An Implementation of Positioning System in Indoor Environment based on Active RFID

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Abstract

The Radio Frequency Identification (RFID) positioning based on the signal strength is the well know and feasible method. But the researches based on signal strength only usually make unsatisfied positioning error because of the instable of RFID signal. In this paper, we propose an indoor RFID positioning system which is based on the analysis of signal strength, the layout of sensing region, and the tracks of users. Different from the other RFID positioning systems, we use only one RFID reader with user, and the tags are layout in the positioning area systematically. The system integrates two phase work of positioning: analysis of signal strength in overlapping sensing area (Level 1), and analysis of users' movement directions with signal comparison (Level 2). The experiments show that the proposed mechanism improves the accuracy of positioning successfully.

Key Words: *RFID, positioning, localization, indoor, signal strength*

1. Introduction

In the past Electronic era, the electrical products that match with the network system gave people more comfortable and convenient living environment at the job, on the traffic and in life. Now, scientific technology has been entered the Ubiquitous computing era already, the concept of Ubiquitous computing proposed by Mark Weiser. Ubiquitous computing pursues the goal of people can carry on obtaining and processing the information in any time, any place with any ways. According this perfection, positioning solution service system is the first to be affected.

Regarding the most familiar GPS navigation system as the example, it spreads out a lot of positioning service application for Navigation system of on-line map or other means of transportation such as Google Map, GARMAN and PAPAGO navigation system. Today, the mobile device is more and more progressively, the electronic products such as EPC, PDA, UMPC, Smart Phone, etc., also combine the positioning function, and that makes communication service inviting. But due to the shelter from building indoor, GPS which applies to the indoor positioning system is ineffective all the time. Regarding the reason about shelter from building, a lot of technology that applied to the indoor positioning system is discussed gradually. While RFID positioning technology became an emerging research topic [1, 2, 3, 4, 5].

In general, a Real Time Location System (RTLS) based on active RFID has two issues to be evaluated. The first is the layout and cost problem. We need to consider how to distribute RFID tags cover all the positioning space with lowest cost, i.e. reducing the number of readers and tags that still could perform the practical localization algorithm. The second one is the accuracy problem. Working for minimizing the positioning error, which is the critical factor to evaluate the whole localization system.

This paper would like to come over the above issues, based on the analysis of the signal strengths, the layout of sensing region of RFID tags, and the tracks of users to reduce tag numbers and improve the positioning accuracy. This paper is organized as follows. Section 2 discusses the works related to RFID localization. Section 3 describes the framework of proposed system. The detailed methodology of positioning is described in section 4, while the section 5 presents the implementation and result of proposed system. Finally, a brief conclusion and future work are presented in the section 6.

2. Related works

2.1 SpotON [1]

This paper designed and built hardware that will serve as object location tags, part of a project called SpotON. SpotON system employs a RFID reader and many electronic tags to construct an indoor wireless

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sensing environment, which based on the received radio signal strength information (RSSI). SpotON uses many collocated nodes, the measured positional accuracy can be improved through algorithmic techniques and erroneous distance measurements caused by signal attenuation can be automatically factored out.

2.2 LANDMARK [2]

LANDMARK is a location sensing prototype system that uses 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, authors demonstrated that active RFID which is a viable and cost-effective candidate for indoor location sensing.

2.3 VIRE [3]

Virtual Reference Elimination (VIRE) used active RFID to present and implement a novel indoor positioning method. It allows efficient and accurate estimation of objection locations in indoor environments. In VIRE, instead of using many real reference RFID tags deployed in the sensing area, authors employed the concept of virtual reference tags to provide denser reference coverage in the sensing area.

2.4 LEMT [4]

A novel algorithm as known as Location Estimation using Model Trees (LEMT), LEMT reconstructed a radio map by using real-time signal-strength readings which are received at the reference points. This algorithm can take real-time signal-strength values at each time point into account and make use of the dependency between the estimated locations and reference points.

Although so many significant RFID localization researches has been undertaken, but instable RFID signals usually make above systems result in unsatisfied localization error. In our system, based on the analysis of the signal strengths and the intersection layout of sensing region, an adaptive RFID localization mechanism was developed to improve the accuracy of RFID localization.

3. System Framework

With the convenience of the mobile device which loads with RFID reader, the device can collect the information data of Tag immediately when user moving and roving in the positioning environment. The information data of Tag would store in the database and retrieve with the pre-store data. Then, the interface will present a piece of 2D fictitious map of output result. The framework of our system is shown as the Figure 1.

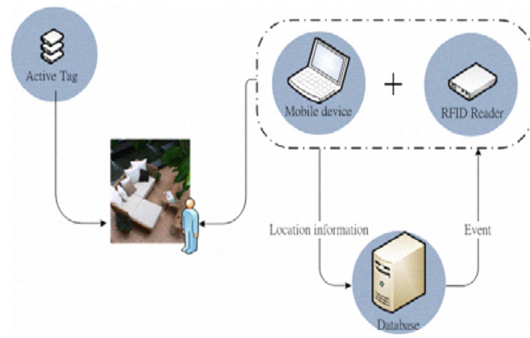


Figure 1. The framework of indoor positioning system

To construct the environment of RFID indoor positioning, we utilize the radius of the most heavy detection distance from RFID reader to Tag. The environment of detection scope is a round shape. Actually, because of a lot of environmental factor such as metal reflection, multiple path effect, hashes, etc., the reader cannot read the signal in this detection scope. According the experiment, there are some differences on the manifestation of the signal strength, because of the electric consumption of tags are different or other factor.

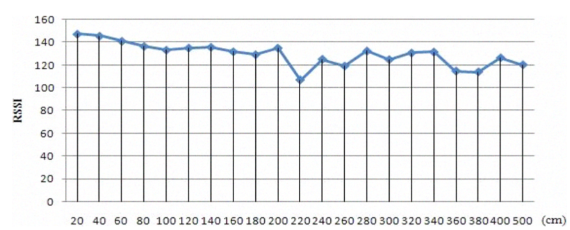


Figure. 2 The illustration of optimum sensing distance of signal strength

Figure 2 shows the illustration of optimum sensing distance of signal strength. This experiment utilized the same one tag to detect the signal strength with 50 times, and calculated the average of RSSI for each different distance. In this experiment, the difference of distance could not be identified from the signal strength when the tag was too close or too far to the reader. When the distance between reader and tag was 20cm and 30cm, the distance could not be identified because they are so close. If the distance between reader and tag was 400cm and 500cm, the detected strength of signal was quality small, so the difference detected strength of signal could not be recognized among them. Finally, we found that when the distance from 20cm to 200cm, the signal strength is more steady, and it can express the relative ship well of the distance and signal strength.

To set up of the sensor tags with uniform distribution is a good way to solve the cost and with a well positioning scope. Considering the obstacle which hinders the tags distribution in the internal environment, our proposed algorithm can still satisfy the accuracy of positioning, when the structural obstacle influenced the placement of sensor tags with uniform distribution in the indoor environment.

4. Methodology

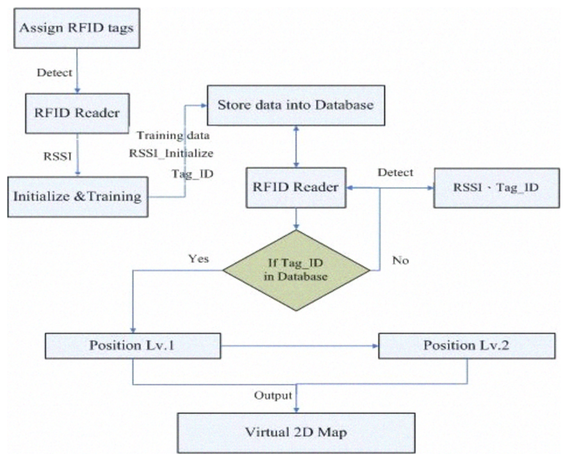


Figure. 3 The flow chart of proposed indoor positioning methodology

The flow chart of proposed indoor positioning methodology is shown as Figure 3. The work includes three main steps: pre-processing step, tag detection step and positioning analysis step as described below.

Pre-processing step: First, setting the tags in the indoor environment. In order to reach the largest region of containing scope, we construct this positioning scope with the unfix way, RFID tags are distributed over the region averagely. Second, according to tag location of real world, we need set the relative location and the number of tags that belong to the fictitious 2D map. The 2D map can represent the location as the same orient as real tag in real world. The third step is to collect the signal strength information of each tag. Then, tuning the strength value of signal to make the signal strength of each sensor tag under the same distance is similar. Because signal strength value will be influence according to the position furnished, electric consumption of the tag, or shelter, so in the pre-processing work, we need store the state of signal of each sensor tag into database. By this way, when the signal strength needs to compare in the procedure of positioning analysis, we can reference the signal strength which already be stored in the database. Figure 4 shows the procedure of Preprocessing.

Tag detection step: User holds the mobile device which loads with RFID reader moving and roving in the positioning environment. The RFID reader will collect the information data of tags immediately. In this work, according the tag information in the database, the tags which are not in this positioning environment will be filter.

Positioning analysis step: In this paper, we propose two Positioning analysis method: Analysis of overlapping sensing area (Level 1) and Analysis of the direction movement and signal comparison(Level 2). Before the work of Analysis of the direction movement and signal comparison, it needs to carry on Analysis of overlapping sensing area first. And Before the work of Analysis of grid signal strength, Analysis of overlapping sensing area and Analysis of the direction movement and signal comparison need to carry out first. Finally, the result of the analysis can represent in the fictitious 2D map, and the location of user will be indicated.

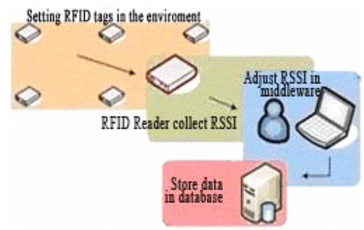


Figure 4. The procedure for Pre-processing

4.1 Analysis of overlapping sensing area

The concept of Analysis of overlapping sensing area is shown as figure 5. We used the code numbers such as A3, A2, ..., B3, B2, ..., C3, C2 to represent the specific number of sensor tag and the fictitious coordinates of 2D map. The relative location of the sensor tag is easy to find in the map, and the sensor scope can be demarcated according the value of signal strength. Then, the code numbers are used to name the overlapping areas which have some fix shape. In figure 5, a square-like area is contained by the four tags A1,A2,A3, and A4, this area can be named as A1A2B1B2. The triangle -like area includes the tags B1, B2 and C2, it can be named as B1B2C2. As so as the rhombus -like area, we can name it as B2B3.

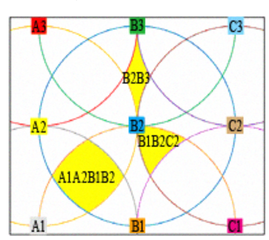


Figure 5. The overlapping sensing area (Level 1)

Under the surrounding of sensor tags, the sensor scopes which are divided out with the intensity value of signal overlaps constantly with square type, rhombus, and triangle separately. In this positioning environment, we can draw up the areas which are unique and not overlap. And we can carry on the positioning for the overlapping sensing area according the name of sensor tag which is received with RFID reader.

4.2 Analysis of the direction movement and signal comparison

The level 2 would use the output of level 1 to evaluate the positioning subtlety. For level 2, the overlapping areas such as square area, triangle area, and rhombus area will be re-divided into more and smaller areas according to the center of gravity of each shape as shown in figure 6. In the phase of Analysis of the direction movement and signal comparison, the accuracy of positioning would be more subtle in these small areas.

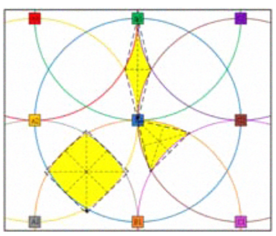
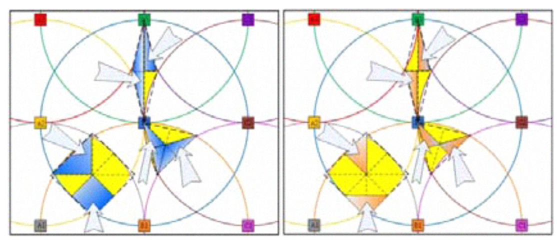


Figure 6. Re-divide areas of each overlapping area

User holds the mobile device which loads with RFID reader, and moving and roving in the positioning environment. The reader will get the serial coordinates of displacement, not the coordinates with a leap or transient. So, in a real positioning environment, the continuing displacement between each near areas for the all overlapping areas would be guaranteed. It would not the displacement with a leap or transient. According to the feature that mention in the above description and the relationship of each unique number of each overlapping area, we can analyze the essential relationship of the direction movement between the connected areas.

On the other side, while user moves and roves in the positioning environment, he will go close or far way to the sensor tags inevitably. In respect to the feature that exits the difference of the relative signal strength of the sensor tags in the positioning environment, we can evaluate the location and distance between user and sensor tags with matching up the training for interval value of signal that is a division into districts from center, and the training for interval value of the max detective distance in the sensor scope. Through the adjacent relationship between areas and the relative value intensity of signal, we can implement the positioning analysis for level 2 more subtle in these overlapping areas.

The feature of signal strength and distance can be identified through the relative experiment. In the specific distance, the intensity value of signal is inversely to the distance. The distance is more far from the sensor tag to RFID reader, the lower signal strength is. On the contrary, the closer from the sensor tag to RFID reading device is, the signal is stronger in strength. We can use this feature to decide the goal location that belongs to which areas. So, in the overlapping area for level 1, we can re-divide these shapes (the overlapping areas: A1A2B1B2, B1B2C2, B2B3) based on center of gravity to bring the more right-angled triangles. After the work of re- division, we can generalize several specific routers of direction movement based on the neighboring relationship between each overlapping region.



(a) (b)

Figure 7. Analysis of the direction movement and signal comparison

As the example shown in Figure 7, there are four triangles and four rhombuses around the square, and the arrow presents movement direction. The movement directions only consider the forward paths, the examples just like as triangle or rhombus advance on square, triangle or square advance on rhombus, and as triangle or square advance on rhombus. It can find the fix movement direction just as the arrow shown in Figure 7(a), and also increase the accuracy of positioning regarding to the feature of nearest neighboring area with matching up the comparative value of signal strength as shown in the Figure 7(b). The other geometric patterns can reach the task based on the same feature as well.

From Level 1 to level 2, the task of positioning just judges the coordinates of positioning according to the received information data simply. Without computation of the complex algorithm, it only references the comparative result which is the setting of the training values of the signal strength. The training values were produced from the signal strength in the phase of preprocessing. User did not need to operate or input any variable such as the value of signal strength or the number of tags which are received by the reader.

In the experiment for level 2, the transient phenomena of displacement can be suppressed when user walked forward, because user held the RFID in front of his chest. However, when user walked backward, the signal strength was in disorder, and this would cause the error positioning.

5. Implementation

Besides the influence of covering or shelter in the positioning environment, irregular walking and the obstacle objects such as desk, chair and door would bring about the cover. A direct way for solving the problem of cover is to raise the positioning plane. This way can reduce the cover phenomenon between sensor tag and RFID reader. So, in our system, the sensor tags are set up at high altitudes under the ceiling. And experiments show that the signal strength of the sensor tag which was suspended in midair is stronger than the sensor tag put on the ground.

After the pre-processing works, user starts to move in the positioning environment. The data received by the RFID reader will compare with the training data that already stored in the database. After comparison, system can identify the code numbers of every sensor tags which are consistent with the code numbers that has pre-stored in the database, then, system will access the information data for positioning from database to finish the work of Analysis of overlapping sensing area.

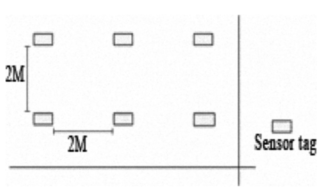


Figure 8. Six active sensor tags are laid out uniformly for positioning in a closed environment

In our research, we lay out six active RFID tags uniformly for positioning in a closed environment as shown in figure 8. The way of uniform setting constructs a steady sensing circle between sensor tags and RFID reader. The blocks such as square, triangle and rhombus are the overlapping areas in this sensing circle, and we can use theses blocks to evaluate the positioning location and compare the relative strength of signal. We have nothing to discuss with regard to the sensing scope which is not in the overlapping area, because of the trigger rate of sensor tag is 100% when the sensor tag just on the boundary of overlapping area.

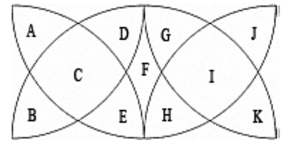


Figure 9. The overlapping sensing areas

Not limited to overlapping areas, User holds the RFID reader with load CF and walks in the sensing areas as shown in figure 9. When user walks into the correct block and the system shows the correct graphic symbol, the positioning will recode as the successful once. In the correct block, however, the system indicates that is wrong block or without any graphic symbol, the positioning will recode the error.

Table 1. Trigger rate in the overlapping areas

Area / Interval	A	B	C	D	E	F	G	H	I	J	K
1m	15.1%	14.2%	70.2%	13.4%	6.2%	0%	15.2%	5.7%	58.6%	7.4%	12.7%
2m	80.0%	26.4%	83.3%	56.2%	85.7%	0%	52.9%	50.0%	73.3%	70.5%	66.6%
2.5m	72.2%	54.5%	86.9%	63.1%	73.6%	3.3%	53.8%	52.9%	80.2%	12.5%	76.4%

Table 1 shows the result of trigger rate in the overlapping areas. In the experiment, the accuracy of positioning would be variable under the situation that the sensor tag is too high or the power energy of tag is too lower. As the case shows in Table 1, interval distance 2m in area B, and interval distance 2.5m in area J. In the area F, the interval distance is 1m and 2m respectively, the trigger rate in this area is 0%, because of the influence of positioning effect under the interval distance 2m. F is the overlapping area which is coved by the areas of D, G, E, H, C, and I. Especially in the interval distance 1m, covering is the most. When the interval value is 2.5m between tags in area F, the trigger rate is 3.3%, even the rate still lower. The scope of covering is reduced in area F, because of the height of sensor tags is raised, and the interval distance is extended to 2.5m. Relatively, the trigger rate is raised.

According to the features of flutter of RFID signal, sensitivity of distance, and the problem for positioning environment, there are the different accuracy rate of sensor tag at different interval distance and in different overlapping areas. The positioning accuracy is the best under the optimum manifestation of sensitivity to the distance of signal strength. In our research, the optimum manifestation of sensitivity to the distance of signal strength is at the interval distance 2m. In regard to this result, we carried on the adjudicative test of positioning error to the square block, triangle block, and rhombus block of the overlapping areas at the interval distance 2m.

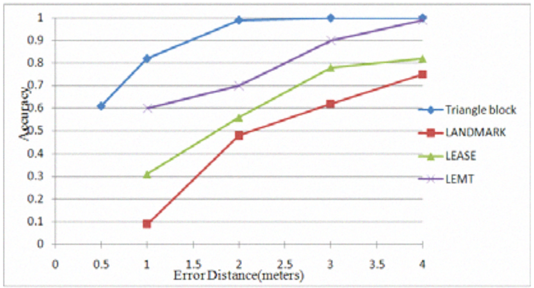


Figure 10. Positioning error to the triangle block at the interval distance 2m

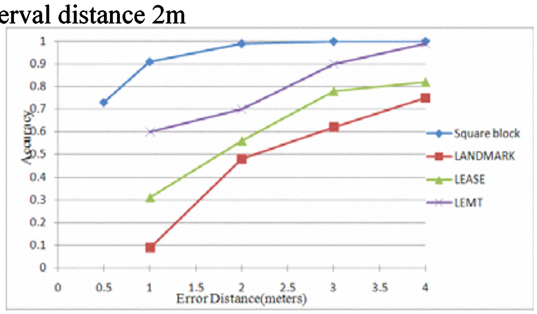


Figure 11. Positioning error to the square block at the interval distance 2m

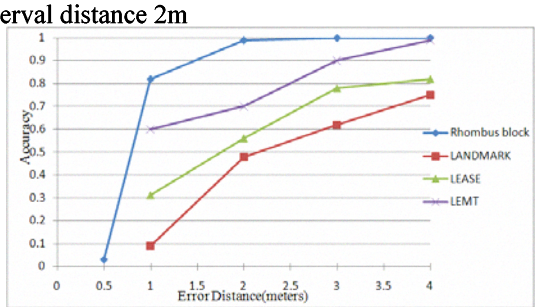


Figure 12. Positioning error to the rhombus block at the interval distance 2m

In our positioning system, we set the maximum error distance as the interval distance between tags, since if we use the positioning error distance to represent the accuracy of positioning, the error distance could not excess 2m in our positioning environment which sets six sensor tags with the interval distance 2m between each tag. As the figure 10, 11, and 12 show, when the error distance at 1m, the positioning accuracy is about 90%. We supposed user stood in the center of gravity in of the geometrical block, and the distance from boundary to the center of gravity in of the geometrical block is less than 1m absolutely as well as other geometry. Under this phenomenon, when positioning error happened, system might reveal the location of the nearest neighbor on 2D fictitious map at most. It would not show the other location of the other areas on 2D fictitious map. Therefore, the feature of our positioning environment is one factor to perform the high positioning accuracy.

6. Conclusion

In this paper, we propose a new RFID indoor positioning system according to the analysis of sensor tag detection, comparison of signal strength, and relation of direction movement. Different from the other indoor positioning systems, we do not use many readers to calculate the distance by the strength of signals directly, but use only one RFID reader with user, and the tags are assigned as the way as uniform distribution in the positioning area based on properly layout method. The evaluative results show that the proposed system procures the goal of lower cost and better accuracy.

The proposed system could be applied to many applications such as museum, gallery and navigation system, etc. When users carry a notebook or mobile device with RFID reader walking into the positioning area, users could know their location immediately and system could further actively reminds users to visit and understand the detailed information of the surrounding exhibitions more deeply.

Acknowledgement

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