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Wireless Sensor Networks Coverage Optimization based on Improved AFSA Algorithm

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Abstract

How to best solve the coverage problem has always been a critical issue in wireless sensor networks; this paper focuses on redundant network nodes, short life cycle and other defects and firstly sets nodes utilization and network effective coverage as optimization goals, so as to establish relevant mathematical model, and then introduce the inverse Gaussian mutation algorithms on AFSA, making the improved algorithm to solve the model, and get the optimal coverage scheme for wireless sensor networks. Simulation results show that the improved AFSA can effectively improve the coverage of wireless sensor network nodes, effectively reducing network costs, and the network lifetime has been extended.

Keywords: *wireless sensor networks; coverage optimization; AFSA; inverse Gaussian variation*

1. Introduction

It is not realistic to charge or replace the sensor when wireless sensor networks (wireless sens or net works, WSN) were deployed in the field, and other complex battlefield environment. How, to extend the network lifetime under the pretext of maintaining network coverage has become a critical issue in sensor network research [1].

Currently, many scholars have conducted a number of studies on the WSN coverage problems [2]. Literature [3] proposed a wireless sensor network coverage optimization algorithm based on PSO genetic, through the genetic algorithm by using adaptive crossover and mutation factor to search the solution space, using powerful global search capability of PSO Particle Swarm to increase the search range, making the particles coverage more efficient, strengthening algorithm optimization. Literature [4] proposed the particle swarm algorithm weighting factors used in the AFSA, which to some extent can effectively avoid the algorithm into puberty and accelerate the convergence of the algorithm. Literature [5] proposed a network coverage algorithm based on optimized firefly, established a mathematical model taking networks uniformity and network coverage as criteria, and derived the relationship between the node redundancy and network coverage, and node deployment division into different stages, at each stage, respectively, using the improved algorithm to solve the model fireflies, and then get the best coverage for wireless sensor networks; the simulation results show that the improved algorithm has a more desirable result of the operation, and can effectively give WSNs network coverage optimization solutions. Literature [6] proposed to use a chaotic particle swarm algorithm, by introducing the concept of chaos into particle swarm algorithm so that the algorithm can effectively improve the coverage effect of wireless sensing. The experiments show that it can improve the efficiency of wireless sensor network optimization. Literature [7] proposed to apply ant colony algorithm to the wireless sensor network node optimal coverage problem. It fully uses the advantages of ant colony optimization algorithm, hence the ants will decide which nodes are to be covered based on the use of pheromone and heuristic information, and to establish the model which makes it become a simple linear programming problem. Literature [8] proposed to use the greedy algorithm and geometry science to build normally distributed network model out of the nodes in coverage area. Simulations show that the algorithm can extend the whole network life cycle at a smaller cost, which has a better adaptability and stability. Literature [9] proposed to work with minimal nodes is an effective method of energy conservation. Looking for Minimal Connected Cover Set (MCCS) in the target area is an NP-hard problem; it designed saving algorithms by CVT + MST structured MCCS; through simulation and performance analysis, these energy-efficient algorithm have a low time complexity, and meet the requirements of the node homogeneous environment, hence provide the basis to the research on how to prolong the network lifetime. AFSA (artificial fish swarm algorithm) is a new intelligent bionic algorithm which simulates fish foraging and survival activities; it is a modern heuristic random search algorithm based on animal behavior autonomous body optimization, is not sensitive with the initial value and parameter selection but is robust, simple, easy to implement, *etc*.. Currently the algorithm has been applied to many engineering fields, and has achieved good results. In order to improve the coverage of wireless sensor networks, this paper made some improvements based on the AFSA. Simulation results show that AFSA node can find an optimal node covering WSN solution in a very short period of time, substantially improve the network coverage, reduce energy consumption, and make energy more evenly throughout the network.

2. WSN Coverage Model

2.1 Description of the Problem

In the WSN, for a sensor node, if its perception area can be completely covered by other sensor nodes, then the node is called redundant node; when other nodes are working, this sensor node enters the sleep state. Thus, in the wireless sensor network initialization phase, the number of working nodes and energy consumption need to be considered at the same time, which brings about the conflict between WSN coverage and number of working nodes.

Let the coordinates of WSN node s_i *as* (x_i, y_i), the target area is the two-dimensional rectangular area, hence the detection probability of the node s_i to the target point p(x_p, y_p) is :

$$f_p(s_i, p) = \begin{cases} 1 & d(s_i, p) \le R_s + R_e \\ e^{(\alpha_1^{\beta_1} - \lambda_1)/(\alpha_2^{\beta_2} + \lambda_2))} & d(s_i, p) > R_s - R_e \end{cases} \quad (1)$$

In the formula, R_s and R_c are sensor nodes sensing radius and communication radius; λ_1 、 λ_2 、 β_1 、 β_2 are measured parameters associated with the sensor nodes characteristics ; R_e （$0 < R_e < R_s$） is the sensor nodes measuring reliability parameter; $d(s_i, p)$ is the Euclidean distance between sensor node s_i and the target point s_i ; $\alpha_1 = R_e - R_s + d(s_i, p)$, $\alpha_2 = R_s + R_e - d(s_i, p)$.

2.2 Coverage Model

Redundant network node coverage is defined as:

$$f_1 = \frac{S_{total} - S_1}{S_{total}} \quad (4)$$

Wherein S_{total} is the total number of sensor nodes, S_{total} is the number of effective sensors during operation.

Actual network coverage f_2 is defined as:

$$f_2 = \frac{\sum_i f_p(s_i, p)}{S_{total}} \quad (5)$$

Taking into account the non-sensor networks optimization has a certain relationship with the network coverage consumption, thus we add a Function f_3 related to energy balance coefficient. Therefore, WSN coverage optimization is the sum of redundant node coverage, network actual coverage and the energy balance; if redundant nodes have low coverage, then actual network coverage is high and energy consumption accounts for a large proportion, so making network coverage effectively meet the requirements for practical use, and ensuring redundant nodes in dormant status can save energy consumption. Therefore, WSN coverage optimization objective mathematical model is:

$$f = w_1 f_1 + w_2 f_2 + w_3(1 - f_3) \quad (8)$$

In the formula, w_1, w_2 and w_3 are the weights; $w_1 + w_2 + w_3 = 1$.

In order to find the optimal WSN coverage solution, we mainly try to solve the E(8).

3. The Wireless Sensor Network Coverage Optimization Algorithm

3.1 AFSA

AFSA is an optimization algorithm simulating fish behavior, which overcomes the local extremum deficiencies of other algorithm, using fish foraging, clusters and rear-end behavior to quickly search global optimal solution by fish; the algorithm has a strong adaptive capacity.

(1) Foraging behavior. STEP is the largest mobile step value; *WSUAL* represents sensing distance of artificial fish. Set the current state of artificial fish as X_i, and randomly select a state X_j in in their visible domain; when food concentration of X_j is greater than the current food concentration, one step further, or, select randomly again. If it cannot meet the advancing conditions after repeating several times, then step randomly further. Namely:

$$\begin{cases} x_i(k+1) = x_i(k) + \dfrac{1}{\| x_j - x_i \|}(step)(x_j - x_i) & FC_j > FC_i \\ x_i(k+1) = x_i(k) + (STEP) & FC_j \le FC_i \end{cases} \quad (9)$$

Where, i = 1,2, ..., k; xj, xi are the state vectors; FC_i respectively represents the concentration of the food corresponding to Xi and Xj ; xi (k +1) is the i-th element of Xi (k +1) .

(2) Clusters behavior. In the visible domain of artificial fish, the number of partners is n, the center position of partners is $X_{c.}$. If there indicates more food in partner center, and not too crowded, so move a step forward in the direction partners center; otherwise perform foraging behavior.

(3) Following behavior. X_{max} is the partner with the highest food concentration in the visible gamut; if meet $FC_{\max} > \delta FC_i$, then partner Xmax has highest food concentrations, which could be set as the center position, otherwise perform foraging behavior.

(4) Bulletin board. Bulletin board will be used to record optimum artificial fish individual status and food concentration of its location. Artificial fish will be compared with bulletin board after each action; if it is better than bulletin board, then it will replace the bulletin board state.

(5) Behavioral choices. For different problems, artificial fish will evaluate the environment, and choose the appropriate behavior.

3.2 Two-dimensional Inverse Gaussian Algorithm

Because when AFSA is in initial state, the individual artificial fish has no initialized, this has led it unable to obtain a more precise location in the feeding stage. We use a two-dimensional Gaussian distribution function in foraging stage (PDF):

$$g(x,y)=e^{-\left(\frac{(x-\overline{\mu_x})^2}{\sigma_x{}^2}+\frac{(y-\overline{\mu_y})^2}{\sigma_y{}^2}\right)} \quad (10)$$

In Equation (10), σ_x and σ_y are the standard differences on the x and y axes, μ_x and μ_y are the means on x and y axis. Therefore, two-dimensional Gaussian distribution $g(x,y)$ can be rewritten as:

$$g(x,y)=e^{-\left(\frac{(x+y)^2}{2\sigma^2}\right)} \quad (11)$$

In this paper, we introduce the factor $\frac{4}{\pi\sigma^2}$ for scaling the two-dimensional Gaussian distribution of PDF, and then get:

$$g(x,y)=\frac{4e^{-\left(\frac{(x+y)^2}{2\sigma^2}\right)}}{\pi\sigma^2} \quad (12)$$

Two-dimensional inverse Gaussian must meet the conditions: cover the cumulative probability as 1. Assuming area sensor network coverage radius as R, the inverse Gaussian cumulative probability distribution is:

$$F(x,y)=\iint\frac{4e^{-\left(\frac{(x+y)^2}{2\sigma^2}\right)}}{\pi\sigma^2}dxdy \quad (13)$$

3.3 WSN Coverage Optimization Steps based on Improved AFSF

Step 1: initialize wireless sensor networks. According to the size of the network to set the artificial fish population size N, the largest artificial fish moving step as STEP, visual field of artificial fish as VISUAL , the maximum number of iterations as number, crowding factor δ and safety factor.

Step 2: Initialize fish. Within the feasible region, to randomly generate N artificial fish individuals, while setting the initial iterations num = 0.

Step 3: after inverse Gaussian distribution on initial individual fish location, calculate the value of food concentration (FC), and then sort them, choose the individual with maximum FC for entering the artificial fish bulletin board.

Step 4: perform simulations of artificial fish rear-end and fish swarming behavior;

select the individual with maximum FC as foraging behavior.

Step 5: when artificial fish are moving, compare their current position food concentration FC with FC bulletin board artificial fish; if it is greater than the value of the FC on the bulletin board, and replace the value on the bulletin boar

Step 6: judge the ending conditions. If it reaches the biggest evolution algebra, output value of FC bulletin board, that is the best solution WSN coverage, otherwise num + = 1, turn Step 4.

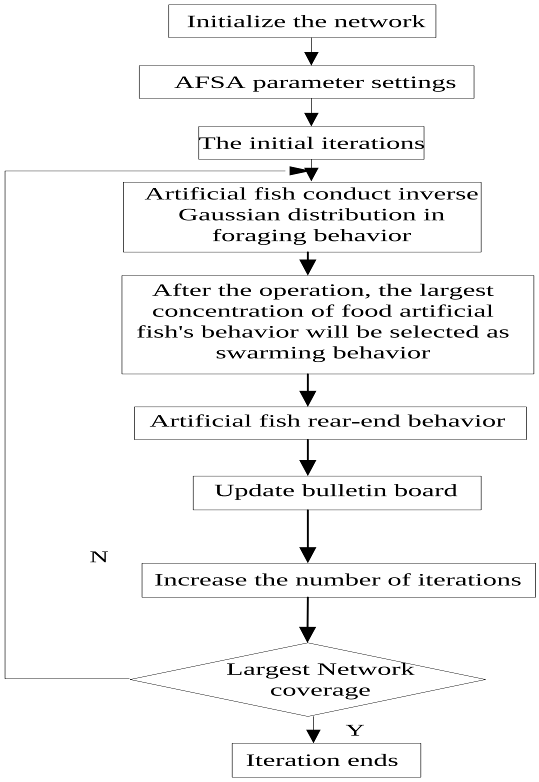

Figure 1. WSN Node Coverage Optimization Process

4. Simulation

4.1 Simulation Environment

Set a wireless sensor network monitoring, and its size is 100m × 100m square area; set sensor nodes sensing radius as 2.0m, communication radius C = 4m, set each sensor node energy as 0.25J, the number of iterations as 200 times; through simulation in Matlab 2012 platform through , wireless sensor network nodes randomly distribute monitoring area, specifically shown in Figure 2.

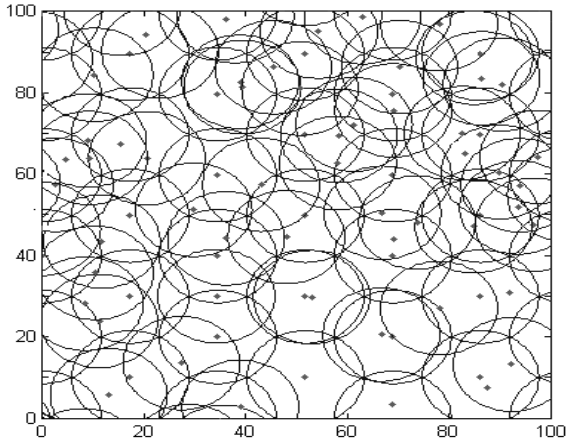

Figure 2. Distribution of Sensor Nodes

4.2 Results and Analysis

4.2.1 The Proposed Algorithm and other Algorithms Optimal Coverage Scheme

Using AFSA to solve sensor nodes coverage scheme as shown in Figure 2, and finally get wireless sensor nodes coverage results shown in Figure 3. According to Figure 3, compare with algorithm in literature references [5, 7], the proposed algorithm significantly improved in terms of the node utilization, achieve a good WSN node coverage optimization goals. Simulation results show that AFSA in this paper is an effective WSN nodes coverage optimization method that can improve the wireless sensor network coverage optimization rate.

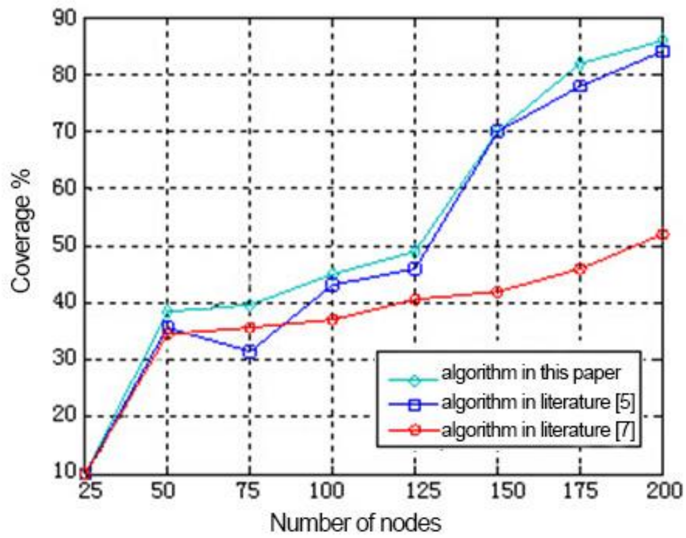

Figure 3. AFSA Optimal Solution Node Coverage

4.2.2 Comparison with other Algorithms in Terms of Transmission Loss Rate

To illustrate the superiority of AFSA for WSN coverage optimization problem, in the same simulation environment, we conduct comparison experiments with the algorithm in literature [4, 6], and comparing results are shown in Figure 4.

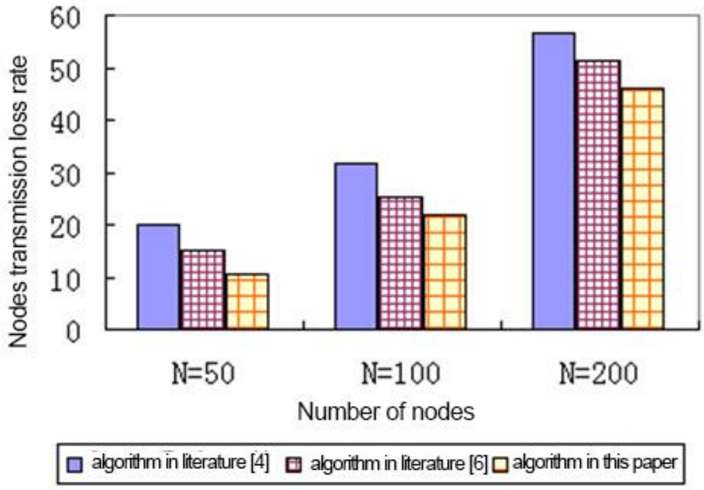

Figure 4. Nodes Transmission Loss Rate of Different Algorithms

Figure 4 shows that the algorithm of this paper and the algorithm in literature [4] and [6]: when the number of nodes increased gradually, he algorithm of this paper has the lowest node transmission loss rate; but in all the network coverage optimization algorithm, AFSA has better and more efficient implementation of the global optimization of wireless sensor network layout: it is possible to maintain high network coverage in a long time, keep the network energy balance, and extend the network lifetime with a broader scope.

4.2.3 The Task Completion Time Comparison between the Proposed Algorithm and Other Algorithms

Wireless sensor network nodes covering completion time is an important part to test wireless sensor network; this paper has compared the proposed algorithm with the literature [8, 9] algorithm as shown in Figure 5:

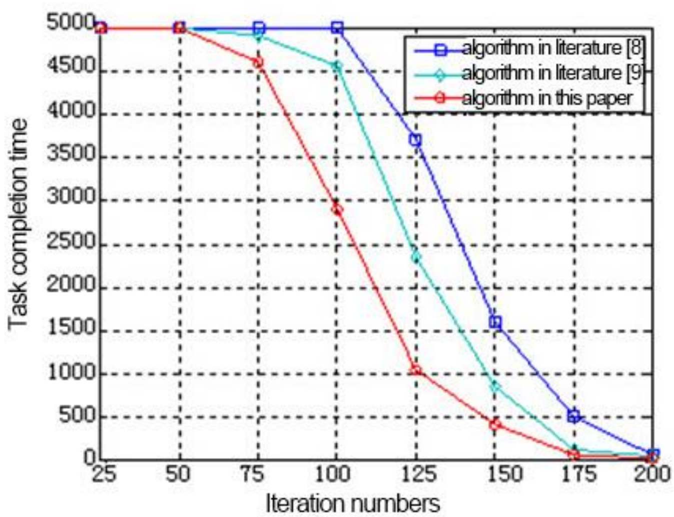

Figure 5 Task Completion Time of Different Algorithms

From Figure 5 it can be found that the algorithm of this paper under the same conditions is better than two algorithms in the literature [8, 9], which indicates to a certain extent, this algorithm uses inverse Gaussian mutation algorithm for a good optimization, which can effectively guarantee the life time of the network.

5. Conclusion

Wireless sensor network coverage is one of the key issues of sensor networks. To get a better perception of service, control node density, reduce energy consumption, the paper proposed WSN coverage optimization approach based on an improved artificial fish swarm algorithm. Simulation results show that AFSA use a little working node to get higher network coverage and extend the network life cycle, and energy consumption of the entire network is balanced. It provides a new method for WSN coverage optimization. In practical applications, how to better optimize foraging, clusters and rear-end behaviors in order to make computing easier, enable wireless sensor network coverage have better performance still need further research.

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