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Better Result for Solving TSP: GA versus ACO

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Abstract— ***Travelling salesman problem, being a problem that is NP hard is studied in the field of Combinatorial Optimization. TSP finds the minimum distance between given set of cities by traversing each of these cities only once except the starting city. The paper aims to find a solution that solves the problem of TSP using two meta heuristics techniques: Ant Colony Optimization algorithm (ACO) and Genetic Algorithm (GA). GA known as a search technique in the field of computer science, finds solution to problems that are combinatorial optimization. ACO have been proved as a successful algorithm and is applied to different optimization problem. Being a heuristic method, ACO is used as computing technique for providing an optimal solution to TSP problem. Also, the paper provides comparison between the two algorithms and this comparison helps to choose the better algorithm based on various parameters.***

Keywords--- Ant Colony Optimization algorithm, Combinatorial, Genetic Algorithm, NP-Hard, Travelling Salesman Problem.

I. INTRODUCTION

A. *Travelling Salesman Problem*

Travelling salesman problem being an optimization problem is used to find shortest path of a given set of cities, by visiting each city atleast once and then returning back to the starting city, such that the total distance travelled is minimized.

TSP was formulated in 1930 as a mathematical problem and is widely studied in the field of optimization. Despite the problem is difficult computationally there are many heuristics and methods that help to solve instances with even thousands of cities easily.

The problem TSP is represented as an undirected weighted graph, where cities are represented as vertices and paths are represented as edges in the graph. As a minimization problem it starts and finishes at a specified vertex by visiting each vertex atleast once. This model makes the problem as a complete graph. In case, if no path exists between the cities, an arbitrarily edge is added between the cities without affecting the optimal tour.

Mathematically TSP can be represented as G=(N, E) where N defines the set of cities and E defines the set of edges connecting all the cities. An edge, edge(i,j) ∈ E,in the graph is assigned a cost dij, where i and j defines the distance between the cities. The The Euclidean distance dij is calculated as:

$$d_{ij}\sqrt{(x_{i-}x_j)^2+(y_i-y_j)^2} \qquad (1)$$

The popular application of TSP are finding shortest route, regular distribution of resources etc., and also in the areas that do not have anything to do with the travel routes [3].

B. *Genetic Algorithm*

Genetic Algorithm was introduced by John Holland along with his colleagues and students in the mid-1970s, at the University of Michigan[4]. The genetic are appropriately known as optimization technique which is totally based on natural evolution. It is based on the idea of survival of the fittest. GA randomly selects the solution and choose the fittest solution and create a new generation from the fittest solution which is better than the previous generations.

As a computational method, Genetic algorithm is designed on the basis of natural selection and is used to simulate the evolution processes. GA follows a sequence as first generating initial population, evaluating the population, selection, crossover, mutation and finally re-generate the population.

The algorithm starts with randomly selecting solution for the initial population. Then the population is evaluated using some problem specific function. GA then selects the fittest solution from the given solutions and applies crossover and mutation to generate new generation. The main idea of GA is to produce a new generation better than the previous generation. This method continues until a stopping criterion is met.

GA method consists of the following:

INTIALIZATION: Random solutions are selected from given population to generate an initial population.

FITNESS FUNCTION: The solutions are evaluated using some fitness function. The fitness function generates fitness value for each of the individual solution. The function provides largest and smallest values for each of the individuals. If the individual has a larger fitness value then result will be a better solution but if a smaller value is obtained then solution obtained will not be better.

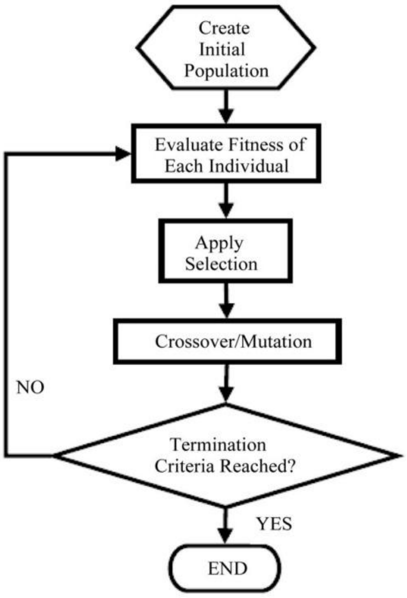

Fig1. Flowchart of Genetic Algorithm [5]

SELECTION: Selection process is done based on the fitness value. Higher the fitness value, is higher the chance of selection. The individuals which have the highest fitness value are chosen to produce the offspring. Selection can be done using different selection techniques such as Steady state, Roulette Wheel, Rank selection and Tournament selection.

CROSSOVER: In crossover new generations are created by recombining the solutions chosen in the selection process.

MUTATION: Mutation is a simple search operator that is applied to genetic algorithm after crossover. Mutation is applied after crossover process is completed.

TERMINATION: This whole process continues until a stopping criterion is met or it executes certain number of iterations.

C. Ant Colony Optimization

Ant colony optimization, a meta heuristic algorithm finds an optimal solution over a discrete search space. The best example of this algorithm is TSP, where the candidate solution in the search space increases exponentially as the size of the problem increases.

Macro Dorigo introduced ACO by observing the behaviour of ants. The ants always stay in their colonies and they are good in exploitation and searching. The ants work in groups and explore the path in search for their food and find the shortest path to reach there. Initially, ants randomly move around their surrounding in search of food. While moving in the surrounding they lay some sort of chemical on the ground which is known as Pheromone. When an ant finds the food it goes back to its nest by filling the ground again with that pheromone trails. Due to these pheromone trails other ants know which path to follow. The path which contains the higher amount of pheromone trails on the ground is chosen by the ants. Larger the concentration of pheromone trail on the path more is the probability of choosing that path by an ant.

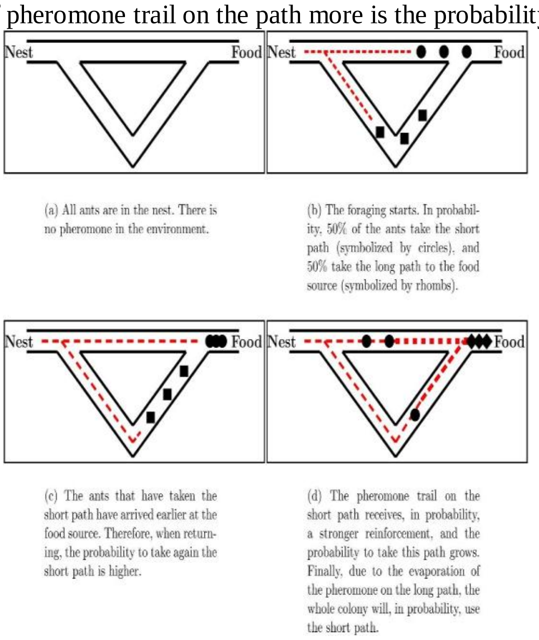

Fig 2. It shows the behaviour of ants[9]

The figure (a) above depicts there are no pheromone on the path. The ants are in their nest. The figure (b) shows that ants have started exploring the path in search of food. 50% of the ants, marked as circle in the nest follow a path and rest of the ants marked as rhombus follows other path as shown in the figure. Figure (c) the ants marked as circle reaches the food earlier than the ants marked as rhombus. This means that the ants marked as circle follow the shortest path than the ants marked as rhombus. In figure (d) depicts that ants choose the shortest path while returning to their nest so the pheromone trail in the shortest path is more than the other paths.

II. RELATED WORK

Varshika proposed a paper on the travelling salesman problem using genetic algorithm [6]. The paper provided a flexible method to solve the TSP using genetic algorithm. TSP is the main domain in the paper to solve the NP-hard problems. The referenced paper provides an implementation using genetic which is used to find shortest path for a specific problem.

A literature survey for solving tsp using genetic algorithm [7] was provided by Naveen kumar, Karambir, Rajiv Kumar. Different genetic operators are used in solving TSP such as mutation, crossover or the combination of them. After analysing the survey the researchers have observed that new operators can also be introduced in the future. These new operators can increase performance of genetic algorithm for solving the TSP problem.

Christian Blum provided a paper on Ant Colony Optimization- Introduction and recent trends in 2005 [8]. The paper proposed a detailed description about the origin and the basic information of Ant colony optimization algorithm. They also gave the general description about the meta-heuristics of ACO.

Ivan Brezina Jr. Zuzana in 2011 proposed a paper on Solving the Travelling Salesman Problem Using the Ant Colony Optimization [3]. He provided a possibility to solve TSP using ACO, which is an evolutionary algorithm. The paper concluded that the quality of the solution in a problem depends directly on the number of ants. If less ants then the path would change frequently by the individual ants. If higher number of ants is there in the population then there will be high accumulation of pheromone on the path so the path does not change faster.

Solving Traveling Salesman Problem by Using Improved Ant Colony Optimization Algorithm Zar[9] was proposed by Chi Su Su Hlaing and May Aye Khine in 2011. The paper presented an improved ACO with two main highlights. The first one is a candidate set strategy to converge speed. Second highlight is an updating rule for the heuristic parameter based on the entropy which is primarily used to improve the performance in solving TSP.

III. METHODOLOGY

The paper solves the TSP problem using both Genetic Algorithm and Ant Colony Optimization algorithm.

A. TSP using Genetic Algorithm

The Algorithm is defined as:

Step 1: Generate random solutions for creating Initial population.

Step 2: Use fitness function, to Evaluate fitness of each solution in the population.

Step 3- Repeat the following procedure until certain criterion is met.

a. Based on the fitness value, select any two solutions with higher fitness value.

b. Crossover the parent in order to form new off springs. If no crossover was performed, the new offspring generated is an exact copy of parents.

c. Mutation, mutate the new offspring generated.

Step 4: If the condition is satisfied then stop the procedure and return the solution which is best in current population

Step 5: Now go back to step 2.

B. Tsp using Ant Colony Optimization

The below listed steps defines the algorithm:

1. Ant colony optimization (ACO)

init pheromone τi = const for each component
while the termination condition doesn't met do the following:
  for all the ants i:- construct_thesolution(i);
  for all ants i:- global_pheromoneupdate
  for all the pheromones i:-evaporate:-
$\tau i = (1 - \rho). \tau i$
end loop;

2. construct_thesolution(i);

init s={};
while s is not a solution:
  choose cj with the probability:-
  $p(ci \mid s)$
  expand s by cj;
end loop;

These probabilities are known as Transition probability and are defined as:

$$p(c_i\,|s) = [\tau i]^{\alpha}.|\eta(c_i)]^{\beta} \;/\; \Sigma_{c_j\,\varepsilon N\,(s)}\,[\tau_j]^{\alpha}.[\eta(c_j)]^{\beta} \qquad (2)$$

∀ $c_i \in \boldsymbol{N}(\boldsymbol{s})$ and η called as heuristic information is used as an optional weighting function.

3. global_pheromoneupdate(i);

for all cj in the solution s:-

Increase pheromone :

$$\tau i = \tau j + \frac{const}{f(s)};$$

IV. EXPERIMENT ANALYSIS

For the implementation, we used Windows 7 laptop of Intel core I5 with 2.5GHz processor and 4 gigabytes RAM. The implementation of GA and ACO algorithms is done in Matlab.

The Fig.3 depicts the graph of solving TSP using both GA and ACO. The path followed by *GA is represented by dashed red colour where as ACO is represented by blue colour.*

To compare, effectiveness of both the algorithms, we have taken three instances, 14 cities, 30 cities and 50 cities to see which algorithm gives better result. The three runs are done on both the algorithm based on the criteria of different number of cities. We started the run by taking 14 cities for both the algorithms. A point in the graph using x-y coordinates is represented as a city.

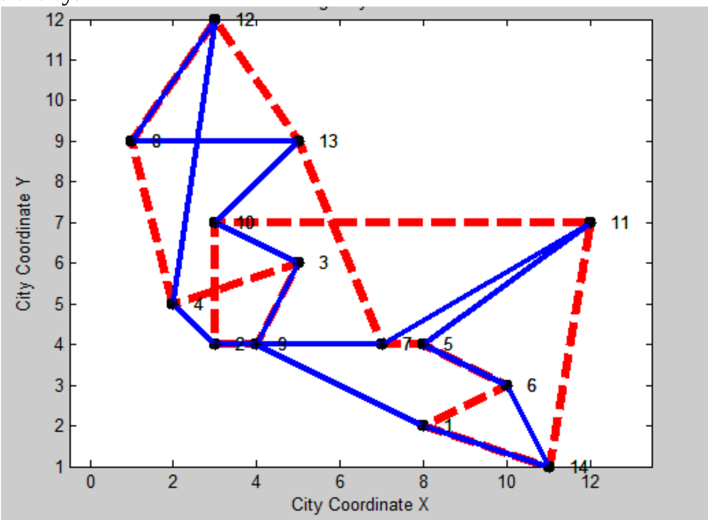

Fig 3. Solve Tsp Using GA and ACO

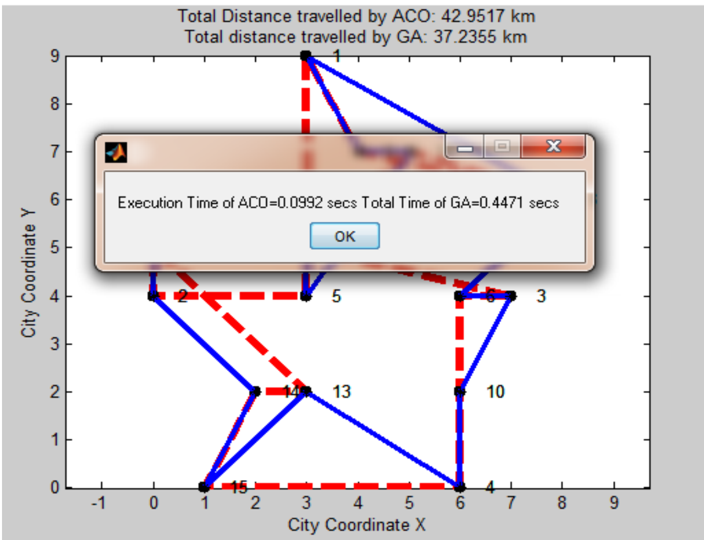

Fig 4 (a). TSP using GA and ACO based on Total Distance travelled and Execution Time based on the criteria of 14 cities.

The Fig.4 (a) depicts the graph solving TSP based on the criteria 14 cities using Genetic Algorithm and Ant Colony.

Similarly did the implementation for 30 cities and 50 cities and compared both the algorithms based on the total distance travelled and execution time to find out the best algorithm to solve TSP. The Fig.4 (b) depicts the graph solving TSP based on the criteria 30 cities using Genetic Algorithm and Ant Colony where as Fig.4 (c) depicts the graph solving TSP based on the criteria 50 cities using Genetic Algorithm and Ant Colony.

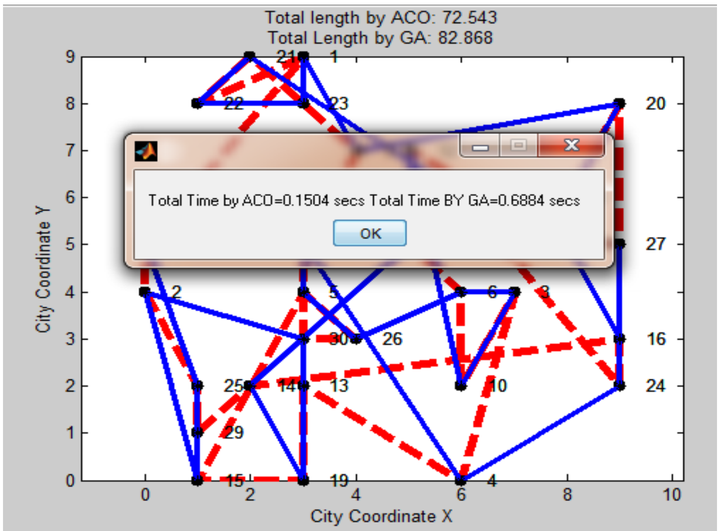

Fig 4 (b). TSP using GA and ACO based on Total Distance travelled and Execution Time based on the criteria of 30 cities.

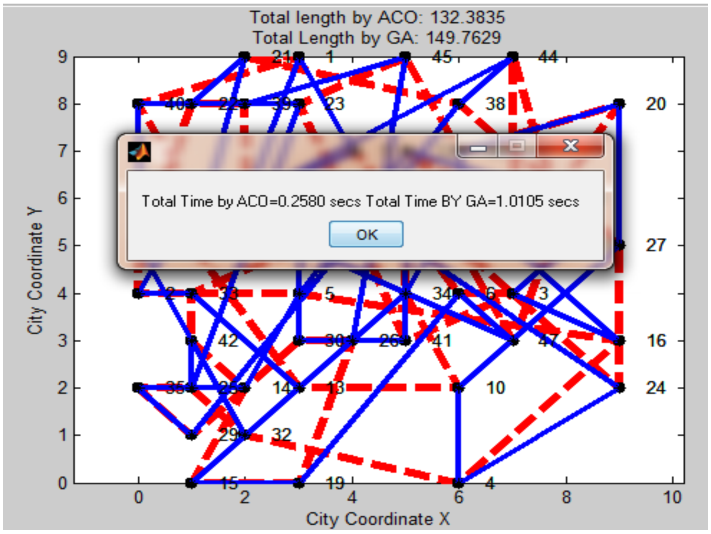

Fig 4 (c). TSP using GA and ACO based on Total Distance travelled and Execution Time based on the criteria of 50 cities.

COMPARISON

Table I: Comparison between GA and ACO based on Total Distance Travelled in kms

Algorithm / No. of Cities	**Genetic Algorithm**	**Ant Colony Optimization**
City :14	37.2355	42.9517
City:30	82.868	72.543
City:50	149.7629	132.3835

Table II: Comparison between GA and ACO based on Execution Time

Algorithm / No. of Cities	**Genetic Algorithm**	**Ant Colony Optimization**
City :14	0.4471	0.0992
City:30	0.6884	0.1504
City:50	0.2850	1.0105

The table I conclude the best results obtained by solving TSP using Genetic algorithm and Ant Colony Optimization based on the Total distance traveller. Whereas the table II concludes the best results obtained by solving TSP using Genetic algorithm and Ant Colony Optimization based on the Execution Time.

V. CONCLUSION

The TSP can be solved using both the heuristic algorithms ACO and GA. The paper gives a comparison between Genetic algorithm and Ant Colony algorithm to solve the travelling salesman problem. The comparison between both the algorithms is based on the number of cities given in the problem and then determines the result on the basis of the distance travelled by them and the execution time.

The result in the table depicts that the Genetic Algorithm gives better result in terms of distance travelled for less number of cities but as we increase the complexity by increasing the number of cities, ACO proves to give better result than Genetic. While considering Execution time as the factor ACO, always prove to be better.

VI. FUTURE SCOPE

The paper presents a comparative analysis among both the algorithms, Genetic Algorithm and Ant Colony Algorithm for solving Travelling Salesman Problem and shows that GA gives better results. There exist many algorithms that can be used to solve TSP. In future tsp can be solved using different algorithms and then compared in order to classify which algorithm gives the best optimal results under a given set of conditions.

We have compared the algorithms on the basis of total distance travelled and execution time based on the number of cities. In the future the comparison for the algorithms can also be done on the basis of cost in order to get the best algorithm which gives the best result for solving TSP.

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