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Solving Traveling Salesman Problem through Optimization Techniques Using Genetic Algorithm and Ant Colony Optimization

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ABSTRACT

Swarm robotic is a new research area in the domain of Artificial intelligence. Particularly, the swarm robot concept is adopted from Mother Nature that combines small robots in a group to solve a particular problem. This work presents decentralization of swarm robots along-with their methods of optimization, development, applications and implementation in real life domain. It also solves the traveling salesman problem using free parameters; i-e, number of cities, number of iteration and number of ants involved in search within solution space. Furthermore, it compares ant colony optimization with genetic algorithm keeping in mind free parameters. Due to metaheuristic approach Ant colony optimization algorithm perform well and deliver global optimal solution for solving traveling salesman problem relate to genetic algorithm. On other hand, the running time of genetic algorithm and ant colony optimization calculated in two scenarios a. altering number of iteration, b. altering the number of cites to nodes in solution space as input and keeping other parameters constant.

KEYWORDS: Swam robotics, ant colony optimization, genetic algorithm, traveling salesman problem, artificial intelligence.

1. INTRODUCTION

Swarm intelligence is comparatively a newer methodology that is concepted by the social behaviour by the animal and insects for specific problem solving. In this the research community tries to develop algorithms to solve optimization issues motivated by behaviour of the insect/s. genetic algorithm and ant colony optimization are the mostly used techniques applied in the field of swarm intelligence. Different researchers have applied both the techniques in many areas. Genetic algorithm works in a search space known as population it is also used to find the set of possible solutions with in the given population. The initial solution is further extended to the next generation. Chromosomes values are updated with in the population [1] [2]. Quality of solution is defined by the fitness value and chromosomes are inspected for the fitness. There are three steps involve to move to the next generation;

a. Finding fitness values
b. Selection and
c. Reproduction

Mathematically the fitness value is calculated as
F=1/D. Where d is the distance between 2 cities. The optimization in tour depends upon the fitness value. In order to find optimized solution GA uses operators like reproduction cross and mutation the intermediate solution can gather information from reproduction obtained from various paths according to fitness value [3].

Whereas ant colony optimization is also among the successful technique used in swarm intelligence. It is mainly based on the heuristic information and is successfully applied to solve combinational optimization problem. It is adopted by seeking the behavior of different ants present in nature [4] [5] it is built using pheromone concentration trailed by following behavior of the ants which is in real applied to find the shortest path between ants colony and food resource. The ants' composite pheromone on the surface to identify possible paths that may be followed by the other ants with in colony [6]. Artificial ant mimic the behavior of the real ants seeking the food but it may also solve the complicated problems other than real ant can do. It also exploits to solve optimization problems. The moment of the ants is depending on the concentration of the pheromone, the higher the concentration is on a path, the move obvious it can be followed by rest of the ants. It means to have a shorter path the probability of pheromone concentration should be higher and ants will always try to select the shorter path [7] [6].

In the start of 1990's the first ant colony optimization algorithm was suggested which attract a large number of researchers. Ant colony optimization is being used to solve different optimization issues like TSP Quadratic assignment problem, Vehicle routing problem VRP and weapon target problems WTA, etc [8]. Both ACO and genetic algorithm may be used to find optimal solutions of various optimization problem. As both the algorithms has the capacity to figure out the possible solutions to the given optimization problem, ACO faces stagnation and pre-mature conversions as well as low speed of conversions as the network size increases the said problems are obvious while using ant colony optimization. Several improvements to ant colony optimization algorithm are introduced ith the passage of time. As in ant evolution rule [9], pheromones update techniques [7] artificial ants' partitions [10] dynamic ant system [11] [12] and path selection by information [13] are taken into consideration to improve the ant colony optimization algorithm. Many algorithms have been applied to solve optimization problem traveling salesman problem.

This paper discusses ant colony optimization algorithm and genetic algorithm for solving traveling salesman problem. Both the algorithms provide the optimal solutions; initially the ant colony optimization algorithm provide better solution to solve TSP and the solution provided by the ant colony optimization solution is near to optimal solution in less number of iteration as compared to genetic algorithm. As the number of iteration increases, gradually the ant colony optimization algorithm and genetic algorithm provide better solution as compared to the previous solutions. Section 2 describes literature review of the ant colony optimization and genetic algorithm, In Section 3, an overview to traveling salesman problem, its constraints and diagram for traveling salesman scenario, including its individual merits, weaknesses and application. Two different possible solutions i-e, ant colony optimization and genetic algorithm are shown in Section 4. Section 5 show the

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experimental results of ant colony optimization and genetic algorithms and discuss their applicability and performance. Section 6focuses conclusion and possible future work.

2. LITERATURE REVIEW

The concept of swarm intelligence was first introduced by Gerardo Beni and Jini Wang in 1989, that swarm robotic is a social inspired intelligence in the area of artificial intelligence [14] having their own characteristics, with no central control mechanism, different optimization problem is solved by different swarm intelligence algorithms. The successive features of Swarm intelligence are based upon decentralization and robustness of the structure, self-organized and flexible system [15] the task will accomplish if some individuals fails. The different Swarm intelligence model proposed from natural inspiration, some of them is given ant colony optimization [16], Cat swarm optimization [17], Bee colony optimization [18] and Particle Swarm optimization [19].

Ants live in colonies, to do some particular tasks distinct move in search space, due to this environment of ant called as swarm, This spectacle is used in robots, we can call it as mobile robots or may called as artificial ant having same assets of swarms by Dorigo M in year 1991 [20] [21] within this proposed system ants use a particular heuristic information which in real ants called as pheromones in solution space in dissimilar concentrations.

The ants move in the route of more concentrated pheromones areas [22]. After a while time some of the paths are accepted to move and some of them become cease to exist, ants moves on the path will have more concentration of pheromones [23] and be wiped out a smaller amount concentrated paths. Doigo start the idea of real ants in mobile robotics systems further this idea was explored by researchers to solve different problems [24].

Swarm intelligence is more adventitious over other related algorithms like other evolutionary algorithms, swarm intelligence algorithm can be applied to the dynamic environment solution space problems [25]. The idea disperse and use in different scenarios for application of ant colony optimization by reviewing the previous work of different researchers. Several optimization problems are explained and solved by an Ant colony optimization method as optimized sequential ordering of operation in a manufacturing industry, that to select individual operation mandatory for the production, here ant colony optimization is a quicker and better algorithm to create optimized sequence or ordering of job as global search technique [26], job shop scheduling problem is also called as resource planning problem. This practical implementation of swarm robotics is nowadays used in computer networks, delivery of packets by airline, allocation of machine to different jobs and project management problems, these problem is NP-hard problems can be solved by metaheuristic algorithm this problem is solved by Swarm intelligence model i.e. ant colony optimization, this technique provide optimized solution, shortest possible time completion of the job [23] [27].

The results compare to other techniques used for the same problem shows the ant colony optimization is better approach than all other methods [27], network routing is nowadays optimization problem to find out shortest path to increase the throughput of network, each packet called synthetic ant simulated from source to destination on the shortest path the packed need to move for finding this shortest path ant colony optimization is applied [28] , in the domain of software engineering project management and scheduling is tough job author [29] propose ant colony optimization algorithm for Resource-Constrained Project Scheduling. Author promote this method due to three purpose first this problem can be solved by searching in graph, 2nd the use of Ant colony optimization response quick as compare to Genetic Algorithm(GA), Tabu Search(TS) and Simulated Annealing (SA). Furthermore author summarized engineering applications of ant colony optimization that this algorithm applicable to peer to peer and Grid computing, networking, tasks assignment in computer architecture, image processing data mining, Biomedical, image processing and many more technologies [8].

Genetic algorithm is classify among evolutionary algorithms. Reproduction and mutation are two reproduction method, to get the desire solution this procedure is repeatedly occur to the number of iterations. It doesn't not necessity the previous knowledge to discover the solution. Genetic algorithm is pertinent to record optimization problems [14]. This computation intelligence method is used to find out solutions to utmost optimization problems like traveling salesman problem, in the work anticipated new demonstration technique for finding the optimal path for traveling salesman problem, technique was the use of fittest criteria and binary matrix. The fittest criteria improve the crossover and mutation process to get optimal solution [3]. For same problem high quality solutions are generated using sequential consecutive crossover operation, the application of genetic algorithm to any problem, researcher encodes the solutions like a better chromosomes combination as the cross over operation leads solution to optimization. Father research work suggest an improved genetic algorithm that solves travel salesman problem and other combinational optimization problems. Research work [30] propose that crossover operation is record an important task due to exchange the characteristics among individual of population. Different operations are used to solve the traveling salesman's problem using population reformulates operation, rearrangement operations, new crossover operation, restricted local optimal alteration operation and multi mutation operation. In proposed work by Otunbanowo Kehinde and Akinwale Adio [31] solve travel salesman problem and prove that genetic algorithm is a better approach to solve problem due to local search algorithm, this approach generate many random tours and then improve the solution till reach to satisfied solution, research work analyses the parameter like mutation rate and population etc was done. In the work proposed by Kylie Bryant "Genetic Algorithms and the Traveling Salesman Problem" [32] Genetic algorithms are an evolutionary technique that use crossover and mutation operators to solve optimization problems using a survival of the fittest idea. They have been used successfully in a variety of different problems, including the traveling salesman problem. In the traveling salesman problem we wish to find a tour of all nodes in a weighted graph so that the total weight is minimized. The traveling salesman problem is NP-hard but has many real world applications so a good solution would be useful. Many different crossover and mutation operators have been devised for the traveling salesman problem and each give different results. We compare these results and find that operators that use heuristic information or a matrix representation of the graph give the best results.

Ant colony optimization is applicable and develop for discrete problem. By mean discrete optimization problem is that problems in which search space is stable for the cooperative performance of ants (search space). Same algorithms is used for continues reorganized examine space, this approach is review by author to use ant colony water resource management [33]. Author [25] discuss the disadvantage that ant colony optimization algorithm applicable for static and dynamic optimization problems but this algorithm is beat by specialist algorithm only in static environment not in dynamic as my research work will try to find out different parameters involve in scenario.

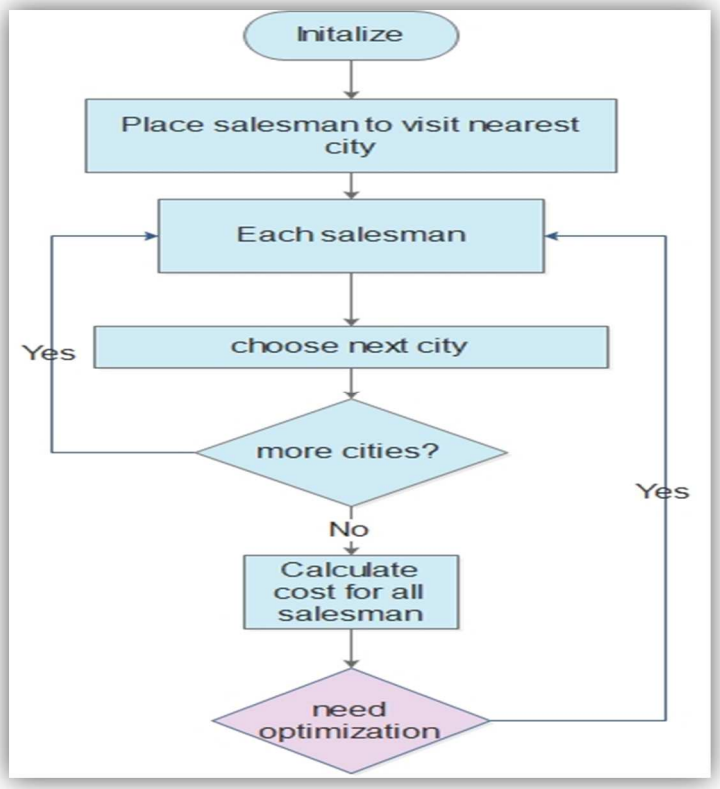

Figure 1. Traveling Salesman Problem.

3. Problem Statement

Traveling sales man problem is new research interest for different research domains. The problem applies to find out the solution that is to visit each and every city once and visit all cities [34].

This problem firstly ascends and expressed in 1930 [35] can then be optimized along new ideas, different area experts tries to solve the problem to minimize the computational cost. Such complex problem need to solve by systematic technique, many algorithms exists to solve such problem. Most area researchers failed to find out different technique for solve the problem, first algorithm used for given problem was linear programming formulation by Johnson and Fulkerson in year 1954 [36]. Branch and bound algorithm used to solve traveling salesman problem support less than 100 cities, also if the number of cities gradually increases from 10 to 100 the branch and bound algorithm fails to provide the optimized path the complexity of the algorithm fails the branch and bound approach [37] [38]. Dynamic programing was more efficient technique for solving traveling salesman problem than branch and bound, but the dynamic programing algorithm did not support cities greater than 100, the complexity of the dynamic programing method is high than the branch and bound lower bound, but for upper bound of the this algorithm fails to give better performance as related to others methods [1].

Each algorithm find out the solution for the given problem. Number of cities are different for various given problems. The salesman have to visit each city least once [2] then return back to start city. This complex problem attract different area experts and due to its complexity, researchers [35] defines that the traveling salesman problem is hard optimization combinational problem.

Combinational Optimization Problem involves the type of problem that can take discrete value rather than continuous. But TSP is NP complete Combinational optimization problem used to find the subjective primary function Distance between two cities [37] [2]. The traveling salesman problem can be solved by the brute force method to create set of all possible solution. Then consider the better solution as optimal solution. The simple 4 steps are used to solve traveling salesman problem that is (a). Find out the possible number of tour applies to traveling salesman problem using $(\boldsymbol{n-1})\,!/_{\boldsymbol{2}}$ mathematical model (b). Create list of all possible path (c). Find distance for each tour (d). Choose the shortest tour that will be the optimal solution [39].

4. Proposed solution

There exists many possible solutions for the traveling salesman problem. It is to understand that preferred method would be to provide a mathematical solution. Their few parameters which are basics to update existing algorithm. Initially, a comparative analysis of genetic algorithm and ant colony optimization algorithm used to optimize traveling salesman problem.

4.1. Genetic Algorithm

The search space of the genetic algorithm called as population. Genetic algorithm is also used to find the set of better solutions from the given population. The first guess solution is further modified to next generation. Chromosome the terminology is used in genetic algorithm each entity with in population titled as chromosome [40]. Fitness defines the quality of solution and all the chromosomes are inspected for the fitness. Mainly three steps are involved to move to next generation (a) finding fitness value (b) selection (c) reproduction. Fitness estimation

function used to calculate the fitness value. The fitness value can calculate mathematically by the function $f = {}^{1}/_{D}$ using heuristic information. The value of D is determine from equation number 2 [41].

The optimization in tour depend upon the current fitness value or can called the initial guess. Three different operators are used in GA to optimize the solution that is reproduction, crossover and mutation. The intermediate solution can gather from the reproduction of various path according to fitness value. The select some "parents" node based on the current fitness value. The genetic algorithm creates children strings (path) using mutation and cross over operators. Random exchange in bits and recombination of individual to create new individual for the next generation called as crossover and the mutation operator used to change the random stings to new strings. The crossover and mutation speed up the execution of algorithm [41]. Number of iteration of algorithm or the optimized solution terminates the execution of algorithm.

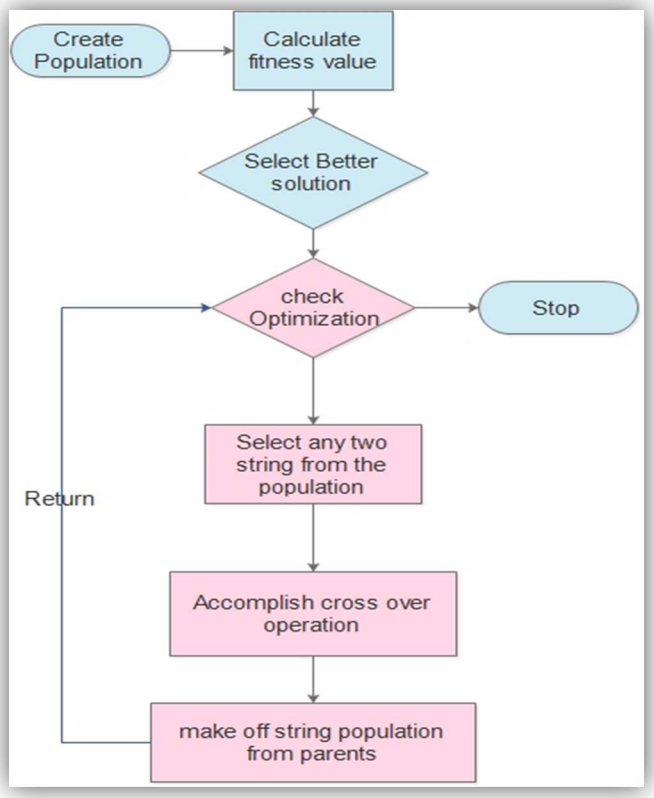

Figure 2. Genetic Algorithm

4.2. Ant Colony Optimization

The ants for the given problem enhanced the plans to achieve an optimized solution and we do modification is an ant colony optimization method to decrease the processing overheads elaborate the cost of processing against the conventional ant colony optimization approach.

The improvement to conventional ant colony optimization is offered in the form of new strategic and modified ant colony optimization approach. In conventional ant colony approach the computational cost is high, different parameters are dependent by this method [22]. The initial aim is to reduce the distance travelled by the salesman for the given problem, to visit all cities and provide the optimal distance travelled by the salesman. The position is clear to give a new solution to solve ant colony optimization [16]. It is achieved by updating alpha, beta, i.e. used or the metaheuristic approach, All of agents move in solution space provided to find out solution all the ants move in different direction to reach the best solution in this type of algorithm is applied to NP Hard Combinational optimization problems [42]. First, we can say that all the ants placed in the solution space they will start searching and visit different cities on every path pheromone concentration will be $_{xy}$ for the path between x and y, first we keep record of start city, after that ant start tour in solution space and visit next city the probability function select next city to visit mathematically we can say that

$$P^{k}_{xy(t)} = \frac{[\tau^{\alpha}_{xy}][\eta^{\beta}_{xy}]}{\sum_{I \in N}[\tau^{\alpha}_{xI}][\eta^{\beta}_{xI}]} \quad \text{. eq no. 1}$$

Where the $P^{k}_{xy(t)}$ Is the model of probability for the ant k to move from city x to city y, respectively the $[\tau^{\alpha}_{xy}]$ Is the pheromone concentration and the $[\eta^{\beta}_{xy}]$ Is the heuristic information gather from the distance between the two points i, j by giving mathematical equation

$$| D | = \sqrt{(x(i) - x(j))^2 + (y(i) - y(j))^2} \quad \text{. eq no. 2}$$

Further the $\eta = {}^{1}/_{D}$ The x represents the current city, y represents city to visit and **N** represents the no of cities in probability equation. Each ant pass through different nodes and complete tour, the amount of pheromones are updated according to the given mathematical equation

$$\tau_{xy}(t+1) = (1-e) * \tau_{xy}(t) + \Delta\tau_{xy}(t) \text{ . eq no. 3}$$

The given equation

$$\Delta\tau_{xy}(t) = \sum_{k=1}^{m} \Delta\tau_{xy}^{k}(t) \text{ . eq no. 4}$$

$$\Delta\tau_{xy}^{k}(t) = \begin{cases} \frac{c}{L_k} & \text{If (i, j) } \in \text{ tour done by ant k .eq no. 5} \\ 0 & \end{cases}$$

Evaporation coefficient e ranges between 0 and 1. That is 0<e<1. For all edges the initial pheromone value is constant. For all the iteration pheromones concentration values update. Different parameters are involved in this meta-heuristic algorithm, generally it is proved that metaheuristic algorithm does not provide us the most optimized solution. But the better solution can obtained by the adjustment of different parameters like alpha, beta, number of repetitions of the algorithm, the total number of ants involve in solution space and the most important is the pheromone dispense trails coefficient that is e. In this article we try to solve traveling salesman problem with different parameters to find out the optimized solution and conclude the computational cost needs to solve traveling salesman problem on different sets of data.

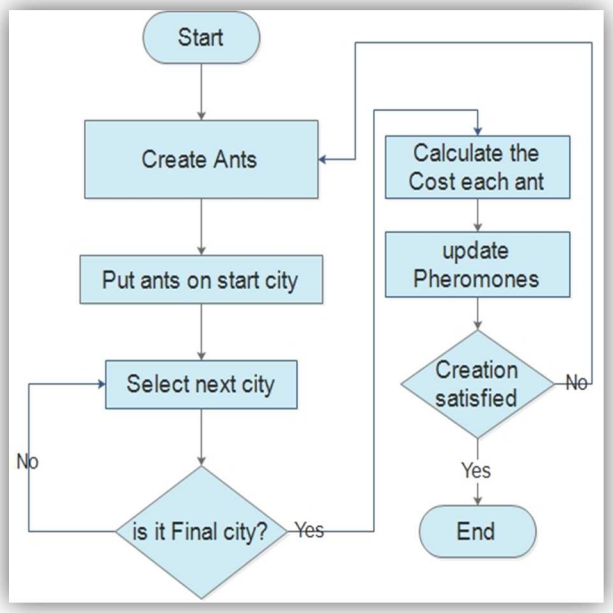

Figure 3. Ant Colony Optimization

5. Experimental results

We accomplish various experiments on different datasets using MATLAB version 7.10 R2010a windows 8.1 Intel core i3 1.7 GHz with 4 GB ram. Both algorithms (ant colony optimization and Genetic algorithm) used for solving traveling salesman problem, therefore we have to find the better approach for solving the given problem. We calculate the optimal distance by both of the algorithm with different scenarios. We calculate the better tour between 10, 25 and 50 cities applying number of iteration 5, 100, 500, 1000, 1500 and 2000.

Using ant colony optimization algorithm for given problem gives different complexity because it's a type of metaheuristic algorithm [43], its mean that this type of algorithm is applied to problems which having two characteristics, first the input to algorithm is not clear and possibly change with situation and second when no algorithm fit for given problem [44].

Most important Parameters that's for both algorithm are given

- No of cities i.e. population size in constant distance
- Square distance (X * Y) in km
- Max no of iteration
- Distance that's calculated as output from both algorithm

Some by default values in algorithm that is constant for given scenario.

- Square area taken as 10 x 10 km xy plane
- No of ants in Ant colony optimization

Data collected from both of algorithm is given as.

For no of cities n=10 result of distance x no of iteration is given as

Table 1. ACO vs GA for No. of cites 10 (10 x 10))

Iterations	ACO	Genetic algorithm
5	39.5	43.62
100	34.98	35.3
500	32.81	32.81
1000	32.81	32.81
1500	32.81	32.81
2000	32.81	32.81

Table 2. ACO & GA for No of Cities 25 (10 x 10)

Iterations	ACO	Genetic algorithm
5	89.66	112.38
100	61.68	70.46
500	61.68	61.68
1000	61.68	61.68
1500	61.68	61.68
2000	61.68	61.68

Table 3. ACO & GA for No of Cities 50 (10 x 10)

Iterations	ACO	Genetic algorithm
5	177.3	230.92
100	88.22	111.67
500	88.22	88.22
1000	88.22	88.22
1500	88.22	88.22
2000	88.22	88.22

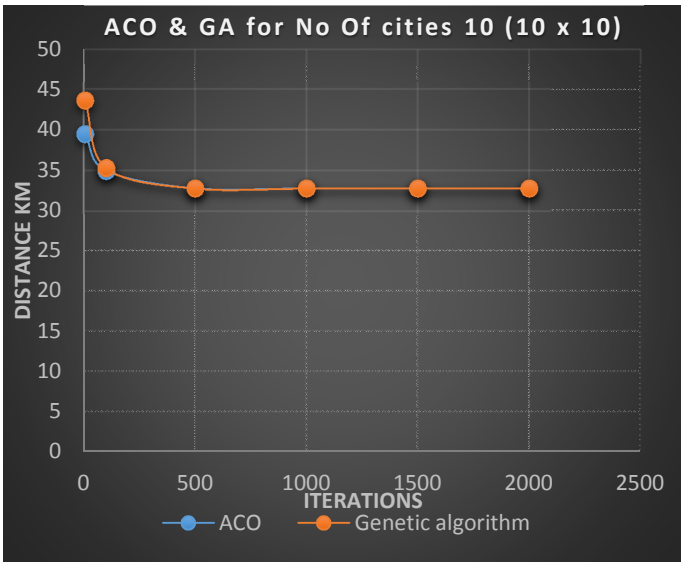

Figure 4. ACO vs GA No of Cites 10

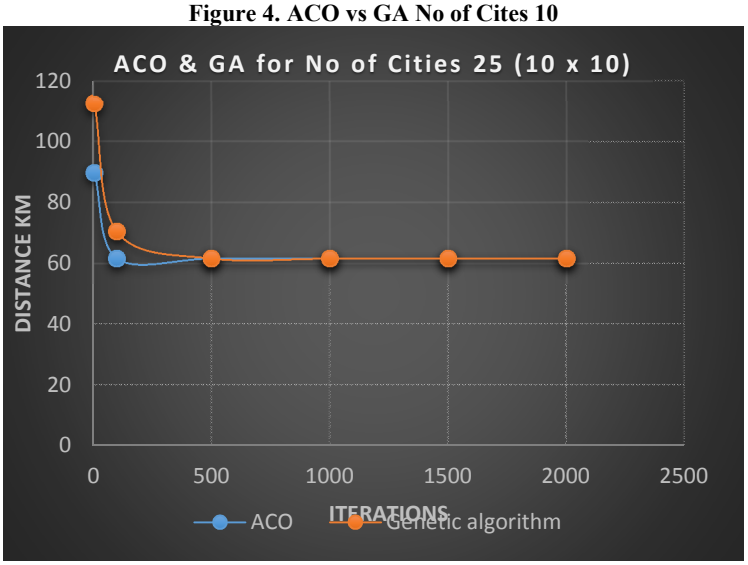

Figure 5. ACO vs GA No of cites 25

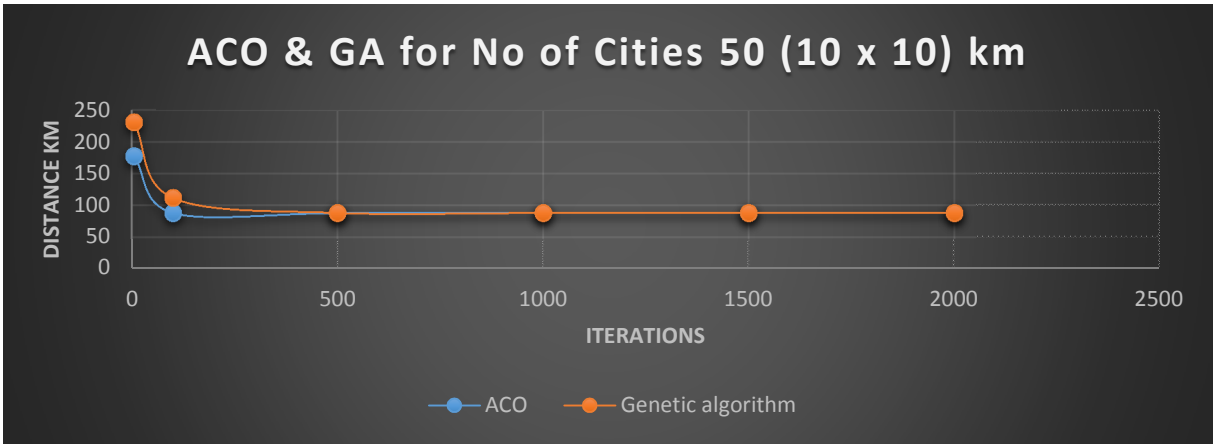

Figure 6. ACO vs GA No of cites 50

6. Conclusion

If the no of cities is less and at first iterations ACO gives better performance its time of execution is also very less this is due to meta-heuristics approach. It provides us minimum distance that is optimize path and proper solution for given TSP and did not stuck in local best solution. From experimental results it's observed that it is problematic to find out the best and accurate solution by ant colony optimization and genetic algorithm, but the iteration depend upon the optimization of both algorithm. The mathematical model explain the evaporation coefficient, if the e (evaporation coefficient) = 0 the effect of ant colony optimization detached, the range of e is 0<e<1, if the e= 0.9 more optimal solution is observed and these parameter directly affect the number of iterations. The number of iteration in the ACO and genetic algorithm congregate the solution to optimization. The running time of genetic algorithm to calculated distance is less than ACO for large no of iteration and cites which might increase gradually. Time taken by the genetic algorithm is not as much of that the calculated time of ACO, the complexity of ant colony optimization is high than genetic algorithm which is proved by experimental analysis. The theoretical analysis of ant colony optimization is still a complex issue. The number of iteration effects the distance calculated by both algorithms.

Whenever no of iteration is less ACO is better than genetic algorithm and calculate the optimal solution but whenever iteration increases ACO the complexity of ant colony optimization increase as compare to genetic algorithm. Both technique provide the optimal solution but the ant colony optimization is better approach and calculate the optimal distance in the first few iterations when the number of searching agent is greater in number. The results generated by genetic algorithm approach using less number of iterations is not satisfactory as compare to ant colony optimization for all cases of no of cities that may 10, 25, 50 with dimension of 10 x 10 or 100 x 100 towards n x n. Also it's concluded that more number of ants involve in searching space, more possibility is to observe optimized path for the ant colony optimization with less computational cost.

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