ANALYSIS AND SYNTHESIS OF ENHANCED ANT COLONY OPTIMIZATION WITH THE TRADITIONAL ANT COLONY OPTIMIZATION TO SOLVE TRAVELLING SALES PERSON PROBLEM

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ABSTRACT

Ant Colony optimization is a heuristic technique which has been applied to a number of combinatorial optimization problem and is based on the foraging behavior of the ants. Travelling Salesperson problem is a combinatorial optimization problem which requires that each city should be visited once. In this research paper we use the K means clustering technique and Enhanced Ant Colony Optimization algorithm to solve the TSP problem. We show a comparison of the traditional approach with the proposed approach. The simulated results show that the proposed algorithm is better compared to the traditional approach.

Keywords

Ant Colony Optimization, Travelling Salesperson problem, Combinatorial Optimization, Pheromone, K-Means Clustering

1. INTRODUCTION

Swarm Intelligence is a new approach to problem solving which is based on the collective behavior of simple agents interacting locally with one another and their environment and was first introduced by Gerardo Beni and Jing Wang in 1980 in the context of cellular robotic systems [1].Ant Colony Optimization is a meta-heuristic technique which is used to solve the various combinatorial optimization problems and was first proposed by the Italian Scholar M.Dorigo in 1991[2,3]. ACO is based the foraging behavior of the ants in real ant colonies. Ants deposit pheromone on the ground while moving. Ants can smell pheromone which is excreted by other ants on their way to the food source. Intially ants wander randomly but with time ants follow shorter path because pheromone concentration on shorter path becomes more.

Travelling Salesman problem is a combinatorial optimization problem and it requires that a salesperson should start from city and in the end return to the same city and all the cities should be visited exactly once. If there are n cities to be travelled then n-1! is the total number of possible routes that can be covered

If the distance between the two cities is same in both the directions, then it is a case of symmetric TSP problem while in asymmetric TSP the path may not exist in both the directions or the distances may be different.

2. REVIEW OF EXISTING WORK

ZHU Ju-fang [12] in his paper used Ant Colony Algorithm to solve Travelling Salesman problem which is a combinatorial optimization problem. The basic principle of Ant Colony Algorithm is realized in his paper. Hongquan Xue[13] in his

paper proposed a new algorithm for solving TSP using Ant Colony Optimization Algorithm based on immunity and multiple ant colonies. The new algorithm was tested on bench mark problems taken from TSPLIB. The experimental results show that the new algorithm effectively relieves the tensions such as the premature, the convergence and the stagnation. Hara.A[14] in his paper proposed a new ACO method using heterogeneous ants for Travelling Salesman Problem. In his proposed method there exist not only the normal ants but also the exploratory ants which construct partial solutions. In the constructing solution phase, the exploratory ant selects the next city from unvisited cities which exist in the neighborhood of ant. This method is called Give-up Ant System. Bifan Li [15] in his paper proposed a new model of Ant Colony Optimization to solve the travelling salesperson problem by introducing ants with memory into the Ant Colony System .In the new ant system ants can remember and make use of the best so far solutions , so that the algorithm is able to converge into at least near optimum solution quickly. Shih-Pang Tseng [16] in his paper presented an efficient method for speeding up Ant Colony Optimization called Pattern Reduction Enhanced Ant Colony Optimization. He used Travelling Salesperson problem to evaluate the performance of the proposed Algorithm. Gao Shang [17] in his paper integrated Ant Colony Optimization and Association rule to solve the TSP problem. The results of this new algorithm are better when compared to simulated annealing, genetic algorithm and the standard ant colony algorithm.

3. ANT COLONY OPTIMIZATION

3.1 ACO Background

1) THE ANT SYSTEM

Ant system was introduced and applied to TSP by Marco Dorigo et al [5,6,7].The main characteristic of the Ant System is that the pheromone values are updated by all the ants that have constructed a solution. Initially each city is assigned an ant and each ant selects the next city depending on a probability The probability that ant K will move from city i to city j is in accordance with the probabilistic decision rule and is given by :-

$$P_{ij}^k(t) = \begin{cases} \dfrac{\tau_{ij}^\alpha(t)\eta_{ij}^\beta(t)}{\sum_{u \in J_k(t)}\tau_{iu}^\alpha(t)\eta_{iu}^\beta(t)} & \text{if } j \in j_k(i) \\ 0 & \text{otherwise} \end{cases}$$

Where τ_{ij} =amount of pheromone that ant k deposits on path between city i and j

η_{ij}=heuristic information where $\eta_{ij} = \frac{1}{d_{ij}}$

and d_{ij} =distance between city i and j

$j_k(i)$=set of cities that ant K has not yet visited when it is at city i.

$\alpha =$ Pheromone affects path selection. This degree can be expressed by α

$\beta =$ Path length affects path selection. This degree can be expressed by β.

In each iteration the pheromone value is updated by all the m ants that have built a solution in that iteration. When an ant traverses the complete tour, the pheromone concentration on the path needs to be updated in accordance with below rule:-

$$\tau_{ij}(t + 1) = (1 - \rho)\tau_{ij}(t) + \Delta\tau_{ij}(t)$$

$$\Delta\tau_{ij}(t) = \sum_{k=1}^{m} \Delta\tau_{ij}^{k}(t)$$

$$\Delta\tau_{ij}^{k}(t) = \begin{cases} \frac{Q}{L_k} & if\ Kth\ ant\ uses\ edge(i,j)in\ its\ tour \\ 0 & Otherwise \end{cases}$$

$\rho =$ pheromone volatization coefficient

$1 - \rho =$ pheromone residual coefficient

$\Delta\tau_{ij}^{k}(t)$ =amount of pheromone that ant k left in the path from city i to city j

L_k =total length of the tour that each ant went through.

m=number of ants

Q=constant value (amount of pheromone that an can release in one iteration)

2) ANT COLNY SYSTEM ALGORITHM

The ACS [8,9,10] introduces a local pheromone update rule in addition to the global pheromone update .

At the end of each construction step each ant performs the local pheromone update. The update is performed only on the edge last traversed.

$$\tau_{ij}(t + 1) = (1 - \rho)\tau_{ij}(t) + \rho\tau_o$$

$\rho\epsilon(0,1)$ is the pheromone decay coefficient

τ_o is the initial value of pheromone

Reducing the pheromone concentration on the edges allows the ants to choose different paths and hence produce different solutions. This is the main goal of performing the local pheromone update.

The global pheromone update is performed by one ant at the end of each iteration which can be iteration best or best so far (edges which are visited by the best ants). The update is performed in accordance with the following rule:-

$$\tau_{ij}(t + 1) = (1 - \rho)\tau_{ij}(t) + \rho\Delta\tau_{ij}(t)$$

$$\Delta\tau_{ij}(t) = \begin{cases} \frac{1}{L_{gb}} & if\ (i,j)\ belongs\ to\ global\ best\ tour \\ 0 & Otherwise \end{cases}$$

$\frac{1}{L_{gb}}$ is the length of the globally best tour found.

Another difference between Ant System and Ant Colony System is the decision rule used by ants to move from city i to city j called Pseudo Random Proportional rule. The probability of an ant to move from one city to another depends on a random variable q uniformly distributed over [0,1] and a predefined parameter q_o.

$$j = \begin{cases} argmax_{u\epsilon allowed_k}(i)\left\{[\tau_{iu}^{\alpha}]\left[\eta_{iu}^{\beta}\right]\right\} & if\ q < q_o \\ j & Otherwise \end{cases}$$

j is a random variable determined in accordance with the probability rule used in Ant system.

3) MAX-MIN ANT SYSTEM

This Algorithm [11] has proven to be an improvement over the original Ant System. In each iteration the pheromone updates are performed only by the best ant. The pheromone update rule in MAX-MIN ANT SYSTEM is as below:

$$\tau_{ij} = \left[(1 - \rho).\tau_{ij} + \Delta\tau_{ij}^{best}\right]_{\tau_{min}}^{\tau_{max}}$$

Where τ_{min} and τ_{max} are the lower and upper bounds on the pheromone value.

$[y]_b^a$ is defined as:

$$[Y]_b^a = \begin{cases} a & if\ y > a \\ b & if\ y < b \\ y & otherwise \end{cases}$$

and $\Delta\tau_{ij}^{best} = \begin{cases} \frac{1}{L_{best}} & if\ (i,j)\ belongs\ to\ the\ best\ tour \\ 0 & Otherwise \end{cases}$

L_{best} is the tour length of the best ant and this can be best tour in the current iteration or the best solution found so far.

4. PROPOSED WORK

4.1 K-Means Clustering

K means clustering is a technique which is used to classify n observations into k clusters with each observation belongs to cluster with nearest mean. The grouping is done in such a way so that the sum of square of distance between the data and the corresponding cluster centroid is minimized [4]. The Algorithm is composed of the following steps:-

1) Initially define K centroids, one for each cluster.
2) The next step is to take each point from the data set and associate it with the nearest centroid.
3) Then again we recalculate K new centroids for the clusters resulting from the previous step and associate the data points with new centroids.
4) Repeat above steps until centroids do not change their location any more.

4.2 Methodology

Intially we plot cities using the coordinate values. Then perform K-Means clustering technique to cluster these points into clusters. Then apply Ant Colony Optimization in each cluster to find the optimal tour for each cluster separately. Then start an Ant at a random city in any cluster .It will traverse all the cities in cluster according to Local Optimal Tour found. After reaching the last city in this cluster, we find the minimum of all the path lengths to other cluster. And will repeat the same procedure again. After reaching the last cluster we first calculate the path lengths of all the cities to the initial city. The one having the minimum distance to the initial city will be reserved. Then we traverse all the cities in this cluster and in the end traverse the reserved city to move back to the initial city. The block diagram for this methodology is shown below.
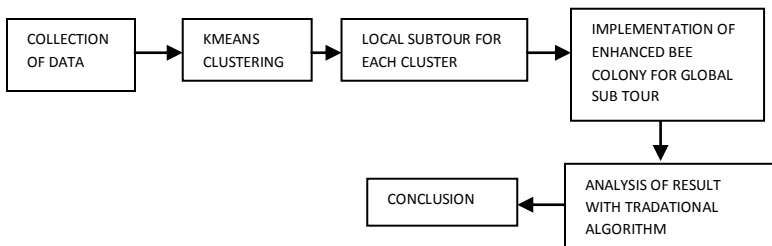

Fig1: Block Diagram of proposed Methodology

4.3 Proposed Algorithm

//For finding the shortest path length in cluster (LOCAL TOUR)
1) For each cluster//p is the maximum number of cluster
    1.1) While iter< itermax // itermax is the maximum number of iterations
    1.2) For each ant do: // m is the maximum number of iterations

        1.2.1) Ant[i].MoveToNextCity();//Each ant moves to next city depending on state transfer probability
        1.2.2) end For.
        1.2.3) A local pheromone updating rule is applied
    1.3) For each ant do
        1.3.1) Compare the path lengths of all the ants in this cycle.
        1.3.2) Record the shortest path and its length.
        1.3.3) end For.
    1.4) Compare the shortest path length in this iteration with the global shortest path length. If the previous path length is shorter, then the global shortest path is updated by the shortest path calculated in this iteration.
    1.5) `Local search (2-opt, 2.5 opt) is applied to improve tour`
    1.6) A global pheromone updating rule is applied.
    1.7) For each ant do
        1.6.1) Ant[i].clear().
        1.6.2) end for.
    1.8) Start with next iteration.
    1.9) end while.
    1.10) Store the optimal value for each cluster

//After finding the shortest path in each cluster(GLOBAL TOUR)
2.1) Start from any randomly chosen cluster.
2.2) For cluster number from 1 to p-1 do
2.3) Traverse according to local tour.
2.4) From last city of each cluster move to next cluster by choosing the minimum of all allowed cities.
2.5) For p^{th} cluster reserve the node from list of allowed city which has minimum distance to initial city.
2.6) Traverse cities in cluster p according to local sub tour;
2.7) Traverse reserved city.
2.8) Move to initial city.
2.9) Store the optimal solution

5. EXPERIMENTAL RESULTS

The proposed algorithm is tested on several TSP problems from the TSPLIB website [18].Table 1 shows a comparison of the path lengths for several TSP problems. In the proposed system the parameters are set to the following values: $\rho=0.1, q_0=0.7, \alpha=1$ β value is dynamically value of the proposed algorithm and $\beta=2$ in Ant Colony System. The maximum iteration is set to 20 times for all TSP instances and the ant number (m) is also set to 20. The experimental results show that proposed algorithm presented in this paper attains optimal results for TSP problems. The efficiency of the proposed algorithm is better than the traditional algorithm.

Table1: Comparison of path lengths for various TSP problems

Instance	Optimum(1)	ACS+2 Opt [19]		Relative Error ((2)-(1))/(1)	Proposed Algorithm		Relative Error ((3)-(1))/(1)
		Best(2)	Average		Best(3)	Average	
berlin52	7542	7542	7762.15	0%	7542	7580.77	0%
eil51	426	429	434.55	0.7%	426	431	0%
pr144	58537	58620	58822.4	0.14%	58537	58687.24	0%
eil76	538	548	557	1.8%	538	547	0%

6. CONCLUSION

The results show that proposed Ant Colony Optimization Algorithm has increased performance and reduced the cost for solving Travelling Salesman Problem. The proposed approach based on clustering the cities and applying ant colony optimization individually in each cluster and reserving the city in the last cluster which has minimum distance to the initial city has proven to be a better methodology for solving the travelling salesman problem. The clustering technique can be further enhanced to provide better solutions. .

7. ACKNOWLEDGMENTS

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