A Vehicle Routing Optimization Problem for Waste Collection

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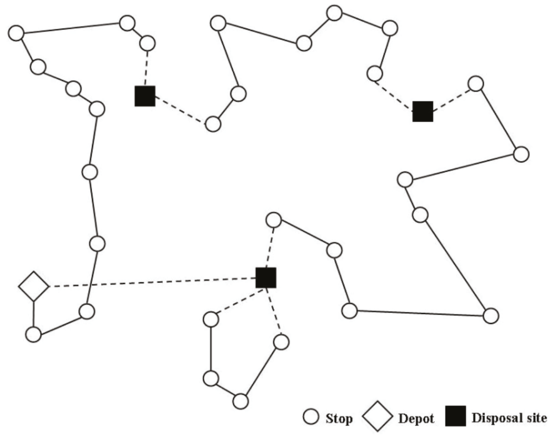
Abstract-
There are sets of vehicles and clients in the metropolitan city in which waste need to be disposed from client's location to disposal facilities. Collection of waste is an important activity in any city. Infinite number of vehicles are located at fixed depot. This can be considered as real life waste collection problem that can be seen as a variant of the vehicle routing problem with time windows. Each client has specific time window in which they must be served. Goal of this project is to solve this problem by covering minimum distance, as the cost will be minimized by keeping in mind infinite supply of vehicles. This solution can easily be extended to tackle extra constraints like fixed lunch period for vehicle drivers, time window for vehicle services. Bio inspired optimization heuristic of Artificial intelligence is used to implement this project. An ant colony based algorithm is used to get the best path. Experimental result was giving good result as we simulate the environment.

I. INTRODUCTION

Now-a-days vehicle routing problem is useful to many real life problems. For example, it can be used to reduce pollution. There are many types of vehicle routing problem. We have implemented one of them that is waste collection problem. The waste collection problem is very crucial in major metro cities. If it is implemented properly then it will be better utilization of vehicles and manpower. Also it reduces the cost of whole process. Eventually it reduces the pollution of the city. Reduction of pollution is major problem of any city. So this problem helps to reduce the same.



[Fig.1 Path sequence]

The waste collection problem consists of routing vehicles to collect customers waste within given time window while minimizing travel cost. This problem is known as the Waste Collection Vehicle Routing Problem with Time Windows. This differs from the traditional VRPTW by that the waste collecting vehicles must empty their load at disposal sites. The vehicles must be empty when returning to the depot. Multiple trips to disposal sites are allowed for the vehicles. The problem is illustrated in Fig. 1 for a single vehicle and multiple disposal sites.

II. ALGORITHM USED

Below algorithm is used for implementation.
"Ant Colony Optimization Algorithm":
Below is the details of ant colony optimization problem.

Ants roam around to find foods. When food has been found, while returning to their original colony it puts pheromone to path it traverse. Many ants find their food the same way and puts pheromone on their path. Next time new ant visits the path which has highest pheromone on the path.

Subsequently path which has short distance to destination (food location here) has highest pheromone on it. So eventually this path will become shortest path from source to destination. However the pheromone gets evaporate after some time.

But finally shortest path will be decided from colony to food location. The same logic is used to find the shortest distance between depot to client in this project.

Consider a complete graph G where V is the set of nodes and E is the set of edges.
Recall that, ACO is based on the natural fact that ants are always able to find the shortest path between a food source and the nest and this path is based on the pheromones previously laid on the ground by other ants. When there are several possible choices for selecting the next node an ant chooses the one with the largest concentration of pheromones with a certain probability. This idea is exploited in our algorithm. Let f_0 be a fixed number between 0 and 1. Now we randomly choose one number f such that the value is between 0 and 1. If $f<f_0$, then, ant k in node i chooses node j such that,

$$y = \arg\max_{p \in T(x)} [\eta(x,p)] \qquad (1)$$

Otherwise, if $f>f_0$ then the selection of the next node will be random based on the following probability.

$$p(x,y) = \begin{cases} \dfrac{[\delta(x,y)]^a.[\eta(x,p)]^b}{\sum[\delta(x,y)]^a.[\eta(x,p)]^b} \\ \qquad if\ y \in T(x), \\ 0, \quad otherwise \end{cases} \qquad (2)$$

where,
a is the relative importance of the pheromone,
b is the relative importance of the heuristic function,
T(x) is the set of nodes where ant k can move from node I satisfying all the conditions,
δ(x;y) is the pheromone concentration between the nodes x and y, and
η(x;y) is a heuristic function of the distance between node x and node y.

After selecting the node, an ant deposits pheromones on the path, i.e., the edge between x and y in this case. This pheromones deposition is inversely proportional to the tour length. As a result, the pheromone concentration on the shortest path will increase faster than other paths. Typical amount of pheromone deposited for a path (x;y) is

$$\mu(x,y) = \begin{cases} \dfrac{K}{L}, & if\ arc(x,y) \in tour, \\ 0, & otherwise \end{cases}$$

where,
K is a constant,
L is the total tour cost. (3)

Another property of the pheromone is volatility. With the increase of time, the pheromone evaporates and the quantity of pheromones on other paths will be much lower than that of the mostly used path, i.e., the shortest path. Here, we consider an evaporation rate ρ. After each round, the pheromone concentration is updated as follows. If edge (x; y) is used in the round, then we have

$$\delta(x,y) = (1-\varepsilon).\delta(x,y) \qquad (4)$$

III. IMPLEMENTATION APPROACH

In this section, we are going to give a detailed explanation of our algorithm.
1) Assumptions: In our algorithm, we consider infinite no of vehicles in the sense of serving each customer. No time window is considered for vehicles. No restriction on number of customers serviced per vehicles. We use inverse of the distance as the heuristic function as follows:

$$\eta(x,y) = \frac{1}{d_{xy}} \qquad (5)$$

And distance is considered to be the Manhattan distance between nodes. Quantity of garbage is randomly generated for simulation purpose.

1) Initialization: The whole procedure starts with by initializing capacity of each vehicle, speed of vehicle, epoch i.e. no of iterations and different other parameters. In each epoch, we execute the ACO algorithm and update pheromones.

2) ACO variant algorithm: In each iteration, we perform the ACO variant algorithm as follows: First, we allocate a vehicle and initialize the current time of the vehicle to the beginning time of the depot. Then we find the next client i based on the procedure described in next section. Then we check whether there is enough space left in the vehicle. If not, then it goes to nearest disposal facility to dump the garbage and go on finding client that can be satisfied within the given time window.
This process repeats with other vehicles also until all the clients are served.

3) Neighbour Selection: This is the procedure for selecting next client mentioned at earlier section. At first, the eligible candidate, considering the time window and remaining capacity of the vehicle and quantity of the client's garbage, saved as the perfect neighbor. Using the (1), (2) and (5) mentioned above we are going to select the next neighbor. If we can find no such client, then those clients who can be reached before the time window begins are added to the simple neighbor list. In this case, the vehicle will reach the selected client, but will have to wait until the client's time window begins. Client is selected using the Equation (1), (2) and (5).

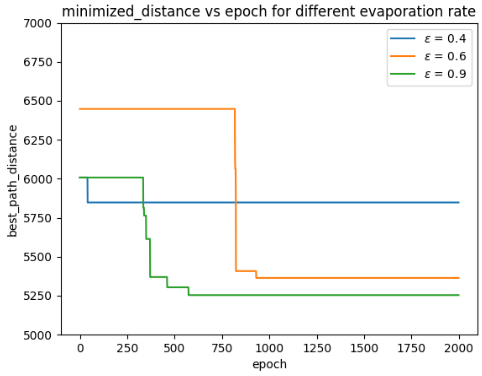
4) Pheromone Updation: We update the pheromones after giving service to every client in one epoch. As has been mentioned before, Using equation (3) and (4) the pheromone has been updated which helps us in exploration.

IV. EXPERIMENT

Below are the observations which have been got during the experiment using simulated environment. The best distance has been converged after 2000 epoch during our experiment. As you can see from Fig.2 with the increasing of evaporation rate, ε we are getting better result. Because, it helps us to explore the map little further and leads us to better result.

epoch	ε = 0.4	ε = 0.6	ε = 0.9
500	5848	6448	5304
1000	5848	5364	5254
1500	5848	5364	5254
2000	5848	5364	5254

TABLE I: epoch vs. ε

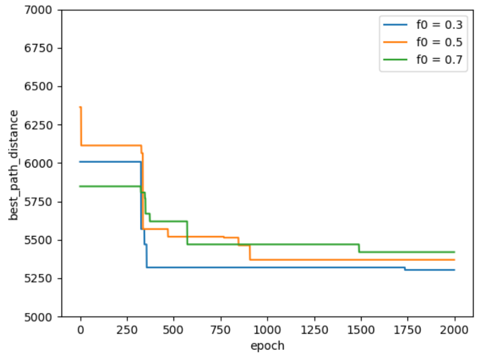


[Fig 2. Best path distance vs. epoch for different **ε**]

In the Fig.3 we are getting better minimum distance path with the increase of f0. This means if we are giving higher likeliness to neighbor selection by equation (2). It is giving better result.

epoch	f0 = 0.3	f0 = 0.5	f0 = 0.7
500	5320	5520	5620
1000	5320	5370	5470
1500	5320	5370	5420
2000	5304	5370	5420

TABLE II: epoch vs. f0



[Fig 3. Best path distance vs. epoch for different f0]

V. CONCLUSION

In this project, we have tried to study a real life waste collection problem. Ant Colony Based optimization algorithm has been used to solve this problem. We have conducted this experiment by simulating a city logistics environment. We believe our algorithm would be highly suitable for giving solution in real life situations and we will encourage the user to improve our algorithm by considering extra constraints.

VI. REFERENCES

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