RESEARCH ON THE EXPERIMENT ENVIRONMENT IN DISTANCE ENGINEERING EDUCATION

Cheng Hua, Ying Wei Yong and Yao Jun
Distance Education Institute of East China
University of Science and Technology
China

Abstract

The engineering course experiment is the key point of distance engineering education. This paper introduces the research and implementation of experiment environment in ECUST (East China University of Science and Technology). As a typical case of remote control laboratory, a two-water-tanks experimental system using programmable automation controller (PAC) was introduced. A virtual experiment based on interactive flash of physical chemistry was briefly introduced. The statistical data of the experiment courses and the feedback from the students were analyzed. It shows that there are some details that should be improved.

Preface

Experimental work is a vital part of engineering education at all levels, and also a big problem in distance education. Traditionally, home experiment kits or intensive residential schools as part of the course are adopted in the teaching process but the high cost prevents us from implementing this in large scale.

The Internet-based experiment environment is a good solution of experimental work in distance engineering education. It is the integration of information communication technologies and education technologies, and must be flexible, user friendly and fault tolerant. Now it mainly consists of virtual experiment and real-time remote experiment.

In virtual experiments, the device is mainly made by multimedia technology, such as Flash, Matlab or VRML. The technology for virtual experiments is getting more mature, and educational organizations and companies have developed many products.

In real-time remote experiments, the device is the real one in the remote laboratory. Through the Internet, the learners could finish the experiments by video, configuration interface and some simulators.

Real-Time Remote Experiments

Recently, some real-time remote experiments have been developed. Although remote laboratory platforms seem developing quickly, they are still not used in large scale. This is because most of them are simple, or not practical in the learning process. Of course, we strongly believed in that software must be developed in practice. Nonetheless, the current software developments try to search existing practical solution for the remote experiments, and it turns out to be in vain. On the contrary, every remote laboratory project implements its own software architecture, but each one obviously lack of a comparison among existing architectures. Therefore it is not easy to assess the future directions in our research (Scanlon, 2004).

Some appliances directly provide an Internet connection, and it seems different from others. However, this is only because they embed a modern operating system inside the device, which therefore does not require a local computer. So it does not make much difference, and there is no breakthrough (Baran, 2004).

Usually, remote laboratories architects build a middleware allowing remote clients to connect to the local computer. It's comparatively easy, and that is why the most remote laboratories are using this kind of software solutions, as it provided them the remote control over the local computer connected to the corresponding device. Nonetheless, many solutions lack security and require too much bandwidth. (Srinivasagupta, 2003)

A two-water-tanks experimental system will be introduced, and this experiment is for the course of Process Automation Instrumentation. It's a common experiment system in the traditional laboratory, and we added the remote elements and \rebuilt it to a real-time remote experiment system. We select it out because it's typical and comparatively successful. From the construction and practice of the system, we have summarized the guidelines of real-time remote experiments. In current condition, the early experiment projects in ECUST which did not comply with the guidelines turned out to be a failure.

A Case: Two-water-tanks Experiment System

In this experiment, the new programmable automation controller (PAC) was used to develop a two-water-tanks real-time remote control experiment based on Internet.

To assure the reliability and safety, a three-layer distributed architecture and B/S (Browser/Server) mode was adopted. PAC was adopted in the host controller to configure the host detection and control system, and a monitoring software was adopted as the middle ware. In the experiment system, we could finish several experiments ranged from simple object characteristic test to Cascade Control in the course of Process Automation Instrumentation.

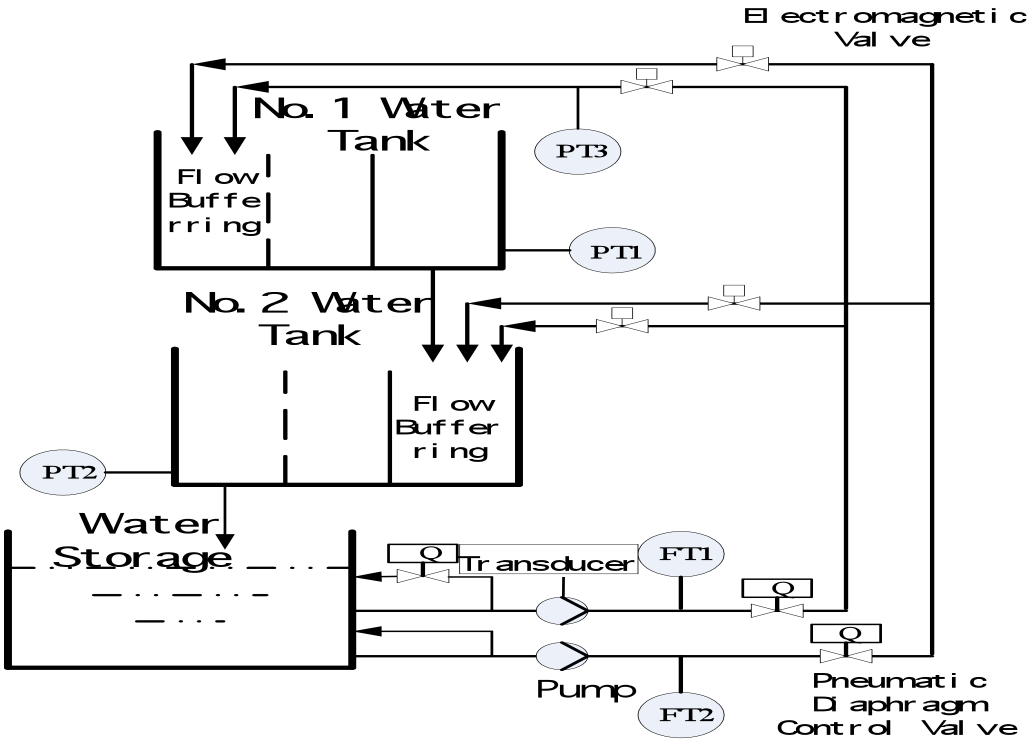
Two-water-tanks Experiment Object. According to the syllabus of the process automation, a two-water-tanks device was developed. The flowchart was shown in Figure 1. In the object, we could finish the following experiment:

1. first-order object and second-order object characteristic test;
2. simple control system experiment, such as first-order object or second-order object set value control or trace control;
3. complex control system experiment, such as proportional control, cascade control;
4. frequency control.

The hardware includes three liquid level detecting instrument, two flow measuring meter, three pneumatic diaphragm control valve, one transducer, four electromagnetic valves, and electrical safety protection appliance. The output of all the instruments is standard signal 4~20mA, and accuracy class is 0.5. In the experiment process, the detection and control system will switch the valve automatically to build up different loops for different experiment function.

The medium of the device is water, and the water was cycled in the closed-system, so overflow would not take place. There are no high-power devices such as the heater. All the action of the device could be implemented automatically, and this is fit for the distance education.

Figure 1: Flowchart of the Two Water Tanks Experimental System

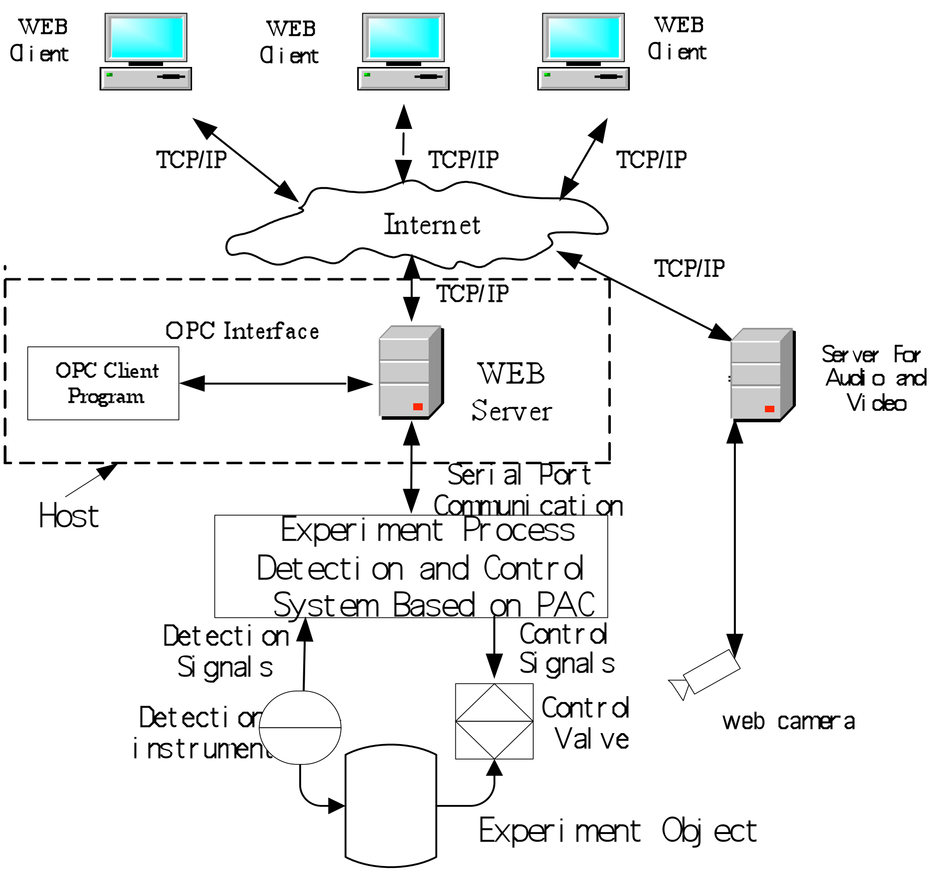


In the design of the water tanks, the multi-vessel structure with flow buffering was adopted. If the cubage was changed, the time constant of the object could be changed; and if the initial level of the flow buffering was set to different value, the pure lag time could be changed. This design makes the simple object possess some complex characteristics, such as time-variant, pure lag, uncertainty, and so on.

The structure design. The structures of most current remote experiment systems are similar. Computers in the system are connected to engineering instruments through the detection and control modules. When students log in to the system over the Internet, they are able to control the equipment through the Internet and server computer. A video camera can also be 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 (Salzmann, 2000)

The diagram of process automation remote experiment is shown in Figure 2. Its principle is the same as that mentioned above, and it is composed of two water tanks, the process detection and control system based on PAC, server for audio and video, Web server, the client for operator and administrators (the computer with Web browser). When Web server accepts the request from the client, it will control the device to accomplish the specific experiment, and transmit the result and live program of audio and video to the remote learner. The lamp will be turned on automatically in the night if the learner comes in, and the learner could control the angle and focus of the web camera for the better observation. (Zhang Fan, 2008)

Figure 2: Principal Diagram of the Remote Experimental System based on Internet



Development of detection and control system based on PAC. The model of PAC in the system as the host controller is ADAM-5510KW, which is developed by Yanhua Company in Taiwan. This PAC has CPU, ROM SRAM and Flash Memory, built-in watch-dog circuit, real-time timer and multiform communication interface

The configuration of PAC system is as following: the analog input chooses the ADAM-5017 module, and the locale transmitters transit the signal of water level and flow rate to 4-20mA electrical current, and this is the input of ADAM-5017; the analog output chooses ADAM-5024 module, and output of 4-20mA signal drives the locale pneumatic valve to implement the control to the water level and flow rate. Besides, the digital input and output are also configured to implement the control to electromagnetic valve

In the host computer, KW-Multiprog, the software in ADAM-5510KW would program for PAC. Several languages such as Trapeziform Diagram and Structural Text were used in the programming. The control program would be downloaded and run in PAC. The learners and administrators could modify the control parameters in the client computer through Web server to accomplish the experiment (Lin Xiaofeng, 2007).

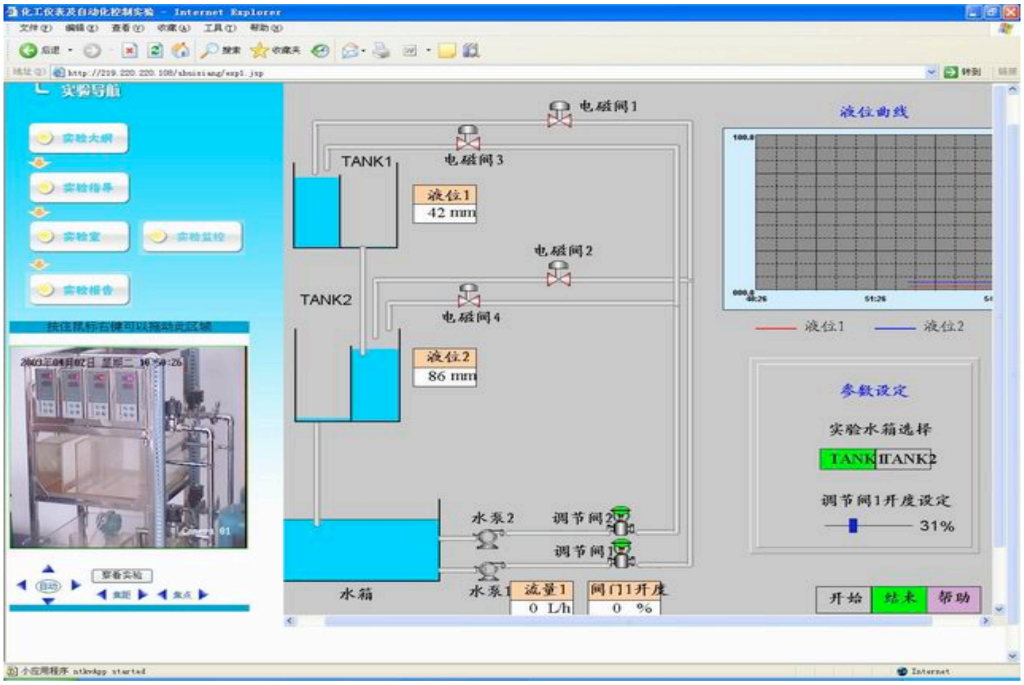
Though the learner could find out what happens in the locale through the configuration software and monitoring audio and video, there is no teacher in the locale. So when a malfunction takes place, the detection and control system must have the function of self-protection and reset. Besides, to avoid any danger, the system must refuse to execute some wrong operation command.

Development of WEB server software. The dynamic data of the experiment is transmitted by socket based on TCP/IP. Now there are two types of program to implement the dynamic data transmission between the client and remote laboratory, and that are remote experiment ActiveX control based on socket or Java Applet program. In this experiment, Java Applet program is adopted. (Tang Hong-ru, 2005)

“Configuration King”, industrial control software developed by a company in China is chosen as the middleware software, and it supports multitask and has the function of OPC server and client.

The system just allows one learner to operate one experiment device, and if the devices were occupied, the other learners only have the right to watch. An online appointment system was developed as a sub-system, and the learners could schedule as their wishes through the system.

Figure 3: Two-water-tanks Experiment System Interface



The experimental report. When the experiment is over, the learner should download the correlative data. This system developed application programs by Visual Basic.net, and this program exchanges the real-time data with Web server through OPC, and records all the data in the experiment and saves it. This is better than the DDE (Chen Shangjun, 2000).

In the process of experiment, the data shown in client is the same as that in locale. However, in the current Internet circumstance, there is lag in the data display sometimes in the trial. For the object which has small time constant, the lag might cause the wrong judgment from the learner. So we should avoid this kind of hidden trouble in the experiment design.

Virtual Experiment

The key point of the virtual experiment is to accept the request from the learner and simulate the experiment appliances and process. As it is mentioned before, the technology is getting mature now. So we just have a brief introduction of a virtual experiment developed by ECUST.

This virtual experiment is developed by Flash technology. Because the graphics system of Flash is based on vector, its file is small in size, and this is important in Internet. The system simulates the mechanism of the appliances, the operation and feedback of the panel. In the virtual experiment, fusion heat of inorganic salt is measured, and the interface of the experiment is shown in Figure 4. It's a common chemical experiment, but even when the learners execute the same input, the output is random in some degree, and different learners will get different experimental report. This makes the virtual experiment approaches the real one more than before.

For virtual experiments, the learning effect of virtual experiment is still in dispute. At least, we think that it can not take the place of traditional experiment circumstance totally.

Figure 4: Interface of Measuring Fusion Heat of Inorganic Salt Experiment

Practice and Discussion

In 2007, when the first version of web laboratory was established, these experiments were open for the distance learners as a trial. Two classes from different major were required to finish the two experiments respectively. This is compulsory, but the result would not be recorded into the final score. For the virtual experiment, there was no time limit, while for the real-time remote experiment, the time was appointed by the learners themselves through the appointment system mentioned above.

The comparison of these two experiments is shown in Table 1. As long as the experimental report was created and passed, we regard this experiment as a successful one. We have recorded all the consultation and complaints on the experiments from the students. The data comes from the students support department of Distance Education Institute of ECUST, and the data from question and answer system in definite time was also taken into account.

Table 1 Comparison of Practice of Virtual Experiment and Real-time Remote Experiments in 2007

	Virtual Experiment	Real-time Remote Experiments
Experimenters	43	35
Successful Number	42	18
Successful rate	98%	51%
Consultation	39	78
Complaints	2	20

For the virtual experiment, it is successful. Only one learner did not finish the experiment, and that was because he was sick at that period of time. Only 2 students complained that the experiment output was too simple, and they just got the same data if they did this experiment repeatedly. In the new version of the experiment this was improved as mentioned before.

For the real-time remote experiments, from Table 1, we could see that it was a failure. The statistics of the complaints were listed as following,

- 2 students complained that they could not enter the experiment system;
- 7 students complained that the system have ever crashed in the process of experiment;
- 11 students complained that the network was so congested that they often could not operate the device, and the quality of video was terrible.

We have investigated all the complaints. For complaint 1, we found the learners had not come here in appointed time. However, when the request from the learners to enter the system had been refused, the system had not given a hint. So the reason is that the interface is not friendly enough.

For complaint 2, we checked the log, and found that the system had never crashed, but some learners had lost the connection. The reason of most problems was that the fault-tolerance of system was not satisfying.

But for complaint 3, it was really complex. As we know that the Internet transmission speed is not stable, while the audio and video require lots of bandwidth. If we reduced the frame and quality of the video, the details of the experiment might not be known well for the learners, and it’s a dilemma. So we concluded that the device should not be too large in volume, or it's difficult for the learner to observe the experiment. Maybe the two-water-tanks device is the ceiling in volume in current Internet circumstance.

In 2008, in the new version of web laboratory, more experiments were open for the distance learner, but they were still trials. We selected two classes to do the same experiment as that in 2007. The comparison of these two experiments is shown in Table 2.

Table 2: Comparison of Practice of Virtual Experiment and Real-time Remote Experiments in 2008

	Virtual experiment	Real-time remote experiments
Experimenters	58	46
Successful Number	58	39
Successful rate	100%	85%
Consultation	42	67
Complaints	0	11

From Table 2, we could see that the both experiments were improved. However, the network congestion was still a problem, and most complaints still concentrated on this.

The trial shows that many experiments are not suitable to be rebuilt to a remote one. We summarized the guidelines of the development on real-time remote experiments. In the guidelines, the experiments with the following characteristics would not be developed to a real-time remote one in current condition:

- there are some heaters and other high-power devices;
- in need of charge and other manpower or manipulator intervention ;
- the medium (most are water) could not be recycled;
- the number of devices exceeds 2, or the number of detection points exceeds 10, or the number of control points exceeds 10, or the number of control points operated in one experiment exceeds 4.

Because we have not enough people, the learning effect of the experiments is not investigated in the research. And most time in the trial, we were obsessed by the complaints from the students about the remote real-time experiments system. And in the further research, more importance will be attached to the learning effect.

Conclusion

In the development of real-time remote experiment system, there are lots of limits, and flexibility, user-friendliness and fault-tolerance of the system are very important. Otherwise it's not a practical in the teaching process. In this paper, we have built up guidelines to evaluate the real-time remote experiment development.

For virtual experiments, it's easy to implement. However, it's just a simulation of reality, and can not take the place of traditional experiment circumstance totally.

In fact, in the Distance Education Institute of ECUST, The traditional experiment circumstance is also kept in some courses.

There are three solutions in the development of the experiment. The choice is based on many factors, such as cost of construction and maintenance, learning effects, fitness for distributed learning, and so on.

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