Location of Underground Parking Lot Based on Bluetooth Ibeacon Technology

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Abstract. With the popularity of electric vehicles in China, how to guide the vehicle to the charging facility in the underground garage has become an urgent problem to be solved. Among them, the realization of real-time vehicle location is one of the keys. In this paper, the location fingerprint scheme based on iBeacon technology is adopted, and the improved k-proximity algorithm is combined to realize the positioning.

1. Introduction
In recent years, China's electric vehicles have developed rapidly. However, how to quickly find charging facilities in underground garages so as to provide better user experience is still an urgent problem to be solved. One of the keys of navigation is positioning. For indoor positioning, due to the inability to use GPS, various attempts and researches have been made at home and abroad. Among them, common indoor positioning schemes include Zigbee technology, WiFi technology and bluetooth. In 2014, apple inc. launched iBeacon technology, which has become a research hotspot for indoor positioning using bluetooth 4.0. Due to the low power consumption, rapid response, stable performance and low cost of bluetooth 4.0 and the popularity of smart phones in recent years, it is obviously a good choice to use bluetooth 4.0 iBeacon technology to solve the problem of accurate positioning of vehicles in underground garage. Based on iBeacon technology, this paper uses position fingerprint and improved k-nearest neighbor algorithm to realize positioning.

2. IBeacon Bluetooth Technology

2.1 Bluetooth 4.0 Technical Features

2.1.1 Apple inc. had strict control over bluetooth devices in the past, so only bluetooth devices certified by MFI can be connected to the iDevice. But there are no such restrictions on bluetooth 4.0 devices.

2.1.2 Accurate positioning and longer distance. Before bluetooth 4.0, devices generally have a transmission distance of 0.1-10m. However, iBeacon signal can be accurate to the millimeter level, and its transmission distance can reach 50m at most.

2.1.3 Ultra-low power consumption. Bluetooth 4.0 also known as low power bluetooth, a common button battery can be used for power supply a Beacon base station hardware for about two years. Bluetooth integrated circuit is simple, low cost, easy to implement, easy to popularize.
2.1.4 Wide application. All devices equipped with bluetooth 4.0 or above can be used as transmitters and receivers of iBeacon technology (in addition to iOS devices, Android and Windows Phone platforms are also applicable) [1].

2.2 Ibeacon Positioning System
Positioning system is a set of indoor positioning system based on low power bluetooth module. It measures the signal strength of iBeacon according to the mobile phone deployed nearby, and calculates the distance between the user and the base station based on the model of signal strength attenuation with distance, so as to complete the positioning. With the help of several small base stations, the system can form a communication area with a radius of tens to hundreds of meters, where devices can interact with each other via Bluetooth. iBeacon can sense the user's position within three ranges through the principle of wireless ranging, and determine the user's position according to different ranges. The schematic diagram of its working principle is shown in figure 1 below.

![Figure 1. IBeacon signal proximity diagram](image)

3. Location Fingerprint Positioning
The main idea of location fingerprint location method is that when the base station involved in location is deployed in a reasonable way in the complex location area environment, it will broadcast transmit the corresponding wireless signal to the surrounding. [2] As the indoor space environment is generally complex, the signal will be interfered by various factors and will be transmitted by means of reflection and refraction, etc., which is unfavorable to the method of calculating distance and then realizing location based on the signal attenuation model. However, in a certain indoor environment, the signal strength received from different base stations at each location is obviously unique, and corresponds to the location one to one, that is, the "fingerprint" of wireless signal strength unique to the space of the current location. So, only need to complete the indoor area "fingerprints" of each location signal strength, and stored in a database, to locate, users use mobile terminal gathers the signal strength of her own place to upload library, with the aid of certain data matching algorithm, the best position estimation for the measurement point can be achieved.

There are two key stages to realize positioning by fingerprint positioning method: (1) offline phase, the acquisition and construction of fingerprint database data.(2) in the positioning stage, the location information to be measured is matched with the information in the database to complete the
positioning of the measured points. The schematic diagram of its positioning realization process is shown in figure 2.

![Diagram of fingerprint location](image)

**Figure 2.** Schematic diagram of fingerprint location

Mobile terminal acquisition Database matching Fingertips taken The signal vector of the position to be measured Location fingerprint matching algorithm Coordinates of position to be measured

In the offline phase, the work is to collect the signal strength "fingerprint" of each reference node in the indoor area. Assuming that there are n Beacon base stations in the range where the mobile device held by the user can receive signals, and there are m reference nodes in the whole positioning area, the signal strength fingerprint information at the ith reference node is \( S_i = \{RSSI_{i1}, RSSI_{i2}, \ldots, RSSI_{in}\} \) \((1 \leq i \leq m)\). Generally, we divide the whole indoor positioning area by means of a grid. Each vertex of the grid can be selected as a reference node of the indoor positioning area. By collecting fingerprint data in the above form at each reference point, an offline fingerprint library belonging to the current positioning area can be constructed. Offline fingerprint database mainly records MAC addresses of all visible base stations, RSSI strength values, physical location information of reference points and feature data obtained by partial calculation [2].

For the online stage, the main work to be completed is the real-time acquisition of RSSI value of the user's current position through the intelligent mobile device. The intelligent mobile device sends a positioning request to the system. After receiving the RSSI fingerprint data uploaded by the device, the system adopts the set matching algorithm to carry out the optimal matching in the database. After matching, the coordinates of the user's position are estimated.

### 4. Simplify the Fingerprint Database

One of the problems of using location fingerprint method to realize positioning is that, for a large positioning area, a large amount of reference point data needs to be collected in order to achieve a more accurate positioning, and a large amount of data is bound to prolong the time spent in matching, which is obviously unfavorable to realize real-time positioning.

In order to improve the positioning efficiency, on the one hand, efficient matching algorithm should be adopted, on the other hand, it is obvious that we should try our best to simplify the
fingerprints in the fingerprint database to reduce the matching range. The idea is to cluster the fingerprint data uploaded by the pending loci and the data in the fingerprint database before the specific matching algorithm is implemented, so as to obtain the class cluster where the pending loci are located. After that, we only need to match in this determined class cluster, and then use a further algorithm to process it. Through clustering processing, the matching range is reduced and the calculation amount is reduced, which is equivalent to simplifying the fingerprint database in a disguised way and improving the positioning efficiency.

The so-called clustering, refers to the collection of similar elements in a cluster based on feature similarity. The basic principle is that the feature similarity of elements in the same class cluster differs greatly from that of elements in other different classes of clusters, while the similarity difference between internal elements in the same class cluster is very small [3]. Its main principle is to divide closely related elements with high similarity into the same class cluster by means of specific calculation methods, and divide the elements with low similarity into different class clusters. Through continuous recursion, when the sample is in a stable state, the processing is finished.

At present, k-means clustering algorithm (k-means) is relatively widely used. This algorithm is simple and easy to understand, with fast clustering speed and good clustering effect. In terms of implementation, it is also easier for other clustering algorithms. However, the algorithm needs to specify the number of clustering clusters K first, and then randomly select K elements as the center of these K classes, and classify other elements into a class with a similar element by iterative method, until the final stable clustering result is generated.

As can be seen from the above, the clustering number K needs to be set artificially in advance. The selection of K will also have an important impact on the clustering effect. Obviously, if the value of K is too large, there will be too many class clusters divided. It is easy to divide the reference points into inappropriate class clusters, which is not conducive to positioning and matching. If the value of K is too small, the similarity difference between the generated class clusters is not big, which cannot narrow the matching range and simplify the initial purpose of the algorithm. The selection of all K values should be determined by certain experiments according to the specific application environment.

5. Matching Algorithm
After the clustering process, the matching algorithm is used to find the best matching result of the fingerprint to be measured. The following is a brief introduction of several deterministic matching algorithms, and the improved k-proximity algorithm is used as the final matching algorithm.

5.1 Nearest Neighbor Algorithm
The nearest neighbor algorithm is the most basic and also the simplest one of the deterministic algorithms. It calculates the Euclidean distance between the RSSI vector uploaded by the user and the vector in the library, and selects the coordinate of the reference point with the minimum distance as the positioning result of the user's position. The formula is as follows:

\[ d_i = \sqrt{\sum_{j=1}^{n}(RSSI_i - RSSI_j)^2} \]  

(1)

Where, \( RSSI_i \) represents the signal strength of the ith base station measured by the undetermined site, \( RSSI_j \) represents the signal strength of the ith base station in the database, and \( n \) represents the number of Beacon base stations around the user. Calculate each Euclidean distance \( d \) value, and compare, take the smallest as the best match. The principle of this method is simple and easy to understand, but the corresponding error is also large.

5.2 K-Proximity Algorithm
The algorithm is actually improved by the nearest neighbor algorithm. This algorithm also needs to calculate the Euclidean distance between the RSSI vector uploaded by the user and the vectors in the library. However, the K-proximity algorithm calculates the mean value of the corresponding
coordinates of each fingerprint point K closest to the target point to obtain the coordinates of the points to be measured. The formula is as follows:

\[
(x, y) = \frac{1}{K} \sum_{i=1}^{K} (x_i, y_i)
\]

(2)

Where, \((x_i, y_i)\) is the fingerprint point coordinate with the ith smallest distance between the central Europe and Europe in the database.

Compared with the nearest neighbor algorithm, the accuracy of K proximity algorithm is obviously improved. However, it is obviously not appropriate to directly calculate the mean value of K neighboring points. Because the nearest RSSI vector to the measured point should be closer to the real coordinates of the measured point. In other words, points that are closer should have more weight. Therefore, the above K proximity algorithm is further improved:

Remember that the Euclidean distance before K is small, such as the Euclidean distance corresponding to the ith small point is \(d_i\), then its corresponding weight should be

\[
\eta_i = \frac{1}{d_i} \sum_{j=1}^{K} \frac{1}{d_j}
\]

Then, the coordinates of the final point to be measured should be

\[
(x, y) = \sum_{i=1}^{K} \eta_i (x_i, y_i)
\]

It should be pointed out that the value of K should be determined by further experiments according to the specific application environment.

6. Brief Summary
In this paper, the positioning of underground parking lot is realized by using iBeacon bluetooth technology and combining with location fingerprint positioning scheme. By means of clustering analysis, the matching range is reduced to improve the localization efficiency. The weighted K proximity algorithm is used to improve the matching accuracy.

7. References
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