ELSEVIER

Autonomous Grabber Robot With Obstruction Detection And Path Finding Capability

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Abstract

This paper illustrates an Autonomous Robot which is basically a manmade four wheeled structure that can detect any obstruction and locate any small object which may come in the path of the robot while traversing and it can hold that object with a mechanical grabber and continue with the directed path. The ultrasonic sensors are included which utilize the concept of ultrasonic sound and act as generators of ultrasonic energy and hence aid in the process of detecting the obstruction & the object. We seek to get better insights into how blind people navigate and to translate this insight into an autonomous navigation strategy useful to mobile robotics. As a programmer one gets an opportunity to teach the robot how to avoid collision thus giving it a human-like property of responding to stimuli.

Keywords: Arduino Severino Project Board, ATMEGA168 Microcontroller, HC-SR04 Ultrasonic Sensor, Servo Motor, L293D Motor Driver IC, Nikon EN-EL20 Li-Ion Battery, Breadboard, Mechanical Grabber, LED, DC Motor, Arduino 0022 Software.

1. Introduction

A robot is a mechanical or virtual intelligent agent that can perform tasks automatically or with guidance, typically by remote control. In practice a robot is usually an electro-mechanical machine that is guided by computer and electronic programming. Robots can be autonomous, semi-autonomous or remotely controlled. By mimicking a lifelike appearance or automating movements, a robot may convey a sense that it has intent of its own. Autonomous Robots are robots that can perform desired tasks in unstructured environments without continuous human guidance. Many kinds of robots have some degree of autonomy. A high degree of autonomy is particularly desirable in fields such as space exploration, cleaning floors, mowing lawns, and waste water treatment.

In this paper, it has been shown that the main technology of the Autonomous Grabber Robot is based on the Arduino Severino Circuit Board where one ATMEGA 168 Microcontroller is mounted [1] . Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing).

2. Literature Review

In recent years, a great deal of time and effort have been spent on developing systems to enable an autonomous robot to follow a path using a vision system. Not surprisingly, the majority of this research has been towards modifying, or designing from scratch, a full-sized road vehicle so that it can drive on ordinary roads without human supervision. Due to the large amount of space available in an ordinary road vehicle, high performance computers can be used to perform complex image processing and, typically, to maintain a mathematical of model of the vehicle and the environment [PW1993] [2] [WSGM1999] [3].

Autonomous vehicles are a relatively new field. There is research on the subject dating back to at least the mid 1970s, however it started becoming a more popular area of research around 1985. From the US Patent Office, over 250 patents have been submitted and over 100 journals have been published relating to autonomous vehicles [4] .

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Extensive research has gone into the projects, papers, and patent which are currently available. The types and uses are extremely varied. Our platform will incorporate some of the features found through our research and also provide the flexibility to grow and change as necessary to include new technologies.

3. Theoretical Aspects

The upcoming different cases are based on the availability of the obstructions and the object.

3.1. Case – I

In the event that no obstruction is there in the given path, the robot will follow the path and when it comes to choosing a direction of turn, the preference will be given to the left direction and only if it is blocked or nonexistent, then the right direction will be availed by the robot to reach the end of the arbitrary path. The path followed is possible because of the four wheel mount of the base.

3.2. Case - II

In that event, there are three obstructions in the path of the robot within the range up to 18 cm. First one is at the front side, second one is at the left side and third one is at the right side. Then, the robot will rotate fully 180 degree on its own axis and will follow its path.

3.3. Case – III

In the event of an obstruction blocking the path ,the grabber will come into action and hold the object blocking its way by utililizing the power of the dc motor and then the robot will continue on its quest to reach the final destination, avoiding collisions of any sort, be it sidewise or from an object in its path. The Light Emitting Diodes (LED) on the robot's face light up when the ultrasonic sensors detect an obstruction in the path at some range up to 18 cm.

4. Some Major Components, Their Specifications and Functions

4.1. HC-SR04 Ultrasonic Sensors

Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object [5] .

Here, 2 HC-SR04 Ultrasonic Sensors are used. One sensor is for detection of the obstruction and another sensor is used to detect an object. Figure 1 shows the HC-SR04 Ultrasonic Sensor. In Table 1, Some of the important specifications of the ultrasonic sensors are listed.

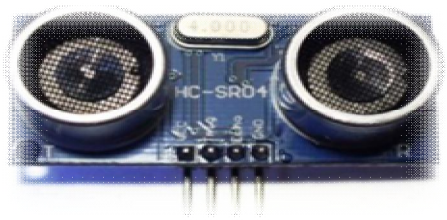

Fig. 1. HC-SR04 Ultrasonic Sensor

Table 1 - Specifications of HC-SR04 Ultrasonic Sensors

Power supply	5 Volt
Quiescent Current	< 2mA
Effectual Angle	$< 15^{O}$
Ranging Distance	2 cm - 500 cm
Resolution	0.3 cm

4.2. Servo Motors

A servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. PWM techniques is used to set the angle of rotation. It consists of a motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors [6] . In Figure 2 and 3, the Servo Motor 1 and Servo Motor 2 have been shown respectively.

Fig. 2. Servo Motor 1

Fig. 3. Servo Motor 2

Table 2 - Specifications of Servo Motor 1

Reference Voltage	4.8 Volt
Stall Torque	≥ 3.6 kg.cm (49.99 oz.in)
Operating Speed	0.23/60 degree at no load

Table 3 - Specifications Of Servo Motor 2

Voltage	6.0 Volt
Stall Torque	≥ 4 kg.cm (55.55 oz.in)
Operating Speed	0.18/60 degree at no load

In Table 2 and Table 3, three main specifications of Servo Motor 1 and Servo Motor 2 are provided respectively.

4.3. Arduino Severino Project Board

The Arduino Severino is a ATmega168 microcontroller based board. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs. The board has also 6 input/output power pins. Arduino can be powered by +9 volt or +5 volt. If, +9 volt pin is not used then external regulated power source can be varied from +7 volt to +20 volt [7] . Here, Figure 4 shows the external view of the Arduino Severino Board and Figure 5 shows the internal circuitry view of that Arduino Board.

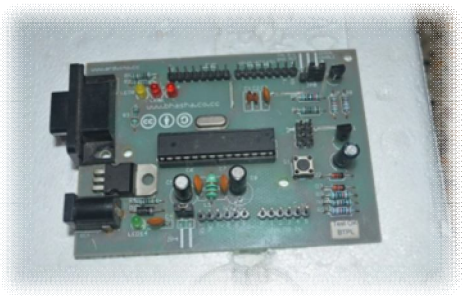

Fig. 4. Auduino Severino Project Board

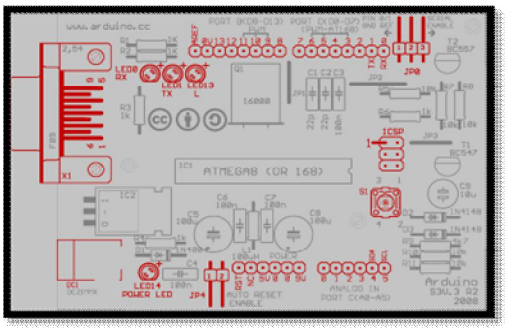

Fig. 5. Internal Circuitry of Auduino Severino Project Board

Arduino Severino Circuit Board has 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button [7]. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

4.4. L293D Motor Driver IC

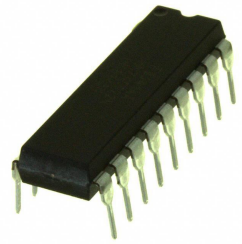

Fig. 6. Motor Driver IC L293D

L293D IC generally comes as a standard 16-pin DIP (dual-in line package). This motor driver IC can simultaneously control two small motors in either direction ; forward and reverse with just 4 microcontroller pins (if enable pins are not used). Supply voltage can be as large as 36 Volts. The logical low in the IC is set to 1.5V. This means the pin is set high only if the voltage across the pin crosses 1.5V which makes it suitable for use in high frequency applications like switching applications (upto 5KHz). One major disadvantage of L293D Motor Driver IC is Output Current capability is limited to 600mA per channel with peak output current limited to 1.2A (non-repetitive). This means, bigger motors cannot be driven with this IC [8] . Figure 6 and 7 illustrates L293D IC and L293D IC Pin Configuration respectively.

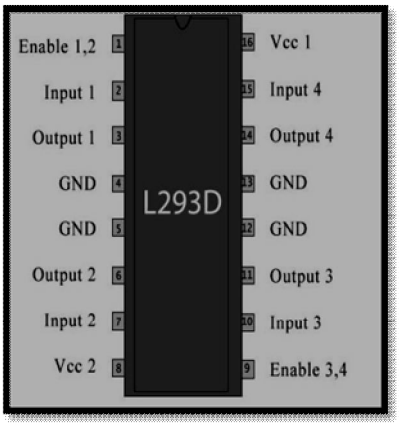

Fig. 7. L293D IC Pin Configuration

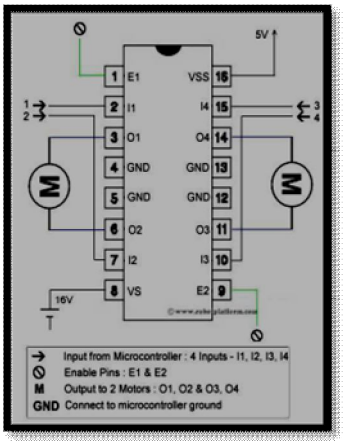

Fig. 8. Two Motors Connected with L293D IC

Figure 8 shows that, the left motor is connected to Pin3 (O1) and Pin6 (O2) , the right motor is connected to Pin11 (O3) and Pin14 (O4). Three pins are required to control any one motor.

In Table 4 , HIGH means +5 Volt, LOW means 0 Volt and X means HIGH or LOW (don't care) [9] [10] .

Table 4 - Truth Table of L293D for Controlling the Left Motor

PIN 1	PIN 2	PIN 7	FUNCTION
HIGH	HIGH	LOW	Turn Anti-Clockwise (Reverse)
HIGH	LOW	HIGH	Turn Clockwise (Forward)
HIGH	HIGH	HIGH	Stop
HIGH	LOW	LOW	Stop
LOW	X	X	Stop

4.5 Power Supply

Figure 9 shows one Nikon EN-EL20 Lithium-Ion Battery of 8.23 Volt which is used as the power supply of the full system [11] .

Fig. 9. Li-Ion Battery

A Lithium-Iion battery (Li-ion battery or LIB) is a member of a family of rechargeable battery types in which lithium ions move from the anode to the cathode during discharge and back when charging.

5. Sectional Representation

5.1. The Basic Structure of The Robot with Mechanical Grabber

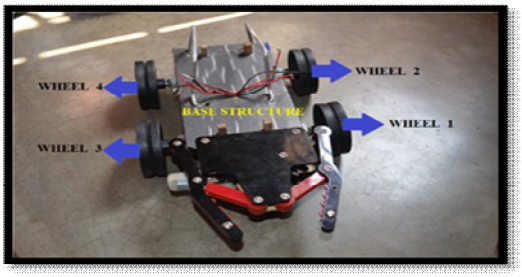

Fig. 10. Top View

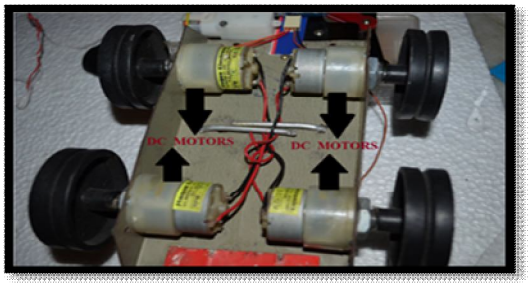

Fig. 11. Back View

This is the basic structure of the Autonomous Robot shown in Figure 10 and 11. It is a four wheeled robot with four dc motors. A mechanical grabber is attached at the front side of the robot so that it can hold any small objects which are irregular in shape.

5.2. Connections of Motor Driver ICs in Breadboard 1

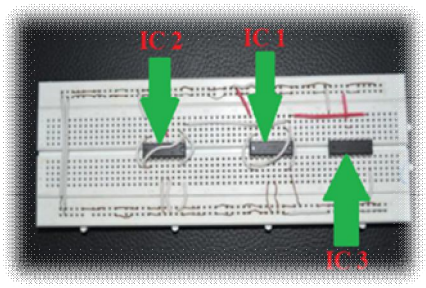

Fig. 12. L293D ICs Connection Diagram

In the Breadboard 1, total 3 Motor Driver ICs are connected via wires with the Arduino Severino Project Board to control four Wheels and the Grabber of the robot as shown in the Figure 12. IC 1, IC 2 are used for the wheels and IC 3 is used for the mechanical grabber.

5.3. Servo Motor 1 and Servo Motor 2

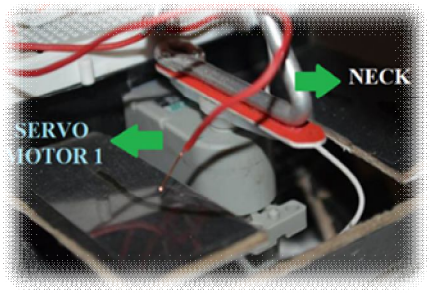

Fig. 13. Servo Motor 1

Figure 13 shows the Servo Motor 1, that is used for the horizontal movement of both the head of the Robot. It is attached at the base of the neck. When, there will be an obstruction, the robot will stop and move around its head to the left side and to the right side i.e; the horizontal movement of the head. That time, Servo Motor 1 works.

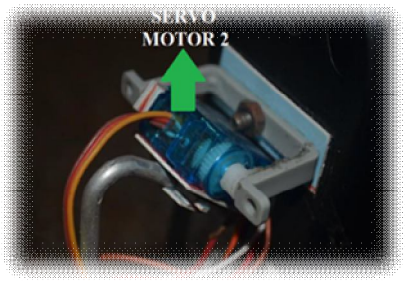

Fig. 14. Servo Motor 2

Figure 14 shows the Servo Motor 2 which is used for the vertical movement of head . It is attached at the back of the head. When, there will be object in the path, the robot will stop, locate the object by going down its head, hold the object by the grabber, going up its head and then it will start to move in its path.

5.4. Ultrasonic Sensor 1 and Ultrasonic Sensor 2

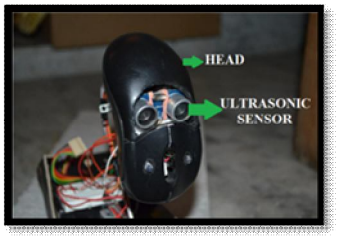

Fig. 15. Ultrasonic Sensor 1

The part shown in the Figure 15 has been assumed as the Head of the Robot. There is an Ultrasonic sensor inside the head which will detect the wall obstruction within the 18cms range from the Robot. There are also two blue LEDs which will glow when an obstruction will come in front of the Robot.

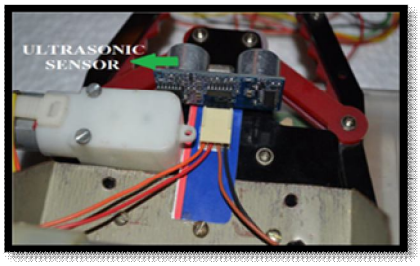

Fig. 16. Ultrasonic Sensor 2

In Figure 16, the 2nd Ultrasonic Sensor has been shown, which is placed under the arm of the Robot and it will detect objects within the 8 cm range from the Robot. The LEDs will glow after, object is sensed by the Ultrasonic Sensor 2.

5.5 Connections Of Servos Motors and Sensors in Breadboard 2

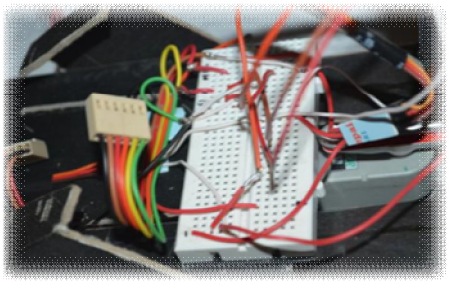

Fig. 17. Servo Motors & Ultrasonic Sensors Coneections

All the Servo Motors and Sensors are connected to the Arduino Project board through this Breadboard 2 as shown in Figure 17 .

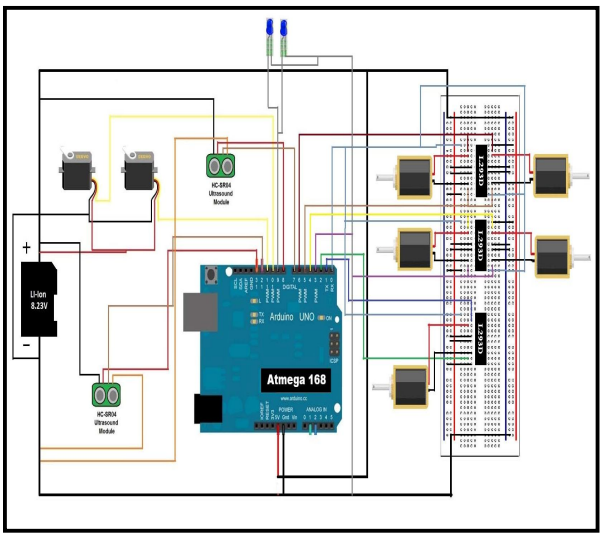

Fig. 18. Overall Circuit Diagram of The Robot

Fig. 18 shows the overall Circuit Diagram of the system. It illustrates the connection of every equipment with the Arduino Severino Board.

7. Circuit Realization

a) Arduino pin +9v is connected to the positive terminal of the battery and the ground pin is connected to the negative terminal of the battery.
b) Pin 0 to 6 are connected to the dc motors through L293D motor driver I.C.
(i) 0 pin is connected to the ENABLE pin of L293D.
(ii) Pin 1,2,3,4,5,6 are connected to pins 1,7,9 and 14 of the three L293D I.C.
(iii) Pin 2,6,10,13 of the three L293D I.C‟s are connected to the positive terminal of the five dc motors.
c) Arduino pin 7,8 and pin 12,13 are connected to the TRIGGER pin and ECHO pin of the two HCSR-04 Ultrasonic sensors.
d) The Vcc and GND terminal of the ultrasonic sensors are connected to the positive and negative terminals of the battery.
e) Pin 10 and 11(PWM pin) are connected to the signal pins of the two servo motors.
f) The positive and negative terminals of the servo motors are connected to the positive and negative terminals of the battery respectively.
g) The positive terminal of the two LED's are connected in a parallel manner with pin 9(PWM) of Arduino and the negative terminals of the LED‟s are connected with the negative terminals of the battery.

8. Functional Block Diagram

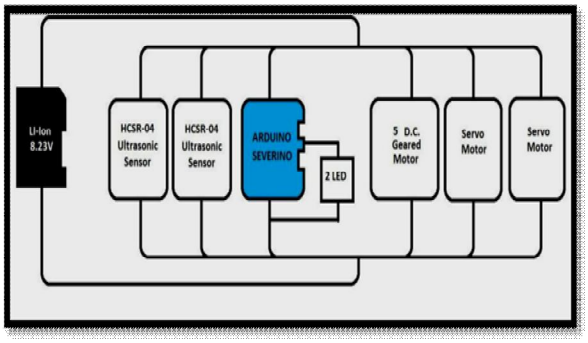

Fig. 19. Overall Functional Block Diagram of The Robot

Figure 19 illustrates the functional block diagram of that Autonomous Robot. Here, all the important components have been arranged according to their functions.

9. Software Tool Used

This Autonomous Robot is totally based on Programming Code. The Coding has been done in simple C Language. Then, the Programming Code is uploaded in ATMEGA168 Microcontroller which is mounted on the Arduino Severino Board. Serial Adder and USB connector are being used for uploading the code in to the Arduino Board. The Software Arduino 0022 is used to write the whole programming code [12] . The window screenshot has been shown in Figure 20.

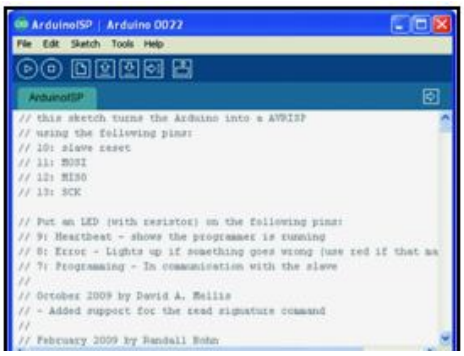

Fig. 20. The Window Screenshot of Arduino 0022 Software

10. Flowchart

Here, Figure 21 illustrates the Overall Flowchart of that Autonomous Robot. The programming code has also been done by keeping the flowchart of the system in mind .

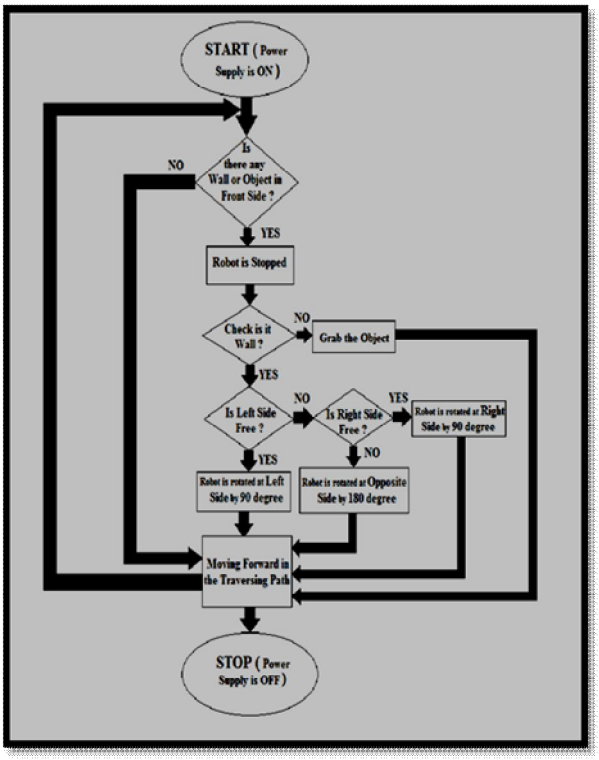

Fig. 21. Overall Operational Flowchart of The Robot

11. Results and Observations

11.1. Step 1

There is no obstruction in front of the Robot , so it is moving along in a straight line as shown in Figure 22.

Fig. 22. No Obstruction, Robot is free to move

11.2. Step 2

In Figure 23, there is an obstruction in front of the Robot in the range of 18 cm from it. No other obstructions are there on the left side or on the right side of the Robot.

Fig. 23. Robot is Stopped due to the Obstruction

Now, in Figure 24 and 25 , it is shown that the Robot is checking its free path in the left and right side by moving around its head.

Fig. 24. Checking Left Side

Fig. 25. Checking Right Side

Then in Figure 26, it is shown that, the Robot takes decision that left side is free. So, it is turning towards its left side by 90^{O} and then moving along the straight path.

Fig. 26. Turned in to the Left Side & Moving Straight

11.3. Step 3

Now, there are two obstructions shown in Figure 27. One is in front of the Robot and another is in the left side of the Robot. Both obstructions are within the 18 cm range from the robot. Right side is free.

Fig. 27. Obstructions are at Front Side & at Left Side

Fig. 28. Checking Left Side

Fig. 29. Checking Right Side

In Figure 28 and 29, the Robot is checking its free path in the left and right side by moving around its head. Then, it takes decision that Right side is free. So, it is turning towards its right side by 90^{O} and then moving along the straight path as shown in Figure 30

Fig. 30. Turned in to the Right Side & Moving Straight

11.4. Step 4

Again, there are 2 obstructions shown in Figure 31. One is in front of the Robot and another is in the right side of the Robot. Both obstructions are within the 18 cm range from the robot. Now, Left side is free.

Fig. 31. Obstruction are at Front Side & Right Side

The Robot is checking its free path in the left and right side by moving around its head as shown in Figure 32 and 33.

Fig. 32. Checking Left Side

Fig. 33. Checking Right Side

Then in Figure 34, it takes decision that Light side is free. So, it is turning towards its left side by 90^{O} and then moving along the straight path.

Fig. 34. Turned in to the Left Side & Moving Straight

11.5. Step 5

Now, there are 3 obstructions as shown in Figure 35. First is in front side, Second is in the left side and third is in the right side of the robot. All obstructions are within the 18 cm range from the Robot. So, no side is free.

Fig. 35. Obstruction are at Front Side, Left Side & Right Side

In Figure 36 and 37, the Robot is checking its free path in the left and right side by moving around its head.

Fig. 36. Checking Left Side

Fig. 37. Checking Right Side

Then, it takes decision that no side i.e; front, left and right side is free. So, it is turning towards the opposite side of its present position by 180^{O} and then moving along the straight path as shown in Fig. 38.

11.6. Step 6

If, there is a small irregular shaped object in front of the Robot within the 8cm range then, the robot is stopped. It will locate the object by moving down its head. This step is shown in Figure 39.

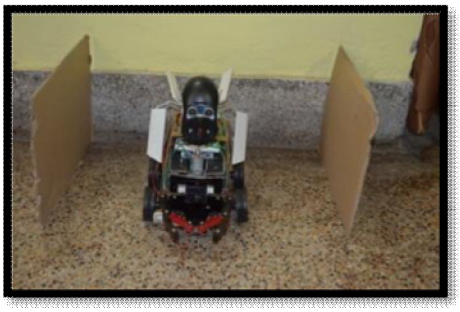

Fig. 38. Turned in to its Opposite Side & Moving Straight

Fig. 39. Small Object is Sensed

Now in Figure 40, the robot grabs or holds that small object by its mechanical grabber and start to move along the straight path.

Fig. 40. Grabbing that Small Object & Robot is then moving Straight

12. Problem During Implementation

Numerous problems arose in the process of making the robot. The initial problem was conceptualization of the entire ordeal. The main encountered problem was the uploading of the program on the Arduino Severino board. The ATMEGA168 Microcontroller was riddled with glitches on various occasions. The wires on the breadboard would often become loose and the robot would stop moving. Many a time proper drilling was required to fit certain new innovative additions such as the steel structures to hold the head of the robot up high.

13. Applications

A fully autonomous robot in the real world has the ability to: Gain information about the environment, Work for months or years without human intervention, Travel from point A to point B without human navigation assistance, Avoid situations that are harmful to people, property or itself Repair itself without outside assistance. Some specific applications are:

- This Autonomous Robot can solve Maze [13] .
- Automated cars running on roads [14] .
- Guidance System for Industrial Robots.

14. Future Scope

Future scope may entail a pressure sensor being used which would be activated on touch giving off an alarming sound and with the help of a mini microphone the corresponding electrical signal is produced for analysis. Two track belts can be used to allow the robot proper movement in difficult terrains. There are cases where smarter versions of maze followers are used. General improvements like using a low dropout voltage regulator, lighter chassis could also be introduced.

15. Conclusion

This paper focuses on the continuous improvement of the principles of robotics and how they can be twisted and tweaked here and there to come up with a solution to solving tricky mazes without any sort of collisions and rmove any object encroaching its path while doing so.

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