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Virtual Prototyping-based Integrated Information Modeling and Its Application in the Jacking System of Offshore Platform

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Abstract

Virtual prototyping is always used to validate a design by simulating the behavior of mechanical products. As concerning problems of the current researches on product integrated information modeling technology, this paper presents a new systematic integrated information modeling technology based on virtual prototyping. After the 800t jacking system of an offshore platform is introduced, the design process of virtual prototyping-based jacking system is discussed in detail, and then the virtual prototyping modeling of the jacking system is also put forward. A computer aided virtual prototyping software system is developed, which has been put into practice in a plant of offshore engineering. The realization of the driving function module is given as an example, which demonstrates that the methodology is obviously helpful for product integrated information modeling.

Keywords: *Virtual prototyping, Integrated information modeling, Offshore platform*

1. Introduction

Virtual prototyping [1] is a modeling technique, which involves using computer-aided design and simulation software to validate a design by simulating the behavior of mechanical product in the real world before committing to making a physical prototype. Based on integrated modeling technology [2] for mechanical product, virtual prototyping covers the solid modeling, finite element simulation analysis and optimization, kinematic and dynamic simulation, control system design and analysis, hydromechatronically-integrated simulation, multimedia simulation, human-computer interaction [3].

The solid model supports entity attribute information, topological relationship and geometric information [4]. With the solid model information, finite element analysis can be used for the definition and discretization of the solution domain, constrained domain and load domain, the determination of state variables and control method, the reduction of element that yields element matrices, the solution of a series of finite element equations, the visualization of the solving results [5-7]. The finite element optimization is used to achieve the update of entity attribute information, topological relationship and geometric information based on finite element analysis and new constrained domain. Kinematic and dynamic simulation is

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used for the solution of linear displacement, angular displacement, linear velocity, angular velocity, linear acceleration, angular acceleration based on the definition of the solution domain, constrained domain and load domain using solid model information. Control system design and analysis is used to control the system by traditional or modern control theory based on the mathematical model, and to simulate the control system by special analysis software. Hydromechatronically-integrated simulation is used for the conversion between the parameters of flow, pressure, velocity, displacement. Multimedia simulation of the solid modeling, finite element analysis and optimization, kinematic and dynamic simulation is fused with text, images, photographs, sounds, animations. Human-computer interaction is used to achieve interacted multimode virtual interaction and collaborative interaction with the solid modeling, finite element simulation analysis and optimization, kinematic and dynamic simulation, control system design and analysis, hydromechatronically -integrated simulation, multimedia simulation and knowledge sharing [8-11].

As the design efficiency can be greatly improved by virtual prototyping-based integrated information modeling, the development of complex product always uses virtual prototyping technology due to its quality, cost, time and service criteria. The design process of offshore engineering equipment is always very complicated and last too long, which involved a variety of product design resource. It is necessary to take advantage of the integrated information modeling system based on virtual prototyping to support the complex product design.

However, the integrated information modeling is the bottleneck of complex mechanical product design. It is so difficult to transfer information modeling based on virtual prototyping into mechanical product design efficiently. It is a crucial issue that how to help designers to do mechanical product design from information based on virtual prototyping, and then ally with these correlative information to mechanical design.

This paper proposes a new systematic integrated information modeling technology based on virtual prototyping for mechanical product. The left part of this paper is organized as follows. Section 2 introduces the offshore platform and the 800t jacking system. In Section 3, the design process of virtual prototyping-based jacking system is discussed in detail. In Section 4, virtual prototyping modeling of the jacking system is proposed. Section 5 concludes this paper.

2. Introduction of Jacking System of 800t Offshore Platform

An offshore platform [12] is a large structure with facilities to drill wells, to extract and process oil and natural gas, and to temporarily store product until it can be brought to shore for refining and marketing. In many cases, the platform contains facilities to house the workforce as well. Depending on the circumstances, the platform may be fixed to the ocean floor, may consist of an artificial island, or may float. Remote subsea wells may also be connected to a platform by flow lines and by umbilical connections. These subsea solutions may consist of one or more subsea wells, or of one or more manifold centers for multiple wells. And in this example, its load is 800t.

The jacking system [13-14] is divided into two types: gear-rack driven jacking system and hydraulic driven jacking system. The 800t jacking system on an offshore platform [15-16] is composed of four cylindrical legs and jacking mechanisms, including jacking device, locking device, wedge part, guiding device and control system, *etc*. And jacking device is used to achieve lift of the legs with motors driven lifting gears via a reduction gearbox, and the locking device is to ensure the lock of mesh between gear and rack, and the wedge part is to ensure the fixation reliability between platform and legs, and the guiding device is to ensure the guiding role between gear and rack during lifting, and the control system is with variable-frequency motor, brake, the load detecting device of climbing gear. The gear-rack mechanism of jacking system is an important link between platform and legs because of the long-time heavy load.

3. Design Process of Virtual Prototyping-based Jacking System

3.1. Functional Model of Virtual Prototyping Integrated Modeling System

The integrated modeling, whose aim is to achieve fusion and relation with related technologies of the research object, consists of two stages, the first is the modeling process of all relevant data models, the second is the integration of various modeling. The functional model of virtual prototyping integrated modeling system is shown in Figure 1.

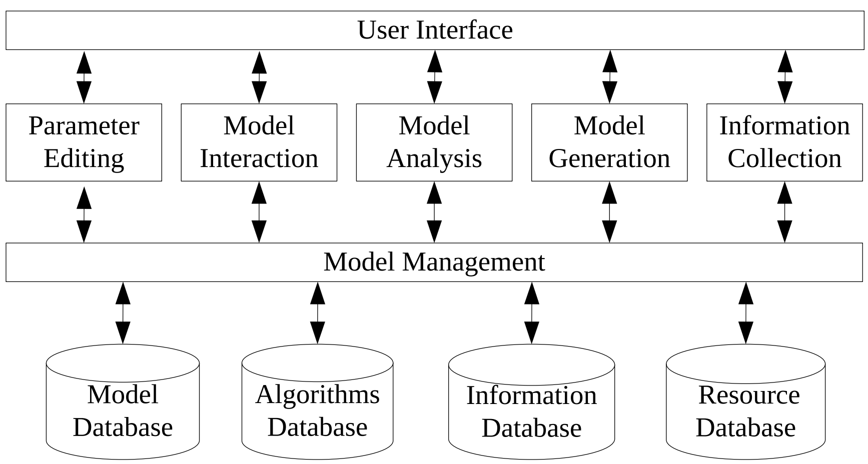

Figure 1. The functional model of virtual prototyping integrated modeling system

3.2. Integrated Design Process Method based on Virtual Prototyping

Based on the functional requirements and the process of integration method, the design process is shown in Figure 2:

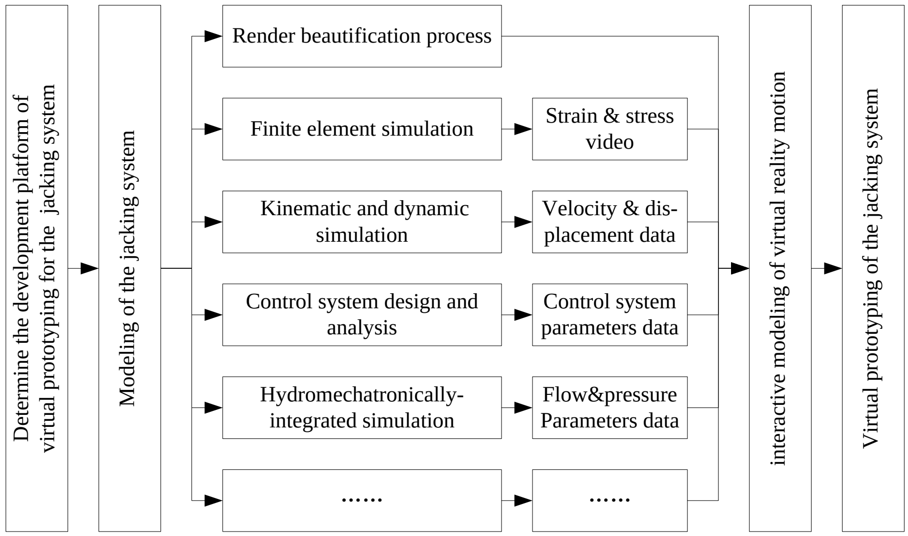

Figure 2. The overall design process of virtual prototyping for the jacking system

(1) Determine the software development platform of the virtual prototyping for the jacking system. The selection criteria of the software are general evaluation and degree of maturity.

(2) 3D modeling software is used to establish a 3D model of the jacking system, and then the model is rendered by 3D rendering software for further processing in virtual reality software imported by compatible formats.

(3) Finite element simulation of the critical components in the jacking system via finite element analysis software is used to get videos of the stress and strain, and then import the videos into virtual reality software.

(4) Kinematic and dynamic simulation of the critical components in the jacking system is used to get information about the velocity and displacement, and then import the information into virtual reality software.

(5) Control system design and analysis is used to establish a mathematical model for mathematical parameters, and then import parameters into virtual reality software.

(6) Hydromechatronically-integrated simulation is used for the conversion function between the parameters of flow, pressure, velocity, displacement, and then import parameters into virtual reality software.

(7) The other technologies of virtual prototyping are used to simulate the critical components in the jacking system for relevant information, and then import the information into virtual reality software.

(8) The behavioral model, motion model and interactive model of virtual objects are built by the virtual reality software to achieve the function of integrated simulation.

3.3. Integrated Modeling Technology based on Virtual Prototyping

Figure 3 is the procedure of integrated modeling for the virtual prototyping. The virtual prototyping is modeled with four steps:

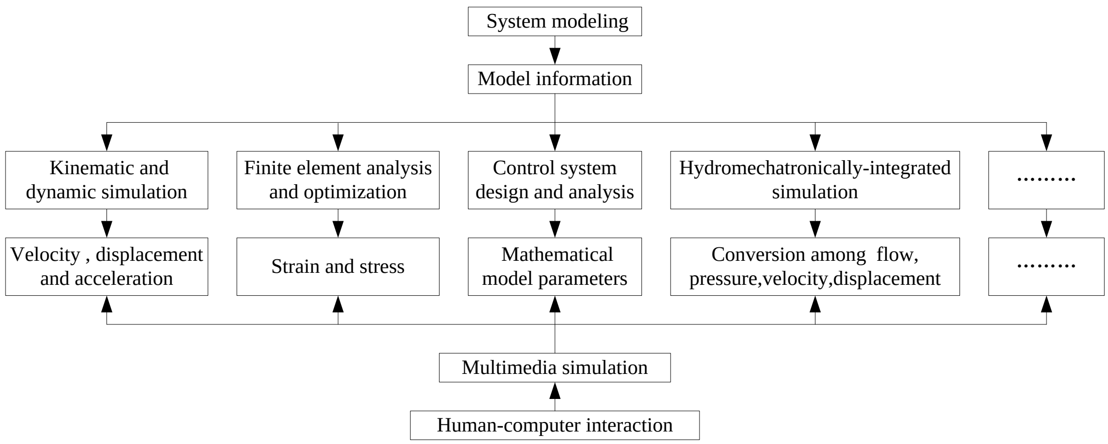

Figure 3. The procedure of integrated modeling for the virtual prototyping

(1) Build a 3D model on a research object to get model data.

(2) Get the information about constraining force, constraining displacement, stress, strain and the update of the entity attribute information, topological relationship and geometric information. In the design and analysis of the control system, the mathematical model is built to analysis parameters of the model, and the hydromechatronically-integrated simulation is used for the conversion between the parameters of flow, pressure, velocity, displacement.

(3) The multimedia simulation of the solid modeling, finite element analysis and optimization, kinematic and dynamic simulation is fused with text, images, photographs, sounds, animations.

(4) The human-computer interaction is used to achieve interacted multimode virtual interaction and collaborative interaction with the solid modeling, finite element simulation analysis and optimization, kinematic and dynamic simulation, control system design and analysis, hydromechatronically-integrated simulation, multimedia simulation.

4. Virtual Prototyping Modeling of the Jacking system

4.1. Virtual Prototyping of the Jacking system

The interface planning of virtual prototyping for the jacking system is based on the function of virtual prototyping, consisting of five sub-modules including operating instructions, the jacking system introduction, self-jacking presentation, finite element analysis video, system reset, as shown in Figure 4.

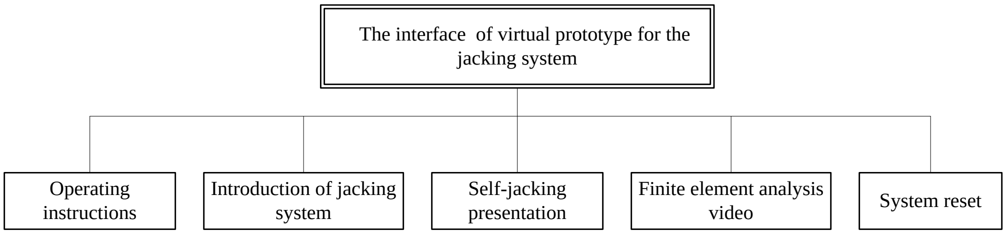

Figure 4. The modules of virtual prototyping for the jacking system

1) Operating instructions: It's shown as figures to introduce functions of all buttons in the interface and operation considerations.

2) Jacking system introduction: The composition of the jacking system, the structure and function of each sub-module are shown as figures.

3) Self-jacking presentation: The whole processes of driving piles, hoisting, landing, pile pulling are presented in the virtual prototyping.

4) Finite element analysis video: The change of stress and stress distribution because of the load from zero to the maximum in the meshing between gear and rack.

5) System reset: It's for system initialization to reset to the state that has no operation.

The software developed in Virtools [17] is shown in Figure 5.

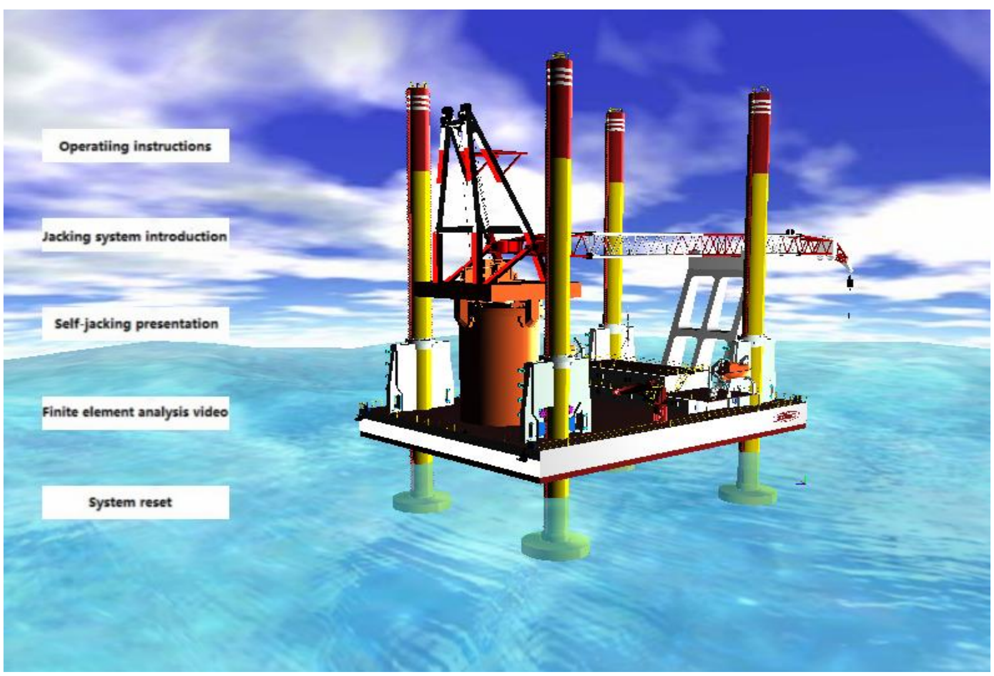

Figure 5. The software interface of virtual prototyping of 800t jacking system of offshore platform

4.2. Realization Principle of the Virtual Prototyping

The realization is based on the principle that the corresponding module information is displayed when the corresponding system module displays, and the other modules are restrained to avoid conflict between modules. The realization principle of the virtual prototyping of the jacking system is shown in Figure 6.

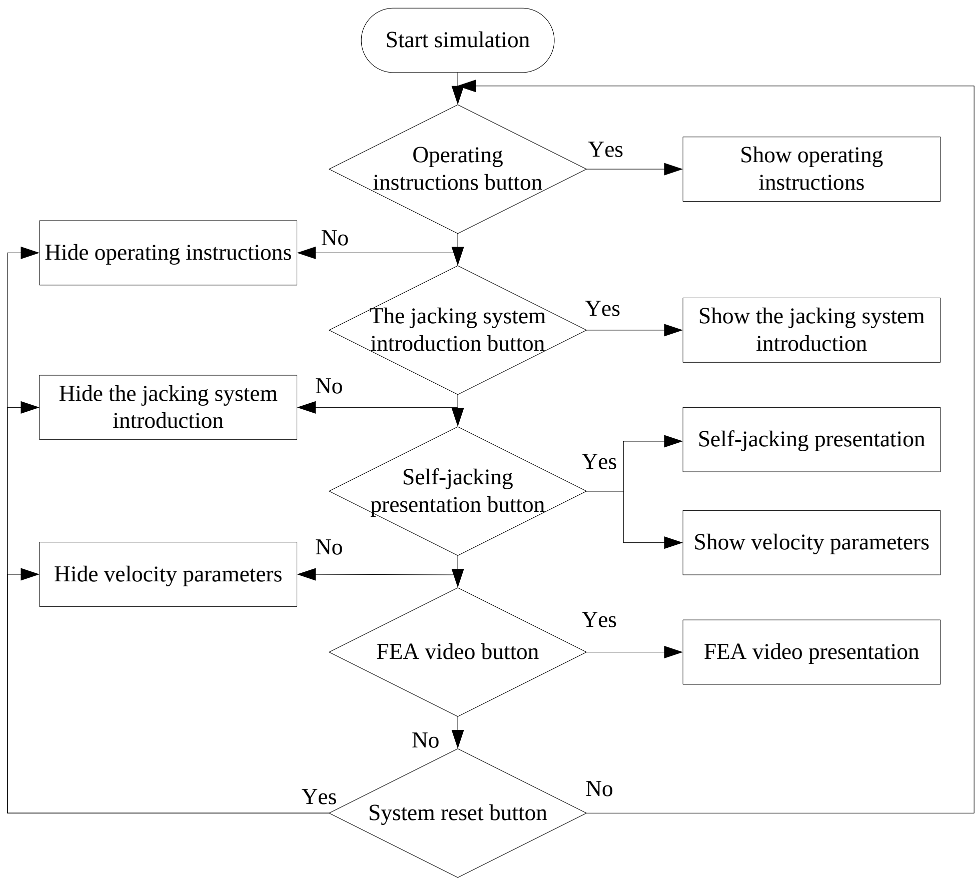

Figure 6. The realization principle of the virtual prototyping for the jacking system

4.3. Realization of Driving Function of the Typical Modules

Because of the multi-module of the virtual prototyping, finite element video module and self-jacking presentation module are chosen to introduce driving function.

4.3.1. Realization of Driving Function in Finite Element Video Module:

1) There are two carriers in Virtools to realize display of finite element video: in the first method, screen carrier is used, while in the second method, 2D Frames are built with materials and textures as the carrier that is used here. And there are two methods for video processing: the first one is that target video is spitted into image sequence frames to show as

the texture with a fixed interval of time by “Movie Player” building block; the second one is that the video file (avi format) is played by “Video Player” building block which is used here shown in Figure 7.

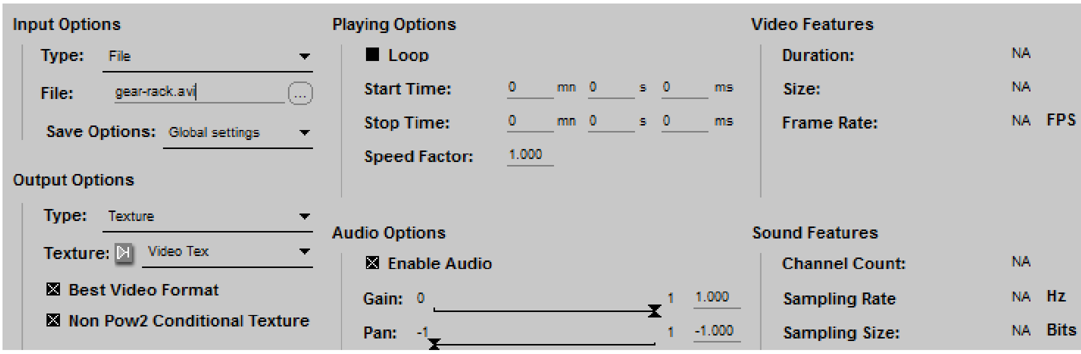

Figure 7. Settings of video processing

2) Driving Principle of Finite Element Video Module

The finite element video module is realized by the combination of “Push Button”, “Send Message”, “Switch On Message” building blocks (BB). And “Push Button” BB is the trigger to finite element module drive, when it's triggered, the message "gear-rack" is sent by “Send Message” BB to the level and got by “Switch On Message” BB in level to load the finite element video by the setting up parameters, otherwise the other corresponding response is triggered. The driving principle of finite element video module is shown in Figure 8.

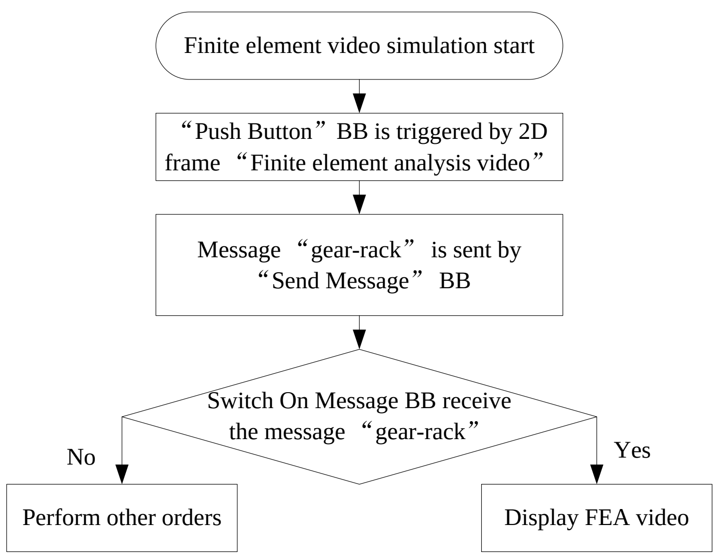

Figure 8. The driving principle of finite element video module

4.3.2. Realization of Driving Function in Self-jacking Presentation Module

1) Self-jacking presentation with the processes of pile driving, hoisting, landing, pile pulling is with some time delay.

And “Push Button” BB is the trigger to self-jacking presentation module drive, when it's triggered, the message "selfjacking" is sent by Send Message BB to the level and got by “Wait Message” BB in level to start self-jacking presentation by the setting up parameters, otherwise the other corresponding response is triggered. And “Translate” BB is used to control locking and deblocking of the locking device, “Rotate” BB is used for the rotation of the lifting gears, “Set Texture” BB is used to display the motion velocities of gears and legs. The sequential motions of the self-jacking presentation are shown respectively in Figure 9, Figure 10, Figure 11, Figure 12.

Figure 9. The simulation process of driving piles

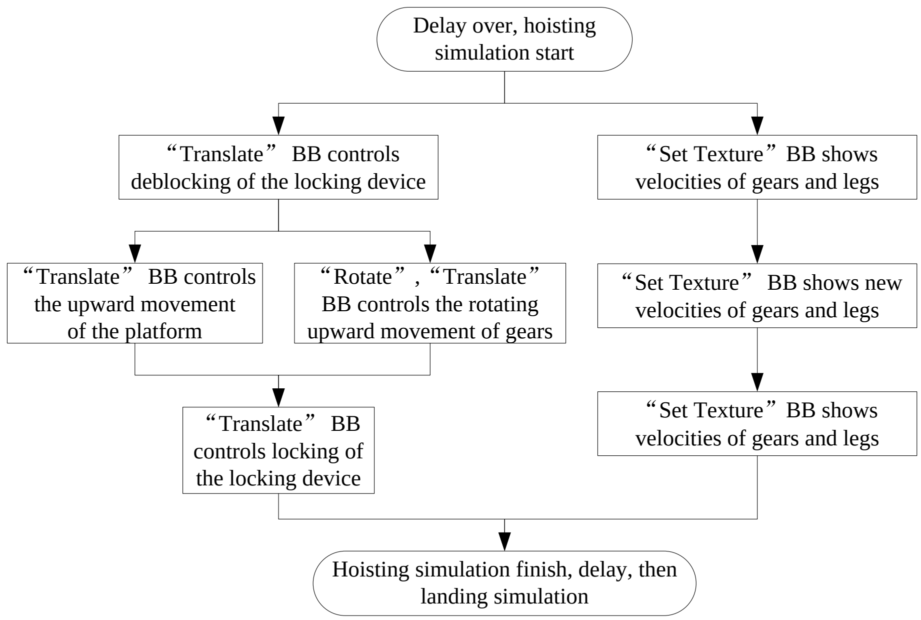

Figure 10. The simulation process of hoisting

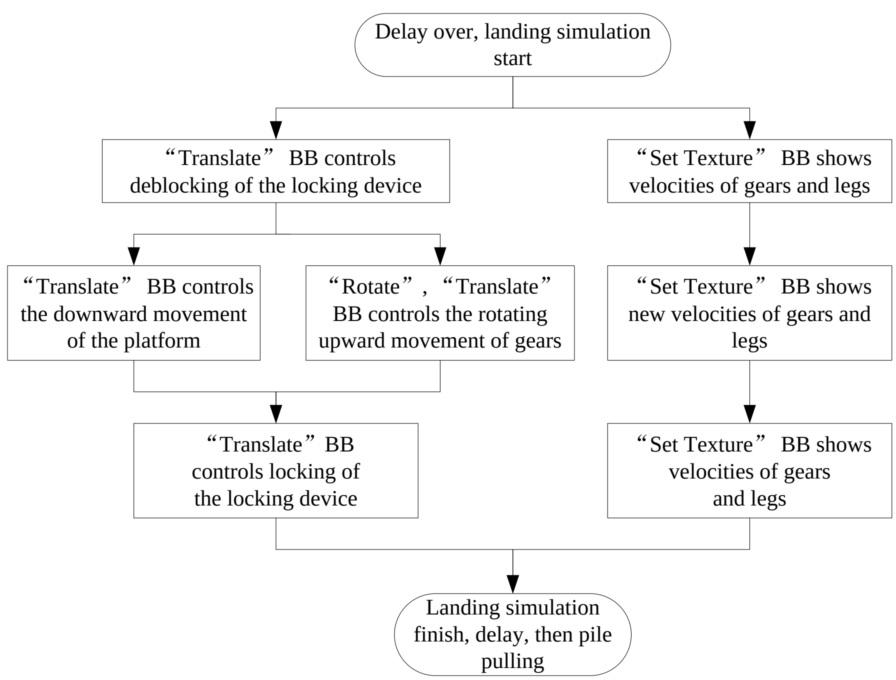

Figure 11. The simulation process of landing

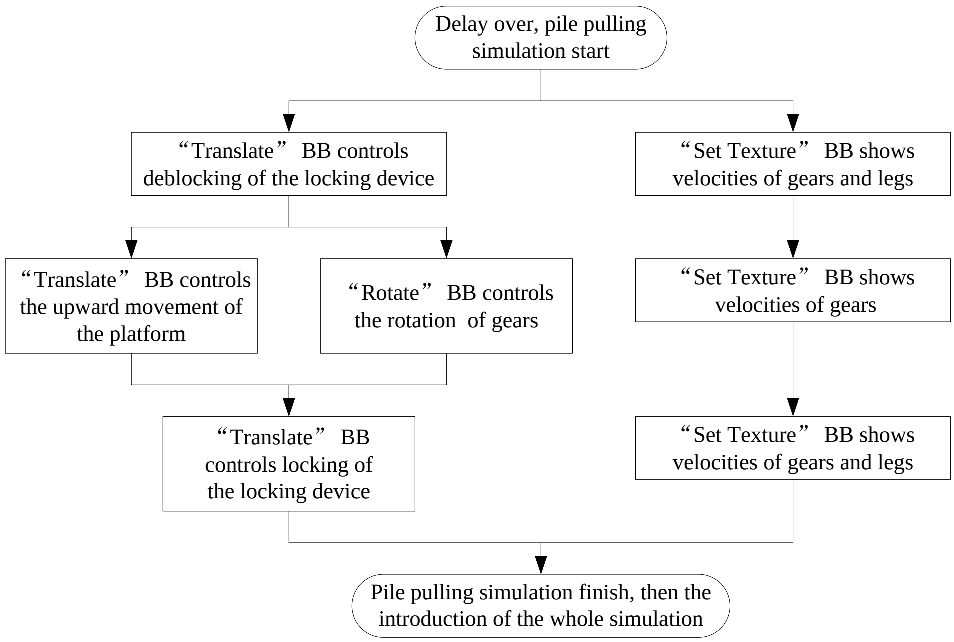

Figure 12. The simulation process of pile pulling

2) The velocities display of the critical components during the self-jacking simulation

Combined with the motion state of gears and legs above, the rotation velocity of gears and the translation velocity of legs can be expressed by three combinations, which is shown in Figure 13.

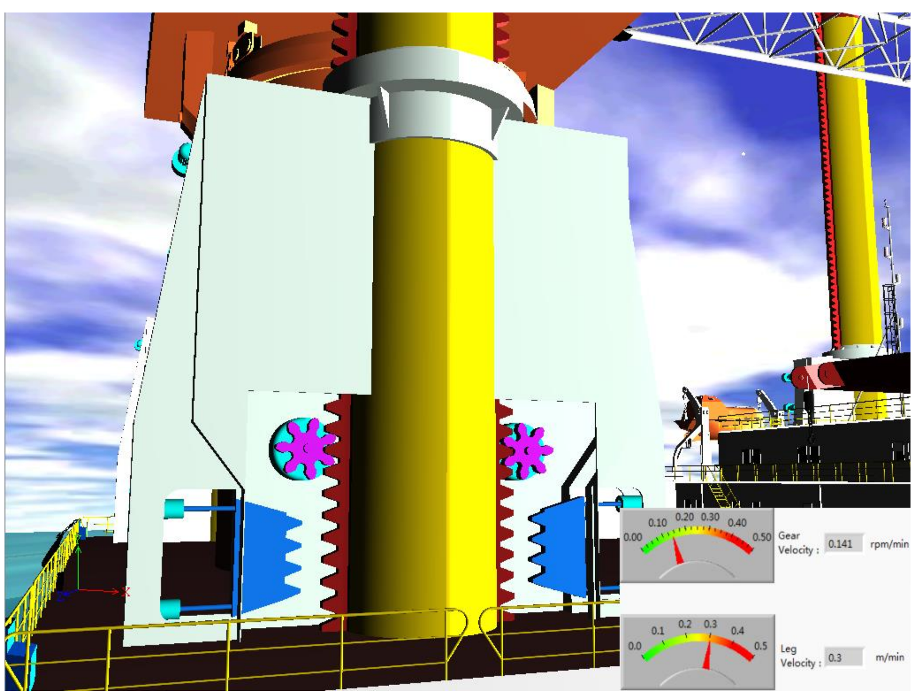

Figure 13. Parameter combinations to velocities of gears and legs

3) The finite element simulation video display of the critical components during the self-jacking simulation is shown in Figure 14.

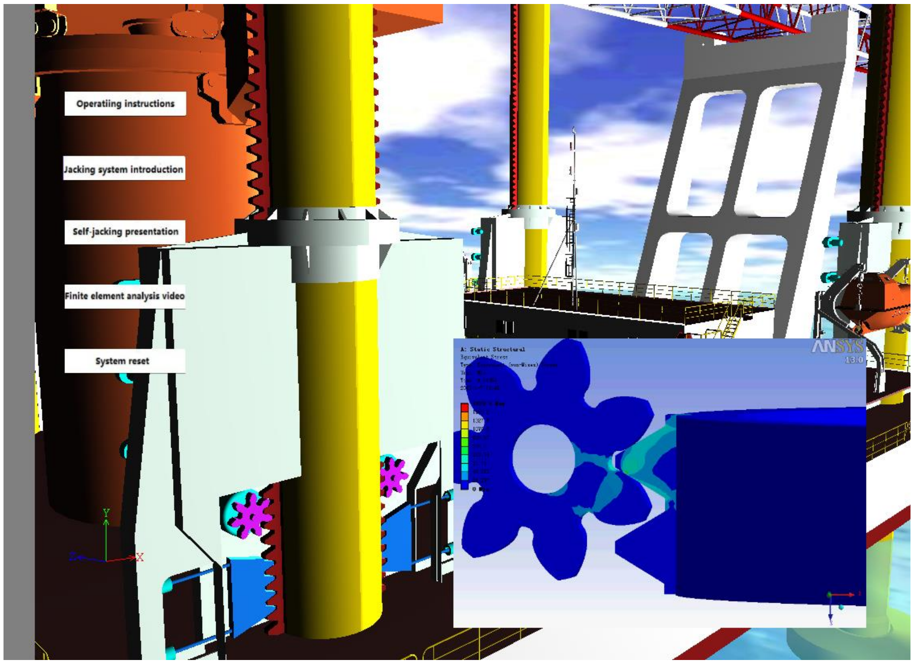

Figure 14 Finite element simulation video of gears and legs

5. Conclusion

As concerning problems of the current researches on integrated information modeling technology, this paper presents a new systematic integrated information modeling based on virtual prototyping. After the jacking system of an 800t offshore platform is introduced, and the functional model of virtual prototyping integrated modeling system is proposed. The integrated design process method based on virtual prototyping is also discussed in detail. The integrated modeling technology based on virtual prototyping is then put forward with the introduction of virtual prototyping of the jacking system. The realization principle of the virtual prototyping is also discussed in detail. A computer aided virtual prototyping software system is then developed, which has been put into practice in a plant of offshore engineering. The realization of driving function is given as a typical module example, which demonstrates that the methodology is obviously helpful for integrated information modeling.

Acknowledgements

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