Scheduling & routing by constraint programming & heuristics

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Abstract. Industrial applications of vehicle routing introduce challenging problems to be solved by many companies nowadays. Our goal is to find routing and schedules for orders coming from different customers while minimizing financial cost in contrast to more classical travel distances. The financial aspect plays an important role, given the common unavailability of the actual data for costs of transportations. The overall optimization process can profit from the consideration of several customers with their vehicle fleets at the same time. Even more, using financial costs allows handling external carriers without actual routing for them, and taking them into account using only their cost instead. Also, the dynamic aspect of the problem must be considered as new orders are coming each day, and changes may need to happen to original orders or vehicles. Altogether this constitutes a large scale problem where efficiency of applied techniques is essential. Our solution approach will be relying on a combination of constraint programming with heuristic or metaheuristic approaches. The important role will play an intelligent clustering of the problem based on characteristics of particular orders and vehicles.

Keywords: Scheduling · Vehicle routing · Constraint programming · Metaheuristics · Dynamic problem · Clustering

1 Introduction

This paper aims to describe the topic of my Ph.D. study and the problem we are going to explore. In my master thesis entitled "Scheduling of mobile robots using constraint programming" [9] we focused on a job shop problem extended with transportations and robot processing. We proposed a novel constraint programming (CP) model for this problem where a proper inclusion of transportation was shown to be crucial in achieving good performance.

We compared our model with the previous mixed integer programming approach [5] and found the CP approach to perform significantly better. We have also described our results in a paper submitted to the CP 2019 conference [10], where it was accepted.

During my Ph.D. study, we would like to focus on a combination of vehicle routing problem and scheduling. Our interests lie in the application of constraint programming extended by additional heuristics to solve large scale industrial problems. Due to the size of the problem, we will look increasingly into metaheuristic approaches to achieve a robust, fast, and scalable approach. We will consider a suitable method of implementation to be useful for our industrial partner.

2 Related work

We will explore existing approaches to pickup and delivery problems [11,12] as well dial-a-ride problems [4,2,8,3]. We will study dynamic vehicle routing problems [13] and their solution using different heuristics [19] and metaheuristics [15,18]. We will explore various search methods, concentrating on large neighborhood search [14] well applicable for large scale problems [1], and adaptive large neighborhood search [16], which was successfully applied to our problem of scheduling with mobile robots in our group [6]. We will also explore existing research regarding robust optimization [17,7] as robust schedules that can avoid potentially pricey adjustments are interesting for industrial use.

3 Problem description

The problem we are going to tackle is an industrial transport scheduling problem on a large scale. There are several customer companies, each with its fleet of trucks. Every customer has a set of new orders coming daily, where an order is a request for transporting goods from the origin to the destination specified by the geographic positions while satisfying pickup and delivery time windows as well as truck capacity.

Customers can make use of external carrier companies, which will serve orders for a contracted fee. These carriers are typically only employed once the customer truck capacity is depleted to avoid unnecessary charges. For orders assigned to external carriers, there is no need to compute routing for the order, as it is under the control of the external carrier (such as DHL).

To improve the quality of the customer solution, the customer can rent its free trucks to another customer. This type of reasoning makes the problem very complicated and leads to significant cost savings at the same time.

Every customer wants to optimize his/her solution. Therefore we have to think of the whole problem as a set of problems, one for each company. Once the customer has a solution, they will see if their fleet is in surplus or deficiency. Using this information, the customer will and lease out or rent trucks from other customers, or employ external carrier contractor.

The goal is to minimize the cost of transport for every customer, rather than the distance traveled. To compute the solution, each order, composed of the pickup and delivery, is assigned to a truck. The routing of the truck path is also a part of the solution. As a part of the solution, we need to decide what orders are to be assigned to external carriers in the case when internal capacity is not sufficient.

The problem needs to be solved dynamically because new scheduling happens every day based on new arriving data. The new data can be new incoming orders, cancellation, or changes of existing orders due to unexpected changes resulting from some latency in production or other problems.

This may result in changes to both non-departed and departed truck routes. Therefore, our solver needs to be able to take the current position of all trucks into account and be capable of extending or making changes to an existing solution with minimal impact.

An additional nontrivial difficulty is added into our routing and scheduling approach by the inclusion of the external data like current weather or road situation. This is yet another level of dynamism and is not typically explored in existing solutions.

4 Methodology

We will tackle the problem in multiple phases. First, we will solve the problem of scheduling and routing trucks for a single customer company. As a comparative solver, we will use solutions computed using Google's OR-Tools[1] which can be applied for simplified instances of our problem. Next, we would like to adapt our solver to be able to schedule all customer companies at the same time. However, since the problem we are solving can get rather large with an increasing number of customers and orders, we expect that the overall problem will be very hard to solve by means of both time and memory.

One possible solution to the scalability issues can be the use of a specific clustering. Therefore our next goal will be to develop an effective strategy to cluster the whole problem into smaller sub-problems. The problem can be naively clustered by regions, but we will also explore other, more sophisticated approaches such as clustering by pickup and delivery position together with time windows. Preliminary evaluation of the clustering approach can be achieved with the help of solution for each sub-problem computed using OR-Tools.

Next, we will need to adapt the solver for a single company we developed initially to be able to solve the sub-problem for a single cluster as well. Last but not least, we will reconsider our original clustering approach to adapt to all characteristics of the enhanced sub-problem solver.

We want to make use of constraint programming to solve this problem which may be hard to achieve due to the large size of the problem. Therefore we will also make use of heuristic methods like large neighborhood search and potentially combine the heuristics with constraint programming as a sub-solver.

5 Novelties

The problem we have discussed includes various novel characteristics not considered by many works before. Optimization by financial cost allows the customer

[1] https://developers.google.com/optimization/

to see the real impact on his/her business, in comparison with the traveled units of distance. This can lead to considerable cost improvements.

However, obtaining the data, that would enable optimization using financial cost is rather difficult. Fortunately, we will have access to complete data of such quality which will be provided by our industrial partner who is developing appropriate data manipulation tools reflecting the needs of the customers. This is not typical in industrial cases since obtaining particular financial costs of the transport can last even a few days, since it is handled manually per request rather than automatically.

Working with financial costs instead of travel distances also allows easy incorporation of the external carriers, since their cost can be directly included in optimization.

Next, sharing of the customer fleets allows the customer in surplus to make a profit from his/her available trucks. The customer in deficiency can make use of a cheaper alternative to external carriers by using trucks from the fleet of the other customers.

Application of dynamic approach is common in many research studies [13]. We would like to enhance our approach by the inclusion of additional data, which allow for a better quality of solutions. The dynamic scheduling can be built on an existing solution and extend or recreate it with the inclusion of the current road situation like weather, roadblocks, or any other exceptional events.

6 Conclusion

Our vehicle routing and scheduling introduce a complex and appealing problem of significant importance. By solving the problem, we can achieve not only saving in costs but also other positive impacts such as pollution or traffic decrease.

The aim is to discuss our ideas in a wide and expert audience to get feedback about the relevant research or existing tools. This can be very helpful given the early stage of this research, which is just now started both by this new Ph.D. study as well as new cooperation with the industrial partner.

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