Web–Based 3D Real Time Experimentation

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INTRODUCTION

Spurred by development in computer science and network technology, the use of the Internet has been expanding exponentially. It is now extensively used as a connectivity and reference tool for numerous commercial, personal, and educational purposes. In education, the Internet opens a variety of new avenues and methodologies for enhancing the experience of learning as well as expanding educational opportunities for a larger pool of students. Specifically, distance education and non-traditional classrooms have the capability to reach more students using specialized instruction and self-paced learning.

In the area of distance education, many **Web-based real time experimentation** systems have been reported in the literature (Ando, Graziani, & Pitrone, 2003; Daponte, Grimaldi, & Marinov, 2002; Ko, Chen, Chen et al., 2000; Ko et al., 2001; Kumar, Sridharan, & Srinivasan, 2002; Yeung & Huang, 2003). These Internet-based remote laboratories allow users or students to carry out physical experimental work at their own pace anytime anywhere. They generally require very little physical space and minimal manpower to maintain, and are ideal for the sharing of expensive equipment. However, all these experimental systems can only provide 2D operation panels. Due to this limitation, the actual shapes of 3D instruments and equipment, some of which may have controls or display components on different sides, may not be possible to be reflected on the remote user's client display window.

BACKGROUND

Although many 3D visualization schemes on the client side have been presented (Geroimenko & Geroimenko, 2000; Hobona, James, & Fairbairn, 2006; Nakano, Sato, Matsuo, & Ishimasa, 2000; Oellien, Ihlenfeldt, & Gasteiger, 2005; Osawa, Asai, Takase, & Saito, 2001; Ueda, 2006; Vormoor, 2001) and some additional collaborative functions have been proposed for communication amongst multiple remote users or between client and server (Bender, Klein, Disch, & Ebert, 2000; Engel, Hastreiter, Tomandl, et al., 2000; Nielsen, 2006; Zhuang, Chen, & Venter, 2000), applications and issues such as Web-based real time control and 3D-based monitoring have not been addressed. We present in this article the development of **Web-based 3D real time experimentation** using Java 3D visualization tools.

Among the various tools available, **Java 3D** is ideal from certain perspectives. Specifically, **Java 3D** is an efficient tool that provides a very flexible platform for building a wide range of Web-based three-dimensional graphics applications, and is becoming one of the most attractive tools for creating 3D user interfaces, **3D visualizations** and virtual environments. It provides not only strong **3D programming** but also excellent integration with previous version of Java components.

In comparison with other 3D virtual experimental systems, this chapter attempts to address all the important issues with an emphasis to provide a complete solution. Specifically, issues on connecting actual experimental instruments, real time data transmission, three-dimensional virtual scene and three-dimensional behaviors are addressed. These ensure that the user will get a more realistic feeling when operating and controlling three-dimensioanl experimental instruments as well as monitoring actual experimental results without any significant delay.

PROPOSED SYSTEM REFERENCE MODEL

Figure 1 shows our reference model for the creation of **Web-based, 3D, real-time experimentation** using Java 3D visualization tool. Note that on the client side, the combination of Java 3D API and Java realizes 3D visualization and network connection. Usually, 3D visualization consists of geometry and **behavior objects**. The former includes the picked, moved, animated and static objects, and the lat-

Figure 1. System reference model for creating Web-based, real-time experimentation
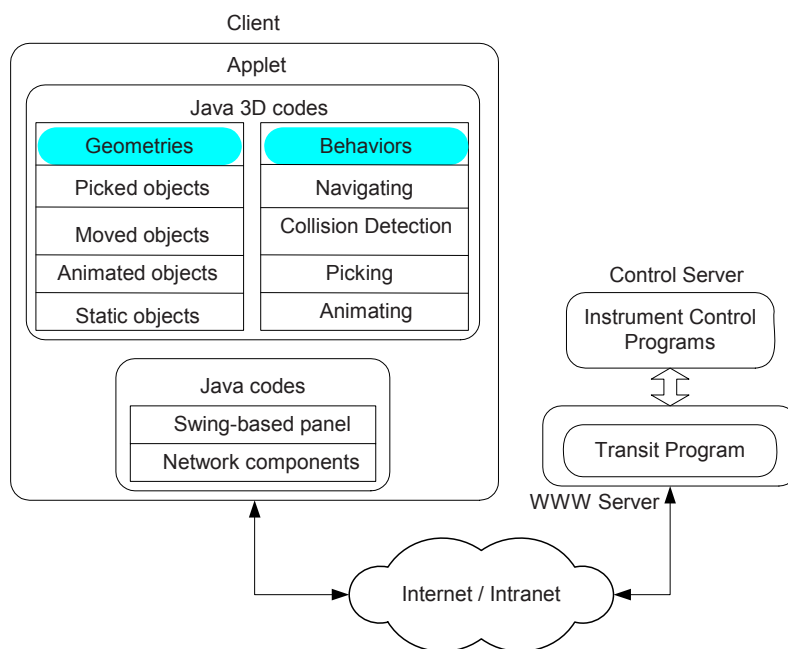
ter consists of navigating, collision detection, picking and animating behaviors.

The picked objects cover all controls such as buttons, knobs, sliders and connectors of the virtual equipment and experiment, while the moved objects include curve, text and screen displays on the **virtual instruments**. The animated objects cover all active and periodically moved objects. The other visual objects, such as walls, windows, tables and certain components of some **virtual instruments**, are taken to be static ones. These **geometry objects** designed using Java 3D helps to promote the rendering efficiency of the 3D virtual scene. In the relevant behavior objects, only the animating behaviors provided by Java 3D API are used without modifications.

PROPOSED HARDWARE ARCHITECTURE

The system reference model of Figure 1 can be supported by the double-server-client distributed hardware architecture of Figure 2. The whole system includes a user's computer on the client side, the Internet and/or an intranet to transmit command and data, a Web server to host the Web site of the remote experimentation, and a control server with control cards attached to programmable instruments together with some circuit boards.

In particular, programmable instruments have to be connected to the control server through control cards and cables in a 3D remote experimentation system. For example, two separate TCP/IP interface modules are used for real time control and retrieval. The commands coming in through the TCP/IP control interface are converted into the format required before being sent to the programmable instrument to be controlled. Experimental data for the generation of real time curve or text for the user is transmitted to the client through the TCP/IP retrieval module.

3D INSTRUMENTS AND SCENE

To be as realistic as possible, and to overcome certain limitation posed by 2-D operation panels, using which the actual shapes of **3D instruments** and equipment cannot be shown, the use of 3D visualization tools in real time Web-based experimentation may be considered. Figure 3 shows a typical example GUI realization on the client computer developed based on Java 3D.

Ideally, anyone conducting an experiment through the Internet should be able to do it in the same manner as in a real laboratory. This can be accomplished in a 3D environment through three behavior modules on navigating, collision detection and picking in the GUI interface.

Figure 2. Hardware architecture for creating web-based real time experimentation
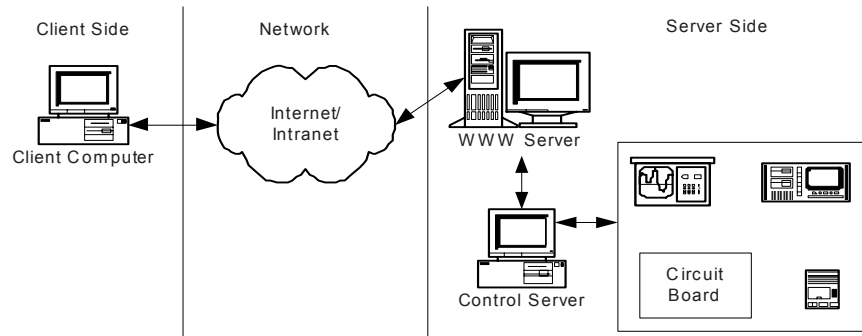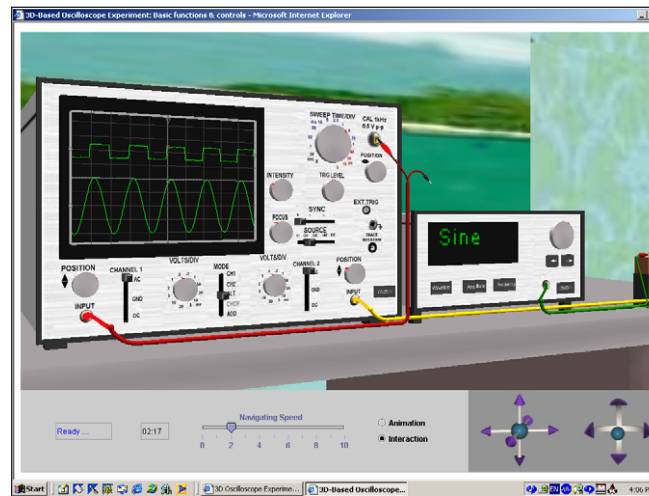

Figure 3. 3D view on an experiment with a battery

The module on **navigating behavior** controls how the user walks around in the **virtual laboratory**. Also, as the user attempts to get a better view, it controls indirectly the positions and angles of the view platform. The **collision detection** module ensures that the user does not traverse any solid objects such as walls, tables and instruments. Through the picking behavior module, the user will be able to adjust the controls of available experimental apparatus precisely.

The experiment is performed when the user enters a virtual laboratory as shown in Figure 4. Apart from the **virtual instruments** and circuit board placed on a table, the virtual laboratory also includes the floor, the ceiling, a few walls, two windows and one door. To enter the virtual laboratory, a user will need to "walk" to the door and press the door open button. Upon opening, the user can walk through the door, move around and carry out the experiment by adjusting the instruments and circuit board on the table.

MAIN FUNCTIONS

The main functions and features in such a **Web-based 3D remote laboratory** system are summarized below:

1. A 3D remote laboratory controlling actual instruments and displaying real signals is implemented through a dynamic **virtual scene** via the Internet. In the example in Figure 3, the laboratory has an oscilloscope, a signal generator, a battery, a few cables and some other visual objects.
2. A navigation tool for walking around the virtual laboratory is provided. For example, the tool on the bottom right hand corner in Figure 3 allows the user to move around the virtual laboratory and view instruments from different positions and directions through the mouse.

Figure 5. Picking controls for instruments

(5a)　　　　(5b)　　　　(5c)　　　　(5d)
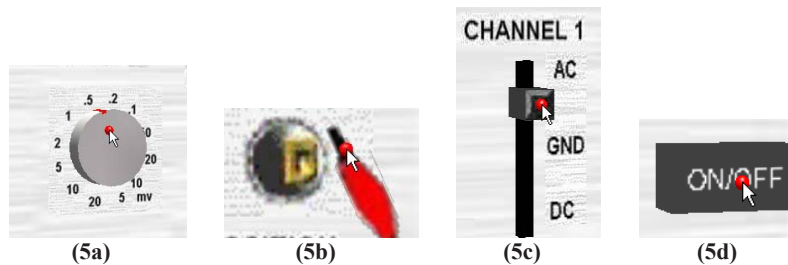
3. A collision detection mechanism is implemented. This guarantees that the viewing platform will not traverse any solid objects such as walls, doors, windows, tables and virtual instruments.
4. Through the appropriate picking function, the user can adjust individual controls on the instruments in the 3D environment and connect circuits in the same way as he or she operates an actual instrument in the real laboratory. As shown in Figure 5, the operations of turning a knob, adjusting a slider, pressing a button, and making a connection to a terminal can be performed by simply dragging the mouse to move the relevant control when the control is in "focus." To make it as user friendly as possible, a red point is displayed when the mouse is over a control that has received focus.
5. The adjusted controls are converted into the relevant commands and sent to a control server to control real instruments in the actual physical laboratory. The result of the experiment is sent back by the server to the client to be displayed in the 3D virtual laboratory in real time.

FUTURE TRENDS

Despite a number of efforts, there are still some limitations on the widespread application of **Web-based, 3D experimentation system**. Specifically, such systems generally require more complicated software and hardware configurations and support such as high-end display card and DirectX/OpenGL plug-in to run DirectX or OpenGL graphic libraries. Also, the Internet has certain inherent constraints for the transmission of large experimental data streams. Lastly, due partly to the variety of non-standard development systems that need to be used and the complexity of integration hardware apparatus and software applications, the number of sites that supports such systems is still rather small.

Nevertheless, as powerful computer hardware becomes more readily available and new development and software tools are introduced, these problems may be overcome to a certain extent in the next five to ten years. Web-based 3D experimentation will perhaps provide an evolutionary influence on 3D network applications, and as the Internet becomes faster and more universities and research institutes become interested in this area, more experimental sites may become available.

CONCLUSION

A 3D Internet oscilloscope experiment has been developed, and has been used to support the teaching of undergraduate courses in the Department of Electrical and Computer Engineering, National University of Singapore. It has also received good rating from experts in the Java 3D interest group on aspects such as user interface, ease of use and usefulness.

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KEY TERMS

Internet Remote Experimentation: The use of the Internet to carry out physical experimental work at a remote location.

Online Experiment: An experiment that is running and controlled by a computer terminal.

Virtual Laboratory: A computer accessible laboratory which may be simulated by running a software package or which may involve real remote experimentation.

Web-Based Control: The control of instruments or apparatus through the Internet.

Web-Based Laboratory: A laboratory that typically involves physical experiments and that can be accessed remotely through the use of the Internet.

Web-Based 3D Navigation: The use of the mouse or keyboard to navigate in a Web-based three-dimensional virtual scene.

Web-Based 3D Picking: The use of the mouse to manipulate the controls of Web-based three-dimensional virtual or real instruments.

Web-Based 3D Visualization: A 3-dimensional scene display that can be accessed through normal Internet explorer such as IE or Netscape.