A Solving Approach for the DVRP Based on Hierarchical Self-Organizing Maps

Jaber JEMAI[1]

Information Systems Department, CCIS
Imam University, Riyadh, KSA
jaber.jemai@ccis.imamu.edu.sa

1 Introduction

The dynamic vehicle routing problem represents a real life extension of the standard Vehicle Routing Problem (VRP). The VRP consists of designing a set of routes for serving a set of geographically dispersed customers over a transportation network using a fleet of vehicle hosted in a central depot. Each vehicle can serve a limited number of customers due to its limited capacity. Moreover, each customer have to be visited exactly once by a vehicle that will give him exactly the required demand. The objectives for the standard VRP are generally to minimize the overall travelled distance or time. In the standard VRP, all data defining the instance to solve are supposed to be available in advance and the solving algorithm will use them and perform just one pass to return a solution. However, that is not realistic and some data may be not available at the beginning of the time horizon. The dynamic data set will be then delivered while the problem is being solved and a partial plan is being applied. Hence, in such dynamic environments, the problem cannot be viewed as static optimization problem but classified as a dynamic optimization problem.

In this paper, we propose an approximate solving approach for the DVRP based on the hierarchical SOM model. The HSOM is a neural model able to find some clusters an input data set by grouping geographically close nodes. Basically, the SOM is composed by an input layer used to gather problem inputs and an output layer used to find via distance minimization some clusters in the input data. In terminology, when SOM are applied to routing problems, the generated clusters are named rings in the HSOM model and they will refer to routes in the solution of the DVRP. Moreover, SOM properties of convergence and gradient descent on the energy function of the network to find better clusters (even local) [1], allow an investigation of their potential to propose good solutions in dynamic environments. The research question in this paper is first about the ability of HSOM to generate flexible temporary plans (partial solutions) able to accept and insert all forthcoming inquiries in the working plan i.e. minimize the rejection rate. Second, we would like to evaluate the quality of final solutions proposed by HSOM and whereas they are able to compete with other solving approaches.

2 the DVRP: A Formal definition

As extension of the classical vehicle routing problem, the DVRP can be defined as a VRP with a timing dimension. This dimension associates to each request an arrival time. In addition to a constraint stipulating that a customer cannot be scheduled or served before the arrival of his request. Formally, the dynamic vehicle routing problem can be stated as follow:

Let $G(V, A)$ be a valued graph where:

- $V = \{0, 1, ..., N\}$ is the vertices set representing N cities or customers to be visited and the depot (index=0). For each customer we associate:
  - a demand d_i.
  - an arrival time a_i representing the time when the request is revealed.
  - a service time s_i representing the time required to complete the service at customer i.
- $A = \{(i, j), i \neq j, i \in V, j \in V\}$ a set of arcs; to each arc is associated a distance d_{ij} representing the cost of passing from i to j.
- A fleet of K vehicles located initially in the central depot, each with specified capacity Q_i.

The DVRP asks for designing a set of vehicle routes to serve customers with minimal routing costs. Generally, the routing costs are defined in term of the overall traveled distance. A feasible DVRP solution should respect the following constraints;

1. Each vehicle starts and ends its route at the central depot.
2. Each vertex in V must be visited exactly once by exactly one vehicle (except the depot).
3. The total quantity assigned to a route don't exceed the capacity of the vehicle performing this route.
4. Every vertex (customer) can be only visited after his arrival time a_i.
5. Some requests may be rejected.
6. Some vehicles may remain idle.

3 A hierarchical SOM for the DVRP

3.1 The problem control bloc

The DVRP can be viewed as sequence of requests generated over the time horizon. Each request asks to be scheduled and inserted into the current plan. To define to data set of the problem to be solved at time t when a new query is revealed, we define the problem control bloc. The PCB_t defines the instance of the problem to solve at time t. The PCB groups all the required data of the problem solve at time t. Explicitly, it will record the following attributes:

1. Data set describing the vehicles:
   - a fleet of K available vehicles; a vehicle serving actually a customer or reached its capacity limit cannot be considered.
   - the available capacity Q_i of each vehicle.
   - the current location of each vehicle given by its the coordinates x_i and y_i.
   - the current performed route (a sequence of already completed visits).
2. Data describing the customers:
   - the set of customers V including newly generated requests.
   - the demand of each customer d_i.
   - the location of each customer given by its coordinates x_i and y_i.
   - the service time s_i of each customer.

Some other inputs may be considered also and integrated into the PCB like a traffic jam in some points (vertices) or some unavailable segments (edges) in the networks.

3.2 Discrete event manager

The proposed approach is based on a Discrete Event Manager (DEM) that will define the problem context guided by a set of standard events. An event is generated at an instant t can be:

- a new request is revealed.
- a traffic jam.
- a vehicle breakdown.
- a canceled request.

For each new request generated at time t, the DEM build the PCB_t. The PCB_t will contain all data of newly generated requests and all not yet served customers. Then, it will call the HSOM solver to find a solution for the offline VRP given in parameter. Once the solution s_t of PCB_t is returned by the solver, the DEM updates the current plan s^*. If no event generated, the discrete event manager will continue applying the current solution s^*.

References

1. E. Erwin, K. Obermayer, K. Schulten, Self-organizing maps: ordering, convergence properties and energy functions, Biological Cybernetics, Volume 67, Issue 1, pp 47-55.
2. V. Pillac, M. Gendreau, C. Guret, A. L. Medaglia. (2013) A review of dynamic vehicle routing problems, European Journal of Operational Research, volume 225(1), pp:1-11.