Study of Fingerprint Location Algorithm Based on Wifi Technology
Ya-Lin MIAO, Jie ZHANG*, Lu-Jun HAO, Tian-tian JI and Li-yi ZHAO
Xi'an University of Technology, Xi'an, Shanxi, China
*Corresponding author

Keywords: Wifi, Fingerprint location, Fingerprint database, Dynamic joint WKNN algorithm.

Abstract. Aiming at the problem that the anti-disturbance poor ability of the wifi fingerprint location algorithm and the positioning accuracy to be improved. This paper takes the direction effect of the signal into consideration and establishes fingerprint database by using a new data acquisition and filtering techniques. At the same time, it uses dynamic joint WKNN algorithm and combines with two different ways of allocating weights to realize localization in the matching phase. Experimental results show that the proposed method can improve the stability and precision of positioning to a certain extent.

Introduction
With the rapid development of the mobile internet and the wide application of pervasive computing technology, the demand of mobile user's location information for lots of public and business services increasing gradually. However, the accuracy of GPS positioning declined even unable to locate because of the building and other disturbances leading to the satellite signal attenuation [1]. People not only need the precise positioning of the outdoor but the indoor positioning accuracy requests are increasingly high. In recent years, a large number of positioning technologies sprang up in the field of indoor positioning including Assistant-GPS technology, infrared positioning, bluetooth location, wifi indoor positioning [2], etc. Wifi technology has been widely used with the advantages of low hardware requirement, low cost, wide coverage, and fast transmission speed [3].

At present, the wifi localization method is mainly divided into two types: based on the model and the signal strength. Algorithm based on the model converts the received signal strength (RSS) value to the distance to determine the current position using the model with high accuracy, but the algorithm based on signal strength compares signal features and fingerprint information which position required to obtain the target location by establishing the wireless signal strength database and location information[4]. The ability of conventional wifi fingerprint location algorithm is poor as well as the positioning accuracy to be further improved. Aiming at the problem, this paper studies a location fingerprint algorithm based on wifi location technology. A new method of data collection and filtering is adopted to build the fingerprint database. And using a kind of dynamic joint WKNN algorithm to carry on the indoor localization to improve the position accuracy to some extent.

Wifi Technology for Indoor Location
Wifi indoor positioning is currently the main application of the algorithm is the location fingerprint matching algorithm, including two stages with off-line acquisition and online match:

Off-line acquisition and construction of fingerprint database, after collecting and processing the fingerprint data from different reference positions in the areas to be located, storing it into the fingerprint database in the form of <site,fingerprint>.

To get location information online through matching the signal from a position to the fingerprint in the database, and let the position corresponding a optimal matching fingerprint to be the positioning results [5]. For instance, the WKNN algorithm with determine the position which needs to be measured though calculating the distance between the RSS vector and the RSS vector in the
fingerprint database. Calculate the distance between the RSS vector of a measured point and the RSS vector in the fingerprint database [6]. Assuming that the area to be positioned has \( n \) access points and \( m \) reference points, therefore, the distance is given by the following equation:

\[
d = \left( \sum_{i=1}^{m} |rssi_{ij} - rssi_{ij}^2 \right)^{1/2}
\]

where \( i=1,2,\ldots,m \), \( j=1,2,\ldots,n \), \( rssi_{ij} \) is the signal strength received from \( j \)-th AP (Access Point), \( rssi_{ij}^2 \) is the signal strength at \( i \)-th reference point in the fingerprint database received from \( j \)-th.

Select the minimum \( k \) reference points of Euclidean distance, calculating the coordinates of the point to be measured according to a certain weight distribution. The weight of the reference point can be represented as following equation:

\[
w_i = \frac{1}{d_i} / \sum_{i=1}^{k} \frac{1}{d_i}
\]

or

\[
w_i = \frac{1}{d_i^2} / \sum_{i=1}^{k} \frac{1}{d_i^2}
\]

where the \( k \) is the sample number, supposing the coordinates of the \( i \)-th reference point is \((x_i, y_i)\), the coordinates \((x, y)\) of the position to be positioned is as follows:

\[
(x, y) = \left( \sum_{i=1}^{k} w_i x_i, \sum_{i=1}^{k} w_i y_i \right)
\]

### Improved Fingerprint Location Algorithm

#### The Fingerprint Database

Wireless signal will produce reflection, diffraction, scattering and other phenomena due to the influence of the electronic device, channel interference between moving object and the AP in propagation environment [7]. The signal strength values of a reference point received in different directions from the same AP wave is in a certain range. Therefore, consideration of direction, this paper samples many times on different directions in each reference point and execute the average filtration to obtain the fingerprint which makes it closer to the actual value to reduce the impact of random fluctuations, the main steps are as follows:

1. Acquire signal strength \( s \) times for different directions in each reference point.
2. Remove the maximum and minimum signal strength corresponding the value recorded in each direction, \( s=s-2 \); then use mean filter as Eq. 5 to get the signal strength value from \( j \)-th AP in the \( i \)-th reference point; finally, store the data to the fingerprint database in the form of \((x_i, y_i, mac_i, rssi_{ij}, strongmac_i)\), where \((x_i, y_i)\) is the coordinates of reference point.

\[
rssi_{ij} = \frac{\sum_{i=1}^{s} rssi_{ij}}{s}
\]

3. All reference points sequentially processing the above steps to get the fingerprint database of test area.

#### Dynamic Joint WKNN Algorithm

In the on-line matching phase, the choice of the first \( k \) according to Euclidean distance is not always the closest point to the actual location [8]. With the help of dynamic joint ideas, this paper makes dynamic weighting of the spatial correlation of different weight distribution patterns [9], then calculates the coordinates through the different weight distribution of each reference point.
First of all, it needs to establish a joint document of specific location environment, using the WKNN algorithm on different test points to get a large number of online positioning and testing experiments (use two kinds of weight distribution methods: Eq. 2 and Eq. 3). According to the results of the experiments, setting the larger weights to the methods get higher positioning accuracy and the smaller weights get lower positioning accuracy. The dynamic joint documents such as Eq. 6:

\[
\begin{pmatrix}
    x_1 & y_1 & w_{11} & w_{12} \\
    x_2 & y_2 & w_{21} & w_{22} \\
    \vdots & \vdots & \vdots & \vdots \\
    x_m & y_m & w_{m1} & w_{m2}
\end{pmatrix}
\]

(6)

where \(w_{11}, \ldots, w_{m1}\) and \(w_{12}, \ldots, w_{m2}\) respectively the weight of Eq. 2 and Eq. 3 in each reference point.

Then to realize online matching location, according to the coordinates and dynamic joint document weight value calculate the coordinates \((x, y)\) of the target point by Eq. 7:

\[
(x, y) = \frac{\sum_{i=1}^{k} \frac{w_{1i}}{d_i} (x_i, y_i)}{\sum_{i=1}^{k} \frac{1}{d_i}} + \frac{\sum_{i=1}^{k} \frac{w_{2i}}{d_i^2} (x_i, y_i)}{\sum_{i=1}^{k} \frac{1}{d_i^2}}
\]

(7)

where \((x_i, y_i)\) is the coordinates of the reference point.

**Experiment and Error Analysis**

In order to verify the effectiveness of the algorithm, choose a teaching building of the department for the test area in which placed four fixed AP (the area size of 5m * 3m), every compartment 0.5m is selected as a reference point. In the online matching phase it will be calculated by the 5 results measured in each reference point. The experimental results are compared by Eq. 8.

\[
E = \sqrt{(x - x')^2 + (y - y')^2}
\]

(8)

**Fingerprint Database Error Analysis**

Positioning results of three fingerprint database using different kinds of collection methods are shown in Table 1.

| Fingerprint Database | Positioning Results(m) | Maximal error | Minimum error | Average error | Variance |
|----------------------|------------------------|---------------|---------------|---------------|----------|
| One direction        | 3.2286                 | 0.1173        | 1.146         | 0.45972       |
| Four directions      | 3.0867                 | 0.1319        | 1.162         | 0.27381       |
| Eight directions     | 3.0151                 | 0.0314        | 0.832         | 0.27347       |

Explain: one direction, continuous acquisition 80 times in the same direction; four directions, acquisition 20 times in each 90 degrees; eight directions, acquisition 10 times in each 45 degrees.

In one direction, the average error of the result of is about 1.146m; in four directions, the average error is about 1.162m; in eight directions, the average error can be reduced to 0.832m, the minimum error can reach 0.0314 m, and the positioning stability and accuracy are also better than the previous two fingerprint databases.

Figure 1 is the positioning accuracy comparison chart of different database, it can be seen from that the percentage of positioning accuracy within 1.6 m in the test points increased from 76.6% to
94.8%, and the overall positioning accuracy is in the acceptable range which does not appear too large offset.

![Cumulative probability distribution of location accuracy](image)

**Figure 1.** Positioning accuracy.

**Improved WKNN algorithm**

The statistical analysis of the experimental results are shown in Table 2, the average localization error of the dynamic joint of weight allocation method is smaller than the joint of any method, the maximum and minimum error are also decreased.

| Weight Distribution | Positioning Results(m) |               |               |                |
|---------------------|------------------------|---------------|---------------|----------------|
|                     | Maximal error          | Minimum error | Average error |
| W1                  | 1.9484                 | 0.0698        | 0.8620        |
| W2                  | 1.9602                 | 0.0844        | 0.8538        |
| W1+ W2              | 1.9399                 | 0.0605        | 0.8449        |

Explain: W1, weight allocation in WKNN algorithm by using the Eq. 2; W2, weight allocation in WKNN algorithm by using the Eq. 3; W1+ W2, weight allocation in WKNN algorithm by using the Eq. 6.

**Summary**

In this paper, multiple data acquisition is carried out in different directions of each reference point, and the data are filtered to reduce the error caused by the random fluctuation, which can improve the accuracy and stability of the positioning. At the same time, in the online matching phase, the WKNN algorithm of the weight distribution is improved. It uses the dynamic joint WKNN algorithm to combine two different ways of allocating weights together which improve the positioning performance by using complementary information of the different methods in local region. Experimental results show that it can reduce the deviation error of $k$ reference points and improve the precision of positioning to a certain extent.

**Acknowledgement**

We would like to thank the anonymous reviews for their valuable comments. This program is supported by Shaanxi Provincial Natural Science Basic Research Program (2009JQ1010), Shaanxi Provincial Department of Education Science Research Program (2010JK702), and Xi’an University of Technology PhD project started (104-210901).

**References**

[1] Yang Fan, Zhao Dongdong. WiFi positioning based on Android platform [J] Electronic Measurement Technology, 2012, 09: 116-119 + 124.
[2] Xu Qiang, Zhao Fang, Shang Guoqiang, Zhu Yanxu, Zuo Chao. Multi-mode indoor map building system using Android system[J]. Journal of Navigation and Positioning, 2014, 04:40-45.

[3] Wang Yue, Zhao Chunyu. Research on key technology of WIFI indoor positioning in fire rescue [J]. Electronic Design Engineering, 2014, 21:63-65 69.

[4] Zhang Yongtuo. Study on the indoor pedestrian localization and tracking technology based on Intelligent mobile phone[D]. Ocean University of China, 2014.

[5] Chen Yongle, Yu Dan, Wang Ze. Study on indoor positioning mechanism based on similar fingerprint characteristics [J]. Journal of Taiyuan University of Technology, 2015, 03:336-340.

[6] Dong Yanxia. WIFI indoor location algorithm based on location fingerprint [D]. Southwest University of Science and Technology, 2015.

[7] Mazuelas S, Lago F A, Blas J, et al. Prior NLOS Measurement Correction for Positioning in Cellular Wireless Networks[J]. IEEE Transaction on Vehicular Technology, 2009, 58(05): 2585-2591.

[8] Huber M, Kamangar F A, Chlamtac I. Indoor Location Tracking Using RSSI Readings From a Single Wi-Fi Access Point[J]. Wireless Networks, 2009, 13(2): 221-235.

[9] Fang S H, Hsu Y S, Kuo W H. Dynamic Fingerprinting Combination for Improved Mobile Localization[J]. IEEE Transactions on Wireless Communications, 2011, 10(8): 4018-4022.