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Localization Research on Fruit Fly Optimization Algorithm-based Wireless Sensor Network

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Abstract: On the basis of conventional DV-Hop algorithm, Fruit fly Optimization Algorithm (FOA) is applied to improving its disadvantages. Simulation result shows that the average localization error and localization coverage of FOA are better than that of DV-Hop algorithm. Besides being less than that of DV-Hop, Fruit fly's average localization error tends to decrease as the number of nodes increase. *Copyright © 2013 IFSA.*

Keywords: DV-Hop Algorithm, Fruit Fly Optimization Algorithm, Average localization error, Localization Coverage.

1. Introduction

With the development of sensor technology, wireless sensor networks have been widely used in various industries. Since wireless sensor networks are mainly used in sensor self-localization, the localization of wireless sensor networks becomes a research hotspot now. Traditional localization algorithm has disadvantages such as large localization error, complicated algorithm and high energy consumption, thus algorithm improvement is an important research direction. This study applied the fruit fly optimization algorithm (FOA) to improving the disadvantages of traditional DV-Hop algorithm. Simulation result showed that localization algorithm of FOA is superior to that of DV-Hop [1].

2. DV-Hop Algorithm

DV-Hop algorithm is proposed by D. Niculescu, B. Nath, et al. The beacon in this algorithm, including location information of anchor nodes and a parameter representing hop count, broadcasts in the networks by flooding method. Each time it is forwarded, the number of pop count increases 1. The receiving node keeps only the beacon with the minimum hop value and discards others. Based on this mechanism, all the nodes in the networks can obtain the minimum hop value of each anchor node [2].

Similar to the range-based algorithm in many ways, DV-Hop also needs to obtain the distance from the unknown node to anchor node. But DV-Ho obtains it by calculating the network typology information rather than radio wave signal measurement [3].

DV-Hop is actually composed of two waves of flooding. The first one is similar to Sum-dist, in which nodes obtain the location information of anchor nodes and the minimum hop distant from anchor node [4]. In the second one, the hop count information is converted into distance information. Based on the recorded hop count information and distance information, each anchor node can estimate average actual distance of each hop [5].

$$Hopsize = \frac{\sum_{j \neq i} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j \neq i} Hops_i}, \quad (1)$$

where (x_i, y_i), (x_j, y_j) are the coordinates of anchor nodes; Hop_j is the hop count between anchor node i and j (i≠j). After obtaining the average distance of each hop, the anchor node will transport information packets with TTL field. The unknown records only the first average distance of each hop received and then transport them to the neighbor node [6]. This strategy ensures the majority nodes receive average distance value of each hop from the nearest anchor node.

DV-Hop consists of three stages. Firstly, the typical distance vector exchange protocol is applied to ensuring all nodes of the networks obtain distance in hops. In the second stage, after obtaining locations of other anchor nodes and distance in hops, the anchor node calculates the average distance of each hop which then is broadcasted to the networks as a correction [7]. The correction broadcasts in the way of controllable flooding. It means the first node receive the first correction obtained and discard other latecomers. This strategy ensures the majority nodes can receive corrections from the nearest anchor nodes.

As shown in Fig. 1, the distance and hop counts between L_1 and L_2, L_1 and L_3 are known. The calculated correction of L_2 is (40+75)/(2+5)=16.42. In the above instance, if A obtains correction from L_2, the distance among A and other three anchor nodes are L_1-3*1.642，L_2-2*1.642 and L_3-3*16.4, then the position of A can be determined by the three-sided measurement.

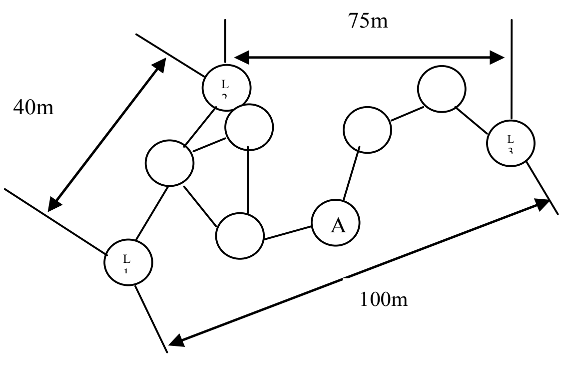

Fig. 1. DV-Hop Algorithm.

3. Defects of DV-Hop algorithm

1) There are some bad nodes in wireless sensor networks due to the random distribution of the nodes.

(i) Only one node exists within one hop of Node N. The coordinate of M is known. The node N, within one hop of M, only knows the location of M. as shown in Fig. 2, N can appear in N1, N2, …Nn and any other places. So it is evident that the location of node N is not unique. In other words, it is unable to judge the location of N. Thus N is called bad node.

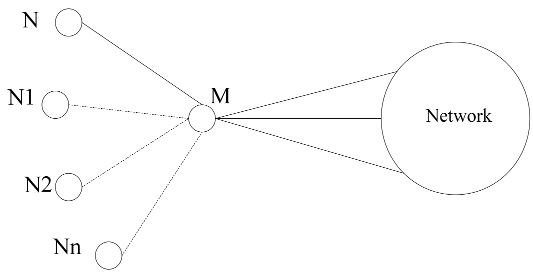

Fig. 2. Diagram of the first class bad node.

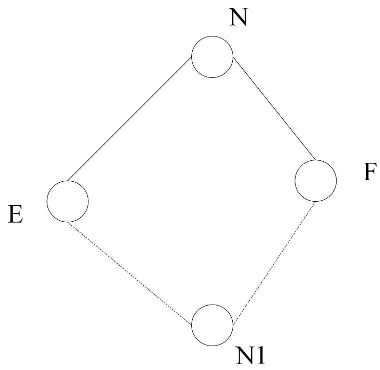

Fig. 3. Diagram of the second class bad node.

(ii) Two nodes exist within one hop of Node N. The coordinates of E and F are known, which are two coordinate known only by node N within one hop [7]. Thus the location of node N can't be determined. In other words, we can't judge the definite coordinate of node N. Therefore, node N is identified as bad node [8].

(iii) Bad nodes are node collection. As shown in Fig. 4, the coordinate of node M is known. Supposing only through node M can the collection of unknown nodes communicate with the networks, then this node collection could turn around the known node M. In other words, their locations are not determinable [9]. Therefore, all the nodes in this node collection are bad nodes.

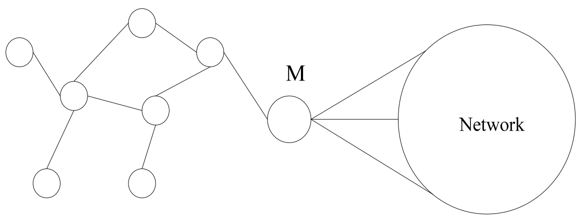

Fig. 4. Diagram of the third class bad node.

2) Each hop distance between the node under test and known test is expressed as the average distance

of each hop. The values of each hop distance are always different, so this method will increase the error [10].

3) With less number of known nodes, the detectable coverage is relative small, which means lower node localization coverage rate. It is a requirement to connect nodes under test with known nodes via intermediate network. Since there were small numbers of nodes, their communication requires the increase of intermediate hops, resulting in the increase of distance error.

4) During the third step of localization, three-sided measurement is used to evaluate the coordinate of nodes under test. This method brings about certain error and features low location accuracy.

4. Fruit Fly Optimization Algorithm (FOA)

4.1. Introduction of FOA

Fruit Fly Optimization Algorithm (FOA) is a new evolutionary computation method proposed by Taiwan's young professor, Pan Wenchao, in 2011. That is due to fruit fly's olfactory and visual superiority, as shown in Fig. 1. The fruit fly searches for food sources in the air. After finding the food, it makes use of its sharp vision to locate the food and its companions, and then fly to the food. Therefore, this study states the fruit fly searches food by locating the approximate position food through olfactory and then confirming the correct position of food through vision. This is a new method of seeking global optimization deducing from the foraging behavior of the fruit fly.

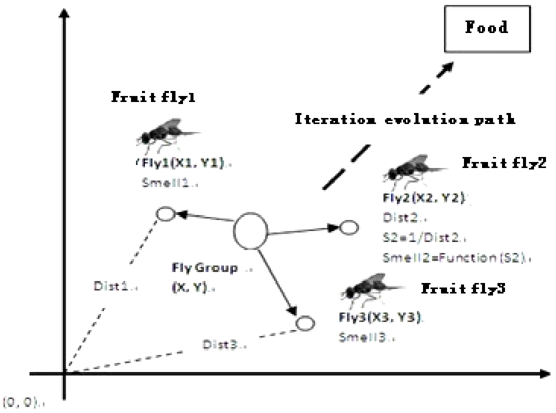

Fig. 5. Fly group iterative food search diagram.

4.2. Steps of FOA

The fruit fly optimization algorithm can be divided into seven steps, specifically shown as follows:

1) Fig. 1 shows initialization of fly group's location, the result is Init X_axis; Init Y_axis;

2) Having determined the searching direction, the random searching distance of fruit fly can be obtained from the equation below:

$$Xi = Init\ X\_axis + RV_x,\quad Yi = Init\ Y\_axis + RV_y, \tag{2}$$

3) Since the location of food is unknown, it is a requirement to evaluate the distance of fruit fly between the current location and base point. Then calculate the flavor concentration judgment value Si, which equals to reciprocal of distance.

$$Disti = \sqrt{Xi^2 + Yi^2},\quad Si = 1/Disti, \tag{3}$$

4) Substitute the flavor concentration judgment value into flavor concentration judgment function, and the flavor concentration of the fruit fly's current location can be obtained.

$$Smelli = Function(Si), \tag{4}$$

5) The optimal flavor concentration of fruit fly group can be obtained in the following equation:

$$[bestSmell\ bestIndex] = \max(Smelli), \tag{5}$$

6) Keep the optimal flavor concentration of fruit fly group and its corresponding x coordinate and y coordinate, at this time, the fruit fly group locate the food source through vision and fly to the food sources.

7) Execute iterative optimization. Iterate step (2)–(5) repeatedly while determining whether the current flavor concentration is better than the previous iterative one. If satisfied, step (6) can be executed.

5. Localization of PSO based DV-Hop Optimization Algorithm

Error localization of wireless sensor networks mainly comes from relative ranging technique, which is inevitable. The essential of localization is to minimize the error. The use of FOA for nodes location correction, essentially, is to minimize the localization error. Assume that *(x, y)* is the coordinate of the unknown node under localization. Distance between the unknown node and the i^th anchor nodes, d_i, can be derived by equation (6). Then the localization error can be defined as

$$F_i(x,y) = d_i - d_j = d_i - \sqrt{(x - X_j)^2 + (y - Y_j)^2}, \tag{6}$$

where d_j is the actual measuring distance.

Take equation (6) as the fitness function to evaluate the fitness of fruit fly. Set relevant iterative numbers. By the end of iteration, the current optimal solution available is taken as the final estimated location of the known node.

$$Fitness(x,y)=\sum_{j=1}^{n}\propto_j^2 F_j(x,y), \quad (7)$$

where $\propto_j$ is the reciprocal of hop value between the unknown node and the anchor node *i*; *n* is the number of known nodes.

6. Algorithm Simulations

Based on the algorithm's principle and process, the Matlab software is applied to conducting simulations. The population of fruit fly is 30, so is the iterative number. In simulation, the node communication radius is 10 m, and the simulation area is 10 m x 10 m square planar. Thus the known nodes locate in the 10 m x 10 m square planar. The evaluation criterion for wireless sensor network localization algorithm is the average localization error, whose calculation equation is as below:

$$ErrorAverage=\frac{\sum_{j=1}^{N}\sqrt{(x_j^{'}-x_j)^2+(y_j^{'}-y_j)^2}}{N\times R}\times 100\%, \quad (8)$$

where N represents the number of known nodes; $(x_j^{'},y_j^{'})$ represents the estimated location of the unknown node I; (x_j,y_j) is the actual location of the known node and R, the node's communication radius.

Fig. 6 refers to relation diagram between anchor nodes rate and localization coverage rate. As shown in Fig. 6, the use of FOA to optimize localization coverage of DV-Hop is superior to conventional DV-Hop algorithm. A comparison of the two methods is shown in Fig. 1: when the anchor node rate reaches 10 %, the localization coverage of FOA has been up to 100 %, higher than DV-Hop's 91 %.

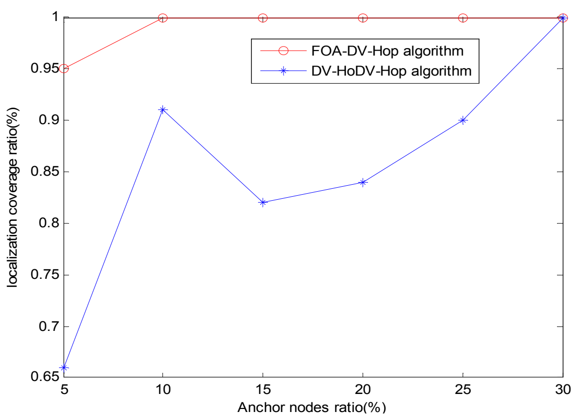

Fig. 6. Relation diagram between anchor nodes rate and localization coverage ratio.

Table 1. localization coverage rate of FOA and DV-Hop.

Anchor nodes ratio (%)	Localization coverage rate of FOA (%)	Localization coverage rate of DV-Hop algorithm (%)
5	0.95	0.66
10	1.00	0.91
15	1.00	0.82
20	1.00	0.84
25	1.00	0.90
30	1.00	1.00

Fig. 7 represents the relation diagram between anchor nodes rate and the average localization error. It shows, with the increase of anchor nodes rate, the average localization errors of both FOA and DV-Hop algorithm tend to decrease, but the former is obviously less than the latter and has higher localization accuracy. The detailed data of the two is shown in Fig. 2.

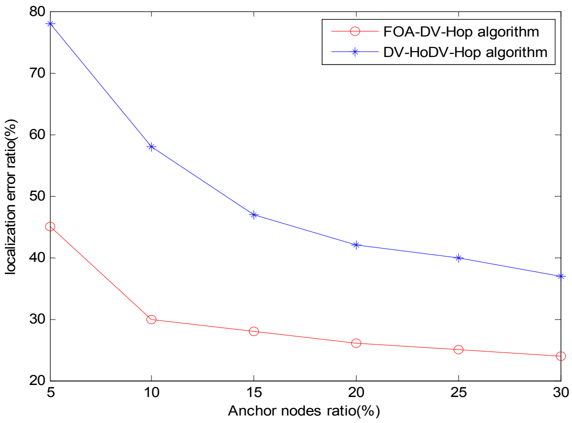

Fig. 7. Relation diagram between anchor nodes ratio and average localization error.

Table 2. Average localization error of FOA and DV-Hop algorithm.

Anchor nodes ratio (%)	Average localization error of FOA (%)	Average localization error of DV-Hop (%)
5	45	78
10	30	58
15	28	47
20	26	42
25	25	40
30	24	37

Fig. 8 indicates that as the number of nodes increase, the average localization error of FOA and DV-Hop algorithm tend to decrease on the whole. It can be obviously found the average localization error of FOA is less than the localization error of DV-Hop, which is an evident that Localization algorithm of FOA is better than DV-Hop.

Fig. 9 and Fig. 10 represent convergence diagram and path optimization diagram, respectively. Those figures indicate that the optimal value can be obtained when PSD algorithm reaches 80 iterations. This optimal value basically remains unchanged with the further increase of iterations.

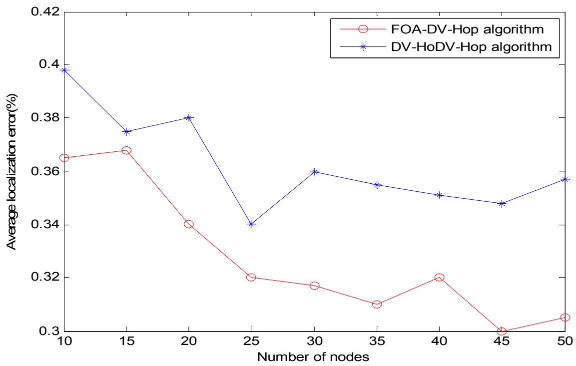

Fig. 8. Relation diagram between nodes number and average localization error.

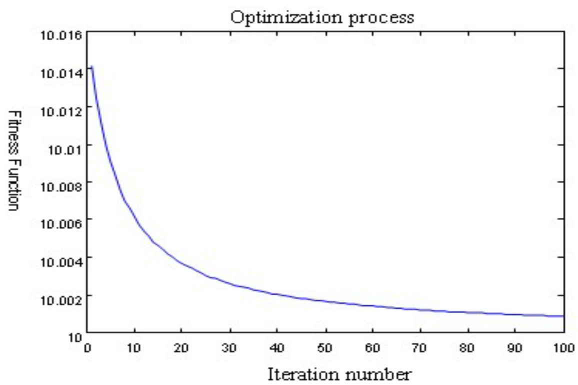

Fig. 9. Convergence diagram of FOA.

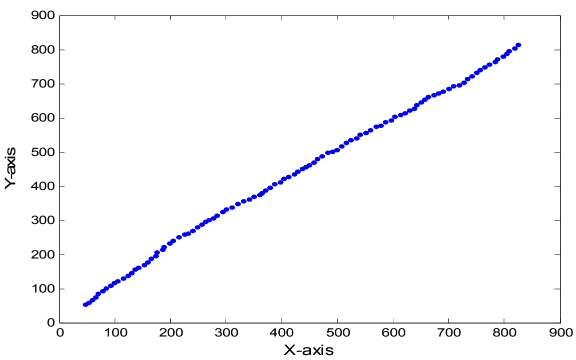

Fig. 10. Optimized path of FOA.

7. Conclusion

On the basis of conventional DV-Hop algorithm, the fruit fly optimization algorithm is applied to optimizing and locating DV-Hop algorithm for overcoming its shortcomings. The simulation results conclude that:

1) The use of fruit fly optimization algorithm to optimize localization coverage rate of DV-Hop is better than conventional DV-Hop.

2) With rising rate of anchor nodes, the average localization error of fruit fly optimization algorithm and DV-Hop algorithm tend to decrease. But the average localization error of the fruit fly optimization algorithm is smaller than that of DV-Hop algorithm, with higher location accuracy.

3) As the number of nodes increase, the average localization error of fruit fly optimization algorithm and DV-Hop algorithm tend to decrease, and the former is smaller than the latter.

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