International Journal of Modern Trends in Engineering and Research
www.ijmter.com
e-ISSN No.:2349-9745, Date: 2-4 July, 2015

Effectual Bio-Inspired Algorithm for Wireless Sensor Networks

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Abstract— A Wireless Sensor Network (WSN) involves a large number of sensor nodes that can be used together data when a specific event occurs in the sensor network. There are numerous challenges in WSNs due to communication link failures, memory and processing restrictions and also limited energy. Many issues in WSNs are approached through bio-inspired techniques such as Swarm Intelligence (SI). Some of the SI based algorithms are Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and Artificial Bee Colony (ABC). A mobile node can be used to gather data from the sensor nodes. A path of minimum length for sensing data collection by using ABC algorithm is proposed. It helps to minimize the energy consumption in WSN. The proposed algorithm is able to successfully improve the efficiency in WSNs in terms of minimizing network traffic and maximizing sensor network lifetime.

Keywords- Artificial Bee Colony (ABC), Mobile Bots, Data Collection Path Planning Travelling Salesman Problem, Wireless Sensor Networks

I. INTRODUCTION

A Wireless Sensor Network (WSN) involves a large number of sensor nodes that can be used together data when a specific event occurs in the sensor network. There are numerous challenges in WSNs due to communication link failures, memory and processing restrictions and also limited energy. Many issues in WSNs are approached through bio-inspired techniques such as Swarm Intelligence (SI). Some of the SI based algorithms are Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and Artificial Bee Colony (ABC). A mobile node can be used to gather data from the sensor nodes. A path of minimum length for sensing data collection by using ABC algorithm is proposed. It helps to minimize the energy consumption in WSN. The proposed algorithm is able to successfully improve the efficiency in WSNs in terms of minimizing network traffic and maximizing sensor network lifetime.

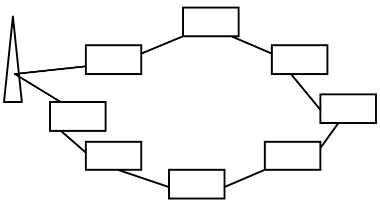

Figure 1: Example of Bot routing in a network with 7 sensors

Considering the energy efficiency, one of the first concerns is to lower the energy consumption on the mobile bot's data collection path travelling. Therefore, it is essential to plan a path that can reach all the disks and is within minimum path length to ensure high energy efficiency. We observe that such data collection path planning (DCPP) is essentially a traveling salesman problem with neighborhoods (TSPN). TSPN is generalization of traveling salesman problem (TSP) that is proved as NP hard. TSPN is different from TSP; on former a client meets the salesman within a region near his/her house, instead of waiting at home, which is the only meeting point in TSP. Therefore, besides the visiting sequence, the meeting point for each client is another critical issue that shall be solved in the final traveling path length in TSPN. Similarly, in DCPP problem, we shall decide both the sensor's visiting sequence as well as the meeting points on all the disks. Motivated by the High efficiency of artificial bee colony (ABC) algorithm [8] in solving combinatorial optimization problem, we apply the concept of ABC and propose an ABC- based DCPP algorithm. However, DCPP is not a pure combinatorial optimization problem since it also includes the decision on meeting points. We carefully design a meeting point selection strategy and integrate it into different phases of our ABC-based DCPP algorithm. Through extensive simulation results, the high energy efficiency that can be achieved by our proposal is validated.

II. LITERATURE SURVEY

To lower the energy consumption of data collection in sparse WSN using mobile robot, considerable efforts have been devoted to finding the shortest robot travelling path. Yuan et al.[14] used an evolutionary algorithm which first constructs the path by sensors coordinates and then fix the meeting point in each sensor by a given angle to the coordinate.

Comarela et al. [3] combine greedy and ant colony optimization (ACO) [6] algorithm to solve the traveling path planning problem. They first construct the initial solution by greedy algorithm and use ACO to shorten the path by adjusting meeting points' permutation.

Tekdas et al. [13] consider a scenario where multi- robots are exploited to collect data from sensors. They split the network into different regions according to the number of robots and then find the travelling path for each region.

Recently, Chiu et al. [2] consider situations involving sensors with overlapping communication ranges and propose a clustering-based parallel genetic algorithm to plan the traveling path. 1) Robot Routing Using Clustering-Based Parallel Genetic Algorithm with migration. In the above paper, author focuses on routing problems with data gathering by a mobile robot in a WSN, also referred as to NP-hard problem. In the above paper, author proposes a clustering-based parallel genetic algorithm with migration (CBPGA), so that the mobile bot can gather all data from all sensors and the travel costs of the mobile bot could decrease. A clustering algorithm is used to reduce the number of visited nodes, especially in situations where sensor density is large or has large sensing radius. The nodes which are visited are encoded as chromosomes by a chromosome generation algorithm (CGA), and the master slave parallel genetic algorithm with migration is performed to more efficiently generate the near-optimal route. A travel cost reduction scheme is used to reduce the travel costs.

Simulation results confirm that the clustering-based parallel genetic algorithm with migration efficiently generates a near-optimal route that reduces the travel costs of a mobile bot in bot routing problems with WSN.

The clustering of distance sensor nodes is done with the help of CBPGA algorithm and distance is calculated by CGA algorithm. However, the distance taken to collect the is much higher than the system being proposed in our paper. [2]. Using Mobile Robots to Harvest Data from Sensor Fields. In the above paper, author explores combined effect among mobile robots and wireless sensor networks in environmental monitoring by a system in which mobile robots collect data gathered by sensing nodes. A proof of concept implementation demonstrates that this approach significantly increases the system's lifetime by conserving energy that the sensing nodes would otherwise use for communication. In this paper the author presents a method to an end-to-end wireless network that forwards the nodes data to a back-end database. Instead, they propose to use autonomous robots as data collectors. These collectors visit locations within the communication distance of each of the static nodes, download their measurements and return to a remote base station to upload the collected data. The benefit of this approach is that nodes can conserve energy that they would use to forward data to sink node or end database, thus increasing the network's lifetime. However, in order to successfully deploy such a robot/sensor hybrid network, the author has faced new challenges such as planning of robots trajectories. Collection of data depends on region of the sensor nodes and then allocates the number of mobile nodes to collect data. However, the path and number of bots are precompiled. This becomes the bottleneck for distance sensors nodes. Failure of any node in path may block the system to collect data.[13] [3].

On the Optimal Robot Routing Problem in Wireless Sensor Networks. In this paper a set of distance distributed sensors in the Euclidean plane, a mobile robot is required to visit all sensors to download the data and finally return to its base station. The effective radius of each sensor is specified by a disk, and the robot must at least reach the boundary of sensor node to start the communication. The goal of author in this paper is to optimize the distance traveled by robot. The EA approach with TSPN calculates the minimum distance for at most 300 sensor nodes. However, there is limitation on number of sensor nodes to gather data in distance wireless sensor network. [14].

III. RELATED WORK

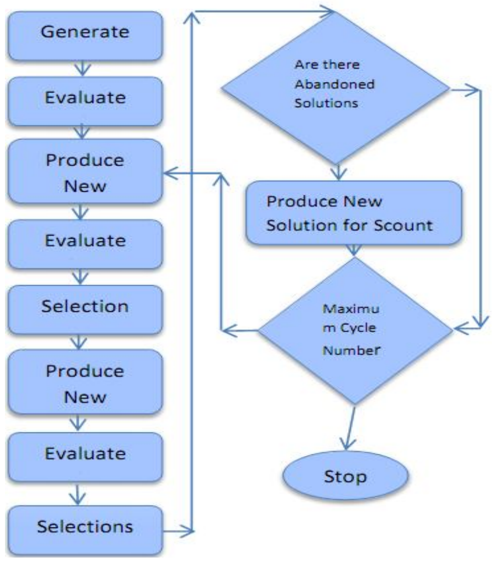

Figure2: Control Flow graph of Proposed Algorithm

Control Flow for Proposed Algorithm

In the following flow chart the first step is to generate the initial population. There after the population is evaluated and new solutions for employed bees are produced. After that the solutions are evaluated and new solutions for onlooker bees are produced. Again the produced solutions are evaluated and it is checked whether there are any abandoned solutions. If yes then new solutions for scout bees are produced, if no then this process is repeated till maximum number of cycles is reached.

Artificial Bee Colony (ABC) Algorithm:

Artificial bee colony algorithm is inspired by foraging behavior of bee and pro-posed by Karaboga et al. [8]. ABC algorithm has been successfully applied to various areas and proved more efficiency than some other optimization algorithms [7, 9]. The original ABC algorithm is developed for solving multi-variable function problem while in TSPN problem the meeting point p is just a multivariable in each circle, so we use ABC algorithm for solving TSPN problem. In ABC algorithm, the ABC contains three groups of bees: employed bees, onlooker bees, scout bees. The search procedures are carried out by those artificial bees iteratively and can be summarized as follows. Employed bees search food sources within the neighborhood of the initial food sources in their memory and they share new food sources information with onlooker bees. These onlooker bees then search a new food source according to the received information, i.e., finding out a new one from the neighborhood of existing food sources. Scout bees search a new food source randomly when an employed bee abandons a food source. At the beginning, ABC algorithm generates a large number of food sources randomly. A food source represents a possible solution. The employed bees produce a modification on the position of the food source in their memory. The quality of a food source, i.e., the amount of nectar, is evaluated by its fitness value. Then, the algorithm calculates all the food sources' selection probabilities by their fitness values. The onlooker bees select the food source with the largest probability value and produce a modification on the position of the food source. The fitness value of the new food source is calculated and compared with the fitness value of the old one. Then, the food source with the larger fitness value is recorded as the temporarily best solution. The best food source is iteratively updated for certain iterations.

The pseudo-code of ABC algorithm as follows:

Step 1 Initialization
Step 2 Evaluation
Step 3 Repeat

i. Employed Bees Phase
ii. Calculate Probabilities for onlooker
iii. Onlookers Bees Phase
iv. Scout Bees Phase
v. Memorized the best solutions achieved so far

Step 4. Until The maximum iteration number is reached.

An ABC-based algorithm for the TSPN problem

According to the principle of ABC algorithm, the proposed algorithm consists of four phases, the initialization phase, the employed bees phase, the onlooker bee's phase and scout bees phase.

```
Rbest
Nbest
For i=1 to S Do
      Ri = {S}
      Seq={S}
         No = S
Rbest
Nbest
For i=1 to S Do
 Ri = {S}
Seq={S}
 No = S
            End For
For j= 1 to n-1 do
Add the node nj with minimum distance to nj-1 int Seq
End for
For j=1 to n-1 do
       Random Select Meeting Point pj on cj
        Ri=Ri U {Pj}
        Evaluate the Ri Fitness value ni
```


If ni >=nbest then

Rbest=Ri
nbest=ni
End If
cycle=0
Repeat
Invoke Employed Bees Phase

Invoke onlooker bees Phase
If ni > nbest then
Rbest=Ri
nbest =ni
I = arg max RS = 1 ni
End if
Invoke Scout bees Phase
Cycle= Cycle+1
The following table describes the notations used in algorithm.

Table 1 List of Notation used in Proposed Algorithm

Particulars	Description
S	The Colony Size or the Number of Candidate Solutions
Rbest	The best Robot Routing with minimum value of Objective
nbest	The best Fitness Value of Best Robot Routing
Ri	The ith Candidate Route i= 1,2,3,4…………S
ni	The Fitness Value of Ri=1,2,3………S
M	Maximum iteration Number

According to the principle of ABC algorithm, our algorithm consists of four phases, the initialization phase, the employed bees phase, the onlooker bee's phase and scout bees phase.
After the initialization phase, the employed bees phase, the onlooker bee's phase and the scout bee's phase are invoked iteratively for M cycles. The best solution after each cycle is registered after each iteration. In initialization phase population of initial solution is created according to the colony size S. Each initial solution corresponds to one employed bee and therefore S initial solutions will be created. In employed bees phase, S numbers of bees are employed to improve the initial paths given in initialization phase. The next phase is the onlooker bee's phase, in which it tries to improve the solutions obtained by the employed bees phase. The employed bees phase uses a forward sequence to make sure that every point is connected to one of its nearest points in a quadrant. The purpose of scout bee's phase is to avoid being trapped into local optimum that usually occurs after running much iteration. In the scout bee's phase, we first find out the routing path with the maximum failures and then re-initialize the path in the hope that the quantity left over at the end of a cycle may find a better solution from the re-initialized path.

IV. MATHEMATICAL MODEL

A proper path enables the mobile bot to visit each disk at least once in order to collect all the sensing data and come back to s. The first point is defined as the point where the mobile bot enters a disk ci as meeting point pi. It is clear that pi will be on the boundary of ci. Though the bot can travel on the circular boundary of the disk more than one time, the first meeting point is important because the bot can start communicating and downloading data from the sensor. For representing a valid path Ri, a sequence of meeting points <s, p0, p1… pn, s> is defined. In order to minimize the routing energy consumption, a valid path with the minimum total distance is represented as

$$\min\ (R_{i)} = d(s,p_1) + d(s,p_n) + \sum_{j=1}^{n-1} d(p_j, p_{j+1})$$

A population of initial solutions, which is the initial routing route, is created according to the size of colony 'S'. 'S' initial solutions are calculated since there is one solution corresponding to every employed bee. A solution comprises of both the meeting points 'P' as well as the visiting sequence P{} to the sensor nodes. A two-phase strategy is used to start with the solution P{I, I} Є [1, s]. In the first phase, as is evident in lines 7 to 9 in above mentioned algorithm, the visiting sequence Seq of the sensor nodes is initialized by adding the nearest node in an iterative fashion into Seq till all the nodes are added in. The central point of each node's disk determines the distance in this phase. In second phase, 'n' meeting points from 'n' circle boundaries are calculated randomly as the initial meeting points. After obtaining an initial path, Ri, its fitness value ni is obtained as:

$$ni = \frac{1}{d(s,p_1) + d(s,p_n) + \sum_{j=1}^{n-1} d(p_j, p_{j+1})}$$

In the end the updating probability of pi of the final best routing path Ri is obtained as

$$\frac{n_i}{\sum_{j=1}^{s} n_j}$$

The above mentioned probability can be considered as the weight of Ri among all the S paths which are updated by employed bees. These will then be used in the onlooker bee's phase

CONCLUSION AND FUTURE WORK

WSNs with less number of nodes, a path of minimum length for sensing data collection by using ABC algorithm can be used. It helps to minimize the energy consumption in WSN and also improves the efficiency of the sensor network. Instead of one mobile node, many mobile nodes can be used in the proposed system as a future work. New algorithm with the joint consideration of mobile robots cooperation and travelling path planning could be proposed.

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