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Real-Time Stacking System for dangerous containers in seaport terminals

Ines Rekik[1], Sabeur Elkosantini[2], HabibChabchoub[3]

[1]*LOGIQ Research Unit, University of Sfax, Tunisia*
[2]*Industrial Engineering Department, King Saud University, Riyadh, Saudi Arabia*
[3]*International school of Business, Tunisia,*
(ines.rekik.86.@gmail.com, selkosantini@ksu.edu.sa, Habib.chabchoub@gmail.com)

Abstract: In container terminals, many operations occur within the storage area including import, export and shifting containers. These operations must respect a set of rules and constraints in order to guarantee an optimal management of the storage area and ensure the port safety during the handling of dangerous goods. However, many unexpected events may occur and affect the storage process and, consequently, scheduled position of containers must be modified. In this paper, we present the architecture of a multi-agent based container stacking system to handle different types of containers including containers with dangerous goods. The aim of the developed system is the real time control of seaport terminals and the determination of the exact position of each import container.

Keywords: Container stacking, container terminal, dangerous goods, multi-agents system, safety.

1. INTRODUCTION

Container terminals management is becoming a difficult task for ports authorities as it involves a large number of complex optimization problems. One of these problems is related to the container stacking which consists on determining the optimal position of each inbound container. The decision for determining better stacking positions for incoming containers in an automated container terminal is crucial as it affects not only the stacking but also the later retrieval of containers.

Indeed, containers terminals are faced with many storage constraints related to the destination or the types of containers which require the determination of specific positions. For example, refrigerated containers must be allocated to storage space equipped by the power point. Dangerous containers must also be separated from each other by a fixed distance according to the class of dangerous goods.

Many container stacking systems were developed and aim to better manage the storage space in seaport terminals as the COntainer Stacking via multi-Agent approach and Heuristic method (COSAH; Gazdar, 2008) or Container Terminal Management with Simulation (CONTSIM; Clausen et al., 2012). These systems use two types of planning for determining containers locations: static and real-time stacking. In static stacking, the exact position in the storage area for each inbound container is determined before the arrival of vessels. As a result, reserved storage area cannot be used before the discharge of the arriving vessel. Real-time dynamic stacking consists on deciding in real time, at the arrival of an imported or exported container, its exact location in the storage area. In general, the location of a container must minimize a given performance criteria (as the number of spaces allocated to containers or the average cycle time). According to Dekker et al. (2006), real-time planning results in higher storage area utilization and a significant decrease in the number of reshuffle. However, existing real-time dynamic stacking systems suffers limitations with several aspects related to disturbances management, distributed control and intelligent containers. Indeed, few works (Gazdar, 2008) have exploited distributed CSP management systems and most of existing works have adopted Multi-Agent Systems for terminal simulation (Rida et al., 2003; Thurston and Hu, 2002). In addition, there are no generic approaches dealing simultaneously with a variety of disturbances. Existing studies treating some disturbances did not take into account the interaction between the different containers stacked in the yard and all disturbances which may occur. Very few works were also interested in the integration of dangerous containers as constraints (Molins et al., 2012; Hamidou et al., 2014.

This paper presents a real time control system for container stacking management in seaport terminals. The objective of the system is to monitor terminals, supervise containers allocation and react to unexpected events, change and disturbances, such as handling of dangerous materials, in an intelligent, self-organizing and real-time manner.

The remainder of this paper is organized as follows: Section 2 introduces the Container Stacking Problem (CSP) and gives a brief survey on existing studies related to CSP and to dangerous goods management in seaport terminals. Section 3 presents the statement of the problem treated. Section 4 presents the architecture of the suggested system and a description of each agent. Finally, section 5 presents the different tools used for the implementation of the system.

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2. LITERATURE SURVEY

2.1 Container Staking Problem

In scientific literature, container terminals are described as an area where containers are stored and handled (Böse, 2011). The stacking area, referred to also as the yard-side or the stacking yard, is a surface in which containers are temporary stacked in order to be exported or imported. A storage yard consists of a number of areas perpendicular or parallel to the berth called blocks. Each block is characterized by a number of bays which represent the length of the block, by a number of rows which represent its width and by a number of tiers which represent its height.

The Container Stacking Problem (CSP) consists on determining the exact position in the storage area (the block, the row, the tier and the bay) of each inbound containers which optimize a given objective function. This problem is always considered as a complex task (Günther et al., 2006; Izquierdo et al., 2012).

To maintain the competitiveness of port terminals and especially container staking operations, many Key Performance Indicators (KPI) were developed as the number of spaces allocated to containers (Lim and Xu, 2006) or the average cycle time (Steenken et al, 2004). These KPI can be categorized into two main families: 1) the storage space KPIs, as the number of spaces allocated to containers which are used to evaluate the capability of ports management systems to optimize the storage space and 2) the allocation process KPIs, as the average cycle time, which are used to evaluate the allocation process with regards to the process time or handling operations.

Many approaches have been developed to solve container stacking problem. For example, optimization approaches have been proposed in the literature including exact methods as Branch and Bound (Kim and Hong, 2006) or approximated approaches as heuristics (Izquierdo et al., 2012) and metaheuristics (Chen et al., 2004). They, however, were used to solve static CSP without considering the real-time changes in terminals. Other approaches issued from artificial intelligence were used to solve dynamic CSP. For example, the multi-agent systems are used to develop distributed system for CSP as the system developed by Gazdar (2008) and denoted COSAH (COntainer Stacking via multi-Agent approach and Heuristic method) Henesey et al., (2003) proposed also an automatic planning of the operations of a container terminal.

The Artificial Neural Network (ANN) is also used by Jin et al. (2004) to control the container stack height. The system forecasts coming container quantity in order to decide the height of a container stack. The ANN is also used in Gronalt et al. (2008) as a decision support system in which the system select the most appropriate allocation procedure from a set of available strategies.

In this context, many staking rules were developed to improve terminals performance and may be related to the selection of a block, a bay, or a stack (Ma and Kim, 2012).Such rules include Dedicated Areas (DA) rule which consists on reserving a specific area or block for specific types of containers (Asperen et al., 2013) as a block for imported containers or a block for some types of containers from a specific vessel. The Nearest Location (NL) rule is another important rule related to the selection of a bay. It consists on assigning the nearest bay to berth for inbound containers (Woo and Kim, 2011). The Random-Stacking with Departure Times (RS-DT) rule, which belongs to the stack selection rules, searches for a random stack where the top container's departure time is earlier than the new container's departure time (Asperen et al., 2013).

Recently, very few works were also interested in the integration of dangerous containers as constraints. For example, Molins et al. (2012) have developed a heuristic to solve Static Container Stacking Problem in which dangerous containers must be allocated by maintaining a minimum distance between them. However, dangerous containers management is not well integrated in exiting real-time container stacking systems. Few works have exploited distributed CSP management systems and most of existing works have adopted Multi-Agent Systems for terminal simulation (Rida et al., 2003; Thurston and Hu, 2002). Few works used such systems for managing all port operations (Henesey, 2006) and not dealing specifically with container stacking operations. However, due to the complexity of the CSP, the distributed nature of the CSP and the diversity of different constraints related to stacking operations, multi-agent system seems to be an appropriate approach to solve the container stacking problem for addressing problems related to both dangerous containers and unexpected events.

2.2 Dangerous goods management in seaport terminals

To the best of our knowledge, few works are paying a particular attention to the storage of containers with dangerous goods. For example, Molins et al. (2012) have proposed domain-dependent heuristics for solving the container stacking problem by means of Artificial Intelligence techniques in order to minimize the number of necessary reshuffles of containers. In their work, dangerous containers were considered by maintaining a minimum security distance between two dangerous containers but without taking into account the different existing classes and rules of dangerous containers. Hamidou et al. (2014) have developed hybrid architecture, using a Cellular Automaton and a Multi-Agent System to handle dangerous container and in order to minimize the safety distance between two dangerous containers. They have considered the storage constraints and rules for each class of dangerous containers. However, they have supposed that the terminal is composed of one unique block of many rows and they didn't take into account several important constraints as the container's size which make their work far from the reality.

According to the International Maritime Dangerous Goods (IMDG) Code (International Maritime Dangerous Goods 2013) proposed by International Maritime Organization, dangerous goods can be classified into 9 main classes (Table 1).Their storage must respect separation rules for each class by maintaining the safety distance between them.