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# Primal Heuristics for the Vehicle Routing Problem with Synchronized Visits

Sohaib Affi · Aziz Moukrim

**Abstract** The aim of the paper is to solve exactly a new variant of the vehicle routing problem with time windows which includes synchronization visits. A new formulation is proposed and solved using boosting methods. We propose some dedicated primal heuristics and node feasibility checks. The results compared to a previous formulation and to a standard solver show the efficiency of this type of combination.

## 1 Introduction

This paper provides a new solution method for a particular variant of the vehicle routing problem (VRP). The problem is called VRP with synchronized visits (VRPTWSyn). In addition to the time windows constraints, we consider that for some customers, we need more than one visit, e.g., two visits from two different vehicles are required to complete the service. Visits associated with a particular customer need to be synchronized, i.e. having the same start time.

VRPTWSyn was first studied by Bredström and Rönnqvist [6] considering an application in home-care services for elders. The authors proposed a mathematical formulation and studied the role of the synchronization constraints. As a continuity, the same authors proposed in [5] a branch-and-price algorithm. A meta-heuristic approach based on a simulated annealing schema with some dedicated local searches has been proposed by Affi et al. [2]. Later, Labadie et al. [8], in a preliminary work, proposed an iterative local search algorithm and presented some results on the small and medium sized instances. Rousseau et al. [9] considered a dynamic case of the problem and proposed a heuristic method with a constraint programming component. General perspectives of temporal constraints for vehicle routing can be also found in the survey [7] and in the paper [8].

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## 2 The method

The formulation presented in Bredström and Rönnqvist [6] uses  $\mathcal{O}(mn^2)$  binary variables and  $\mathcal{O}(mn^2)$  constraints, where  $n$  is the number of customers and  $m$  the number of vehicles. In this paper, we propose a new linear formulation for VRPTWSyn adapted from the one presented in Bard et al. [4]. It uses  $\mathcal{O}(n^2)$  binary variables and  $\mathcal{O}(n^2)$  constraints.

Beside the use of the light formulation, our aim in this work is to boost its execution by keeping the Branch-and-bound tree small and by discovering feasible solutions earlier in the process. Primal heuristics are a very important aspect for MIPs. We developed and tested a number of heuristics dedicated to our problem and discussed their integration into the branch-and-bound process. We count three types of primal heuristics: start heuristics, diving heuristics and improvement heuristics. Most of them explore the components developed and presented in [2].

Start heuristics aim at finding a feasible solution before the beginning of the tree exploration, usually at the presolving stage or at the root node. It uses the construction operator described in [2] and is run only at the beginning of the process.

Diving heuristics aim at finding a feasible solution early in the Branch-and-Bound-process without the need to branch on all the variables following the quickly go-down strategy. One can simply change the feasibility graph according to the fixed variables at the current node and then run the construction algorithm on the new reduced problem defined by this graph.

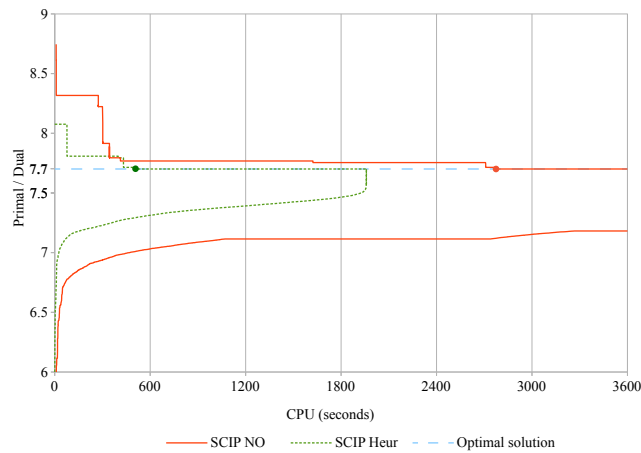
Improvement heuristics are algorithms that aim to form a new feasible solution of better objective value out of the current incumbent. This counts four neighborhoods which are randomly executed in some nodes, TwoOpt\*, OrOpt, Move and Exchange [2].

Another strategy is to keep the Branch-and-bound tree small by checking the feasibility of the current node using dedicated checkers which explore the problem specifications. In this path, we used the energetic reasoning and the clique methods proposed in [3] for the VRPTW. At every node a new problem is created considering the local constraints defined at the current node. Then either energetic reasoning or maximum clique are checked so the number of tours needed to serve all the visits respecting the current constraints should not exceed the maximum number of vehicles.

## 3 Experimentation

The experimentations are done on the standard instances of Bredström and Rönnqvist [6]. The benchmark, which was generated to simulate the scheduling problem in home-care services, comprises 10 data sets. Each contains three types of instances based on the size of the time windows. We implemented the branch-and-cut algorithm in C++ using the framework SCIP [1] with IBM ILOG CPLEX 12.6 as underlying LP solver. The program is compiled with GNU GCC in a Linux environment.

The heuristics presented here are able to generate feasible solutions quickly. They reduce the calculation time while keep improving the quality of the solutions. In the other hand, the feasibility check used can predict infeasibility in earlier stages and hence reducing the time used to improve the dual bound. Figure 1 shows an example on an average size instance and how introducing these techniques reduced considerably the cpu time on both sides, primal and dual solutions.



**Fig. 1** Development of the primal and dual bound, if MIP processes instance 6M, with default settings (continued line) and with our heuristics (dashed).

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