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Solving Traveling Salesman Problem (TSP) using Ants Colony (ACO) Algorithm and comparing with Tabu Search, Simulated Annealing and Genetic Algorithm

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ABSTRACT

In the present age, energy is considered as one of the important economic indicators. It is obvious that with regard to the limitations of resources and also the attention to the importance of reduction in the cost of production activities, service activities and other activities of this kind, decision-makers are seeking for new methods together with accurate and rapid answers to access the optimum tools. Thus, it is no doubt that with benefiting from the new and heuristic methods in solving complicated problems, we have taken an important step towards efficiency and optimization. Nowadays the expansion of problems and increase in the importance of acceleration in finding a solution has lead to the failure of classical methods in finding the solution for many problems. So, we should get help from heuristic methods in solving the problems. This research discusses the traveling salesman problem and by presenting the history of the methods used in solving the travelling salesman problem intends to solve the problem by the help of Meta-heuristic Algorithms such as Ant Colony, Simulated Annealing, Tabu Search and Genetic. The results obtained through this research, shows that in larger scales, the Ant Colony Algorithm has higher efficiency in solving the Traveling Salesman Problem than other Algorithms. In this article, at first, the Traveling Salesman Problem is introduced in detail and its various perspectives are discussed. Then, the algorithms of problem solving are described. At the end, each problem is solved by the help of the mentioned algorithms and Matlab software. Then; the results are compared with each other.

Key words: Traveling salesman problem, Meta-heuristic Algorithm, Ant Colony Algorithm, Simulated Annealing Algorithm, Tabu Search Algorithm, Genetic Algorithm

Introduction

Nowadays, human beings have been replaced by machine in most of the cases and machines do many physical works which

Were done by human beings in the past. Even though, the power of computers in saving and retrieving data, official automation and etc, is undeniable, there are still some cases in which the human has to do the work himself or herself. But, in general, the machine related cases contain systems in which there are complicated relations between the parts, so the human brain fails to have a mathematical comprehension of these relations due to the complexity of them.

As time passes, the human brain can detect the system’s habit to some extent. He does this by observing the sequence of the system’s behaviors or experimenting with the results obtained from manipulating some parts of the system. This process of learning by observing various sectors of the system leads to gaining experience. Human brain is unable to analyze the internal functions of such systems. It can estimate the system’s internal functions and predict their reactions only by noticing the external behaviors of such systems.

In recent decades, one of the important issues having a high practical use is Route Search and it has been propounded for increasing the efficiency of transportation system. The Route Search problem is a set of problems in which some people centralizing in one or more locations should call on a set of customers and offer them services which are according to their certain requests. This issue intends to function in such a way that minimize the being passed distance, the time of the whole journey, the number of people, the delay fines, and finally the cost function of transportation by the help of optimization and mathematical models. It also aims to maximize the customer satisfaction at the end. The existence of diverse constraints in such matters, leads to the formation of various types of classical problems. These problems are of the NP-hard problem type, the solution of which through the linear programming and existing software will take a lot of time. Today, timing is regarded as one of the merits of the competition in the age of Electronic Evolution and quick production. With regard to the quick production, factories think about taking an optimized rote for Starting point and destination. The Meta-heuristic Algorithms can be more suitable methods than the classical methods.

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2-Review of the Related Literature:

Masaya Yoshikawa (2010) in a research titled “Ant Colony Optimization Routing Algorithm with Tabu Search” initially talks about the importance of Route Search in various engineering fields and states that recently, many researchers study the meta-heuristic Algorithms which can find the sub-optimal solution at a short time. These meta-heuristic Algorithms in Ant Colony Optimization (ACO), which is inspired by feeding behavior of ants, shows the better capability than Genetic Algorithm (GA) and Simulated Annealing (SA) when it is applied to Traveling Salesman Problem (TSP). Then, he proposes a hybrid routing algorithm which combines Tabu Search with Ant Colony Optimization and claims that it is more effective in comparison with the classical methods and other meta-heuristics algorithms.

Thamilselvan (2009) in a research titled “A Genetic Algorithm with a Tabu Search (GTA) for Traveling Salesman Problem” applies the Traveling Salesman problem with various constraints in which the main objective is to minimize the traveling cost and time. Both Genetic and the Tabu search algorithms is tested independently and also tested combine for the Traveling Salesman problem. After presenting a short introduction of the Meta-heuristic algorithms and also the Travelling Salesman Problem, he discusses the Genetic Algorithm, Simulated Annealing and Tabu search Algorithm. Then, he propounds his proposed Algorithm which is a combination of the Genetic Algorithm with the Tabu Search Algorithm. Finally, Thamilselvan concludes that solving traveling salesman problem by the Tabu Search Algorithm yields a better solution than each of them in isolation.

Klenk (2005) in a research titled “solving the hybrid problems by modeling of ant’s behavior” gives an introduction of Ant Algorithm and in particular Hybrid Ant Colony Optimization. Then, discusses the application of Ant Colony in solving the known problems, especially the Traveling Salesman Problem (TSP). Finally, compares the result of Ant Colony’s function with Tabu Search Algorithm and Genetic Algorithm. Then, he shows that the Ant Colony Algorithm has a better function.

Gómez & Barán (2004) in a paper titled “Relationship between Genetic Algorithms and Ant Colony Optimization Algorithms” introduce the Genetic Algorithms (GAs) as a computational analogy of adaptive systems. They consider this algorithm based on the mechanics of natural selection procedures. They introduce Ant Colony Optimization (ACO) as an important meta-heuristic algorithms inspired by the foraging behavior of ant colonies. Gómez & Barán also state that this algorithm was introduced by Dorigo for the first time and has evolved significantly in the last few years by others. They claim that the combination of both algorithms have shown high effectiveness in the solution of optimization problems. This paper shows the relationship between these two evolutionary algorithms and their significance in the solution of traveling salesman problem.

3-Meta-heuristic Algorithms:

Meta-heuristic Algorithm methods were are fundamental part in methodical solutions which are have applicability in solving the problems of Hybrid Optimization. The Meta-heuristic methods have been developed effectively since their beginning in the early 1980’s. They have had great success in solving difficult and particular hybrid optimization problems. This family of methods includes Ant Colony Optimization Algorithms, Genetic Algorithms, Memetic Algorithms, Problem-space search, Evolutionary Algorithms, Simulated Annealing, Tabu Search Algorithms and Hybrid Algorithms.

In recent 10 to 15 years, the Meta-heuristic Algorithms have changed our view towards the solution of difficult and complicated problems. They also relate the concepts which are based on Biological Evolution, Intelligence problems solution, mathematics, physical science, nervous systems and static mechanisms to each other.

4- Traveling Salesman Problem:

In early 1932, the Traveling Salesman Problem has been mentioned in a book published in German. In 1984, the Rand Company introduced the Traveling Salesman Problem and the popularity of this company in Europe, brought the Traveling Salesman Problem fame. Afterwards, this issue has attracted the attention of many interested scientists for years; so that up to now, many articles on solving this problem, have been published. Traveling Salesman Problem is of famous classical problems in research in operations.

This problem is among the Hybrid Optimization problems whose solution time is a non-polynomial function, i.e. as the volume of problem increases, the solution time it increases respectively. Defining the problem is formed on the basis of the person’s journey from his/her residential city to other cities and eventually returning to his/her residential Place. In other words, in geographical area of traveling salesman, there are a number of cities and the distance between each pair of cities is a certain and static number. The salesman is to begin his journey from one city and visit all cities, each one just once, and finally, come back to the starting point. The Traveling Salesman Problem has various applications.
Periodical evacuation of the postal boxes by delivery man and various activities done by a mechanical man on an under construction device, are cases of such problems. Traveling Salesman Problem is among the intractable problems and its exact resolution will take much time. This problem was propounded by two scientists called Irish Hamilton British Corkman for the first time. The first case, similar to this problem was brought up in 1759. That case was in a way that a horse piece should move on the chess board, crossing each square only once.

In this problem we want to find the Hamiltonic iteration by the minimum cost. In a directional graph, a Tour –also called a Hamiltonic Tour –is a route leading from one vertex to itself passing the other entire vertex only once.

The important point is that a graph may have no tour at all and also the length of the optimum tour is not dependent on the selection of vertex. It is easy to comprehend the Traveling Salesman Problem but as the size of problem increases, its solution will be difficult and in much larger scales, it will be impossible to solve the problem.

This problem can also be simulated mathematically. In such a way that in a Weighted graph $G(v,e)$, minimizing the total weight is sought. The probing all the methods in normal state may be very time-consuming. In mathematical methods the problem is probed by finding the number of permutations and then evaluating each state. The number of is permutations is $O(n!)$ to find the minimum of iterations we also need the maximum of $n!$ Calculations, too. But if we presume that the number of $n$ is high, we will have so many calculations. For this reason it is said that the problem solving Algorithm per time is non-polynomial.

5- Types of Traveling Salesman Problem:

5-1-Symmetry Traveling Sales person problem and Asymmetry Traveling Sales person Problem:

Symmetry Traveling Sales person problem differs from the Asymmetry Traveling Sales person Problem in two general ways. Firstly, the computer memory for solving Symmetry Traveling Sales person Problem, is half than the needed memory for solving the Asymmetry Traveling Sales person Problem. Another difference is that in asymmetry problems, it will be more difficult to optimize and approximate.

In other words, if we show the distance between two groups of i and j by $d_{ij}$, if $d_{ji}=d_{ij}$, it is said that the problem is of Symmetry type. Otherwise, the problem is of Asymmetry type.

In Johnson’s view, experimental studies in the field of Asymmetry Traveling Sales person Problem has not been much developed. Extensive studies including a wide variety of heuristic methods on the solution of Asymmetry Traveling Sales person Problem have not been implemented yet. What have been accomplished are TSPLIB and they are mostly based on the cases derived from the random cases which have not much applicability. Despite the abundance of resources for Symmetry Traveling Sales person Problem; a reliable resource for Asymmetry Traveling Sales person Problem has not been introduced yet. Fortunately in recent years there has been done a comprehensive study on this problem.

5-2-Probabilistic Traveling Salesman Problem:

Probabilistic Traveling Salesman Problem is one of the diverse Traveling Salesman problems (TSPs) in which each city is being visited by a certain probability which is independent of visiting other cities. The aim of Traveling Salesman Problem is to find a Tour having the least average length so that if among the set of cities, we select a random sub-set and visit them by the same order of their location, the tours have the least average length. This kind of Tour having the least average length is called the Initial Tour. Probabilistic Traveling Salesman Problem is of NP-hard problems and it was first introduced in a PhD thesis by Dr. Jaillet. Various strategies have been reported for determining the initial tour. The strategy of initial tour is consisted of two parts. Determining an initial solution and a method of update. An initial solution is a tour in which the length of each possible sub-set of cities is minimum. The update method, omits the cities which won’t be visited and visits other cities with that same order which they have appeared in the initial tour. A simple example of the update method is as follows: Visit every sub-set of cities in the same order which they have appeared in the initial tour and disregard the cities which exist in the initial tour but do not belong to the sub-set (skip the cities which don’t need to be visited). This strategy is called Mutation Strategy. Up to now, different algorithms’ and heuristic tactics for finding the answer have been reported.

Multiple Traveling Sales Problem (MTSP):

Multiple Traveling Sales Person (MTSP) like the TSP is a normal problem. The difference is that this time the problem is not solved by one salesman but it is solved by two, three or perhaps more salespersons. In this type of problem solving there must not exist a joint city between the traveling salespersons. In other words, the
iterations of each sales person must be different from the iterations of the other sales persons. This very type of problem also can be propounded in the heart of one of the above-mentioned types of Traveling Salesman problems. However, the Multiple Traveling Sales Person (MTSP) has its own specific solution Algorithms, too.

6- Defining the problem:

The planned Traveling Salesman Problem in this research has been solved by Heuristic Algorithms in different ways whether regarding the number of cities or the numbers of iterations of the solution. we have solved the Traveling Salesman problem by the help of the Ant Colony algorithm, Simulated Annealing algorithm, Genetic Algorithm and Tabu Search Algorithm, in the similar situations. Then we have compared the results with each other and evaluated them. in the following parts, we will explain the problem and its solution* by the help of Matlab software in detail, by the help of Ant Colony algorithm, Simulated Annealing algorithm, Tabu Search algorithm and Genetic Algorithm, we have solved the problem, with considering 75 cities having the iterations of 30 and 100 respectively, it worth mentioning that with regard to the fact that the solution algorithm in each method, begins selecting the first city randomly, in each stage we have get the help from ten-item samples. To put it simply, in each stage, we have obtained separate responses through software for 10 times and considered the relevant average as the determinate factor in the final conclusion. In each stage, we have calculated not only average but also the maximum, minimum, mode, standard deviation, and we have made use of these data in our conclusions. We have taken the minimum response as the algorithm’s best response in problem solving and maximum response as the worst response. The amount shown by the mode is the maximum iterations of an answer and standard deviation shows the dispersion or integration of the Algorithm in problem solving. Prior to beginning the problem solving, we have shown the coordinate of the points related to the cities.

In the following table, the cities’ coordinate with various dimensions, have been considered differently. Also these numbers have been selected randomly. It worth mentioning that the shortest route for each city has been solved by the Fogel Method and its numerical amount has been calculated. Finally, its results have been compared with the results obtained from each method.

7-problem solving:

In this part, the Traveling Salesman Problem has been solved with considering 75 cities and 100 iterations by the help of Ant Colony Algorithm. Then it has been compared by Simulated Annealing Algorithm, Genetic Algorithm and Tabu Search Algorithm. In the following figures you see the results obtained from the Ant Colony Algorithm.
Fig. 1: TSP with 75 cities and 100 Iterations in solving by Ants Colony Algorithms

Table 1: General conclusion from 75 cities problem solving by Ants Colony Algorithms

<table>
<thead>
<tr>
<th>Problem</th>
<th>Distance</th>
<th>Minimum</th>
<th>Average</th>
<th>Mode</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>568.308</td>
<td>555.323</td>
<td>560.632</td>
<td>556.698</td>
<td>5.05</td>
</tr>
<tr>
<td>2</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
</tr>
<tr>
<td>3</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
</tr>
<tr>
<td>4</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
</tr>
<tr>
<td>5</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
</tr>
<tr>
<td>6</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
</tr>
<tr>
<td>7</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
</tr>
<tr>
<td>8</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
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<tr>
<td>9</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
</tr>
<tr>
<td>10</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>556.676</td>
<td>5.05</td>
</tr>
</tbody>
</table>

Regarding the following Table and Histogram the numerical amount of Average is 560.63, Minimum: 555.32, maximum: 568.31, Mode: 556.68. By the way, the standard deviation of the data is 5.05

Table 2: Conclusions of TSP with 75 cities and 100 Iteration by ACO

<table>
<thead>
<tr>
<th>Maximum</th>
<th>Minimum</th>
<th>Average</th>
<th>Mode</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>568.308</td>
<td>555.326</td>
<td>560.632</td>
<td>556.676</td>
<td>5.05</td>
</tr>
</tbody>
</table>

Fig. 2: conclusion Histogram of TSP with 75 cities and 100 Iterations by ACO

8-Comparing Algorithms in TSP with 75 cities & 100 Iterations:

As it is seen, in this stage, the Ant Colony Algorithm again renders a better response than the other algorithms in TSP. Despite the fact that there is a little difference in the responses of Ant Colony Algorithm and

Table 3: Comparing the functions of different Algorithms

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Average</th>
<th>Mode</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ant Colony</td>
<td>568.31</td>
<td>555.32</td>
<td>560.63</td>
<td>-</td>
<td>5.05</td>
</tr>
<tr>
<td>Simulated Annealing</td>
<td>576.08</td>
<td>550.63</td>
<td>563.43</td>
<td>-</td>
<td>7.05</td>
</tr>
<tr>
<td>Genetic Algorithm</td>
<td>1772.23</td>
<td>1259.89</td>
<td>1448.51</td>
<td>-</td>
<td>129.78</td>
</tr>
<tr>
<td>Tabu Search</td>
<td>888.45</td>
<td>770.42</td>
<td>816.63</td>
<td>-</td>
<td>41.81</td>
</tr>
</tbody>
</table>

Fig. 3: Histogram of Comparing Algorithms in TSP with 75 cities and 100 Iterations

9-General Conclusion:

In the first part of the comparisons, what has been certainly corroborated is that in each algorithm for problem solving, the more is the number of iterations in solution, the better is the obtained result than the state in which the problem was solved by less iteration, but the important fact is to find a number of iterations. These kind of Iterations, not only help to the improvement of responses but also they have the required optimization in the rate of problem solving. In problem solving by nearly many iterations, what happens is spending the time in vain; Because after a number of iterations the algorithms do not render more optimized responses necessarily but in their own final response, they just consume the time so that the iterations end the problem solving.

In the first part of comparisons, with regard to Traveling Salesman Problem (TSP), by the help of Ant Colony Algorithm, Simulated Annealing Algorithm, Tabu Search Algorithm and Genetic Algorithm in different mentioned types, Ant Colony Algorithm can be considered as the most efficient algorithm in among the other algorithms. It worth noting that the responses of Ant Colony Algorithm and Simulated Annealing Algorithm had little differences in most of the stages. We can consider the Simulated Annealing Algorithm in the second place regarding efficiency among the algorithms being applied in problem solving, the Genetic Algorithm was known as the most inefficient algorithm in TSP, yielding the worst answers in the most cases.

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