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A Review of Memetic Algorithm and its Application in Traveling Salesman Problem

Rajiv Kumar[1] and Minakshi Memoria[2]
[1]Research Scholar, Department of Computer Science and Engineering, Uttaranchal University Dehradun, India.
[2]Associate Professor, Department of Computer Science and Engineering, Uttaranchal University Dehradun, India.

(Corresponding author: Rajiv Kumar)
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ABSTRACT: The transportation department of numerous private and government companies, large wholesalers, distribution networks, warehouses, and other related organizations faces the transportation scheduling and route optimization problem, which is very complicated and most demanding in nature. After a rigorous review of the literature, we observed that over the past two decades TSP has received considerable attention. It has diverse practical applications such as road transport, scheduling or planning, logistics, which microchip manufacturing. DNA sampling, point soldering, etc. But TSP is seen as a problem with NP - Hard Benchmark. Several deterministic algorithms have been developed to achieve the optimal outcome, but the time complexity of the algorithm is exponential in nature. So it's wasting a massive amount of memory capacity and computation power. So, there is need to develop an algorithm which can deliver the best solution in polynomial time. The memetic algorithm is meta-heuristics, and is capable of thoroughly exploring the solution space while preventing exhaustive searching. It's capable of balancing global search with local search. So, this algorithm needs to be studied and implemented for TSP. Potential future scope of Memetic algorithm for TSP has been given to further improve the research in this area.

Keywords: Combinatorial problems, Genetic operators, Local search, Memetic algorithm, Metaheuristics, TSP.

I. INTRODUCTION

Over the past two decades many combinatorial optimization problems are developed and studied which include real world industrial problem or business environment problems. For some problems exact algorithms are available to get the optimal solution. But many problem comes in the category of NP-Hard [7]. Exact algorithm method requires large amount of computation time to get optimal solution [36]. It is impractical to get solution by spending large computational time. When problem size increase then exact algorithm's time complexity increases in exponential order. To tackle this type of problem stochastic or heuristic algorithm comes into the practice with compromise on solution optimality Heuristic algorithms are normally applied to the problem when exact algorithm is computationally expensive to provide the optimal solution in polynomial time. Stochastic (approximation) and Heuristic algorithms are problem specific; they have less robustness with respect to the combinatorial problem such as travelling salesman problem (TSP). So to tackle this type of problem meta-heuristic approach is best option. A metaheuristic is guided heuristic algorithm which intelligently use the concept of exploitation and exploration to search the large space and learning adaptability guide the heuristic to find the near optimal solution [13].

Travelling Salesman Problem: Travelling Salesman Problem or TSP has been studied by many researchers since the early of 19th century. This problem deal with the salesman visit all possible cities and return to its starting city with objective that each city is visited exactly once with follow shortest route [18]. The first mathematical formation for the problem was given in the 19th century by the Irish mathematician W.R. Hamilton [3]. The first mathematical approach for solving the problem was given in 1930 by Merrill Flood, and the name Travelling salesman problem was coined soon after by Princeton University's Hassler Whitney [7]. TSP is one of the famous benchmarks, significantly real-world problem which is come in the class of classic combinatorial problem. It has fundamental prospect with respect to the fields of computers Science and engineering, operation research and so forth [13]. Generally, TSP deals with the real-world problems related to transportation [18]. Supply chain and logistics etc. In transportation, the school buses routing problem which deal to find out the cheapest link through every stop. Where as in logistic and Supply chain problem is to found out the low cost route to deliver the goods to the customer. To find out the optimal solution to these real world problems are a big challenge. TSP is considered as NP Hard problem and it has no known efficient algorithm available.

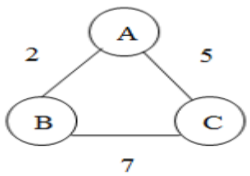
In literature different type of travelling salesman problem exist based on the structure of the distance matrix of the cities. Such as symmetric and asymmetric. If $C_{ij} = C_{ji}$ for $\forall i,j$ where i and j represent the row and column of distance(cost) matrix. Further TSP can be defined as the complete undirected graph G=(V,E), Where V={1,2,3,…..n} is the set of n vertices and E ={(i,j); i,j $\in v$ and i ≠j} the set of edges (Which represent the distance between cities). The cost $C_{i,j}$(Can be distance, time etc) Where all the cost must satisfy the constrain $C_{i,j} \leq C_{ik} + C_{k,j}$. The vertices are assumed to be points $P_{i=}$

(X_i, Y_i) in the plane and $C_{i,j} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$ is the Euclidean distance between P_i and P_j

Travelling salesman problem is computational difficult with exact algorithm. It is not practical to check all the possibilities and select best routes? Just check the statistics of TSP

In 3 Cities Problem

In case of 3 cities, you have only – one solution A-B-C-A



General formula for all possible routes are given by (n-1)!/2

For 3 cities, 1 possibilities.

4 cities 3!/2=3 possibilities.

7 cities 6!/2 =360 possibilities.

31cites30!/2=6525285981219105863630848000000 possibilities.

If any computer can do 10^6 calculation in 1 second then it will take computation time is shown in the Table 1.

Table 1: Number of possibilities and Computation time by the number of cities [1].

Number of Cities	Number of Possibilities	Computation Time
5	12	12µs
12	181440	18 ms
15	43billions	12 hours
20	60E+15	1928 years
25	310E+21	98 Billions of years
32	4.11141932708896140886278144e+33	6,30 Trillion of years (Approx.)

For 32 cities, computational time is more than the life of earth. So it is impossible to find the all possible route and then get optimal solution. So it is pure NP Hard problem.

II. METHODOLOGY

Metaheuristics: Metaheuristics are general heuristic approach that guides the search process through the solution space, the evolutionary algorithm is starting by manipulating the initial solution built by some heuristic, metaheuristics improve the solution quality iteratively until a some stopping criterion is met. The stopping criterion can be a number of iterations, elapsed time, and etc. [39] described a metaheuristic as "Iterative principal processes that guide and modifies the operations of subordinate heuristics to efficiently create high-quality results" [32] provide a wide-ranging bibliography on metaheuristics and its applications in different combinatorial optimization problems. Examples of metaheuristics are the Evolutionary Algorithm [41], Memetic Algorithm [28].

Genetic Algorithm: Genetic algorithm (GA) is metaheuristic global search algorithm .GA is inspired by Darwin's theory of survival of fittest and natural selection. It was first invented by Prof. Holland [16] and its students in 1975. GA is a deal with the population individual in the evolution process. In the iterative evolution process new population of individual is generated by the application of selection, crossover and mutation operators. The GA flowchart is shown at Fig. 2. GA has been used broadly in combinatorial problem optimization such as travelling salesman problem.

Following are the steps used in the Genetic Algorithm

Step 1: Generate an initial population of individual

Step2: While stopping criteria not met repeat the following steps

Step 3: Select the best individuals for making matting pool

Step6: Appling crossover operation with a certain crossover probability P_c to create offspring.

Step7: Appling mutation operation certain crossover probability P_m.

Step9: Replacement

Stop10: End

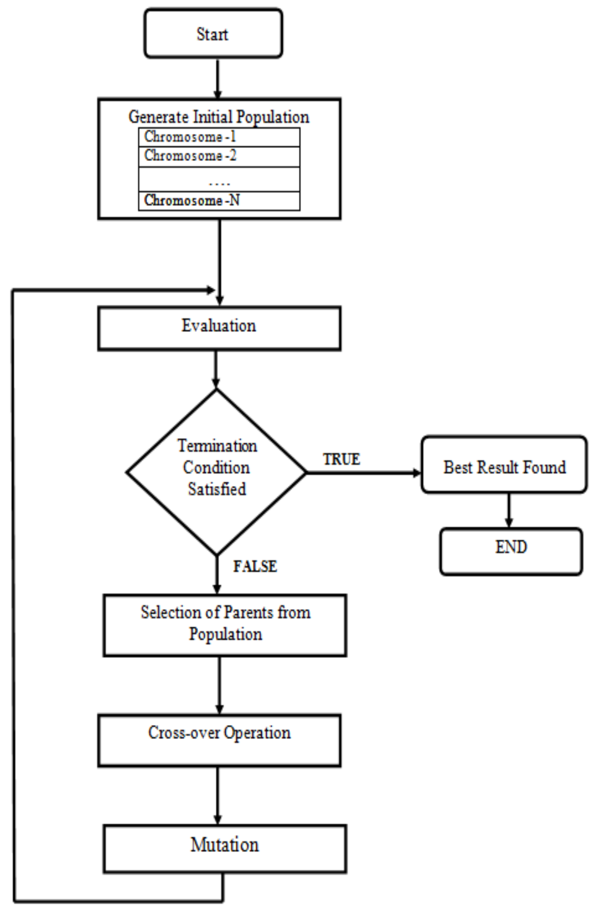


Fig. 1. Genetic Algorithm

Memetic Algorithm: Memetic algorithms are also population-based metaheuristic search algorithm. This algorithm is a combination of evolutionary algorithm and local search algorithm. Basically, MA is advance version of Genetic algorithms (GA). The concept of meme is borrowed from the philosophy and is expressed as cultural transmission unit [30]. The name Memetic Algorithm (MA) is devised by Pablo Moscato [27] but as always, the same idea was also given under the name of Baldwinian GA [20] , local searchers [24] , Hybrid GA [15], Lamarckian GA [31], others MAs consist of the concept of combining global and local search algorithms [30]. Memetic Algorithm can be used to solve combinatorial problem (Such as TSP , Scheduling problem etc.) The working of the memetic algorithm is same as in genetic algorithm except local search, which help the algorithm to converge toward global maxima. The MA flowchart is shown at Fig. 3.

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Step6: Appling crossover operation with a certain crossover probability P_c to create offspring.

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Step8: Perform local search

Step9: Replacement

Stop10: End

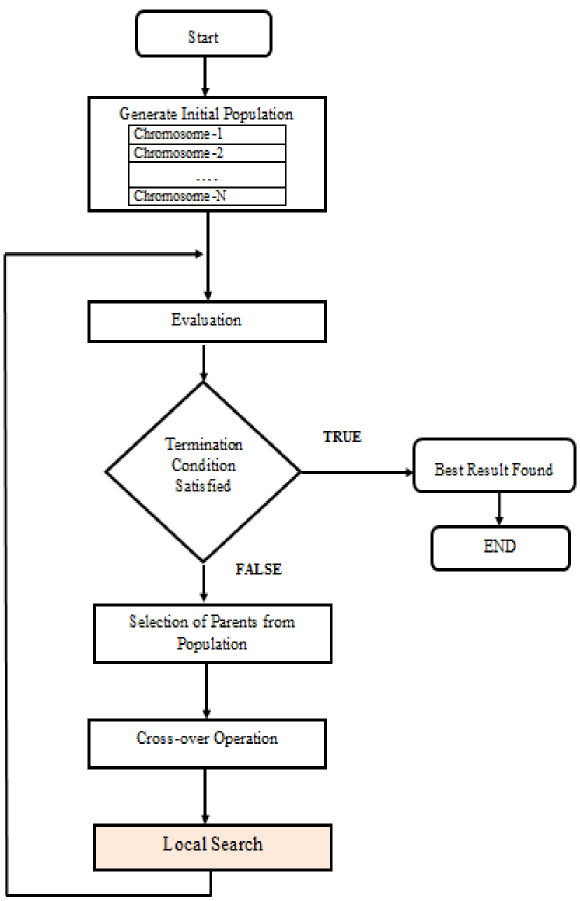

Fig. 2. Memetic Algorithm.

Local Search approach: Enhancement in the Memetic algorithm is incorporated by the application of local search techniques. The most critical and unique feature of MA is the inclusion of local search. Local search is an iterative process; it makes local modification on the configuration. This process repeated until a specified condition is met. Local search may be termed as local winners [26]. Normally Local search is work by application of mutation operator on the current solution. This technique improves the solution at the local level. The Genetic Algorithm is the global search algorithm, it has the capability to globally searching potential. But it takes the feature of local search. But the memetic algorithm has a tendency to balance the global search as well as the local search.

III. LITERATURE SURVEY

The researcher presents the result in the paper and explains that MA can be successfully applied to the combinatorial optimization problem. i.e TSP. There is a need for an empirical study to optimize the local search used in the memetic algorithm for the TSP problem [35]. How we can reduce the computation time in the local search.

The author provides the details knowledge of metaheuristics and their application to combinatorial problems. Metaheuristics are robust powerful approaches that have been applied to difficult combinatorial problems. Before applying to any 5problem its characteristic must be known [13].

The Researcher illustrates the theoretical and practical relevance of Memetic algorithm and their design issue. Different design issues are present when we implement the Memetic algorithm [19]

Metaheuristic with hybridizing approach is the best way to improve the method which is applying to solve the problem. The optimal parameter setting of the hybridization is not known. When hybridization techniques are applied. So the data mining techniques help to set the parameters. Further improvement is required [17].

The researcher in the present paper combines the evolutionary algorithm with local search and clustering process. The proposed algorithm shows better results. The computational time can be reduced by applying the clustering technique [23].

The researcher presents Two-Level Genetic Algorithm for Clustered Traveling Salesman. Which favors neither intra-cluster paths nor inter-cluster paths. The experimental results show that clustering TLGA for the large scale TSPs is more effective and efficient than that of traditional classic genetic algorithm [11].

Földesi & Botzheim [12] present the Road transport travelling salesman problem. He solve the problem by using the bacterial evolutionary algorithm. In the present paper researcher explain with road transport travelling salesman problem that it has practical application. A novel construction and formulation of the problem is presented. Simulation result shows better results. Further the results can be improved by apply the hybrid evolutionary algorithm.

In the present paper Intelligent Transportation Systems, Traveling Salesman Problem (ITS-TSP) is described. The proposed algorithm is to deal with transportation problems. The proposed heuristic algorithm provides the best solution. Further, this algorithm can be improved for the route prediction [25].

The author presents the survey report of Machine learning and its applicability to the Evolutionary algorithm. This report provides the research direction that how to improve the evolutionary algorithm and its different elements, such as initialization of population, evaluation of the fitness of solution, selection operation, local search, and reproduction process.

This is the survey paper on machine learning and its applicability to the evolutionary algorithm. There is scope to improve the EA by using machine learning [42].

The funding of the researcher of this paper shows that the Memetic algorithm is developed by using tabu search techniques. It shows better results with respect to the TSPHS. The gap that we found in this paper is that we can use other local search techniques which may give better results. The present research use 1000 customer. We do not know what will be the result of n number of customers with respect to the tabu search [8].

The researcher works on the 11 different TSP problems and concludes that the component property of the local search techniques change with respect to the problem under consideration. The results of the present paper show that the properties of the local search change with respect to the problem. So there is scope to design a new local search technique that will adapt itself [38].

The researcher in the paper present uses two different local search techniques that are applied together. The new techniques better results with respect to the traditional GA. The computational complexity of the proposed algorithm increases with the increase in problem size. There is scope to work in this area to reduce the computation complexity of the algorithm [40].

The researcher uses new techniques to apply the different operators. Also, the result shows that multiple uses of the operators are better as compared to the single operator. The researcher applies the different operators, but the probability crossover i.e. Pc and Mutation i.e Pm is not clear [10].

The researcher uses new techniques of self-adaptive multi-mems. Hybridize the algorithm with a hill-climbing technique. The result shows that self-adaptive self-configuration is better than a static memetic algorithm. The Computational Complexity of the existing algorithm is high [33].

The author implements the improved genetic algorithm with a local search technique on the android platform. The result shows that the improved algorithm show better results as compared to the simple GA. The researcher use a very small instance of 20 cites. It is not clear when the size of the problem increases, what we will be the performance of the algorithm [29].

The experimental results show in this paper is better. Researchers only use mutation operators to get the best results. Only mutation operator is used to get the high-quality solution for the TSP. The crossover probability is 0%. Which means, it is not applied? [4].

The researcher in the paper applies the evolutionary algorithm i.e GA for finding the shortest optimal route for Istanbul Electricity Team. The proposed algorithm provide the optimal route for the IETT audit Team. The result can further improve by applying local search techniques [14].

The researcher uses a variable population-based algorithm. It uses 13 instances an out of which 42 popular problems. The exploration power of the algorithm increase with an increase in the population size. After analyzing the results of this paper. It has a scope to apply to TSP. Which is a combinatorial problem? [43]

In the present paper, new permutation rules and GA is proposed to solve the TSP. The proposed algorithm shows better results with respect to the TSP. Improved in the present algorithm can be made by apply local search approach [18].

The researcher of this paper uses the route based crossover operator, random greedy, and variable neighborhood technique. The results are better. The researcher uses six different operators. This research can be extended by using more operators with different ways of applicability [22].

The author of the paper shows the use of machine learning in bioinformatics. Where data will be analyzed. He successfully uses the ML for data analysis. The author explains the use of machine learning to analyze huge data [6].

The author presents different types of machine learning clustering algorithm, such as K mean, decision tree, logistic regression, K-nearest Neighbors, etc. He concludes that machine learning algorithms can minimize the human effort to analyze the large data and increase the efficiency of the machine. An unknown pattern can be analyzed with the use of clustering algorithms. These algorithms were implemented by the researcher in Python language [2].

IV. CONCLUSION

Several deterministic algorithms have been developed to get the optimal result, but their time complexity is in exponential form. So it spends huge memory space as well as computation time. The memetic algorithm is meta-heuristics and has the ability to explore the solution space thoroughly while avoiding exhaustive search. The performance of the Memetic algorithms depends upon its parameters i.e. crossover operator, population size, mutation, selection, and local search. Thus new genetic operator and local search technique need to be built in order to improve the algorithm for TSP problems.

V. FUTURE SCOPE

This study has paved the way for further research by developing new local search method for memetic algorithm that solve the TSP problem. How the efficiency of the memetic algorithm can be enhanced

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