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MANAGING SPACE-TIME NETWORKS FOR THE DYNAMIC TIME-CONSTRAINED VRP

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Abstract. Vehicle Routing problems are highly complex problems for which different Artificial Intelligence techniques have been used. In this paper, we propose an agent-oriented self-organization model for the dynamic version of the problem with time windows. Our proposal is based on a space-time representation of the agents' *Action Zones*, which is able to maintain a good distribution of the vehicles on the environment. This distribution answers the objective of the dynamic problem, since it allows the agents to take their decisions while anticipating future changes in the system's parameters.

Keywords. Self-Organization, Multiagent Systems, Applications, Planning, Scheduling.

1 Introduction

Several operational distribution problems, such as the deliveries of goods to stores, the routing of school buses, the distribution of newspapers and mail etc. are instantiations of NP-Hard theoretical problems called the Vehicle Routing Problems (VRP). In its original version, a VR-P is a multi-vehicle Traveling Salesman Problem: there exists a certain number of nodes to be visited once by a limited number of vehicles. The objective is to find a set of vehicles' routes that minimizes the total distance traveled. Besides their practical usefulness, the VRP and its extensions are challenging optimization problems with an academic stimulating issues. One of the most widely studied variant of the problem is the time (and capacity) constrained version: the Vehicle Routing Problem with Time Windows (VRPTW henceforth), in which the requests to be handled are not simply nodes, but customers. For each customer, the following information are informed: the concerned node, two temporal bounds between which he desires to be visited and a quantity (number of goods to receive, number of persons to transport, etc.). Each vehicle has a limited capacity, which should not be exceeded by the quantities that it transports. The addition of time windows increases the complexity of the problem, since it narrows the space of valid solutions. The VRPTW can be formally stated as follows.

Let $G = (V, E)$ be a graph with node set $V = N \cup 0$ and edge set $E = (ij)|i \in V, j \in V, i \neq j$, $N = 1, 2..., n$ is the customer set with node 0 is the depot. With each node $i \in V$ is associated a customer demand $q_i(q_0 = 0)$, a service time $s_i(s_0 = 0)$, and a hard service-time window $[e_i, l_i]$ i.e. a vehicle must be at i before l_i but can be at i before e_i and must wait until the service starts. For every edge $(i, j) \in A$, a distance $d_{ij} \geq 0$ and a travel time $t_{ij} \geq 0$ are given. Moreover, the fleet of vehicles is homogeneous and every vehicle is initially located and end its route at a central depot. Each customer demand is assumed to be less than the vehicle capacity Cap. The objective is to find an optimal set of routes (with the minimal cost) such that:

1. All routes start and end at the depot;
2. each customer in N is visited exactly once within its time window;
3. the total of customer demands for each route cannot exceed the vehicle capacity Cap.

The performance criteria are in general (following this order):

1. The number of vehicles used,
2. the total distance traveled,
3. the total waiting time.

Since the problem is NP-hard, exact approaches are only of theoretical interest, and heuristics are performed in order to find good solutions, not necessarily optimal, within reasonable computational times. The VR-P and the VRPTW can be divided into two sets [20]: static problems and dynamic problems. The distinction between these two categories relies traditionally on the knowledge (static problem) or the ignorance (dynamic problem) before the start of the solving process of all the customers that have to be visited. The operational problems are rarely fully static and we can reasonably say that today a static system cannot meet the mobility

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