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Discrete Optimization

A fast heuristic for solving a large-scale static dial-a-ride problem under complex constraints

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Abstract

This paper presents a heuristic, which concentrates on solving a large-scale static dial-a-ride problem bearing complex constraints. In this heuristic, a properly organized local search strategy and a diversification strategy are used to improve initial solutions. Then the improved solutions can be refined further by an intensification strategy. The performance of this heuristic was evaluated by intensive computational tests on some randomly generated instances. Small gaps to the lower bounds from the column generation method were obtained in very short time for instances with no more than 200 requests. Although the result is not sensitive to the initial solution, the computational time can be greatly reduced if some effort is spent to construct a good initial solution. With this good initial solution, larger instances up to 2000 requests were solved in less than 10 hours on a popular personal computer.

Keywords: Transportation; Vehicle routing problem; Dial-a-ride problem; Heuristics

1. Introduction

In this paper, we consider a kind of dial-a-ride problem (DARP) which involves scheduling a heterogeneous vehicle fleet and a group of drivers with different qualifications based at a single depot to cover the transportation requests of customers. After negotiating with the agency, the customer specifies the pickup time window and the tolerable extra travelling time on the trip. Customers of different types may require different type of accommodations. Each type of vehicle varies in the number and the type of accommodations and it can only be driven by the corresponding qualified

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drivers. Drivers are under the constraints of the maximum driving duration of one trip, the break time between two successive trips and the upper bound of the accumulated driving time in one servicing horizon (e.g., one day). To the authors' knowledge, these real life constraints are seldom discussed together in literatures, especially the matching among customers, vehicles and drivers. The aim of the scheduling is to find the least cost trips to serve the maximum number of customers.

The DARP is a generalization of the capacitated pickup and delivery problem with time windows, which was first examined by Wilson et al. (1971). Thereafter, extensive studies were carried out over the past three decades (see the recent reviews of Desaulniers et al., 2002; Cordeau and Laporte, 2002). Since in practice the transportation requests are usually known in advance, most of the work has focused on static DARPs. However, a fast static algorithm is also very helpful for dynamic scenarios, where schedules are adjusted in real time.

Although the DARP is NP-hard (Healy and Moll, 1995), efforts were still made to get exact solutions. Early approaches (Psaraftis, 1980, 1983a,b) focused on solving single-vehicle problems using pure dynamic programming (DP) method. Then Desrosiers et al. (1986) introduced the concept of *dominance* to reduce intermediate states. This technique greatly speeds up the DP process if the problem subjects to strong constraints. Based on this work, some multi-vehicle problems can be exactly solved by the combination of the column generation (CG) method and the branch-and-bound process (Dumas et al., 1991). Instead of using the DP algorithm, some heuristics can also be used to get approximate solutions of the auxiliary subproblem (SP) in the CG framework (Savelsbergh and Sol, 1998; Xu et al., 2003). Thus, this method is capable of approximately solving large-scale and less strongly constrained problems.

Owing to the complexity of the DARP, the most popular approaches are still varieties of heuristics, which are usually characterized with two phases: a construction phase in which an initial schedule is obtained, and a tuning phase in which the solution is improved further.

In the construction phase, the techniques of sequential insertion (Jaw et al., 1986; Nanry and Barnes, 2000; Cordeau and Laporte, 2003) and parallel insertion (Roy et al., 1984a,b; Toth and Vigo, 1997) are commonly used, according to a certain criterion, e.g., the nearest distance or the minimum cost. The concept of *cluster first and route second* (Bodin and Sexton, 1986) may also be introduced into this step, in which the geographically close customers are grouped together before applying the single vehicle routing algorithm to each cluster. To overcome the difficulty arising from the dispersion of the two locations (pickup and delivery) represented by each customer, the use of mini-clusters is recommended (Dumas et al., 1989; Desrosiers et al., 1991; Ioachim et al., 1995).

In the tuning phase, the solution is improved by some local searches, which consist of intra-trip exchanges and inter-trip exchanges. The intra-trip exchanges adjust the sequence of stops within a single trip. The corresponding algorithms are usually based on Lin's (1965) λ-opt mechanism, which can be accomplished in $O(n^{\lambda})$ time (n is the number of stops in a trip). Several modifications were also developed, such as the algorithms of Lin and Kernighan (1973) and Or (1976). The inter-trip exchanges involve the exchange of stops among multiple trips. The details can be found in the work of Van Breedam (2001) and Kinderwater and Savelsbergh (1997).

Classical heuristics use only some local searches in a descent way, i.e., the value of the objective function at current iteration step is better than those at previous steps. The final result is usually observed as local optimum and is sensitive to the initial solution (Van Breedam, 2001). Modern heuristics, on the contrary, can temporarily accept some worse solutions during the optimization procedure. Thus, it is possible to drive the search out of local optima. The rules for accepting the worse solutions are termed *diversifications*. And these modern heuristics are often called *meta-heuristics*, for example, the simulated annealing (SA) (Kirckpatrick et al., 1983), the genetic algorithm (GA) (Holland, 1975), the Ant algorithm (AA) (Dorigo et al., 1991), the Tabu search (TS) (Glover and Laguna, 1997), the guided local search (GLS)