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STUDENT COMPETITION IN MULTIVARIABLE CONTROL DESIGN - EDUCATION THROUGH E-GAME

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Abstract: In the paper some ideas of studying multivariable control are presented where special attention is devoted to step – by step transition to e-learning. Introduced ideas are realized through design projects between which one is chosen as a competition game and is realized using E-CHO system, Matlab and a pilot plant. All preparation for the game can be realized using remote virtual and actual laboratory device while the competition itself is taking place in the laboratory to preserve personal contacts between the students and the staff.

Keywords: multivariable control, education, project work, e-learning, coupled – drive apparatus

1. INTRODUCTION

At the Faculty of Electrical Engineering in Ljubljana (Slovenia) intensive efforts are focused into introduction of the so called Bologna study (common studies structure in EU) where also the aspects of e-learning are becoming more and more significant. This kind of study is not important only for the students from distant locations and countries but can revive postgraduate and life-long study which have become an important strategy also in our country. For a working population it is often very difficult to begin with additional education even in the afternoon hours as working time is increasing.

There is another problem, specific for technical area. The interest for engineering studies is relative low in spite of the fact that employment in the field is not problematic. The consequence is that the number of excellent and very successful students who choose this area of education is far from expectations.

These were the reasons which have motivated us to introduce suitable forms of ICT (Information and Communication Technology) supported remote education also in the field of automatic control. As usually experiences, when introducing new technologies and methods are very precious, the idea was to realize new approaches step – by step. We have also taken into account that at the end of the study students are more self - dependent and have enough knowledge to be encouraged in project work as this kind of approach can represent also an introduction to diploma work.

The proposed idea, which is being introduced in the period 2007-2008, is connected with the subject regarding Multivariable systems on the Department of Automatic Control, Faculty of Electrical Engineering, University of Ljubljana. The idea was accomplished through cooperation with the experts from the Laboratory for Telecommunications (LTFE) at the same faculty as they are developing complete e-learning solutions and supported implementations in different target academic and business environments.

Mentioned e-learning competition or educational game represents subject specific e-learning implementation. Extensive interdisciplinary cooperation was required during application development, as no existing commercial or open source e-learning software can be used without adaptations and further development. Thus, technical implementation of the proposed idea is based on the E-CHO Learning Management and Content Management System that was developed at the LTFE and is being used by more than 10000 users in Slovenian corporate and academic institutions.

The paper is structured as follows. In the Section 2 the organization of education process is presented, while in the 3rd Section some possibilities which were used through E-CHO program are explained and illustrated. In the Section 4 competition project through which the transition to distance learning approach is enabled is explained in some more details. The paper ends with concluding remarks where also the possibilities and plans for further extensions are given.

2. ORGANIZATION OF EDUCATION PROCESS

As stated in (Atanasijević-Kunc and Karba, 2006b; Matko, *et al*., 2001) the standard approach to teaching on university studies is to give lessons, then to perform some kind of auditorial and/or laboratory exercises and to finish with the written and/or oral part of the exam. This style of education is used also in our faculty and was the reason why indicated improvements were realized inside such concept.

Lectures on Multivariable systems attend the students of the Faculty of Electrical Engineering, University of Ljubljana in the fifth year (ninth semester) of university study on the Department of Automatic Control by choosing modules Process Automation or Intelligent Systems. They include 4 hours of lectures, 2 hours of auditorial and 1 hour of laboratory exercises per week. In the last few years we had 15 to 30 students per year.

To use the hours as efficiently as possible we normally start with the lectures, which are later on (after approx. 1 month) complemented by auditorial exercises, while laboratory exercises, where main attention is devoted to the students' activity, are realized at the end of semester in cycles of 3 to 4 hours, which can be supplemented by home work (Fig. 1).

In the past few years we have introduced project work (Atanasijević-Kunc and Karba, 2006b) which was mainly realized during laboratory exercises. With these projects we tried

- to increase students' creativity and self - dependence,
- to develop capabilities of team - work,
- to stimulate components of motivation,
- to enable avoidance of classical forms of exams,
- to indicate further possibilities of research, which can result also in the participation to students' competitions and
- to prepare students for diploma work.

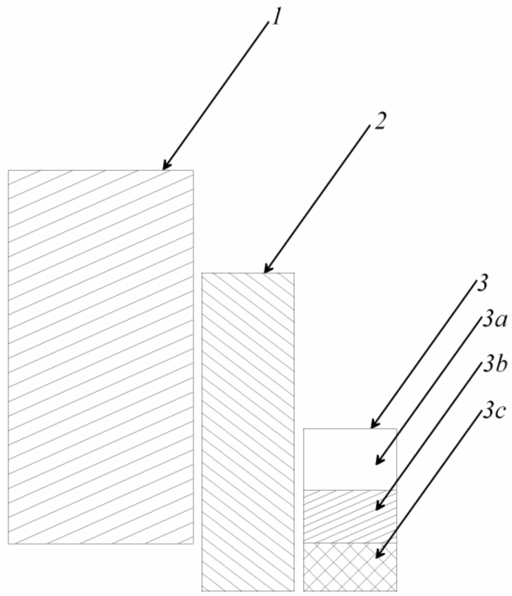

Fig. 1. Subject activities organization: 1 – lectures (4 hours per week), 2 – auditorial exercises (2 hours per week), 3 – laboratory exercises (1 hour per week); 3a – introduction ; 3b – project work ; 3c – competition ;

As this kind of work was very well accepted we have been encouraged to additional improvements where we are focused to:

- examination of e-education possibilities regarding multivariable control and
- realization of competition project, which should be organized (at least partly) as a PC-game,
- however, at the same time we want to preserve a certain amount of hours which are devoted to personal contacts and discussion between students and teaching staff.

Tasks and subtasks of each project are organized in four levels which are also correspondingly marked in the prepared materials (Atanasijević-Kunc, 2006a). The levels are:

- obligatory part which is meant to be treated mainly during laboratory exercises cycles,
- part enabling written part of the exam avoidance,
- part enabling oral part of the exam avoidance,
- and part enabling continuation of the work in the sense of some publication, competition for certain student's award or even theme for diploma degree acquirement.

By solving obligatory part the students repeat some important aspects of system theory in general and of course a special attention is devoted also to the multivariable processes which are introduced through lectures and partly repeated during auditorial exercises.

In the frame of auditorial exercises also the toolbox for system analysis is presented (Atanasijević-Kunc and Karba, 2002; Atanasijević-Kunc *et al*., 2003), which was developed specially for educational purposes. It consists of a great number of functions which represent an extension and enlargement of the functions available in Matlab (Matlab, 2005; Simulink, 2005), Control System Toolbox (Control System Toolbox, 2005) and Multivariable Frequency Domain Toolbox (MFD Toolbox, 1990). They are organized in graphical windows and can be started also only by pushing the corresponding button. For all functions the explanation, and where possible also graphical representation of results is added. The amount of additional explanations can be controlled by the so called communication vector. Mentioned functions can be divided in several different ways. Some of them can be used with single input - single output (SISO) systems, some with multiple input - multiple output (MIMO) systems and some are suitable for both kind of problems. Regarding different design situations both groups are organized into four levels: open-loop analysis, closed-loop analysis, absolute validation (for evaluation of matching desired design goals) and relative validation functions, which tend to help the user to compare the efficacy of different design solutions and to prepare him to the real situation where also such problems have to be expected. When building this toolbox a great attention have been given to the possibilities of stressing some degree of parallelism in treatment of SISO and MIMO problems.

Concerning the written and/or oral exam avoidance it must be stressed that students have a chance to pass them also in a classical way. However when avoiding classical exam they are obliged to prepare written report as well as oral representation of results shown on a computer.

As each project, chosen from the prepared set, is treated by a team of two to three students they have to cooperate in a suitable way not only when preparing the solutions, but also in mentioned oral presentation which is public. It means that beside the professor and the assistant the presentation can be attended in an active way also by the students. Everyone can pose the questions or contribute to the discussion of presented results. Such collaboration which is well accepted by the students, is of great importance not only for the students themselves, but also for the staff and the candidates. The latter are preparing themselves for future presentations (presentation of diploma work is very similar for example) and teachers can get some information of the efficacy of such approach.

In this way also the components of contacts between the professor and the candidate (which is important aspect of classical oral exam) is covered.

The time needed to finish the whole project depends on the candidates themselves and their interest on the subject. They can prepare their solutions also at home and in the laboratory in the time when it is not occupied with lectures or exercises. In spite of the fact that it is difficult to estimate the exact time needed for preparation it is comparable to the classical way as confirmed also by the students.

All the problems have to be discussed first among the partners in the team and then also with the assistant who is attainable through the whole time of exercises.

In spite of the fact that each project is quite complex and somehow rounded up, research and design work can be continued. Several possibilities depend mainly on the fact if for discussed process also the real plant exists or the process is described only with the mathematical model(s). In the first case some further possibilities of experimenting with the real system are enabled. This kind of work has strong practical importance as software and hardware is available for direct computer controller realization, for the use of industrial controllers or programmable logic controllers (PLC). In this way a systematic transition from theoretical work to industrial realization of designed results is enabled. On the other hand when the project is described only with mathematical model(s), more attention is devoted to simulation and theoretical possibilities of experimenting in the sense of different design and optimization procedures usage.

Regarding good experiences with presented project approach and taking into account developing technology enabling e-education one of the mentioned projects was further transformed into the so called competition game in which each team can take an active part if desired. This kind of competition which demands the same problem for all players should in addition stimulates on-line study and therefore shorten the used time from lectures to examination. All the preparation for the competition can be realized from a remote position including experiments with the pilot plant. However final results evaluation is realized in the laboratory at the end of semester where all the students and stuff can observe and discuss the results. In the case of successful result, which includes automatically evaluated and ranged closed-loop experiment with the device and oral work presentation (evaluated by the staff) can also be recognized as passed examination.

3. E-CHO SYSTEM

E-CHO e-learning platform (Fig. 2) is the result of experiences with e-learning implementation, extensive analysis and usage of related products in Laboratory for Telecommunications at Faculty of Electrical Engineering (Pustišek *et al.* 2003a; Pustišek *et al.* 2003b). It comprehends e-learning functionalities and can also be integrated to other web - based applications. E-CHO system is internet based platform which provides:

- E-learning management (LMS – Learning Management System)
- E-learning content managing (LCMS – Learning Content Management System)
- Tracking of teacher's activity and progress
- Knowledge assessment / testing
- E-learning standards support (SCORM and QTI) and multilingualism

System functionality enables different user's roles. Roles define level of rights to system access. Users can access personalized functionalities through specific interfaces.

Fig. 2. E-CHO system teachers interface

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

4. COMPETITION PROJECT

It consists of several steps which must be realized one after another.

In the 1[st] step each team access to E-CHO system is enabled where the work is starting with opening the window as shown in Fig. 3.

Here further information can be accessed regarding lectures (1. Lecture presentation), corresponding literature (2. Literature) (basic in Slovene language and additional (Maciejowski, 1989; Morari and Zafiriou, 1989; Patel and Munro, 1982; Skogestad and Postlethwaite, 2005;)) and defined work flow of the competition (3. Work flow). Then the problem to be solved (4. Problem presentation) is described. This year for the competition Coupled Drive Apparatus TQ-CE108 was chosen (Wellstead, 2004) which is schematically presented in Fig. 4.

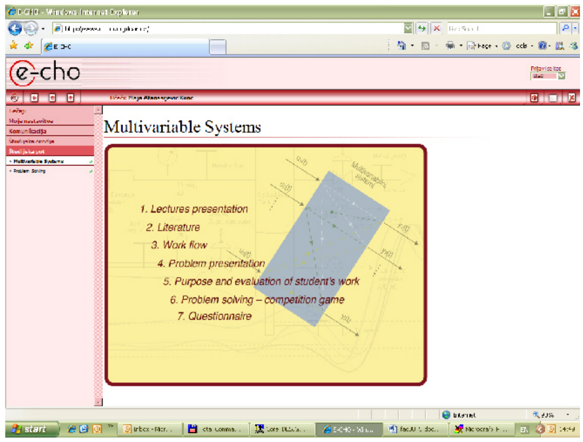

Fig. 3. Starting E-CHO window for game competition

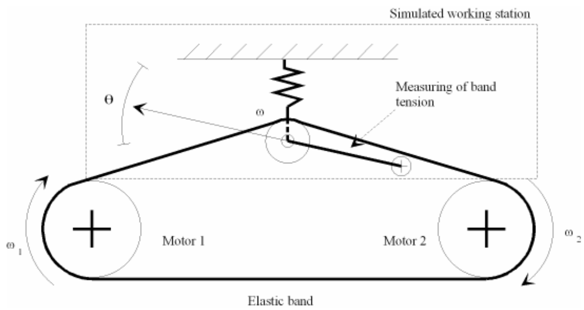

Fig. 4. Schematic plant presentation

The apparatus is MIMO - system where inputs are voltage signals with which it is possible to influence the rotation velocity of both motors, while outputs are suitably measured voltage signals which are proportional to rotation velocity of the working station and elastic band tension.

The choice of the laboratory plant is crucial because it must be of corresponding complexity but at the same time fast enough to fit the requirements of the proposed competition.

The main goal of the work is to design as efficient controller as possible for reference tracking where limitations of control signals have of course to be taken into account. The complexity of the controller is not prescribed.

In addition the information regarding chosen working point and maximal step – reference changes are defined.

For the system also two linearized models in state-space are presented (more complex and simplified one).

In this phase students can start with the work at their own computers or at the computers in the laboratory taking into account also the evaluation criteria (5. Purpose and evaluation of students' work).

In the next step computer game can be started by choosing '6. Problem solving – competition game'. This step is separated into 3 phases, each representing the game level.

At the first level the users must correctly answer to 3 randomly chosen groups of 5 questions (15 questions all together) regarding multivariable systems theory, regarding the properties of the given simpler mathematical model and regarding more complex mathematical model taking into account important differences regarding both presentations. The idea is illustrated in Fig. 5. Each question offers several possible answers where at least one is correct, but in general it is possible also that all answers are correct. When the user is sure that all right answers are marked he/she can continue with the next question. Two mistakes return the user at the beginning of this level, which can be started after one hour break intended for additional study. As the questions are randomly chosen at each trial the set of questions can be different. If at least 14 questions are correctly answered, the solving can be proceeded at the second level.

After successfully solving the 1st level in the 2nd level closed-loop system responses can be observed regarding more complex model. In this phase the structure of designed controller and its parameters are first transfered into the E-CHO system, which is communicating with Matlab environment. Then reference signals are randomly chosen from the set of prepared possibilities and simulation run is started. The results (model responses) are returned to the user. When the user evaluates obtained result as acceptable he/she can continue with the 3rd level.

In this level the procedure is equal as in the previous one. However now simulation run is realized with the real plant instead with the model. That in our case means that in the Simulink's simulation file block, which is representing the model, is replaced with the block which ensures communication with A/D-D/A converters and therefore with the real pilot plant. Its operation can be observed in the screen (Fig. 6). After the experiment all signals are transfered to the user in the corresponding file.

It must be mentioned that this phase enables also open-loop experiments which can be used for additional model improvement if the user is not satisfied with the given descriptions.

Competition itself is performed in the last week of the semester. It is expected that all players (teams) have realized at least one acceptable experiment. The information of the best one is stored in the system. Before the start of the final phase also presentation with short description of the realized design has to be uploaded into the system.

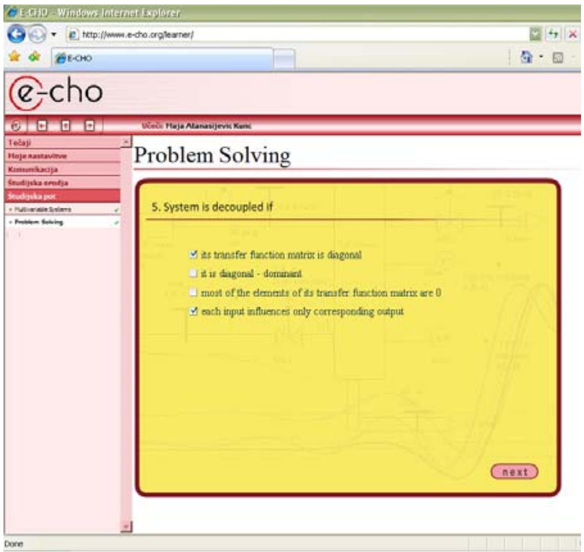

Fig. 5. Randomly chosen group of questions from the corresponding prepared question set

The last phase of the competition is taking place in the laboratory in the presence of all students and staff. First the experiment of the closed-loop operation, as prepared by a team, is repeated and automatically evaluated. Experiment is followed by short presentation of design procedure where all players of the team must be present and able to answer the questions of the staff and their colleagues. The quality of presentation and answers together with the position regarding experiment evaluation in the competition participate in the overall exam mark.

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. Idea is realized on the bases of the prepared projects.

New possibilities are enabled and tested through the competition which can be started by using presented

E-CHO system. As the work flow was realized in several phases also all communication possibilities could be developed and tested in this way.

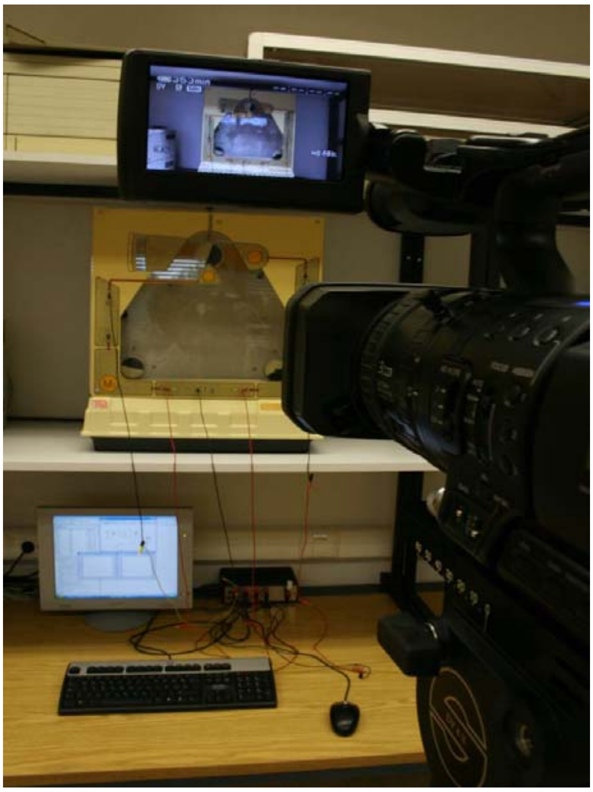

Fig. 6. Coupled drive apparatus in the laboratory

In this year of study (2007/2008) the selected process was Coupled Drives Apparatus, but in the future also additional experiments can be prepared in the similar manner.

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

- new possibilities of laboratory exercises were interesting for students (all students have decided to participate in the game) and very well accepted;
- students agree that such work organization stimulates cooperation between the partners of the team,
- stimulates on-line study,
- and enable freedom in study organization;
- it is also interesting that they prefer to preserve part or even all auditorial exercises and lectures in classical way.

We belive that together with the additional materials and enabled self – testing possibilities the system can be effectively extended for long-distance learning courses. It is true that also exams could be automatized but it can be expected that a certain amount of personal contact is still important as well for students as for the teaching staff.

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