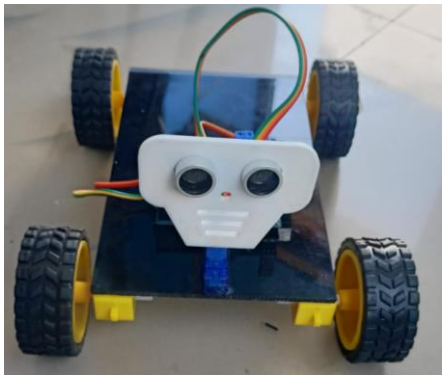

Fig. 1. Wheel Model

B. Microcontroller Board

When it comes to the controller part, there are several controllers available in the market. Identifying the target specification and choosing the correct microcontroller for our project makes the robot much more efficient. For developing the obstacle avoidance robot, the most compatible microcontrollers are Atmel AVR, PIC18F877A, Arduino Uno, AT mega 328P, ARM. These microcontrollers have the same function but differ in the communication protocols, memory and power consumption. After analysing all microcontrollers, Arduino Uno is used in this project which is shown in Fig. 2 . It is an 8-bit microcontroller and it has 32KB of flash memory and it is able to process the data and execute the instructions at a speed rate of 20MPS. The operating voltage of the Arduino Uno is 5V and its attached circuits also operate at 5V. The Arduino Uno board has ATmega328 which is called the brain of the controller board where the program is stored. To control the speed of the

different motors, the microcontroller board has PWM (Pulse width Modulation) which is primarily used for the control of speed.

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Fig. 2. Arduino Uno microcontroller

C. Sensor selection

The main motto of the obstacle avoidance robotic vehicle is to sense the obstacle and avoid the collision. The sensor which is fixed in the robot is able to sense the obstacle by measuring the distance between the robot and obstacle and send the command to the controller. Depending on the obstacle information, the robot will make the move in the desired direction. To sense the obstacle, several sensors are available in the market. Choosing the right sensor for the robot is very important, so that the robots can work smoothly. In practice proximity, infra-red and ultrasonic sensors are widely preferred for obstacle avoiding robots. Basically, IR sensors emit light and get reflected from the object and reflected light will be received by the receiver. Based on this reflection time, the distance between the obstacle and robot will be calculated. Proximity sensors sense the presence of the nearby obstacle without any physical contact. Generally, it emits a beam of electromagnetic radiation which gets reflected by the objects and received by the receiver. When it comes to ultrasonic sensors, it measures the distance between the sensor and object by emitting sound waves, usually between 23KHz and 40KHz. The ultrasonic sensor consists of two parts namely transmitter and receiver. The transmitter emits sound at a certain frequency range and the receiver receives the sound reflected back from the obstacles. By comparing all these sensors, there are limitations in all these sensors. IR sensors will give less accuracy when the obstacle is in transparent or in bright coloured objects. Due to poor tolerance to the reflection of the light, the results may vary. Proximity sensors detect only metallic objects, whereas the obstacles will be either metallic or non-metallic objects. There are no limitations for using the ultrasonic sensor and it gives better accuracy results by comparing others. By considering all these limitations, an ultrasonic sensor is used in this project which is shown in Fig. 3.

Fig. 3. Ultrasonic sensor

D. Chassis selection and design

A chassis is a frame or a supporting structure of a vehicle which allows the robot to carry the robot's circuits, devices and other components. The chassis is responsible for handling the different forces applied by the input load of the robot or some other external forces. While the sensors and motor drivers are attached with the chassis and transmit the forces to the overall robot, so the chassis is considered as the backbone of the robot. The chassis for an autonomous robot needs to be more elegant. Because sometimes the obstacle avoidance robot has to carry the load and needs to reach the destination part safely. For the selection of chassis, shape, width, weight, material and the distribution level of stress is to be considered.To build the chassis of the robot, numerous traditional materials like aluminium, steel frame, wood, carbon fibres are used. A suitable material can be selected depending on the specifications and requirements of the robot. Aluminium can withstand high levels of stress and it is a light-weight material and highly ductile. Steel is a hard material and is highly resistant. So, it can be used in harsh environments. Steel is quite challenging in welding parts and also due to the high weight of the frame the motor rotation speed may vary. Wood is cheap and light-weight, able to withstand a capacity of 3-4Kg and carpentry work is easy when compared to others. But the life-time of the wood material is average. Acrylic sheet is a strong, stiff material and waterproof. It is a light weight material, easy to cut and drill as compared to steel. Carbon fibre is a good choice to build the frame because of absorbing and retaining the vibrations and movements. It is rigid, strong enough and at least 3 times stronger than steel and the weight ratio is more or less than steel. For developing light-weight robots and also has the capacity to withstand 3-4Kg, acrylic sheet material is chosen for this project which is shown in Fig. 4. Next factor is to consider the shape of a chassis. It can boost the load bearing capacity. Some basic shapes for the chassis are rectangle, square, cross and octagonal shaped chassis. Rectangle shaped chassis offer more flexibility and stress level distribution. Next one is the size factor. The size of the chassis is an essential one for the better mobility of the robot. The chassis dimension for this robot should not be either too large or too small.The limitations for the size of the chassis is: When the chassis size is large then the chassis weight would be heavy and there will be a difficulty for the robot in navigating in a small place. When the chassis size is small, the robot will not be able to withstand the high stress distribution. So, keeping this in mind, the chassis dimension for this robot is taken as 200mm×125mm.

IV. CIRCUIT DESIGN

Fig. 4. shows the circuit diagram of the obstacle avoidance robotic vehicle which is developed in the TinkerCad tool. Arduino Uno is the main processing unit of the robot which connects all the sensors and motor drivers of the vehicle. The ultrasonic sensor (HC-SR04) has 4 pins, two supply pins V_{CC}, GND and two control pins namely TRIG, ECHO. The supply voltage of V_{CC} is +5V. The GND pin is connected to the ground. The ECHO pin is connected to pin 8 of the Arduino Uno and the TRIG pin is connected to pin 9 of the Arduino Uno. First need to set the trigger pin on a high state of 10µs to generate the ultrasound. This trigger pin will send the ultrasound which travels at the speed of sound and it will be received by the echo pin. The echo pin will receive the output in microseconds which is the sound wave travelled in time. For example, let's take the obstacle that is 30 cm away from the ultrasonic sensor, then the speed of the sound is 0.034cm/µs. It means that the sound wave will need to travel about 882 microseconds. But the output of the echo pin will show the time in double instead of showing real time because these sound waves have to travel forward and reach the obstacle and then

it bounces back from the obstacle. In order to get the distance between the obstacle and the robot, one must multiply the received travel time from the echo pin by 0.034 and divide it by 2. With this, the sensor is able to find the distance between robot and obstacle. The ultrasonic sensor is mounted with a DC servo motor which has three pins. Two pins for positive and negative supply and the other one is for signal. It is connected with Arduino to get the information. Servo motor is connected to pin3 of the Arduino. Then there is a motor driver (L298N) which is used to control the speed of the wheel motors. In this project, for mobility of the robot four dc motors are used. Two wheels on the right and other two on the left. To control the right-side motors, the output pins 5 and 6 of the Arduino are connected to the L298N Motor drive's input pins of 1 and 2 respectively. For left-side motors, the output pins 4 and 7 of the Arduino are connected to the L298N Motor drive's input pins of 3 and 4. For the required power supply of the robot, a 9V lithium-ion battery is used.

V. OPERATION

First step is to define the required inputs and outputs declarations. The ultrasonic sensor which is mounted with the servo motor is initialized with 90 degree or the middle position. The ultrasonic sensor always senses the presence of the obstacle in each and every second. When the sensor detects the presence of the obstacle, the distance between the robot and the obstacle is calculated in cm. Then the measured distance gets compared with the specified distance. The specified distance for this project is 20cm. If the measured distance is less than the specified distance, then the robot stops moving forward. Then the servo motor turns to the right side or 0 degree of its position and the ultrasonic sensor which is mounted on the servo motor senses the presence of the obstacle. If there is no obstacle, the robot turns right and moves forward until the obstacle finds out. If there is an obstacle on the right side, then the servo motor turns left or 180 degrees and the ultrasonic sensor senses the presence of the obstacle. If there is no obstacle on the left side, the robot turns to the left side and moves forward until the obstacle finds out. Suppose both the left and right side of the vehicle have an obstacle then, the robot moves backward for a certain distance and the ultrasonic sensor senses the presence of the obstacle again. The whole process is repeated and the vehicle is automatically controlled and moved by detecting the obstacle and avoiding them. This is the operation of the obstacle avoidance robotic vehicle which shows in the Fig. 5.

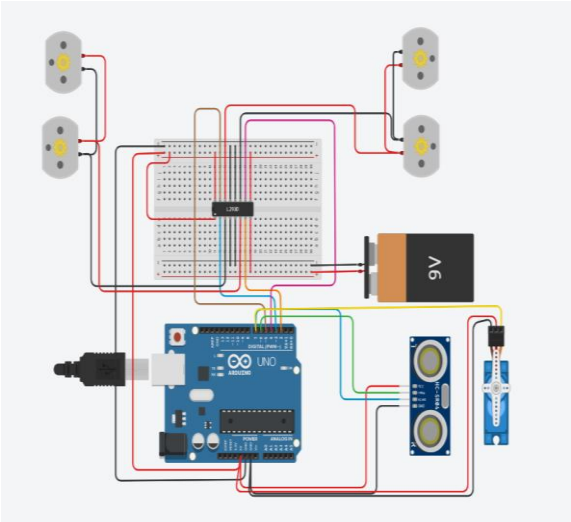


Fig. 4. Circuit diagram

VI. DEVELOPMENT

The whole development process consists of attaching the sensors with servo motors, attaching the microcontroller and rotating parts, and writing codes for the motor rotation procedure and the whole robot operation procedure. The rotating parts consist of four gear motors, two on the right, two on the left. These motors are fixed with the customized wooden chassis. The chassis size has been designed to be suitable to the wheels which is shown by Fig. 6. Attaching the microcontroller and breadboard on the chassis and ultrasonic sensor is mounted on the servo motor which is fixed on the robot front as shown in Fig. 6.

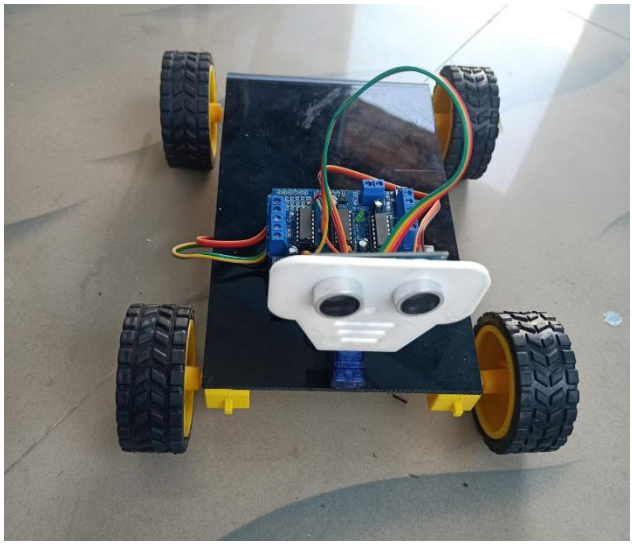


Fig. 6. Obstacle Avoidance Robot

VII. IMPLEMENTATION

The Program includes setting up ultrasonic sensor modules and signals to motor pins for controlling robot direction. Initially defined as TRIG and ultrasonic sensor as mentioned.

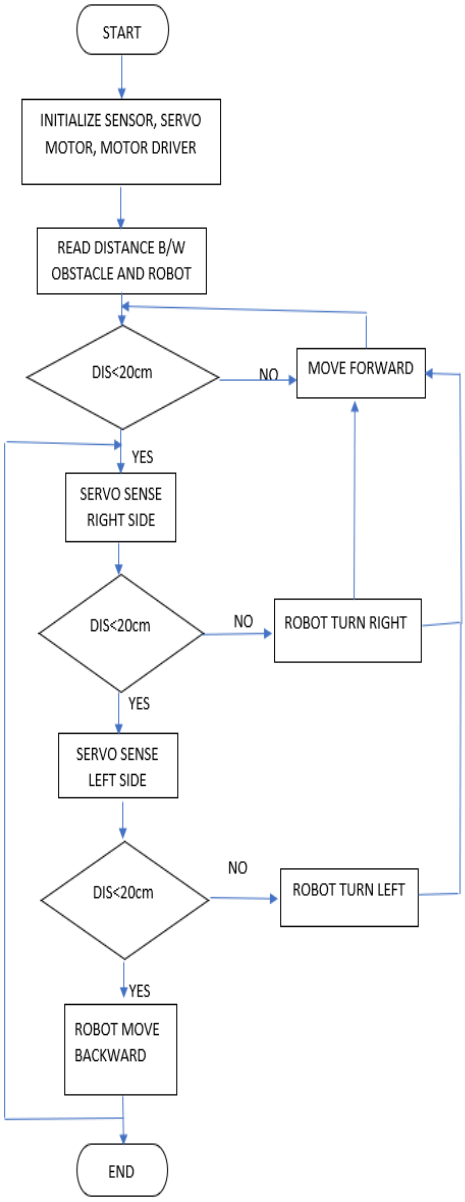


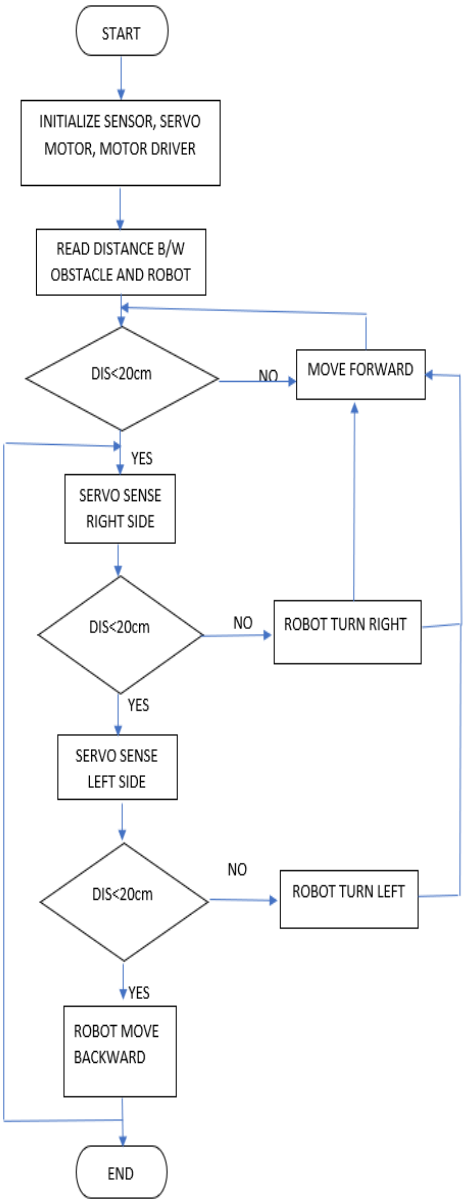
Fig. 5. Flowchart

First of all, the TRIG pin is taken and given connection to the Arduino GPIO9 and then the Arduino port GPIO10 will get connected with the ECHO pin. After that, the pins for the input of the L298N motor driver module are defined. The direction of the motor is controlled using the 4 data pins of the driver module. In the void () setup function, the GPIO pins are defined. The input and output are set as ECHO pins and TRIG pins along with 4 motor pins respectively. Now based on the obstacle's distance from the robot, the distance from the sensor module is obtained in the void loop () function. The robot will move forward or backward depending upon the distance measured by the ultrasonic sensor. Forward for a distance greater than 20cm and backward for a distance lesser than 20cm. For a distance lesser than 20cm the robot stops moving backward and sees left or right and senses. Depending on the detection of the ultrasonic sensor, the robot automatically changes directions to avoid collisions.

VIII. RESULTS AND DISCUSSION

After connecting the components and implementing the code in the microcontroller, the robot is tested by placing obstacles and setting a start and an end point of 2 meter distance. Then tested the robot with three possible cases. a) Without load b) With load1 c) With load2.

Table. 1. Analysis of robot with different Payload



TYPE	TIME (sec)	AVERAGE TIME (sec)
Without Load	20	20
	17	
	23	
With load (1Kg)	27	28.6
	31	
	28	
With load (2Kg)	43	39.7
	37	
	39	

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