Design and Implementation of Indoor Positioning System Based on Bluetooth in Computer Room

Xiaoxu Cui, Liping Liu, Zhi Tian, Mingliang Wang and Zuowen Wang

ABSTRACT

The amount of indoor material management is huge and widely distributed. This paper designs and implements the indoor positioning system of the computer room by using Bluetooth technology for the problems of traditional manual management, large management, difficult management and low efficiency. The Bluetooth positioning beacon is accepted by the material positioning tag card through the periodic broadcast signal, and the distance between the two is calculated according to the distance-RSSI loss model, and then the material coordinate is calculated by the three-side positioning algorithm, and the coordinate data is uploaded to the server through the Bluetooth gateway, and the user can Remotely view the material of the equipment room in real time on the client. The experimental data shows that the maximum error of indoor positioning is within 35cm and the positioning is accurate.

1. INTRODUCTION

With the development of Internet of Things technology, indoor real-time positioning has been paid more and more attention. For indoor material management, due to its large quantity, wide distribution, and difficult management, it often disappears; the inventory of artificial materials is not only inefficient, the workload is large, and the information lags, resulting in repeated purchase of assets, resulting in increased operating costs of enterprises. The Bluetooth-based in-room material location management mode perfectly validates the importance of controlling the spatial location of materials for material management. In this mode, it is only necessary to install a positioning label for each material, and deploy an indoor positioning network in the equipment room. It is easy to see the real-time position and movement track of the material in the equipment room, without the need to manually count the quantity, management Personnel can remotely view the material counts.
2. SYSTEM DESIGN

2.1 Overall System Design

The overall structure of the system is shown in Figure 1. The indoor positioning design of the equipment room is divided into three modules:
1) Data acquisition module: collect data through the positioning beacon with Bluetooth Beacon and Bluetooth gateway, and then transfer to the server through the Bluetooth gateway [1];
2) Data receiving module: the server receives the RSSI data and performs calculation and storage into the MySQL database [2], and sends the processed data to the front-end web page through the indoor positioning algorithm;
3) Client: The client is divided into two main functions: information entry and item management.

2.2 Hardware Design

The Bluetooth Position Beacon (BPB)[3] needs to be deployed in the equipment room. Usually, it needs to be deployed every few meters. Then, using the Beacon broadcast function of the BPB, the BPB periodically broadcasts the signal [4]; The positioning tag card (Tag) is fixed at the bottom of the material, and the BPB is used as the base station to measure the distance between the BPB and the positioning tag card, and the relationship between the signal strength and the distance is established by the distance-RSSI loss model, and is calculated by the trilateral positioning algorithm.
algorithm. The coordinates of the material, coordinate data is uploaded to the server [5] through the Bluetooth gateway TD05.

2.3 Software Design

Information entry is to enter the information about the item to which the tag belongs into the corresponding UUID (Bluetooth Unique Identification Number), and the entered information is sent to the server and stored in the MySQL database. The front end sends an http request request to the server, and after receiving the response response, the user is displayed to the user, and the user can view the specific location of the label and the specific information of the attached item through the management interface.

3. KEY MODELS AND ALGORITHMS

3.1 Signal strength-distance loss model

To use Bluetooth for indoor positioning, you need to establish the distance-RSSI loss model [6-9].

Firstly, the RSSI value acquisition preprocessing is performed. The Bluetooth positioning beacon should be deployed to select the position of the surrounding unobstructed object to reduce the signal loss. After the signal is stable, the RRSI value is collected to prevent other signal interference and reduce the environmental error. Multiple RSSI values are collected at the same place. Mean filtering preprocessing is used to reduce measurement error, as in equation (1):

\[
RSSI = \frac{1}{n} \sum_{i=1}^{n} RSSI_i
\]  
(1)

Secondly, the distance-RSSI loss model is established. The experimental data shows that there is a logarithmic relationship between the wireless signal strength and the distance, as in equation (2). Among them, PL(d) and PL(d0) respectively represent the signal strength loss of the wireless signal at d and d0 meters, and n is the environment. The variable factor, Xσ, is a normal random distribution with a variance of σ in dB. Let d0=1m, and (2) be changed to formula (3):

\[
PL(d) = PL(d_0) - 10n \log \left( \frac{d}{d_0} \right) + X_{\sigma}
\]  
(2)

In equation (3), RSSI(d) represents the wireless signal strength value at d meters, and R1 represents the wireless signal strength value when the
Bluetooth Beacon beacon is at a distance of 1 m from the positioning tag card. The distance \( d \) and the signal strength \( \text{RSSI}(d) \) are obtained from actual measurements, and \( n \) and \( R_1 \) are the pending parameters of the model.

Finally, the optimal estimates of the parameters \( R_1 \) and \( n \). The least square method is used to find the optimal matching value by minimizing the sum of the squares of the errors to determine the optimal parameter value. The error function is given by equation (4):

\[
RSSI(d) = R_1 + 10n \log_{10}(d) + X_{\sigma}
\]

\[
J(R, n) = \frac{1}{2m} \sum_{i=1}^{m} (r - \text{RSSI}(d_i))^2
\]

\[
R_1 \text{ and } n \text{ are continuously cycle-optimized according to the initial value, as in equation (5):}
\]

\[
\begin{cases}
R_i = R_i - \alpha \frac{1}{m} \sum_{i=1}^{m} (\tilde{r} - \text{RSSI}(d_i)) \\
n = n - \alpha \frac{1}{m} \sum_{i=1}^{m} (\tilde{r} - \text{RSSI}(d_i))10\log_{10}(d)
\end{cases}
\]

Where \( \alpha \) is the gradient factor and \( \alpha = 0.02 \), so that \( J(R_1, n) \) is minimized to obtain the desired \( R_1 \) and \( n \). The distance-RSSI loss model established according to the optimal parameters is as shown in equation (6):

\[
d = 10^{\frac{\text{RSSI}(d) - R_i}{10m}}
\]

3.2 Trilateral Centroid Localization Algorithm

The coordinates of the material can be calculated by deploying the coordinates of the Bluetooth positioning beacon and the distance between the signal strength and the distance model [10].

In Figure 2, let A, B, and C represent the position of the Bluetooth beacon device, and set the intersection location node D \((x_d, y_d)\). The coordinates of the three points A, B, and C are known as \((x_1, y_1)\), \((x_2, y_2)\), \((x_3, y_3)\). Their distances to \( D \) are \( d_1, d_2, \) and \( d_3 \), respectively. Then the coordinates of \( D \) can be solved by any two of the following equations (7), and the E and F coordinates are the same.
\[
\begin{align*}
(x-x_i)^2 + (y-y_i)^2 &= d_i^2 \\
(x-x_j)^2 + (y-y_j)^2 &= d_j^2 \\
(x-x_k)^2 + (y-y_k)^2 &= d_k^2
\end{align*}
\]
(7)

\[
\begin{align*}
x &= \frac{x_d + x_e + x_f}{3} \\
y &= \frac{y_d + y_e + y_f}{3}
\end{align*}
\]
(8)

Figure 2. Intersection region model under noise interference.

r1, r2, r3 represent the distance d between the material and the three nearest Bluetooth positioning beacon devices that are closest to it by the equation (6). The three vertex coordinates of the shaded triangle that have been obtained by equation (6) are D (xd, yd), E (xe, ye), F (xf, yf), respectively, and the centroid coordinate P (x, y) of the triangle is to determine the position coordinates of the material, as in equation (8).

4. EXPERIMENT AND RESULT ANALYSIS

4.1 Distance-RSSI loss model parameter selection experiment

In order to determine the undetermined parameters n and R1 of the model, 15 points are selected at the indoor distance device 0.1m, 0.4m, 0.7m, 1.0m..., and the RSSI values collected by the pairing algorithm are averaged according to the positioning algorithm step, and then according to the steps. Second, use the least squares method to select the optimal parameters, and get R1=-68.451, n=2.556.

In order to verify the validity of the model, the distance-RSSI loss model curve is compared with the actual measured data, as shown in Figure 6. The red circle represents the actual measurement data, the blue line represents the function curve, and the curve shown in Figure 6 can effectively reflect the relationship between the Bluetooth Beacon signal strength and the distance, and R1 and n are selected reasonably.
4.2 Material Positioning Experiment

In order to measure the error of the positioning algorithm, three Bluetooth positioning beacon devices are deployed in the 5.4m*16.2m indoor, and the two-dimensional coordinates are A (0,7.2), B (2.7,0), C (2.3,16.2), respectively. Randomly select 30 sampling points, substitute the collected data into the distance-RSSI loss model, and then calculate the material position coordinates according to the positioning step 3. Compare with the actual measured coordinate data to obtain the positioning error value as shown in Figure 7. It can be seen that the positioning error is always less than 35cm, and most of the errors are less than 25cm, and the positioning accuracy is good.

![Figure 6. Model curve and actual data](image1)

![Figure 7. Material positioning.](image2)

5. CONCLUSIONS

For the indoor positioning of the equipment room, this paper first establishes the distance-RSSI loss model through experiments, and uses the three-edge centroid method to realize the indoor positioning of the equipment room. The experimental results show that the maximum positioning error is within 35cm, the positioning effect is accurate, and it can meet the indoor positioning of the equipment room demand. However, due to the large amount of material in the equipment room, the Bluetooth signal is easily affected by obstacles, and the increase, decrease or movement of materials will cause the environment to change, and the optimal R1 and n values will change accordingly. Therefore, the next step is to continue to improve the distance. The model enables it to adapt to the environmental transformations to make the positioning results more realistic.
REFERENCES


