Web-based Virtual Laboratory for Mechanical Engineering

Yu Hou
College of Mechanical Automation
Wuhan University of Science and Technology
Wuhan, China
fly_houyu@163.com

Fang Wang
College of Management
Wuhan University of Science and Technology
Wuhan, China
Wfang305@163.com

Abstract—**Web-based information technologies are being applied to create content-rich and flexible student laboratory environments in undergraduate mechanical engineering lecture and laboratory courses. In this paper, the characteristics of the web-based virtual mechanical laboratory and its implementation are introduced. The overall system architecture, hardware and software configuration, as well as the virtual experimental process, are presented. The key technologies such as system's user interface design, 3D modeling, motion simulation and results assessment are discussed emphatically. The virtual laboratory offers tremendous flexibility by enabling the access to laboratory resources at any time and from anywhere without students having to be physically present in a laboratory facility.**

Index Terms—**virtual lab, 3D modeling, motion simulation, virtual reality modeling language**

I. INTRODUCTION

The virtual experimental technologies which are combined with the current vigorous web technologies can be used to establish web-based virtual laboratory. Virtual laboratory integrates web technology, database technology, multimedia technology, graphical and image technology, instrument technology and specialty knowledge into a whole to create a virtual 3D visualization experimental environment. The union of virtual instrument technology and cognitive simulation method make the virtual laboratory have the characteristics of intelligence. The biggest advantages of virtual laboratory are independency, interaction, flexibility and diversity, and currently become an important research direction in higher education [1].

The experimental teaching is an important tache in mechanical engineering courses. The students can not only deepen the understanding of fundamental theory, but also further cultivate their spatial thinking ability, practical ability, innovation ability and engineering thought, and raise learning interest and motivation.

Traditional mechanical experimental teaching has some limitations: most experiments use cookbook type teaching method, which is given specific steps and let students do experiments according to fixed course, so students lack initiative and experiment process is relative bald; the experiments can not display the dynamic relationship between mechanism size and the kinematics and dynamics property of mechanism; the experiments have strong dependency on equipments, so a large number of experimental instruments is needed, the same is true of experimental teaching staff and equipment maintenance personnel. And these limitations become more serious with the scale of expansion of Chinese college enrollment and the increase of experimental course ratio. Therefore, the web-based virtual laboratory for mechanical engineering is studied and developed as a useful and necessary complementarity for traditional experiment mode.

Web-based virtual mechanical experiments have the following advantages. (1)The virtual 3D simulation experiments use visualization technology, animation technology and 3D graphics technology to achieve a realistic 3D graphics effect, and create an immersive experiments environment. (2)With virtual experiments, students can complete the entire experiments processes from preparation, operation to the analysis of experiments results, during which voice and image processing technology can make all kinds of experimental phenomena and results obvious and vivid, and make students feel in real experimental environment, so that they can better achieve their goals. (3)Compared with traditional experiments, virtual simulation experiments make students have greater initiative and autonomy, and its operation process is simple and direct, save a great deal of preparatory work and accessorial work, so the users can concentrate on the properties and laws of research objects. Furthermore, the powerful interactive ability and diversification of virtual experiments can also stimulate the learning motivation by the greatest degree. (4)Virtual experiments overcome the bottleneck problems of limited number of equipment, and can accommodate more students participate in the experiments. The virtual lab can be repeatedly used without equipment consumption, save the costs of usage and maintenance, and easier to upgrade old experiments and set up new ones. (5) The rise and popularity of Internet make it possible for online distance learning. Virtual lab link resources in many different formats and abundant resources can be made available from any location and at any time. It provides a chance for part time, mature, or work based students to learn by Internet. All of these are impossible to traditional experiments [2-3].

II. TEACHING MODE OF VIRTUAL EXPERIMENTAL SYSTEM

Virtual experimental system has complete theoretical knowledge system, not only suitable for classroom teaching but also for experimental teaching of mechanical engineering. Virtual experimental system can be used in teaching practice as following methods.

(1) Classroom teaching is combined with experimental teaching. When teaching mechanical theoretical knowledge in classroom, the virtual experimental system can be used to present the animation and movement curves of common mechanisms. This will enable students more easily understand and grasp knowledge, and make classroom teaching more vivid.

(2) Real experiments are combined with virtual experiments. Virtual experiments are the simulation of real experiments, and real experiments are the basis of virtual experiments. Real experiments have an irreplaceable role on cultivating practical hands-on training ability and error analysis capability. Both ones have their own advantages, and should be combined with each other. Specific process of teaching can be a variety of patterns, such as firstly by virtual experiments understand the principles and procedures, establish a preliminary concept, and then do the real experiments to acquire true personal feelings, finally through the virtual experiments get summarization and promotion. For those fundamental and equipment-operation experiments, it is inclined to adopt real ones, and for those integrated, analytical and design experiments, it is commonly inclined to adopt virtual ones. Whether from the experiment costs, or from the experimental effect, the virtual experiments have greater advantages.

(3) Classroom experiments are combined with open experiments. In practical Teaching, limited by the total number of study units, classroom experiments arrangement is limited, so a large number of integrated and innovative experiments set up as an open experiment. The virtual experiments lab system will be installed on the campus server, students can be in the public computer rooms, dormitories, etc., to do experiments at any time. Besides these, the virtual system identify students' needs; provide effective, local support; and combine conventionally taught components with the use of up to date multimedia resources, including books, course guides, videotapes, audiotapes, television, e-conferencing, and discussion groups.

III. SYSTEM ARCHITECTURE AND PROCESS OF VIRTUAL EXPERIMENTAL SYSTEM

Virtual laboratory is a kind of isomeric learning environment, and it allows the learners at different locations simultaneously on an experiment project. Virtual lab requires the participants sharing experiment environment and experiment rules, and such a requirement makes it easy to achieve on the web. Web technologies provide a basic platform for realization of virtual lab. Web-based browser/server (B/S) computing mode is a kind of fundamental mode to achieve online virtual lab.

As show in Figure 1, the server created simulative experiments environment by software technologies, and received the operation requests from the clients. According to different requests, the server adjusted the state of virtual apparatus, simulated the experimental phenomena, and exported corresponding data and results. To keep synchronization and harmony in a cooperation experiment for many students, the background database on server provides sharing experimental data and methods. Virtual experiment process is shown in Figure 2.

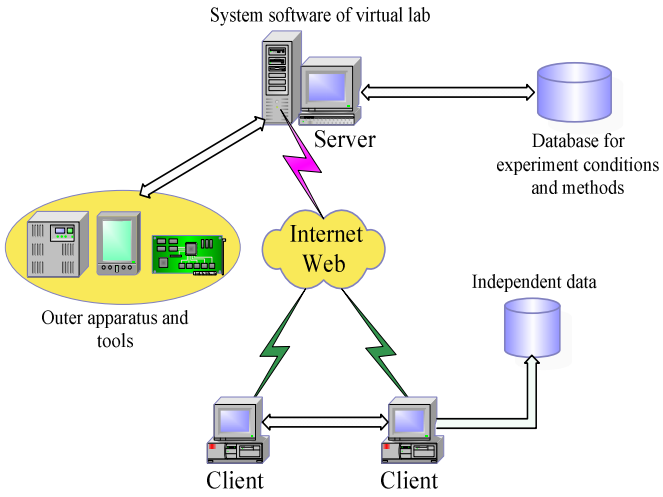


Figure 1. System architecture of virtual lab

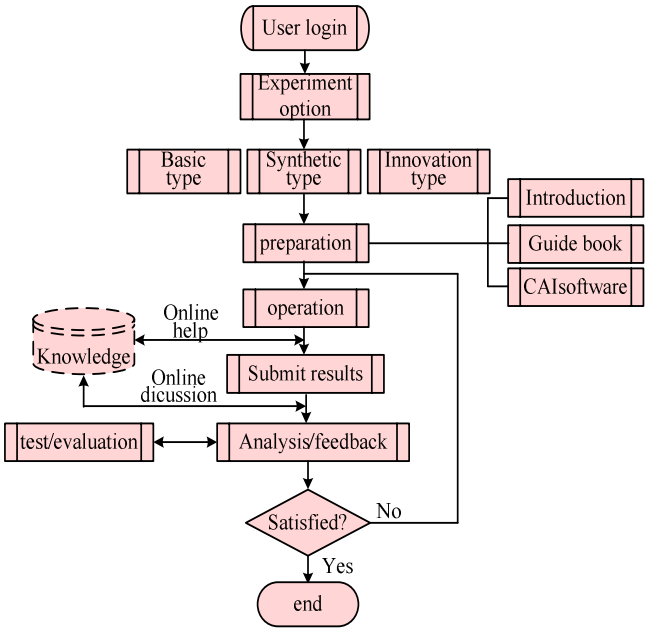


Figure 2. Flowchart of virtual experiment

IV. REALIZATION OF VIRTUAL EXPERIMENTAL SYSTEM

Virtual experimental teaching is built on the basis of the general process of teaching activities, the cognitive process and practice of students, and the basic law of teaching.

A. User Interface

Virtual experimental system is different form real laboratory environment, and students interact with the virtual lab by user interface. Therefore, the design of the interface should be friendly and easy to operate, and also makes the

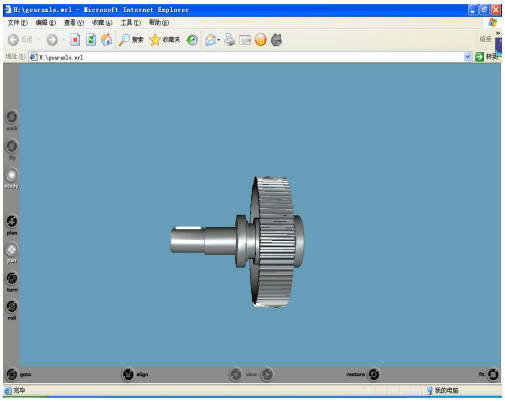
students feel in a real environment to solve the problem. With the gradual progress, the students will feel the sense of accomplishment for finding knowledge and solving problems.

B. *3D modeling*

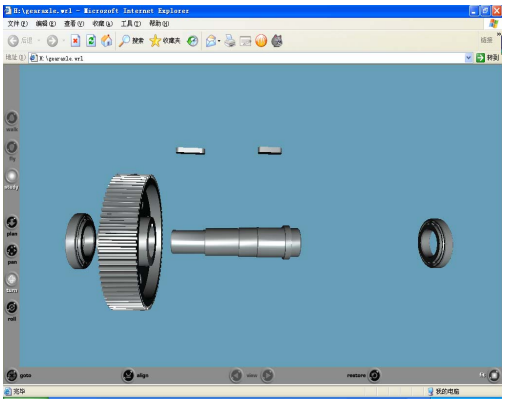
The mechanisms in virtual mechanical experiments are realistic 3D model, so it is a key tache to choose appropriate modeling technology. Virtual Reality Modeling Language (VRML) is one of the many potential education tools on the Internet. It is the acknowledged three dimensional web standard for visualization. It allows the viewer to examine the model at different angles and at different distances, all within a web browser. Animations, sounds and interactivity are also possible with VRML.

VRML is a platform-independent file format for sharing 3D worlds on the Web. VRML world are extremely versatile in that they support interactivity, animation, user modification, and embedded hyperlinks to other Web documents. Furthermore, VRML file formats are independent, therefore all computers (PC, Mac, UNIX, etc) that use a Web browser can use and view VRML models with a VRML player. VRML format is less complex when compared to other 3D CAD programs and can easily be published on any web site. In addition to these advantages, VRML is inexpensive and flexible, hence this file format was chosen for this research project.

The 3D mechanism model based on VRML is shown in Figure 3.



a) Assembly



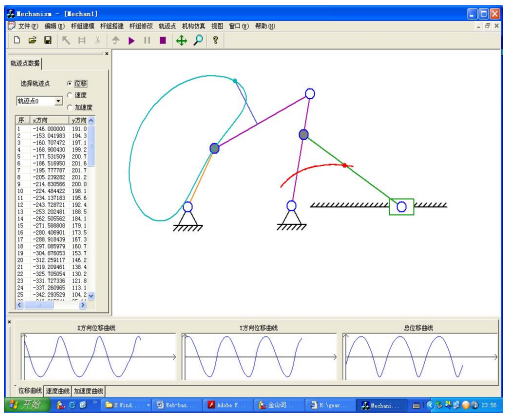
b) Disassembly

Figure 3. 3D mechanism model based on VRML

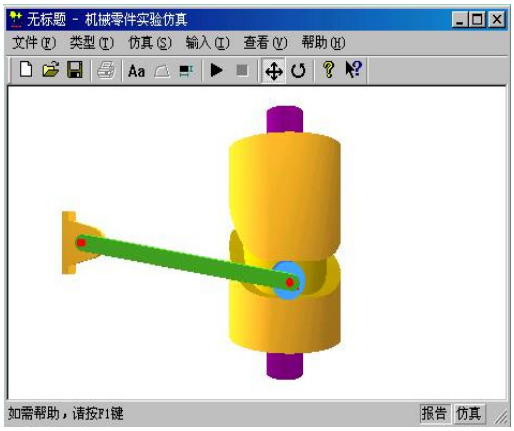
C. *Motion simulation*

The purpose of developing mechanical virtual lab is to realize traditional and innovative experiments on computers. According to the input mechanism parameters, computer animation technology and dual-caching technology are applied to dynamically plot the image of mechanism and show the motion situation of mechanism in each position, that is, design the mechanism by real-time three dimensional varying parameters.

The virtual experiment system includes user interface, interactive module, geometric modeling module, kinematical parameters calculation module, motion simulation module, display and analysis module, data storage and print output module, and online help module, and so on. The motion simulation interface is shown in Figure 4.



a) 2D motion simulation



b) 3D motion simulation

Figure 4. The interface of motion simulation

D. *Results assessment*

With all types of learning, including web-based learning, it is useful for students to receive constructive, timely, and relevant feedback on their progress. Through online assessment, Students can receive quick feedback on their performance.

In the virtual experiments, the students observe and analyze the experiments phenomena, deal with experiment data, adjust strategy according to feedback, clarify misconceptions, and test their assumptions and experimental design. Students must have a sense of attention to their own experiences, depict

experiments results definitely and synthesize those using existing thoughts. At the same time, through the online assessment and summary of instructor, students should find existing problems and shortcomings, compare virtual environment with real world, and link virtual experiments with practical application. Thus the ability which acquired form virtual experiments can be expanded to practical engineering.Authors and Affiliations.

V. CONCLUSIONS

Web-based virtual lab can empower and engage students by bringing everything they need in to one place: they can browse their courses; search for resources; receive personalized activities and return assignments; communicate directly with their teachers; and check their own progress using the detailed mark book.

Web-based virtual lab will bring forth positive action and far-reaching effect on the innovation of the teaching contents, methods and means, and on the promotion of experimental teaching quality. The research and development of virtual lab will produce great application potential.

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