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Study on Location of Wireless Sensor Network Node in Forest Environment

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Abstract

Because of the extensity and complexity in forest environment, the question about how to locate wireless sensor network node in monitoring on forest environment become the most important focus in wisdom forest built project. In present study, the main consideration is the complexity of the forest environment and energy consumption in the transmission of wireless sensor data. The purpose is to do the widest area which wireless sensor networks can maximize coverage. The method of Particle swarm optimization(PSO) was used to get the results of location of wireless sensor network node in Forest environment. Simulation results showed that it is useful to use Particle swarm optimization(PSO) which can get optimum solution on wireless sensor network employed. PSO algorithm to solve the problem of wireless sensor network deployment is feasible.

Keywords: forest environment； Wireless sensor networks; location; Particle Swarm Optimization

1. Introduction

In the forest environment, the factors such as tree species, canopy density, structure, age,forest grass, shrub layer characteristics have a great impact on the forest environment. It also provides a theoretical basis for the forest fire, silviculture work. Observations of forest ecological environment are generally using parallel observation, comparison observation, mobile observation and gradient observation and so on. But, data collect about Forest Ecology Environment is a big difficult thing due to the complexity of the forest environment and climate. Existing forest ecological monitoring methods are not able to achieve a good and details monitoring on forest ecological environment. It has been an urgent problem in forest management which is how to do this dynamic, every-time monitoring to detect within a small area of forest ecological environment. In present study, Wireless sensor networks were used to analyze. Using a large spread over wireless sensor nodes in forest area can do real-time

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sensing, collecting and monitoring the data of temperature and humidity inside the forest, PM2.5, negative oxygen ions, wind speed, wind direction and other data. Realization of monitoring on the forest ecological environment can be implemented.

2. Problem Analysis and Design of Wireless Sensor Location in Forest Environment

2.1 Monitoring Characteristics of Wireless Sensor in Forest Environment

When using wireless sensors to achieve information transmission in certain area, there is close ties between the design of Wireless sensor network and the application environment[1]. Wireless sensor nodes need to complete the collection, processing and transmission of forest environmental data in the wireless sensor monitoring system for forest environment. Data collected includes humidity nodes surrounding, light intensity, temperature, wind and rainfall. Then the data would be sent to the data processing center the data with the characteristics of wireless sensor after the appropriate treatment on data.

Generally, Forest environment and the ecological environment has the following characteristics: ① forest spatial span. Forest area is one hundred thousand hectares of the general number; ② harsh Forest environment; ③ forest environment are generally stable. The collected data redundancy and correlation are high.

Due to the special nature of the forest environment, It makes wireless sensor solutions has the following characteristics for environmental monitoring: ① a large number of wireless sensor nodes; ② large forest area. Wireless sensor nodes are generally battery powered. Battery power is limited; ③hops of data transmission in wireless sensor nodes gather are more.

2.2 Location Analysis and Design of Wireless Sensor in Forest Environment

There is large number of wireless sensor nodes in Forest ecological environment monitoring process. Most of them are battery-powered. The multi-hops are need in the data transmission of each node. Because of this, it must be a reasonable location in the process of laying the wireless sensor node[2]. Well-designed data transmission routing strategy is need to reduce the number of wireless sensor nodes while minimizing the number of nodes involved in data transmission. Energy consumption of Wireless sensors can be saved.

In particular, location of forest environment wireless sensor nodes need to focus on the following aspects: ①according to the actual situation of forest environment to achieve data collection of a variety ecological forest types; ② take reasonable location strategy. Reduce the number of wireless sensor nodes laid as much as possible; ③ selecting appropriate data transmission strategy. Reduce the hops number of data transmission. Energy of wireless sensor can be saved.

According to the characteristics of the forest environment and wireless sensor networks, the overall structural design of forest wireless sensor networks as follows:

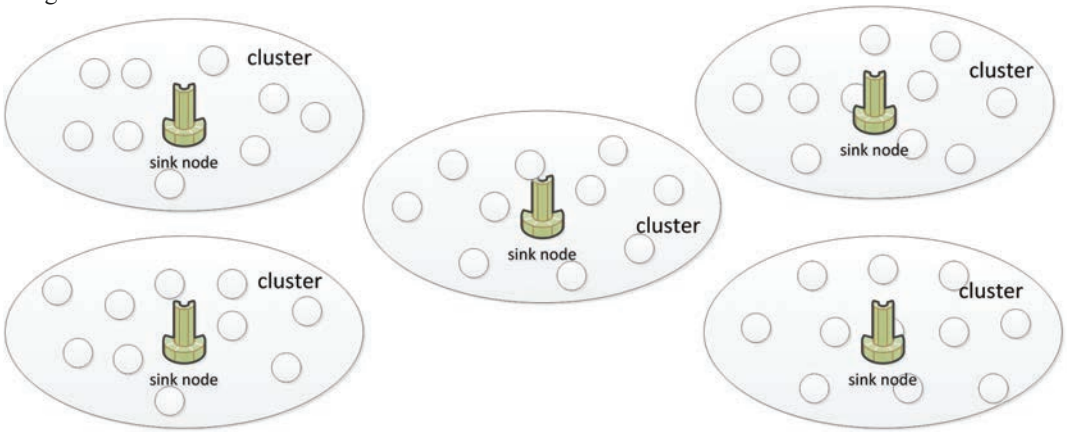

Figure 1 general structure of wireless sensor networks in forest environment

As can be seen from the Figure 1, because of the forest environment have a greater influence on the communication distance of wireless sensors, the location of wireless sensors nodes are different in different areas. It is necessary to change with specific geographical, vegetation, climate of environment forest and so on. convergent node in wireless sensor network should sent climate information which collected by wireless sensor nodes in its area to the data center with network cable or satellite communications technology. In present study, the location optimization of wireless nodes within each cluster was studied.

3. Design of Location Optimization Model of Wireless Sensor in Forest Environment

Because of the complexity of the forest environment have a greater impact to the communication distance of wireless sensor node[3], it is necessary to optimization of wireless sensor networks based on the actual site conditions in the wireless sensor location process in forest environment. The requirements of environmental data collection for Forest ecological environment can be implemented.

3.1 Description of Location Optimization Model

Through the above analysis on wireless sensor network in forest environment, we can see the deployment of wireless sensor network node is essentially a problem of optimization problem[4]. Based on this, it needs to design a suitable mathematical model change forest wireless sensor network deployment optimization problem into a two-dimensional space question. We need to establish the following hypothesis in establishing wireless sensor network deployment optimization model forest environment.

Hypothesis 1: All nodes have the same transmit power in the same environment. Data transmission radius r of all wireless sensor nodes are not the same.

Hypothesis 2: within the monitored area. Transmission radius r_n in region p of one wireless sensor node should be different affected by the environment surrounding. Generally, $r_n < r$.

Hypothesis 3: when layout wireless sensor nodes within the forest area. Transmission radius r_n of Wireless sensor nodes at any point in the region is known.

Hypothesis 4: wireless sensor enables 360 ° omni-directional detection. According to the data transmission radius r_k. Detection area range of wireless sensor node is $D = \pi r_k^2$.

Hypothesis 5: Based on the above hypothesises, we can adjust the transmission radius r_n of wireless sensors in the region point p. The three-dimensional spatial mapping of forest changed to a continuous two-dimensional plane Γ. And wireless sensor nodes can be deployed any place in the two-dimensional plane Γ. For analytical purposes, two-dimensional plane Γ can divided into a discrete matrix D based on equidistant λ. The corresponding d_{ij} in matrix D is equal the point $(i \times \lambda, j \times \lambda)$ on the two-dimensional. Wireless sensor nodes can be deployed only on a two-dimensional plane in the matrix D it represents.

3.2 Location Optimization Model Construction

First make the following definition in the Location Optimization Model:

Definition 1: A monitoring forest area defining as a two-dimensional continuous space as follows:
$Z^2 = \{(x, y), 0 \le x \le a, 0 \le y \le a\}$

Definition 2: set of monitoring wireless sensor node in Forest environmental: $\Omega = \{T_1, T_2, \cdots, T_k, \cdots, T_n\}$

Definition 3: The distance between two nodes: $d_{kh} = \sqrt{(x_k - x_h)^2 + (y_k - y_h)^2}$

Definition 4: The shortest path hops L_k of a wireless sensor node T_k to the sink node are the data transmission distance of wireless sensor node T_k.

Definition 5: deployment point of wireless sensors T_k which deployed in coordinate p_1 defined as $T_{k\,p}$.

Definition 6: $T_{k\,p_1} \to T_h$ defined as the distance between the wireless sensor node $T_{k\,p_1}$ deployed in the coordinate p_1 and wireless sensor node T_h is less than r_n.the wireless sensor node $T_{k\,p_1}$ can contribute to the wireless sensor node T_h.

Definition 7: the sum effectively cover area of all wireless sensor nodes (region of overlap are counted once. the covering area of wireless sensor node which unable to transmit data to aggregation nodes is 0) . it is defined as the coverage area S of wireless sensor networks Ω.

Constraints: (1) Number constraint of a set of wireless sensor; (2) shortest path hops constraints from the wireless sensor node to T_k the convergent node.

The final wireless sensor network optimization model for forest environment can be expressed as: using a certain number of wireless sensors, and the determining premise of maximum hop count of data transmission in wireless sensor, it makes wireless sensor set covered area S of forest is the largest.

4. Analyze on Location of Wireless Sensor Network Node Based on Particle Swarm Optimization

Deployment optimization model of the wireless sensor network nodes is established previously which make Wireless sensor node deployment problem change to an optimization problem. Currently, there are many methods to solve the optimization problem. Particle swarm optimization is a simple, effective optimization tool[5]. In present study, Particle swarm optimization was used to solve optimization problems on deployment wireless sensor networks in forest.

4.1 Introduction of Particle Swarm Optimization(PSO)

Particle swarm optimization is inspired by the group behavior of birds. It is an optimization technologies based on swarm intelligence algorithm. In particle swarm optimization, all the birds do not know where the food is located in the initial state. So what is optimal strategy in find food for birds? The most simple and effective way is to search the surrounding area of the bird which nearest the food. Particle swarm optimization is inspired by such biological behavioral characteristics and for solving optimization problems[6].

Individual is as a certain speed flight particles which no size and no weight in Particle swarm optimization. Individual speed will be adjusted according to experience during the flight[7]. In initialization process of Particle swarm optimization. We need to set the following data structure: ① $X_i = \left(x_{i1}, x_{i2}, \cdots, x_{in}\right)$. It indicates the current position of the particles in the particle group; $V_i = \left(v_{i1}, v_{i2}, \cdots, v_{in}\right)$ indicates speed of the particles in the each dimension of space. $P_i = \left(p_{i1}, p_{i2}, \cdots, p_{in}\right)$ represents the best location for the fitness value of particles going through. P_g is best location one Particles can be obtained in the entire particle group. PSO evolution equation is:

$$v_{ij}\left(t+1\right) = v_{ij}\left(t\right) + c_1 r_{1j}\left(t\right)\left(p_{ij}\left(t\right) - x_{ij}\left(t\right)\right) + c_2 r_{2j}\left(t\right)\left(p_{gj}\left(t\right) - x_{ij}\left(t\right)\right) \quad (1)$$

$$x_{ij}\left(t+1\right) = x_{ij}\left(t\right) + v_{ij}\left(t+1\right) \quad (2)$$

In them, j defined as dimension serial number of the search space. i is particle. t is the first iteration. c_1 and c_2 are accelerate constant. r_1 and r_2 are independent random function.

When using Particle swarm optimization to solve the optimization model, setting $f\left(x\right)$ as the minimize objective function. P_i is the best adaptation value position which particle i experienced. The determine function of best position to the particle i experienced is as follows:

$$P_i\left(t+1\right) = \begin{cases} P_i\left(t\right) & if \quad f\left(x_i\left(t+1\right)\right) \geq f\left(P_i\left(t\right)\right) \\ X_i\left(t+1\right) & else \end{cases} \quad (3)$$

In the last, best location $P_g\left(t\right)$ of all particles in Particle swarm optimization are defined as area best position which is as follows:

$$P_g\left(t\right) \in \left\{P_0\left(t\right), P_1\left(t\right), \cdots, P_m\left(t\right)\right\} \mid f\left(P_g\left(t\right)\right) = \min\left\{f\left(P_0\left(t\right)\right), f\left(P_1\left(t\right)\right), \cdots, f\left(P_m\left(t\right)\right)\right\} \quad (4)$$

Design of Particle swarm optimization process is as follows[8]:

① initialization. Including the initialization of particulate collection, initial position and initial velocity of each particle is initialized. Fitness function $f\left(x_i\right)$ of particle is initialization.

② calculated particle fitness value $f\left(x_i\right)$;

③current location of one particle should be compare with the best location experienced. If the current location is better than P_i. Then the current location is setting as P_i.

④current location of one particle should be compare with the area best location P_g. If the current location is better than P_g, the current location is set to be as area best location.

⑤ check does P_g less than a preset value, or whether the number of iterations is a preset maximum number of iterations. If it is, Iteration is terminated. The group as a area optimal solution to output. Otherwise ⑥ can be process.

⑥ update the location and velocity of a particle by the equation (1) and Equation (2). And checks whether particles out of range. If it is out of range, then the current location is as the particle boundary value. And go to step ②. You should to plus a number of iterations and to the next one iteration.

4.2 Problem Solving Model Design

Using Particle swarm optimization to solve problem of location optimization of wireless sensor networks in forest environment, the wireless sensor network data transmission hops is less than or equal to 10 as a constraint condition, Wireless sensor networks coverage optimization problem as the location optimization target. Wireless sensor networks location in forest environment turn into an optimization problem. There are four stages in problem solve process which using PSO algorithm to deployment optimization problem solving in forest environment for wireless sensor network.

(1) initialize particle location

According to above hypothesis, The forest environment space is mapped to a flat two-dimensional space Γ. Algorithm search space is $N=2$ dimensions. Let number of Wireless sensor nodes in each region of space is n. set of Wireless sensor nodes is $\Omega=\{T_1,T_2,\cdots,T_k,\cdots T_n\}$. Setting initial location of i wireless sensor $(x_i,y_i)\in\Gamma$.

(2) adjusting the node location

In the particle swarm algorithm, each wireless sensor nodes are required to calculate the next move location depending on the target of location optimization model. Because of the different locations have an impact on the coverage area radius of wireless sensors in the two-dimensional space Γ. In order to effectively control the distance of each mobile wireless sensor nodes, we proposed a method to adjust the location of the nodes in present research.

First, the coverage radius node matrix D of sensor nodes in different locations was set within a two-dimensional space Γ.

$$D=\begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{m1} & \cdots & d_{mn} \end{bmatrix}$$

Element d_{ij} in Matrix D is transmission radius of wireless sensor which the location of wireless sensor is $(i\times\lambda, j\times\lambda)\in\Gamma$. For any wireless sensor node T_k, you should find out its nearest node T_h. Assuming that the error between desired position $P_{\sigma,}$ of the wireless sensor nodes T_k and the current location $P_{T,}$ is $e_k=(P_{\sigma,}-P_{T,})$. To reduce errors and improve the convergence rate of Particle Swarm the error signal function was used as process speed of wireless sensor nodes. Trends of wireless sensor eventually be deployed to the desired location. Let $V_k=\alpha e_k, V_h=\alpha e_h$. The iterative formula of deployment location and speed of wireless sensor node is designed as follows.

$$V_k(t+1)=\alpha\left(P_{g_k}-P_{T_k}\right) \quad (6)$$

$$X_k(t+1)=X_k(t)+V_k(t+1) \quad (7)$$

To prevent overshoot problem in location adjustment range of wireless sensor is too large, maximum moving speed of wireless sensor nodes was set. Equation changed as follows.

$$V_k\left(t+1\right)=\begin{cases}\alpha\left(P_{g_k}-P_{T_k}\right) & if\ V_k\left(t+1\right)\le V_{\max}\\ V_{\max} & else\end{cases} \tag{8}$$

(3) location and velocity update

Each wireless sensor nodes based on population history best location P_g and own best location before to update the velocity and location of the iteration. In iterative process, iterative formula of velocity and location of wireless sensor nodes is as follows:

$$v_{ij}\left(t+1\right)=v_{ij}\left(t\right)+c_1r_{1j}\left(t\right)\left(p_{ij}\left(t\right)-x_{ij}\left(t\right)\right)+c_2r_{2j}\left(t\right)\left(p_{gj}\left(t\right)-x_{ij}\left(t\right)\right) \tag{9}$$

$$x_{ij}\left(t+1\right)=x_{ij}\left(t\right)+v_{ij}\left(t+1\right) \tag{10}$$

(4) Fitness Function

In the particle swarm algorithm, fitness function of wireless sensors can direct impact convergence speed of PSO algorithm and whether can find the optimal solution. Therefore, it is necessary to determine the fitness function according to the optimization goal. In the wireless sensor networks location optimization problem in forest environment, Optimization goal of wireless sensor networks is cover the largest area. So fitness function join the formula is:

$$f\left(X_i\right)=S_i \tag{11}$$

As shown above, in the forest environment, the methods of wireless sensor location optimization problem solving based on particle swarm algorithm can be summarized as follows: according to the location information of wireless sensor nodes, construct a optimization functions which contain a set Ω of each wireless sensor node location information. When the number of iterations exceeds the maximum number of iterations, or optimization function value better than a preset value, the iteration is end. Maximum variable value of optimization function f value is the node location of wireless sensor network.

4.3 Experimental Analyze on Location Problem

The MATLAB simulation software was used to design simulation experiments to verify the feasibility of the proposed solutions on the problem of wireless sensor location under forest environment which is solved by the particle swarm algorithm.

Setting forest area Γ is 100m × 100m. The sink note locate in the center of Γ. Step length $\lambda=1m$. So the continuous space Γ changed into a discrete interval which can represent by a 100 × 100 matrix D. One random number from the set $\{8,9,10\}$ was chosen as data transmission radius of the wireless sensors location in forest area Γ which represent in one element from matrix D. 20 sensors placed in the forest area. The number of data transmission hops sensor is set to not more than 5 steps. PSO algorithm to solve the maximum range of 20 sensors can cover.

Result of using particle swarm optimization shown in Figure 2:

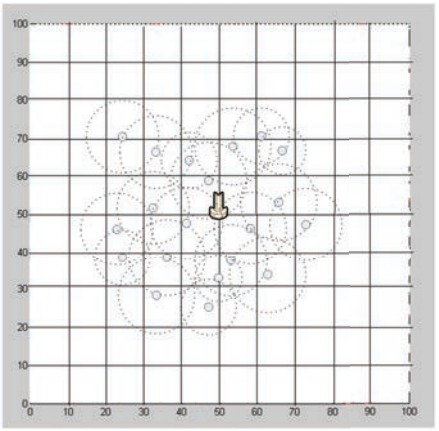

Figure 2 result of optimization solving

The final covering is 2994.32 square meters area. The average hops number of a wireless network node data transmission is 2.5. Changes of coverage area on each iteration shown in Figure 3.

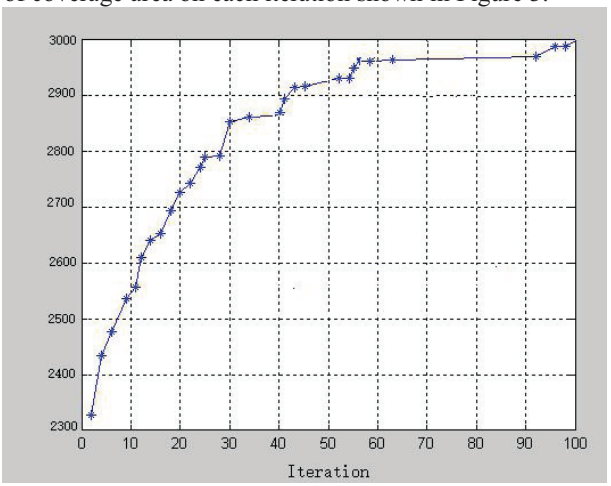

Figure 3 relationship between iterative times and coverage area change

As can be seen in Figure 3, the converge speed of particle swarm optimization algorithm is very fast when using it to solve the optimization problem of wireless network location in forest environment. When the iterative is to 60 times, the results is close the best answer. At last, it get the best answer in 100 iterations. The answer is 2994.32 square meters which is very close with 3000 square meters a preset iteration termination condition. This indicated that it is feasibility to use particle swarm optimization algorithm solve the location of wireless sensor network optimization problem.

5. Conclusion

In present study, PSO was used to analyze location problem of wireless sensor network node in forest environmental characteristics. The energy consumption in wireless sensor data transmission was considered. The best design of wireless sensor network covers largest area with fixed wireless sensor through iteration and o ptimization ultimately. Simulation results show that it is feasibility to use particle swarm optimization algorithm solve the location of wireless sensor network optimization problem.

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