DESIGN AND DEVELOPMENT OF A ROBOTIC MECHANISM FOR PATH PLANNING

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ABSTRACT- The main focus of this project was to design and develop the robotic mechanism for path planning in unknown environment. The proposed mechanism allows a mobile robot to navigate through static obstacles, and finding the path in order to reach the target without collision. This mechanism provides the robot the possibility to move from the initial position to the final position (target). The robot moves within the unknown environment by sensing and avoiding the obstacles coming across its way towards the target. When the mission is executed, it is necessary to plan an optimal or feasible path for itself avoiding obstructions in its way and minimizing a cost such as time, energy, and distance. The proposed path planning must make the robot able to achieve these tasks: to avoid obstacles, and to make one's way toward its target. This mechanism is equipped with Arduino micro controller, ultra-sonic sensors to detect the obstacles in the path of given environment where it moves. The Arduino board microcontroller was chosen as the platform and Arduino Software, was used to carry out the programming. The hardware used in this project is widely available and inexpensive which makes the robot easily replicable. This robotic mechanism was under testing and validating its performance and the results indicate that it can perform its task by deeding the path properly. Therefore, it was designed and programmed to accomplish accurately safe path without obstacles to assist in the production line in any industry.

Keywords Arduino , Design , Obstacles , Path detection , Robotic mechanism

1- INTRODUCTION

Robotics is defined as the branch of technology that deals with the design, construction, operation, and application of robots. Robots are generally used to perform unusual, unsafe, hazardous, and unpleasant tasks instead of using manpower (Punna et al., 2015). And also, they are widely used in manufacture, assembly, packing, transport, earth and space exploration, surgery, weaponry, laboratory research, and mass production of consumer and industrial goods (Elfasakhany et al., 2011). Robots are now widely preferable in factories to perform high precision works where it contains electronic circuits and movements can be controlled by signals from a computer or from software installed into the robot (Olson, 2000). However, designing an efficient navigation strategy for robots and ensuring their securities are the most important issues in robotics. Motion being a vital characteristic of mobile robots in obstacle avoidance and path recognition. This enables an autonomous robot to be able to navigate from one place to another without human intervention.

Mobile robot development has been receiving attentions from researchers worldwide in recent years, especially in developing autonomous mobile robots. Therefore, the path planning and obstacles detecting problem is one of the most interesting and researched topics nowadays. Earlier, sonar was used for vehicle localization and navigation. Unfortunately, the major drawback of sonar is that a single sensor is inadequate to acquire enough information about environment around an autonomous vehicle (Madhavan and Whyte, 2004). Cruz et al., 2013 presented the use of vision and laser scanner for unknown planet to avoid obstacle. The use of radar, infrared (IR) sensor and ultrasonic sensor for developing an obstacle detection system had started as early as the 1980's (Hatem et al., 2018). A study on the use of industrial robot in various industries in America has been conducted. Finally, the use of ultrasonic sensor for an obstacle avoidance robot vehicle to create a clear path for locomotion (Azeta et al., 2019).

The aim of this developed strategy is to solve the problem when the robotic mechanism is located between two obstacles such as the following: how the robot can detect that the distance between the two obstacles is safe enough to reach the target without collision and how to avoid obstacles and move between two obstacles. That is why this work is based on detecting obstacles in an environment encumbered by obstacles firstly. After that, Arduino coding is applied to develop turning distance to determine the endpoint of the path.

2. MATERIALS & METHODS

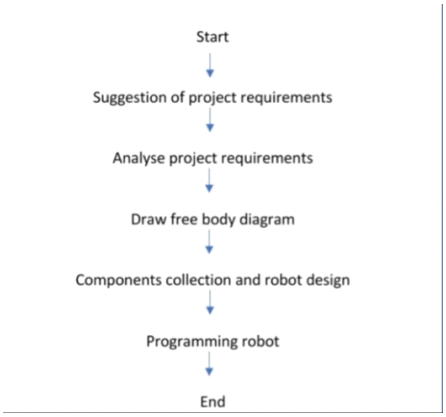

Figure 1: Overall research methodology in brief.

This section discussed the compositions of the hardware components needed to design the overall mobile robot and the development of robot control coding, used for designing and constructing the project. In this work, the research was carried out following the procedures shown in Figure 1.

First the requirements of the robot were suggested based on the expectations from the project itself. Then they were analyzed and further, required devices and components were selected and finally, overall robot design with hardware needed was modelled and Arduino coding was developed in Arduino software.

Here, the robot was developed based on the following requirements.

- Robot should be light in weight for reducing power consumption from the given 6V battery.
- The robot should be controlled by a switch attached to battery.
- The application coding should allow the robot to be controlled for moving forward, backward and turning right while detecting obstacles.
- It should be able to avoid a preceding obstacle (within 20cm) while moving.

2.1 Hardware Design

During this design process, various modifications were made to the model and errors were corrected to enable proper meshing of parts and simulation. Then, the design was fabricated using the requirements of the robot which were collected based on the expectations from the project itself. The robotic frame is with two front wheels, made up of plastics which are attached directly to the Direct Current (DC) motor and a caster wheel was used as a rear wheel due to its light weight and also to avoid overload of the mobile robot. The bodywork of the robot was designed to accommodate all the essential component of the system.

2.2 Electrical and Electronic Components of the Robot

The system consists of power supply unit (AA R6 typed 1.5V four batteries), ultrasonic sensor, Arduino Microcontroller (MCU) and the geared DC motors, DC motor drive (L298N). The Arduino Uno is a microcontroller board based on the ATmega328 processor. It consists of 14 digital input/output (I/O) pins (6 of the pins can be used as PWM (Pulse Width Modulation) outputs), 6 analogue inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. This is a preferred choice because of its power consumption and relatively cheap. Ultrasonic sensor was used in order to improve on sensitivity and reliability of existing systems.

An Arduino Uno R3 microcontroller was selected since it enables full control of the robot. Motor driver circuit helps to control the mobile robot using two front wheels. The control mechanism from the MCU is based on PWM signal. The PWM signal with high percentage of availability means that full power is applied to the motor. While 0 percentage of the PWM signal means there is, no power applied to the motor, hence, the robot is stationary. A 6V AA R6-typed battery was used to power up the entire robot circuit. Ultrasonic sensor (HC-SR04) was used based on ultrasonic wave emitted from the sensor and it helps to identify if an obstacle appearing in front of the mobile robot. It was placed just on top of the robot high enough to follow the path to avoid hitting the obstacle. The circuit was designed using Circuito.io as shown in Figure 2.

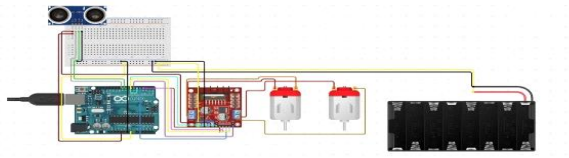

Figure 2: Schematic circuit diagram of the robot

This robot circuit was developed according to the Arduino coding what we code. In the Arduino coding, first two DC motor wires Left Motor(LM) and Right Motor(RM), joining with Arduino Uno was defined as,

```
int LM_pin1 =8;
int LM_pin 2=9;
```

for left motor and also similarly to right motor as well joined to the pins 10 & 11 in Arduino Uno board.

Then, the pins in the ultrasonic sensor (trigpin and the echopin) was defined. These were joined with the pins 5 & 6 in Arduino Uno. It is coded as,

```
const int trigpin =5;
const int echopin=6;
```

Then all these pins defined were setup for the output signal as coded below,

```
void setup () {
  pinMode (LM_pin1, OUTPUT);
  pinMode (LM_pin2, OUTPUT);
  pinMode (RM_pin1, OUTPUT);
  pinMode (RM_pin2, OUTPUT);
   pinMode (trigPin, OUTPUT);
    pinMode (echoPin, INPUT);
   Serial.begin(9600);
}
```

Further, DC motor (Left and Right) was coded for the forward, backward, stop and turning movements as shown below.

```
void LeftM (int val) {
  if(val==1) {
  digitalWrite (LM_pin1, HIGH);
  digitalWrite (LM_pin2, LOW);
   } else if(val==-1) {
   digitalWrite (LM_pin1, LOW);
   digitalWrite (LM_pin2, HIGH);
   } else {
  digitalWrite (LM_pin1, LOW);
  digitalWrite (LM_pin2, LOW);
   }}
```

Here, the value (1) was given for forward movement, value (-1) for backward movement and else it is coded to stop in a position. Likewise, coding was done for right motor (RM) as well.

Finally, the coding for turning in 90 ^{0} clockwise (Right side) when the obstacle meets within 20cm was done as,

```
  Serial.println(dVal);
  Delay (10);
  //============================//
  if (dVal>20) {
  LeftM (1);
  RightM (1);
  } else {
  T90Clock (500);
  }
  }
```

Further, after developing the robotic mechanism, a simple experiment was conducted through the Arduino to calculate the time duration to detect the actual distance of object by the ultrasonic sensor with the help of serial monitor.

2.3 Analysis on Arduino Coding

The developed system was tested by placing obstacle at various distances across its path. A right-angle wall surface was selected and got the results for forward, backward, turning, and obstacle detecting movements of mobile robot.

2.4 Analysis on Time Taken to Detect the Obstacle

In order to compare the actual and experimental time taken to detect an obstacle, experimental time taken was measured by using multi-function stopwatch while actual time taken can be calculated using the given equation.

$t_N = (D*2) / V$ ……Eq. 1

t_N =Time between transmitted and received reflected wave

D = Distance between the sensor and the detected object

V = Ultrasonic wave propagation speed in air at normal speed 344 ms^{-1}

2.5 Analysis on Accuracy and the Probability of Failure of Mobile Robot

The developed system was tested by placing obstacle at various distances across its path. Then, accuracy and the probability of failure was calculated by using the equation given.

$$\text{Accuracy} = O_a/O_t \quad \text{..... Eq. 2}$$

O_a = Total number of obstacles avoided

O_t = Total number of obstacles tested

where and also, the probability of failure () was calculated using eq. 3.

P_f = Total number of failed detection and avoided / Total number of obstacle tested Eq. 3

P_f = Probability of failure

3. RESULTS & DISCUSSION

In this work, the developed robot is shown in Figure3.

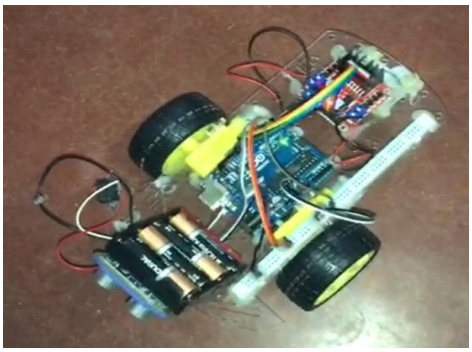

Figure 3: Top view of developed robot.

According to the coding, the maximum distance to the obstacle (Max Obstacle Distance) is set to 20 cm. The robot made to move forward towards the obstacle. If the current detected distance from the robot to the obstacle (if any) is more than Max Obstacle Distance, robot kept moving towards the obstacle. When the detected distance to the obstacle is less than or equal to the Max Obstacle Distance, the robot maneuver itself and found a suitable way by avoiding the obstacles. When this happens, robot stopped for a short period (10 ms). Then it moved its sensor to the right side (clockwise) 90^0 and detected if there is any obstacle at that side. If an obstacle is found, it measures the distance to the obstacle and if the detected distance is less than or equal to Max Obstacle Distance, it further turns to right side(clockwise) 90^0 else, moves straight freely until find another obstacle within 20 cm on its path. Thus, the obstacle can be avoided automatically.

Coding in Arduino software also defined according to the connected wires on made robots. After the development, the robot was tested with several functions such as,

- Effective stopping distance when moving toward an obstacle.
- Turning right while detecting an obstacle.

Table 1 summarizes the testing results in this research. Both functions in this robot running well. Thus, all the requirements for the designed robot are achieved.

Table 1: Results of robot function test

No.	Function	Result
1	Moving forward	Yes
2	Moving backward	Yes
3	Effective stopping distance	Approximately 20cm
4	Turning right	Yes
5	Obstacle avoidance	Yes

The developed system was tested by placing obstacle at various distances across its path within a known area. The responses of Ultrasonic sensor were evaluated. The accuracy and probability of failure are given at five different circumstances in Table 2.

Table 2: Analysis on accuracy and probability of failure of the robot.

Circumstance	Total number of obstacles tested	Total number of failure detection or avoided	The percentage of accuracy (%)	Probability of failure
1	10	0	100	0
2	15	0	100	0
3	20	1	95	0.05
4	25	1	96	0.04
5	30	1	97	0.03

It clearly showed that the accuracy of the robot above 95% in all instances and the probability of failure less than 0.05 proved that mobile robot navigates through static obstacles, and finding the

path in order to reach the target without collision. And when there is an increase in the number of obstacles within 20 cm distance, the robot may not have enough delay time to send its response according to its received ultrasonic signals.

The comparison between results of calculated time and the experimental time for the ultrasonic sensor to detect the actual object distances is presented in Table 3.

Table 3: Analysis of ultrasonic sensor for different actual object distances

No.	Actual distance of object (cm)	Calculated time t_N (µs)	Experimental time (µs) by ultrasonic sensor
1	10	581	1
2	20	1163	1
3	30	1744	1534
4	40	2326	2144
5	50	2907	2684
6	60	3488	3152
7	70	4070	3720
8	80	4652	4320
9	90	5233	4821
10	100	5814	5487
11	150	8720	8403
12	200	11627	10540
13	250	14534	13502
14	300	17442	16320
15	350	20349	19014

The characteristic profile generated by the ultrasonic sensor is linear and stable which can be observed in Figure 3. This is as result of the smooth and good refraction surface of obstacle used in the experiment. Also, the experimental duration time is always less than calculated duration time and there is variation in the comparative profiles for both calculated and experimental time durations obtained. It is established that as the distance of the obstacle gradually increases, time taken for the ultrasonic sensor to detect the object decreases and it turned quicker than the calculated duration time.

Figure 3: The relationship between results of calculated time duration and the experimental time duration for the ultrasonic sensor to detect the actual object distances.

4. CONCLUSION

This research has presented the design and development framework of a robot to detect and avoid obstacles on its path. This robot can run well with the functions; moving forward, backward, turning right and obstacle detecting. It is able to detect obstacle within 20 cm while moving forward and always turn right side until reach its target place. Overall, the robot is able to move under control of Arduino coding and avoid obstacle automatically if detected. This mechanism considerably has an accuracy more than 95% and minimum probability of failure of 0.05 while navigating through static obstacles to reach its target without collision. Hence; the results are promising for next future work of this domain.

It is highly recommended to develop further by keeping this work done as a base for improvements to increase accuracy and adaptability of obstacle detection in diverse environments and also for further developments in which a design of a robotic arm to carry/ transport objects from one place to another.

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