AUTONOMOUS OBSTACLE AVOIDING DIFFERENTIAL WHEEL DRIVEN ROBOT

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ABSTRACT
Navigation of autonomous mobile robots or vehicles has been widely adopted in industry. Such a navigation strategy relies on identification and subsequent recognition of distinctive environment features or objects that are either known a priori or extracted dynamically. This process has inherent difficulties in practice due to sensor noise and environment uncertainty. With the existing obscurity and restriction, we have considered constructing a two wheeled differential robot, with advance maneuvering techniques. The robot will have the capability of moving from one position to another by detecting and avoiding obstacles. The robot will also calculate the shortest path in order to reach the destination.

Key words: Autonomous Robot, Obstacle Avoiding, Robot Localization, Path Planning, Position, Algorithm

1. INTRODUCTION

A mobile robot is an automatic machine that is capable of movement in any given environment under the guidance of a user or autonomously [1, 2]. Designing mobile robotic systems capable of real-time autonomous navigation is a complex, multi-faceted problem. Accomplishment in navigation requires the success of the four building blocks of navigation [3]; perception-the robot must interpret its sensors to extract meaningful data; localization [10] - the robot must determine its position in the environment; cognition [9] - the robot must decide how to act to achieve its goals; and motion control- the robot must modulate its motor outputs to achieve the desired trajectory. The development of an unmanned robot with the aptitude to autonomously [4] transport is not a trouble-free mission. Several important factors must be considered in the planning phase of such a project. Very accurate sensors for detection of humans as well as other obstacles in the vicinity of the vehicle are needed. Another important part of the project is the path tracking behavior of the vehicle. This behavior is made up of two parts. The first part is the initializing phase [3], for which a human operator manually enters the final destination coordinates for which the vehicle will travel by it calculating the shortest path [4]. The second phase is the path tracking mode, in which the robot travels along the planned route, by using algorithms such as Bug 0 or Bug 1 algorithms[7], as close as possible considering any errors in position. During this second phase any obstacles detected[1,3] in the direction of travel would either cause the vehicle to stop and return control to the driver, or in case of static obstacles like trees or stubs a detour around and then returning to the original track. The rest of the paper explains background details of design and implementation in section 2. Section 3 and 4 concludes the paper.

2. DESIGN AND IMPLEMENTATION

The system architecture diagram shown below in figure 1, shows the data and instruction flow route from the user interface, sensors and encoder to the control unit and the output instructions flow back to the motor drivers and thereafter to the motors.

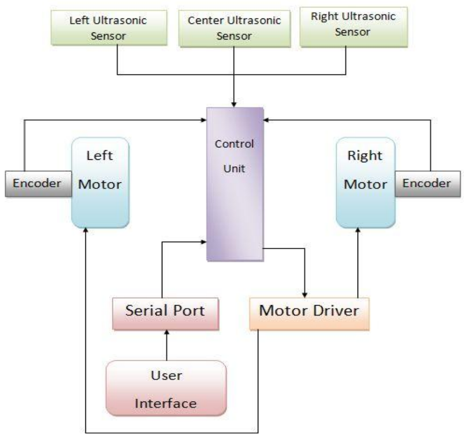

Figure 1: System Architecture

First stage consists of the preliminary research and design of the differential two wheeled robot, which will not include any sensors and also the implementation of the coding (Figure 2). The main objective of this phase will be to design the robot which will move from an initial starting position to a designated coordinate.

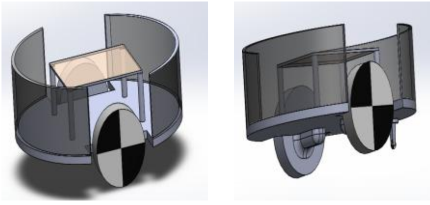

Figure 2:Three Dimensional Perspective Drawing

We have designed an oval shaped base (Figure 3) to make the robot's rotation smooth and it's easy to place the sensors. It has been designed according to the dimensions as given in Figure 3.

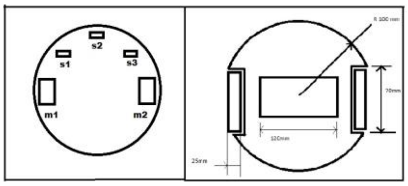

Figure 3: Sensor Configuration and Base design with dimensions

In the second part of the project we implemented the sensors to the two wheeled robot which detect any obstacles and avoiding them. In the process of object detection, sensors such as proximity sensor and ultra-sonic sensors will be used to detect the distance to the obstacle and the algorithm will be made to smoothly avoid the obstacle. The secondary coding for this task will be executed and finally the ultimate testing and troubleshooting will be carried out. The robot is also equipped with three ultrasonic sensors placed around the base module (Figure 3). These sensors consist of Ultrasonics which allows Measurement of sound wave reflected from obstacles. This type of measurement is done by using both the emitter and the receiver. The difference between the two values is returned. Ultrasonic sensors "are based on the measurement of the properties of acoustic waves with frequencies above the human audible range," often at roughly 40 kHz. They typically operate by generating a high-frequency pulse of sound, and then receiving and evaluating the properties of the echo pulse. Three different properties of the received echo pulse may be evaluated, for different sensing purposes. They are time of flight (for sensing distance), Doppler shift (for sensing velocity), and Amplitude attenuation (for sensing distance, directionality, or attenuation coefficient).

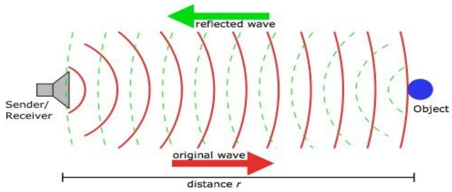

Figure 4: Ultrasonic sensor operation method

In this stage we studied the differential kinematics with the help of the preliminary research we caried out in the research stage.

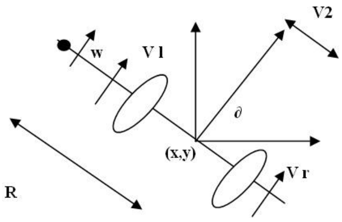

Figure 5: Differential kinematics Schematic

Each wheel follow a path that moves around the ICC at the same angular rate ω thus

$$\omega\ (R + l/2) = v_r$$
$$\omega\ (R - l/2) = v_l$$

Where l is the distance between the two wheels, the right wheel moves with velocity v_r and the left wheel moves with velocity v_l. R is the distance from the ICC to the midpoint between the wheels. All these control parameters are functions of time, which gives

$$R = l/2 * (v_l + v_r)/(v_r - v_l)$$
$$\omega = (v_r - v_l)/l$$

We have two special cases that come from these equations. If $v_l = v_r$, then the radius R is infinite and the robot moves in a straight line. If $v_l = -v_r$, then the radius is zero and the robot rotates in place. In all other cases the robot moves in a trajectory around the ICC at some angular rate ω.
The forward kinematics equations can be derived easily now that we have established the basics. Our focus is on how the x and y coordinates and the orientation change with respect to time. Let θ be the angle of orientation, measured in radians, counter-clockwise from the x-axis. If we let m (t) and $\theta_{(t)}$ be functions of time representing speed and orientation for the robot, then the solution will be in the form:

$dx/dt = m(t)\cos(\theta(t))$ .....(1)
$dy/dt = m(t)\sin(\theta(t))$.......(2)

The change of orientation with respect to time is the same as the angular rate ω. Therefore

$d\theta/dt = \omega = (v_r - v_l)/ l$... (3)

Integrating this equation yields a function for the robots orientation with respect to time. The robots initial orientation θ (0) is also replaced by θ_0:

$\theta (t) = (v_r - v_l)t/l + \theta_0$..... (4)

Since the velocity in functions (1) and (2) above simply equals the average speed for the two wheels, that is $m(t)=(v_r+v_l)/2$, integrating this in (1) and (2) gives:

$dx/dt = [(v_r + v_l)/2]\cos(\theta(t))$ .....(5)
$dy/dt = [(v_r + v_l)/2]\sin(\theta(t))$ .....(6)

The final step is to integrate equations (5) and (6) and taking the initial positions to be x (0) = x0, and y (0) = y0 to get:

$x(t) = x0 + l/2(v_r + v_l)/(v_r - v_l)[\sin((v_r - v_l)t/l+\theta_0)-\sin(\theta_0)]$.....(8)
$y(t) = y0 - l/2(v_r + v_l)/(v_r - v_l)[\cos((v_r - v_l)t/l+ \theta_0)-\cos(\theta_0)]$……(9)

Noting that $l/2(v_r + v_l)/(v_r - v_l) = R$, the robots turn radius, and that $(v_r - v_l)/l = \omega$, equations (8) and (9) can be reduced to:

$x(t) = x_0 + R[\sin(\omega t + \theta_0)-\sin(\theta_0)]$ .....(10)
$y(t) = y_0 - R[\cos(\omega t + \theta_0)-\cos(\theta_0)]$ ....(11)

This is the theory that lies behind implementing dead reckoning on a wheeled mobile robot using differential steering. The only thing one has to do is to substitute the terms v_r and v_l with s_r and s_l, indicating the calculations of displacements rather than speeds, and as a result of this also drop the time value t. Here s_r and s_r are the distances traveled by the left and right wheels respectively. Finally when this has been k2done equations (8) and (9) becomes:

$x(t) = x_0 + l/2(s_r + s_l)/(s_r - s_l)[\sin((s_r - s_l)/l+ \theta_0)-\sin(\theta_0)]$ .....(12)
$y(t) = y_0 - l/2(s_r + s_l)/(s_r - s_l)[\cos((s_r - s_l)/l+ \theta_0)-\cos(\theta_0)]$ .....(13)

which are the forward kinematics equations used by differential drive vehicles when turning

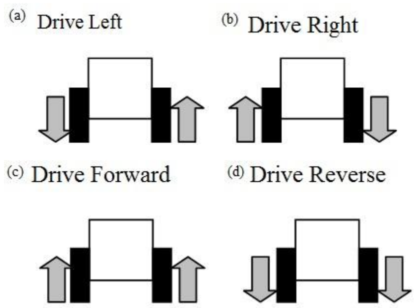

Figure 6: The effect of wheel rotation on robot movement direction

2.1. Incremental Optical Encoders

A common question in robotics is: where am I? It's not hard to spin a robot's wheels around, but often we want to move a specific distance, or turn clockwise by a specific angle. Encoders provide a way of measuring the motor's position so that you can do more consistent motion control.

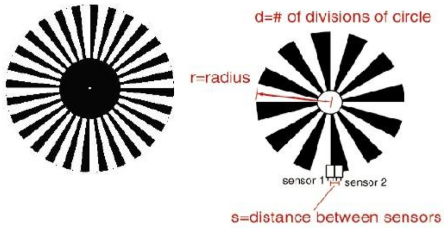

Figure 7: Encoders Designs and Encoder Sensor Arrangement

Table 1: Encoder Design Specifications

Diameter	60mm
Distance between sensors	7mm
n	1
No. of dark segments	28

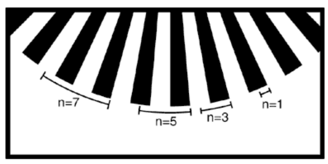

Figure 8: Graphical Interpretation of n

2.2. Path Planning

The simplest forms of algorithm for path planning of mobile robots are the bug algorithms. In this project we decided to implement the Bug

2 algorithm for the autonomous robot. Once the robot is given the final destination coordinate through the user interface, the robot will define a straight route called the m-line in which it will travel. When the robot encounters an obstacle, it will encircle the obstacle until it hits the m-line again and continue its path along the m-line until it reaches its goal and finally the algorithm is terminated.

Let $q^L_0 = q_{start}$; i= 1
repeat
-repeat

- From q^L_{i-1} move toward q_{goal} along the m-line

-until goal is reached or obstacle encountered at q^H_i
-if goal is reached, exit
-repeat

- follow boundary

-until q_{goal} is reached or q^H_i is re-encountered or m-line is re-encountered, x is not q^H_i, $d(x,q_{goal})<d(q^H_i, q_{goal})$ and way to goal is unimpeded
-if goal is reached, exit
-if g^H_i is reached, return failure
-else

- $q^L_i = m$
- i = i +1
- continue

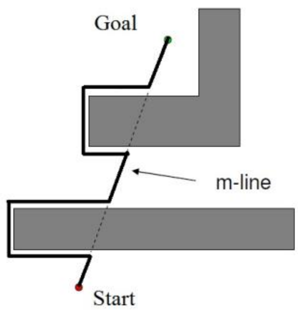

Figure 9: Path Following Process

3. CONCLUSION

So far in this paper, we have understood the basic system for object detection and avoidance of an autonomous ground vehicle. In the learning phase, data was collected regarding the task and was used to develop an algorithm for object detection and avoidance by the use of ultrasonic sensors

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