Study on the Positioning Scheme of Charging Pile Based on Ibeacon

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Abstract. With its advantages of low power consumption, anti-interference and low cost, ibeacon can not only provide users with positioning services, but also well adapt to the market. Therefore, this paper mainly studies and discusses the positioning scheme based on the ibeacon charging pile. According to the RSSI value, the distance between the bluetooth base station and the undetermined position node is derived, and the weighted triangulation algorithm is used to locate the undetermined position node. Finally, the a-star algorithm is used to quickly plan the shortest path.

1. Introduction

In recent years, with the booming development of the electric vehicle industry, driving the rapid economic growth and providing great convenience for the service industry, the problem of difficulty in charging has also limited the further breakthrough of the industry. Mainly due to the indoor environment, GPS signal is often unable to cover, can not provide users with convenient and accurate positioning services, so there are a series of problems in the charging pile addressing direction. In order to realize accurate positioning in indoor environment, also appeared many positioning technology at present, mainly including wi-fi signals, UWB, RFID, visible, ultrasonic, ZigBee, ibeacon, but from the point of view of commercial applications, ibeacon fast response speed, good signal penetrability and difficulty of deployment and small size, low cost and low localization accuracy can reach the level meters.

This paper is based on the study of ibeacon positioning scheme. The scheme discussed can be divided into three stages. The first stage is the RSSI ranging stage, the second is the positioning stage, and the last is the planning path stage.

2. RSSI Ranging

2.1 Selection of Ranging Principle

Since the wireless signal strength propagates in space and decays with distance, and this wireless signal strength (RSSI) is measurable to the receiver on the phone, the distance between the user and the sending device can be extrapolated from this value.

The core idea based on the attenuation model of transmission signal is: the attenuation relationship between infinite signal strength and propagation distance makes the signal strength value different. Therefore, the attenuation process of signal can be simulated by establishing an appropriate signal gradient model, so as to obtain the conversion between signal and distance, namely the attenuation model of transmission signal [1]. In general, the model can be expressed in the following form:
\[ P_L(d) = P_0(d_0) + 10n\log \left( \frac{d}{d_0} \right) + X_0 \]  \hspace{1cm} (1)

Where, \( P_L(d) \) is the path loss of the signal after the distance \( d \), \( P_0(d_0) \) is the path loss after the signal passes through the unit distance, \( d_0 \) is a unit distance, usually 1m, \( X_0 \) follows a normal distribution and the mean value is 0, the scope of standard deviation \( \sigma \) is \( 4 \sim 10 \), \( X_0 \) stands for external interference; \( n \) is the signal attenuation factor.

The value of RSSI during transmission can be expressed as:

\[ \text{RSSI} = P_T - P_L(d) \]  \hspace{1cm} (2)

Where \( P_T \) represents transmitted power.

When setting the ideal, the signal strength at \( d_0 \) is \( A \), there is:

\[ P_L(d_0) = P_T - A \]  \hspace{1cm} (3)

\[ P_L(d) = P_T - A + 10n\log \left( \frac{d}{d_0} \right) + X_0 \]  \hspace{1cm} (4)

\[ P_L(d) - P_T = -A + 10n\log \left( \frac{d}{d_0} \right) + X_0 \]  \hspace{1cm} (5)

In a general way, the value of \( d_0 \) is 1m, mean value of \( X_0 \) is 0, so there are

\[ \text{RSSI} = A - 10n\log(d) \]  \hspace{1cm} (6)

It can be seen from the above equation that the value of RSSI is closely related to \( A \) and \( n \). Both \( A \) and \( n \) are based on the empirical value of the experiment. Because the signal is constantly refracted and reflected in the medium, the signal propagation process is not the same in different environments, and the values of \( A \) and \( n \) are not the same. Therefore, the accuracy of \( A \) and \( n \) is directly related to the measurement accuracy.

2.2 Selection of Filtering Algorithm

In the process of collecting RSSI signal value, due to the influence of complex indoor environmental noise, the RSSI signal value collected at the same location will appear jitter, and the farther the distance is, the larger the jitter range of RSSI value will be. Therefore, it is not possible to use only one sample value as the final value; multiple samples are needed for the same location, then the data is preprocessed to reduce the error. If mean filtering is adopted, due to the large jitter range of RSSI measured at points far away from the transmitter, many details will be lost in the mean value processing, resulting in a large deviation between the result and the real value. By selecting kalman filter algorithm to process the collected data, the obtained RSSI value can be more accurate.

2.3 Kalman Filtering Algorithm

By using kalman equation to estimate the overall data optimally. No matter the observation data or the empirical data, they will be affected by the noise data to some extent. Therefore, the kalman filter algorithm adopts the linear equation to make the optimal estimation of the data, which can not only smooth the historical linear data set to denoise, but also predict the data of the next stage.
The realization process of kalman filter is to calculate the optimal value at a certain time by using the observed value and experience value at the previous time and using the linear equation. The specific equation can be divided into prediction process and update process.

The prediction process is to predict the state value $\theta'$ at the current moment by estimating the optimal value $\theta$ of the previous state, then the error $\Sigma'$ at the current moment can be predicted by the error covariance $\Sigma$ of the previous state [2].

Prediction equation:

$$
\begin{align*}
\theta'_k &= A\theta_{k-1} + B\mu_{k-1} \\
\Sigma'_k &= A\Sigma_{k-1}A^T + Q
\end{align*}
$$

The update equation:

$$
\begin{align*}
Kal_k &= \Sigma'_k C^T (C\Sigma'_k C^T + R)^{-1} \\
\theta_k &= \theta'_k + Kal_k (O_k - C\theta'_k) \\
\Sigma'_k &= (1 - Kal_k C)\Sigma'_k
\end{align*}
$$

In the above formula, $\theta'_k$ is the Kth empirical prediction value calculated according to the k-1 th system model, a is the state transformation matrix, B is the input control matrix, $\theta_k$ is the estimated value, $\mu_k$ is the system model parameter, $\Sigma_k$ is the error of state estimation, Namely, the error covariance matrix between the real value and the empirical value; sigma $k$ is the error covariance matrix between the actual value and the estimated value; Q is the customized prediction noise variance, $kal_k$ is called the kalman gain or mixing and factor. C is the observation data matrix, and R is defined as the measurement error. As the collected data is a set of one-dimensional data, parameters can be set according to the characteristics of the signal strength value. The filtering results are as follows:
Figure 1. RSSI values are constantly being revised

Figure 2. The variance between the true value and the estimate

Different from other traditional filtering algorithms, kalman filter does not smooth the data, but "correct" each data. Each correction is based on the previous result. The more the sampling points, the smaller the variance, and the closer the estimated value is to the real value.

3. Positioning Stage

3.1 Selection of Positioning Algorithm
After the relatively ideal RSSI value is obtained by kalman filtering, the positioning algorithm can be used to locate the user's position. The commonly used positioning algorithms are proximity method, triangulation method and fingerprint method.
3.2 Weighted Triangle Centroid Algorithm

3.2.1 Triangulation
For the traditional triangulation method, its principle is: suppose there are three non-collinear nodes A, B and C in the plane. In practice, they represent the signal transmitting end, and the receiving end is represented by node D. The distance from node D to the other three points can be obtained through the ranging stage, respectively, as Ra, Rb, Rc, then take A, B and C as the center of the circle, Ra, Rb and Rc as the radius to draw A circle, so that the three circles intersect at point D, and then the relative coordinates of point D for the three points A, B and C can be obtained, that is, the coordinates of the receiving end (undetermined node).

**Figure 3. Triangulation**

Suppose the coordinates of A, B and C are (x1,y1), (x2,y2), (x3,y3), and D are (x,y) respectively. According to the mathematical relationship, we can get:

\[
\begin{align*}
\sqrt{(x-x_1)^2+(y-y_1)^2} &= Ra \\
\sqrt{(x-x_2)^2+(y-y_2)^2} &= Rb \\
\sqrt{(x-x_3)^2+(y-y_3)^2} &= Rc
\end{align*}
\]

Solution of:

\[
\begin{bmatrix}
x \\
y
\end{bmatrix} = \frac{1}{2(x_1-x_3)} \begin{bmatrix}
2(x_1-x_3) & 2(y_1-y_3) \\
2(x_2-x_3) & 2(y_2-y_3)
\end{bmatrix}^{-1} \begin{bmatrix}
x_1^2 - x_3^2 + y_1^2 - y_3^2 + Re^2 - Ra^2 \\
x_2^2 - x_3^2 + y_2^2 - y_3^2 + Re^2 - Rc^2
\end{bmatrix}
\]

The (x,y) obtained from the above equation is the coordinate of the undetermined node. However, this is an ideal situation. In fact, due to the existence of ranging error, the real node coordinates should be within a range of the intersection of three circles, so the triangle centroid algorithm is proposed [3].

3.2.2 Triangle centroid algorithm
In reality, due to the complex indoor wireless signal transmission environment and the multipath effect, the error of the ranging model parameters will result in the deviation of the measurement results. The real location of the node to be measured is actually located in a small area where three circles intersect [4], as shown in the figure below:
In order to make the measurement result more close to the real value, the following rules are stipulated in the selection of point positions in this paper:

Assume that A, B and C are three terminal nodes, and their distances to the nodes to be tested are $R_a$, $R_b$, $R_c$, and, respectively, and the distances between the centers of A and B are $L_{AB}$. For these three circles, two and two are A group, and A total of three groups are obtained. The approximate values of these three represent unknown node coordinates are obtained, two circles intersect in the following four ways:

When $L_{AB} > R_a + R_b$, connect the centers of A and B to intersect the two circles at D and E, respectively. At this point, the coordinate of the midpoint of DE is taken as an approximate coordinate of the unknown node.

When $L_{AB} = R_a + R_b$, the point D coordinates at the pointcut of the two circles are used as the approximate point coordinates.

When $L_{AB} < R_a + R_b$, the intersection point of the two circles is D,E. The coordinates of the point closest to the node of the third transmitting terminal in D and E are selected as the approximate point coordinates.

When $R_b = L_{AB} + R_a$, connect the centers of A and B and extend the line segment to intersect A and B at two points D and E respectively. Take the coordinates of M in DE as the approximate coordinates.
According to the above rule, we can get the coordinates of three approximate points and connect them to form a triangle, whose center of mass is the final coordinate of the receiving terminal point.

The formula for calculating the center of mass is:

\[ x = \frac{x_1 + x_2 + x_3}{3}, \quad y = \frac{y_1 + y_2 + y_3}{3} \]  

(14)

### 3.2.3 Weighted trigonometric centroid localization algorithm

The general triangle centroid algorithm does not take into account the distance between the three approximate points and the undetermined position node, but directly considers the effect of the three points on the positioning node as the same, however, due to factors such as environment and multipath effect, the influence of one node at different distances on the positioning node is also different, therefore, the idea of weight is introduced, and different weights are given to nodes at different distances to represent the influence on positioning nodes, so that the accuracy of the results after processing will be higher. The weighting formula is as follows:

\[
(x, y) = \frac{\sum_{i=1}^{n} w_i A_i(x, y)}{\sum_{i=1}^{n} w_i}
\]

(15)

Where \( w_i \) corresponds to the weight of the \( i \)th transmitting terminal point, and \( A_i(x, y) \) to the coordinates of the \( i \)th transmitting terminal point. In the triangulation algorithm, \( n=3 \).

The selection of the weight has a great influence on the accuracy of the final positioning result. It is easy to know that the distance measurement error is small when the distance is close, and this error will increase with the increase of the distance. Therefore, this factor should be considered in the selection of weights. The approximate points far away from the receiving end should be given a small weight to prevent error accumulation, while the approximate points near the receiving end should be given a large weight. Since the selection of coordinates of each near-point of view is related to the
radius of the two circles, the weight can be selected as \( \frac{1}{R_a + R_b} \), and the formula of positioning coordinates can be changed to:

\[
\begin{align*}
    x &= \left( \frac{x_1}{R_a + R_b} + \frac{x_2}{R_b + R_c} + \frac{x_3}{R_a + R_c} \right) + \left( \frac{x_1}{R_a + R_b} + \frac{x_2}{R_b + R_c} + \frac{x_3}{R_a + R_c} \right) + \left( \frac{x_1}{R_a + R_b} + \frac{x_2}{R_b + R_c} + \frac{x_3}{R_a + R_c} \right) \\
    y &= \left( \frac{y_1}{R_a + R_b} + \frac{y_2}{R_b + R_c} + \frac{y_3}{R_a + R_c} \right) + \left( \frac{y_1}{R_a + R_b} + \frac{y_2}{R_b + R_c} + \frac{y_3}{R_a + R_c} \right) + \left( \frac{y_1}{R_a + R_b} + \frac{y_2}{R_b + R_c} + \frac{y_3}{R_a + R_c} \right)
\end{align*}
\]

4. Path Planning

4.1 Dijkstra Algorithm and A-star Algorithm

After the completion of positioning, navigation is the most critical part of the whole pile seeking process, which can provide users with an accurate, feasible and shortest path from the current node to the destination node.

Dijkstra is a typical single-source path algorithm, which is based on the greedy idea. The disadvantage is that when the local map is large, the number of nodes traversed will be very large, and the time cost is huge. Without loss of generality, a single-layer planar map is constructed, the traversal process is shown in the following figure:

![Figure 6. Dijkstra looks for shortest paths](image)

In figure 3.1.1, the dark green square represents the starting point of the path, while the red square represents the end point of the path. The black square is simulated as an obstacle in the path, the light blue square is the node visited during the operation of the algorithm, and the light green square is the node not visited but included in the observation node. The yellow route gives us the earth path. From the actual results, the Dijkstra algorithm is a breadth-first search, which visits all the nodes around and below the starting point. It is a divergent search method, and only when it spreads to the end point can it get the correct results. Therefore, it will waste a lot of time when the map is large.

A-star algorithm is a heuristic algorithm based on the extension of Dijkstra algorithm. The core principle is based on the following formula:

\[
f(n) = g(n) + h(n)
\]

Where \( g(n) \) refers to the cost from the starting node along the generated path to the node \( n \). While \( h(n) \) is the estimated cost of getting the optimal path
from node n to the target node, $h(n)$ is also known as the heuristic function. For path planning, it is advisable to adopt the hamanton method, which is characterized by high efficiency of path finding.

The detailed flow chart is as follows:

**Figure 7. A-star algorithm flow chart**

Vs is included in the Open table and Closed table is initialized to empty, is the Open table empty? Vi is equal to the Vd? Update the f value of Vi's child nodes, and judge and extend the Open and Closed tables of the nodes. Search failure

4.2 Improved A-star Algorithm

In the process of path-finding, with the increasing number of nodes in the Open table, step (4) has the greatest impact on the efficiency of the algorithm, that is, the node with the lowest f value is found. Therefore, an appropriate sorting method can effectively reduce the running time of the program. Here, the concept of heap sorting is introduced, and a small top heap is constructed. The top element is the smallest element. [6] therefore, the time complexity of finding the node with the lowest f value after the heap is constructed is of $O(1)$ constant level. Each time the smallest node is selected, the last element in the heap is replaced by the top element, and a heap sort is performed to construct a new small top heap, and so on.
The time efficiency of heap construction is $O(n)$, and n-1 downward adjustment operation is carried out after the completion of heap construction. The time complexity of each adjustment is $O(h)$. In the best, worst and average cases, the time complexity of heap sorting is $O(n \log n)$ [7]. Moreover, the performance of heapsort is very significant when finding the smallest or largest element among many keywords, which can greatly improve the efficiency of the path planning algorithm.

The operation effect of A-star algorithm is shown in the following figure:

![Figure 8. A-star algorithm looks for the smallest path](image)

A-star algorithm, as an extension of Dijkstra algorithm, introduces the idea of heuristic function, which greatly reduces the number of inspection nodes, and the overall algorithm efficiency is much higher than that of the latter, so it is more suitable as an algorithm of pile seeking path planning.

5. Conclusion
In this paper, the addressing scheme based on ibeacon new energy vehicle charging pile is studied and discussed, hoping to find a more economical and reasonable addressing scheme, which is mainly done in three aspects:

(1) In the ranging phase, the corresponding relationship between RSSI and distance d should be established, that is, the transmission signal model should be constructed. Through experiments, appropriate A and n can be selected, and the infinite signal strength value can be collected at the same location for many times. Then, the real value can be approximated by kalman filtering algorithm to obtain the distance between the undetermined node and the bluetooth base station.

(2) In the positioning stage, the weighted triangulation centroid positioning algorithm is adopted to calculate the coordinate position of the node to be measured. Since the traditional triangulation method does not consider the influence of different distance sources on the positioning node, the idea of weight is introduced to improve the positioning accuracy.

(3) In the path planning stage, without loss of generality, the shortest path search with the basic single-layer plane taken into consideration is selected. The deficiency is that more complex cases need to be discussed separately. At the same time, in the necessary sorting stage of the whole path planning algorithm, the idea of heapsort is introduced to optimize its time performance, which has a certain practical significance.

6. References
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