Application of Virtual Reality Technology in Experimental Teaching of Mechanical Engineering

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***Abstract*—The virtual experiment technology, with the help of multimedia, simulation, artificial intelligence, database technology and virtual reality (VR) technology, can create a computer-assisted, partially or totally replace the relevant hardware and software operating environment of the traditional experiment operation links. Virtual experiment technology is based on a virtual experimental environment (platform simulation), which focuses on the interaction of experimental operation and the simulation of experimental results. The experimenter can accomplish all kinds of experimental projects as in real environment, and the experimental results obtained are equivalent to or even better than those obtained in real environment. In the process of experiment teaching, Northeast University attaches great importance to the construction of virtual simulation experiment. It adheres to the experimental teaching ideas of "laying equal stress on physical experiment and virtual experiment", "laying equal stress on in-school learning and off-campus practice", "laying equal stress on theoretical learning and scientific research", and develops a series of virtual simulation experiment teaching courseware based on virtual reality technology. Practice shows that reasonable application of virtual reality technology can enhance the vividness of experimental teaching content, deepen students' perceptual understanding of complex mechanical equipment, facilitate students to understand and master the design method, manufacturing process, assembly process and fault diagnosis method of complex mechanical equipment, and help to cultivate students' practical ability and innovation ability.**

Keywords—virtual reality technology; virtual simulation experiment; mechanical engineering; virtual manufacturing

Virtual Reality (VR) refers to the technology that generates an analog environment by computer and enables users to "invest" in the environment through a variety of special devices, thus realizing direct natural interaction between users and the environment. VR technology can not only directly inspect or operate objects in virtual environment, but also provide visual, auditory and tactile real-time perception[1-3]. Virtual simulation experiment is the essential realization of the actual experimental process on the computer. It uses computer modeling and simulation technology, virtual reality and visualization technology to simulate the whole experimental process. It enables students to perceive the working principle, design process, processing and manufacturing, performance analysis, functional demonstration and fault diagnosis of complex mechanical assembly in a highly immersed virtual environment, so as to enhance students' abilities. Interest in learning and improvement of experimental teaching effect[4-8]. The virtual simulation experimental teaching center of mechanical equipment of Northeast University is a comprehensive virtual simulation experimental teaching center established to solve the shortcomings of high-grade numerical control machine tools, full-face road headers, aerospace equipment, metallurgical complete sets of equipment and other large and complex mechanical equipment, such as expensive physical experimental equipment, large space occupation, high maintenance costs, poor safety and so on.

I. CHARACTERISTICS AND MAIN TYPES OF VIRTUAL REALITY SYSTEMS

Virtual reality system is fundamentally a high-level human-computer interaction interface, which can simultaneously give users visual, auditory and tactile and other intuitive and natural means of real-time perception interaction. Virtual reality system has three basic characteristics: Immersion, Interactivity and Imagination, which are known as "3I" characteristics [9-12].

Immersion: Users can immerse themselves in computer-generated virtual environments and their ability to invest in computer-generated virtual scenes. Users feel "immersed" in virtual scenes. What he sees, hears, smells and touches is exactly the same as what he feels in the real environment. It is the core of VR system.

Interactivity: The ability of users to interact with various objects in a virtual scene. It is the key factor of man-machine harmony. After entering the virtual environment, users can interact with the environment of multi-dimensional information through a variety of sensors, and users can carry out necessary operations.

Imagination: By immersing users in the "real" virtual environment and interacting with the virtual environment, we can get perceptual and rational knowledge from the integrated environment of qualitative and quantitative, so as to deepen the concept, germinate new ideas, and produce a leap in understanding.

A. *Desktop virtual reality*

Using personal computer and low-level workstation to simulate, the computer screen is used as a window for users to observe the virtual realm. Full interaction with the virtual reality world is achieved through various input devices, such as mouse, tracking ball, moment ball and so on. It requires participants to use input devices to observe virtual realms within 360 degrees through computer screens and manipulate objects in them, but at this time participants lack complete immersion, because it will still be disturbed by the surrounding real environment.

B. *Immersive virtual reality*

Advanced virtual reality system, fully immersed in the experience, so that users have a sense of being in the virtual realm. It includes helmet-mounted displays, other position trackers, data gloves, other hand-controlled input devices, voice and other devices, which encloses participants' vision, hearing and other sensations, and provides a new, virtual sense space. Common immersion systems include helmet-mounted display system, projection virtual reality system and remote presence system.

C. *Augmented reality (AR) virtual reality (VR)*

Augmented Reality (AR) virtual reality (VR) uses virtual reality (VR) environment to enhance participants' perception of the real environment, that is, the perception that is not perceptible or inconvenient in AR. Typical examples, such as a fighter pilot's head-up display, can project instrument readings and weapon aiming data onto a penetrating screen installed in front of the pilot. It can enable the pilot to focus on the enemy's aircraft or navigation deviation without having to look down at the instrument data in the cockpit.

D. *Distributed virtual reality*

Distributed Virtual Reality System (DVR) is a system in which multiple users are connected through computer networks and participate in a virtual space to experience virtual experiences. Typical distributed virtual reality systems such as SIMNET system. SIMNET is made up of tank simulator connected by network, which is used for joint training of troops. Through SIMNET, the simulator in Germany can run in the same virtual world as the simulator in the United States and participate in the same combat exercise.

II. BASIC COMPOSITION OF VIRTUAL REALITY SYSTEM

Most virtual reality systems are composed of five parts: computer system, virtual reality software, virtual world, input device and output device. The computer system is used to process all kinds of information. The virtual reality software is the foundation of the virtual world and realizes it. The virtual world is a virtual environment (human-machine interface) which can be interacted by users. The computer system will eventually act on the users through the output device. From the perspective of information flow processing, a complete virtual reality system should consist of several parts as shown in Figure 1.

After the virtual environment is ready, the system first activates the tracking device, voice device and other equipment monitoring system. Users and external monitored objects will send instructions to the computer through these devices. After the virtual environment responds to these instructions, the computer system will first make necessary updates in the virtual environment database, then adjust the current virtual environment scene and send the new image to the display device. At the same time, the virtual environment feedback information (voice, tactile, etc.) to the user is output to the user through the feedback system; and the virtual environment to other external physics. The object feedback control information will be output through the monitoring system.

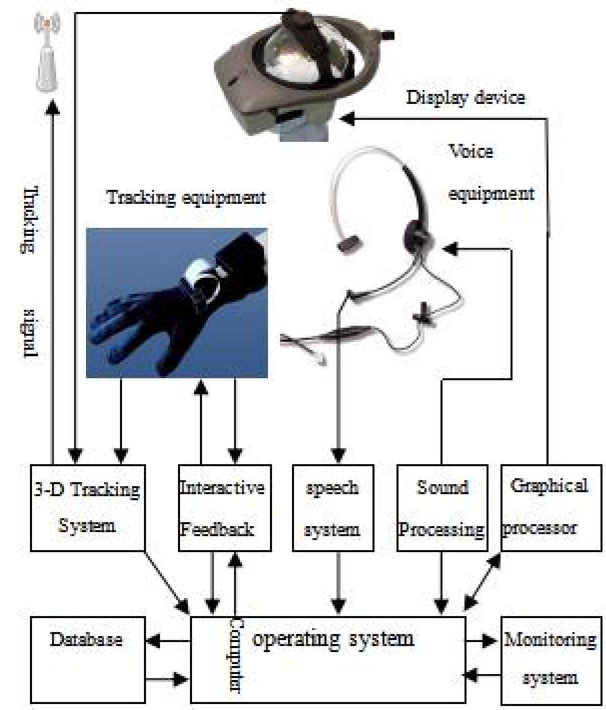


Fig. 1 Composition of Virtual Reality System

III. VIRTUAL SIMULATION EXPERIMENT TEACHING SYSTEM

A. *System constitution*

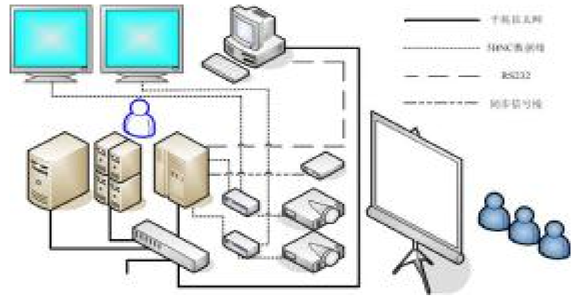
In order to help students understand and master the design, manufacture, operation and fault diagnosis process of large and complex mechanical equipment, such as high-grade CNC machine tools, full-face road headers, aerospace equipment, metallurgical complete sets of equipment, and to solve the shortcomings of expensive physical experimental equipment, large occupied space, high maintenance cost and poor safety, Northeast University carried out virtual simulation of complex mechanical equipment earlier. Based on the research and application of the experiment, a domestic advanced virtual simulation experiment teaching system is constructed. Fig. 2 is the hardware block diagram of the virtual simulation experiment system.

The Onyx4 visualization system of SGI company is selected as the main body of the simulation system, and the virtual reality system in the form of Power Wall is constructed by projector and projection curtain wall. The active stereo display function is realized by using synchronous signal transmitter and active stereo glasses, so as to realize multi-user visual immersion. In addition, a PC is used for Onyx4 console operation, a data server provides database services, and an application server is responsible for other external devices and input and output control.

The Onxy4 output video signal is sent to two projectors and two 22-inch CRT monitors through five BNC connections (RGBHV data for each line) through video distributor, and the synchronous signal of active stereoscopic display is output to the infrared synchronous signal transmitter through the display channel numbered 0.

The computer responsible for the operation of Onyx4 system console is connected with Onyx4 system through RS232 interface and Ethernet interface respectively. RS232 interface is mainly used for remote login and control of control terminal by super terminal program. Under this login mode, administrators can control, set and adjust the working conditions of hardware system, and can use most shell commands after the operating system is running; while the Ethernet connection is mainly used to transfer some file data to the system host, or the control terminal can login and control through the X windows remote login software based on ethernet. In this case, besides convenient and fast transmission of file data, powerful remote login software can also be used to manipulate the system host. In general, this software can get the window interface of the host after login, through which administrators can use almost all the functions of the host system.

Data servers and application servers are connected to the host through Ethernet respectively. These two servers are used to provide database services or control of other external devices. In practical applications, these two servers will be retained or deleted as options according to specific application requirements.



1-CRT display; 2-development and maintenance; 3-data server 4-application server; 5-Onyx4; 6-operator; 7-switch; 8-video distributor; 9-projector; 10-synchronous signal transmitter; 11-projection screen; 12-users wearing stereoscopic glasses

Figure.2 Hardware Composition of the System

B. *Main functions of the system*

Virtual simulation technology provides a new method for principle demonstration, function simulation, fault diagnosis of large-scale complex mechanical equipment, process verification of complex precision parts, simulation analysis of complex integrated control and operation training of large-scale complex mechanical equipment, and makes up for many shortcomings of physical experiment of large-scale complex mechanical equipment. Virtual simulation experimental teaching system can provide undergraduates with virtual prototype design and development, virtual assembly and functional simulation, virtual processing and simulation analysis, virtual experiment and virtual measurement, virtual driving and virtual operation, virtual engineering practice training for large and complex mechanical equipment such as high-grade numerical control machine tools, full-face road header, Aerospace long equipment, metallurgical complete set equipment, Virtual experiment and virtual practice training courses such as NC programming and PLC programming.

Figure.3 Virtual simulation system

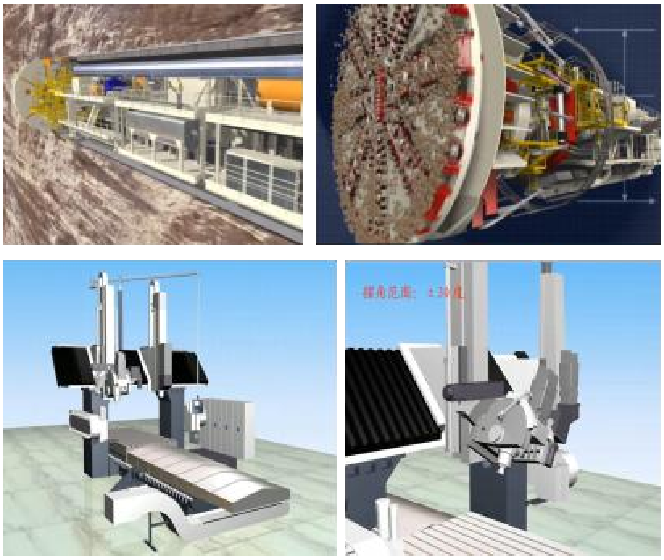


Figure.4 Virtual simulation experiment interface

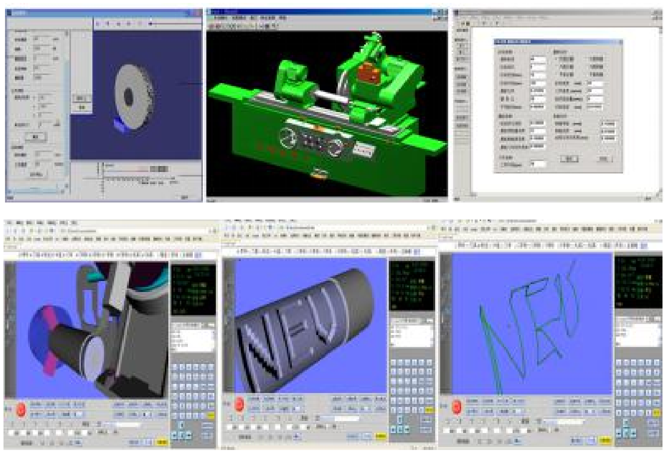


Fig. 5 Virtual simulation experiment interface

IV. CONCLUSION

Practice shows that virtual simulation experiment has many advantages, such as good vividness, intuitive experimental effect and good safety. It is helpful for students to understand and master the principle, manufacturing and assembly process, use and operation of complex mechanical structures, to stimulate students' learning enthusiasm and innovative thinking, and to students' innovative practical activities.

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