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Column generation based primal heuristics for routing and loading problems

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Abstract

In this paper, we explore a set of new heuristic strategies integrated within the column generation algorithm to solve the Capacitated Vehicle Routing Problem with 2-Dimensional Loading constraints. These heuristics rely on constructive procedures that iteratively build a solution using the solutions of a mixed integer linear programming model. The pricing subproblem is also heuristically solved, using strategies relying on variable neighborhood search algorithms proposed in literature. Column generation approaches for the 2L-CVRP are not quite explored. This paper aims to contribute with new strategies to tackle this problem. All the approaches were implemented and an exhaustive computational study is performed.

Keywords: vehicle routing problem, column generation, heuristics.

1 Introduction

Column generation algorithms may have very slow convergence for hard optimization problems. This limitation motivated several column generation based heuristics approaches. In some cases, the pricing subproblem is solved through

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heuristic methods, while in others the heuristics are applied in the space of the master problem, ensuring that the subproblem remains tractable. In this paper, we will give special emphasis to the latter type of heuristic methods. Two different methods were analyzed in [4]. The first one is the so-called restricted master heuristic which consists in confining the Restricted Master Problem (RMP) to a subset of columns and solving it as an integer programming formulation. The authors stated that this subset can be heuristically created or it can rely on the columns generated within the Linear Programming (LP) relaxation. Additionally, this confined subset can result from the combination of both procedures. However, the simple selection of a subset of columns can lead to infeasible solutions, and in this sense, some additional procedures may be needed. In contrast to the first method, the second one starts from an empty solution. It relies on the definition of heuristic procedures to select columns to be added to the RMP until a feasible solution is reached. Rounding heuristics are common examples of this method [8]. They consist in iteratively selecting a column with fractional value to take an integer value. However, and as stressed in [4], it can be difficult to achieve a feasible solution, and to overcome this limitation, several works make use of diving heuristics. These heuristics consist in fixing the variables to take a given value and solving again the LP relaxation of the RMP, which corresponds to a depth-first heuristic in the branching tree.

In the last decade, several contributions focused on the explicit consideration of loading constraints in the capacitated routing field [7]. In these approaches, loading specificities are considered by integrating the two- or three-dimensional bin packing problem with the capacitated vehicle routing problem. This integration is known in literature as the Capacitated Vehicle Routing Problem with Loading constraints (L-CVRP) [1,2,3]. The L-CVRP is NP-hard, and this complexity may explain the disparity between the lack of exact approaches and the large number of heuristic approaches. In the context of the L-CVRP with 2- or 3-dimensional Loading constraints (2L-CVRP and 3L-CVRP, respectively), it is usual to explicitly consider sequential constraints. These constraints impose that the demand of a given customer must be unloaded without unloading or moving items to be delivered later.

This paper is organized as follows. In Section 2, we define the problem tackled in this work. A set of column generation based heuristics for the 2L-CVRP is presented in Section 3, while in Section 4, exhaustive computational experiments are conducted. Finally, some conclusions are drawn in Section 5.