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A Review on Optimization with Ant Colony Algorithm

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Abstract – Ant colony optimization (ACO) is an algorithm based on the behavior of the real ants in finding the shortest path from a source to the food. It utilizes the behavior of the real ants while searching for the food. It has been observed that the ants deposit a certain amount of pheromone in its path while traveling from its nest to the food. Again, while returning to the nest, ants follow the same path marked by the pheromone and again deposit the pheromone on its path. In this way the ants following the shorter path are expected to return earlier and hence increase the amount of pheromone deposit in its path at a faster rate than the ants following a longer path.

In this paper, we determine the possibility of solving the well-known Travelling Salesman Problem (TSP), which ranges among NP-hard problems, and offer a theoretical overview of some methods used for solving this problem. We discuss the Ant Colony Optimization (ACO), which belongs to the group of evolutionary techniques and presents the approach used in the application of ACO to the TSP. We study the impact of some control parameters by implementing this algorithm. The quality of the solution is compared with the optimal solution.

Index Terms – Ant Colony Optimization, Pheromone, TSP.

1. INTRODUCTION

A salesperson must visit n cities, passing through each city only once, beginning from one of the city that is considered as a base or starting city and returns to it. The cost of the transportation among the cities is given. The problem is to find the order of minimum cost route that is, the order of visiting the cities in such a way that the cost is the minimum.

Let's number the cities from 1 to n and city 1 be the start-city of the salesperson. Also let's assume that c(i, j) is the visiting cost from any city i to any other city j. Here is the systematic way of solving this problem:

Algorithm TSP

First, find out all (n -1)! Possible solutions, where n is the number of cities. Next, determine the minimum cost by finding out the cost of everyone of these (n -1)! Solutions, finally, keep the one with the minimum cost. even a complete undirected graph G=(V, E) that has nonnegative integer cost c(u, v) associated with each edge (u, v) in E, the problem is to find a Hamiltonian cycle (tour) of G with minimum cost.

A salespersons starts from the city 1 and has to visit six cities (1 through 6) and must come back to the starting city i.e., 1. The first route (left side) 1→ 4 → 2 → 5 → 6 → 3 → 1 with the total length of 62 km, is a relevant selection but is not the best solution. The second route (right side) 1 → 2 → 5 → 4 → 6 → 3 → 1 represents the most better solution as the total distance, 48 km, is less than for the first route.

Suppose c(A) denoted the total cost of the edges in the subset A subset of E i.e.,

$$c(A) = \sum u,v \text{ in } A \; c(u, v)$$

Moreover, the cost function satisfies the triangle inequality. That is, for all vertices u, v, w in V, w have $c(u, w) \leq c(u, v) + c(v, w)$.

Note that the TSP problem is NP-complete even if we require that the cost function satisfies the triangle inequality. This means that it is unlikely that we can find a polynomial-time algorithm for TSP.

2. ANT COLONY ALGORITHM

Initially every path between cities has some initial amount of pheromone. Each ant starts from a randomly assigned city and goes from a city to the next city until all cities are visited exactly once. From the last visited city the ant returns to the start city.

The ant in city **i** selects the next city to visit by calculating probabilities:

$$p(c_{ij} \mid s^P) = \frac{\tau_{ij}^{\alpha} * \eta_{ij}^{\beta}}{\sum_{c_{ij} \in N(s^P)} \tau_{il}^{\alpha} * \eta_{il}^{\beta}}, \forall \, c_{ij} \in N(s^P), \quad (1)$$

Here

- **sp -** partial solution #p
- **N** - set of all paths from the city i to all adjacent cities still not visited by the ant

- **cij** - path from the city **i** to the city **j**
- **p -** probability
- **tij** - amount of pheromone on the path **cij**
- **hij** - some heuristic factor, usually $\eta_{ij} = Q/d_{ij}$; where **dij** is a distance between cities **i** and **j, Q** is some constant
- **α** and **β** - algorithm parameters.

The ant compares $p(c_{ij} \mid s^p)$ for each **j** to be traveled to some random number $n_j \subset [0,1)$. If $p(c_{ij} \mid s^p) \geq n_j$, the ant immediately moves to the city **j**. It means that the ant does not always select the path with maximal pheromone, thus diminishing chances to get caught into a local loop. There always is a very, very tiny probability of never satisfying the condition $p(c_{ij} \mid s^p) \geq n_j$. So in this application I use a modification proposed in Ant Colony Optimization. For the given city **i** I still generate a random number $n_i \subset [0,1)$ but compare it to the moving sum $\sum_j p(c_{ij} \mid s^p)$. The sum is updated with each new calculated $p(c_{ij} \mid s^p)$. The first **j** that gives $n_k \leq \sum_j p(c_{ij} \mid s^p)$ is the index of the next city to move. Actually, this modification makes a difference only in the very first trial's steps, when the pheromones deposited on the travel paths are very close to each other. At the end of the test, the ant usually takes the maximum p path.

The ants travel concurrently. It means that there is no pheromone correction until all ants return to their start cities.

The ants update pheromones on paths connecting the cities according to the formula:

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

where

- **m** - number of ants,
- $\Delta\tau_{ij}^{k} = \frac{Q}{L_k}$ if the ant **k** traveled the path $c_{i,j}^{k}$ between cities i and j; **Q** is some constant, and **Lk** is the length of the **kth** ant's travel
- $\Delta\tau_{ij}^{k} = 0$ 0 otherwise.

In this application, **Q** is a city's extent, i.e. the side of the least square that contains all cities. Because **Q** appears only as a numerator in fractions where denominators are distances, it keeps the results independent of the scale of the city's coordinates.

There are very different recommendations related to the values of **α**, **β**, ρ, start values of pheromone, and the number of ants (ρ is an evaporation factor, see below). One article recommends **α = 1, β=2, ρ=0.5,** and start pheromone **t=1/m,** where **m** is the number of cities. Anyway, you can play with them in this application.

It seems that the number of ants is not so important if there is enough number of trials, so set of the start cities for each ant could contain all customers' cities. In this application, we employ only ten ants.

3. COMPUTATIONAL EXPERIMENTS

The moving of ants provides the parallel and independent search of the route with the help of dynamical change of pheromone trail. The ant represents an elementary unit with the ability to learn, and due to collective-cooperative work with other members of population, it is able to find acceptable solution to the given problem. For experiment, we used the problem of 32 cities in Slovakia. We were able to get an optimal solution to that problem with the help of GAMS (Solver Cplex, 17498 iterations, optimal length of route 1453 km). Secondly, we try to solve that problem using ACO algorithm (6 functions in C#).

4. CONCLUSION

This paper is a study to overcome the problem of Stagnation and congestion by using Multiple Ant-Colony Optimization. In the improved version, of ACO, Multiple Ant-Colony Optimization can find more than one optimal outgoing interfaces are identified as compared to only one path, which are supposed to provide higher throughput and will be able to explore new and better paths even if the network topologies gets changed very frequently. This will distribute the traffic of overloaded link to other preferred links. Hence the throughput of the network will be improved and the problem of stagnation will be rectified. In the future work we intend to simulate the same using ns simulator so that exact results can be found.

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