Modified Ant Colony Optimization Algorithm with Uniform Mutation using Self-Adaptive Approach for Travelling Salesman Problem

[1]Ramlakhan Singh Jadon, [2]Unmukh Datta
[1]ramjdn86@gmail.com, [2]unmukh62@hotmail.com
Maharana Pratap College of Technology, Gwalior (M.P.)

ABSTRACT
Ant Colony Optimization (ACO) algorithm is a novel meta-heuristic algorithm that has been widely used for different combinational optimization problem and inspired by the foraging behavior of real ant colonies. It has strong robustness and easy to combine with other methods in optimization. In this paper, an efficient modified ant colony optimization algorithm with uniform mutation using self-adaptive approach for the travelling salesman problem (TSP) has been proposed. Here mutation operator is used for enhancing the algorithm escape from local optima. The algorithm converges to the final optimal solution, by accumulating most effective sub-solutions. Experimental results show that the proposed algorithm is better than the algorithm previously proposed.

General terms
Algorithm, Experimentation, verification

Keywords
Ant Colony optimization, ACO, Mutation operator, Travelling salesman problem, TSP

1. INTRODUCTION

The problem of optimization is the most crucial problem in today's era and a great work has been done to solve it. During last few years, many optimization algorithms, like Ant Colony Optimization (ACO), Particle Optimization Problem (PSO), Artificial Bee Colony Algorithm (ABC), Differential Evolution (DE), Genetic algorithm (GA) etc., has been proposed.
Ant Colony Optimization (ACO)[1] algorithm was proposed firstly in 1991 by Dorigo M. and was designed to simulate the foraging behavior of real ant colonies. ACO algorithms have been widely used for solving different combinational optimization problems such as Job-Scheduling Problem, Traveling Salesman Problem, and Vehicle Routing Problem etc. Various enhanced versions of the original ACO algorithms have been done over the years. For improving the quality of final solution and speedup of the algorithm, various strategies like dynamic control of solution construction[4], mergence of local search[3,12], partition of artificial ants into two groups: common ants and scout ants[11], strategies for updating new pheromone[7,3] and using strategies of candidate lists[2,13,14] are studied.
The principle of the phenomenon is shown in Fig (a), Fig (b), Fig(c) and Fig (d).

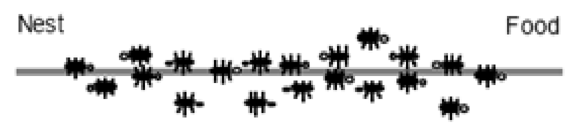

Fig (a) Real ants follow a path between nest and food source

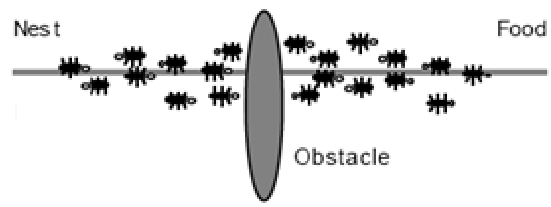

Fig. (b) An obstacle appears on the path: ants choose whether to turn left or right with equal probability

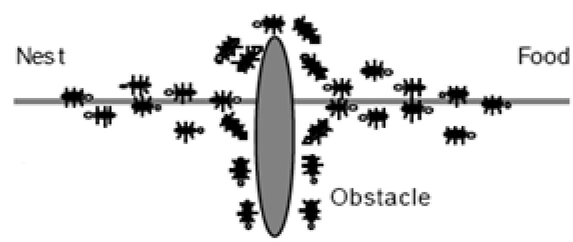

Fig.(c) Pheromone is deposited more quickly on the shorter path

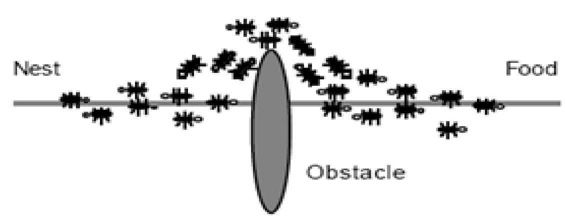

Fig (d) all ants have chosen the shorter path

The remainders of this paper are organized as follows. Section 1 introduces the mathematical model of ant colony algorithm. Section 3 explains self-adaptive approach. Section 4 defines the travelling salesman problem and Section 5 explains the proposed algorithm. Finally, in Section 6, experiments are conducted on different TSP problems.

2. MATHMATICAL MODEL OF ANT COLONY ALGORITHM

The mathematical model of ant colony optimization has first been applied to the TSP [15]. TSP is to find out the minimal total cost given a set of fully connected weighted graph G(V,E).

Here the transition probability from city i to city j for the k-th ant as follows:

$$p_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}[n_{ij}]^{\beta}}{\sum_{k \epsilon allowed_k}[\tau_{ij}(t)]^{\alpha}[n_{ij}]^{\beta}} & \text{if } j \in \text{allowed} \\ 0 & \text{otherwise} \end{cases}$$

After the ants completed their tours, the pheromone trail values are updated according to following formula:

$$\tau_{ij}(t+n) = \rho.\tau_{ij}(t) + \Delta\tau_{ij}$$

Where ρ = local pheromone decay parameter and $\rho \subset (0,1)$. then 1- ρ represents the evaporation of trail between time t and t+n,

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

Where $\Delta\tau_{ij}^{k}$ = quantity of per unit length of pheromone trail laid on edge (i, j). And calculated as

$$\Delta\tau_{ij}^{k} = \begin{cases} \dfrac{Q}{L_k} & \text{if k-th ant uses (i,j) in tour} \\ o & \text{otherwise} \end{cases}$$

Here Q is constant and L_k = tour length of k-th ant.

3. SELF-ADAPTIVE APPROACH

In Self-Adaptive Approach, the parameters are encoded into pheromones and undergo mutation and recombination. The idea is that better parameters leads to better pheromones for finding shortest path. In [5], a self-adaptive approach, a single mutation rate is used. With this mutation rate p[0,1], a new mutation rate p'[0,1] is found using equation(1). In this equation, γ is the learning rate which controls the adaption speed and it is taken as 0.22 in [5]. The mutation rate is not allowed to go below 1/L.

$$P' = \left(1+\frac{1-p}{p}.\exp(-\gamma.N(0,1))\right)^{-1} \quad (1)$$

4. TRAVELLING SALESMAN PROBLEM

Traveling salesman problem (TSP) is one of the well-known and extensively used combinational optimization problems. TSP is to find a routing of salesman who starts from initial location and visits a prescribed set of cities and returns to the original location in such a way that the total distance travelled is minimum and each city is visited exactly once. It is an NP-hard problem and it is so easy to describe and so difficult to solve.

A complete weighted graph G= (V, E) can be used to represent a Travelling Salesman Problem, where V is the set of n cities and E is the set of edges (paths) fully connecting all cities. Each edge (i,j) belongs to E is assigned a cost d_{ij}, which is the distance between cities i and j, d_{ij} can be as follows:

$$d_{ij} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$$

5. PROPOSED ALGORITHM

In this proposed method, Ant colony optimization algorithm with mutation using self-adaptive approach is used. Here mutation is used for enhancing the algorithm escape from local optima. In this method, ACO algorithm generates the tour T(i,j) by visiting all the locations. Then, an additional mutation operator is applied on the tour T(i,j), by using new mutation rate generated by self-adaptive approach, a new tour $T_{new}(i,j)$ is generated. Then compare the new tour $T_{new}(i,j)$ with T(i,j). If the cost of new tour is less than the cost of T(i,j). Then replace T(i,j) with $T_{new}(i,j)$. This process is repeated until maximum iteration is not reached.

The Steps of proposed modified ACO algorithm are:

Step 1: Initialize all edges to (small) initial pheromone τ_0

Step 2: Place each ant on a randomly chosen city

Step 3: **for** i=1 to m **do**
  Candidate list i to the c closest cities of i
 End of i

Step 4: **for** t = 1 to t_max **do**
  for i=1 to number of ants **do**
   until (tour T(i,t) for ant i is complete) **do**

if there is at least one unvisited city is candidate list i then choose the next city among the candidates by applying the probabilistic transition rule;
else
Choose the next city as the next city still to be visited;
Perform local trail update;

if mutation criteria is met **then**
Select random city from current tour T(i,t) for mutation operator.
Apply mutation operation to generate new city new tour Tnew(i,t) generated from the result of mutation.
end
If tour T_{new} (i,t) < tour T(i,t)
then update tour T(i,t) with tour T_{new} (i,t) ;

for every edge on the T(i,t) **do**
Apply global trail update;

end of i
end of t

Step 5: Algorithm stops here and output the shortest distance.

6. EXPERIMENTAL RESULTS

In order to evaluate the efficiency of the proposed algorithm, several TSP problems are considered. These all problems are obtained from the TSPLIB.
For every algorithm, there are some control parameters which are used for its efficient working. Here, control parameters for the proposed algorithms are shown in table 1:

Table 1. Control parameter values

Parameters	Value
ρ	0.1
q_0	0.7
α	1
β	2
Max number of iterations	20 times

To compare the proposed modified algorithm with reference [9] and [10], some TSP instances (eil51, eil76, bBerlin52, st70) are used.

Table2: Experimental results using different TSP problems

TSP	Best length of proposed algorithm	Best length of reference [9]	Best length of reference [10]
eil51	425.23	-	429.98
eil76	534	548.2376	-
bBerlin52	7539	7544.3659	-
st70	672.45	677.1076	677.1096

7. CONCLUSION

This paper presents an efficient approach for solving travelling salesman problem based on modified ant colony optimization problem based on self-adaptive approach. Here one additional step in the form of mutation operator is used in the original ACO algorithm for finding the global optimal solution. The use of adaptive mutation is for enhancing the algorithm escape from local optima. The experimental final results showed that the proposed algorithm performs better than the previous algorithms. Future work is to apply the proposed algorithm to other combinational problems and check the efficiency by comparing this method with other proposed methods.

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