Computers & Operations Research 52 (2014) 84–93

Contents lists available at ScienceDirect

Computers & Operations Research

journal homepage: www.elsevier.com/locate/caor

Location assignment for outbound containers with adjusted weight proportion

Canrong Zhang [a,b], Tao Wu [c,*], Ming Zhong [a,b], Li Zheng [b], Lixin Miao [a]

[a] Logistics Engineering and Simulation Laboratory, Graduate School at Shenzhen, Tsinghua University, Shenzhen 518055, China
[b] Department of Industrial Engineering, Tsinghua University, Beijing 100084, China
[c] Business Analytics and Optimization, University of Phoenix, Apollo Group, Inc., Phoenix, AZ 85040, USA

ARTICLE INFO

Available online 1 July 2014

Keywords:
Outbound container
Location assignment
Dynamic programming
Heuristics
Container rehandling

ABSTRACT

This paper studies the location assignment for arriving outbound containers during container-receiving stage. For the problem, the literature assumed that the proportion of the remaining containers on a weight group keeps unchanged throughout the container-receiving process. This assumption is inconsistent with the practice that it should be constantly adjusted according to the containers that have already been received. We therefore propose two other handling ways in this paper, leading to two new dynamic programming models. These two models are compared with the existent model on small-scale instances. For large-scale instances, a two-stage heuristic is proposed. In the first stage, a neighborhood searching heuristic is developed to generate the priority sequence of stacking patterns for each weight group of containers; in the second stage, a rollout-based heuristic is proposed to improve the incumbent solution by simulating more stack alternatives for each arriving container. The numerical experiments show that the model with adjusted weight proportion can significantly reduce state size and improve stacking quality, and that the proposed two-stage heuristic is effective and efficient for large-scale instances.

© 2014 Published by Elsevier Ltd.

1. Introduction

With the rapid development of container transportation, container terminals have become an important hub for loading and unloading containers. Containers are normally piled up in the yard to thoroughly utilize the scarce space, but only those located at the top are directly accessible to yard cranes. Extra movements (i.e., the rehandling) occur when a target container is buried beneath others. Therefore, how to determine the yard location for an arriving container during container-receiving stage has become a key issue for container terminals.

To place a newly arrival container onto a stack in the yard, the following three decisions at different levels need to be made: (1) allocating yard blocks or sub-blocks to the outbound containers destined for each arriving vessel; (2) allocating yard bays to the containers of the same group (i.e., the containers of the same length, destined for the same destination port and the same vessel); (3) assigning a yard location, within the range of a single yard bay, to each newly arrival container. This paper is concerned about the lowest-level decision. For the higher-level decisions, refer to [6,13,10,3,16,15] and the papers therein.

In practice, container weights are generally classified into three groups: heavy (H), medium (M) and light (L). It is preferred that the heavier containers are loaded at the bottom of the vessel and the lighter ones are loaded on the top so that the vessel's center of gravity stays low, helping maintain the stability of the vessel during sailing. Therefore, during container-receiving process, the heavier containers should be stacked on the top of the yard and the lighter ones should be stacked at the bottom. However, it is always difficult to achieve this desired result, as the arrival sequence of outbound containers is usually uncertain and the lighter containers may not always arrive earlier than heavier ones, resulting in that some heavier containers must be stacked into the bottom. Researchers and practitioners have been extensively working on this problem for finding better solutions.

Kozan and Preston [9] integrated container transfer model with container location model. In that paper, the models were evaluated by the transfer time between the storage location and the destined vessel. The related research can be found in [11,8]. Dekker et al. [2] used a simulation method to compare random stacking with category stacking by the number of relocation movements. Kang et al. [5] attempted to accommodate all realizations of container arrivals by a stacking strategy, which was also evaluated by the number of relocation movements via simulation. Chen and Lu [1] proposed a hybrid sequence stacking algorithm

* Corresponding author.
E-mail addresses: crzhang@sz.tsinghua.edu.cn (C. Zhang), tao.wu@phoenix.edu (T. Wu), zhongm07@mails.tsinghua.edu.cn (M. Zhong), lzheng@tsinghua.edu.cn (L. Zheng), lxmiao@tsinghua.edu.cn (L. Miao).

http://dx.doi.org/10.1016/j.cor.2014.06.012
0305-0548/© 2014 Published by Elsevier Ltd.

and compared it with a random stacking algorithm and a vertical stacking algorithm. Jang et al. [4] suggested a genetic algorithm to determine the storage location for each arriving container in order to minimize the expected number of relocation movements. In contrast to using the heuristic rules, Kim et al. [7] and Zhang et al. [12] proposed a dynamic programming model to minimize the expected number of relocation movements. Zhang et al. [14] is an extension to the previous two papers by discriminating the punishment for different stacks in terms of the number of heavier containers stacked beneath.

Kim et al. [7] and Zhang et al. [12] assumed that the proportion of the remaining un-arrived containers on each weight group remains the same during the whole container-receiving stage. The assumption reduces state size and makes the problem easier to solve. However, such a handling way is apparently inconsistent with the practice in which the proportion of containers on each weight group does not remain constant and is significantly determined by the weight information gathered by line carriers or brokers from their customers. The recorded information for the proportions may not be exactly correct but generally fits the real data. The availability of such information motivates the research of this paper that suggests the proportion of the remaining un-arrived containers on each weight group be adjusted whenever the yard bay configuration is changed, in contrast to the assumption made by [7,12]. Numerical experiments show that, by adjusting the proportions for fitting the reality, stacking quality can be significantly improved.

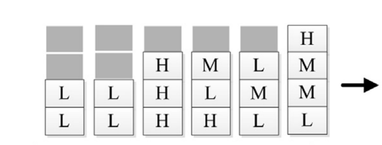
The remainder of this paper is organized as follows: three dynamic programming models are presented in Section 2, followed by their comparison in Section 3; a two-stage heuristic is presented in Section 4, followed by extensive numerical experiments in Section 5; and the conclusions are drawn in the last section.

2. Mathematical models

The definitions related to the model are presented as follows:

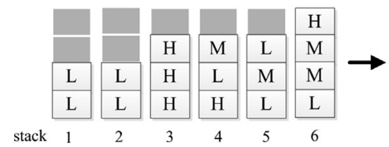
Stage: The total number of empty slots in a yard bay. The example as shown in Fig. 1, which has a bay pattern with 6 stacks, 4 tiers and 3 weight groups (heavy (H), medium (M) and light (L)), is in stage 7, as its total number of empty slots is equal to 7.

State: The state of a yard bay consists of the combination of the number of empty slots in each stack and the combination of the representation of each stack. A commonly used way to represent a stack is the heaviest weight group of its loaded containers. An example is shown in Fig. 1, which is represented as "221110 LLHHMH". According to [7,12], the stack representation of this kind can significantly reduce state size but omit too much information about the stack at the same time, especially the information about the number of containers on each weight group. Since this paper focuses on the adjustment of weight group proportion and certainly needs such information, we prefer to not use the heaviest weight group representation for the stack as employed in Fig. 1. As a replacement, the three weight groups (H, M, L) are respectively represented as (100, 10, 1), and a stack is represented as the sum of the weight groups included in the stack. For example, (M, H, L) in stack 4 in Fig. 2 is represented as 10+100+1=111. The new state representation is sorted by the number of empty slots in a decreasing order. If a tie exists, the stack with a greater sum of its loaded containers is placed in front of the other.



Number of empty slots	Heaviest-weight group of each stack
2 2 1 1 1 0	L L H H M H

Fig. 1. An illustration of bay representation.



Number of empty slots	Components of each stack
2 2 1 1 1 0	2,2,300,111,12,121

Fig. 2. An illustration of the new bay representation.

The parameters related to the model are presented as follows:

- s — the number of stacks in a yard bay.
- t — the number of tiers in a stack. In practice, t is normally less than 6. That is why we can represent the three weight groups (H, M, L) respectively as (100, 10, 1). Otherwise, ten "L" containers may be seen as an "M" container if t is allowed to be larger than or equal to 10.
- N — the total number of stages (containers in the yard bay) which is equal to $s \times t$.
- n — the stage number, that is, the number of empty slots in the yard bay.
- G — the set of weight groups which are indexed by g in a decreasing order of their weight groups.
- r^g — the proportion of the number of containers with weight group g. Therefore, the number of containers with weight group g is equal to $N \times r^g$. As mentioned previously, these numbers, that are gathered by line carriers and brokers from shippers, almost fit the real data. In this paper, we assume that the container number for each weight group is distributed exactly according to r^g. The uncertainty is existed only in their arrival sequence.
- X_n — the input state of the nth stage (see Fig. 2).
- X_n^g — the number of containers with weight group g already stacked in the yard bay when the input state is X_n.
- k_n — the weight group of an arriving container at stage n.
- $p_n(k_n)$ — the probability that a newly arrival container is with weight group k_n.

The decision variables related to the model are presented as follows:

- D_n — the stack assigned to an arriving container at stage n.
- $R_n(X_n, D_n, k_n)$ — the punishment coefficient for placing a newly arrival container with weight group k_n onto stack D_n when the input state is X_n. As applied in [7,12], this punishment coefficient is equal to 1 when at least one of containers in stack D_n is heavier than k_n and 0 otherwise. It is obviously a simple treatment way, and discriminating $R_n(X_n, D_n, k_n)$ in terms of the number of heavier containers stacked beneath will be studied in the future study.
- $T_n(X_n, D_n, k_n)$ — the state transfer function that maps X_n to X_{n-1} when a newly arrival container with weight group k_n is assigned to stack D_n.
- $f_n(X_n)$ — the minimization of the total expected punishment of $R_n(X_n, D_n, k_n)$ from the starting input state X_n to fully filling the yard bay.

The decision process is shown in Fig. 3, from which we see that a decision (D_n) is made at each input state (X_n) after knowing the weight group (k_n) of the newly arrival container, with consideration of the impact of the output state (X_{n-1}) on the subsequent stacking for the remaining empty slots. The objective function is to minimize the total expected punishment of $R_n(X_n, D_n, k_n)$ after fully filling a yard bay.

One of the problems we are facing is how to identify the probability $p_n(k_n)$ that a newly arrival container is with weight group k_n when the current state is X_n. The literature typically assumed that

Download English Version:

https://daneshyari.com/en/article/474641

Download Persian Version:

https://daneshyari.com/article/474641

Daneshyari.com