VIRE and Recursive-Verify Based RFID Location Algorithm

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Abstract. Currently RFID is a widely used technique in indoor location. Some related technology and algorithms using active tag for indoor location is studied in this paper. Based VIRE algorithm, an improved location algorithm is proposed by the introduction of a correction mechanism called recursive-calibrate to reach a higher accuracy of location. Simulation are also shown here to prove that the accuracy of localization is improved.

Introduction

Radio Frequency Identification (RFID) has become popular and typical application, spanning from asset tracking, service industries, logistics, and manufacturing, to supply chains in 1990s. The RFID technology has the advantages such as contact-less, non-line-of-sight, multi-object recognition, long transmission range, scalability and promising cost effectiveness, so it has been regarded as a viable and popular candidate for indoor location sensing.

Typically a RFID system consists of reader, tag and application software system. The product of RFID technology can be divided in about three category: active, semi-passive and passive RFID product. Because active tags contain more hardware than passive RFID tags, they are more expensive and can reach a far more distance [1]. In paper [2] various location technologies are studied with different RFID product. Currently the most common method is to locate an object with the RFID tag: the reader is fixed at a position and scans tags nearby. When the tag is scanned, the distance from tag to reader can be calculated by the received RF signal strength (Received Signal Strength Indicator, RSSI). Theoretically, the RSSI obtained from the reader is used to measure the distance between the tag and the reader in many propagation models. However, in practice, there are many problems in applying these models. Such as multipath effects caused by obstacles and moving objects makes RSSI change unsteadily [3].

This paper is organized as follow. In section 2 we describe relative location algorithm. Section 3 an enhanced approach based on VIRE and recursive-calibrate will be proposed. Simulation is presented in section 4. Finally, we conclude our work in section 5.

Relative Work

In recent years, lots of indoor location method have been proposed. Such as triangle-centroid localization algorithm [4], SpotOn [5], LANDMARC [6], VIRE [7].

Triangle centroid localization algorithm uses three reader to locate objects. When the reader receives a signal of a tag, distance between them can be calculated out according to the practical and theoretical model. Then with three readers, a position range can be figured in a 2-D environment. But the change of environment may cause a lot of problem in location.

The LANDMARC approach was one of the effective methods. Reference tags was proposed in the

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system. When locate a tracking tag, it compares its RSSI value with reference tags at known locations. Every reader can get the RSSI readings from a tracking tag and reference tags. Numbers of readers can coordinate their readings of the tracking tag to identify some nearby reference tags. Then the location of the tracking tag can be estimated by those nearby reference tags whose location is fixed.

LANDMARC system can compensate the environmental dynamic because that the reference tags are in the same environment as tracking tag is. But as it computes all the reference tags as the candidate for the neighbor tags, this process causes some unnecessary computation [8]. An improved algorithm based on LANDMARC was proposed to get a higher accuracy by reducing the reference tags to be calculated [9].

VIRE (Virtual Reference Elimination) algorithm is based on the LANDMARC algorithm using virtual tags. The main idea of VIRE is: eliminate those unlikely locations to reduce the estimation error without adding additional reference tags [7].

Improved Algorithm

The practical and the theoretical relationship between the RSSI value and the distance shows as Fig. 1:

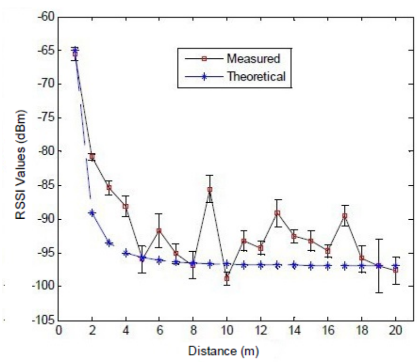


Figure 1 the relationship of distance and RSSI

Moreover, according to several experiments, 1. When there are moving obstacle between a reader and tag, or when the tag is nearby some electronic equipment, RSSI values are mutated; 2. When tag is far away from reader, RSSI value becomes very unstable; 3. Sometimes RSSI value is missing.

location with virtual reference tags

In this paper we will use simulation experiments to simulate the location algorithm. First, we put three readers and 16 real reference tags in a 10 * 10 m room as Fig. 2.

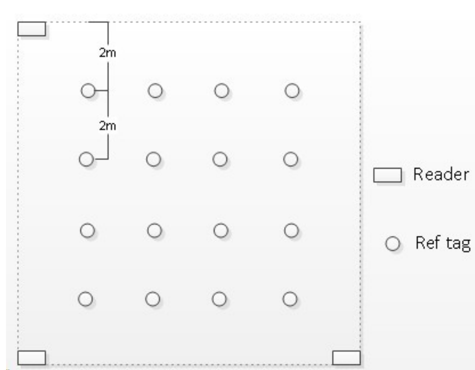


Figure 2 layout of readers and ref tags

Assuming the left bottom as the origin of coordinate, taking the impact on RSSI of the wall into account, the coordinates of the circle, each virtual reference tag should be at least 0.3 m away from the wall. Then we set 100 virtual reference tags in the room uniformly and the RSSI value of those virtual reference tags can be calculated by the nearest real reference tag. A vector of the RSSI value for each virtual reference tag is maintained to store the recent RSSI values.

Assuming that we have m readers, n virtual reference tags and t tracking tags to be tracked. We could define the RSSI vector of a tracking tag as where denotes the RSSI value of the tracking tag perceived on reader i. At the same time, for the virtual reference tags, we denote the RSSI vector as. Then for each tracking tag p, where p ∈ (1, t), we define

$$E_p = \sqrt{\sum_{i=1}^{m}(\theta_i - S_{pi})} \tag{1}$$

The smaller the value of E is, the nearer reference tag is to the tracking tag. Then the coordinate (x, y) of the tracking tag can be calculated by

$$(x, y) = \sum_{i=1}^{k} w_i (x_i, y_i) \tag{2}$$

where is the weighting factor to the neighboring reference tag. The weighting factor is given by

$$w_i = \frac{1/E_i^2}{\sum_{i=1}^{k}(1/E_i^2)} \tag{3}$$

The number of the nearest virtual reference tag and the reader will have an effect on the location result.

recursive-calibrate

In last section we need to find the k-nearest neighbors. Since the RSSI value doesn't always decrease while the distance increases, a RSSI value may be mapped to lots of distances that the k virtual reference tags got in last section is not the most nearest to the tracking tag in fact. We introduce the recursive-calibrate techniques [10] to make location more accurate and reliable.

Suppose k = 4, then R= {Tag 1, Tag 2, Tag 3, Tag 4} and the Tag A is the tracking tag, as shown in Fig. 3.

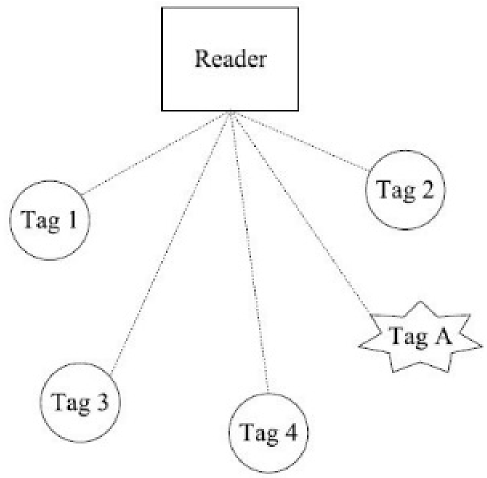


Figure 3 four reference tags and tracking tag A

For each reference tag in the set R, we can calculate its coordinate according to Tag A and the other K-1 reference tags because we already know the coordinate and RSSI vector of tracking tag. For example, in Fig.3, we can obtain tag2's coordinate according to tag1, tag3, tag4 and tagA. Note that if the coordinate of tagA computed in the first time is larger than the real coordinate, then the coordinate of reference tag computed by tag A will also be a little larger than its real coordinate. The difference between the computed reference tag's coordinate and the real coordinate can be computed and used to calibrate the tracking tag's coordinate. Repeat the calibration until the coordinate tend to be stable or we continue the calibration for some times.

Formula is given from ideas above:

$$\Delta x = \sum_{i=1}^{k} w_i (x_i' - x_i) \tag{4}$$

$$\Delta y = \sum_{i=1}^{k} w_i (y_i' - y_i) \tag{5}$$

is the real coordinate of reference tag w_i can be obtained by formula (3). Then the coordinate of tracking tag can be regulated by the following formula:

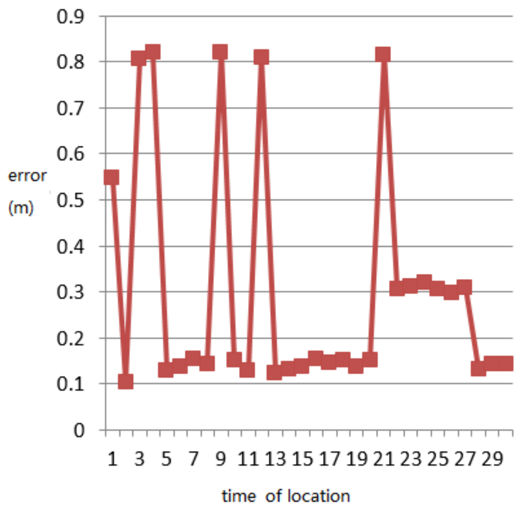
$$x' = x - \Delta x \tag{6}$$

$$y' = y - \Delta y \tag{7}$$

is the corrected coordinate. Repeat the steps above until stable.

Simulation and Result

Taking into account the relationship between RSSI value and distance, a random number is added to each RSSI value in the simulation, so that the simulation is close to the actual situation as much as possible. Fig. 4 shows the experimental results:



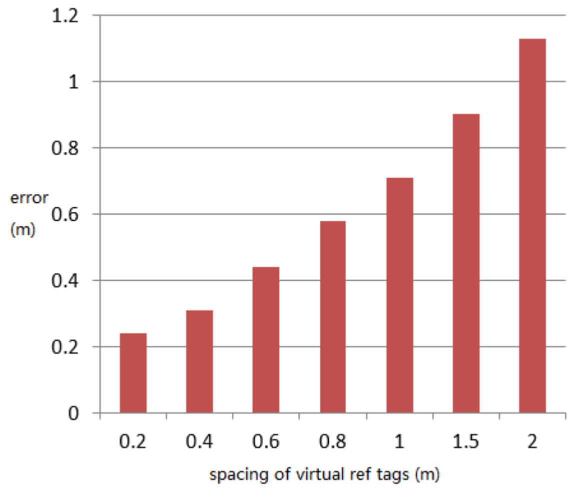


Figure 4 deviation of location Figure 5 deviation of different spacing

Fig. 4 shows the error when the spacing between virtual reference tags for 30 times location. We can see that each error is less than 1 meter. The errors of first few times is a little big because the impact of mutated RSSI values. As we got enough RSSI values, i.e. after the fifth location, historical RSSI values can help to smooth those mutated values, improving the accuracy.

The error in different spacing between virtual reference tags is also measured in simulation. As shown in Fig. 5, the x-axis is the spacing between virtual reference tags while y-axis is the error of average value of 30 times location error. Fig. 5 shows that as the spacing increases, the accuracy of location gradually decreases.

Meanwhile it was observed that when the tracking tag is placed close to the wall of the room, the accuracy decreased evidently. That's because the wall has some impact on the RSSI and the tracking tag is not totally covered by virtual reference tags.

Summary

In the paper a number of RFID location algorithm are discussed. With the advantages of VIRE and the idea of recursive-calibrate, we combined them together with some changes. The simulation shows that we can reach an accurate result with little readers and tags. In the feature, we will commit on eliminating the impact of environment to get a better result.

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