E-LEARNING GAME USING VIRTUAL AND REMOTE LABORATORY ENVIRONMENT

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Abstract.   In the paper an approach to a study of multivariable system control is presented. It has been realized through an e-learning environment, which has been developed at the Faculty of Electrical Engineering, Ljubljana, Slovenia. The introduced e-learning ideas were implemented as a competition game in a frame of laboratory exercises at lectures Multivariable systems. The presented approach bases on E-CHO and Matlab software, which are used for communication with the users, as well as for running both virtual and remote real-time experiments using laboratory pilot plant. Experimental environment enables testing and evaluation of modelling and control design results. The e-learning idea was very well accepted by the students, since it introduces a novel, alternative approach to the study, which enables also more freedom in work organization. In addition direct extensions are possible in the sense of virtual and remote experiments.

1 Introduction

In this paper we present an approach to an e-learning system, used for studying multivariable control using a laboratory pilot plant. In the past few years, the Faculty of electrical engineering in Ljubljana, Slovenia, invested intensive efforts into the introduction of the Bologna study, which is a common study structure in most of the European faculties. The introduction of the new study also involves a renovation of the existent lecture programs. Since the new study allows more freedom for students to select their lectures, a large portion of the program renewal is focused on the attractiveness and new technologies presented in the scope of the individual lectures. Therefore, in the past semester (2007-2008), at the Department of Automatic Control, in the frame of Multivariable systems lectures, we decided to introduce an alternative approach to laboratory exercises - an e-learning system, including a real laboratory pilot plant.

The laboratory practices in previous years required the students to be present at each practice, where students in groups of two solved different exercises, regarding various algorithms for multivariable control. The new laboratory practices, using e-learning system, required the students to solve similar exercises as in previous years, but their presence at the laboratory practices was no longer required. The solving of the problem could be performed at any time and on any computer, running Matlab software [1], with access to the internet, since the implementation of the system included everything necessary for the experiment (pilot plant, visualization, data acquisition, signal measurements etc.); therefore, no additional programs (except the internet browser and Matlab software) were needed. The Matlab software in this case was only used to find a solution to the given problem and not for the actual communication between the user and e-learning system.

The whole e-learning system was built in a manner that allowed students to examine open-loop and closed-loop characteristics of the model and the pilot plant, using appropriate control structures. Also, the complexity of the controller could be defined by users themselves and could range from the simplest P controllers to a complex combination of observers, feed-forward, output and state controllers.

To make the exercises more interesting and to stimulate the students to achieve better results, the performance of the solution of each group was recorded and later compared to the performance of other groups to obtain a winning, second and third group, which was also the basis for the experiment evaluation.

Since the e-learning approach presented, introduces a subject specific e-learning implementation, extensive inter-disciplinary cooperation was required during application development, as no existing commercial or open source e-learning software could be used without adaptations and further development. Thus, the technical basis of the idea was realized using the so called E-CHO software, which is already extensively used for a variety of e-learning solutions in different target academic and business environments (more than 10000 users in corporate and academic institutions), but has yet never been used in a configuration with a virtual or real pilot plant. The E-CHO environment was developed exclusively at the Faculty of Electrical Engineering, in the Laboratory for Telecommunications (LTFE), while the whole e-learning environment was built in cooperation of the LTFE and the Laboratory for modelling, simulation and control (LMSV & LAIP) [2, 3].

The paper is structured as follows. In the Section 2, both hardware and software realizations of the project are discussed. Section 3 explains an e-competition project through which the transition to distance learning approach is enabled. In the Section 4 some future plans are presented. The paper ends with concluding remarks.

2 Project realization

As mentioned before, because of the specific problem, no commercial or open source e-learning software could be used. Instead, E-CHO software with a completely new interface for the communication between the main server and the computer, running a pilot plant, was developed.

2.1 Hardware

The pilot plant used for the implementation is a Coupled Drive Apparatus TQ-CE108 [4], which is a MIMO system (multiple inputs, multiple outputs). The inputs are voltage signals with which it is possible to influence the rotation velocity of both motors. The outputs are measured voltage signals, proportional to rotation velocity of the working station and elastic band tension. The schematic representation of the plant is shown in Figure 1.
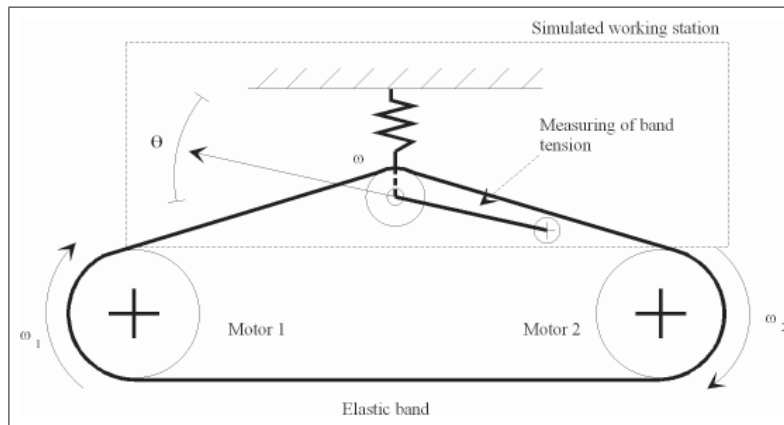

Figure 1: Schematic representation of the pilot plant

The selection of the pilot plant is crucial, since it needs to be complex enough for the development of the control algorithms, but also fast enough to suit the requirements of the proposed system.

The pilot plant was connected to the computer through the National Instruments PCI AD/DA (analog-digital, digital-analog) card, used for sending control signals and recording the necessary measurements. The computer was connected to the main server, running E-CHO software, through the WWW. The schematic representation of the hardware part is shown in Figure 2.
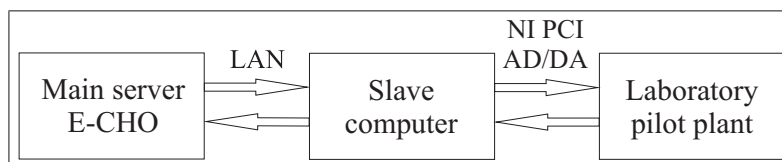
Figure 2: Schematic representation of the hardware realization

The visualization part of the project was implemented using an USB web camera, connected to a laptop computer. The reason for using a separate computer for video capture is because of the CPU usage needed to encode and stream a video source. Since the computer, controlling the pilot plant has already been near its maximum potential, the extra CPU load for the visualization would jeopardize the accuracy of the obtained measurements and the speed of the video stream. The laptop computer was connected to the server through LAN. The schematic representation of the visualization system is shown in Figure 3.

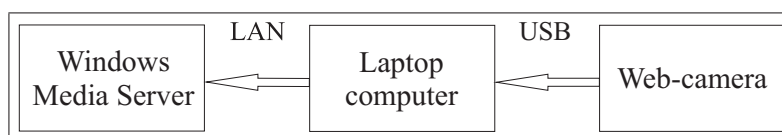**Figure 3:** Schematic representation of the visualization hardware realization

2.2   Software

As mentioned in the Introduction section, the basis for the whole e-learning project was the E-CHO software, running on the main server using Apache Server 2.0, PHP and a MySQL database. E-CHO e-learning platform (Figure 4) is the result of experiences with e-learning implementation, extensive analysis and usage of related products in Laboratory for Telecommunications at the Faculty of Electrical Engineering [5, 6].
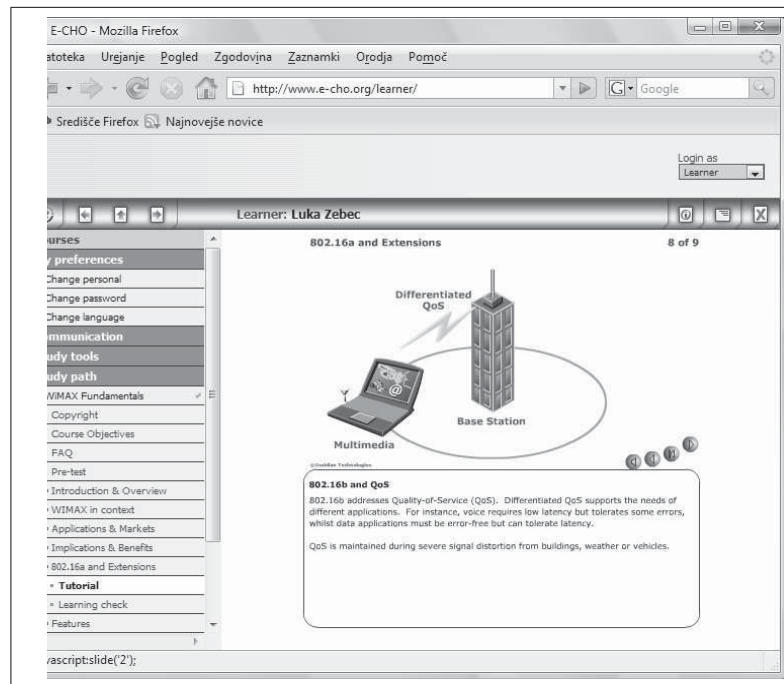

Figure 4: E-CHO system teacher's interface

The E-CHO system comprehends e-learning functionalities and can also be integrated to the other web-based applications. The system platform provides:

- e-learning management (LMS - Learning Management System),
- e-learning content managing (LCMS - Learning Content Management System),
- tracking of teacher's activity and student's progress,
- knowledge assessment and testing,
- e-learning standard support (SCORM and QTI) and multilingualism.

System functionality enables different user roles. The roles define the level of rights to system access. Users can access their personalized functionalities through a specific interface, similar to the one presented in Figure 4.

When developing the e-learning idea, core functionalities of the E-CHO were of significant importance. Besides the mentioned properties, the E-CHO system enables importing and downloading of different sorts of electronic material, communication between students and the mentor, forum and questionnaire. Therefore, the process of content development was simplified.

The software on the computer, which was used for the actual execution of experiments on the pilot plant, was Matlab 7.0 with Simulink. Since, the requests from the E-CHO received through WWW could not be executed all at the same time, a PHP script was used for handling the requests and sorting the waiting queue. The queue was implemented using a MySQL database, which also contained the data about the user's id, the files uploaded, number of trials etc. The queue was served by a PHP script, executing each minute, using a PyCron task scheduler. The same script also checked the user's uploaded data for consistency. If the structure of the data file was error-free, the request was passed to Matlab for the actual execution of the experiment. On the other hand, if the errors were present, the data file had to be corrected and re-uploaded.

The PHP script executed a Matlab m-file, which contained all the necessary code for successful trial on the pilot plant (input/output data handling, creating result files, controller structure etc.); all that user's needed to do, was to upload a file containing the controller parameters. When the experiment ended, the m-file script generated data files containing the results of the experiment. If any problems arose during the experiment, an error file was generated. The PHP script then returned the result or the error files to the main server, which displayed them in the E-CHO environment to the user over the internet browser, at the next scheduled run.

When the user was performing an experiment on the pilot plant, a real time video stream of the plant performance was available. The video was captured on a laptop computer through the web-camera. The software used for the video capture and streaming was Windows Media Encoder. The stream was sent to the server, running Windows Media Server software, which handled the stream and redirected it to the main server running E-CHO. During the experiment the video was displayed in the internet browser on user's computer.

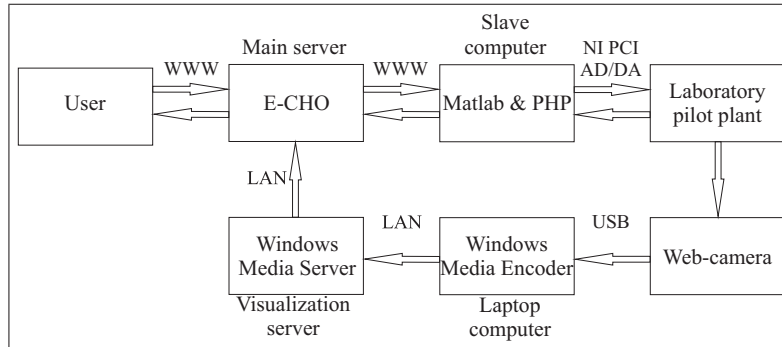The schematic representation of the software and hardware realization is presented in Figure 5.

Figure 5: Schematic representation of the software realization

3   E-competition

All the students who attended lectures were given a choice to select in which way they want to pass the laboratory practice, i.e. by participating in the newly introduced e-learning competition or in a classical way. All the students decided to try the new e-learning project.

To make the practice through an e-learning more interesting and to stimulate the students to put more effort into the development of the controllers, the experiment was designed as an e-competition. The e-competition consisted of three phases which needed to be realized one after another if the user wanted to accomplish the practice goal.

The main target of the work was to design an efficient controller for tracking the reference signal, taking into account the limitations of the control signals. Beside that, an extent of knowledge in multivariable control of the users participating was also one of the main interests. Therefore, beside the actual implementation of the controller, students also had to study some literature in order to successfully pass the experiment.

The e-competition phases were designed as follows. At the first phase the users needed to answer correctly to 3 randomly chosen groups of 5 questions (15 questions all together) regarding multivariable systems theory. Each question offered several possible answers where at least one is correct, but in general it was also possible that all the answers were correct. When the user was sure that all right answers are marked he or she could continue with the next question. Two false answers returned the user to the beginning of this level, which could be restarted after one hour break designated for additional study. As the questions were randomly chosen at each trial the set of questions could be different. If at least 14 out of 15 questions were correctly answered, the solving could be proceeded to the next level.

The second phase involved planning and development of the controller, which could be tested using a Simulink model. This step was thus only a virtual experiment. In this step the users were able to measure the open and closed-loop responses of the system, which were needed for successful tuning of the controllers. Setting the state-space control parameters to appropriate values it was also possible to measure different data about the system, such as: output values, state estimation, open- and closed-loop response etc. The control scheme used for running the experiments is shown in Figure 6. After the users uploaded their own data files containing the controller parameters, the environment performed the experiment, returning the measured results. If the closed-loop properties were acceptable (i.e. the closed-loop system was stable) the user got the access to the third step. If the system response was unstable, the controller parameters had to be re-tuned to meet at least the stability criteria.

Similar to the second, the third step also involved planning and development of the controller, but this time the system allowed testing of the designed controllers on the real pilot plant. This in our case means that the Simulink's simulation block, representing the model, was replaced with the block which ensured communication with A/D - D/A converters and therefore with the real pilot plant. The control scheme is similar to the one in Figure 6, where the state-space model is replaced with Simulink's AD/DA block. Here also the users were given an opportunity to measure open- and closed-loop characteristics of the pilot plant, which are of special importance, since the built-in model used in phase 2 was fairly different from the real pilot plant used in this phase. This means that control structures needed to be adjusted to achieve optimal control. When users achieved stable and acceptable control of
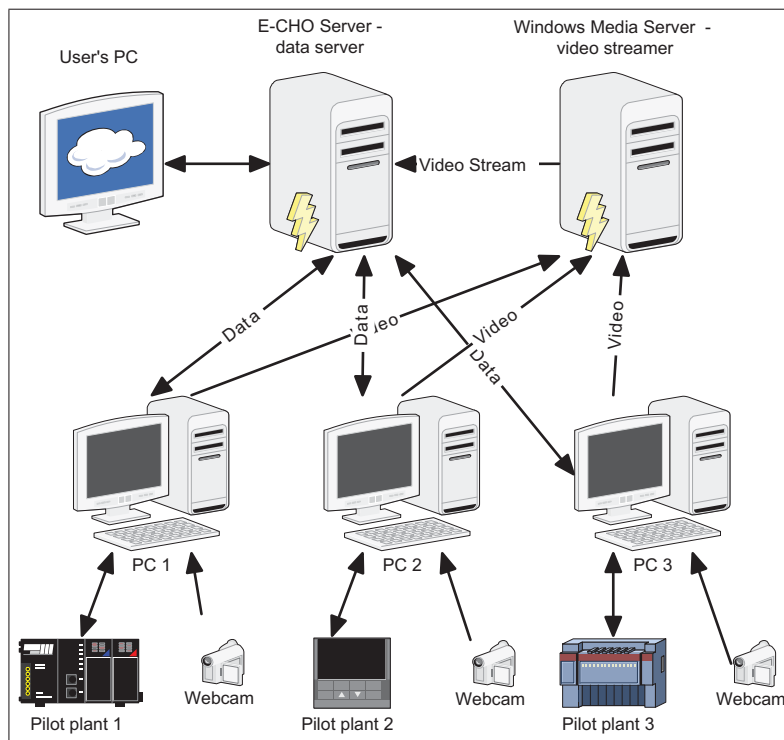
Figure 6: Control scheme used for running virtual and remote laboratory experiments

the plant the experiment was finished. However, the users had a possibility to upload as many sets of controller parameters as they wanted to achieve better response and more accurate reference tracking.

The best result of each student group was stored in the system and used for the final evaluation of the competition procedure.

Beside the three main steps described above, in the frame of E-CHO system, users had access to a variety of literature linked to the multivariable control, such as Maciejowski - Multivariable Feedback Design [7], Morari and Zafiriou - Robust Process Control [8], Patel and Munro - Multivariable Systems Theory and Design [9], Skogestad and Postlethwaite - Multivariable Feedback Control, Analysis and Design [10].

After the official part of the competition all groups were requested to answer the questionnaire from which the following can be concluded:

- new possibilities of laboratory exercises were interesting for all the students and very well accepted,
- students agree that such work organization stimulates cooperation between the partners of the team,
- stimulates on-line study,
- e-learning enables freedom in study organization,
- students prefer to preserve a part or even all auditory exercises and lectures in a classical way.

4   Future plans

Since the presented e-learning system has been successfully realized and well accepted among the students, further effort is invested into the development of similar systems with other laboratory pilot plants. The presented system is very adaptable and could, with some modification, easily be used as a basis for a virtual laboratory involving several computers and laboratory devices. The advantage of the presented system is in its modularity, since it works as a whole, but is consisted of a several independent units (main server, streaming server, executive computer, pilot plant), which can easily be exchanged with a similar one to suit the needs of another experiment. Mostly, this means that only a Matlab routine, on the executive computer needs to be replaced or modified to meet the requirements of another plant. Thus, everything else, regarding the E-CHO system, visualization and communication between the computers can stay intact.

A possible structure of the virtual laboratory with multiple computers and pilot plants is shown on Figure 7. Since more powerful computers are available nowadays, such setup would allow each computer to be used as a data and video acquisition/exchange tool. In that manner the number of computers for each plant will be halved, which significantly reduces the cost of such a project. The setup of the main servers, running E-CHO and Windows Media Server will remain the same as in the presented system. However, very likely more powerful servers will be needed to cope with multiple data and video transfers from several computers and devices.

Besides the introduction of new technologies in the study program, the implementation of the virtual laboratory would significantly reduce the load in the actual laboratory, since it would allow higher student traffic and 24/7 access to each pilot plant. Therefore, a more pleasant approach to the laboratory practice is possible, as students are no longer obliged to attend the exercises on a certain day in a week, but have a possibility to access the system 24 hours a day, 7 days a week and thus organize their study time themselves.

Figure 7: A possible structure of the virtual laboratory

5 Conclusions

In the paper some ideas are presented regarding the sequential transition from classical to e-education possibilities in the field of multivariable control. The idea is realized on the basis of the prepared projects.

At this point it should be mentioned that the whole e-learning approach was accepted very well among the students, since the feedback received from them was very positive. Also, the students agreed that such work stimulates the cooperation between the partners of the team and enables more freedom in study organization, compared to the conventional methods.

Therefore, considering the students' response, the introduction of the virtual laboratory would be appropriate and well accepted. Such a laboratory could also be applicable to practices at other lectures, auditory exercises and exams, but it can be expected that a certain amount of personal contact is still important as well for the students as for the teaching staff.

6 References

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