Research on Immersive Virtual Assembly Based on Virtual Reality Technology

ZHINAN QIN, LIANG CHEN and XI-PING LEI

ABSTRACT

Existing virtual assembly systems are lacking in sense of reality. This paper explored a new assembly simulation system based on virtual reality technology to enhance immersion. After comparison of available technologies, the new system was built with Unity3D as the virtual reality simulating platform, virtual reality helmet as the virtual assembly displayer, Leap Motion as the interactive device, and corresponding algorithms to assist gesture recognition and collision detection. The new system enriches the interaction between the operator and the device, reflects the assembly process more real and increases the efficiency of actual assembly problems solving.

INTRODUCTION

The increasingly fierce competition in the global market is putting great pressure on the manufacturing industry to shorten the product development cycle and improve the product quality. Assembly plays an important role in the product development cycle, in which the efficiency and quality of assembly influence the manufacturing process and the product quality. Traditional assembly consumes much manpower, material, money and time during the product design and the process planning, inevitably accompanied by failing cases. Besides, traditional assembly cannot fulfill the idea of concurrent design. In face of these challenges virtual assembly provides a solution to eliminate the drawbacks of traditional assembly.

Most of the present virtual assembly solutions display 3D graphics in two dimensions in the desktop virtual environment. 2D images can create 3D visual illusion by displaying different gray on the computer screen. The majority of virtual assembly are achieved in virtue of engineering softwares, which results in the lack of the sense of reality. Interactions between the operator and the virtual assembly system are mostly visual feedback and mouse actions, which is different from the real-world experience. To sum up, the present virtual assembly technology cannot fully reflect the real assembly process, and is not sufficient for the actual assembly problems solving.

Zhinan Qin, South China University of Technology, Higher Education Mega Center, Guangzhou, Guangdong 510006, P.R.C.
Liang Chen, South China University of Technology, 381 Wushan Road, Guangzhou, Guangdong 510641, P.R.C.
Xiping Lei, South China University of Technology, Higher Education Mega Center, Guangzhou, Guangdong 510006, P.R.C.
VIRTUAL ASSEMBLY

Virtual assembly (VA) is defined as: The use of computer tools to make or “assist with” assembly-related engineering decisions through analysis, predictive models, visualization, and presentation of data without physical realization of the product or supporting processes [1]. Virtual assembly achieves two levels of mapping. On the first level (bottom), product physical model is mapped to digital product model. On the second level (top), assembly process is mapped to virtual assembly simulation process. The bottom mapping exonerates the physical model of product to achieve assembly analysis and tolerance analysis. The top mapping achieves the planning, simulation and evaluation of assembly, etc [2].

Sanker et al. designed a virtual assembly system called Virtual Assembly Design Environment (VADE) [3]. In this system, designers are able to consider problems about assembly and disassembly in the early stage of the design to avoid the defects in the assembly design. Designers first import part models built in CAD softwares into the virtual assembly system, and then assemble these models directly. The assembly ability of products is tested and the information about product design and manufacturing process is obtained. State University of New York designed the Virtual Prototype Assembly Validation Environment [4]. Dassault Aircraft Company designed a set of Digital Enterprise Lean Manufacturing Interactive Application [5]. Gifu University designed the Virtual Assembly Cell-Production System [6]. University of Porto developed a theory about mixed virtual assembly of rigid body and soft body, which provided direction for the application of soft body virtual assembly [7].

The researches on virtual assembly started relatively later in China, and there is a big development gap compared with abroad. National CIMS Engineering Research Center designed the Virtual Assembly Support System based on Pro/Engineer. This system can check for assembly in the early stage of design and export relevant files [8]. Dalian Jiaotong University developed a multi-level information model for virtual assembly with Pro/ToolKit, which provided a means to transform the information from CAD softwares to virtual assembly systems [9]. Taiyuan University of Technology developed an assembly data model based on XML Schema [10]. Offshore Oil Engineering Co., Ltd. studied the virtual assembly of large-scale crane based on Unigraphics NX [11].

The present virtual assembly systems of China pay more attention to techniques, and ignore the interaction between the operator and the virtual assembly system, which cannot rival the real-world assembly.

VIRTUAL REALITY

Based on the information technology, virtual reality (VR) creates a digital environment simulating the hearing, sight and touch of the real-world environment. Operator uses necessary equipment to interact with the objects in the digital environment, which creates real-world experience for the operator. Virtual reality is a technique which is used to recognize nature, simulate nature, and make better adaptation to and use of nature [12].

Burdea and Coiffet put forward "three Is" of virtual reality—imagination, interaction and immersion. Imagination means virtual reality broadens the scope of human cognition, builds the real-world environment, and creates fictitious environment;
interaction means the operator acts on objects in virtual environment [13]. Immersion means the operator has difficulties distinguish the virtual environment.

Virtual reality has been widely used in various fields. Virtual Architecture 3D Simulation System is considered to be one of the world most successful virtual architecture simulation systems. Virtual Reality Endoscopic Surgical Simulators is the most extensive and mature application of virtual reality in medical science [14]. Virtual reality can provide a virtual environment for students to experience space travel, volcano eruption, etc. Digital archaeology is becoming a new trend with the development of virtual reality. The battlefield simulation module can be used to simulate the battlefield conditions [15]. Digital model substitutes for physical model to assemble parts in industrial simulation field [16].

RESEARCH FRAMEWORK

The advantages of virtual reality can be used to overcome the drawbacks of the present virtual assembly systems.

This paper explored a virtual assembly system based on virtual reality head mounted display using Unity3D, virtual reality helmet, Leap Motion and corresponding algorithm. This virtual assembly system chose Unity3D as the virtual reality simulating platform, helmet virtual display as the virtual assembly display mode and Leap Motion as the interactive device. Reasons for these selections will be explained in the following text.

Virtual Reality Simulating Platform

Virtual reality simulation platform is the engine to develop virtual reality system, which can also provide a complete solution to achieve virtual reality. The solution integrates multiple functions such as 3D rendering system, virtual walkthrough system, collision detection, etc.

The present widely used virtual reality simulation platforms include Vega Prime, World Tool Kit, Quest3D, OpenGL Performer, Virtools, ENO Studio, Virtual Reality Platform and Unity3D. Vega Prime, World Tool Kit, Quest3D and OpenGL Performer are based on OpenGL. Virtools achieves programing rapidly through its own function modules and connect to various virtual reality devices through hardware interfaces. ENO Studio is a software based on GUI, and achieves the function through C++ programming language. Virtual Reality Platform is a domestic large-scale virtual reality engine, and some physical engine plug-ins for network transmission have been developed in recent years. Unity3D uses interactive development modules to develop virtual reality environment through C# or Javascript programing language, which is convenient for developers to create a virtual assembly environment with stronger immersion. Furthermore, Unity3D can release programs to various platforms.

Through comparison, Unity3D was chosen as the simulation platform for virtual assembly simulating platform.

Virtual Assembly Displayer

The present virtual assembly displayers include: desktop virtual displayer, helmet virtual displayer, CAVE virtual displayer and large screen projection virtual displayer [17].
Desktop virtual displayer creates 3D virtual assembly environment based on computer or graphic workstation. Operator watches 3D images with stereo glasses and its immersion is rather poor. Helmet virtual displayer creates virtual assembly environment based on Helmet Mounted Display (HMD), and its immersion is relatively rich. CAVE virtual displayer creates virtual assembly environment with a room composed of screen walls. Operator can see 3D images with stereo glasses. However, the cost of this virtual assembly environment is high and the operator’s movement is limited by the real-world space. Large screen projection virtual displayer creates virtual assembly environment with a large screen to achieve high resolution display and its immersion also poor.

To provide better immersion with reasonable cost, helmet virtual displayer was chosen as the virtual assembly displayer.

**Gesture Recognition**

Researches on gesture recognition are rich. Sony launched a gesture recognition device called EyeToy which transfers player’s actions into game screen to achieve interaction between player and game [18]. Microsoft Corporation launched Kinect which can identify user’s gestures to help user control game [19]. Lee et al. used entropy analysis to segment the gesture region and recognize gesture from video streams with complex background [20]. Yu et al. performed gesture recognition basing on the vision combination features of hands [21]. Zhu et al. performed gesture recognition by estimating inter frame image motion [22-24]. Wang et al. performed gesture recognition with AdaBoost Algorithms and optical flow matching [25], which can recognize gesture by analyzing 2D gesture video clips. Zhang et al. used stereo vision to obtain positive gesture images and matched the gestures with predefined templates [26]. Ma et al. performed gesture recognition using dual camera to obtain the geometry rotation angles [27].

Vision-based gesture recognition improves gesture recognition accuracy. There are four main vision-based interactive devices at present, including Kinect, PS Move, Wii Remote, and Leap Motion. Kinect is able to capture full-body motion. PS Move and Wii Remote capture gesture motion through handheld device worn on user. Leap Motion capture gesture motion on high accuracy with on handheld device. Leap Motion was chosen as the interactive device to achieve gesture recognition.

Gesture interaction actions of virtual assembly can be divided into grab, move and release. The grab gesture is captured when the entire or part of the object locates in the envelop space formed by the fingers and palm, and besides the hand shapes matches with the object shape and size. A probability statistics method based on Hidden Markov Model was chosen to identify dynamic assembly gestures for its high accuracy. The method improved the immersion of virtual assembly and interaction between operator and virtual environment.

**Model Data Transformation**

Virtual product models created by mainstream engineering softwares were converted into STL format and import into 3DSMAX. After the model structure tree traversal, hierarchy information, constraint information, size information and tolerance information were obtained, stored and import into Unity3D. Because models built by engineering softwares are based on Nurbs algorithm, and the models built by
3DSMAX are based on the Polygon Style algorithm, 3DSource parts library can be used as parts model support.

Collision Detection

Collision detection is key to virtual assembly process. Oriented Bounding Box Algorithm based model hierarchy was chosen for its high accuracy and reduction of computational complexity. The algorithm constructs an oriented bounding box (OBB) for each part model and runs intersect tests of these OBBs with separation axis theory.

CONCLUSIONS

This paper first studied the research status of virtual assembly and virtual reality and suggested that virtual reality technology could be used to make up for the lack of immersion in virtual assembly systems. Secondly, existing technologies of virtual reality development platform, virtual assembly display mode, gesture recognition, model data transformation and collision detection were analyzed and compared. Finally, a new assembly system was explored based on Unity3D, helmet display, Leap Motion and corresponding algorithms about gesture recognition and collision detection. The new system enhances the sense of reality of virtual assembly and improves the efficiency of assembly problems solving.

REFERENCES


