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Providing a laboratory for students everywhere

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ABSTRACT: This article reports on a Web-based mechatronics system for remote learning in engineering education. Using communication and network technologies, Web-based learning occurs remotely, bi-directionally and interactively, beyond the limitations of time and space. Current technology enables remote access to laboratory equipment via the Internet, which is particularly useful for part-time students learning. The study was carried out with 36 students in the Department of Industry Education and Technology at the National Changhua University of Education in Taiwan. Eighteen students were in each group, experiment and control groups. The preliminary evaluation of the laboratory mechatronics module was encouraging and demonstrated its effectiveness. This article also presents the results of a survey questionnaire conducted among students taking the laboratory module, in order to determine its advantages and performance.

INTRODUCTION

The global connectivity of the Internet and new generations of hardware and software applications make e-learning one of the fastest-moving trends in higher education [1]. Using new media and information technology in a classroom makes studying more attractive to a student, and makes teaching much easier. Another advantage of e-learning is the independence of study locations and times. Many e-learning educational systems have been developed, which are targeted to specific environments [2].

A very important element of engineering education is the laboratory requirement, where the student verifies the learned theory in physical systems and develops some practical skills. The laboratory is also important in engineering research, where the developed novel theory is verified and evaluated in different systems. Due to the rapid diffusion of the Internet, the ever increasing number of institutions and easy access to the net, distance learning is becoming more common. The creation of remote laboratories that allow students to perform measurement experiments over the Internet proves to be an essential issue during the realisation of distance learning projects [3]. Emerging and innovative methods that enhance learning and expand educational opportunities are readily available. Experiments allow students to compare reality to simulations, and give them opportunities to explore areas of curiosity [4]. Many engineering programmes consider laboratories as an essential element of education, particularly at the undergraduate level [5]. Distance and e-learning systems could play an important role in providing incentives for university faculty to teach distance education courses [6].

In the field of education, the laboratory is a potential tool for all institutions that offer engineering programmes at undergraduate and postgraduate levels. The students can access and familiarise themselves with operations of the laboratory for conducting experiments [7]. Unfortunately, many campus engineering courses do not include a lab component due to significant expense and space considerations, nor is this module available to distance students, whose numbers are steadily increasing for science and engineering courses. In response to this, the creation of Internet remote Web-accessible laboratories is providing a new framework for science and engineering courses [8]. Remote laboratories allow for greater efficiency in the use of laboratory equipment and give students an opportunity to conduct experiments from the comfort of their home, with an Internet browser. It is proposed that remotely accessible laboratories have a potential role in enabling student's understanding of such key concepts [9].

The global spread of the Internet, acceptance of programmes and flexibility in location and time, have resulted in many new selections for distance education. The new selection performs complete online courses, making education accessible to those who do not fit the model of the traditional full-time student.

Instructional systems design is a process to ensure that learning does not occur haphazardly, but is developed using a process with specific measurable outcomes. The responsibility of the teacher in instructional design is to create an instructional experience, ensuring that students will achieve the aims of the instruction. The Analyses, Design, Development, Implementation and Evaluation (ADDIE) model is a generic, systematic approach to the instructional design process, providing teachers with a framework to ensure their instructional products are effective and their creative processes are as efficient as they can possibly be. The five phases in ADDIE are: (1) Analysis: define the needs and constraints; (2) Design: specify learning activities, assessment, and choose methods and media; (3) Development: begin production, formative evaluation and revision; (4) Implementation: put the plan into action; (5) Evaluation: evaluate the plan from all levels for the next implementation [10][11]. The five phases work like a loop. They are continually and regularly repeated to see if further improvements can be made. Below is a detailed description of each.

SYSTEM ANALYSIS

In the research process, analysis occurs after a literature review, consulting with an expert panel and interviews with students. In this phase, teachers analyse both students' characteristics and teaching content in advance. Two functions are used for analysing the progress and characteristics of students. The first function is students' basic information analyser and manager, which records students' basic information, including their past learning experience, ability, and what students feedback to teacher throughout the learning process. The second function is students' score manager. Students' score data accumulate over time with tests and exams as learning progresses [12].

SYSTEM DESIGN

The fundamental objective of this study is to develop a Web-based laboratory, which utilises physical equipment to teach Programmable Logic Controller (PLC) programming and control mechatronics modules over the Internet. During this phase, teachers produce their teaching outline and plan based on the analyses in the previous stage. Teachers often draw on past experience and personal beliefs about teaching as they teach [13]. The design constraints and requirements are listed as follows: (1) To design a Web-based mechatronics system architecture that allows remote students to access equipment and conduct laboratory exercises over the Internet; (2) To provide flexible and robust features that minimise any potential drawbacks for remote students; (3) To integrate the system to the Internet without losing hardware efficiency and system capability; and (4) To integrate a reservation system in order that remote students can conveniently reserve a Web-based laboratory environment for laboratory assignments.

SYSTEM DEVELOPMENT

During this phase, teachers prepare supplementary materials according to the outline teaching plan prepared in the design stage and the actual teaching needs. The key task in this stage is, therefore, to produce the materials necessary and teaching activity implementation in a Web-based support environment.

SYSTEM ARCHITECTURE FOR IMPLEMENTATION

The laboratory system architecture for implementation is built on three tiers as shown in Figure 1. The client user is on Tier-1, the system controller and Web server, via the Internet, is located on Tier-2, and communications with mechatronics modules are located on Tier-3.

Tier-1: Client user is equipped with Web browsers containing the developed PLC programs, which are executed on the mechatronics module. Restated, they can apply their control software to an actual mechatronics module, and then, follow system operations via IP-CAM installed in the laboratory and simultaneously view the actual system on their monitors.

Tier-2: The Web server for the system is based on IIS (Internet Information Service) technology, and is developed by Advantech Studio software. It provides a Web interface for user to logon and access a remote laboratory. The students are connected to the Web server through the Internet, and the Web server and remote client user must have robust characteristics for easy and reliable use.

Tier-3: The Web-based laboratory can be established through the design of the experimental content, such as user interface for remote laboratory and instructions. The student follows the instructions to conduct a remote experiment. The experiments can be performed by connecting to a Web page of a Web-based laboratory platform. The students use software to prepare their own control programs for their mechatronics module. The RS-232 to RS-422 converts the COM Port of a programmable logic controller (PLC) into a communications interface, which provides the PLC with network functions. The mechatronics module responds to commands from the server by means of PLC controller.

Live video is provided through network cameras in order that the client user can monitor the execution of a mechatronics module. A network camera is a Web-based real-time video-streaming camera, with built-in video server capability. A network camera has its own IP address. At the remote client user end, Advantech Studio software sets up the sockets for TCP communication with the Web server. When the student clicks a button intended for camera control, it generates the corresponding command string and writes it to the TCP connection. Combined with the IP-CAM video camera, the processes of the entire experiment are clearly visible on the screen.

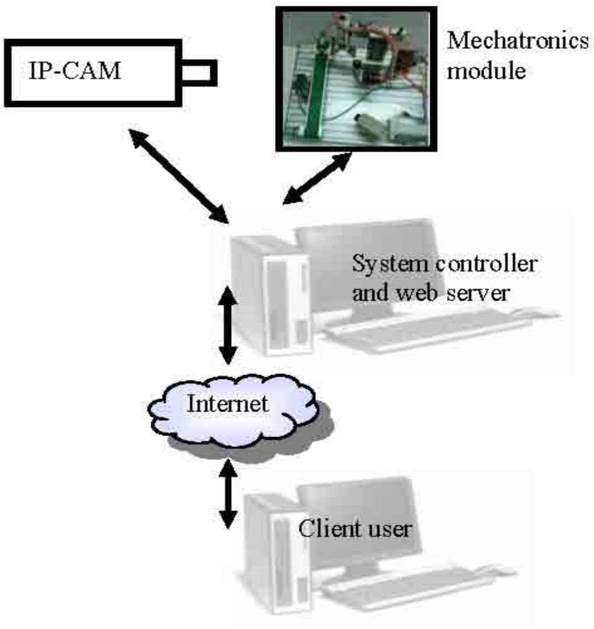

Figure 1: The laboratory system architecture.

Figure 2 presents a robotic capturer mechatronics instrument for use in a remote laboratory experiment. The experiment was performed as follows. The transmission belt moves any material on it. When the material has moved to the end of the transmission belt, the proximity sensor receives a signal. When the proximity sensor signal is on, the robotic capturer catches the material and moves it to the right. When the robotic capturer has shifted to the farthest right end, the limit switch sensor receives a signal. When the limit switch sensor signal is on, the robotic capturer releases the material and returns to its original position to stand by for additional processing. An IP-CAM can also be used for live broadcast of the actual experiment. Students can perform the experiment whether they are on the campus itself or on the other side of the world (see Figure 3). The ladder diagram for PLC is shown in Figure 4.

The mechatronics experimental module is simple to develop and other mechatronics systems can be integrated with this module. This module can even be reconfigured for different laboratory work. This study concentrates on the robotic capture experiment as a case study to illustrate the processes involved in the development and evaluation of the remote experimental procedure.

The following steps are performed to operate the robotic capture mechatronics remotely:

1. Connect to the home page of the Internet-based remote laboratory.
2. Obtain user authorisation on the Web server side, and obtain a valid session ID for the remote laboratory.
3. View the corresponding Web pages.
4. Run the remote experiment and view real-time images of the experiment in the browser.
5. End the session by closing the server connection and the session ID.

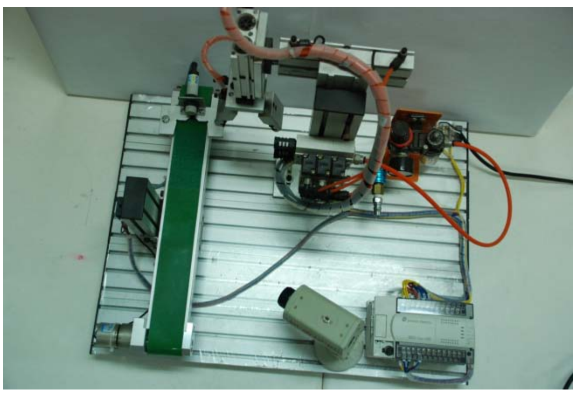

Figure 2: Mechatronics module for use in the laboratory.

Figure 3: IP-CAM remote monitoring panel.

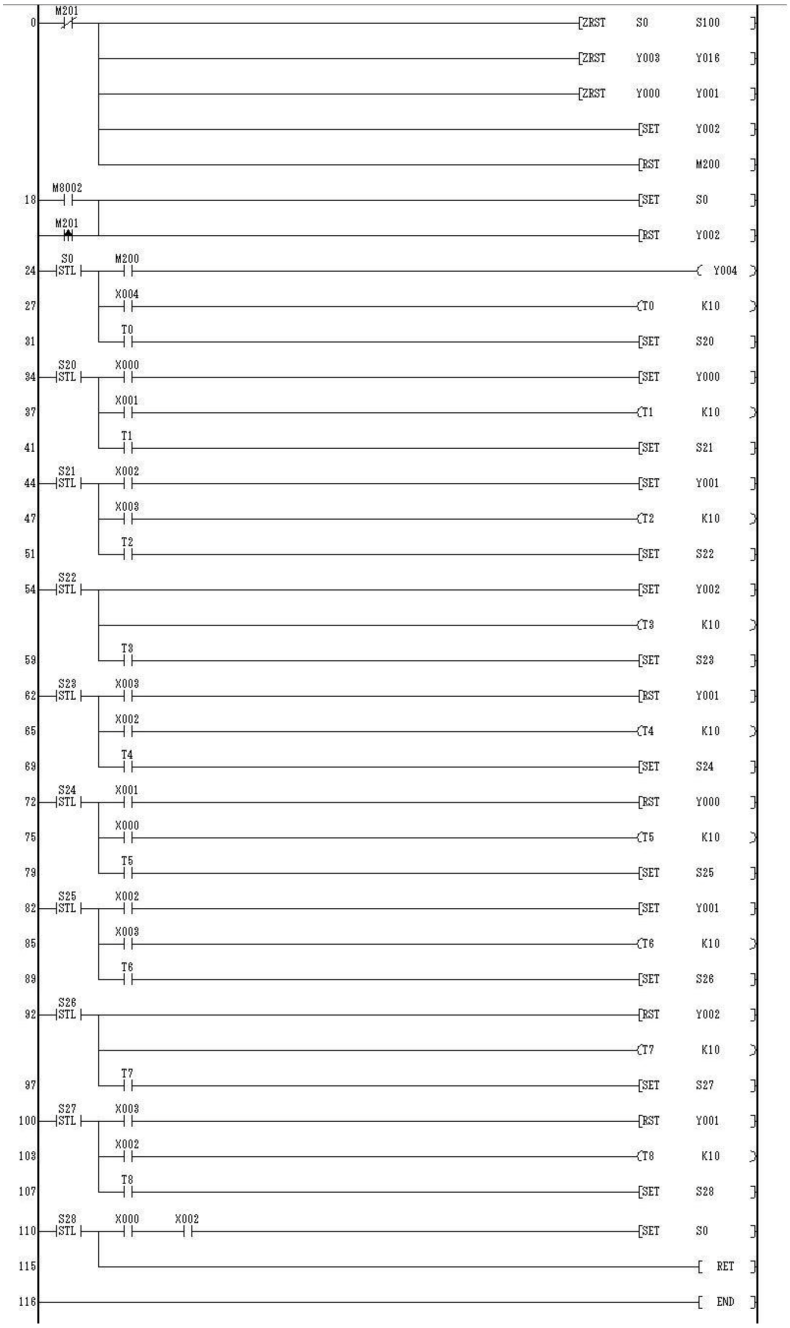

Figure 4: The ladder diagram for PLC.

METHOD

The pre-test and post-test exams are comprised of questions on basic mechatronics topics. The pre-test is composed of ten questions, designed to discover how much experience the teachers and students have in operating equipment. The pre-test was given to both groups at the start of the education period, and a post-test was given to both groups after the experiment, which lasted for 3 hours a week, over 4 weeks. Students were also asked to examine five specific aspects of the laboratory exercises as to their value in promoting the understanding of course concepts: (1) System configuration; (2) PLC programming; (3) Test and implementation of mechatronics module; (4) Discussion of the results; (5) Laboratory report.

SAMPLING

This investigation uses a quasi-experimental, non-equivalent control group design that can be adopted when randomisation is not possible. The non-equivalent control group design can be exploited as a non-equivalent comparison group design that involves two treatments. Since the subjects were not randomly assigned, entire classes of students were randomly assigned to either the experimental group or the control group. Both groups took a pre-test and a post-test. Thirty-six students of the intact class at the Department of Industrial Education and Technology at National Changhua University of Education in Taiwan participated. Each group comprised eighteen students. The experimental group was taught through Web-based laboratories, and the control group through conventional education. All students had the same initial level, as none had ever attended a mechatronics course.

SYSTEM EVALUATION AND DISCUSSION

This work uses SPSS data analysing software to analyse the research data. A significance level was set at 0.05 for the statistical analysis. A pre-test was executed to equalise the experimental and control groups. According to these test results, no significant differences were found between the experimental and control groups (t=1.802, p>0.05), showing that the experimental and control groups were identical.

To identify a significant difference between the post-test score averages of the experimental and control groups, this study performed t-test at a 0.05 significance level. The post-test scored averages of the experiments are significantly different from those of the control group. The experimental group obtained a higher average than the control group (t=3.704, p<0.05), indicating that the proposed platform raises the academic success of students.

Table 1 shows the paired-sample t-test results for comparing pre-test and post-test results. These test results showed significant differences between the experimental and control groups.

The following findings came out of this study: (1) All the students possessed the same initial level; (2) The post-test results demonstrated that the experiment was valuable to both groups; (3) The students in the experimental group were more successful than the control group students.

Experimental results demonstrate that the proposed Web-based laboratory, as applied to the experimental group, was an effective method in that field of study. Further analyses of the results demonstrate that the laboratory significantly enhanced the quality of the course, and course methodology proved satisfactory as well.

Table 1: The paired samples t-test results of the experiment and control groups according to pre-test and their post-test scores.

	Control Group			Experimental Group		
	M	SD	t	M	SD	t
Pre-test	63.61	5.893	5.196*	66.94	5.185	7.459*
Post-test	72.22	8.782		83.06	8.678	

* $p < 0.01$

CONCLUSIONS

In this article, a Web-based platform for distance teaching of a mechatronics module is presented. The architecture allows remote users to access a mechatronics module over the Internet. The proposed system architecture was implemented as a Web-based mechatronics laboratory. Introduction and implementation of the Web laboratories in educational practices was carried in the Department of Industrial Education and Technology at the National Changhua University of Education in Changhua, Taiwan.

Based on the experience acquired through the analysis, design, development, implementation, and evaluation of the proposed Web-based mechatronics laboratory architecture, the following conclusions have been reached:

1. If effectively scheduled, students can share the same equipment over the Internet, regardless of their geographical location;
2. Universities can share facilities, instead of individual investments in laboratory equipment, which improves the quality of learning;
3. Remote experimentation using a Web-based mechatronics module is not limited to education. In the manufacturing and automation industries, remote access to distant facilities provides unique opportunities by providing a means of remote monitoring and control systems located at different geographical locations.

The author hopes that the facilities and friendly user interface of the system will be able to reduce teachers' workloads and increase the quality of teaching plans and materials designed on the Internet.

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