Metaheuristic Approaches for Vehicle Routing Problems

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ABSTRACT

Routing of service vehicles are the heart of many service operations. Exclusively vehicle routing problem (VRP) plays a central role in the optimization of distribution networks. The routing of service vehicles has a major impact on the quality of the service provided. In distribution of goods and services, it is time and again required to determine a combination of least cost vehicle routes through a set of geographically scattered customers, subject to side constraints. The case most commonly studied is where all vehicles are identical. Due to the complexity involved in solving the VRP, most researchers concentrate on using meta-heuristics for solving real-life problems. In this paper, heuristic methods based on Ant Colony Optimization and Simulated Annealing algorithms are developed and search strategies are investigated. Computational results are reported on randomly generated problems. These methods significantly improve in minimizing the total distances travelled by the vehicles.

Keywords: Ant Colony Algorithm, Ant Colony Optimization, Meta-heuristics, Simulated Annealing, Vehicle Routing Problem

INTRODUCTION

Transportation comprises a significant fraction of the economy of most developed nations. The economic importance has motivated both private companies and academic researchers to vigorously pursue the use of operations research and management science to improve the efficiency of transportation. For some services such as school buses, trucking firms, postal service, public health nursing and many installation or repair businesses and service delivery is critical to the performance of the service. Various modes of transportation exist including air, rail, ship and motor vehicle. The research on transportation has focused on different issues in each mode. The literature on both motor vehicles and ships has focused on a common problem i.e., the efficient use of a fleet of vehicles that must make a number of stops to pick up and/or deliver passengers or products. Finding efficient routes is an important transportation problem, which has been studied for several decades. Hence, transport operators in the real world face many constraints. When a firm is able to reduce the length of its delivery routes or is able to decrease its number

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of vehicles, it is able to provide better serve to its customers, operate in a more efficient manner. Many practical transport logistics and distribution related issues can be formulated as a vehicle routing problem whose objective is to obtain a minimum cost route plan serving a set of customers with known demands. Each customer is assigned to exactly one vehicle route and the total demand of any route must not exceed the vehicle capacity.

The vehicle routing problem (VRP) concerns the transport of items between depots and customers by means of a fleet of vehicles. Examples of VRPs are: milk delivery, mail delivery, school bus routing, solid waste collection, heating oil distribution, parcel pick-up and delivery, dial-a-ride systems, and many others. Although finding the most cost efficient way to distribute goods across the logistic network is the main objective of supply-chain systems, only in the early '90s enterprise resource planning software vendors started to integrate tools to solve the VRP in supply chain management software. The practical interest of the VRP includes a number of studies, which tackled the problem from many sides.

**ROUTING AND VEHICLE ROUTING PROBLEMS**

Routing problems are often presented as graphical networks. The use of networks to describe these problems has the advantage of allowing the decision maker to visualize the problem under consideration. As an example, refer to Figure 1 (see Figure 1 in the Appendix). The Figure 1 (see Figure 1 in the Appendix) consists of five circles called nodes. Four of the nodes (node 2 through 5) represent pickup and/or delivery points, and a fifth (node 1) represents a depot node, from which the vehicle’s trip originates and ends. The depot node is the home base, from which the vehicle originates and ends.

The depot node is the home base for the vehicle or product. Connecting these nodes are line segments referred to as arcs. Arcs describe the distance required to travel from one node to another. The numbers along the arcs in Figure 1 (see Figure 1 in the Appendix) are distances in kilometres. Directed arcs represent the direction of travel in routing problems. The small network in Figure 1 can be viewed as a route for a single vehicle. The route for the vehicle, also called a tour, is 1-2-3-4-5-1. The total distance for tour is 51 kilometres.

The tour described in Figure 1 (see Figure 1 in the Appendix) is a solution to a simple routing problem where the objective is to find the route that minimizes cost or any other criterion that may be appropriate. The minimum-cost solution, however, is subject to the tour being feasible. Feasibility depends on the type of problem, but, in general, implies that:

1. A tour must include all nodes;
2. A node must be visited only once;
3. A tour must begin and at a depot.

The output of all routing systems is the route of each vehicle. Generally, the route specifies the sequence in which the nodes (or arcs) are to be visited.

Restricted capacity of multiple vehicles and couple with it the possibility of having varying demands at each node, the problem is VRP. The classic VRP expands the multiple traveling salesman problems to include different service requirements at each node and different capacities for vehicles in the fleet. Given the existence of these very real problems, the solution no longer seems as simple. It is obvious that solution approaches and techniques are needed that allow the decision maker to consider a multitude of variables and adapt to changes quickly and efficiently.

**INDUSTRIAL IMPLICATIONS**

Finding efficient vehicle routes is a representative logistics problem which has been studied for the last 40 years. Effectively transportation management is more vital for a number of reasons. Among them first, transportation is one
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