A New WSNs Localization Based on Improved Fruit Flies Optimization Algorithm

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Abstract. A new node localization approach of Wireless Sensor Networks based on improved fruit fly optimization algorithm is presented to optimize the location accuracy. This approach reduce the distance error between the unknown node and beacon node by improved fruit fly optimization algorithm. Then, instruct the influence of different initial position, different population group and different number of beacons on the localization accuracy. Simulation results indicate that the localization algorithm is simple, fast convergence and high accuracy. Compared the localization accuracy that is optimized by improved APIT and improved PSO with improved fruit fly optimization algorithm, the algorithm based on improved fruit fly optimization algorithm is more accurate than other intelligent algorithm in WSNs node localization.

1. Introduction

Wireless sensor networks (WSNs) are systems of small, low powered networked sensing devices deployed over an area of interest to monitor interesting events and perform application specific tasks in response to them [1]. It is used in environment monitoring, military defense, industrial and agricultural control, ect. However, military or environmental monitoring are not only need monitoring information but also need location information. For a sensor, determining its location information has become an attractive research issue in WSNs. Localization algorithms are divided into two broad categories according to the type of information used: range-free and range-based [2-5]. In this paper, we use the range-base localization scheme to locate the unknown nodes.

The sections of this paper is organized as follows: In this section, recommend some background information of localization algorithms, then introduce the purpose and significance of this paper; In section 2, distance measurement method and calculation method of node coordinate will be introduced; Section 3 will introduce node localization approach based on improved FOA; Section 4 will work out the experimental simulation and analyses the result of localization; This paper is concluded in section 5.

2. WSNs Positioning Technology

Through studying the range-based localization algorithm, it can be classified into distance measurements and calculating the coordinates. First of all, calculate the distance between nodes by range-based localization algorithm. Then calculate the coordinates of the unknown nodes by node coordinate calculation method.

2.1 The calculation method of node coordinates

Trilateral measuring method is kind of location algorithm which is easy to realize and its cost is little in localization algorithm. The advantage of trilateral measurement method is that just need to know the coordinate of three beacon nodes. Calculation is simple, but the distance between unknown nodes to the three beacon nodes is not accurate in the practical application due to measurement errors. Such as A, B, C are known location beacon nodes. The unknown node should be located in the circle with A as the center. The same node should be located in the circle with B, C as the center as shown in Fig. 1(a). In theory, the three round of intersection is the location of the unknown node. However, the three round does not intersect the circle at one point in actual positioning system as shown Fig. 1(b), (c). Therefore, it needs to optimize the distance error by optimization algorithm, reducing the shaded area.

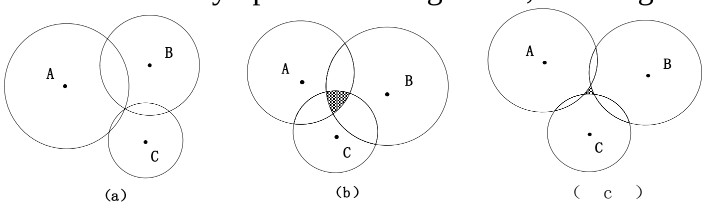


Fig.1 The case of Trilateration graph

If there are multiple beacon nodes as: $(x_1,y_1),(x_2,y_2),(x_3,y_3),\cdots,(x_i,y_i),\cdots,(x_n,y_n)$.Each beacon node to the unknown node distance is r_1, r_2,…,r_i,…,r_n, . The relationship between the unknown node and beacon nodes are :

$$\varepsilon_i = \left| \sqrt{(\hat{x}-x_i)^2 + (\hat{y}-y_i)^2} - r_i \right| , \quad i = 1,2,3,\cdots,n \tag{1}$$

Where $(\hat{x},\hat{y})$ is the estimated position of unknown node. ε_i are error which between estimation distance and actual distance. Therefore, the sum of the measured error between the node and the beacon nodes can be expressed as:

$$g(\hat{x},\hat{y}) = \sum_{i=1}^{n} \varepsilon_i , \quad (n \ge 3) \tag{2}$$

When $g(\hat{x},\hat{y})$ take the minimum value, the value of $(\hat{x},\hat{y})$ is closest to the actual value.

3. Node Localization Approach Based on Improved FOA

3.1 Fruit Fly optimization algorithm

The Fruit Fly Optimization Algorithm (FOA) is a new method for finding global optimization based on the food finding behavior of the fruit fly. Based on the food finding characteristics of the fruit fly, it is divided into several necessary steps. The steps areas follows [6]:

Step 1: Random initial fruit fly group location (*IntX_axis*,*IntY_axis*), determine the number of group *sizepop* and the maximum iterations *maxgen*.

Step 2: Give the random direction for the search of food using osphresis by an individual fruit fly.

$$X_i = X\_asix + Randvalue \qquad Y_i = Y\_asix + Randvalue$$

Step 3: Estimating the distance ($Dist_i$) between fruit fly and the origin, then calculate the smell concentration judgment value (S_i).

$$Dist_i = \sqrt{X_i^2 + Y_i^2} , \quad S_i = 1/Dist_i$$

Step 4: Substitute smell concentration judgment value (Si) into smell concentration judgment function so as to find the smell concentration ($Smell_i$).

$$Smell_i = Function(S_i)$$

Step 5: Find out the fruit fly with maximal smell concentration among the fruit fly group.

$$[bestSmell \quad bestIndex] = max(Smell_i)$$

Step 6: Keep iterative best smell concentration value and *x, y* coordinate, and at this moment, the fruit fly swarm will use vision to fly towards that location.

$$Smellbest = bestSmell , \quad x = X(bestIndex) , \quad y = Y(bestIndex)$$

Enter iterative optimization to repeat the implementation of step 2-5, then judge if smell concentration is superior to the previous iterative smell concentration, if so, implement step 6.

3.2 Node localization based on improved FOA

This algorithm will obtain the unknown node coordinate by reducing the measured distance error between nodes and beacon nodes.For the trilateral measurement method, we use three beacon nodes to locate unknown nodes. Where (x_A , y_A),(x_B , y_B),(x_C , y_C) represent the coordinate of three beacon nodes. The error function is shown as (4):

$$\delta = \frac{1}{3} g(\hat{x},\hat{y}) = \frac{1}{3}\sum_{i=1}^{3}\varepsilon_i$$
$$= \frac{1}{3}\left(\left|\sqrt{(\hat{x}-x_A)^2+(\hat{y}-y_A)^2}-r_A\right|+\left|\sqrt{(\hat{x}-x_B)^2+(\hat{y}-y_B)^2}-r_B\right|+\left|\sqrt{(\hat{x}-x_C)^2+(\hat{y}-y_C)^2}-r_C\right|\right) \quad (3)$$

When δ taking the minimum, it means that unknown node $(\hat{x},\hat{y})$ close to the actual measure value. r_A , r_B , r_C is the distance between beacon node to unknown node. In order to improve the positioning accuracy, we can use improved fruit fly algorithm to reduce the error.

Set up initial location of fruit fly flying range is [0, 5]randomly, the random fly direction and distance zone for fruit fly searching food is [-0.5 , 0.5] , fruit fly population size is *sizepop*=30, and iterative number is *maxgen*=100. Estimate the distance between fruit fly and the origin point $D(i)$, that is the distance between unknown node and beacons, as (5):

$$D(i) = \left|\sqrt{(\hat{x}-x_i)^2+(\hat{y}-y_i)^2}-r_i\right| \quad (4)$$

Substitute smell concentration judgment value $D(i)$ into smell concentration judgment function:

$$Smell(i) = \frac{1}{3}\sum_{i=1}^{3} D(i) \quad (5)$$

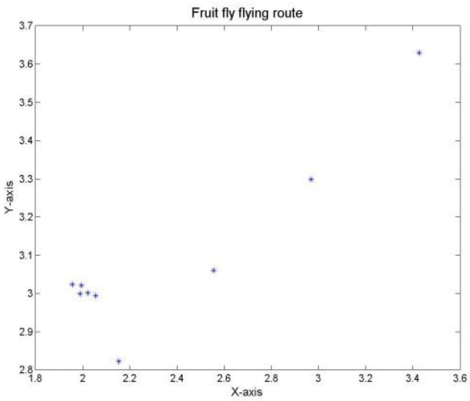
Find the largest smell concentration of fruit flies in order to make the smallest error sum of squares. Retain the best ($X(i)$,$Y(i)$) coordinates. Enter iterative optimization to repeat the implementation of steps 2-5, then judge if the smell concentration is superior to the previous iterative smell concentration, if so, implement step 6.

4. Simulation and Performance Analysis

For validating the performance of improved fruit fly algorithm, this paper implements a series of simulation for this localization algorithm. Assume the P(3,2) is coordinates of the unknown node. Three beacon nodes coordinates are A(0,0), B(5,0),C(0,5). It can calculate the P to A,B,C distance are $r_1 = \sqrt{13}$ 、 $r_2 = \sqrt{8}$ 、 $r_3 = 3\sqrt{2}$. In the initial parameter set up of the fruit fly population size is 30, and iterative number is 100. Analyze the influence of different initial position, initial population, the number of beacon nodes and communication distance on the positioning accuracy. Compared with the relative error and standard deviation of node localization of WSNs based on improved APIT algorithm (APIT) [7] and improved particle swarm optimization (PSO)[8], the accuracy of improved fruit fly optimization algorithm(FOA) is more accurate than other intelligent algorithm in wireless sensor network node localization.

4.1 The improved fruit flies algorithm convergence

After optimization by the fruit flies algorithm, the fruit flies focus on (3, 2) as shown in the Fig. 2. Due to the increased number of iterations, the unknown node error decrease. After seven iterations, the mean square error almost close to zero in Fig.3. After 100 times of iterative evolution, meet the requirements of the positioning error with a coordinate of (3.0043, 1.9961). It is very close to actual coordinates of the point P(3,2). It also shows that the fruit flies optimization algorithm convergence speed is quick.



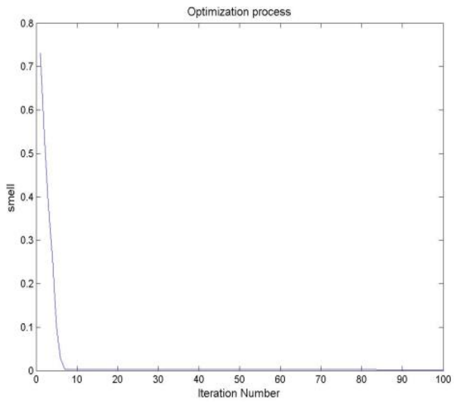


Fig.2 Fruit Fly Flying Route Fig.3 Optimization Process of unknown node

4.2 The influence of initial position and initial population on positioning

In the initial parameter set up of the fruit fly, the random initialization fruit fly swarm location range is [0, 5], the random fly direction and distance zone of iterative fruit fly food searching is [-0.5 , 0.5], fruit fly population size is *sizepop*=30, and iterative number is *maxgen*=100. Setting the unknown node is (2, 3). The first line of two graphs in Fig. 4(a) is the iterative and the flight path of fruit flies.

(a) Different initial position and optimization process

The random initialization fruit fly swarm location range is [0, 30]. The second line of two graphs in Fig.4(a) is iterative and flight path figure which is changed initial fruit position. Because of changed initial position, it finds the final fruit flies gather points diffically.

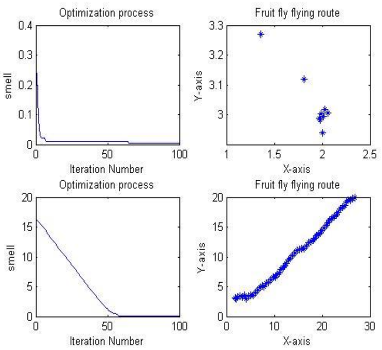
(b) Different population group and optimization process

Choose a different population size *sizepop*=10 .The second line of two graphs in Fig.4(b) is iterative and flight path figure which is changed population size of fruit flies. After change the population size, the fruit flies flight path is not clear and the convergence speed is slowed.

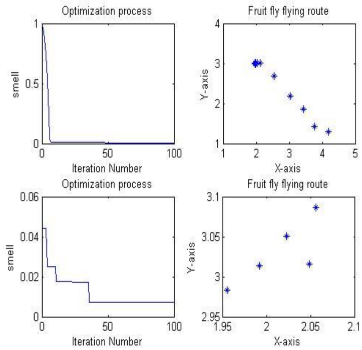
(c) Different initial position, population group and optimization process

The random initialization fruit fly swarm location range is [0, 30] , fruit fly population size is *sizepop*=50. The second line of two graphs in Fig.4(c) is iterative and flight path figure which are changed population size and changed initial of fruit flies. After change the population size and initial, it is not easy to find the final fruit flies gather points and slow the convergence speed.

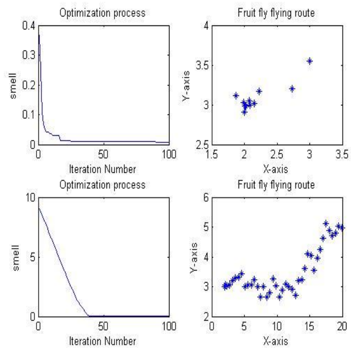
After testing shows that choose the appropriate number of iterations, population size, initial position and flying range are very important for localization.



(a)



(b)



(c)

Fig. 4 The influence of initial position and population group on positioning

4.3 Improved FOA compared with other intelligent algorithms

As shown in table 1, compared with the relative error and standard deviation of improved APIT and improved PSO, the accuracy of improved FOA is more accurate than other intelligent algorithm in WSNs node localization.

Table 1 Comparing Improved FOA with Improved APIT and Improved PSO in localization

Actual coordinate /m	improved APIT		Improved PSO		Improved FOA	
	measured coordinate /m	relative error	measured coordinate /m	relative error	measured coordinate /m	relative error
(0.4 , 3.0)	(0.400 , 2.960)	1.33%	(0.399 , 2.889)	0.24%	(0.399 , 2.996)	0.15%
(2.5 , 3.2)	(2.490 , 3.210)	0.36%	(2.491 , 3.188)	0.37%	(2.496 , 3.203)	0.11%
(1.2 , 2.4)	(1.200 , 2.390)	0.42%	(1.199 , 2.389)	0.27%	(1.200 , 2.396)	0.17%
(2.5 , 1.4)	(2.470 , 1.370)	1.67%	(2.510 , 1.399)	0.24%	(2.518 , 1.399)	0.16%
(3.6 , 3.5)	(3.600 , 3.470)	0.86%	(3.588 , 3.498)	0.17%	(3.600 , 3.505)	0.09%
standard deviation	1.18%		0.30%		0.17%	

5. Conclusion

This paper propose a new node localization approach based on improved FOA. The approach can reduce the distance error between unknown node and beacon node to improve accuracy. Instruct the influence of different initial position, different population group and different number of beacons on the localization accuracy. By simulation results indicate that the localization algorithm is simple, fast convergence and high accuracy. Compared with the relative error and standard deviation of improved APIT and improved PSO, the accuracy of improved FOA is more accurate than other intelligent algorithm in WSNs node localization.

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