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IMPLEMENTATION OF AN OBSTACLE AVOIDANCE ROBOT FOR SURVEILLANCE

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Abstract

This project is aimed at implementing an obstacle avoidance robot using ultrasonic sensor mounted on a servo motor for its movement and navigation without damaging itself. Atmega 328P microcontroller is used to achieve the desired operation and Arduino software was used to carry out the programming. The word "Robot" simply means any man-made machine that can perform work or other actions normally done by humans, either automatically or by remote control. Robotics is the blend of computational intelligence and physical machines (motors). In this project differential drive method will be used as the obstacle avoidance algorithm and the algorithm is implemented in the main microcontroller which is on the mobile robot. The Algorithm implemented is used to avoid the obstacle and to drive the robot to a locally generated goal. The use of servomotor provides great precision rotation as a scanner mechanism for the ultrasonic sensor. This autonomous robot, successfully maneuvered in any given environment without collision, the hardware used in this project is commonly available and inexpensive which makes the robot easily replicable.

Keywords: Ultrasonic Sensor, Microcontroller, Robotics.

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1. Introduction

Over the years' human's interest and logical ability has led in the innovation and invention of tools and machines that some only envisioned as impossible. Robot comes from the Czech word "robota" which means "forced work or labor". Most robots are used to perform tasks that are dangerous to human; they are also used in cars assembly plant, hospitals, military environment and so no. Robotics is a science of modern technology in which machine systems are programmed for general use. Obstacle detection and avoidance been an aspect of robotics, it involves the task of carrying out some preprogrammed objective which is subject to non-collision position constraints. The growing need of unmanned aerial and ground vehicles especially for military surveillance and city wars has made the idea of obstacle avoidance a much desirable. The obstacle avoidance robot is designed to find the way without any sort of external influence through an unknown environment by avoiding collisions or obstructions.

All mobile robots feature some kind of collision avoidance, ranging from primitive algorithms that detect an obstacle and stop the robot in order to avoid a collision. There are some very famous algorithms like wall-following, edge detection, line following and S-shape. These algorithms waste time to cover the entire room for avoiding obstacles. In 1988 a mobile nursing robot system was proposed, it was designed as an aid to bedridden patients who acquire constant assistance for the most elementary need. Such a device was hoped to return a measure of independence to bedridden patients and also reduce the number of people who need hospitalization and constant attendance. (Borenstein and Koren,1988).

The concept of obstacle detection and avoidance works essentially with the aid of robotic sensors. These sensors make available the means for the robot to detect information about the environment and itself. A single sensor integrated into an obstacle detector robotic vehicle is sufficient to navigate the system through its environment, although increase in the number and variety of sensors can greatly increase the ability of the robot to accumulate a more thorough information and understanding of the world around it. Most autonomous robotic systems will have multiple sensors (Brooks, 1986).

Autonomous Intelligent Robots are robots that can execute desired tasks in unstructured environments without continuous human guidance. An autonomous robot is equipped with software intelligence to sense its environment, detect obstacles in its path and move around an unknown environment overcoming the obstacles. There are many robotic designs that are employed in designing of autonomous robots. These designs are usually developed considering the physical environment in which the robot has to be deployed. There are autonomous robots like snake robots, walking robots, autonomous drones and autonomous robotic cars or rovers. Sensors are mainly used to sense physical quantities around is environment like angular and linear acceleration, forces, sound, light, distance and so on. In most cases the first sensor often incorporated into a mobile robot is a distance sensor, which is can also be called an Ultrasonic sensor. Ultrasonic sensors are not affected by dust, dirt or high-moisture environment and they are easier, cheaper and computationally friendly. Ultrasonic transducers are preferable in obtaining three-dimensional information from the environment (Borenstein and Koren, 1988).

Robot are incapable to think or make decision, whenever environmental changes occur robots can run into objects, therefore it is necessary for the robot to be able to adjust to the changes by avoiding any object in it pathway. The problem of path planning is what has led for the need of a robot to detect and avoid objects in a pre-computed path, or objects that suddenly appears. The solution to this path planning problem involves the use of a sensor and servomotor to detect objects and avoid them thereby improving on time management, accuracy and precision in the delivery of services. The aim of this research work is to develop an obstacle avoidance robot with the ability to detect obstacles on its path and avoid collision using random walk algorithm. Normally obstacle avoidance is considered to be distinct from path planning in that one is usually implemented as a reactive control law while the other involves the pre-computation of an obstacle-free path and a controller that will guide the robot along.

Saddam (2016) built Raspberry Pi based obstacle avoiding robot using ultrasonic sensor were Raspberry Pi and Motor driver was use to move the robot while Ultrasonic sensor for detecting objects in the path of Robot. Amruta et al 2017, built an autonomous robot using Raspberry Pi as a processing chip. An HD camera was used to detect obstacles from the surrounding. Aryuanto Soetedjo et al, 2019 developed a wall-following obstacle avoiding robot using a Fuzzy Logic Controller. The Fuzzy Logic Controller was employed to steer the mobile robot to follow the wall and avoid the obstacles using multi sensor inputs. The experimental results show that the developed mobile robot could be controlled properly to follow the different wall positions and avoid the different obstacle positions with the high successful rate of 83.33%. RaghavTola et al, 2020 presented the prototype design of real-time line tracking and obstacle avoiding robot, the robot is designed around Raspberry Pi microcontroller and python was used for coding. It had a good near range obstacle detection but was limited by indoor use only. TS Arulananth, M Baskar, 2020 designed an IR sensor-based obstacle detection and avoiding robot. This robot uses an IR sensor to detect the objects or obstacles in its path. Then uses a relay-based switching mechanism to control its motion and to avoid the obstacles. It was a small attempt to make use of basic electronic components in order to build detection and avoidance mechanisms so that anyone with basic knowledge of electronic can easily understand and implement it.

2. Robotics and Robots

Robotic is a branch of technology that deals with designing, construction, operation, and application of robots using computer systems for their sensory, control, information processing and feedback, also require knowledge on mechanics, electronics, and programming skills. These technologies deal with automated machines that can replace humans in manufacturing companies or dangerous environments also have similar features like humans in terms of behavior, appearance, and/or recognition. Robots are machines and are of a wide range. The common feature of robots is their capability to move, perform physical tasks like lifting an object, for surveillance purpose and so on. They range from industrial robots, whose appearance is dictated by the function they are to perform or humanoid robots, which mimic the human movement and other form.

Robots can be grouped generally based on the task it performs, structure, and operation of the robots:

- Manipulator robots;
- Mobile robots; and
- Self-reconfigured robots.

Robots may act according to their own decision-making ability, provided by artificial intelligence or by the information stored in there memory, and controlled directly by a human using remote-control. However, majority of robots falls into the category of being controlled by pre-programmed computers.

3. The Description of Components for Obstacle Avoidance Robots

The interconnections of the various components for the development of obstacle avoidance robot are shown in figure 1 below, which comprises of power supply unit, sensing unit, controller unit, motor driver unit.

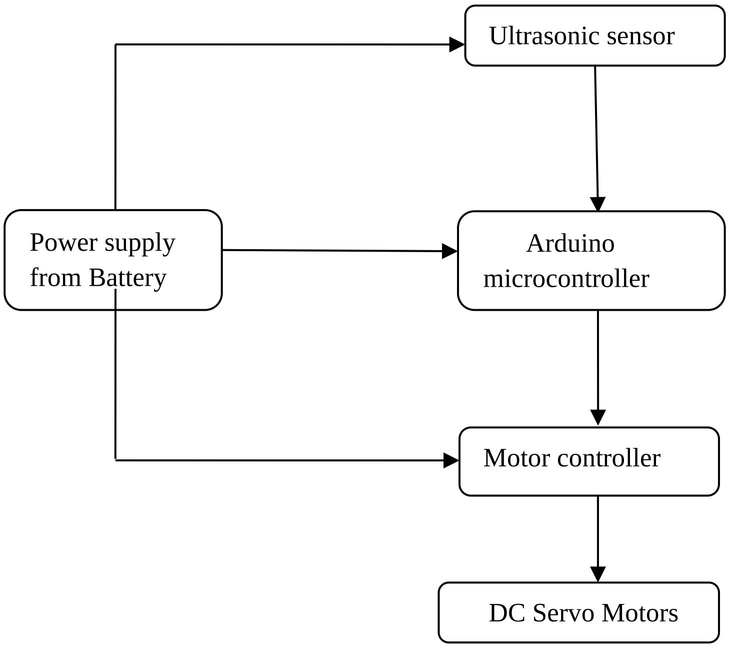

Figure 1: interconnection diagram of obstacle avoidance robot.

3.1 Power Supply Unit (Battery)

Power supply unit is from a lithium battery due to their high current density. Lithium ion (Li-ion) batteries are mainly used as primary power source for portable electronics, despite the charging limit of the battery to avoid damaging the cell and causing hazard to the environment. Fortunately, today's Li-ion batteries are more robust and can be charged far more rapidly using "fast charging" techniques. The concept behind lithium-ion (Li-ion) batteries is simple but took about four decades for researchers to develop the technology that now makes it more reliable powers source for today's portable electronics products. The earliest cells were fragile and prone to overheating during charging, but developments have corrected those effect. Nonetheless, recharging still needs to follow a precise regimen that limits charge currents to ensure full capacity is reached without overcharging with its associated risk of permanent damage. The good news is that recent developments in materials science and electrochemistry have increased the mobility of the cell's ions. The greater mobility permits higher charge currents and speeds up the "constant current" part of the charging cycle.

Li-ion battery charging follows a profile designed to ensure safety and long life without compromising performance. If a Li-ion battery is deeply discharged (for example, to below 3 V) a small "pre-conditioning" charge of around 10% of the full-charge current is applied. This prevents the cell from overheating until such a time that it is able to accept the full current of the constant-current phase. In reality, this phase is rarely needed because most modern mobile devices are designed to shut down while there's still some charge left because deep discharge, like overcharging, can damage the cell. the battery is typically charged at a constant current of 0.5 C or less until the battery voltage reaches 4.1 or 4.2 V (depending on the exact electrochemistry). When the battery voltage reaches 4.1 or 4.2 V, the charger switches to a "constant voltage" phase to eliminate overcharging. Superior battery chargers manage the transition from constant current to constant voltage smoothly to ensure maximum capacity is reached without risking damage to the battery.

Figure 2: Power Supply Unit

3.2 The Servo Motor

They are used as the rotary actuator that allows for precise control of angular position, velocity and acceleration of the robot based on the information received from the ultrasonic sensors. It consists of a control circuit that provides feedback on the current position of the motor shaft; this feedback allows the servo motors to rotate with great precision.

Servo motors are good in rotating an object at some specific angles or distance. They are made up of a simple motor which runs through a servo mechanism. Servo motor when powered from a DC power supply it is called DC servo motor, and when powered from AC source, it is called AC servo motor. Apart from these major classifications, there are many other types of servo motors based on the type of gear arrangement and operating characteristics. A servo motor usually comes with a gear arrangement that allows us to get a very high torque servo motor in small and lightweight packages. Due to these features, they are being used in many applications like toy car, RC helicopters and planes, Robotics, etc. Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm describes how much weight the servo motor can lift a load at a particular distance. For example: A 6kg/cm Servo motor is able to lift 6kg of load suspended about 1cm away from the motors shaft, the longer the distance the lesser the weight carrying capacity.

3.2.1 The Working Principle of a servo motor

They consist of an electric Motor either DC or AC, a potentiometer, gear assembly, and a controlling circuit. The gear assembly system is used to reduce speed and to increase torque of the motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now the difference between these two signals, one comes from the potentiometer and another comes from other sources, will be processed in a feedback mechanism and output will be provided in terms of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with the potentiometer and as the motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating. Interfacing the Servo motors like s90 servo motor with MCU is very easy. Servos have three wires coming out of them. Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU. An MG995 Metal Gear Servo Motor which is most commonly used for RC cars humanoid bots etc. The picture of MG995 is shown below:

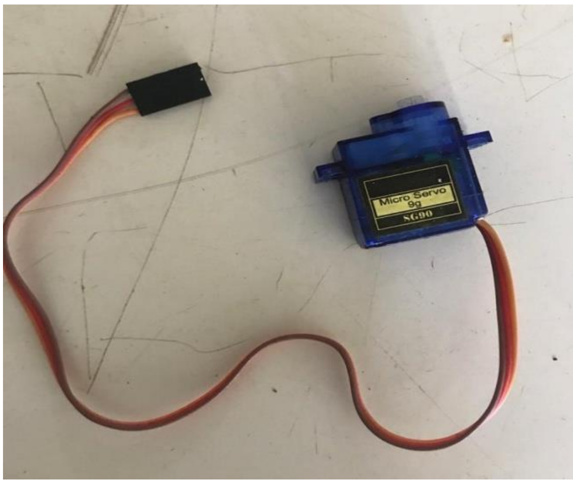

Figure 3: Pictorial view of Servo motor

All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume if you are planning to use more than two servo motors a proper servo shield should be designed. All motors have three wires coming out of them. Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU. Servo motor is controlled by PWM (Pulse Width Modulation) which is provided by the control wires. There is a minimum pulse, a maximum pulse and a repetition rate. Servo motor can turn 90 degrees from either direction form its neutral position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°. Servo motor works on PWM (Pulse width modulation) principle, means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears. High speed of DC motor is converted into torque by Gears. We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High and distance is less. The potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on the required angle. Servo motor can be rotated from 0 to 180 degrees, but it can go up to 210 degrees, depending on the manufacturing. This degree of rotation can be controlled by applying the Electrical Pulse of proper width, to its Control pin. Servo checks the pulse in every 20 milliseconds. The pulse of 1 ms (1 millisecond) width can rotate the servo to 0 degrees, 1.5ms can rotate to 90 degrees (neutral position) and 2 ms pulse can rotate it to 180 degrees. All servo motors work directly with your +5V supply rails but we have to be careful about the amount of current the motor would consume if you are planning to use more than two servo motors a proper servo shield should be designed.

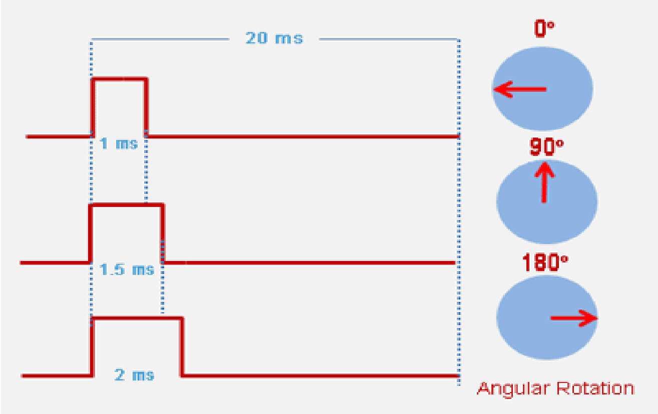

Figure 4: Servo Motor Rotational Operation

3.3 Microcontroller

A single board microcontroller is used to coordinate and control the function of servo motor and ultrasonic sensor. It sends angular information to servo motor on which the robot moves to a specified direction and making the sensors to work with respect to that direction. Arduino drives the motor according to sensors' output.

3.4 Motor Driver

Motor driver used is based on L298 motor shield. This motor driver module is a high power motor driver module for driving DC and Stepper motors. Motor driver is used for driving motors because Arduino does not supply enough voltage and current to motor. Arduino sends commands to this motor driver and then it drives motors in any direction as we want. The ultrasonic sensor, servo motor and motor driver are connected to microcontroller. The MCU reads the digital input from the ultrasonic sensor, sending this data to the motor driver and also positioning the servo. The ultrasonic sensor continuously emits waves which within a given range are reflected as echo. Echo of these waves is received by the receiver and is processed by the microcontroller based on the embedded design. Based on the design, the time required for the emitted signal to be received as echo can be calculated. Consequently, it detects object, calculates the distance and moves right or left to avoid collision with detected obstacle.

3.5 Acrylic Sheet

Acrylic sheet is used to construct the body of the robot. This material has unique physical properties and performance characteristics. Acrylic sheets are less in weight and highly durable. It is also an excellent insulator, so that the electronics and electrical parts of the robot are safe in terms of electrical hazards.

3.6 Wheels

The wheel is the final stage of the drive-train. It is what makes contact with the ground to propel the robot. A larger wheel diameter travels farther than a shorter wheel diameter. Logically, this makes sense because each time the motor output shaft makes one complete revolution, the bot must travel the same distance as the outer circumference of the wheel. So a larger wheel travels faster than a smaller one, using the same motor RPM.

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Figure 5: Wheels

4. Methodology

In this research work, the hardware and software implementation were demonstrated for an obstacle avoidance robot.

4.1 Hardware Implementation

The choice of material for the robot based on the specification of the ultrasonic sensor was discussed in this section. These include Microcontroller Unit arduino-uno, Ultrasonic Sensor, Motor driver, Servomotor, Power Supply Unit (lithium battery), Acrylic Sheets and Wheels.

4.1.1 Ardino-uno Microcontroller

The microcontroller deployed on this research work is Arduino ATmega 328P, the primary function of this controller is to: (1) Read the digital input signal from the ultrasonic sensor when sensing obstacle; and (2) Send control signal to the motor driver for proper positioning of the servo motors.

4.1.2 Motor Driver

The motor driver used for this research work is L298N motor driver module; it is a high power motor driver use mainly to driving DC and Stepper Motors. This module consists of an L298 motor driver IC and 78M05 5V voltage regulator, resistors, capacitor, Power LED, 5V jumper in an integrated circuit. L298N Module can control up to 4 DC motors, or 2 DC motors with directional and speed control. The 5V voltage regulator is enabled only when the jumper is placed, if the power supply is less than or equal to 12V, then the internal circuitry will be powered by the voltage regulator and the 5V pin can be used as an output pin to power the microcontroller. The jumper should not be placed when the power supply is greater than 12V and separate 5V should be given through 5V terminal to power the internal circuitry. ENA & ENB pins are speed control pins for Motor A and Motor B while IN1& IN2 and IN3 & IN4 are direction control pins for Motor A and Motor B. Internal circuit diagram of L298N Motor Driver module is given below:

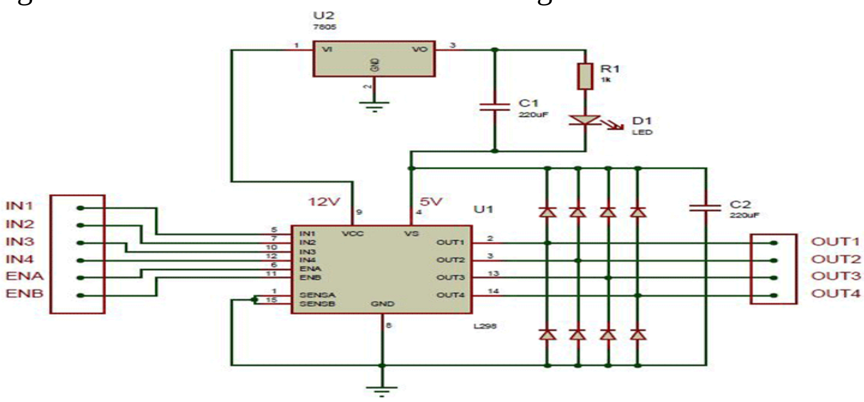

Figure 6: Motor Driver Circuit Diagram

4.1.3 Ultra Sonic Sensor

Ultrasonic sensor is the main component that causes the vehicle to avoid obstacle. This sensor is mounted on the servo motor to scan it environment for possible obstacle location.

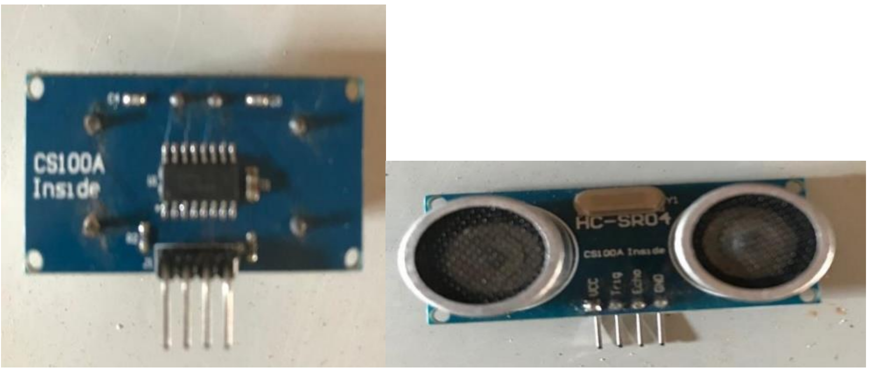

Figure 7: Ultrasonic Sensor

The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object like bats do. It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use package. It comes complete with ultrasonic transmitter and receiver modules.

The transmitter (trig pin) sends a signal: a high-frequency sound. When the signal finds an object, it is reflected and the transmitter (echo pin) receives it. The time between the transmission and reception of the signal allows us to calculate the distance to an object. This is possible because we know the sound’s velocity in the air.

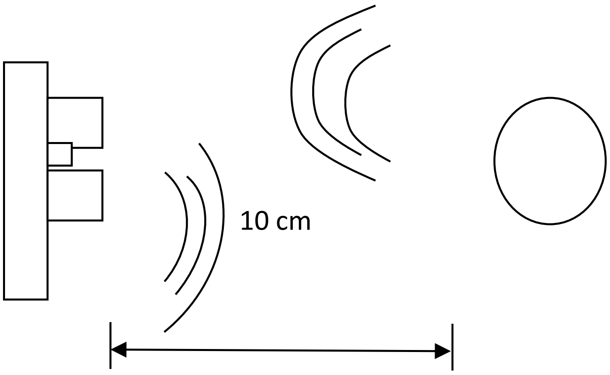

Figure 8: Object distance from the sensor

For example, if the object is 10 cm away from the sensor as shown in figure 8, and the speed of the sound is 340 m/s or 0.034 cm/µs the sound wave will need to travel about 294µ seconds.

That is, Time = $\frac{\text{Distance}}{\text{Speed}} = \frac{10}{0.034} = 294\mu s$

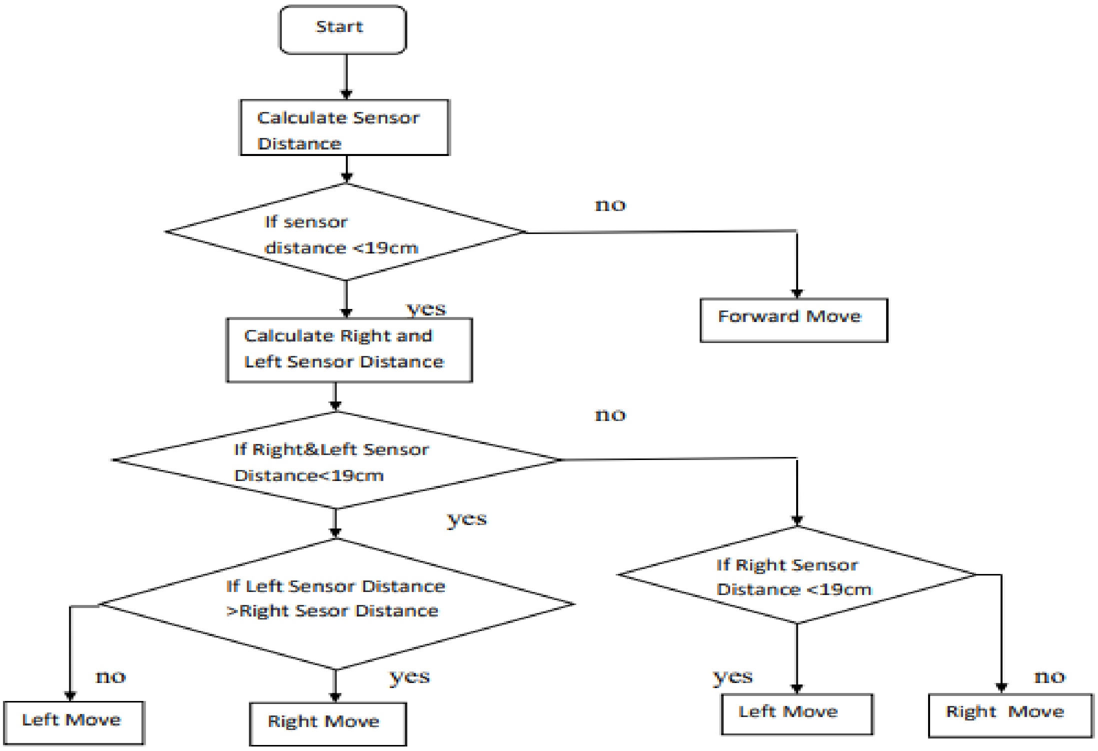

Figure 9: The flow chart representation for an obstacle avoidance robot.

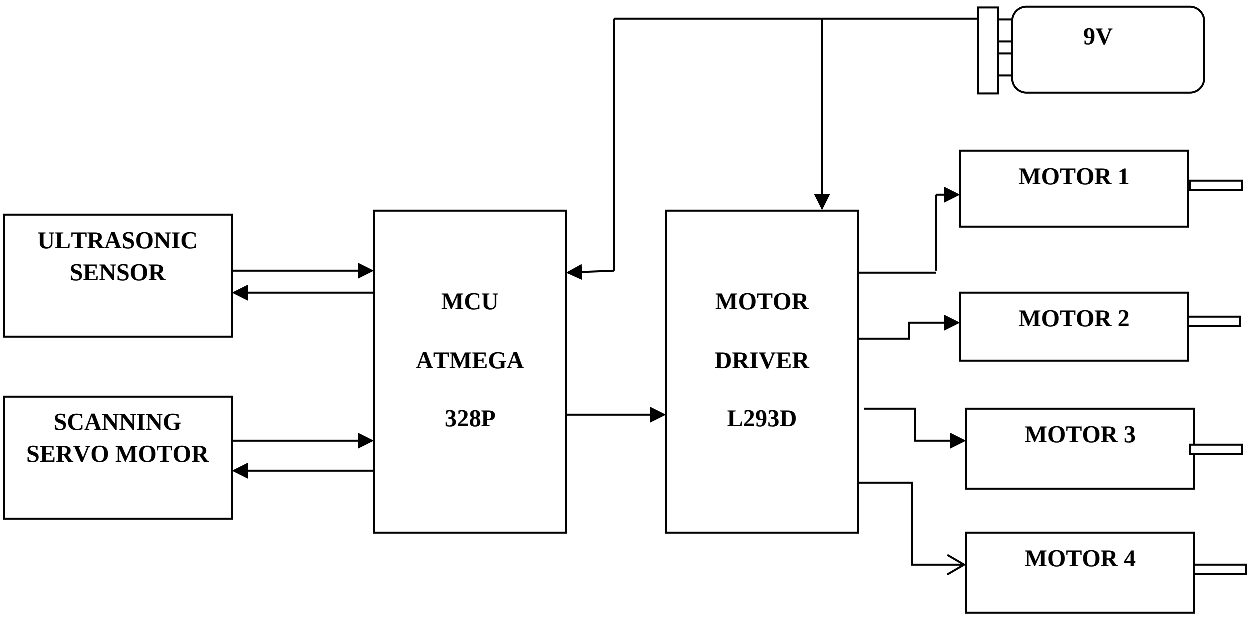

Figure 10: The Hardware Implementation of an obstacle avoidance Robot.

5. Testing and Results

Several testing process was conducted ranging from the component testing and implementation stage.

i. Bread boarding testing: In this method components were used in real time hardware to do the circuit interconnections without soldering work. The purpose for this type of testing is to conduct testing for every stages of the design work, to see if they will respond to the design intentions.

ii. Component testing: Involves testing each individual component, checking to see whether the component values are correct.

a. **Testing of Equipment**

Electronic test equipment's are used to create signals and capture responses from the device under test. There are various types of test equipment used during for this research work. The following are the type of test tools used to create stimulus for the circuit under test.

i. Power supply unit.
ii. Signal generator.
iii. Pulse generator.

While digital multi-meter was used to capture the responses from the test conducted.

5.2 Testing Procedures

The work was tested after the construction was completed; the testing procedure is as follows:

i. After the construction work was done continuity testing was carried out using digital multi-meter, to check for possible short circuits.

ii. After this procedure dc power was applied, the voltage across the PSU was tested using multi-meter to see if the supply is at the rated volt.

5.3 Performance evaluation

Table 1: Performance evaluation table

Type of Environment	Obstacle	Detect obstacle	Avoid obstacle	Accuracy(%)
Well-lighted room	Solid objects	Yes	Yes	98%
Dark room	Solid and semi solid objects	Yes	Yes	80%
Semi-lighted room	Solid objects scattered	Yes	Yes	90%
Clear terrain	Solid objects	Yes	Yes	98%
Unclear terrain	Tightly clustered objects	Yes	No	47%

6.0 Conclusion

The implementation of obstacle avoidance was constructed with the aid of an ultrasonic sensor that helps to sense the environment and giving back report to microcontroller (Ardino-uno) with the help of the written program language in the Microcontroller unit. The robot was able to produce the basic walking movements using DC motors capable of sensing obstacle and perfectly maneuvering obstacles on its path at a distance range of 30cm. the robot uses the left, right, forward and backward movement to avoid the obstacle autonomously. The accuracy recorded from several testing trials showed that the robot performed well scoring 85% considering the scope under which it was examined.

6.1 Recommendation for Future Works

In the future, Global Positioning System (GPS) and camera can be used with this technology to control and operate the robot without human interference.

References

1. Amruta et al. (2017). An Autonomous Robot using Raspberry Pi, Global Journal of Research in Engineering, pp13-15
2. Arulananth TS., & M Baskar. (2020). IR Sensor based obstacle detection and avoiding robot, Palarch's Journal of Archaeology of Egypt/Egyptology vol.17, pp9
3. Aryuanto Soetedjo et al. (2019). Implementation of fuzzy logic controller for wall following and obstacle avoiding robot, Journal of Applied Intelligent System vol. 4, pp7-9.
4. Aziza M. et al. (2014). Microcontroller based mobile robot positioning and obstacle avoidance, Journal of Electrical Systems and Information Technology Vol.1, pp 58 –71
5. Barik, R., et al. (2013). An interactive robotic design for object detection and follow up action. Proceedings of the International Conference on Computing, Communication and Sensor Network, pp: 32-37
6. Baskar, M. (2020). IR sensor based obstacle detection and avoiding robot. Journal of Engineering and Technological Science, vol. 43, no. 7, pp. 138-169.
7. Borenstein, J., Koren, Y. (1988). Obstacle avoidance with ultrasonic sensors, IEEE Journal of Robotics and Automation, vol.4, no. 2, pp. 213-218.
8. Borenstein, J, Koren, Y. (1991). The vector field histogram-fast obstacle avoidance for mobile robots, IEEE Transactions on Robotics and Automation, vol. 7, no.3, pp. 278-288.
9. Budiharto. W. (2014). Design of tracked robot with remote control for surveillance, in Proceedings of the IEEE International Conference on Advanced Mechatronic Systems (ICAMechS), pp. 342-346.
10. Chih-Hao, C et al. (2005). Complete Coverage Motion Control of a Cleaning Robot Using Infrared Sensors, Proceedings of the 2005 IEEE International Conference on Mechatronics (pp. 17-25).
11. Demidenko, S. (2008). Towards a Simple Mobile Robot with Obstacle Avoidance and Target Seeking Capabilities using Fuzzy Logic", Instrumentation and Measurement Technology Conference Proceedings, pp. 1003-1008.
12. Dudek. G and Jenkin. M. (2018). Computational Principles of Mobile Robotics, Cambridge University Press, New York, pp. 20-100
13. El-Halawany, B.M. et al. (2012). Vision-based obstacles detection for a mobile robot, A Informatics and Systems (INFOS), vol. 6, no.17-27.
14. Ganapathy. (2009). Fuzzy and Neural controllers for acute obstacle avoidance in mobile robot navigation, IEEE/ASME International Conference on Advanced Intelligent Mechatronics. pp. 1236-1241.
15. Grefenstette. J and Schultz. A. (1994). An Evolutionary Approach to Learning in Robots, Machine Learning Workshop on Robot Learning, New Brunswick, pp. 19-44.
16. Margolis, M. (2012). Make an Arduino-Controlled Robot. O'Reilly Media, Inc., USA., ISBN: 9781449344375, Pages: 238
17. RaghavTola et al. (2020). Real time line tracking and obstacle avoidance robot. 3RD International Conference on Condensed Matter and Applied Physics, pp. 4-8
18. Ram, B. (2016). Fundamental of Microprocessors & Microcontrollers, Dhanpat Rai Publication,Seventh Edition, ISBN:978-81-89928-60-5

19. Saddam M. (2016). Raspberry Pi based obstacle avoiding robot using ultrasonic sensor, in Proceedings of the IEEE International Conference on Advanced Mechatronic Systems, pp. 16-34
20. Santoso, D. (2012). A new obstacle avoidance method for service robots in indoor environments," Journal of Engineering and Technological Science, vol. 44, no. 2, pp. 148-167.