

Travelling Salesman Problem: A Review on Optimization Techniques and Genetic Algorithm

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Abstract - The Travelling Salesman Problem (TSP) is an optimization problem which might look simple to understand but faces difficulty in precise calculation. Solving TSP includes an imaginary salesman who finds the most efficient path sequence from the starting location and covers the entire destination by stopping only once at each destination. Several techniques to solve TSP have been proposed by many scholars like, Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization Algorithm (ACO), and Bacteria foraging etc. that work on the principle of survival of the fittest. Similarly, various heuristics algorithm, stochastic approach, fuzzy conditions are set up to solve TSP. This paper deals with review on different techniques or group of techniques that are used by several researchers in order to have optimized path solution using various languages and software like java, Python MATLAB etc.

Keywords: Genetic Algorithm (GA), Cross Over Operators, Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO).

I. INTRODUCTION

Once we have the choice of multiple paths, then depending on our purpose to minimize the efforts, time and cost we choose only one path. The problem lies in selecting the path which is optimal. The stated problem is the real problem related to Travelling Salesman. The salesman is provided with the list bearing number of cities and has to cover all the cities, once in a while, in stipulated time duration, without much efforts and cost. The problem becomes cumbersome when considered for getting the optimal solution. Let, n be the number of cities the salesmen has to cover then according to the idea of integrated iterations then $(N-1)!/2$ gives the total number of possible paths for salesmen that adds difficulty.

The concept of issues related to travelling salesmen was stated in 18th century by Sir Hamilton and Thomas Kirkman [1]. The statistical study on general travelling salesman problem is proposed by Karl Menger in 1930. The further

development in the TSP study and solving techniques is done by either introducing a new problem or introducing a new technique. Prior to the development of algorithmic approaches, several techniques were introduced by many scholars such as, linear/non-linear systems, integrating solution systems, low/high bound control strategies etc. Also, other evolutionary key study in development of TSP solution like, column problem, sets, subsets, branch and bound method and Kraps theorem etc. are developed. The first heuristics algorithm was introduced by B.W. Kemighan in 1973 that shows solution for 110 cities in just 25 seconds with 95% credibility. The concept of Genetic Algorithm for solving TSP is initiated in 1985. Briefly, different methods used in GA like, population modelling, crossovers strategies, also several other techniques such as binary, matrix hybridization, annealing, drop-down algorithm etc. Each of the evolutionary approach developed has the main goal i.e. to find the optimal solution of TSP with minimum time lapse and maximum accuracy.

1.1 Concept of TSP with example

The travelling salesmen problem consists of number of cities and a salesman. The salesmen has to travel each of the listed city from his origin spot and return to the starting point after covering all cities. The main problem that a salesman faces is to find the sorted path. Mathematically, the TSP can be defined as follows,

$$TSP = (G, f, t)$$

Where, $G = (V, E)$ i.e. a complete graph, $f =$ function. The G represents the complete graph of salesman tour. The cost of G must not exceed t .

To understand the TSP let us consider the set of cities as shown in fig 1. As stated earlier that the main aim of salesmen is to find the minimal/optimal path while covering all the vertices at least once. We do consider the fig 1 has two paths i.e. path 1 that follows the travel sequence like A, B, C, D, E and A and has a total length of 24. whereas, path 2 following the travel sequence as A, B, C, E, D and A and has a total length of 31. This discrimination in solution of finding paths is the main concern for salesmen.

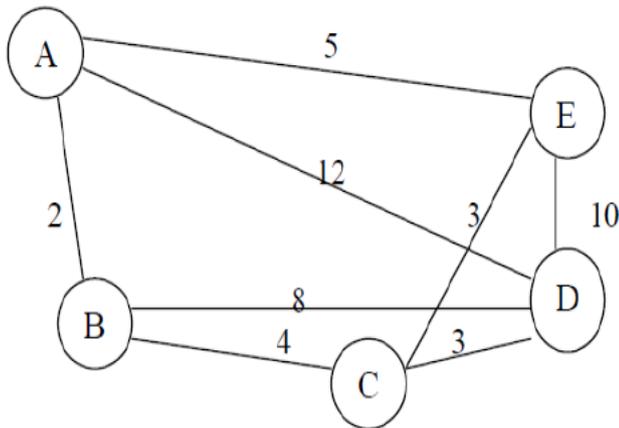


Figure 1: Graph with weights on edges

The minimum number of paths gives better flexibility with more accuracy and less efforts and cost thereby development in several approaches is a prior concern. This paper deals with state-of-art review on various issues of TSP, methods for TSP solution and more focus is done on widely accepted approaches like, ACO, PSO, GA etc.

II. APPLICATIONS OF TSP

The TSP serves several applications in variety of work like, logistics, planning, vehicle routing computer wiring, job sequencing and many more. It has significant role in DNA sequencing and sometimes in astrology too. In most of the cases, the degree of time and resources adds constraints to the application of TSP. Numerical computation techniques describes the purely hypothetical computation in order to get the solution in applications of TSP and many of the computational algorithms developed are expected to rise exponentially with respect to the time and number of cities assigned. Among the several applications of TSP following pointed applications clears brief idea.

- Genome
- DNA fragmenting
- DNA sequencing
- Scan Chains
- Starlight
- Trips and tours
- Distance travelling
- Remote sensing
- Optimum path finding
- Delivery of goods and services
- Disaster relief etc.

Owing several applications the major task is to find the precise solution with less computation complexity and running time.

III. TSP RELATED ISSUES

With widespread advancement in network technology and future realistic on Internet of Things, the interconnection of appliances/automobiles to IoT is proposed and preferred so as to have condition monitoring on the things that are supposed to avails interconnections. Several fields such as, logistics, remote sensing, delivery of goods and services, trips and tours etc. involves problem of travelling multiple locations. Obviously, such problem is defined as the TSP, and finding the solution of such problems should be on priority that will surely reduce the waste of resources, reduce the time of reaching/delivery and increase the efficiency. The several TSP related issues are as follows,

3.1 General Travelling Salesman Problem

The TSP has several applications and in order to avail the best practical approach of TSP, many extensions are added to TSP such as, auto-drive Arial Vehicle TSP, Dynamic Travelling Salesman Problem (DTSP) and Multiple Travelling Salesman Problem (MTSP) [2]. While in graph theory of solving TSP, the Hamilton loop has been formed which has smallest weight leading to completely undirected graph. According to the mentioned theorem, TSP which solves Euclidean metric generally describes the straight line between several meet points [3]. No exact and precise solution can solve TSP accurately with minimum options; only the various approaches that have been developed are focused on minimizing the efforts and getting the speedy results.

3.2 Multiple TSP

It is general consideration of extension to the TSP. Here, the salesmen travels several cities and gathers at starting point. Every city can be visited only once but so as to have the shortest path the salesmen can travel through a city several/multiple time i.e. the reason this is termed as MTSP. All the cities are divided into groups so that each group can use TSP to solve the issue of shortest path. The MTSP is subdivide into two methods namely, clustering and multi-object optimization problem.

3.3 Vehicle Routine Problem

Various customers are provided with goods at their places from store-rooms, warehouses, and go down etc. Each of the customer demands variety of goods resulting in deciding the transporting path that covers shortest distance and provide the supply of goods without repeating the rout. Thus to concur the issue more focus has to be done on unmanned Arial vehicle or auto-drive Arial vehicle. However, the coordination between the vehicles do add several constraints to the transporter thus,

concentration must be on getting an unique advanced algorithm development which focuses on optimization and can give high accurate results [4].

3.4 Other Expansion related issues

This issue is subdivided in three categories namely, planning dubins path, orienteering problem, and path planning problem. The dubins path finding issue is related to the grabbing the shortest path to have continuous waypoint connections. Implementing TSP-drone can resolve the problem caused. The TSP-D is segmented solution of TSP patrol using GRASP i.e. Greedy Random Adaptive Search Program [5]. The path planning problem works on network optimization that focuses on sequence of waypoints and lapse out the vehicle trajectories. However, with cumbersome transportation path, change in route essential to add feasibility in delivery. The Path planning problem or route planning problem; when combined can give trajectory optimization [6]. The arc weight with capacity plays important role as it may add constraints in finding the best path, this is referred to as the orienteering issues in TSP [7].

IV. REVIEW ON ANT COLONY OPTIMIZATION TECHNIQUE

Several algorithms and optimization techniques have been proposed by many scholars. Each of these developed techniques has its own advantage and sometimes lacuna in finding the best path in TSP. In this paper a state-of-art review is done on major and widely accepted algorithm namely, Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA). As these methods provide best optimal solution for TSP thus are preferred.

4.1 Ant Colony Optimization (ACO)

The ACO is basically a probabilistic approach helpful getting the computational flexibility in reducing the solution to the problem and finding the better path or shortest path though graph. The approach is inspired from the behavior of ants i.e. how the ants do find their shortest path for getting food from their nest to food source. Based on this observation the concept of ACO is developed and designed. The major application of ACO is in combinational optimization problems where, in most of the problem cases it is treated as meta-heuristic technique.

Let i and j be the two nodes that defines the path of ants from their nest to food source, the designated probability can be defined for the same as,

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

Where,

$T_{i,j}$ = Edge pheromone

α = Control parameter for $T_{i,j}$

$\eta_{i,j}$ = Edge desirability

β = Control parameter for $\eta_{i,j}$

4.2 State-of-Art review on ACO

The new model named, Ants Carrying Memory is developed where ants are found to memories the best solution availed [8]. The parameters for newly developed model have been defined on the basis of existing knowledge on Ant behavior, their memory, TSP and merging it to Ant colony system. Therefore, the most promising algorithm is obtained that is result of ant memory combination. The algorithm developed is capable of getting optimal solution and is fast responding thus can be used for small/medium size problems [8]. The Travelling Salesman Problem can be resolved with the enhancement in ACO [9]. The Held-Karp selective mechanism can be used so as to have enhancement in ACO and fruitfully an optimal path for TSP can be gained. The pheromone deposition is used for getting the information and where it is shared to HK mechanism that in results selects the best desirable and shortest path [9].

A desirable solution can be obtained based on the enhancement in ACO. A probabilistic algorithm is developed as the result of combination of upgraded heuristic parameters and salesman list with local finding solutions [10]. The preferred list is assigned in the method which is followed by ants when they move in search of food/nest. Thereby, the new proposed scheme is capable of gaining the better solution with effective speed slot [10]. The ACO is probabilistic approach bearing enhanced heuristic algorithms and parameters. The approach has successful wide applications and can be used to several issues related to combinational optimization [11]. The flexibility in operation and easily understanding quality of ACO makes it user friendly and can be used in several application to solve TSP and provides standard base in developing much better algorithms. The new approach developed/proposed/presented has mesmerized results in solving TSP and getting optimal solution [11].

V. REVIEW ON PARTICLE SWARM OPTIMIZATION

The PSO technique is categorized as probabilistic algorithm that plays main role in optimizing the path. It serves much credibility like, easy to implement, capability of storing part iterations, enhanced simulation, robust and easily

implacable along with parallel distribution algorithm. The combination of PSO with other evolutionary algorithm; initially engages random solutions and follows iterative upgradation so as to find an appropriate optimal solution.

PSO was proposed for first time and is referred as population based optimization algorithm inspired by foraging behavior of birds [12]. Each of the birds is considered as particle and based on the bird's flight behavior; the iterations are updated according to the current position and speed of bird's flight. PSO serve vital role in space optimization [12]. A novel algorithm based on PSO has been developed for solving TSP. It uses unique searching practices and crossover elimination for increasing the convergence speed which gives better results compared to existing algorithm developed using swarm intelligence [13]. This developed algorithm gives satisfactory results when used for large problem. The chromosomal extension can be added to the developed algorithm so as to extend the response for large operations [13].

The development of PSO based on hybrid discrete model inherits more response factor such as, reversion operator, heuristic factor etc. [14]. The working efficiency of PSO can be enhanced by upgraded kinetic equation mechanism resulting increase in efficiency irrespective of velocity or accuracy. The use of heuristic factor in this approach encourages search operations which in turn avails better path [14]. The lacuna of getting suboptimal solution or in other word the premature convergence in GA is overcome by a new proposed PSO algorithm. This developed approach is nothing but combination of ACO-GA-PSO which forms a hybrid, 2-stage swarm intelligence results in much better and efficient solution to TSP [15].

VI. REVIEW ON GENETIC ALGORITHM FOR TSP

The Genetic Algorithms offers better search ability, user friendly, easy to understand and robust in nature thus adds evolutionary approach in solving TSP with better credibility. The operation of GA is basically categorized in three parts namely,

- Coding
- Fitness evolution of an individual
- Genetic operation

Many researchers have opted GA in finding the better solution for TSP issues which mostly focuses on evolutionary approach in problem solving. The evolutionary computation involve in solution finding is consist of evolutionary strategy, programming, genetic algorithm and genetic programming. Similarly, the operators used follows selection, crossover and

mutation. The simple operation of Genetic Algorithm is stated in stepwise manner as below,

1. Creating initial population of P number of chromosomes.
2. Fitness evolution every chromosome.
3. Choosing parents from existing population i.e. 1/2 of P.
4. Implementing crossover operator for random selection of two parents so as to create offspring.
5. Correction in results using mutation operators.
6. Repetition of step 4 and 5 till selection and mating confirmation of parents.
7. Replacing odd parent population with new.
8. Repeating step 2 for new population.
9. End, if generations meets else follow step 3.

The use of GA for solving TSP issues is done by focusing on topological function so as to order the number of vehicles that a salesman is visiting [16]. Presented a new crossover operator similar to natural moon which helps in random selection of population subset and combining it with selected parents to have offspring. The results gained by new developed moon crossover operator are compared with existing operators like position based and OX operator were it has been observed that the results gained by newly developed moon crossover operator gives optimum solution than existing operators [16]. The approach stated by authors is more efficient for small to medium scale problems but sometimes miss optimal solution for large problems/issues.

The quality of solution can be enhanced by using indigenous search method. Use of Elitism method for chromosome selection which is initially a copy of best chromosome from new generated population and other are selected based on conventional method of selections [17]. The new searching method follows defining the location of crossover on chromosome and exchanging the information by using SCX operator. This approach avails the satisfactory solution to TSP in gaining the proximal solution but couldn't offer an optimal solution for TSP. The newly proposed SCX operator along with local searching techniques is capable of enhancing the quality of results [17].

The provision of GA based methods using the process of natural evolution to solve TSP related issues avails best results compared to existing algorithm approaches [18]. On surveillance of enormous approaches/methods/techniques by many scholars the enhancement in solution of GA can be done by developing a new genetic operator [18]. Development of enhanced GA for solving TSP issues is done by using Euclidean formula and matrix formation [19]. This is done by using Euclidean formula for calculating the distance in

between the various cities of travel followed by the matrix formation based on the data evaluated. The sequence of solution implemented is as, focus on symmetric TSP, random generation of initial population, assigning the fitness value followed by tournament selection and implementation of interchange mutation. On doing so, the new population is generated which gives better symmetric solution for TSP problem [19].

VII. CONCLUSION

After engaging with several articles and research contribution to solve travelling salesman problem, we can conclude that, the development in heuristics algorithms like ACO, PSO GA etc. have overcome the conventional strategies to solve TSP. These algorithms are more efficient and provide solution with lessor tome lapse covering more accuracy. The algorithms provide better, effective and reliable solution for small and medium sized problem contrary to conventional approaches. Further enhancement in GA can be done by combining the GA with genetic operator and chromosomal operator. Also, best solution can't be denied when GA is engaged with upgrading mechanism of memory addition. In this paper more focus is done on state-of-art review on heuristics algorithm and enhancement approaches.

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