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Event-based scenario manager for multibody dynamics simulation of heavy load lifting operations in shipyards

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Abstract

This paper suggests an event-based scenario manager capable of creating and editing a scenario for shipbuilding process simulation based on multibody dynamics. To configure various situation in shipyards and easily connect with multibody dynamics, the proposed method has two main concepts: an Actor and an Action List. The Actor represents the anatomic unit of action in the multibody dynamics and can be connected to a specific component of the dynamics kernel such as the body and joint. The user can make a scenario up by combining the actors. The Action List contains information for arranging and executing the actors. Since the shipbuilding process is a kind of event-based sequence, all simulation models were configured using Discrete EVent System Specification (DEVS) formalism. The proposed method was applied to simulations of various operations in shipyards such as lifting and erection of a block and heavy load lifting operation using multiple cranes.

Keywords: Scenario management; Discrete event simulation; DEVS (Discrete EVent System Specification); Multibody dynamics; Shipbuilding process

1. Introduction

Requests for accurate dynamic analysis using a simulation tool have been increasing in many engineering fields, including in the shipbuilding industry, as shown in Fig. 1. Unlike the conventional mechanical systems such as car and machinery, all ships and offshore structures are different from each other in purpose, shape and size. Thus, even though process planning may be set up based on past experience of similar ships and offshore structures, many problems which are not expected in advance may occur during production.

Moreover, according to the recent increase in the demand for offshore plants and new concept ships, reviews of new manufacturing methods to confirm their availability and safety have been performed frequently with their dynamic analysis in shipyards. Past studies on shipbuilding process and virtual manufacturing in shipyards were not focused on dynamic analysis of certain partial operations, but entire shipbuilding process planning and job assignment (Hwang et al., 2014; Lee et al., 2014). Since various existing simulation tools based on multibody dynamics focus on conventional mechanical systems (Cha et al., 2010a), such as machinery, cars, and spacecraft, there are some problems in the application of these simulation tools to shipbuilding domains due to the absence of specific items in naval architecture and ocean engineering, such as hydrostatic, hydrodynamic, wake, and mooring forces. Therefore, some recent studies focused on developing a simulation tool for the shipbuilding process based on the multibody dynamics theorem (Cha and Roh, 2010; Cha et al., 2010a, 2010b, 2012).

Since all ships and offshores differ in purpose, their production processes in shipyards also differ. Even if the mix of

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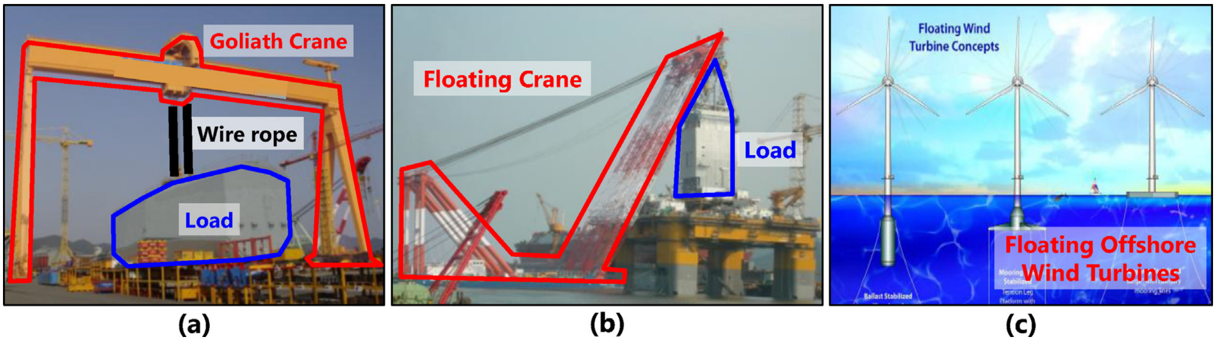

Fig. 1. Various types of mechanical systems in the shipbuilding industry: (a) goliath crane, (b) floating crane, and (c) floating offshore wind turbines.

vessel on the order is familiar, the master schedule could be non-repeatable due to a different order in which the different ships appear in the order book. Thus, developing a procedure for describing the production of ships may be costly and time-consuming. In this paper, a scenario manager capable of creating and editing a scenario for the simulation of shipbuilding processes is proposed. To describe the process of shipbuilding in a multibody dynamics simulator, the user-defined inputs to the simulator were analyzed, and the shipbuilding scenario was broken down into modularized units. Due to the discontinuous process of shipbuilding, event-based formalism was applied to the scenario manager. It is expected that the scenario manager might be very useful even if there are not unusual ship-types in the orderbook.

The remainder of this paper is as follows. Section 2 reviews previous studies related to this paper. In Section 3, the developed multibody dynamics simulator for the shipbuilding process is briefly introduced. Section 4 describes the key ideas of the proposed scenario manager and its implementation, and its application to shipbuilding follows in Section 5. Finally, Section 6 summarizes this study and briefly discusses the next study.

2. Related works

2.1. Dynamics simulator and its application to shipbuilding process

There are various open-source-based or commercial software programs that are based on the multibody dynamics theorem. Since most of them are general-proposed programs and do not include all the force modules as hydrostatics, hydrodynamics, etc., there are a little cases of their application to shipbuilding production process simulation.

ADAMS (Automatic Dynamic Analysis of Mechanical Systems) is a software system that consists of a number of integrated programs that aid an engineer in performing three-dimensional kinematic and dynamic analysis of mechanical systems based on multibody system dynamics (Orlandea et al., 1977; Schienhlen, 1990). Various external forces can also be applied to multibody systems, but hydrostatic and hydrodynamic forces, which are the dominant forces exerted on the floating platform and frequently used in shipyards, cannot be handled by ADAMS. ODE (Open Dynamics Engine) is an open-source library for simulating multibody dynamics (Smith, 2006). Similar to ADAMS, ODE derives equations of motion for multibody systems using augmented formulation. However, ODE also cannot handle hydrostatic and hydrodynamic forces. RecurDyn (FunctionBay, 2003) is a three-dimensional simulation software program that combines dynamic response analysis and finite element analysis tools for multibody systems. It is two to 20 times faster than other dynamic solutions because of its advanced fully recursive formulation. RecurDyn cannot also handle hydrostatic and hydrodynamic forces.

Unlike these software that are based on multibody dynamics, MOSES (Multi-Operational Structural Engineering Simulator) is a simulation software that can analyze the movement of a single body in a fluid by applying hydrostatic force and hydrodynamic force to it (Ultramarine, 2013). With this software, a multibody system that is connected in a restrictive condition cannot be simulated because a connective relation between the bodies is not supported, but a simulation that considers hydrostatic force and hydrodynamic force from external forces is possible. Thus, MOSES is often used for ocean shipyard simulation for floating single bodies.

In other areas of studies not using these software, some researches related to shipbuilding domains have been conducted in the past. Cha et al. proposed and developed a simulation framework for dynamic analysis of shipbuilding production process (Cha and Roh, 2010; Cha et al., 2010a, 2010b, 2012). Related works described above are summarized and compared with this study in Table 1.

From the view of scenario management, ODE and MOSES have not tried to fully handle the scenario. It means that the user should configure and manage the simulation time and give certain action to change the motion of rigid body. In order to change the motion of rigid body, for example, the user should act an external force to certain rigid body manually. Moreover, these all simulators have not tried to handle discontinuous-state variables and event- and state-triggered conditions, so it is difficult to flexibly generate a scenario related to various application domains that requires the simulation in shipyards because the process of shipbuilding is a kind of event-based sequence. Thus, this study focused on a concept of managing a multibody dynamics simulation