An Adaptive Threshold VIRE Algorithm for Indoor Positioning

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Abstract. At present, global positioning system (GPS) is the most widely used positioning technology for outdoors, but when it is indoors, its positioning accuracy will become lower. The anti-jamming ability of radio frequency identification (RFID) is strong, and it can be carried out in bad environment. Because of its advantages of non-sight distance, non-contact, relatively low price and so on, the application of RFID can realize the requirement of high-precision positioning. By analyzing the existing indoor positioning system, an algorithm of selecting the adaptive threshold value in virtual reference elimination (VIRE) is proposed in this paper, it can find the appropriate threshold values for each target to accommodate complex changes in the indoor environment, simulation results manifest its effectiveness.

Keywords: Radio Frequency Identification · Adaptive threshold · Indoor positioning

1 Introduction

The most famous positioning technology is the Global Positioning system (GPS) in the United States. However, because of the shielding of satellite signals by buildings, GPS cannot provide an accurate indoor positioning. Radio Frequency Identification (RFID): a technology that uses radio frequency signals for contactless communication to identify and exchange information [1]. The data exchange is bidirectional and the RFID carries large information capacity, which can be used for identification. It can also be used for information exchange. Radio frequency can be divided into high frequency, microwave frequency, identification distance can reach tens of meters in microwave frequency band, the anti-interference ability of RFID without manual intervention is strong, and it can also be carried out in harsh environment [2]. It can be widely used in traffic scheduling, toll station, anti-counterfeiting, tracking, medical, library,

This work was supported by the National Natural Science Foundation of China under Grant 61501176, Natural Science Foundation of Heilongjiang Province F2018025, University Nursing Program for Young Scholars with Creative Talents in Heilongjiang Province UNPYSCT-2016017, the postdoctoral scientific research developmental fund of Heilongjiang Province in 2017 LBH-Q17149.

S. Liu and G. Yang (Eds.): ADHIP 2018, LNICST 279, pp. 145–150, 2019.
https://doi.org/10.1007/978-3-030-19086-6_16

production, logistics and other fields. It can meet the requirement of high precision positioning when it is used in positioning [3].

Based on the research of indoor positioning technology of the RFID, there are a variety of positioning methods, TOA, TDOA, AOA, RSSI method. TOA method relies on signal propagation time parameters, usually by using triangulation to achieve the positioning. TDOA method relies on signal propagation time difference as parameters, usually uses triangular positioning. AOA is mainly dependent on the signal propagation angle [4].

LANDMARC is a classical localization algorithm, which uses reference tags to achieve localization. In short, if the RSSI value of the target tag is consistent with that of the reference tag, the target tag is considered to be at the same location with the reference tag (the position of the reference tags are known at first). In the case of the same precision, this method uses the cheap reference tag to replace the expensive RFID reader, and the cost is greatly reduced [5]. But under the condition of high precision, a large number of RFID tags need to be arranged, which is not only expensive, but also prone to interference. The idea of VIRE is not to add additional reference tags, but to introduce grid virtual reference tags. The grid virtual reference tag is not an entity, but assumes that there is an existing reference tag at some coordinate point [6]. The power value of the virtual grid reference tag is not read from the reader, but is introduced by interpolation. When introduced, the grid virtual tag can be used as a reference value.

In this paper, an improved VIRE algorithm—IMP_VIRE is proposed. First, we analyze the existing LANDMARC and VIRE system, and propose a method of selecting the adaptive threshold value in VIRE. We use the method to find appropriate threshold values for each target tag to accommodate complex changes in the environment. The purpose is to enhance the accuracy of indoor localization.

2 Improvement of VIRE Algorithm

In LANDMARC, the RSSI values of virtual tags are not read by readers, they are calculated by linear interpolation. However, a large number of researches show that the signal attenuation basically accords with the log-distance path loss model, so the signal change is nonlinear, and the linear interpolation method does not accord with the signal attenuation law. So VIRE uses log-distance path loss model to interpolate.

In the proposed algorithm, we consider finding the appropriate threshold value for each target tag to adapt to the complex changes of the environment. We use $\omega_i = \omega_{1i} \times \omega_{2i}$ as a merge weight in VIRE, based on the theoretical analysis of clustering analysis of virtual reference tags selected by proximity map method is carried out. The adjacent virtual tags that are to be joined together are divided into a class. The weight value of each class is:

$$\omega_m = \frac{n_{cm}}{\sum_{m=1}^{n_s} n_{cm}} \tag{1}$$

where n_{cm} represents the number of adjacent virtual tags adjacent to each other in class, n represents the total number of classes. $m \in (1, n_s)$, ω_m is a function related to the density of the selected virtual reference tag. The densest area has the largest ω_m. Using the following formula to represent the weights of each virtual reference tag in the same class:

$$\omega_q = \frac{1/E_q^2}{\sum_{q=1}^{n} cm \; 1/E_q^2} \tag{2}$$

where $q \in (1, n_{cm})$ is the signal intensity Euclidean distance between virtual tag and target tag. In the same class, the greater the difference between the RSSI value of the virtual reference tag and the target tag, the bigger the E_q, the smaller the ω_q. Based on the weights ω_m and ω_q, it is determined that the location of the target tag is estimated as:

$$(x, y) = \sum_{m=1}^{n_s} \omega_m \sum_{q=1}^{n_{cm}} \frac{1/E_q^2}{\sum_{q=1}^{n} cm \; 1/E_q^2} (x_q, y_q) \tag{3}$$

where (x_q, y_q) is the coordinate position of the adjacent virtual tag. And we call this algorithm IMP_VIRE.

VIRE not only provides the concept of virtual reference tag but also provides another concept: proximity maps. The entire region is divided into regions centered on each reference tag. When the target tag is compared with the RSSI value of a certain region, and when the difference is within a certain threshold, the area is marked as 1, on the contrary, the area is marked as 0. At this point, the map obtained is called the approximate map. After the approximate maps of each reader are obtained, the most likely region is found by using the intersection function. This process eliminates some areas where the location is not possible, thus improving the positioning accuracy.

The IMP_VIRE algorithm adaptively finds the appropriate threshold for each target tag using the following methods: First determine the target tag's range of adjacent tag.

$$R(A, V) = \left(1, \frac{\mu V}{A}\right) \tag{4}$$

where μ is the optimization parameter of the LANDMARC and A is the total number of actual reference tags. The initial threshold value th_0 is set according to the signal strength of the virtual tag, and the signal strength of the target tag and the signal intensity of the virtual tag are compared respectively. When the difference of the signal intensity between the target tag and the virtual tag is not greater than the initial threshold value of th_0, then select the virtual tag as the pseudo-adjacent virtual target tag. K readers select K groups of pseudo-adjacent virtual tags and select the same location's pseudo-adjacent virtual tags as the target tag's adjacent tag. Then judging the relationship between the number of adjacent tags m and the range of $R(A, V)$. Adjust the threshold with the following formula:

$$th_0 = th_0 - t_0 \times \frac{th_0}{V}, t > \left(\frac{\mu V}{A}\right) \tag{5}$$

$$th_0 = th_0 + \frac{th_0}{V}, t < 1 \tag{6}$$

So the process of IMP_VIRE can be describe as Fig. 1.

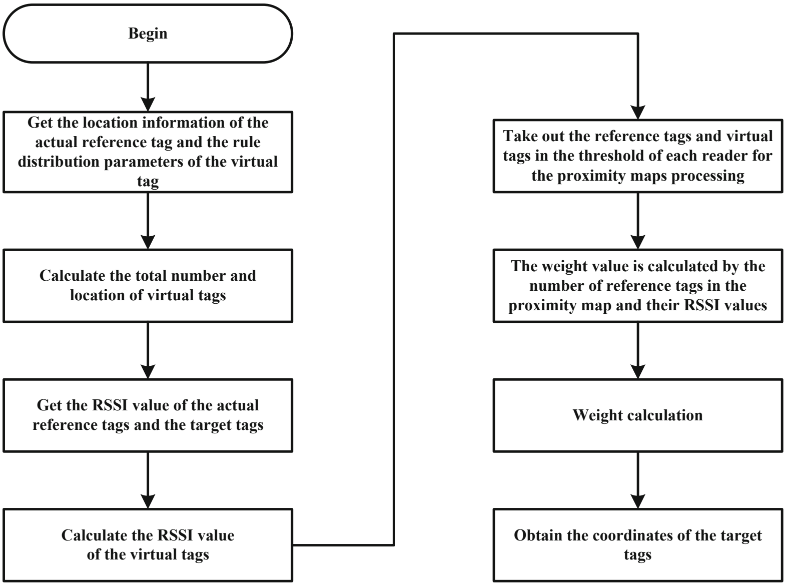

Fig. 1. The process of IMP_VIRE.

3 Experiment and Results

In order to verify that the improvement on the basis of VIRE does improve the positioning accuracy, the improved system simulation will be carried out in this chapter, and compared with the system before the improvement. The whole simulation was done in MATLAB 2014 environment. The entire area to be located is assumed to be located in a two-dimensional plane of 8 m $\times$ 8 m, while the reader is assumed to be placed on four angles of the plane, that is, the coordinates of the four readers are (0,0), (8,0), (0,8), (8,8) respectively. The simulation system will use the high frequency passive label as the reference tags and the target tags. The Experiment result is shown in Fig. 2, and the CDF curves in different regions can be clearly understood through Fig. 3.

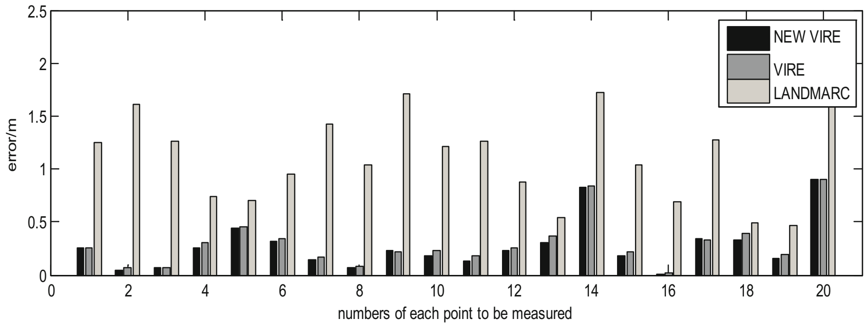

Fig. 2. Experiment result.

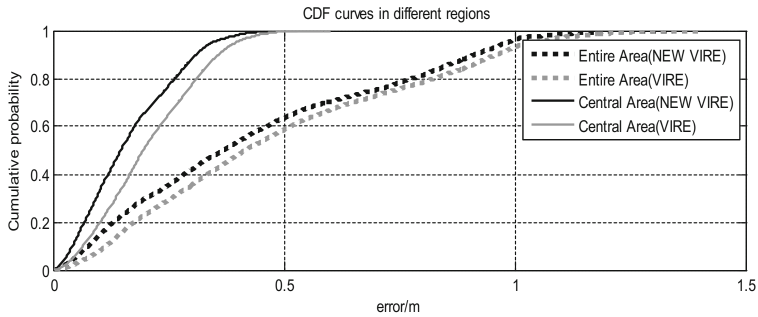

Fig. 3. CDF curves in different regions.

From these experiment results, it can be seen that the positioning error of each point is obviously decreased, and the positioning accuracy can be improved obviously by using NEW_VIRE. In the entire area, the positioning error of NEW_VIRE has more than 60% probability to lower than 0.5 m, and VIRE has less than 60% probability to lower than 0.5 m. The same argument to the comparison of the central area. It can be seen that compared with LANDMARC and VIRE, NEW_VIRE has higher localization accuracy.

4 Conclusion

In this paper, a new algorithm—IMP_VIRE is proposed. Considering the complexity of indoor environment, the single signal intensity threshold is no longer used. Instead, it adaptively finds the signal strength threshold for each tag to be positioned. In order to further improve the positioning accuracy, the new algorithm classifies the virtual reference tags selected by the proximity maps, and combining the weight value of Euclidean distance formula to estimate the location of the target tags. The effectiveness of IMP_VIRE is verified by simulation results, IMP_VIRE is the optimal algorithm in this paper. Its ability to adapt to the complex changes of the environment is better than

LANDMARC and VIRE, and the positioning accuracy is better than these two algorithms too. So it is more suitable for the RFID positioning system.

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