Computer-Aided Design 44 (2012) 241–252

Contents lists available at SciVerse ScienceDirect

Computer-Aided Design

journal homepage: www.elsevier.com/locate/cad

Development of a simulation framework and applications to new production processes in shipyards

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ARTICLE INFO

Keywords:
Modeling & Simulation
Simulation framework
Floating crane
Production process
Block lifting
Block turn-over

ABSTRACT

Recently, a floating crane is frequently used for the block lifting, transportation, turn-over, and assembly processes in waves. For these production processes, it is important to detect collision in advance between assembly blocks or the block and the other facilities like the wire rope and the barge which are carrying the block. The tension of the wire rope also needs to be calculated to check that the maximum value is less than the safety criteria. In this paper, a mathematical model is constructed based on multibody system dynamics considering the external forces such as the hydrostatic, hydrodynamic, wind force, etc. To observe the dynamic motions of the floating crane and the block, and to calculate the tension of the wire rope, the time and event simulations are performed by solving the mathematical model in the computer. For applying the simulations to the various production processes in shipyards, a simulation framework is developed. The simulation framework consists of a simulation kernel, application-specific modules, a simulation coordinator, development tools, and post-processing tools. The simulation kernel manages both DEVS (discrete event system specification) and DTSS (discrete time system specification) to deal with various simulation requests. The application-specific modules provide the functions used in application systems, such as dynamic analysis, collision detection, visualization, wire rope force calculation, hydrostatic force calculation and hydrodynamic force calculation. The simulation coordinator manages the data of the simulation kernel and the application-specific modules. The development tools provide a development process, a scenario manager, and a simulation model generator. The post-processing tools are used to report the simulation results. The examples of block lifting, transportation, turn-over, and assembly simulations are developed based on the framework to show that the framework is useful for the simulations of the production processes using one or more floating cranes.

1. Introduction

1.1. Background of this study

A floating crane is a crane-mounted ship used to lift heavy block using buoyancy. It is one of the most important production facilities in shipyards. Since the lifting capacity of the floating crane is 3600 tons (Fig. 1), some new production processes that have never been tried before could be introduced. For example, in February 2010, DSME (Daewoo Shipbuilding and Marine Engineering, Co., Ltd.) introduced the 'one-time setting' process to install a new gantry crane of about 180 m long, 90 m high, and 5300 tons. Compared to the conventional assembly process at the dock side, which takes more than three weeks, the installation was accomplished in one day with the new process. The gantry crane was assembled first outside the shipyard and then transported and installed using the two floating cranes. Since transporting the gantry crane using parallel connected floating cranes and a barge is a new process never tried before in the world, a dynamic simulation is required for safety reasons. In this paper, a simulation framework that supports the simulations efficiently for the new production processes using one or more floating cranes is developed and applied to several simulations.

1.2. Related works

Praehofer et al. proposed and developed a simulation framework which could handle the discrete event and the discrete time

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doi:10.1016/j.cad.2011.06.010

Fig. 1. Transportation of the gantry crane using parallel connected floating cranes and a barge in DSME (Daewoo Shipbuilding and Marine Engineering, Co., Ltd.)

simulations [1–3] for the material flow simulation system of a factory. Since, however, the framework does not include the modules like dynamic analysis, collision detection, and calculation of hydrostatic and hydrodynamic forces, it is not appropriate to the new production processes in shipyards, such as block lifting and transportation.

Woo developed a simulation framework based on a commercial simulation tool, QUEST (Queuing Event Simulation Tool, Dassault System Co., Ltd.), and applied it to the shipbuilding process [4]. He analyzed the shipbuilding process as a combination of the production, process and resource (PPR) elements, and defined simulation models using IDEF (ICAM definition) and UML (unified modeling language). Since Woo's simulation framework is based on a commercial tool, the entire framework has to be modified if the commercial tool is changed in any way. Furthermore, the simulation framework does not incorporate any dynamic analysis, collision detection, calculation of hydrostatic and hydrodynamic forces, etc.

Cha et al. proposed and developed a simulation framework for shipbuilding process planning [5–7]. The simulation framework consists of a combined discrete event and discrete time simulation kernel, basic simulation components, and application-specific simulation components. However, the simulation middleware which integrates and interfaces the simulation components is not considered in the simulation framework. Also, there is no consideration of hydrodynamic, mooring, wind, current, swell forces, etc. The simulation framework is applied to typical process planning in shipyards.

In this paper, by improving the functionality and usability of the simulation framework [5–7], the simulation middleware is newly developed, the application-specific modules, such as the wire rope force calculation module and the hydrostatic/hydrodynamic modules are enhanced, and the external force calculation module is added into the application-specific modules. This improved simulation framework is applied to new production processes using one or more floating cranes in shipyard to verify the safety and possibility of the processes.

2. Simulation framework

Fig. 2 shows the configuration of the simulation framework developed in this paper and the application systems based on the framework. The framework consists of the following elements: a simulation kernel, application-specific modules, a simulation coordinator, development tools, and post-processing tools. The application systems can be developed using these elements.

The simulation kernel consists of the simulation engine and simulation model architecture and supports both the discrete event and the discrete time simulations. The application-specific modules consist of a dynamic analysis module, a collision detection module, a visualization module, a wire rope force calculation module, a hydrostatic/hydrodynamic force calculation module, external force calculation modules, etc. The application systems use some functions of these modules depending on the simulation purpose. The simulation coordinator is a kind of middleware that integrates the data from the application-specific modules and delivers them to the simulation kernel. For usability and convenience, the development tools provide the developer with the development process, scenario manager, and simulation model generator. The post-processing tools include a simulation result viewer that draws the graph or table of the simulation results. In the simulation framework, the simulation engine and the simulation model architecture are developed in this paper based on the Praehofer studies [1–3]. The dynamic analysis, the collision detection and the visualization modules are modified from the open program sources to the public. The wire rope force calculation, the hydrostatic/hydrodynamic force calculation, the external force calculation and the geometry calculation modules are developed in this paper. Also, the simulation middleware, all of the development tools and post-processing tools are developed newly. The application systems, such as block lifting simulation, block transportation simulation, block turn-over simulation, and block assembly simulation, are developed based on the simulation framework. As applying the simulation frame into various application systems, the generalization of the simulation can be proved.

3. Simulation kernel

The simulation kernel consists of a combined discrete event and discrete time simulation model architecture and a combined discrete event and discrete time simulation engine [5–8]. Fig. 3 shows the floating crane model as an example of a combined