An Indoor Localization Mechanism Using Active RFID Tag

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Abstract

The location-aware technology and its application are prerequisite to realize the ubiquitous computing. However, another special system for indoor localization is needed in the complicated indoor environment, where the Global Positioning System (GPS) is not available. RFID technology makes the building up of indoor localization system with low cost possible. LANDMARC is an indoor localization system using RFID technology, which introduces the concept of reference tag to reduce the number of deployed RFID readers and provides high possibility to be used in reality, and we can guarantee the accuracy of localization and thus lower the cost of importing system with it. In this paper, we analyze the existing LANDMARC system, solve the potential problems within it and propose a more efficient mechanism to enhance the accuracy of indoor localization.

1. Introduction

Ubiquitous computing is the major infra technique of the next generation of information technology, which means all things such as human, objects, buildings etc., are equipped with embedded processor and are able to connect with networks to compute and exchange information.

Ubiquitous Computing system is composed of objects which are equipped with embedded processors and connected together through communication modules, and it can be accessed anytime and anywhere and can be easily provided into real world. In other words, ubiquitous computing system is very useful in our daily life. Localization application, which is one of the important usages of ubiquitous computing system, is obtaining more and more attentions recently, which makes the development of ubiquitous localization technology and the ubiquitous computing system based on the technology very necessary.

There have been many universities and research centers doing researches on automatic localization technology for years [1]. And these technologies can be categorized into three main aspects: Triangulation, Scene Analysis and Proximity, each of which can be further divided into several detailed technologies. Global Positioning System (GPS) [2] is a commonly used localization system nowadays. But for GPS is a system depending on satellite, it is hard to localization in the complicated indoor environment.

In order to overcome the disadvantage of GPS and locate object accurately in the complicated indoor environments, researchers developed several indoor location sensing system, such as: Active Badge [4], which used diffuse infrared technology to realize indoor location positioning; RADAR [3] [5], an RF based system for locating and tracking objects inside buildings using a standard IEEE 802.11 network adapter; Cricket Location Support System [6] and Active Bat [8] location system based on ultrasonic technology; and SpotON [7][9][10], which is a well-known location sensing systems using the RFID technology. Some other technologies, such as composing Sensor network or RFID system with sensors which are embedded with reading Tags [12], are also being investigated. All these indoor localization systems have their own advantages and limitation as well, among which the location sensing system use commercially available RFID devices can reduce construction cost.

LANDMARC [11] which is developed by Michigan State University and Hong Kong University of Science & Technology together is a typical example (prototype) of indoor localization system using RFID technology. LANDMARC introduces the concept of reference tag to reduce the number of deployed RFID readers and guarantee the accuracy of localization at

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the same time, and thus can lower the cost of importing system and can be easily used in the real world.

In this paper, we analyze the existing LANDMARC system, and propose a mechanism with more efficiency, stability and accuracy to solve the potential problems within LANDMARC, and our purpose is to enhance the accuracy of indoor localization.

2. LANDMARC System

With the purpose of increasing the locating accuracy with less RFID Reader, LANDMARC utilize the concept of Reference Tag. Reference Tags are the Active Tags whose locations are fixed to help location calibration, and they serve as reference points in the system. This approach has three major advantages:

First, there is no need for a large number of expensive RFID readers, and use extra, cheaper RFID tags instead, thus can be more practical due to cost constraint.

Second, the environmental changes can easily be accommodated. The signal strength and detecting range of a same tag can be various in a complicated indoor environment, so it is hard to estimate the distance between Reader and Tag only by the detected signal strength. But for the reference tags are subject to the same effect in the environment as the tags to be located, this approach helps offset many environmental factors that contribute to the variations in detected range.

Third, the location information is more accurate and reliable.

The main focus of LANDMARC is to find out the tracking tags' nearest neighbour Reference Tags by comparing the signal strength of tracking tags and reference tags detected by reader, and grant the selected reference tags whose signal strength is close to the tracking tags' higher weighting value, and then obtain the object location by computing the weighting value and the reference tags' real positions.

Suppose we have n RFID Readers along with m reference tags in an indoor location sensing system, and each RFID reader is configured with continuous mode, which means it reports the tags that are within the specified range continuously. We define the signal strength vector of a tracking tag as $\vec{S}=(S_1,S_2,...,S_n)$ and the corresponding signal strength vector for reference tags as $\vec{\theta}=(\theta_1,\theta_2,...,\theta_n)$. The Euclidian distance in signal strength between a tracking tag and a reference tag r_j can be defined as $E_j=\sqrt{\sum_{i=1}^{n}(\theta_i-S_i)^2}$, $j\in(1,m)$. The E vector denotes the location relationship between the reference tags and the tracking tag, and the smaller the E value is, the nearer reference tag is to the tracking tag. And then, with the E vector $\vec{E}=(E_1,E_2,...,E_m)$ of m reference tags, LANDMARC will choose k reference tags with smallest E values as the neighbour tags, and obtain the tracking tag's location by

$$(x,y)=\sum_{i=1}^{k}w_i(x_i,y_i),\ w_j=\frac{\frac{1}{E_i^2}}{\sum_{i=1}^{k}\frac{1}{E_i^2}}.$$

3. Problems with LANDMARC

LANDMARC approach does show that active RFID is a viable cost-effective candidate for indoor localization, but it still has the following problems:

First, all the reference tags are supposed to be candidates when choosing the neighbor tags and this will bring in much unnecessary computation. For to choose the neighbor tags, LANDMARC will compute all the Euclidian distances between the tracking tag and every reference tag using the function $E_j=\sqrt{\sum_{i=1}^{n}(\theta_i-S_i)^2}$, $j\in(1,m)$ and compare different E values. As shown in Figure 1, only reader 2, 3 and 4 are able to detect the target tag, so the reference tags which are beyond the detecting range of reader 2, 3 and 4 have little chance to be near to the target tag. But if we use the function above directly, the reference tags which are only within the reader 1's detecting range will participate in the computation too, and thus lead to unnecessary computations and increase the server's working load, and this will also contribute to the system latency and affect the reporting of the target's location in time.

Second, for the target tag's location is obtained by the neighboring tags, the accuracy of locating result relies on the placement of reference tags, especially the density of the deployed reference tags. In other word, because we simply compute the location of tracking tag with neighboring reference tags and their weighting values, the error range of the locating result can be constrained in a polygon composed of neighboring reference tags. The lower deployment density of reference tags, the higher error range will be result in. So in order to decrease the result error, we should deploy the reference tags at a high density, and as a result, we need more reference tags. But with more tags, the interference among tags will be more serious when reader detecting signals from them, and the accuracy of the detected signal strength between tags and reader will be affected.

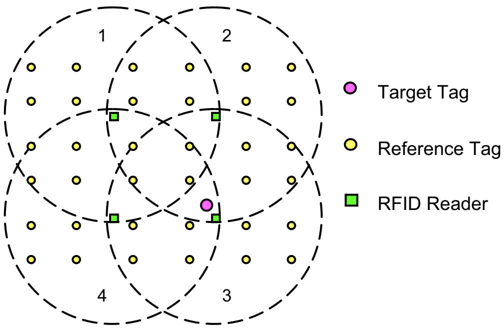


Figure 1. Four readers are deployed and only three readers can tag the target object.

This paper overcomes the above problems of LANDMARC and proposes a more efficient, effective and accurate mechanism for indoor localization.

4. Proposed Mechanism

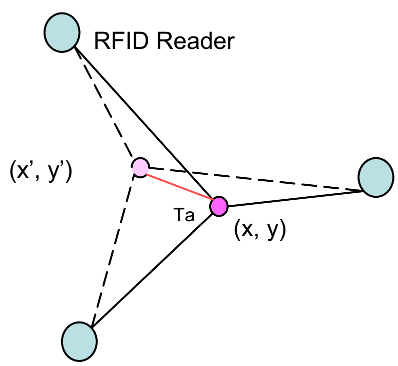


Figure 2. The estimated error between the actual position and the computed position

Just like LANDMARC, we still use n RFID Readers along with m reference tags to construct an indoor location sensing system, and each RFID reader is configured with continuous working mode. Supposing we have p RFID Readers tracking the target object, and R stands for the collection of reference tags which are simultaneously detected by $q(3 \le q \le p)$ RFID Readers. Let r donates the number of reference tags belong to R , and we use R as the collection of candidate tags for neighboring tags and obtain the vector $\vec{E} = (E_1, E_2, ..., E_m)$ by $E_j = \sqrt{\sum_{i=1}^{q} (\theta_i - S_i)^2}$, $j \in (1, r)$.

Then we choose k reference tags with lowest E values as the neighboring tags, and use K donates the collection of the k neighboring tags. The coordinate (x_i', y_i') of each tag in K can be gained through Triangulation mechanism, and the average error range of the k neighboring tags can be obtained by $(\Delta x, \Delta y) = (\frac{1}{k}\sum_{i=1}^{k} \Delta x_i, \frac{1}{k}\sum_{i=1}^{k} \Delta y_i)$. We can also use the Triangulation mechanism to get the coordinate (x', y') of the target tag, as shown in Figure 2. Then the accurate location of the target can be obtained by adding the computed coordinate result (x', y') with the average error range of the k neighboring tags.

5. Experiment and Result Analysis

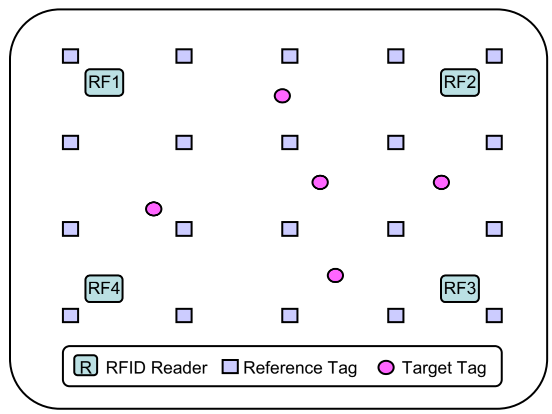
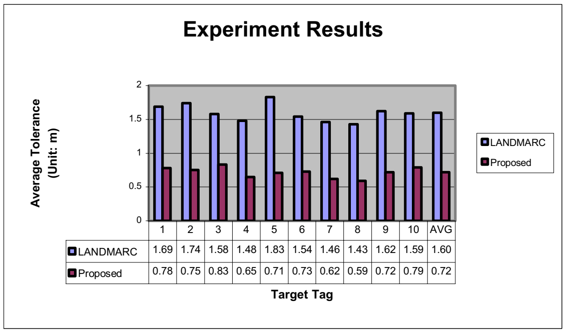


Figure 3. Experiment Environment

The experiment environment is illustrated in Figure 3.We place 4 RFID Readers in a room and 20 active tags as reference tags, and the distance between reference tags is set to 2m uniformly. The number of candidates for neighboring tags is $k = 4$ [11], and there are 10 tracking tags on different positions and we conduct the experiment by locating each of them 100 times. The locating result is defined as $(x_{t,c}, y_{t,c}), t = 1,2,...,10, c = 1,2,...100$.

Let $(x_t, y_t), t = 1,2,...,10$ donate the actual coordinates of the target tags and $e_{t,c} = \sqrt{(x_{t,c} - x_t)^2 + (y_{t,c} - y_t)^2}, t = 1,2,...,10, c = 1,2,...,100$ donate the Euclidian distance between the computed coordinates and the actual coordinates. Then we can use the average estimate error of each target

$\bar{e}_t = \frac{1}{100}\sum_{c=1}^{100} e_{t,c}$, $t = 1,2,...,10$ and the sum of all the average error $\bar{e} = \frac{1}{10}\sum_{t=1}^{10} \bar{e}_t$ to evaluate our proposed mechanism.



	1	2	3	4	5	6	7	8	9	10	AVG
LANDMARC	1.69	1.74	1.58	1.48	1.83	1.54	1.46	1.43	1.62	1.59	1.60
Proposed	0.78	0.75	0.83	0.65	0.71	0.73	0.62	0.59	0.72	0.79	0.72

Figure 4. Experiment Results

From Figure 4 we can see that, in the same indoor environment, the estimate error can be remarkably reduced using the proposed mechanism to locate the target tag than using the existing LANDMARC system.

6. Conclusions

This paper analyze the LANDMARC system, an indoor location sensing system based on RFID technology, and proposed a more efficient, effective and accurate mechanism and solve the problems with LANDMARC. The proposed mechanism can reduce computing load by reducing the number of candidates for neighboring tags, and thus reduce the latency in locating. When the neighboring tags are selected, while LANDMARC just simply compute the target coordinate with positions of the neighboring tags and their granted weighting values, the proposed mechanism get the target coordinate by further adding the computed coordinate result with the average error range of all the neighboring tags, and thus can reach higher locating accuracy.

7. Acknowledgement

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