

A Web-based virtual laboratory for distance education

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ABSTRACT: In distance education, students find it hard to come to an institution's school laboratory to complete experiments. The Web virtual laboratory, which is a development of the virtual laboratory, allows virtual experiments in the Internet environment. The research reported in this article developed the basic structural and network features, and operating mode, of the on-line virtual laboratory for distance education based on the Web. The system architecture, building the component library and the design of the human-computer interface as key technologies in the implementation, are presented and discussed in this article.

INTRODUCTION

With the rapid development and popularity of the Internet, distance education based on the Web has become a key feature of modern distance education [1]. However, distance education learners find it hard to attend school laboratories to complete individual experiments. This difficulty has become an important restriction on the quality of distance education.

The virtual laboratory, which is based on the Web, uses computer simulation, mathematical modelling and multimedia technologies. Its characteristics include low cost, high efficiency, good availability, resource sharing, safety of use and ease of operation. The virtual laboratory has the ability to remedy the problem of laboratory access in distance education, thus, effectively spreading and extending the traditional laboratory availability in both time and space. Hence, it promises to become a key development trend in the practical teaching of future distance education.

CONCEPT AND CHARACTERISTICS OF THE WEB VIRTUAL LABORATORY

Virtual laboratory refers to the operational environment created on a computer by using simulation, mathematical modelling and multimedia technologies. Such a system can be used to partially or even completely replace traditional experiments [2][3]. It realises the laboratory teaching function by using computer software to simulate the experiment environment, subjects and processes. A Web virtual laboratory is a virtual laboratory, running in the Internet environment. In addition to the functions required by a virtual experiment, a good Web virtual laboratory should also have the following [4][5]:

- Generation of the experiment scheme:

The experiment software should provide a good human-machine interface; provide the convenience of manual operation; and automatically generate suitable experiment schemes, with parameters provided by the user.

- Visual window support:

The experiment software should provide visual support for the whole process, including the generation of the experiment scheme, network operation and experiment data analysis.

- Open system structure:

A means whereby users can easily extend software, update modules or add new functions.

- Assistant functions:

Assistant or help functions should include self-learning and preview, experiment direction and demonstration, experiment information querying and retrieval, experiment report submission and review, as well as experiment assessment and evaluation.

WORK MODE AND NETWORK STRUCTURE OF THE WEB VIRTUAL LABORATORY

The Web virtual laboratory is a computer software simulation system based on the Internet, and uses the classic browser/server three-tier computing architecture. The structure is shown in Figure 1.

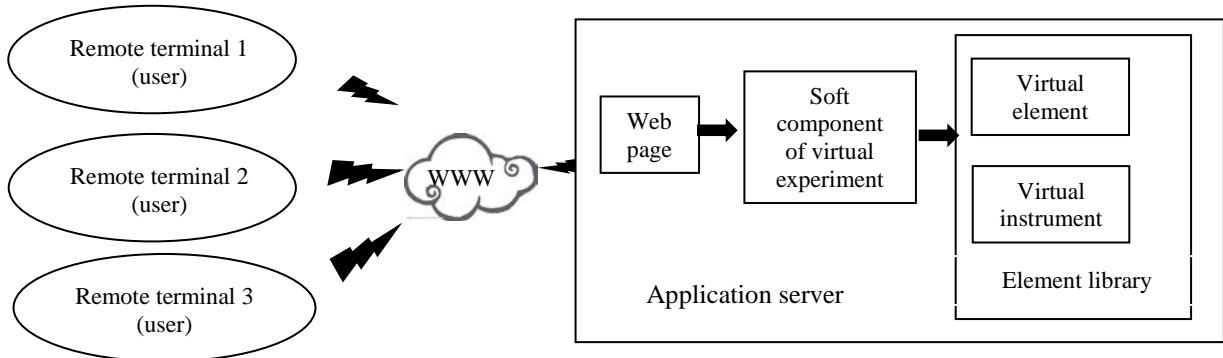


Figure 1: Structure of the Web virtual laboratory.

In this system structure, the browser on the remote terminal visits Web pages embedded within the software of the virtual experiment. This simulates the experiment environment for various experiments, and accepts experiment operating requests from the terminal (user). The virtual experiment software adjusts the status of the virtual elements, generates experiment subjects, and then outputs experiment data [6].

While users operate at the remote terminal, the experiment data and results can be stored at the terminal or the server. The server mainly stores public experimental data and experiment instructions, which can be stored in the form of a static Web page on the server. The logic for a specific experiment is embodied in the software of the virtual experiment [7].

STRUCTURAL DESIGN OF THE VIRTUAL LABORATORY

The virtual laboratory is a subsystem of a teaching system and a part of a school’s on-line teaching resources. A Web virtual laboratory in its complete sense can not only provide students with a virtual, realistic experiment environment for all kinds of experiments, it also realises such functions as managing experiment courses, experiment teaching, teaching and students’ learning, adding and deleting experiments, uploading and downloading experiment data and submitting experiment reports. This requires the virtual laboratory to have a series of assistant function modules. These modules serve as a bridge between the virtual laboratory platform and experiment personnel. The design of the virtual laboratory is shown in Figure 2.

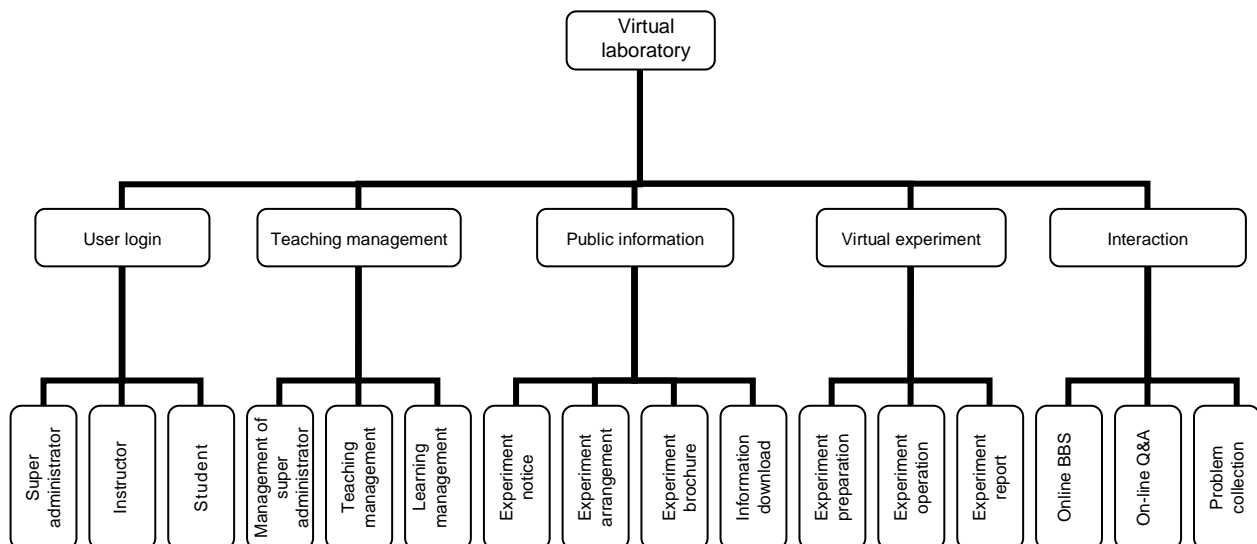


Figure 2: System structure.

A description of the modules follows:

- User login module:

This module supports three roles; super administrator or experiment administrator, instructor and student. The experiment administrator has the highest authority and the student the lowest. All the services are available to students.

- Teaching management module:

This includes three types of teaching management, viz. for teachers, students and experiment administrator [8], as shown in Figure 3. Management of teachers' teaching includes setting up a new experiment, publishing the experiment, arranging the experiment, reviewing the experiment report, experiment evaluation, score collection, feedback release, providing courseware and multimedia materials (e.g. video, flash), providing on-line Q&A and tutoring. Management of students' learning includes identity authentication, selecting an experiment, carrying out the experiment, getting experiment instructions, submitting experiment reports on-line, saving and submitting experiment results, checking scores and comments. Management of the experiment administrator includes experiment news release, adding experiment courses, course management password, system account and subgroup management, authority management, course management, system audit and system maintenance.

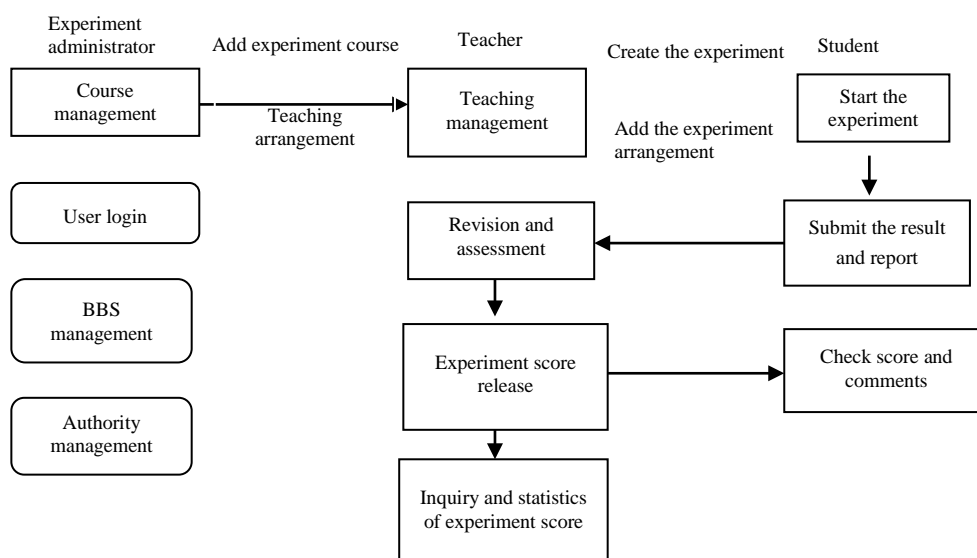


Figure 3: Teaching management for teacher, student and experiment administrator.

- Public information module:

This module mainly is for releasing experiment announcements, issuing experiment notices, and providing experiment courseware and information to be downloaded.

- Virtual experiment module:

This is the core module of the virtual experimental system and is composed of three sub-modules, viz. experiment preview, experiment operation and experiment report, as shown in Figure 4.

The experiment preview sub-module has three components; namely, instrument introduction, experiment principle and experiment notice. The instrument introduction is presented using 2D or 3D Flash or 3ds Max, supplemented by a text description. Multimedia technology, such as text, graphics, pictures, flash, videos and audio are used to present the principle, purpose, content, instrument and items of the experiment. This requires a clean, effective and well-designed interface.

The experiment operation sub-module has three parts; namely, default setting of the experiment, the experiment process and the experiment result. The default setting refers to the experiment parameters. The server processes based upon experiment parameters, returns data to the client to control changes to the experiment model, and returns experiment results, including data and figures.

The experiment report sub-module is an important link to the experiment teaching. The formats of experiment reports differ for different courses and different experiments. The experiment instructor can configure each process of each experiment, thus, causing students to carry out experiment as per such processes. When writing an

experiment report, a student can not only briefly introduce the experiment content, principle, elements and instrument, but also record the data collected, results and graphics observed during the experiment and, finally, analyse, perform calculations and draw conclusions about the results. After the experiment, the system can automatically generate an experiment report, according to experiment process, for students to revise and upload to the server. Teachers can review and revise students' experiment reports or even check experiment data and results.

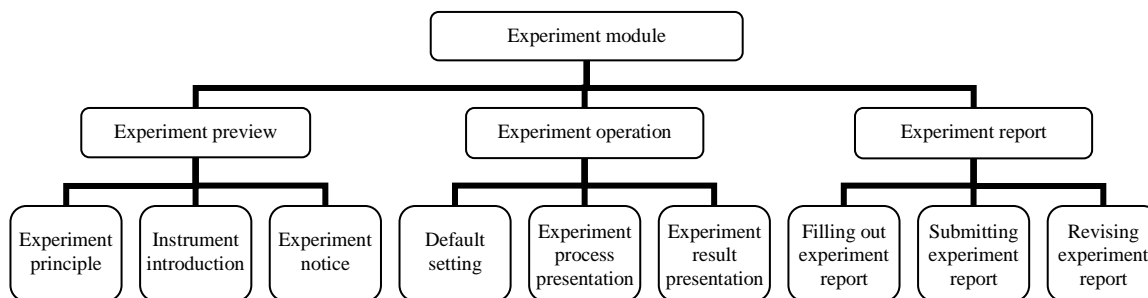


Figure 4: Design of the experiment module.

- Interaction module:

This module mainly has two functions, viz. on-line communication and leaving messages. On-line communication allows students to communicate and co-operate with classmates, with the help and direction of the teacher when undertaking the experiment. *Leaving messages* allows students to write problems during the experiment on the message board so that teachers can give individual tutorship for these questions.

KEY TECHNOLOGIES OF THE WEB VIRTUAL LABORATORY

Technology for the Virtual Element/Instrument

The element library of the Web virtual laboratory is used for storing virtual elements/instruments. These virtual elements/instruments are the subject of interactive operations on the virtual laboratory platform, as well as a direct representation of the real instrument. Herein lies the challenge of the design of the virtual laboratory system. The virtual element/instrument model will directly influence the system performance and the efficiency of the simulation. A good virtual element/instrument model has these features: good encapsulation, extendibility, reusability and completeness [9].

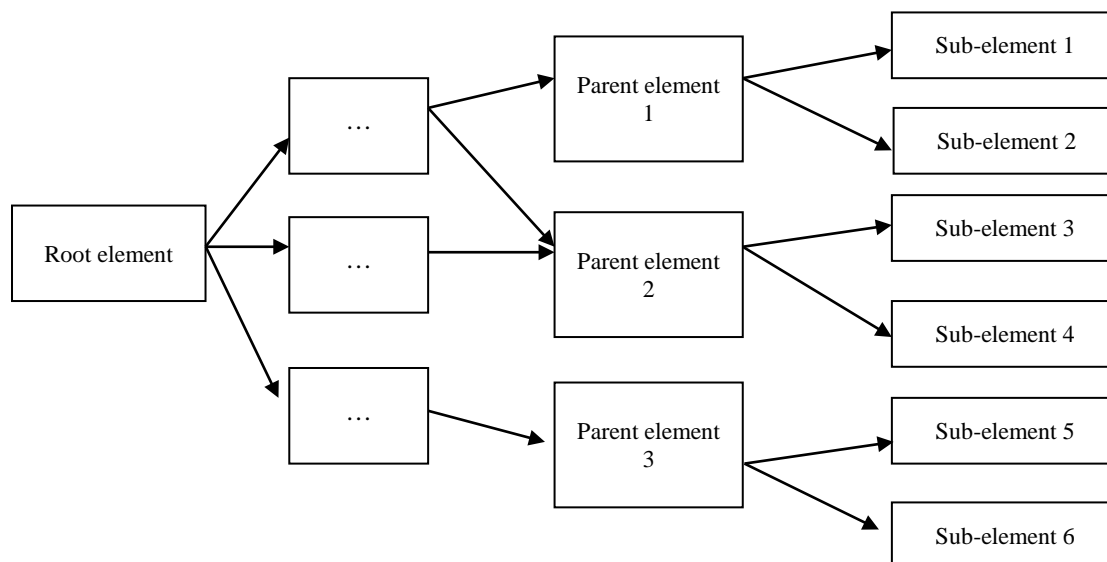


Figure 5: Structure of the virtual element library.

- The virtual element/instrument library:

The object-oriented construction of a virtual element takes the real world element as the subject. The object-oriented design approach is used, to classify elements according to features and functions. Thus, is formed the element library, as shown in Figure 5. In the library, every element encapsulates an individual subject. Each subject has its own attributes, such as extrinsic features, geometrical shape, parameter variables and a special region. In addition, there are self-mapping, self-updating, and other methods to realise the interactive functionality. During the experiment, when an element is needed, it can be realised by the attributes and methods [10].

For example, the special region of the element category can be used to determine whether an event occurred on a graphic subject; by modifying the parameters, the display can be changed. Hence, the interaction with users is implemented through event management.

- Construction of the virtual element/instrument:

First, define a parent element that includes the attributes and methods to be inherited by the other elements, e.g. element name, area, symbol attribute and self-mapping method. Individual elements inherit the attributes and methods of the parent element and add new functions or override the parents' functions to form a sub-group. Take the digital circuit experiment as an example; LogicChip is a virtual base class, from which CombChip and SequenChip can be derived. Furthermore, other chips can be derived by inheriting and combining.

Object-oriented class descriptions for an element subject include class attributes and methods. Class attributes include interior/exterior attributes; synchronous display variables, which are appearance variables corresponding to actual physical appearance; asynchronous display variables, which are display variables independent of exterior factors; and controlled variables, such as type identifier of a device and unique identifier. Such attributes are variables in Java and C++.

Object-oriented class methods include a construction method to instantiate the default object; a message response method to interact with users, e.g. to locate the point coordinates of a mouse, to adjust parameter values; an appearance drawing method to generate and modify the appearance and shape of an element; an exterior method to provide an accessible interface for other objects; and other supporting methods, e.g. determining the connection port. Such methods are implemented as the member function in Java and C++.

The UML (unified modelling language) is used to construct class and status diagrams, according to which the codes are written in a programming language such as C++ or Java, to complete the encapsulated construction of an element.

- Implementation of the virtual element/instrument:

The virtual element/instrument is a modular computer system based on standard technology, usually composed of a control module and an instrument module. Full use is made of the latest computer technology to realise and extend the functions of traditional instruments [11]. During the virtual experiment, the virtual instrument provides such services as signal display and detection. The virtual instrument has the following features: centralised analysis, display, save, print and management; the instrument is defined by the user. The function, sizing, etc. of the system can be modified by software and the instrument can be easily connected to peripheral devices, networks and other instruments. Using object-orientation and modularisation, the instruments required in the virtual laboratory can be constructed.

- Operation of the virtual element library:

Operations of the virtual element library include calling, adding, deleting and modifying virtual elements. The inheritance down the tree structure of the virtual element library and virtual element encapsulation makes once-complex operations of the element library much easier. When the system is to construct an experiment or simulation, it retrieves the element/instrument from the library. The retrieval proceeds as follows: first, find out the element node according to the identification of the potential element/instrument. Second, according to the inheritance relationship of the element node, perform a traversal search from the bottom until the root node is reached. Finally, generate the final model description of the element/instrument and return as the node [12].

The Human-Machine Interface

- Operation of the interface:

The virtual laboratory interface should be able to provide the following operations: selection of the experiment; selection, layout design, editing and parameter settings for the virtual element/instrument; connection to the element/instrument; programming and editing as required by the experiment; circuit testing and simulation of the experiment; experiment data display; experiment report upload and download.

The design of the virtual laboratory interface should include a main interface design and specific experiment interface designs. The main interface leads the user into the virtual laboratory and allows experiment selection. The experiment interface is used for operation, demonstration and simulation. The experiment interface is composed of an experiment panel and menu. The experiment panel is used for placement of elements needed in the experiment, connection between the element and the instrument, indication of an element's pin state and experimental data. The menu should include options, such as operation, testing, programming and editing, simulation, data production, saving results and help. The system should also include an experiment report

processing interface for processing experiment data, writing and submitting the experiment report, and help. There should also be provision of on-line Q&A and information download, for the students to interact with the teacher.

- Implementation of the human-machine interface:

The key to the implementation of the human-machine interface lies in simulation technology. At present, some key technologies for developing simulations include VRML (virtual reality modelling language), ActiveX, Flash and Java. One or more of these technologies can meet the simulation requirements of an experiment. For example, a simple Java program can be used to simulate an experiment and produce a 2D output of the outcome, for example, on an instrument panel. The VRML can be used for 3D simulations of the virtual experiment to produce an immersive experience. Combining Java and VRML for combined 2D and 3D simulations can achieve an effect comparable to a real experiment. Users need only to set up a normal browser with the VRML plug-in element to view VRML scenes of the experiment on the client. Most browsers, e.g. Microsoft Internet Explorer, have VRML plug-ins and support Java. As an example of use, a user may input parameters into the Java program embedded in an HTML page to submit an experiment request. The Java program executes using the experiment data and maps the 2D outcome. Of course, the 3D experiment instrument mapped by VRML depends upon the experiment content.

CONCLUSIONS

The Web virtual laboratory for distance education has broad application potential in education and science and is a main development trend for distance experiment education. As a new model of education, the virtual experiment injects new energy into experiment teaching and extends the scope of experiment teaching. Furthermore, the development of the virtual laboratory based on the Web should follow systematic and scientific principles.

Appropriate application of educational psychology, and computer hardware and software technology, coupled with awareness of research in the area, is the key to successfully developing the virtual laboratory system for distance education based on the Web.

REFERENCES

1. Zhu, Q., Li, C., and Cui, X., Teaching model based on virtual experiment system. *Laboratory Research and Exploration*, 27, 6, 84-86 (2008).
2. Gadzhanov, S., Nafalski, A. and Nedic, Z., Computerised measurement laboratory for engineering students. *World Trans. on Engng. and Technol. Educ.*, 12, 3, 380-385 (2014).
3. Kang, S., Wang, Y., Wang, P., Lu, D., Zhou, M. and Liang, X., Development of a teaching experiment platform for a signal generator based on LabVIEW. *World Trans. on Engng. and Technol. Educ.*, 12, 2, 261-265 (2014).
4. Ma, L., Yang, L. and Lang, T., A case of the design of online education distance teaching system. *Jiangxi Educ.*, 15, 4, 27-31 (2004).
5. Zhao, J., Li, B. and Chuan, X., *Network Teaching Courseware Fabrication*. Beijing: People's Posts and Telecommunications Press, 10-12 (2004).
6. Yang, J., Research of Web virtual laboratory. *China Education Informationization*, 12, 27-29 (2008).
7. Zhan, Z., Zeng, W. and Ding, Y., Research and realization of virtual laboratory system based on Web. *J. of Hangzhou Institute of Electronic and Technol.*, 22, 6, 53-56 (2002).
8. Wen, F., Research and Application of Distance Virtual Experiment Education Environment. China Education Information Network, 2009-08-05/2009-09-02, <http://www.e-chinaedu.cn/zhuanti.luntan2009/gaodengjiaoyu/html>
9. Zeng, Z., Design and implementation of digital logic virtual experiment platform. *Computer Times*, 1, 32-33 (2006).
10. Lan, H., Research of computer hardware system Web virtual laboratory. *J. of Guangxi University of Technol.*, 18, 2, 41-44 (2007).
11. Li, Y., Construction of Web virtual laboratory and application of virtual reality technology. *J. of Changchun University of Science and Technol.*, 30, 2, 59-62 (2007).
12. Yang, L., Duan, X. and Peng, J., Research of virtual element/instrument of network hardware virtual laboratory. *Modern Electronic Technol.*, 5, 103-106 (2004).