Particle Evolutionary Swarm Multi-Objective Optimization for Vehicle Routing Problem with Time Windows

Angel Muñoz-Zavala, Arturo Hernández-Aguirre, and Enrique Villa-Diharce
Centro de Investigación en Matemáticas (CIMAT)
Jalisco s/n, Mineral de Valenciana, C.P. 36240, Guanajuato, Guanajuato, México
aemz@cimat.mx, artha@cimat.mx, villadi@cimat.mx

Summary. The Vehicle Routing Problem with Time Windows (VRPTW), is an extension to the standard vehicle routing problem. VRPTW includes an additional constraint that restricts every customer to be served within a given time window. An approach for the VRPTW with the next three objectives is presented: 1) total distance (or time), 2) total waiting time, 3) number of vehicles. A data mining strategy, namely space partitioning, is adopted in this work. Optimal routes are extracted as features hidden in variable size regions where depots and customers are located. This chapter proposes the sector model for partitioning the space into regions. A new hybrid Particle Swarm Optimization algorithm (PSO), and combinatorial operators ad-hoc with space partitioning are described. A set of well-known benchmark functions in VRPTW are used to compare the effectiveness of the proposed method. The results show the importance of examining characteristics of a set of non-dominated solutions, that fairly consider the three dimensions, when a user should select only one solution according to problem conditions.

10.1 Introduction

In transportation management, there is a requirement to provide goods and/or services from a supply point to various geographically dispersed points with significant economic implications. The vehicle routing problem (VRP), first introduced by Dantzig and Ramser [1], is a well-known combinatorial optimization problem in the field of service operations management and logistics.

Vehicle Routing Problems (VRP) are all around us in the sense that many consumer products such as soft drinks, beer, bread, snack foods, gasoline, pharmaceutical products, etc., are delivered to retail outlets by a fleet of trucks whose operation fits the vehicle routing model. In practice, the VRP has been recognized as one of the great success stories of operations research and it has been studied widely since the late fifties.

The typical VRP can be stated as follows: design least-cost routes from a central depot to a set of geographically dispersed points (customers, stores, schools, cities, warehouses, etc.) with various demands. Each customer is to be serviced exactly once by only one vehicle, and each vehicle has a limited capacity. In practice, the problem is aimed at minimizing the total cost of the combined routes.
for a fleet of vehicles. Since cost is closely associated with distance, in general, the alternative goal is to minimize the distance traveled by a fleet of vehicles with various constraints.

The Vehicle Routing Problem with Time Windows (VRPTW) is a generalization of the VRP involving the additional constraint that every customer should be served within a given time window. Examples of practical applications of the VRPTW include school bus, taxi scheduling, courier delivery/pickup, airline fleet scheduling, industrial refuse collection, etc. The objective of the VRPTW is to minimize the number of vehicles and total distance traveled to service the customers without violating the capacity and time window constraints. A vehicle may arrive early, but it must wait until start of service time is possible.

Many research works on VRPTW solve the problem by a weighted-sum approach in which the number of vehicles is given implicit priority, and consequently the scoring procedure must prioritize this dimension of the problem. The VRPTW is naturally multi-modal, and neither dimension is fundamentally more important than the other from a theoretical perspective and even from a practical aspect.

This chapter proposes a natural interpretation of the VRPTW as a multi-objective problem that prevents the introduction of solution bias towards either of the problem dimensions that commonly affect the weighted sum methods. The Multi-Objective Optimization (MOO) approach generates a set of equally valid VRPTW solutions. These solutions represent a range of possible answers, with different numbers of vehicles, distances and waiting times. The decision maker, who makes the final decision among the alternatives, can decide which kind of solution is preferable under different problem conditions.

Several VRP approaches use a Euclidean distance to form clusters of customers, and then approximate a route that visits all the customers in the cluster. In this work, the customers are clustered by applying spatial data mining principles. Spatial Data Mining (SDM) means to discover interesting relationships between space and the non-space data. A new space partitioning technique, called sectors model, is proposed for grouping the customers in neighborhoods (clusters) according to their spatial location.

A MOO algorithm based-on Particle Swarm Optimization (PSO) and Pareto dominance is introduced to solve the VRPTW. The rest of this chapter has the following structure: in Section 10.2 we give a formal definition of the VRPTW. Section 10.3 provides an overview of MOO research. The outline of our algorithm is presented in Section 10.4. Also Section 10.4 describes the sectors model technique. In Section 10.5 we present and analyze the experimental results performed. Finally, we draw some overall conclusions and suggest directions for future work in Section 10.6.

10.2 Vehicle Routing Problem

The Vehicle Routing Problem concerns the transportation of items between depots and customers by means of a fleet of vehicles. In general, solving a VRP