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A general purpose Lagrangian heuristic applied to the train loading problem

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Abstract

In this paper we face the train loading problem (TLP) at seaport terminals by proposing a general purpose Lagrangian heuristic. The TLP consists of assigning import containers to the trains departing from the terminal, maximizing the utilization of trains, minimizing the distance travelled by containers from their locations in the storage area to the wagons, as well as the number of needed unproductive movements of containers (re-handles). We define a 0-1 LP formulation consisting of a network flow model complicated by additional constraints. We design a Lagrangian heuristic, which exploits a mixed integer programming (MIP) heuristic to find a first feasible solution in an acceptable time and then to improve it. We show the effectiveness of this approach by comparing the obtained results with the ones provided by a state-of-the-art MIP solver.

Keywords: MIP heuristic; Train Loading Problem

1. Introduction

Mixed Integer Programming (MIP) is a valuable tool for formulating decision problems. In the last ten years the confidence in the possibility of using MIP for solving complex real world problems greatly increased due to the improvements showed by MIP solvers (Bixby, 2002). However, very often models for real world problems, even simplified, involve a large number of variables and constraints to make the use of available solvers not practical. Therefore, new heuristic methods for solving challenging MIP problems were proposed in literature. Among the most known, Local Branching (Fischetti & Lodi, 2003), Relaxation Induced Neighbourhood Search (Danna, Rothberg & Pape, 2005), Evolutionary Algorithm for Polishing (Rothberg, 2007) have been embedded in the Cplex MIP solver. These methods start from an initial feasible solution and perform a solution space exploration by iteratively executing local search (LS) steps in a neighbourhood of the incumbent solution carried

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out by solving MIP sub-problems. We recently proposed a simple but effective MIP heuristic, called Randomized Neighbourhood Search (RANS) (Anghinolfi & Paolucci, 2011), which was successfully applied to a planning problem in railway freight transportation (Anghinolfi, Paolucci, Sacone & Siri, 2011). Unfortunately, often also finding a starting feasible solution for large MIP problems turns out to be quite difficult. Rounding and diving methods (Berthold, 2006) and primal heuristics, as the Feasibility Pump (Fischetti, Glover & Lodi, 2005; Bertacco, Fischetti & Lodi, 2007), were designed to speed up the generation of a first integer feasible solution.

In this work we propose a new general purpose heuristic to face complex MIP problems by combining a primal heuristic, which exploits concepts from Lagrangian relaxation to determine a first feasible solution, with the RANS heuristic, which guides a MIP solver to rapidly improve such a solution. This approach has been defined and first applied to face the Train Load Planning (TLP) problem at a seaport container terminal. TLP regards the loading of import containers from the terminal storage area to trains. This process must be performed quickly and efficiently, and it involves the use and coordination of different types of handling equipment. According to the classifications proposed in several surveys (e.g., Stahlbock & Voss, 2008), the TLP problem deals with landside transport optimization at an operational level, as it considers the generation of detailed loading plans for the trains departing from the terminal. A loading plan assigns a subset of containers from the storage area to the wagons of a train taking into account the destination, type and weight of containers, the maximum load of the wagons and the train composition. The loading plan should optimize both the pick-up operations in the terminal and the train load operations. Therefore, also the container locations in the storage area can affect the planning decisions. Few works in literature deal with the TLP problem and often they focus on landside intermodal terminals rather than to seaports. The TLP is considered as a sub-problem of the gantry cranes scheduling in rail–rail transhipment optimization (Boysen, Fliedner & Keller, 2010). Several models and heuristics for containers allocation to trains in rail-rail terminals equipped with rapid transfer yards are proposed in (Bostel & Dejax, 1998). Some techniques for defining the assignment of containers to the slots of a train in intermodal road-rail terminals are considered by Corry and Kozan (2006) and (2008). Three different integer linear programming models are introduced by Bruns and Knust (2012) for the TLP problem in intermodal terminals to maximize the train utilization and minimize the transportation costs for the handled containers and the setup costs for changing the configuration of wagons, considering many types of containers.

The model here proposed extends the ones in (Ambrosino, Bramardi, Pucciano, Sacone & Siri, 2011), as (a) we define the planning problem considering a sequence of trains with different destinations, (b) we minimize the distances between the container locations in the storage area and the assigned wagons, and (c) we manage the repositioning of re-handled containers in the storage area. In the remainder of the paper Section 2 introduces the TLP problem; Section 3 defines the mathematical model; Section 4 illustrates the Lagrangian approach; Section 5 shows the experimental tests and finally Section 6 draws some conclusions.

2. The Train Load Planning problem

We consider a set $C=C_{20}\cup C_{40}$ of containers, partitioned in the subsets of 20' and 40' containers. We model the storage area as a set of locations univocally identified by a pair (k, t), where $k\in K$ denotes the stack and $t\in T$ the tier. Each location can store a 20’ container, whereas two adjacent $(k\text{-}1, t)$ and (k, t) locations a 40’ one. We assume to assign 40’ containers to a location in an even stack $k\in K_E\subset K$ so that it occupies also the adjacent k-1 odd stack location. K_c denotes the subset of stacks compatible with container c. Each container $c\in C$ has a weight class g_c, length l_c, destination d_c, commercial value π_c and an initial location (k_0, t_0) in the terminal storage area. The containers can be loaded on a set of wagons W which compose a set of trains I departing in sequence from the terminal and in general bound for different destinations. Each train $i\in I$ includes a set of wagons $W_i\subseteq W$, it has a destination d_i and a maximum weight capacity Ω_c. Each wagon $w\in W$ is has a length, maximum weight capacity Φ_c and a set of alternative configurations $B_w\subset B$, where B is the set of all the possible configurations. In general, more containers can be loaded on a wagon depending on its physical configuration (refer to (Bruns and Knust,