A New Method for Indoor Location Base on Radio Frequency Identification

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Abstract: - In recent years, there has dramatic proliferation of research concerned with Radio Frequency Identification (RFID). The RFID technologies are getting considerable attentions not only academic research but also the applications of enterprise. One of most important issues of applications is the indoor position location. Many researchers have used varied technologies to perform the tracking of indoor position location. In this paper, we will purpose a new method using RFID tags to perform indoor position location tracking, too. This method uses Received Signal Strength (RSS) to collect signal strength from reference tags beforehand. Next, signal strength is used to set up Power Level areas of ranges by reference tags. And then, using signal strength from reference tags to match signal strength by track tags. Finally, when track tags is set up into indoor environments, it will find out the position of neighboring reference tags, and using arithmetic mean to calculate the location values. A preliminary experiment proves that our method provides a better precision than LANDMRC system.

Key-Words: -RFID, indoor position location, RSS, Powel Level, location identification, LANDMRC

1 Introduction

In recent years, the position location system with ubiquitous computing has become great importance and the use of technology in the position location system has increasingly the object of study and enterprise applications. Pertinent to the applications of position location system: such as in the hospital, the location system can be used to track iatrical apparatus and check tabs on patient; personnel management of the office block; merchandise management in market and the process management of the manufacturing industry etc. The position location system can enhance the manager to manage efficiently and expediently [2][8][12][20][22].

One of the rapidly advancing technologies of position location system research is Global positioning system (GPS), but GPS has to keep Light of Sight (LoS) with satellite otherwise GPS can't perform position of track object. And then in the indoor environment, the receiver should not receive Signal because Signal subject to buildings impact. This congenital limit make GPS can't be used for indoor position location system. A growing number of research studies are now available to perform indoor position include Infrared, Ultrasonic Bats, IEEE 802.11, sensor and Radio Frequency Identification (RFID)[3][7].

Indoor position location systems have been ceaseless innovating and developing. Researchers have indicated that these location systems have some disadvantages. For examples, infrared has weak in penetrability and it transmits distance too short; Ultrasonic Bats can get better location accuracy but the apparatus is too expensive; although IEEE 802.11 is easy to construction, it can't provide better accuracy. By contrast, RFID is convenience to use and the RFID apparatus is inexpensive, so RFID is a better scheme to applying to indoor position than other technology [9][13][18].

In this paper, we will purpose position schemes placed four RFID readers in environment corners and placed several RFID tags in environment beforehand, and then use Received Signal Strength (RSS) to collect signal strength from reference tags. Set up Power Level area of the range with the signal strength from the relative distance of reference tags and readers. Next, we collect these signal data to construct relative environmental models. While the track tag is entered indoor environment, first, we get information that track tags in which area range by Power Level concept. Then, we use signal strength from reference tag to match signal strength from track tag to find out neighboring reference tags position, and then using arithmetic mean to make a calculation of these position location values, by this method to figure down track tags position location.

The rest of the paper is organized as follows. In section 2 we discuss about background knowledge of relevant research. In section 3 we discuss the mixture indoor position location system. In section 4, system simulations and experiment results are given. Finally, we make conclusions and future works in section 5.

2 Related Work

In this section, we will discuss the background knowledge of constructing our indoor position location system by RFID methods. We would further introduction include: A Review of Relevant Position Technology, Location identification based on dynamic active RFID calibration (LANDMRC), Received Signal Strength (RSS), and Power Level.

2.1 A Review of Relevant Position Technology

The relevant position technology used in recent year are (1) Infrared, (2) Ultrasonic, (3) IEEE 802.11, (4) Sensor and (5) Radio Frequency Identification (RFID). We described as follows.

2.1.1 Infrared

In 1992, infrared technology was applied to indoor position location system. In AT&T laboratory, "Active Badge" position location system was purposed by R. Want, et al [19]. This system provides indoor position location service by infrared technology. It uses a badge worm by a person, and the badge will emit signal of infrared every 10 seconds. Infrared sensor will be placed in indoor environment and relay infrared signal form badge. The position location system can estimate location information of badge. However infrared technology still has disadvantages when it is used to indoor position location. Infrared has to keep Light of Sight (LoS), so it has weak in penetrability and its transition distance is too short. Due to these disadvantages, infrared technology does not suit to indoor position.

2.1.2 Ultrasonic

"Cricket Location" position location system and "Active Bat" position location system are typical system of Ultrasonic technology [15][21]. They used "Time-of-flight" technology to measure location information of a track object.

These Ultrasonic systems have better location accuracy when they are used in indoor position, but their apparatus are too expensive. Therefore, Ultrasonic technology can't get low-cost when the system will be practically built.

2.1.3 IEEE 802.11

In 2000, "RADAR" position location system was purposed by research department of Microsoft. It uses wireless sensor network to track object. In this system, it uses equipment of network which equipment conform IEEE 802.11. "RADAR" position location system used many AP (Access Points) to lay over area of position environment. In the systematic procedure, the procedure has two parts, first part is the off-line phase and second part is the real-time phase. In the off-line phase, the system will record information about the radio signal as a function of the user's location. And then they collect these signal information to construct model of environment. In the real-time phase, the system will match signal strength of user's with signal strength of remote database to calculate user's location [1].

The disadvantages of "RADAR" position location system are (a) the track object has to worn related department; (b) the communication technology is apt to receive the interference of other communication apparatuses; (c) the system mean error about 3~4 meter, therefore the system accuracy doesn't accord with expecting.

2.1.4 Sensor

In 2000, "Smart Floor" position location system was purposed by R. J. Orr, et al. [14]. It used pressure sensors to achieve position location. In this method, they put pressure sensors under the floor. When person or object goes through the floor, sensor will receive the change of pressure. By this way, the system can get location information. The accuracy of "Smart Floor" system is conform request, but the cost of construction has to considerable when sensor put a large number.

2.1.5 Radio Frequency Identification (RFID)

In recent years, a lot of research used RFID technology to do indoor position location. "SpotON" position location system is one of examples of RFID applications for indoor position location which was proposed by J. Hightower et al[5][6]. "SpotON" position location system used Aggregation algorithm to estimate signal strength. In their system, the position estimation of track tag used other homogeneity sensors and estimate of dispersing type to perform position location.

After "SpotON" position location system has been proposed, it made a dramatic proliferation of research concerned with indoor position base on RFID technology. Subsequently, "LANDMRC" position location system was developed [13]. This method uses Active Tags to displacement hardware standards of SpotON. The results of experiments are better than "SpotON" position location system. We will detail to describe LANDMRC method in next section. The advantages of indoor position location base on RFID technology include: (a) it is not Light of Sight, (b) the penetrating of radio frequency is high, (c) it can adapt to bad environment, and (d) the cost is low. So, in the paper, we use RFID technology to perform indoor position location.

2.2 LANDMRC

A number of RFID technologies have been used for indoor position location system, and the most famous indoor position location system is LANDMRC (Location identification based on dynamic active RFID calibration) [13]. LANDMRC have been developing by a research team of Michigan State University and Hong Kong University of Science and Technology. This system provides a position method already become a typical reference system in the indoor position location system based on RFID. This method is based on the basic concept of SpotON system [5][6]. LANDMRC used the signal strength of RFID tags of SpotON system. Then, join a new algorithm to the system.

In indoor position location system, it would put RFID readers to position environment for getting a bigger cover and better position accuracy. The cover area of RFID readers hopes have smaller density and bigger cover range, which not only effectively position location to cover bigger area, but also improve the accuracy of the position. However, RFID reader is too expensive. In the LANDMRC method, it uses cheaper active tags to assist RFID readers for position location. These auxiliary tags would become reference tags in the position system. These reference tags put on stationary location beforehand. These reference tags would enhance the available cover range of RFID readers and promote the accuracy of position. The displacement of expensive RFID readers is replaced by active tags. This scheme would enhance the feasibility of RFID technology for indoor position and save cost. The displacement of expensive RFID readers by extensive active tags is the main characteristic of LANDMRC. Fig. 1 is the workflow of the LANDMARC system.

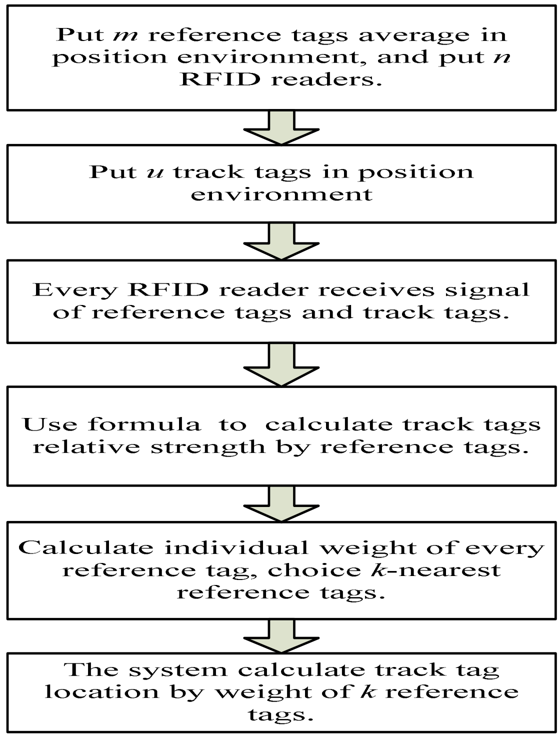

Fig. 1 The workflow of the LANDMARC system

2.3 Received Signal Strength (RSS)

In general, there are four kinds of methods for measuring distance [3].

(1.) Angle Of Arrival (AOA)
(2.) Time Of Arrival (TOA)
(3.) Time Difference Of Arrival (TDOA)
(4.) Received Signal Strength (RSS)

AOA method uses at least three reference coordinates to locate the target object location. Both TOA and TDOA use response time and time difference to identify the object locations. Indeed, Received Signal Strength (RSS) is relatively suitable for applying to the indoor position location system than other methods. Since in these models of measure distance, Received Signal Strength didn't need auxiliary apparatus of the hardware, and didn't need highest accuracy of time synchronicity such as Time Of Arrival (TOA) and Time Difference Of Arrival (TDOA)[4]. While objects are moving, RSS is more easily to forecast that signal changes than other models, so RSS can gain higher accuracy. Therefore our research used RSS to collect signal strength.

The basic conception of Received Signal Strength (RSS) [11][24] uses transmitters to sent signals to receivers and then to measure the signal values between transmitters and receivers. Formula (1) is a typical of The Wall Attenuation Factor (WAF) model. This formula can be used to calculate relative distance between receiver and transmitter.

$$P(d)=P(d_0)-10n\log\left(\frac{d}{d_0}\right)-\begin{cases} nW\times WAF & nW<C \\ C\times WAF & nW\geq C \end{cases} \quad (1)$$

In the formula (1), $P(d)$ is the signal intensity of measurement at d distance. $P(d_0)$ is the signal intensity at reference distance of d_0. n is the factor of fading. C is the maximum number of the attenuation factor. W is quantity of the walls between transmitter and base Station; nW is the number of walls between the transmitter and the receiver and WAF is the attenuation factor of wall.

2.4 The concept of Powel Level

The electric wave transmission models of free space that hypothesis of signal between transmitter and receiver is no barrier on the path of Light of Sight (LOS) communication [1]. The air-waves signal transmission loss is related to distance between transmitter and receiver. The Friis free - space formula derives from the electric wave transmission model of free space. Formula (2) is the Friis free - space formula [6]. This formula can calculate the relative distance between transmitter and receiver.

$$P_r(d)=P_tG_tG_r\left(\frac{\lambda}{4\pi d}\right)^2 \quad (2)$$

In formula (2), $P_r(d)$ is the received power. P_t is the transmited power. G_t is the antenna gain of the transmitter. G_r is the antenna gain of the receiver. λ is the wavelength. d is the distance between transmitter and receiver. In the formula (2), except d is an unknown value, other parameters can be measured work act known value. So we can use received signals intensity to substitute formula (2) to calculate distance between transmitter and receiver. The relation of signal intensity and distance is inversely proportional. For this reason, formula (3) is derived from the range of reading of RFID reader [10][16] which is based on Friis free - space,

$$r=\frac{\lambda}{4\pi}\sqrt{\frac{P_tG_rG_t\tau}{P_{th}}} \quad (3)$$

In the formula (3), r is the effective reading range of RFID readers. λ, P_t, G_r, and G_t are the same as formula (2). τ is the coefficient of transmitting power. P_{th} is the touch off the minimum energy threshold value of RFID Tag chips. We detect r values from formula (3). The RFID readers can change effective reading range of RFID readers by tuning control of transmit power of readers. As LANDMRC, the authors used Spider System from RF Code Company to accomplish their prototype system on this condition that readers can change effective reading range. RFID readers of LANDMRC system used tuning control of reading range by eight of increment instruction to control reading range and used API to accomplish the controlling of read range. Therefore, system could set up switch power level continuously to change reading range while readers read signal from tags. Make the readers to neglect or to receive ID information from tags to control system [7].

With the concept of this system, readers can enhance or reduce read range by control the power level. Relatively, these power levels make parameter of relative distance. In order to use signal fading models to calculate relative distance between reader and tag, some RFID systems have provided the function of reading signal intensity of tags directly. Basis on Friss free - space concept, we can figure out formula (4) by the signal fading models.

$$PL(d)=PL(d_o)-10N\log\left(\frac{d}{d_o}\right)-WAF \quad (4)$$

$PL(d)$ is the signal intensity at d distance. $PL(d_0)$ is the signal intensity at reference distance of d_0. d_0 is the segment distance between reader and reference tag. N is the factor of fading; it usually changes by the altered of the environment. While the environment has big interference, the value of N would be big. In general, the value of N is between 2 and 5. WAF (Wall Attenuation Factor) is the attenuation factor of wall, and one wall bring about between 3db and 15db fading of signal intensity. By signal fading models of formula (4) to divide the area of Power Level, it let system utilize the relation between signal intensity and distance to set up threshold value of signal intensity of Powel Level at the range of area. In the related research of Power Level, ALS (Area Position Scheme) [23] provided NAMING scheme. This scheme provided a way to name concepts by Powel Level, and then capture the rough information. In this paper, we will utilize reference tags of the block which derived from ALS to reach more accuracy information of position location in the indoor environment.

3 Research methodology

3.1 Procedure of research

In this paper, we will purpose a method to combine Powel Level to analyze object location. The procedure of the research is shown in Fig. 2. The procedures have two parts, first part is the learning phase, and second part is the locating phase.

As follows, we would specify the learning phase and the locating phase individually.

3.2 The learning phase

The learning phase includes five steps explained as follows.

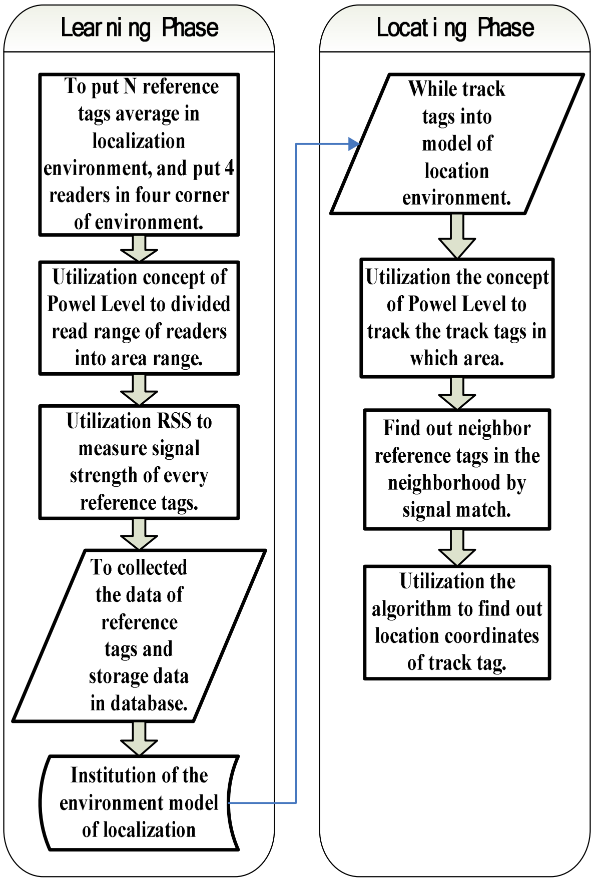

Fig. 2 The workflow of the location identification

Step1. Put reference tags and readers in environment. In indoor location environment, we will put four readers in the corner of environment and put the number of N reference tags such as Fig. 3. The amount of reference tags would be changed by the environment size and the acceptable level of accuracy. In this paper, the amount of reference tags can be considerable quantities because after the system has collected signal strength of every reference tags and has created the model of location environment, we can remove all reference tags. In the future, the system will track the tags and utilize this model to get the location information of tags. By this way, it not only can reduce cost but also can increase the accuracy on tracking the tags.

Step2. Utilize Powel Level to divide the reading range of the readers. We used 8 Powel Level to stand on LANDMARC to divide reading range of RFID

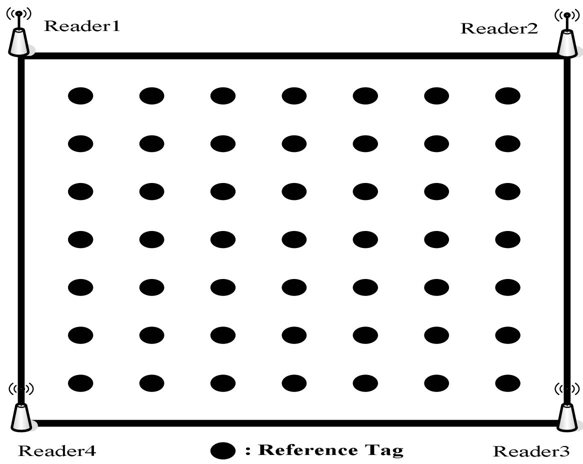

Fig. 3 The readers and tags in the testing environment

readers for the sake of location system can made decision zone faster for tracking the tracking tags. The system used the formula of signal fading models to calculate relative relation between signal strength and distance. And then set the threshold value of signal strength range of every area. The test environment will be divided into 8 area ranges by RFID readers such as shown in Fig. 4.

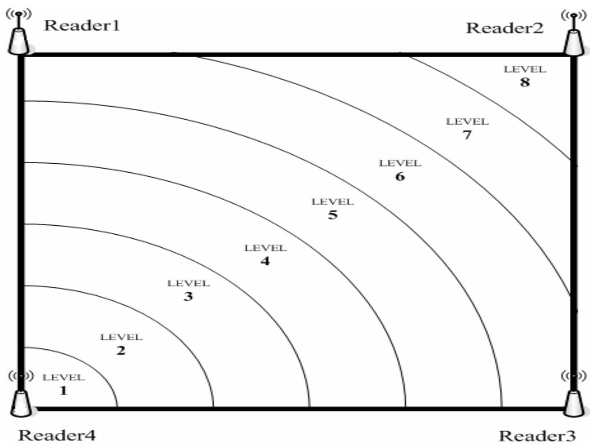

Fig. 4 The reader's range of Powel Level concept

For example, Reader 4 can divide reading range into 8- Level based on Powel Level scheme. The other three readers also can divide reading range into 8- Level respectively. Therefore, we can get many smaller zones at indoor position location environment by the reciprocal of reading range of the four readers.

At these zones, we used NAMING scheme based on ALS (Area Position Scheme) to define data type that in accordance with relative four readers in turn to record of a four-dimensional values $(P_{R1}, P_{R2}, P_{R3}, P_{R4})$ [23]. An example shows in Fig. 5. When space zone at 5762 zone, it means the Reader 1 read level is at the reading range Level 5; the Reader 2 reading level is at the reading range Level 7; the Reader 3 reading level is at the read range Level 6 and the Reader 4 reading level is at the read range Level 2. This scheme can get a rational position range fast. So, it locates an area easy but the accuracy is not good.

Step3. Utilize RSS to measure signal strength of every reference tags. In order to get the higher

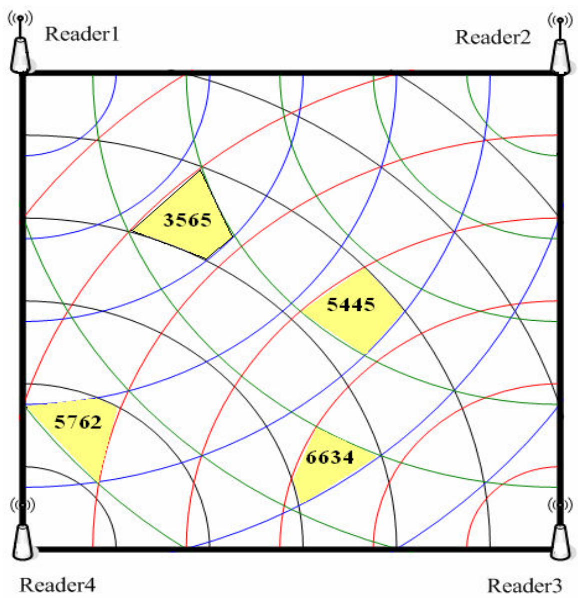

Fig. 5 The diagrammatic drawing of ALS.

accuracy of location information on track the tags, ALS is not enough. The ALS scheme only divides zone into position environment, but it cannot find out location coordinate of the track tag accuracy. Therefore, we join signal match. In learning phase, we have to use formula to calculate signal strength of every reference tags after we distributed the number of N reference tags in position environment averagely such as Fig. 6. And then the data has a four-dimensional value $(R_1S_1, R_2S_2, R_3S_3, R_4S_4)$ to record signal strength in database. Table 1 is an example of reference tag of at the coordinates (X, Y), it signal strength is $(R_1S_1, R_2S_2, R_3S_3, R_4S_4)$.

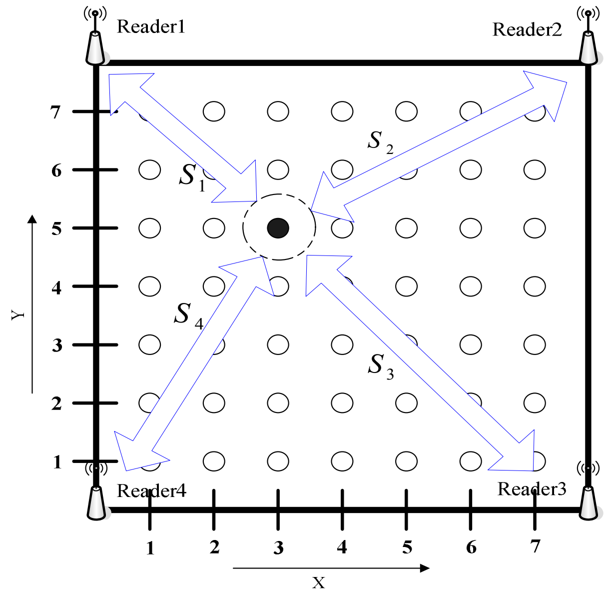

Fig. 6 The diagrammatic drawing is signal strength of reference tags

Step4. Collect the data of reference tags and storage data in database. Utilize measure and set Powel level area range in position environment, and record relative signal strength of every reference tags, and then record these data shown in Table 1 to create graphic chart. The indoor location model conforms to practical landform ratio in system because that topography is in compliance with practical landform ratio to create. And then the learning phase is finished. While the environment model has been created, we could recycle all reference tags. This step not only reduces cost but also recycles the reference tags.

Table 1. The data type of tags

TagID	Tag Coordinates	ALS Location	Signal Strength of Tag
Tag_1	(X, Y)	$(P_{R1}, P_{R2}, P_{R3}, P_{R4})$	$(R_1S_1, R_2S_2, R_3S_3, R_4S_4)$

3.3 The locating phase

Although the learning phase is more complicated, the system can fast locate the tracking tags location by learning phase. Indeed, it tracks the tracking tags has higher accuracy and lower cost that let user get information of tag location easy. Figure 7 is the procedures of locating phase. The system gets the location information of the tracking tags by ALS scheme and neighborhood tags selecting to select tags.

Finally, the system estimates position location by the arithmetic mean of the tree tags.

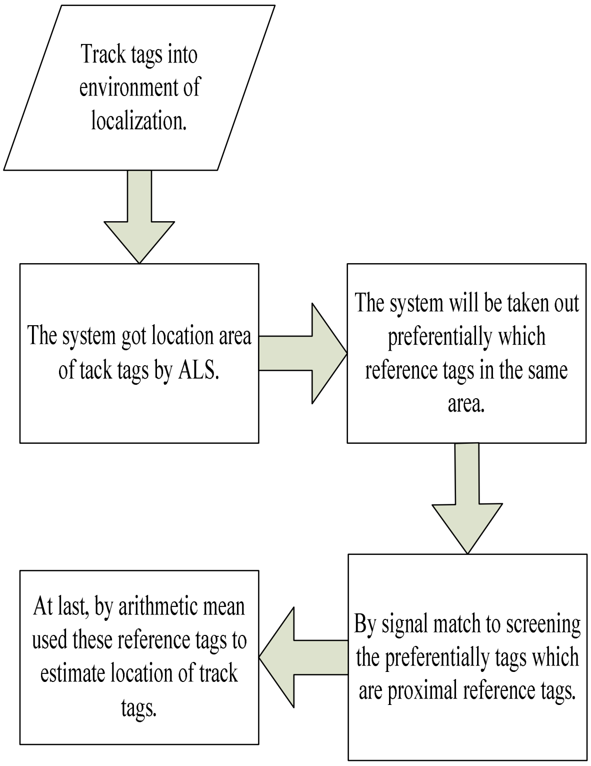

Fig. 7 Procedure of locating phase

Step1. Initially, the system records the tag information in the database by learning phase. When the tracking object is into the position location environment, the locating phase will be started.

Step2. Next, the position system will get the location of track tag by ALS method.

Step3. The reference tags in the same area will be taken out by neighborhood tags selecting method. If the number of reference tags which located in the same area less than three, the system will go to Step 4. In other side, if the number of reference tags in the same area is great than three, the system will go to Step 5 to estimate coordinates of track tag.

Step4. The system matches signal strength of reference tags to select neighborhood reference tags.

Step5. Use the coordinates of reference tags to estimate position location of track tag by formula (5).

$$(\overline{X}, \overline{Y}) = \left(\frac{\sum_{i=1}^{n} X_i}{n}, \frac{\sum_{i=1}^{n} Y_i}{n}\right) \tag{5}$$

4 Experiment

In this section, we will introduce the RFID devices are used to simulated in this method and introduce the tools be used in the simulation environment. In addition, we will show the results of our experiments and compare our method with LANDMARC system.

4.1 Device of experiment

This study used RFID readers and active tags to construct the experimental environment. The device brand is Mantis$\prod$ was made by RF Code enterprise. The parameters of experimental environment are shown Table 2 using the standard functions of the two kinds of devices. The frequency is 433.92MHz. The range of communication is 45 meters and signal strength is at the range from -58 dB to -108 dB [17].

Table 2. The standard of RFID device in simulation.

	
Operating Frequency	433.92 MHz
Antenna	Omni
Receiver Sensitivity	> 50 dB dynamic range (-58 dB to -108 dB)
Default Range Settings	8 factory programmable range settings in 5 dB increments
Tag Density	Up to 140 tag reports per second (TRPS)

4.2 Simulation of the experiment

We used Borland Developer Studio 2006 to development the system. The range of the indoor environment is 20 meters$\times$20 meters such as Fig. 8. Red dots represented the 4 readers and Blue dots represented the 32 reference tags locations. Green dots are 20 track tags which put randomly in the regions. The testing results indicated that our method could provide a lower cost and better accuracy system for indoor position location.

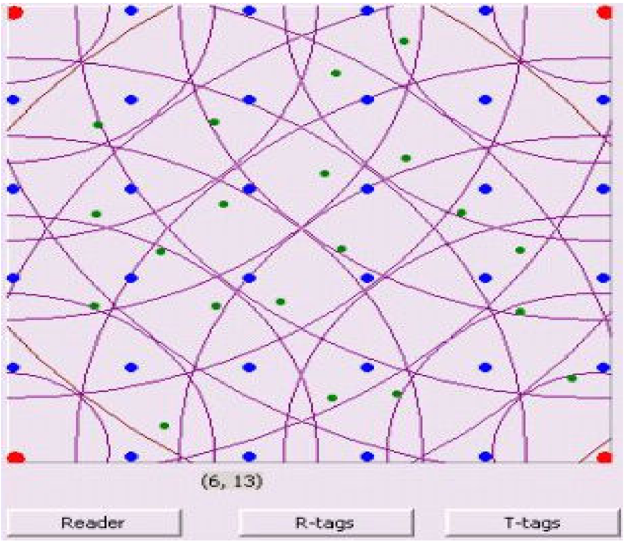

Fig. 8 The screen of experimental environment

4.3 Data types

The data fields are defined in learning phase shown in Table 3. The position system can estimate position location of track tags by those data. Table 3 shows the data field of track tags and reference tags accorded with data types of the position system. Table 3 includes tag ID, tag coordinates, signal strength and ALS location.

In order to understand whether the position location information can get the coordinates of track tags correctly or not, we have to calculate the errors of practical location of track tags and estimate location information of track tags by mean square errors. The information shows in Table 4. In next section, we would evaluate the errors by Euclidean distance.

4.4 Results

In order to know the accuracy of using our position location system to estimating unknown track tag's location. We used Euclidean distance, shown in formula (6), to calculate mean square error between practical coordinates and estimate coordinates. We compare our method with LANDMRC about maximal error and mean error.

$$e = \sqrt{(X - X_0)^2 + (Y - Y_0)^2} \qquad (6)$$

e : the mean error.

(X_0, Y_0) : the practical coordinate of track tags.

(X, Y) : the estimation coordinate by our mixture indoor position location system.

Table 3. Data types of 32 reference tags

TagID	Tag coordinates	ALS location	Signal strength
0	(0 , 4)	(2,6,8,5)	(4,20.4,25.6,16)
1	(0 , 8)	(3,7,7,4)	(8,21.5,23.3,12)
2	(0 , 12)	(4,7,7,3)	(12,23.3,21.5,8)
3	(0 , 16)	(5,8,6,2)	(16,25.6,20.4,4)
4	(4 , 0)	(2,5,8,6)	(4,16,25.6,20.4)
5	(4 , 4)	(2,5,7,5)	(5.7,16.5,22.6,16.5)
6	(4 , 8)	(3,6,6,4)	(8.9,17.9,20,12.6)
7	(4 , 12)	(4,6,6,3)	(12.6,20,17.9,8.9)
8	(4 , 16)	(5,7,5,2)	(16.5,22.6,16.5,5.7)
9	(4 , 20)	(6,8,5,2)	(20.4,25.6,16,4)
10	(8 , 0)	(3,4,7,7)	(8,12,23.3,21.5)
11	(8 , 4)	(3,4,6,6)	(8.9,12.6,20.0,17.9)
12	(8 , 8)	(4,5,5,5)	(11.3,14.4,17.0,14.4)
13	(8 , 12)	(5,5,5,4)	(14.4,17.0,14.4,11.3)
14	(8 , 16)	(6,6,4,3)	(17.9,20,12.6,8.9)
15	(8 , 20)	(7,7,4,3)	(21.5,23.3,12,8)
16	(12 , 0)	(4,3,7,7)	(12,8,21.5,23.3)
17	(12 , 4)	(4,3,6,6)	(12.6,8.9,17.9,20)
18	(12 , 8)	(5,4,5,5)	(14.4,11.3,14.4,17.0)
19	(12 , 12)	(5,5,4,5)	(17.0,14.4,11.3,14.4)
20	(12 , 16)	(6,6,3,4)	(20,17.9,8.9,12.6)
21	(12 , 20)	(7,7,3,4)	(23.3,21.5,8,12)
22	(16 , 0)	(5,2,6,8)	(16,4,20.4,25.6)
23	(16 , 4)	(5,2,5,7)	(16.5,5.7,16.5,22.6)
24	(16 , 8)	(6,3,4,6)	(17.9,8.9,12.6,20)
25	(16 , 12)	(6,4,3,6)	(20,12.6,8.9,17.9)
26	(16 , 16)	(7,5,2,5)	(22.6,16.5,5.7,16.5)
27	(16 , 20)	(8,6,2,5)	(25.6,20.4,4,16)
28	(20 , 4)	(6,2,5,8)	(20.4,4,16,25.6)
29	(20 , 8)	(7,3,4,7)	(21.5,8,12,23.3)
30	(20 , 12)	(7,4,3,7)	(23.3,12,8,21.5)
31	(20 , 16)	(8,5,2,6)	(25.6,16,4,20.4)

Table 4. Data types of 20 track tags

TagID	Tag coordinates	ALS location	Signal strength
0	(6.875 , 5.0625)	(3,4,6,5)	(8.5,14.1,19.9,16.4)
1	(17.25 , 10.8125)	(6,4,3,6)	(20.4,11.2,9.6,19.5)
2	(17.25 , 13.5625)	(7,4,2,6)	(21.9,13.8,7.0,18.4)
3	(19 , 16.5625)	(8,5,2,6)	(25.2,16.6,3.6,19.3)
4	(13.0625 , 17.25)	(7,6,3,4)	(21.6,18.6,7.5,13.3)
5	(10.875 , 17.4375)	(6,6,3,4)	(20.6,19.7,9.5,11.2)
6	(9.125 , 13.125)	(5,5,4,4)	(16.0,17.0,12.9,11.4)
7	(11.1875 , 10.75)	(5,4,4,5)	(15.5,13.9,12.8,14.5)
8	(7.1875 , 8.75)	(4,5,5,4)	(11.3,15.5,17.1,13.4)
9	(15.25 , 9.125)	(6,3,4,6)	(17.8,10.3,11.9,18.7)
10	(10.625 , 7.375)	(4,4,5,5)	(12.9,11.9,15.7,16.5)
11	(11 , 2.875)	(4,3,6,6)	(11.4,9.4,19.3,20.4)
12	(5.0625 , 10.875)	(4,6,5,3)	(12.0,18.5,17.5,10.4)
13	(5.1875 , 18.6875)	(6,7,5,2)	(19.4,23.8,14.9,5.4)
14	(2.8125 , 13.3125)	(4,7,6,3)	(13.6,21.7,18.4,7.3)
15	(2.875 , 9.1875)	(3,6,6,4)	(9.6,19.4,20.3,11.2)
16	(13.375 , 6.6875)	(5,3,5,6)	(15.0,9.4,14.9,18.9)
17	(13.3125 , 1.4375)	(4,2,6,7)	(13.4,6.8,19.7,22.8)
18	(2.9375 , 5.1875)	(2,6,7,5)	(6.0,17.8,22.6,15.1)
19	(6.9375 , 13.3125)	(5,6,5,3)	(15.0,18.7,14.7,9.6)

Fig. 9 shows the results of experiments by Euclidean distance formula. The results show mean error is 0.45 meter, maximal error is 1.83 meter and minimum is 0.04 meter. The result of experiment is shown in Table 5.

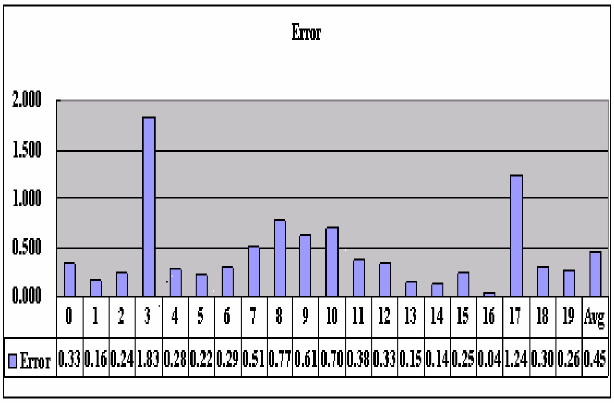

Fig. 9 Result of our location system

Table 5. Comparison of experiment

	Maximal error (m)	Mean square error(m)
LANDMARC	3.04	1.21
Our research	1.83	0.45

In next experiment, we use our method and LANDMARC system to perform the experiments six times. The range of indoor environment was 20 meters × 20 meters. There are 32 reference tags and 8 track tags. The results of the experiments were shown in Fig 10. This experiment shows our method is better than LANDMARC on the stability and the accuracy.

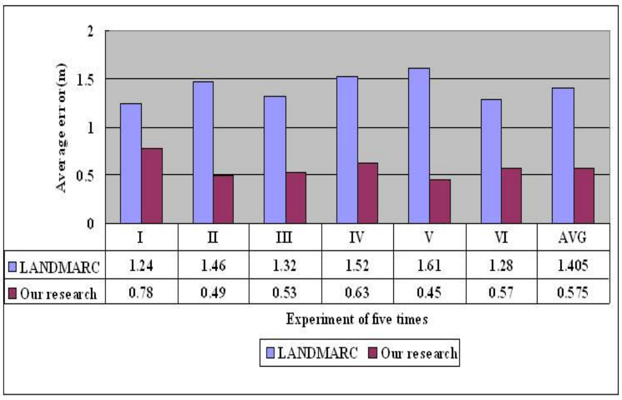

Fig. 10 Repeatedly experiment of comparison with LANDMARC

By the result of experiment in our research, our indoor position location system can promote accuracy effective. It has better accuracy than LANDMARC on repeatedly experiment and experiment of different quantity of reference tags. On the cost of position system, the system can remove reference tags after collected location information of reference tags. The system use the model of reference tags to track the position location for unknown tags. This indoor position location system used the way of mixed method, so it can reduce cost and recycle reference tags. The cost is lower than ever, so it can be applied to practical applications.

5 Conclusions and future works

In this paper, we have purposed a new mixed system for indoor location identification based on RFID devices with Power Level schemes and neighborhood tags selecting. In our method, while system collects position data from reference tags, we create a data set about tags and readers. Although it is more complicated, the system can locate position faster and more efficient than LANDMARC. The system can recycle reference tags which put on the position environment, while system have constructed position model. This method not only saves cost, but also let RFID tags recycling. In the future, we will add fuzzy method to our system for selecting neighborhood reference tags and then do position location estimations to improve accuracy.

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