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DEEP REINFORCEMENT LEARNING WITH DISCRETE EVENT SIMULATION FOR STEEL PLATE STACKING PROBLEM

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ABSTRACT

In shipyards, newly supplied steel plates from steel-making companies are stored in steel stockyards until they are retrieved according to the pre-determined cutting schedule. Steel plates are grouped into lots, and all steel plates of the identical lot are retrieved and transported into the cutting workshop at the same time. In this study, we developed the two-stage stacking algorithm to minimize the workload of overhead cranes for the rehandling work in the retrieval process. In the proposed algorithm, a reinforcement learning-based agent which learns the stacking policy in the simulation environment determines the initial stacking location of the steel plates only considering the cutting schedule. After the initial arrangement of steel plates is created, steel plates are reshuffled using the simulated annealing considering both the cutting schedule and lot information.

1 INTRODUCTION

Steel plates are supplied to shipyards from the steel-making companies, stored in a number of vertical stacks in steel stockyards, and put into the cutting process according to the cutting schedule. Each steel plate belongs to one of the lots which are determined based on the usage in ship construction, and steel plates are retrieved and transported to the cutting workshop in the unit of the lot. When each steel plate is retrieved on the pre-determined cutting date, rehandling work is required to move the other steel plates which are stacked above the target steel plate. In addition, the constraint that steel plates with the same lot are transported to the cutting process at the same time increases the load of rehandling work. Therefore, to minimize the workload of overhead cranes, it is necessary to arrange the steel plates in the steel stockyard considering the cutting schedule and lot to which the steel plates belong.

2 PROPOSED STACKING ALGOTIHM

In this study, we developed a two-stage stacking algorithm using reinforcement learning and simulated annealing as represented in Figure 1. In the first stage, the agent determines the initial stacking location of the steel plates, applying the stacking policy learned using the A3C (asynchronous advantage actor-critic) algorithm, which is based on the method proposed by Woo et al. (2020). A discrete-event simulation model mimicking the dynamics of the steel stockyard is constructed and used as the learning environment with which the agent interacts to learn the (near-) optimal stacking policy. The agent observes the current stacking state of the steel stockyard which is defined as the 2D image with one channel encoding the remaining time to the planned cutting dates of the steel plates. The agent decides which stack the steel plate is to be located in and receives the reward feedback calculated by the simulation model. The reward is defined as the reverse of the maximum number of rehandling moves to minimize the workload of overhead cranes for rehandling work. The stacking policy which is approximated as a deep neural network with convolutional layers is adjusted based on the rewards. In the second stage, the steel plates are reshuffled considering the lot information of the steel plates using simulated annealing. Lot information is reflected in the remaining time to retrieval by subdividing the cutting dates so that each lot of steel plates has a unique retrieval date. The reshuffling solution is represented as a list of pairs of stacks where the first element means the stack where the target steel plate is in and the second means the stack to which the target steel plate is moved. In this study, we proposed two strategies for searching the neighbors of the current solution, where the randomly selected two pairs in the solution change their locations, and then the second elements of the corresponding pairs randomly change.

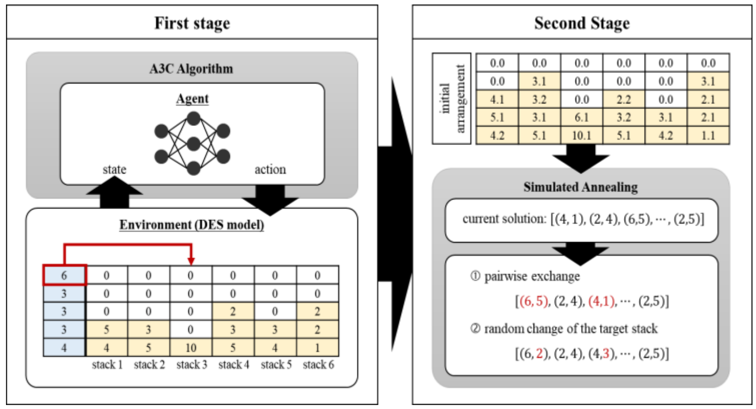

Figure 1. Two-stage stacking algorithm.

3 EXPERIMENT

We tested the proposed stacking algorithm on the randomly generated stacking problem where a total of 200 steel plates are to be stored at 20 stacks with the constraint that a maximum of 30 steel plates can be located at each stack. The upper left graph in Figure 2 shows that the stacking policy is adjusted to reduce the number of rehandling moves as the training progresses. The upper right graph in Figure 2 shows that the solution found using simulated annealing further decreases the workload of overhead cranes in retrieval work. The lower image in Figure 2 represents the final stacking arrangement of the steel plates obtained from the proposed algorithm. The darker color means the remaining time for the retrieval of the corresponding steel plate is longer. As a result, except for 8 steel plates, all steel plates are stacked in order of the cutting dates.

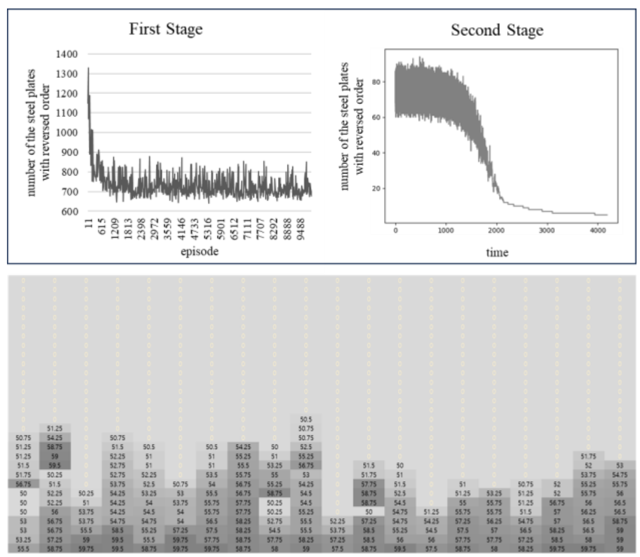

Figure 2. Stacking results of the proposed algorithm.

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