

A Case Study of Virtual Circuit Laboratory for Undergraduate Student Courses

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Abstract - The purpose of this study is to design and develop a Web-based circuit virtual laboratory for undergraduate student courses, which can be treated as an accessorial tool for enhancing instruction. The study firstly reviews the general concept of virtual laboratory and some related works. Secondly, the design and development of the system framework of this circuit virtual laboratory is discussed. Finally, the paper introduces the evaluation from the tutors and students using the virtual laboratory. One of the major objectives of this project is the client adopted Rich Internet Applications (RIAs) to enhance the students' learning experience and provides significant impact on users' learning motivation. With the support of this system, the students' uninfluenced learning and experiment process can be carried out at any place of the world where Web access is available.

Index Terms – Case Study, Circuit Simulation, Virtual Laboratory, Undergraduate Courses.

INTRODUCTION

In engineering education, written exercises are necessary for undergraduate students to master conception while experimentations reinforce the understanding of the subject. Real experiments are indispensable for developing skills to deal with instrumentation and physical processes. There is no doubt that nothing will replace synchronous learning through face to face interaction, but it is not always feasible for students to do experiment uninfluenced[1]-[2]. Virtual Laboratory (VL) can be treated as an accessorial tool of real laboratory to enhance instruction for conventional on-campus students, which can enable students to improve the skills before going to the actual laboratory ,to learn breaking the restriction of ordinary arrangement and enhance the instruction[3]-[4].

Besides, virtual laboratory can also benefit distance education and learning-on-the-job students, who maybe asynchronous in time or in space, even more, for the cost and time needed for traveling to a local lab would often prevent them from using such real laboratories. Moreover, the virtual laboratory resources can be shared by many institutions and

students worldwide, which can save much money. So VL can effectively help to overcome the barriers imposed by the traditional education by using an innovative combination of a new approach to education and the application of new technologies.

I. General Conception of Virtual Laboratory

Virtual Laboratory is a heterogeneous, distributed collaboration and experimentation environment, which allows scientists all over the world to work on a common group of projects, to generate and deliver results using distributed information and communication technologies.

The prototype of VL is Remote Access Laboratory (REAL)[5]. Computers are connected to manipulate instruments, which could be remotely accessible. When students log in and control these machines via the network, they are able to control both the computer and the equipment. A video camera is used to live broadcast what is happening in the physical world. It does not matter if the student is in a nearby dorm room or on the other side of the world. Client/Server(C/S) architecture is widely used in REAL. With the development of simulation technology, REAL gradually replaced by the Simulation-based Laboratory (SLab), which adopts pure simulation components or software-supported common simulation hardware named virtual instrument. The world-wide famous virtual instrument provider is National Instrument(NI).Many VL system adopted products from NI are installed in wide area[6]-[8].With the emergency of WWW technology, more and more VL systems are transplanted on the Web platform[9].Using Browse/Server(B/S) architecture, Web-based simulation systems adopt many new web technologies such as CORBA, PORTAL and using Virtual Reality (VR) or flash front-end to enhance the instruction and learner's experience[10]-[15].

II. Rich Internet Applications

As an application development platform, Internet emerges rapidly from obscurity to the dominant position. During the last seven years, the web has seen explosive growth. With more than 4 billion static pages and 400 million users, it has affected the conduct of business, education, and government

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SYSTEM DESIGN

worldwide. Over the brief life of the Internet, Web applications have grown in prominence and capability. Though the growth and success of the web are great, the Internet's potential constrained by the limitations of user experience. Lack of rich and complex interaction leads users to ask whether the Web can provide the same use experience as that tradition client/server applications provide [16]. In response to the opportunity for a more effective and rich Internet, a new generation of Internet applications is emerging: Rich Internet Applications (RIAs) [17].

RIAs combine the user interface functionality of desktop software applications with the broad reachable and low-cost web applications and the best of interactive, multimedia communication. The RIAs aim at offering more intuitive, responsive, and effective user experiences on the web. Rich client technology makes it possible to build RIAs by providing a runtime environment that can host compiled client-side applications delivered as files using HTTP. The client-side applications connect to existing application server back ends using an asynchronous client/server architecture that's secure, scalable and well-suited to the new service driven by the adoption of RIAs technology [17].

BACKGROUND AND RELATED WORKS

The case addressed in this paper was about a virtual laboratory, which has been used in Zhejiang University and EastSouth University for undergraduate student analog/digital circuit instruction. The VL system was developed by College of Computer Science and Technology, Zhejiang University, who has developed the first VR-based chemical virtual laboratory in 2001 [14].

There are four major reasons to propose this project. Firstly, circuit course has already become the major foundational course in engineering education for undergraduate students. Circuit related teaching and experiments is really in demand at the levels of undergraduate on-campus students. Due to the limitation of real circuit laboratory equipments and instructional arrangement, students can't go to the laboratory and do the experiment at their pleasure. This VL system can provide an excellent means for our students to solve the problem. Secondly, using VL system, our students can preview and prepare the experiment, which can improve the students skills before going to the actual laboratory and reduce the risk of students' manipulate mistake. Thirdly, this system can be integrated with Chinese flourishing distance education system. It is known to us, the quality of distance education can't be ensured without the support of VL system, especially in distance engineering education. Finally, because of robust pure software simulation components, our students can create and design any circuit system they want without worrying about the damage of laboratory instrument, which can facilitate the training of the sprite of innovation.

I. Framework Architecture

Although VL system can be used in wide area, the common architecture can be described in four layers: access layer, grid layer, supervision layer and resources [18]. Access layer consists of tools which enable access to the laboratory resources and the presentation of data. Grid layer provides the services which we can use under distributed environment, such as global scheduling and data transport middleware, which connect user-side front-end to background service. The main task of Supervision layer is local scheduling, resources monitoring and user management. Resources layer which consists of devices to experiment execution and also the necessary software used by system.

In our project, the VL system architecture we designed is shown below.

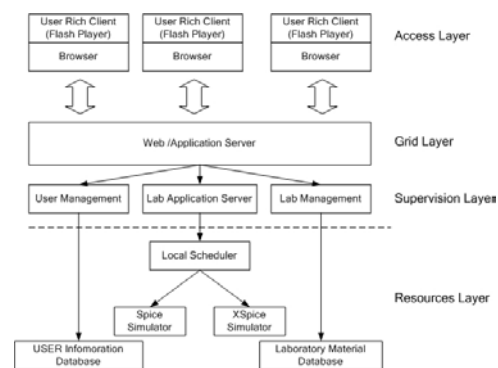


FIGURE 1
THE ARCHITECTURE OF VIRTUAL LABORATORY

Access layer provides user the function of design circuit, collaborative tools with other students, including instructor. The most important components are:

- **Working panel:** Analog/digital circuit design workspace.
- **Experimental instruments:** For getting the circuit output, such as oscilloscope, multimeter
- **Communication panel:** Inner-group collaboration.
- **User management panel**

In this project, grid layer mainly provides the function of user response and user authentication. The most important components are:

- **Web server:** Responses users' request
- **User authentication modules:** Check user validity
- **Global scheduling:** Responses for choosing the appropriate laboratory application server and load balancing when possible.
- **Data transfer modules:** Fetches the user-side circuit information and forwards to Lab application server.

On the supervision layer specific services are gathered. These services have to be implemented taking into consideration a given device and their specification. Usually it consists of:

- **User management:** Responses to users' login/logoff and manages user information.

- **Lab application server:** Receives the user circuit data, generates circuit netlist file and sent to local scheduler.
- **Lab management:** Provides the manage function of laboratory instructional material.

Finally we defined the resources layer which consists of modules of experiment execution, circuit simulation and also the necessary software and database. These modules are:

- **Local scheduler:** Arranges the circuit netlist file into a FIFO queue according to each simulator.
- **User database:** Storage of user information and log file
- **Laboratory material database:** Storage of laboratory instructional material.
- **Spice simulator:** Responses for simulate analog circuit netlist.
- **XSpice simulator:** Responses for simulator digital circuit netlist.

I. RIAs Supported Client

A friendly, interactive user client enables the instructors to develop a virtual laboratory environment which the intended students can interact with. Modern Electronic Design Automation (EDA) software, such as PSpice, Electronic Workbench, is used to establish virtual laboratory for educational purpose. However, most of the EDA software cannot provide sufficient educational instruction to users, for the lack of friendly user interface, especially web-based, interactive visual interface, which can enhance user experience, and significant impact on users' motivation and learning effect. Concerning more complex and friendly interaction, system involves a user dragging and dropping a wire from a pin of circuit component to assemble a circuit. After submit the circuit to background server, students can actually view the waveform together with any relevant diagrams or data instead of the long plain text form paragraph output description, which the students may have difficulty in understanding. Not only will this explain the process more clearly, but also the students would derive more enjoyment from learning in such a rich and creative Internet environment.

System adopts RIAs to build the system instead of VRML (Virtual Reality Model Language). Though VRML is a popular web tools for generating the immersing learning material via Internet and there are many helpful cases have been developed [14]. The main disadvantage of using VRML is high hardware and network bandwidth requirement and low efficiency of appending new experiment items. Using flash can build user interface with less file size. Furthermore, it is support XML data exchange protocol.

System adopts the flash MX2004 to build the user interface. The user interface consists of some circuit instruments and apparatus, such as oscillograph, signal generator, multimeter, and circuit board with a set of diodes, transistors, resistances, potentiometer and other circuit components. Users can generate a wire through drag and drop on any pin of components, build any circuit as they wish, power the circuit and use oscillograph and multimeter to check any pin's waveform and voltage value. When the power is on, users can change adjust the circuit and apparatus, for example,

turn the knob of a potentiometer, or change the signal frequency of the signal generator. Once the users do that, the displayed result will be refreshed in real time.

IMPLEMENTATION AND EXPERIMENTS

The system has been tested by more than 200 undergraduate students from Zhejiang University and EastSouth University in circuit course instruction, at 2004 autumn. In order to analysis the instructional effect of this system, we made an survey on students' attitude to system. From the feedback and data from survey, we found more than up to 95% students hold positive attitude. The detail of survey result is shown in following figure.

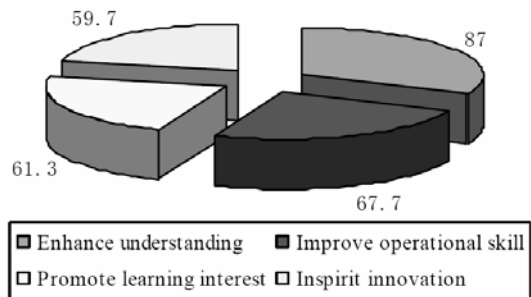


FIGURE 2 STUDENTS ATTITUDE TO SYSTEM

To illustrate the application of this system, we select a analog experiment circuit--Single-Transistor Amplifier:

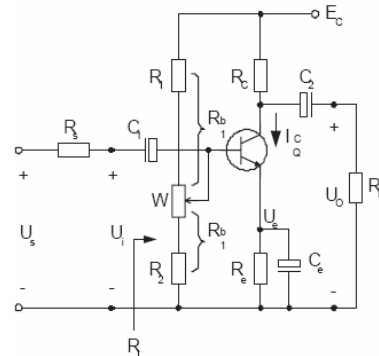


FIGURE 3 THE SCHEMATIC DIAGRAM OF SINGLE-TRANSISTOR AMPLIFIER

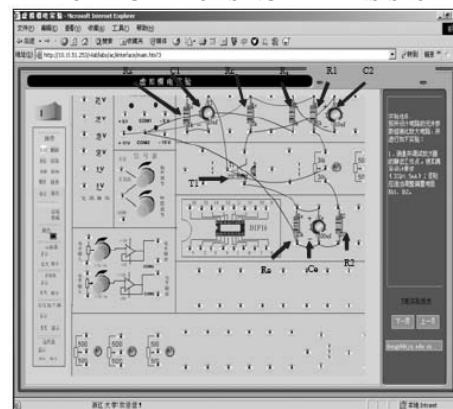


FIGURE 4 THE DESIGN OF SINGLE-TRANSISTOR AMPLIFIER

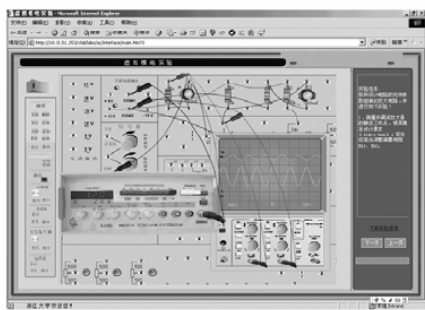


FIGURE 5
THE CIRCUIT OUTPUT OF SINGLE-TRANSISTOR AMPLIFIER

FURTHER WORK

Because all the users using the system is on-campus students, so the server architecture is centralized and system suppose the users' bandwidth is sufficient. The next step of system is to develop a multi-users collaborative system; especially the serve architecture is distributed. According to the new system requirement, some new feature maybe considered. Firstly, design a distributed multi-server architecture, such as Grid-based supported. Secondly, because of the communication between servers is via Internet, the network QoS can't be guaranteed, so adoption the mechanism of interest management to reduce and filter the data flow of network is needed. Finally, we need to develop a new scheduling algorithm to realize the load balance between servers real-time according to users' action.

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