A Survey Review on Solving Algorithms for Travelling Salesman Problem (TSP)

Thi Thi Htun

Faculty of Computer Studies
University of Computer Studies
Myanmar

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Abstract- Travelling Salesman Problem (TSP) is one of the best known NP-hard problems. It is also a classic tour problem in which a hypothetical salesman must find the most efficient sequence of destinations in his territory, stopping only once at each, and ending up at the initial starting location. To handle with this problem there is no suitable algorithm that solves it in polynomial time. Many algorithms were applied to solve TSP with more or less success. There are many ways to classify algorithms, each with its own merits. This paper is a review on various algorithms like Ant Colony Optimization Algorithms (ACO), Particle Swarm Optimization (PSO) and Genetic Algorithms (GA) available with respective attributes to find the nearest optimal solution for the traveling salesman problem. It also relates the traveling salesman problem with the available algorithms and provides the advantages in providing a solution for TSP.

***Index Terms*-** Travelling Salesman Problem, And Colony Optimization, Particle Swarm Optimization, Genetic Algorithms,

I. Introduction

Traveling Salesman Problem (TSP) is a classical combinatorial optimization question, which now can only be solved by meta-heuristics to get the approximate solution. The travelling salesman problem is quite simple: a travelling salesman has to visit customers in several cities, exactly one customer in each cities. Since he is interested in not being too long on the road, he wants to take the shortest tour. He knows the distance between each two cities which he wants to visit. So far, nobody was able to come up with an algorithm for solving the traveling salesman problem that does not show an exponential growth of run time with a growing number of cities. There is a strong belief that there is no algorithm that will not show this behavior, but no one was able to prove this (yet). The Pictorial and mathematical structure of the TSP is a graph in which the nodes, edges, vertices etc.. are termed as the attributes.

TSP is a problem to find the best shortest suitable path by the salesperson to visit *n* cities so that we can reach each and every city exactly once & finally comes to the initial position with least resources utilization as well as time. It can be well represented by a graph *G* having *N* no. of cities and *E* no. of paths between cities. Let G = (N, E) be a graph where N is a set of vertices representing cities and E is set of edges representing paths. Let C_{ij} be a cost matrix (or distance matrix) associated with E. C_{ij} can be defined in Euclidean Space as follows:

$$C_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

The path with least values is considered as shortest path.

II. APPLICATIONS

The TSP has several applications even in its purest formulation, such as planning, logistics, and the manufacture of microchips. It appears as a sub-problem in many areas, such as vehicle routing, microchips manufacturing, DNA sequencing, logistics, resource allocation, job sequencing, computer wiring and many more. In these applications, the concept city represents, for example, customers, soldering points, or DNA fragments, and the concept distance represents travelling times or cost, or a similarity measure between DNA fragments. The TSP also appears in astronomy, as astronomers observing many sources will want to minimize the time spent moving the telescope between the sources.

III. LITERATURE REVIEW

This paper reviews on solving algorithm for Travelling Salesman Problem (TSP). TSP belongs to the category of NP-hard problems. A various number of algorithms have been designed to solve this problem. The aim of this literature survey is to study and analyze the available algorithms to predict a prominent or optimal solution for TSP. TSP is defined as a permutation problem with the objective of finding the path of the shortest length (or the minimum cost). TSP can be modeled as an undirected weighted graph, such that cities are the graph's vertices, paths are the graph's edges, and a path's distance is the edge's length. Over the last three decades, TSP received considerable attention and various approaches are proposed to solve the problem, such as branch and bound, cutting planes, 2-opt, particle swarm, simulated annealing , ant colony, neural network, tabu search, and genetic algorithms. Some of these methods are exact, while others are heuristic algorithms.

A. Ant Colony Optimization Algorithm

The ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. By analyzing the ants behavior the ACO algorithms are designed to search for a shortest path between their nest and a source of food. It is a relatively novel meta-heuristic technique and has been successfully used in many applications especially problems in combinatorial optimization.

An ant will move from node i to node j with probability

$$p_{i,j} = \frac{(\tau_{i,j}^{\alpha})(\eta_{i,j}^{\beta})}{\sum(\tau_{i,j}^{\alpha})(\eta_{i,j}^{\beta})}$$

where
$\tau_{i,j}$ is the amount of pheromone on edge i, j
α is a parameter to control the influence of $\tau_{i,j}$
$\eta_{i,j}$ is the desirability of edge i, j (typically $1/d_{i,j}$)
β is a parameter to control the influence of $\eta_{i,j}$.

The following are paper reviews on ACO algorithms for solving TSP.

In 2008, [1] proposed a paper on ACO where the new ants remember the best solution present so far. The presented model was termed as Ants carrying Memory. In this paper, they did some important work like introducing the previous knowledge of the TSP, Ant System & ACS & define the parameter used and explain about ants with memory and merge them in ACS, and then the results were obtained by modified ants and compare the efficiency of each algorithm. This algorithm is capable to unite into at least a proximate optimal solution swiftly. The presented algorithm is so easy as well as better performing. This algorithm suits for small and mid-size problems however in case of larger problem it may trap into local optima.

In 2008, [2] offers an enhanced ACO for solving TSP. In the paper they proposed a selection mechanism that is based on Held-Karp lower bound to obtain the optimal path for TSP. it obtains information from deposition of pheromone & heuristic information and uses the HK method for the selection of best route.

In 2011, [3] gives a solution for TSP based on enhanced Ant Colony Optimization. They proposed an algorithm mixed with candidate list approach& dynamic upgrading of heuristic parameter of local search solution. In dynamic candidate list a number of preferred nodes are stored in a static list. When an ant moves from one node to other then it selects the node that is present in the preferred list. This strategy is used to put up searching scheme of ant colony system on bigger data. The upgrading was based on entropy & emergence of solution. From their experimental results, the proposed system is much effective in order of speed (convergence) & the ability to discovering better solutions.

In 2012, [4] affirmed that the Ant Colony Optimization (ACO) is a heuristic algorithm which has been proven a successful technique and applied to a number of Combinatorial Optimization (CO) problems. There are several reasons for the choice of the TSP as the problem to explain the working of ACO algorithms it is easily understandable, so that the algorithm behavior is not obscured by too many technicalities; and it is a standard test bed for new algorithmic ideas as a good performance on the TSP is often taken as a proof of their usefulness. They presented an approach for solving traveling salesman problem based on improved ant colony algorithm.

B. Genetic Algorithm

A simple and pure genetic algorithm can be defined in the following steps.

Step 1. Create an initial population of P chromosomes.

Step 2. Evaluate the fitness of each chromosome.

Step 3. Choose P/2 parents from the current population via proportional selection.

Step 4. Randomly select two parents to create offspring using crossover operator.

Step 5. Apply mutation operators for minor changes in the results.

Step 6. Repeat Steps 4 and 5 until all parents are selected and mated.

Step 7. Replace old population of chromosomes with new one.

Step 8. Evaluate the fitness of each chromosome in the new population.

Step 9. Terminate if the number of generations meets some upper bound; otherwise go to Step 3.

In 2001, [5] proposed a paper for solving TSP with precedence constraints using genetic algorithm. In this paper, they used topological sort to order the vertices to be visited by the salesperson. Also they give a new crossover operator which is similar in many aspects of natural moon i.e. half-moon, full moon etc. are implemented. This crossover operator selects a random subset from population and is mixed with the selected parents to produce an offspring. The author compares their newly developed moon crossover operator with earlier operators that are OX operator and position based operator where they found that their performance is almost equivalent but the OX and position based operators do not give optimal results for the trials. However their approach is much efficient for small and mid-size problems but in case of bigger problems it gives best solution but there is no guarantee for the optimality.

In 2012, [6] used an indigenous search technique to increase the solution quality. In this paper they used Elitism technique for selection which initially imitates the best chromosome to newly generated population and the rest is performed in conventional way. It can swiftly escalate the performance of GA because it avoids losing the preeminent found solution. In searching procedure a crossover location on a chromosome is defined and then SCX operator is applied to exchange the information. This newly generated crossover operator is superior in terms of cost and time as compared to traditional SCX operator. In this way a proximal optimal solution is achieved but not an optimal solution. They presented a comparative study among greedy approach, dynamic programming & genetic algorithm for solving TSP. GA seems to seek better options for TSP, and nonetheless it is dependent very much on the way the problem is described& the strategies of crossover & mutations used. They proposed a new crossover operator (SCX) which is better in terms of quality of solutions. They used a local search technique to improve the solution quality.

In 2012, [7] proposed that genetic algorithm is one of the best methods which is used to solve various NP-hard problem such as TSP. The natural evolution process is always used by genetic Algorithm to solve the problems. They presented a critical survey to solve TSP problem using genetic algorithm methods that are proposed by researchers. They observed that there is requirement to design new genetic operators that can enhance the performance of the GA used to solve TSP. There is lot of scope for the researcher to do work in this field in future.

In 2013, [8] stated an enhanced genetic algorithm for TSP problem. In their paper they calculate the distances between various cities visited using Euclidean formula and form a matrix from the data evaluated. They work on a symmetric TSP i.e. the distance between two cities is same in both orders while moving from city a to city b and vice versa. They generated an initial population randomly and then assign them a fitness value which is taken as the distance between the cities. After this they applied the tournament selection for selecting best population from the given set and applied two-point crossover method combining the knowledge from heuristic methods & GA for solving the TSP. Finally interchange mutation is implemented for generating new population. It appears to find better solutions for symmetric TSP but it is not much efficient for asymmetric problems.

C. Particle Swarm Optimization

In 2007, [9] offered an algorithm based on novel particle swarm optimization for TSP. An undetermined searching approach & a crossover elimination method are used to increase the speed of convergence when compared with the predominant algorithms for solving TSP using swarm intelligence; it has been proven that the problems with large size can be solved with presented algorithm. Moreover, the generalized chromosome technique is used to further extend the algorithm.

In 2010, [10] had presented a hybrid discrete PSO algorithm that adds adaptive disruption factor, reversion operator and heuristic factor, into the approach. In the work he implemented an update mechanism for kinetic equations to improve the efficiency of particle swarm optimization (PSO). Here they use heuristic factor for search operations i.e. to find a better route and adds reversion mutant for swapping between the paths and correlates it with noise. This adaptation increases the efficiency considerably irrespective of the convergence velocity or accuracy.

In 2012, [11] proposed a new PSO algorithm which overcomes the drawbacks of GA like premature convergence i.e. giving suboptimal solution. They mixes the three approaches i.e. PSO-GA-ACO and makes a 2-stage hybrid swarm intelligence optimization algorithm which offers a better and much efficient solution to TSP problem.

IV. CONCLUSION

After reviewing various research papers to solve TSP the heuristic algorithms (GA, ACO, PSO etc.) are proved to be much efficient algorithms than the conventional ones (like dynamic programming, greedy algorithm, branch and bound methods etc.). Heuristic algorithms are more effective for small and mid-sized problems than other algorithms. There are certain issues with these also that are confinement to sub-optimal solution only like stagnation behavior in case of ACO, premature convergence in case of GA and convergence speed in case of PSO. From the beginning of these approaches a lot of amendments are done for improving their performance such as different – 2 selection, mutation, crossover strategies are given from time to time in order to improve GA. Different updating mechanisms and route selection mechanisms and adding memories in ants are implemented for the enhancement in ACO as well as in PSO. But still there is a lot of work to do for betterment of these algorithms.

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