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# A Simulation Study on the Automated Container Storage Yard Cranes System

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**Abstract.** In this paper, we introduce a configuration of container storage yard, in which lift AGVs and shuttle carrier are used. We address the approach for building one detailed simulation system for this automated container storage yard system. Simulation frame, several control logic and decision making rules are presented. Simulation experiments for scheduling triple RMG cranes are carried out to evaluate the effects of the scheduling strategy. The objective of the study is to maximize the productivity of the system, which might be applied to import containers set and export containers set at the same time.

**Keywords.** Automated container storage yard system, automated container terminal, lift AGV, Railmounted Gantry Cranes (RMG) Scheduling, simulation

## Introduction

In recent years, an increased number of attention has been paid to automated container terminal, which improves operating efficiency and provides better service. Since improving operatring efficiency and service level is not easy, it may be affected by many factors. Generally, scholars focus on the configuration design of automated container terminal, considering it as the main factor. So we can see some container yards of different configurations.

In general, an automated container terminal consists of berth and quay crane, container storage yard, transport vehicles and gate.

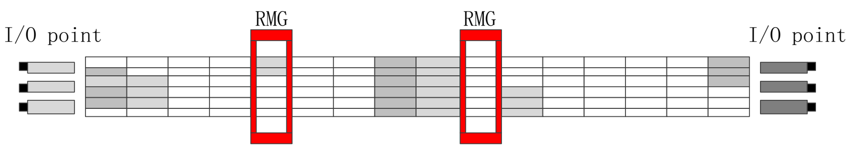


**Figure 1.** Basic configuration of container storage yard.

Figure 1 is the basic configuration of container storage yard in the automated container terminal. A container block with two input/output (I/O) points has two non-passing Railmounted Gantry Cranes (RMGs), in which one RMG serves one I/O point. In this configuration, two RMGs are unable to pass each other, and automatic guided vehicles or trucks pick up and drop off containers at I/O point.

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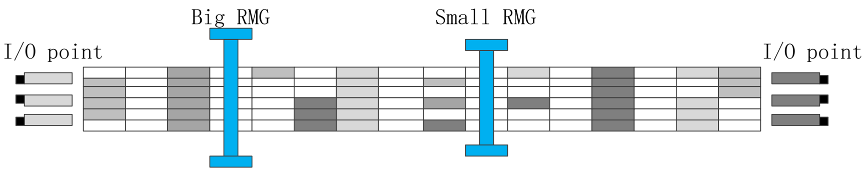


**Figure 2.** Container storage yard with double different size cranes.

In Figure 2, the container storage yard is using double different size cranes. In this way, big RMG and small RMG are able to serve two I/O points without interfering with each other.

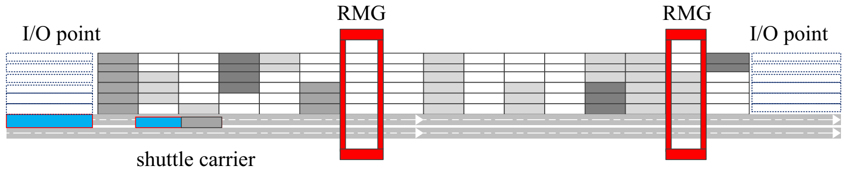


**Figure 3.** New configuration of container storage yard.

Figure 3 shows a new configuration of container storage yard to be applied the automated container terminal. At I/O point, lift AGV are adopted to pick up and drop off container without waiting for RMG to transit the container. The shuttle carrier can transmit the container to any position in the block to solve the handshake problem between RMGs (RMG cannot pass anther RMG to place the container in the block). Gharehgozli et al. addressed the problem of scheduling twin automated yard crane with the consideration of inter-crane interference [1]. The scheduling problem was modeled as traveling salesman problem with precedence constraints, and solved by a heuristic [2].

However, there is also another factor, which may impact on the operating efficiency and service level, rarely taken into account [3][4]. It's the scheduling control logic of storage yard equipment. We need to compare different control logics to get the better one, which means that different control logics must be realized and compared. Due to the high cost in finance and time, realizing the control logics with real automated container terminals is not a wise choice. This is why simulation needed. By designing models of automated container terminal with simulaiton software instead of building real ones, much time and money will be saved, in addition, we can change the design whenever we want.

## 1. Literature Review

A brief summary of yard crane scheduling problem follows: Source [5] proposed a mixed integer programming (MIP) model of one yard crane routing problem. Source [6] also studied one yard crane problem to reduce the total amount of delay time. They proposed a Lagrange relaxation-based algorithm to determine the optimal number of cranes to be assigned to each block in one planning period. Source [7] studied the multiple cranes scheduling problem. They proposed a heuristic algorithm to minimize the total loading time without loading sequence requirement. Source [8] also discussed the twin yard crane system for optimal scheduling problem. In the paper, the loading plan is assumed to be known in advance. Source [9] developed Priority/ACO (Ant Colony Optimization) heuristics to solve multiple cranes scheduling problem. They discussed how crane interference affect make-span and crane utilization. Source [10] studied the yard crane problem as a continuous time MIP model, considering constraints, i.e. crane interference, separation distances, same time storage/retrievals handling tasks. Source [1] addressed the problem of scheduling twin automated yard crane with the consideration of inter-crane interference. The scheduling problem was modeled as a traveling salesman problem (TSP) with precedence constraints, and solved by a heuristic. Source [11] designed a twin automated stacking cranes with a handshake to solve the inter-crane interference As to the double different size cranes system, source [12] studied two RMG system of different height and width, and assumed that there is only type of container to be handled in one yard slot.

## 2. Simulation model

In this paper, the automated container storage yard employs non-passing RMGs with two shuttle carriers, which can transfer the containers to any position in the yard block. This configuration solves the RMG non-passing constraint and RMG handshake problem to bring the storage container to its final location as shown in Figure. 4. At both ends of the block, lift AGV can pick up and drop off container at platform without the handshake with RMG like Figure 5.

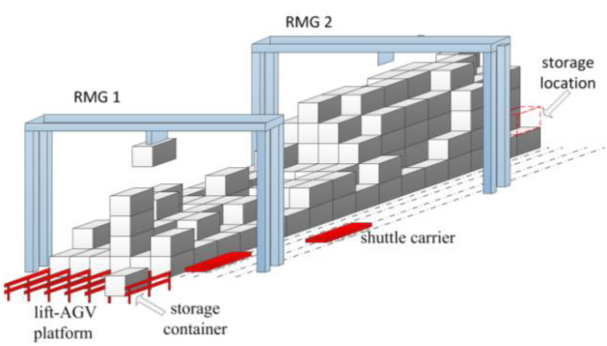


**Figure 4.** Side view of RMGs with shuttle carriers.


**Figure 5.** Lift AGV (http://www.konecranes.de/).

Figure 6 shows the frame of the simulation model designed in this paper. The first step is the layout initialization. The layout elements include container, lift AGV platform, vehicle track and control sensors. In the simulation model, the movement of

RMG and shuttle carrier are controlled by the control sensors. So the sensor control logic is created in advance. The number of elements can be customized by the parameters input (see Figure 7). The second step is the handling equipment initialization. Handling equipment includes RMG, shuttle carrier and lift AGV. Handling equipment characteristics define the type and the basic operational procedures of each handling equipment. Handling equipment control logic dictates the motion of the each handling equipment to perform tasks. The number and the setting of handling equipment can also be customized. Lastly, the decision making rules such as task planning rule and task assignment rule are defined in the third step to have a complete simulation model.

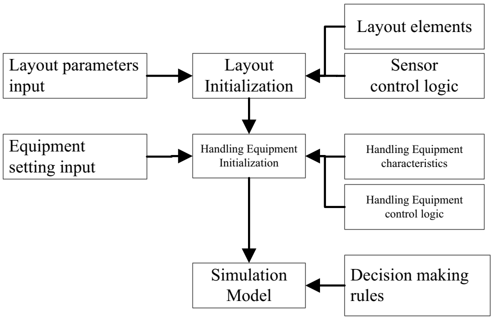


**Figure 6.** Frame of the simulation model.

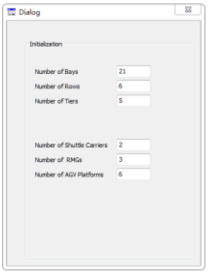


**Figure 7.** Layout parameters input.

Figure 8 shows the final layout of the simulation model.

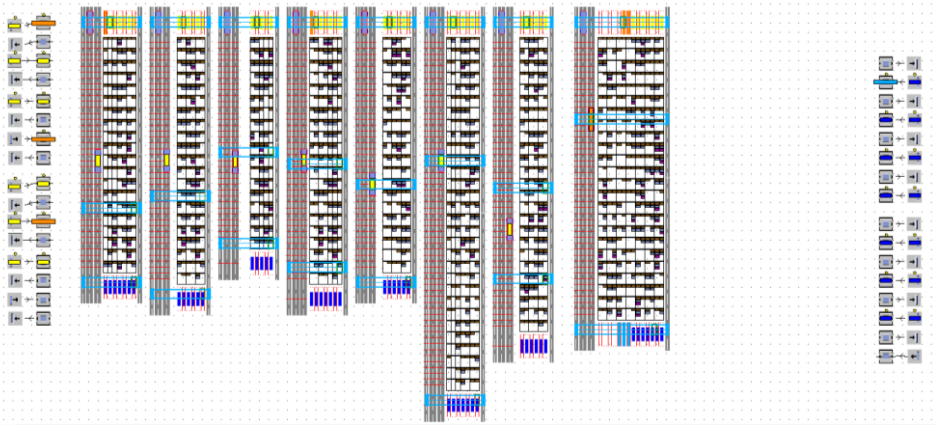

**Figure 8.** Layout of the simulation model.

## 3. Control Logic

There are two types of control: “RMG oriented” and “Lift AGV oriented”. The following control logics are based on “RMG oriented” scheduling control logic.

### *3.1. RMG Control Logic*

In this paper, there are two type of RMG control logic. One type of control logic is designed for RMG, away from shuttle carrier platform and working with shuttle carrier. The control logic is shown in Figure 9, where RMG needs to waiting for an idle shuttle carrier to do the container handling task. The second control logic of RMG is designed for RMG, next to shuttle carrier platform. This type of RMG can do carry container from or to shuttle carrier platform without handshake with shuttle carrier, and also needs to serve for shuttle carrier to carry container from or to shuttle carrier platform. The control logic is shown in Figure 10. The task type A is container handling task without handshake with shuttle carrier. The task type B is container handling task together with shuttle carrier.

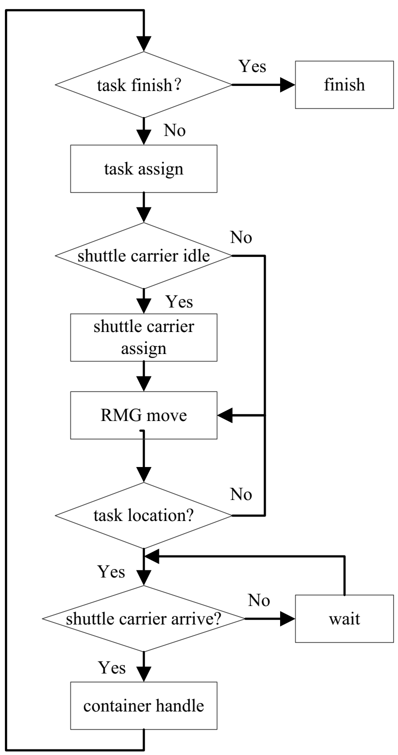


**Figure 9.** Control logic of RMG together with shuttle carrier.

### *3.2. Shuttle Carrier Control Logic*

The tasks of shuttle carrier are mainly created by the RMG. Once a RMG is assigned a task, which needs to work with shuttle carrier, an idle will be also assigned. Once shuttle carrier becomes idle, it will check whether it is needed for the task of RMG and will work for it.

### *3.3. Decision Making Rules*

For RMG dispatching problem, each yard block is divided into several parts. Each part will be assigned one RMG to serve the handling tasks. And export container handling tasks to be given higher priority to be handle than inport container. And task sequence is based on task arrive time and updated by the priority.

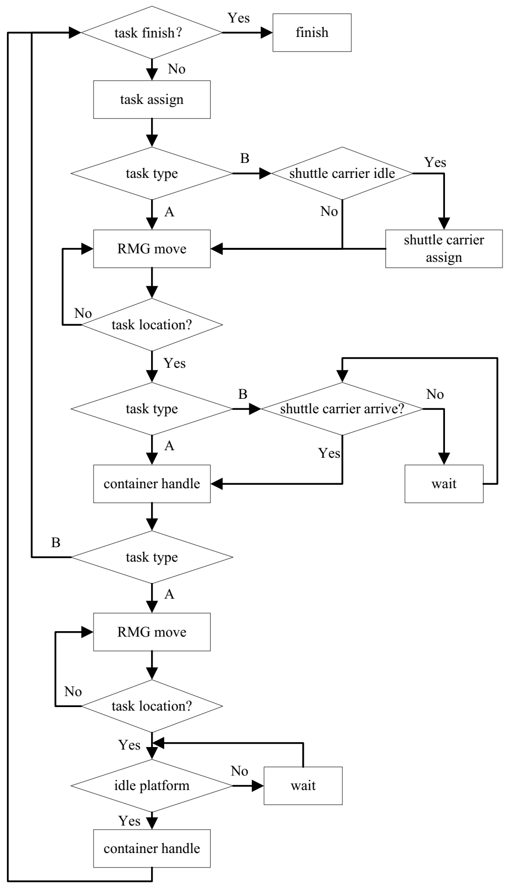


**Figure 10.** Control logic of RMG.

## 4. Experiments

### *4.1. Assumptions*

There are some assumptions to be made in the experiments:

(1) All containers are 20 feet standard.

(2) Safety space regulation is not considered.

### 4.2. Input Data

The input data to be used in the simulation model are provided in Table 1.

**Table 1.** Equipment Setting.

| Equipment | | |
|---|---|---|
| RMG | Number in one block | 3 |
| | Speed | 100 m/min |
| | Avg. handling time | 2 min |
| Shuttle carrier | Number in one block | 2 |
| | Speed | 200 m/min |
| Shuttle carrier platform | Number in one block at each end | 3 |

### 4.3. Results

In Figure 11, the performance (Average makesan of one yard block tasks) of Lift AGV oriented control logic and RMG oriented control logic proves that RMG oriented control logic is better.

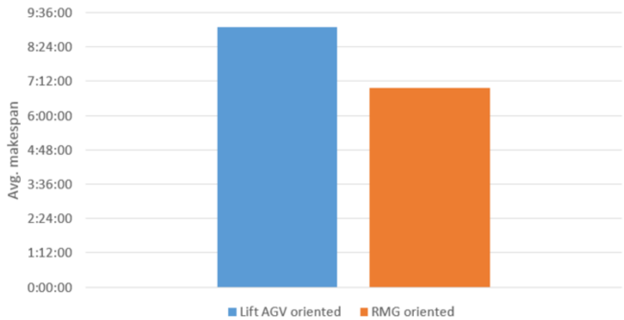


**Figure 11.** Performance using Lift AGV oriented and RMG oriented control logic.

The performance with different yard block division for RMG assignment is presented in Figure 12. The configuration case 7 (block): 7 (block) : 7 (block) has a minimum makespan of 6 hours 44 miniutes 52 seconds. All the tasks in the block are evenly assigned to each RMG.

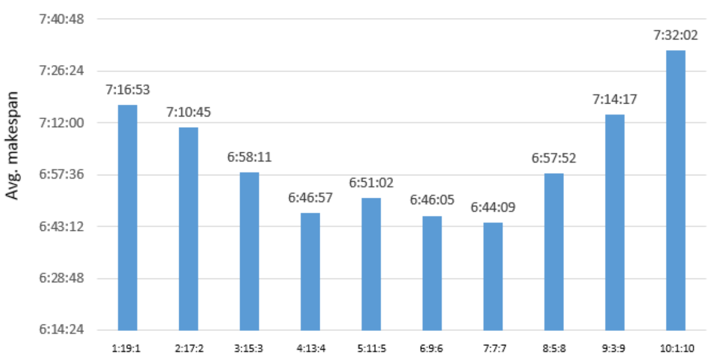


**Figure 12.** Performance with different yard block division.

## 5. Conclusions

Firstly, a new designed container storage yard and its simulation model have been described. Lift AGVs and platforms are adopted at I/O point to eliminate the handshake with RMG. And shuttle carriers are used to solve the RMG interference problem. The simulation frame and control logic are presented in detail. The experiments show that the "RMG oriented" scheduling control logic is superior. And the best configuration of block division is 7 (block): 7 (block) : 7 (block).

## Acknowledgement

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