http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (9): 1845-1850, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.1845.1850

Petri-net Modeling of Container-port Work Flo

[1,2]Jianxin Liu, [1]Yuyue Du, [3]Peng Li and [1]Yongfa Hong
[1]College of Information Science and Engineering, Shandong University of Science and Technology, Qingdao 266590, China
[2]Modern Education Center, SDUST, Qingdao 266590, China
[3]Department of IT Management, Affiliated Hospital of Medical College, Qingdao University, Qingdao 266555, China

Abstract: This study first introduces the operation flow of the container port and port business subsystems, then establishes, on the container dock operation system, integration model, berth system model and loading/unloading operation system model by using Petri net modeling technology. The model is analyzed, given the nature of model and verified. The modeling approach makes dynamic model and function running of the system closely linked and set the stage for analyzing the dynamic characteristics of the system, So as to facilitate the improvement and optimization of practical business system.

Key words: Container port, petri net, work flow, optimization, verification

INTRODUCTION

With social and economic progress, the rapid development in trade between china and other countries has made port container throughput soar, made container vessels more and more large-scale, high-speed, intelligent and led to a breakthrough. With the container transportation development of automated container ports, how to grasp the dynamic performance of the port system and materialize automatic monitoring of the container port system is the urgent need for port enterprises.

Therefore, a study on the operational processes of the container port is of practical significance to improve the efficiency of port operations, control costs and improve the management level.

Petri net, as the most widely applied distributing system model, has a natural advantage to interpret asynchronous, concurrent and collaborative cases. It is intuitively graphical and it also introduces many mathematical methods to analyze its nature. Not only can it characterize the structure of the system but also can describe the dynamic performance of the system (such as state changes of the system). For complex systems, Petri nets can also give hierarchical refinement, much in line with the mode of human thinking. Therefore, applying Petri net modeling to port container operation flow is an appropriate choice. There are few automated port logistics systems using Petri net. Degano and Di Febbraro (2001) established a Petri net model involving day-to-day work plan of the dock, study in accordance with the resources divided into subnets to monitor the dock. Domestically, Wei (2003) applies Petri net is to port logistics system modeling, describes system running process with Petri net but gives no analysis or application of the model. Xinyan (2002) in accordance with the mobile carrier of the container in port container logistics system, establishes a hierarchical model of port container logistics system but she fails to further analyze and apply the model.

The Petri net model reflects the Dynamic characteristics and the whole picture of the operation flow. Analyzing the model and identifying the bottlenecks of the work flow help to materialize the process of restructuring, optimization, improvement and integration of allocation of resources and ultimately raise operating efficiency. At the same time, its unique advantage of dynamic representation sets the stage for real-time monitoring of the system. This paper adopts hierarchical modeling approach for the complex system model of port container work flow. First, it introduces the container port operational processes and various port business subsystems, then, according to the composition and characteristics of the port container work flow, establishes an integrated model and the detailed models of berths system and ship loading/unloading operating system on container dock business operating system based on Petri net. And it further analyzes the model. Thus it contributes to the improvement and optimization of the actual

Corresponding Author: Jianxin Liu, College of Information Science and Engineering, Shandong University of Science and Technology Qingdao, 266590, China

business and it provides a theoretical basis for the programming design and operational management of port container work flows (Hong and Bae, 2000; Liu *et al.*, 2011; Li and Du, 2009).

INTEGRATED MODEL OF CONTAINER PORT WORK FLOW

Container port work flow system is a complex dynamic system discrete events, the entire system is decomposed into target-specific subsystems. And the port business can be divided into a number of subsystems, by decomposition and integration, a complex system becomes easy to grasp and control. Thus, according to different functions, the whole system can be divided into six major subsystems: berths system, reactor tank system, ship unloading system, loading system. These subsystems are interconnected and bound with each other and well integrated, in a series of discrete events and various chance factors, ships, trucks, containers and other dynamic entities transfer between the various subsystems within the system, which constitutes the dynamic process of the whole dock.

To improve the operational capability and efficiency of the container port, some major segments must be o combined systematically and appropriately, to bring their maximum potential in to play and serve the arriving ships., establishing an integrated model of container dock business operating system With Petri net modeling to represent the relationship of various work segments. Integrated model not only represents the links of various work segments but fully display the working condition of the entire system and facilitates real-time monitoring. An integrated model of container port operational processes is devised as shown in Fig. 1. The Petri-net integrated model of Container port operational process describes the operational workflow of the entire port system as well as the structure and function of the entire system. Transition and place of the Petri net model are shown in Table 1 (Kim and Kim, 1997; Jian-Xin *et al.*., 2011).

The dynamic process of the entire port container work system shown by the integrated model is: When the container ship arrives at the port, the data is sent by the

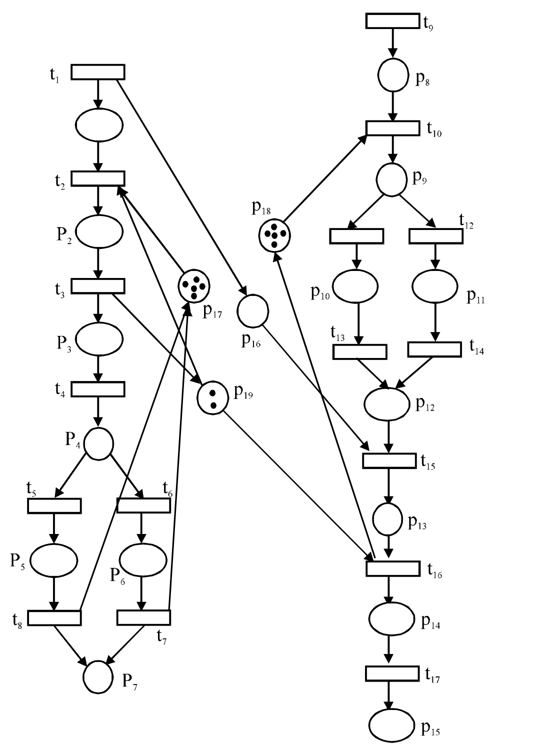

Fig. 1: Petri net model Σ_1 of container terminal integrate processes

Table 1: Transition and place of the petri net model

Place	Transition
p_1: Ship sails into its berth	t_1: Ship arrives in the port
p_2: Unloading	t_2: Start unloading
p_3: Imported containerized cargo shipped to the specified area in the yard	t_3: Unloading completed
p_4: Ready for distributing imported containers in designated area	t_4: Start distributing
p_5: Distributing via highway	t_5: Distributing imported containers via highway
p_6: Distributing via railway	t_6: Distributing imported containers via railway
p_7: Distribution completed	t_7: Distributing via highway
p_8: Completing exported-container preparation	t_8: Distributing via railway
p_9: Choosing transportation way exported containers	t_9: Preparing for exported containers' arrival
p_{10}: Adopting highway for container transportation	t_{10}: Start container transportation
p_{11}: Adopting railway for container transportation	t_{11}: Choosing highway for container transportation
p_{12}: Transporting exported containers to the yard	t_{12}: Choosing railway for container transportation
p_{13}: Transporting exported containers to specified area for loading	t_{13}: Transporting via highway
p_{14}: Quay cranes move exported containers on board	t_{14}: Transporting via railway
p_{15}: Ship sails out of port	t_{15}: Start transporting goods from the yard to the specified area
p_{16}: Sending information of ship's arrival to yard system	t_{16}: Start lading
p_{17}: Laying area for imported containers	t_{17}: Checking the ship before departure
p_{18}: Laying area for exported containers	
p_{19}: Quay cranes available for loading and unloading	

computer system to export container system, informing that containers to export are shipped to the specified location of the dock. When a ship moves into its berth, it is provided unloading service by the pre-allocated quay crane and unloading begins. During the process, the unloaded goods are transferred to the specified area in the yard by the pre-arranged trucks and then laid by unloading tired cranes in the yard. Containers transported to the yard can be distributed by either way: Highway distribution or railway and distribution. While the Ship is unloaded, another portion of trucks in the yard transport containers to export to the appropriate location of the dock and they are loaded upon unloading to reduce the vessel's waiting time in port, optimize utilization of equipment and in various segments and improve the efficiency of the entire system.

SUBSYSTEM MODELS OF CONTAINER PORT WORKFLOW

The integrated model of Container port reflects the overall framework of the operating processes; however, the integrated model can't reflect the structure of the subsystems involved. Here are Petri net models of several subsystems.

PETRI NET MODEL OF ENTER/DEPARTURE SYSTEM

The petri net model of enter/departure system is as shown in Fig. 2. The dynamic process of the ship enter/departure system model is as follows: When the container ship arrives at the port, first it enters the outer anchorage in the harbor waiting for entry. When a berth in the harbor and the waterway in and out of the dock are available, the ship moves into the anchorage in the harbor through the waterway and then berths in the specified berth, waiting for the quay crane for loading and unloading services. When Loading and unloading the ship are completed, it moves out through the anchorage and the waterway, leaving the dock. In this way, thus a service cycle of ship loading and unloading is done (Nishimura *et al*., 2001).

Transition and place of the petri net model in Σ_2 are illustrated in Table 2.

PETRI NET MODEL OF LOADING/UNLOADING SYSTEM

Loading and unloading system of port container operation can be divided into unloading system and loading system. When the containership berths, resources of quay cranes, container trucks or trailers, forklifts and tired cranes co-work to complete unloading if the imported containers need unloading. Its main

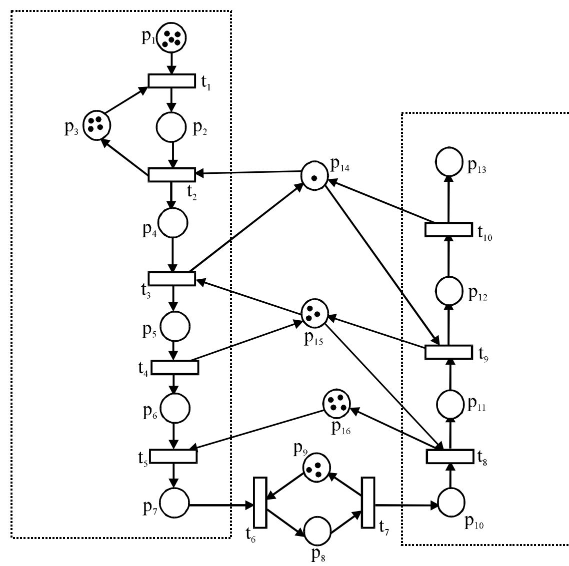

Fig. 2: Petri model of enter/departure system Σ_1

Table 2: Transition and place of the petri net model

Place	Transition
p_1: Container ship waits for entry	t_1: A ship reach the port and occupy anchorage outside the port
p_2: A ship sails at anchorage for entry	t_2: A ship enters the port via waterway
p_3: Anchorage resource outside the port	t_3: A ship sails into the port and occupy anchorage in the port
p_4: Container ship enter via waterway	t_4: A ship leaves anchorage in the port
p_5: Container a ship enter anchorage in the port	t_5: A ship sails into the berth, ready for loading/unloading
p_6: A ship leave anchorage for the pre-allotted berth	t_6: Quay cranes start loading/unloading
p_7: A ship berth	t_7: Quay cranes complete loading/unloading
p_8: Quay crane load/unload containers	t_8: A ship leaves the berth for anchorage in the port
p_9: Quay crane resources	t_9: A ship sails out of the port via waterway
p_{10}:Loading/unloading containers is completed	t_{10}: A ship departs from the dock
p_{11}: Container ship enters anchorage in the port	
p_{12}: A ship sails out of the anchorage in the port via waterway	
p_{13}: A ship departs from the dock	
p_{14}: In-and-off-port waterway resources	
p_{15}: Berth resources at anchorage in the port	
p_{16}: Berth resources for a ship	

Table 3: Transition and place of the petri net model

Place	Transition
p_1: Trucks or trailers are available ; token indicates number of available trucks or trailers	t_1: Container trucks are driving to unloading area of the dock via empty-truck lane
p_2: Empty-truck lane is occupied	t_2: Container trucks wait for available lane
p_3: Container trucks wait for quay cranes unloading the ship and loading trucks	t_3: Quay cranes get ready for loading containers into trucks
p_4: Quay crane are unloading	t_4: Quay cranes load containers into trucks
p_5: loading is completed	t_5: Trucks are driving to the yard through loaded-truck lane
p_6: Loaded-truck lane to the yard are occupied	t_6 : Quay cranes start loading/unloading
p_7: Loaded-truck lane to the yard are available, token number stands for number	t_8: Tired cranes unload containers from trucks
p_7: Tired cranes get ready for unloading containers from trucks of available lane	
p_8: Container tucks at yard waiting for unloading	
p_9: Tired cranes unload container tucks	
p_{10}: Tired crane available	
p_{11}: Empty-truck lane available	
p_{12}: Quay crane available	

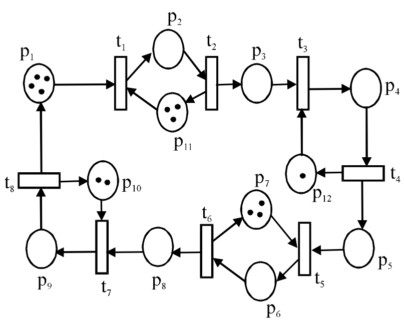

Fig. 3: Petri model of loading/unloading system Σ_3

function can be described as follows: quay crane remove imported containers from the ship, container trucks or trailers transport imported containers to the specified location of the yard and then tools like tired cranes lay the containers in order. Unloading system model of dock Work can be devised as shown in Fig. 3.

Transition and place of the petri net model Σ_3 are illustrated in Table 3.

Dynamic process of the above unloading model goes: Container trucks are available; they move to the dock through empty-truck lane waiting for the quay cranes unloading the ship and loading them; quay cranes complete loading; container trucks deliver goods to the yard through loaded-truck lane, waiting in line for tired-cranes unloading; when unloading is completed trucks return to the dock and reload until all imported containers are moved to the yard. Loading in Port container operations is similar to the unloading process, which will not be repeated here.

Analysis of port container work flow model: The main purpose of modeling the actual system with Petri net is to make use of the model to analyze and verify the nature and function of the system. The system model established with Petri net has intuitive graphical representation and formal representation. Some dynamic features of the Petri net model are closely linked with some properties of the analog system. Therefore, it is possible to take advantage of nature analysis of the model to test performance of the actual modeling system.

In The initial state of the integrated model shown in Fig. 1, run Σ_1 and it can be found each transition is solvable. That is, for any transition t, there is an accessible token (condition), prompting t, which shows Σ_1 solvable. Therefore, every segment of container port business operation process, under certain conditions, can be achieved and the whole system can run smoothly without any deadlock or livelock.

Verification: Ship arrives in the t_1 port, transition occurs. M_0 [t_1>M_1, M_1 (p_1) = 1, when location for imported containers is available, i.e., when M_1 (p_{17})> = 1, M_1 (p_{19})> = 1, M_1 [t_2>M_2 then unloading can be done and M_2 (p_{19}) = M_1 (p_{19})-1, M_2 (p_{17}) = M_1 (p_{17})-1. Unloading is completed, release resources of quay cranes, M_2 [t_3>M_3 and M_3 (p_{19}) = M_2 (p_{19})+1, M_3 (p_3) = 1. Here, M_3 [t_4>M_4, when high way is chosen for imported container distribution: M_4 [t_5t_8>M_5 and M_5 (p_{17}) = M_4 (p_{17})+1, M_5 (p_7) = 1 if railway is chosen, M_4 [t_6t_7>M_5 and M_5 (p_{17}) = M_4 (p_{17})+1, M_5 (p_7) = 1. Imported container distribution is completed.

During exported container distribution, M'_0 [t_9]>M'_1, M'_1 (p_8) = 1, here, if M'_1 (p_{18}), transition t_{10} may occur, i.e., container transportation starts, M'_1 [t_{10}>M'_2. When high way is chosen for container transportation, M'_2 [$t_{11}t_{13}$>M'_3. When rail way is chosen for container transportation, M'_2 [$t_{12}t_{14}$>M'_3. Here, if the yard gets information that ships arrive in the port, M'_3 (p_{16}) = 1 transition t_{15} may occur, M'_4 [t_{15}>M'_4, exported containers are delivered form the yard to the dock. When quay cranes are available, i.e., M'_4 (p_{19})> = 1, start loading, M'_4 [(t_{16}>M'_5 (p_{18}) = M'_4 (p_{18})+1, M'_5 (p_{19}), = M'_4 (p_{19})-1. M'_5 [t_{17}>, he ship can move out of the port. Thus it is verified.

Similarly, port container enter/departure operating system model and unloading operating system have no deadlock or livelock.

The model reflects the entire business operation process of port container and it cannot demonstrate detailed aspects of the process. Thus, model Σ_2 in Fig. 2 will be analyzed in order to understand the nature and problems of the actual modeling system. Supposing, initial token M_0 in Σ_2 is M_0 (p_1) = n, M_0 (p_3) m, M_0 (p_4) = i, M_0 (p_{15}) = j, M_0 (p_{16}) = k, M_0 (p_9) = h and for $\forall p \notin \{p_1, p_2, p_3, p_4, p_{15}, p_{16}, p_9\}$: M_0 (p) = 0.

In Fig. 2, the loading and unloading system of port container offers every ship such service in accordance with a certain order. By running and analyzing Petri net mode in Fig. 2, properties of the container dock operating system can be drawn, except that the ship loading and unloading operation is limited by the resources of quay cranes, operations of imported/exported containers can be carried out in parallel.

Verification: In model Σ_3, the transition sequence $t_1t_2t_3$ with the sequence $t_9t_{10}.......t_{15}$ can run in parallel, when transition t_3 is completed, release quay crane resources, t_{16} will occur and start unloading. The transition sequence $t_4t_5t_8(t_4t_6t_7)$ and transition t_{16} can occur in parallel, i.e., distributing unloaded imported containers and loading exported containers can co-occur. Thus, it is verified.

While the ship receives loading and unloading service of port container operating system, it is restricted by anchorage, enter/departure waterways, the number of berths as well as quay cranes which provide specific services. Due to the rich resources of anchorages outside the port, the number of quay cranes and waterways become the bottleneck of system efficiency.

Verification: When container trucks are available to distribute containers, i.e. , transition t_1 is restricted by the resource of empty-truck lane, if available, i.e., M_0 (p_1)> = 1 then M_0 [t_1>M_1 and M_1 (p_2) = M_0 (p_2)+1, M_1 (p_{11})-1, M_1 [t_2>M_2 in M_2 state, t_3 is restricted by the resource of quay cranes, i.e., if M_2 (p_{12})>1, then M_2 [t_3>M_4.

Similarly, when loaded trucks run through loaded-truck lane, they are also restricted, i.e., only when M_6 (p_7)> = 1, transition t_5 will occur. Loaded trucks run into the yard and unloading is restricted by the resource of tired cranes, only when M_8 (p_{10})> = 1, transition t_7 will occur, tired cranes get ready for unloading trucks, thus the verification.

The above analysis of the system model can ensure all segments of the actual system run smoothly and it can detect bottlenecks in the system and laid the foundation for raising the efficiency of the system.

CONCLUSION

Modeling is the basis of system simulation. Due to randomness and complexity of port container logistics system, object-oriented modeling is commonly used for port container logistics system. Although this method has decomposing, abstract and hierarchical characteristics suitable for tackling complex problems, the establishment of the system object model, function model and dynamic model cannot establish an organic link, resulting in difficulty of description and analysis of the system structure and the dynamic characteristics. This study applies the Petri net modeling technology, establishes the corresponding Petri net models, which of the whole port operating system, the ship entering and leaving systems and discharge system, according to the parallel and other dynamic features of the port operations. This paper also analyzes and verifies some important features. The modeling approach makes dynamic model and function running of the system closely linked and set the stage for analyzing the dynamic characteristics of the system.

ACKNOWLEDGMENTS

This study was supported in part by the National Natural Science Foundation of China under Grants 61170078 and 60773034; the National Basic Research Program of China (973 Program) under Grant 2010CB328101; and the Scientific and Technological Developing Program of Shandong Province of China under grant 2011GGX10114.

REFERENCES

Degano, C. and A. Di Febbraro, 2001. Modelling automated material handling in intermodal terminals. Proceedings of the IEEE/AISME international Conference on Advanced Intelligent Mechatronics, Volume 2, July 8-12, 2001, Como, pp: 1023-1028.

Hong, J.E. and D.H. Bae, 2000. Software modeling and analysis using a hierarchical object-oriented Petri net. Inf. Sci., 130: 133-164.

Jian-Xin, L., S. Lin-Lin, D. Yu-Yue and H. Yong-Fa, 2011. The analysis and verification of cooperative workflow based Interactive abstract graph. Am. J. Eng. Technol. Res., 11: 3215-3221.

Kim, K.Y. and K.H. Kim, 1997. A routing algorithm for a single transfer crane to load export containers onto a containership. Comput. Ind. Eng., 133: 673-676.

Li, P. and Y. Du, 2009. Modeling and design for dynamic workflows based on flexible activities. Inform. Technol. J., 8: 750-756.

Liu, J., P. Li, R. Cui and L. Sun, 2011. A framework based on workflow and multi-agent supporting virtual enterprise dynamic formation. Inform. Technol. J., 10: 51-60.

Nishimura, E., A. Imai and S. Papadimitriou, 2001. Berth allocation planning in the public berth system by genetic algorithms. Eur. J. Oper. Res., 131: 282-292.

Wei, G., 2003. Modeling and simulation of container terminal logistics system based on WITNESS. Ph.D. Thesis, Wuhan University Of Technology, Chinese.

Xinyan, Z., 2002. The research of scheduling and simulation modeling of seaport container logistics system. Ph.D. Thesis, Wuhan University of Technology, Chinese.