Artificial Bee Colony (ABC) Algorithm for Vehicle Routing Optimization Problem

Ashita S. Bhagade, Parag. V. Puranik

Abstract— This paper involves Bee Colony Optimization for travelling salesman problem. The ABC optimization is a population-based search algorithm which applies the concept of social interaction to problem solving. This biological phenomenon when applied to the process of path planning problems for the vehicles, it is found to be excelling in solution quality as well as in computation time. Simulations have been used to evaluate the fitness of paths found by ABC Optimization. The effectiveness of the paths has been evaluated with the parameters such as tour length, bee travel time by Artificial Bee Colony Algorithm. In this article, the travelling salesman problem for VRP is optimized by using nearest neighbor method; evaluation results are presented which are then compared by the artificial bee colony algorithm. The pursued approach gives the best results for finding the shortest path in a shortest time for moving towards the goal. Thus the optimal distance with the tour length is obtained in a more effective way.

Index Terms— Artificial Bee Colony algorithm, Bee travel time. , Nearest neighbor method, Tour length, Travelling Salesman Problem

I. INTRODUCTION

The vehicle routing problem (VRP) is one of the classic combinatorial optimization problems, which is *NP*-hard. While trying to solve the optimization problems, the classical optimization methods are found to be inefficient in optimizing the process parameters. They need completely defined constraint functions and objective functions. They are also found to be inefficient in solving the real wirld problems which are very complex in nature because of the involvement of more number of steps (numerical steps) and need for more computation time. Even for the traditional vehicle routing problem, only small instances can be solved to optimality by exact methods [15], [3]. Many heuristic algorithms are used to find the suitable paths for the vehicle considering some vehicle routing problems to be optimized. Artificial Bee Colony is one of the algorithms which is used to find the solutions in a considerably shorter time. This difficult combinatorial problem contains the Traveling Salesman Problem (TSP) as a special case to be considered for its optimization by using ABC. The Artificial Bee Colony algorithm was introduced by Dervis Karaboga in 2005. As it is a newly developed algorithm, the research is still going on to study and improve this algorithm. In this paper, a new approach has been proposed to develop this algorithm in a more effective way. This Paper is organized as follows: From the literature survey of Travelling Salesman Problem and Artificial Bee Colony Algorithm, the two algorithms has been studied. In the first section the travelling salesman problem is studied. It is then optimized by the nearest neighbor method whose disadvantages are observed. In the next section, artificial bee colony algorithm is studied which is then used for the optimization of the travelling salesman problem. In the further next section, the methodology used for simulation is explained and simulation results are observed and thus the limitations of nearest neighbor method has been removed by using Artificial Bee Colony Optimization. Thus the shortest path is obtained more effectively by considering very few control parameters.

Manuscript received on April 26, 2012.

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II. TRAVELLING SALESMAN PROBLEM

A. Literature Survey

One of the best vehicle routing problems is the Traveling Salesman Problem (TSP). In TSP a number of cities have to be visited by a salesman who must return to the same city with the solution of shorter routes. A Salesman travels around a given set of cities, and return to the beginning of the path (from where he started), covering the smallest total distance. The traveling sequence has to comply with a constraint, that is the salesman will start at a city, visit each city exactly once, and back to the start city. The resulting route should incur a minimum cost [16].Finding an optimized route in various fields is the main application of TSP. Efficient solution to such problems will ensure the tasks are carried out effectively and thus increase productivity. Due to its importance in many industries, TSP is still being studied by researchers from various disciplines and it remains as an important test bed for many newly developed algorithms [19], [20]. The Vehicle Routing Problem (VRP) is the m-TSP, each vehicle has to solve the problem of routing the paths in an effective way. The behavior of some animals has the tendency to solve the TSP. The animals which are focused to such behaviors are Bees or Ants. The travelling Salesman problem can be efficiently solved by taking their behavior under consideration.

B. Problem Solution

In solving the problem one tries to construct the route in such a way that the total distance traveled by the salesman is minimized [13].

To solve the TSP, nearest neighbor method is used. The nearest neighbor algorithm was one of the first algorithms used to determine a solution to the travelling salesman problem. In this, the salesman starts at a random city (or node) and repeatedly visits the nearest city (or node) until all have been visited once. Thus it obtains a shorter tour, but usually not the optimal one. The nearest neighbor method is based on comparing the distribution of the distances that occur from data point to its nearest neighbor in a given data set with the randomly distributed data set [8]. The important steps of the algorithm are:

- Step 1. Start from a random node at the beginning of the path.
- Step 2. Move to the nearest unvisited node
- Step 3. Repeat Step 2 until all nodes are visited by the vehicle. Then, join the first and last nodes. Based on it, the procedure for nearest neighbor method to compute an efficient path for TSP problem is as given below,
- Input-M: A city map, which is a matrix of 2D city coordinates.
- Enter the number of cities.
- Compute the distance matrix.
- Initialize the path.
- Perform nearest neighbor path finding loop
- Find each path, and then evaluate the minimum of the paths.
- Compute the path length.

The nearest neighbor algorithm is easy to implement and executes quickly, but it can sometimes miss shorter routes which are easily noticed with human insight, due to its "greedy" nature.

Thus there is a disadvantage of greedy strategy in this method, due to which some errors occur such as the optimal path obtained is not exactly the shortest path, time required to find the optimal path is more, etc.

III. ARTIFICIAL BEE COLONY (ABC)

A. General Description

Artificial bee colony (ABC) Algorithm is an optimization algorithm based on the intelligent behavior of honey bee foraging. This model was introduced by Dervis Karaboga in 2005, and is based on inspecting the behaviors of real bees on finding nectar amounts and sharing the information of food sources to the other bees in the hive. These specialized bees try to maximize the nectar amount stored in the hive by performing efficient division of labour and self-organization [10]. The three agents in Artificial Bee Colony are:

- The Employed Bee
- The Onlooker Bee
- The Scout

The employed bees are associated with the specific food sources, onlooker bees watching the dance of employed bees within the hive to choose a food source, and scout bees searching for food sources randomly [1]. The onlooker bees and the scout bees are the unemployed bees. Initially, the scout bees discover the positions of all food sources, thereafter, the job of the employed bee starts. An artificial employed bee probabilistically obtains some modifications on the position in its memory to target a new food source and find the nectar amount or the fitness value of the new source. Later, the onlooker bee evaluates the information taken from all artificial employed bees and then chooses a final food source with the highest probability related to its nectar number. If the fitness value of new one is higher than that of the previous one, the bee forgets the old one and memorizes the new position [5]. This is called as greedy selection. Then the employed bee whose food source has been exhausted becomes a scout bee to search for the further food sources once again.

In ABC, the solutions represent the food sources and the nectar quantity of the food sources corresponds to the fitness of the associated solution. The number of the employed and the onlooker bees is same, and this number is equal to the number of food sources [11].

Employed bees whose solutions cannot be improved through a predetermined number of trials, specified by the user of the ABC algorithm and called “limit”, become scouts and their solutions are abandoned [1], [9].

B. Formal Definition

In this algorithm, the employed bee produces a modification in the position (i.e. solution) in its memory and checks the nectar amount (fitness value) of that source (solution).

The employed bee then evaluates this nectar information (fitness value) and then chooses the food source with the probability related to its fitness value.

Movement of Onlookers: Probability of selecting the source,

$$P_i = \frac{F(\theta_i)}{\sum_{k=1}^{s} F(\theta_k)} \qquad (1)$$

P_i : Probability of selecting the i^{th} employed bee.

S : No. of employed bees

θ_i : Position of the i^{th} employed bee.

$F(\theta_i)$: The fitness value.

Calculation of new position:

$$x_{ij}(t+1) = \theta_{ij}(t) + \emptyset(\theta_{ij}(t) - \theta_{kj}(t)) \qquad (2)$$

x_i : Position of the onlooker bee.

t : Iteration number.

θ_k : Randomly chosen employed bee.

j : Dimension of the solution.

$\emptyset(\blacksquare)$: Series of random variables in the range [-1,1]

This is known as greedy selection strategy.

Movement of Scout bees:

$$\theta_{ij} = \theta_{j\,min} + rand \cdot (\theta_{j\,max} - \theta_{j\,min}) \qquad (3)$$

r : Random number and rand Є [0,1]

IV. METHODOLOGY

The general scheme of the ABC algorithm is as follows:

Bee Initialization Phase

Set the Loop

Employed Bee Phase

Onlooker Bee Phase

Scout Bee Phase

Memorize the best solution found so far

Until the loop is terminated

The essential control parameters in the Artificial bee colony algorithm are, the number of food sources which is equal to the number of employed/onlooker bees (CS-Colony Size), the working to onlooker bee rate, the value of the limit (L) and the number of cycles or the number of iterations (MCN) that are required to terminate the program.

The implementation of Artificial Bee Colony algorithm for solving the TSP problem is explained with the help of flow-chart shown below:

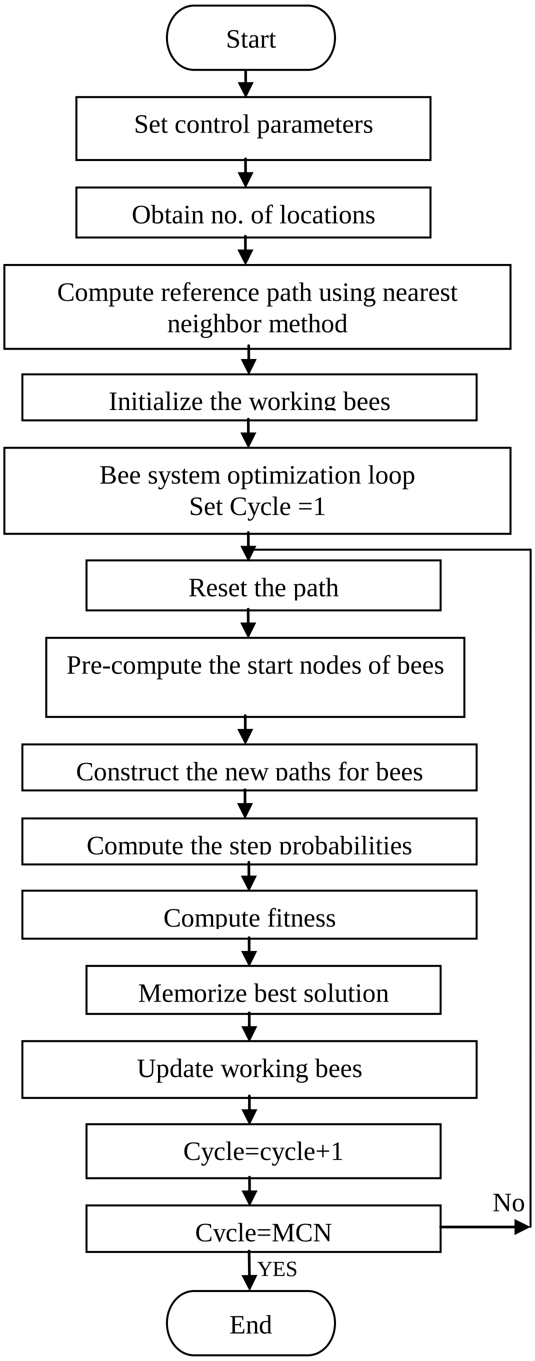

Fig.1 Flowchart of ABC algorithm for Travelling Salesman problem

Fig.1 shows the flowchart of implementation of Artificial Bee Colony algorithm for optimization of the Travelling Salesman Problem. In the initialization phase, the control parameters are set, such as colony size, iteration number (bee travel time), working to onlooker bee rate. In the next phase, the map is given as an input to the vehicle with the number of locations that are to be visited by the vehicle. Then a reference path is obtained by using nearest neighbor method. Further when the working bees are initialized, the bee optimization loop is set. Then the random node is assigned for the bee to start, then by computing the probabilities given by (1) the bees will work and draw the next node to obtain the path by using (2) and will memorize the best solution found so far using the greedy selection strategy. Finally the bees become scout bees and the number of working bees is updated, that is the employed bee which is exhausted becomes the scout bee again. The optimization loop is terminated when the numbers of iterations are completed and the best result is obtained. The scout bees then again start to search for the new path by (3).

The features of a vehicle that are to be considered for its optimization as shown in table(I) are related with the parameters of the Artificial Bee Colony algorithm.

Features of VRP	Options to ABC
Number of vehicles	Colony size (number of bees)
Input to vehicles	Data (map consisting locations in the given areas)
Maximum time on route	Working time (time constraints)
Number of depots	Number of food sources
Kind of demand	Non Deterministic
Activities of a vehicle	Working, Onlooker and Scout bees
Constraints to the vehicle	i)It starts from a random position ii) visit each source only once iii) Begin & end their route at the same source.

Table (I) Parameters to relate ABC with the VRP

V. SIMULATION RESULTS

These are the simulation results achieved by using Artificial Bee Colony algorithm to the Travelling Salesman Problem. The Artificial Bee Colony system consists of the parameters such as population size (no. of working bees), number of iterations (bee travel time), and working to onlooker bee rate (0 to 1). In table (II), there are presented the names of the areas that are to be considered, the number of locations and optimal length achieved by ABC and without using ABC.

Name of Areas	*No. of locations*	*Optimal distance Without ABC*	*Optimal distance Using ABC*

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Telankhedi	38	9748.95	6788.49
Hingna	194	11892.89	11698.54
Dharampeth	734	102594.36	100426.70
Sadar	**929**	**117733.70**	**116761.46**

Table (II) Definition of areas for case study.

The input parameters are:
Enter the bee travel time: 900
Enter Number of Bees: 80
Enter Working to On-Looker Bee Rate (0-1): 0.7
The output obtained:

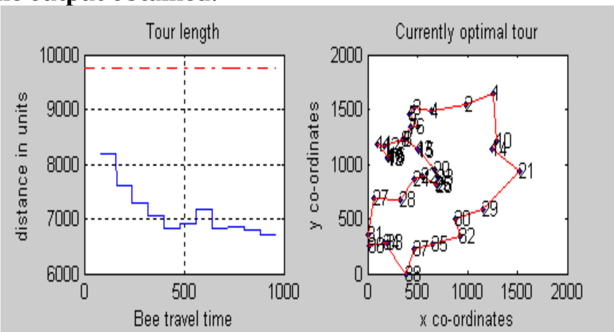

Fig.2 (a)

Fig 2(a) demonstrates the path obtained by the bees in the area defined as Telankhedi having 38 locations and it also gives the tour length consisting of the no. of iterations and the distance that is optimized by using artificial bee colony algorithm.

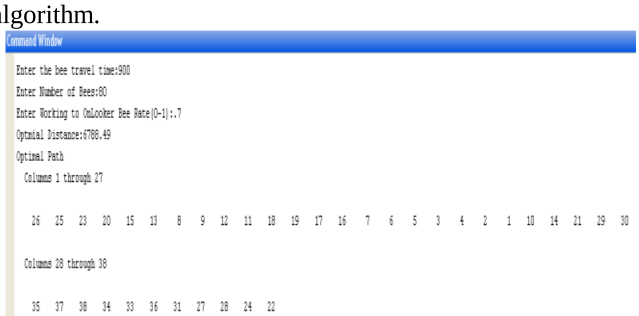

Fig.2 (b)

Fig 2(b) shows the optimal path and the optimal distance obtained as,
optimal distance: 6788.49 and the *optimal path* as
Columns 1 through 27
26 25 23 20 15 13 8 9 12 11 18 19 17 16 7 6 5 3 4 2 1 10 14 21 29 30 32
Columns 28 through 38
35 37 38 34 33 36 31 27 28 24 22
Similarly the graphs for other areas are shown in the following figures. Fig 3(a) demonstrates the path obtained by the bees in the area defined as Hingna having 194 locations and it also gives the tour length consisting of the no. of iterations and the distance that is optimized by using artificial bee colony algorithm.

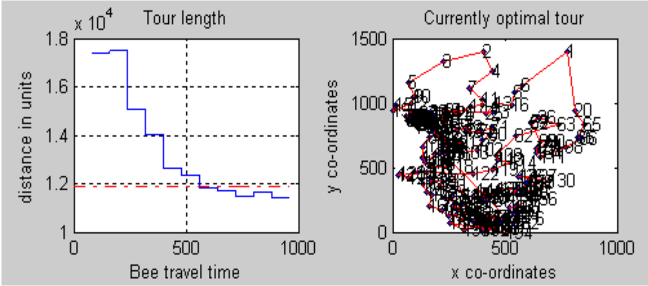

Fig.3 (a)

The black part in the optimal tour graph indicates the number assigned to each node. As the locations are increased in further figures, the dark region is more. Fig 3(b) shows the optimal path and the optimal distance obtained.

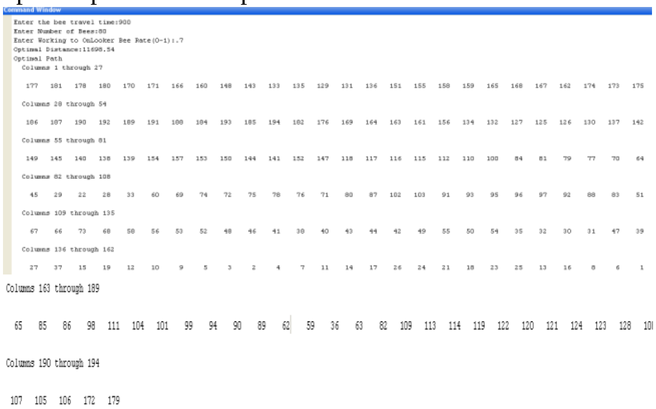

Fig.3 (b)

Also the path can be obtained even with the large number of locations (or nodes) such as for 900 locations or even more than that. Those are defined here for the areas such as Dharampeth and Sadar.

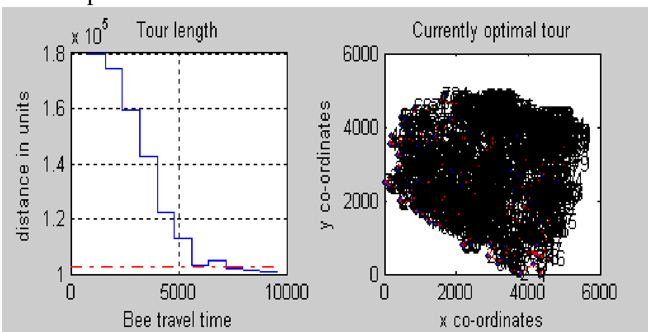

Fig.4

Similarly Fig (4) and Fig (5) shows path obtained by the bees in the areas Dharampeth and Sadar with their respective tour length and the optimal distance.

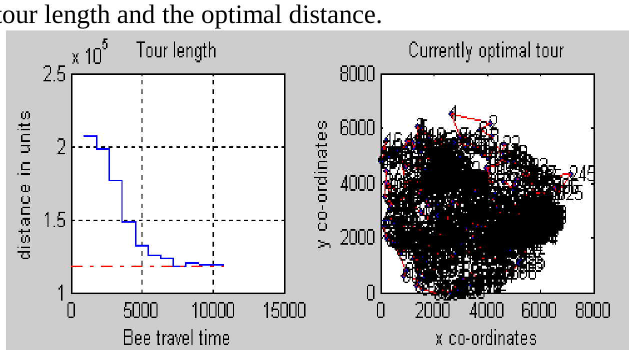

Fig.5

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The Bee matrix can also be shown in the output which demonstrates the type of bees that are working in the respective areas. Fig (6) shows the working bees/onlooker bee's matrix. Here, the color coding for the bee desirability matrix for the area telankhedi is as follows,

Red – Employed bees phase
Green – Onlooker bees phase
Blue – Scout bee phase

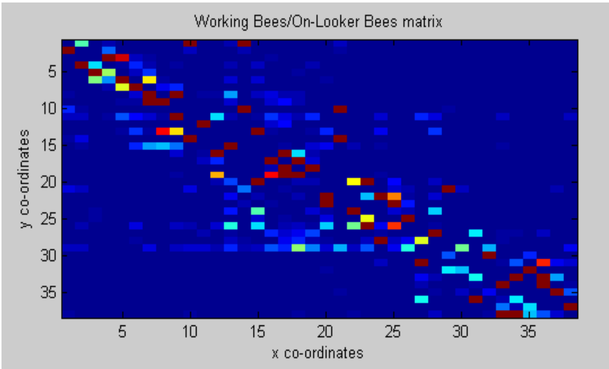

Fig.6

VI. CONCLUSION AND FUTURE SCOPE

In this paper, Artificial Bee Colony algorithm is presented by considering a new approach. The Artificial Bee Colony Algorithm can be used to solve several optimal problems. It is aimed to minimize the length of the tour and find the optimal path. To obtain performance comparisons with the other method, simulation framework is developed. The simulation outputs show that the optimal distance achieved by ABC Algorithm is smaller and error free as that of the one without ABC. It is thus concluded that the Artificial Bee Colony Algorithm can be efficiently used for solving the Travelling Salesman Problem in this paper. Thus the Artificial Bee Colony Algorithm is highly flexible and can be effectively used to find the shortest path by considering *very few control parameters* as compared with the other heuristic algorithms.

Future work might incorporate the comparative study of Artificial Bee Colony algorithm with the other optimization algorithms.

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