Research On An Improvement Of Indoor Positioning Algorithm

Yunfeng Ni¹, Xiaohong Shi²*, Changcong Li³
School of Communication and Information Engineering, Xi’an University of Science and Technology, Xi’an, Shaanxi 710054, China
²*E-mail: 1049065782@qq.com

Abstract: Aiming at the relatively large positioning error in the traditional ranging positioning algorithm. This paper proposes a positioning algorithm based on the relationship between time and distance. The main advantage of this algorithm is that it does not need to measure the signal strength value, which avoids the positioning error caused by the attenuation of the signal during transmission. The algorithm mainly uses uw1000 as the positioning tag. When calculating the position coordinates, it first detects the positional relationship between the unknown node and the known node, and then enters the step-by-step algorithm to calculate the position coordinates under different positional relationships. Finally, the algorithm is verified by experiments. Compared with the traditional ranging positioning algorithm, the error is reduced and the accuracy is improved. The calculation process is simple and the algorithm complexity is low, but the used uw1000 has higher price than other ranging hardware. but the positioning effect is greatly improved and the application value is better.

1. Introduction
With the continuous development of science and technology, the development of positioning technology is becoming more and more perfect, and the continuous improvement of positioning technology requires the support of positioning algorithms, which makes the accuracy of positioning algorithms more and more high[1]. According to its nature, the localization algorithm can be divided into ranging algorithm independent of ranging and ranging based positioning algorithm[2]. The advantage of the former is that the algorithm is simple and easy to implement, and the hardware requirements of the node are not high, but the disadvantage is that the positioning accuracy is poor. The latter has the advantages of high positioning accuracy, high requirements on node hardware, and high energy consumption[3]. This paper mainly analyzes the reason why the ranging algorithm has errors in the ranging positioning process and improves a new algorithm.

2. Improved algorithm design
Through the analysis and comparison of the literature [1], [2], [3], [4], [6], [8]the main reason for the error leading to the error is the complexity of the indoor environment. And the inevitable noise caused by noise interference[4], based on this paper, a positioning algorithm based on time and distance is proposed. The main schematic diagram of the algorithm is shown in Figure1. The biggest advantage of using the arrival time between nodes as the main factor of ranging is to reduce the signal strength value of the measured signal[6], which avoids the partial error of the interfering signal strength. The calculation steps of the algorithm are divided into the following steps.

*Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd*
The basic principle of the algorithm is to use step-by-step calculation. A and B are two fixed nodes and the position coordinates are known. \( P_1 \) and \( P_2 \) are the process of the node location information of the node to be tested.

(1) When the mobile node is in the \( P_1 \) position, \( P_1 \) forms a certain angle with the A and B nodes. When the A point sends a signal to the \( P_1 \) point, the node A starts timing. When the \( P_1 \) point receives the signal of the A point (the reaction time is \( t \)) immediately send back to point A. When point A receives the signal returned by node \( P_1 \), it stops timing. Assuming that the time to complete the entire process is \( T_1 \), the distance between them is:

\[
d_1 = \frac{c \times T_1}{2} \tag{1}
\]

Since there is a reaction time \( t \) in the middle, its true distance should be:

\[
d_{1\text{real}} = \frac{c \times (T_1 - t)}{2} \tag{2}
\]

The distance measurement method from point B to point \( P_1 \) is the same as (1). Assuming that the measured time is \( T_2 \), the distance is:

\[
d_2 = \frac{c \times T_2}{2} \tag{3}
\]

Its true distance is:

\[
d_{2\text{real}} = \frac{c \times (T_2 - t)}{2} \tag{4}
\]

The distance between the two points A and B is measured as \( d \) when the node is laid. The distances from A and B to the node \( P_1 \) are respectively \( d_1 \) and \( d_2 \), and then the information of the coordinate points based on the distance formula between the two points is as follows (5):

\[
\begin{align*}
(x - x_1)^2 + (y - y_1)^2 &= d_1^2 \\
(x - x_2)^2 + (y - y_2)^2 &= d_2^2 \\
d_{1\text{real}} - d_{1\text{real}} \leq d &\leq d_{1real} + d_{2real}
\end{align*}
\]

(2) If the mobile node and the fixed node are on the same line: When the ranging signal is sent from point A (the signal transmission speed is recorded as the speed of light), the timer itself comes into time. When the signal hits the node \( P_2 \), \( P_2 \) returns the signal immediately sent (the reaction time of \( P_2 \) is \( t \)). When the return signal is received by A, A stops counting, and this time is recorded as \( T_{AP2} \). Then the distance between A and \( P_2 \) is:

\[
d_{AP2} = \frac{c \times T_{AP2}}{2} \tag{6}
\]

Since \( P_2 \) also has a reaction time \( t \), its true distance is:

\[
d_{AP2\text{real}} = \frac{c \times (T_{AP2} - t)}{2} \tag{7}
\]

When the signal from point A passes through point \( P_1 \) and reaches point B, the signal from point B is sent to point \( P_2 \) and starts to count. When the signal hits node \( P_2 \), \( P_2 \) immediately sends a return signal to point B. The processing time of \( P_2 \) is still \( t \). When the return signal is received by B, B stops timing immediately. This time is recorded as \( T_{BP2} \), then the distance between B and \( P_2 \) is:
\[ d_{BP2} = \frac{c \times T_{BP2}}{2} \]  

(8)

The true distance is:

\[ d_{BP2real} = \frac{c \times (T_{BP2} - t)}{2} \]  

(9)

Since the distance between \( A \) and \( B \) is known, the constraint is:

\[ d_{AB} = d_{AP2} + d_{BP2} \]  

(10)

After measuring the distance, the position coordinates can be obtained by using the distance relationship between the points and the points. It is calculated as:

\[
\begin{align*}
(x_1 - x)^2 + (y_1 - y)^2 &= d_{AP2real}^2 \\
(x_2 - x)^2 + (y_2 - y)^2 &= d_{BP2real}^2 \\
d_{AB} &= d_{AP2real} + d_{BP2real}
\end{align*}
\]  

(11)

According to equation (11), the position coordinate information of the mobile node can be obtained.

3. Error analysis of the algorithm

In the above two methods, when the position coordinate information is finally obtained, the distance relationship between the points is selected. One of the points is selected for analysis. The dormitory corridor test is used. The length is 40 meters and the width is 1 meter. The equipment includes 3 UW1000 modules. As a ranging tag and receiving tag, a laptop computer, a serial port to usb wiring, a meter ruler, the test tag is placed 25 meters apart, and then the algorithm is compared and verified. It is measured that the time at which point \( A \) receives node \( P_2 \) is \( T_{AP2} \), and the reaction time is \( t \), so the actual distance is \( d_{AP2real} = \frac{c(T_{AP2} - t)}{2} \) and \( d_{BP2real} = \frac{c(T_{BP2} - t)}{2} \) is equivalent. Therefore, the distance formula \( d_{AP2real} + d_{BP2real} = d_{AB} \) can be obtained as follows:

\[ t = \frac{c(T_{AP2} + T_{BP2}) - 2d_{AB}}{2c} \]

Bringing the measured data to \( t \approx \pm 0.6 \times 10^{-8} \) s, so the error distance value is \( s = c \times t = \pm 1.8m \). Because there is a variety of noise effects in this calculation, there is a certain error, which needs to be optimized in one step.

4. Kalman filter algorithm processing error

Kalman filter (Kalman filter) is an autoregressive filtering algorithm that can effectively filter out Gaussian noise[8][9] and suppress signal mutation. Gaussian noise includes noise caused by human disturbances, multipath effects, etc. in the indoor environment. The system can be described by a Linear Stochastic Difference equation. This time only considers the time axis direction. First, the motion of the target motion along the axis can be described by the following equation of state:

\[ x(k+1) = x(k) + Tx(k) + (T^2 / 2) \mu_x(k) \]

(12)

\[ \dot{x}(k+1) = \dot{x}(k) + T \mu_x(k) \]

Its matrix form is \( X(k+1) = \phi X(K) + \tau W(K) \); where:

\[
\begin{bmatrix}
X(k+1) \\
\dot{X}(k+1)
\end{bmatrix} =
\begin{bmatrix}
x(k) \\
\dot{x}(k)
\end{bmatrix}, \quad
\begin{bmatrix}
\phi & T \\
0 & 1
\end{bmatrix}, \quad
\begin{bmatrix}
\frac{1}{2} T^2 \\
T
\end{bmatrix}, \quad
W(K) = \mu_x
\]

(13)

The observation equation is \( Z(K) = C(K)X(K) + V(K) ; \) where \( C(K) = \begin{bmatrix} 1 & 0 \end{bmatrix}, \) \( V(K) \) is a noise sequence with a mean mean, and the variance is known. To predict the target, the following iterations can be obtained from the relevant theory:
\[ \hat{X}(K | K-1) = \phi \hat{X}(K-1 | K-1) \]

Where \( \hat{X}(K | K-1) = E[X(k) | Z^{k-1}] \), reflects the estimation of the current state by the observations of the previous \( K-1 \). The predicted error covariance can be expressed by the following formula:

\[ P_{\epsilon}(k | k-1) = \phi P_{\epsilon}(k-1 | k-1) \phi^T + \tau Q(K-1) \tau^T \]

For optimal filtering, the iteration expression is:

\[
\hat{X}(k | k) = \hat{X}(k | k-1) + K(k) [Z(k) - C(k) \hat{X}(k | k-1)]
\]

In the formula, \( K(k) \) is the Kalman gain. The covariance of the filtering error is:

\[ P_{\epsilon}(k | k) = [I - K(k)C(k)] P_{\epsilon}(k | k-1) \]

5. simulation results map

Through the analysis of error and simulation analysis using matlab, Figure 2 is the original node layout diagram, Figure 3 is the improved algorithm node distribution diagram, Figure 4 is the improved algorithm error analysis diagram, and Figure 5 is the introduction of the filter smaller error analysis diagram.
6. Conclusion

It can be concluded from Fig. 2 that the positioning error is also less than 5 meters, so the improvement of the algorithm is necessary. The node distribution diagram of Fig. 3 is the node placed according to the design of the improved algorithm node distribution diagram of Fig. 1. It can be seen that the closer When the node is fixed, the positioning error is smaller. The farther away from the fixed node, the larger the positioning error is. If the distance between the fixed node and the fixed node is neglected, the main cause of the error is other interference signals. Therefore, the filtering algorithm is introduced to eliminate the problem. The error caused by such a signal, FIG. 5 is a positioning trajectory diagram after introducing a filtering algorithm, and it can be seen that the improved algorithm does reduce the positioning error.

References

[1] Song Yangguang, Yin Feng, Yuan Ping. Research on Indoor Positioning Algorithm Based on CSI for Regional Particleization2018(36):12-16.

[2] Yin Yabo, Xu Qing. Optimization of centroid localization algorithm for wireless sensor networks based on RSSI ranging [J]. Computer and Digital Engineering, 2018, 46(12): 2425-2429+2462.

[3] Zhu Guang. Application of Improved RSSI Weighted Centroid Algorithm in Underground Personnel Positioning[J]. China Mining Industry, 2018, 27(12): 198-201.

[4] Zhu Hengjun, Wang Guanxi, Zhang Wei. Coal mine underground positioning algorithm based on improved Kriging interpolation[J]. Journal of Northeast Petroleum University, 2018, 42(06): 114-120+12.

[5] LUO Xiaoyuan, ZHONG Wenjing, LI Xiaolei, GUAN Xinping. Rigid graph-based three-dimension
localization algorithm for wireless sensor networks [J]. Journal of Systems Engineering and Electronics, 2018, 29 (05): 927-936.

[6] Fan Haihong, Shen Shuijin. DV-HOP localization algorithm based on weighted squares[J]. Electronic Design Engineering, 2018, 26(22): 63-67.

[7] Lu Yushuai. Design of underground coal mine personnel positioning system based on improved weighted centroid algorithm[J]. China Mining Industry, 2017, 26(02): 169-173.

[8] LUO Xiaoyuan, ZHONG Wenjing, LI Xiaolei, GUAN Xinping. Rigid graph-based three-dimension localization algorithm for wireless sensor networks [J]. Journal of Systems Engineering and Electronics, 2018, 29 (05): 927-936.