



An ant colony optimization model: The period vehicle routing problem with time windows

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ABSTRACT

This paper proposes an improved ant colony optimization (IACO) to solve period vehicle routing problem with time windows (PVRPTW), in which the planning period is extended to several days and each customer must be served within a specified time window. Multi-dimension pheromone matrix is used to accumulate heuristic information on different days. Two-crossover operations are introduced to improve the performance of the algorithm. The effectiveness of IACO is evaluated using a set of well-known benchmarks. Some of the results are better than the best-known solutions. Results also show the IACO seems to be a powerful tool for PVRPTW.

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1. Introduction

Vehicle routing problem (VRP), related to many real-life applications, holds an important place in operation research (Laporte, 2009). Vehicle routing problem with time windows (VRPTW) is a well-known generalization of VRP where each customer must be served within a specified time window. VRPTW has been widely studied both in theoretical researches and practice applications in the last 20 years (Bräysy and Gendreau, 2005a,b; Liu et al., 2009).

In VRP or VRPTW, each customer is visited exactly once during the same planning period (a single day). Differing from standard VRP or VRPTW, the VRP with multiple periods (e.g. 1 week) is defined as PVRP. PVRP has extensive real-world applications, including the collection of waste, the distribution of equipment for intermodal operations, elevator maintenance and repair, and vending machine replenishment (Francis et al., 2008).

Early heuristics for PVRP are proposed by Beltrami and Bodin (1974), Russell and Igo (1979). Chao et al. (1995) presented a two-stage heuristic which consisted of initial solution construction phase and solution improvement phase. In the first phase, they assigned delivery day combinations to customers by solving an integer programming problem. Then, some strategies were used to improve the solution. Baptista et al. (2002) presented a case study of PVRP which was about the collection of recycling paper containers in the Almada Municipality, Portugal. Compared with classical PVRP, a novel feature of their case was that the frequency of visits to containers was considered as a decision variable in their model. Similarly, Francis et al. (2006) presented a special PVRP in which service frequency of customer was variable. They modeled the PVRP with service choice (PVRPSC) in which service frequency was a decision variable, and developed an exact solution method with heuristic variations for PVRPSC. Matos and Oliverira (2004) applied the Ant System in PVRP and presented a new updating strategy of pheromone information. Then, they tested their algorithm by a waste collection system involving 202 locations in

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the municipality of Viseu, Portugal. Other heuristics for PVRP were developed by Paletta (1992, 2002); Blakeley et al. (2003), Bertazzi et al. (2004), Drummond et al. (1999), Hadjiconstantinou and Baldacci (1998), Russell and Gribbin (1991).

The focus of this paper is on the period vehicle routing problem with time windows (PVRPTW), which is a generalization of PVRP. In PVRPTW, each customer can be served more than once within a specified time window during the planning period of several days. To the best of our knowledge, there is little literature to use heuristics for PVRPTW.

Ant colony optimization (Dorigo et al., 1996) is an artificial intelligence procedure inspired from food-seeking behaviors of ant colonies in nature. It has been successfully applied to some classic compounding optimization problems, e.g. traveling salesman (Dorigo et al., 1996; Stützle and Hoos, 2000), telecommunication routing (Schoonderwoerd et al., 1997), product design (Albritton and McMullen, 2007), etc. Recently, it has also been applied to solve VRP or VRPTW. Bullnheimer et al., 1997; Bullnheimer et al., 1999 presented an Ant System to solve the vehicle routing problem; Bell and McMullen (2004) presented an ACO with multiple colonies for VRP; Yu et al., 2009; Yu et al., in press presented an improved ACO, introduced ant-weight updating strategy and mutation operation, to solve VRP. Further researches were interested in ACO for VRPTW. Chen and Ting (2006) presented a hybrid algorithm combined ant colony system (ACS) and simulated annealing algorithm for VRPTW. Gong et al. (2007) presented a two-generation ACS for VRPTW. In their algorithm, the sub-tours were constructed during the child generation, while the feasible route was constructed during the parent generation. Tan et al. (2005) presented an improved ACS to solve VRPTW, in which two respective ant colonies were used to identify a multiple objective minimization. Zhu and Zhen (2009) presented a hybrid ACS with dynamic sweep algorithms for VRPTW. Qi and Sun (2008) proposed an ACS with a randomized algorithm for VRPTW.

This paper aims to test the feasibility of ACO in PVRPTW. The remainder of the paper is organized as follows. In Section 2 we describe PVRPTW. In Section 3, ACO and some improvement strategies are presented. In Section 4, some computational results are discussed and lastly, the conclusions are provided in Section 5.

2. Problem description

Standard PVRPTW can be considered to have a fleet of identical vehicles starting, serving customers and ending at the depot in each day; every customer node can be visited exactly once in the same day; customer demands can be satisfied in the period and can be serviced according to its service frequency. Moreover, service time of each customer must meet the time window constraints. An implicit constraint on the tours is that the total demand of a tour cannot exceed vehicle capacity.

PVRPTW is different from VRPTW in that the planning period for all customers is not a single day but a period of several days. The service frequency of each customer could be different, e.g., either once, twice, or three times. Fig. 1 shows an example for PVRPTW. The planning period is set to 3 day. There is a depot and 15 customers in the example. The service frequency of each customer could be once, twice, or three times, i.e., each type of customers has different service schedules.

For PVRPTW, it is important how to serve all the customers during period under the capacity and time constraints, etc. Firstly, the combination of customers on each day should be determined. Then, for the customers required service on each day the routes of vehicles are optimized like standard VRPTW, respectively. From the literature on VRPTW, there are two

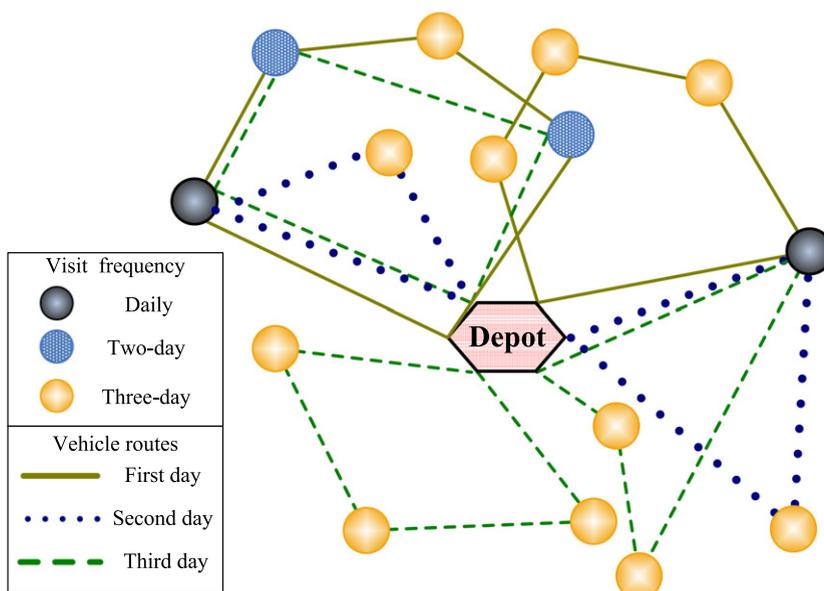


Fig. 1. An example for period vehicle routing problem.

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