Positioning and Navigation of Mobile Robot

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ABSTRACT

Positioning tracking is not a new idea as we have been seen from the ability of the GPS (Global Positioning System) to track the position of the object, in general with acceptable accuracy but the cost of installation GPS is expensive. However, in the case of detecting the exact position in signal-blocked closed environment (e.g. inside building, forest, mines and others); the GPS is not able to provide such great accuracy to do so. This project presents a Positioning Tracking System that is able to track the movement of an object within a small area or inside building. A complete set of the Positioning Tracking System consists of a pair of computer mechanical mouse and a microcontroller. From the position displayed on the computer screen, the position of the object can be located. The pair of mouse detects each movement of the object and sends the movement data to microcontroller. Linear, angular displacement and positioning calculation are also being discussed. From the results, it's shown that the positioning system is applicable. However, some small errors are also occurred but in acceptable range.

Keywords: Positioning calculation, GUI, linear and angular displacement.

1. Introduction

Position tracking or position estimation long originates from the beginning of the time when human had tried to discover a dependable way to know where they were and to guide them to where they wanted to go and get back again. In the earliest days, this was done by simply following landmarks (mountains, trees or leaving trails of stone) or landmarks that consisted of prominent landmarks on the coastline. When traveling across ocean or desert, this method of navigation was obviously very limited. After that, the navigation by reference to the sun, moon and the stars was the next logical progression [2].

Major developments in early navigation were the compass and the sextant. The sextant measures the exact angles of the stars that are to measure the latitude. Most of the sailors use sextant to track their position when they travel across ocean. However, this method of navigation has a great disadvantage. That is it only worked at night and in clear weather. Then, the first practical radar system was produced in year 1935. Radar means Radio Detection and ranging system. This system is a method of detecting distant objects and determining their position, velocity, or their characteristics by analysis of very high frequency radio waves reflected from their surfaces. However, the radar had the limitations of generally working over a relatively short range. In year 1943, LORAN (Long Range Navigation) was developed. Then, Global Positioning System (GPS) has become an indispensable aid to navigation around the world, and important tool for map-making and land surveying since the first experimental satellite was launched in year 1978 [6][7].

2. Mobile robot description

The mobile robot is a self-driven personal robot. It was built so that it can navigate itself to the destination by using two continuous servo motors. Beside that, a robot main controller board is developed as the centre processing unit (CPU) of the self-driven personal robot. Furthermore, a specially designed power distribution system and a real-time battery level indicator is designed and applied. The type of batteries used are nickel-cadmium due to it energy/weight ratio, high load current and fast charging time. Wireless video camera is also used as tool to do obstacle avoidance based on vision system. Figure 2 is the complete hardware system of the mobile robot.

Figure 1: Mobile robot used for navigation and positioning

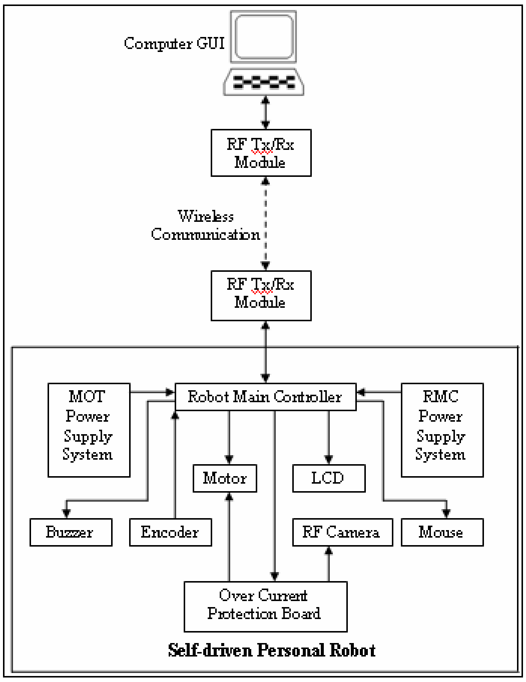

Figure 2: Hardware system of the mobile robot (MOT: Motor, RMC: Robot main controller)

For navigation and positioning of the mobile robot, two PS/2 mechanical mouse are used to measure the displacement due to low cost reason.

3. Methodology

3.1 Linear and Angular Displacement Calculation

By referring to figure 3, below are the equations used for positioning consideration. SL and SR give the displacement (distanced traveled) for left and right wheels, r is the turn radius for right wheel, b is the distance between wheels and Θ is the angle of the turn in radians ($\theta_{radians} = \theta_{degree}(\frac{\pi}{180})$). SM is the displacement at the center point on the main axle. The axle's center point is treated as the origin of the mobile robot's frame of reference. The wheels maintain a steady velocity assumption is made to simplify the curve of the mobile robot trajectory [5].

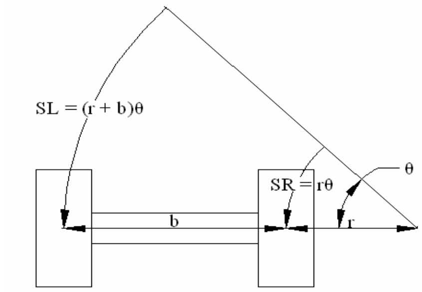

Figure 3: Path of wheels through a turn

$$SL = (r+b)\theta \text{ ---- } (1)$$

$$SR = r\theta, \text{ --------- } (2)$$

$$SM = \frac{SL+SR}{2} = \frac{(r+b)\theta + r\theta}{2} = (r+\frac{b}{2})\theta \text{ -------------------- } (3)$$

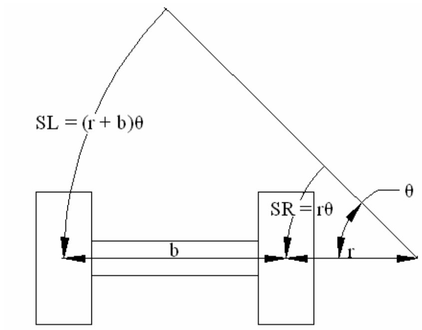

Figure 4: Wheels at different velocities

3.2 Position Calculation

The position of the mobile robot can be calculated if the value of SL and SR are given. By referring to figure 4, all the points on the robot are in motion as the robot changes its position. The reference point is treated stationary, while other points in the system are treated as moving relative to the reference point. The robot is considered as a rigid body. By using this assumption, if the robot turns 10° about the right wheel, all points undergo a 10° change of orientation. Based on this observation, a differential equation describing the change in orientation is derived as with respect to time of time. The definition of an angle given in radians is the length of a circular arc divided by the radius of that circle.

The relative velocity of the left wheel gives the length of arc per unit time. The length from the wheel to the center point gives the radius. By combining this fact, the equation (4) is obtained. The equation (4) is integrated and the initial orientation of the robot is taken as $\theta(0) = \theta_0$.

$$\frac{d\theta}{dt} = \frac{(VL - VR)}{b} \text{, ---- (4)}$$

$$\theta(t) = \frac{(VL - VR)t}{b} + \theta_0 \text{, ---- (5)}$$

The mobile robot's overall motion depends on the velocity its centre point (the midpoint of the axle), VM. That velocity is simply the average of that for the two wheels, or

$$VM = \frac{(VL + VR)}{2} \text{, ---- (6)}$$

By combining this fact with the orientation as a function of time:

$$\frac{dx}{dt} = [\frac{(VL + VR)}{2}] \bullet \cos(\theta(t)) \text{, --- (7)}$$

$$\frac{dy}{dt} = [\frac{(VL + VR)}{2}] \bullet \sin(\theta(t)) \text{, --- (8)}$$

The equations (7) and (8) are integrated and the initial position of the mobile robot $x(0) = x_0$ and $y(0) = y_0$ is applied, the following equations is obtained:

$$x(t) = x_0 + \frac{b(VL+VR)}{2(VL-VR)}[\sin(\frac{(VL-VR)t}{b}) + \theta_0) - \sin(\theta_0)] \text{, ----- (9)}$$

$$y(t) = y_0 - \frac{b(VL+VR)}{2(VL-VR)}[\cos(\frac{(VL-VR)t}{b}) + \theta_0) - \cos(\theta_0)] \text{, ----- (10)}$$

The equations given in (9) and (10) confirm the earlier assertion that, when the wheels turn at fixed velocities, the mobile robot follows a circular path. It is necessary to implement special handling for cases where the wheel speeds are nearly equal or $VL - VR \approx 0$. In such cases, the mobile robot travels in a nearly straight line. The equations (9) and (10) can be used to calculate the position by substituting SR and SL for the terms VR and VL respectively and the time value t is dropped, then the values x, y and θ is solved. Many popular authors on robotics recommend the formulas shown in (11) – (14) below as a way to avoid the complications in equations (9) and (10) [5].

$$\overline{S} = \frac{SL + SR}{2} \text{, --------------- (11)}$$

$$\theta = \frac{SR - SL}{b} + \theta_0 \text{, --------- (12)}$$

$$x = \overline{S} \bullet \cos(\theta) + x_0 \text{, --------- (13)}$$

$$y = \overline{S} \bullet \sin(\theta) + y_0 \text{, --------- (14)}$$

4 Experimental Results and Discussion

In order to show the result of the robot's navigation and positioning, a program has been developed with GUI (graphical user interface). This is shown in figure 5.

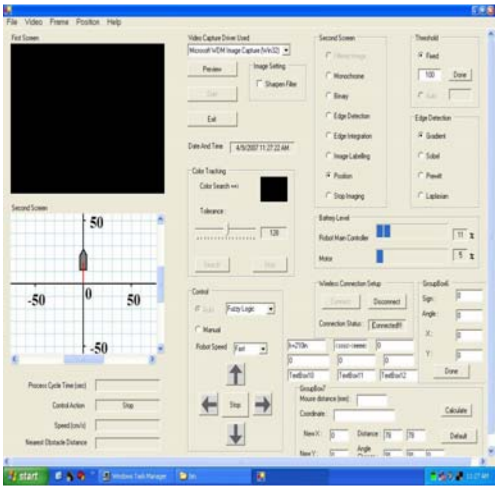

Figure 5: Graphical user interface (GUI) for navigation and positioning of mobile robot.

Figure 6 is showing that the mobile robot is moving forward with 0° angle. Figure 7 is showing the mobile robot is making 45 º turning left. Figure 8 is showing the mobile robot is making 90 º turning left. Although the position of the robot can been seen clearly from the developed GUI for user interface, however there is unavoidable error which is accuracy problem. From figure 9, the actual distance traveled by the robot is measured using tape. The reading is 19cm. However in the screen of the computer (GUI) the distance shown in the map is just 17cm. For small scale this condition is negligible, however for bigger scale this kind of problem needs to be solved.

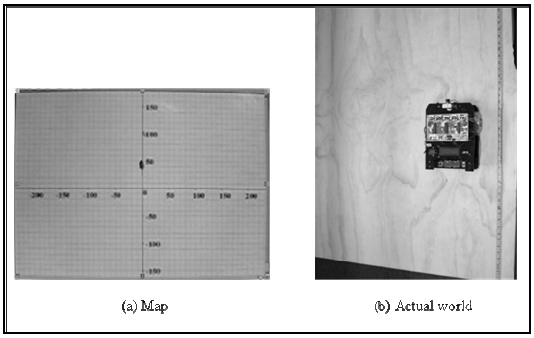

Figure 6: Path of Mobile Robot When Move Forward at Angle = 0 º

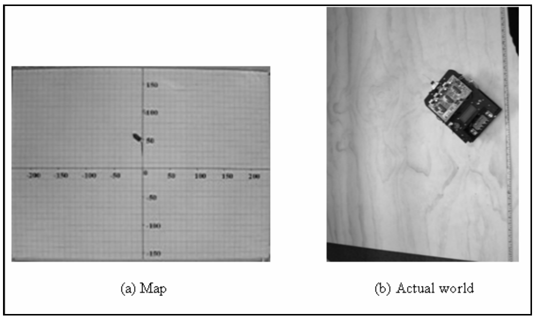

Figure 7: Path of Mobile Robot When Turn Left 45 º.

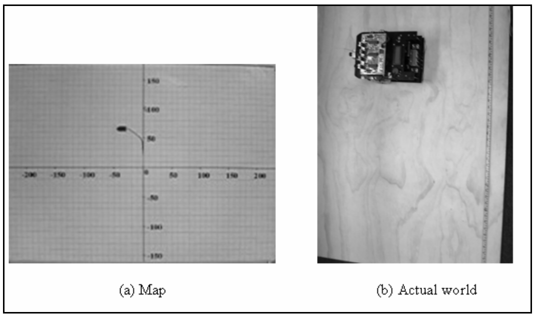

Figure 8: Path of Mobile Robot When Angle = -90 º.

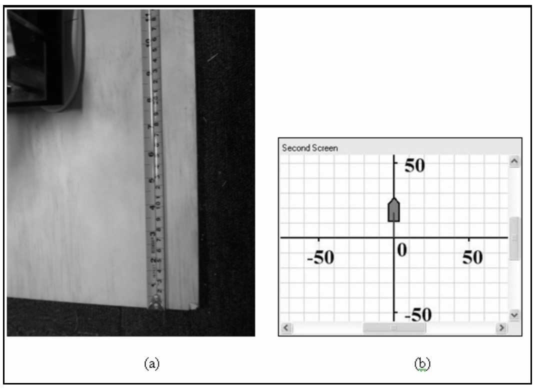

Figure 9: Inaccuracy in Path Drawing:
(a) Actual Distance and (b) Mapped Distance

5 CONCLUSIONS

The program which has GUI (graphical user interface) is developed for the position tracking system with reasonable performance. In addition, the software offers an easy and user-friendly way in calibrating the system. The second form will appear if double click the map in the main form. This is ensuring that the user can easily see the position of mobile robot relative to the origin point.

However, the results were inaccurate, that is the position of the mobile robot cannot be pinpointed exactly. This is because of the unwanted factor, friction or slipping occurs when the mobile robot is moving. Although the positioning system has inaccuracy problem, it can show the almost accurate relative position of the mobile robot to origin on the map for small scale basis. In future, it is hope that the inaccuracy problem can be solved by studying in detail both hardware and software problems for larger scale application.

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