TSP Solution Using Dimensional Ant Colony Optimization

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Abstract: This paper describes Dimensional Ant Colony Optimization (DACO), a distributed algorithm that will be applied to solve traveling salesman problem (TSP). In an Any Colony System (ACS), a set of co-operating agents called ants co-operate to find the good solutions of TSPs. Ants co-operate using an indirect form of communication that is mediated by pheromone they deposited on the edges of the TSP graph when building solutions. The proposed system (Dimensional ACO) based on basic ACO algorithm with well defined distribution strategy in which entire search space area is initially being divided into N numbers of hyper-cubic quadrants where N is the dimension of entire search space area for updation of heuristic parameter of ACO and to improve the performance while solving TSP. From our experiments, this proposed algorithm has better performance than other standard bench mark algorithms.

Keywords: *ACO, TSP, pheromone, global minima, DACO.*

Introduction

In recent years, there are so many research works have been done in ant colony optimization (ACO)[1,5,4] techniques in various different areas. It is relatively novel meta-heuristic technique that has been successfully used in many areas especially problems in combinatorial optimization. ACO algorithm states the behavior of real ants to establish shortest path between sources node and nest. Ants can communicate with each another through chemical called pheromones. Ants release pheromone while walking from their nest to food and go back to their nest. Ants move as per the amount of pheromones, the richer the amount of pheromone on a path is, more likely it will be followed by other ants. A shorter path has a higher amount of pheromones, so ants will probably tend to choose a shorter path. Through this ants will eventually find out the shortest path. Artificial ants state the behavior of real ants and can solve more complex problems than real ants can [10, 13].

Ant colony optimization is being widely applied to solve various combinatorial optimization problems such as Traveling Salesman Problem (TSP) [4], Vehicle Routing Problem (VRP), Job-shop Scheduling Problem (JSP), Quadratic Assignment Problem (QAP) etc. Even ACO has a strong capacity to find the solutions of combinational optimization problems but it has the problems of stagnancy, premature convergence and the convergence speed of Ant colony optimization is very slow. Those problems will become more complicated when size of the problem increases. So, various extensions and improved versions of ACO algorithm have been introduced over the years.

We proposed a new optimization algorithm (Dimensional ant colony optimization) based on ant colony optimization to solve travelling salesman problems for both continuous and discrete domains. This algorithm uses number of ants, number of iterations, dimensions, lower pheromone value and upper pheromone value. The node that is nearest from the source node has maximum dimension (i.e. number of nodes in the simulation -1). Here, the dimension of a node/point denotes that how many edges are unexplored or how many nodes are left. Search process of this optimization technique is directed towards the region of hypercubes in multidimensional space area where the value of pheromone deposited is maximum after predefined number of iterations. Initially entire search space is being divided in N numbers of hyper-cubic quadrants. Here N is the dimension of search space. Each ant traverses the path as the number of iterations. We sort the coordinates according to the distance from the source. Dimensional ant colony optimization system use pheromones update to find out the shortest path from source node to the destination node. After

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predefined number of iterations we find out global minima from source node to destination node. When we call the algorithm
on a number of artificial ants, it uses best ant technique to find out the path and based on that we found the global minimum of that path.

This paper is organized as 1.Introduction 2.Ant Colony Optimization Background 3.Travelling Salesman Problem 4.Dimensional Ant Colony Optimization 5.TSP tour construction using Dimensional Ant Colony optimization method 6.Comparison 7.Conclusion.

The main objective of Dimensional ant colony optimization is to solve travelling salesman problem and compares it with other standard algorithms.

2. ACO background:

Ant System was applied on TSP by Marco Dorigo [4, 9]. Initially, each ant is randomly stated on a city. While constructing optimal solution, ants select the next city to visit through *a probabilistic decision rule*. When an ant *k* be in city *i* and we have to construct a partial solution, the probability of moving to the next city *j* that is neighbor to the city *i* is given by $\tau_{ij} = (1-\rho)*\tau_{ij} + \Delta*\tau_{ij}$ (h Є N^k) where τ_{ij} is the intensity of trails between edge (i, j) and η_{ij} is heuristic visibility of edge (i, j), and $\eta_{ij}=1/d_{ij}$. d_{ij} is the distatnce of edge(i, j). N^k is the set of cities that are remains to be visited when ant is at city *i*. α and β are adjustable positive parameters that control heuristic visibility and relative weights of the pheromone. After an ant completes its tour, the pheromone value on each path has to be adjusted with equation $\tau_{ij} = (1-p)*\tau_{ij} + \Delta_{\tau_{ij}}$. Here (1-p) is the decay parameter (*0<p<1*) and it represents the evaporation on trail when the ant decided to move on a city. Where $\Delta_{\tau_{ij}}$ is defined as

$\Delta_{\tau_{ij}}$ = F(k),if edge (*i, j*) is the part of solution constructed by an ant *k*,
0 otherwise

$F(k)=1/L_m$, L_m is the cost of m^{th} ant tour.

3. Traveling Salesman Problem (TSP)

The problem to find out the shortest closed tour that visits all cities in a given is known as Traveling salesman problem (TSP) [4] .In this paper, we take the data set from TSPLIB (http://elib.zib.de/pub/mp-testdata/tsp/tsplib/tsplib.html) and we assume that the TSP graph is completely connected. TSP searches for the shortest roundtrip of total minimal cost visiting exactly once to each given node (city). TSP is an NP-hard [13, 16, 17] problem. TSP is defined as: If N cities are given and a salesman starts from his home city has to visit each city exactly once and then return to his home city, TSP has to find out the order of the tour such that total travelled distance (costs) is minimum. Cost can be taken as time, money, distance, energy or a combination of two or more factors. In this paper, we assume that Euclidean distance is the distance between two cities. The distance between two city i and j is d (i, j) = d(j, i)= $\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$. TSP is to find a tour that minimizes the objective function S: S = $\sum d(i, j)$.

4. Dimensional Ant Colony Optimization

We proposed an efficient ant colony optimization algorithm named as Dimensional ant colony optimization technique to optimize mathematical functions. The search process of this optimization is directed towards the hyper-cubic region in a multidimensional space area where the deposited amount of pheromones is maximum after the predefined number of iterations. Initially entire search space area is divided into N numbers of hyper-cubic quadrants. Here N is the dimension of entire search space area. After that the pheromone level of each quadrant is being measured and the search jumps to a new region where pheromone level is maximum and then restart the search process again in the new region. Now, the new search area is reduced as compared to the previous search space area. Therefore, search jumps to a new space where search area is reduced after several stages. This process runs until the algorithm is terminated. Now, space of the new search area is smaller than that of previous hyper-cubic search area. In this way reduction of the search space is done among all the dimensions. If the search space area is being reduced slowly, then the possibility to find out local optima is increased and convergence possibility to find out the global optimum will also increase. if the search space area is reduced faster then there may be a possibility to miss global optimum as the process has no capabilities for backtracking.

4a. Functional optimization using Dimensional Ant Colony Optimization

Global optimization problem can be stated as a pair of (S, f) where S is the subset of R^n and f: S --> R is an real valued function in N dimension. We have to find out a point x_{opt} that belongs to S on R^n such that value of $f(x_{opt})$ is global optimum on S. We have to find out x_{opt} that belongs to S as per the following:

$\forall$X that is subset of S: $f(x_{opt}) <= f(x)$………………(1)

Where f is bounded but may not be continuous.

Initially Dimensional ant colony optimization algorithm starts searching to find out the global optimum in the entire search area. The entire search space i.e. multi-dimension space is divided into a number of quadrants based on dimension of the problem where each quadrant will be taken as hypercube. The partitioning of the search space is necessary to measure the level of pheromones in each partition. If dimension of the problem is denoted by N then we will calculate number of quadrants as:

q=N ……………………………….(2)

The Dimensional ant colony optimization method runs for certain number of iterations, I_k and when it completes I_k iterations then it will measure the level of pheromones in every quadrant. This measurement is directed towards the searching of the quadrants having maximum pheromone value. We take p as the pheromone value deposited in each iteration and p is defined as p=1/N.

Dimensional ant colony optimization technique runs in multiple stages iteratively and in that we find the quadrant in each iteration in which the best pheromone value of that iteration lies. Then the pheromone level p_j of j^{th} quadrant i.e., for corresponding quadrant has increased by 1/N in each iteration. When this optimization method completes I_k iterations, then it calculates the deposited amount of pheromone p_j in each quadrant. If the deposited pheromone amount p_m of m^{th} quadrant (1<=m<=N) is maximum, then search will move towards that m^{th} quadrant. The space area for search is being re-defined and ant population is regenerated again. Now, Dimensional ant colony approach restarts in a new search space area and it continues for I_k times until it is being transferred to another new space area by considering the highest pheromone value. The Dimensional ant colony optimization method finally terminates when it complete its I_{max} iterations.

4b. Algorithmic representation of Dimensional Ant Colony optimization technique

STEP 1: Initialize iteration I=1, population of ants and other parameters;
STEP 2: Partition the search space into N quadrants and create solutions for all ants.
STEP 3: Find out the quadrant in each iteration where best solution lies. Increase pheromone level of that quadrant by 1/N.
STEP 4: Clear all the values of phereomone of all the edges when the ants find the same next node in each iteration for five times continuously.
STEP 5: Identify quadrant q_m having highest amount of deposited pheromone value after completing I_k iterations.
STEP 6: Clear all the values of phereomone of all the edges when the ants find the same next node in each iteration for five times continuously.
STEP 7: Refine search space area by excluding the quadrant q_m. Restart the search process again after moving the search into new search space area that is smaller in size than previous.
STEP 8: Increment $I=I + I_k$ if $I <= I_{max}$ then go to STEP 2.
STEP 9: Stop.

5. TSP tour construction using Dimensional Ant Colony optimization method

For TSP Construction, this algorithm has inferred as follows:

1: First initialize all the co-ordinates.

2: Initialize starting node/ position.

3: Compute the distance from starting node to all neighboring nodes.

4: Then sort all the nodes by considering the distance from the source node.

5: Dimension of each coordinate are initialized.

6: Apply Dimensional ant colony optimization method for each sorted coordinates.

7: Find the node/coordinate which has lowest value of global minima.

8: The coordinates that has the lowest global minima value from the source is taken as new source node.

9: New Search space is reduced as the previous source node is being traversed.

10: Go to 3.

11: exit.

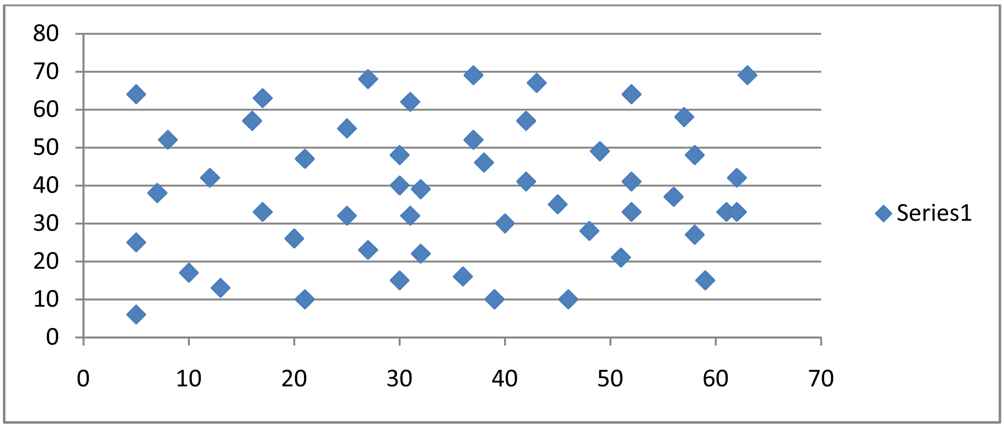

Fig-1A

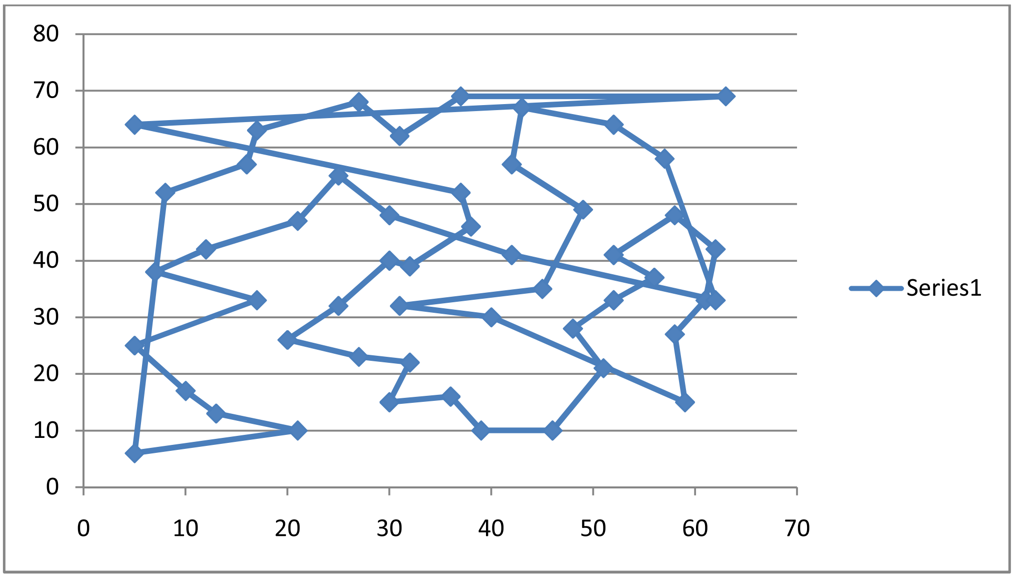

Fig-1B

Fig 1: Graphical representation of EIL51 in space

In FIG-1A, all the nodes are given and in FIG-1B, we start from a node (x_i , y_i) and moving towards a node that is having lowest value of global minima. By doing so iteratively a tour is build for TSP. We can calculate cost of this tour by the summation of all the global minimum value of two connected nodes.

The performance of Dimensional ant colony optimization algorithm on a set of nodes is examined to find how the construction of tour using DACO is efficient than another algorithms. In this, we have considered a set of 50 ants (population of ants). We have assumed that the upper limit of pheromone is +10 and lower limit of pheromone is -10. We select the path that has lowest amount of global minima from a source node to all the neighboring nodes. We add that path to our solution. The dimension of the space is shown in the table. We complete this tour by doing this procedure iteratively.

6. Comparison with other algorithms

Here, the performance of Dimensional ACO technique to solve TSP has been evaluated to find out how Dimensional ACO is efficient.
In this setup we have considered 50 as the population size of ants. In this algorithm Dimensional ACO was run 50 times and average of the 50 optimum results has tabulated.

TABLE I and TABLE 2 shows the best and average result, relative error and running time. In this, "Best" is taken as the best result of 10 times run and "Average" is average of the lengths. "Optimal" is taken from TSP lib whereas "Error" is calculated as ("Average"-"Optimal")/ "Optimal" and "time" is taken as system time to complete the task and is measured in milliseconds. In this experiment we take all the test cases from TSPLIB (http://elib.zib.de/pub/mp-testdata/tsp/tsplib/tsplib.html).

As shown in these tables that Dimensional ACO is more efficient than other algorithms It can get the solutions easily and have faster convergence as it takes relatively less time to get the optimum result.

EIL51 Optimal =426	ACO	MST-ACO	PSO without C3	C3D PSO	DACO
Best	426	426	441	426	426
Average	433.17	426.18	468.45	434.24	427.63
Error	1.6	0.04	9.96	1.9	0.0038
Time(ms)	5128	781	3867	3989	3350

TABLE-1 (EIL51)

Berlin52 Optimal= 7542	ACO	MST-ACO	PSO without C3	C3D PSO	DACO
Best	7542	7542	7710	7542	7542
Average	7685.73	7567.65	8560.45	7593.26	7555.91
Error	1.9	0.34	13.50	0.67	0.0018
Time(ms)	5231	798	3897	4067	3456

TABLE-2 (Berlin52)

7. Conclusion

In this paper an improved Ant Colony Optimization algorithm has been proposed named as Dimensional ACO. Simulation results shows that TSP solution using Dimensional ACO method is capable of providing improved performance as compared to other TSP solution/Optimization techniques. This algorithms helps avoid stagnation and improve performance. It has been seen that the solutions of Dimensional ACO depends on the number of ants. Less number of ants allows changing the path much faster. The higher number of ants causes the higher deposition of pheromones on edges, and hence an individual keeps a path having higher concentration of pheromones with high probability.

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