An Intelligent Multi-agent System for Efficient Gate Operation in a Container Terminal

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Abstract

Recently the container volume in the global trade is steadily increasing. In an effort to cope with this trend, major ports of the world are stepping up the introduction of high-tech equipments, trying to establish a highly efficient information system, and improving the internal work processes of their container terminals. For speedy and effective cargo handling, they are making every effort in the diverse fields.

The purpose of this study aims at developing an intelligent multi-agent system for the gate work of a container terminal, which is the place of authority transfer in a container terminal. The agent system suggested in this study has made a comparison between COPINO information by TOS (Terminal Operating System) and information on containers and trucks recognized at the gate passage, checking up their efficiency, and performing the function of controlling outside truck's input-output. Also, based on the records of outside truck's gate passage, some gates can be operated flexibly, consequently enhancing the efficiency of the gate function. The results of job performance will immediately be notified to the customers and terminal managers, thus helping them make decisions speedily.

Keywords: Container Terminal, Gate Operation, Multi-agent System

1. Introduction

The container volume is steadily increasing all over the globe, and in particular, in case of Northeast Asia, the transshipment cargoes are rapidly expanding. It is forecasted that the container volume will reach 13.2 million TEU in 2011 and 21 million TEU in 2020 [1]. Under this circumstance, in order to be a mega hub port, many countries are making every effort to increase the efficiency of their container terminals, creating diverse strategies, and trying to introduce an intelligent information system and technology. Recently, as the RFID (Radio Frequency Identification) technology comes into the spotlight, it is rapidly expanded into the related industries [2]. Especially in the port logistics field, many efforts to introduce the automatic identification of vehicles and containers are being made with the Korean Ministry of Maritime Affairs and Fisheries taking the lead in this project.

In case of a container terminal, many researches for the development of a non-stop gate system through RFID technology are being made [3], and thanks to these efforts, before long the port logistics industry is expected to undergo dramatic improvements. However, if we focus only on obtaining logistics information by means of the tag and reader based on the RFID technology, we will fail in improving the job processes, and also meet with confusion owing to the overflowing information coming from this new technology. In particular, in case of a container terminal, all the trucks and containers accessing to the container terminal has to be identified, and accordingly, the data to be handled are rapidly increasing. Therefore, current gate operation system cannot handle the enormous information data, and is liable to make many mistakes, and finally will result in deteriorating its operational efficiency. For this reason, we need a new system to deal with a huge amount of information effectively.

Such a new system will require a wide range of research and development in many related sectors of port logistics. However, under the assumption that RFID tags will, before long, be attached to the trucks and containers, this study tried to develop an intelligent agent system in order to improve the efficiency of gate operation, which is based on the automatic identification of inbound or outbound trucks and containers accessing to the container terminal gate, consequently minimizing the turnaround time of visiting trucks.

Meanwhile, under the current gate system of a container terminal, it is impossible to gain information on various environmental changes immediately and on a real time basis, thus not being able to make use of them in management. This means the necessity of a new system, i.e. a more flexible gate system that can respond quickly. For instance, when inbound containers enter the container gate, the flexible gate system can read quickly the information on the coming trucks and containers, also checking on a real time basis the information on the ship to be loaded, the yard location, and the condition of yard cranes, and consequently, giving a help in deciding the container location and reducing the working time of the yard cranes. Moreover, if there is congestion in the inbound lane or outbound lane, the number of inbound or outbound lanes can be coordinated to reduce the congestion.

In order to make such an efficient gate system like this, all the information on the gate, container yard, and yard equipment as well as information on their capacity has to be obtained on a real time basis, and simultaneously, response measures have to be taken according to the environmental changes during their operation. To this end, this study has introduced a multi-agent technology. A complex and dynamic problem cannot be easily solved by the combination of separate application programs. The multi-agent system can make use of the agents, which perform a variety of functions under the changing environments, while taking the advantages of information sharing, communication exchanges, and mutual cooperation.

Because of these merits, the multi-agent system is coming to the fore as an appropriate alternative in dealing with various environmental changes and complex matters [4]. Accordingly, many researches are being made for the development of models based on a multi-agent system [5, 6].

The multi-agent system suggested in this study focuses on minimizing the bottlenecks taking place at the container terminal gate, reducing the waiting time of visiting trucks, and improving the productivity of yard cranes. This paper is composed as follows. Session 2 analyzes the work process of inbound/outbound container in the container terminal. Session 3 presents the system environment to be developed under the RFID environment, designing a multi-agent system suitable to the new environment. Session 4 presents the system environment to be developed under the RFID environment, developing a multi-agent system and final session mentions the expectations and limitations of this study, along with our future research direction.

2. Work Process of Gate-in/out Container in a Container Terminal

The major jobs to be done in the container terminal can be divided into three: containers loading and unloading, checking the incoming and outgoing containers, and container transfer. The job of checking the incoming and outgoing containers is related to the gate operation. In order to put the containers into the container yard, the trucker has to send a COPINO (Container Pre - Notification Notice).

When a truck arrives at the container terminal gate, based on the COPINO, the gate manager checks, compares, and confirms the truck driver's ID card and the container number. And if it is all right, he will inform the truck driver of the position information in the container yard. Figure 1 shows the overall process of handling an incoming container in the container terminal. Figure 2 and 3 show the detailed processes of incoming containers, which take place at the gate and landside TP.

The container terminal gates targeted in this paper are using RFID technology in order to identify the trucks and containers. Also, each block of CY (container yard) is using two units of crossing ATC (automatic transfer crane). However, the container loading and unloading at the landside TP of each block is performed manually by a remote controller.

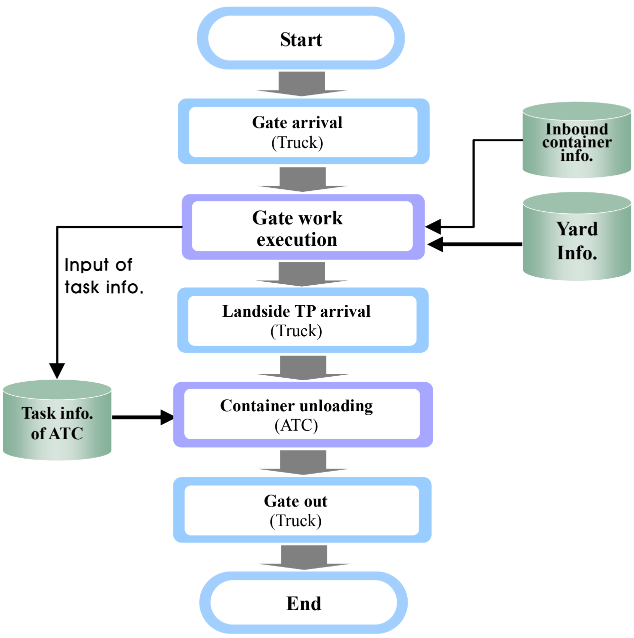

Figure 1. Overall work flow to process an inbound container

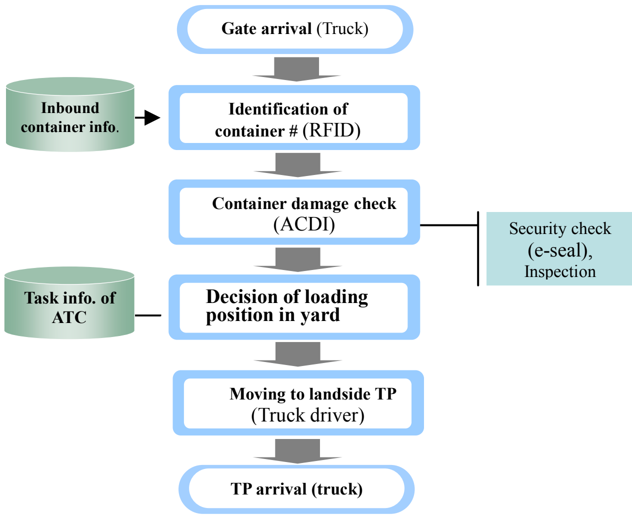

Figure 2. Gate work flow of an inbound container

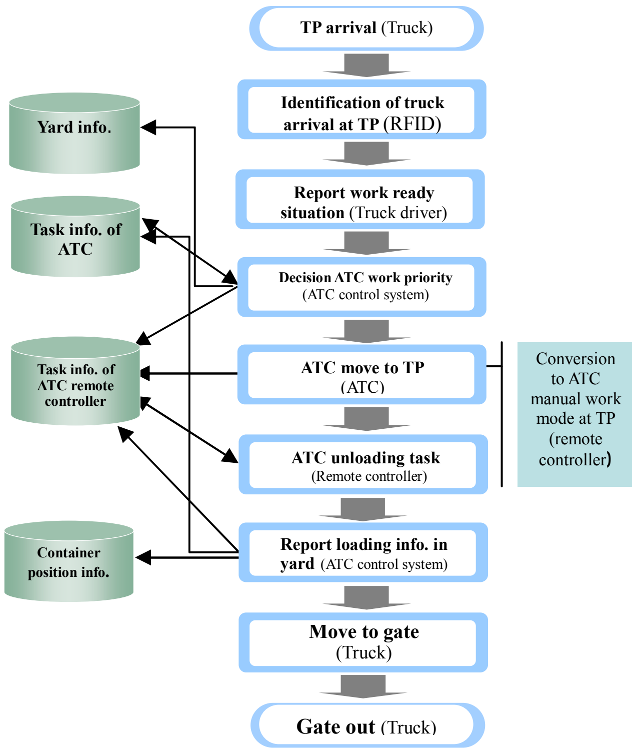

Figure 3. Landside TP work flow of an inbound container

Figure 4 and 5 illustrate the detailed processes of handling the outgoing containers taking placing at the gate and landside TP.

In order to perform the process of gate job automatically, the information on the container terminal yard and ATC job has to be shared on a real time basis, and the information of the yard position of incoming containers through the gate is to be delivered. Also, in order to automatically perform ATC job scheduling, job dispatching, and ATC operation in the process of handling the incoming and outgoing containers, an intelligent system is vitally necessary. In an effort to make the above-mentioned processes more streamlined, this study has transformed the key objects of the processes into intelligent agents, so that the processes can be automated. Furthermore, to avoid congestion at the peak time of the gate job, this study has introduced an intelligent gate agent system, so that the gate lanes for inbound or outbound containers can be coordinated flexibly.

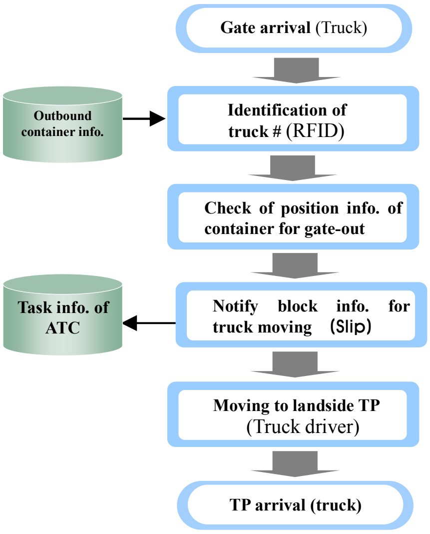

Figure 4. Gate work flow of an outbound container

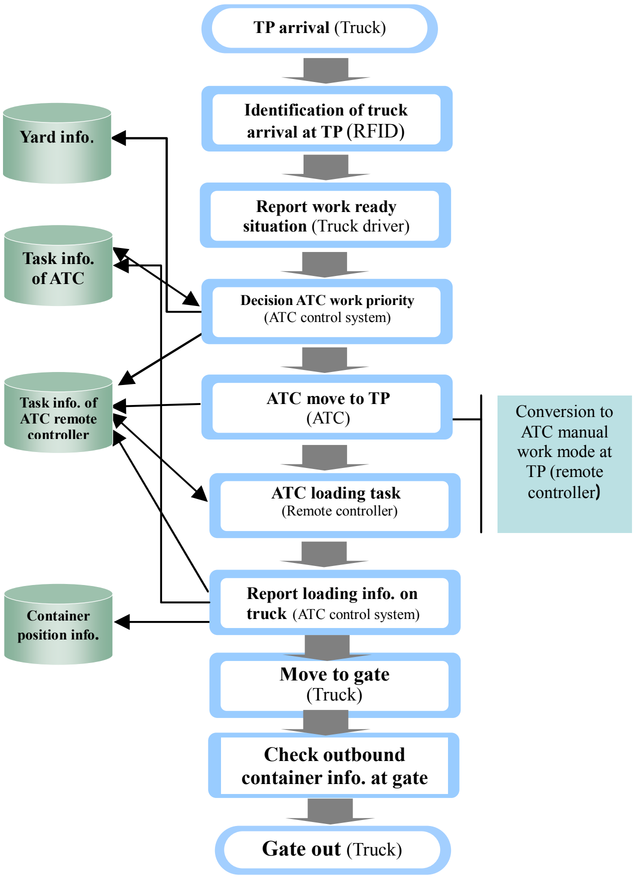

Figure 5. Landside TP work flow of an outbound container

3. Design of Intelligent Gate Multi-agent System

3.1 Multi-agent System Structure

The Intelligent Gate Multi-agent System (IGMS) developed in this study is consisted of a gate lane allocation agent, gate agents, a process management agent, a block allocation agent, ATC agents, ATC management agent and ATC remote controller management agent as figure 6. The functions of each agent in the IGMS are as follows.

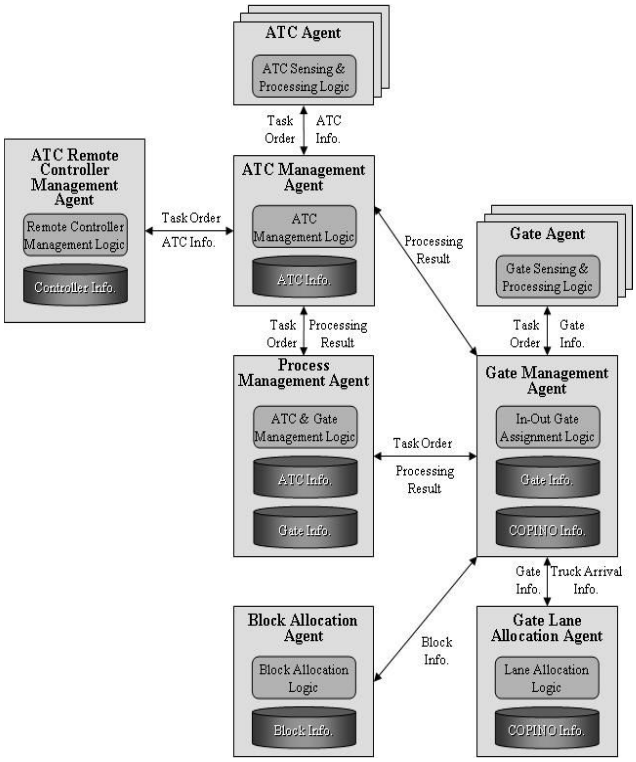

Figure 6. Intelligent Gate multi-agent system structure

• Gate lane allocation agent: recognizes the arrival of trucks at the entrance of the container terminal and allocates the incoming or outgoing trucks to a gate lane.

• Gate agent: checks and compares the trucks and containers with the COPINO, and if it doesn't correspond, the cargoes are not allowed to enter. Also, its results are to be sent to the gate management agent.

• Gate management agent: according to the gate allocation information received from the gate lane allocation agent (in time of gate-in) and the process management agent (in time of gate-out), this agent gives a task order to the gate agent. Also, it sends the information on the gate passage of trucks and containers to the process management agent and ATC management agent. By considering the container yard situation and the workload of ATC, it provides the truck driver with the information on block position for effective handling of incoming or outgoing containers.

• Process management agent: manages the whole process in order to connect the job of gate and the job of container yard including the task orders for ATC and gate.

• Block allocation agent: delivers the information on CY (container yard) storage situation to the gate management agent.

• ATC agent: according to the task order of ATC management agent, this agent handles container loading and unloading, and send the information on each block's ATC job situation to the ATC management agent. Also, ATC agent collect information of truck arrival at TP and information of container loading/unloading ready completion from truck driver.

• ATC management agent: according to the task order of the process management agent, this agent chooses the ATC for the task, and also gives a task order to the ATC agent. This agent has an algorithm for ATC task allocation. Also, this agent manages the information on the ATC workload in each block, and delivers this information to the gate management agent.

• ATC remote controller management agent: informs the remote control worker of the work order of the remote controller, which comes from the ATC management agent, and also inform the ATC management agent of the work completion information.

3.2 Message Definition

The IGMS is generally based on the FIPA-OS [7], a multi-agent standard, and used an ACL (agent communication language) for communication. ACL is not a knowledge expression, but a form of communication to deliver the expressed knowledge like figure 7.

```
(request
   :sender      ATC_Management_Agent
   :receiver    ATC_Agent_2_2
   :content     (loading
                        (Truck_ID    HDTB0823)
                        (Container_ID ANGB9823752)
                    )
   :language    igas_acl
   :ontology    igas_ontology
)
```

Figure 7. ACL structure

The above message shows how ATC management agent gives an order for loading to the ATC agent 2-2, along with attached truck ID and container ID. By using ACL, IGMS performs the function of sending information, requesting for tasks, and responding to the task order. All the performatives are based on ACL, and each agent delivers his performative to its counterpart.

4. Development of Intelligent Gate Multi-agent System

4.1 Development environment

IGMS has been developed based on the Java2 standard edition 1.5, and its database management system has used MS-SQL 2000. The development environment of IGMS is shown in table 1.

Table 1. IGMS development environment

O/S	MS-Windows 2003 STD Edition
Language	Java2 Standard Edition 1.5
DBMS	MS-SQL 2000
Editing Tool	Eclipse 3.2
Hardware	Intel Zeon 3.06GHz, 1GB RAM, 160GB SATA HDD

Figure 8 and 9 show how to monitor the current situation of the gate and CY and how to confirm the results of task handling under the IGMS environment.

As illustrated in figure 8, the information on trucks and containers handled in each gate and CY is available on a real time basis. Also, as in figure 9, the results of the work previously done are available by date and by time.

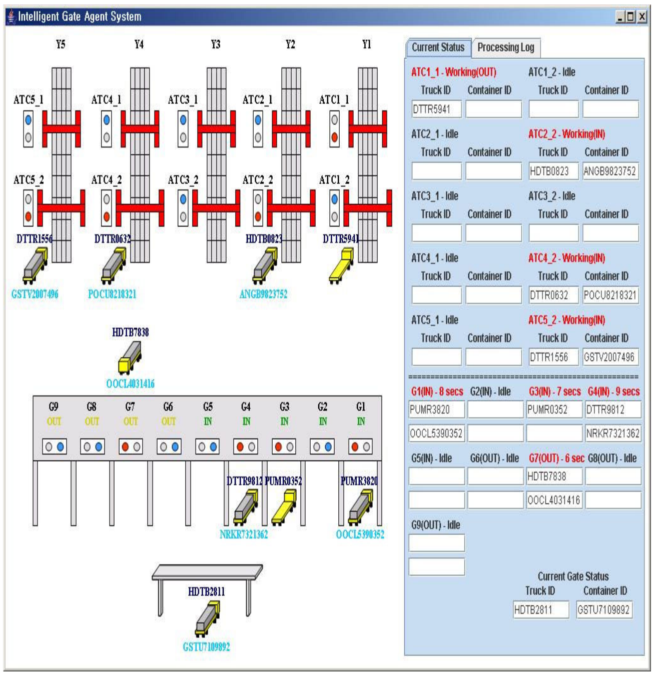

Figure 8. Monitoring screen of multi-agent system

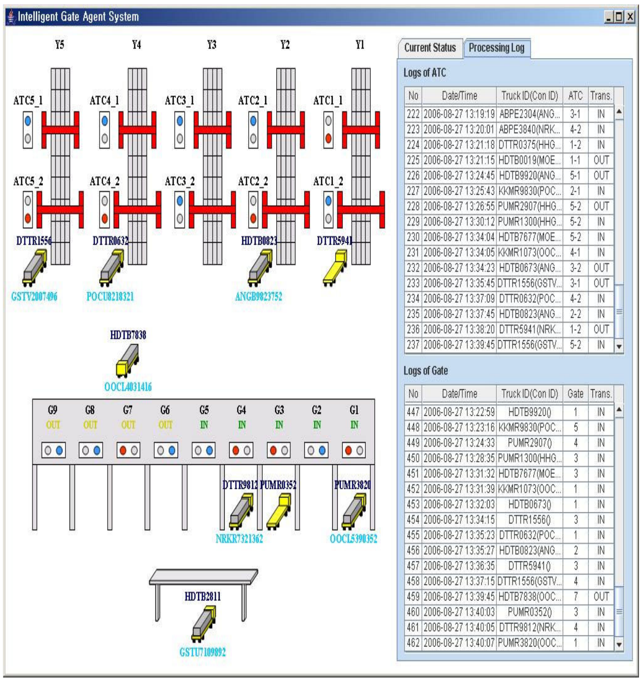

Figure 9. Log information of multi-agent system

4.2 Case Study

In order to show the whole process of handling incoming and outgoing containers, that is to say, from the arrival at the entrance gate of a truck loaded with containers until it passes through the exit gate after unloading containers at the CY, this case study summarized the operation process of the multi-agent system.

(1) Truck arrival at the gate

① Gate lane allocation agent receives information on the truck from the RFID reader of an auxiliary gate installed in front of the main gate.

② Gate lane allocation agent asks the gate management agent for current situation information on all the entrance gates.
Gate management agent asks each gate agent for current situation information.

③ Gate agent delivers information on the waiting for work to the gate management agent.

④ Gate management agent informs the gate lane allocation agent of the information on the waiting for work at all the entrance gates.

⑤ Gate lane allocation agent allocates the gate to the visiting truck by considering the entire work situation at each gate. But if congestion is expected at a certain gate, the number of an entrance gate or exit gate can be coordinated by considering the number of incoming or outgoing trucks.

⑥ Gate agent receives the information on the trucks and containers that pass through the appointed gates and compare and confirm it with COPINO.

⑦ Gate agent delivers the confirmed information on trucks and containers to the gate management agent.

⑧ Gate management agent asks the block allocation agent for the information on current CY situation, and simultaneously asks the ATC management agent for ATC workload information of each block.

⑨ Gate management agent receives from the block allocation agent and ATC management agent the information that it has asked, and based on this information, it decides the location of the block where the incoming containers will be placed, and then issues the slip to the truck driver.

⑩ Gate management agent delivers the information on the appointed block location to the block allocation agent and process management agent.

⑪ Block allocation agent updates the information on current CY situation of each block, and the process management agent gives an order of work preparation to the ATC management agent, so that the ATC of relevant blocks can prepare for the work.

⑫ ATC management agent delivers the order of work preparation to the corresponding ATC agent.

(2) Truck arrival at the landside TP

① ATC agent unloads the containers after receiving the information on the completion of work preparation.

② ATC agent informs both the truck driver and ATC management agent of the information on work completion.

③ ATC management agent informs the process management agent, block allocation agent and gate management agent of the information on work completion. The message screen related to this process in multi-agent system is like Figure 10.

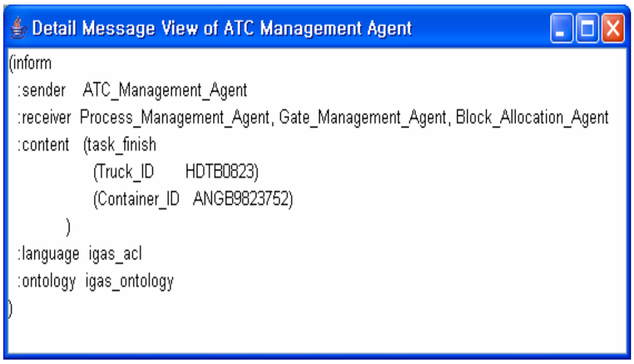

Figure 10. Message of ATC management agent

④ Gate agent receives the information on the trucks arrived at the exit gate.

⑤ Gate agent delivers the collected information on the trucks to the gate management agent. The message screen related to this process in multi-agent system is like Figure 11.

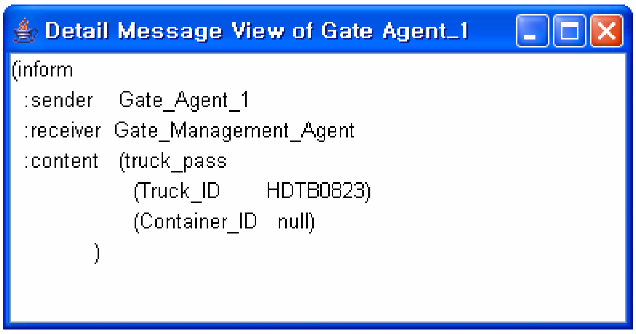

Figure 11. Message of Gate agent

All the inbound containers go through this process in the multi-agent system.

5. Conclusion

For the sake of effective gate operation, this study developed an intelligent gate system based on the multi-agent system, in which we can monitor, on a real time basis, the current situation information on the gate, CY, and yard equipment in the container terminal and also information on their capacity as well, so that the container terminal can quickly respond to the environmental changes. The multi-agent system suggested in this study is expected to minimize the bottleneck in the terminal gate, reducing the waiting time of the incoming and outgoing trucks, and enhancing the productivity of yard cranes. As a result, it will improve the productivity of the whole container terminal, saving the turnaround time of visiting trucks, and eventually enhancing the service level and competitiveness of the container terminal. From now on, we will make efforts to perform simulations to test the performance of this intelligent gate system.

Acknowledgement

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