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Research Article

Research on Intelligent Control Engineering of Green Low-Carbon Buildings Based on Improved Trilateral Positioning Algorithm

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Industrial production, military applications, and environmental monitoring all require corresponding positioning functions as science and technology advance. The location information service has gradually grown in popularity. However, large-scale applications will consume a lot of energy and cause environmental issues. Our further development will therefore focus on how to maintain low-carbon development and advance green technology. The improvement of triangular location algorithm is used in this paper to realize the research of low-power Bluetooth indoor location using the intelligent control project of green low-carbon buildings as the research object. The results show that the improved algorithm significantly improves the accuracy. The daily monitoring of the elderly and the alarm processing in an emergency are experimentally practiced and analyzed through the research of low-power Bluetooth indoor location algorithm. The research on intelligent control engineering of green low-carbon buildings is realized.

1. Introduction

In recent years, wireless network communication technology has grown rapidly and steadily in popularity across the country. People are increasingly interested in wireless positioning technology. Location information research has gradually become a hot field. Wireless positioning technology has gradually progressed from its initial scientific and military applications to the civil domain, where it has a subtle impact on people's daily lives [1].

In their daily lives, people often use location services, takeout services, navigation services, and so on. In outdoor environments, GPS (Global Positioning System) and cellular network positioning are common positioning systems [2]. Among them, GPS has been developing for a long time, so it is the most mature and widely used. However, the limitation of GPS technology is that it can only be used in an outdoor environment without obvious obstacles. It can limit positioning accuracy to five meters and ignore environmental interference to a large extent [3]. The satellite can even be accurately positioned using the GPS system [4]. However, due to the complex layout and large number of furniture in the indoor environment, the positioning effect of GPS is severely hampered [5]. With the rise of smart homes, sweeping robots and other products that rely heavily on positioning services, the demand for wireless positioning is increasing. Among these, how to find a positioning technology suitable for indoor environment, capable of quickly distinguishing furniture layout and avoiding furniture obstacles, merits in-depth exploration.

Infrared positioning technology, ultrasonic positioning technology, UWB positioning technology, and Bluetooth positioning technology are currently among the most widely used positioning technologies [6]. In terms of positioning effect, ultrasonic technology and ultrawideband technology are at the top of the list. Ultrasonic positioning can travel a long distance, and ultrawideband positioning has high penetration. At the same time, both have low power consumption, and ultrawideband has a high level of security [7]. However, due to the great influence of ultrasonic technology by multipath effect and nonline of sight propagation, in the process of practical application, a large number of ultrasonic receiving sensors must be installed, and the price of UWB positioning itself is high. Therefore, given the cost, neither can be widely used in indoor positioning algorithms [8]. Although the remaining infrared positioning technology is inexpensive and easy to use and consumes little energy, the infrared cannot penetrate obstacles and can only rely on visual transmission [9]. Therefore, when there are obstacles, the infrared transmission distance is reduced, resulting in poor positioning accuracy and the inability to be widely used [10].

Bluetooth positioning technology, on the other hand, is well-suited for indoor short-distance positioning due to its small volume and ease of integration [11]. Bluetooth positioning technology not only finds equipment quickly, but it is also unaffected by visual obstacles in signal transmission [12]. It also has some disadvantages, such as a high device cost, a small amount of transmission data, and a short transmission distance, but these disadvantages do not involve the function of traditional Chinese medicine for indoor positioning, so it can be widely used [13]. At the same time, Bluetooth technology can be accessed directly via electronic devices such as Bluetooth headsets, mobile phones, and smart homes. While incorporating traditional Bluetooth technology, Bluetooth 4.0 also exhibits a high-speed transmission efficiency of 1 Mbps and significantly reduces transmission time [14]. At the same time, it supports low-power operation and enters the sleep state when not in use, which greatly extends the service life of Bluetooth devices and makes up for their high cost to some extent [15].

Using the intelligent control project of green low-carbon buildings as the research object, this paper realizes the research of low-power Bluetooth indoor location through the improvement of triangular location algorithm. The research contributions include introducing the condition number of river reference node coefficient matrix as the weight factor into the trilateral location algorithm. The results show that the improved algorithm significantly improves accuracy. The daily monitoring of the elderly and the alarm processing in an emergency are experimentally practiced and analyzed using the research of low-power Bluetooth indoor location algorithm. The research on intelligent control engineering of green low-carbon buildings is realized.

This paper realizes the research of low-power Bluetooth indoor location by improving the triangle location algorithm. The research structure is divided into five parts. The first part describes the rapid development of wireless network communication technology. Global positioning system (GPS) has developed into one of the most mature and widely used technologies. The second part describes the research status of different location algorithms. The third part expounds the method and content of trilateral positioning algorithm used in the implementation of a green low-carbon buildings intelligent control project. The fourth part expounds the practical application results of indoor green low-carbon buildings intelligent control. The last part summarizes the research. The daily monitoring of the elderly and the alarm processing in an emergency are experimentally practiced and analyzed as part of the research on the low-power Bluetooth indoor location algorithm. The research on intelligent control engineering of green low-carbon buildings is realized.

2. Related Work

Because foreign research in wireless network positioning is still in its early stages, there are many mature and widely used positioning systems. Radar is developed by Microsoft Research Institute. It processes the signal fading eigenvalues in a specific environment by constructing the signal strength distribution map. The positioning system combines the position fingerprint method and the signal attenuation model. Therefore, it has little impact on the multipath effect and nonvisual signal propagation. Active Badge is a positioning system developed by AT&T in 1992. The system uses infrared positioning technology to locate objects. Therefore, it has limitations such as a short infrared transmission distance, which greatly affects positioning accuracy. AT&T then developed the Active Bat positioning system, which has high positioning accuracy and good real-time performance but has a high network cost and poor scalability.

Considering the various environments in various situations, no system is generally applicable in all environments, and the positioning systems described above are designed and proposed according to the specific environment. In addition, research on location algorithms is emerging one after the other, and researchers from various countries have proposed many creative new location algorithms, such as RSSI, TOA, TDOA, AOA, and other ranging based positioning algorithms, which primarily reduce the impact of ranging error on positioning accuracy via multiple measurements and different algorithms. Nonranging positioning algorithms such as the centroid algorithm, DV hop algorithm, APIT algorithm, and convex programming algorithm do not directly measure the distance or angle of nodes but rather calculate the coordinates of different nodes based on network connectivity.

Among them, trilateral location algorithm is one of the ranging location algorithms. Because of its simple principle and ease of implementation, it is also the most widely used in location services. Therefore, this paper focuses on improving the trilateral positioning algorithm and achieving green and low-carbon intelligent control of indoor buildings via Bluetooth positioning technology.

Some scholars have successively proposed the triangular centroid algorithm in response to the trilateral positioning algorithm, in which the trilateral equation is solved in pairs, and the position relationship between the intersection point and the position point is judged using the algorithm. Because each two circles may have two focal points, the two sets of solutions will record the intimate center of the three focal points as the position of the unknown node. The principle of this method is simple and easy to understand, but there is some deviation in positioning accuracy. Later, some scholars proposed a distance weighted trilateral positioning algorithm, which is also solved by three simultaneous equations. However, in order to improve the positioning accuracy, different distance weights will be given to the three intersections. However, these two methods require the calculation of three binary quadratic equations, which is cumbersome. At the same time, when the measurement error is large, the triangular area of the intersecting circle is large, making large positioning errors easy. Therefore, subsequent scholars proposed a weighted combined trilateral positioning algorithm, which abandoned the calculation method of simultaneous equations and instead used the matrix to calculate the position of position nodes after subtracting the equations. Similarly, the algorithm assigns different weights to different reference nodes. The size of the weights affects the minimum internal angle of the triangle. The greater the angle, the closer the three reference values are to a straight line, and the less accurate the measurement. However, because the correction method only passes through the minimum internal angle of the triangle and does not take into account the influence of side length, there are also deficiencies in the weight assignment selection.

Centroid localization algorithm, APIT localization algorithm, and DV hop localization algorithm are commonly used, nonranging localization algorithms. Although the centroid algorithm is simple, its accuracy is insufficient; although APIT positioning algorithm has high accuracy, it requires judging the geometric relationship between unknown nodes and reference nodes, which is complex to run and difficult to implement. In contrast, DV hop localization algorithm does not require a large number of reference nodes. At the same time, as a nonranging localization algorithm, DV hop can fully meet the needs of situations that do not require high positioning accuracy. At the same time, DV hop localization algorithm has low hardware requirements and is easy to implement. However, the algorithm also has shortcomings, and the sum of different weights is not one.

At present, the positioning technology of wireless sensor networks is more complex and there are numerous related theories. Because environmental complexity, multipath effect, nonline of sight propagation, and other factors have different effects on different algorithms and scenes, no algorithm or technology can be applied to all scene environments. Therefore, this paper improves the trilateral positioning algorithm in the ranging algorithm and realizes the green and low-carbon control project of indoor buildings based on Bluetooth positioning technology.

3. Method

Because the trilateral positioning algorithm is mainly based on the wireless signal propagation model in the implementation of green low-carbon buildings intelligent control project, it divides the ranging and positioning problem into two stages: distance measurement and specific positioning. Given that the purpose of the subsequent trilateration algorithm improvement is to reduce the error, in the ranging stage, firstly, the maximum error of RSSI value is removed using the Grobus criterion to improve the accuracy of ranging stage. The algorithm can effectively mitigate the impact of indoor complex environment on the positioning accuracy of wireless sensor networks, reducing the dependence of indoor positioning system on the environment. Simulation results show that the algorithm has higher positioning accuracy and better robustness than the weighted trilateral positioning algorithm and can adapt to different sizes and types of positioning systems. Therefore, it can play an important role in the intelligent control of green and low-carbon buildings.

RSSI ranging technology has been widely used in positioning services because of its low energy consumption, simple principle, and low cost. The specific position is determined by the difference between the transmitted signal power and the received signal power, which is the principle of RSSI positioning. As shown in Figure 1, the static node is a reference node with a known position. It is necessary to collect the signal of the reference node to determine the unknown node and the node with an undetermined position. Because the RSSI value decreases with the increase of signal propagation distance, the RSSI value can be converted into the propagation distance with its own position as the reference point under certain conditions using the signal propagation model. Finally, the location information of the unknown node can be calculated using the positioning algorithm embedded in the node.

At present, the two commonly used signal propagation models are mainly empirical models and theoretical models. An empirical model needs to carry out a large number of experiments. According to the experimental law obtained through many experiments, establish the relationship database between RSS value and distance in order to build the model, so it is called an empirical model. The model has high accuracy, but as the environment changes and new nodes join or exit, the law calculated by the original system no longer corresponds, necessitating extensive correction at a high cost. Theoretical models mainly include Free-Space model, Two-Ray Ground Reflection model, and Shadowing model. The calculation formulas are as follows:

$$\begin{aligned} &\text{Free}-\text{Space model}: p_r(d)=\frac{p_r G_r G_t \lambda^2}{16\pi^2 d^2 K},\\ &\text{Two}-\text{Ray Ground Refection model}: p_r(d)=\frac{p_r G_r G_t h_r^2 h_t^2}{d^4 K},\\ &\text{Shadowing model}: \text{RSSI}(d)=\text{RSSI}(d_o)-10n\lg\left(\frac{\mathrm{d}}{\mathrm{d}_o}\right)+x_\delta. \end{aligned} \tag{1}$$

Above, we introduce the related contents of wireless sensor network positioning and introduce and elaborate the common models of ranging algorithms. So far, it is the algorithm content in the ranging stage. Next, it mainly improves and introduces the trilateral positioning algorithm in the positioning stage.

Firstly, for the correction of measurement data error, usually the data obtained by repeated ranging will have large errors between individual data and other data, which is referred to as gross error. In actual measurement, voltage influence, external mechanical shock, external vibration, electromagnetic wave or electrostatic interference, and other objective interference, as well as subjective interference such as machine failure may cause gross errors. Gross errors have a great impact on our data analysis and subsequent calculation, introducing outliers with no reference value into our calculation process, so they must be eliminated. The two commonly used correction criteria are Douglas criterion and Dixon criterion. The former is applicable to a group of normally distributed measurement data by calculating the arithmetic mean, residual error, and standard deviation of the group of data. Then arrange the data from small to large, and the gross error will appear in the extreme value, that is, the maximum or minimum value. According to the GRABBS criterion, refer to the significance α. The maximum error value can be determined. The specific calculation method is as follows:

$$\begin{aligned} \overline{x} &= \frac{1}{n}\sum_{i-1}^{n} x_i, \\ \lambda_i &= x_i - \overline{x}, \\ \sigma &= \sqrt{\frac{\sum_{i-1}^{n} \lambda_i^2}{n-1}}. \end{aligned} \tag{2}$$

Secondly, we consider the influence of reference nodes on location. The principle of trilateral positioning algorithm is mainly to make a circle with three reference nodes as the center and three measured distances as the radius. The intersection of three circles is the solution range. The smaller the intersection range, the more accurate the solution. The existing theory has proved that when the three reference nodes are placed in an equilateral triangle, the positioning error is the smallest. Therefore, based on this theory, this paper reduces the error by weighting the reference points and then improves the trilateral positioning algorithm. The specific algorithm is as follows.

Suppose there is a known reference node $A(x_1, y_1)$, $B(x_2, y_2)$, $C(x_3, y_3)$ in the two-dimensional plane, and the unknown node $O(x, y)$ distance is measured. The distances of the three known reference nodes are d_1, d_2, d_3 respectively. Equation (3) can be obtained by establishing the equation:

$$\begin{cases} (x - x_1)^2 + (y - y_1)^2 = d_1^2, \\ (x - x_2)^2 + (y - y_2)^2 = d_2^2, \\ (x - x_3)^2 + (y - y_3)^2 = d_3^2. \end{cases} \tag{3}$$

Two simultaneous equations are established, respectively, and six intersections of three circles are obtained, and then the coordinates of unknown nodes are determined by solving the centroid of convex triangle. However, the calculation steps of this method are cumbersome; three binary quadratic equations need to be solved, and the amount of calculation is large. Considering the placement position of the reference node, it is easy to reduce the positioning accuracy when the area of the convex triangle is large. Therefore, this paper changes the method of finding the intersection of intersecting circles to locate unknown nodes through matrix calculation. Thus, the three binary quadratic equations are simplified as follows:

$$\begin{cases} 2(x_1 - x_3)x + 2(y_1 - y_3)y = \left(x_1^2 + y_1^2\right) - \left(x_3^2 + y_3^2\right) - \left(d_1^2 + d_3^2\right), \\ 2(x_1 - x_3)x + 2(y_2 - y_3)y = \left(x_2^2 + y_2^2\right) - \left(x_3^2 + y_3^2\right) - \left(d_2^2 + d_3^2\right). \end{cases} \tag{4}$$

Equation (5) can be obtained by simplifying to equation:

$$AX = b. \tag{5}$$

In which

$$\begin{aligned} A &= \begin{bmatrix} 2(x_1 - x_3) & 2(y_1 - y_3) \\ 2(x_2 - x_3) & 2(y_2 - y_3) \end{bmatrix}, \\ b &= \begin{bmatrix} \left(x_1^2 + y_1^2\right) - \left(x_3^2 + y_3^2\right) - \left(d_1^2 - d_3^2\right) \\ \left(x_2^2 + y_2^2\right) - \left(x_3^2 + y_3^2\right) - \left(d_2^2 - d_3^2\right) \end{bmatrix}, \\ X &= \begin{bmatrix} x \\ y \end{bmatrix}. \end{aligned} \tag{6}$$

Therefore, the unknown node coordinates are

$$X = A - b. \tag{7}$$

When the three reference points are in the same straight line, it can be obtained from the plane geometric relationship:

$$\frac{y_1 - y_3}{x_1 - x_3} = \frac{y_2 - y_3}{x_2 - x_3}. \tag{8}$$

That is, obtain the relationship:

$$(y_2 - y_3)(x_1 - x_3) - (y_1 - y_3)(x_2 - x_3) = 0. \tag{9}$$

Through the above changes, it can be obtained from the knowledge of matrix theory. When the condition number of coefficient matrix does not change, the solution of the equation remains unchanged. Therefore, for the three

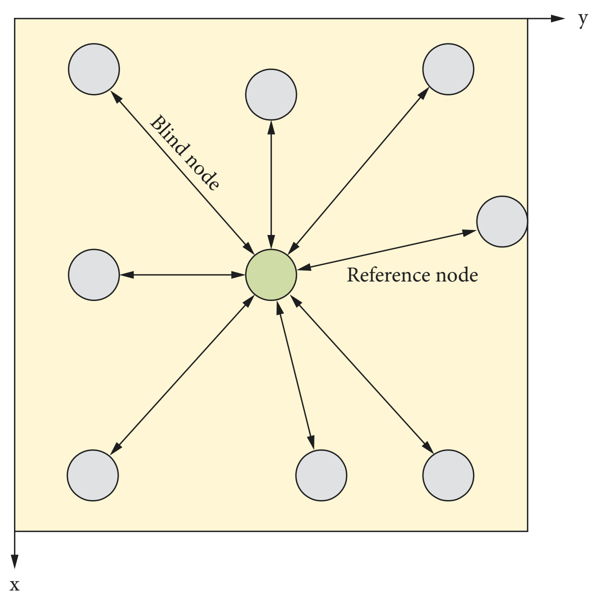

Figure 1: Positioning principle of RSSI.

reference node combinations, it can be considered to reflect the difference between the triangle surrounded by the three known reference points and the regular triangle surrounded by the three known reference points by weighting the distance of the three known reference points; that is, the condition number of the three coefficient matrices is introduced into the three-pass location algorithm as a weighted attractor, and then the solution is processed.

The above is an improvement of the classical trilateral algorithm, but the design and proposal of the algorithm is only an improvement process, and the final improvement effect and results need to be further verified through experiments. There are two commonly used verification methods, theoretical verification and practical verification. The actual verification requires the actual measurement of the algorithm using a machine at the specific verification location, and the actual results are obtained through calculation and analysis. The theoretical verification refers to the theoretical verification results obtained by simulating relevant experiments on the computer. Due to the limitation of experimental conditions, the theoretical verification, computer simulation experiment, is selected in this experiment,.

Finally, through computer simulation, under the condition of randomly taking three reference node coordinates, we conduct 100 simulations to calculate the randomly generated unknown node coordinates. The positioning error statistics of the classical trilateral positioning algorithm, the previous improved algorithm, and the improved algorithm in this paper are shown in Figure 2. In order to control independent variables, the coordinates of the three algorithms correspond to the same in each simulation process.

The abscissa in Figure 3 shows the positioning times of the algorithm. From the above simulation results, it can be seen that the classical trilateral positioning algorithm and the improved trilateral positioning algorithm are greatly affected by the number of reference nodes. When there are more reference nodes, the smaller the intersection area, the smaller the positioning error. Therefore, under the condition of the same number of reference nodes, the improved algorithm in this paper has high positioning accuracy, which is different from the classical trilateral positioning algorithm and the previous improved algorithm. At the same time, considering the error in the ranging stage, the experiment shows that the smaller the variance of the random variable of ranging error, the smaller the ranging error, and the larger the variance, the larger the ranging error. Under the same ranging error, the accuracy of the improved algorithm in this paper is higher than that of the previous improved algorithm and the classical trilateral positioning algorithm (as shown in Figure 3).

The information presented above is based on the improvement of the trilateral positioning algorithm in ranging and positioning technology, but in the course of practical application, ranging and positioning technology must measure the distance between a reference point and an unknown point, which not only improves the requirements for node hardware, but also necessitates numerous repeated measurements to ensure the accuracy of measurement. Therefore, the cost is higher than that of nonranging positioning algorithm. Nonranging based positioning algorithms do not need to measure the distance or angle information between the reference node and the unknown node but locate the unknown node through network connectivity. Therefore, these algorithms do not require ranging and have low requirements for positioning hardware, but they are less accurate than ranging and positioning technology. Therefore, in large-scale wireless sensor networks with low requirements for positioning accuracy, rough positioning, which can meet the basic positioning requirements, can be realized.

Therefore, this paper also proposes a related improvement, namely, DV hop algorithm, for the trilateral positioning algorithm based on nonranging positioning technology. The simulation results show that the improved DV hop algorithm improves the positioning accuracy by 12.1%–17.7% and 3.3%–9.4% compared with the classical trilateral positioning algorithm. The specific simulation scenario is shown in Figure 4.

When the position proportion and communication radius of the same node are the same, the positioning accuracy of the improved algorithm is better than that of the previous DV hop algorithm. The position proportion of reference node and the communication radius of signal propagation are two main indexes of DV hop algorithm. When the reference ratio of the algorithm is the same, with the gradual increase of the node communication radius, the positioning error of the traditional DV hop algorithm also increases gradually. The positioning error of the improved algorithm decreases first and then tends to be stable. When the relative position proportion of the reference node reaches 16%, the positioning error tends to be stable (as shown in Figure 5).

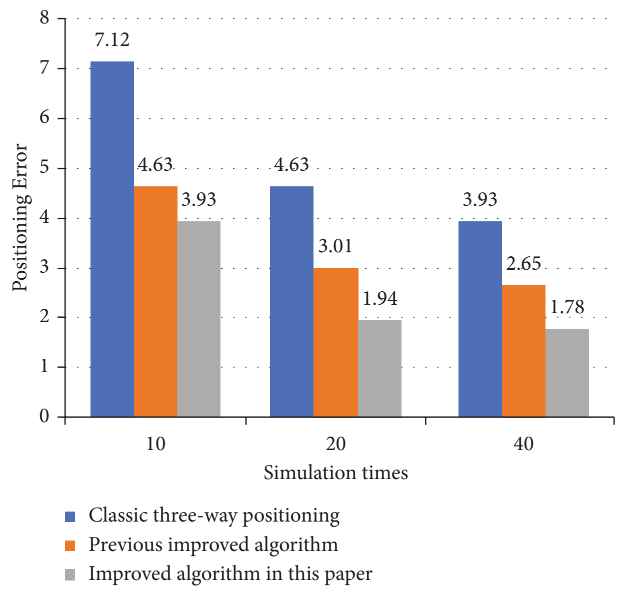

Figure 2: Statistical chart of positioning error.

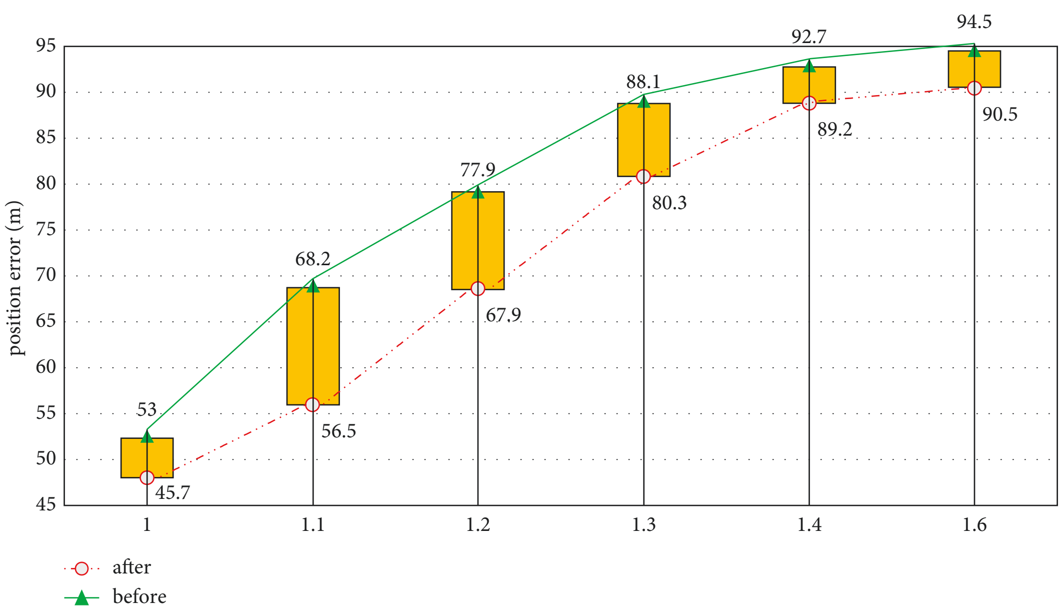

Figure 3: Comparison of algorithm positioning errors.

4. Result Analysis and Discussion

Through the improvement of the algorithm, it is finally transformed into the practical application of intelligent control of indoor green and low-carbon buildings. Taking the indoor low-power Bluetooth fall monitoring system for the elderly as an example, this paper discusses the practical application based on the improved trilateral positioning algorithm.

At present, a large number of elderly individuals in China live alone. When faced with an emergency, it is difficult to ask for and receive assistance. In order to address the current issue of insufficient medical monitoring for the elderly, we hope to implement real-time monitoring for the elderly via the building intelligent control project. The premise of real-time monitoring needs to locate the indoor location precisely. Therefore, the purpose of this paper is to achieve indoor fall monitoring for the elderly using the improved trilateral algorithm. In the process of daily monitoring, we can determine whether the elderly has fallen or needs other assistance, as well as relevant indoor information, by collecting the wearer's angular velocity, acceleration, and indoor position information, fusing the collected human physiological information parameters such as blood pressure, heart rate, and oxygen saturation, comparing with normal values, issuing a warning and performing a prefabricated analysis. When it is confirmed that the life of the elderly is in danger, the alarm device will

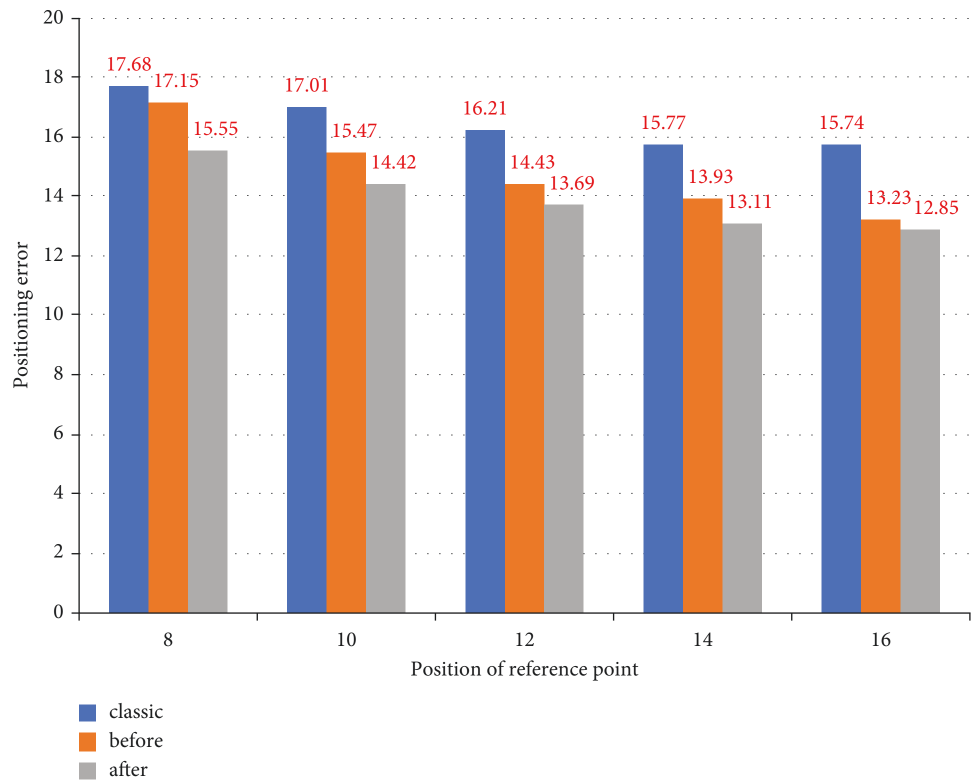

FIGURE 4: Statistical graph of algorithm positioning error.

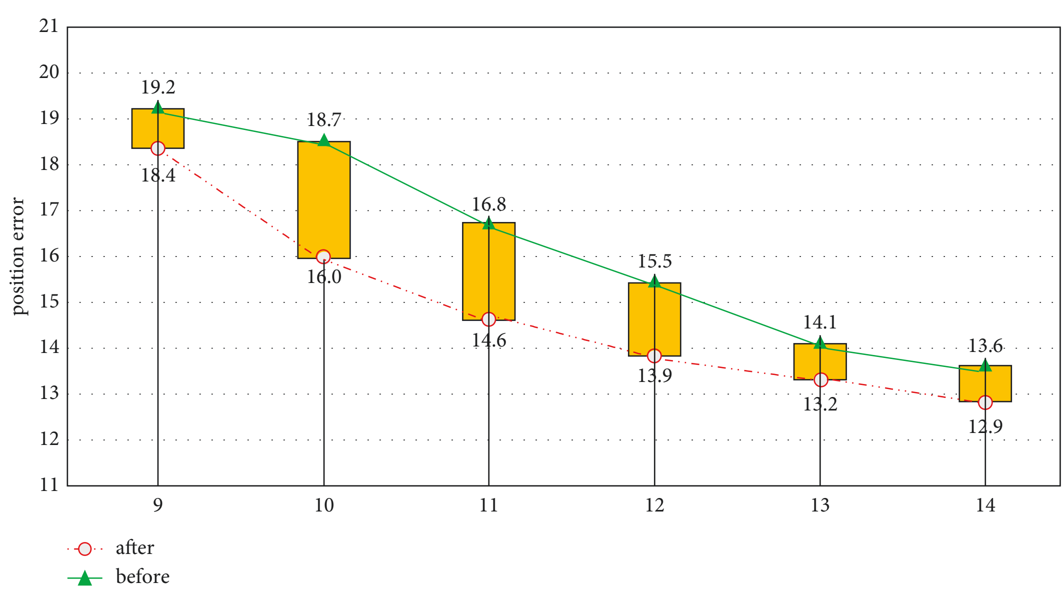

FIGURE 5: Comparison of algorithm positioning errors.

automatically activate and the fall position of the elderly will be automatically confirmed. That is, the trilateral positioning algorithm can effectively reduce the energy consumption in the monitoring process and realize the concept of low-power consumption, green and low carbon. The specific simulation scenario is depicted in Figure 6.

In the actual positioning test, we arbitrarily select six scattered coordinate values as known test points. At each test point, 100 groups of random RSSI values were taken. Firstly, the value is processed by Gaussian mixture filtering through ranging error correction and reference point position error correction, and the corrected signal strength value is used as

Figure 6: Indoor wireless signal location simulator.

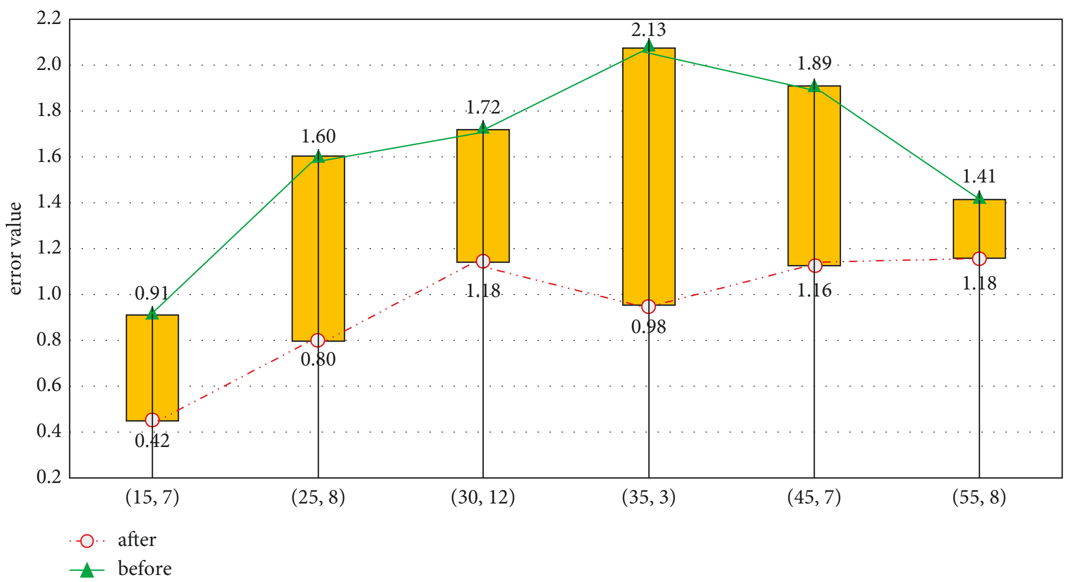

Figure 7: Comparison of error value broken line between two algorithms.

the final RSSI value of the test point. The final RSSI value is substituted into the improved algorithm formula. After corresponding weighting, the distance between the fitted logarithmic function and the three Bluetooth base stations closest to the test point is obtained in the matrix. Finally, the position coordinates of the unknown point are obtained through matrix rapid linearization and least square iteration, combined with the traditional trilateral positioning least square algorithm. The coordinates obtained by the two algorithms are compared with the actual coordinates, and the results are shown in Figure 7.

It can be seen that the maximum error between the unknown point coordinates obtained by the improved trilateral positioning algorithm and the actual test point coordinates is 1.2 m, while the error between the test coordinates obtained by the traditional trilateral positioning algorithm and the actual coordinates is 2.2 m. As shown in Figure 6, the algorithm error calculated in this paper is less than the error value generated by the traditional trilateral positioning algorithm at different known reference points. Therefore, we can say that the low-power consumption based on the improved trilateral algorithm and the indoor positioning accuracy of Bluetooth are higher than those of the traditional trilateral positioning algorithm, which can well realize the intelligent control project of green and low-carbon buildings.

5. Conclusion

Wireless sensor network technology is the most important and widely used field of wireless network sensing technology, and its related technologies are also complex. This paper analyzes and introduces the specific indoor wireless sensing scene and improves the underlying basic ranging algorithm and trilateral positioning algorithm. Firstly, the positioning error of indoor radio frequency signal propagation model RSSI value is improved. In the ranging stage, the large error of RSSI value is corrected by using Grub's criterion to improve the data accuracy in the ranging stage. Secondly, the trilateral algorithm is analyzed and improved in the positioning stage. According to the previous analysis conclusions, when all three reference points are on the same line, the positioning error is the smallest. Therefore, the concept of weighting factor is introduced in this paper, and the corresponding relationship between the intersection of all reference points besieged after the weighting calculation is verified by computer simulation. The condition number of riverside reference node coefficient matrix is introduced into the trilateral positioning algorithm as a weighting factor. The results show that the improved algorithm significantly improves the accuracy. Finally, through the research of low-power Bluetooth indoor location, the improved algorithm carries out experimental exercises and analysis on the daily monitoring of the elderly and alarm processing in emergency. The research on intelligent control engineering of green low-carbon building is realized. However, the content of indoor wireless sensing scene is not discussed in this paper. The influence of environmental factors is not considered, so further analysis is needed in future research.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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