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Indoor location algorithm based on RBF neural network[1]

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Abstract. At present, indoor location technology is widely used in the field of wireless communication network. Due to the relatively complicated indoor environment, the wireless signal changes at any time, which brings great difficulty to the establishment of fingerprint map. In this study, a location algorithm based on RBF neural network was designed for the indoor location technology. Then, the prediction model of radial RBF neural network was adopted by the prediction technique and the K neighborhood algorithm was used to test the performance of this method. In order to make the fingerprint map adapt to the changing state of the environment at any time, the map construction method of the dynamic RF fingerprint was adopted. After optimizing the algorithm, the map was compensated according to the environmental parameter value.

Key words. RBF neural network, indoor positioning, wireless sensor network.

1. Introduction

Wireless sensor network is a comprehensive interdisciplinary. In practical applications, the number of nodes of the wireless sensor network is relatively large, and after the detection, the sensor passes the data to customers. Wireless sensor network location technology is the core technology of the wireless sensor network technology, which has a strong application value [1]. Then, the indoor location application is to use the navigation system, and the global application is to use GPS

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outdoor location system, the location effect shows that the anti-interference ability is relatively strong. However, GPS is only suitable for outdoor open environment. Without the block of buildings or other objects, the energy consumed in the process of completing the task is relatively large. Thus, GPS is not suitable for being applied to WSN [2]. Indoor location can bring great convenience for human life, such as the office object location and the rescue location in the emergency circumstances. As a result, the market demand for indoor location technology is relatively large, more researchers are concerned about this aspect, furthermore, the value of research has a very broad prospect [3]. Indoor location technology uses the distance measurement and the non-distance measurement location calculation methods. The distance measurement location technology can carry out the time difference location, angle location, the location accuracy is relatively high, and meanwhile, the original cost is reduced. The non-distance measurement location algorithm includes the mass center calculation method and the RSSF RF fingerprint matching algorithm [4]. The requirements on the nodes are relatively low and the influence of the indoor environment is relatively low. RSSI radio frequency (RF) maps have low technical costs for the indoor RBF neural networks, while the achievement efficiency of the installation and operation is high. As a result, more scholars are focusing on this research.

2. State of the art

Wireless sensor network was launched in the US military industry in last century. In the later period of development, the wireless sensor network has made great progress in theory and practical application [5]. Then, key technologies are widely used in the fields of environmental observation, medical care and building inspection. The foreign countries have attached great importance to the application given in this respect, which have provided a lot of manpower and material resources [6]. Although the domestic WSN research starts relatively late, the country's policy support in this area is more. With the development and progress of wireless sensor networks, indoor location technology has also been widely studied. Then, the non-distance measurement location technology has obtained great attention in the academic field in the indoor location technology research and development [7]. The research on the RF map matching method based on RSSI is more concentrated, and the location algorithm and the latter part of the training location phase also obtain researchers' attention. In the offline trial, the construction of the fingerprint RF map requires the acquisition of most of the reference position signals. If the indoor area is large, the construction of RF fingerprint map will consume relatively large human and material resources [8]. In addition, the signal will encounter the role of obstacles in indoor communication, and the changes with the time and space are relatively large.

If the map can not adapt to the current real environment, then, the node geographical position of the calculated position needs to be reestablished [9]. Therefore, the offline algorithm training stage is the core technology of indoor location. And it has become the key to indoor location technology about how to optimize the algorithm, so as to build dynamic RF fingerprint [10]. RADAR indoor location system proposed by the scholars is the design work completed by adopting the WSN indoor location technology. In the system, using the method of collecting data point by point to create a fingerprint RF is special, which is relatively close to the actual results. However, the workload is relatively large, which is not suitable for the indoor environment location system [11]. The difference calculation method given in the literature can reduce the work of collecting data point by point, and the workload of training can be reduced in the later stage. The method is more suitable in the case of that there are a few obstacles in the indoor environment [12]. The classical algorithm in the location phase is the calculation method of K value approaching location, the advantages and disadvantages of the localization algorithm are analyzed, and the algorithm is further optimized and transformed into RSSI's RF fingerprint map internal location calculation method.

3. Methodology

Indoor location algorithm is applied into the location process of RF fingerprint. In order to obtain high algorithm accuracy and practical application effect, the sample point fingerprint data needs to undergo a lot of training, so that the better spatial characteristics of the indoor environment can be show. However, the collection of the fingerprint data for indoor spatial characteristics requires a point-by-point measurement to each position, and this work method consumes physical strength [13]. At the aspect of nonlinear measurement, the neural network shows the advantages of this, and RBF neural network convergence performance is better, which makes up for the BP neural network's local shortcomings and restrictions in many places. The precision of the method of taking data point by point is higher than that of the prediction method, and the main idea is to conduct the derivation according to the grid data acquisition part, then, the correlation between the basic coordinates of the measurement point and the signal intensity is obtained, so that a map of the RF fingerprint is constructed in accordance with the signal strength of the model prediction grid [14]. Figure 1 shows a prediction method of the propagation model, this method can efficiently establish the radio frequency fingerprint map in a short time, and the workload of the later data training is relatively small. At the same time, the data predicted by this model will also have errors, so it is the best to use the point sampling method with higher precision.

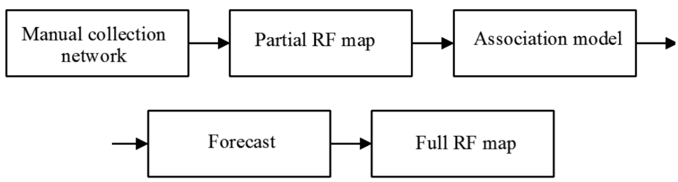

Fig. 1. Propagation prediction model

According to the propagation model, the linear interpolation algorithm is more widely used. The algorithm is simple to use, and the signal strength of the detected nodes is predicted according to the propagation distance of the theoretical signal and signal. Linear interpolation can reduce the intensity of training. Set up $\mathrm{RSSI_R}$ and $\mathrm{RSSI_L}$ respectively for the interpolation points on the right and left position of the adjacent signal strength value, set $\mathrm{RSSI_D}$ and $\mathrm{RSSI_U}$ for the interpolation point of the lower and upper position near the signal strength value, horizontal direction interpolation $\mathrm{RSSI_H}$, vertical interpolation with $\mathrm{RSSI_V}$. The expressions calculated by interpolation in horizontal and vertical directions are considered as follows

$$\mathrm{RSSI_H} = \frac{\mathrm{RSSI_L} + \mathrm{RSSI_R}}{2}\,, \tag{1}$$

$$\mathrm{RSSI_V} = \frac{\mathrm{RSSI_U} + \mathrm{RSSI_D}}{2}\,. \tag{2}$$

Although the linear interpolation method can reduce the workload of offline training, there will be non-line-of-sight problem in the actual application process. Therefore, the indoor location calculation effect is relatively poor in the case of that there are obstacles. The fingerprint database established by adopting the interpolation method by neural network can save training time. Most of the indoor location systems can use the method of taking the average after the point-by-point sampling to establish a fingerprint map. In the stage of offline training, evenly divided small grids can be divided in the locating area. The average value of the signal strength of each grid node is collected, and the data is summarized into the database, at the same time, more data points are required to collect, therefore, the workload is relatively large and the measurement accuracy obtained is relatively high.

According to the radial basis function of multivariable interpolation, Darken proposed neural network structure (RBF). This kind of network structure also belongs to a kind of forward neural network structure, which can realize the continuous function of infinitely approximating to the real value. The RBF neural network uses three layers of structure, the first layer belongs to the input layer, which constitutes the initial structure of the signal source; the second layer is the hidden layer, which determines the specific requirements of the specific problem; the third layer is the output layer, and the corresponding value is made for the input signal. The data transformation between the first and second layers is non-linear and the data conversion between the second and third layers is linear. Figure 2 is a schematic diagram of the neuron structure of neural network structure. The distance between the weight and the input vector is used as an independent variable.

The expression for the activation function R is

$$R(\|\mathrm{dist}\|) = \mathrm{e}^{-\|\mathrm{dist}\|^2}\,. \tag{3}$$

In the formula, $\|\mathrm{dist}\|$ is the distance between the weight vector and the input vector, and it is also the independent variable of the formula.

According to the structure function role of the input layer, output layer and hidden layer of the neural network structure, the input layer is only responsible for the transmission of the signal, and the works of the output layer and the hidden layer are only different learning strategies. The output layer needs to adjust the

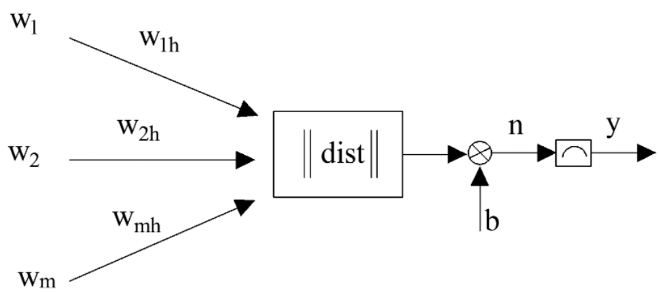

Fig. 2. Schematic diagram of neural structure of neural networks

linear weight, which has a strong learning speed. The hidden layer simply calls and activates the function, and the learning strategy is not linear, so the learning speed is relatively slow. Then, the learning method used by RBF neural network is the center selection method of the intelligent self-organization. The radial basis function used by RBF neural network is generally a Gaussian selection function, the expression is

$$R(x_{\mathrm{p}} - c_i) = \mathrm{e}^{-\frac{\|x_{\mathrm{p}} - c_i\|^2}{2\sigma^2}}\,. \tag{4}$$

In the formula, $x_{\mathrm{p}} - c_i$ represents the constant, c_i represents the center value of the Gaussian function, and σ is the variance of the Gaussian function.

Neural network is the total intelligent information processing technology in the future, which can build the model according to the data's ontology characteristics, and it has strong self-learning and adaptive features. RBF can conduct the adaptive learning and self-regulation in accordance with the specific problems described, so as to make the network have a good practicality. In addition, RBF neural network training algorithm can realize the adjustment of intelligent hidden layer unit data, the excellent learning performance is shown.

According to the description above, the prediction method based on radial nerve RBF network was proposed and the uniform indoor sampling was selected for fingerprint database finishing. In order to minimize the impact brought by the signal acquisition fluctuations, the average of the collected 100 200 data was taken as the basic database of the radial basis function neural network. Figure 3 shows a predictive model of the network. According to the coordinates of the nodes, the receiving intensity of different signal nodes was predicted and the node signal strength of the trained network prediction target was used effectively. This algorithm can restrain the incomplete map problem of the fingerprint radio frequency training method.

Affected by the indoor environment, after matching the measured values received during the location calculation process with the previous RF fingerprint map, it is found that the effect of location is not ideal. According to the RSS value of the node received by the reference node, the calculated expression for the compensation is

$$\mathrm{RSS}_i' = \mathrm{RSS}_i - \frac{\sum_{j=1}^{n}(\mathrm{RSS}_{ij}' - \mathrm{RSS}_{ij})}{n}\,. \tag{5}$$

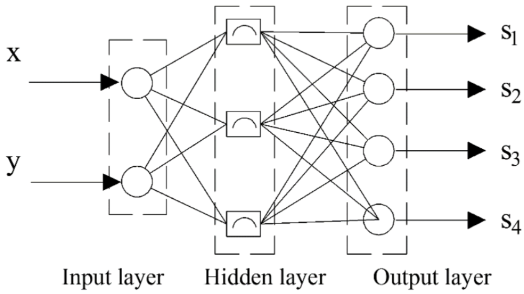

Fig. 3. Prediction model of network

In the formula, n represents the number of reference nodes and RSS_i is the average value of the offline training. This kind of calculation method can compensate the dynamic error of spatial data motion measurement to a great extent, and the periodic precision is relatively high. At the same time, the position reference point arranged will increase the input cost of the hardware, sometimes the dynamic compensation formula (5) and the actual environmental signal changes may not be consistent.

The mobile node and the prearranged reference node are set as the receiving node, and then, the emission signal of the confidence node is received. Assuming that the signal strength values received establish a mapping relationship at different spatial positions, the mapping relationship is relatively stable, then, a prearranged signal acquisition point can be used as an estimated value of the signal strength of the spatial location. The calculation expression is:

$$s = f((r_j)_{j=1}^{J}) \,. \tag{6}$$

In the formula, f is the mapping function expression and $(r_j)_{j=1}^{J}$ represents a wireless signal received by a prearranged reference node.

The offline training phase selects massive beacon nodes to construct RF fingerprint maps. According to the previous research results, it is shown that the influencing factors of RF fingerprint map have time variability. In this paper, a dynamic RF fingerprinting method based on environmental status parameters was proposed in accordance with RBF neural network optimization indoor location algorithm. The method can be divided into two stages for the arrangement of the algorithm. The first stage is the calibration environment parameter confirmation of the fingerprint database, the previous RBF neural network prediction model is established and the data is sent out through the mobile node, then, the convergence node signal is transmitted to the computer through the serial port, and the RF fingerprint composition is completed. The map is constructed according to the RF fingerprints of the established environmental status parameters. Assuming the environmental state parameters and combining with the signal intensity values, the calculation formula of the environmental change degree is

$$C = \frac{(\mathrm{RSS}_2 - \mathrm{RSS}_2') + (\mathrm{RSS}_3 - \mathrm{RSS}_3') + (\mathrm{RSS}_4 - \mathrm{RSS}_4')}{3} \,, \tag{7}$$

where RSS_2, RSS_3 and RSS_4 are the assumed environmental state parameters.

4. Result analysis and discussion

In this paper, the interpolation calculation method and the algorithm proposed in this study were compared and analyzed. The RBF neural network prediction algorithm and the linear interpolation calculation method were used to construct RF fingerprint maps respectively. When the value of k was 3, the location verification analysis of the indoor environment was carried out, and the probability of sampling was 0.9, 0.7, 0.5 and 0.3 respectively. The cumulative results of the two methods are shown in Table 1. Due to the impact of indoor obstructions, the collected data may show that the signal of some points is weak, while the signal of some points is very strong, so the calculated results may not be in line with the actual situation. And furthermore, the data of the random two collection points uses the interpolation method to calculate will bring a lot of data error. RBF neural network is the total intelligent information processing technology in the future, and the model is established according to the correlation of the data itself. The algorithm can have a good nonlinear ability of approximating to the actual value. In addition, it also has good adaptability and good learning performance, which has strong superiority in the intelligent processing of data. The experimental results show that the smaller the probability value of the collected data is, the more reasonable the neural network prediction result of the interpolation method is. The experimental results show that when the probability of the acquisition point was greater than 0.9, the cumulative error would be between 1.5 m and 3 m, and the algorithm in this paper was superior to the interpolation method. When the probability of collecting data was about 0.5, the indoor location error reached the cumulative error ratio of 2.5 m to 3.5 m. Besides, the RBF neural network prediction method is superior to the precision control of the interpolation calculation method. In the status of using the point-by-point acquisition method, and the indoor location RF fingerprint map building process, the indoor location algorithm of RBF neural network can be reduced at least half of the work, and the location accuracy can be improved by at least 5 %.

Table 1. Cumulative results of two methods

Error	Linear interpolation ratio (70%)	Paper algorithm (70%)	Linear interpolation ratio (50%)	Paper algorithm (50%)	Linear interpolation ratio (30%)	Paper algorithm (30%)
0.5	25	23	18	18	5	11
1.5	54	60	51	58	25	46
2.5	88	91	81	88	57	77
3.5	98	100	93	98	80	91
4.5	100	100	100	100	96	100
5.0	100	100	100	100	100	100

Figure 4 shows the location comparative results of the proposed reconstructed updating algorithm and the linear compensation algorithm. In order to show the results more clearly, when the c value was less than or equal to 1.34, the curve changed relatively gentle. The results show that the impact of the environmental state parameters to the results was relatively small, and the errors of the reconstructed updating calculation method and linear compensation algorithm to the indoor location calculation were basically the same. According to the previous algorithm features, it was considered that the stage that c was less than or equal to 1.34 was more suitable for dynamic compensation algorithm. When c was greater than 1.34, the slope of the curve changes was relatively large, which showed that the influence of the environment state parameters to the results was relatively large. However, in contrast, the indoor location error of the reconstructed updating algorithm method was smaller than the linear compensation calculation method. Therefore, this stage is more suitable for the reconstructed calculation method with higher accuracy.

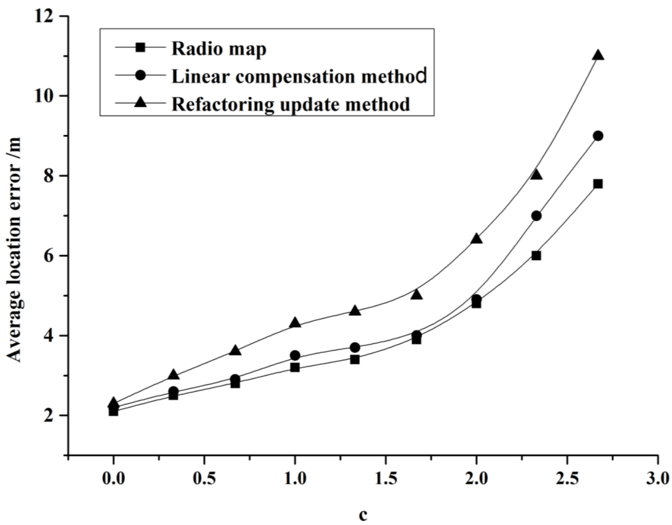

Fig. 4. Location comparison results between the reconstructed update algorithm and the linear compensation algorithm

In the indoor online location based on RBF neural network, the first was to confirm the observation value to the environment, and what kind of algorithm was adopted to optimize the RF fingerprint map database to build the database was determined according to the consignment of the measured value c. Then, the comparative analysis was carried out to the dynamic RF fingerprint map construction algorithm and the static RF fingerprint map construction algorithm. The results are shown in Fig. 5. It can be seen from Fig. 5 that the indoor location error rate of the environment adaptive dynamic RF fingerprint map construction algorithm was reduced and the reduction value was about 20 %. Due to the signal in the network environment, the indoor location had time variability, therefore, there might be the static RF fingerprint data map location matching defects. Then, a dynamic RF fingerprint mapping algorithm was proposed. According to the algorithm advantages and disadvantages of the fingerprint database which is nearly mature application currently, this paper proposed a two algorithm tradeoff selection algorithm based on the environmental parameter values. The experimental results show that the indoor location algorithm based on RBF neural network dynamic environment can improve the location accuracy.

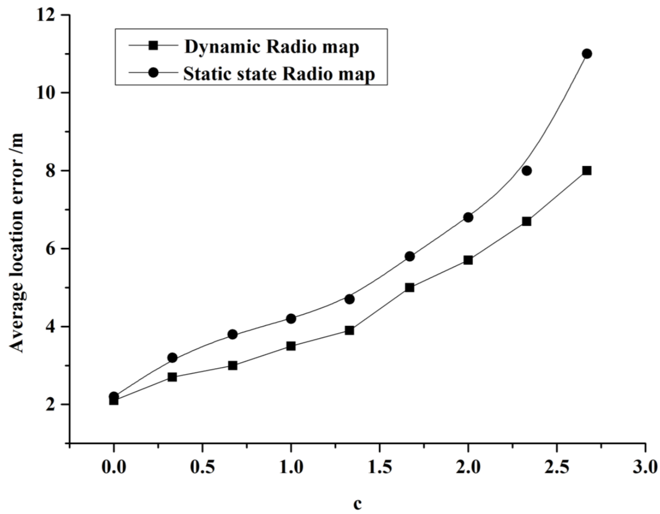

Fig. 5. Construction algorithm of dynamic RF fingerprinting map and construction algorithm of static radio frequency fingerprinting map

5. Conclusion

The convenience of the location technology to the mankind is obvious, GPS location also provides a great help for driving and navigation, and human life environment is mostly indoors. However, the indoor location data collection will be affected by obstacles, so it is necessary to set a reasonable indoor location algorithm according to different environmental state parameters. In this study, a prediction algorithm based on RBF neural network was proposed, and an indoor location RF fingerprint database was established. At the same time, this algorithm was compared with the linear interpolation algorithm, and it was considered that the indoor location algorithm based on RBF neural network was superior to the linear interpolation algorithm. As the indoor wireless signal environment changed with time, the environmental state parameter values were used to determine the positioning algorithm under the online location state. Then, 1.34 was taken as the boundary of environmental state parameter, when the environmental parameter was less than or equal to 1.34, the dynamic compensation algorithm was adopted to match. When the environmental parameter was greater than 1.34, the RBF reconstructed updating algorithm was used for the indoor location. The experimental results showed that the location error value of the dynamic RF fingerprint was smaller than that of static error value, and the ratio of error reduction was about 20 %. The algorithm proposed in this paper can effectively balance the calculation complexity of the algorithm and the precision effect of indoor location. Under the premise of not adding the computational cost and the hardware cost, the algorithm and the corresponding location method can show good environmental adaptability.

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