A hybrid method for the bi-objective Dial-A-Ride Problem with private vehicles and alternative nodes

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1 Introduction

This paper addresses an extension of the Dial-A-Ride Problem (DARP) [1] that use Private Vehicles and Alternative Nodes (DARP-PV-AN) in a bi-objective context. The classical DARP defines routes for a fleet of vehicles in order to transport a set of users from their pickup to their delivery locations. These transportation requests should be performed considering a number of operational constraints and taking into account the Quality of Service (QoS). A survey of recent works dedicated to the DARP can be found in [2]. In the DARP-PV-AN [3], the transportation requests can be performed either by a public fleet or by clients using their own vehicle (private vehicles). Moreover, the privacy of the clients is enforced by setting several potential pickup/delivery nodes (called alternative nodes) for each transportation request, masking the private address. In this paper, we consider the DARP-PV-AN in a bi-objective context where both the length of the routes and their cost have to be minimize. A hybrid metaheuristic based on NSGA-II [4] and integer linear programming for solving Set Covering Problem (SCP) is used on a set of instances.

2 Bi-objective DARP-PV-AN

The DARP-PV-AN is formally defined on a complete weighted digraph $G = (N, A)$, with a heterogeneous fleet F of K vehicles and a set R of n transportation requests. The graph is defined by the set of nodes $N = \{0,1, \dots, 2n\}$, with 0 representing the depot, and the set of arcs A. For each node $i \in N$, $[e_i; l_i]$ is its time windows (e_i is the earliest starting time and l_i is the latest starting time), its service duration is d_i and its demand is q_i. Given an arc $(i,j) \in A$ where $i,j \in N$, t_{ij} is the transportation time and c_{ij} is the transportation length (in our case, both are equivalent). The set of transportation requests $R = \{1, \dots, n\}$ is created such that for each request $r \in R$, its pickup node is r and its delivery node is $n + r$. Thus $P = \{1, \dots, n\}$ and $D = \{n + 1, \dots, 2n\}$ are, respectively, the pickup and the delivery subsets. Each vehicle k in the fleet F has a capacity Q_k. A subset $R' \subseteq R$ of clients can use their own vehicle, both for their request and for handling the requests of other clients. In case client $r \in R'$ uses its vehicle, the trip starts at r, stops at $n + r$ and the vehicle's capacity is Q_r. If the request $i \in R$ of a client is handled by a private vehicle, its privacy is ensured by a set of alternative pickup nodes N_i in addition to its initial pickup node i and a set of alternative delivery nodes N_{n+i} in addition to its initial delivery node $n + i$. For each client i transported by a private vehicle, a node $\lambda^+ \in N_i$ and a node $\lambda^- \in N_{n+i}$ have to be selected for the solution; the initial pickup i and the initial delivery $i + n$ nodes can only be used for the public fleet.

In our context, the bi-objective DARP-PV-AN has two objectives to minimize: the sum of all the distances travelled by the vehicles and the financial cost of each route. This financial cost is computed in two parts that depends of the vehicle used: (i) the number of clients transported by the vehicle and (ii) the distance travelled by the vehicle. Both objective are optimized simultaneously using scalar based method to obtain a good approximation of the Pareto front.

3 Numerical experiments

To solve this problem, we propose a hybrid method combining NSGA-II with the resolution of the SCP by integer linear programming. In our hybrid method, the NSGA-II part assign each client to its vehicle, then compute each trip by a branch and bound algorithm to find the best visiting order if it exists. The resolution of SCP is performed at the end of each generation of NSGA-II: it consists of selecting the best routes, among all computed ones, in order to generate new additional solutions introduced in the population before the next generation. Solving the SCP in the bi-objective context is performed by scalarisation methods, in order to transform it into the resolution of successive mono-objective SCP.

Different scalarization methods have been compared such as dichotomic weighted sum, ϵ-constraint, or the aggregation method proposed by [5]. Results show that using the SCP to generate new solutions at the end of each iteration of the GA improve both speed convergence and solutions of the algorithm. Moreover, the scalarization method proposed by [5] applied on the SCP provides the best Pareto Front on the DARP-PV-AN problem.

4 Concluding remarks

We presented a bi-objective version of the DARP-PV-AN that minimize the length of the computed route as well as their cost. A hybrid GA metaheuristics is proposed to compute solutions of good quality. Using the Set Covering Problem to generate new solutions of good quality with scalarization methods is shown to be effective in order to accelerate the convergence of the algorithm. Results are reported on a set of instances to show the impact of the proposed hybrid method on the DARP-PV-PN. Work is currently done on the method that compute the visiting order, using heuristic approaches instead of optimal ones to improve the speed convergence. This will allow the GA to perform more iteration and thus, solve larger instances.

References

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