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# Uniform Deployment of Water Quality Sensor Networks Based on Particle Swarm Optimization

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**Abstract:** In order to improve the fast detection ability of water quality monitoring equipment and guarantee the reliability and correctness of measured data, this paper takes advantage of particle swarm optimization (PSO) algorithm based on adjusted factors and compares the particle numbers' effect on the network coverage ability. According to the simulation results, under the conditions of maximum coverage, the sensor nodes can achieve fast-adaptive and well-distributed deployment, as well as avoiding local optima. With the increase of swarm size, the coverage of the sensor network is becoming larger, however decreasing after 20. It is of high importance that uniform deployment can ensure the reliability of the water quality data.

**Keywords:** sensor network, covering deployment, water environment monitoring, Particle Swarm

## 1. Introduction

Water quality monitoring is used to detect and reflect the pollution trends of water quality by scientific methods. It is also used to measure the types of pollutants, the density and tendency of various pollutants, to evaluate the process of water quality. In the actual monitoring system of water quality, sensors have to monitor various water quality parameters, such as temperature, pH, nitrogen, phosphorus, turbidity and permanganate index, each type parameter in different waters reflect the water quality varies. Reasonable deployment of sensor nodes to make the network coverage maximum, so to obtain the greater reliability of real-time data which reflect the full information of the water quality.

Traditional water quality monitoring systems usually use a large-scale and exhaustive casting method, which is difficult to deploy sensors in a suitable locations and is easy to form a perception of overlapping areas and blind spots. Another way is to divide the object waters into fixed-size grid and put one sensor at the center of each mesh grid. This method is simple, but easily leading to similar monitoring results in the adjacent sections and resulting in waste of resources.

Ant colony algorithm is used to realize the non-uniform coverage of the sensor network nodes. Although the results compared the impact of another several algorithms, it did not show good supporting outcomes [1] . The method of simulating the behaviors of fish is used to make the node autonomously cover with combined degree of congestion control, but it did not specify arrangement of sensors under the entire region of waters [2] . A localization algorithm of wireless sensor network based on a bounded particle swarm optimization, which improved the positioning accuracy of the node with a lack of explanation of network coverage problem [3] . PSO is used to achieve coverage enhancement for sensor networks, but did not specify the distribution network [4] [5] . The concentration degree was viewed as determination condition in particle swarm optimization, with key parameters self-adjusting, whose simulation showed that the algorithm can improve network coverage [6] .

In this paper, the complexity and variety of the underwater environment have been in consideration, monitoring the impact of strong water dynamics, applying PSO intelligent deployment algorithm to optimizing the ultimate goal in the use of the good mobility of sensor nodes. It is to accommodate the sensor nodes to achieve uniformly adaptive deployment and adjust them by neighboring nodes, ensuring the maximum coverage, rapid deployment and high reliability.

## 2. Network coverage metrics

In this paper, it automatically deploys sensor nodes to cover the two-dimensional monitoring waters, which aims at maximizing total coverage. The particle swarm optimization algorithm ensures the objectivity of the monitoring data and to overcome the problems of the conventional deployment methods, which can also be extended to three-dimensional space.

The deployment of sensor nodes is carried out in the water area of a factory, making the largest network coverage. The waters, with a size of 100m × 100m, is divided into a grid of 2m, as shown in Fig.1. The coverage rate is calculated as the ratio of the area being monitored versus the size of the entire target area. The grid points in fig.1 denotes as K, while the total number of grid points within the entire area as KK. In this paper the Boolean sensing model is applied to solve the sensor coverage monitoring, whose mathematical model is as follows.

$$c(s_i,K)=\begin{cases}0. & d(s_i,K)>R_c \\ 1. & d(s_i,K)<R_c\end{cases} \qquad i=1,2,3,\cdots\cdots,m \tag{1}$$

While m denotes the number of sensor nodes, $d(s_i,K)$ is the euclidean distance between the sensor node $s_i$ and the grid point K. That is to say the sensor $s_i$ is deployed on the point of $(x_i,y_i)$, then the distance $d(s_i,K)=\sqrt{(x_i-x)^2+(y_i-x)^2}$ . $R_c$ is the effective monitoring radius. When $d(s_i,K)$ is greater than the effective radius, the grid point K will not be detected. For a monitoring network by the grid, it will be monitored throughout the region all the sensor nodes detected. The probability of monitoring the entire region by the sensor network is defined as the joint probability of all nodes, which shows as follows.

$$C_K(s_{all},K)=1-\prod_{i=1}^{n}(1-C_K(s_i,K)) \tag{2}$$

The node with the probability of detection equal to 1 will be counted, and then the total coverage of the target area can be concluded.

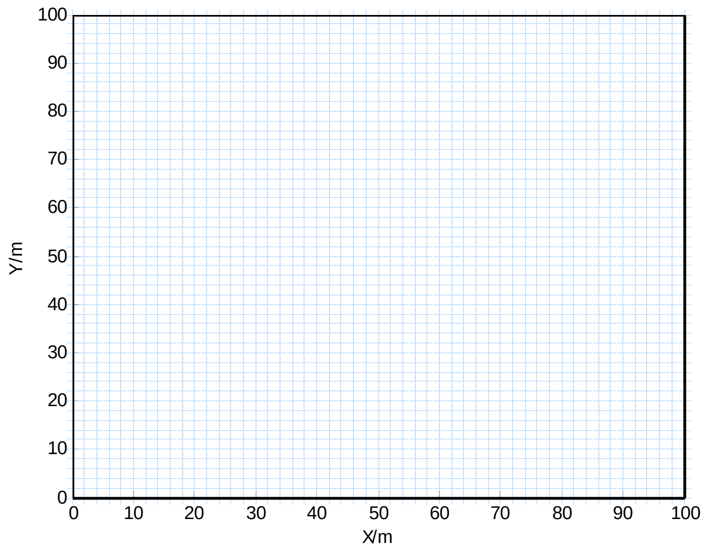


Fig.1 Schematic diagram of monitoring water area model

## 3. Algorithm design

Assuming that the area monitored on the two-dimensional plane is S, there are n preliminary solutions to the D-dimensional search space. Then the number of m nodes is randomly deployed, and the position of the i-th particle is

$s_i = (x_{i1}, y_{i1}; x_{i2}, y_{i2}; x_{i3}, y_{i3}; \ldots\ldots\ldots\ldots; x_{im}, y_{im})$. In the each step of updating the speed vectors of nodes, the new position will be obtained. During this process, there will be two optimal solutions. One represents the optimal position of the single sensor node and the other the optimal position of all nodes. The current speed of the sensor node is updated by the speed and position in the last step as well as neighboring nodes. When the speed and position of the node are both updated, it will conclude an adaptive value. According the adaptive value, the particles will search the single optimal solution $P_{id} = (p_{i1,} p_{i2,} p_{i3,} \ldots\ldots\ldots\ldots p_{iD})$ and the global optimal solution $P_g = (p_{g1}, p_{g2}, p_{g3}, \ldots\ldots, p_{gd})$. The adaptive value is defined by the coverage rate of the sensor nodes, which should increase in total during the iteration process until the stop criterion or the maximum iterations.

## 4. Simulation results

PSO is to obtain the optimal deployment of the sensor nodes for the maximum coverage in the monitoring area. In the waters of 100m * 100m, with side length of 2m meshed to calculate coverage. Setting the Sensor radius of 10m, the maximum number of iterations to 300, the minimum coverage of 0.5. As to particle velocity, linear variation was used to update the weighting factor, and weighting constant C1 and C2 is set to 2. In the iterative calculation, when the number of iterations is greater than the maximum or the coverage rate is less than the minimum, the calculation is stopped, saving the best results and exiting the update process.

In order to select the most appropriate number of particle swarm, this paper conducted a number of different sets of particle swarm simulation experiment, the results are shown in Fig.2. Experimental results show that the coverage of the sensor network is becoming larger with the increase of swarm size, but reached the maximum at 20.

The network coverage based on PSO optimization algorithm of the final simulation results are shown in Figure 3- 5. Fig.3 shows the location of the random deployment of sensor nodes in the monitored water area, and is generally used in the initial deployment of sensor networks. Fig.4 is the optimization position of randomly deployed nodes after PSO iterative update. At this time, a uniform deployment and the maximum coverage are achieved.

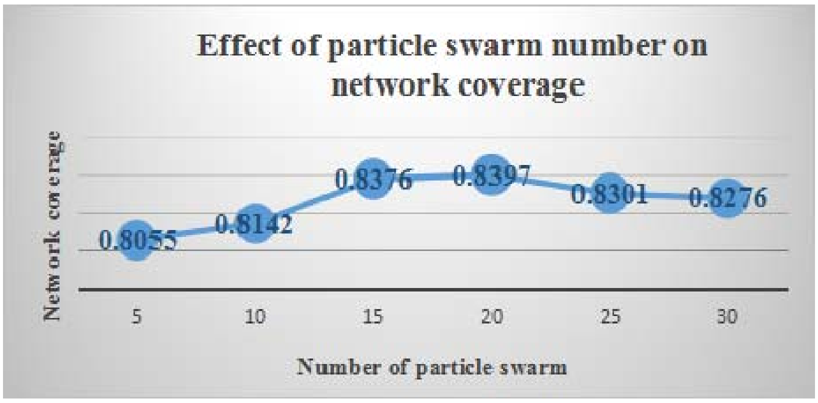


Fig.2 Effect of particle swarm number on network coverage

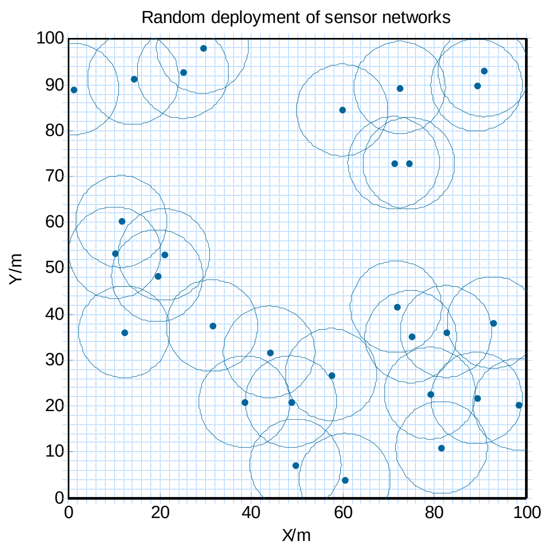


Fig.3 Random deployment of sensor networks

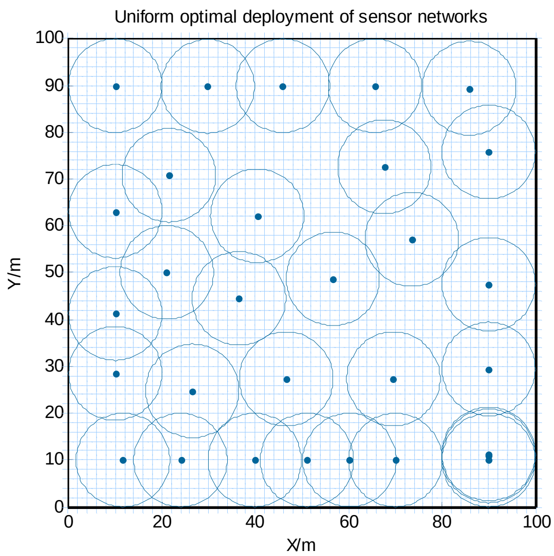


Fig.4 Uniform optimal deployment of sensor networks

Fig.5 is an update process of change of network coverage under PSO, it is obvious that the initial random deployment of the sensor coverage is not very great. This situation reflects a traditional deployment, randomly tossed sensor nodes to achieve a certain coverage, is not much better than PSO optimized deployment.

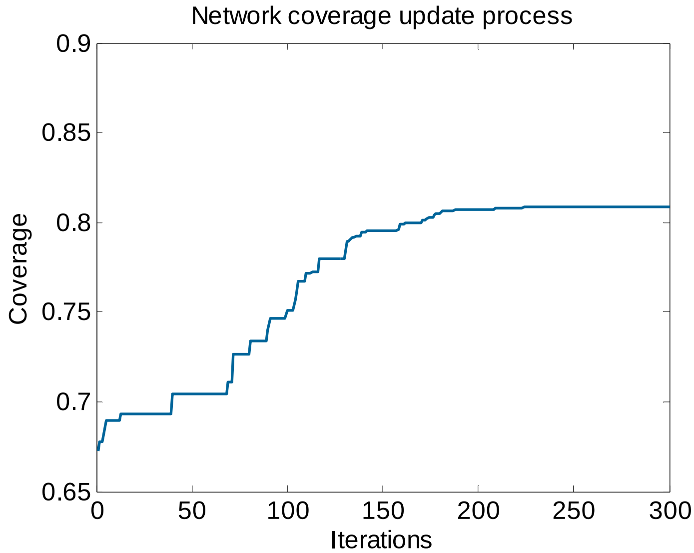


Fig.5 Network coverage update process

## 5. Conclusion

In this paper, the PSO algorithm was used to make the optimal deployment of sensor nodes with the target of maximum coverage ratio, so that the most complete and accurate water quality information can be measured in the monitoring area. The simulation results show the effectiveness of the algorithm, and the even cover of sensor network realized by PSO also makes this study has important practical significance. It is worth noting that the number of selected particle swarm needs to be based on empirical and experimental judgment, to select the optimal parameter values, to ensure the best simulation results.

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