An Iterated Local Search Algorithm for the Dial-A-Ride Problem with Transfers

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1 Introduction

The Dial-A-Ride Problem (DARP) models an on-demand passenger transportation system in which a set of passenger transportation requests must be met at minimum cost. Each request consists of two points: a pick-up place and a destination place. A set of identical vehicles of capacity Q is available to service the requests. Passengers can share one vehicle as long as its capacity is respected. The solution of the DARP consists of a set of routes satisfying all passenger requests and minimizing the cost. Additional constraints can be taken into account in the problem formulation, e.g. the time windows in which the vertices can be visited by a vehicle, the maximum trip duration between the pick-up and the delivery or the latest arrival time to the delivery place. These constraints reflect the comfort of passengers, which is an important attribute of the system in its real-life applications.

The DARP with transfers (DARPT) is an extension of the DARP which involves the possibility of passengers to change vehicles during their trips. This transfer might be performed through transfer points situated in the network. Both the DARP and the DARPT are NP-hard since they are a generalization of the Vehicle Routing Problem (VRP).

Practical applications of the DARPT can be situated to city or rural areas. In cities the transportation system can offer the service to handicapped or elderly people for which the public transport is accessible with difficulties. In rural areas the DARPT-based transportation system can provide an alternative to an individual car transport. For an illustration of the rural application consider a transportation company providing regular bus or train connections between cities or towns. For people resident in a countryside the only possibility to get to the nearest town is often to use their own car. In that case people might prefer to make the whole trip by car instead of using a regular connection for a part of their journey. On the other hand, if the transportation company provided the on-demand transport from the home to the regular connection and vice versa, some people would prefer this service instead of the individual transport.

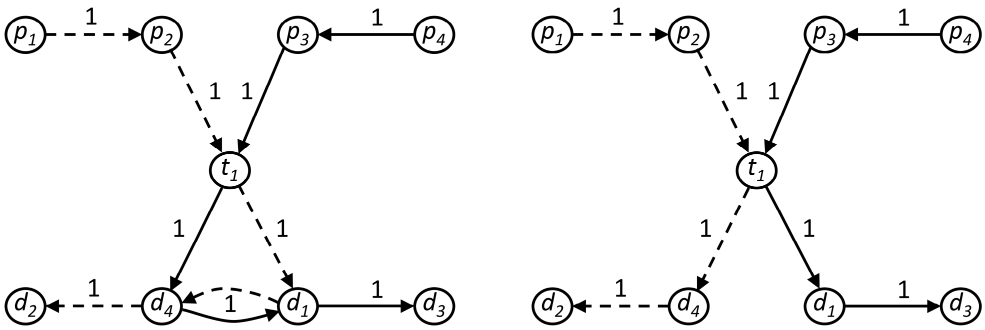
The DARPT tackled in this paper is motivated by the rural application. The problem is formulated on a complete directed graph $G(V, A)$. The set of vertices V is composed by a subset of pickup points P, a subset of delivery points D, a subset of transfer points T and a depot vertex denoted 0. A set K of identical vehicles of capacity Q is available at the depot. Each arc $a(i, j) \in A$ has assigned a nonnegative travel cost c_{ij} and a nonnegative travel time t_{ij}. A request $r \in R$ is defined by a pair $(i, j) : i \in P, j \in D$, a maximum trip time U_r and a latest arrival to the delivery place L_r.

The difference between the DARP and the DARPT is illustrated in Figure 1. The example consists of four pickup points (p_1, p_2, p_3, p_4), the corresponding delivery points (d_1, d_2, d_3, d_4) and a transfer point t_1. The available arcs have all equal cost 1. Figure 1a shows a solution in which transfers passengers are not allowed. The solution consists of two routes and its total cost is 10. Figure 1b presents a solution which uses the transfer point. Requests (p_1, d_1) and (p_4, d_4) are exchanged in t_1 and the total cost is 8.

The literature related to the DARPT is not large. Due to the problem complexity, most solution algorithms are metaheuristics. An Adaptive Large Neighborhood Search is presented in [3, 4]. An insertion algorithm was proposed in [1].

2 The Iterated Local Search Algorithm

Iterated Local Search (ILS) [2] is a simple metaheuristic framework based on the idea that an iterative search in the solution space $\mathcal{S}$ has the ability of finding far better solutions than a simple



(a) A DARP solution, cost = 10. (b) A DARPT, cost = 8.

Fig. 1: Illustration of the benefits of transfers.

random walk in $\mathcal{S}$. The ILS constructs a chain of solutions using three key components: a perturbation, a local search and an acceptance criterion evaluation. The perturbation makes small changes in the current solution s^* and returns an intermediate solution s'. The local search is then applied to s' if the resulting solution s passes the acceptance criterion test, s^* is replaced with s. The perturbation is usually parametrized such that the strength of the perturbation can be controlled during the search.

In the present application the perturbation consists of the removal and reinsertion of p requests from a route. If the request is split into two routes due to a transfer, the corresponding transfer point is removed together. The reinsertion into another route is then executed. The feasibility of the solution is preserved.

The local is composed of a set of operators applied sequentially to a solution:

1. Vertex relocate: relocates one or two vertices within the same route,
2. Vertex exchange: exchanges a pair of vertices within the same route,
3. Request relocate: relocates either a part of the request (pickup or delivery) or the entire request,
4. Request exchange: exchanges a pair of requests or a part of them (pickup or delivery or a combination of both).

Request relocate and request exchange operate on a pair of routes. If the operation involves only a part of the request, it must be checked whether a transfer point must be visited in the affected routes. If yes, the cost of the move is evaluated taking into account the insertion of the transfer point. The first improving move is performed and the search continues until no improvement is determined.

References

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