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A Modified Genetic Algorithm Method for Maximum Coverage in Dynamic Mobile Wireless Sensor Networks

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ABSTRACT

Coverage issue is mainly about how to organize a set of sensor nodes scattered on a region in the best way to provide a good communication interface between them. They prone to fail due to energy depletion or technical problem causing the wireless network varied in time. This paper presents the development of Genetic Algorithm-based method to select the minimum number of sensor node required for the maximum coverage in the dynamic environment. A self-deployment mobile network is designed which working as hole recovery with minimum possible energy consumption utilizing Modified Genetic Algorithm (MGA). MGA shown the better performance in selecting which node need to be moved to create a maximum coverage with the minimum movement.
KEYWORDS : Genetic Algoritm, Wireless Sensor Network, Coverage.

INTRODUCTION

The important aspect that needs to be considered in Wireless Sensor Network (WSN) is the coverage and energy consumption. These two constraints are important because if the node runs out energy it will be dead, causing interfering in the information transfer process. Basically depletion of energy is mainly due to data transfer and sensor motion. Intensive literature review will be carried out on how to solve both problems using Genetic Algorithm approach.

Many researchers had focused on topology of sensor node for coverage optimization using the intelligent method including Ant Colony Optimization (ACO) [5], Genetic Algorithm (GA) [6,16,8,10,9] and Particle Swarm Optimization (PSO) [1,2,4]. Some of the algorithms proposed has been improved or combined to enhance the algorithm's ability. Researcher [1] solve the premature convergence problem of PSO using Improved Practical Swarm Optimization (IPSO) which is mainly inspired by Genetic Algorithm. Simulation proves that IPSO provides a better coverage ratio than using virtual force (VF) technique. Based on [9] GA is improved to a method called NSGA II, which able to perform faster coverage than proposed NSGA before. The added criteria is the use of Pareto ranking process to show the non dominating individual and sharing process to maintain convergence of the algorithm.

The Particle Swarm Optimization (PSO) aided with voronoi diagram to evaluate the fitness function has been proposed by [2]. In the paper, PSO is the major mechanism to determine the position of sensor nodes located in the region of interest while voronoi diagram will calculate the fitness. The algorithm works by creating a polygon shape for each sensor. A set of points chosen along the polygon boundary marked as interest points. The distance from the interest points to the nearest sensor node will be the fitness function describing the coverage behavior.

Individual Particle Optimization (IPO) is a method proposed by [14] based on how human brain works. IPO only used single particle instead of population like in GA or PSO. Therefore IPO utilizing chaos term to increase the diversity of the possible solutions. There will be always tradeoffs exists between minimizing the selection of the best solution and the exploration that would greatly decrease the runtime.

Research conducted in [6] also focusing on coverage and energy optimization. They proposed HN-GA method which is a hybridization of GA and Hopfield Network (HN). HN minimizing the GA search space by always validating each individual while satisfying the requirement of coverage rate and energy consumption.

This research is focused on proposing an efficient sensor network utilizing Genetic Algorithm (GA) as the main gear to localize the sensor node for maximum coverage and minimum energy in redundant node case. The method proposed called MGA used double elitism to create the tolerance in selecting the best node to be moved towards the virtual point. It is found that MGA gives the ability for WSN to adapt in dynamic environment providing maximum coverage with minimum movement of the mobile sensor node.

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THE PROPOSED ALGORITHM

The main idea of the proposed method is concerning the localization technique of sensor nodes using the grid approach with modified Genetic Algorithm. With the information of node communication range (r), the solution space is divided to form an organized location that supposedly fit by the node for a full coverage called as virtual point.

$$V = V_1, V_2, \dots, V_n \tag{1}$$

Modified Genetic Algorithm will responsible in choosing the random placement of sensor node to move towards the virtual point for maximum coverage. Movements of sensor node would degrade the battery life. Therefore MGA will have to assure that the selected sensor node moves at the lowest distance.

Firstly, initial population is generated. Inside the population there are list of chromosome strings. Each chromosome string is represented by genes (sensor node).

$$S = S_1, S_2, \dots, S_n \tag{2}$$

The fitness value of new population is evaluated by calculating the euclidance distance from each gene to selected virtual point. MGA has double elitism to avoid greedy of selection for the best node. Double elitism will drove the algorithm to be more tolerate in selecting the nearest node to move towards the virtual point. Double elitism is referring to two selected elite parents from the best gene and chromosome. First elite parent is chosen from the smallest distance travelled by individual sensor node (gene) towards the virtual point. Second elite parent representing the total minimum distance travelled by the sensor node (chromosome) forming a complete coverage area.

Then crossover will generate another form of chromosome to vary the elite parent found earlier. They will undergo exchange process of gene among one another to produce new entity called child or offspring. While in order to make sure that the selected nodes are the optimum ones to form the network, the child will undergo the mutation process. Where the chosen nodes are exchange randomly to other virtual points to make sure the selected nodes is at the best position for that virtual point only. The mutation will be repeated until the same number of population is gained back.

The algorithm is repeated and will stop when maximum generation allow reached. Eventually the final node selected is activated to move to the corresponding locations and other available nodes will turn to be in sleep state. Figure 1 shows the flow charts of the whole process.

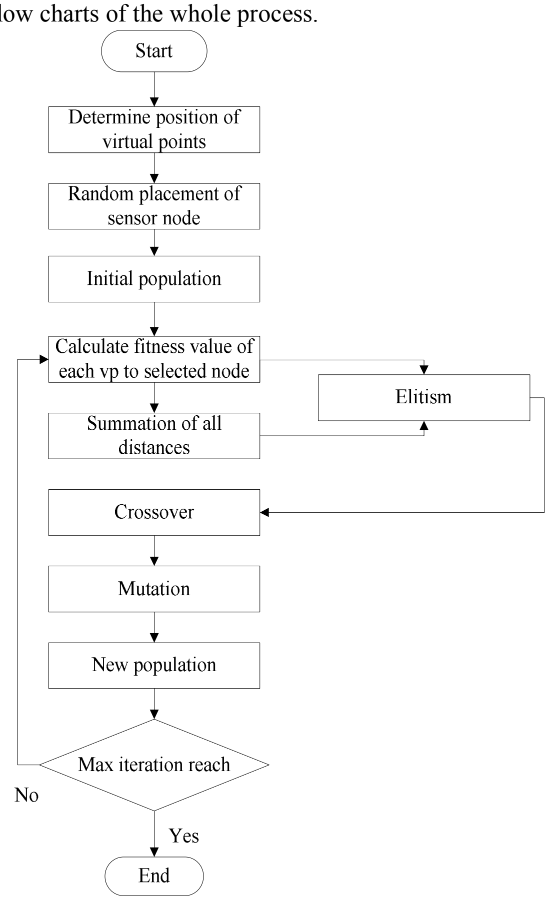

Figure 1: Flow chart

To solve the problem, following algorithm step is proposed.
Algorithm
Step 1: Evaluate the region of interest (ROI) using grid based approach. Virtual point (VP) is arranged on the ROI covering the whole region whereby the number of VP is equal to the number of required sensor nodes for the hole recovery.
Step 2: Initialize the GA population.
Step 3: Start GA operation
For iter=1:num_iter
Calculate fitness value from each virtual point to selected sensor node form from the population:

$$D(S,V) = \sqrt{(S_{nx} - V_{nx})^2 + (S_{ny} - V_{ny})^2} \quad (3)$$

Choose the nearest sensor node (gene) found for each virtual point as first elite parent:

$$E_1 = \min(D(S,V)) \quad (4)$$

Sum all distances of selected sensor nodes in a chromosome string:

$$T(S,V) = \sum_{n=1}^{p} \sqrt{(S_{nx} - V_{nx})^2 + (S_{ny} - V_{ny})^2} \quad (5)$$

Choose the total minimum distance travel by all sensor nodes (chromosome) as second elite parent:

$$E_2 = \min(T(S,V)) \quad (6)$$

Two selected elite parent undergo crossover and mutation forming a new population
End for
Step 4: Plot the result. Optimum sensor node chosen from GA operation becomes active and move to the selected location while others become inactive in sleep mode.

RESULTS AND DISCUSSION

Two scenarios is presented to show how MGA will contribute in performing minimum movement of the mobile sensor node while saving energy by performing sleep mode for the unused sensor node. In both scenarios, sensor node will be randomly placed in the predetermine network size. MGA then dynamically finds the most suitable sensor node to be moved towards the virtual point to cover the whole network. The algorithm is implemented in MATLAB with assumption of redundant sensor node case.

A. First Scenario

The first scenario shows how MGA perform to achieve maximum coverage with minimum distance traveled by the sensor node. Table 1 presents the parameter value used in generating the result.

Table 1: Simulation parameters

Parameter	Value
Network size	12m x 12m
Sensor node sensing range	2m
Number of sensor node	50
Number of population	100
Number of iteration	100

Based on the predetermine parameter MATLAB will randomly generate a network with distributed sensor node. For a full coverage localization technique of sensor nodes using grid approach is concerned. With information of node communication range (r), the solution space is divided to form an organized location that supposedly fit by the node to cover whole network called virtual point. Figure 2 shown the location of virtual point that should be filled by the randomly located sensor node. The virtual point is numbered accordingly for a better view.

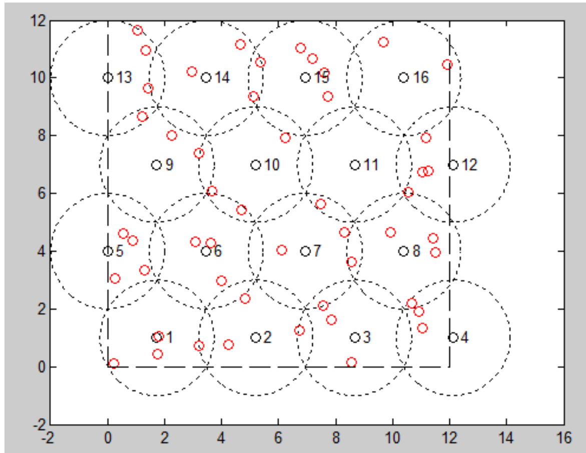

Figure 2: Location of sensor nodes and virtual point

The dynamic environment gives challenge on how to arrange the random position of sensor node for a maximum coverage. Figure 3 shown the chosen sensor node to be moved towards the selected virtual point after execution of MGA algorithm. MGA finds the best way to organize the scattered sensor node around the network providing the maximum coverage utilizing the minimum possible number of sensor node by minimizing the overlapping area.

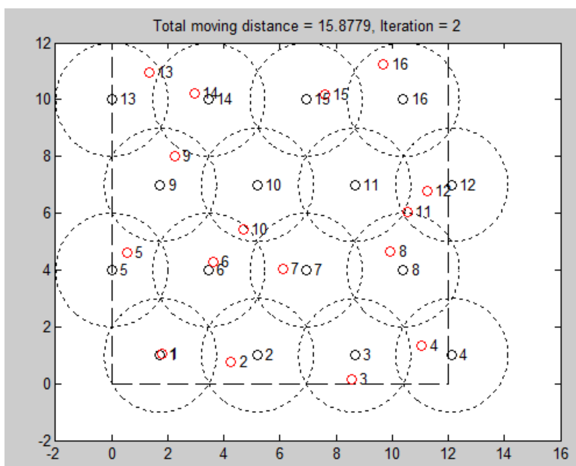

Figure 3: Selected node to respective virtual point after MGA execution

The selected node by MGA ensuring minimum movements will be in active state while the others will be in sleep states. The active nodes will always be ready for the data transfer. The sleep nodes will be awake only when they are needed to cover the hole replacing the active node that runs out energy. This continual process helps in providing full coverage area plus minimizing the energy from the unessential waste. Figure 4 shows the selected sensor node is moved to the selected virtual point and the unused sensor is turned to sleep mode.

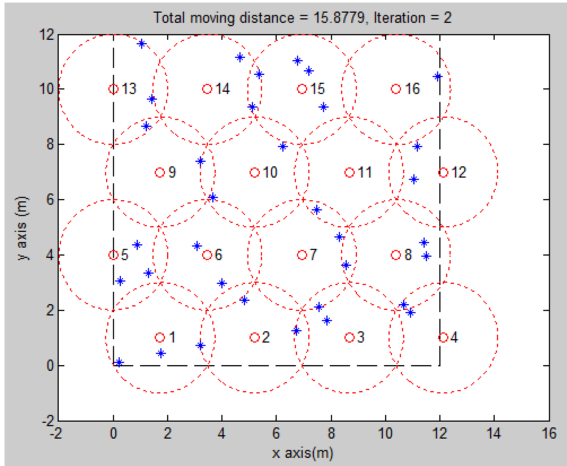

Figure 4: Complete network

B. Second Scenario

For performance comparison MGA method used in this paper will be compared with the ordinary GA. To analyze the effect of MGA and GA towards the sensor localization both methods is simulated with same parameters shown in Table 2.

Table 2: Simulation parameter

Parameter	Value
Network size	25m x 25m
Sensor node sensing range	2m
Number of sensor node	100
Number of population	100

The initial location of sensor is kept constant while the number of iteration is varied in order to see the robustness of the method developed. Since GA is a random search method, each result would be varied. Therefore mean and standard deviation is calculated to measure the consistency of proposed algorithm. The simulation is run 10 times to get the mean value and standard deviation for each iteration. Those value is then presented in figure and table form for a better analysis. The number of iteration would limit the time for the algorithm to find the optimum solution. Figure 5 shown MGA always able to perform better than GA in term of finding the lowest distance travelled regardless of iteration number.

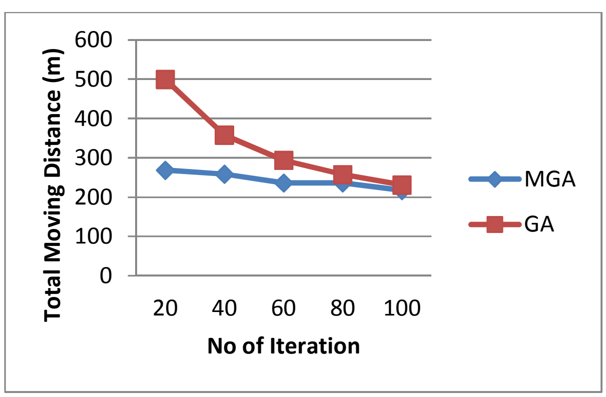

Figure 5: Performance graph

Further analysis is well shown in Table 3, showing MGA provides the lowest median and standard deviation value for the total distance travelled by all sensors. Using double elitism proves to be the benefit of MGA by avoiding the greedy search of GA method preventing it from premature convergence to local optima. Therefore MGA always provides better consistency than GA.

Table 3: Performance evaluation

Number of iteration	Total Minimum Distance			
	MGA		GA	
	Median	Standard Deviation	Median	Standard Deviation
20	268.83	12.32	499.69	20.84
40	258.58	14.68	357.88	15.99
60	236.67	14.77	293.95	16.63
80	236.67	14.77	257.77	13.83
100	217.06	14.56	231.29	14.95

CONCLUSION

In this paper it is found that MGA is a promising method to dynamically solve the coverage optimization in a random network size. MGA gives ability for WSN to adapt in dynamic environment providing maximum coverage with minimum possible number of sensor nodes. Producing a cost effective of self deployment wireless sensor network extending the network lifetime as much as possible. Moreover, MGA uses two elite parents to choose not just the nearest node to the virtual point but also the node that is most suitable to be moved for the overall system. Double elitism in solving random sensor node deployment is proven to be better than single elitism as ordinary GA could perform. Therefore the objectives successfully achieved where the optimum coverage for a complete network with minimum movement is attained.

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The authors declare that there have no conflicts of interest in this research

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