Intelligent Support Systems for Resilient Port Terminals

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Outline

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Introduction

- **Ports** are **critical infrastructures** within multimodal transport networks that integrate maritime and terrestrial environments.
- They are **vulnerable to unforeseen events** caused by Nature or by deliberate or accidental human actions.
- The consequences range from the reduction of the productivity to the temporary closure of the port.
- In order to manage the risks and to improve the robustness of the system, **mechanisms that increase the resilience of these infrastructures** are important.
- **Resilience** is the ability to withstand and recover eventualities intelligently facilitating the development of activities in the shortest possible time.

Introduction

- Port operators must have tools to help them identify what unforeseen events can affect the port and what their consequences are.
- They must design strategies to minimize their occurrence (**proactive approach**).
- If despite this fact, the event occurs, they should enable protocols and adopt decisions to remedy the situation by minimizing the response time or the impact of such an event (**reactive action**).

Global goal of the project

Global goal

The current project deals with the design, implementation and validation of a support system for the intelligent management to ensure the resilience of a port container terminal. The system must support the **proactive** (simulation tools) and **reactive** (intelligent re-planning algorithms) phases.

Main contributions so far

Who?

- J. Marcos Moreno-Vega (University of La Laguna)
- Belén Melián-Batista (University of La Laguna)
- Christopher Expósito Izquierdo (University of La Laguna)
- Israel López Plata (University of La Laguna)

- Jésica de Armas (University Pompeu Fabra)
- Eduardo Lalla Ruiz (University of Hamburg)

Optimization Problems

Seaside

- Berth Allocation Problem (BAP)
- Tactical Berth Allocation Problem (TBAP)
- Berth Allocation Problem under Time-Dependant Limitations (Tidal-BAP)
- Ship Routing and Scheduling Problem (SRSP)
- Quay Crane Scheduling Problem (QCSP)
  - Static
  - Dynamic

Yard

- Pre-Marshaling Problem (PMP)
- Blocks Relocation Problem (BRP)
- Blocks Relocation Problem with Waiting Times (BRP_WT)
- Stacking Problem (SP)

Landside

- Rich Vehicle Routing Problem with Time Windows (RVRPWT)
- Dynamic Vehicle Routing Problem with Time Windows (DBRPTW)

BRP-WT: problem definition

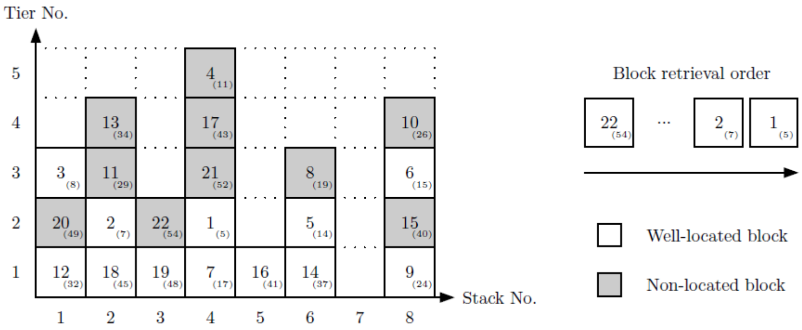
- The Blocks Relocation Problem with Waiting Times is an $\mathcal{NP}$-hard optimization problem that seeks to retrieve a set of homogeneous robust blocks from their current locations in a stacking facility, in order to minimize the sum of waiting times of the blocks.
- The waiting time of block c is defined as the elapse of time between its expected retrieval time and its real retrieval time, denoted as $r(c)$ and where $r(c) \geq e(c)$. This waiting time is denoted as follows:

$$wt(c) = r(c) - e(c) \quad (1)$$

- The stacking facility is represented as a well-delimited two-dimensional storage. This is composed of a set of stacks, $S = \{1, 2, \ldots, nS\}$, which are vertically organized into a set of stacking tiers, $T = \{1, 2, \ldots, nT\}$.

Israel López-Plata , Christopher Expósito-Izquierdo, , Eduardo Lalla-Ruiz , Belén Melián-Batista , J. Marcos Moreno-Vega. **Minimizing the Waiting Times of Block Retrieval Operations in Stacking Facilities**, *Computers & Industrial Engineering*, doi 10.1016/j.cie.2016.11.015.

Example of the BRP-WT



Example of the Blocks Relocation Problem with Waiting Times composed of $nS = 8$ stacks, $nT = 5$ tiers, and $nC = 22$ blocks

BRP-WT: problem definition

- All the potential changes in the expected retrieval times of the blocks can be handled as dynamic variants of the BRP-WT in further research (reactive action).
- The waiting time of a given block is measured in terms of crane movements.
- According to the technical characteristics of the stacking crane used in the retrieval process, this can be easily translated into temporal units.

BRP-WT: problem definition

The two-dimensional storage is served by a single stacking crane, which is dedicated to provide and arrange the blocks. This way, it is assumed that the crane can perform at most one movement during each time period. The allowed movements are described as follows:

- *Block retrieval*. A block placed at the top of a stack is removed from the storage when its expected retrieval time has been achieved.
- *Block relocation*. A block placed at the top of a stack is moved to the top of another stack with at least one empty slot.

According to the previous description, the feasible solutions of the BRP-WT are defined as sequences of crane movements in which all the blocks are removed from the two-dimensional storage at least during their expected retrieval times.

Assumptions

The following assumptions are considered in the optimization problem:

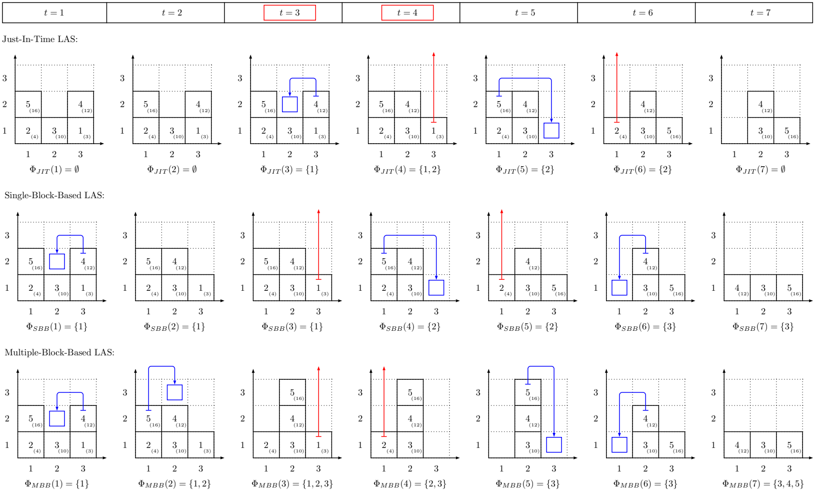
- The problem is concerned with a single stacking facility.
- The stacking crane can move only one block at a time due to its physical characteristics.
- The expected retrieval times of the blocks are known in advance and these do not change over time. Addressing changes in the information related to the blocks is an open direction for further research.
- No new blocks arrive to the stacking facilities.

Heuristic algorithm

- An algorithm called *Look Ahead Heuristic* is proposed with the goal of obtaining high-quality solutions in short computational times.
- The heuristic progressively anticipates the availability of the subsequent blocks to retrieve from the two-dimensional storage in the coming time periods by using look ahead strategies.

Look ahead strategies

1. Just-In-Time Look Ahead Strategy
2. Single-Block-Based Look Ahead Strategy
3. Multiple-Block-Based Look Ahead Strategy


t = 1
t = 2
t = 3
t = 4
t = 5
t = 6
t = 7
Just-In-Time LAS:
$\Phi_{JIT}(1) = \emptyset$
$\Phi_{JIT}(2) = \emptyset$
$\Phi_{JIT}(3) = \{1\}$
$\Phi_{JIT}(4) = \{1, 2\}$
$\Phi_{JIT}(5) = \{2\}$
$\Phi_{JIT}(6) = \{2\}$
$\Phi_{JIT}(7) = \emptyset$
Single-Block-Based LAS:
$\Phi_{SBB}(1) = \{1\}$
$\Phi_{SBB}(2) = \{1\}$
$\Phi_{SBB}(3) = \{1\}$
$\Phi_{SBB}(4) = \{2\}$
$\Phi_{SBB}(5) = \{2\}$
$\Phi_{SBB}(6) = \{3\}$
$\Phi_{SBB}(7) = \{3\}$
Multiple-Block-Based LAS:
$\Phi_{MBB}(1) = \{1\}$
$\Phi_{MBB}(2) = \{1, 2\}$
$\Phi_{MBB}(3) = \{1, 2, 3\}$
$\Phi_{MBB}(4) = \{2, 3\}$
$\Phi_{MBB}(5) = \{3\}$
$\Phi_{MBB}(6) = \{3\}$
$\Phi_{MBB}(7) = \{3, 4, 5\}$

Computational Results I

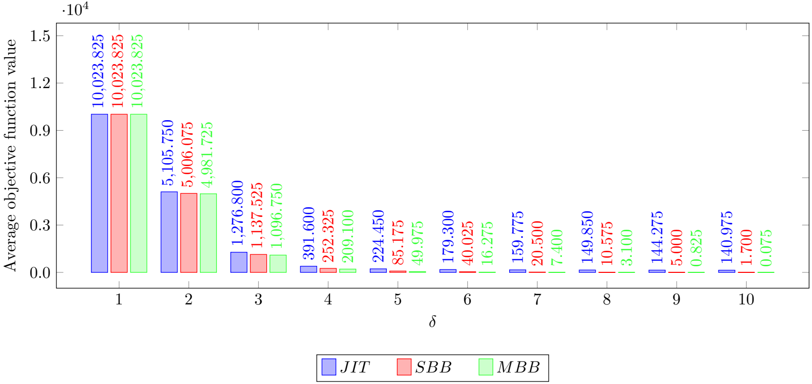


Figure: Computational results reported by the Look Ahead Heuristic by varying the look ahead strategies when solving the adapted problem instances

Computational Results II

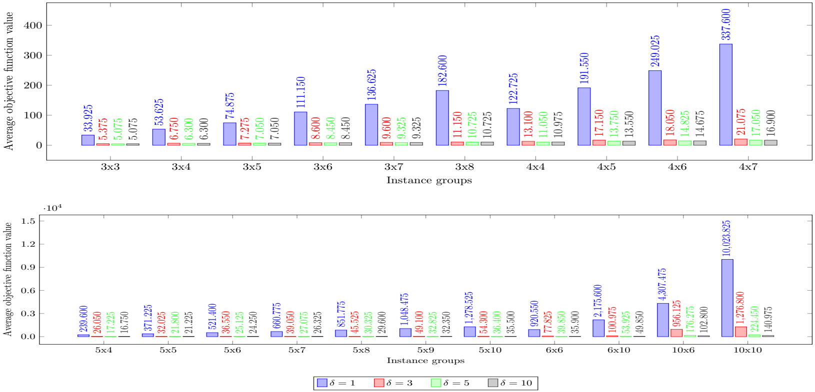


Figure: Computational results reported by the Look Ahead Heuristic by using the Just-In-Time Look Ahead Heuristic when solving the adapted problem instances

Computational Results III

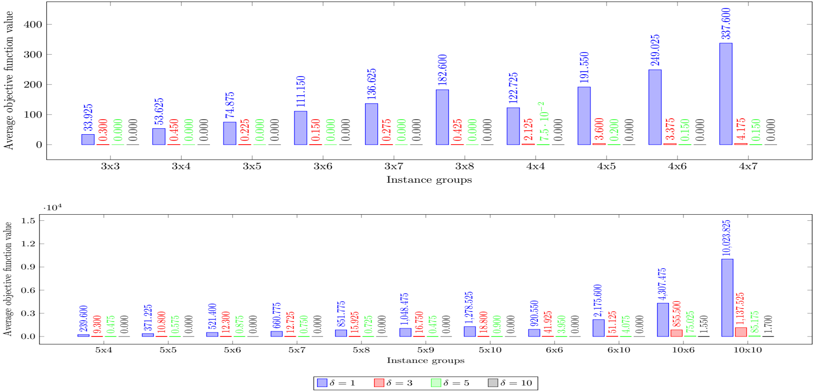


Figure: Computational results reported by the Look Ahead Heuristic by using the Single-Block-Based Look Ahead Heuristic when solving the adapted problem instances

Computational Results IV

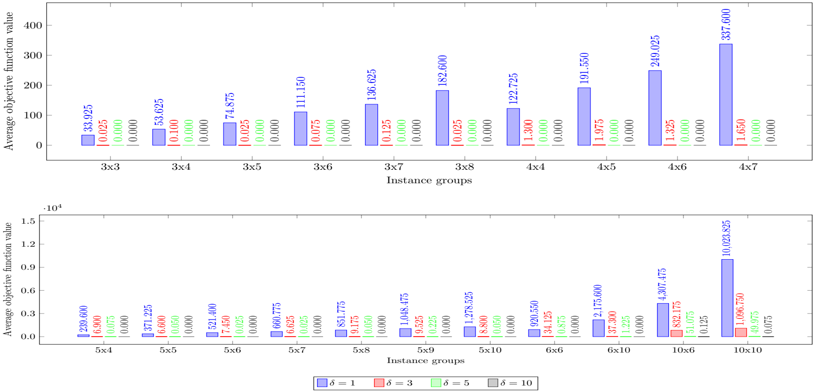


Figure: Computational results reported by the Look Ahead Heuristic by using the Multiple-Block-Based Look Ahead Heuristic when solving the adapted problem instances

Conclusions

- Integration schemes
- Resilience (reactive and proactive actions)
- Intelligent Support System