An Improved Genetic Algorithm for Solving Multi Depot Vehicle Routing Problems

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ABSTRACT

The classical Vehicle Routing Problem (VRP) tries to minimise the cost of dispatching goods from depots to customers using vehicles with limited carrying capacity. As a generalisation of the TSP, the problem is known to be NP-hard and several authors have proposed heuristics and meta-heuristics for obtaining good solutions. The authors present genetic algorithm-based approaches for solving the problem and compare the results with available results from other papers, in particular, the hybrid clustering based genetic algorithm. The authors find that the proposed methods give encouraging results on all these instances. The approach can be extended to solve multi depot VRPs with heterogeneous fleet of vehicles.

KEYWORDS

Genetic Algorithm, Heterogeneous Fleet, Hybrid GA, Multi Depot VRP

1. INTRODUCTION

The classical Vehicle Routing Problem (VRP) is one of finding a minimum cost set of routes from a depot to a set of customers, visiting each customer exactly once to satisfy demand, and using vehicles with limited capacity. The paper by Dantzig and Ramser (1959) was the first to address this problem under the title “The Truck Dispatching Problem”. As a generalization of the Traveling Salesman Problem (TSP), the VRP is known to be NP-hard. The problem has practical applications in the logistics function of firms where items are to be dispatched from one or more depots to customers at scattered locations. The problem is further challenging when there are multiple depots, and the manager also needs to decide the assignment of each customer to one of the depots. The availability of vehicles with different carrying capacities and cost structures adds further to the complexity, both in theory and in practice.

Genetic Algorithms (GAs) have been widely used to solve such discrete optimization problems. However, we note that much of the VRP research has focussed on the single depot case. While some researchers have addressed the problem of multi-depot VRP (MDVRP), they often make the simplifying step of pre-assigning the customers to the nearest depot and then solving the problem as a collection of single depot problems. We show that this approach may not always be optimal.

The present paper contributes to the research by providing a generic approach to the application of GA approach to solving the multi-depot VRP. The proposed representation schema for GA is flexible to allow (i) an assignment of customers to the optimal depot rather than to the closest depot,
and (ii) an assignment of vehicles to each trip from a set of heterogeneous vehicles with different capacities, speeds, and cost structures. As in the hybrid approach by Prins’ (2004), the chromosome structure used in the paper does not have trip delimiters. Rather, a feasible sequence of customer visits is generated using various crossover operators, and then from the optimal GA solution, the optimal feasible trips are generated for each depot by finding the shortest path in the corresponding auxiliary graph (Prins, 2004). The proposed GA variants are tested on standard test data to assess their performance.

This paper is organized as follows: in section 2, we present a detailed review of the literature on MDVRP. In section 3, we present a description of the problem addressed in this paper and a mathematical formulation. In section 4, a numerical example is presented showing the optimal routes for visiting customers. In section 5, we describe the various genetic algorithms and a hybrid GA for solving MDVRP. In section 6, we compare the results obtained from various authors. Finally, in section 7, we conclude the paper.

2. LITERATURE REVIEW

Earlier research on multi-depot VRP can be seen in the decade of 1970’s from the works of Cassidy and Bennet (1972), Wren and Holliday (1972), and Gillett and Johnson (1976). The works of Laporte et al. (1984), Kulkarni and Bhave (1985), Laporte et al. (1988), Renaud et al. (1996), Cordeau et al. (1997) and Salhi and Sari (1997) can be considered as pioneering in MDVRP. Due to the complexity of the problem, MDVRP has continued to attract the interest of researchers (Skok et al., 2000a; Dondo et al., 2003; Tarantilis et al., 2004; Nagy and Salhi, 2005; Ho et al., 2008; Kek et al., 2008; Liu and Shen, 1999; Contardo and Martinelli, 2014; Rahimi-Vahed et al., 2015). Several heuristics for solving the problem can be found in the literature (Crevier et al., 2007; Ramalingam and Vivekanandan, 2014; Salhi et al., 2014). Among the recent works, Malairajan et al. (2013) proposed a decision support system for real-time VRP with backhaul for the Indian dairy industry. Saravanan and Sundararaman (2013) developed heuristics methods based on Ant Colony Optimization and Simulated Annealing algorithm to solve the VRP. Golias et al. (2013) deal with the scheduling of inbound and outbound trucks to the available inbound and outbound doors at a crossdock facility. A memetic algorithm has been developed to solve the resulting problem with reasonable computational effort. Table 1 provides a summary list of select publications in this area along with the heuristic approach used to solve the MDVRP.

A strong presence of GA can be observed in the literature of VRP (Thangiah et al., 1991; Blanton and Wainwright, 1993; Jeon et al., 2007; Salhi and Petch, 2007; Pasandideh and Niaki, 2010; Lau et al., 2010). Thangiah and Nygard (1992) reported an application of GA in bus routing problem. Thangiah and Gubbi (1993) presented the effect of genetic sectoring on vehicle routing with time windows. Potvin et al. (1996) addressed the use of hybrid GA with neural network for solving VRP. Sivakumar et al. (2013) explored a multistage supply chain considering two-stage collection and distribution model with capacity constraint. Optimization at both the stages is done using GA.

GA has also been used to solve multi-depot VRP (Salhi et al., 1998; Skok et al., 2000(a); Skok et al., 2000(b); Ombuki-Berman and Hanshar, 2009; Surekha and Sumathi, 2011). Skok et al. (2000a) solved the multi-depot capacitated VRP by using steady-state GA. They used several crossover and mutation schemes, of which cyclic crossover, fragmented reordering crossover, and scramble mutation were found to perform better over the others. Dondo and Cerda (2007) presented a heuristic based clustering algorithm for the multi-depot routing problem with time window and heterogeneous vehicles service time constraints. However, GA does not seem to have a great impact on multi-depot VRP with non-homogeneous fleets.

Thangiah and Salhi (2001) were among the researchers who initiated the clustering approach for solving MDVRP with a fixed destination. They proposed a genetic clustering adaptive heuristic for solving the problem. Ho et al. (2008) proposed two different hybrid GAs for multi-depot VRP where
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