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POSITION CALCULATION FOR MOBILE ROBOT WITH ULTRASONIC SYSTEM

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Abstract

It is more common to find navigation systems that are fundamentally based on dead reckoning. To build robot navigation systems that would allow a mobile robot to navigate in unmodified environments. Localization systems are good solution to get the information of unmodified environments, but these systems are usually expensive to install or to modify after installation, because they require specially prepared environments. This paper proposes that Local Positioning System (LPS) indicates the current position of the mobile robot by using the concept of Global Positioning System (GPS). Since LPS is expected for local propose, therefore three ultrasonic bases are used to determine distance differences. Three ultrasonic devices on ground use to point to the object in space and only one point that is the position of the mobile robot. The positioning program is written to use distance differences from travelling times as inputs of positioning equations. After finished calculation, the answer that is the position of the mobile robot will be shown on PC. Three ultrasonic bases are control by PC station using

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to calculate the current position. The positioning program is written to use distance differences from travelling times as inputs of positioning equations. After finished calculation, the solution that is the position of the mobile robot will be shown on monitor.

1. Introduction

Automated Guided Vehicles are robots built for one specific purpose, controlled by a pre-supplied control program, or a human controller (Clarke [1]). Modifying them for alternative routes is difficult, and may even require modifications to the environment. Localization systems are expensive to install or to modify after installation, because they require specially prepared environments. It is more common to find navigation systems that are fundamentally based on dead reckoning, but that use sensory information in addition. To build robot navigation systems that would allow a mobile robot to navigate in unmodified environments. As said before, the fundamental competences of navigation are localization, path planning, map-building and map-interpretation. The former uses dead reckoning strategies based on odometry, the latter sensor signal processing strategies to identify and classify landmarks. Because of the odometry drift problems, it is rare to find mobile robot navigation systems based solely on dead reckoning. There are also hybrid models have elements of both dead reckoning and landmark recognition. One good example of a robot navigation system purely based on a Cartesian reference frame and dead reckoning is the use of certainty grids. Occupancy grid systems start with an empty map, which is completed as the robot explores its environment. They therefore face the problem that any error in the robot's position estimate will affect both the map-building and the map-interpretation.

2. The Global Positioning System (GPS)

It provides reliable positioning, navigation, and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the Earth which has an unobstructed view of four or more GPS satellites (McElroy [5]). Also, the precise time reference is used in many applications including the scientific study of earthquakes and as a time synchronization source for cellular network protocols. The Global Positioning System (GPS) is a worldwide radio-navigation system as shown in Figure 1. In fact, with advancer forms of GPS, we can make measurements to better than a centimeter. In a sense it is like giving every square meter on the planet a unique addressed. GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. The quest for greater and greater accuracy has spawned an assortment of variations on basil GPS technology. One technique, called *Differential GPS*, involves the use of two ground based receivers. One monitors variations in the GPS signal and communicates that variation to the other receiver (Floyd [4]). The second receiver can then correct its calculations for better accuracy. Another technique called *Carrier-phase GPS* takes advantage of the GPS signal's Carrie signal to improve accuracy. The carrier frequency is much higher than the GPS signal which means it can be used for more precise timing measurements.

The aviation industry is developing a type of GPS called *Augmented GPS* which involves the use of a geostationary satellite as a relay station for the transmission of differentia corrections and GPS satellite status information. These corrections are necessary if GPS is used for instrument landings. The geostationary satellite would provide corrections across an entire continent.

Figure 1. Example of GPS navigation device.

3. Local Positioning System (LPS)

The comparison (Miller [2]; Schilling and Belove [3]) between GPS and LPS is shown in Table 1.

Table 1. Comparison between GPS and LPS

	GPS	**LPS**
1. Area	Global	Local
2. Receiver	On vehicle	On ground
3. Transmitter	Satellites	On mobile robot receiver
4. Medium	Radio wave	Ultrasonic
5. Finding a position	Absolute time checking	Travelling time differences

GPS uses 3 or more satellites and a receiver equipped on a vehicle to find the position in global area by using radio wave to measure absolute travelling times while LPS has a transmitter equipped on the mobile robot and 3 receivers arranged on ground. Ultrasonic is used to be the instrument for measuring travelling time differences and then the position in local area can be determined (Kheir [6]).

4. Trilateration Ultrasonic Positioning System

This instrument is designed for robot's positioning. It uses the principle of distance measurement that needs at least two landmarks with Cartesian's reference position. This can calculate the object's position by using the relation of distance measurement from ultrasonic bases. With two ultrasonic distances from $\mathbf{U_1O}$ and $\mathbf{U_2O}$ and triangular relationship of $\Delta\mathbf{U_1U_2O}$ from Pythagorean Theorem, the robot's position can be calculated and detailed later. From Figure 2, two ultrasonic send two intersection points, which are possible to be right $(\mathbf{O})$ and false $(\mathbf{O'})$ solution, so the third ultrasonic plays an important role to specify the right solution.

In work space limited in half area only two ultrasonic are required to determine the right solution. The first ultrasonic base is located at point $\mathbf{U_1(X_{u1}, Y_{u1})}$ and another ultrasonic base is placed at point $\mathbf{U_2(X_{u2}, Y_{u2})}$. Before the object's position can be calculated, it must be considered that the intersection of two ultrasonic occurs or not. If the distance between point $\mathbf{U_1}$ and point $\mathbf{U_2}$ is more than the summation of distance reading from ultrasonic bases 1 and 2, then the intersection of two ultrasonic does not occur.

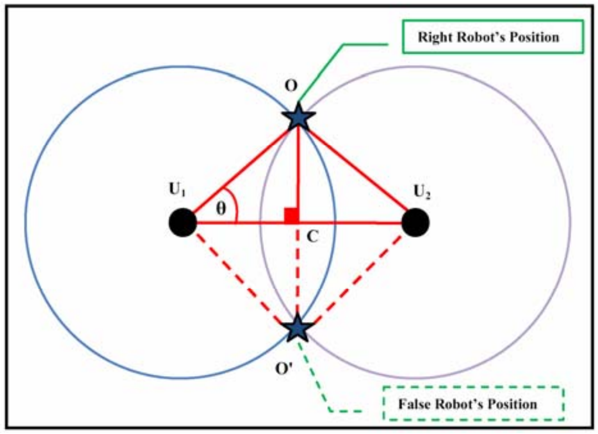

Figure 2. Intersection points from ultrasonic bases.

Next, the robot's position $(\mathbf{O})$ can be calculated from Pythagoras as below. From ultrasonic base 1, the relation is given as

$$(\mathbf{U_1C})^2 + (\mathbf{CO})^2 = (\mathbf{U_1O})^2, \tag{1}$$

and from ultrasonic base 2 is

$$(\mathbf{U_2C})^2 + (\mathbf{CO})^2 = (\mathbf{U_2O})^2. \tag{2}$$

From the subtraction of equations (1) and (2), the result is obtain as

$$(\mathbf{U_1C})^2 - (\mathbf{U_2C})^2 = (\mathbf{U_1O})^2 - (\mathbf{U_2O})^2, \tag{3}$$

then

$$[(\mathbf{U_1C}) + (\mathbf{U_2C})][(\mathbf{U_1C}) - (\mathbf{U_2C})] = (\mathbf{U_1O})^2 - (\mathbf{U_2O})^2. \tag{4}$$

With $\mathbf{U_2C} = \mathbf{U_1U_2} - \mathbf{U_1C}$ and $\mathbf{U_1U_2} = \mathbf{U_1C} + \mathbf{U_2C}$, this gives the following expression as

$$[\mathbf{U_1C} - (\mathbf{U_1U_2} - \mathbf{U_1C})] * \mathbf{U_1U_2} = (\mathbf{U_1O})^2 - (\mathbf{U_2O})^2, \tag{5}$$

and

$$2 * \mathbf{U_1C} * \mathbf{U_1U_2} - (\mathbf{U_1U_2})^2 = (\mathbf{U_1O})^2 - (\mathbf{U_2O})^2, \tag{6}$$

then

$$\mathbf{U_1C} = \frac{(\mathbf{U_1O})^2 - (\mathbf{U_2O})^2 + (\mathbf{U_1U_2})^2}{2 * \mathbf{U_1U_2}}. \tag{7}$$

The angle (θ) is calculated as

$$\cos\boldsymbol{\theta} = \frac{\mathbf{U_1C}}{\mathbf{U_1O}} \tag{8}$$

and

$$\boldsymbol{\theta} = \cos^{-1}\left(\frac{\mathbf{U_1C}}{\mathbf{U_1O}}\right). \tag{9}$$

Finally, the robot's position is

$$\mathbf{X}_{\text{Robot}}^{\text{ref.}} = \mathbf{X_{U_1}} + (\mathbf{U_1O})\cos\boldsymbol{\theta}, \tag{10}$$

$$\mathbf{Y}_{\text{Robot}}^{\text{ref.}} = \mathbf{Y_{U_1}} + (\mathbf{U_1O})\sin\boldsymbol{\theta}. \tag{11}$$

5. Results

The positioning program is written to do polling check used for information from ultrasonic sensors. Polling check as shown in Figure 3 will follow in flowcharts of positioning program and does continuously until all ultrasonic bases receives their ultrasonic information. After the polling check terminated, it means that the program can find solution from positioning equations that are equations of sphere centered on each receiver and intersect at the transmitter. The program computes the position according to the equations and the robot position will be shown as Figure 4. The robot runs in square shape through four black marks from start point to stop point. The robot's position is calculated by using two ultrasonic bases. Some points of robot's position are not shown because the software cannot receive one or both of information from two ultrasonic bases. The software will be set this condition as empty point.

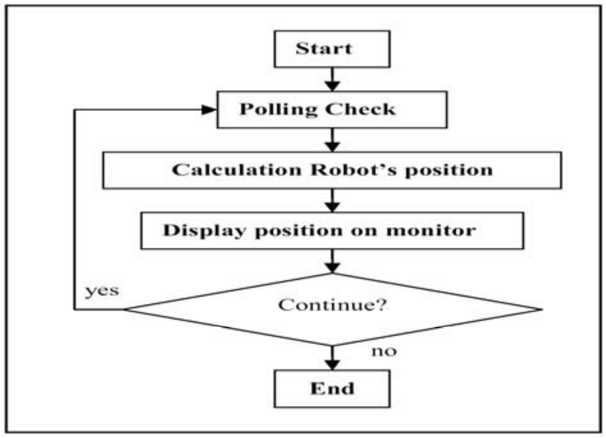

Figure 3. Flowchart of the positioning program.

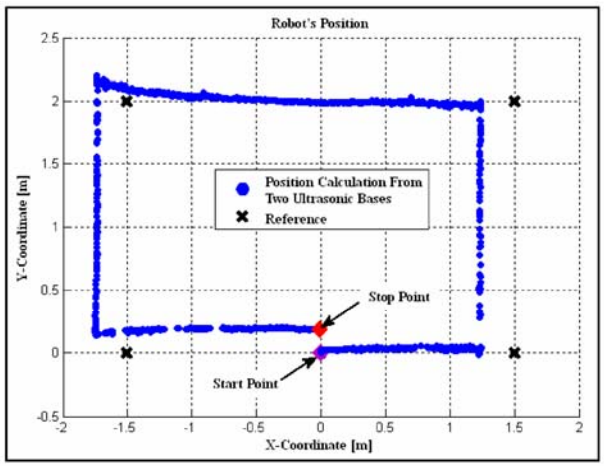

Figure 4. Robot position from ultrasonic bases.

6. Conclusion

The main objective of this paper is to introduce the localization of mobile robot. Since the high accuracy GPS is very expensive thus the cheaper positioning sensor is needed. LPS is developed by using concepts of GPS with high precision and cheaper than GPS. Two ultrasonic bases are control by PC station using to calculate the current position. The positioning program is written to use time differences from travelling times as inputs of positioning equations. After finished calculation, the position of the robot will be shown on monitor. Within this work, LPS is only a prototype thus it needs to modified and tested to become a reliable and precise positioning sensor for automatic control mobile robot.

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