Sensors & Transducers, Vol. 23, Special Issue, July 2013, pp. 32-37

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Analysis on Deployment Optimization Algorithms of Sensor Based on Coverage Rate

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Received: 20 May 2013 /Accepted: 19 July 2013 /Published: 30 July 2013

Abstract: Deployment of sensors is the primary task in sensor networks, in large part, it is in relation to the network running status and life, and it also has a great impact on feasibility of optimization calculation. And coverage controlling is the first consideration that people should consider when deploy wireless sensor network nodes for it affects the performance of wireless sensor network (WSN) in a certain extent. Deployment way should be connected with practical application, so as to realize node deployment optimization based on coverage. In this paper, the triangle subdivision method we proposed belongs to this type of deployment. The optimization of sensor nodes is helpful to network space resource rational distribution as well as the environmental awareness, accessing to information has a positive effect to the promotion and network survivability.

Keywords: Coverage rate, Sensor, Optimization, Deployment, Algorithms.

1. Introduction

Sensor network has been developing fast, in the current information research field closely watched around the world, has become a hot research topic. Because it involves many other disciplines and technologies, but also exists some problems need to solve. The connectivity and coverage is the key to network can be normal operation, the network life span, energy consumption and the influence of service quality is crucial. Sensor network operation costs and monitoring ability can be reflected through the sensor deployment, and its job is to sensor nodes deployment, including connectivity, coverage, and power consumption), therefore, the study of sensor nodes deployment optimization based on coverage has important significance and positive value.

To optimize the sensor arrangement, must first determine the optimization objective function. In sensor optimization, the purpose is different, the corresponding standards is different also, constructs the function also is varied, by optimizing the function to obtain the final deployment optimization results; Second, choose the optimal method is reasonable and effective. As a combinatorial optimization problem, directly affects the sensor placement optimization calculation of the efficiency and feasibility. Node deployment algorithm, this paper described the

Article number P_SI_398

probability of node perception model, on the basis of the monitoring area taking into account the different requirement of realizing the efficient in the area of the plane triangle dissection, so as to realize node deployment optimization based on coverage.

2. Normal Models of Coverage Optimization for Wireless Sensor Networks

According to the requirements of the coverage area and application of wireless sensor network can be divided into regional coverage, coverage and cover three kinds of fence. In wireless sensor networks, regional coverage is the most common, is also one of the most studied, it is primarily responsible for maintaining the reliability of the communication between network nodes, nodes, to minimize the need to reduce the network cost. To achieve the maximization of the target area covered, area covered each point should be at least one node. Especially in some areas with higher detection quality requirements, this method should be applied to every point carefully detection, such as military combat [1].

Fig. 1 is the regional coverage in black nodes represent sensor nodes, 6 black spots can be done completely covered area.

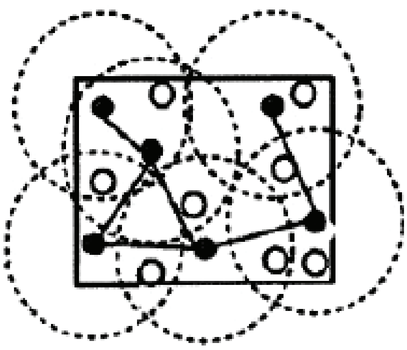

Fig. 1. Region coverage diagram.

The point coverage covers area of a set of discrete points as main research object, it only need to detect a limited number of discrete points, and to determine the discrete point at least need to knot points and the position of each node and don't need to make testing throughout the region. Point coverage optimization, mainly in order to guarantee the sensor nodes to monitor each of the target points, as shown in Fig. 2. Square represents the target figure, black spots, the circle represents the node, and only three goals, work on the target coverage can be completed. In general, the regional coverage can also use this method. So, regional coverage and point coverage have similarities in research methods, the difference is: covering algorithm for detecting target, and network topology organization division of information and the regional coverage in addition to these, also need to understand the information such as the geometrical characteristics of the monitoring area.

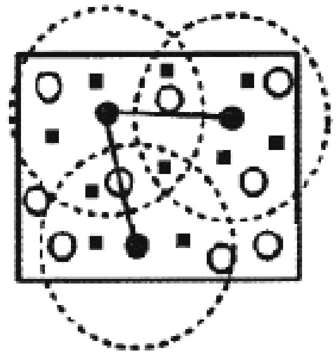

Fig. 2. Point coverage diagram.

Barrier coverage uses more widely in the mobile target monitoring, the main question is: when the target from the deployment area of nodes, network node can explore them, and related issues of probability calculation [2]. Fig. 3 represents the fence overlays, in circular on behalf of sensor nodes, curve represents the target's movement track. Study barrier coverage, underpinning the best solution for network deployment, increase the probability of the target can be detected, and the guarantee from the enemy surveillance area, detected the probability of a minimum.

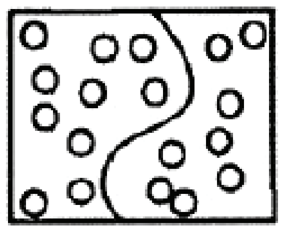

Fig. 3. Barrier-coverage diagram.

2.1. Complete Coverage and Incomplete Coverage Algorithms

According to the working state of the can node of monitoring area completely covered, nodes short hair can be divided into completely covering algorithm and the complete coverage algorithm. The former is much used in the field of high security, such as military combat, emergency rescue, which is suitable for the low safety degree of area, such as forest fire warning, environmental monitoring, etc. On the former, in accordance with the deployment area target different coverage degree, can be divided into 1 - and K -, K coverage refers to all the target area by using a sensor node K to cover at the same time.

2.2. Centralized Coverage and Distributed Coverage Algorithms

Based on the algorithm of the implementation of the strategy, node algorithm can be divided into Centralized covering algorithm and distributed coverage algorithm. Centralized global coverage algorithm is the first step of network information are collected, and will collect good data transmitted to a central processing node, central processing order node coverage algorithm work finished, then will override control information distributed on each node. Analysis of two kinds of algorithm implementation process, covered in centralized network scalability of the algorithm has certain limitations, so practical in small sensor network; Distributed coverage algorithm, the sensor nodes with the aid of local information network, active contact with adjacent nodes work together to complete the task, can be used in large scale sensor networks.

3. Triangulation Generation Algorithm

3.1. Idea of the Algorithm

For planar point set, can be based on Delaunay principle theory Bowyer - Watson algorithm to complete the task. Process is roughly: first is conducted, including all stay subdivision regions, the establishment of the initial grid work, then with the help of a Bowyer - Watson algorithm, in turn, insert the given point, and the grid subdivision, modified until all points have been inserted.

3.2. Algorithm Description

Input content for the coordinates of n points on the plane (X_{pi}, Y_{pi}), which I value as a natural number between 1 to "n", which set down for P, the content of the output for the linked list contains n points in the triangle subdivision, such as equation (1):

$$T = (P_2, P_1, P_0) \rightarrow (P_3, P_2, P_1) \rightarrow ... \rightarrow (P_{n-2}, P_{n-1}, P_n), \quad (1)$$

Establish a rectangle inclusive box as the initial mesh to cover the whole calculating area. First of all, we need a bounding rectangle W named inclusive box or auxiliary window which has enough room and contains the given point set in equation (2), where the value of i is as in equation (3). And than determine the point W, expressed in equation (4) and the value of *i* is 1, 2, 3 or 4.

$$V = \{P_i\}, \quad (2)$$

$$i = 1,2,3...n, \quad (3)$$

where n is the number of nodes.

$$W = \{w_i\}, \quad (4)$$

where w_i represents the four vertexes of the rectangle, (X_{wi} , Y_{wi}) is the coordinate of w_i.

So there are the following equation (5), (6), (7) and (8):

$$X_1 \le \min\{X_{pi}; i = 1,2,...,n\}, \quad (5)$$

$$Y_1 \le \min\{Y_{pi}; i = 1,2,...,n\}, \quad (6)$$

$$X_3 \ge \min\{X_{pi}; i = 1,2,...,n\}, \quad (7)$$

$$Y_3 \ge \min\{Y_{pi}; i = 1,2,...,n\}, \quad (8)$$

where (X_{pi}, Y_{pi}) is the coordinates of P_i.

Subdivision, the auxiliary window W will get two large as the initial mesh triangles, and the information recorded work.

Through the Bowyer - Watson algorithm, combine boundary point in inserted into the original grid. Boundary point by artificial given in advance, assumes that the boundary points in a state of reasonable distribution.

Calculation area of the triangle will not delete, and ensure the correctness of the boundary surface triangle subdivision.

By Bowyer - Watson algorithm, in turn, create insert new inside the computer, until all interior point insertion is complete, has reached the standard of subdivision or grid, needing attention, create the new insert for the given point set, only need to insert in the relevant order, if the point is automatically generated, you will need to generate interior point according to certain strategy.

Grid generation, after carries on the grid to patronize and topological consistency check, etc.

3.3. Strategy for Generating Interior Point Automatically

By Bowyer - Watson algorithm, can do planar point set of triangular subdivision work, also can on a particular area of the triangle subdivision, in a particular area, can through the points on the boundary discrete method, and regional internal point is need to using technology to obtain corresponding putting. Node deployment algorithm of this article described the practice basis of the circumcenter points strategy, that is to say the circumcenter inserted into the creation of a new triangle, then with the help of a Bowyer - Watson algorithm to regenerate cells. Select the triangle standard has many, such as the largest area, the shape of the worst, the radius of the circle is bigger than fixed value. Use the radius of the circle as the standard, can ensure the uniformity of the grid size. Circumcenter is realized by using incremental insertion, local triangular subdivision of the network to complete the construction work.

4. Design of Deployment Optimization Algorithms of Nodes Based on Coverage Rate

Mainly through deployment algorithm design, make the area may have obstacles, optimize the sensor nodes deployment, to achieve maximum node's perception of the detection range.

In the initialization stage, initial data from the monitoring area can provide configuration document [3], as shown below:

Configuration file:
//size of sensing area
4 0 0 100 0 100 100 0 100
3//number of obstacles
5 23 21 35 21 41 34 30 43 19 34
…
3//number of pre-deployed sensors
50 180
…

Within this document, including monitoring area, the position information of obstacles, probabilistic sensor model parameters, etc. Sensor network detection area is defined as the internal area, there may be any shape obstacles.

Main part of the algorithm has the following two phases:

Stage 1: the initial area of contour line or obstructions weeks online node deployment, to be able to eliminate all possible coverage holes, it guarantees the connectivity between the nodes.

Where r_s is the covering radius and r_c is the communicating radius of the nodes [4]. The specific steps are as the following:

$$r = \min(r_s, r_c), \tag{9}$$

Step 1: When the angle degree θ satisfy the equation (10) or (11), Along the y direction to do the edge of the parallel lines, node deployment, along the spacing for the r, as shown in part (a) of Fig. 4.

Fig. 4. Line for deploying nodes.

$$\theta \le 45°, \tag{10}$$

$$135° \le \theta \le 180°, \tag{11}$$

where θ is the inclined angle between the side of the barrier and horizontal.

Step 2: When the angle degree θ satisfy the equation (12), Along the x direction to do the edge of the parallel lines, node deployment, along the spacing for the r, as shown in part b of Fig. 4.

$$yos = \{P_1, P_2, ..., P_n\} \tag{12}$$

Stage 2: optimize the sensor node deployment, the focus is on sensor nodes generate alternative location, steps as follows:

Step 1: For phase 1 deployment node number n0 node coverage *Cov0* calculation;

Step 2: Deployment in a phase of *yos* nodes with equation (12), with the help of a triangular subdivision algorithm constructing triangle mesh subdivision, and calculate the whole triangle circumscribed circle radius and center coordinates;

Step 3: All triangle circumscribed circle radius is obtained, and through the sensor node probability model for the comparison, find the radius of the largest inscribed circle, and calculate its center, as the next node deployment of alternative locations;

Step 4: Test alternative location if there are any obstacles, if yes, select radius circle radius smaller than three steps, for the center, back to the fourth step;

If no, to that point to increase the coverage ΔCov_i。

Step 5: Judge equation (13) is set up or not, if found, the node number of the statistics, and calculate the coverage;

$$Cov0 + \sum_{i=1}^{n} \Delta Cov_i \ge Cov\_\mathrm{Re} \tag{13}$$

If not, find the radius of the largest inscribed circle, and calculate its center, as the next node deployment of optional location, return to the second step, to do a good job of rebuilding the triangle subdivision network, calculate the new produce of the radius of the circle and the coordinate of the triangle algorithm to continue.

5. Experiment and Results

There are two kinds of simulation environment: case 1 and case 2 [5]:

Case 1: Monitoring area size: 100 x 100 two-dimensional plane area, through monitoring, in the area without any obstacle, but early arrangement of the three nodes; Node perception model parameters: the value of r_s is 10, r_e is 1, and value of α is 0.2, 0.5 for β.

Case 2: Monitoring area size: 200x200 two-dimensional plane area, through monitoring, the area is one obstacle area; Node perception model parameters:
The value of r_s is 10, r_e is 2.5, and value of α is 1.22, 0.5 for β.

Part effect of algorithm simulation of case 1, case 2 is showing in Fig. 5:

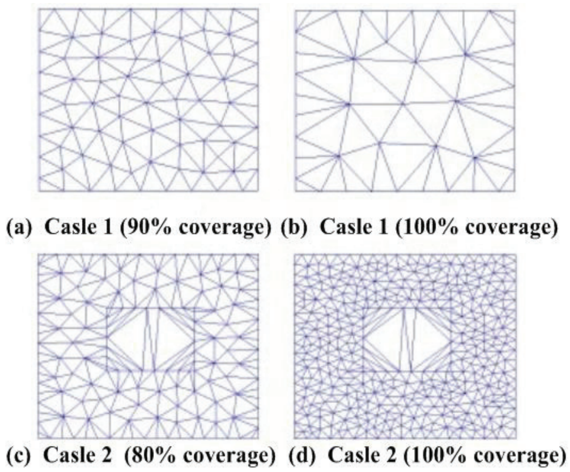

Fig. 5. Simulated effect parts in case 1 and case 2.

In order to compare to the MAX_MIN_COV algorithm, assuming the grid point for 5, 10 units, the test results as shown in Fig. 6 and Fig. 7.

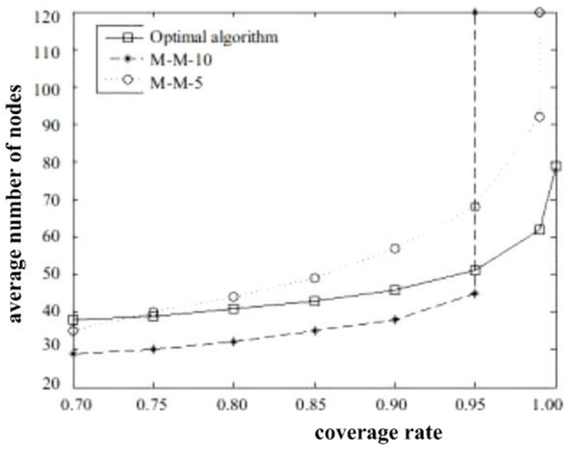

Fig. 6. Testing results of case 1.

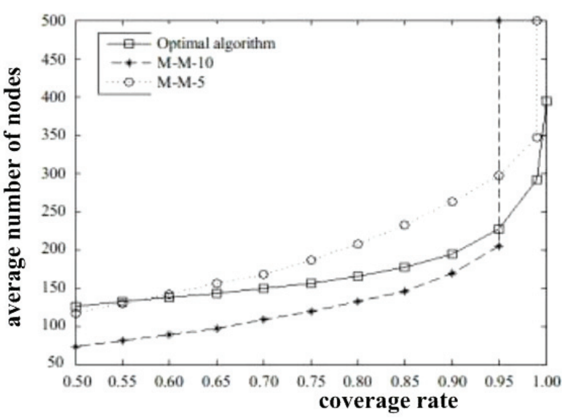

Fig. 7. Testing results of case 2.

From the above figure, we can know that the higher requirement for coverage, deployment node covering the better the results of this algorithm, and can realize seamless coverage, to avoid the problems of boundary effect when the sensor node coverage [7]. However, in the initial stage, the algorithm of node deployment amount is higher than other algorithms, mainly lies in the fact that "the initial region contours and node deployment" obstacles around online a link you need to use the node coverage boundary area is more, due to the effect of the initial node to the monitoring area than other algorithms, especially when larger grid units, the differences are more obvious.

Of course, the sensor network deployment and application usually closely linked together. Sensor networks deployed in different application environment also is not the same way, it's easy to cause research results appear in the sensor nodes radius of perception and communication range under certain constraints, the problem such as poor monitoring area set [6]. This study node deployment algorithm with the aid of the probability of sensor nodes perception model, aiming at monitoring area have different coverage requirements, implement efficient triangle subdivision in the area of the plane, so as to realize node deployment optimization based on coverage, aimed at the given monitoring area that may contain obstacle nodes using the algorithm to maximize coverage efficiency [8].

6. Conclusions

Now the computer technology has been developing very fast, modern information analysis technology has also constantly progressed. The research of structural health inspection no matter in the breadth and depth has the corresponding ascension and expansion. Meanwhile optimal placement of the sensors is also paid more and more attention. If the sensor placement is not appropriate, it will affect the accuracy of the identification of parameters. In addition, the sensor itself needs certain cost, and price of the related technology and equipment for it complete set is high, too. Considering the economy, people should pay as little as possible and get information as much as possible.

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