Fingerprint Database Optimization Method for Indoor Localization Based on Neighbor Mean Filter

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***Abstract*—Wi-Fi is widely used for network communication in our daily life here and there. In addition to communication, it is also the reference information that is widely used in indoor positioning, such as localization based on RSSI (Radio Signal Strength Indicator) fingerprint database and range based localization. However, the broadcasting signals from wireless access point suffers from the complex indoor environment, such as multi-path fading and non-homogeneous environment. And the received signals' strength at the mobile terminal is instable, which must influence the positioning precision in indoor localization. Although these factors are existed, localization based on RSSI fingerprint database are still used widely indoors. There are 2 stages in the RSSI fingerprint database localization, offline fingerprint database building and online positioning. And the quality of both fingerprint database and real time RSSI values influence the precision of localization. However, the RSSI based indoor localization algorithms existed are almost conducted on the original fingerprint database which is not optimized. Some abnormal RSSI values in fingerprint database must destroy the distribution of the RSSI road map and result in low precision. In order to decrease the influence of original data containing bizarre RSSI possibly, filtering technology should be applied for the database. Considering the geographic correlation among RSSI values in road map, the neighbor mean filter (NMF) is introduced to optimize the fingerprint database in this paper. The idea of NMF is simply to replace each pixel value in an image with the mean value of its neighbors, excluding itself. Thus, it has the advantage for filtering the bizarre RSSI values in fingerprint database. In the paper, the introduction of NMF algorithm is described firstly, then, the bizarre value of RSSI fingerprint database is analyzed and the optimization on fingerprint database with NMF is narrated, especially, the method of determining threshold for optimization. Second, the indoor localization with optimized fingerprint database is put forward, which includes the architecture for RSSI fingerprint database localization, cosine calculation of RSSI vectors and their similarity judgement, and the localization based on optimized fingerprint database. Through these measures, the abnormal RSSI values found by NMF method and replaced with mean RSSI values could make the fingerprint database more accurate for the indoor positioning. In the end, with Java programming language, the positioning system based on optimized fingerprint database is developed in Eclipse environment. Then both original RSSI fingerprint database and the database filtered are tested and experimented in the positioning system, and the result shows that the optimized RSSI fingerprint database can increase the accurate of indoor localization.**

Keywords— RSSI, optimization, NMF, indoor positioning

I. INTRODUCTION

Location based services have been widely used in our daily life, and key technologies of mobile localization are also concentrated with great interest by lots of researchers. The mobile localization technologies can be categorized into two classes of indoor and outdoor positioning. In comparison, outdoor positioning is mature with several global positioning systems, such as Chinese Beidou Navigation Satellite System [1], American Global Positioning System (GPS) [2] and Russian Global Navigation Satellite System (GLONASS) [3]. And they have enough accuracy to meet the needs for outdoor applications. At the same time, location information is also necessary in indoor environment, for example, localization of patients in hospital is an important information for smart human care services. However, global positioning systems cannot work well indoors as the positioning signals are decreased greatly caused by all kinds of obstacles, such as walls. Thus global positioning systems cannot be applied indoors, and it is result to a hot and difficult issue to get accuracy indoor position for researchers.

Currently, the indoor localization technologies are divided into two categories, ranging and non-ranging based. Among them, ranging algorithm is implemented in the way of trilateration, triangulation or maximum likelihood estimation by measuring the distance and angle between receptors and transmitters, such as time of arrival (TOA), time difference of arrival (TDOA) and angle of arrival (AOA). Non-ranging localization algorithm is implemented by the connectivity or signal features between different devices, and need not the information of distances and angles [4-7]. RSSI based mobile user localization method with signal feature has recently attracted significant attention. Perhaps this happened because RSSI measurements from the Wi-Fi access points in indoor scenarios provide a cost-

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effective positioning system. It does not require any additional hardware unlike TOA, TDAO and AOA. [8-11].

At the same time, the sensors used for localization are also continuously enriched, such as Bluetooth, UWB, RFID, Wireless-Fidelity (Wi-Fi) etc. Laoudias developed Airplace system with fingerprint database, and its accuracy can be 2~4 meters [12]; Yang developed 3 dimension's real time LIFS positioning system with the sensors in mobile terminals based on Wi-Fi signals [13]; Ozdenizci proposed an assistant positioning method by scanning NFC mark nearby [14]; Yang put forward the method of improving accuracy through monitoring the status of physical channel [15]; Liu make the position more precise with multi-users positioning collaboratively [16]; Fang improves the localization accuracy by 40% with extracting featured received signal strength (RSS) signals, and the measure drop down the multi-path effect in indoor environment [17]; The RADAR system [18] uses the radio frequency (RF) signal strength as an indication of the distance between the transmitter and receiver. During the offline phase, the system builds a radio map for the RF signal strength from a fixed number of receivers. In the online localization, the RF signal strength of the mobile client is measured by a set of fixed receivers and is sent to a central controller. Then, the central controller uses a K-nearest approach to determine the location from the radio map that best fits the collected signal strength information. The Horus system is unique in defining the possible causes of variations in the received signal strength vector and devising techniques to overcome them, namely providing the correlation modeler, correlation handler, continuous space estimator, and small-space compensator modules. Moreover, it reduces the computational requirements of the location determination algorithm by applying location-clustering techniques. This allows the Horus system to achieve its goals of high accuracy and low energy consumption [19].

Some cluster methods are also used to optimize fingerprint database for improving the positioning accuracy and it also can decrease the complexity of calculation, such as k-means and principal component analysis (PCA) in some works; Fang proposed the method of dynamic hybrid projection (DHP) to get the complementary advantages of PCA and multiple discriminant analysis (MDA), and it gets a higher positioning accuracy. MA [20] optimized the fingerprint database by deleting the collected bad-points through the theory of cluster based on the k-means algorithm, and get higher accuracy in some extent.

It is a popular way for indoor positioning by matching the scanned RSS with fingerprint database. But the data in fingerprint database always has some noise signals, because the power's instability and the situations change indoors take place in the course of fingerprint data collection. But the optimization of fingerprint database has not been enough concentrated yet, it results in low positioning accuracy with raw RSSI database. Therefore, it is urgent to solve the problem of eliminating noise signals and optimize the fingerprint database, then the positioning accuracy can be improved accordingly.

The optimization of fingerprint database based on neighbor mean filter (NMF) is proposed in this paper. It eliminates the noise RSSI data to each wireless access point (AP) with the algorithm of NMF. Then it is experimented with the RSSI data collected, which gets obvious higher accuracy in contrast to the localization on fingerprint database without optimization by means of NMF.

II. NEIGHBOR MEAN FILTER ALGORITHM

NMF is a simple, intuitive and easy to implement method of smoothing images, i.e. reducing the amount of intensity variation between one pixel and the next. NMF is the most common linear smoothing algorithm, and it is probably the most popular filter amongst interpreters.

A. *Mathematical Model*

Let an image f(x,y) with m×n pixels, and an image g(x,y) is got after smoothing process. Then,

$$g(x,y)=\frac{1}{M}\sum_{(m,n)\in S} f(m,n) \tag{1}$$

Where m=0,1, 2..., x-1, n=0,1, 2..., y-1, S is the coordinates set neighbored point (x, y), excluding point (x, y), and M is the total of coordinates points in the set. Thus, all the values in image g (x, y) smoothed are determined by the several pixels in image f(x, y) neighbored with point (x, y).

B. *How It Works*

The idea of NMF is simply to replace each pixel value in an image with the mean value of its neighbors, excluding itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. NMF is usually thought of as a convolution filter. Like other convolutions, it is based around a kernel which represents the shape and size of the neighborhood to be sampled when calculating the mean. For example, a 3×3 square kernel is shown in Fig. 1. Then, computing the straightforward convolution of an image with this kernel carries out the mean filtering process.

3	3	3
3	3	3
3	3	3

Fig. 1. 3×3 square kernel

In general the mean filter acts as a low-pass frequency filter and, therefore, reduces the spatial intensity derivatives present in the image. Thus, it also can be used for the filtering of RSSI fingerprint database.

III. OPTIMIZATION METHOD FOR FINGERPRINT DATABASE

In order to optimize the fingerprint database, the RSSI data must be analyzed and processed.

A. *Bizarre Value of RSSI Fingerprint Database*

RF signals encounter impairments when they propagate through the air, such as interference and multi-path propagation, this results in the bizarre signals arising. An anomalous value of RSSI is one that doesn't fit with most of the data, which can be shown in the Fig. 2.

mac integer	c01 integer	c02 integer	c03 integer	c04 integer	c05 integer	c06 integer	c07 integer	c08 integer	c09 integer	c10 integer	c11 integer	c12 integer	c13 integer	c14 integer	c15 integer	c16 integ	c17 integ	c18 integ	c19 integ	c20 integ	c21 integ	c22 integ	c23 integ	c24 intege	c25 integ	c26 integ	c27 integ	c28 integ
1	-58	-53	-54	-67	-59	-67	-64	-66	-65	-65	-72	-74	-64	-63	-71	-77	-72	-75	-75	-74	-74	-78	-77	-76	-74	-77	-76	-77
2	-58	-50	-54	-58	-50	-55	-63	-69	-69	-59	-71	-73	-71	-67	-79	-76	-70	-67	-78	-76	-73	-76	-75	-73	-76	-77	-75	-74
3	-56	-62	-65	-57	-57	-54	-63	-73	-74	-64	-68	-75	-72	-57	-76	-72	-69	-74	-75	-77	-74	-74	-77	-75	-78	-77	-75	-80
4	-58	-53	-65	-66	-57	-62	-65	-70	-69	-67	-72	-72	-76	-65	-76	-72	-73	-69	-77	-77	-72	-76	-77	-76	-78	-77	-74	-73
5	-64	-60	-63	-72	-58	-66	-68	-70	-66	-69	-71	-74	-73	-69	-76	-73	-71	-71	-76	-77	-78	-75	-77	-76	-78	-79	-79	-77
6	-55	-59	-71	-70	-64	-68	-68	-67	-67	-69	-73	-72	-71	-72	-75	-78	-74	-70	-76	-76	-78	-76	-79	-80	-76	-80	-80	-75
7	-59	-65	-72	-69	-64	-66	-69	-73	-69	-68	-74	-72	-73	-75	-76	-80	-76	-73	-79	-79	-74	-78	-81	-79	-79	-72	-78	-73
8	-61	-64	-72	-72	-61	-68	-71	-73	-64	-67	-72	-77	-71	-74	-73	-77	-71	-75	-75	-77	-75	-76	-80	-71	-76	-76	-80	-69
9	-65	-69	-66	-75	-62	-70	-72	-72	-69	-69	-74	-73	-72	-72	-73	-79	-73	-72	-75	-74	-75	-80	-77	-74	-76	-79	-77	-77
10	-66	-67	-68	-74	-71	-69	-75	-72	-62	-65	-76	-74	-75	-71	-80	-75	-73	-67	-77	-77	-76	-77	-80	-78	-74	-74	-74	-75
11	-63	-74	-71	-77	-65	-67	-74	-71	-60	-73	-76	-74	-71	-73	-81	-76	-70	-75	-76	-76	-77	-76	-79	-78	-78	-75	-75	-70
12	-67	-74	-72	-77	-69	-69	-76	-72	-62	-69	-78	-76	-75	-73	-78	-74	-74	-75	-80	-75	-76	-79	-80	-77	-77	-78	-78	-74
13	-71	-69	-75	-73	-70	-73	-75	-77	-67	-70	-75	-77	-73	-75	-74	-78	-73	-73	-78	-77	-76	-76	-77	-79	-81	-78	-79	-78
14	-73	-69	-78	-79	-68	-71	-75	-74	-65	-73	-75	-81	-69	-74	-78	-74	-74	-74	-79	-78	-79	-76	-77	-80	-77	-78	-79	-71
15	-67	-75	-73	-75	-68	-76	-81	-79	-69	-71	-75	-77	-78	-73	-78	-77	-78	-77	-80	-79	-77	-77	-76	-81	-79	-79	-81	-72

Fig. 2. RSSI data with bizarre value

As shown in the figure above, cell values framed with red are not fit with their neighborhood. These bizarre values in the RSSI fingerprint database will decrease the accuracy of indoor positioning. In order to get higher localization precision, the bizarre values must be disposed beforehand. And how to detect the bizarre values is important to process them firstly, which is related to the determination of threshold and NMF.

B. NMF Used in Fingerprint Database Optimization

The RSSI fingerprint database can be optimized by means of NMF. Generally speaking, there are two steps for RSSI fingerprint database optimization which are noise determination and filtering. In the course of noise determination, similarity of two RSSI values is introduced to represent their correlation. In a whole, the noise is determined when the similarity of the point with its neighborhood is larger than the average similarity of other points with their neighborhood.

Let the RSSI values at point P, Q are R1, R2, then, the similarity between the two points is as formula 2.

$$SM_{(P,Q)} = (R_1 - R_2)^2 \tag{2}$$

Assume a 3*3 square kernel of point A in the RSSI fingerprint database is shown in Fig. 3.

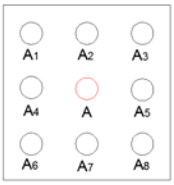

Fig. 3. 3*3 square kernel of point A

The formula of similarity between point A and its neighborhood is as formula 3.

$$\overline{SM}_1 = \frac{1}{8}\sum_{i=1}^{8} SM(A, A_i) \tag{3}$$

The formula of similarity between other points (excluding point A) and their neighborhood is as formula 4.

$$\overline{SM}_{A_i} = \frac{1}{n_{A_i}}\sum_{j\neq i}^{U} SM(A_i, A_j) \tag{4}$$

Where A_j is neighbor of A_i excluding point A, U is neighborhood of A_i in the kernel, and   is the entry number of U.

Therefore, the mean similarity of other points (excluding point A) is as formula 5.

$$\overline{SM}_2 = \frac{1}{8}\sum_{i=1}^{8} \overline{SM}_{A_i} \tag{5}$$

Finally, whether the signal is a noise can be determined through the contrast between $\overline{SM}_1$ and $\overline{SM}_2$. And if point A is a noise, the replaced value for point A is as formula 6.

$$RSSI_A = \frac{1}{n}\sum_{i}^{n} RSSI_i \tag{6}$$

In the RSSI fingerprint database, the RSSI values collected from an AP is stored into a separate data table. So every RSSI data table can select its convolution kernel, and all the tables can be filtered with NMF, then the RSSI fingerprint database can be optimized.

C. Determination of Threshold for Optimization Method

The deviation between $\overline{SM}_1$ and $\overline{SM}_2$ is key to the quality of RSSI fingerprint database optimization. That is to say, the threshold of the deviation must be determined firstly. In the base of formula (1), the improved mathematical model is shown as formula 7.

$$g(x,y) = \begin{cases} \frac{1}{M}\sum_{(m,n)\in S} f(m,n) & \left| f(x,y) - \frac{1}{M}\sum_{(m,n)\in S} f(m,n) \right| > T \\ f(x,y) & \text{Others} \end{cases} \tag{7}$$

Where T is the threshold. The expression means that those values will keep when the difference between them and neighborhood is less than threshold T, on the contrary, those values will be replacing by the mean value of neighborhood.

IV. OPTIMIZED FINGERPRINT DATABASE FOR INDOOR LOCALIZATION

As a radio signal propagates through the air, it experiences a loss in amplitude. If the range between the transmitter and receiver increases, the signal amplitude declines exponentially. In an open environment, one clear of obstacles, the RF signals experience what engineers call free-space loss, which is a form of attenuation. The atmosphere causes the signal to attenuate exponentially as the signal propagates farther away from the antenna. So the radio signal can be used for localization.

A. Architecture for RSSI Fingerprint Database Localization

Location determination or estimation is a process of finding the approximate position of a stationary or mobile object using a sensor technology, a location model, and an estimation algorithm. Location determination infrastructure with Wi-Fi RSSI fingerprint database consists of two phases - offline phase and online phase. The offline phase (finger printing process) is a learning process in which the system is trained; the online phase is the real-time function of the system in which location of a mobile node is determined. Typical location estimation algorithm based on RSSI fingerprint database employs one scalar value as the RF specification to describe the physical location of a mobile object. Fig. 4 shows the architecture for RSSI fingerprint database localization.

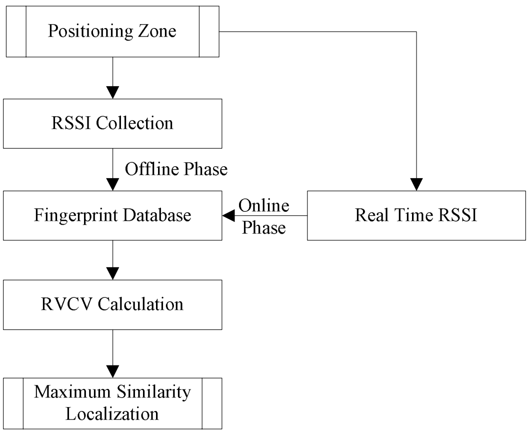

Fig. 4. Architecture for RSSI Fingerprint Database Localization

B. *Cosine Calculation of RSSI Vectors and Its Similarity*

With a given database, the received wireless AP RSSI value vector will compare with the vectors at each location in the fingerprint database in terms of certain matching algorithm, and the mobile location will be estimated. Among them, the matching algorithm is one of the keys to the efficiency and positioning accuracy of localization. The usual matching algorithms are K-nearest neighbor and neural networks [11]. The cosine value between the real time RSSI vector and fingerprint database is also a good matching method, which is calculated and used to stand for the similarity. Then, the value of similarity can be as the index for indoor localization. The cosine calculation of RSSI vectors and its similarity are discussed in [21].

C. *Localization Based on Optimized Fingerprint Database*

In the course of wireless localization based on RSSI fingerprint feature vector, the RSSI values received from all of the wireless access points (APs) make up the fingerprint feature vectors of the location grids, and the fingerprint database is established. Then, the real-time RSSI value vector received can be identified for fingerprint positioning. Its positioning process is divided into three stages, which are the establishment of fingerprint database, optimization for the fingerprint database with NMF and real-time positioning. The framework of RSSI localization based on NMF is shown in Fig. 5.

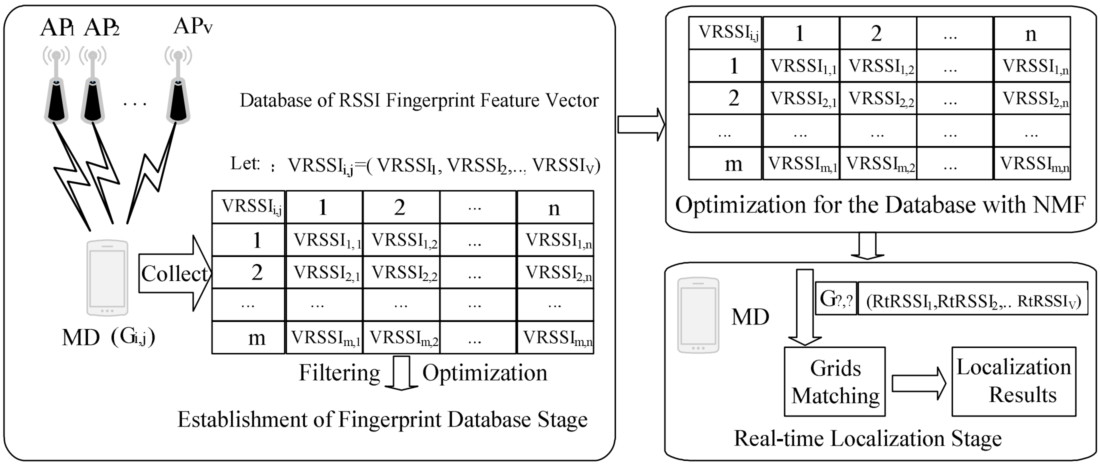

Fig. 5. Framework of Wi-Fi localization based on NMF

In the course of wireless localization based on RVCV, first, a lot of Wi-Fi signal devices are arranged, such as wireless APs (Access Point), and the number of APs are correspondence to the dimensions of vector, here represented by v. Then, the localization area is divided into a number of grids, here represented by $G_{i,j}$ ($i<m$, $j<n$). Next, all the $G_{i,j}$ will be filtered with NMF. Finally, the mobile device (MD) can be located via grid matching between real-time RSSI value vector and RVCV in the fingerprint database.

In the stage of establishment of fingerprint database, the RSSI values of each MAC (Media Access Control) address in each center of all the grids are collected, and they are stored into the database. In the stage of filtering, the square kernel size and the threshold must be determined; In real-time localization stage, the real-time location of the grid is obtained by calculating the similarity between real-time RSSI value vector received and grid vectors in the database, which can be reference to [10].

V. EXPERIMENTAL EVALUATION

Using Java programming language [22], fingerprint database optimization method for indoor localization based on NMF has been designed and implemented. Among them, RSSI data collection for mobile devices is developed in Android platform, and the collected RSSI data can be stored into SQLite database. Then the data in SQLite is dumped into PostgreSQL database, and all the data is filtered and optimized with NMF. Finally, the data management and application services are implemented by the use of Eclipse + Mybatis programming tools, so the cosine between real-time RSSI vector and fingerprint feature vector can be calculated, and also the positioning result can be acquired.

In this section, the experimental testbed will be described firstly, then, the experimental data will be collected and optimized with the algorithm, finally, the performance of localization based on NMF will be shown.

A. Experimental Testbed

We performed our experiment in the first floor of the gym building in the Xiamen University of Technology. The testbed has a dimension of 56 meters by 30 meters. The technique was tested in the Xiamen University of Technology wireless network with TP-LINK access points. 20 access points cover the building and were involved in testing. The radio map has 420 locations inside the experimental testbed. On the average, each location is covered by 20 access points.

B. Data Collection and Results of NMF

The grids of floor were mapped in the radio map firstly. Then, users moved in grids on the floor in turn, and clicked on the grids of map accordingly. The training grids were placed 2 meters (6.56 feet) apart for the testbed. Then, we selected 420 test locations to cover the entire test area. The results of RSSI data distribution and storage of the grid with the MAC address of 00: 24: b2: eb: 21: 21wireless AP are shown in Fig. 6.

And the effect of neighborhood mean filter on fingerprint database is shown in Fig. 6. At the same time, the noise values processed by way of neighborhood mean filter is framed up in blue.

mac integ	c01 integer	c02 integer	c03 integer	c04 integer	c05 integer	c06 integer	c07 integer	c08 integer	c09 integer	c10 integer	c11 integer	c12 integer	c13 integer	c14 integer
1	-58	-53	-54	-67	-59	-67	-64	-66	-65	-65	-72	-74	-64	-63
2	-58	-50	-54	-58	-59	-55	-63	-69	-69	-68	-71	-73	-71	-67
3	-56	-62	-65	-57	-57	-54	-63	-73	-74	-64	-68	-75	-72	-72
4	-58	-61	-65	-66	-57	-62	-65	-70	-69	-67	-72	-72	-76	-65
5	-64	-60	-63	-72	-58	-66	-68	-70	-66	-69	-71	-74	-73	-69
6	-55	-59	-71	-70	-64	-68	-68	-67	-67	-69	-73	-72	-71	-72
7	-59	-65	-72	-69	-64	-66	-69	-73	-69	-68	-74	-72	-73	-75
8	-61	-64	-72	-72	-61	-68	-71	-73	-64	-67	-72	-77	-71	-74
9	-65	-69	-66	-75	-62	-70	-72	-72	-69	-69	-74	-73	-72	-72
10	-66	-67	-68	-74	-71	-69	-75	-72	-62	-65	-76	-74	-75	-71
11	-63	-74	-71	-77	-65	-67	-74	-71	-60	-73	-76	-74	-71	-73
12	-67	-74	-72	-77	-69	-69	-76	-72	-62	-69	-78	-76	-75	-73
13	-71	-69	-75	-73	-70	-73	-75	-77	-67	-70	-75	-77	-73	-75
14	-73	-69	-78	-79	-68	-71	-75	-74	-65	-73	-75	-81	-69	-74
15	-67	-75	-73	-75	-68	-76	-81	-79	-69	-71	-75	-77	-78	-73

mac integ	c15 integer	c16 integ	c17 integ	c18 integ	c19 integ	c20 integ	c21 integ	c22 integ	c23 integ	c24 integ	c25 integ	c26 integ	c27 integ	c28 integ
1	-71	-77	-72	-75	-75	-74	-74	-78	-77	-76	-74	-77	-76	-77
2	-69	-76	-70	-67	-78	-76	-73	-76	-75	-73	-76	-77	-75	-74
3	-76	-72	-69	-74	-75	-77	-74	-74	-77	-75	-78	-77	-75	-80
4	-76	-72	-73	-69	-77	-77	-72	-76	-77	-76	-78	-77	-74	-73
5	-76	-73	-71	-71	-76	-77	-78	-75	-77	-76	-78	-79	-79	-77
6	-75	-78	-74	-70	-76	-76	-78	-76	-79	-80	-76	-80	-80	-75
7	-76	-80	-76	-73	-79	-79	-74	-78	-81	-79	-79	-72	-78	-73
8	-73	-77	-71	-75	-75	-77	-75	-76	-80	-71	-76	-76	-80	-69
9	-73	-79	-73	-72	-75	-74	-75	-80	-77	-74	-76	-79	-77	-77
10	-80	-75	-73	-67	-77	-77	-76	-77	-80	-78	-74	-74	-74	-75
11	-81	-76	-70	-75	-76	-76	-77	-76	-79	-78	-78	-75	-75	-70
12	-78	-74	-74	-75	-80	-75	-76	-79	-80	-77	-77	-78	-78	-74
13	-74	-78	-73	-73	-78	-77	-76	-76	-77	-79	-81	-78	-79	-78
14	-78	-74	-74	-74	-79	-78	-79	-76	-77	-80	-77	-78	-79	-71
15	-78	-77	-78	-77	-80	-79	-77	-77	-76	-81	-79	-79	-81	-72

Fig. 6. RSSI data filtered with NMF

C. Overall System Performance

With the RSSI data of all the APs is collected and stored in the fingerprint database, then, the database should be filtered by NMF, and the performance of real time localization of times 420 with and without NMF is shown in table □.

TABLE I. LOCALIZATION RESULTS BASED ON RSSI WITHOUT AND WITH NMF FILTERED

No	Real-time RSSI observations (20 deviations with samples training data)			Correct rate of localization without NMF	Correct rate of localization with NMF
	7APs	*7APs*	*6APs*		
1	1	1	1	100%	100%
2	2	2	2	100%	100%
3	4	4	4	100%	100%
4	7	7	7	99%	100%
5	11	11	11	96%	98%
6	13	13	13	88%	93%
7	16	16	16	66%	79%
8	-1	-1	-1	100%	100%
9	-2	-2	-2	100%	100%
10	-4	-4	-4	100%	100%
11	-7	-7	-7	99%	100%
12	-11	-11	-11	95%	98%
13	-13	-13	-13	87%	92%
14	-16	-16	-16	69%	78%
15	-1	1	-1	100%	100%
16	2	2	-2	87%	96%
17	-4	4	-4	52%	25%
18	-7	7	7	8%	11%
19	11	-11	-11	7%	2%
20	13	-13	-13	5%	2%
21	16	-16	-16	4%	2%

In this scenario, the RSSI values of 20 APs were divided into three groups of 7+7+6 in Table 1, and the same deviation will be assigned to the same group, which are referred as the real time RSSI vectors. At the same time, different RSSI value deviations are given to the three groups, whereby the corresponding different real time vectors are obtained.

As shown in Table II, (1) the larger deviation of the RSSI value is set, the less correct rate of positioning accuracy, it is fit for both the same and different signs of the deviations; (2) when signs of the RSSI value deviations of the three groups are different, the larger deviation of the RSSI value is set, the less correct rate of positioning accuracy, and correct rate of positioning reduced quickly at deviation 2–4, that is, 87%–52% (96%–25%); (3) the accuracy of localization with NMF is higher than that of localization without filtering. Under the conditions of the fingerprint database and the deviations of the real-time RSSI vector elements being within 10, the correct rate of localization is more than 79%, which can meet necessity for the mostly actual application. Meanwhile, with the vector dimension increasing, the correct rate of localization will be improved to some extent.

At the same time, the computational complexity and cost of NMF have been tested with Dell Inspiron 13 7000 Series, and the results are shown in Table 2. As shown in Table 2, with the increase of the times of NMF in scenario of this paper, the computational complexity and time costs are also increased, and the growth of time costs is not obvious with the increase of times of localization. At the same time, time costs with NMF is less than that without NMF.

Table III. Computational Complexity and Cost of NMF

Times of Localization	Time costs (s) with NMF	Time costs (s) without NMF
420	0.27	0.39
12600	3.15	3.60
29400	10.0	12.8
63000	21.0	25.4
105000	33.82	40.6

VI. CONCLUSIONS

Considering the error occurred in RSSI fingerprint database, this paper designs the optimization method for fingerprint database based on NMF. It can decrease the influence of bizarre RVCVs on the positioning accuracy comparing to merely matching similarity between real-time RSSI feature vector and RSSI feature vectors in fingerprint database. At the same time, with an actual experiment, a good results of localization are achieved.

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