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Optimization of Wireless Sensor Network Coverage using the Bee Algorithm

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In this paper, a method for optimizing the wireless sensor network coverage was introduced using the bee algorithm. We simulated the proposed method in MATLAB software and compared the obtained results with the genetic algorithm. The results showed that the bee algorithm gives more optimal coverage percentage compared to the genetic algorithm and uses less time to use the system resources and implement the algorithm.

Keywords: bee algorithm, wireless sensor network, WSN coverage, sensors, optimization

1. INTRODUCTION

A wireless sensor network consists of a number of sensors. To determine the initial location of sensors, the network is firstly divided into close up multi-node clustering, and then in each cluster, using an election algorithm, a head cluster is selected, and then the head clusters send their own and sub clusters' data to the destination sensor. Due to the energy limitations of the sensors, each sensor monitors the environment over its lifetime and sends the obtained information with the intermediate nodes to the destination. After the setup, the main goal of these networks primarily gathered information and then the longer the network life. In sensor networks, each sensor node has at least one sensor unit and a communication unit that can collect information through these parts and transfer it to a station, laptop, or the nearest region proportion to the node in the sensor surface [1].

Each node in this network consists of three main parts of the sensor, processor and wireless transmitter / receiver, and sends the data received from the environment such as temperature, humidity, movement, pressure, light, and constituents of the material and so on, to a main station for the final processing. The source of energy supply in these networks is a fundamental challenge, therefore, providing energy efficient methods that increase the life of the nodes and, consequently, the life of the sensor networks, are of considerable interest to the researchers. Optimization issues are issues in which one or more target functions are defined as minimizing or maximizing with consideration of certain constraints

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and parameters. Global optimization in computer science and operational research is the search for approximate solutions that target the best possible status for the target characteristic. Ideally, the approximation rate for optimal solutions is acceptable to a small fixed error. But sometimes the process of searching around the problem converges to solutions that are optimally local rather than convergence to the optimal across the space. On the other hand, in high-dimensional search spaces, it is possible to have local optimal functions, so the likelihood of local optimization also increases in these spaces. The problem of optimization is more difficult in nonlinear and hybrid problems. Concrete methods and probabilistic methods can be used for the methods presented in solving optimization problems. Traditional or definitive methods in solving these problems can only map simple and linear relationships between the existing solutions in the problem space. In addition, they are not suitable for the wide range of issues, including multi-model issues, multi-objective issues, and issues with a large number of limitations, as they move toward local optimization, while, the probabilistic methods of problem solving are done approximately on nonlinear and obscure relationships [2].

If we consider an environment with a specific area, we can use meta-heuristic algorithms to optimize the coverage level by wireless sensors. Recently, meta-heuristic algorithms have been used to solve optimization problems, because these algorithms can find a set of potential solutions (populations) to identify the optimal solution through collaboration and compete among components in a repetitive process. These include GA, ACO, PSO, BEES, and other algorithms. Meta-heuristics have random components in their structure to better explore the search space. In fact, the common feature of meta-heuristic algorithms is to use the local optimal escape mechanism. They have the possibility to solve discrete and continuous problems. On the other hand, these algorithms also deal with issues, including: several parameters that should be set correctly for the problem. Furthermore, each of them has some kind of early convergence in solving the optimization problems. The early convergence is due to the lack of diversity in the population of solutions. In various meta-heuristic algorithms, different mechanisms are embedded for creating diversity in the population of solutions in a moment of the search process. Another issue that addresses these algorithms is the issue of guiding convergence toward global optimization. To do this, having background knowledge in relation to the problem, as well as, using the search mechanisms of different algorithms as complementary can contribute to global convergence [3].

In this paper, using bee algorithm, we achieve to a more optimal coverage and compared the result with the genetic algorithm, and we used Matlab for simulation, which is a software environment for numerical computing and a fourth-generation programming language.

2. THE PERFORMED WORKS

Fang and *et al.* (2018) was reviewed "Novel proficient organization plans for sensor inclusion in portable remote sensor systems." In this article two the novel sensor deployment conspire are proposed to the location the is inclusion issue in MWSNs. The initial a plan is visually impaired zone center-based a plan (BCBS) and the subsequent one is upset center-based plan (DCBS). The fundamental thoughts both in the BCBS and DCBS are the proposed plan to discover the objective areas for sensors to mend the inclusion gaps efficiently. The meaning of the Voronoi daze zone polygon is a given for presenting the proposed two plans. In the request to obviously an outlining the impact of the Voronoi daze zone polygon, three a potential instance of it are a concentrated in detail. In BCBS, the Voronoi daze zone polygon of every sensor is right off the bat the dictated by thinking about the situations with its neighbors. And afterward the centroid of the Voronoi daze zone polygon is a viewed as the objective area of every sensor if the inclusion can increment. In the DCBS, sensors a discover inclusion openings as indicated by the center-based the plan from the outset in each round. They at that point move to the objective areas under the neighborhood an annoyance and a nearby remaking administrators. These two administrators are structured by considering two types of neighborhood intermingling. Under the rule of proving ground based multi-metric the quality estimation of a sensor organization plan, recreation results are an adequately displayed to the exhibit the viability of the proposed two usage algorithms [4]. Suun and *et al.* (2018) was surveyed "A novel connectivity and coverage algorithm based on shortest path for wireless sensor networks". In this article the redundant nodes on the shortest path are a woken up in order to guarantee the connectivity of the network. Simulations results show that the number of working nodes of SPCCA is stables and they do the not increase with the number of the deployed nodes. Moreover, the SPCCA has a better performance than the most homogeneous algorithms in terms of the network coverage, connectivity, connection the cost and network lifetime [5].

Wang and colleagues proposed an algorithm for wireless sensor networks that increase the coverage and connection of wireless sensor networks in individual measurements, although they paid very little attention to the independence and accuracy of sensor nodes. In fact, due to the need for high-precision and system consistency, collaborative measurement is required in most applications. The practical results confirm that VF acts very good for sensor networks that only consist of mobile nodes, and some generalizations have been performed to improve the performance of this algorithm in wireless sensor networks. This is while wireless sensor networks always consist of both mobile nodes and fixed nodes to reduce cost and energy consumption. [6, 7] DPCP algorithm: The distribution of sensors in this type of coverage, due to the difficulty of the covered area from the point of view of its availability and extent, primarily is done as a result of firing with a rifle or splashing the plane, which in terms of the density of the sensor nodes or have the uniform distribution with Poisson's rate, or linear distribution that are the most abundant along the particular lines of the route. One of the most well-known models of border coverage is detection models. Considering the assumption that by increasing the distance between the sensor nodes, their monitoring accuracy decreases, consequently the probability of not identifying target increases, in detector models, the regions are identified with such characteristics that have the lowest visibility by the sensors around and measure is performed to deploy a new node or displacement of existing sensor nodes. Also, using the path Verron diagram methods with minimum coverage and Delaney triangulation method, the path has the maximized coverage which is controllable. In order to increase the network life span, the algorithms of division and capture are used to detect sensors with the same but different coverage, at any time a number of sensors are active and in the rest time they are in sleep or standby mode [8]. Megwardis *et al.* [9] have considered coverage as a criterion for measuring the service quality in the sensor network. They have provided an algorithm for solving the worst (violations) and best (supporting) coverage. This algorithm provides a violation path that the distance from a point p to its closest sensor is the maximum, and provides a supporting path that the distance from one point p to its closest sensor is the minimum. P is a point on the path. Cardy *et al.* [10], by considering the full coverage for the division of sensors, proposed an approximate algorithm to the maximum number of distinct regulator sets, where each distinct regulator set can fully cover the monitored area. Therefore, at any time, only one of the regulator sets is separate, active and responsible for the monitored area. They plan to achieve better energy savings, but they may create a point in the monitored area that is not covered by any sensor in the regulator's set. Gupta *et al.* [11] studied network connectivity and full coverage for displaying spatial data by introducing the concept of connected sensor coverage. They provided a centralized and distributed self-organizing algorithm that selects a subset of sensors that is sufficient to process the spatial data display in one area. Zhou *et al.* [12] generalized the issue of full coverage to the k problem, which aims to find a set of sensors so that each point in the monitored area is covered by at least k sensor in the selected sensor set. They measured the coverage problem with the assumption of providing a distributed algorithm. It also evaluates the issue of $r_c < 2r_s$ by providing an exploratory algorithm.

3. PROPOSED ALGORITHM

Bee algorithm is a meta-heuristic algorithm that using it, we optimized the coverage of a wireless sensor network in an area with a specific area.

In this algorithm, we have certain conditions for the problem, so that we have two types of leading and workers bees. In the first place, like the previous algorithms, we need to have primary random answers that for this, we spread sensors in the environment in which we obtain a flower. We need a number of flowers or answers in the problem, so we produce this number of the initial response. Then, the leading bees are sent to the flowers, and the flowers are randomly selected, and the number of leading bees is equal to the number of acceptable responses to the problem, which we consider it 50 leading bees. According to Fig. 1, after the bees return to their hive begins to dance.

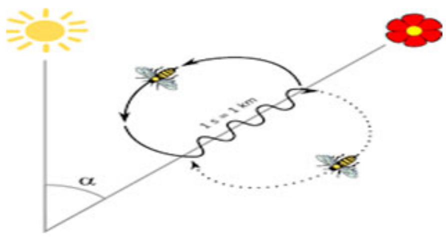

Fig. 1. Dance of the bees.

This dance is performed according to the angle of the sun and the angle of the flower's position, which α is the angle of the flower with the sun. The duration of the dance determines the distance to the source, and as the zigzag movement is higher shows the good amount of the source. Then, after referring the bee, we can take the high values through dance, and we do this in our simulation using the fitness function, and we save the weigh the sensors in one vector. After knowing the answers and the amount of their fitness and sorting them, we choose half of the good answers among them. We call these answers the chosen answers. Among the chosen answers, we choose the best answers to one tenth, which are called the top answers.

We will replace the rest of the answers with other random values. We send the worker bees to the selected answers and the top answers, but with the difference that we assign more bees to the top answers. Leading bees that did not have an acceptable answer are resubmitted to get the optimal answer.

Given that the worker bees identify the source according to the dance, the precision of the source is relative, and in the neighborhood of the good answer, they are looking for better answers and returning the results. At this stage, the response of the worker bees and the response of the leading bees, which did not have a good initial response, are compared with the selected and top answers, and the selected and top answers are re-elected and the worker and leading bees are sent, and this operation continues until the condition of the problem continues. And the result of the best answer is displayed at the end.

3.1 Setting the Initial Parameters

(1) The area of the environment in which we want to optimize the coverage is considered as a square (100 × 100) for the convenience of working, which can be converted to any conventional and unconventional form in the problem. The radius of each sensor is r that is calculated with respect to which coverage area of each sensor (πr^2), which this radius is considered to be 10 in this problem.
(2) The size of the total population (*n* pop) is equal to the number of scout bees, which we considered it to be 50 in this issue.
(3) We consider the range of selected answers as 50% of the total population size.
(4) We consider the range of excellent answers as 10% of the selected answers.
(5) We consider the range of worker bees dedicated to excellent solutions twice as much as the number of worker bees assigned to the selected answers.
(6) We consider a vector to store the coordinates of the existing sensors in the answer, each of the two components of the vector is corresponding to the coordinates x and y of a sensor.
(7) The fitness function for this problem is defined in the form of (sum of total coverage of sensors divided by the area of the evaluated region). To solve the problem of overlapping adjacent sensors, we use the relation $A \cup B = A + B - (A \cap B)$, and the socialization property is assisted for the calculation of the total coverage of all sensors. Considering the possibility of overlapping in the problem, Eq. (1) is used, which the answer is the sum of all the covers of the sensor, minus the overlapping points.

$$\left|\bigcup_{i=1}^{n} A_i\right| = \sum_{i=1}^{n} |A_i| - \sum_{1 \le i < j \le n} |A_i \cap A_j| + \sum_{1 \le i < j \le n} |A_i \cap A_j \cap A_k| - \ldots + (-1)^{n-1} |A_1 \cap \ldots \cap A_n| \quad (1)$$

(8) Using the fitness function, we evaluate the answers and sort them out.

3.2 Steps for Implementing the Bees Algorithm

(1) Generate the initial responses and evaluate them
(2) Select better responses and send worker bees to those sites
(3) Return the bees to the hive and perform a special dance (produce a neighbor response).

(4) Compare all the bees of a site and select the best case.
(5) Unselected bees (sites) are replaced with random answers.
(6) Save the position of the best answer
(7) Return to step (2) if the conditions are not met
(8) The end

4. SIMULATION AND COMPARISON

We implemented the bee algorithm in MATLAB software and the results of comparing the bee algorithm and the genetic algorithm (ga) with the same variables in the problem are as follows.

We run the program ten times and each time we used new random numbers. rng () is used in order to make the random numbers the same in the comparison performed with the genetic algorithm.

In the tables below, the results of the implementation of the algorithms are expressed as the percentage of coverage, the total run time, the time of the best answer, and the number of replies needed to achieve the best answer.

In Table 1, during ten repetitions with 32 sensors and the environment with the same area, the number of repetitions, the time of the best answer, the total run time, and the coverage percentage were calculated with the bee algorithm.

Calculated the calculated values by maintaining the same conditions with the genetic algorithm and we compiled the results in Table 2.

Table 1. Calculated values with the bee algorithm.

Random number range	Coverage percentage	Total time of run	Time of the best answer	Repetition
1	94.96	59.51	7.51	99
2	16.96	3.52	3.52	100
3	54.97	70.51	18.51	99
4	7.96	23.51	20.5	98
5	88.95	59.51	59.51	100
6	11.97	90.51	90.51	100
7	87.97	78.51	78.51	100
8	50.97	56.51	56.51	100
9	3.97	56.51	56.51	100
10	94.95	20.52	68.51	99

Table 2. Calculated values by genetic algorithm.

Random number range	Coverage percentage	Total time of run	Time of the best answer	Repetition
1	87.55	54.1	46.32	60
2	89.22	53.84	84.25	48
3	89.63	54.2	43.31	58
4	85.6	55.06	48.32	59
5	89.23	53.96	7.35	65
6	86.5	54.2	10.27	50
7	89.26	54.45	51.18	34
8	85.61	54.34	54.25	47
9	88.46	56.54	16.38	70
10	86.88	53.92	3.28	52

As you can see, the highest coverage of the bee algorithm in the same conditions that gives us 32 sensors in the same area is 97.87%, while the highest coverage in the genetic algorithm is calculated to be 89.63%. Also, the total run time to achieve the highest coverage in the bee algorithm is 51.78 seconds, if the amount in the genetic algorithm is 54.20 seconds.

Although, the best response and the rate of repetition in the genetic algorithm are lower, but the coverage that has been run at ten times with the same conditions is less than the bee algorithm shown in Fig. 1.

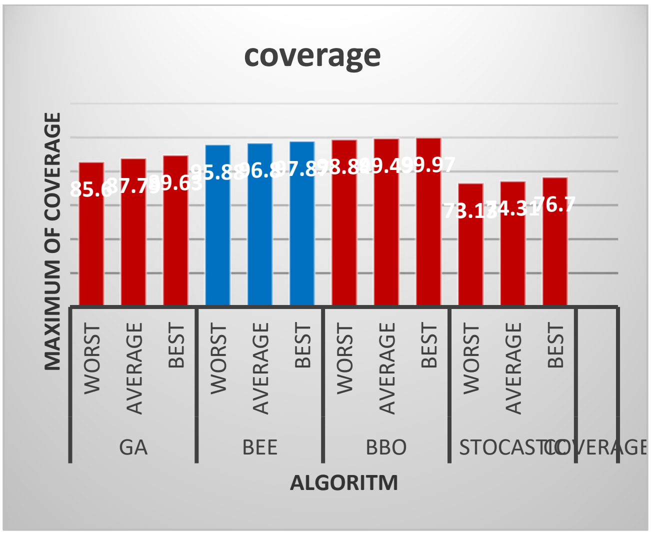

Diagram 1: Comparison of bee algorithm coverage and genetic algorithm under the same conditions.

According to diagram 2, if we assume the coating equal to 100%, the bee algorithm needs 33 sensors to reach 100% coverage, while in the genetic algorithm this value is 40 sensors, in this case the bee algorithm needs a smaller number of sensors.

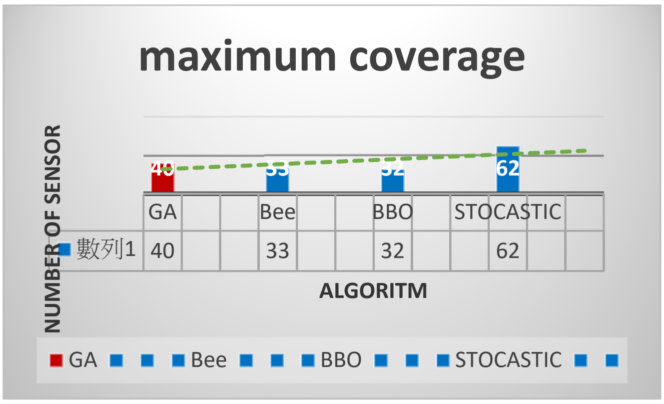

Diagram 2: The number of needed sensors for 100% coverage.

5. CONCLUSIONS

In this paper, a method for optimizing the coverage in a wireless sensor network was introduced using the bee algorithm. We simulated the proposed method in MATLAB software and compared the results with the genetic algorithm. The results showed that the bee algorithm gives the optimum coverage percentage compared to the genetic algorithm and takes less time to use the system resources and implementation of the algorithm, and also requires a smaller number of sensors. Finally, according to the obtained results, bee algorithm gives us a better coverage of the wireless sensor network than the genetic algorithm.

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