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The Block Retrieval Problem

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ABSTRACT

Retrieving containers from a bay in a port terminal yard is a time consuming activity. The *Block Retrieval Problem* (BRTP) aims at minimizing the number of *relocations*, the unproductive moves of hindering containers, while retrieving target containers belonging to a customer. The choice of relocations leads to alternative bay configurations, some of which would minimize the relocations of forthcoming retrievals. The Bi-objective Block Retrieval Problem (2BRTP) includes a secondary objective, the minimization of the expected number of relocations for retrieving the containers of the next customer. This paper provides $\mathcal{NP}$-Hardness proofs for both the BRTP and 2BRTP. A branch-and-bound algorithm and a linear time heuristic are developed for the BRTP; a branch-and-bound algorithm and a beam search algorithm are presented for the 2BRTP. Extensive computational tests on randomly generated instances as well as instances adapted from the literature are performed, and the results are presented.

1. Introduction

Container terminals are exchange hubs for containers flowing from one transportation mode to another, or between container ships. Container terminals are typically located at ports, where containers are loaded to/unloaded from cargo boats and delivered to the customers for the last mile transportation. Containers can be classified as *export* (or *outbound*) containers, *import* or (*inbound*) containers, and *transshipment* containers (Caserta, Schwarze, & Voß, 2011; Kim & Park, 2003). Export containers arrive by trucks or trains to the terminal landside area, then they are placed in the storage yard by internal vehicles, and relocated to the seaside area when the corresponding cargo boat is available (Daganzo, 1989). Import containers follow the reverse path; they arrive in the port by cargo boats, then they are unloaded by quay cranes, and placed in the storage yard to be picked up by trucks or trains in the landside area. Transshipment containers are restricted to the seaside and the storage yard areas; they are unloaded from a vessel and stored in the port yard until they are loaded to another cargo boat. A schematic representation of a container terminal together with a classification of container flows is depicted in Fig. 1.

Container terminals provide temporary storage space for preventing the need of synchronization between the transportation modes, in addition to their function as exchange areas. Thus, containers arriving in the terminal by ship, or by external trucks, or by trains are temporarily kept in storage areas until they are requested for shipment. The dwell times for export, import, and transshipment containers are different. Export containers typically arrive in the port up to weeks before the time they have to be shipped and import containers stay in the terminal yard until they are claimed by the customers.

The storage yard is a scarce resource just as berths, cranes, and internal vehicles, and its usage needs to be carefully planned. Containers are stored in stacks in order to avoid spreading them around the terminal yard, which would have required larger areas and would have demanded a more substantial transportation effort. Stacks are aligned to form bays and blocks, as illustrated in Fig. 2. This configuration optimizes the space utilization and allows for crane operations. Nevertheless, by adopting this storage policy, a trade-off between space saving and handling effort for loading and unloading operations arises. More precisely, hindering or obstructing containers may need to be relocated in order to provide access to the blocked target containers during a retrieval request.

We assume each bay stores uniformly shaped containers, consisting of S stacks of maximum height H. Each container belongs to a group $g \in \{1, \dots, G\}$ which can be defined according to its weight, destination, owner, or any other classification criterion that can be used during the retrieval process. Containers in a group have to be

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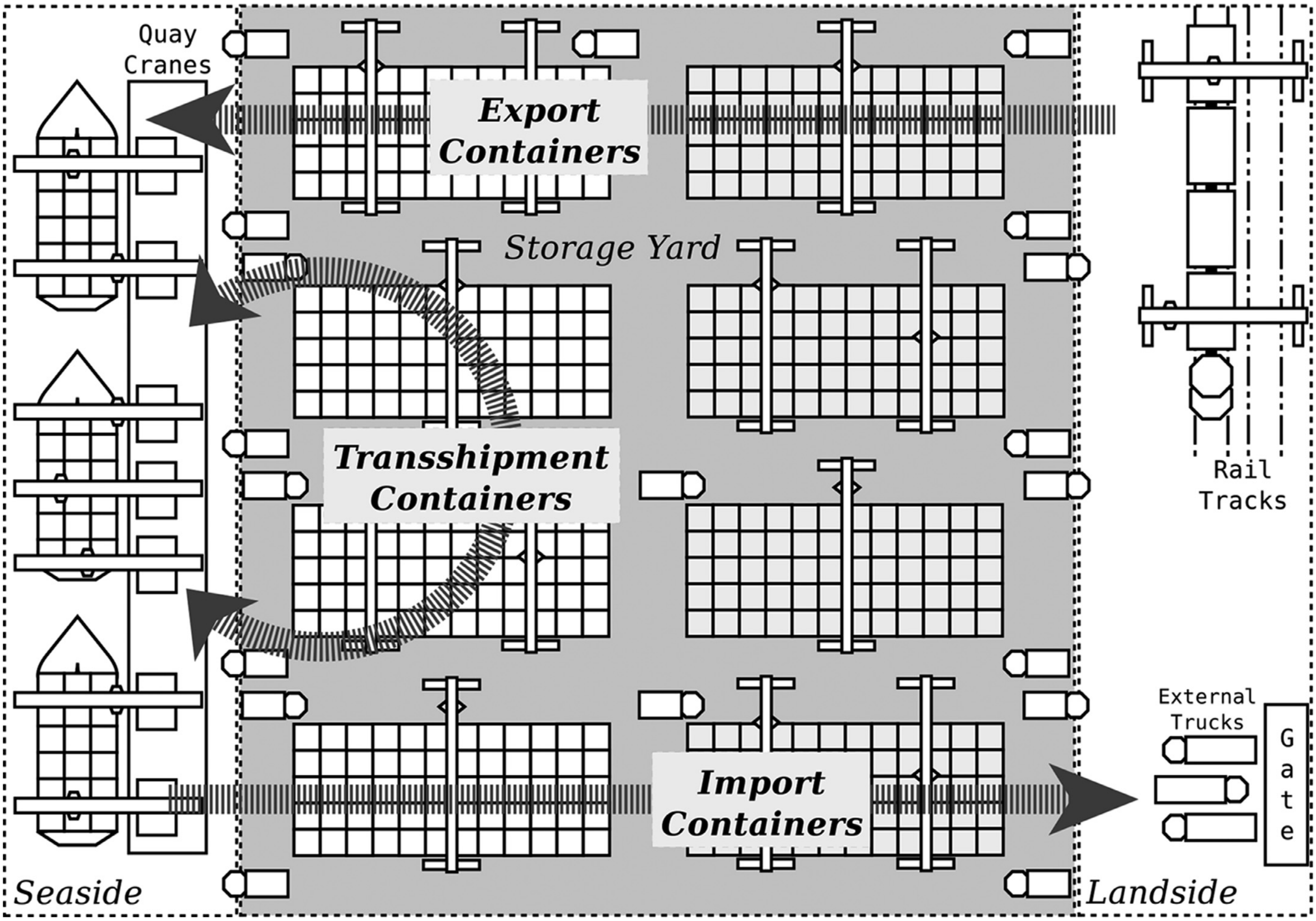

Fig. 1. A typical container terminal and the three types of container flows.

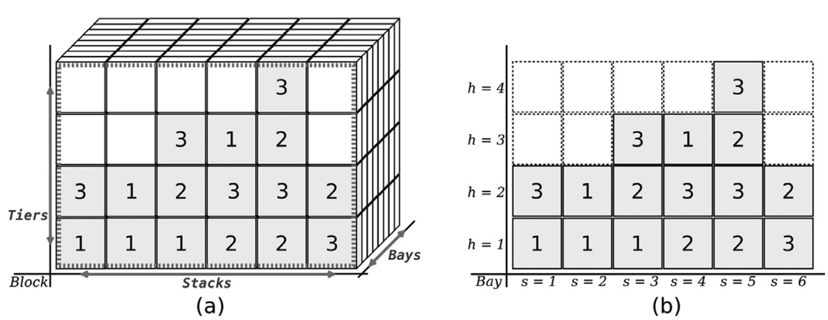

Fig. 2. (a) Container storage block, and corresponding (b) bay representation.

retrieved at the same time. The *target group* refers to containers of the group $t \in \{1, \ldots, G\}$ which are about to be retrieved (note that $t > 1$ is allowed, in contrast to the related problems in the literature). The LIFO policy has to be observed; i.e., only the topmost containers can be directly reached by a crane or a gantry. Thus, retrieving a container that is not positioned in the top tier requires all containers above it to be moved to other stacks. Obstructing containers on top of target containers are called *deadlocks*. A *relocation* occurs when a deadlock has to be moved from one stack to another. A *retrieval* is performed when a container of the target group is picked and leaves the bay. It is assumed that containers can be relocated to other stacks and hence there exists enough space above the stacks to perform the necessary relocations. In practice, it is not always possible to assure enough space above the stacks to perform the necessary relocations, in such cases the non-target containers are relocated to a temporary *dummy stack* at the side of the bay. Once the retrieval process is finished, the containers in the dummy stack have to be put back into the bay.

Although it is optimal to place the containers of a group in adjacent empty stacks and bays upon arrival, lack of available space may force the group to be divided in partially occupied stacks and non-adjacent locations. Furthermore, retrieval operations for the other groups may further disperse the containers within the same