International Journal of Smart Home
Vol. 10, No. 5 (2016), pp. 195-206
http://dx.doi.org/10.14257/ijsh.2016.10.5.18

Research on the Localization Algorithm of Transmitting Station Based on RSSI and GPS

Mingji Yang[1,2], Chenyi Zhan[1,2] and Haoqun Shi[3]

[1]*The Higher Educational Key Laboratory for Measuring and Control Technology and Instrumentations of Heilongjiang Province*
[2]*Harbin University of Science and Technology, Harbin, China, 150040*
[3]*No. 703 Research Institute of China Shipbuilding Industry Corporation*

Abstract

This paper presents an intelligent positioning algorithm for transmitting station. By using GPS and RSSI, the influence of RSSI value can be reduced. The advantages of multi angle positioning method and centroid localization method are combined. The algorithm required less precision positioning device, also the least square method is used to reduce the error of location in urban areas. The method is simple and convenient, and the simulation results show the practicability of the algorithm.

***Keywords**: localization algorithm, multi angle positioning method, centroid localization method*

1. Introduction

With the rapid development of communication technology, mobile communication technology has been popularized to people's daily life. It has brought us convenience, however it also has caused a certain problem. The phenomenon that the transmitter station sends spam messages and telecommunications fraud is common. Determining the precise location of the station can effectively prevent the occurrence of this phenomenon. Since active positioning has defect, people pay more attention to the development of passive technology. The passive location technology has the characteristics of far distance, strong anti-interference, meeting reconnaissance of electronic intelligence, so it also plays an important role in the development of tracking and positioning technology.

In the paper [1], the problem of localization of wireless sensor network in indoor environment was studied, and the problem was completed by using the nearest neighbor algorithm and K algorithm. The experimental evaluation of the performance technology in the environment with a small number of obstacles is shorter and the accuracy is higher. In wireless sensor networks, sensor nodes can be used for monitoring and tracking, but errors are often during measuring the angle and distance between sensor nodes. Therefore, the papers [2-3] introduce a new algorithm using the angle of view to change the physical data, so as to avoid the occurrence of errors between the nodes of the wireless sensor and the angle of measurement, and further spread of error. In the paper [4], the measurement is assumed to be noise and unknown bias, the maximum likelihood algorithm is used for effective statistics, the sub product of the algorithm is used to estimate the deviation range, and then we can obtain matrix expression of the information, and ultimately measurement can be achieved by using range measurement and anchor node localization in a specific wireless network transmission. A new environmental monitoring system is proposed in paper [5]. The integrated system architecture of the system is proposed, which integrates the wired sensor and the wireless sensor to realize the long-term, remote monitoring and real-time monitoring. In the case of a new standard, the use of a unified framework to complete the operation of the sensor data, is the most outstanding

ISSN: 1975-4094 IJSH

contribution of wireless sensor technology. In view of many wireless channels, it is difficult to obtain the appropriate propagation loss model of network equipment.

The new method proposed by [7] is to solve the problem of target location in large space. By using a new routing algorithm DOA in the TOA localization, the node position information is used to control the field of the fixed node, the delay and the system overhead in the localization process is optimized. The paper [8] is used to analyze the indoor positioning system of WiFi, which is based on the traditional sampling theory and system performance. The new algorithm is used to calibrate the reference test equipment, and the performance and difficulty of the system are improved. In the literature [9], the assumption that the sensor is allowed to swing, the perturbation data is measured, a new algorithm that can work under arbitrary dimension obtains arbitrary general strict ggr. The paper [10] based on two kinds of slack variables lp and lr, and rr are combined with the greedy mode, and the matching and allocation problem is completed on the basis of distributed heuristic algorithm.

To sum up, this paper presents an algorithm using modern means, locating through continuous GPS coordinates and RSSI value, thus the effect brought by the error of RSSI values are greatly reduced. Then, by using the advantages of multi angle positioning method and centroid localization method, also the least square method is used to reduce the error of location in urban areas, an algorithm requiring less precision positioning device can be obtained.

2. Single Station Positioning Algorithm

The target is detected by a single observer, and on the basis of some positioning parameters which were obtained from the target, we can make use of appropriate data processing means to determine the position points of the target in space. This is the process that the positioning system completes the spatial orientation for the target.

From the view of geometric, to identify the position of a point in space, we can obtained it from intersect of three or more than three flats or Surfaces in three-dimensional space. The direction and the Parameters related to positioning which are obtained from the radiation source target, such as azimuth, pitch angle, direction cosine, slant range, distance difference, height *etc.* are corresponding to a flat or curved surface in geometric.

The implementation process of Single Station Passive Location is that a single observation station continuous measures the parameters of the radiation source. On the basis of the accumulation of a certain amount of location information, we can obtain the location data of the radiation source target from appropriate data processing, From the geometric sense, the position is obtained by the intersection of several curves surfaces. In the tracking, multiple observation data are always used to fit the target trajectory, then they are used to estimate the state parameters of movement. So a primary issue of Single Station Passive Location tracking is to get the relevant parameters of the positioning. The parameters include incoming wave angle (DOA), frequency (FOA), time (TOA) and their rate of change and combination of multiple observations, In the coordinate system, these observations are nonlinear functions of state variables, so the observation equation can be expressed as: for different positioning methods, observation equation has different specific expression.

Traditional single station Passive Location Technology mainly use the pulse arrival direction, the pulse arrival time and pulse Doppler frequency of the radiation source to achieve the passive positioning of the goal .Its implementation methods are only for angular positioning method, Doppler frequency positioning method, arrival time positioning method, orientation arrival time positioning method.

(1)Angular positioning method only uses the information of measurement position to determine the location of the radiation source which is unknown, and it is the most studied, the most classic single observer passive location technology. The disadvantage is that its accuracy of direction is high demands because the positioning accuracy is influenced deeply by the direction of the measurement error.

(2)Doppler frequency positioning method is the Doppler frequency caused by the frequency which includes the relative motion between the target and observer, Substantially it contains the amount of change information of the radial distance of the target. The disadvantage is also that its error and estimation accuracy depends on the motorized and equipment of the stations.

(3)Arrival time positioning method is for Pulse Emitter Target, If the transmit pulse repetition period is constant, the Pulse repetition interval can be obtained through the accurate measurement of the arrival time, and it is possible to determine the distance of the target from its changing information. The disadvantage is that the equipment requires a higher clock precision.

Accordance to the positioning parameters, it can be divided into Finding Method, TDOA location method, the Doppler frequency change rate positioning method, phase change rate - location, direction finding measure TDOA location method and DF Doppler frequency location method. Finding positioning method mainly makes use of location information to determine the target state; TDOA location method is usually used for electromagnetic radiation pulse repetition period or carrier frequency of the goals, and then use the time difference of the adjacent pulses or the frequency of the adjacent pulses to obtain status information; Doppler frequency change rate positioning method is for continuous wave or longer duration of radiation signal, the frequency of the signal arrived includes Doppler components caused by the relative motion between the target and the observers, Using the Doppler frequency information can calculate the movement state of the target, phase change rate location, direction finding measure TDOA location method, DF Doppler frequency location method is the combination of two of finding method, TDOA location method, the Doppler frequency change rate positioning method.

RSSI location algorithm has been widely applied to the application of intelligent terminal positioning, because the location of its transmitting station is known, the approximate location can be get through RSSI value of the intelligent terminal received. But if we want to positioning the launch pad through the RSSI, we need to get changing RSSI value of the launch pad when the Intelligent terminal constantly moving and the GPS coordinates when location were changing. According to the two aspect we can get the approximate location of the transmitting station by the least squares method.

3. Space Location Algorithm

RSSI can estimate the distance between nodes with the help of the dissemination of the spreading signal. Generally, the average power of the received signal is exponential decay with the increasing distance, can be described by Logarithmic path loss model. Transmission power is expressed as P_t , Received power is P_r , Power loss is P_l , Path fugitive index related to environment is h , h has different values for different environments. The values of h in the line of sight and the region in the building is 1.6-1.8, d_0 is fall into distance, and its typical values is $d_0 = 1m$ (distance in transmission side), $P_l(d_0)$ is the Power loss in the position which has a distance of d_0 meters from the transmission, which can be calculated by the Loss model in the free-space path. The distance from the sender to the receiving end is d , X_σ is a Gaussian random variable whose average value is 0. Standard deviation is $\sigma \in 4 \sim 10 dB$, then RSSI ranging formula can be described as;

$$RSSI = P_{rssi} = P_{rssi}(d_0) - 10h \times \lg(d / d_0) + X_\sigma$$

In the positioning system based on RSSI ranging technique, Transmitting signal strength of the transmitting node is known, the receiving node can be gotten according to the received signal strength, and then the propagation loss can be calculated. The transmission loss can be changed into distance by using theoretical model, the location of the node can be calculated through the existing algorithm. The relationship between RSSI and distance can be formulated as follows:

$$RSSI = -(10h \times \lg d + A)$$

Where, A represents the absolute value of the signal strength indicator value at 1m from the transmitting node, d represents the distance between the transmitter and receiving nodes, h represents path loss coefficient related to environment.

In the RSSI location algorithm, the fixed location is usually used to locate the mobile terminal, this method is through the channel attenuation model to calculate the distance formula. Can be positioned by two methods, one is based positioning method by ranging, including the least squares method, maximum likelihood method, trilateration, triangulation method. Another non-ranging positioning meth, which has centroid localization method, APIT law. Whether through the kind of positioning method, are to ensure that the position of the transmitting station is known, the position of the mobile terminal position, then estimated by calculating the moving end position, but not studied how RSSI location algorithm locate the position of the transmitting station. Compared to other single station passive location algorithms, RSSI and GPS localization algorithm by combining more subtle, accurate positioning location of the transmitting station.

In geometry, in order to locate the position of the transmitting station, it is necessary to ensure that the mobile terminal constantly moving, in order to more measured RSSI values, to pinpoint the location of the transmitting station, the location of the mobile terminal through the built-in GPS module to get the data. Assuming the position of the transmitting station is (x0, y0), t the mobile terminal of the sampling interval is 1s, each moving mobile terminal position is (x1, y1), (x2, y2) ... (xn, yn). Distance between the transmitter station and a mobile terminal for d1, d2 ... dn.

$$\begin{cases} (x_1 - x_0)^2 + (y_1 - y_0)^2 = d_1^2 \\ (x_2 - x_0)^2 + (y_2 - y_0)^2 = d_2^2 \\ \vdots \end{cases}$$

among them $x = \begin{pmatrix} x_0 \\ y_0 \end{pmatrix}$, Ranging model can be converted into：

$$RSSI = 10h \times \lg\left(\sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2}\right) + A$$

To convert it into a linear equation is:

$$\begin{cases} 2(x_1 - x_n)x_0 + 2(y_1 - y_n)y_0 = x_1^2 - x_n^2 + y_1^2 - y_n^2 + d_n^2 - d_1^2 \\ 2(x_2 - x_n)x_0 + 2(y_2 - y_n)y_0 = x_2^2 - x_n^2 + y_2^2 - y_n^2 + d_n^2 - d_2^2 \\ \vdots \end{cases}$$

The equation above is non-linear, hard for solving, so convert it into $AX = B$

$$A = \begin{pmatrix} 2(x_1 - x_n) & 2(y_1 - y_n) \\ \vdots & \\ 2(x_{n-1} - x_n) & 2(y_{n-1} - y_n) \end{pmatrix}$$

$$B = \begin{pmatrix} x_1^2 - x_n^2 + y_1^2 - y_n^2 + d_n^2 - d_1^2 \\ \vdots \\ x_{n-1}^2 - x_n^2 + y_{n-1}^2 - y_n^2 + d_n^2 - d_{n-1}^2 \end{pmatrix}$$

When the matrix $A^T A$ is nonsingular, the least squares solution is:

$$X = \begin{pmatrix} x_0 \\ y_0 \end{pmatrix} = \left(A^T A\right)^{-1} A^T B$$

Least squares estimation method is easy to implement, algorithm complexity is lo-w. Geometric meaning of the least squares method on the basis of measurements on a multilateral solving: multilateral measurement can be determined with reference node as the center of a plurality of positioning circle. These orientation round two if the two intersect, this intersection is the least-squares solution of over determined equations, and this can be seen as the intersection in front of all intersections obtained an optimal synthesis. Obviously, if the higher the degree of aggregation of these intersections, the generalized intersection better positioning effect as the optimal solution; on the contrary, if these intersection more dispersed, then this intersection as a generalized optimal positioning error is greater.

Movement of intelligent terminals, Will be solved after obtaining different RSSI value and a lot of GPS coordinates as the coordinates, if the iterative least-squares method has been down, the coordinates obtained because of RSSI interference affected the results of this operation more departing from the true anchor point .

$$X = \begin{pmatrix} x1_0 & x2_0 \ldots xn_0 \\ y1_0 & y2_0 \ldots yn_0 \end{pmatrix}$$

As it can be seen, if the result of the positioning of enough, this is an area located by mistake RSSI value and GPS coordinates out of a launch pad that may exist. Centroid algorithm is based on network connectivity localization algorithm, beacon nodes periodically sent to the neighbors carry their identity and location information, to be located node to receive and analyze information transmitted beacon nodes, within its communication range beacon nodes polygon geometry centroid position as its own estimates. Because the location coordinates matrix intelligent terminal is obtained by calculation yourself, there is no connectivity issues. It can be calculated directly by the coordinate matrix obtained.

$$(x_0, y_0) = \left(\frac{\sum_{i=1}^{n} x_0}{n}, \frac{\sum_{i=1}^{n} y_0}{n} \right)$$

By centroid algorithm can improve the positioning accuracy of the first phase. Reduce erroneous results due to the noise RSSI value brought. Such algorithms, computational complexity is not high, the number of required data only requires intelligent terminal, repeated the move to take a new sample is calculated.

4. Simulation Results

MATLAB 2012b is used to test in the experiment, the position of the transmitting station is located through GPS coordinates and RSSI values of different geographic locations in the algorithm. In order to close real life needs, the simulations are carried out at different distances, different geographical environment and under different observation points.

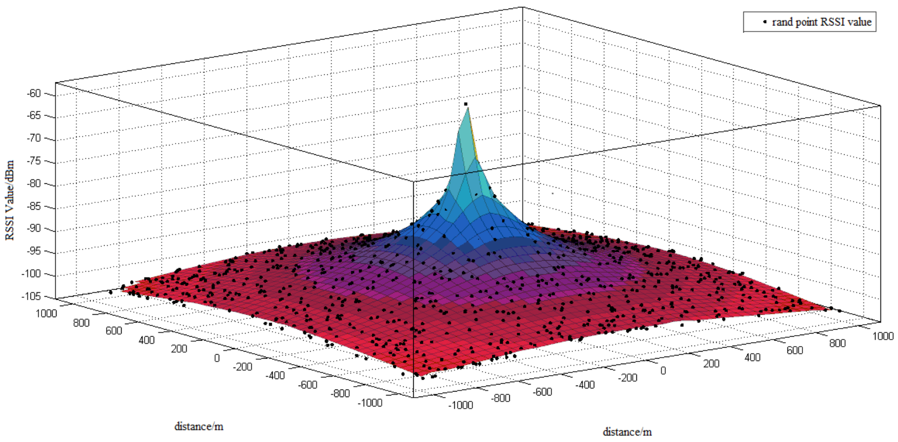

Figure 1. Ideal Distribution of RSSI Values

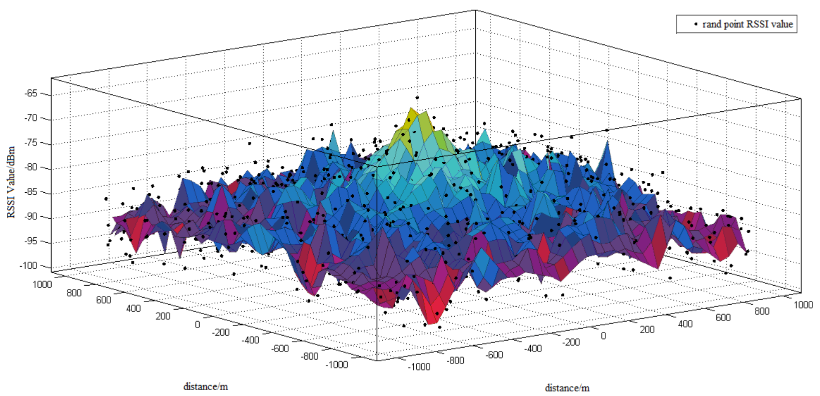

Figure 2. True Distribution of RSSI Values

In real life, RSSI value is unstable. Random variables X_σ are given by radio channel model. In simulation, we take into account different indices fugitive, noise is added to make the simulation closer to the real environment.

Figure 1 is change of RSSI status in ideal environment, Figure 2 is change of RSSI status in real condition, it can be seen that RSSI values drastic jump in real situations, which brings the wrong result for positioning work.

Suppose the disturbance between the intelligent terminal and the transmitter is different. The range of the coordinates is -50 meters to 50 meters, the launch pad is at (126.621509, 45.721741). A matrix composed of 50 GPS coordinates and RSSI values from 200 random locations, and then the coordinates of its location can be calculated by the simulation algorithm. The mean value, the minimum and maximum value can be calculated after iterative 20,000 times. Then coordinate range expand 50m, the range is -100 meters to 100 meters, repeat the experiment until coordinate range is -2000 m to 2000 m. In the test, geographical environment is assumed to be open area, so h = 2, the transmitted power is -40dbm, σ is 4 in the X_σ . The results are obtained after 20,000 experiments, Precision positioning error at different distances algorithms are calculated to analyze whether the algorithm has a high precision positioning capability for various distances on the launch pad. From Figure 3 and Figure 4, the improved algorithm can improve the positioning accuracy at different distance. However, for the minimum error, the improved algorithm did not improve positioning accuracy in the range of 1000 meters.

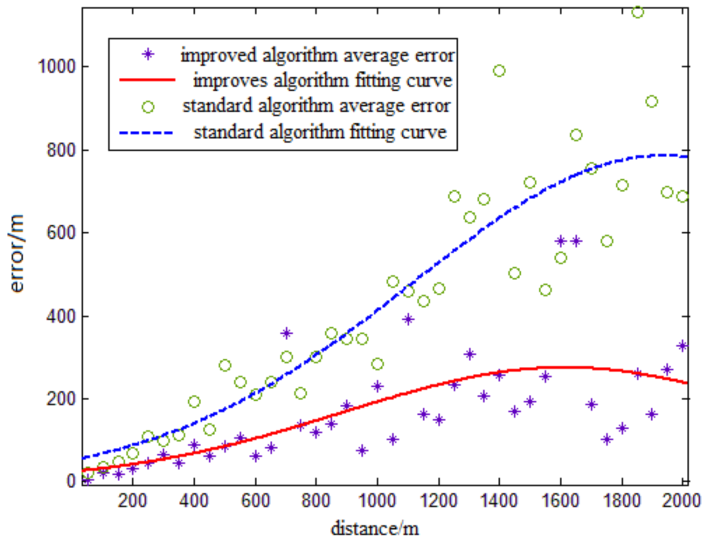

Figure 3. Average Positioning Accuracy at Different Distances

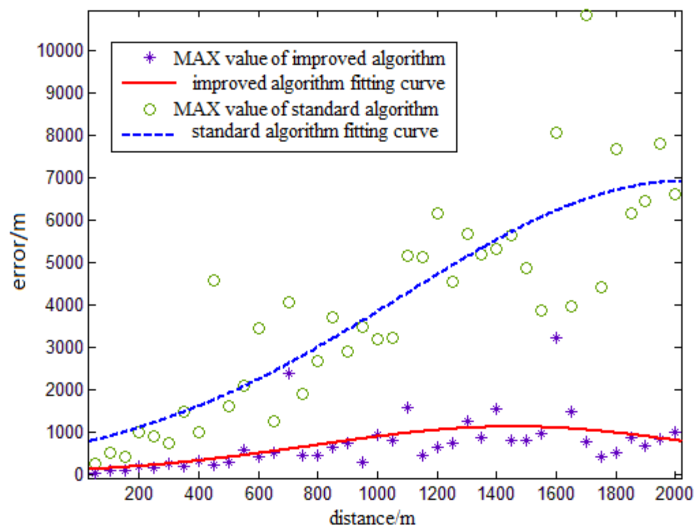

Figure 4 . Maximum Value of Positioning Accuracy at Different Distances

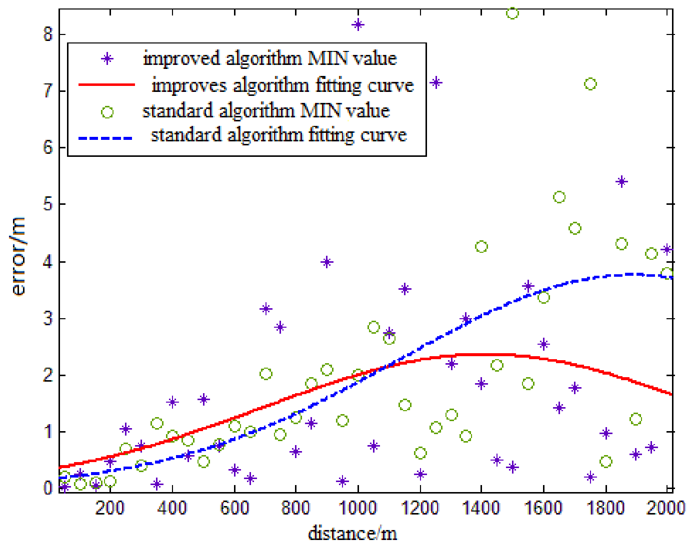

Figure 5. Minimum Value of Positioning Accuracy at Different Distances

Set the smart terminal and the transmitter at different geographical environments, keeping the environment size, transmit power, the number of samples, fugitive index are test from area of sight, smooth space, shaded areas to urban areas and urban areas. Simulation testing results are shown in Figures. 6, 7 and 8, it can be seen that positioning accuracy can be improved in different geographical environment.

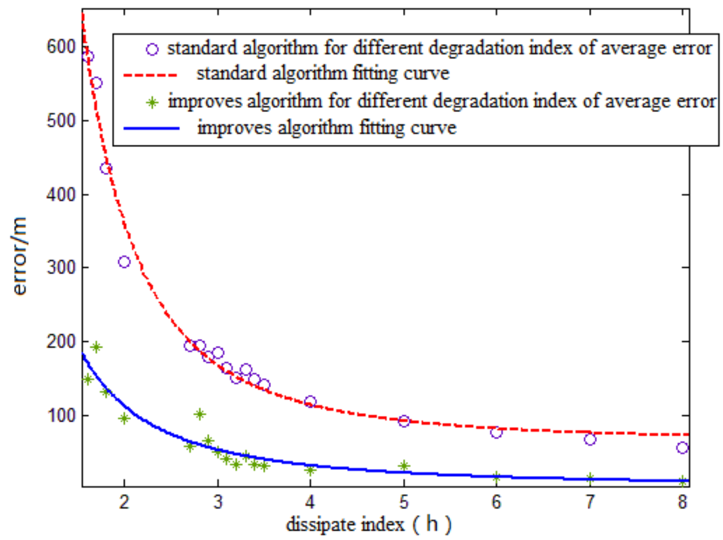

Figure 6. Average Positioning Accuracy at Different Dissipate Index

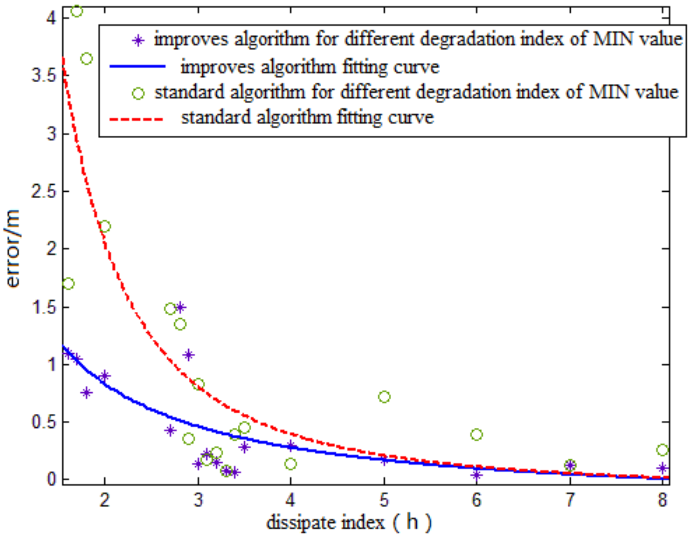

Figure 7 . Minimum Value of Positioning Accuracy at Different Dissipate Index

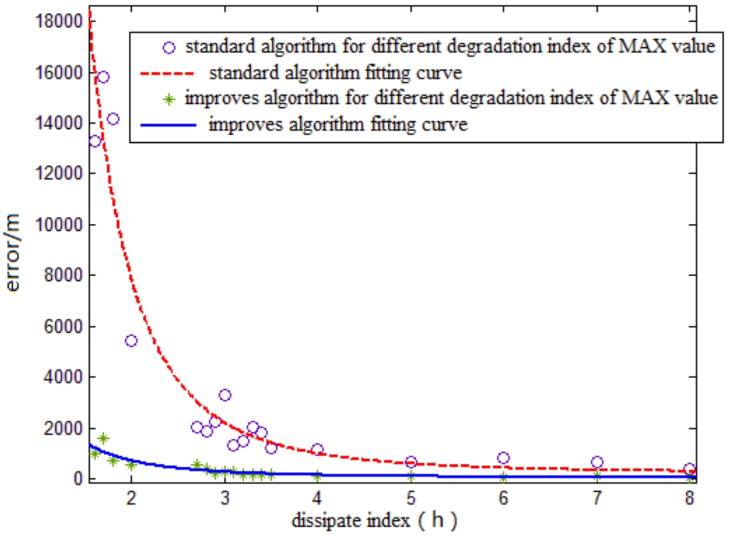

Figure 8 . Maximum Value of Positioning Accuracy at Different Dissipate Index

The number of sampling points is test for intelligent terminal during movement. In the two-dimensional plane from -1000m to 1000m, random sampling points rise from 10 to 5000 successively. The algorithm can effectively reduce positioning errors, and find the most adaptive positioning points.

It can be seen from Figure 9, when the sampling points rise to 200, the error rate was stable. In order to avoid the situation that computational complexity is too high, you can choose a reasonable number of measurement points. In order to improve the positioning accuracy, it is not necessary to do more sampling for more points.

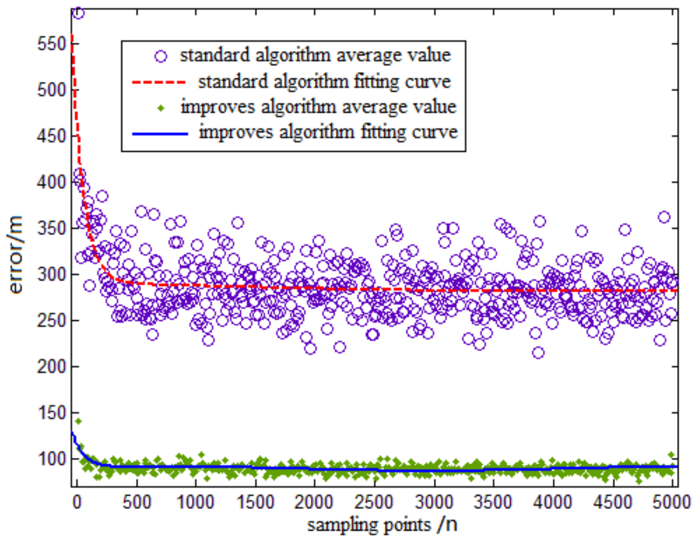

Figure 9. Average Positioning Accuracy at Different Sampling Points

The probability distribution histogram is drawn for positioning error from 1.6 million times simulation experiments. The frequency of the maximum error appears low, its comparative tests are only used in the theoretical analysis, and they are difficult to appear in the actual positioning. Most of the locations are near the average of the results, which means the comparison of average value is meaning to algorithm performance. We can see in Figure 10, under normal circumstances, the majority of errors are near the average of 20 or so.

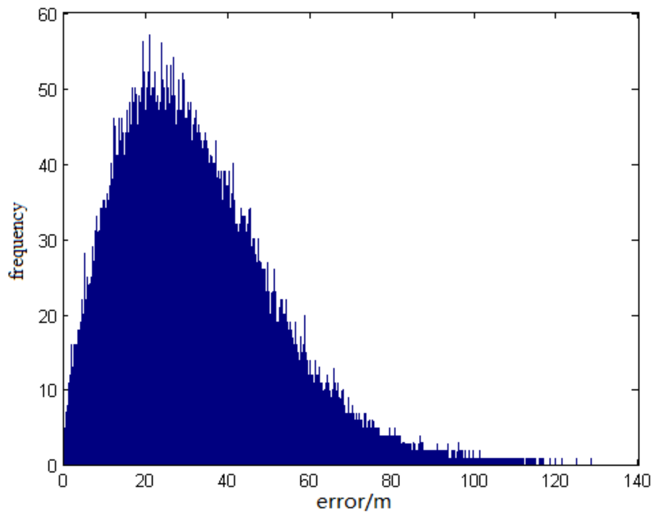

Figure 10. Probability Statistics of Repeated Experimental Data

5. Conclusions

In this paper, localization algorithm combined GPS and GIS is studied intensively. In order to reduce the effects of errors brought by RSSI value, an improved algorithm more suitable for positioning intelligent terminal transmitting stations is proposed. The algorithm requiring less precision positioning device combined the advantages of multi angle positioning method and centroid localization method, also the least square method is used to reduce the error of location in urban areas. The simulation results show that the improved algorithm are not affected by the dissipation factor, can improve the positioning accuracy in a variety of distance, is a universal positioning algorithm. Only a certain number of samples were collected to support the operation of precision. This algorithm is designed for portable device applications, you can put the device on the flow of vehicles in the monitoring, it is more conducive for detection and location.

References

[1] L. Di and L. Shiqi, "An Improved Localization Algorithm of APIT in Wireless Sensor Network". Journal of Harbin University of Science and Technology, **(2014)**, pp. 95-99.

[2] Y. S. Lee, J. W. Park and L. Barolli, "A Localization Algorithm Based on AOA for Ad-hoc Sensor Networks". Moblie lnformation Systems, no.8, **(2012)**, pp.61-72.

[3] W. Chcngqun, C.Jiming and S. Youxian, "Sensor Network Localization Using Kerncl Spectral Regression". Wireless Communications and Mobile Computing, no.10, **(2010)**, pp.1045-1054

[4] A. J. Weiss and J. S. Picard, "Network Localization with Biased Rank Measurements". Wireless Commumcations, no.7, **(2008)**, pp. 298-304.

[5] J. Yang, "Integration of Wireless Sensor Networks in Environmental Monitoring Cyber Infrastructure". Wireless Netw, no.16, **(2010)**, pp.1091-1108.

[6] M. S. Rahman, Y. Park and K.D. Kim, "RSS-Based Indoor Localization Algorithm for Wireless Sensor Network Using Generalized Regression Neural Network". Research article-electrical engineering, **(2012)**, pp.1043-1053.

[7] Q. H.Wang, "Research on the WSN Node Localization Based on TOA", Journal of Applied Mathematics, no.9, **(2013)**, pp.64-76.

[8] Z. Zhaohao, "Study of Measure System on Train Miles Traveled Based on GSM, GPS and CAN Bus Technology". Journal of Harbin University of Science and Technology, **(2005)**, pp.84-87.

[9] Z. Y.-Chen, S. J. Gortler and D. Thurston, "Sensor Network localization using Sensor Perturbation". ACM Transactions on sensor Networks, no.7, **(2011)**, pp.1-23.

[10] M. Naderan, M.Dehghan and H. Pedram, "Upper and Lower Bounds for Dynamic Cluster Assignment for Multi-target Tracking in Heterogeneous WSNs". J.Parallel Distrib Comput, no.7, **(2013)**, pp.1389-1399.