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Virtual Force Coverage Enhancement Optimization Algorithm Based on Node Energy Balance in Wireless Sensor Networks

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ABSTRACT

In this paper, a virtual force coverage enhancement algorithm based on node energy balance is proposed. Through the virtual force between node and node and the target region between mobile node positions, nodes in the network finally a rational distribution and uniform, and improve the network coverage performance, with a minimum of sensor nodes to maximize the coverage area. Reducing the monitoring blind area had in wireless sensor networks, reducing the cost of the network. Finally, the feasibility of the algorithm is verified by the experimental data.

Key words: WSN; virtual force; coverage; energy

INTRODUCTION

Wireless sensor networks (WSN) [1-2] is an open network formed by a large number of sensor nodes, which are characterized by their ability to perceive, compute, communicate and store. Widely used in national defense military, intelligent transportation, medical and health, and environmental monitoring and intelligent home and other engineering fields [3-5].

Coverage problem is a basic problem in wireless sensor network research, and it is also the core problem [6-8]. In WSN, the target area is covered is directly related to the overall performance of sensor networks, the network is able to accurately and efficiently complete the task has a critical influence. In order to improve the network's overall coverage, reduce the number of sensor nodes in the network, usually need to target the coverage area of in-depth study, the node layout more reasonable [9-11]. In recent years, with the progress of science and technology, the development of mobile robots technology promotes the emergence of mobile sensor nodes, makes the target coverage area in randomly deployed sensor nodes according to the actual situation of heavy deployment was made possible, this new technology will also with the emergence of mobile sensor nodes and become a hot issue.

Therefore, how to use the least sensor nodes to complete the coverage and connectivity of the designated area and to restrain the excessive energy consumption of nodes is a challenging problem. This paper draws on the research idea of virtual force. According to the different direction of energy consumption of nodes in the application, the wireless sensor coverage problem is studied by using the node's energy consumption as the target instead of the moving distance.

PROBLEM DEFINITION AND NETWORK MODEL

Definition 1: the distance between any two nodes called $d\left(s_i, s_j\right)$ node S_i and S_j Euclidean distance, when $d\left(s_i, s_j\right) < 2R$, R is the radius of node sensing, called S_i and S_j node to the neighbor node.

Definition 2: coverage

$$p(s_i, s_j) = \begin{cases} 0, R_s \le d(s_i, s_j) \\ 1, R_s - R_e \ge d(s_i, s_j) \end{cases} \quad (1)$$

In R_s representation for a node's sensing radius, R_e represents the dynamic parameters monitoring sensor node, where $d = d\left(s_i, s_j\right) - \left(R_s - \mathrm{R_e}\right)$, $d\left(s_i, s_j\right)$ is the Euclidean distance between sensor nodes; when $d\left(s_i, s_j\right) \le \left(R_s - R_e\right)$, s_i node is detected, otherwise, is not detected [5-8].

Definition 3: The moving distance of the sensor node energy consumption of the mobile and sensor nodes are closely related, we assume that the energy consumption of the sensor nodes to mobile unit distance, sensor nodes in coverage in the process of energy consumption can use formula (2) to say:

$$E(s_i) = d_i \times E_p \quad (2)$$

Among them, d_i is the moving distance of the node s_i in the process of covering.

Objectives of the algorithm is to make wireless sensor network to meet the heavy conditions of connectivity, energy consumption minimization, equalization of nodes in a sensor network, maximize the wireless sensor network's overall coverage.

COVERING ALGORITHM BASED ON VIRTUAL FORCE

Stress analysis of node

In the experiment, using mathematical methods to the virtual force into moving distance and add energy factors. Wireless sensor networks in the initial random deployment, some nodes may are arranged in the far distance monitoring point position, even is arranged on the outside of the whole monitoring area, in order to make the random deployment of sensor nodes can be deployed in the target coverage area of internal and need to in the target area arranged to attract the source, provide attractive to the surrounding nodes [12-14].

Assuming that the center of the target coverage area is the target coverage, we regard it as an attractive source of the target area, and it plays a role of attraction to the randomly deployed wireless sensor network nodes. In addition, sensor node and the target area center distance farther, by the center of attraction is greater, this can remote sensor nodes faster into the target within the coverage area and improve the algorithm's efficiency. This paper uses Hooke's law to simulate the target region of attraction. Hooke's law stipulates: the spring and the spring is proportional to the change of shape. Similar goals covering the region of attraction and node and a regional center distance proportional to, according to Hooke's law formula $\overline{F} = -k\overline{x}$, we define target coverage regional center of any sensor node attraction [9-10]:

$$\overline{F_a(s_i)} = -k_a \overline{d(o, s_i)} \quad (3)$$

Among them, k_a is the target area center attraction coefficient, Euclidean distance is $d(o, s_i)$. Obviously, the regional center of attraction $F_a(s_i)$ direction is determined by the sensor node s_i points to the target area center.

This paper studies the target coverage area grid division; each grid center provides attractive target area to its peripheral nodes. But if only the target area center attraction, then all the sensor nodes will converge to the target area center, the entire network covers only to a central point, no practical significance. Therefore, in order to balance the regional center of attraction cover so that nodes can be in force balance of the stationary state, we introduce the repulsion between neighbor nodes, in order to enable the network to uniform coverage.

The introduction of the neighbor node repulsion between the role is to ensure that sensor nodes can force balance, the coverage area of adjacent nodes not excessive overlap. Ensure that the adjacent sensor nodes to achieve the optimal distance, improve the network coverage. Assume that when the distance between adjacent sensor nodes is less than the best distance, it will produce the corresponding repulsive force greater than the optimum distance, there is no such repulsion. For the deployment of wireless sensor networks, sensor nodes to maximize the network coverage at least are the ultimate purpose. In order to meet the above conditions, when the sensor node distance between the hours and by the repulsion should be more, such ability and the smaller the distance and the value center of the target area more attractive to maintain the state of equilibrium, the repulsion between the repulsion and same-sex charged particles are very similar. According to the formula of Coulomb's law, the repulsive force between the single hop neighbors can be obtained as follows:

$$\overline{Fr(s_i, sj)} = \begin{cases} k_b \overline{(1/d_{ij}^2 - 1/d_{opt}^2)}, 0 < d_{ij} < d_{opt} \\ 0, d_{ij} > d_{opt} \end{cases} \quad (4)$$

When the distance between nodes is less than the best distance d_{opt}, it will produce a corresponding repulsive force. This repulsion with the distance between nodes increases exponentially, until the distance between the nodes is larger than the optimal distance d_{opt}, the repulsive force disappears. In line with the actual situation, we define the optimal distance between adjacent nodes is:

$$d_{opt} = \begin{cases} \min(R, 2r_i), C_{\lim}(A) < 1 \\ \min(R, \sqrt{3}r_i), C_{\lim}(A) = 1 \end{cases} \quad (5)$$

Cover the area, become useless nodes, resulting in waste of resources, affect the performance of the network. Therefore, we must take some measures to ensure that the sensor nodes in the target coverage area will not move the target coverage area. The concept of boundary repulsion is introduced. Through the comprehensive effect of the three forces, sensor nodes are randomly deployed in the region to the best position to the target mobile coverage.

Energy is a basic problem in wireless sensor networks, sensor networks, should try to reduce and balance the network energy consumption and maximize the lifetime of the sensor network. The residual energy of nodes and friction combination put forward the concept of mobile node friction. Friction formula for mobile sensor nodes:

$$F_c = 1/(\mu E_i), F_s \neq 0 \quad (6)$$

Among them, μ is the coefficient of friction, E_i is the residual energy of the sensor nodes, F_c is the sensor nodes are subject to the joint force in addition to friction. Seen from the above formula, when the friction of mobile sensor nodes and node's residual energy is inversely proportional, so that when the residual energy of the nodes is small, received from the sensor node friction is large, it is difficult to move, reduce the mobile sensor nodes, energy consumption will be reduced. In this way, the balance of the residual energy of the entire sensor network is guaranteed, and the network lifetime is prolonged.

It force sensor nodes, but also do not know how the role of sensor nodes in these mobile forces. After the formation of the network, the wireless sensor network nodes are randomly deployed, not all nodes are not in the target coverage area. When the node coverage area within the target, the use of four kinds of virtual force can ensure that the sensor nodes as much as possible to achieve the best position. And when the nodes in the target coverage area outside, in order to make the external node can faster into the target coverage area, improve the network performance; we assume that at this time all external nodes only by the target coverage of regional center of attraction. The sensor node is expected to:

$$\overline{F(si)} = \begin{cases} \overline{F_a(s_i)} + \overline{F_r(s_i)} + \overline{F_b(s_i)} + \overline{F_c(s_i)}, s_i \in S \\ \overline{F_a(s_i)}, s_i \notin S \end{cases} \quad (7)$$

S represents a collection of sensor nodes in the target coverage area. The stress analysis and the nature of the tangent function of the sensor nodes are integrated, and the formula for the single step distance of the sensor nodes is as follows:

$$d(s_i) = \arctan(\left|\overline{F(s_i)}\right|) \times \frac{2}{\pi} \times d_{\max} \quad (8)$$

The direction of movement of the node is the direction of the joint force. Each sensor node according to the virtual force to move to a new position, and update the coordinates (x, y) for the new coordinate (x', y'), the following formula:

$$x' = \begin{cases} x + \dfrac{F_x}{F_{xy}} \times \arctan(\left|\overline{F(s_i)}\right|) \times \dfrac{2}{\pi} \times d_{\max}, F_c \geq F_{th} \cap F(s_i) \neq 0 \\ x, F_c < F_{th} \cup F(s_i) = 0 \end{cases}$$
$$y' = \begin{cases} y + \dfrac{F_y}{F_{xy}} \times \arctan(\left|\overline{F(s_i)}\right|) \times \dfrac{2}{\pi} \times d_{\max}, F_c \geq F_{th} \cap F(s_i) \neq 0 \\ y, F_c < F_{th} \cup F(s_i) = 0 \end{cases} \tag{9}$$

Virtual force node coverage algorithm
When we need to monitor the target coverage area in a random deployment of wireless sensor network nodes, the algorithm begins to run.

First, each sensor node to broadcast the situation to transmit their position information and residual energy information, and through the sink node will send the information to the control terminal, the control terminal after getting the information according to the formula of the mobile node distance of the sensor, simulate the movement of sensor nodes, adjusting the sensor node position, repeat the process, until the sensor nodes are not mobile, the termination of the algorithm. The control terminal of each sensor node had location information is sent to the sensor network, each sensor node according to the information received by the mobile to the corresponding position.

In order to make the algorithm converge faster and avoid the state of infinite loop, we need to set a threshold value of Cth. Sensor nodes on a simulated mobile, namely algorithm for cycle time, when the algorithm cycles to reach the threshold CTH, regardless of the results, to the end of the algorithm, sensor nodes are not mobile, improve the algorithm's efficiency.

In addition, considering the residual energy of sensor nodes not much, if to continue the nodes of mobile, so that the node energy faster depletion, the region of the monitoring node will become vulnerability monitoring, affect the performance of the whole network. Therefore, the threshold value of a friction force is provided, and the sensor node does not move when the friction force of the sensor node is greater than the threshold value. In this way, the service time of the sensor nodes can be extended as far as possible, which improves the performance and the lifetime of the whole sensor network, and also balances the energy consumption of the whole sensor network.

Algorithm process and rationality analysis
The preceding discussion and research are in two-dimensional space, and in the practical application, the nodes of wireless sensor network is deployed in 3D space. Therefore, in the research of three dimensional sensor nodes deployment algorithm has more practical significance. In three dimensional spaces, it is assumed that the target coverage area is a three-dimensional cube space. Sensor nodes need to deployed in the region of the cube and at the same time, based on the assumption that the front, sensor nodes in which by the combined action of the various forces, under the action of these forces in the nodes corresponding mobile, the sensor network to achieve the best state.

In the three-dimensional space, the force of the node is similar to that in the two-dimensional space, the moving distance of the node is the same, and the difference is the expression of the moving coordinate, because of the need to consider the movement of the Z axis in the three-dimensional space.

Solutions for the perceptual model of wireless sensor network after the initial deployment, sensor node position distribution unreasonable, resulting in vulnerability monitoring, node resource waste and coverage area was smaller is proposed in this paper. On the basis of the traditional virtual force model is introduced based on node residual energy of sensor nodes move friction, thus to reduce waste of network resources, improve network performance and increase coverage of sensor nodes at the same time, reduce and balance the node energy consumption and prolong the network lifetime. In addition, the now booming wireless multimedia sensor networks, this paper presents the idea of combined sensor nodes, the deployment of multimedia sensor nodes transformation for sensor node deployment problem, reduce the difficulty of algorithm, the algorithm is used more and more widely.

SIMULATION ANALYSIS AND PERFORMANCE TEST
In order to further verify the algorithm's effectiveness, the experimental platform is MATLAB7. In length of 1000 meters square area in randomly deployed 40 wireless sensor network node, target monitoring area edge is 800 meters square area. The sensing radius of all the sensor nodes is 90 meters, and the communication radius of the sensor nodes R is also 90 meters. The basic parameters of the virtual force algorithm: $k_a = 1, k_b = 10^{10}, k_c = 10^9$,

sensor nodes in a single step moving maximum distance d_{max}=5 and cycle times of algorithm is 100, the unit distance the energy consumption of the mobile Ep=1, sensor node threshold friction for 5. Figure 1 shows the value data of 40 sensor nodes in wireless sensor networks at different iterations under coverage.

From Fig.1 it can be found that the number of iterations and the coverage rate is proportional to growth and coverage is indeed increase with the increase of the number of iterations when the number of iterations to reach about 50 times when, coverage rate remained stable and reached the optimal coverage.

In practical applications, has a great influence on the performance and cost of many network sensors, we always hope to minimize the cost and maximize the network coverage rate. Therefore, this paper also analyzes the influence of the number of sensor nodes on the coverage rate. Fig.2 shows the coverage data of different nodes.

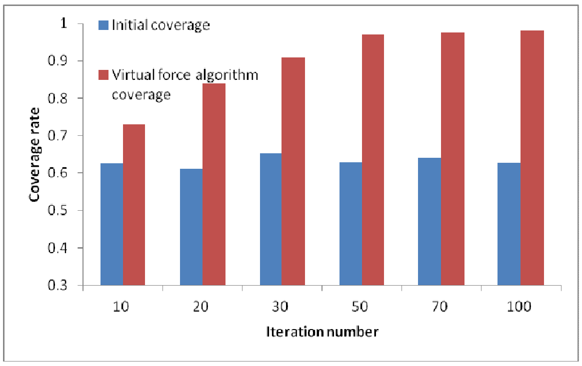

Fig.1 *t*=50, An ontology concept hierarchy tree

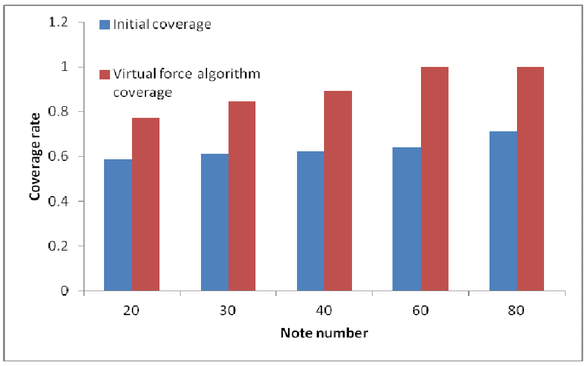

Fig.2 *t*=100, An ontology concept hierarchy tree

The experimental results show that the algorithm can balance the energy consumption of sensor network nodes, eliminate the monitoring blind area in the target coverage area and the overlapping coverage area, and increase the coverage rate of the network. The effect of the number of iterations and the number of sensor nodes on the performance of the algorithm is verified by experiments.

CONCLUSION

Based on the characteristics of the previous algorithms, this paper proposes a virtual force coverage enhancement optimization algorithm based on energy balance. In this algorithm, the target monitoring area is divided into grid, which can accelerate the convergence rate, and provide the basis for the study of uneven coverage. On the basis of the existing virtual force coverage model, this paper simulates the residual energy of the node as the friction force, reduces the energy shortage node movement, balances the overall energy consumption of the network, and prolongs the lifetime of the network. The coverage enhancement algorithm proposed in this paper is carried out in detail by using the Matlab7 platform, and the effectiveness of the algorithm is verified.

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