

The Optimization of Genetic Algorithm in Wireless Sensor Network Coverage

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Abstract

According to the maximum coverage problem in wireless sensor networks, GA algorithm combined with the standard processing method can improve the network coverage based on, but there is a risk of falling into local optimum, and costs more computation time. On the condition of analysis and proof of the effectiveness by the employment of normalization processing to resolve coding redundancy of MCS DP, further details of the evaluate conditions are proposed, and new parent selection mechanism is introduced, which both are verified by compared experiments. The experiment results show that the optimization processing method proposed in this paper retains the characteristics of existing methods, and has better optimization performance and improves the network coverage rate as well as calculation speed, which verifies the effectiveness and superiority of the method proposed in this paper.

Keywords: *Genetic algorithm; Maximum coverage; New parent selection mechanism; Solution space*

1. Introduction

The wireless sensor network is widely employed in localization and trace, etc. and provides human the accurate environment information. In the detection system of air quality, earthquake prediction system, the wireless sensor technology takes an important part to prepare people better for the natural disaster and protect own lives and property. It is still necessary to consider that how to sense the largest scope with the least sensors, though the price of sensors declines with the improvement of the technology.

Some research consider on enlarging the sensing coverage in static sensors [1-4], and these research focus on the mobile phone field. Some research emphasizes the problem hoe to utilize the cheap static sensors and the relatively expensive mobile sensors to establish the low cost and large coverage sensor network [5], and some study on how to monitor the goals effectively [6]. The optimal employment localization of the sensors benefits us with more sufficient information of the monitor goal in the condition of reducing the manpower [7-9]. In this research field, it is considered that how to get efficiently the maximum sensing coverage with the given sensors type and amount [10-12].

2. Problem Description

2.1. Assumption

The coverage model of the geometrical relationship between the sensor and the sensing point is chosen to measure the sensor quality and ability. The common coverage model is:

$$f(d(s, x)) = \begin{cases} 1 & d((s, x)) \leq r_s \\ 0 & else \end{cases} \quad (1)$$

The distance between the sensor s and the sensing point x is presented as $d(s, x)$, the constant r_s indicates the sensing range of the sensors. This model is omnidirectional, and the sensing area is discoid. If the sensing point is in the sensing range, the model value is 1, otherwise is 0. Different sensor type has different sensing range.

According to the contents of research, the coverage in the sensor network can be divided into three categories: the regional coverage, the impedimental coverage and the objective coverage. The sensors are regarded as the same, and the Boolean model is employed to process the regional coverage problem. It is considered that how to maximum the coverage range with the certain sensor amount. A certain coverage problem is assumed, and the coverage method proposed in the paper, is easily applied in other coverage problem with change of the evolution-function.

2.2. Problem Description

There are k kinds of static sensors, and every kind of sensors has been set, and the sensing radiuses are r_1, r_2, \dots, r_k . There are n sensors of all kinds in amount. It is assumed that there is one sensor at least of every kind, and the numbers of sensors i type are from n_i to $n_{i+1}-1$. The given $k+1$ sensors meet $n_{k+1} = n+1$ and $n(=1) < n_2 < \dots < n_{k+1}(=n+1)$, and the kind of i has $n_{i+1} - n_i$ sensors, and $i = 1, 2, \dots, k$.

The location $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ will be found to get the maximum coverage area with n sensors meet the field A .

The circle $C_r(x, y)$, locating its center at (x, y) , has the radius r , and it is expressed as:

$$C_r(x, y) := \{(v, w) \in R^2 : (v-x)^2 + (w-y)^2 \leq r^2\} \quad (2)$$

and can also be described as:

$$\begin{aligned} & \max_{\substack{x_i, y_i \\ i=1, \dots, n}} \left\{ \bigcap_{i=1}^k \left(\bigcup_{j=n_i}^{n_{i+1}-1} C_{r_i}(x_j, y_j) \right) \cap A \right\} \\ & \text{subject } (x_i, y_i) \quad i=1, 2, \dots, n \end{aligned} \quad (3)$$

r_i is positive real number, $1 \leq i \leq k$, is incremental positive number, $1 \leq i \leq k+1, n_1 = 1, n_{k+1} = n+1$, A is two-dimension field [13].

2.3. Solution Domain

In this example, the coverage area does not change while the sensor's parameters change of the same type. The same solving progress can be carried out in more than one coding scheme. Hence, the coding scheme and the solution domain are different.

Make G be the coding set, and $g(g_1, g_2, \dots, g_n)$, $h(h_1, h_2, \dots, h_n)$, and are Euclidean distance. The equivalence symbol is defined as \sim :

Definition 1: $x \sim y$ if and only if the sequence $\sigma_i \in \sum_{n_{i+1}-n_i}$, and $i \leq k$. $\sigma_i \in \sum_{n_{i+1}-n_i}$ is a sequence with the length of $n_{i+1} - n_i$, and $\sigma(x)$ is σ sequence of x .

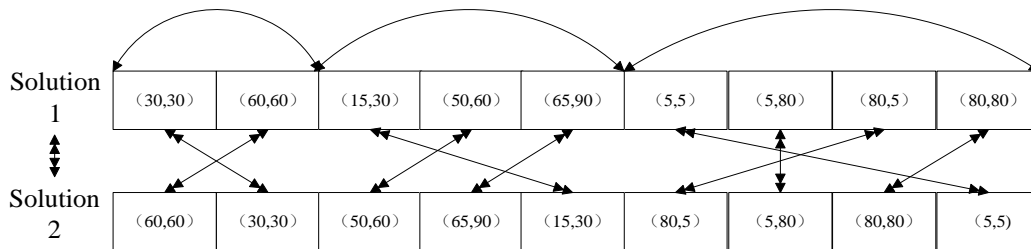


Figure1. The Comparison of the Two Equivalent Solutions

$n_{i+1} - n_i$ is the amount of the type i sensor. $(g_{n_i}, g_{n_{i+1}}, \dots, g_{n_{i+1}-1})$ is the coordinate sequence of type i sensor. The solution 1 and solution 2 is equivalent as shown in Fig.1. $(n_2 - n_1)!(n_3 - n_2)! \dots (n_{k+1} - n_k)!$ is the equivalent expression of $g \in G$. According to the definition 1, G/\sim is the solution set of coded set.

The coded set G is established by employing the intelligent algorithms e.g. genetic algorithm, neural network, as well as its equivalent solution G/\sim . So the efficient method is required to find the solution G/\sim in the coded set.

3. The Optimization of Normalization

3.1. Genetic Structure

The genetic structure is described based on the contents of the paper. The population is N , and randomly sampled $N/2$ sets. Each set produces $N/2$ offspring through crossing and mutating. The best N samples are chosen to be the genetic male parent of the next generation by disorganizing the male parent and children. In the experiment, the population is 50, namely $N=50$ and the genetic mutation is set at 1000 generations. The cross parameter and mutation parameter are respectively $BLX - \alpha$ and Gaussian.

3.2. Evaluation Function

The purpose of the evaluation function is to solve the coverage range of the sensor. Therefore, the results are calculated by resampling in Monte Carlo. X is the coverage area, and:

$$\bigcup_{i=1}^k \bigcup_{j=n_i}^{n_{i+1}-1} C_{r_i}(x_j, y_j) \cap A \quad (4)$$

$$S(X) = \iint_A I_X(x, y) dx dy = \lim_{L \rightarrow \infty} \frac{S(A)}{L} \sum_{l=1}^L I_X(\tilde{x}_l, \tilde{y}_l) \quad (5)$$

In (5), $I_X(\cdot)$ is defined as:

$$I_X(x, y) = \begin{cases} 1 & (x, y) \in X \\ 0 & (x, y) \notin X \end{cases} \quad (6)$$

$(\tilde{x}_l, \tilde{y}_l)$ is the point of the field A. It can assess whether the sample $(\tilde{x}_l, \tilde{y}_l)$ is in the range of the sensor by solving the value of $I_x(\tilde{x}_l, \tilde{y}_l)$ corresponding to each $l=1,2,\dots,L$. Therefore, the maximum time complexity of Monte Carlo evaluation function is $O(nL)$. With more samples, the estimation results are more accurate. As shown in the Fig.2.

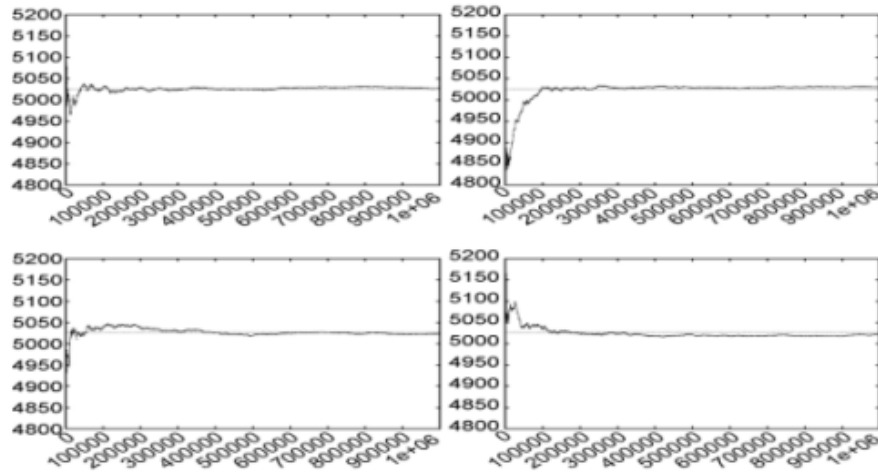


Figure 2. The Relationship between Samples and Estimation Value

However, calculated quantity of GA is more with more samples, namely the operating cost of estimation results will be higher. Hence, it is more effective to reduce the operating cost than improve the accuracy of the estimation results with the large quantity of samples. Based on the analysis, the employed calculation method is calculating a small number of samples at the initial stage, and the calculating samples increase with the augment of the genetic algebra.

3.3. Normalization

The coded set and solution set are different because of the coding redundancy. The solution set P is related to the entropy G/\sim , and G is the coded set domain. The normalization is utilized to lower the impact of the redundancy on the calculation. The normalization transfers the coded set of the male parent into another coded set.

Assumption: make $g = (g_1, g_2, \dots, g_n)$ and $h = (h_1, h_2, \dots, h_n)$ subject G . g_i and h_i are 2-D collaboration, and $i = 1, 2, \dots, n$. Make

$$D(g, h) = \sum_{i=1}^n d(g_i, h_i) \quad (7)$$

It is one matrix of G , and d is one matrix of R^2 . So,

$$\tilde{D}(g, h) := \min_{\sigma \in \prod_{i=1}^k S_{n_i+1-n_i}} D(g, \sigma(h)) \quad (8)$$

It is one matrix of G/\sim .

Demonstration: s is made be one value of the set $\prod_{i=1}^k S_{n_i+1-n_i}$. The number of the addend has no relation with the result for the addend is limited when $D(g, h) = \sum_{i=1}^n d(g_i, h_i)$ is calculated. Therefore, $D(g, h) = D(\sigma(g), \sigma(h))$. So each s in the coded set is equidistant as well as $\prod_{i=1}^k S_{n_i+1-n_i}$. The relational symbol \sim represents the equivalence relation. Hence, $\tilde{D}(g, h)$ is a matrix of G/\sim .

Therefore, if the normalization is not adopted to solve the MCSDP with the application of GA, the GA will only find the coded set, and will not affect the original solution. Changing the parameters of the same kind of sensors does not influence the solution set in MCSDP. So the appropriate rearrangement of the gene does not change the original solution, and makes the search to the solution domain more efficient. A normalization way to the MCSDP is proposed.

Literature [13] made comparisons of the effects between maximization, random and minimization, and research results show that minimization process has the best effect in terms of employing GA algorithm to solve MCSDP. Therefore, on the basis of literature [13], to further normalization method optimization was proposed in the paper. First, the algorithm randomly generated initial parents, and uses the appropriate method to reorder crossover and mutation, and chooses from the $N/2$ samples with good effect to be the next parents. The normalization flow diagram of the optimized processing step is shown in figure 3.

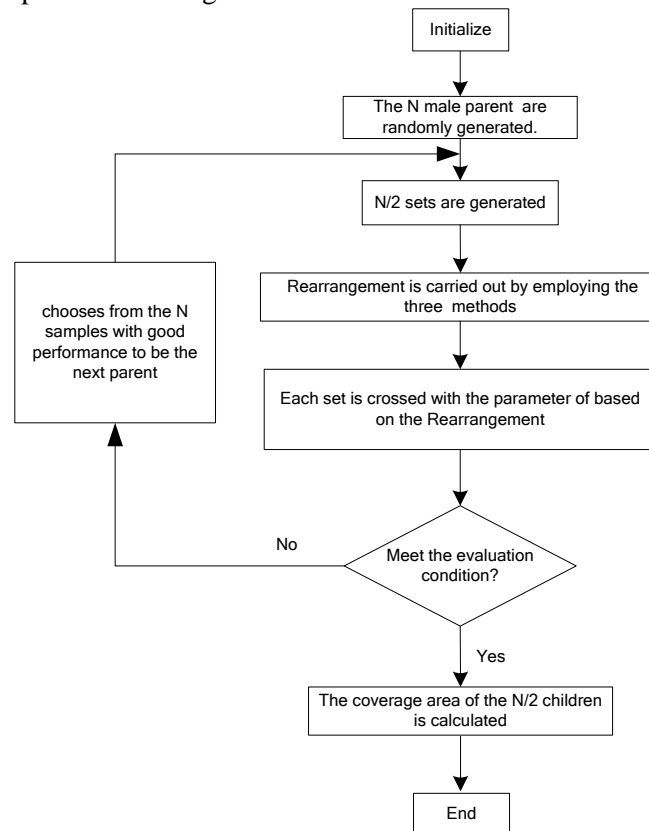


Figure 3. The Flow Chart of Normalization Processing Steps

4. Experiment Results

In order to verify the effectiveness and superiority of the proposed optimization method, experimental environment is consistent with the [13], and the experiment results compared with the experimental results in [13]. The experiment environment is as:

It is assumed that $A = [0,100] \times [0,100]$, and three kinds of sensors are employed, and the radius of every kind is respectively r_1, r_2 and r_3 , meanwhile, the radiuses meet the demand $r_1 = 0.8 \times r_2, r_2 = 0.8 \times r_3$. The amount of every kind sensor is related to the coverage compactness α , $\alpha=0.5$.

The Exp.1 is under the method proposed in this paper, and the Exp.2 adopts the method of [13]. The experiment results are shown in Fig.4 to Fig.9, and the corresponding relationship between the sensor and the x-axis is shown in Table.1.

Table.1 The corresponding relationship between the sensor and the x-axis

No.	1	2	3	4	5	6	7	8	9	10	11	12
Instance	S1-0.7	S2-0.7	S3-0.7	S4-0.7	S1-0.8	S2-0.8	S3-0.8	S4-0.8	S1-0.9	S2-0.9	S3-0.9	S4-0.9

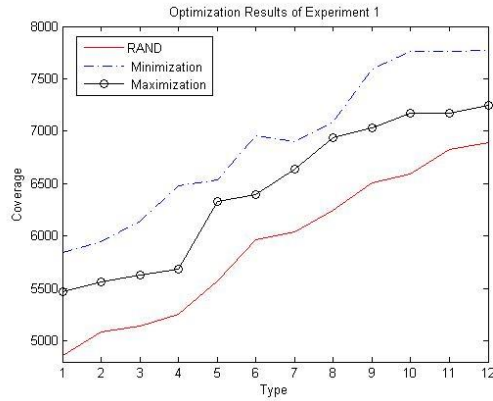


Figure 4. The Comparison of Experiment Results between Three Methods in Exp.1

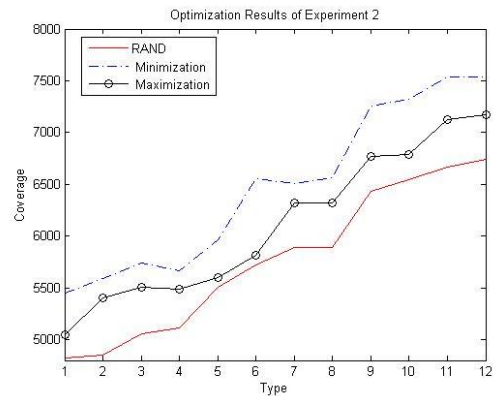


Fig.5 The Comparison of Experiment Results between Three Methods in Exp.2

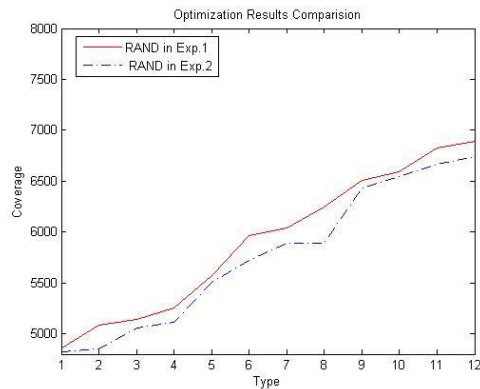


Figure 6. Result Comparison of Randomnes Processing Method between Exp.1 and Exp.2

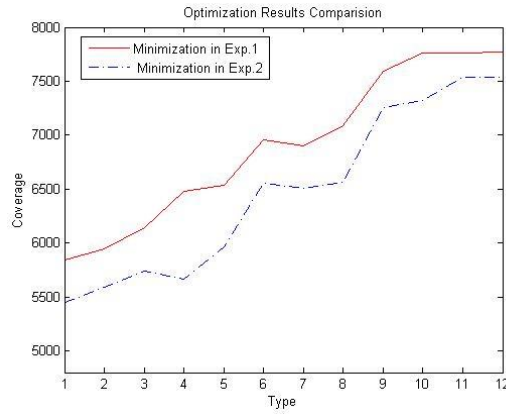


Figure 7. Result Comparison of Minimization Processing Method between Exp.1 and Exp.2

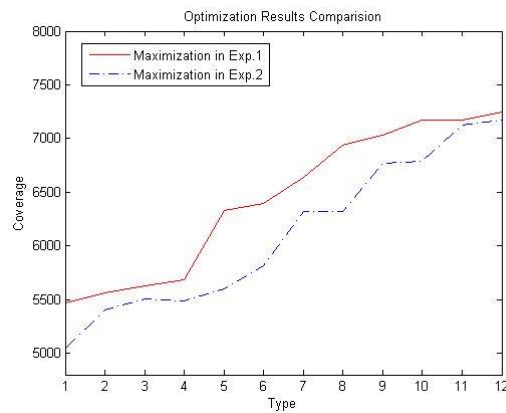


Figure 8. Result Comparison of Maximization Processing Method between Exp.1 and Exp.2

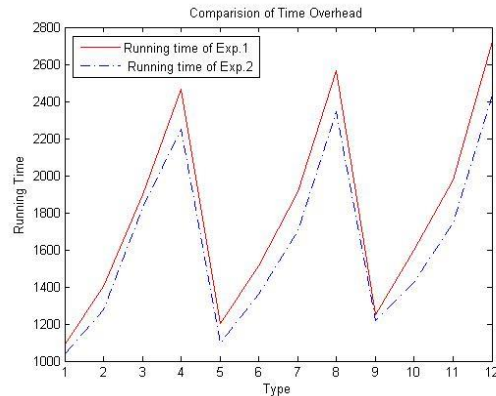


Figure 9. The Comparison of Time Overhead of Minimization Method between Exp.1 and Exp.2

In Fig.4 and Fig.5, there are the optimization method proposed in this paper and the method proposed in [13], and the characteristics of the two methods, which shows that minimization has the best performance, and the random processing is the worst, are consistent with each other. The random processing method randomly selects samples, and cannot inherit the characteristics from the parent generation; however, the minimum processing method retains the father generation characteristics at the extreme, which leads to the best performance.

Based on Fig.6, Fig.7 and Fig.8, with regard to the three kinds of random, minimization, maximization methods, the optimization method proposed in this paper has better performance than the proposed method in [13]. On the basis of method proposed in [13], further details of the evaluate conditions are proposed, and new parents selection mechanism is introduced. The samples with good performance are randomly selected to be the next parent, which not only reduces the parent sample range, but also ensure the excellent father characteristics. The new proposed method can effectively reduce the probability of trapping in local optimum, and can produce offspring with more coverage to improve the coverage area of the whole network. At the same time, the new proposed method has a faster optimization speed, and saves processing time overhead. The comparison of running time between two experiments of minimization method is shown in Fig.9.

5. Conclusions

This paper proved that the validity of introduction of normalization in processing of coding redundancy resolution of MCSDP based on GA algorithm, and optimization are based on the existing normalization method, further details of the evaluate conditions are proposed, and new parent selection mechanism is introduced, which both are verified by experiments. Experiment results show that the optimization processing method proposed in this paper retains the characteristics of the existing methods, and has better optimization performance and improves the network coverage rate and the speed of calculation, which validates the effectiveness and superiority of the method proposed in this paper.

Acknowledgements

The paper was supported by Natural Science Foundation of China (61172131; 61271377), and extend sincere gratitude to prof. Chen and research team.

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