An Ant Colony Optimization and Hybrid Metaheuristics Algorithm to Solve the Split Delivery Vehicle Routing Problem

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ABSTRACT

Split Delivery Vehicle Routing Problem (SDVRP) is a relaxation of the Capacitated Vehicle Routing Problem (CVRP) that allows the same customer to be served by more than one vehicle. Existing literature has applied Ant Colony Optimization (ACO) and Genetic Algorithm (GA) to other variants of VRP but no known research effort has applied ACO or a combination of ACO and GA to solve the Split Delivery Vehicle Routing Problem (SDVRP). Hence, two algorithms using ACO and hybrid metaheuristics algorithm comprising a combination of ACO, Genetic Algorithm (GA) and heuristics is proposed and tested on existing benchmark SDVRP problems. The results indicate that the two proposed algorithms are competitive in both solution quality and solution time and for some problem instances, the best ever solutions have been found.

KEYWORDS

Ant Colony Optimization, Genetic Algorithm, Metaheuristics, Optimization, Split Delivery Vehicle Routing Problem

DISCLAIMER

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INTRODUCTION

The Vehicle Routing Problem (VRP) is a prominent problem in the area of logistics, operations research, and transportation management. With an objective to minimize the delivery cost of goods to a set of customers from depot(s), numerous variants of the VRP have been developed and studied over the years. One such variant is the Capacitated Vehicle Routing Problem (CVRP) where the objective is to minimize the cost of delivering a single product to a set of customers from a single depot using a homogenous fleet of vehicles (Liu et al., 2009). The Split Delivery Vehicle Routing Problem (SDVRP) is a relaxation of the Capacitated Vehicle Routing Problem (CVRP). In the case of a CVRP, each customer is served by only one vehicle, whereas in SDVRP, the customer demand can be split between vehicles.
Several heuristic methods such as a construction heuristic (Wilck and Cavalier, 2012a), a genetic algorithm (Wilck and Cavalier, 2012b), and Tabu search algorithm (Archetti et al., 2006) have been applied to solve the SDVRP. An IEEE conference proceeding paper by Sui et al. (2008) presents an ant colony optimization (ACO) approach for the SDVRP but does not present empirical results compared to published methods. Hence, an ACO approach for the SDVRP is developed and further, by using the initial set of population (vehicle routes) generated by ACO, a hybrid metaheuristics algorithm comprising a combination of genetic algorithm and heuristics is applied to discover a more optimal vehicle route. The capability of the proposed algorithms is tested on different benchmark test problems found in the literature.

SDVRP Formulation, Literature Review, and Benchmark Data Sets

SDVRP Formulation

SDVRP was first developed by Dror and Trudeau (1989; 1990). They showed that if the demand is relatively low compared to the vehicle capacity and triangular inequality holds, an optimal solution exists in the SDVRP in which two routes cannot have more than one common customer. In addition, it was proven that the SDVRP is a NP-hard problem (Archetti et al., 2005; Archetti and Sperenza, 2012) and there are potential savings in solving instances of the problem in terms of both minimizing the total distance traveled in serving all demands as well as the total number of vehicles used. As an NP-hard problem, the SDVRP increases in combinatorial complexity as the problem size grows (Archetti et al., 2005). This makes finding an optimal solution technique difficult and the SDVRP is a candidate for the application of metaheuristic algorithms that cannot necessarily guarantee the discovery of an optimal solution, but that do efficiently search the solution space of complex problems for improved solutions (Griffis et al., 2012).

According to Aleman et al. (2010), the SDVRP is defined on an undirected graph \( G = (V, E) \) where \( V \) is the set of \( n \) nodes of the graph and \( E = \{(i, j); i, j \in V, i < j\} \) is the set of edges connecting the nodes. Node 1 represents a depot where a fleet \( M \) of identical vehicles with capacity \( Q \) are stationed, while the remaining node set \( N = \{2, \ldots, n\} \) represents the customers. A non-negative cost, usually a function of distance or travel time, \( c_{ij} \) is associated with every edge \((i, j)\). Each customer \( i \in N \) has a demand of \( q_i \) units. The optimization problem is to determine which customers are served by each vehicle and what route the vehicle will follow to serve those assigned customers, while minimizing the operational costs of the fleet, such as travel distance, gas consumption, and/or vehicle depreciation. The most frequently used formulations for SDVRP found in literature are from Frizzell and Giffin (1992), and Dror et al. (1994).

In this paper, SDVRP flow formulation is adapted from Wilck and Rajappa (2010). This formulation assumes that \( c_{ij} \) satisfies the triangle inequality and that exactly the minimum number of vehicle routes, \( K \), is used. The formulation does not assume that the distances are symmetric.

Indexed Sets:

\[
i = \{1, 2, \ldots, n\} \text{; node index; 1 is the depot}
\]
\[
j = \{1, 2, \ldots, n\} \text{; node index}
\]
\[
k = \{1, 2, \ldots, m\} \text{; route index}
\]

Parameters:

\( m \): The number of vehicle routes
\( n \): The number of nodes
Application of Hybrid Firefly Algorithm-Tabu Search Technique to Minimize the Makespan in Job Shop Scheduling problem

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