

# Indoor Positioning Based on RFID

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## Abstract

With the rapid development of mobile computing and embedded system, people have taken an increasingly keen interest in location awareness, and positioning service system has received more and more attention as well. Radio frequency identification technology has the advantages of non-contact, non-line-of-sight, large transmission range and high cost performance, etc. Therefore, this paper mainly studies RFID positioning algorithm based on RSSI, and analyzes LANDMARC algorithm and VIRE algorithm. The paper comes up with the triangular grid layout on the basis of VIRE system algorithm, and makes a comparison of the positioning performance between it and the rectangular grid layout. Without the application of other data processing means, the positioning accuracy of the triangle grid layout is higher than that of the rectangular grid layout. At the same time, because of the defect that the linear interpolation in VIRE algorithm cannot adapt to the indoor electromagnetic environment, this paper adopts the BP neural network model for solving the signal strength value of virtual tags, and compares it with the Newton interpolation method, and the results show that the positioning accuracy of the neural network-VIRE algorithm is higher than that of the linear interpolation-VIRE algorithm and Newton interpolation-VIRE algorithm by 14.9% and 10.2% respectively.

Key Words: RADIO FREQUENCY IDENTIFICATION, INDOOR POSITIONING, LANDMARC, VIRE, BP NEURAL NETWORK

## 1. Introduction

In recent years, wireless communication system has been growing at an alarming rate. Wireless technology has entered the fields such as communications, industry, medical care, consuming applications, logistics transportation and public security, including indoor and outdoor positioning [1]. Its development is closely bound up with people's daily life. At present, the self-organizing wireless sensor networks can provide information services including tracking, navigation, etc. While the development of wireless networks enable the users to widely gain wireless information access, thus they put forward higher requirements of accurate positioning in wireless networks, including

ing indoor and outdoor positioning. Now, the main wireless technologies include GPS [2-3], Zigbee [4], Bluetooth [5], UWB [6] and so on. It is the wide access to wireless information that makes accurate positioning of wireless technology particularly important. But in the above wireless positioning technologies, satellite signal required by GPS positioning indoors is very weak, therefore accurate positioning in the indoor environment is basically impossible; other wireless technologies are not suitable for the positioning of the indoor environment due to the high cost.

Radio frequency identification technology

(RFID) is a kind of automatic identification technology sprang up in the 1990 s, which could make use of radio frequency signal to automatically identify object targets [7-8], and to obtain related information of object targets on the basis of the different types of signals. RFID tags realize non-contact operation, and have the characteristics of small volume, large capacity, being free of visible source of light, good penetrability, strong pollution resistance and durability, etc. Moreover, RFID line-of-sight identification and tags can work under the bad environment, support fast reading and writing of multiple targets at the same time, and realize real-time positioning and long-term tracking management [9-10]. Its cost is low cost but it has high positioning accuracy, and can be used on a large scale in indoor positioning. This paper mainly studies the indoor positioning technology based on RFID.

Therefore, this paper is mainly based on the application of FRID technology in indoor positioning, and focuses on different positioning algorithms' influence on the positioning accuracy. First, this paper introduces the positioning methods of RFID technology system, and emphatically analyzes LANDMARC algorithm and VIRE algorithm which are based on received signal strength, and analyzes the influence of algorithms' parameters on the positioning accuracy. Secondly, the paper makes an improvement in the VIRE system which uses the linear interpolation, with the distance between the tag and the reader as the input information, the received signal strength as the output information, and then the BP neural network model is introduced to connect them. Finally, on the basis of the experimental test, the paper makes a comparison between simulation results and the existing RFID positioning algorithm, and makes an analysis of the algorithm accuracy of the optimized and improved model.

## 2 RFID Positioning Algorithm and Its Optimization Based on RSSI

The main components of RFID system are tags, readers, antenna and a wireless network processing system. According to the different measuring techniques, we can get the strength, reception time, time difference and the angle of the signals fed back to the reader by different electronic tags. So the RFID indoor positioning methods can be mainly divided into the following four types: method of received signal strength indicator (RSSI), time-of-arrival method (TOA), time-difference-of-arrival method (TDOA) and angle-of-arrival method (AOA). And the paper focuses on the analysis of RFID positioning algorithm based on received signal strength indicator (RSSI).

### 2.1 LANDMARC System Algorithm

Assume that in the environment needing positioning, there are U readers, H reference tags and M to-be-positioned tags, and then the process of solving the positions of to-be-positioned tags with LANDMARC algorithm is as follows, and the LANDMARC system structure is shown in Figure 1 below.

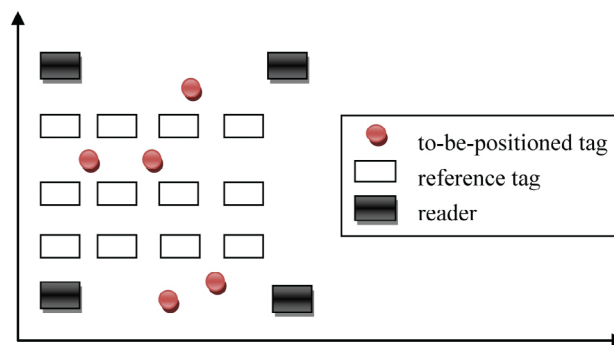


Figure 1. Schematic diagram of LANDMARC system structure

1: Define the field intensity vector of the signal reference tag  $RT_j$  receives in each reader is  $S_R^j = (S_{R1}^j, S_{R2}^j, \dots, S_{RU}^j)$ , therein:  $S_{Ru}^j$  is the RSSI value of  $RT_j$  in the reader, define the field intensity vector of the to-be-positioned tag  $LT_i$  receives in each reader is  $S_L^i = (S_{L1}^i, S_{L2}^i, \dots, S_{LU}^i)$ , therein:  $S_{Lu}^i$  is the RSSI value of  $LT_i$  in the reader  $\xi_u$ , and define the field intensity distance between  $RT_j$  and  $LT_i$  as in formula 1 below:

$$E_{LR}^{ij} = \sqrt{\sum_{u=1}^U \phi_u^{ij}}, j \in (1, M), i \in (1, H) \quad (1)$$

$$\phi_u^{ij} = (S_{Lu}^i - S_{Ru}^j)^2$$

Therein:  $\phi_u^j$  is Euclidean distance component of field intensity in the reader, and the smaller  $E_{LR}^{ij}$  is, the smaller the field intensity difference in the signals  $RT_j$  and  $LT_i$  receive in their respective readers is, namely the closer the distance between the reference tag and the to-be-positioned tag is.

2: Vector  $E_{LR}^i = (E_{LR}^{i1}, E_{LR}^{i2}, \dots, E_{LR}^{iH})$  is formed according to the calculated Euclidean distance component of field intensity between  $LT_i$  and respective reference tags  $RT_j$ ; select k smallest elements and form collection  $EP_{LR}^i = (EP_{LR}^{i1}, EP_{LR}^{i2}, \dots, EP_{LR}^{ik})$  according to the elements' value and identify k reference tags corresponding with  $EP_{LR}^i$  as the nearest neighbor reference tags.

3: Give each reference tags different weight in the positioning process according to the value of  $EP_{LR}^i$ , and reckon the estimated coordinates of  $LT_i$  on the basis of empirical formula as shown in formula 2 below:

$$(x_{LT}^i, y_{LT}^i) = \sum_{j=1}^k w_j^i (x_{RT_j}^i, y_{RT_j}^i) \quad (2)$$

$$w_j^i = \frac{1}{\sum_{j=1}^k \frac{(EP_{LR}^{ij})^2}{1}}, j \in (1, k)$$

Therein:  $w_j^i$  is the weight value of the  $j$ th nearest neighbor reference tag,  $(x_{RT_j}^i, y_{RT_j}^i)$  represents the known physical position of  $LT_i$ 's  $j$ th nearest neighbor reference tag. And if the reference tag is closer to  $RT_j$  in position, the weight value given to its position information during the positioning process will be bigger.

### 2.2 VIRE System Algorithm and Its Optimization

On the basis of LANDMARC algorithm, under the premise of adding no additional reference tags, VIRE algorithm further introduces virtual reference tags, gets more accurate positions of tracking targets by eliminating positions with small probability, and further improves the positioning accuracy of LANDMARC algorithm. The structure schematic diagram of the introduced virtual tag is shown in Figure 2.

The introduction of virtual reference tags in the algorithm means that signal intensity values of the virtual reference tags are mainly considered in the algorithm, and the common VIRE system is mainly obtained by linear interpolation, so  $n-1$  virtual tags are placed between two adjacent actual reference tags. Therefore each virtual physical grid contains  $(n+1)2-4$  virtual reference tags and the actual reference tags. The signal strength values of the virtual reference tags on the level line and vertical line can be calculated by formula 3 and formula 4 below respectively.

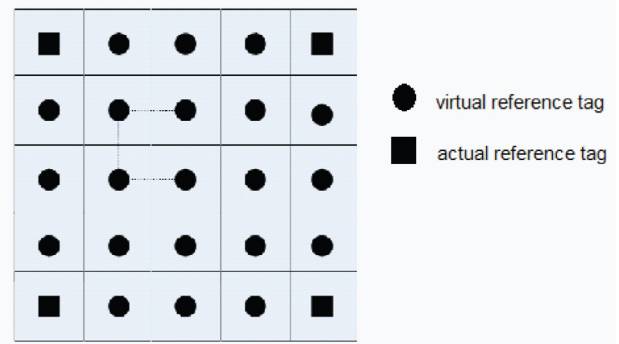


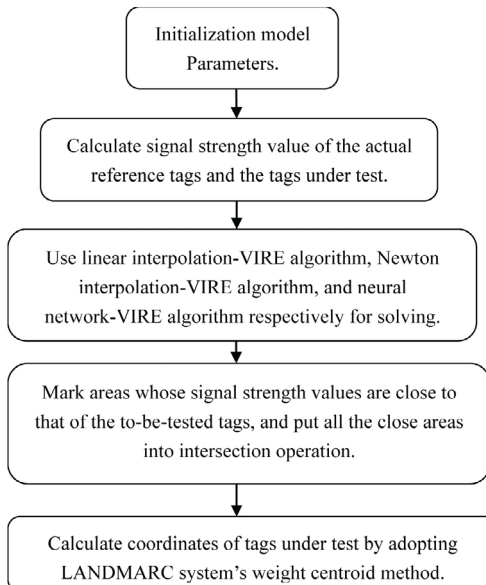
Figure 2. The structure schematic diagram of VIRE system

$$S_k(T_{p,b}) = S_k(T_{a,b}) + p \cdot \frac{S_k(T_{a+n,b}) - S_k(T_{a,b})}{n+1} = \frac{p \cdot S_k(T_{a+n,b}) + (n+1-p) \cdot S_k(T_{a,b})}{n+1} \quad (3)$$

$$S_k(T_{a,q}) = S_k(T_{a,b}) + q \cdot \frac{S_k(T_{a,b+n}) - S_k(T_{a,b})}{n+1} = \frac{q \cdot S_k(T_{a,b+n}) + (n+1-q) \cdot S_k(T_{a,b})}{n+1} \quad (4)$$

Therein:  $S_k(T_{i,j})$  is the signal strength of the virtual tag on the coordinates  $(i, j)$  to  $k$ th reader;  $a = [\frac{i}{n}]$ ,  $b = [\frac{j}{n}]$ ,

$0 \leq p \leq n-1$ ,  $p$  stands for modular operation of  $n$  by  $i$ ;  $0 \leq q \leq n-1$ ,  $q$  stands for modular operation of  $n$  by  $j$ .



In virtual grid, the signal strength of the actual reference tags can be gained through the reader, the signal strength of virtual reference tags can be solved through the signal strength interpolation of actual tags or other fitting models, and then the areas whose signal strength values are close to that of the to-be-tested tags can be marked, finally all the close areas are put into intersection operation, and the coordinates of the tag under test can be obtained.

Through the above analysis of VIRE positioning algorithm, it is known that the key of the algorithm is how to get the signal strength value of the introduced virtual tags; the traditional VIRE algorithm uses the interpolation algorithm, but the relationship between the signal strength value and its distance is not linear, so the traditional VIRE algorithm also has a big error. Therefore, the BP neural network model is established in this paper to optimize its VIRE algorithm; by defining the distance between the tag and the reader as the input information, the received signal strength by actual tags as the output information, the neural network model is established; and then the paper analyzes the positioning accuracy based on Newton interpolation-VIRE algorithm, linear interpolation-VIRE algorithm and neural network-VIRE algorithm. Among them, the block diagram of model solving process is shown in Figure 3.

### 3 Model Simulation Results Analysis

This paper mainly makes a simulation, comparison and analysis of the factors affecting the indoor positioning accuracy, which include the influence of the virtual reference tag's number on the positioning accuracy and the influence of the different reference tags' layout on the positioning accuracy; and makes a simulation and comparison among four algorithms---LANDMARC system and linear interpolation, Newton interpolation-VIRE system, neural network-VIRE system at the same time and evaluates the advantages and disadvantages of each algorithm.

Simulation experiment setup is as follows: set up the coordinates of four card readers as (0, 0), (0, 8), (8, 0), (8, 8) respectively, namely the 8\*8m positioning area; there are 16 reference tags in total, reference tag and reader are 1 m apart, each reference tag is 2 m apart from each other. Since the distance between reference tags is 2 m, path loss exponent might be set as 2. Here, take the nearest neighbor tag  $k = 4$ , take 20 points on the tag under test. The experimental distribution diagram is shown in Figure 4:

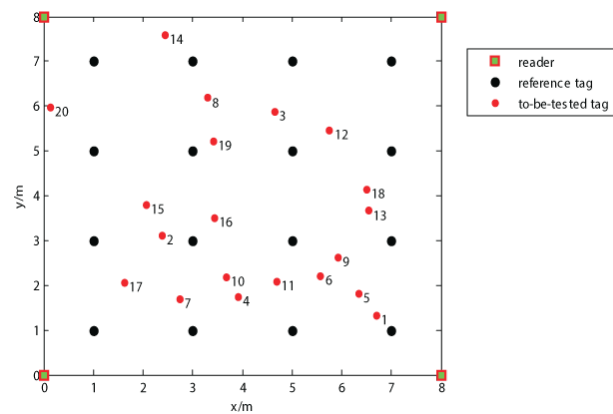


Figure 4. Simulation experiment distribution diagram

### 3.1 Simulation and Comparison of Reference Tag Layout

RSSI's RFID positioning algorithm analysis shows the influence of the introduced reference tags' different layouts, and the commonly used layout form is rectangular layout. Rectangular layout, however, to a great extent, directly calculates the coordinates of the tags under test according to the rectangular distribution in spite of the triangular that the nearest neighbor tags form, so the error in the coordinates of the tags under test error is big. The triangle layout of the reference tag is used for positioning monitoring to reduce the positioning error resulted from reference tag layout, as shown in Figure 5.

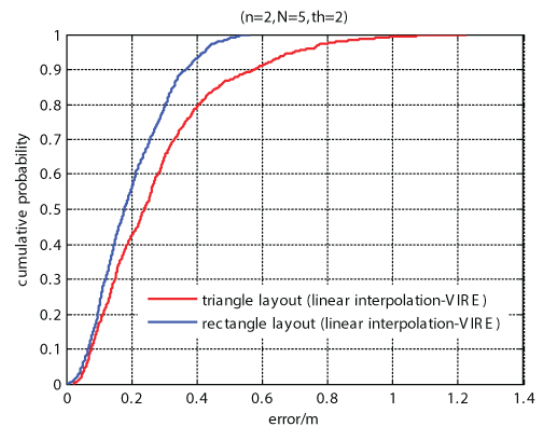
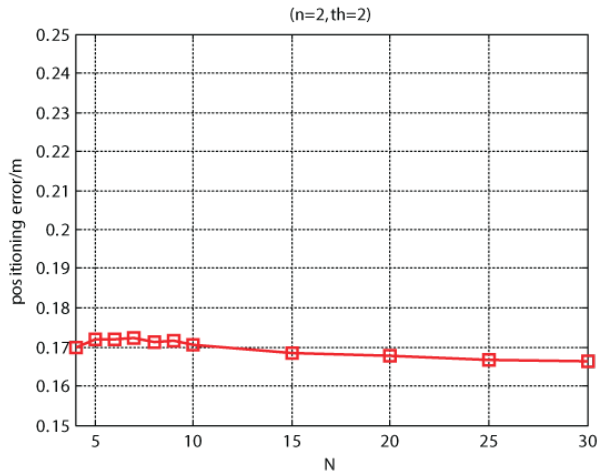


Figure 5. The cumulative error probability curves of different layouts

It can be seen from the simulation results diagram 5, when changing rectangular layout to triangle layout without any increase in the number of reference tags, the cumulative error probability curve of the triangle layout is lower than that of the rectangular layout. We can see from the diagram that when the error is 0.4 m, the cumulative error probability of the triangle layout is only 78%, while the cumulative error probability of the rectangle layout reaches 93%, and therefore the positioning accuracy of the triangle layout in the reference tag is higher than that of the rectangular layout.

### 3.2 Simulation and Comparison of Different Number of Virtual Tags

In general, it may be thought that the greater the number of virtual tags is and the higher the density is, the higher positioning accuracy will be. Meanwhile, because the virtual tags need no cost, people may blindly increase the number of virtual tags. For VIRE system algorithm, the experimental simulation is taken to find how virtual tag number affects positioning accuracy, as shown in Figure 6:



**Figure 6.** The influence of different virtual tag number on positioning error

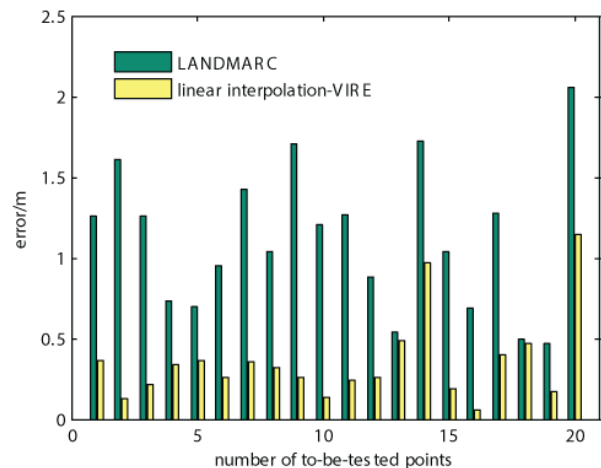
It can be seen from Figure 6 that when  $N * N$  (the sum of virtual tags) is  $4 * 4$ , positioning error is 0.173 m, when  $N * N$  is  $5 * 5$ , the positioning error is 0.173 m, when  $N * N$  reaches  $10 * 10$ , the positioning error is 0.169 m, when  $N * N$  is  $15 * 15$ , positioning error is 0.168 m, when  $N * N$  is  $25 * 25$ , positioning error is 0.166 m, when  $N * N$  is  $30 * 30$ , the positioning error is 0.166 m. We can see that when the number of virtual tags reaches  $25 * 25$ , basically the positioning error stays at 0.166 m or so without change. Therefore, when the number of the virtual reference tags reaches a certain value, the improvement of positioning accuracy won't have too much influence.

### 3.3 Simulation and Comparison of Different Algorithm Models

In the third chapter, we introduce two kinds of indoor positioning system algorithms in detail: LANDMARC system algorithm and VIRE system algorithm. In the fourth chapter, we come up with a method which uses Newton difference value for indoor positioning on the basis of the above-mentioned system algorithms. In the following part, there is an experimental simulation and comparison in the influence of the three algorithms on positioning accuracy. The model's initialization parameters are: path loss exponent  $n = 2$ , threshold value  $th = 2.2$ , the nearest neighbor tag number  $k = 6$ , virtual tag number  $n = 5$ .

#### 3.3.1 Comparison between LANDMARC Algorithm and Linear Interpolation-VIRE Algorithm

The experiment makes a comparison of simulation error in 20 points under test with LANDMARC system algorithm and VIRE system algorithm respectively, as shown in Figure 7 below. We can see from the diagram that, except that the errors at No.13 point and No. 18 point among the 20 to-be-tested points are relatively close with the two algorithms, positioning errors of VIRE system algorithm are much smaller than those of LANDMARC system algorithm, be they the points under test in the center position, such as No. 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 15, 16, 19, or the points at the edge position, such as No. 1, 5, 14, 17, 20. Experiments show that by introducing the method of linear interpolation, and making use of the similar graphs to eliminate the impossible positions of the points under test, at the same time introducing two weighting factors to reduce the error calculated, VIRE algorithm greatly improves the positioning accuracy, and the positioning system errors of LANDMARC system algorithm and linear interpolation-VIRE algorithm are 1.1158 and 0.3554 respectively.

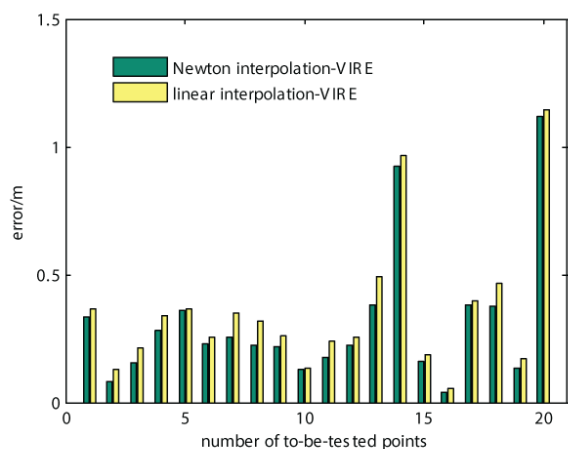


**Figure 7.** Positioning error comparisons between LANDMARC algorithm and linear interpolation-VIRE algorithm

#### 3.3.2 Comparison between Linear Interpolation Algorithm and Newton Interpolation-VIRE Algorithm

Compared with LANDMARC system algorithm's positioning accuracy, VIRE system positioning algorithm has a very big enhancement for it introduces virtual reference tags and uses linear interpolation to insert virtual tags. However, due to the complex and changeable indoor environment and multipath effect, virtual tags cannot obtain the signal strength value completely depending on the linear interpolation method, which makes a big error resulting from the use of linear interpolation for positioning, so we introduce the Newton interpolation method for solving

virtual tag's signal strength, thus reducing the error of virtual tag's signal strength value. Simulation experiment is performed on VIRE system algorithm and Newton interpolation-VIRE algorithm, as shown in Figure 8:



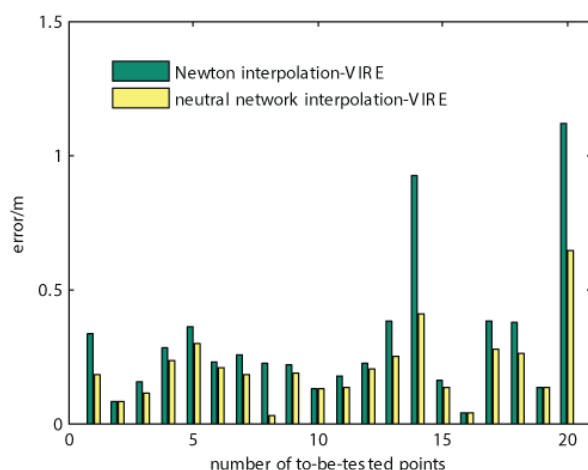
**Figure 8.** Positioning error comparisons between Newton interpolation-VIRE algorithm and linear interpolation-VIRE algorithm

We can see from Figure 8, be they the points under test in the center position such as No. 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 15, 16, 19 or the points at the edge position such as No. 1, 5, 13, 17, 18, positioning errors of Newton interpolation algorithm are smaller than those of VIRE system algorithm. And the positioning system errors of the Newton interpolation-VIRE algorithm and linear interpolation-VIRE algorithm are 0.3087 and 0.3554 respectively.

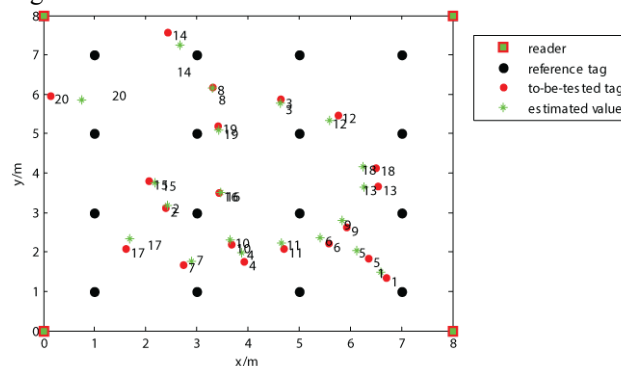
### 3.3.3 Comparison between Newton Interpolation-VIRE Algorithm and Neutral Network-VIRE Algorithm

Through the above analysis of Newton interpolation-VIRE algorithm, it is known that when there are multipath effects and interference factors in the positioning environment, virtual tag's signal strength value need to be solved by nonlinear interpolation method. But in terms of Newton interpolation method, it is mainly of smooth transition, without taking into consideration the existence of fitting effect in the data itself. In terms of this problem, therefore, this paper puts forward that BP neural network model as the core for virtual tag's solution.

The signal strength values of virtual tag are obtained by BP neural network's solution, and it is positioned and simulated. And therein, positioning error distribution diagram and positioning distribution results of Newton interpolation-VIRE algorithm is shown in Figure 9 and 10 below:



**Figure 9.** Positioning error comparisons between neutral network-VIRE algorithm and Newton interpolation-VIRE algorithm



**Figure 10.** Positioning distribution results of neutral network-VIRE algorithm

It can be seen from Figure 9 that for all the to-be-positioned points, all positioning errors by neural network algorithm prediction are lower than those of the Newton interpolation method, and No.14 and No. 20 tags under test are particularly significant, whose error positioning results are lower as much as around 0.5. Therefore, using neural network to solve the virtual tag's signal energy values are more in line with the actual situation; therein the positioning system errors of neural network-VIRE algorithm and Newton interpolation-VIRE algorithm are 0.3087 and 0.2064 respectively.

### 4. Summary

The following conclusions can be reached through the above model simulation results: (1) For there is a defect of magnifying error in rectangular reference tag layout, a triangle reference tag layout is here put forward, and whose superiority has been proved; at the same time, through the comparison of cumulative error probability diagram with rectangular layout, the results show that the triangular layout positioning accuracy is higher than that of the rectangular layout. (2) The simulation experiment shows that in the VIRE algorithm, the bigger number of introduced

virtual tags does not necessarily lead to the higher positioning accuracy. When the virtual tag number reaches a certain degree, it won't have much influence on the positioning accuracy. (3) Error comparison and simulation is taken in LANDMARC algorithm, the linear interpolation-VIRE algorithm-VIRE algorithm, Newton interpolation-VIRE algorithm and neural network-VIRE algorithm respectively. The experimental results show that the positioning accuracy of the linear interpolation-VIRE algorithm is higher than that of LANDMARC algorithm, and the positioning accuracy of Newton interpolation-VIRE algorithm is higher than that of VIRE system algorithm, but neural network-VIRE algorithm has the higher positioning accuracy, and can better conduct high-accuracy positioning in the extreme environment.

### 5. Acknowledgment

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### References

1. Yi Zhigang, Yang Lin (2008) Research on Train Tracking and Positioning System Based on RFID. *Railway Computer Application*, 17, p.p.9-12.
2. James Bao-Yen Tsui (2005) Fundamentals of Global Positioning System Receivers: A Software Approach 2nd ed. *John Wiley Sons, Inc*, Canada, p.p.1-10.
3. A. El-Rabbany, (2002) Introduction to GPS, Boston, London, Artech House Publisher, p.p.1-10.
4. Wang Quanping, Wang Li (2004) ZigBee Technology and Its Applications. *Modern Science & Technology of Telecommunications*, 11(1), p.p.33-37.
5. Serthth C, Tsuji E, Nakagawa M, et al. (2009) A switching estimated receiver position scheme for visible light based indoor positioning system. *Proceedings of the 4th international conference on Wireless pervasive computing*, p.p.1-5.
6. Fontana .R. Gunderson. S. (2002) Ultra Wideband Precision Asset Location System. *Proc. of IEEE Conference on Ultra Wideband Systems and Technologies*, p.p.147-150.
7. Manuel Laguna, Javier O. Roa, Antonio R. (2009) Jiménez, et al. Diversified local search for the optimal layout of beacons in an indoor positioning system. *Iie Transactions*, 41(3), p.p.247-259.
8. Peng L I, Ning M A, Yang Y J, et al. (2013) Boundary virtual reference tag improved algorithm based on RFID. *Application Research of Computers*, 30(1), p.p.158-160.
9. Jia Ruo, Zhang Kun, Zhang Lei (2014) Study on Adaptive RFID Indoor Location Algorithm. *Computer Simulation*, 31, p.p.33-37.
10. Han Xialin, Zhao Weidong, Ji Jun et al. (2008) Indoor Location Algorithm Based on RFID Technology and Its Improvement. *Computer Engineering*, 34(22), p.p.266-267.



## Image Feature Classification Based on Particle Swarm Optimization Neural Network

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### Abstract

Image feature classification is one of the basic questions of image processing and computer vision and it is also a key step of image analysis. BP neural network has been extensively applied in feature classification and it can classify specific objects or features through early learning; however, BP algorithm also has many defects, including slow convergence speed and easiness to be trapped in local optimum.