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## Integrated simulation framework for the process planning of ships and offshore structures

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### ABSTRACT

Recently, requests for accurate process planning using simulation have been increasing in many engineering fields, including the shipbuilding industry. To date, designers of shipyards have developed in-house simulation systems or used commercial systems such as the QUEST by Dassault system when requests for the simulation of process planning have occurred. However, these methods have some limitations. First, it requires a lot of time to develop a new in-house simulation system. In addition, it is hard to reuse previously developed systems when developing a new one and it is also hard for these to satisfy the various needs of shipyards effectively.

To solve these limitations, an integrated simulation framework is proposed in this study. The proposed simulation framework provides an environment for developing various simulation systems for shipbuilding process planning. It consists of a simulation kernel, basic simulation component and application-specific simulation component. The simulation kernel manages both DEVS (discrete event system specification) and DTSS (discrete time system specification) to deal with various simulation requests. The basic simulation component provides commonly used simulation models and modeling strategies, which are used to make a simulation system more efficient. The application-specific simulation component implements the dynamics analysis, collision detection and realistic three-dimensional visualization.

To evaluate its efficiency and applicability, the proposed simulation framework is applied to the block erection process of ships and offshore structures. The results show that the proposed simulation framework, as compared with those of existing studies and of commercial simulation systems, can provide a consistent, integrated development environment for a simulation system.

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## 1. Introduction

### 1.1. Background of this study

Shipyards are constructing huge ships and offshore structures. For instance, a deadweight 300,000 ton VLCC (very large crude carrier), which can carry 300,000 ton of crude oil, can be delivered to a ship owner after a total design and production period of about 14 months. During this time, it is very important for a shipyard to deliver the ship to its owner on delivery day. Thus, the shipyard should set up accurate process planning by investigating a number of design alternatives as early as possible.

However, even though process planning may be set up based on past experience, many problems which are not expected in advance may occur during production, since all ships and offshore structures to be constructed are different from each other in purpose, shape and size. To grasp these problems and to prepare design alternatives beforehand, designers of shipyards are now developing and using in-house systems themselves or are setting up process planning by using commercial simulation tools. However, for the case of developing in-house systems, it is hard to reuse simulation systems which have already been developed by various designers using different methods in different development environments. Thus, developing a new system using this approach requires a lot of time and effort when an application domain of the systems changes. In the case of using the commercial simulation tools, it is difficult for the designers to use existing design and production information, such as CAD information, process planning information, scheduling information, and so on, for simulation. Furthermore, it is difficult to reflect

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various requirements of the designers and to maintain the security of design and production information.

Therefore, if a consistent, integrated simulation environment ('simulation framework') that can support the development of a new simulation system is developed, then it is possible to set up accurate process planning in the early stages of development and to provide varied, flexible design alternatives that can increase productivity.

## 1.2. Related works

Many studies related to simulation model architecture and simulation engines have been conducted in the past. Here, the simulation model architecture represents a method for defining the simulation model according to a predefined form, and the simulation engine plays the role of operating the simulation model by progressing the simulation time. Especially, Zeigler [1,2] have studied a simulation model architecture of discrete event simulation called DEVS (Discrete Event System Specification) and are now conducting many other studies related to DEVS.

On the other hand, very little research related to simulation frameworks has as yet been carried out. Here, the simulation framework represents an integrated simulation environment that can support the development of a new simulation system. Praehofer and Zeigler et al. [1–5] proposed a modeling and simulation method that can handle simulation models of discrete event and discrete time, and they also developed a simulation framework based on the proposed method. In the case of discrete event simulation, the operation of a simulation system is represented as a chronological sequence of events. Process or material flow simulation systems and the like are included in the category of discrete event simulation. On the other hand, in the case of discrete time simulation, the operation of a simulation system is represented as the progress of time. State changes only occur at discrete time instants. Dynamic simulation systems and the like are included in the category of discrete time simulation. However, the developed simulation framework focuses only on the material flow simulation system of a workshop. Thus, it was difficult for it to be applied to a large factory such as a shipyard, and it was also hard to use existing design and production information for simulation.

Woo [6] developed a simulation framework based on a commercial simulation tool called QUEST (QUEuing Event Simulation Tool) by the Dassault System Co., Ltd. and applied it to the shipbuilding process of a shipyard. He analyzed the shipbuilding process from the viewpoints of production, process and resource (PPR), and he then defined simulation models for the shipbuilding process by using IDEF (ICAM DEFINITION) and UML (unified modeling language). In addition, he tried to use the shipyard's existing scheduling information for simulation. However, because the developed simulation framework is based on a commercial simulation tool, the existing framework had to be newly developed from the beginning if the simulation tool had been changed for any reason. Furthermore, it was difficult to use the CAD information, which is one of existing design and production information sources of the shipyard, for simulation.

Some studies related to the simulation framework have been made but have had some limitations, as mentioned above. To overcome these limitations, we proposed a new simulation framework for process planning in shipbuilding. The proposed simulation framework can reuse the already developed simulation systems and have various modules required for applications in shipbuilding, including a dynamic calculation module, a collision detection module, and so on. In addition, it can be applied to various application domains by introducing a similar concept to the research of Praehofer and Zeigler et al.

## 2. Overview and various application domains of the simulation in shipbuilding

There are various application domains which require the simulation in shipyards. There are several pressing matters related to the shipyards that require attention, which are as follows.

### 2.1. Concept of modeling and simulation

Before introducing various application domains, let us first look at the concept of modeling and simulation. This concept aims to estimate the results from the object, which will have occurred in the future, after making a virtual object that acts as an actual object. Here, the virtual object is called a 'model,' and the model stores the attributes (or states) and action principle (or transition) of the actual object. According to the role of the model, we divide it in this study into two groups, a simulation model and a dynamics model. The simulation model changes its state by the logics, and the dynamics model changes its state by the dynamics calculation. The process that makes such an object is called 'modeling.' In addition, finding results by operating the model over time according to the action principle is called 'simulation.'

Thus, the process for performing modeling and the simulation for preventing follow-up problems by estimating the result of a certain behavior and for finding a better solution is called 'modeling and simulation.' In addition, the process of modeling and simulation can be referred to simply as 'simulation,' since the modeling is first performed in order to perform the simulation.

### 2.2. Block erection and turn-over process

A ship is constructed by joining together its parts on the dock after dividing it into a number of blocks and assembling them. This is called the block erection (see Fig. 1). Recently, many shipyards make and erect the blocks into large sizes. These blocks are called mega blocks and some of them weigh from about 1000 to 3000 ton. While erecting these mega blocks, interference between a current block and the already erected block can be generated. As for blocks of offshore structures, these have a large number of outfitting features such as pipes, ducts, cables and ladders. Thus, a lot of interference in these blocks is being made. Currently, if interference between the blocks is made, it has to be solved after the fact. As a result, many problems occur, including the additional commitment of man-hours and materials due to the redoing of the work and the decrease of productivity due to the increase in follow-up work. Fig. 1(a) shows the block erection process used to erect Block 1 on Block 2 by using four crawler cranes. Here, each crawler crane can lift the maximum weight of 1000 ton. At this time, we can see interference between Block 1 and Block 2. If this interference can be grasped before the erection, additional loss in time and cost can be minimized.

As for certain blocks, it is easier to assemble the blocks under the turn-over condition than under the normal condition. Thus, many shipyards assemble such blocks at the turn-over condition and then reverse them during the block erection. This is called a turn-over process (see Fig. 1(b)). Fig. 1(b) shows the block turn-over process used to erect a block weighing about 400 ton using one floating crane and three crawler cranes. Here, the floating crane is a piece of equipment used for lifting very heavy blocks on seawater by use of buoyancy and can lift the maximum weight of 3600 ton. During the turn-over process, the floating crane lifts the block vertically. At this time, the tension on the wires between the floating crane and the block is at its maximum. If the tension exceeds the allowable value of the wires, the block may fall to the

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