The Improvement of RSSI for Mine Personnel Positioning

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Abstract. The current mine personal positioning is not precise. An improved RSSI is present in this paper to improve the precise of mine personal positioning. The personal positioning system will be completed with trilateral localization algorithm and differential correction algorithm finally.

Introduction

The paper will propose the improvement of RSSI algorithm for mine personal positioning system. With the improved RSSI algorithm the more precise distance of between target node and reference node could be gained. Then take quadrilateral localization algorithm based on trilateral localization algorithm to compute the location of target node. At last, differential correction algorithm will be used in the paper to increase the precise of target node location and complete the positioning system.

INTRODUCTION of RSSI

RSSI(Received Signal Strength Indication) is a simple and practical range-finding algorithm. The power of the wireless signal will loss during transmission and the RSSI bases on the loss of signal power. The distance of receiver and sender will be computed by the loss of power. However the algorithm must combine theoretical model of path consumption and empirical model to compute the distance between target node and reference node.

The relation expression of signal power consumption between receiver and sender is as follows:

$$P^{d} = P^{0} / d^{n} \qquad (1.1)$$

P^d is the signal strength of the receiver. P^0 is the signal strength of the sender. The d is the distance of receiver and sender. The n is propagation factor.

The relation expression 1.2 could be derived by 1.1 with logarithm.

$$10n \lg d = 10 \lg P^{0} / P^{d} \qquad (1.2)$$

As the sending power of node is known, 1.3 could be derived by 1.2

$$10 \lg P^{d} = A - 10n \lg d \qquad (1.3)$$

$10 \lg p^{d}$ is the receiver power and its unit is dBm. If the value of d equals 1 the value of A could be computed.

$$P^{d}(dBm) = A - 10n \lg d \qquad (1.4)$$

There is a relation expression between A and n. A and n is empirical value in different environment. We should confirm the value of A and n in different environment. The accuracy of distance depends on A and n seriously. We call A and n the value of RSSI.

RSSI-BASED DV-DISTANCE ALGORITHM

RSSI-based DV-distance evolves from DV-hop. There are two steps in the RSSI-based DV-distance algorithm. First, the target node receives every signal sent by the reference nodes in the range and computes the beeline distance through RSSI. Then the target node will send the beeline distance and fold line distance to the reference nodes. The target node will compute the fold line distance through distance vector protocol and the ratio of beeline distance to fold line distance. The average value of ratio should be computed after the target node got all ratios. Then the target node will send the average radio to all reference nodes. As the reference nodes have got the fold line distance, the beeline distance could be computed through the average ratio. At last, all the reference nodes send beeline distance to the target nodes.

The DV-distance improves the detection accuracy of straight line distance greatly than DV-hop. However the DV-distance relies on the environment highly and the DV-distance algorithm is not reliable.

We could take some measure to improve the reliable of DV-distance.

First the position of reference point is very important. The reference points should not be put in a line. As the theory of the DV-distance pointed, the target node gets the straight line through the average ratio. When the reference points stay in a line the ratio will be not reliable. In a word, the fold line distance should be as far as possible.

The DV-Distance algorithm relies on RSSI and RSSI will make a huge difference in different environment. This paper proposes an intelligent correction for the value of A and n. The procedure is as follows:

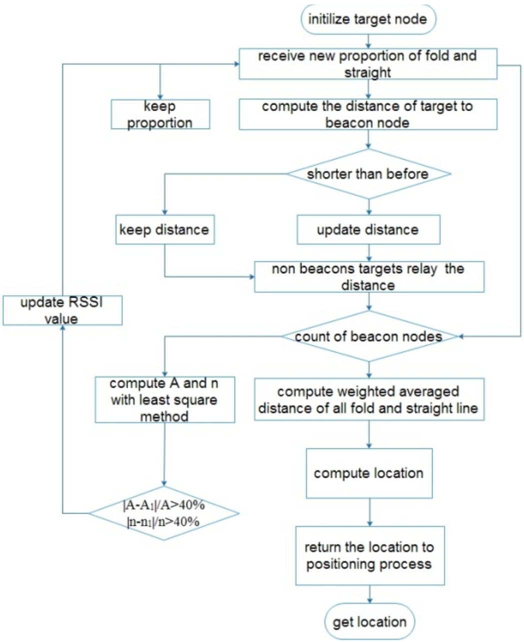

Figure1. The procedure of intelligent correction

Trilateral localization Algorithm

Trilateral localization algorithm is a simple positioning algorithm. The paper proposes quadrilateral localization algorithm based on trilateral localization to increase the precise of the target node location.

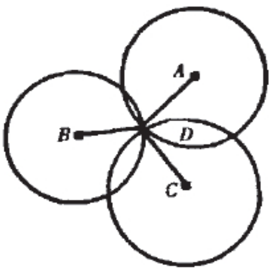

Figure2. Trilateral localization

There are three reference points in the map Figure2.The coordinate of A (x_A, y_A) $A(x_A, y_A)$, $B(x_B, y_B)$,C (x_C, y_C) have been given. After computed the value of RSSI we can get the length of AD(d_A),BD(d_B),CD(d_C) through the DV-Distance.

Then we can get the relation expression:

$$(x_A - x_D)^2 + (y_A - y_D)^2 = d_A^2 \qquad (2.1)$$

$$(x_B - x_D)^2 + (y_B - y_D)^2 = d_B^2 \qquad (2.2)$$

$$(x_C - x_D)^2 + (y_C - y_D)^2 = d_C^2 \qquad (2.3)$$

Obviously, the D (x_D, y_D) could be calculated from the relation expression.

In the practical context signal may be disturbed so the circles may not intersected in a point. As the follows:

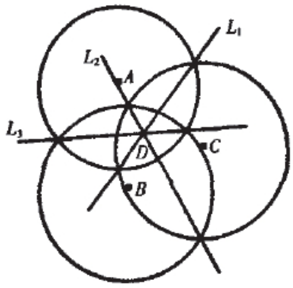

Figure3. Trilateral localization in the actual environment

We can take a measure to reduce the error resulted by the signal transmission. The straight line of $L1, L2, L3$ in the map of 2.5 could be gained by subtracting each other of 2.1,2.2,2.3.

As is shown in the follows:

$$2(x_B - x_A)x + 2(y_B - y_A)y = d_A^2 - d_B^2 - x_A^2 + x_B^2 - y_A^2 + y_B^2 \qquad (2.4)$$

$$2(x_C - x_B)x + 2(y_C - y_B)y = d_B^2 - d_C^2 - x_B^2 + x_C^2 - y_B^2 + y_C^2 \qquad (2.5)$$

$$2(x_C - x_A)x + 2(y_C - y_A)y = d_A^2 - d_C^2 - x_A^2 + x_C^2 - y_A^2 + y_C^2 \qquad (2.6)$$

We could treat the crossover point of $L1, L2, L3$ as the target node. Based on the trilateral localization algorithm, we could achieve quadrilateral localization algorithm. The map is as follows:

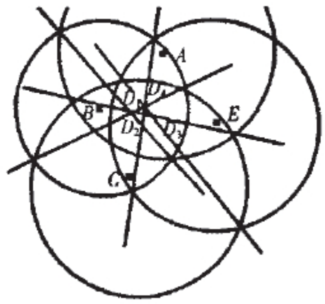

Figure4. Quadrilateral localization in the actual environment

We can compute the location of target node with three edge algorithm. There are four crossover points in the map, D1(xD1,yD1),D2(xD2,yD2), D3(xD3,yD3),D4(xD4,yD4). The four crossover points can form a quadrilateral and the barycentre of the quadrilateral is the location of target node. The location of target node is as follows:

$$\left(x_D = \frac{x_{D1} + x_{D2} + x_{D3} + x_{D4}}{4},\ y_D = \frac{y_{D1} + y_{D2} + y_{D3} + y_{D4}}{4} \right)$$

The nearer the actual distance is, the more accurate the distance is computed with RSSI. We could take weighted factor to the location to increase the distance precise.

$$\frac{1}{d_A + d_B + d_C}$$

For example, there are four beacon nodes $A(x_A, y_A)$, $B(x_B, y_B)$, $C(x_C, y_C)$, $E(x_E, y_E)$ and the distance of target node $D(x_D, y_D)$ to beacon node is d_A, d_B, d_C and d_E .The target node location $D_1(x_{D1}, y_{D1})$ could be computed by trilateral localization algorithm from A,B and C. Similarly, we can get $D_2(x_{D2}, y_{D2})$ from A, B and E. $D_3(x_{D3}, y_{D3})$ from A, C and E. $D_4(x_{D4}, y_{D4})$ from B,C and E.

The coordinate $D(x_D, y_D)$ could be computed by weighted centroid algorithm.

$$x_D = \frac{\frac{x_{D1}}{d_A + d_B + d_C} + \frac{x_{D2}}{d_A + d_B + d_E} + \frac{x_{D3}}{d_A + d_C + d_E} + \frac{x_{D4}}{d_B + d_C + d_E}}{\frac{1}{d_A + d_B + d_C} + \frac{1}{d_A + d_B + d_E} + \frac{1}{d_A + d_C + d_E} + \frac{1}{d_B + d_C + d_E}} \qquad y_D = \frac{\frac{y_{D1}}{d_A + d_B + d_C} + \frac{y_{D2}}{d_A + d_B + d_E} + \frac{y_{D3}}{d_A + d_C + d_E} + \frac{y_{D4}}{d_B + d_C + d_E}}{\frac{1}{d_A + d_B + d_C} + \frac{1}{d_A + d_B + d_E} + \frac{1}{d_A + d_C + d_E} + \frac{1}{d_B + d_C + d_E}}$$

Differential correction algorithm

$M_1(x_1,y_1)\dots M_n(x_n,y_n)$ are reference nodes and $D(x,y)$ are mobile node. $M_0(x_0,y_0)$ called differential correction node is the nearest to $D(x,y)$. $d_{01}\dots d_{0n}$ are the actual distance between $M_0(x_0,y_0)$ and $M_1(x_1,y_1)$, $M_2(x_2,y_2)\dots M_n(x_n,y_n)$. $d_1\dots d_n$ are differential correction distance between mobile node $D(x,y)$ and reference node $M_1(x_1,y_1)\dots M_n(x_n,y_n)$.

The RSSI difference correction coefficient formula:

$$\alpha=\sum_{i=1}^{n}\frac{(d'_{0i}-d_{01})}{d'_{0i}}$$

The d0i is the measured distance between differential correction node and the reference node $M_i(x_i,y_i)$. d_{0i} is the actual distance between differential correction node and reference node $M_i(x_i,y_i)$.

The differential formula coefficient of distance between mobile node $D(x,y)$ and $M_i(x_i,y_i)$ is as follows:

$$\rho_i=\lambda e^{1-\frac{d'_i}{d'_{0i}(1-\alpha)}}(i=1,2,...,n)$$

λ is ratio adjustment factor. The di is actual distance of mobile node to Mi(xi,yi). The n is the count of mobile node.

The differential correction location formula of mobile node to Mi(xi,yi):

$$d_i=d'_i-\rho_i e_{i0}(i=1,2,...,n)$$

e_{i0} is reference node error of distance $e_{i0}=d'_{01}-d_{0i}$. The d_i is the distance between target node and Mi(xi,yi). The n is the count of reference node.

The count of target node location is Cn3. The Cn3 target node location can form a polygon and the barycenter of the polygon is the most accurate location of the target node.

$$x=\sum_{i,j,k=1}^{n}\frac{x_{ijk}}{C_n^3}(i\neq j\neq k)$$

$$y=\sum_{i,j,k=1}^{n}\frac{y_{ijk}}{C_n^3}(i\neq j\neq k)$$

Conclusion

a) Trilateral localization algorithm

There are three reference nodes (0,0), (0,20), (20,0) and nine target nodes (1,1), (2,2), (3,3), (4,4), (5,5), (6,6), (7,7), (8,8), (9,9). The result is as follows(The solid point is target node and the hollow point is detected node)

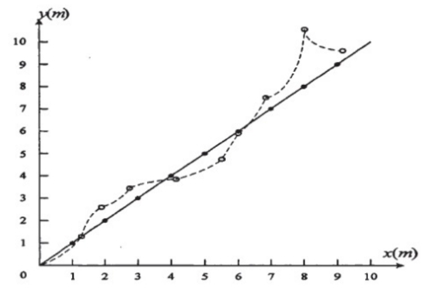

Figure5. The result of trilateral localization algorithm

b) Centroid correction algorithm

There are six reference nodes (0,0), (0,20), (20,0), (20,20), (10,40) and nine target nodes (1,1), (2,2), (3,3), (4,4), (5,5), (6,6), (7,7), (8,8), (9,9). The result is as follows

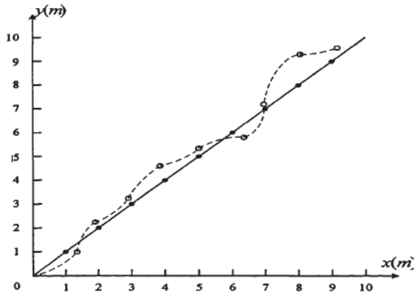

Figure6. The result of centroid correction algorithm

a) Differential correction algorithm

There are six reference nodes (0,0) , (0,20) , (20,0) , (20,20) , (10,40) , (5,35) and nine target nodes (1,1) , (2,2) , (3,3) , (4,4) , (5,5) , (6,6) , (7,7) , (8,8) , (9,9) .The result is as follows.

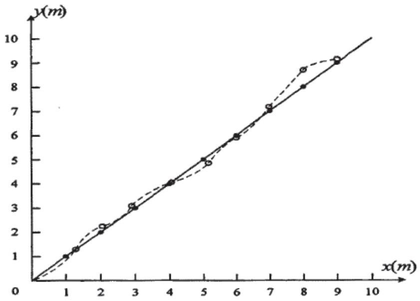

Figure7. The result of differential correction algorithm

b) Result analysis

The following conclusions can be obtained from the above: There is not much difference of result between trilateral localization algorithm and centroid correction algorithm. Although the maximum error of centroid correction algorithm is lower than trilateral localization algorithm, their average error is almost equal. What is worse, the error will be larger in the complex environment. The error of differential correction algorithm is much lower than the other location algorithm.

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