Self Localization of Mobile Robot Using UHF RFID Landmark

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< Abstract >

The goal of this paper is to develop a self localization of mobile robot using UHF RFID landmark. We present landmark, a location sensing archetype system that uses UHF Radio Frequency Identification (UHF RFID) technology for locating objects inside buildings. The major advantage of landmark is that it improves the overall accuracy of locating objects by utilizing the concept of reference tags. Based on experimental analysis, we demonstrate that passive UHF RFID is a viable and cost-effective candidate for indoor location sensing. We conduct a series of experiments to evaluate performance of the positioning of the landmark System. In the standard setup, we place RF Reader which has two antennas and 25 tags in our lab. This research uses the assumption-based coordinates (ABC) algorithm[3] for determining the localization of robot. Also, we show how Radio Frequency Identification (UHF RFID) can be used in robot-assisted indoor navigation for the visually impaired. The experiments illustrate that passive UHF RFID tags can act as reliable landmark that trigger local navigation behaviors to achieve global navigation objectives.

Keywords: RFID, indoor navigation, landmark, localization

1. INTRODUCTION

Growing convergence among mobile computing devices and embedded technology are developing for location technology of mobile robot. The proliferation of wireless technologies, mobile computing devices has fostered a growing interest in location-aware systems. Many mobile robot platform applications need to know the physical location of objects. Especially, the automatic location sensing of mobile robot has some principal techniques way. One of the most well known location-based systems is the Global Positioning System (GPS), a satellite-based navigation system made up of a network of 24 satellites placed into orbit [8]. GPS is widely used to track moving objects located outdoors. However, it is satellite dependent, has an inherent problem of accurately determining the location of objects located inside buildings. Generally, localization of the mobile robot has used sensors of type that compare in Table 1[4-7]. Recent advances in the field of Radio Frequency Identification (RFID) techniques [9, 10] have reached a state that will allow us within the next years to equip virtually every object in an environment with small, cheap Radio Frequency Identification (RFID) tags. Such tags contain circuitry that gains power from radio waves emitted by Readers in their vicinity. They use this power to reply their unique identifier to the Reader. A microchip attached to an antenna that is packaged in a way that it can be applied to an object. The tag picks up signals from and sends signals to a Reader. The tag contains a unique serial number, but may have other information, such as a customers' account number. Tags come in many forms, such smart labels that can have a barcode printed on it, or the tag can simply be mounted inside a carton or embedded in plastic. RFID tags can be active, passive or semi-passive. RFID tags open up a wide variety of applications. For example, an important problem in the health-care sector is the recognition of daily activities a home patient is engaged in. And location context can provide important information for the interpretation of RFID readings. The objective of this research is to develop an indoor location sensing system for the navigation system of the mobile robot.

Table 1. Comparison of sensor type.

Type Character	RFID	GPS	Ultra Sonic	Stereo Camera
Mainly used In place	Indoor	Outdoor	Indoor or Outdoor	Indoor or Outdoor
Price	Middle	High	Middle	High
Processing Data quantity	Some	Some	Many	Too many
Hardware Complex	Low	Middle	High	Low

Then, we set a goal to implement a prototype the self localization of mobile robot in the building that system using easily accessible wireless devices.

2. SYSTEM SETUP

The RFID system divides along by electromagnetic energy transfer method. There are, (1) Inductively coupled method (2) Electromagnetic wave. In this paper, the mobile robot is used the inductively method. Because, the inductively method is recognized more rapidly than electromagnetic wave also and too small size of tags. Additionally, it has a high performance more than the general RFID technique.

2.1 The mobile robot platform structure

The mobile robot platform structure consists of five blocks that shows in Fig. 1.

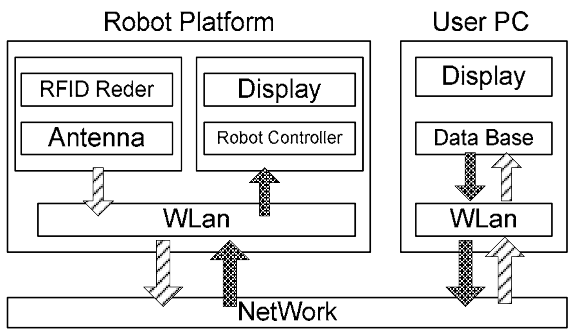


Fig. 1 The mobile robot platform.

RFID is divided into Read part and Tag part. There are two types in Tag part, one settles its own ID and the other lets user write and read ID data. This research uses the former type, which have its own ID. We get information and data about its own ID and robot analyze them. Then we make robot move autonomous, and deliver motion of robot and information to user PC using network.

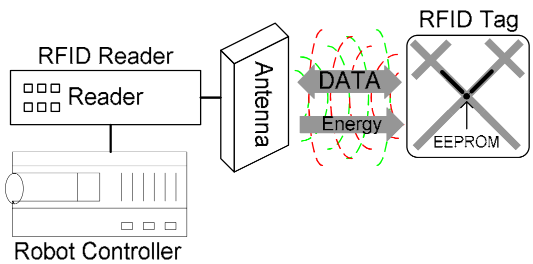


Fig. 2 Basic concept of RFID data acquisition.

Through the RFID Reader, energy is made and it is judged whether an object is located in perception range or not. For this process, output power of RF antenna is set on first, and Reader is put in motion. When less than 3 tags are detected, transmitting output of antenna increased slowly until more than 3. If tags more then 3 are detected, computation for localization is performed (Fig. 3). Location of robot is detected using information such as location of tags (coordinates), height from surface, distance of tags etc., which are prepared.

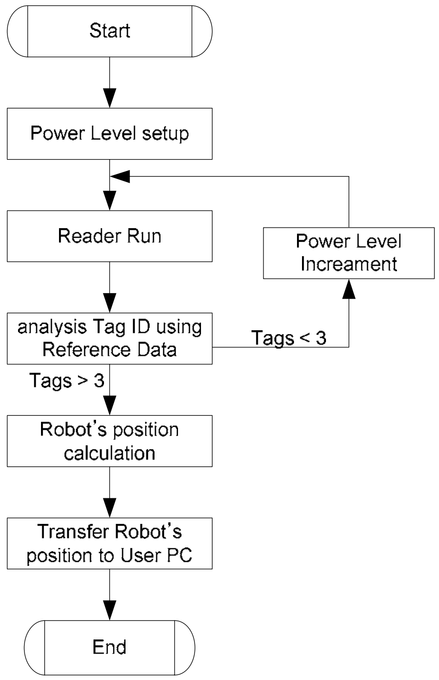


Fig. 3 User Navigation flow chart.

After robot perceives its location, movement path of robot is informed to User pc, and robot performs its goal. Robot acts that repeatedly until it arrives at its destination and performs successfully.

2.2 Method of calculating localization

This research uses the assumption-based coordinates (ABC) algorithm[3] for determining the localization of robot.

This description of the general algorithm assumes the perspective of node v_0 and can be solved successively, reducing the amount of necessary computations Fig. 4[2, 3].

The algorithm begins with the assumption that v_0 is located at the origin (0, 0, 0). The first node to establish communication with v_0, v_1, is assumed to be located at (r_{01}, 0, 0), where r_{01}= dist(v_0, v_1). The location of the next node, v_2, can then be explicitly solved for, given two assumptions: the square root involved in finding y_2 is assumed to yield a positive result, and z_2 is assumed to be 0.

$$x_2 = \frac{r_{01}^2 + r_{02}^2 + r_{12}^2}{2r_{01}}, \quad (1)$$

$$y_2 = \sqrt{r_{02}^2 - x_2^2}, \quad (2)$$

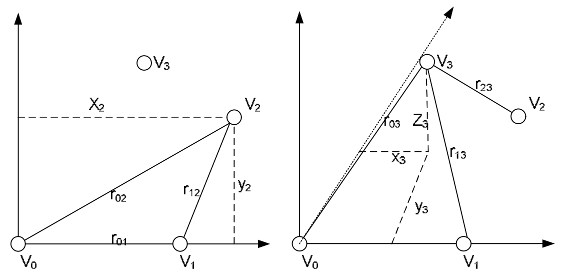
$$z_2 = 0 \quad (3)$$

The next node, v_3, is handled much like v_2, except that only one assumption is made: the square root involved in finding v_3 is positive.

$$x_3 = \frac{r_{01}^2 + r_{03}^2 + r_{13}^2}{2r_{01}}, \quad (4)$$

$$y_3 = \frac{r_{03}^2 - r_{23}^2 + x_2^2 + y_2^2 - 2x_2x_3}{2y_2}, \quad (5)$$

$$z_3 = \sqrt{r_{03}^2 - x_3^2 - y_3^2} \quad (6)$$



(a) (b)

Fig. 4 Fixing a local set of coordinates starts topology discovery, as shown for the ABC algorithm.

3. ANALYSIS OF RFID

In order to make out standard data of RFID, we detect distance measurement data of RFID using serial port of computer. We use one antenna among several ones, and change output of antenna. We make output range of antenna at intervals of 10 stages, which output range of antenna can be changed from 0 ~ 255(0mW ~ 1000mW) stages. For about 10 seconds, we measure distance of total 5 tags, every 10cm up to 700cm from antenna. Program for measurement is what RFID company supply. Composition of program is like Fig. 5.

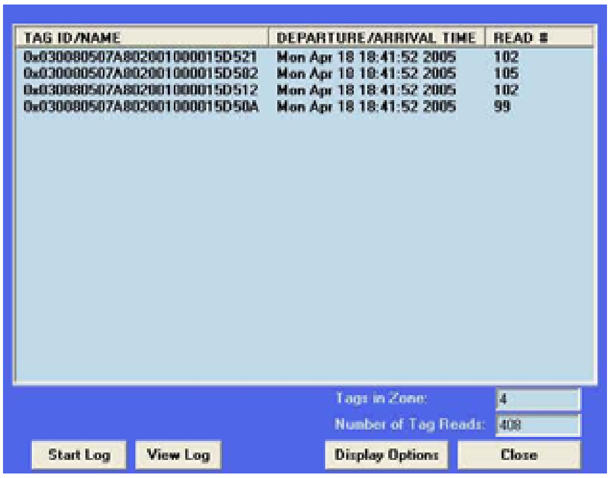


Fig. 5 Program used in measuring.

Fig. 6 illustrates the procedure for making standard data. When we start first, output of antenna begins at 10(100mW). Also location of tag is 10cm from antenna.

We read the number of RFID counted for about 10 seconds. After reading is completed in present location, tag is moved 10cm from antenna. Output of antenna increase as much as 100mW, program starts to read location again. In this way, standard data is getted up to 700cm from antenna.

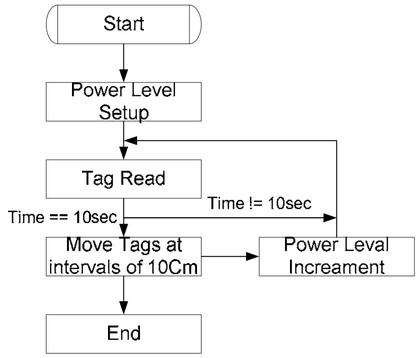
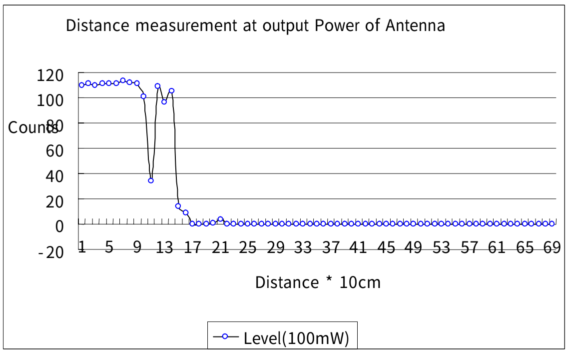
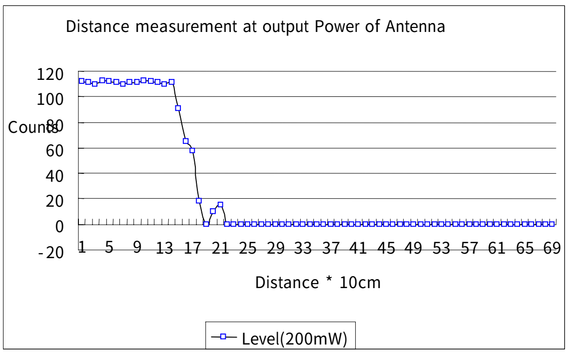


Fig. 6 Standard data detection flowchart.

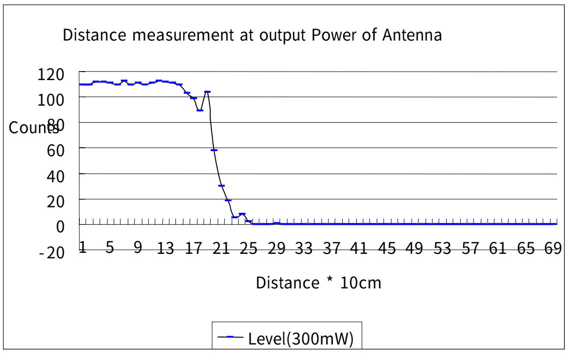
Every picture of Fig 8 is graph when every 100mW among level of 0~1000mW stage increases. The horizontal axis indicates distance and the unit is 10cm. The vertical axis does the number of counters every 10 seconds. The number of counters less than 20 is ignored because they have no practical use.



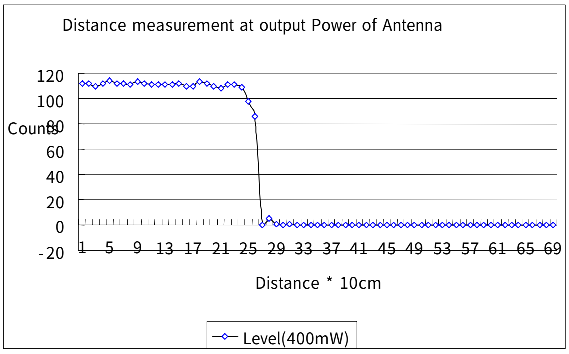
(a) Output at level 100mW.



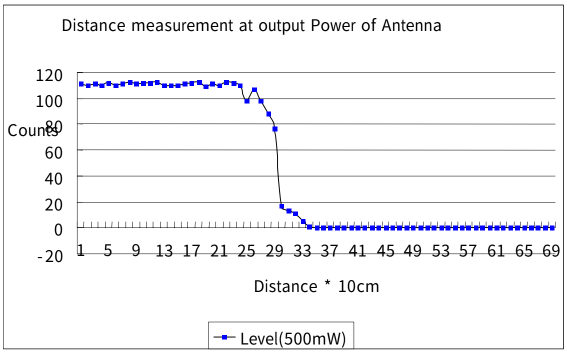
(b) Output at level 200mW.



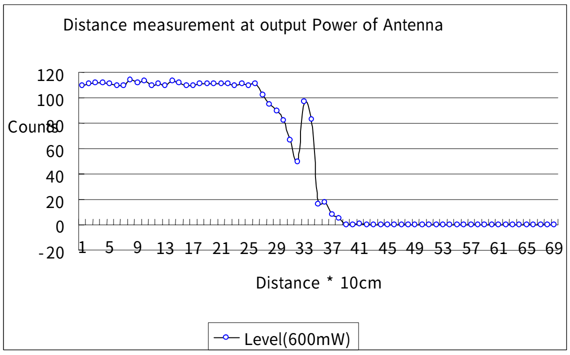
(c) Output at level 300mW.



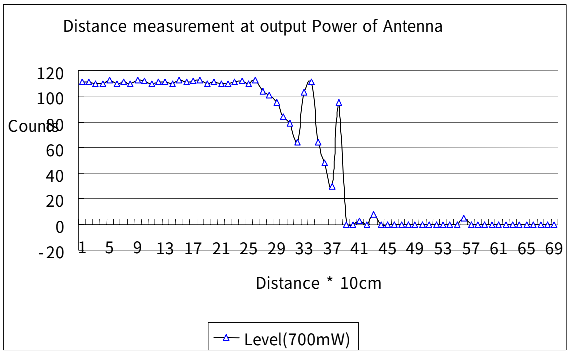
(d) Output at level 400mW.



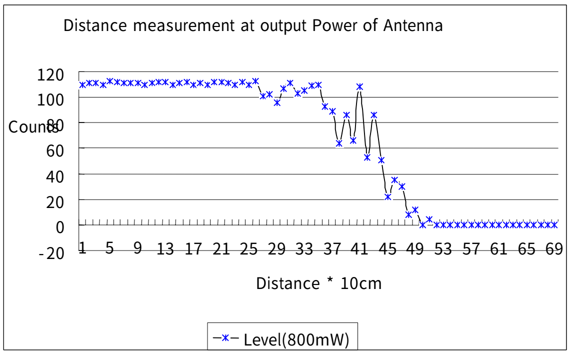
(e) Output at level 500mW.



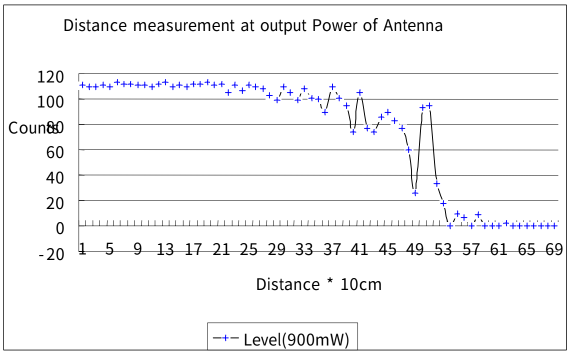
(f) Output at level 600mW.



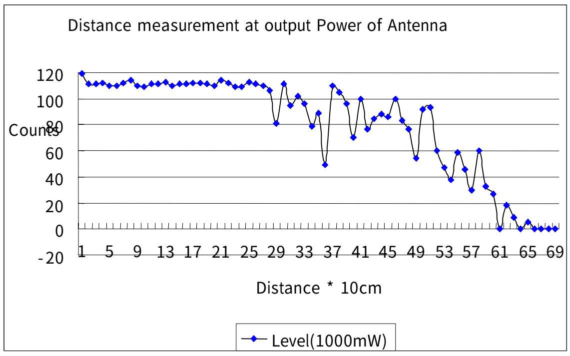
(g) Output at level 700mW.



(h) Output at level 800mW.



(i) Output at level 900mW.



(j) Output at level 1000mW.

Fig. 7 Result of output at each level.

Counter value is up and down rapidly at 110cm in Fig. 7 (a). This problem could be happened due to the characteristics of RF. We can find that clear outputs appear in Fig. 7 (d).

Through the results of output at each level, we can get distance data about the antenna power like Fig. 8. First, output of RFID Reader perceive tag like linear shape (that is distant detection), though there are some up and down points according to power level. Second, when outputs of RF antennas are same level, tags of same distance have similar perception rates, though they are not same.

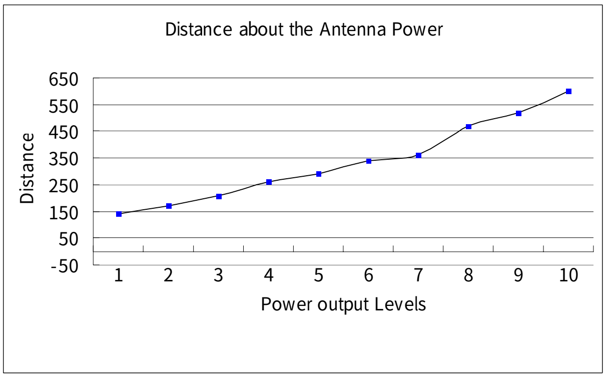


Fig. 8 Distance about the Antenna Power.

4. EXPERIMENTAL RESULT

In this paper, we investigate how RFID technology can be enhanced by location information. We use a mobile robot equipped with RFID antennas to determine the locations of RFID tags attached to objects or the wall in an indoor environment like Fig. 9.

Fig. 9 Experimental of our environment.

According to office rooms and corridors which are criterion of every building, experiment space is general office room size (500cm * 800cm). Also RFID tags are fixed at intervals of 100cm at a height 50cm on the wall.

The front of coordinates is the section from the corner of right to left when we show the entrance at the door. Also the back of coordinates is vertical line showed in front of the door.

It means that coordinates set up as below ; right end on the wall of the door is (0,0), left end on the wall of the door is (500,0), right end on the opposite side of the door is (0,800), left end on the opposite side of the door is (500, 800). Which based on, computation is performed.

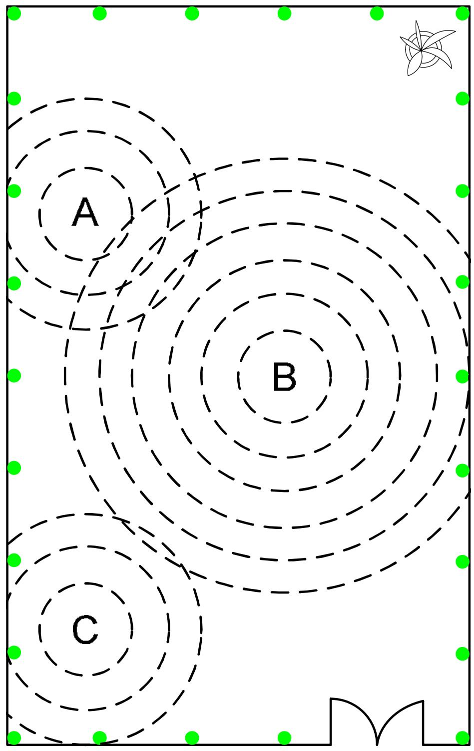


Fig. 10 Detected location of coordinates about each points.

Moving around place where experimental environment is prepared, robot makes power increase and decrease and perceives tags.

In Fig. 10, we read data of the points of A, B, C from RFID Reader, and store them in memory. Then we calculate location information based on them.

Table. 2 Result of experiment.

	Real distance	Calculated distance
A	700, 425	673, 415
B	400, 200	400, 205
C	125, 425	123, 420

In the result, error of calculated distance is 1.3%. Therefore we verify possibility that robot embody navigation system indoors using RFID, though there is a few errors of distance.

5. CONCLUSION

Because characteristics of RFID tag differ from each other, we find out there are errors of perception range. Also distance errors about power level are happened because traits of antennas differ.

Although data is detected indoors, we have to embody information which navigations need, and delivering information of robot to user PC through WLAN. After embodiment is completed, remote control of robot is practicable very usefully.

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