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# ACO Parameters Analysis of TSP Problem

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***Abstract- A recently proposed algorithm named Ant colony optimization algorithm (ACO) is simple to merge with additional methods. The application of Ant Colony Optimization is much wider and it is always the key algorithm. A meta-heuristic algorithm Ant Colony optimization which is applied on the combinatorial optimized problems to get the optimal solution. Among common combinatorial problems one is Travelling-Salesman Problem (TSP). In this paper, we analyze the ACO algorithm with different parameters values using MATLAB tool. The analysis is shown in form of graph showing the optimal solution corresponding to the values set for the parameters.***
***Keywords: ACO-Ant colony optimization; Traveling Salesman Problem***

## I. INTRODUCTION

Ant Colony Optimization is a meta-heuristic technique that is adapted by many researchers for their research work and successfully implemented in many applications. Initially, the planning of ACO is done by the scholar of Italian M.Dorigo .et.al. in 1991 [1]. The concept that inspired the scholars to propose the ACO is the exploring conduct of the real ants. The main concept behind ACO algorithm is the communication among the ants done indirectly through the pheromone trails. A pheromone is like a chemical substance discharge by the ants during their search for foodstuff. ACO algorithm helps in evaluating the shortest path from home to food. More concentration of pheromone on any path attract more ants follow that path and this will give the probability of getting the shortest path. Initially, ACO algorithm famous with its three variations: Ant Cycle; Ant-Density; and Ant Quantity. The major difference among them depends on the update in pheromone value. In Ant-Cycle, after the completion of each and every ant's tour, the pheromone (the sum of pheromone is in inverse proportion of length of tour) is deposited on the paths traversed during the ant's route. The edges traversed by the ants during the tour are remembered by ant's memory. In Ant-Density and Ant-Quantity, the value of pheromone is reset at every city before the movement of ants to the next city. The Ant-cycle algorithm worked superior than the other two algorithms on a number of analysis problems [2].

## II. LITERATURE SURVEY

Zar Chi Su Su Hlaing, et.al. [7] proposed a system based on basic ACO algorithm to get the better performance in solving TSP with strategies like sound distribution and information entropy which in continuation applied on the configuration policy to modify the prior informational parameter. Then, the improvement in ACO for TSP has been done by including local optimization in search space. The planned algorithm shows improvement than the ACO algorithm. Xianmin Wei [3] chooses the best combination of parameters like m, α, β, ρ and Q by gathering the efficient selection technique. Apply the enhanced ant-colony algorithms together with best preservation policy ant system; max-min ant system; ant-based sorting systems; and best-worst ant system. Then, do the performance judgment with the same TSP problems and parameters. Now, the conduct experiment shows that the planned method of parameter combination really improves the rate of convergence. Zar Chi Su Hlaing, et.al. [5] presented a paper that proposed an improved ant colony optimization algorithm which resolves the issues of high cost and solution traps in local optima. To discover an optimal solution for TSP problems uses two highlights- candidate set strategy and a dynamically update rule for heuristic parameter works on entropy. Daniel C. Asmar, et.al. [2] try to execute a comparative study with different ACO algorithms. Outcomes clearly designate that ASrank gives the preeminent solutions for the entire specified target due to its capability to travel around and utilize the solution space successfully. They also compare the other meta-heuristics such as GRASP, Tabu Search, Genetic Algorithms and Simulated Annealing with the performance of ACO algorithms on the TSP problem. Ping Guo, et.al. [8] examine and evaluate several ACO algorithms that use different improving methods, and then wrap up two sorts of strategies (an improvement on the construction of solutions and on the update of pheromone trails ) from them. Based on experiments, they examine and prove the effectiveness of performance and usage of the two strategies. These two strategies possess their own features and offer a clear guideline for designing new ACO algorithms.Thomas St¨utzle et.al. [9] done the experiment on computation time, by taking different parameters values, can boost the performance of an algorithm in two ways - in prescheduled ways and based on the search progress. Evolutionary algorithms have two frequent themes - Parameter control; and parameter. Mahesh Mulani et.al [10] presents the fundamental plan that works on the concept of the analytical behavioral study to mutually help in designing the algorithm with the parameter settings and problem instance characteristics. This paper is considered as the remarks on algorithm design criterion TSP and its analytical outcome. Shigang Cui et.al [11] describes the base of the ant colony algorithm using TSP problem its model, benefits and shortcomings. The existing understanding process of ant colony algorithm is used in solving traveling salesman problem and the execute simulation results shows that ant colony algorithm works better than others with benefits of fast and high precision of convergence speed; strong robustness and many others. But, randomly possible in case when the number of ants is small and the search time will be more when there is more ants.

## Ant Colony Optimization: A Metaheuristic

Metaheuristic implies higher level search. The new heuristic have the below desirable features:
**Versatile**: It adapt the changes occur in some event. This can be applicable when type of problem is same; for example, asymmetric traveling salesman problem (ATSP) produced from the traveling salesman problem (TSP).
**Robust:** With the small change, it can be applicable to other optimized combinatorial problems such as the graph coloring problem (GCP) and the sequential ordering problem (SOP).
**Population-based approach**: This is popular because it uses positive feedback as a search mechanism. It also allows the system available for parallel implementations.

## The Concept of Ant Colony Optimization:

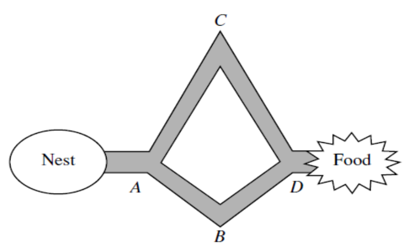


**Fig 1: Asymmetric Bridge**

With the help of asymmetric bridge, we explain how ants discover the shortest and straight path to obtain the foodstuff. The bridge is connected with two paths from the nest to food. Initially, ants move along both the paths ABD and ACD. But, as the time passes, the ants follow the shorter path ABD. It is explained as; initially, there is no pheromone on the paths. Ants move along the paths at equal rate. But, ants move along ABDBA path reach the nest with food sooner than the ants along the path ACDCA, so laid pheromone on the shorter path. Next time when ant has to select the path, they follow ABD path because the concentration of pheromone at that path is high. Ant's self-organization can be implemented in four components when work with the optimization of the traveling [3] salesman route. *Several communications:* is achieved by several ants simultaneously by iteratively searching the route in TSP problem. It is considered that each ant solves his own problem independently. *Positive feedback*: The more pheromone on a path or on the edge of the graph in the traveling salesman problem, more ants choosing that path. It concludes that more ants follow that path in further iterations. The optimistic feedback is implemented by the following imaginary rule. The possibility of edge of a graph is integrated in the ant's route depends on pheromone value, that is, ant's route directly proportional to pheromone value. The amount of pheromones that are concentrated on the edge of graph is considered as inverse of its path measurement lengthwise. The shorter path contains more quantity of pheromone than the longer path on the corresponding edges of the graph therefore more ants will use

 

pheromones in creation of new paths. If only positive reaction is taken into consideration, this creates a problem called stagnation in which all ants follow a single sub-optimal path. To stay away from the negative reaction, pheromone evaporation is taken into consideration. The rate at which evaporation of pheromone takes place should not be very high or not too fast. If too high, the search area will contract. If too fast, then situation occurs in which the colony forgets too early its knowledge that the ants achieve in the past (loss of memory) which spoils the supportive activities of ants [4].
Currently, ant k is in city/node i and wants to go to city/node j with probability formula given by

$$p_{i,j}^{k} = \frac{[\tau_{i,j}]^{\alpha}\,[\eta_{i,j}]^{\beta}}{\sum_{l} \in N_i^{k}\ [\tau_{i,j}]^{\alpha}\,[\eta_{i,j}]^{\beta}} \quad , \quad \text{if } \ j \in N_i^{k} \qquad (1)$$

Where $\eta i,j=1/d_{i,j}$ and $\alpha,\beta \geq 0$

$d_{i,j}$ = distance between cities/nodes i and j
$\tau_{i,j}$ = intensity of pheromone trail between cities/nodes i and j
$\eta_{i,j}$ = representing the heuristic information to travel to the city *j* from the city *i* : the closer the city, stronger the wish to visit it.
$\alpha$ = parameter that decides the relative control or weight of the pheromone trail.
$\beta$ = parameter to show visibility when selecting the route.

When value of $\alpha$=0, ant selects the nearest city to move on and when value of $\beta$=0, the only the value of pheromone is taken into consideration that show that all ants will follow one sub-optimal path. For superior optimization, dynamics $\beta \geq \alpha$. Equation (1) represents the probability of choosing a next particular city. The choice rule is based on "roulette-wheel" principle in which each city that it contains has its own sector with the area proportional to probability (1). The selection of next city is same as throwing a roulette ball, i.e. to know the sector position of where it stops, it generates a random number. The pheromone release by $k^{th}$ ant on edge (i, j), when tour is completed, is given by

$$\Delta\tau_{i,j,k}(t) = \begin{cases} \frac{Q}{L_k(t)}, & \text{if } (i,j) \in T_k(t) \\ 0, & \text{if } (i,j) \notin T_k(t) \end{cases}$$

where Q>0 is a adjustable parameter, $T_k(t)$ is assumes to be the route of ant k at 't' iteration, $L_k(t)$ is assume as the length of the route $T_k(t)$
Pheromone update rule with evaporation rate coefficient ρ is given by:

$$\tau_{i,j}(t+1) = (1-p)\,\tau_{i,j}(t) + \sum_{k=1}^{m} \Delta\tau_{i,j,k}(t)$$

## Travelling Salesman Problem (TSP):

The TSP is the one of the well-known combinatorial optimized problem-solving approach. It states that with given 'N' cities, starting from home city, a salesman has to travel all cities exactly once and return back home. The path (cost) traveled by the salesman should be minimum. The cost can be evaluated in metrics of distance; time; money; energy; etc. TSP [5][7] is an example of NP-hard problem and is used by researchers especially mathematicians and scientists since 1950's because it is easy to illustrate but difficult to solve. In graph theory TSP is solved by finding the Hamiltonian cycle with the least weight for a given complete weighted graph. A complete weighted graph G= (N, E) is made to solve the corresponding TSP problem, where N is the set of n cities and E is the set of edges (paths) fully connecting all the cities. Each edge (i, j) ∈ E assigned a cost dij, which is the distance between cities/nodes i and j. dij can be defined in the Euclidean space and is given as follows:

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

In our experiment, the shortest route follows by ants is shown in Figure1. The parameters taken are as follows. Number of iteration=300, Number of ants=40, $\alpha = \beta = 1$, $\rho$=0.05

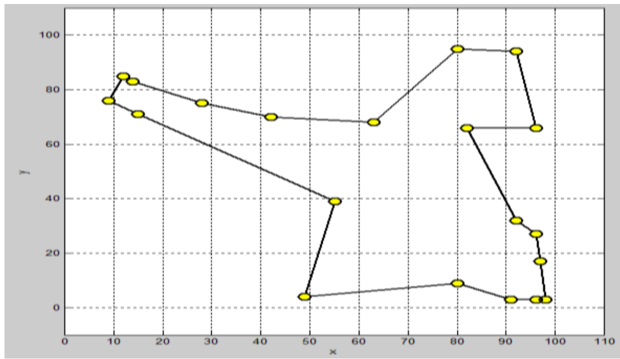


**Fig. 1: Optimal path follow by ants**

## III. EXPERIMENT ANALYSIS

With the help of Matlab Tool, we execute the ACO code with TSP problem taken from TSPLIB [5] and analyze the results. The parameters are set to values $\alpha = 1$; $\beta = 1$; $\rho = 0.05$; Q = 1; m (no. of ants) = 40. In Fig. 2, when we increase the number of iterations, initially cost varies but after 100 iterations onward cost is fixed and minimum.

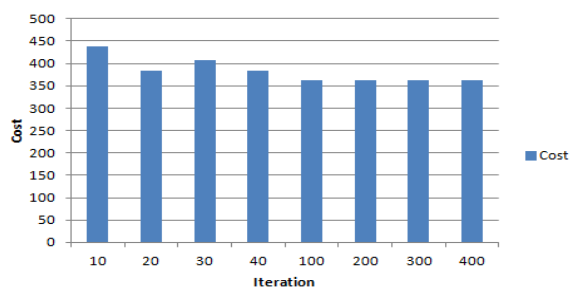


**Fig. 2: Graph between Iteration and Cost of Route**

In Fig.3, when the number of iterations=100, the effect of a number of ants on the cost of the route followed by the ants is shown. As number of ants going to increase, cost going to decrease and after m=50 onwards remains constant.

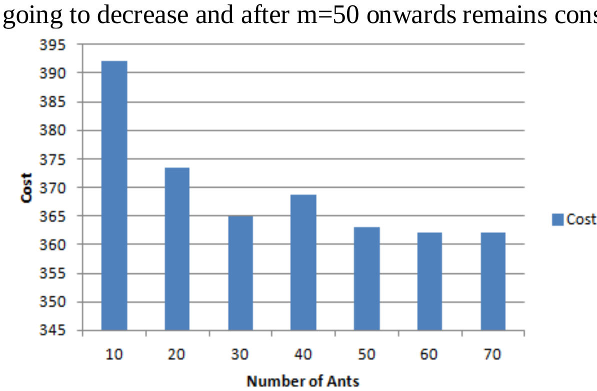


**Fig. 3: Graph between Number of Ants and Cost of Route**

 

When number of ants (m) is 50 and number of iteration is 100 our experimental analysis shows the optimal solution in terms of cost and length of tour in Fig 4.

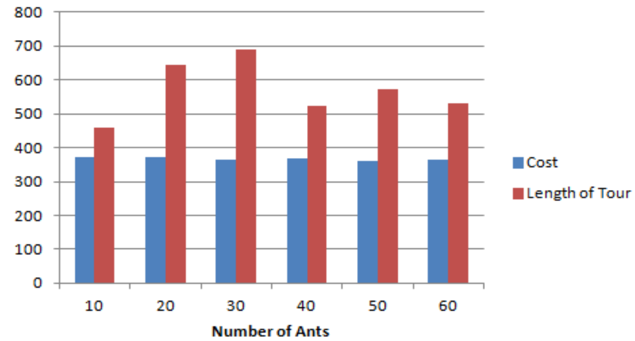


**Fig4: Graph between Cost and Tour Length versus the Number of Ants.**

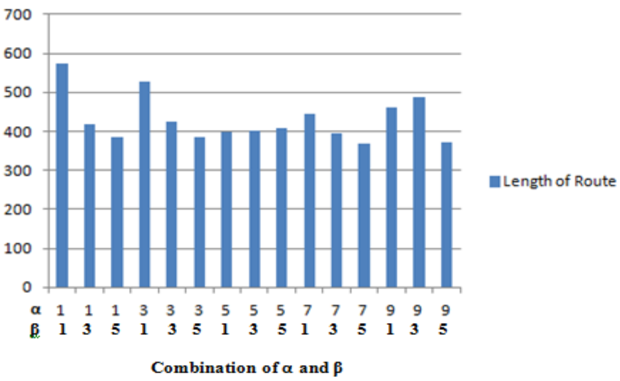


**Fig 5: Length of route based on combination of α and β**

When number of iterations = 100, α = 7 and β = 5, the cost is minimum among the other combination, the solution is optimal according to our experiment.
The algorithm performance is shown in Table 1. This table shows that the length of a tour and cost of a tour when the number of ants increases. It also shows the running time of algorithm depending on the parameter setting.

| Number Of Ants | Length of Tour | Cost of Tour | Running Time (sec) |
|---|---|---|---|
| 5 | 525.9002 | 373.2861 | 5.600416 |
| 7 | 477.701 | 374.0091 | 6.2106 |
| 9 | 637.4041 | 394.351 | 6.333013 |
| 11 | 620.3311 | 379.9295 | 6.384614 |
| 13 | 531.6595 | 380.0284 | 6.628696 |
| 15 | 554.4251 | 363.1002 | 6.394008 |
| 17 | 504.1052 | 372.8865 | 6.48241 |
| 25 | 470.3923 | 370.8865 | 7.550025 |
| 30 | 448.9444 | 368.6596 | 7.925583 |
| 35 | 671.496 | 362.038 | 7.991354 |
| 45 | 563.6013 | 362.038 | 9.471083 |
| 55 | 662.6173 | 363.897 | 9.91556 |
| 70 | 476.2206 | 370.3737 | 11.212728 |
| 90 | 455.0726 | 362.038 | 12.977688 |
| 110 | 559.8344 | 362.038 | 14.881629 |

**Table1: Effect of Number of Ants on Length and Cost of tour with Running Time in seconds**

## IV. CONCLUSION

This paper shows the optimal solution of the algorithm based on the parameters values. At α = 1; β = 1; ρ = 0.05; Q = 1; m (no. of ants) = 40, when we increase the number of iterations, initially cost varies but after 100 iterations onward cost is fixed and minimum. When a number of ants going to increase, the cost going to decrease and after m=50 onwards remains constant. With our analysis m=50 shown the best possible solution in terms of cost and length of the tour. The choice of the value of α, β, m and ρ are taken on the base of experiment and the literature survey. The experimental results show the performance of ant colony algorithms when solving TSP problems. The evaluation of the performance of the algorithm is also analyzed on the basis of other properties like the number of iterations, the iteration time, etc.

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