



Traveling Salesman Problem Using Various Optimization Techniques

Sudepta Thukral¹, Chander Diwaker²

^{1,2}Department of Computer Engineering

U.I.E.T, Kurukshetra University, Kurukshetra, Haryana, INDIA

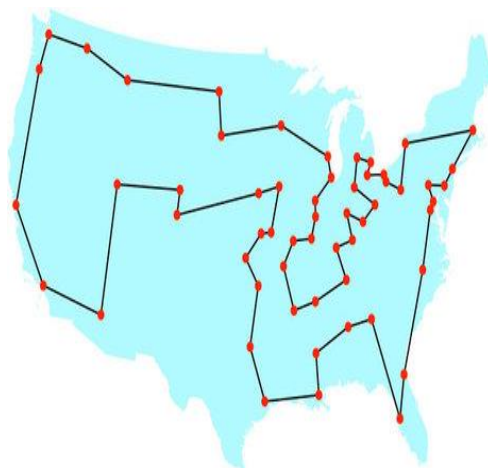
Abstract: The Traveling Salesman Problem (TSP) is the combinatorial optimization dilemma mostly used to trial new heuristics. Various optimization procedures are there to get to the bottom of TSP. One is Swarm Intelligence field which provides superior solutions in reasonable instant to complex problems. Other one is GA which is useful when search space very large or too complex for analytic treatment This paper discusses the survey of heuristics solution approaches for the TSP. TSP is easy to understand, but, it is extremely complex to solve. Because of complexity concerned with exact solution processes is tough to resolve TSP in feasible time. That's why unlike heuristics are frequently applied to resolve TSP. Finally, chosen approaches shows the effectiveness of approaches in provisions of key quality and time contained to solve the TSP.

Keywords: Traveling salesman Problem, Ant Colony Optimization, Genetic Algorithm, Particle Swarm Optimization

I. Introduction

Routing is the method of finding path from starting place to ending place in network. TSP is one of routing problem which come under node based routing problems. Traveling salesman problem (TSP) is a familiar, popular and broadly considered problem in the area of combinatorial optimization which magnetizes computer researches, mathematicians and some others [1]. TSP means when salesman wants to travel around given number of cities, and returns back to beginning, such that the total distances (cost) traveled is minimum. Cost may be time distance, energy, money etc [2]. TSP is searching for the shortest Hamiltonian tour through all the cities. TSP is a famous NP-hard problem. The Pictorial and arithmetical structure of TSP is graph as shown in Fig. 1 where nodes, edges, vertices etc are termed as attributes. The nodes are cities present in the problem. Edges are vectors connecting a pair of cities along with having each edge cost connected with it which may be time, distance or else additional attribute. Let n be the total input vertices that represents cities, for G weighted graph, TSP is to utilize the cycle for least costs which visit each one vertices of G just once.

Figure 1 Overview of TSP



There are more than a few mathematical formulations for TSP, employing variety of restrictions that enforce the supplies of problem [7]. As this is not the suitable forum of review all of potential formulations, one has chosen in turn to express how such a formulation is specified. The following memo is used:

n = The sum of cities to visited; sum of nodes in network.

i, j and k = Cities indices which can take integers values starting from 1 to n

t = Time period, otherwise step in route among the cities

x_{ij} = is 1 if edge of network as of i to the j is use in step t of route, and otherwise.

d_{ij} = The distance or cost as of city i to city j

The TSP can formulated as,

$$\text{Minimum of } \sum_{i=1}^n \sum_{j=1}^n \sum_{t=1}^n d_{ij} \cdot x_{ij}$$

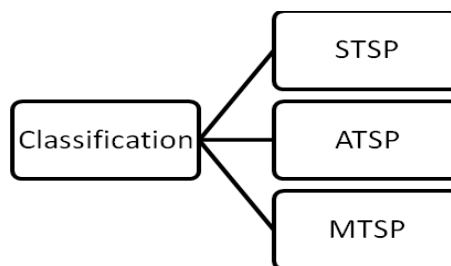
(for all i, j and k goes from 1 to n)

The problem involves starting from given city. The best route is choose, that reduces the whole distance from $(n - 1)!$ feasible tours.

II. Variants Of TSP

The TSP can categorize as Symmetric-TSP (STSP) and Asymmetric-TSP (ATSP), and Multi-TSP (MTSP). There are three forms of TSP are explained as follows [1],

Figure 2: Classification of TSP



(i) STSP:

In STSP, the distance connecting two cities are equal in both directions with having same cost that mean it will produce undirected graph. STSP is problem for finding shortest length closed trip in which each city is visited only once [10].

(i) ATSP:

In ATSP, the distance among two cities are dissimilar in both directions. This is a directed graph.

(ii) MTSP:

In particular all nodes, suppose there be ' m ' salesmen placed at single start node. The last nodes (cities) are intermediary nodes which are yet to be visited. It finds the visits for all ' m ' salesmen, which starts and finished at the place, so that each intermediate node (city) visited only once and entire expenditure of visiting all node is reduced. A fundamental model hypothesis to restrict visits to just one for one city may also omitted; TSP with numerous visits is called as MTSP [5].

III. Applications of TSP

The TSP has many diverse real world applications, which makes it to be accepted for solving problem [3].

- a) *Vehicle routing problem*: This problem is finding which vehicle should be allotted to which customer and the minimum vehicles needed to serve each customer. Numerous variants of that problem are there such as finding the least time to serve all customers [14].
- b) *Computer wiring*: In this various modules each one has number of pins. In which to attach subset of pins with wires so that no pin has extra than two connected to it and length of the wire is decreased.
- c) *Overhauling gas-turbine engines in aircraft*: This application is found by Lowe, Plate and Chandrasekaran Nozzle-guide vane assemblies, which consist of the nozzle-guide vanes that fixed to circumference, are placed at every turbine phase to ensure even gas flow. The vanes are placed in turn to reduce fuel utilization which can model as symmetric TSP.
- d) *Scheduling of jobs*: The scheduling of job on a particular machine given the time allotted for every job and the time it takes to prepare the machine for every job is also TSP. The challenge is to reduce total time to perform each job.
- e) *Robotics*: A robot ought to carry out many different actions to complete process. In this application, it has precedence restrictions. This problem cannot be modeled by TSP but methods used to solve TSP which can be modified to solve this problem.
- f) *Mission planning problem*: The objective is finding the best path for army men to achieve goals of the mission in the minimum possible time.
- g) *Printing-press-scheduling problem*: The main purpose of m -TSP arises in scheduling of printing press with multi-editions. Here, there exist five pairs of cylinders between which the paper rolls and two sides of a page are printed simultaneously. There be three kinds of form, which are 4-, 6- and 8-page forms,

that are used to print the editions. The scheduling problem choosing which form will on in which run and the length of every run. In *mTSP* vocabulary, cost of problem are inter-city cost.

IV. Related Work

Akhand *et al* [4] initiated the proposal of Swap-Operator (SO) and Swap-Sequence (SS) in PSO for handling the TSP. Every particle signified a complete tour and speed was calculated as a SS consisting with number of SOs. Since every SO implantation on a solution given a new solution and checked all the solutions that found for the velocity and the optimal one was considered for the update of solution. The proposed PSO contained Partial-Search (PSOPS) algorithm which showed best solution within minimal time than standard PSO.

M. F. Alves and R. Lopes [5] performed comparative with GAs, by using different combinations of selection and crossover, to solve m-TSP. The proposed GAs had two objectives to be minimized, the whole distance and standard deviation for traveled distance by each salesman. In this, two kind of GAs, multi-objective GA and mono-objective GA having fitness function that combines both objectives. Whereas the mixture of Roulette Wheel with PMX was predominant for the mono-objective GA and multi-objective GA found the best solutions using different combinations in each problem.

Zbigniew Swiatnicki [6] focused on the ACO algorithm to solve TSP by using the different heuristics. The algorithm using heuristic had delivered good results regardless from size of problem. The algorithm used the grouping of the two global pheromone update heuristics - BSF (best-so-far route) and IB (iteration-best route) showed high effectiveness. When operating "alone", neither method of pheromone updating delivered satisfactory results. The neighboring pheromone update heuristics - CE (current edge) - delivered worse results than the NN (nearest neighbor) heuristics.

Li *et al* [7] explained that knowledge-based-initialization technique (KI) to improve ability of GA for resolving TSP. It was an effective mechanism to make use of the knowledge about the features of evolved population to produce high quality initial population. Superior initial solution without path crossover can be fast generated with this technique. Instances in TSPLIB were used to check different initialization methods. The presentation of GA was also determined by operators and parameters.

Amara *et al* [8] presented the new Hybrid Discrete Bat Algorithm for solving TSP (HDBatTSP) that combined Bat algorithm, genetic operators and 3-opt algorithm for solving TSP. The fundamentals for Bat-Algorithm (BA) proposed a new bio-inspired meta-heuristic algorithm. Consequently, using the concepts of Swap-Operator (SO) along with Swap-Sequence (SS) to redefine correspondingly BA position plus velocity operators of TSP. Additionally, depended on ordered crossover and 3-Opt algorithm, proposed to redefine the Bat's local search method.

M. Mahi *et al* [9] provided hybrid method that contained PSO, ACO and 3-Opt-algorithms in line to solve TSPs. 3-Opt heuristic methods was to improve the local solutions. The PSO algorithm was useful to detect optimal values of parameters α and ρ which meant for city selection operation in ACO algorithm and find out significance for inter-city pheromone with distances. The 3-Opt algorithm make use for the principle of improving the city selections operation, which should not improved because of falling in local minimum by the ACO algorithm. The performance for this method was investigated by considering average route length, standard deviation plus percentage relative error values according to average value on ten different test problems taken from TSPLIB.

B. Escario *et al* [10] proposed an Ant-Colony-Extended (ACE) which was new algorithm belongs to general ACO framework. Two explicit features of ACE were partition of tasks among two types of ants, specifically patroller and forager, and the completion of rule policy for controlling each kind of an ant through searching procedure. In adding up, ACE did not use construction graph usually employed by classical ACO algorithms. Instead, the search was performed using a state-space exploration approach.

Hingrajiya *et al* [11] presented the technique designed for solving multiple TSP depending on ACO. In this revision of evading of stagnation behavior and early convergence by using distribution strategies of primary ants and active heuristic factors updating based on entropy. Then emergence of local search solution was provided. The results and performance comparison showed that the projected system reaches the better search performance over ACO algorithms do.

András Király and János Abonyi [12] represented new approach to decrease activities about material handling with expanding of serving locations. A m-TSP with extra constraints was introduced and solved by this method. It presented the multi-chromosome techniques for solving m-TSP. Then operators depended on problem specific

demonstration proved to more efficient in term of elasticity, complication and clearness, and in efficiency than previous methods. The algorithm has carry out in MATLAB with integrated with the Google Maps to give complete frame for distance calculation, definition of the early routes, and visualization.

Zalilah Abd Aziz [13] designed a generalized heuristics method (hyper-heuristics) depended on ACO algorithm for solving TSP. In this approach, pheromone with visibility value considered a non-domain exact knowledge. Ant-colony hyper-heuristics performed the similar methodology as in ant-colony algorithm where it involved two pheromones updating actions; local update and global update. The global inform employed the finest solution originate at the present iteration for updating the pheromone trails and local updates were performed subsequent to every ant tour. It applied on single routing problem; the TSP.

Yang and Wang [14] constructed an enhanced ACO algorithm intended for solving TSP. By changing sum of information and searching for the optimal parameters, it can rate up convergence velocity. The simulation experiment outcomes showed that better ACO was efficient for solving TSP, which not merely accelerates convergence velocity, but also inhibits early stagnation in convergence procedure. The result for TSP problem showed that proposed method may converge to global optimal solution quickly and speed up convergence rate.

Tan *et al* [15] explained two better genetic algorithms depending on clustering to examine the best results of TSPs, i.e. KGA and AGA. The key process was clustering, intra-group progress operations and intergroup connection. Clustering contained two ways to divide large range TSP into numerous sub-problems. Each sub-problem corresponded to cluster. K means and affinity propagation clustering methods were respectively adopted in KGA and APGA. Then, GA was use to calculate the minimum Hamiltonian cycle for every cluster. Finally, proposed an effectual connection way to combine every clusters into one for integral optimization with the aim of shortening the whole traveling route.

C. Changdar *et al* [16] described a new Genetic ACO base algorithm for the solid multiple-TSP (mTSP) in a fuzzy rough environment. It was hybrid algorithm with some properties of GA and a few properties of ACO. Route selection done by the ACO and routes were controlled by the GA. Modified ACO had a special feature 'refinement'. The algorithm used cyclic crossover and two-point's mutation for solving problem. The travelling cost was calculated as imprecise in natural world (fuzzy-rough) and was compact to its approximate crisp using fuzzy-rough expectation.

Masutti and Castro [17] presented Bee-inspired algorithms that had capability of given good results in reasonable time to the difficult problems. The opt-Bees, an bee-inspired algorithm applied for continuous optimization, and proposed the necessary modifications for solving TSP, generating the TSP-opt-Bees. There were three forms of bees: 1) recruiters, which were responsible to recruit other bee to exploit promising regions of search-space, 2) scouts that were responsible to explore novel regions of search space, 3) recruited, which follow the recruiter bees to exploit new solutions in their surroundings.

Hassan Ismkhan [18] proposed a new strategies including effective representation and heuristics, which speed up ACO and enabled it to concerned to large-scale instances. The proposed ES-ACO (Effective Strategies+ACO) achieved enhanced performance than further versions of ACO in term of speed and accuracy, and when the range of instance was increased, the ESACO significantly overcomes the further versions. The results showed that ESACO was quick, accurate, and applicable to solve very large instances up to 20000 while other versions of ACO seldom had been exercised to the instances through size of more than 1500.

Table 1 Short survey of different methods for Solving TSP

S. No	Year	Contribution	Algorithm Used	Research Gaps
1.	2012	Akhand et al	PSO with Partial Search (PSOPS)	- Each time the updation of SS is difficult by SO's. - More energy consumption.
2.	2015	Amara et al	Hybrid Discrete Bat Algorithm for TSP (HDBatTSP)	- In this the population size was very less (25 only) - Time consumption by proposed methods is more than others.
3.	2015	András Király and János Abonyi	M-TSP with additional constraints	- All user must have a map with Google services. - The amount of goods delivered is much less than the capacity of vehicles.

4.	2016	Changdar et al	Genetic ACO based algorithm for solid m-TSP	- The travel cost of tour is increased. - Various vehicles are involved in this approach.
5.	2016	Masutti and Castro	Bee-inspired algorithms (TSPoptBees)	Further improvement can be made in the operators such as in the recruitment and in the exploration phases.

V. Conclusion

This paper discusses the surveys various optimization ways to resolve the TSP. It includes the various ACO, PSO and GA techniques for solving the symmetric or asymmetric TSP. All these techniques have immense potential and scope of application ranging from engineering to software engineering, and real world optimization problems. These techniques need to be further explored to find their suitability to certain applications. Also, there is a need to combine two or more techniques so that those techniques complement each other and nullify their respective limitations.

VI. References

- [1] K. Ilavarasi, and K. Joseph, "Variants of Travelling Salesman Problem: A Survey", International Conference on Information Communication and Embedded Systems (ICICES), pp. 1-7, 2014.
- [2] Z. Hlaing and M. Khine, "Solving Traveling Salesman Problem by Using Improved Ant Colony Optimization Algorithm", International Journal of Information and Education Technology", vol. 1(5), pp. 404-409, December 2011.
- [3] M. Abid and I. Muhammad, "Heuristic Approaches to Solve Traveling Salesman Problem", Telkomnika Indonesian Journal of Electrical Engineering, vol. 15(2), pp. 390-396, August 2015.
- [4] M. A. H. Akhand, S. Akter, S. S. Rahman and M. M. HafizurnRahman, "Particle Swarm Optimization with Partial Search to Solve Traveling Salesman Problem", International Conference on Computer and Communication Engineering (ICCE) , pp. 118-121, July 2012.
- [5] R. M. F. Alves and C. R. Lopes, "Using Genetic Algorithms to minimize the distance and balance the routes for the multiple Traveling Salesman Problem", Congress on Evolutionary Computation (CEC), IEEE Press, pp. 3171-3178, 2015.
- [6] Z. Szwiatnicki, "Application of Ant Colony Optimization Algorithms for Transportation Problems Using the Example of the TSP", Proc. 4th IEEE International Conference on Advanced logistics and Transport (ICAIT), pp. 82-87, 2015.
- [7] C. Li, X. Chu, Y. Chen and L. Xing, "A knowledge-based Initialization Technique of Genetic Algorithm for the TSP", Proc. IEEE 11th International Conference on Natural Computation (ICNC), pp. 188-193, 2015.
- [8] J. Amara, T. M. Hamdani and A. M. Alimi, "A new Hybrid Discrete Bat Algorithm for Traveling Salesman Problem using ordered crossover and 3-Opt operators for bat's local search", Proc. 15th International Conference on Intelligent Systems Design and Applications (ISDA), pp. 154-159, 2015.
- [9] M. Mahia, O. K. Baykanb and H. Kodazb, "A new hybrid method based on Particle Swarm Optimization, Ant Colony Optimization and 3-Opt algorithms for Traveling Salesman Problem", Applied Soft Computing, pp. 484-490, 2015.
- [10] J. B. Escario, J. F. Jimenez, J. M. Giron-Sierra, "Ant Colony Extended: Experiments on the TSP", Expert Systems with Applications (Elsevier), vol. 42, pp. 390-410, 2015.
- [11] K. H. Hingrajiya, R. K. Gupta and G. S. Chandel, "An Approach for Solving Multiple TSP using Ant Colony Optimization", Computer Engineering and Intelligent Systems, vol. 6(2), pp. 13-17, 2015.
- [12] A. Király and J. Abonyi, "Redesign of the supply of mobile mechanics based on a novel genetic optimization algorithm using Google Maps API", Engineering Applications of Artificial Intelligence, Elsevier, vol. 38, pp. 122-130, 2015.
- [13] Z. A. Aziz, "Ant Colony Hyper-heuristics for Travelling Salesman Problem", Proc. IEEE International Symposium on Robotics and Intelligent Sensors (IRIS 2015), vol. 76, pp. 534 - 538, 2015.
- [14] X. Yang and J. Wang, "Application of Improved Ant Colony Optimization Algorithm on Traveling Salesman Problem", Proc. IEEE 28th Chinese Control and Decision Conference (CCDC), pp. 2156-2160, 2016.
- [15] L. Tan, Y. Tan, G. Yun and Y. Wu, "Genetic Algorithms Based on Clustering for Traveling Salesman Problems", Proc. IEEE 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD), pp. 103-108, 2016.
- [16] C. Changdar, R. K. Pal and G. S. Mahapatra, "A genetic ant colony optimization based algorithm for solid multiple travelling salesmen problem in fuzzy rough environment", Springer-Verlag Berlin Heidelberg, pp. 1-15, 2016.
- [17] T. A. S. Masutti and L. N. Castro, "TSPoptBees: A Bee-Inspired Algorithm to Solve the Traveling Salesman Problem", Proc. IEEE 5th IIAI International Congress on Advanced Applied Informatics, pp. 593-598, 2016.
- [18] H. Ismkhan, "Effective Heuristics for Ant Colony Optimization to Handle Large-Scale Problems", Swarm and Evolutionary Computation, vol. 32, pp. 140-150, 2017.