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# Combining Genetic and Artificial Bee Colony Algorithms to solve Travelling Salesman Problem

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**Abstract**
One of the main graph algorithmic problems is Travelling Salesman Problem (TSP). This problem is one of the NP-Hard optimization problems that has no calculating solution and maybe there's no exact solution in polynominal time. The goal of TSP is achieving the shortest path among a collection of cities, so that each city is visited just once in the path and constructed path leads to the first city. In this article, for solving TSP, artificial bee colony (ABC) and genetic algorithm (GA) were combined, we compared it with GA and ABC algorithms.

**Keywords:** Travelling Salesman Problem, Genetic Algorithm, Artificial Bee Colony Algorithm, NP-Hard Problem.

## Introduction

Optimization problems are considered as the main part of research areas in different sciences. Most of optimization problems in engineering are naturally more complicated and more difficult that are not solvable with common optimization methods such as math programming and so on (Asadi et al, 2012), therefore to solve these problems we use natural or intelligent methods. TSP consists of n cities that one path can be existed between each two cities that each of these paths has special distance or cost. In this problem that is called Hamiltonian shortest path, travelling salesman wants to start his path from one of these cities, then travels to all cities and passes each city only once and finally goes back to the source city. Here, the goal is finding the order of cities that travelling salesman passed in such a way that the total travelled distance is minimized.

TSP is one of the NP-Hard problems that is considered important and frequent in computer science. Three main methods to code this problem solutions in different algorithms have been presented which are as follows:

- Showing answer in the form of discrete sequence permutation.
- Showing answer in the form of Random Keys.
- Showing answer in the form of pheromone-like matrix.

In this article we want to solve TSP using the combination of GA and ABC algorithms.

## Artificial Bee Colony Algorithm

ABC is one of the newest optimal algorithms and simulating the behavior of food searching by bees (Karaboga and Akay, 2009). This algorithm was discussed first by karaboga that used it for solving optimization problems (Karaboga, 2005).

A bee colony includes three groups: employed, onlooker and scout bees that first a random population of them is distributed in colony (Kheyrihassankandi et al, 2012). The position of any food source shows a possible solution of problem space and the amount of nectar each food source identifies obtained solution quality and the number of employed bees around the hive equal to the number of food source or the number of solutions. Generally floral lands with the abundant nectar must be met by more bees. This algorithm is expressed in the following general steps:

1. Choosing primary solution by employed bees:

In early stage, bees in the colony are divided into two categories: Employed and onlooker bees. Employed bees first without any recognition search in the space around hive and choose primary solutions randomly and keep each food source and its location in their mind.

2. Primary solutions assessment and choosing scout bees:

After searching process, employed bees return to hive and share their information about the quality of food sources with onlooker bees. Onlooker bees are as goal function that assess the quality of sources nectar that employed bees have found. The amount of nectar related to each food sources is appropriate with the quality of problem solution that is gained by that source which is calculated as followes:

$$F(nectar_i) = 1/cost_i \quad (1)$$

In above equation $F(nectar_i)$ is the amount of food source $i$ and $cost_i$ is cost function of bee solution $i$. therefor onlooker bees using selection methods such as elitism, consider the number of solutions with more quality as scout bees. In another word, if the amount of food source nectar is more compared to other ones, it means that this source has more chance for choosing and is converted to scout bees with more possibilities by onlooker bees. The possibility of bee $k$ choosing is calculated as scout according to below equation:

$$P_i = \frac{F(nectar_i)^{\mu}}{\sum_{k=1}^{N} F(nectar_k)^{\mu}} \quad (2)$$

In this equation $F(nectar_i)$ is the amount of food source $i$ nectar and denominator is equal to the amount of whole available nectar around the hive. Whatever $\mu>1$ is, scout bees choice will be in elitism.

3. Recruitment process for scout bees:

After choosing the number of bees with better solution as scout bee, we will consider some soldiers appropriate with population for each scout. The meaning of recruitment is employed bees for scout bee to search food source around proposed solution by scout bee. The number of bees that are given to each scout bee is calculated according to equation 3:

$$S_i = \beta \times (P_i / H) + \gamma \quad (3)$$

$P_i$ is the priority of scout bee $i$ and $H$ is the whole number of scout bees. In above equation $S_i$ is the number of soldiers that is given to scout bee $i$. $\beta$ and $\gamma$ determine the kind of recruitment and can be stable or variable. If $\beta=0$ the number of soldiers for all scout bees are chosen appropriate with y and if $\beta>0$ less soldiers are given to better qualified scout bees and vice versa and as result if $\beta<0$ more soldiers are given to better qualified scout bees. $\gamma$ also is always a positive parameter.

4. Searching food sources guiding by scout bees:

Each employed bee moves in its scout bee food source's neighborhood for searching a new food source in problem space. In another word soldiers must investigate points besides more qualified answer guiding scout bees. Each scout bee has a Gaussian probability function that the pick of this probable function is related to scout bee solution. The points that related soldiers of each scout must search will be identified by this function. Whatever the soldiers' solution is closer to its scout bee solution, the possibility of their searching will increase toward farther soldiers solution. The location select of nearby food source in location $\theta_i$ in repetition $t$ follows below equation according to Gaussian probability law:

$$\theta_i(t+1) = \theta_i(t) \pm \phi_i(t) \quad (4)$$

In this equation, $\emptyset_i(t)$ is food source that is obtained completely random around $\emptyset_i$, and has an amount between zero and one maximum amount. $\emptyset_i(t)$ is the location of scout bee neighborhood is in repetition $t$ (Repeat ago) and $\emptyset_i(t+1)$ also is the location of scout bee neighborhood in current repetition.

Therefor in ABC primary random searching cause algorithm scape from local minimum trap and searching in better neighbor points causes achieving optimal algorithm. After searching process and creating new population, all bees again return to hive and the level of assessment will be repeated to stop conditions will be provided.

## Genetic Algorithm

Mr. Goldberg could provide framework and rules of GA by publishing "Genetic Algorithms in Search, Optimization and Machine Learning" book in 1989 and in 1990 convergence of GA was proved (Choi and Moon, 2007). GA is search heuristic and optimization algorithm that running in parallel and inspired by Darwin's principle of natural selection and genetic replication. In another word, these algorithms are optimization techniques based on the selection and recombine of promising solutions. The purpose of running GA on these problems is evaluating the ability of this algorithm to achieve optimal solutions and also evaluation of convergence and its performance per various settings (Singhi

and Liu, 2006). In the traditional GA, solutions are displayed as binary strings of 0 and 1. Coding according to the type of problem can be binary or real.
GA starts with generation an initial population that it is shown by chromosome. In this algorithm, generated answers from present population is used for new population that must be optimated. Selecting answers to provide new answers or child will be based on propriety function. In any step for having a new child, parents will be combined and to improve answer mutation is used. Generally GA uses four following operators: initial population, selection, crossover and mutation. General framework of GA can be as the following pseudo code:

```
Create initial population of size n;
Repeat
{
For i=1 to k
{
Choose parent1 and parent2 from the population;
Offspring ←crossover (parent1, parent2);
Offspring ←mutation (offspring);
}
Replace (population, [offspring1, offspring2, offspring]);
} until (stopping condition);
Return the best solution;
```

**Fig.1. Genetic Algorithm steps.**

## Background of Research

Methods of solving TSP can be divided into two groups of accurate and meta-heuristic algorithms.
Banding algorithm is one of optimized algorithms for solving TSP which was presented (Beardwood et al, 1959). This algorithm was introduced as a tool about treatment of optimized net's length. The other one of oldest and most effective research in the use of branch and bound method to solve this problem provided (Little et al, 1963). In this method counting is done based on all the paths on the tree of travelling salesman. Space filling curve algorithm was invented by Platzman et al (Platzman and Bartholdi, 1989). They proved that space filling curve algorithm does not produce net at time worse than O(log N) never. Storage algorithm is a perception of symmetric TSP which by heuristic algorithm of vehicles' path that was introduced by Clarke and Wright (Clarke and Wright, 1964). Also CCA algorithm which stands for three algorithms of Convex shell, cheapest insert and angle choose and is presented (Golden and Stewart, 1985). It is claimed this method is the best method of making the net. Lin and Kernighan algorithm does not limit its search to movements that changes a limited number of edges. In fact it can change almost all the edges of the net in the individual movements (Lin and Kernighan, 1971). Heuristic-Greedy methods was used by Cheng and Mitsuo that this method leads to changes in the decomposition action of GA and its aim is path length in children (Cheng and Mitsuo, 1994). Bontoux et al solve the TSP by using memetic algorithm in 2010. In this problem, cities divided into different categories, so that each of these categories should be visited exactly once. The purpose of this problem is to minimize costs (Bontoux et al, 2010). Yan et al solve the TSP by using Particle Swarm Optimization algorithm. They compared the results with GA (Yan et al, 2012). GA was used by Gupta and Panwar in 2013 that combining the knowledge from heuristic methods and genetic algorithms is a promising approach for solving the TSP (Gupta and Panwar, 2013). Combining genetic and tabu search algorithms was used by Thamilselvan and Balasubramanie in 2009 that the main goal of this is reducing cost and time. In this article, result of combination were compared with each of algorithms that is to show the superiority of it (Thamilselvan and Balasubramanie, 2009). Karaboga and Gorkemli solve this problem by using a combinatorial ABC algorithm. They use experimental data to prove the superiority of their method (Karaboga and Gorkemli, 2011).

## Proposed Model

In present study, we combined GA and ABC algorithms to solve the TSP. The combination is so that at first creates a series of random answers for GA and then we continue repeating and generation by running permutation crossover and mutation functions. In normal mode a series of random answers considered as initial answer for ABC. In suggested model, we enter obtained answer of GA as the initial solution set into ABC and then the final result is obtained that convergence rate of the algorithm is increased. Convergence is the time or repetition number to achieve the optimal answer by that algorithm which the sooner you get the result, the more you are converge to the optimal answer. Since the ABC first answer is generated from GA, the problem answer is smaller than an original state of algorithm or in other words, it tightens the answer space and we face a smaller space compared to the original space that means we are close to the optimal answer so we achieve the result with small repetitions. The proposed combination model has been shown in figure 2:

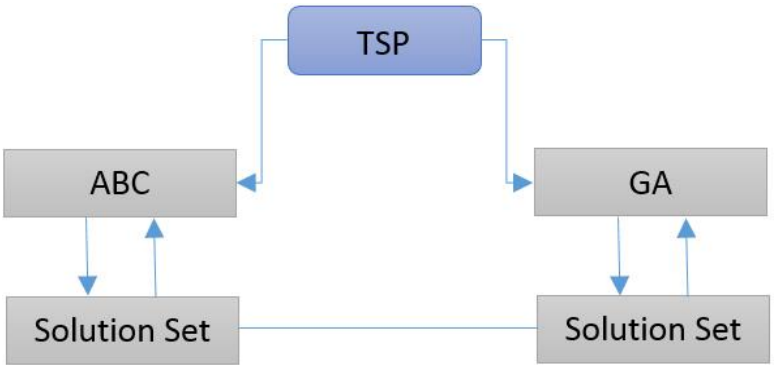


**Fig.2. Diagram of proposed model.**

## Result

In this part, the obtained results from GA, ABC algorithems and proposed combination model to solve TSP is investigated. The maximum circle of any olgorithm is 200 that if we can't get the optimal answer in any circle after 5 iterations, the answer space will change, it means that limit variable in algorithm is 5, also high and low limit of parameters is 5 and -5. The achieved results from GA, ABC algorithms and proposed combination model by Matlab simulation has been shown in figures 3 to 5:

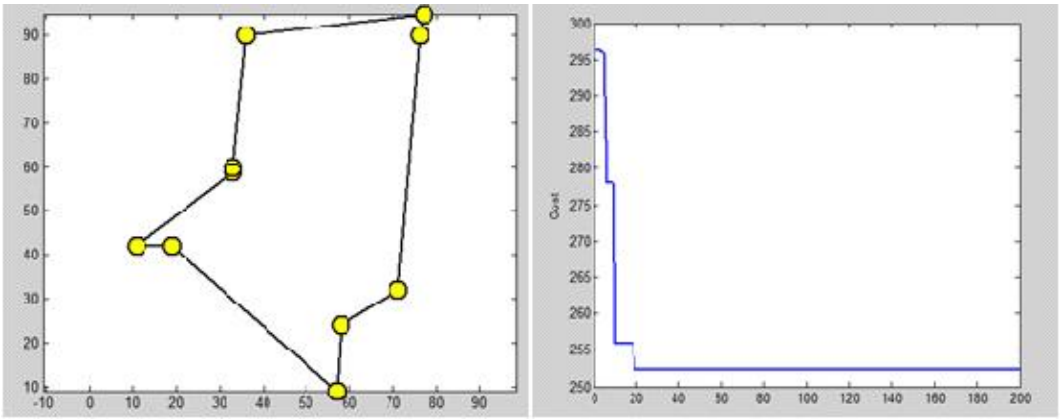


**Fig.3. Chart of running and the cost function of GA to solve the TSP.**

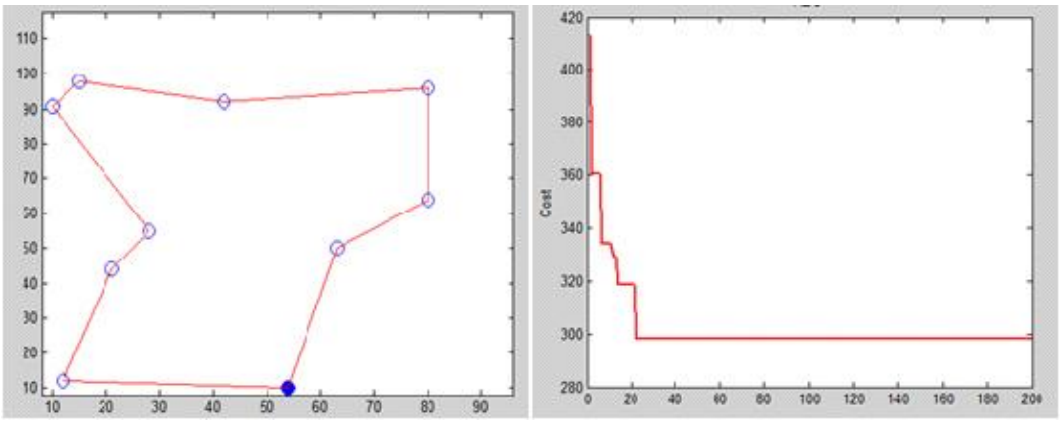


**Fig.4. Chart of running and the cost function of ABC to solve the TSP.**

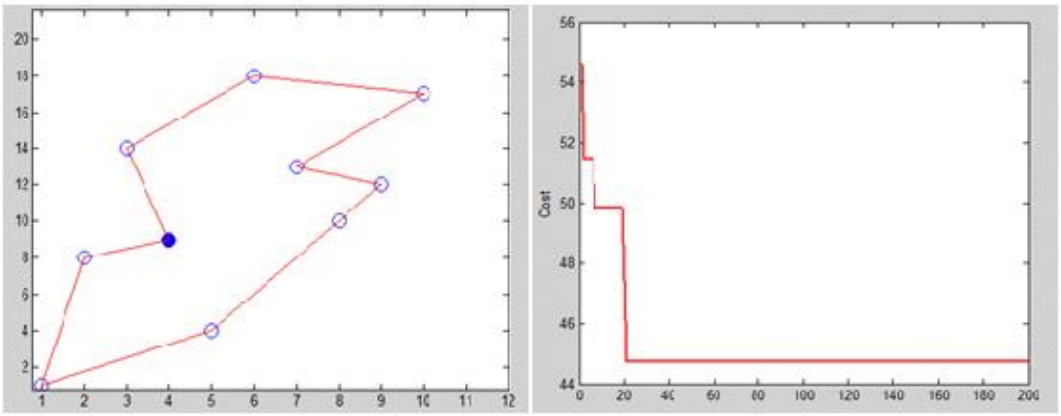


**Fig.5. Chart of running and the cost function of proposed model to solve the TSP.**

The proposed combination model was applied on a directed and weighted graph with 10 node and the result was the Hamiltonian shortest path in graph. Also to show superiority of this model, it was compared with GA and ABC algorithms. According to the results from they algorithms It was showed that the proposed combination model works better than other algorithms itself, Although GA and ABC are among the best optimization algorithms.

As you see, using GA to solve TSP leads to convergence After 20 iterations and the amount of cost function is 252.1969. ABC algorithm leads to convergence after 8 iterations and the cost function is 298.0704 and proposed combination model leads to convergence after 54 iterations and cost function is 44.7096. based on the descriptions and results in graphs, it is clear that the proposed combination model have a better performance than GA and ABC algorithms and leads more quickly to optimal answer and because of this capability it is considered as a superior model.

## Conclusion

GA and ABC algorithms achieved an acceptable results in solving optimization problems and of their good qualities you can refer to high speed and simplicity in terms of complexity in comparison with other optimization algorithms. Capabilities of this algorithms in solving hard problems provides the motivation to solve TSP with combination of these two algorithms, that is one of the important problems in gragh theory that using this method we managed to solve this NP-hard problem and achieved efficient results. combination is in a way that after utilizing GA, the result is entered to ABC algorithm as an initial data, Cost function amount in combination model is better than GA and ABC algorithms. According to the results the proposed combination model had a successful performance in solving TSP.

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