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Housekeeping: Foresightful container repositioning☆

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This paper deals with crane scheduling in a block of a container terminal equipped with twin cranes when repositioning moves turn out necessary. While one crane is working on a given schedule we aim to anticipate as many repositioning jobs as possible using the second crane without disturbing the first crane. In seaport operations, this situation is commonly called housekeeping. We formulate this problem as a MIP and show that it is strongly $\mathcal{NP}$-hard. Further, we provide an exact procedure based on dynamic programming and a Greedy heuristic procedure to solve it. A comparison of both algorithms with CPLEX concludes this paper.

1. Introduction

Using containers makes the transshipment of cargo fast and cost-efficient at the same time. For this reason the container flow has been increasing over the past years (e.g. see Chatman et al., 2013, pp. 22–25). Especially at seaports, where a great flow of containers is coming in and going out, a well thought-out storage system is essential. Here we presume a storage system mainly characterized by a high degree of automation. The stacking area in these ports often has a layout like the HHLA Container Terminal Altenwerder in Fig. 1.

As Fig. 2 shows, the containers arrive at one side of the terminal either by train, by truck or by vessel. Then, they are unloaded by a crane and put on automated guided vehicles (AGVs), which take the containers to the stacking area. This area is made up of separate blocks each consisting of many rows of stacks. Each stack can be several containers high. The blocks are arranged perpendicular to the quay as in Fig. 1. Here the containers are stored until they are loaded to an AGV again and taken to either side of the terminal for further transport.

There are several means for transporting the containers like straddle carriers or quay cranes, which are for example described by Steenken et al. (2004) and Stahlbock and Voß (2008). Here we assume that each block is assigned one or more automated stacking cranes (ASCs), which take the container from the AGVs and handle the container transport within the block. Although ASCs are currently only used in few (mostly European) container terminals, there has been some research on this topic, lately, as described in the survey paper by Carlo et al. (2014).

Considering the scheduling problem for single stacking cranes, several methods have already been developed by Kim and Kim (1999), Kim et al. (2003), Lee et al. (2007), Narasimhan and Palekar (2002), and Ng and Mak (2005a,b).

When working on the scheduling of multi-gantry cranes it is important to consider interference. The first approaches on this topic mostly simplify interferences, for example by setting up movement ranges for the gantries. This method is also used in Froyland et al. (2008) and Saanen and van Valkengoed (2006), and the solution procedure in Ng (2005). Restricted areas for each crane might make sense if the handover area is on the long side of the block, but seem to restrict opportunities if it is on the short side as in Fig. 2. Another technique used quite often in this context is mixed integer programming as in Ng (2005), Li et al. (2009), Park et al. (2010), Vis and Carlo (2010) for instance.

Dorndorf and Schneider (2010) discuss a scheduling algorithm for triple cross-over stacking cranes. They explicitly pay attention to crane interference by using a heuristic to decide on priority in cases of conflicts. Then a branch and bound algorithm is used. The subproblem of deciding priority is also considered in Briskorn et al. (2016) for two crane settings – either twin cranes or cross-over cranes. Another heuristic approach is introduced by Wu et al. (2015). So far these three papers are to the best of our knowledge the only ones that take crane interferences and waiting times into account and still provide exact solutions. Nevertheless, according to Speer et al. (2011) interference times add a good share to cranes' driving times.

Another quite time consuming task are repositioning activities. They are necessary or reasonable whenever a container is to be taken to the handover area but it is not on top of its stack or it

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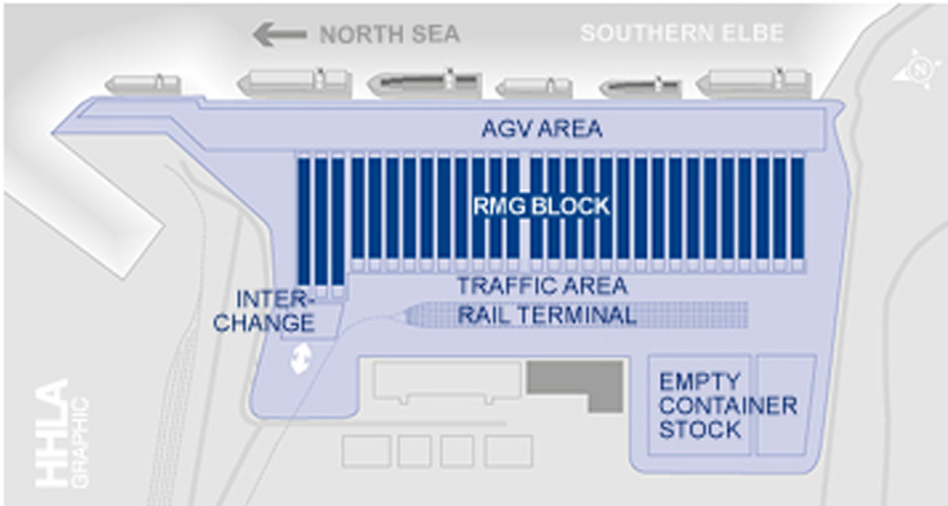

Fig. 1. Layout of the HHLA Container Terminal Altenwerder, taken from HHLA (2014).

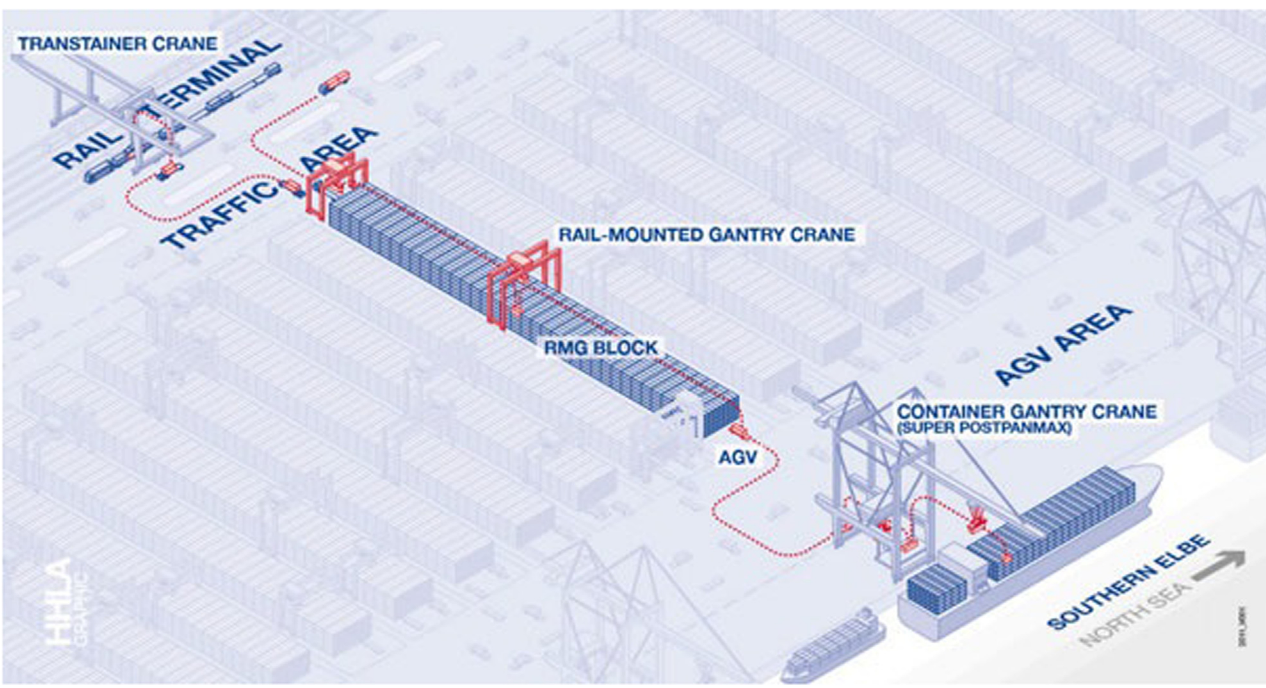

Fig. 2. Process flow at HHLA Container Terminal Altenwerder, taken from HHLA (2014).

cannot be reached by the responsible crane, yet. Pure repositioning is for example considered in Kim and Hong (2006), where the authors determine new storage positions for containers, which have to be repositioned. For the repositioning problem with a single crane see also Lee and Hsu (2007), Lee and Chao (2009) and, more recently, Hakan Akyüz and Lee (2014).

We have a quite different situation if the schedule for one of the cranes has already been developed on another stage of planning. This crane could for example be occupied with taking outbound containers to its handover area. As the second crane cannot directly take part in this process it can be used for housekeeping, i.e. for repositioning activities, which are not necessary right now, but which speed up processes at a later point in time.

We assume that there are no additional storage or retrieval requests at the second crane's handover area within our planning horizon. Basically, any one of the two cranes can be the one with the fixed schedule.

If there is no vessel to be served by the seaside crane at the moment, but the landside crane is working on a fixed schedule for loading or unloading a train for example, then the seaside crane has time to do repositioning in order to save time during an upcoming high seaside workload caused by a newly arrived vessel. As there are no containers arriving from the seaside, if there is no vessel berthed, the seaside crane can fully concentrate on housekeeping moves.

If the seaside crane is serving a vessel and the landside crane is idle, the workload is split reversely. As we only consider a single block for a fixed time window, any storage request could easily be assigned to a different block, while retrieval requests would be handled before or after the specific time window, so this is not a strong limitation.

Of course we have to make sure that the unloading crane is