

Three-dimensional wireless positioning method based on symmetric "Bluetooth" base station

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Key words: Three-dimensional positioning, Bluetooth, RSSI, Common mode error.

Abstract: Aiming at the problem that the indoor three-dimensional positioning algorithm is complex and the accuracy is not high, this paper proposes a three-dimensional wireless positioning method based on symmetric Bluetooth base station. First, several groups of Bluetooth base stations are placed symmetrically in the x, y, and z directions of the spatial three-dimensional Cartesian coordinate system. The base station in the x-axis direction needs to set its x coordinate, and the base stations in the y and z directions are correspondingly set with y and z coordinates. In the space, the base station detects the RSSI value of the tag Bluetooth signal, obtains the distance between the base station and the tag, cooperates with the preset base station coordinates, and uses the simple algorithm designed in this paper to determine the X-axis coordinate of the tag according to the X-direction base station data. So, you can determine the Y and Z axis coordinates, making the positioning algorithm more simple and reliable. Due to the particularity of symmetry, the method can reduce the influence of common interference factors (such as air humidity, temperature, electromagnetic interference, etc.) in the environment, greatly eliminating the common mode error and improving the positioning accuracy.

1. Introduction

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In recent years, the application of spatial three-dimensional positioning technology has become more and more extensive, especially the indoor three-dimensional positioning (such as indoor personnel in large factories, equipment positioning, etc.) technology has been paid more attention [1]. At present, the commonly used indoor three-dimensional positioning method utilizes technology ranging such as Bluetooth, ZigBee, WiFi, etc [2] and then applies the distance to the three-dimensional spherical space localization algorithm, and calculates the three-dimensional coordinates of the target by x, y, and z. due to Bluetooth [3], ZigBee [4], WiFi signal strength (RSSI) value is easily affected by environmental temperature, humidity, electromagnetic interference, object occlusion and other factors, the calculation results are more error after applying into the spherical model, and the spherical model algorithm is complex. It takes up a lot of CPU resources and affects the refresh rate of the location [5]. In order to solve these problems, this paper proposes a new three-dimensional spatial positioning method, which is simple in calculation and can reduce the common mode error caused by environmental interference to some extent.

In the method, the base station is symmetrically placed in the three-dimensional space of x, y, and z (two symmetric base stations are called a group), and the tested tag is in the space formed by the base station, and the system uses the RSSI to calculate the measured tag and a group. The distance of each base station in the symmetric base station is projected onto the corresponding coordinate axis to obtain the coordinate value of the point on the coordinate axis. Similarly, the coordinates of the other two directions of the point can be obtained. thereby the x,y,z coordinates be determined. This method converts the traditional spherical calculation into plane calculation, which

greatly simplifies the calculation process and can eliminate the common mode interference in the environment to a certain extent.

Bluetooth technology is a low-cost, short-distance transmission wireless technology with high reliability, fast connection, high-speed and large-range transmission, low power consumption, low cost, high security, etc. Bluetooth is small and the communication range is up to 100M [6], so it is widely used in indoor positioning.

2. Three-dimensional positioning algorithm based on symmetric Bluetooth base station

2.1. Symmetric base station placement method

Taking the cuboid space as an example, the area to be tested is placed in a three-dimensional Cartesian coordinate system (a three-dimensional coordinate system is established, taking a certain vertex of the three-dimensional space of the cuboid as the origin, and three mutually perpendicular vertices of the space are taken as the X, Y, and Z axes. In the three-dimensional coordinate system, symmetrically arranged type A (z-direction base station: x, y coordinates are the same), type B (x-direction base station: y, z coordinates are the same), type C (y-direction base station: x, z coordinates are the same). There are three types of base stations, and the coordinates of each base station are known. Each type of base station can place multiple groups according to actual conditions. As shown in Fig 1 (A, B, C three types of base stations each placed a group):

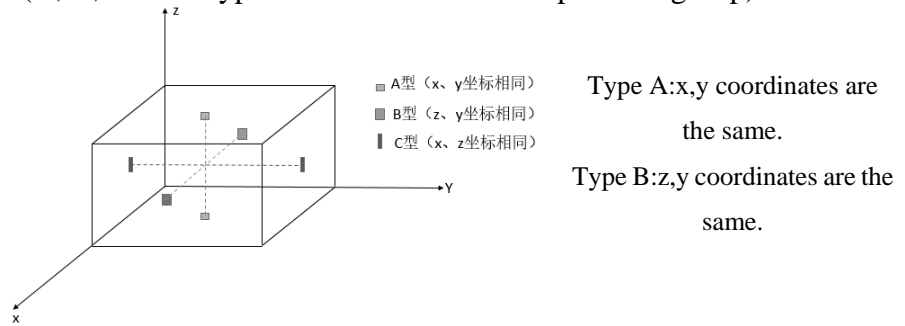


Figure 1. Three types of base stations each placed a group

2.2. Determination of the distance from the tag to each base station

When the tag to be tested is in working state, the scanning signal is transmitted outward, and the three types of base stations A, B, and C detect the strength of the signal, that is, the RSSI value, and convert the RSSI value to the distance between the corresponding tag and each base station. [7]. The specific algorithm is as follows:

$$d = \frac{10^{((ABS(RSSI) - A))}}{10 * n}$$

Where d is the distance between the tag and the base station, the unit is m; RSSI is the signal strength, which is a negative number; A is the absolute value of the RSSI value when the base station is 1 m away, and the optimal range is between 45 and 49; n is the environmental attenuation factor, which need to be tested and corrected; The best range of n is between 3.25-4.5 [8].

2.3. Establishment of coordinates

Take the B-type base station as an example: M1 and M2 are the distances between the tags and the two symmetrically disposed B-type base stations, and X1 and X2 are the known abscissas of the two symmetrically set B-type base stations. Theoretically, $M1 + M2 \geq |X1 - X2|$, since there is an error between the value of the distance measurement and the actual distance, when the measured distance is smaller than the real distance, $M1 + M2 \geq |X1 - X2|$ (case 1) and $M1 + M2 < |X1 - X2|$ (case 2) may occur.

The closer the tag is to the connection of a pair of type B base stations, the more likely $M1+M2 < |X1-X2|$ appears, and the following two cases are analyzed separately.

2.3.1. $M1+M2 \geq |X1-X2|$

According to the coordinates of the deployed B-type base station (as shown in FIG. 2) and the distance between the B-type base station and the tag, it is obtained:

The abscissa of the label is:

$$X = \frac{(M1^2 - M2^2) + (X1^2 - X2^2)}{2 * (X1 - X2)}$$

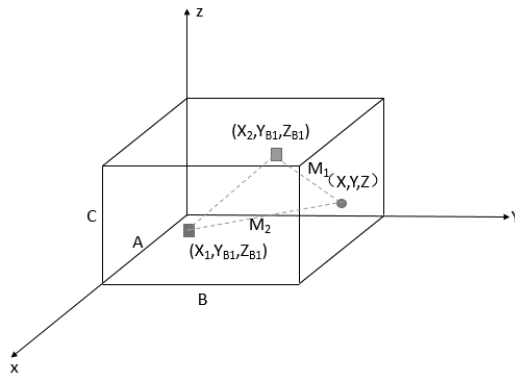


Figure 2. B-type base station

The formula derivation process is as follows:

The plan view of the two base stations and the tags to be tested is shown in Fig3:

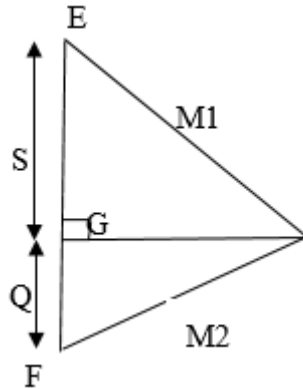


Figure 3. B-type base station

S and Q are the distances between EG and GF, therefore:

$$S = |X - X2| \tag{1}$$

$$Q = |X - X1| \tag{2}$$

So according to the equation:

$$M1^2 - S^2 = M2^2 - Q^2 \tag{3}$$

Substituting (1) and (2) into (3) can solve the abscissa :

$$X = \frac{(M1^2 - M2^2) + (X1^2 - X2^2)}{2 * (X1 - X2)}$$

Similarly, according to the layout diagram of the C-type base station described in FIG. 1, it can be obtained:

The Y coordinate of the label is:

$$Y = \frac{(P1^2 - P2^2) + (Y1^2 - Y2^2)}{2 * (Y2 - Y1)}$$

P1 and P2 are the distances between the tag and the two symmetrically disposed C-type base stations, respectively, and Y1 and Y2 are the ordinates of the two symmetrically disposed C-type base stations.

According to the layout diagram of the type A base station described in FIG. 1, it can be obtained:

The Z coordinate of the label is:

$$Z = \frac{(N1^2 - N2^2) + (Z1^2 - Z2^2)}{2 * (Z2 - Z1)}$$

N1 and N2 are the distances between the tags and the two symmetrically arranged A-type base stations, and Z1 and Z2 are respectively the vertical coordinates of the two symmetrically arranged A-type base stations.

Through the above method, the position of the label is determined.

2.3.2. $M1+M2 < |X1-X2|$

However, in this case, since the triangle cannot be formed, the above algorithm is not applicable. We use another algorithm: To reduce the error, the measurement results are proportional magnification to solve the abscissa of the tag to be tested.

$$X = \frac{M1 * |X2 - X1|}{M1 + M2}$$

Similarly, the Z and Y coordinates of the tag to be tested can be obtained:

$$Y = \frac{P1 * |Y2 - Y1|}{P1 + P2}$$

$$Z = \frac{N1 * |Z2 - Z1|}{N1 + N2}$$

3. Optimization of 3D Positioning Algorithm for Bluetooth Base Station

The range of Bluetooth devices used for positioning functions can reach 30-50 meters^[9]. Since the actual space is not necessarily a regular rectangular parallelepiped, in order to improve the measurement accuracy, each type of base station is arranged in several groups, and a large number of experiments are passed. After comprehensive consideration, it is considered that the three sets of base stations are most suitable in terms of cost and accuracy.

The simple layout model is shown in Fig 4. The B-type base stations are arranged in three groups. The formulas in 2.3.1 can be used to find that the X coordinates measured by the B-type base station are X1, X2, and X3, and the coordinates of the target to be tested are finally calculated.

$$X0 = \sum_{i=1}^3 X_i$$

Similarly, the Z coordinates measured by the three groups of A-type base stations are Z1, Z2, and Z3, and the Y coordinates measured by the C-type base stations are Y1, Y2, and Y3, and the coordinates of the target to be tested are calculated as follows:

$$Y0 = \sum_{i=1}^3 Y_i$$

$$Z0 = \sum_{i=1}^3 Z_i$$

Comparing the three sets of base stations with a set of base stations, and using the distance between the measured coordinates and the actual coordinates to express the error (unit: meter). Some results are shown in Table 1:

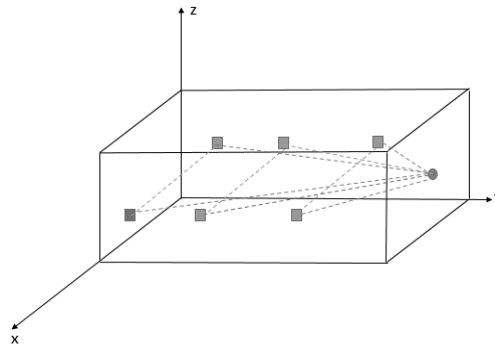


Figure 4. Simple placement map of three groups of base stations

Table.1. Comparison of measurement results between three groups of base stations and a group of base stations

	1	2	3	4
a set of base stations	1. 23	1. 55	0. 94	1. 87
three sets of base stations	0. 79	1. 45	0. 98	1. 21
	5	6	7	8
a set of base stations	1. 45	1. 04	1. 34	1. 75
three sets of base stations	0. 87	0. 89	1. 21	1. 06

1-8 indicates the experimental serial number, and the corresponding data of the base station indicates the difference between the measured position of the tag to be tested and the actual position. It can be seen from the table that the error of using three sets of base stations is mostly less than a group of base stations.

4. Comparison between the program and the spherical model

In order to verify the superiority of this scheme, we carried out the actual measurement with the scheme and the spherical scheme in the open room of 10m*5m*2.68m, the total number of base stations is 6 and the position of the tested label is 4 different positions. The measurement data is as shown in Table 2 below.

Table.2. Comparison of real data, spherical measurements and symmetric base station measurements.

True xyz coordinates	(5.0,3.0,1.5)	(2.0,2.5,1.0)	(8.0,1.5,2.0)
The xyz coordinates measured by this scheme	(4.9,3.2,1.4)	(2.5,2.5,0.9)	(7.7,1.2,2.5)
Spherical model measurement gives xyz coordinates	(4.5,3.0,1.5)	(3.0,3.0,1.2)	(8.2,2.1,2.5)

The data in the table shows that the error of this scheme is significantly lower than that of the spherical model. Although the spherical model can improve the accuracy by modifying the algorithm, the complexity of the algorithm will also increase. Considering the cost and real-time

performance of the positioning system, in practical applications, this scheme has certain advantages compared with the spherical model.

5. Conclusion

A three-dimensional wireless positioning method based on symmetric Bluetooth base station proposed in this paper, the core content of the method is to use a plane perpendicular to the X, Y, and Z directions to intersect a point to determine a space coordinate, thereby avoiding the traditional three sides complex positioning algorithm^[10]. The use of differential methods on the method of layering Bluetooth base stations reduces the impact of co-existing environmental factors.

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