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An Improved Weighted Centroid Localization Algorithm

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Abstract

As one of the most important applications of wireless sensor network, positioning technology has become a extremely hot research filed. Taking into account of the position of beacon nodess, they make an effect on the positioning accuracy of unknown nodes. Therefore, in this paper, it proposes a new weighted centroid localization algorithm based on the traditional algorithm. For the selection of weight, the distance between beacon nodes and unknown nodes, and the slide length of the triangle are used to formed as the weighted factor. Experiment Simulation results show that this algorithm increased localisition accuracy than that of traditional algorithm.

Keywords: *Wireless Sensor Networks；Positioning Technology；Weighted Centroid Localization；Nodes Position*

1. Introduction

Wireless sensor networks (WSN) is considered to be one of the most important technologies in the 21st century that have a huge influence on the production and life. It has broad prospects in the military, environment, health, family, and other commercial fields. Node localization has been a topic of active research in recent years. The positioning algorithm can be divided into range-based and range-free.

Range-based localization algorithm need to measure the relative distance or orientation between adjacent nodes at first, then use the triangulation method, trilateration or maximum likelihood estimation method to calculate the unknown node's location. Ranging techniques used commonly include the received signal strength indicator (RSSI) method, the time of arrival (TOA) [1] method, the time difference of arrival (TDOA) and the angle of arrival(AOA) [2] method. Range-free localization algorithm using the additional information between nodes to estimate the distance to calculation node locations. It includes centroid algorithm, DV-HOP algorithm, Amorphous location algorithm [3] and APIT algorithm [4].

2. Traditional Centroid Localization Algorithm Model

Traditional centroid localization algorithm is one of the Range-free localization algorithms. The beacon nodes within the wireless communication of unknown node form a polygon. We regard the centroid of the polygon as the unknown node’s locations. It is shown in Figure 1.

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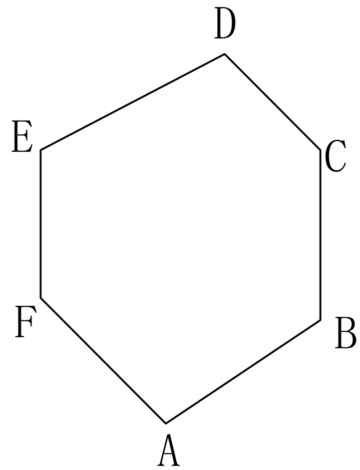

Figure 1. Schematic of Centroid Localization Algorithm

For six given anchors: $A(x_a, y_a)$, $B(x_b, y_b)$, $C(x_c, y_c)$, $D(x_d, y_d)$, $E(x_e, y_e)$, $F(x_f, y_f)$, the coordinates of the unknown node can be calculated as follows :

$$x = \frac{x_a + x_b + x_c + x_d + x_e + x_f}{6} \tag{1}$$

$$y = \frac{y_a + y_b + y_c + y_d + y_e + y_f}{6} \tag{2}$$

Centroid algorithm can be achieved only with the node connectivity, calculation method is simple, fast, this method is simple. However, we need more beacon node to improve the accuracy.

3. Weighted Centroid Localization Algorithm

Theoretical proof, the larger the RSSI value that the unknown node receive from the beacon node, the smaller the distance between two nodes, then the beacon nodes have greater influence on unknown node, and vice versa. In addition, when the beacon nodes form triangles or polygons, its positioning accuracy is higher than that any deployment in the area to be positioned.

In order to reflect the effect that the beacon nodes' position has on the unknown nodes, we use the weighted centroid localization algorithm. There are a total of n beacon nodes in the wireless range of the unknown node N .Any three of these beacon nodes can form a triangle. The model shown in Figure 2 illustrates the algorithm.

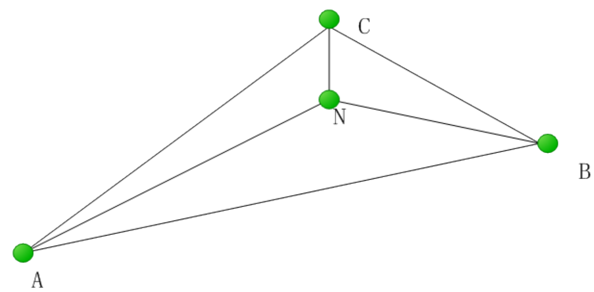

Figure 2. Schematics of Weighted Centroid Localization Algorithm

In literature [6], the algorithm takes the reciprocal of the sum of distance as the weight. As shown in the following formulas:

$$x_i = \frac{x_a \times (\frac{1}{d_a + d_b}) + x_b \times (\frac{1}{d_b + d_c}) + x_c \times (\frac{1}{d_a + d_c})}{\frac{1}{d_a + d_b} + \frac{1}{d_b + d_c} + \frac{1}{d_a + d_c}} \tag{3}$$

$$y_i = \frac{y_a \times (\frac{1}{d_a + d_b}) + y_b \times (\frac{1}{d_b + d_c}) + y_c \times (\frac{1}{d_a + d_c})}{\frac{1}{d_a + d_b} + \frac{1}{d_b + d_c} + \frac{1}{d_a + d_c}} \tag{4}$$

Where (x_i, y_i) is the coordinates of the node N that estimated by the triangle, ΔABC. d_a, d_b, d_c are the distance of the node N to nodes A, B, C. (x_a, y_a), (x_b, y_b) and (x_c, y_c) are the intersection point of the three circles by using trilateration.

$$x = \frac{\sum_{i=1}^{k} [x_i \times (\frac{1}{d_{a(i)} + d_{b(i)} + d_{c(i)}})]}{\sum_{i=1}^{k} [\frac{1}{d_{a(i)} + d_{b(i)} + d_{c(i)}}]} \tag{5}$$

$$y = \frac{\sum_{i=1}^{k} [y_i \times (\frac{1}{d_{a(i)} + d_{b(i)} + d_{c(i)}})]}{\sum_{i=1}^{k} [\frac{1}{d_{a(i)} + d_{b(i)} + d_{c(i)}}]} \tag{6}$$

Where, (x, y) is the approximate coordinates of the unknown node, $k = C_n^3$, x_i, y_i is the coordinate of unknown node calculated by the triangle, $d_{a(i)}$, $d_{b(i)}$, $d_{c(i)}$ are the distance of the unknown node to the three vertices of the triangle.

The weight factor reflect the smaller the distance between unknown node and beacon nodes, the greater the influence that beacon nodes have on the unknown node.

In literature [7], the algorithm takes the sum of the reciprocal of the distance as the weight. The weight factor in formulas (3), (4), (5), (6), become $\frac{1}{d_a}+\frac{1}{d_b}$, $\frac{1}{d_b}+\frac{1}{d_c}$, $\frac{1}{d_a}+\frac{1}{d_c}$, $\frac{1}{d_{a(i)}}+\frac{1}{d_{b(i)}}+\frac{1}{d_{c(i)}}$.

In literature [6, 7],the proposed algorithm takes advantage of the distance information between the nodes, but the two weights did not reflect the influence that beacon nodes' deployment have on the unknown node.

Literature [8] presents a new method. It regards the angles as the weights. It is shown as $w_j = 1 - \frac{\alpha_{max} - \alpha_{min}}{\pi}$, where α_{max} and α_{min} are the maximum and minimum angle of a triangle. Then the coordinates of the unknown node can be calculated by the following formulas.

$$x = \frac{\sum_{j=1}^{k} w_j x_j}{\sum_{j=1}^{k} w_j} \tag{7}$$

$$y = \frac{\sum_{j=1}^{k} w_j y_j}{\sum_{j=1}^{k} w_j} \tag{8}$$

Where x_j and y_j are the coordinate of unknown node calculated by the triangle.

In literature [9], the algorithm takes the angles and the edge length of a triangle as the weighting factor. It is shown as follows:

$$\angle\beta = \left|\angle A - 60^0\right| + \left|\angle B - 60^0\right| + \left|\angle C - 60^0\right| \tag{9}$$

$$L = \frac{AB + AC}{BC} \tag{10}$$

$$W_j = \frac{1}{\angle\beta + L} \tag{11}$$

Take W_j instead of w_j into the formulas (7) and (8), we can get the approximate coordinates of the node.

The positioning algorithms proposed in literature [8, 9] do not consider the distance impact on the positioning.

4. An improved Weighted Centroid Localization Algorithm

This paper presents a new weight which compensates for the lack of the weight presented in the above algorithms. Calculated as follows:

$$x_i = \frac{x_a \times (\frac{1}{d_a + d_b}) + x_b \times (\frac{1}{d_b + d_c}) + x_c \times (\frac{1}{d_a + d_c})}{\frac{1}{d_a + d_b} + \frac{1}{d_b + d_c} + \frac{1}{d_a + d_c}} \quad (12)$$

$$y_i = \frac{y_a \times (\frac{1}{d_a + d_b}) + y_b \times (\frac{1}{d_b + d_c}) + y_c \times (\frac{1}{d_a + d_c})}{\frac{1}{d_a + d_b} + \frac{1}{d_b + d_c} + \frac{1}{d_a + d_c}} \quad (13)$$

$$x = \frac{\sum_{i=1}^{k} [x_i \times (\frac{1}{d_{a(i)}} + \frac{1}{d_{b(i)}} + \frac{1}{d_{c(i)}} + \frac{1}{L_i})]}{\sum_{i=1}^{k} [\frac{1}{d_{a(i)}} + \frac{1}{d_{b(i)}} + \frac{1}{d_{c(i)}} + \frac{1}{L_i}]} \quad (14)$$

$$y = \frac{\sum_{i=1}^{k} [y_i \times (\frac{1}{d_{a(i)}} + \frac{1}{d_{b(i)}} + \frac{1}{d_{c(i)}} + \frac{1}{L_i})]}{\sum_{i=1}^{k} [\frac{1}{d_{a(i)}} + \frac{1}{d_{b(i)}} + \frac{1}{d_{c(i)}} + \frac{1}{L_i}]} \quad (15)$$

Where L_i is the ratio of the largest side length and the smallest side length of the triangle, Other parameters have the same definition with (3), (4), (5), (6).

5. Implementation Process of Algorithm

The improved weighted centroid localization algorithm can be calculated as follows:

First, choose three points arbitrarily from all of the beacon nodes in the wireless communication range of the unknown node. Suppose the number of beacon nodes is m, the triangle is k, then we can get $k = C_m^3$.

Second, calculate the estimated coordinates of the unknown node determined by i-triangle, $i = 1, 2, 3, \ldots\ldots, k$. (See Equation (9), (10)).

Third, calculate the average coordinates(x0, y0) and standard deviation σ of the k set of coordinates. Filter the data that has a large error which exceed 3σ.

Fourth, secondary weighting to the processed coordinates to obtain the approximate coordinates of the unknown node. (See Equation (11), (12)).

6. Algorithm Simulation

Simulationing the weighted centroid localization algorithm in the MATLAB platform. Where, the region to be detected is 64m×64m,the number of unknown nodes is 30 and beacon nodes is 7.The following figures showed are the results obtained by one time of simulation.

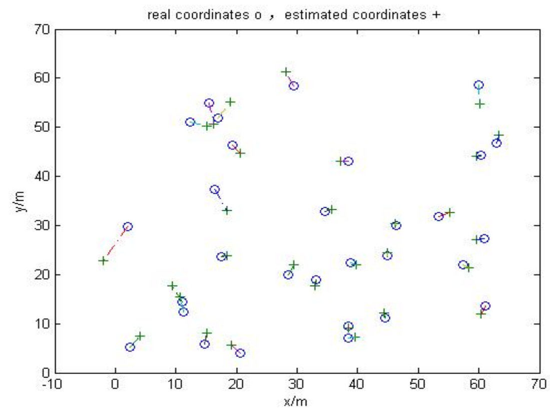

Figure 3. Simulation Diagram of Improved Algorithm

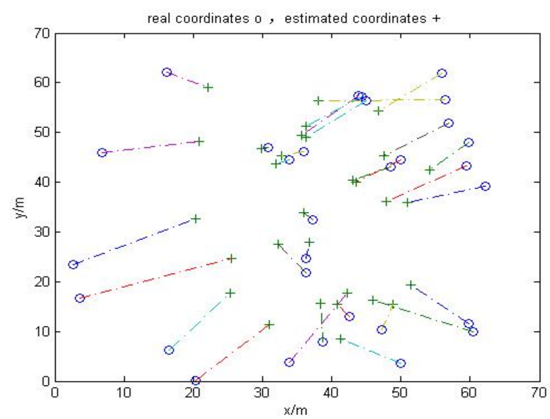

Figure 4. Simulation Diagram in Literature [6]

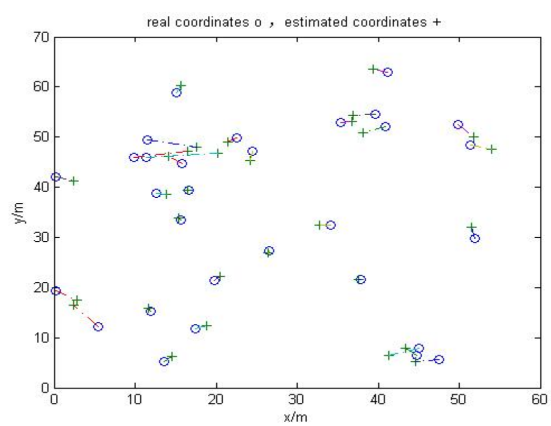

Figure 5. Simulation Diagram in Literature

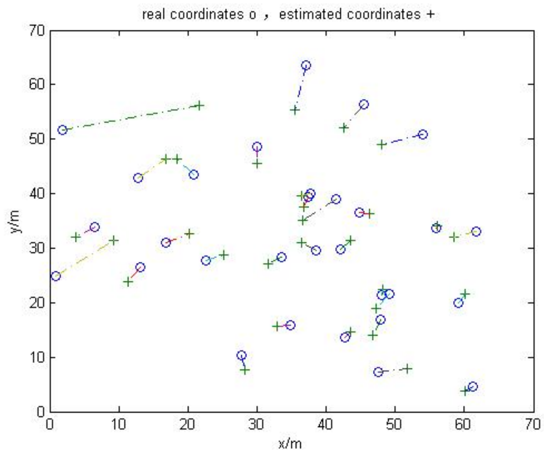

Figure 6. Simulation Diagram in Literature [8]

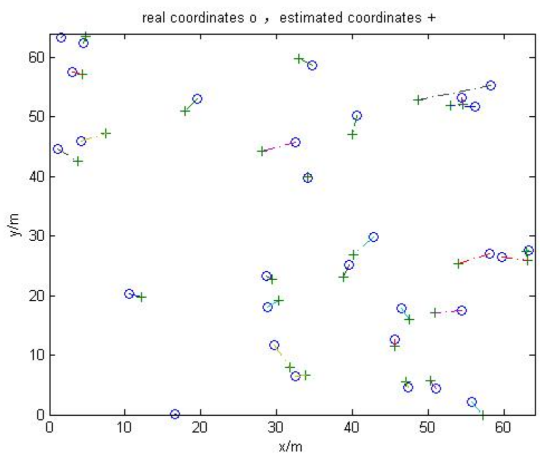

Figure 7. Simulation Diagram in Literature [9]

After 100 times simulation, we can obtained the average error of each algorithm, where the improved algorithm is 2.33m,the algorithm proposed in literature [6] is 10.14m, the algorithm proposed in literature [7] is 2.54m,the algorithm proposed in literature [8] is 2.87m,the algorithm proposed in literature [9] is 2.57m.

7. Conclusion

In this article, we put forward a new weighted centroid localization algorithm to improved the accuracy. We take the distance between nodes and the side length of triangles formed by beacon nodes as the weighting factor. Simulation results show that the new algorithm has improved the positioning accuracy greatly.

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