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An Improved DV-Hop Algorithm Based on Artificial Fish Swarm Algorithm

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DV-Hop localization algorithm is the most commonly used node localization algorithm in wireless sensor networks, but it does not take into account the impact of average distance per hop in calculating the position of unknown nodes, resulting in reduced positioning accuracy. To solve this problem, a new AFSADV-Hop (Artificial Fish Swarm Algorithm DV-Hop) algorithm based on artificial fish swarm algorithm was proposed in this paper. As artificial fish swarm algorithm has a faster convergence rate and can solve nonlinear function optimization problem, it is used to solve the optimization of the average distance per hop, so the location error caused by the average distance per hop is reduced, so that it is closer to the actual value. The simulation results show that the improved algorithm can effectively improve the algorithm's accuracy and stability without increasing the hardware cost.

1. Introduction

Internet technology has been very mature today, the application of the network in all walks of life has been popularized, C. Wang et al. (2015), Y. Li et al. (2015), Q. Huang et al. (2014), S. Shang et al. (2014) reported. Sensor Network Wireless (WSN) is one of them. Node location information is very important in the application of WSN, such as target detection and tracking, automatic configuration of network topology, Bachir A et al. (2010), Saber R O et al. (2008), Teng J et al. (2010), Oka A et al. (2010) reported, etc. DV-Hop algorithm is one of the most widely used algorithms in wireless sensor network node localization, A. Zhang et al. (2012), J. Wen et al. (2014), Z. Guo et al. (2013) reported. However, the algorithm has low accuracy, so many scholars have improved it, W .Li et al. (2011), Y. Wang et al. (2012), J. Feng et al. (2012) reported. All of them had improved the DV-Hop algorithm in the second or the third stage during the localization, but all the improved algorithms still not achieved the desired results, so DV-Hop algorithm still needed to be improved.
In this paper, a new DV-Hop algorithm based on artificial fish swarm algorithm (AFSADV-Hop) is proposed. The algorithm uses artificial fish swarm algorithm to optimize and improve the average distance per hop of anchor nodes, and improve the accuracy of the average distance per hop of anchor nodes, which makes it more close to the actual value. The simulation results show that the algorithm has good performance.

2. DV-Hop algorithms

Niculescuet al. (2003) proposed the DV-Hop algorithm which can obtain the estimated distance between the beacon nodes and unknown nodes by hop count, and then use the three edge measurement method to estimate the coordinates of the unknown nodes. The positioning process is as follows:
(1) The anchor nodes are grouped into the network broadcast by flooding method. All nodes obtain the minimum hops from each anchor node.
(2) The average distance per hop of each anchor node is calculated by using the formula (1).

$$hopsize_i = \sum_{j \neq i} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \Big/ \sum_{j \neq i} hop_j \quad (1)$$

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Among them, (x_i, y_i), (x_j, y_j), respectively, is the location of the beacon nodes i and j, hop_j is the minimum hop count of the two. The unknown node uses the average distance per hop of the nearest anchor nodes and the minimum hop between them to estimate the distance.
(3) Unknown nodes use distance of 3 or more anchor nodes to estimate their coordinates.

3. AFSADV-Hop algorithms

3.1 The shortcomings of the traditional DV-Hop algorithm

In the traditional DV-Hop algorithm, the ratio of the actual distance and the hop count is used as the average distance per hop of the anchor nodes. When the number of hops between nodes is increased, the error of the hop distance is greater. The unknown node uses the average distance per hop of the anchor nodes with larger error to estimate the distance between the nodes, which leads to large position error.

3.2 Artificial fish swarm algorithm

Artificial fish swarm algorithm is proposed by X. Li (2003), which is an optimization method based on autonomous animals. The algorithm according to the characteristics of waters fish to survive the largest number of places is the waters which are the richest in nutrients places to simulate fish foraging, swarm and follow, in order to achieve the global optimum. The algorithm has the advantage of low initial value and parameter setting and the optimization speed is quick.
(1) Random behavior: artificial fish random moves in visual field. When it discovers food, it will fast moves to direction of food gradually increasing.
(2) Foraging behavior: a behavior that fish moves follow the direction of multi food.
(3) Group behavior: in order to ensure the survival and avoidance, the fish will naturally gather in groups.
(4) Follow behavior: a behavior of fish moving to the optimal direction of the visual area.
(5) Bulletin board: place where records state of the optimal artificial fish.

3.3 AFSA algorithm is used to solve the average distance per hop

The location accuracy of DV-Hop algorithm mainly depends on the accuracy of the average distance per hop in the process of localization. So the optimal average distance per hop is obtained by using the artificial fish swarm algorithm, therefore, the positioning error of DV-Hop algorithm is reduced.
According to the recorded node position information, the anchor node uses the type (2) to calculate the actual distance between the anchor node i and the anchor node j.

$$d_{tij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{2}$$

The estimated distance between the anchor nodes i and j is equal to the minimum number of hops obtained by the first stage and the average jump distance obtained by using the formula (1), that is $d_{eij} = hops_{ij} \times hopesize_i$. $\varepsilon = \left| d_{tij} - d_{eij} \right|$ is the error caused by $d_{eij} = hops_{ij} \times hopesize_i$. Reasonable $hopesize_i$ should make ε minimum, therefore, the calculation of $hopesize_i$ turn into problem of minimization. When construct a mathematical model to calculate the average distance per hop, we used minimum mean squared error criterion to completed, W. Ji (2008) reported. The mathematical model is shown in the formula (3).

$$\begin{cases} Min \quad \varepsilon = \sum\limits_{i \neq j} (d_{ij} - hopsize_i \times hop_{ij})^2 \\ s.t. \quad 0 \le hopsize_i \le R \end{cases} \tag{3}$$

So the solution of $hopsize_i$ is transformed into $hopsize_i$ optimization problem. The sum of squares of the errors is used as the objective function $G(hopsize_i)$, which is shown in the formula (2). Select the appropriate $hopsize_i$ to make the minimum of the function value.

$$G(hopsize_i) = \min \sum\nolimits_{i \neq j} (d_{tij} - hopsize_i \times hop_{ij})^2 \tag{4}$$

Based on the above analysis, the average distance per hop $hopesize_i$ of anchor nodes is calculated by using artificial fish swarm algorithm. Steps are as follows:

Step 1: Initial artificial fish swarm, including the size of the fish swarm N, random initial the position of the artificial fish, the visual field $visual$ of artificial fish, the maximum step size $step$, crowding factor δ, try numbers $trynumber$, the maximum number of iterations $Iterate-\max$;

Step 2: By formula (4), the food concentration (objective function) of each individual is calculated, and the optimal value is placed in the bulletin board;

Step 3: Through individual foraging, cluster, following behavior to update it and generate new fish;

Step4: Evaluate all individuals. If an individual is better than that on the bulletin board, the board is updated to the individual;

Step5: When the optimal solution on the bulletin board on achieve satisfactory error bounds, end the algorithm output the optimal solution to a variable $hopesize$, or turn step 3 until the maximum number of iterations is reached.

The introduction of artificial and swarm algorithm to calculate the average distance per hop of anchor node, AFSADV-Hop algorithm positioning flow is shown in figure 1.

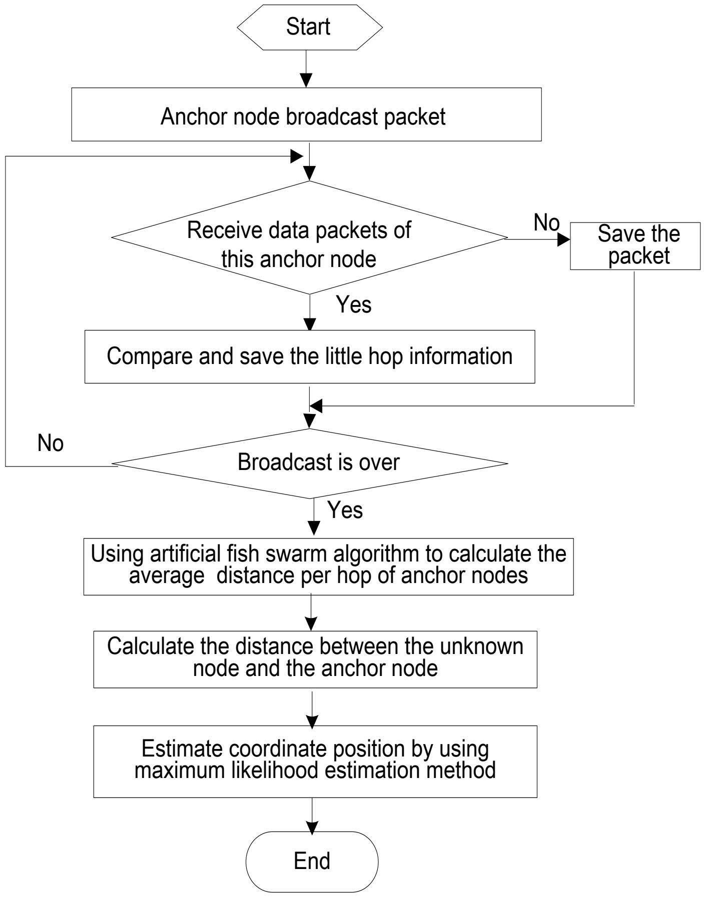

Figure 1: AFSADV-Hop algorithm flow

4. Simulation experiment

4.1 simulation environment

In this paper, MATLAB7.0 is used to simulate the algorithm. Anchor nodes and unknown nodes are randomly distributed in the region. In the artificial fish swarm algorithm in this paper, set the size of fish N =10, the visual field $visual$ =5, the maximum step $step$ =8, crowding factor δ =0.8, try the number $trynumber$ =10, the maximum number of iterations $Maxitera$=20.

Algorithm accuracy is the most important measure of the algorithm. The performance of the algorithm is verified by comparing the positioning error between the $DV-Hop$ algorithm and the $AFSADV-Hop$ algorithm to. The positioning error is calculated by using formula (5).

$$\delta_i = 100\% \times \sqrt{(x_t - x_e)^2 + (y_t - y_e)^2} / R \quad (5)$$

Where (x_t, y_t), (x_e, y_e) respectively, are the true position and the estimated position of the node. R is communication radius of node. The experimental scene is executed many times and the results are averaged, which makes the experimental data more objective.

4.2 Result analysis

The total number of nodes in the network is 100 and the communication radius is changed. The DV-Hop algorithm and the $AFSADV-Hop$ algorithm are simulated with the different anchor nodes, and the positioning algorithms are executed multiple times used to calculate the coordinates of the unknown nodes. The simulation performance is shown in Figure 2 (a) (b) (c) (d).

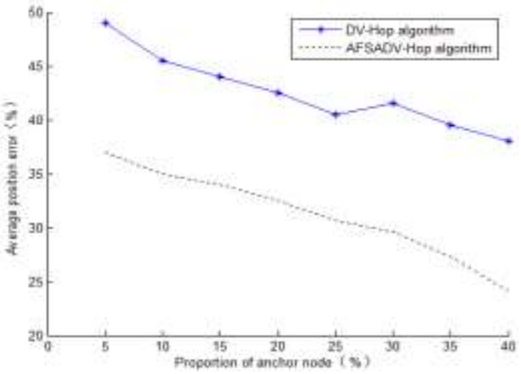

Figure 2 (a): R=15 m

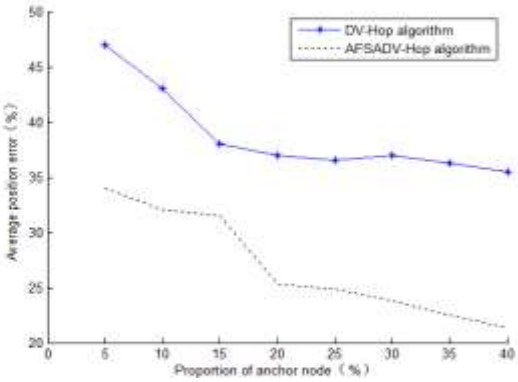

Figure 2 (a): R=20 m

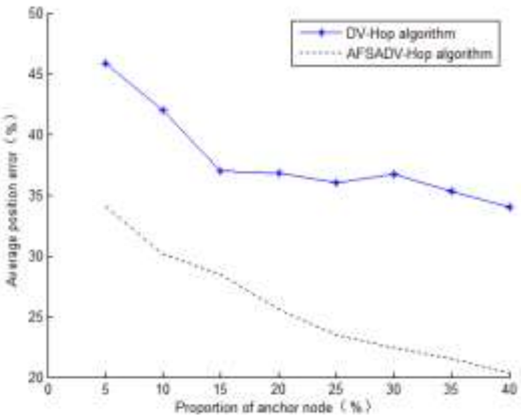

Figure 2 (c): R=25 m

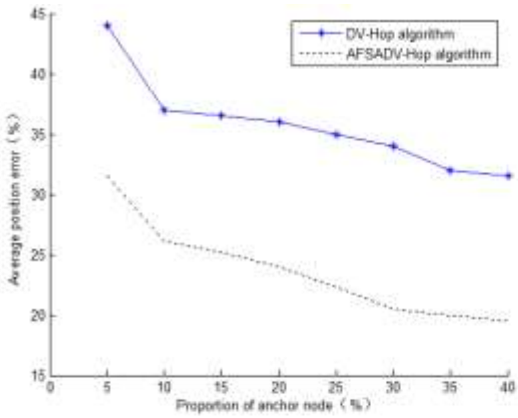

Figure 2 (d): R=30 m

Figure 2 shows that with the increase of the proportion of the anchor nodes, the average positioning error is reduced. In the same communication radius, the ratio of anchor nodes is the same, and the traditional DV-Hop algorithm has large error and the error of $AFSADV-Hop$ is small. Other conditions are the same, the communication radius becomes large, and the positioning error can be reduced. The localization accuracy of $AFSADV-Hop$ than the traditional DV-Hop algorithm is improved by an average of 19.5% ~27%.

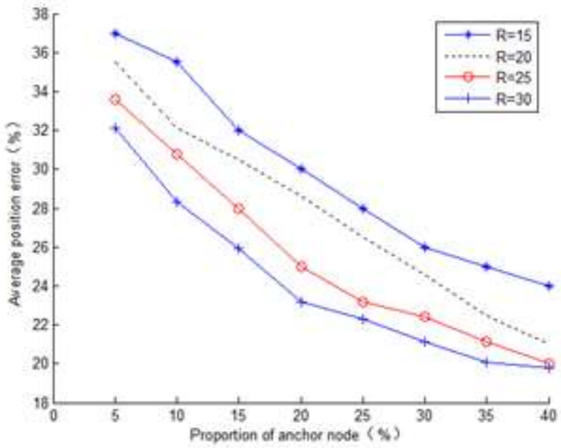

Figure 4: Positioning error of RMDV - Hop in different communication radius

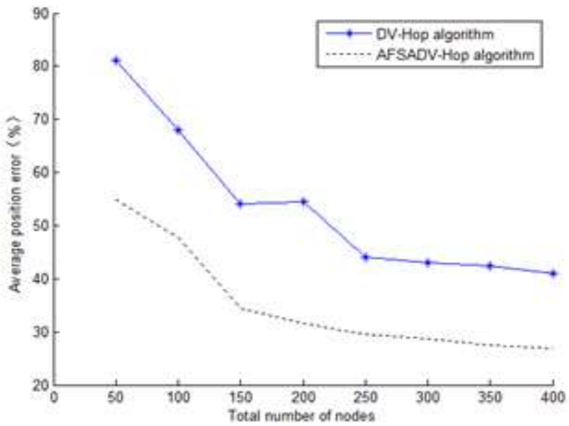

Figure 5: The comparison of the two algorithms

Figure 4 shows that the average positioning error of *AFSADV - Hop* decreases with the increase of the proportion of the anchor nodes in different communication radius. With the increase of the radius of communication, the error of positioning is gradually reduced, and the minimum positioning error is obtained at 30.

The 50 nodes are randomly distributed, the beacon node number remains unchanged, the number of unknown nodes, the communication radius of R=50 m, other conditions do not change, the average positioning error of *AFSADV - Hop* and *DV - Hop*.

Figure 5 shows the results of the comparison of the two algorithms. The positioning error of the two algorithms is reduced with the increase of the number of nodes. The positioning accuracy of the beacon node number is constant when the number of nodes is 300. The accuracy of this algorithm is improved by 15% ~21% compared with the traditional DV-Hop algorithm.

5. Conclusions

Positioning accuracy is one of important performance of evaluating localization algorithm. The DV-Hop localization has a low positioning accuracy as the average distance per hop of anchor node was not optimized after calculating, result in increasing the positioning error. The problem of the positioning error caused by the average hop distance in DV-Hop algorithm is improved. The accuracy of the average hop distance of each hop is improved without increasing the hardware cost. Simulation results show that the improved algorithm can effectively improve the accuracy of the algorithm, and has good stability, good performance of the algorithm, because of the introduction of artificial fish swarm algorithm, and therefore increased the amount of calculation, how to reduce the amount of energy consumption will be done in one step.

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