Remote Experiments for Control Education

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Abstract: This paper suggests remote experiments using the internet for the control education. The remote experiment is composed of equipment server computers, networks accessible to internet, and real plants such as inverted pendulums, crane systems and microcontrollers. Additionally, it requires a server program that has I/O functions with plants and calculate the control, an interface program bridging between web and the server program, and the home page including the detail explanation for the usage. For effective educations, how to perform experiments and how to combine the experiment with lectures will be discussed. The simple experiments by entering a few control parameters and the complex experiments by designing overall controls, will be explained. Technologies related with the remote experiment and other possible remote experiment will be introduced. It is demonstrated that the remote experiment will be very useful, particular for control education where students have difficulties in performing the experiments for lack of experimental equipments.

Keywords: Remote experiments; Control education.

1. Introduction

In most classes, the design and the analysis of control systems are focussing on algebraic or numerical computations since the lecture are based mainly on deriving theories in textbooks and working on exercise problems. Via simulation with a computer aided control system design (CACSD), plotting of calculation results and repeated trials to satisfy given performance specifications can be done as assignments by students. Through plotting using graphic function of CACSD, students are able to find out some trends of results according to variations of specific parameters. By simulation of control systems designed in conformity with theory in textbooks, students can obtain partially some insights and feeling about real problems at their convenience without spending time and cost. However, it is true that real experiments are essential to make students get the clear concepts and feeling for theories. But, real experiments are ignored since it costs a lot to have enough experiment devices to accommodate many students in universities who take courses and it is difficult to set aside the space for large experiment devices. Actually, for the control area, the experiment is very important since the contents concerning to control theory is based on difficult mathematics and most books do not deal with real problems. Textbooks include only beautiful theories derived clearly in view of mathematics. Usually, theories hold under some strong assumptions that might be different from the real world. However, practically, many theories do not work under the real situation. Some tuning and modification of the theory is necessary. These days, it is easy to access the internet, specially, in university and lectures making use of the internet are increasing rapidly. Before lectures, the instructor can uploads all the material and handouts for students, who can download them. Using the web board, the instructor can see questions and comments that are raised by students. Thus, the lecture can be done inside and outside classrooms through the internet. As far as the teaching and research in universities are concerned, there are many applications using the internet such as on-line or off-line remote teaching, virtual experiments using graphics, and simple operation of remote devices. Actually, these applications can be found in medical area. Remote medical service is very helpful in the country, where proper medical equipments are not furnished [9][10]. Using the internet, experiment devices can be shared between universities or research institutes [5][6]. To give all students more chance to do experiments when a laboratory is equipped with small number of experiment devices, it is suggested that the experiment can be done remotely through the internet at any time. Specially, experiment devices related with control engineering are large and some expensive. So it is difficult to buy many devices for teaching of many students. In order to accommodate the large number of students, the remote experiments can be a good substitute for the real experiment in the control education area. The remote experiment can be carried out anywhere at any time for students. Remote experiments through the internet, is used in some areas, i.e, [3] for communication education, [7] for semiconductor education, and [4] for robotics. Some results related with control education exist for specific systems [8]. In [8], there is no guide to the systematic teaching methods using the remote experiments and to the student management systems such as grading of the experiment result and checking of attendance. This work provides methods on how the remote experiments can be carried out for the efficient control education and combined with some class managements. For the effective education, the experiment will start from easy operation such as movements of robot arms and then proceed to more complex ones. In case of simple experiments, only a few parameters such as P, I, and D coefficients of PID control and weighting matrices Q and R of LQ controls will be used for the experiment. In case of complex experiments, all design procedure can be left to students so that they have to determine what kind of control will be used for the specifications that should be met. In this paper, how to operate the remote experiment well and how to manage students efficiently are investigated. All information related

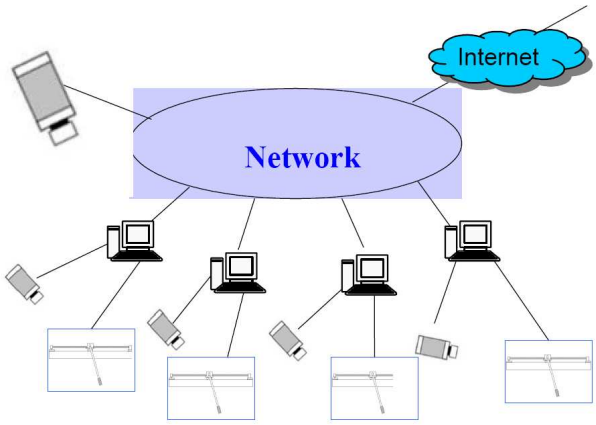

Fig. 1. Overall systems

with students experiments is stored in database server and is used for instructor to give grades to students and find ideas for better lecture in next time. This paper is organized as follows. In Section 2, basic components for remote experiments are explained. In Sections 3 , 4 and 5, how to use remote experiments for the control education and how to combine the experiments with the lecture are discussed, respectively. In Section 6, some technologies related with remote experiments are introduced. By constructing an environment of the remote experiment, an example for the remote experiment is shown in Section 7. Finally, our conclusions follow in Section 8.

2. Basic Components for Remote Experiment

In this section, basic components required for the remote experiment will be discussed. The remote experiment is composed of equipment server computers, networks accessible to internet, and real plants such as inverted pendulums, crane systems and microprocessors. First, equipment plants and equipment server are necessary. The S/W in side of the equipment server computer should have I/O functions. Some H/W in the equipment server plays a role of conversion of analog to digital signal or digital to analog signal and makes the proper input signals to the actuator of devices. Second, a web camera is necessary to make a moving picture for the experiments and transfer one to clients. The moving picture have to be transferred in time to the clients even though the client is some far from the server. It is desirable that even the subtle movement can be checked and displayed in side of the client. To guarantee the real time of the data transferring and make students see the real experiment more lively, web cameras with some technologies as data compression is preferable. Third, to give students a chance of complete control design, computer aided control system design (CACSD) packages including graphic editor based on blocks are required for easy control design. These packages help students to design the control quickly and checking whether their controls work well or not. In addition, the editor must provides the file transfer protocol (FTP) service and thus help the client with transferring the file related with controls to equipment server computer. Fourth, an interface program is required to link the web to CACSD in side of equipment server computers, which is called a program interfacing web and CACSD (PIWC). The request from the web should be transferred to the PIWC in the server, which sends the message to CACSD in the server, which drives the experiment devices and returns the result. Conversely, PIWC receives results from the CACSD in the server and sends them to clients. Fifth, there should be networks in a remote laboratory. This network should be linked to the internet. The equipment server linked to the network should provide the function of the web service. Sixth, data base server is necessary for operating the remote experiment and managing students. Whether plants are now available and work well is always checked. In addition, which student comes in and goes out the site for the remote experiment and how well they perform the experiments are reported and stored. Besides, security procedure is required for identifying the client and processing the grade of students. Web Network Internet Internet includes the detailed explanation on how to experiment. Additionally, every client can check how many people are ahead of them. After the experiment, they are able to get the result for experiment. In Figure(6), the simple overview for the remote experiments is shown. The clients that mostly correspond to students, are linked with the server and the web camera through internet. The experiment device works with the server computer, which receive the request form clients

3. Level of Control Design

For control education, remote experiments can be applied in various ways for students to get the feeling of controls quickly and catch the physical and mathematical meaning of the theory in the textbook. There may be four different kinds of methods for learning the effect of control algorithms. First, generation of command signal can make students conduct their experiments. For example, a robot arm can be moved to right or left according to the request from students. This class of the remote experiment is called the command and guidance mode. This type of experiments is very simple. However it is meaningful that students watch the robot arm moving according to the command signal. This is different from just seeing the robot arms in the textbook. Second, the structured control such as PID and LQ controls are given to the students, who have only to enter a couple of parameter values in the blank box. In this way, students can get the feel about controls before they go into detailed study. For example, the proportional, integral, and differential gains of PID controls can be understood well by students. Students can observe the effect of control gains as they perform the experiment. Additionally, they can check some consistency or inconsistency between real experiments and theories in textbooks. In similar way, a role of a state weighting matrix Q and a input weighting matrix R in linear quadratic control (LQC) can be selected by students. As a student increases the value of R, he observes that overshoot or fluctuation

is getting larger or smaller. It is important that physical meanings or concepts should be firstly carried to students before the detailed mathematical derivations are explained to them. Third, students should have a chance to design overall control algorithm after getting some feeling through previous simple experiments. Students can exercise some creativeness to design some better controls in addition to the well known controls such as PID, LQ, and H1 control. Computer aided control system design (CACSD) packages including graphic editor based on blocks are used to give students a chance of complete control required for easy control design. Designed control algorithms using the CADSD package is send to experiment server by file transfer protocol (FTP) service. They can experiment their own algorithm and get the result of their algorithm. The third experiment is very meaningful in that students can have a chance to find out their potentiality together with learning the knowledge included in textbooks. Fourth, students can make the simulation before real experiments, if necessary. This method give students a chance to invalidate their designed control and, if necessary, modify their control. This can save time since it doesnt take long to perform the simulation.

4. The flow of remote experiment

In real experiment education, students are demanded that make preliminary report and final report. Through prepare preliminary reports, students can know about the theories, the flow chart and other things which is related with experiment. So, remote experiment also have these element of experiment education. The flow of remote experiment is as following. First, student make a preliminary report which is provided through the internet. The form of preliminary report can be fill up by writing keyboard. By this process, students can understand the lecture materials and experiment. Second, students simulate the simulation which is provided through the internet. Simulation also operate in experiment server and the result is transmitted to students through the internet. Simulation can be repeat when students is satisfied with their simulation result. In this process, students can get their feeling and knowledge about the experiment. Third, students make a real experiment by their algorithms which get through previous processes. With moving pictures obtained from the remote experiment, how to perform the experiment and how to get the result can be clearly explained to students. Fourth, Students should change their opinion and result to consider their experiment through the internet. They can exchange their opinions in bulletin board which is provided in education system. Finally, students make a final experiment after remote experiment after these process. In final report, students should answer about some questions and write comparison by comparing simulation result and remote experiment result. They can get the feeling and knowledge of theories and experiment.

5. Overall Experimental Education System

How to combine the remote experiment with classroom education is investigated in this section. Figure (2) shows the

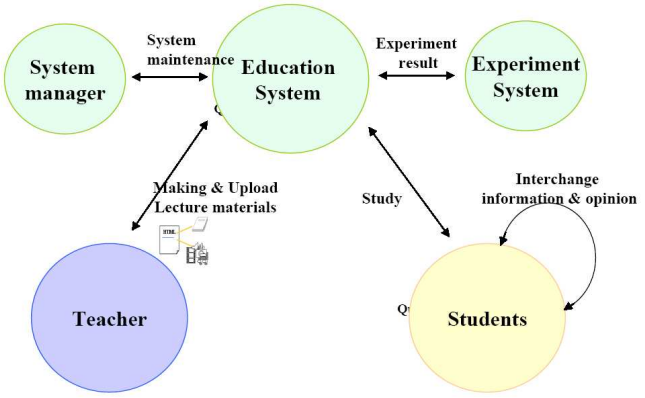

Fig. 2. Overall experimental systems

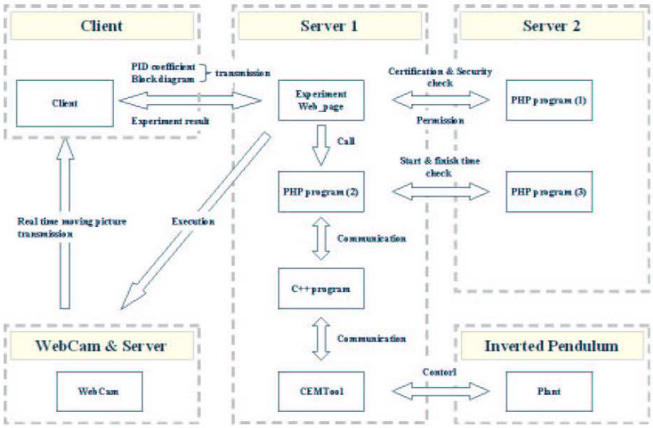

Fig. 3. Mechanism for implementing the remote experiment

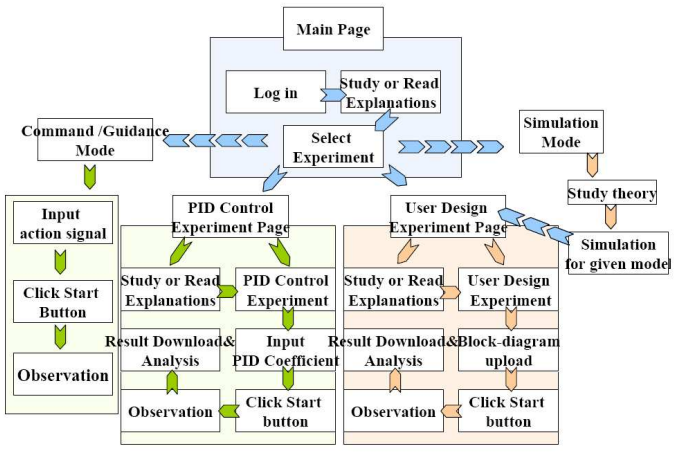

Fig. 4. Access Flow Chart on Web

overall experimental systems. Figure (3) and (4) show how to implement the remote experiment in detail. For the efficient remote experiment, cooperation between a instructor and students is required. Before class, the instructor uploads the lecture material to the web. This material contains some background and the information on the experiment. With moving pictures obtained from the remote experiment, how to perform the experiment and how to get the result can be clearly explained to students. They will learn basic backgrounds and mathematical results. Then, the instructor can ask students to begin experiments. Through these experiments, students can obtain some concepts and feelings of what they have learned in class. They can easily understand the lecture even though the contents are stuffed with the complex and difficult mathematics. After experiment, instructor and students want to know their experiment record. Management system which is called AMS(Academic Management System) shows previous experiment record. They can get the information of experiment which is done such as devices, control coefficients, date and result of experiment. Through web, questions raised by students can be answered by other students, not only by instructors. And they students can exchange their opinion about experiment. The database in side of the server has every kind of information on when a student come into the site and how he or she performs the experiment. Based on these information, instructor evaluates students activities and can provide the academic scores for the students.

6. Necessary Technologies

To implement the remote experiment, some peripheral technologies are required. Security is very important since the attendance of the students are checked or professors give students the grade. For every students, how many times they perform the experiments, what kind of experiment they carry out, and how good their results are, are all recorded in database. According to these data, how well students understand, are also checked to instructors. All reports of students are registered and delivered to the instructor with safety. To show the real experiment to students more lively, a real time technology for data transmission is required. To transfer the moving pictures to the client in time, data compression such as MPEG 4 is surely necessary. Thus web cameras have to be able to encode the moving picture and send the data shrunk in small size. Internet-related technology such as common gate interface (CGI) is required to makes the server communicate with the client in both way. CGI can be implemented by various languages as C, perl, and PHP. In case of the remote experiments, CGI should transfer the request from the clients to the server and various messages that happen in side of the server to the clients, respectively. H/W is necessary for AD/DA to drive the experiment devices. Using the real time operating systems, real-time clocks can guarantee the sampling intervals within specific errors. If the conversion between analog and digital signal is done within sampling time and operating systems gurantee the real time, the control action is exerted to plants with very small delay so that systems work well under control.

7. Demonstration

In this section, the web site constructed to implement the remote experiment is introduced. At the first time, the main page with the blank for ID and password is shown. Entering our ID and password, we are qualified to perform the experiment. Putting the button, we can go directly to the page for the experiment. In this page, two experiments are carried out for crane systems. One is the PID control and the other is the LQ control. Only entering simple parameters can implement the PID and the LQ control for crane systems as seen in Figure (5). Through these experiments, students can learn about roles for each coefficient for PID control and weighting matrix such as Q and R, After filling in blanks and pushing the execute button, the experiment starts and we can see the experiment lively in the web browser. The figure (6) shows the page during the experiment.

Fig. 5. Page with three boxes for coefficients of PID controls

After experiment are finished, we can check the result for experiment and can make the plot by downloading the data from the server. The S/W called CEMTool provides the plot function. Figure (8) shows the page where you can design the control and then submit the designed control to the server. The editor, called SIMTool, provides the various blocks. Using these blocks, the control can easily be designed.

8. Conclusion

In this paper, remote experiments using the web for the control education are suggested. Using the remote experiment, it is possible to accommodate many students with small number of experiment devices. Thus, it does not cost so much to have the environment of remote experiments for the control education. Basically, server computers, network accessible to internet, and real plants constitute a environment for a remote experiment. Additionally, an S/W that has I/O functions with plants, an interface program bridg-

Fig. 6. Page during the experiment

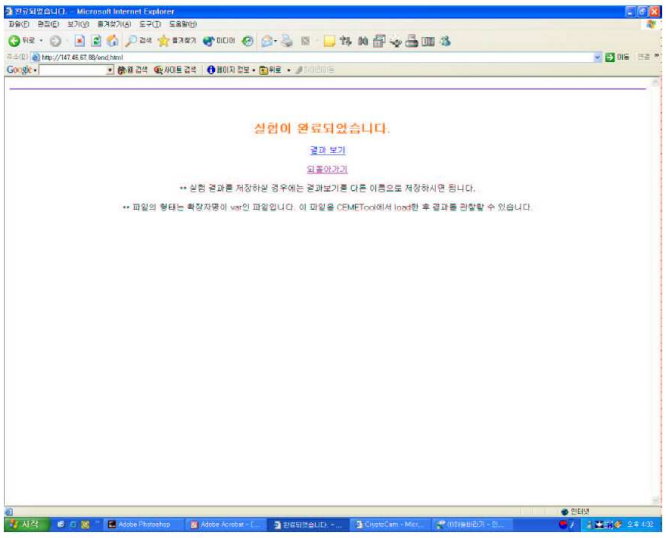

Fig. 7. Page when the experiment is finished

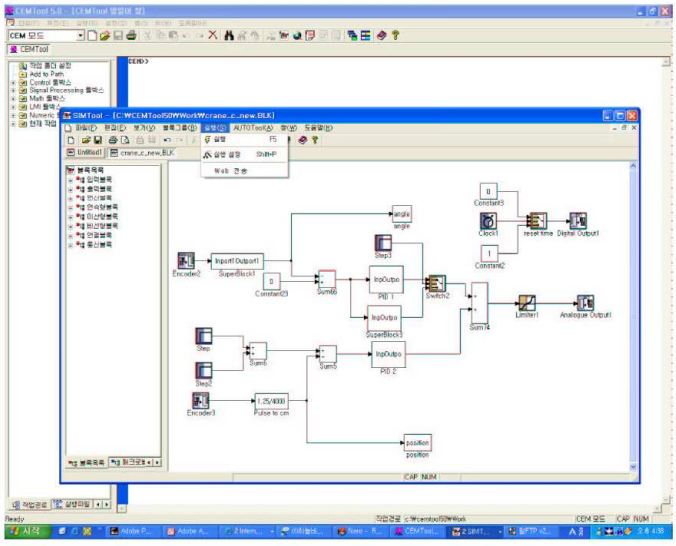

Fig. 8. Graphic editor : SIMTool

ing between web and executable files in side of server, and the home page including the detail explanation for the usage are required. The role and the function of each component is explained one by one. In this paper, four methods for remote experiments is given to make step by step learning possible. It is shown that from simple handling of robot arm to the complex design of the control is covered in the remote experiments. Technologies related with the remote experiment is introduced for securities, real time data transferring, internet, and H/W. Also, we are working to extend the remote experiment devices such as microcontroller, water tank systems and 3D crane systems. By constructing the environment of the remote experiment, it is demonstrated that the remote experiment have good effects on control educations. To accommodate many students with a small number of experiments and to teach them real phenomena together with theories in textbooks , the remote experiment proposed in this paper will be very useful in universities afterwards.

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