Research on 3D Positioning of Handheld Terminal Based on Particle Swarm Optimization

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Abstract

This paper mainly studies the problem of handheld terminals by using the base station for 3D positioning. Firstly, analyzing the positive correlation between the measured distance and the actual distance from the base station to the handheld terminal by using the algorithm of particle swarm optimization. Then using the least square method to solve the position coordinates of the terminal and determining the terminal position that at least 5 base stations are needed to complete the precise positioning. Afterwards, the motion trajectory of the handheld terminal is obtained by the method of the nonlinear optimization. And the number of base stations that can most effectively locate the terminal is deduced. Finally, the positive correlation function between the degree of connection, the number of base stations and the communication radius is analyzed.

The model used in this paper has the characteristics of low complexity and high accuracy, which lays a theoretical foundation for the research on the posterior aspect of the communication positioning.

Keywords: Three dimensional positioning of wireless terminal, Particle swarm, Base station

1 Introduction

With the rapid development of science and technology, the communication technology is changing with each passing day, and the function of mobile phones is becoming more and more perfect. Gradually, it becomes a “small secretary” that people rely on. GPS is one of the functions of the mobile terminal, people can use it to navigation, look for targets, share location and so on. From traditional GPS navigation to consumer information services and social software based on geographical location such as Public Comment and WeChat, the basis of realizing its function is to send and receive signals through the terminal equipment such as mobile phone, navigator and so on to obtain the distance, angle and other measurement information. The location information is converted into coordinating information by using the location algorithm. With the development of intelligent mobile phone, commercial GPS has been used widely, but it only stay in the two-dimensional space, can not be able to achieve data acquisition, accurate positioning, and even mature applications in vertical direction (such as in high-rise buildings, mines, on the roof). Therefore, the study of three-dimensional positioning has aroused great attention from all walks of life, and it has become the focus of society.

In this paper, the C question type of Chinese Postgraduate Mathematical Modeling Contest in 2016 is taken as an example to study the three-dimensional positioning of wireless base station network. Due to the obstruction of the barrier, when the base station transmits or receives data to the handhold terminal, the propagation time or speed will be affected. When the barrier is not blocked, the propagation environment is called the sight distance environment, otherwise it is called the NLOS environment. As shown in Figure 1.

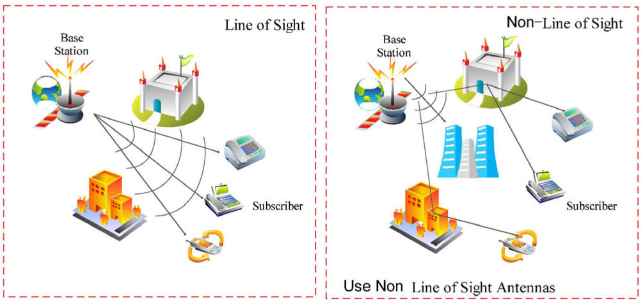

Figure 1. NLOS environment and sight distance environment

The data used in this paper is the real and sample data provided by a science and technology company. Coordination data source including the infinite signal propagation time, the base station, the number of base stations and wireless terminal number. In addition to the above parameters, the sample data also has the exact position coordinates of the corresponding handhold terminals. Then refer to the relevant knowledge, and set up the model for location. It provides theoretical guidance for the positioning analysis, data reasoning, and accurate service for the

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communication industry.

2 Problem Formulation

With the rapid development of wireless communication networks and mobile Internet, providing servers which is based on the information of geography (Location Based Service, referred to as LBS) has been one of the most market prospects and development potential of the business. Such as the traditional GPS navigation, public comment, WeChat and other software which are location-based information services and consumer based on social software, the foundation of realizing its function is to transmit and receive signals to attain the information of distance and angle such as the mobile phone, GPS and other terminal equipment, and taking advantages of this methods to transmit the data of measure information into the algorithm data.

The location [1] based on wireless mobile communication network aims at obtaining the position of the handheld terminal (including mobile phones or tablet devices). The method of reaching goals is measuring the intensity, arrival time, physical index angle of the radio signal transmission, and convert it into the distance between the terminal and the base station and angle information, finally attain the terminal coordinate information. How to do the equipment calculation or determine the position coordinates of the terminal in three-dimensional space basing on the measurement information of the base station, which is the three-dimensional positioning problem, and which is considered as the challenge of the real technical difficulties for the positioning system in the modern commercial communication network. The high precision 3D positioning is also expected to provide more value for customers, for examples, in the intelligent warehousing, smart factories, fixed asset tracking and the yield which is sensitive, as well as provide fundamental technological servers for the shopping mall where is interested by traditional businessmen, indoor navigation based on position information and crowd flow analysis in the office building, and business push.

From the technical point of view, the demand of modern commercial communication network for three-dimensional positioning is to use less base stations to complete the positioning of the terminal equipment as possible, the algorithm converges fast, and it has the advantages of robustness to interference and noise.

(1) Given the 10 sets of LOS or NLOS propagation environment, the measure data between handheld terminals and base station, please calculate the three-dimensional coordinates of the terminal according to the data above [2-3].

(2) Given 10 sets of TOA measurement data and all the base stations three-dimensional coordinates, please design algorithm, use the minimum number of base stations, to achieve the approximate optimal three-dimensional positioning accuracy.

(3) Given 5 sets of TOA data collected in the mobile terminal, please design algorithm to calculate the trajectory of the terminal.

(4) On the basis of 3 question ahead, the assumption of a given region terminal to each base station distance is known, but in fact, the communication radius of base station is limited, therefore, only in the base station communication terminal within the coverage radius can be measured by its distance to the base station. Only when the distance between a terminal and a sufficient number of base stations is measured can the location be completed. Assuming that each base station communication radius is *200* meters (over range although the measurement data, but invalid). Please measured data for a given 5 set of information, to find out the design of algorithm can be the base station positioning all terminal. Further, answer the following questions:In each scene, the average "connection degree of the terminal" λ is :

$$\lambda = \frac{\begin{array}{c}\textit{All connections that can be positioned}\\ \textit{from the terminal to the base station}\end{array}}{\textit{Terminal number}}$$

Please establish a model to analyze the relationship connection between the degree λ and the positioning accuracy [4].

3 Problem Solution

Firstly, from the base station to the handhold terminal, the time consumed can be defined as "time of arrival", it also can be referred to as t_{TOA}. Secondly, taking advantage of sample data to find the corresponding relationship between measurement distance and actual distance. Lastly, the position coordinates of the corresponding handhold terminals are obtained by using this relation.

3.1 Model Establishment

3.1.1 Locking of Three-dimensional Handhold Terminal Position

When the infinite signal propagates in NLOS case, because the signal of refraction, reflection or in other media, the signal propagation speed will be affected. So the propagation time will be longer, and all data in the t_{TOA} will be slightly larger [5-7]. Propagation speed of infinite signal is $c = 3\times10^{8} m/s$, so can suppose that:

$$R_{me} = R_{re} + R_{err} \tag{1}$$

$$R_{err} = k \cdot R_{re} + b \tag{2}$$

That is:

$$R_{me} = (k+1)R_{re} + b \tag{3}$$

There into: R_{re} refers to measurement distance between a base station and a handhold terminal device; R_{re} refers to true distance between a base station and a handhold terminal device; k refers to primary coefficient; b refers to constant term.

$$R_{re} = ct_{TOA} \tag{4}$$

$$R_{re} = \sqrt{(x_i - x_i^{'})^2 + (y_i - y_i^{'})^2 + (z_i - z_i^{'})^2} \tag{5}$$

There into: x_i, y_i and z_i are the coordinates of the i handhold terminal. $x_i^{'}$, $y_i^{'}$ and $z_i^{'}$ are the coordinates of the i base station. The dimension of the base station and terminal data given in the sample data is shown in Table 1.

Table 1. Sample data dimension

Data	1	2	3	4	5
Base station number	30	40	50	60	20
Terminal number	1100	1200	1300	1400	1000

In the above data, the first group and fourth group of data were selected for analysis. Two terminal coordinates, one base station coordinate and the t_{TOA} of the base station to the terminal are selected from the two sets of data respectively. By using formulas (4) and (5), the measuring distance and the real distance can be obtained. Then, the function relation between the measured distance and the real distance can be obtained by using formula (3). Next, putting t_{TOA} in the prediction data into the relation, and the measurement distance and actual distance can be obtained step by step. Then, any three base station coordinates in the corresponding group can be put into the relation, and then the three-dimensional coordinates of the terminal position can be obtained. And so forth, the coordinates of each position can be obtained gradually.

3.1.2 Base Station Number Optimization Model

In the given 10 sets of data, the number of base stations is more than 20, and they are greater than 4. Considering the location distribution of the base station, and then classifying the base station. Several key stations which can play key roles are found out, and then the optimal location is achieved [8].

Supposed that in a D dimensional search space, there are m terminal positions to form a particle swarm, where the i particles are located in space:

$$X_i = (x_{i1}, x_{i2}, x_{i3} \cdots x_{iD}) \tag{6}$$

It is a potential solution to the optimization problem. Putting it into the optimization objective function, the corresponding value can be calculated. According to fitness, the advantages and disadvantages of x_i can be measured. The best position of the i particle is known as the best position of its terminal history, denoted by:

$$P_i = (p_{i1}, p_{i2}, p_{i3} \cdots p_{iD}) \tag{7}$$

The corresponding fitness value is the best fit for individuals F_i; At the same time, each particle has its own flight speed.

$$V_i = (v_{i1}, v_{i2}, v_{i3} \cdots v_{iD}) \tag{8}$$

The best position of all terminals experienced is called the best position of global history, denoted by: $Pg = (pg_1, pg_2, pg_3 \cdots pg_D)$, and the corresponding fitness value is the global historical optimal fitness. In the basic PSO algorithm, the N particles, the D dimension($1 \le d \le D$) elements of speed and position update iteration as shown in following formula:

$$\begin{aligned} v_{id}^{n+1} &= w \times v_{id}^{n} + c_1 \times r_1 \times (p_{id}^{n} - x_{id}^{n}) \\ &+ c_2 \times r_2 \times (p_{gd}^{n} - x_{id}^{n}) \end{aligned} \tag{9}$$

$$x_{id}^{n+1} = x_{id}^{n} + v_{id}^{n} \tag{10}$$

There into: w refers to inertia weight; c_1 and c_2 are normal numbers, they are called as acceleration coefficient; r_1 and r_2 are random numbers changing within [0, 1]. The position change range and velocity range of d dimensional particle elements are limited to [$X_{d,\min}$, $X_{d,\max}$] and [$V_{d,\min}$, $V_{d,\max}$]. In the iterative process, if an one-dimensional particle element $X_{i,d}$ or $V_{i,d}$ ultrasonic boundary value, it makes it equal to the boundary value.

The procedure of particle swarm optimization is as shown in Figure 2.

Assumed that the number of base stations participating in the positioning is $m^{'}$, the confidence factor of base station is γ_i.

According to the principle of using the base station positioning terminal, in positioning process, the more base stations are used, the higher the accuracy of positioning. However, the more base stations are used, the greater the possibility of error. In order to find an optimal solution between them, objective function is established:

$$\min \sum_{i=1}^{m} \sum_{j=1}^{n} (R_{me} - R_{re})^2 \tag{11}$$

In general, three coordinate equations are needed to obtain the three-dimensional coordinates of a terminal. In other words, the equations can be listed using the data of the three base stations corresponding to a terminal:

Supposed that the location of the i terminal is determined:

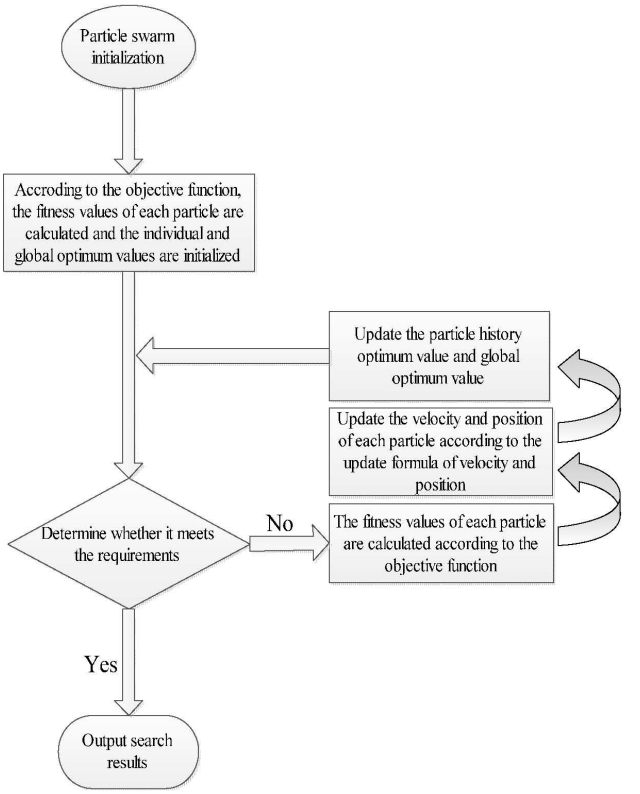

Figure 2. Flow procedure of particle swarm optimization algorithm

$$
\begin{aligned}
R_{re_{i1}} &= (x_1^{'} - x_i)^2 + (y_1^{'} - y_i)^2 + (z_1^{'} - z_i)^2 \\
R_{re_{i2}} &= (x_2^{'} - x_i)^2 + (y_2^{'} - y_i)^2 + (z_2^{'} - z_i)^2 \\
R_{re_{i3}} &= (x_3^{'} - x_i)^2 + (y_3^{'} - y_i)^2 + (z_3^{'} - z_i)^2
\end{aligned} \quad \textbf{(12)}
$$

As long as there is no linear correlation between the three equations, the values of three unknown quantities (x_i, y_i, z_i) can be solved. Therefore, in a problem of three-dimensional positioning, a terminal needs at least three base stations to determine. However, due to the interference of other signals or the long time interval caused by the refraction and reflection of the wireless signal, it may cause errors in the measurement results. It is very difficult to determine the coordinates of the terminal accurately only through the three base stations. In addition to the three base stations, the coordinates of at least one base station should be used to verify the coordinate results [9-11]. So the number of base stations required for precise three-dimensional positioning is at least four, that is $m^{'} = 4$. Obviously, the number of base stations should be in the range of the total number of base stations, and the constraint conditions can be obtained by combining the upper type:

$$4 \le m^{'} \le m \quad \textbf{(13)}$$

By colligating the above equations and combining with practice, equations still need to be listed:

$$
\begin{cases}
-200ns < \Delta t_b < 200ns \\
-200ns < \Delta t_z < 200ns \\
\bar{R}_{me} = \gamma_i R_{me}
\end{cases} \quad \textbf{(14)}
$$

3.1.3 Motion Analysis Model

As shown in Figure 3, the terminal moves from A to B, and the TOA data of all base stations can be measured at A and B respectively. According to the estimation method of the terminal position, the initial coordinates of A and B can be obtained.

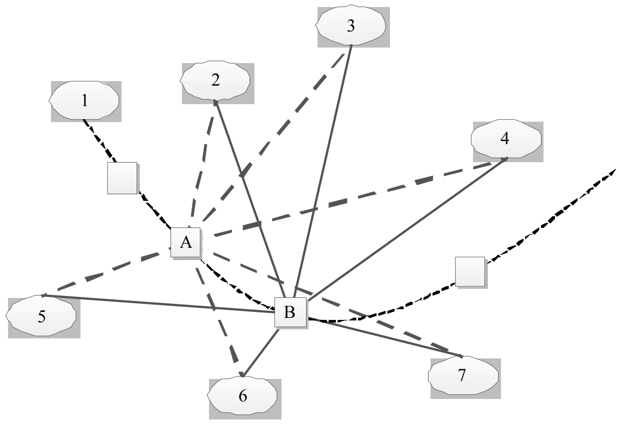

Figure 3. Trajectory model diagram of mobile terminal in base station

Trajectory estimation is the state estimation of a discrete-time system. The position of the recording terminal is $r_k = [x, y]_k$ at each moment. K refers to the discrete time coordinate of the terminal in the trajectory. Two equations can be used to describe state estimation problems [12]:

$$
\begin{cases}
r_k = f(r_{k-1}, u_k, w_k) \\
z_k = g(r_k, v_k)
\end{cases} \quad \textbf{(15)}
$$

There into: f refers to state equation; g refers to observation equation; u refers to input; w refers to System noise; v refers to Observation noise; $r_k^{"}$ refers to state prediction; $r_{k-1}^{"}$ refers to state estimation; $z_k^{"}$ refers to measurement prediction.

The corresponding prediction equations and observation equations are as follows:

$$
\begin{cases}
r_k^{"} = f(r_{k-1}, u_k, w_k) \\
z_k = g(r_k^{'}, v_k)
\end{cases} \quad \textbf{(16)}
$$

Residual equation structured as: $e_k = z_k - g(r_k^{"}, v_k)$. Residuals reflect the errors of prediction and measurement. The least residual indicates the best agreement between prediction and measurement. To reduce the influence of noise through the feedback form, finally get the coordinates of each position is the solution of the minimization of squared residuals. The specific algorithm procedure is as follows [13]:

Step 1: According to the algorithm, the initial coordinates of the terminal in each position and the corresponding k, d, and mean square error.

Step 2: According to the initial coordinates in *step1*, the estimated distance between the terminals and the real distance of each base station is calculated $R_i^{'}$. And the new $TOA_i^{'}$ is calculated according to $TOA_i^{'} = ((k+1)R^{'}+b)/c$.

Step 3: If the mean square error is reduced, then the current coordinate is used as the initial coordinate to go back to *Step1*. If the mean square error increases or the number of iterations to achieve, then stop. The current position coordinate is a point in the trajectory of the terminal.

Step 4: Repeating *Step1-3* for each location of the terminal. The mean square error of all the positions in the graph reaches the minimum, and all the terminal positions are obtained, and the trajectories of motion are constructed.

3.1.4 Terminal Location Model with Given Base Station Communication Radius

Supposed that the communication radius of each base station is r meters. The actual distance from the base station to the terminal is R_{re}. To ensure that the base station can measure the arrival time of the electrical signal sent by the terminal, it is necessary to ensure the actual distance between the base station and the terminal within the communication radius, that is:

$$R_{re} \le r \tag{17}$$

The above process has shown that there is a positive correlation between TOA measurement time and loci propagation time, that is:

$$t = a \times t_0 - b \tag{18}$$

There into, *t* refers to stadia propagation time, combining formulas (17) with (18) can be obtained:

$$(a \times t_0 - b^{'}) \times v \le r \tag{19}$$

When the equation is satisfied, the terminal can measure the distance from itself to the i base station.

In the case that the communication radius of the base station is r meters, people can locate the terminal location model according to the given communication radius of the base station. Finding that the positioning state of all terminals s_j and the number of effective base stations connected to the terminal n_j. Definition of average connection degree based on definition of terminal [14].

$$\lambda = \frac{\textit{All connections that can be positioned from the terminal to the base station}}{\textit{Terminal number}}$$

The expression of the average degree of connection available is as follows:

$$\lambda = \frac{1}{n}\sum_{j=1}^{n} s_j \tag{20}$$

There into, $s_j = \begin{cases} 0 \; \textit{Cannot locate} \\ 1 \quad \textit{Can locate} \end{cases}$

The accuracy of the positioning can not be determined according to the error degree between the positioning coordinate and the actual coordinate after the terminal is determined. Therefore, this method can't be used to establish the positioning accuracy.

To improve the positioning accuracy of the terminal, equivalent to reduce the positioning range of the terminal, there are two ways to optimize [15]:

(1) Increasing the number of effective base stations *n*;

(2) Selecting the appropriate communication radius r, not too big and not too small. Therefore, it can be found that the positioning accuracy is related to the number of effective base stations n and communication radius r, that is:

$$\xi = f(n,r) \tag{21}$$

Therefore, the positioning accuracy can be measured by the effective number of base stations n and communication radius r.

The connection degree λ expression contains two parameters.

The positioning status of all terminals are s_j.

The number of effective base stations connected to the terminal is n_j. Since the denominator in the expression is a fixed value, there are two ways to increase the degree of connection: (1) Increasing communication radius r; (2) Increasing the number of effective base stations *n*.

Thus the connection degree $\lambda \propto n, r$ can be obtained. Obviously, the more the number of effective base stations, the higher the accuracy of positioning, that is $\xi \propto n$. Using transfer thought, $\lambda \propto \xi$ can be known by people, that is, there is a positive correlation between the positioning accuracy and the connection degree.

3.2 Model Solving

3.2.1 Locking of Three-dimensional Handhold Terminal Position

Because the dimensions of the fourth groups are large, the data of the first terminal in the fourth sets of sample data and the coordinate data of the first and second base stations can be used to obtain two actual distances:

$$R_{rel,1} = \sqrt{(x_1 - x_1^{'})^2 + (y_1 - y_1^{'})^2 + (z_1 - z_1^{'})^2}$$
$$\approx 726.5754236m$$

$$R_{rel,2} = \sqrt{(x_1 - x_2^{'})^2 + (y_1 - y_2^{'})^2 + (z_1 - z_2^{'})^2}$$
$$\approx 587.5860953m$$

$$R_{rel,1}\text{-}ct_{TOA_{1,1}} \approx 969.160509m$$

$$R_{rel,2}\text{-}ct_{TOA_{1,2}} \approx 784.294869m$$

Putting above results into formula(3) and getting answer is $k = 0.33, b = 2.8$. Also putting other data of this group into formula(3), and can be known the result is very similar to the true coordinate value. Next, the corresponding data is extracted from the first set of data to recalculate the function relationship. The result of recalculation is $k = 0.33, b = 2.8$. Therefore, all measurement distance and actual distance have linear relationship:

$$R_{me} = 1.33 R_{re} + 2.8 \qquad \textbf{(22)}$$

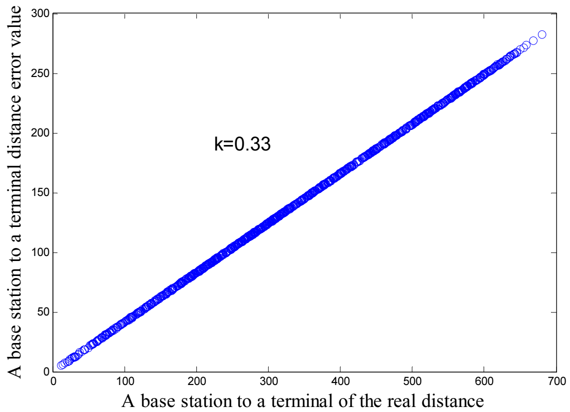

Figure 4. The relationship between the distance difference between the terminal and the base station and its true value

The formula (20) can be sorted out as:

$$R_{re} = \frac{R_{me} - 2.8}{1.33} \qquad \textbf{(23)}$$

Then putting the other prediction data and the results into formula(21), and the coordinates of the first terminal in the first set of data are obtained as $(\text{-}306.378,\ 92.449,\ 1.524)$. The coordinates of the first terminal in the fourth set of data are obtained as $(\text{-}456.268, 550.7802, 0.286)$. According to this method, the three-dimensional coordinates of each terminal can be obtained. Some of the results are shown in Table 2 and Table 3.

Table 2. The first ten terminal coordinate values in the first set of data

Data group	X coordinate	Y coordinate	Z coordinate
1	-306.378	92.449	1.524
2	99.91	60.45	3.89
3	-45.65	-3.98	2.25
4	11.62	158.38	3.88
5	-18.81	297.04	3.68
6	-47.93	-34.97	0.19
7	-315.55	278.95	3.88
8	145.60	278.95	0.76
9	-201.25	-320.55	2.54
10	105.44	-85.58	1.29

Table 3. The first ten terminal coordinate values in the seventh set of data

Data group	X coordinate	Y coordinate	Z coordinate
1	-269.79	230.49	1.25
2	-20.37	231.05	3.17
3	-265.56	74.10	3.23
4	12.51	-40.26	0.21
5	-153.06	-131.57	3.18
6	-121.18	-180.08	0.05
7	238.58	254.06	2.2
8	121.72	61.26	1.95
9	191.77	-201.18	2.76
10	-25.96	120.49	0.28

3.2.2 Base Station Quantity Optimization Model Solution

It is necessary to introduce a single base station accumulative error parameter err_i to solve the optimization model of base station number. err_i represents an accumulated base station measurement error for all handhold terminals. The concrete expression is as follows:

$$err_i = \sum_{j=1}^{n} (R_{re} \text{-} \bar{R}_{me})^2 \qquad i = 1, 2, 3 \cdots, m \qquad \textbf{(24)}$$

Thus, the larger the err_i, the greater the gap between the location of the handhold terminal and its actual location. That is, the base station has low positioning accuracy, so the base station is not chosen as the base station for positioning. The optimal location of the base station can be obtained by repeating the selection process.

Taking the first set of data as an example, drawing the relation diagram between the objective function value and the number of base stations in the iterative process (Figure 5).

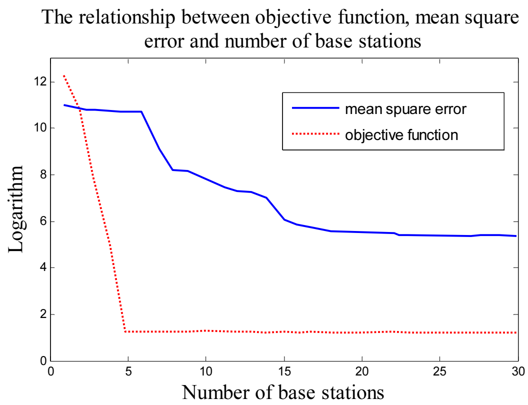

Figure 5. Relation diagram of objective function, mean square error and number of base stations

It can be found that the more the number of base stations, the more accurate the location. With the increase of the number of base stations, the error is gradually reduced. When the number of base stations is reduced to 5, the error has a significant reduction. So the choice of using 5 base stations to locate is the most accurate.

3.2.3 Kinematic Analysis Model Solving

For the given 5 sets of TOA data collected during the moving process, the calculated trajectory is shown in Figure 6 to Figure 10.

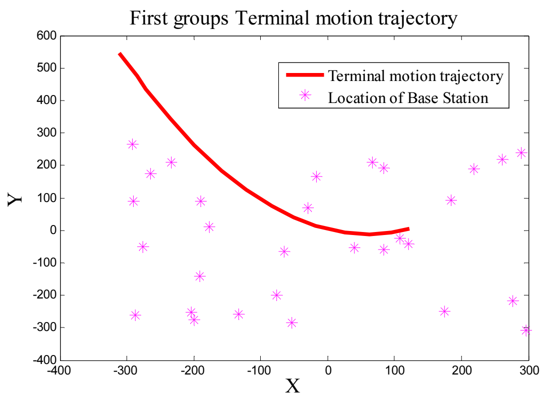

Figure 6. The terminal motion trajectory of the first group

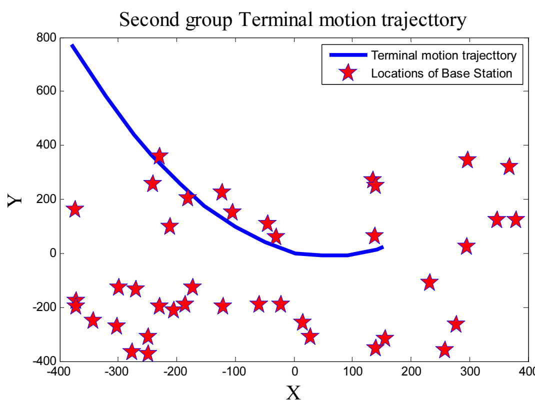

Figure 7. The terminal motion trajectory of the second group

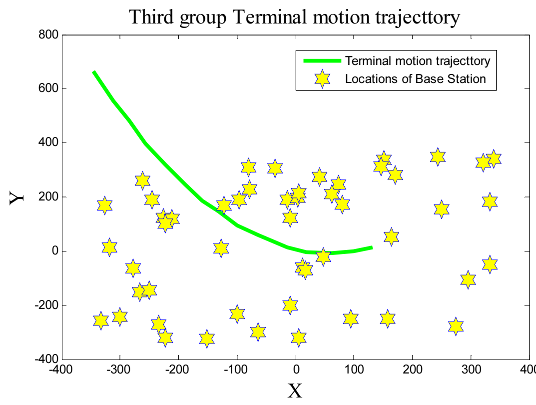

Figure 8. The terminal motion trajectory of the third group

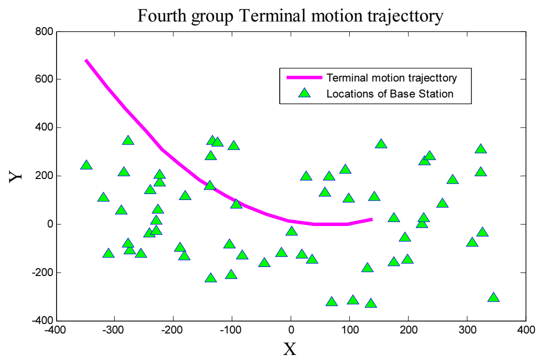

Figure 9. The terminal motion trajectory of the fourth group

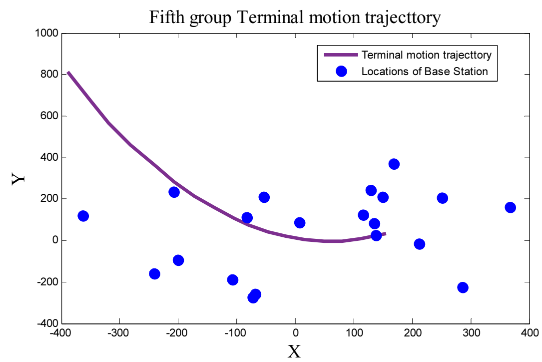

Figure 10. The terminal motion trajectory of the fifth group

The trajectory equation of each terminal is as follows:

The first group:

$$y = 0.0040x^2 - 0.49923x + 3.9532$$

The second group:

$$y = 0.0040x^2 - 0.5025x + 4.6274$$

The third group:

$$y = 0.0040x^2 - 0.5023x + 9.1369$$

The fourth group:

$$y = 0.0040x^2 - 0.4983x + 12.2384$$

The fifth group:

$$y = 0.0040x^2 - 0.5028x + 9.8873$$

3.2.4 Terminal Location Model with Given Base Station Communication Radius

Considering the limited communication radius of the base station in the actual physical world, and assuming that the communication radius is 200 meters. By measuring the TOA data of the mobile terminal and the base station, the distance between the terminal and the base station is calculated by using the initial estimate of the first step in the model, and then the data less than 200 meters is screened out. According to the selected valid data, the author counts the number of TOA data available at each terminal (That is the number of connections). Since each terminal location needs to be detected by 5 base stations, the author locates the terminals with the number of connections greater than or equal to 5. In the positioning calculation, the aforementioned-predictor-corrector adaptive model is still needed to precisely locate the terminal.

It is necessary to establish model to analyze the relationship between connection degree λ and positioning accuracy. The following definition of positioning accuracy can be used:

$$LAC = \sqrt{\frac{n}{\sum_{i=1}^{n}(X_{o,i} - X_m)^2}} \quad \textbf{(25)}$$

There into, n is the number of approximate coordinates of the positioning terminal. (For example, when a terminal can only be detected by 5 base stations, the number of approximate coordinate is $C_5^4 = 5$). $X_{o,i}$ is a model for approximate coordinates. X_m is the approximate coordinate obtained by the model. X_m is a more accurate terminal coordinate calculated with all connected base stations. The significance of LAC index is that the smaller the positioning error is, the greater the precision is. After obtaining the position and connection number of the terminal which can be positioned, the λ is obtained by the definition of the average degree of connection given in the question. Finally, the relation curve between connection degree and positioning accuracy is plotted.

The labels and coordinates of the terminals which can be located in different scenes are calculated. The relationship between the number of connections and the precision that can be located from the terminal to the base station in different scenarios is shown in Figure 11.

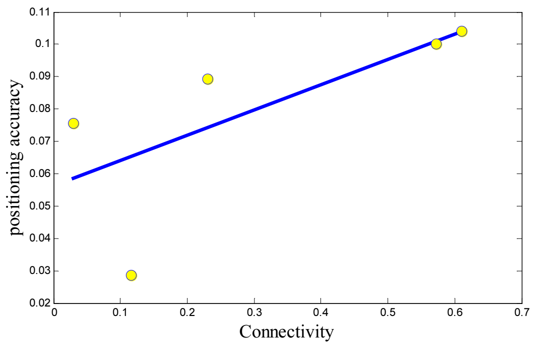

Figure 11. Relationship between positioning accuracy and connection degree

According to the fitting results of the above test samples, the regression equation is $LAC = 0.0764\lambda + 0.0566$, and the communication radius is $r = 200m$. They can be solved by iteration solution.

Because the positioning accuracy can be measured by the communication radius and the number of effective base stations, people can use the control variable method to observe the change of the communication radius or the number of effective base stations to observe the relationship between the measure index and the connection degree (Table 4).

Table 4. Connection accuracy and degree

Scene	Connection number	Terminal number	Connection degree	Accuracy
1	130	1100	0.1182	0.0283
2	739	1200	0.6158	0.1035
3	299	1300	0.2300	0.0890
4	804	1400	0.5743	0.1002
5	27	1000	0.027	0.0752

(1) Fixed minimum base station $n_{max} \geq 5$. Changing communication radius r. When the number of fixed minimum base stations is fixed, the connection degree of the five groups of test samples rising with the increase of communication radius. This is consistent with the conclusion that there is a positive correlation between the degree of connection and the radius of communication [16].

(2) Fixed communication radius r=200m. Changing the minimum number of base stations n_{max}. In the case of fixed communication radius, the connection degree of the five groups of test samples decreases with the increase of the number of the minimum base stations. The higher the floor level of the location base station, the less the number of effective base stations. And the lower the connection degree at this point. This is consistent with the conclusion that there is a positive correlation between the degree of connection and the effective number of base stations [17].

According to the above results, the positive correlation between the connection degree λ and the number of base stations and the radius of communication is consistent with the actual situation [18].

4 Conclusion

A three-dimensional positioning model suitable for any scene is established in this paper. In the verification data, the relationship between the distance from the terminal to the base station and the real distance is calculated. Therefore, the X and Y coordinate values of the terminal can be calculated by the time difference of propagation. The average error is 0.3m, and the Z axis coordinate error is 0.5m. According to the location information of the base station in space, the base station selection strategy based on particle swarm algorithm has been proposed. It is concluded that the minimum number of base stations is five when the location has high accuracy. Based on a conclusion that the NLOS error is positively correlated with the distance of the terminal base station, people can infer that the base station that is most likely to effectively locate the terminal must be the nearest base station from the terminal. Therefore, the base station nearest to the terminal is selected to estimate the terminal position, and the validity of these base stations for positioning is verified reversely according to the estimated position, so as to determine whether the terminal can be located or not.

The algorithm presented in this paper has the characteristics of low complexity, strong robustness and strong noise immunity. Although the observation TOA has some deviations, the parameters can be determined by the model in any scene, and the location of the two or three-dimensional scenes can be located accurately.

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