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# Research on the Mine Personnel Localization Algorithm based on the Background of Weak Signal

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***Abstract***

*For the mine complex physical environment, signal will weaken in the transmission process, it is difficult to guarantee the accuracy of the mine personnel positioning, this paper proposed a RSSI algorithm combined with weighted centroid localization algorithm to achieve improved operations at the mine location algorithm; Making use of communication technology wireless sensor network to improve the traditional positioning algorithm effectively, and then the data collected in the information loop of the process, makes the final collected data tend to the theoretical value, thereby improving the positioning accuracy, ensure the operational safety of underground personnel; Finally through the simulation experiment showed that the localization accuracy of the optimized positioning algorithm is more precise, less amount of calculation, suitable for weak signal under the mine personnel positioning.*

***Keywords***: *weighted centroid;RSSI; positioning; mine*

## 1. Introduction

Over the years, the mining accidents often happen in our country, the personal safety of staff has received the serious threat, once appear the situation, to rescue trapped personnel lack of reliable information, and cause casualties and property losses[1-3]. Therefore, to realize the coal mine wireless communication, accurate analysis of underground personnel location and quantity has the very vital significance.Now, as one of frontier hotspot in the research of the wireless communication technology of wireless sensor network has rapid deployment, self-organization, strong concealment, *etc*, due to the flexibility and diversity of wireless sensor network node, sensor network after explosion processing and optimization of the improved technology, can be used for monitoring and real-time monitoring of dangerous working conditions, especially for the staff and places of signal monitoring, has a broad application prospect[4-7]. Sensor node itself has the function of RSSI collection, RSSI ranging can help coal mine safety monitoring for node localization. However, in practical application.

The underground environment is very complex, with a large number of roadway, the roadway has the feature of long and narrow, the distribution of node is very uneven, cannot guarantee the high density of beacon nodes .the RSSI is interfered by many factors, the single RSSI ranging,cannot meet the requirements of the environment complex coal mine personnel positioning accuracy[8-9].

Aiming at the defects of the current location algorithm of WSN in the environment of complex coal mine well personnel,in order to improve the positioning accuracy,this paper proposes a RSSI algorithm combined with weighted centroid localization algorithm, realize the localization algorithm of underground operations improvement,finally,the positioning performance of the simulation is verified by simulation.

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## 2. Relative Positioning Algorithm and Positioning Principle

### 2. 1 Target Location Algorithm

According to the specific positioning mechanism, the existing wireless sensor network node localization algorithm is divided into two categories: Based on the distance (based - range) measurement of the positioning algorithm and no distance (free - range) measurement of the positioning algorithm [10].

Generally, when the node localization algorithm is discussed, it is assumed that the sensor network nodes are distributed in a two dimensional space, and the location of a part of the nodes is known, called the anchor node (nodes anchor). In general, the anchor node equipped with GPS signal receiving equipment, through the GPS signal to determine its own position. The number of anchor nodes in the sensor network is very small, and the remaining common nodes (called unknown nodes) are determined by the joint action of anchor nodes and positioning algorithm.

A distance measurement based algorithm is required to determine the distance between the anchor node and the unknown node, and then to determine the location of the unknown node based on the three edge measurement (trilateration), triangulation (triangultion) or maximum likelihood estimation (multilateration). According to measurement technology can be divided into RSSI (Signal Sthengh Indicator Received), based on TOA/TDOA (of Arrival/Time Difference ofArrival Time) and based on AOA (of Arrival Angle)[11-12]. Sensor node itself has the function of RSSI collection, RSSI ranging can help coal mine safety monitoring for node localization. However, in practical application, the RSSI is interfered by many factors, the single RSSI ranging, cannot meet the requirements of the environment complex coal mine personnel positioning accuracy.

### 2.2 The Positioning Principle of Underground Personnel Signal

In the process of mine personnel positioning, it is needed to describe the position of the mine sensor nodes, which is called the anchor node. On the other hand,the mobile node, which is not known to the position, can be called the waiting node.

Among them, the anchor nodes usually use the GPS system to get their own information, the number is scarce, the anchor nodes are placed in the normal state of the mine roadway. All of underground personnel equipped with a die erste installation node under test,so it can be be measured in time to the mine personnel positioning by judging the position of the sensor nodes. Therefore, the basic principle of the mine personnel positioning is to locate the sensor nodes, Specific expression is: the anchor node is used to locate the nodes, the acquisition of the data and the direction of the transmission to the ground through the network terminal system, so that it is able to grasp the state of the underground personnel and location information. Specific detailed steps are as follows:

Any anchor nodes generated candidate solution space of initial population, the anchor nodes of i can be expressed as a candidate solution: $x_i = (x_{i1}, x_{i2}, ..., x_{in})$, Among them,**Error! Reference source not found.** represents the dimension of the solution.

Basis for initial population within the fitness of complete initialization setting on population, which contains all the initial position of the anchor nodes. $\delta$ stands for congestion level facto, *T-value* represents a threshold for the execution of a localization behavior.

Assuming the current position of the anchor node i is represented by $x_i(t)$, $x_i(t+1)$ represent the next state, Each iteration of the anchor node will choose one kind of behavior to complete the information of its own position update,it can increase a avector represent by $\Delta x_i(t+1)$ on the basis of the initial position is $x_i(t)$.

The update formula position of the anchor nodes can be represented as follows:

 

$$\Delta x_i(t+1) = Rand() \cdot step \cdot [x_{better}(t+1) - x_i(t)]) \quad (1)$$

$$x_i(t+1) = x_i(t) + \Delta x_i(t+1) \quad (2)$$

upper type, $Rand()$ represents an arbitrary number between 0 and 1. $x_{better}(t+1)$ represents the optimal position of anchor nodes.

After iterative update, if $x_i(t+1)$ is better than $x_i(t)$, $x_{better}(t+1)$ can replace $x_i(t+1)$, on the other hand, the optimal solution is based on the last iteration until the search to the overall positioning.

In summary, it can be used to explain the principle of mine personnel positioning, but the use of traditional algorithm for mine personnel positioning is to determine the location of the mobile node information, there is a problem of poor adaptability and low positioning accuracy.

## 3. The Improvement of Localization Algorithm

Literature [13] proposed to improve the RSSI ranging algorithm, realized the requirements of large scale, low power consumption in the process of coal mine personnel positioning; Literature[14]proposed a Dv-hop localization algorithm based on wireless sensor network, which is used to change the position of the anchor nodes and the number of hops to get the specific location; Literature[15]proposed the three edge location algorithm to the research of. mine personnel positioning research, and through the ant colony algorithm and genetic algorithm to optimize the path of underground personnel; Literature [16] proposed a based on wireless sensor network localization algorithm, through the wireless sensor network will locate area is divided into several sub areas, and select an anchor node in the sub region as the base node to communicate with the base station.The above algorithms have been done in a certain degree to the personnel positioning process of the covered area, but the complexity of the algorithm is higher, due to the influence of some physical parameters, the deflection will make the final result with the theoretical value, makes the deviation of the final result is bigger the theoretical value deviation.

### 3.1 The Main Idea of the Improved Algorithm

First, after solving the corresponding results by the centroid algorithm,using RSSI ranging received signal strength indicator to correct,in the process of solving the weight factor of the centroid algorithm, accurate estimate area of the node being tested, so as to enhance the accuracy of the results.In the process of correcting the weight factor, the parameters of the weight factor make the algorithm more suitable for the actual situation in the process of the algorithm, and can better reflect the restriction and binding force of the anchor nodes to the unknown nodes, and improve the positioning accuracy.

RSSI ranging process is mainly embodied in the use of signalattenuation in the transfer process for effective distance value calculation; The constitution of the model is made up of three ways: The free spacemodel; the two-way ground reflection model;the shield model, as we know, The environment of mine operation is very complex,and the physical parameters of the mine are more variable, although the environment is complex, the problem of the mine personnel location can be represented by the model.By measuring the received signal strength, and estimate the distance between the transmitting node and the receiving node. The mathematical model of transmission is:

$$R_L(d) = p_l(d_0) - 10\delta \lg(\frac{d}{d_0}) + x_\sigma \quad (3)$$

upper type, $R_L(d)$ is the intensity of the received signal at d; $d_0$ is a reference distance; $p_l(d_0)$ is in the reference distance $d_0$ path signal attenuation index; *n* is a path

attenuation index; $x_\sigma$ is the mean value of 0 of Gauss distribution random index. In the process of practical application, the RSSI signal strength in wireless transmission path loss more influence on the positioning accuracy.In the centroid algorithm, with the property of the anchor nodes broadcast routing broadcast broadcast node's own identity and location information communication to neighbor nodes which less than its with the property of the anchor nodes broadcast routing,the unknown node is limited to the anchor nodes within the geometric center of gravity as a monitored object, in order to obtain the location of the final value.The algorithm complexity is small, small amount of calculation and low power consumption, in line with the requirements of large-scale network personnel positioning as shown in figure 1:

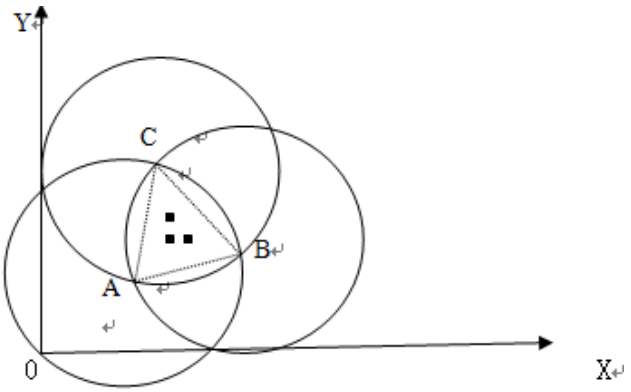


**Figure 1. Centroid Algorithm**

The improvement process is modified by modifying the weight factor and the coordinate of the target， the mathematical model is:

$$X = \frac{x_a\left(\frac{1}{da^a}+\frac{1}{db^a}\right)+x_b\left(\frac{1}{db^a}+\frac{1}{dc^a}\right)+x_c\left(\frac{1}{da^a}+\frac{1}{dc^a}\right)}{2\left(\frac{1}{da^a}+\frac{1}{db^a}+\frac{1}{dc^a}\right)} \quad (4)$$

$$Y = \frac{y_a\left(\frac{1}{da^a}+\frac{1}{db^a}\right)+y_b\left(\frac{1}{db^a}+\frac{1}{dc^a}\right)+y_c\left(\frac{1}{da^a}+\frac{1}{dc^a}\right)}{2\left(\frac{1}{da^a}+\frac{1}{db^a}+\frac{1}{dc^a}\right)} \quad (5)$$

$a$ is a dynamic adjustment factor, the value range from 2 to 5, in Different circumstances with different dynamic parameters to complete the valuation of the target node calculation, among them $da, db, dc$ is the measurement distance between the anchor node and the target node.

### 3.2 Iterative Refinement Cycle

Error is inevitable in the process of actual calculation, according to the analysis of error calculation process can be roughly classified into three kinds, the first is due to the choice of the reference node itself contains certain error; The second is in the process of RSSI ranging, due to the error signal attenuation; The third is also exist certain error in calculation of itself. Since the error is inevitable, it is required to produce the error for further correction, the correction function is:

$$\Delta f(x) = \sum e_{ij}(D_{ij} - d_{ij})p(i \mid j) \quad (6)$$

 

*Dij* is the euler distance between node *i* and *j*; $d_{ij}$ is the RSSI measurement distance of the node *i* with respect to the node *j*; $e_{ij}$ is directional unit vector; $p(i/j)$ is the conditional probability of nodes i and j. Order the *Cov (X)* is the average variance of gaussian distribution, $D(X)$ is the covariance of gaussian distribution function, its mathematical model is:

$$Cov(X)=\frac{1}{n-1}\sum_{i-1}^{n}(x-x_0)(x-x_0)^T \quad (7)$$

The probability density of the posterior probability j node is

$$E(Z_{ij})=p(C_j \mid X_i)=\frac{p(c_j)\ p(x_i \mid c_j)}{p(x_i)}$$
$$=\frac{p(c_j)\,p(x_i \mid c_j)}{\sum_{j=1}^{k}p(c_j)\,p(x_i \mid c_j)} \quad (8)$$

When the iterative refinement cycle to a certain theoretical value. In the implementation of the next cycle adjust implementation process, when the node position correction value tend to the true value. Terminates the loop. The calculated values can be considered to be the final value of the theory of the target node. The main purpose of the iterative convergence is the comparison between the real and estimated vector of the i of any node, $(x_i, y_i)$, $(x_j, y_j)$,the real distance and estimated distance between node *i* and *j* are respectively.

$$\begin{cases} d_{ij}=x_i-x_j=\sqrt{(x_i-x_j)^2+(y_i-y_j)^2} \\ \hat{d}_{ij}=\hat{x}_i-\hat{x}_j=\sqrt{(\hat{x}_i-\hat{x}_j)^2+(\hat{y}_i-\hat{y}_j)^2} \end{cases} \quad (9)$$

$$E_{rr}=\frac{\sum_{i,j}\frac{(d_{ij}-\hat{d}_{ij})^2}{d_{ij}}}{N} \quad (10)$$

$E_{rr}$ is the compromise coefficient，that means the absolute error and the relative error square of the average hop distance between all adjacent nodes is a compromise factor.N is the total number of nodes.Absolute error is normal change appears with RSSI measurement distance change, thus, under the different communication radius Err will grow bigger and not as a standard positioning error of the rules to use, this is because with the increase of the distance between the nodes, the positioning error, which affects the range the final result. Therefore, the use of iterative refinement process can make the distance between the anchor nodes and unknown nodes more tend to be a real theoretical value. algorithm steps: Combined with the RSSI ranging and weighted centroid algorithm, the steps of the improved algorithm are as follows:

(1) The anchor node takes a certain time period as the periodic broadcast, so that the neighbor node receives the information of its own beacon, which includes the position information of the anchor node and the identity information.
(2) An unknown node records the same anchor node RSSI values, the average value of the measured value is calculated, and the value is used as a result of the final calculation.
(3) When an unknown node received the anchor node RSSI values beyond a certain threshold,using the formula (4) ,(5)and weighted centroid algorithm to calculate the unknown node coordinate values, On the contrary, executive step (2).

(4) To sort the coordinates of the unknown node, cycle through the modified formula (6),(7),(8)for its computation result of iterative refinement, and record the final result..
(5) Put the final calculation value and the theoretical value into the tradeoff coefficient formula tradeoff coefficient,make its compromise coefficient absolute error converge to zero.

## 4. The Simulation Result of Experiment

There has a test to verify the effectiveness of the improved algorithm, Matlab7 is used to be the simulation platform, the simulation area is a rectangular area of 200m×200m.,in a fixed size of two-dimensional plane experimental area, the communication radius of each node is 10m, and the ratio of anchor nodes is 25%. In order to make the experimental data more objective and accurate, the results of the data obtained using the average of the same experiment for 100 times.

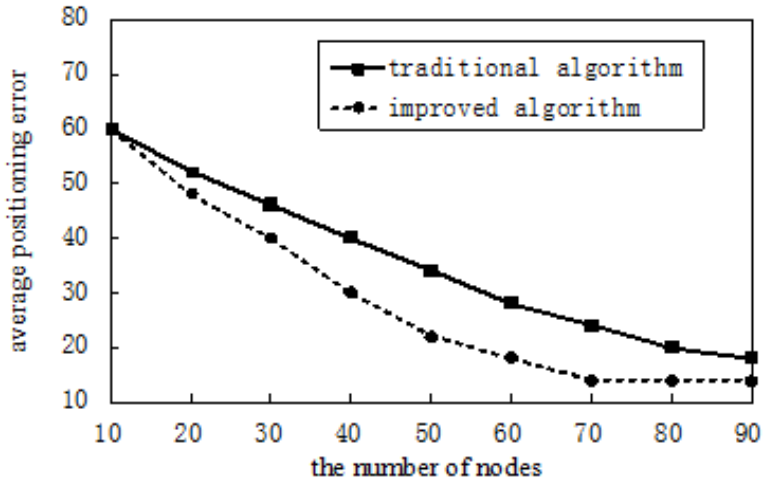


**Figure 1. The Number of Nodes and the Average Position Error**

Figure 1 is the relationship between the number of nodes and the average position error,in the process of simulation, maintain the total number of nodes is 90.With the increase of the number of nodes, the average positioning error of the traditional algorithm and the improved algorithm are both reduced.The average positioning error of the two positioning algorithms is altered obviously,But the average position error of the improved algorithm changes quickly.To the speed of the theoretical value is much higher than the traditional algorithm, the locating accuracy is much higher than the basic localization algorithm.

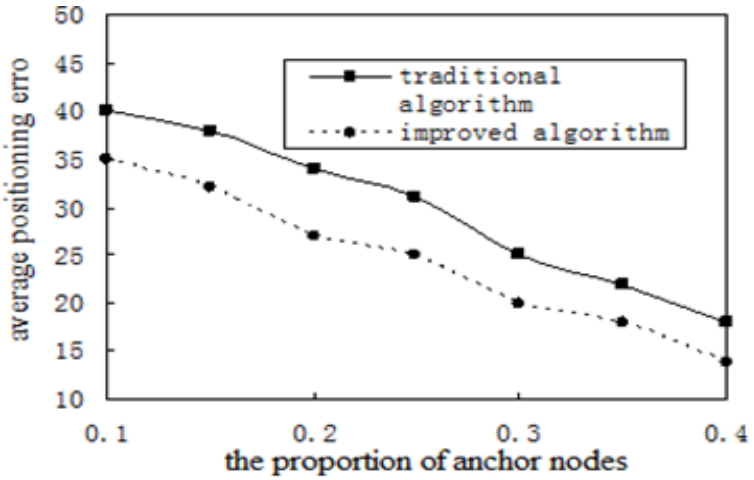


**Figure 2. The Proportion of Anchor Nodes and the Average Position Error**

Figure 2 is the relationship between the proportion of anchor nodes and the average position erro,the number of nodes in the experiment area is 90, from the graph, we can see that the proportion of the anchor node in the process of increased from rom 10% to 40%. The average positioning error of the two algorithms is decreased, but the improved algorithm is significantly more accurate than the traditional algorithm, and the decline range is more obvious.

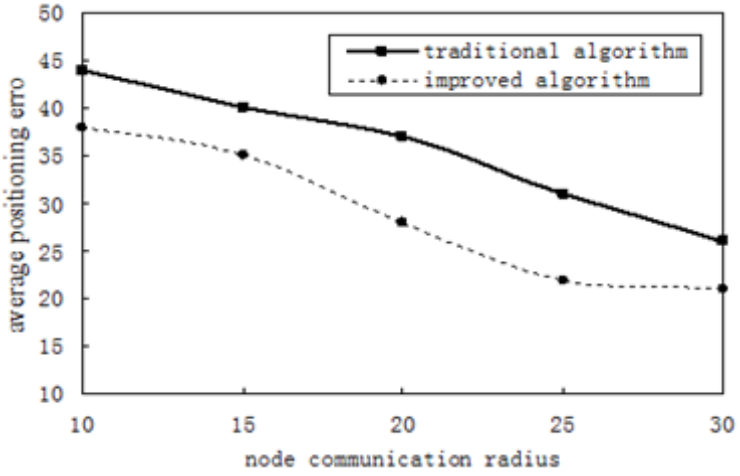


**Figure 3. The Node Communication Radius and the Average Position Error**

As can be seen from Figure 3, when the node communication radius is 10 meters, positioning error is reduced by 8%, when the communication radius is 20 to 30 meters, positioning error reduction of about 20%, thus,the positioning error of the improved algorithm is less than that of the traditional algorithm, and the positioning accuracy is relatively accurate.

In the end the main reason is that, the improved algorithm is obtained by iterative refinement process calculation, but the traditional algorithm is through consume large amounts of time and the energy of network to provide positioning accuracy of the system, it further illustrates that the improved algorithm prolongs the network lifetime.

## 5. Conclusion

The safety of underground work is directly related to the safety of the mine personnel, once appear the situation, how to carry out rescue work fast and orderly become a top priority, but rescue time is mainly reflected on the homework personnel's high precision positioning, this paper firstly made a carefully analysis to the positioning system to the unknown node coordinate values, using the measured RSSI is apart from the received signal strength indicator for correction, in the process of solving given certain weighting factor to centroid algorithm, the parameters of the weighting factor makes the algorithm more suitable for the actua situation in the process of locating, improve the accuracy of results,and using cyclic iterative refinement again to effectively calculate the final result, make the results of the calculation of error value to 0. Through the experiment proved that the improved localization algorithm improved the precision of positioning, implements the downhol positioning of high precision,which is suitable for the weak signal under the background of the mine personnel positioning.

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