# Comparison and Analysis of Solving Travelling Salesman Problem Using GA, ACO and Hybrid of ACO with GA and CS

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***Abstract*— The Travelling Salesman Problem (TSP) is a very popular combinatorial optimization problem of real world. The objective is to find out a shortest possible path travelled by a salesman while visited every city once and returned to the origin city. TSP is one of the NP hard problems and several attempts have been done to solve it by traditional methods. Computational methods give better solution for TSP as most of them are based on repetitive learning. In the proposed paper four optimization techniques are presented such as ant colony optimization (ACO), genetic algorithm (GA), hybrid technique of ant colony optimization (ACO) and genetic algorithm (GA) and hybrid technique of ant colony optimization (ACO) and cuckoo search (CS) algorithm is proposed and implemented for travelling salesman problem. The result shows that shortest efficient tour is obtained by new hybrid algorithm.**

***Keywords- Optimization, Metaheuristic, Travelling Salesman Problem (TSP), Genetic Algorithm (GA), Ant Colony Optimization (ACO), Cuckoo Search (CS)***

## I. INTRODUCTION

Travelling salesman problem is one of the commonly studied and interesting problems of every researcher. Day by day evolution of nature inspired heuristic algorithms draw the attention of today's researchers and almost every new algorithm or hybrid algorithm is firstly implemented and its behavior is observed for travelling salesman problem. TSP looks very simple but it can not be accurately solve by conventional mathematical techniques. Therefore various optimization techniques can be applied to obtain better result. In this paper four techniques have been applied to analyze the result, these are genetic algorithm, ant colony optimization, hybrid of ant colony optimization with genetic algorithm and hybrid of ant colony optimization with cuckoo search.

## II. TRAVELLING SALESMAN PROBLEM

In 1800, the mathematical form of travelling salesman problem was first defined by two mathematicians W. R. Hamilton and Thomas Kirkman. The general form of travelling salesman problem (TSP) has been defined by Karl menger in the year 1930 but the popularity of TSP increases in research domain during 1960s to 1980s. From that onwards a number of NP hard and other optimization algorithms have been applied to solve TSP and find out the shortest tout travelled by salesman in relatively short time interval. There are many ways via which TSP can be explained and implemented in real time. A salesman has to visit number of cities, starting and end should be in same city while moving to other cities once during that tout only. Objective of the problem is to travel minimum distance, cover all cities with minimum time and to minimize travelling cost also.

There are a number of techniques, which can be applied to solve Traveling Salesman Problem. Some of the commonly used methods are: greedy algorithm, k-opt heuristic, V-opt heuristic, stimulated annealing, neural network, genetic algorithm, swarm intelligence etc.

The TSP algorithm can be easily explained by Fig. 1. Let us assume that the path a-b-c-d-e-f-g-h-a is the initial solution and $\infty$ is the length of non-existent edge. When a triangle f-g-h is taken then there are six possible ways to reorganize this particular path, which are:

$e \rightarrow f \rightarrow \mathbf{g} \rightarrow \mathbf{h} \rightarrow a \quad 4 + \infty + 4 + \infty \quad = 2{\cdot}\infty + 8$

$e \rightarrow f \rightarrow \mathbf{h} \rightarrow \mathbf{g} \rightarrow a \quad 4 + 3 + 4 + 1 \quad = \mathbf{12}$ **minimum value**

$e \rightarrow g \rightarrow \mathbf{f} \rightarrow \mathbf{h} \rightarrow a \quad \infty + \infty + 3 + \infty \quad = 3{\cdot}\infty + 3$

$e \rightarrow g \rightarrow \mathbf{h} \rightarrow \mathbf{f} \rightarrow a \quad \infty + 4 + 3 + \infty \quad = 2{\cdot}\infty + 7$

$e \rightarrow h \rightarrow \mathbf{g} \rightarrow \mathbf{f} \rightarrow a \quad 3 + 4 + \infty + \infty \quad = 2{\cdot}\infty + 7$

$e \rightarrow h \rightarrow \mathbf{f} \rightarrow \mathbf{g} \rightarrow a \quad 3 + 3 + \infty + 1 \quad = 1{\cdot}\infty + 7$

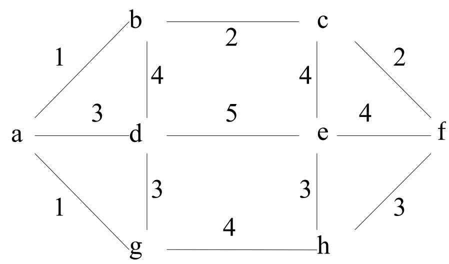


Fig 1. Basic diagram to explain TSP

## III. GENETIC ALGORITHM

The idea of Genetic Algorithm (GA) was conceived by John Holland in 1975. GA is an optimization algorithm based on natural evolution. GA is commonly used in very large search space. It is based on greedy initial population, where population is represented by set of solutions. Every new population is generated on the basis of previous population and it is motivated by assuming that new generated population will be better than previous one. This process is repeated until some satisfactory condition is achieved.
Generally GA can be expressed by following five stages:

- Encoding
- Evaluation
- Crossover
- Mutation
- Decoding

Basically six parameters are there to control the operation of genetic algorithm, they are: Population size, Neighborhood or Group size, Mutation, nearby cities, nearby city odds and Maximum generations.

*The steps involved in Genetic Algorithm can be summarized in following steps:*
Step-1: define cost function, variables, GA parameters
Step-2: determine the fitness of every solution in current generation population
Step-3: record the best fitness
Step-4: generate new solution for next generation population
Step-5: if termination condition satisfies, update the generated solution as the best solution otherwise go to step 2

## IV. ANT COLONY OPTIMIZATION

The concept of Ant Colony Optimization (ACO) was given by Marco Dorigo in 1991 in his Ph.D thesis. It is a metaheuristic algorithm which is more suitable for combinatorial optimization problem. ACO algorithm is based on the behavior of real ants, ants are blind and they are capable to determine the shortest path from nest to food. When ants move, they deposit pheromone on the path and other ants follow the path which is having high intensity of pheromone.
Ants communicate with each other by the amount of pheromone deposited. Transition rule from initial position i, and is defined by below mentioned equation:

$$P_m(i,j) = \begin{cases} \dfrac{\left[\tau_{(i,j)}\right]^{\alpha} \cdot \left[\eta_{(i,j)}\right]^{\beta}}{\sum_{k \in S_m(i)} \left[\tau_{(i,j)}\right]^{\alpha} \cdot \left[\eta_{(i,j)}\right]^{\beta}} & if\ j \in S_m(i) \\ 0 & otherwise \end{cases} \text{ ---- (1)}$$

Where,
$\tau_{(i,j)}$ : intensity of the pheromone deposited by each ant on the path $(i,j)$
$\alpha$ & β: intensity control parameter and visibility control parameter
$\eta_{(i,j)}$ : visibility measure of the quality of the path $(i,j)$ and $\eta_{(i,j)}=1/l_{(ij)}$
$l_{(ij)}$ : distance between two nodes
$S_m(i)$ : the set of sessions to be observed

*Pheromone Updating Stage:*

Ants update the pheromone level on the paths by the following equation: $\tau_{(i,j)} \leftarrow \rho \cdot \tau_{(i,j)} + \Delta\tau_{(i,j)}$ ------------ (2)

Where,
$\rho$ : evaporation parameter
$\Delta\tau_{(i,j)}$ : pheromone level

*The steps involved in Ant Colony Optimization algorithm can be summarized as:*
Step-1: initialize parameters like no. of ants, pheromone trails and other parameters
Step-2: determine the probability of pheromone on every path
Step-3: apply local search and store best solution
Step-4: update the value of pheromone on each path and reach at max. iteration
Step-5: pick the optimal solution and if termination condition satisfies, update the generated solution as the best solution otherwise go to step 3

## V. HYBRID OF ANT COLONY OPTIMIZATION ALGORITHM WITH GENETIC ALGORITHM

Here a proposed hybrid algorithm of ant colony optimization algorithm with genetic algorithm is explained and is applied for solving travelling salesman problem because the structure of ACO and GA is almost same. The objective of proposed hybrid algorithm is determining shortest path. This algorithm takes the advantages of ACO and GA, the limitation of ACO algorithm is that ants follow the path having more intensity of pheromone therefore search process takes more time sometimes.
The genetic algorithm utilizes all effective paths of ACO and then identifies an effective and efficient way in search space to obtain a better solution for movement towards better solution. This hybrid algorithm is capable of increasing convergence speed and optimum solution is achieved in relatively less number of iterations.
*The steps involved in hybrid technique of ACO with GA can be summarized as:*
Step-1: initialize pheromone matrix and first population
Step-2: start first city of every ant to calculate fitness
Step-3: determine a route of every ant according to probability rule and chromosome
Step-4: to calculate shortest path, evaluation process is hybridized
Step-5: for every cycle update pheromone and population
Step-6: if termination condition satisfies, update the generated solution as the best solution otherwise go to step 3

## VI. HYBRID OF ANT COLONY OPTIMIZATION ALGORITHM WITH CUCKOO SEARCH

The idea of Cuckoo Search (CS) was given by Yang and Deb in year 2009. It is also a population based optimization algorithm. The tendency of cuckoo species is to lay their eggs in the nest of other host birds whereas host birds have a tendency to either destroy the eggs or leave its nest within specified space which is known as Egg Laying Space. This characteristic of cuckoo is used to solve different kind of optimization problems in engineering domain. CS can be easily explained by three step rules:

At a time every cuckoo lays one egg only and randomly dump egg into the chosen nest

- For next generation, the best nests with high quality of eggs will carry over
- Available number of host nest is fixed and egg laid by a cuckoo is discovered by the host birth with probability

The proposed hybrid algorithm combines the advantages of ACO and cuckoo search algorithm to find out the optimized path for travelling salesman.

*The steps involved in the hybrid technique of Ant Colony Optimization algorithm with Cuckoo Search algorithm can be summarized as:*

Step-1: initialize parameters like no. of ants, pheromone trails, nests and other parameters

Step-2: determine the probability of pheromone on every path

Step-3: apply local search and store best solution to get best nest

Step-4: update the value of pheromone on each path and reach at max. Iteration

Step-5: pick the optimal solution and if termination condition satisfies, update the generated solution as the best solution otherwise go to step 3

## VII. SIMULATION RESULTS AND DISCUSSION

To compare the performance of GA, ACO-GA and ACO-CS for travelling salesman problem various parameters have been calculated and analyzed. Parameters are best distance, propagation delay and best distance.

To compare and identifying the best proposed algorithm, every algorithm is being executed for various number of cities along with 100 iterations. The average result of 100 iterations is compared with all to find out the best result to achieve convergence. The values of parameters taken in proposed algorithm affects on the performance of algorithm. Table 1 summarizes the values of parameters:

TABLE 1: SELECTED VALUES OF PARAMETERS

| Parameter | $\alpha$ | B | $\rho$ | $P_c$ | $P_m$ |
|---|---|---|---|---|---|
| Value | 1.5 | 3 | 0.6 | 0.9 | 0.8 |

Simulation results of all four techniques are shown from Fig. 2 to Fig. 6. Values obtained from different techniques discussed in paper have been shown in Table 2-5 while table 6 summarizes the result obtained from all four techniques.

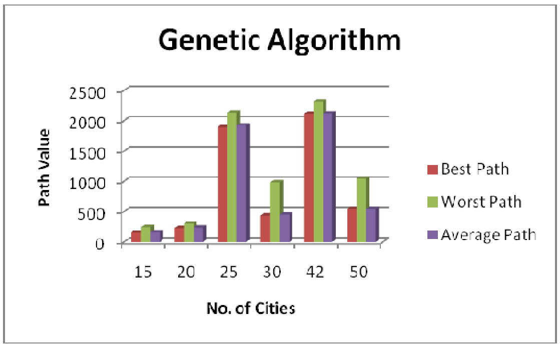


Fig.2

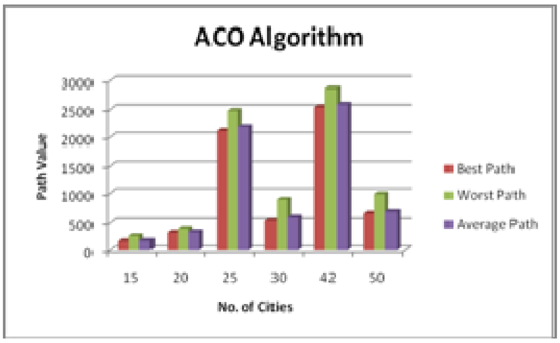


Fig. 3

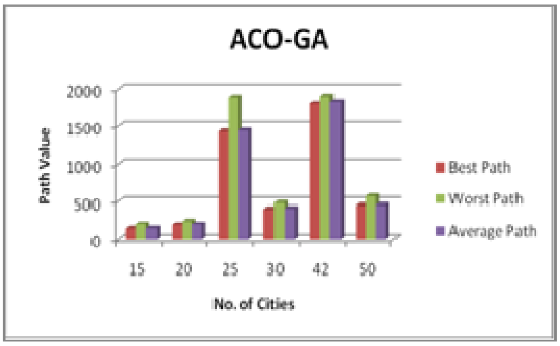


Fig. 4

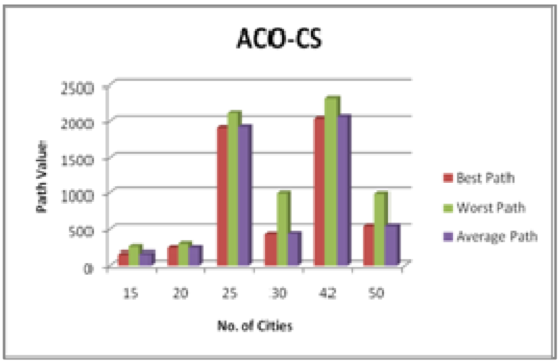


Fig. 5

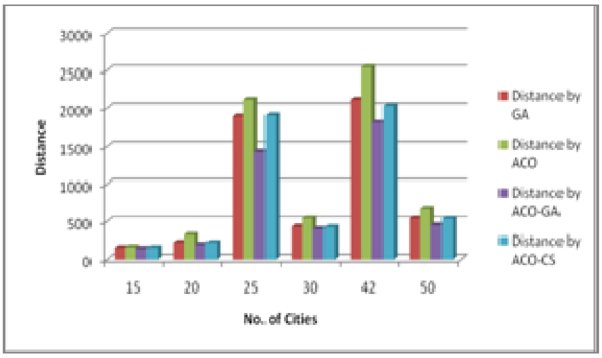


Fig.6: Comparison of distance calculated by all four algorithms

TABLE 2: RESULTS OBTAINED BY GA

| Number of Cities | Best Path | Worst Path | Average Path |
|---|---|---|---|
| 15 | 158 | 245 | 163 |
| 20 | 231 | 299 | 239 |
| 25 | 1889 | 2132 | 1923 |
| 30 | 433 | 984 | 451 |
| 42 | 2114 | 2312 | 2121 |
| 50 | 542 | 1041 | 542 |

TABLE 3: RESULTS OBTAINED BY ACO

| Number of Cities | Best Path | Worst Path | Average Path |
|---|---|---|---|
| 15 | 167 | 260 | 173 |
| 20 | 321 | 389 | 330 |
| 25 | 2113 | 2481 | 2186 |
| 30 | 543 | 887 | 602 |
| 42 | 2543 | 2865 | 2590 |
| 50 | 669 | 987 | 700 |

TABLE 4: RESULTS OBTAINED BY ACO-GA

| Number of Cities | Best Path | Worst Path | Average Path |
|---|---|---|---|
| 15 | 146 | 208 | 149 |
| 20 | 199 | 247 | 205 |
| 25 | 1430 | 1891 | 1441 |
| 30 | 402 | 480 | 411 |
| 42 | 1807 | 1903 | 1832 |
| 50 | 449 | 576 | 453 |

TABLE 5: RESULTS OBTAINED BY ACO-CS

| Number of Cities | Best Path | Worst Path | Average Path |
|---|---|---|---|
| 15 | 158 | 249 | 161 |
| 20 | 229 | 290 | 229 |
| 25 | 1902 | 2117 | 1917 |
| 30 | 425 | 988 | 433 |
| 42 | 2032 | 2329 | 2061 |
| 50 | 538 | 981 | 540 |

TABLE 6: SUMMARY OF DISTANCE CALCULATED BY ALL FOUR ALGORITHMS

| Number of Cities | Distance by GA | Distance by ACO | Distance by ACO-GA | Distance by ACO-CS |
|---|---|---|---|---|
| 15 | 158 | 167 | 146 | 158 |
| 20 | 231 | 321 | 199 | 229 |
| 25 | 1889 | 2113 | 1430 | 1902 |
| 30 | 433 | 543 | 402 | 425 |
| 42 | 2114 | 2543 | 1807 | 2032 |
| 50 | 542 | 669 | 449 | 538 |

## VIII. CONCLUSION

In past few years various researchers have applied genetic algorithm, ant colony optimization algorithm and particle swarm optimization algorithm to analyze and solve Travelling Salesman Problem.

This paper presents the extended work to solve the same problem by applying hybrid techniques and for hybridization ACO is combined with others because it is very adaptive in nature with changing environment and convergence is must. Hybrid algorithms were developed by combining ant colony optimization with genetic algorithm and cuckoo search algorithm to improve performance and achieving better results. According to the analysis and comparison of simulation results of techniques discussed in this paper, it has been concluded that ACO-GA gives better result as compared to GA and ACO-CS algorithm presented here. It is also concluded that the methods using heuristic information gives good results in terms of, fast rate and convergence.

All these techniques have enormous prospective and scope of application in the field of science, engineering and even in real world optimization problems because of less computation time with increased efficiency.

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