Operational impact of in-advance travel requests dispatch optimization in Dynamic Demand Responsive Transportation

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1 Industrial Context

Nowadays, Demand-Responsive Transport companies can help the elderly or disabled citizens in their everyday journeys as well as provide an important link between big cities and their outer suburbs. In practice, many of those trips are scheduled in-advance (offline) but many others are asked on the fly (online) by the users while the drivers are already on their routes. To answer those online requests, dispatching centers often rely on fast heuristics based on some myopic objectives. However, this deteriorates the quality of the dispatch over time.

This work shows the potential of a re-optimization of the planning of the vehicles at the start of the day under the hypothesis that the operator is able to forecast the requests that will arrive during the service. The type of problem we are dealing with imposes to use a new objective that maximizes the expected acceptance rate of future requests, since the requests scheduled in-advance are mandatory. This objective function is incorporated in a Combinatorial Benders Decomposition to solve the Dynamic Dial-a-Ride Problem. A key ingredient for the success of this solver is the use of a new clustering-based initialization of the Master Problem.

The computational results show the effectiveness of this approach when applied to instances extracted from actual services provided by Padam Mobility, an international company working in Shared Mobility Systems. The proposed method provides a substantial performance gain though traditional heuristics are kept to manage online insertions afterwards.

2 Problem Description

The problem faced by Demand Responsive Transport companies is commonly known as the Dial-a-Ride Problem (DaRP). It is a Vehicle Routing Problem where a fleet of vehicles must serve a list of travel requests from pick-up to drop-off locations with respect to a time window and a service time at both places as well as a maximal ride time for each customer. The DaRP can be *static*, when all of the travel requests are known in-advance, or *dynamic*, when some of them are unknown during the optimization process. The latter describes the best our use case.

Our Mixed-Integer Linear Programming formulation of this problem is derived from the three-index formulation of J.-F. Cordeau [1] where we maximize the expected number of travel requests that can be inserted in the starting routes of the drivers. However, this model is too complex to solve as it is for real-world instances. In the literature, various approaches to solve such a model through the use of exact methods have been proposed to tackle this scaling issue: Branch-and-Cut, Branch-and-Price and Branch-and-Price-and-Cut paradigms notably [2].

Still, another way to look at this problem is to decompose it as one assignment problem per agent. This is the reason why we thought of applying a Combinatorial Benders Decomposition [3] approach to this problem. Furthermore, recent studies using this technique on similar problems have shown promising results, such as for the Selective Dial-a-Ride Problem [4].

3 Methodology

Our optimization framework is based on a Benders Combinatorial Decomposition paradigm with a Master Problem and one Sub-Problem per driver.

The Master Problem iteratively assigns to each agent a set of requests to serve based on the already known assignment constraints. On their side, each Sub-Problem checks its assignment and return Benders Combinatorial Cuts to the Master Problem when the provided assignment is not feasible. They also try to heuristically repair the current assignment when necessary.

The initialization of the Master Problem plays a major role with regards to the convergence of this process. One of our core focus has thus been to design an efficient heuristic in order to find Irreducible Infeasible Subsystems of requests to add to the initial pool of constraints. We also worked on improving the existing heuristics used to compute new Benders Combinatorial Cuts, to repair the broken assignments as well as to preprocess the underlying graph.

4 Computational Results

We tested our Combinatorial Benders Decomposition framework on benchmark instances [1, 4] as well as on 25 real-world instances provided by Padam Mobility. On the latter, ranging from small instances of 4 agents, 30 offline and 30 online requests up to 30 agents, 100 offline and 200 online requests, our solver has been able to solve more than 80% of them to global optimality and obtain a gap of only a few requests on most of the other instances in less than an hour.

We then considered for each real-world instance two ways to optimize the initial planning of the agents: one where it is computed solely with the in-advance requests and the traditional objective function that minimizes the Total Duration of the Rides, and another one where it is designed by maximizing the insertion rate of the expected online requests using our solver. We then compared those starting schedules by simulating the successive arrival of the online requests during the service's day using a classical greedy online insertion module based on the Total Duration of the Rides minimization to answer the users. Those simulations show that the initial plannings computed with our non-myopic objective function insert on average 11% more online requests than the ones computed with the traditional objective function. Furthermore, while the initial routes of the agents are on average 17% longer with our method, the final routes of the agents are only 7% longer on average while serving 11% more passengers.

Those results show the potential of working on new non-myopic optimization techniques.

References

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