Visual Simulation Platform for Complex Products

Xiaomei Hu1,*, Jiashu Miao1, Chuan Wang1, Xiao Ma1 and Chenjun Wei2

1The Key Laboratory of Intelligent Manufacturing and Robotics, School of Mechatronic Engineering and Automation, Shanghai University, Shanghai, China
2Shanghai Institute of Radio Equipment, Shanghai, China

*Corresponding author e-mail: sufeimasohxm@163.com

Abstract. In order to meet the needs of modern product development, aiming at the problem of product’s long development cycle, difficulty and lack of functionality, we propose a visual simulation platform for complex products. The platform satisfies almost all product requirements, and integrates the function of product design, display, simulation and post-maintenance management. High visibility, high degree of integration, product versatility and friendly human-computer interaction improve the development efficiency. And based on WebGL technology, the platform system is successfully built, which achieves the visualized development of the product.

1. Introduction
The development of information technology has provided opportunities for the design and manufacture of complex products such as robots and airplanes [1]. There are also some visual development platform in China, such as Rosidy of Shanghai Jiao Tong University, etc. But the platform architecture is relatively simple, When multiple layers of simulation design are required for products, portability is not high which makes designing more difficult [2, 3].

Foreign companies are progressing faster than domestic ones. In 1990, Boeing took the lead in implementing the 100% digital development technology on the Boeing 777 aircraft, and established the world's first digital prototype by three-dimensional digital definition, assembly and concurrent engineering. Canada's Robotmaster platform of robot simulation not only has the programming simulation function, but also has the Kinematics plan and collision detection function and enriches in the function level. However, these platforms are not very user-friendly and require very high professionalism. In addition, the current domestic and international platforms have a low degree of visualization, which cannot meet the requirements for higher development and design. This requires a platform with more complete and comprehensive architecture and better versatility.

2. Platform System Architecture

2.1. Platform Overview
The visual simulation platform for complex products covers five different stages and it runs through the product's complete lifecycle [4].

In the design stage, the data information of the product model can be obtained from the platform, such as the dimensions and features, so as to design the components that meet the requirements. The second is the simulation phase, which simulates the movement process and life span of parts based on the behavioral properties of the model. The protection phase mainly manages the materials and reminds the staff to supplement them when the materials are lacking. The operation management stage
allows the users to detect the operating environment and working conditions during the operation process and to record the changes of the product to facilitate the later maintenance and management. Finally, in the maintenance phase, the system can automatically warn and prompt status details when experiencing unexpected conditions such as product loss or damage, providing predictive solutions.

2.2. System Architecture

![Platform architecture diagram](image)

The architecture of a visualization simulation platform for complex products is shown in Figure 1. It is divided into three layers from the top down: the data support layer, the business support layer, and the application layer. The data support layer contains all the data information related to the model, and these data are the basis of the business support layer. The business support layer is the main body of the system and supports the implementation of most of the functions of the system including multidimensional display of the model, human-machine interaction and secondary development interfaces. The application layer provides a state detection system and a maintenance management system.

2.3. Platform Advantages

(1) visualization

In the case of sparse and complex data sets, the platform uses graphical and user interface means to deliver the product model's attributes, states, and animations to the user more intuitively through both static and dynamic display modes, thereby giving the platform a high degree of visualization.

(2) generalization

The platform has a unified, complete, and extensible platform architecture. In terms of vertical versatility it can meet the needs of the same product at different stages of the change, and can meet the development requirements of different business systems in terms of horizontal versatility.

(3) High efficiency

The platform provides a unified interface component and friendly human-computer interaction interface, which bring an immersive interactive experience. Rich business support and secondary development interfaces improve product development efficiency.

(4) integration

The architecture determines the highly integrated platform. The first is data support layer, which enables the integration of basic data. Followed by the business support layer, it achieves integration in functionality. Finally, the application layer enables integration of complex product management.
3. Platform Function Description

The platform function consists of a data support layer, a business support layer, and an application layer, which achieve different types of functions [5].

3.1. Data Support Layer

The data support layer is the basic data support for the operation of the platform system, including model definitions, model types, and rights management.

(1) Model definition

The model definition includes geometric attributes, physical attributes, behaviour attributes and LOD attributes, which separate and classify the basic elements of the complex product model, so as to express it more three-dimensionally and provide the most basic data support for the platform.

Geometric attributes are the most basic attributes of a product model. They include face features, body features, and analytic features are described in terms of area, volume, slope, etc. The physical properties mainly consider its material, stiffness and strength, and the material also determines its mechanical properties such as stiffness and strength. Behavioural attributes include kinematic properties of speed, acceleration, mechanical properties of torque and energy characteristics including kinetic energy and potential energy, providing a reliable physical basis for virtual simulation.

The LOD attribute determines the resource allocation of the object rendering according to the position and importance of the node of the object model in the display environment, reduces the number of faces and details of non-important objects, and finally obtains a more efficient rendering operation, avoiding the waste of resources with the model of large.

(2) Model type

The model needs to distinguish between types in addition to its own various attribute information. We divide the product model as shown in Figure 2:

![Figure 2. Model type diagram.](image)

The ontology model is the main object. The operations we perform are based on the ontology model. In the simulation platform, the product model needs both the overall observation and the zoom-in to the local display of detailed information. Therefore, for the ontology model, we need its overall model and local model to apply to different scenarios. For a complex product, it also needs an attached, supporting model, which we call the external general model. For example, the ontology model is a ship, then the external general model will have airplanes, materials, and shipboard crew models.

(3) Authority management

The platform’s rights management includes attribute rights management and hierarchical rights management, as shown in Figure 3:

![Figure 3. Authority management diagram.](image)
From a vertical perspective, the operational needs of different development staff are also different. This requires a hierarchy of people, and a hierarchy has only the change permissions that the hierarchy has. This layered privilege management guarantees independence between product developments. From the horizontal point of view, the rights management of attributes is assigned to the rights of multiple developers with the same attribute to achieve collaborative development, thereby improving the development efficiency.

3.2. Business Support Layer

The business support layer has static multidimensional display capabilities, human-computer interaction systems, dynamic enhanced development and secondary development interfaces, integrates relatively complete business functions, and enhances support for product models.

(1) static multidimensional display

The model is the basis of the visual simulation platform [6, 7]. The platform supports the import of 3DMAX, MAYA, SolidWorks, UG, CATIA and other format models.

Static multidimensional presentation allows the user to change the viewing angle and zoom the model through the movement of a device such as a mouse. Detailed information can be displayed by clicking on the model. In addition, the information of the model can be displayed in a unified manner on the platform to analyse and manage the information. For example, when displaying a product model, the display content should include information such as dimensions, stress simulation results etc.

(2) human-computer interaction

Human-computer interaction means that the user interact with the system through the human-computer interaction interface to enhance user friendliness. The operation interface is the carrier of human-computer interaction, and the implementation of the corresponding function of the platform is completed by triggering the interface components on the interface. The interface component refers to a visual "component" that can be placed on a form, such as a button, a file edit box, a label, a popup, and the like. These components have the ability to perform functions or cause the code to run and complete the response through "events."

Model interaction is the operation of the model itself, to achieve some of the model's functions. For example, an explosion map of a product model is generated; a model is enlarged locally; and a model-related information is displayed. The scene interaction allows users to use mouse, keyboard and other interactive devices to perform scene roaming around the distance, and fully understand the spatial structure of the product.

(3) dynamic enhanced development

The dynamic enhanced development includes simulation animation and path planning. Which gives the product a stronger visibility. Simulations use the system platform to translate uncertainty to a specific level into their impact on the product model. This impact is expressed at the level of the whole system. Through the simulation of the animation, it is possible to obtain the dynamic changes of the product model such as operating conditions, life span. With these changing data, targeted improvements can be made to the product model.

Path planning is very important for complex products that need to move between different work locations. It directly determines the rationality and efficiency of the entire work process. Through path planning, it is possible to effectively solve the problem of optimal placement and derivation of equipment such as vehicles in equipment warehouses, and optimize the placement and placement efficiency of equipment.

(4) secondary development interface

With the continuous advancement of technology, the diversity of development methods have become increasingly rich. The platform reserves a variety of secondary development interfaces. Virtual Reality Interface is based on the visualization principle of VR engine. During the development process, users are allowed to wear VR glasses and are immersive in the product model scene. The user's gestures and actions are recognized by tracking sensors, and then they can perform operations on product models as in reality.
The hardware-in-the-loop simulation interface is to link the controller and the simulation model of the control object implemented on the computer together to conduct experiments. It takes the real-time data from the real-time input into the system for simulation, to some extent to reduce the over idealized bias brought by pure simulation.

3.3. Application Layer

The application layer is a series of integrated management systems used to monitor and maintain the product development process.

(1) Condition Monitoring System

The condition monitoring system is to meet the real-time monitoring of the status of the product during its operation. Through the system’s real-time feedback, the operating parameters of the product at different time node can be obtained, and the time needed to take corresponding maintenance measures can be predicted. By this maintenance strategy, it is possible to avoid unnecessary outages, reduce unnecessary spare parts, so as to achieve the purpose of improving maintenance efficiency.

(2) Maintenance Management System

For one thing, inevitably losses occur during the actual operation of the product. For another, changes in the functions of the later stages of the product and the fine-tuning of the product model structure will affect the actual operation of the product. Through the maintenance management system, we perform data structure processing on the product information such as available functions, easy-to-lose points and maintenance records to achieve traceability management throughout the entire process.

4. Platform Application Instance

In order to meet the requirements for cross-platform development on different devices and visually analyse the terrain of the subsea pipeline and the operating status of the pipeline pigs, running the platform system on the Web is a common and feasible choice.

(1) Application technology

WebGL calls the OpenGL-ES-2.0 API, which uses the GLSL shader language to write the program and execute it on the GPU’s shader, allowing Web developers to use the system graphics card to smoothly display 3D scenes and models in the browser, and to create complex navigation and data visualization. It is based on B/S mode that the main program runs on the server side and the client uses the browser without plug-ins, so it has cross-platform nature. The platform can be run on PCs or mobile devices such as mobile phones and tablets.

(2) System interface

The system interface of WebGL platform application is shown in Figure 4. Figure (a) is the main interface of the platform and in the scene is the 3D submarine pipeline model. The menu bar and human-machine interaction buttons are at the top. The slider can adjust the radius of the pipe and terrain height in real time to facilitate the display of different viewports. Figure (b) is an enlarged model of the submarine pipeline. The display options can be selected to display the wireframe or surface to visualize the submarine topography. Figure (c) is a demonstration of the business function.
The pipe pig is operated by pipe pig control option to advance it in the subsea pipeline. The system's viewport will automatically follow the progress of the pipe pigs, so you have real-time understanding of the operating status. In figure (d) is an enhanced function of the submarine pipeline and you can observe after cut or achieve perspective conversion. Furthermore, it also allows users to adjust the gradient of the contour line, providing a richer display.

5. Conclusion

The visual simulation platform for complex products takes the functional requirements of complex products and the basic data information of the product model as the starting point, realizing the all-round development of design, display, simulation, monitoring, maintenance, and management of the product, which improves the lack of functions and overly simple architecture. And the concept of visualization run through the entire platform process thus to maximize the simplification of operations and improve development efficiency. Advanced model permission hierarchical management and secondary development interfaces are in line with the current trend of technological development, meets the future development needs of products, and has broad application prospects. Application platform of WebGL already has a basic functional architecture, which enables the free viewing of submarine pipeline product models, terrain visualization and better human-computer interaction.

Acknowledgments

This project is supported by Shanghai Grand Science and Technology Program of China (Grant No.16111105900) and Shanghai Municipal Commission of Economy and Informatization (Grant No.160646).

References

[1] Guo Cong, Wang Shouzun, Design of Visualized Flight Simulation System Based on Unity3d [J]. Electronic Design Engineering, 2016, 24:47-50.
[2] Gao Yi, Ma Guoqing, Yu Zhenglin, Cao Guohua. Kinematics Analysis and Three-dimensional Visualization Simulation of a Six-DOF Industrial Robot [J]. China Mechanical Engineering, 216, 27:1726-1731.
[3] Feng Xiaobing, Liu Wenlong, Du Dong. The role of visualization technology in intelligent manufacturing [J]. Manufacturing technology and machine tools, 2016 (a): 43-50.

[4] Liang Huilin, Xiangki, Bian Jingwei. Four rotor underwater vehicle motion control and visualization simulation [J]. Industrial Control Computer, 2015, 28:5-6.

[5] Xie Guangqiang, Zhang Yun, Li Yang, Tian Jianfeng, Zeng an. Research on visual simulation platform for multi-agent consistency protocol [J]. Computer Science, 2014, 41:146-151.

[6] Sun Shuhong, Wang Jian. The application of human-computer interaction three-dimensional visualization simulation system in ship construction [J]. Software industry and engineering, 2015 (a): 52-56+41.

[7] Zhang Zhi, Zou Shengtao, Li Jiatong, Li Chao. Three-dimensional visual simulation of a six-degree-of-freedom manipulator [J]. Computer emulation, 2015, 32 (02): 374-377+382.