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Mobile Robot Navigation and Mapping

Using Optical Encoders

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***Abstract*—This paper proposes a control architecture of a mobile robot which is capable of performing various task such as cleaning of the house as a cleaning robot. The key idea behind the working of these robots is simultaneous localization and mapping. The mobile robot uses an ultrasonic sensor to avoid unexpected obstacle detection in the environment and map the environment. Along with Ultrasonic sensors we have used Encoders which will give us the tic values with the help of which robot can map the environment by detecting its simultaneous position. In this paper, we have described the mapping and obstacle avoidance algorithm in detail.**

Keywords- Architecture,localization&mapping,Encoders,Slam

I. INTRODUCTION

This paper describes some of the features of an autonomous mobile robot. The proposed model is capable of working in a known and unknown environment with the help of the feedback from the onboard sensor on the robot. The purpose of the mobile robot is to autonomously navigate the environment and create a 2-D map of the Arena. As a result, this mobile robot will be of great help to humans as this will autonomously clean the house and office. This system will require less human intervention will save a lot of time.

Localization and mapping need to work simultaneously while mapping the arena robot needs to keep track of its position to acquire the organized information required for map creation. With the acquaintance of the current location of the robot, the mapping software can recognize the exact boundary of the Arena and obstacles present in the Arena. The control unit will store the data from the encoder that will help us in designing a map of the Arena.

Our model is composed of two parts that are a differential drive of the robot based on tick value from the motor and using an ultrasonic sensor to detect the obstacle in the environment and create a 2-D map of the Arena. the working of the robot depends on the utilization of the various sensor:

(i)Ultrasonic sensors are mounted on the robot(which works as a range finder) to detect the obstacle and avoid them while navigating through the environment.

(ii)Wheels of robots are attached to the optical encoders with the help of which we can detect the position of the robot.

(iii)Micro-switches are attached to the robot with the help of which the robot can detect the obstacle which remained undetected by the ultrasonic sensor.

This robot finds a wide range of applications in various filed such as cleaner robots to clean the house. It is also capable of performing complex tasks in the field of security and surveillance.

II. PROPOSED MODEL

In the initial stage, the robot will be provided with the starting point and the estimated shape and size of the arena without accounting for the obstacle present in the arena. After getting the desired information about the starting point and the heading direction robot will start to move straight. In our algorithm, the dynamic points will be allocated with the help of which the robot will track each corner of the arena. To cover the whole arena there are two ways in which the robot will move in the arena to map the arena while avoiding the obstacle

(i)The robot will go inside the arena from the starting position and will start to move in a spiral formation, this will cover the entire arena.

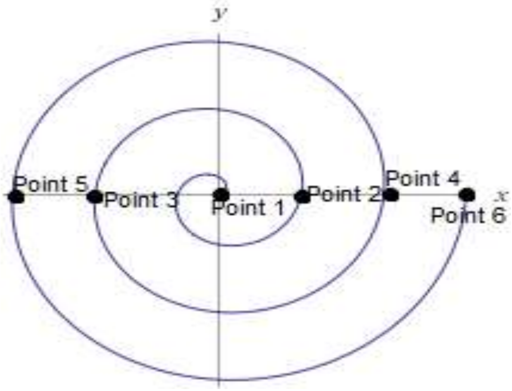

Fig 2.1 Spiral movement of robot

(ii)The second most effective way is that robots will follow a grid path inside the arena in this way it is capable of covering the whole arena and obstacle

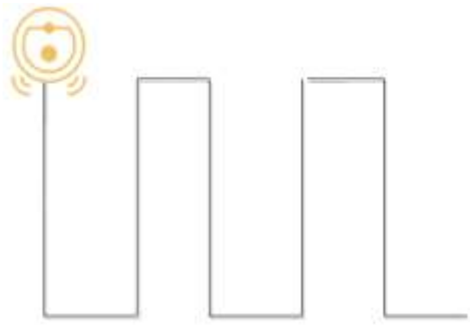

Fig 2.2 Grid movement of robot

After navigating through the environment the second most important task is to detect obstacles. Our robot will follow a defined path and go off the path if any obstacle will be detected. After covering the whole path, in the end, it will compare the defined path and the actual path it covered. Hereby applying the iterative closest point algorithm we could detect the position of the obstacle on the map. The robot would require multiple runs to get a better map and to distinguish between static and dynamic objects. Suppose an obstacle was found in the corner and the center of the arena and in the second trial the obstacle was found shifted towards the right, then the robot will compare the location and calculating the mean along with the desired threshold. This will help us to analyze the map of the arena and will help a robot to navigate through the environment while avoiding obstacles.

III. HARDWARE

STM32

We used STM32 as the main controlling unit for the robot. We preferred STM32 over ATMEGA because it has high clock frequency that is 72Mhz and we can control the frequency according to our requirement which makes it more customizable in comparison to ATMEGA. They are suitable for low power consumption and STM has low power series which consumes the current up to nanoamps. Blue-pill an open source board available with stm32 did the work in our case. It also supports firmware like Free RTOS which provides the ability of parallel processing.

Ultrasonic Sensor

We have used an ultrasonic sensor to detect the obstacle present in the environment and detect the corner of the arena to create a 2-D map of the arena. The ultrasonic sensor emits high-frequency sound and whenever the sound reflects calculating the distance based on the time required. In this way, we can detect the location.

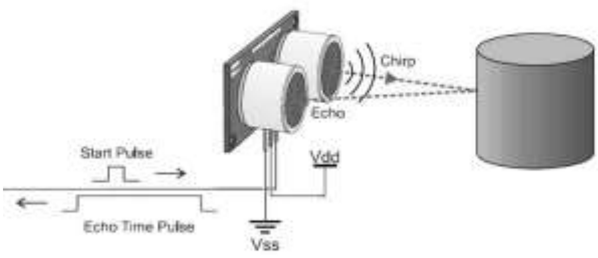

Fig 3.1 Working of sonar sensor

Encoders

*Encoders can generally be of two types: Hall effect and optical encoders. These components are used to detect the rotation of the motor. It can be used to give feedback to the controller. For example, if the controller gives the command to make one revolution, the only way to detect whether the motor took one full revolution or not is by tracking the tic count provided by the encoders. We used encoders to get the current position of the robot in the arena. With the help of this, we can create a 2-D map. Encoders are the device that converts the rotatory or linear displacement into digital or pulse signals (**Tics)** with the help of photo detector (light sensor).*

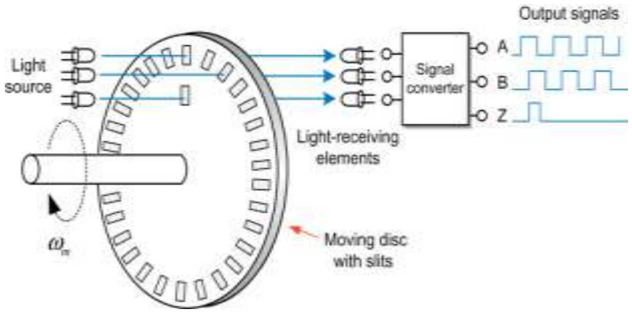

Fig 3.2: working of encoder

Micro Switches

Micro switches are used in the robot so that with the help of these switches the robot can detect the obstacle which remained undetected by the ultrasonic sensor. Micro switches react to the dynamic environment. And help in controlling the device with the help of switching action of Micro Switches.

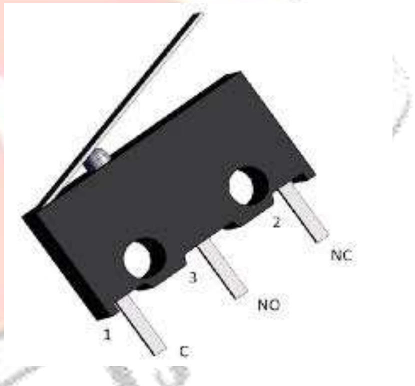

Fig 3.3: micro switches pin out

IV. DIFFERENTIAL DRIVE AND POSITION TRACKING

To move from location **A** to location **B** the robot follows the following strategy. The robot is provided with the start point and the robot calibrates its sensor with the environment to collect accurate values from the sensors.

To map and navigate through the environment the robot follows two different types of motion, either motion in a straight line in which both the wheels runs at the same angular speed and same direction, or robot takes rotation about its center where both wheels run at the same speed but the direction of wheels are opposite to each other.

Here we were initially given with motor tics of left and right side motor.

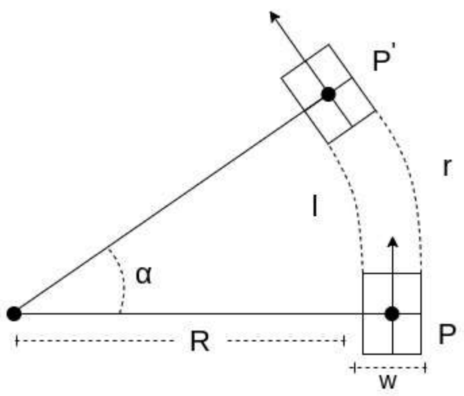

Fig 4.1: angular turn of robot

To move from location **A** to location **B** the robot follows the following strategy. The robot is provided with the start point and the robot calibrates its sensor with the environment to collect accurate values from the sensors.

To map and navigate through the environment the robot follows two different types of motion, either motion in a straight line in which both the wheels runs at the same angular speed and same direction, or robot takes rotation about its center where both wheels run at the same speed but the direction of wheels are opposite to each other.

Here we were initially given with motor ticks of left and right side motor.

For this experimentation we are using quad encoder motors which outputs 540 pulses per revolution of the wheel. Diameter of wheels is equal to 65mm.

Circumference of wheel = π x diameter
= π x 65mm
= 204.28 mm

Distance travelled per motor tick is equivalent to

$$= \frac{circumference of wheel}{No. of pulse per revolution}$$

$$= \frac{204.28}{540}$$

= 0.378mm per motor tick

Distance travelled by left wheel can be denoted by l and r for right wheel.

Arc length $\mathbf{l} = \frac{\alpha}{2\pi}$ **x 2 x π x R**

$$\mathbf{l = \alpha \times R} \qquad \textbf{(1)}$$

Similarly,

arc length $\mathbf{r = \alpha \times (R + w)}$ **(2)**

[W is width of the robot]

By solving equation 1 and 2 we can remove R which is the radius of the imaginary reference circle and whose value cannot be directly measured.

$$\therefore \quad \alpha = \frac{r - l}{w} \qquad \textbf{(3)}$$

We can now calculate the value of R by using the calculated α which would play an important role in further calculations.

From equation 1,

$$\mathbf{R} = \frac{l}{\alpha}$$

Further we can resolve the robot into x and y direction to calculate other parameters along their respective axis.

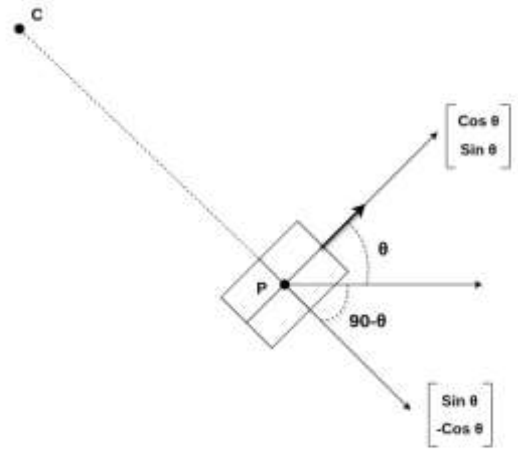

Fig 4.2:robot orientation

Now we can calculate P' that is the new position of the robot. Before we calculate the new position of the robot, we require a reference point. Here center C can act as a reference point which we need to calculate before calculating P'**.**

By using the results from fig. 2 we can calculate the center C.

$$\mathbf{C = P + (R + \frac{w}{2})} \begin{bmatrix} sin\theta \\ -cos\theta \end{bmatrix} \qquad \textbf{(4)}$$

Here **C** → **C_x , C_y** , **P→P_x, P_y** , θ is the heading angle of the robot.

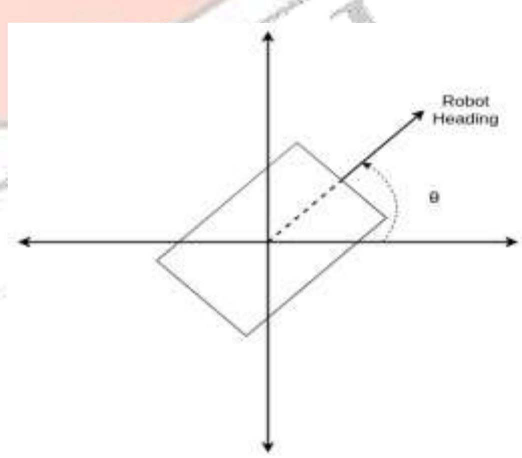

Fig 4.3: robot heading

The general equation 3 can be written as,

$$\mathbf{C_x = P_x - (R + \frac{w}{2})\ (\ sin\theta\ )} \qquad \textbf{(5)}$$

$$\mathbf{C_y = P_y - (R + \frac{w}{2})\ (\ -cos\theta\ )} \qquad \textbf{(6)}$$

The above equations give the x and y coordinates of the centre. By taking centre as the reference, the new position and heading of the robot can be found.

New heading $\mathbf{\theta' = \theta + \alpha}$

[α calulated from equation 3]

New robot position **P'→ P'_x, P'_y**

$$\mathbf{P'_x = C_x + (R + \frac{w}{2})\ (\ sin\theta\ )}$$

$$\mathbf{P'_y = C_y + (R + \frac{w}{2})\ (\ -cos\theta\ )}$$

The above equations are valid when the robot is not moving in a straight line, which means the right motor tick count is not equal to the left motor tick count.

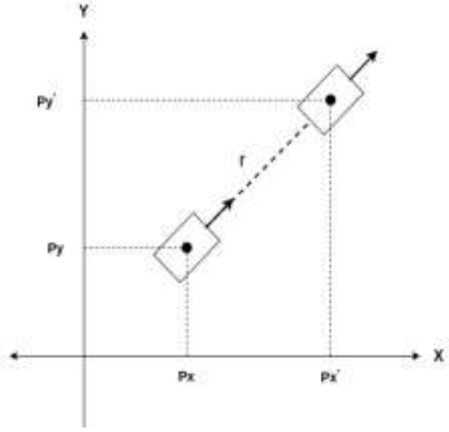

Fig 4.4: robot motion in straight line

Hence when robot moves in a straight line, the following equations take into place

r = l

New heading will remain the same i.e. $\theta' = \theta$

$P'_x = P_x + l\cos\theta$

$P'_y = P_x + l\sin\theta$

The above calculations are used for determining the new position and heading of the robot and also storing the positions of the robot for the creation of map.

V. DIFFERENT MODES IN CLEANING ROBOT

With the help of an ultrasonic sensor and encoder, a motor robot tries to reach a destination position without human interference. Tough in the initial stage the user has to feed the map of the room with approximate dimensions. All these data are fed into the robot database whenever introduced to a new environment. The robot has to face an unexpected obstacle to avoid these unexpected obstacle we take help of ultrasonic sensors and micro switches. For autonomous movement of the robot through arena, the robot work in two mode that is scanning mode and measuring mode.

A. Scanning Mode

This mode starts from the beginning when the robot starts from its start point and heads toward the arena. In this mode, the reading from the range scanner is alternately collected from both the sensor in every 50ms which is equivalent to the 2.75cm of distance covered by the robot in a straight line.

If $R_j(J) < T_D$ && $R_i(j) <= R_i(J-1)$

Then obstacle is detected

where

T_D = threshold

$R_i(J)$ = range reading of transceiver I,

$R_i(J-1)$ = previous reading of transceiver I.

The value of the threshold is determined experimentally. This algorithm helps us to determine the obstacle in the arena and alert the robot that is approaching the obstacles. This algorithm has helped us in eliminating errors that may occur due to various reasons.

B. Measuring Mode

Post detection of any obstacle, the robot will act as an obstacle avoider to avoid the detected objects and cross it while following the boundaries of the object. In the case of multiple edge detection, the robot will consider it as a whole. This will also help in avoiding any unwanted detection from the sensors. The main aim of the process is to avoid the object and try to come back to its allotted path. The deviation of the path is detected by matching the recorded path from the encoders. An excessive amount of points are recorded and stored while traversal so that the error in the output while comparing the actual path and assumed path is minimal.

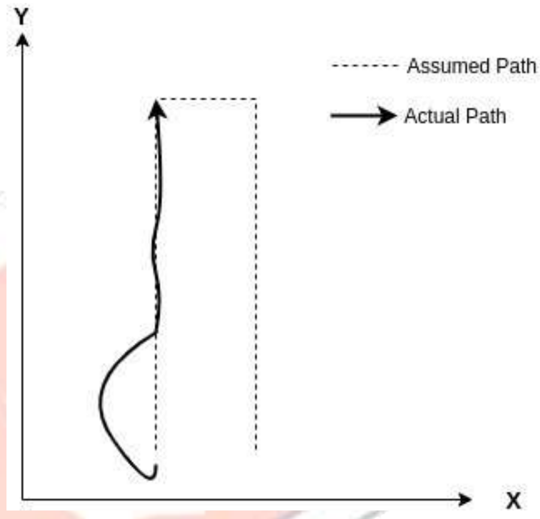

Fig 5.2 edge detection

VI. OBSTACLE AVOIDANCE ON THE BASIS OF INFORMATION FROM SENSOR

The obstacle avoidance algorithm used for this robot is very effective. According to this algorithm, the estimated map of the arena will be fed in the robot system. The X-Y coordinate is assigned to the two of the wall of the arena. In this system the wall. The obstacle boundaries are expanded in computer representation by shifting them parallel to the real boundaries by a distance equal to the half-width of the robot plus a safety factor(ş=8.65cm). This way of avoiding the obstacle is known as the configuration space approach.

In-case the obstacle remains undetected by the ultrasonic sensor and robots get hit by the obstacle, the micro switches attached to the boundary of the robot will notify the robot about the obstacle, and the robot stops within a short distance.

A time can come when the robot is not able to reach the final destination and finds too many edges in between the path. For this situation, the robot is capable to erase the temporarily formed map and the robot will try from the beginning of the start point.

VII. CONCLUSION

Through this paper, we were able to build an autonomous cleaning robot that is capable of navigating and mapping the unknown environment. To make this mobile robot autonomous we used sensor value data from ultrasonic sensors and encoders. With the help of this mobile robot, human work will be reduced, this mobile robot can be useful for domestic as well as industrial purposes. With the help of data from the sensor, we can create a 2-D map of the arena.

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