COMBINATION OF LEARNING APPROACHES IN MODELLING AND SIMULATION

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ABSTRACT
Modelling and simulation are disciplines which have an important influence to the learning processes in technical fields, but are well accepted also in many other scientific areas. So is also at the Faculty of Electrical Engineering, University of Ljubljana where such lectures have long-lasting tradition. Through the last year we have introduced a new program called E-CHO with which additional e-learning approaches have been opened for teaching staff as well as for students. The question arises: how to take the advantage of these new possibilities and how to combine them with the established approaches in an efficient way? Some of the solutions are presented in the paper.

Keywords: modelling, simulation, education, E-CHO program

1. INTRODUCTION

Modelling and simulation are disciplines which have an important influence to research and learning processes in technical fields (Löscher et al. 2005, Karer et al. 2007, Sodja and Zupančič 2009, Bicher et al. 2012, Logar, Dovžan, and Škrjanc 2012a, 2012b, Glavan et al. 2013, Mušič et al. 2013, Štampar, Sokolić, and Karer 2013. Fathi et al. 2015), but are well accepted also in many other scientific areas (Atanasijević-Kunc, Drinovec, and Mrhar 2008, Čorović et al. 2015). At the Faculty of Electrical Engineering, University of Ljubljana (FE-UL), Slovenia, several subjects are devoted to mentioned contents, but even more are using actively the knowledge learned through these lectures. The history of the subjects is rather long, but the last major reorganization has been realized through the so called bolognia study in 2009-10. As can be observed in Figure 1 the study has three levels. The first and the third one are lasting three years, while for the second one two years are needed. At the first level students can choose between University program and Professional higher education program, the latter being more oriented to the practice, while the University program gives strong theoretical starting points. Graduates of both first-level programs can, when passing the corresponding evaluation, enroll the second – master level, while the best of them can later on continue at Doctoral Study.

The majority of the first and the second level subjects are organized in the form of lectures and laboratory exercises, while at the end of the semester first written and then oral exam are carried out. In some subjects, especially those in the first year, during the semester teaching staff sometimes prepares also colloquia to intensify students' work. Very high colloquia's exam mark sometimes means that student has also passed written examinations.

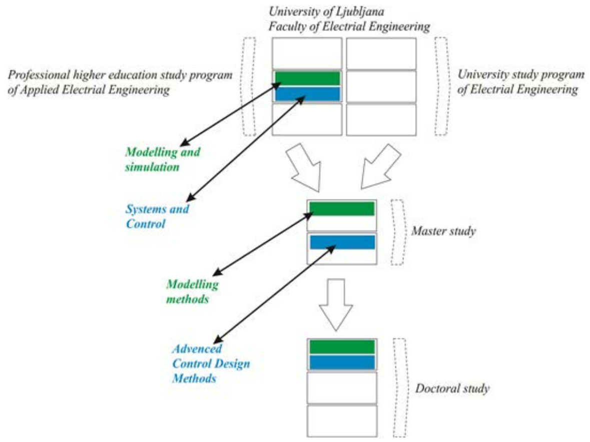

Figure 1: Organization of education process at the Faculty of Electrical Engineering, University of Ljubljana

In 2014/15, we have, in addition to the aforementioned forms, introduced an e-learning approach. It was decided to use program E-CHO (Čorović, Bešter and, Miklavčič 2009, Papić et al. 2011, Atanasijević-Kunc et al., 2011, Logar et al. 2011), as the development of this program has long been conducted by the Laboratory for Telecommunications at FE-UL. The efficacy of this program was tested and complemented for the purposes of studies at FE-UL already in previous years (Čorović, Bešter and, Miklavčič 2009, Atanasijević-Kunc et al., 2011). Because of many positive experiences we have decided to try now even more intensively to develop the so-called combined or blended learning taking into account new possibilities. The goals are numerous, but some of the most important are the following:

- gradualness,
- flexibility and multi-functionality,
- enhancement of motivation,

- step by step improvement of program E-CHO regarding specific experiences and arising needs,
- explicit subjects' connections, where possible (some possibilities are indicated in Figure 1).

The paper is organized in the following way. In the next section some of the most important features of the program E-CHO are described where the emphasis is given to its new properties and to those features which enable the extensions and/or improvement of education process. The subject Modelling and simulation is presented in the third section regarding lectures and laboratory exercises education flow. Here also Toolbox LABI is introduced which was developed in program MATLAB as a Laboratory of mathematical models, where also efficient analysis in the form of toolbox is prepared and can support education process at different levels of the study. In the fourth section the realization of blended learning approach is presented taking into account lectures, laboratory exercises, homework, online testing and exams, motivation seminars and projects, and the possibilities to extend the work to a diploma thesis. The paper ends with the concluding remarks and some ideas for future investigations.

2. E-CHO PROGRAM

E-CHO is an e- learning internet-based platform. It is the result of a long lasting development of experts from Laboratory for Telecommunications at the FE-UL (Čorović, Bešter and, Miklavčič 2009, Papić et al. 2011, Atanasijević-Kunc et al., 2011, Logar et al. 2011) It is therefore not surprising that it associates and combines numerous e-learning functionalities. It can also be integrated into other web-based applications.

E-CHO provides e-learning management (LMS – Learning Management System), e-learning content managing (LCMS – Learning Content Management System), tracking of the teacher's activity and progress, knowledge assessment/testing, e-learning standards' support (SCORM and QTI) and multilingualism.

During the last few years improved version of E-CHO was developed where special attention was devoted to the following new and/or extended program properties:

- Simplification of content development procedures:
  Rapid and user-friendly content development is now possible. This means that each user with sufficient access rights can add text, pictures, videos, questions or other learning objects within the developed interface. No special program knowledge is needed. This content can be delivered to selected users or groups directly after the development. E-CHO enables also fully automatic video lectures content development process. Arbitrary multimedia element can be added to the video and played synchronously.
- Improvement of progress tracking tools and learning statistics reports:
  Several different filters were added to the progress tracking mechanisms. The users with sufficient access rights can analyze in depth data regarding learning statistics, they can assess quality of developed learning objects on the large scale (whole courses) or on the individual learning objects level (e.g. assessing quality of questions and tests).
- Adaptive access – rights management:
  E-CHO program maps system features with user roles. That means that desired user role within E-CHO can be defined and the system use can be generalized. Users and group management can also be simply integrated with Active Directory (AD) or other Human Resources Management (HRM) systems.
- Video and multi – media support:
  E-CHO enables simple uploading of different video formats with corresponding multimedia learning objects. Video is converted to the format which is the most appropriate for web or mobile viewing and corresponding multimedia is added. It supports catalogue of all video and other multimedia objects, which can be reused in any way for learning purposes.
- Simplified third party integration through open interfaces:
  E-CHO provides open interfaces, enabling third party developers to integrate their application for various e-learning purposes. As an example, third party remote experiment can be simply integrated into E-CHO. Open web interfaces enable exchange of data between the remote experiment and E-CHO LMS in order that remote experiment is delivered through E-CHO system and results of experiment are saved within the E-CHO system progress tracking tools.
- New mobile interfaces (tablets, smart-phones):
  E-CHO program provides mobile interfaces for Android and iOS operating systems and corresponding terminals. This enables users to access e-learning from tablets or smart phones.
- Improved knowledge assessment (new question types, simplified tests and questionnaires development and delivery):
  E-CHO supports more than 20 different question types for knowledge assessment. Video and other multimedia can be added to questions. Questions can be sorted into folders (directories) and E-CHO test player can deliver random numbers of questions from folders, based on their difficulty level. Tests development is simplified and time to delivery is shortened. Each test or question can also be delivered to the users or groups directly, without first integrating it into courses or groups of learning objects.

As already mentioned in the school-year 2014/15 we have chosen E-CHO to be an official e-learning support for the whole FE-UL. The consequence was that special adaptations were introduced for this purpose.

Each professor and his/hers assistants, as well as all students, can enter E-CHO through corresponding user name and password information. Starting window is illustrated in Figure2.

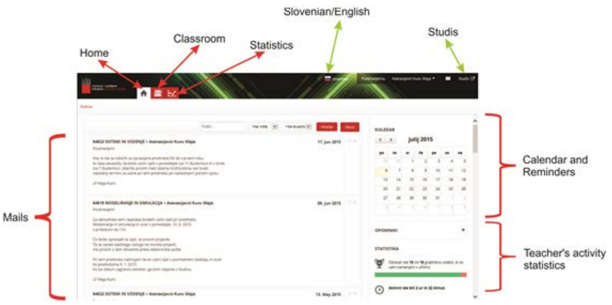

Figure 2: E-CHO starting window

E-CHO has been connected to program *Studis* (see upper part of Figure 2) which is the environment for managing all the information of education processes at FE-UL. In corresponding data basis information of students, teaching staff, lectures, exams, diplomas, etc. is stored. For entering *Studis* also digital certificate and additional password is needed due to security reasons.

To each person involved into education process corresponding rights are assigned regarding the information transferred from *Studis* data base.

For example, each professor can develop e-learning contents for the subjects he/she is responsible for by clicking the button *Classroom* (see upper part of Figure 2). This opens the window of the form as is presented in Figure 3.

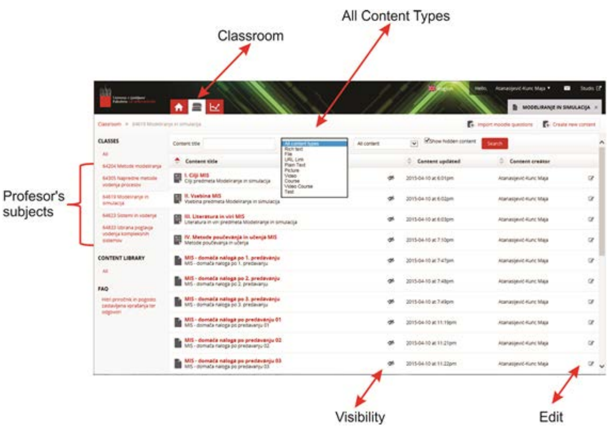

Figure 3: E-classroom with professor's subjects and developed content elements

In the left part of the window the titles of the subjects are displayed. Below also the access to the short manual is available and some answers to frequently asked questions.

Titles of already developed contents are displayed in the next column. It is possible to observe all developed contents or only those which are connected to the certain subject.

The user can develop contents in the following forms: file, figure, questions, folder with questions, web-page, url-address, video, different tests, group of contents, course, video course.

Content types *video*, *figure,* and *file* enable file transfer from the user's computer or definition of url-address where the file is available.

When developing content type *web-page* it is possible to edit text, to add figures and video clips and to use prepared UL-FE templates.

Content type *url-address* enables a definition of corresponding address which is not inside E-CHO application.

Content type *course* enables aggregation of developed content types into corresponding sequence. In the same time the user can generate multi-level table of contents.

In addition also *video-course* can be prepared where the user can combine video clips with corresponding transparences and/or tests or other prepared graphic material.

All prepared contents can be connected to one or more subjects in corresponding way. During development or during education process the chosen contents can be made visible only for developers. When desired this status can simply be changed and the chosen content is than delivered to the chosen students' group or groups.

It is important to mention that teaching staff and students can develop contents in the same way. Of course if students are uploading their homework, projects, or exams these materials can be accessed by teaching staff only, but if their project results can represent interesting information to the whole group it can also be made visible for everyone from corresponding group. These properties are important because in this way developed contents can also be combined into different course forms and flexibility of education can be increased.

3. MODELLING AND SIMULATION

As presented in Figure 1, students from Professional higher education program of Applied Electrical Engineering Program have in the third semester subject entitled Modelling and simulation if they choose to study Control Engineering (other options are Electronics, Power Engineering Technology and System Automation, Telecommunications, and Quality Engineering). It is organized into lectures (3 hours per week) and laboratory exercises (2 hours per week). Main chapters, which are presented through lectures (Atanasijević-Kunc 2013), (similar courses are rather frequent: Cellier 1991, Matko, Zupančič, and Karba 1992, Close and Frederick 1993, Cellier and Kofman 2006) are the following:

1. Introduction
2. Dynamic systems presentations
3. Introduction to simulation
4. Experimental modelling

5. Theoretical modelling

Due to time-limitations the main focus is given to continuous systems.

It is important to mention that through systems' presentations also computer presentations are taken into account. Different programs can be chosen for demonstration purposes. We have decided to use Matlab as it is very suitable for modelling and simulation problems but also for control design of dynamic systems and so the time needed for program teaching can be minimized also regarding several other subjects. During introduction to simulation also basic information regarding Simulink and Control System Toolbox is given.

In laboratory we have installed a great number of pilot plants (see Figure 4) which mimic different dynamic processes.

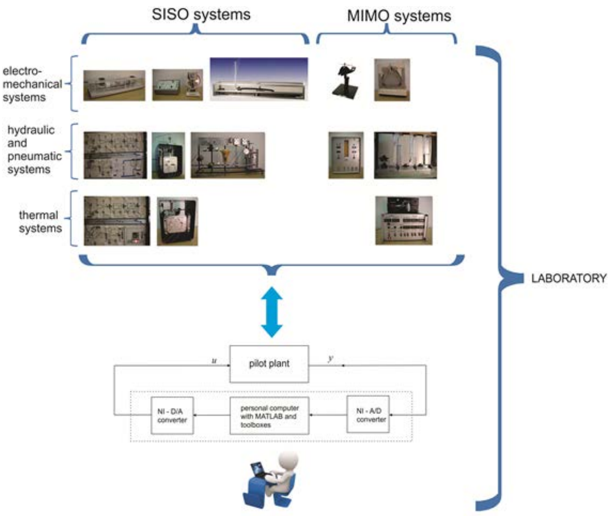

Figure 4: Laboratory work organization

They can be divided regarding different criteria. Some of them are for example single-input single-output (SISO) systems, some can operate as multivariable (MIMO) devices, some are stable and some not. When time for experimentation is very limited (and this aspect is important during laboratory exercises) also systems' time constants are important. Regarding presented groups of devices in Figure 4 it can be expected that the fastest are electro-mechanical pilot plants, while the slowest are thermal, where another problem can be expected and that is very slow cooling. This is problematic when we want to repeat experiments with the same initial conditions in short time intervals.

Each pilot plant is through A/D and D/A converters connected to the personal computer, where also Matlab with corresponding toolboxes is installed. In Simulink library one block was added which enables the communication with mentioned A/D and D/A converters. In this way experimentation with pilot plants can be realized in the same way as with mathematical models. So the gap between theory and practice was minimized.

During lectures also a great number of examples are explained and for some of them also computerized interpretation is given (Atanasijević-Kunc 2008). This has motivated the development of the so called LABI (Atanasijević-Kunc, Karba, and Zupančič 2011) which stands for the Laboratory of mathematical models of dynamic systems and consists of a group of files which are organized through graphical user interface (GUI) in Matlab. The development started in Slovene language but now we are trying to realize it bilingually. This is important because the number of foreign students is constantly growing, but also our students can in this way learn some important expressions.

The starting window of LABI is illustrated in Figure 5.

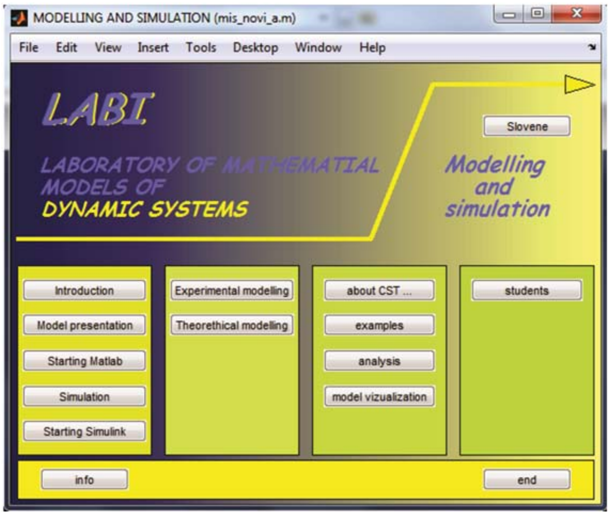

Figure 5: Starting window of LABI

This and also all other windows of the GUI are organized in a similar way. In the upper part the title or short description of the current level is given with the possibility to switch between English and Slovene language. In the frame of the bottom part push-buttons enable to finish the work (*end*), to obtain some information about the current level (*info*) and to return to the previous level (*back*) or to the very beginning (*beginning*) if possible.

The push-buttons of the central part enable to observe prepared information or files, or to execute developed files if buttons are active. If certain button is not active there are two possibilities: this part of LABI is still under development or needed data for file execution is not available in Matlab's workspace.

In the name of each graphical window (top of Figure 5) also the name of the m-file which generated the window is given. So it is very simple to trace the information needed for observed calculations. This aspect is very important as all the users are invited to participate in extensions and improvement of this software.

In Figure 5 presented buttons of the first and the second column open windows where information is available regarding each chapter of the lectures (pdf-files). In addition Matlab files with illustrative examples can be observed and executed.

The role of the buttons of the third column is the following. Button entitled *about CST* ... displays very short manual of Control System Toolbox and presents some of its functions, button *examples* enables to observe modelling and simulation results of simple, but also more complex problems (case studies) where in many cases (if of interest) also animation of the problem is illustrated. One such example is presented in Figure 6 for TQ CE9 Ball & Hoop pilot plant.

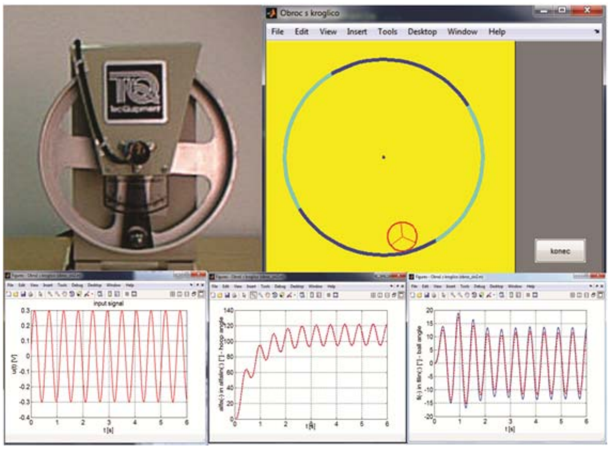

Figure 6: Simulation with animation window of mathematical model of TQ CE9 Ball & Hoop pilot plant

Very precise instructions for graphical results presentation in Matlab can be observed by pushing the button *model visualization*.

For analysis purposes we have developed a toolbox which can be started by pushing the button *analysis*. This opens the window as is illustrated in Figure 7.

Figure 7: Starting window of analysis toolbox

Analysis toolbox consists of a great number of functions which represent an extension and enlargement of the functions available in Matlab and Control System Toolbox in the way that several functions have been added, they are organized through graphical windows and can be called also only by pushing the button if all needed information is in workspace. In all functions explanation and where possible 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 SISO systems (see Figure 8), some with MIMO and some are suitable for both groups of problems.

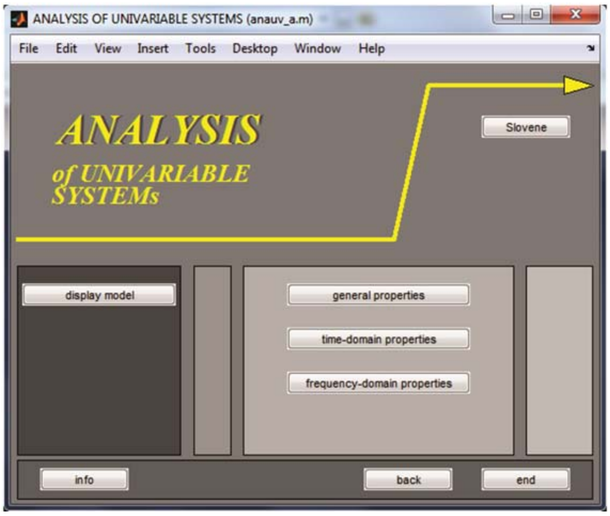

Figure 8: Analysis of SISO systems

Regarding different design situations both groups are organized into four levels.

Open-loop analysis functions are using only the information of linear system model. They are grouped into *general*, *time-domain, and frequency-domain properties*, as is for SISO systems illustrated in Figures 9, 10, and 11.

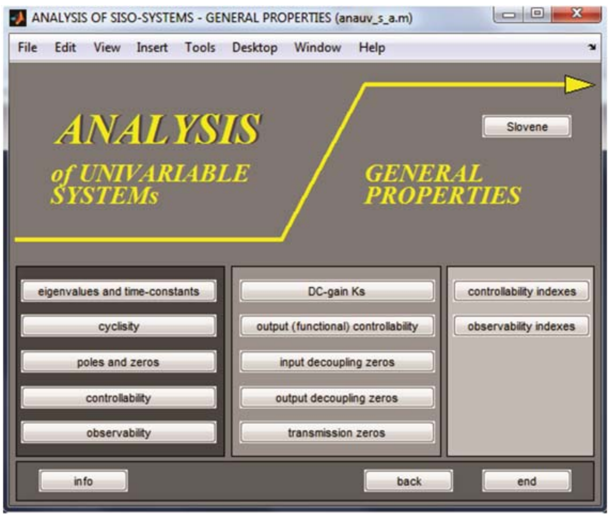

Figure 9: Functions available in the group of general properties

Closed-loop analysis functions are organized identically however in this case also the information of used controller is needed.

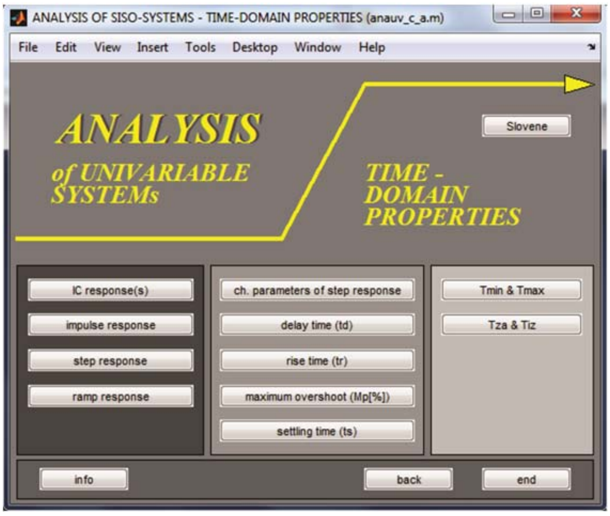

Figure 10: Functions available in the group of time-domain properties

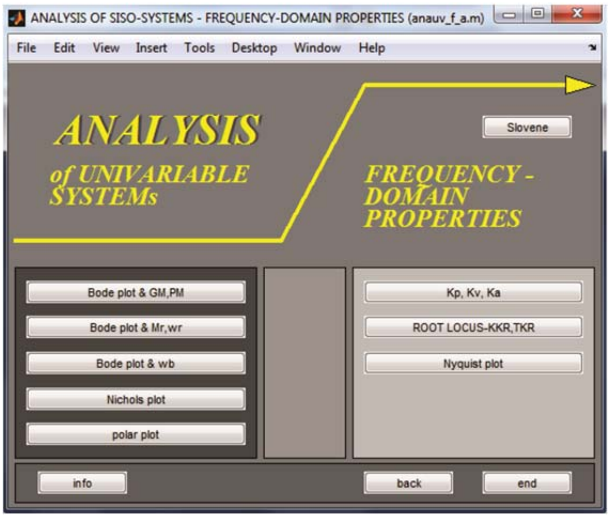

Figure 11: Functions available in the group of frequency-domain properties

Absolute validation functions are used for evaluation of matching desired design goals. In comparison with closed-loop analysis here also design goals have to be specified. Suitable and enough general specification of design goals can of course be very difficult especially in earlier design stages where needed information is not available or in situations where the user can define contradictory design goals. To avoid somehow these problems we have introduced the possibilities with which the user can define the importance of each specified design goal. In this way design goals can be specified either very precise or in a very approximate manner. The result of absolute validation is in the range between 0 and 1. If the result is 0 design solution is unacceptable as one or more design goals are violated more than allowed. If the result is 1 this means that all design goals are completely satisfied. If the result is between 0 and 1 the solution is acceptable, but all design goals are not completely fulfilled. Better are of course solutions which are closer to 1. These results can also be used for some kind of relative validation. But it can occur that several solutions have the same validation result. In this case the next level can be used.

Relative validation functions tend to help the user to compare the efficacy of different design solutions and to prepare him/her to the real situation where also different kind of non-linearities have to be expected. One, which is in practice always present, is for example limitation of control signals. Relative validation functions can simultaneously compare up to five design solutions. The validation result is calculated regarding the first solution. Result greater than 1 therefore means that solution is better than the first one. Higher validation values mean better or more efficient solutions.

It is important to mention also the button *students* which opens the graphical window for students work. Students are during laboratory exercises organized into groups of two persons and each group organizes their resulting files into a folder and they connect their files with the buttons of GUI. In this way documentation of their work is transparent and also potential problems are easier to be debugged.

The work flow through the semester is usually organized so, that first few weeks (5-6) all hours are used for the lectures and work in the classroom. When the first two chapters are explained lectures and exercises are running in parallel and at the end of semester lectures end earlier and students have time to finish all laboratory work and to prepare themselves to written and oral exams which are organized at the end of the semester.

Our experiences have indicated the following problems:

- Some students are not motivated enough because they have problems with combining abstract and practical knowledge.
- Some students like to postpone their study. This is problematic because they come to laboratory exercises unprepared and desired studying goals cannot be reached.
- Addition problem is that the knowledge of this subject is necessary already in the fourth semester (for example for the subject Systems and Control, see Figure 1) and online study is therefore very important.
- These students are relatively young and sometimes not capable to organize their work effectively.

So we have decided to slightly reorganize our work and have at the end of the semester introduced the so called seminars. These are small projects which are different for each student. If the student choose to solve one such seminar this work is evaluated as written part of exam.

These seminars have improved the situation but we are still not satisfied. So, further improvements are designed taking into account new possibilities which have been opened by introduced e-learning approach.

4. BLENDED LEARNING

As already mentioned we have introduced E-CHO into the studying process systematically in the year 2014/15 but some features of this program have been tested at UL-FE also earlier (Čorović, Bešter and, Miklavčič 2009, Atanasijević-Kunc et al 2011, Logar et al 2011). From these testing experiments and of course from previous education experiences the following was learned:

- New teaching approaches are usually interesting for students and can attract their attention to certain degree, but young people are critical and their suggestions are important.
- E-learning is opening new and/or additional and/or complementary possibilities in education processes and it is important to investigate and to develop efficient forms of these new opportunities. It can be expected that all novelties are not equally efficient so it is important to evaluate them and to be prepared for further modifications if all effects are not positive.
- Established, efficient, and well accepted forms should not be eliminated (at least completely) from education process because of (especially unverified) novelties.
- Project work, especially if organized in small groups of students, is intensifying cooperation between the students and consequently also slower workers are forced to become more active.
- From well prepared projects also the reasons why certain knowledge is important can be become more convincing.
- Additional positive effect can be expected with the organization of work in a form of a game, perhaps even competition game. Natural reaction to competition is to try to be better (Matko, Blažič, and Belič 2001, Atanasijević-Kunc et al 2011).
- E-learning contents are in general available 24 hours per day and as such they introduce a certain degree of freedom into learning processes which is always an important advantage.
- It can be expected that a lot of effort and time is needed for teaching staff to prepare all new technical equipment and to become familiar with these new possibilities. New equipment also demands corresponding adaptation of materials and education flow.

Taking into account mentioned experiences we have started with the adaptations of lectures and exercises in the form as is illustrated in Figure 12. Each week the file (ppt-file) of corresponding lectures was added. This file was complemented by the file describing the homework. It is important to mention that it was not checked if the given material was studied online and if homework was done. Later on (after the lecture no. 6) also instructions for laboratory exercises were uploaded. Matlab files were installed at the computers in the laboratory. At the end of semester also files describing project work were added. All the materials were generated in Slovene.

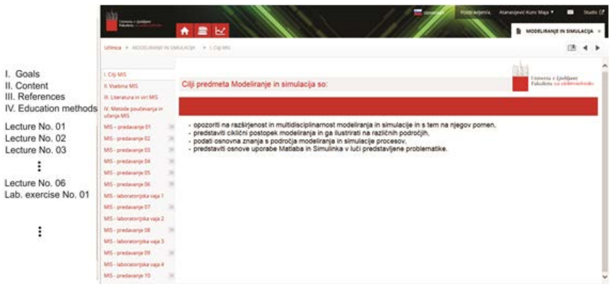

Figure 12: E-classroom of the subject Modelling and simulation: content development

It was observed that after few starting problems students have adapted to this new extension very promptly. It is interesting that practically all decided to download the prepared files in spite of the fact that they can be equivalently used also online.

In the last year different projects were prepared for each student. All students decide for this form of written part of exam.

After the first year the following was observed and/or suggested and/or already modified:

- The level of online study should be improved. To achieve this goal some kind of online knowledge verification is necessary. This solution was suggested even by the students (of course after the end of semester). This seems to be very important because learning efficacy of laboratory exercises depends crucially on this knowledge. As a consequence we have started with the preparation of short tests, which can now be relatively simply prepared and evaluated in E-CHO. Each lecture and corresponding homework is now followed by a short test verifying understanding of the presented material as illustrated in Figure 13.
- Some students needed quite long time to prepare results of project work and so also oral exams were postponed in these cases. This problem is not simple to solve, but perhaps positive results can be expected by the reorganization of project work (as will be described) in combination with previously mentioned short tests.
- Final average level of presented knowledge should and could be improved, especially regarding more ambitious students. It is usually a stimulating aspect if the achieved level (and with this also the current achieved mark) can be observed where at the same time

further steps are well defined and lead to more demanding final results.
- Students' questionnaires further revealed that even more practical work is desired.

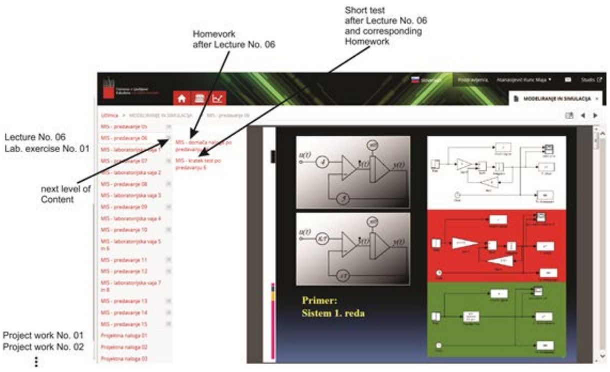

Figure 13: E-classroom of the subject Modelling and simulation: multi-level content development including lectures, exercises, homework, testing and project work

In the previous years we have developed remote experimentation using E-CHO learning environment, corresponding pilot plants and computers, web-cameras and Matlab with Simulink as described in details in (Logar 2011, Atanasijević-Kunc et al. 2011). In these cases the situation, as presented in Figure 4, was extended in a way that the computer connected to the pilot plat was as a slave computer through the LAN connected to the main server where E-CHO was installed. Students can start prepared experiments by uploading corresponding parameters. During experiment it is possible to observe video-stream of the pilot plant and after the experiment the responses can be observed and measurement data can be uploaded from the main server. In the same way also virtual experiments were realized.
It is important to notice the following:

- The guided work in the laboratory where the students obtain important basic information is very valuable and should not be replaced with other forms of education.
- Remote experimentation is convenient for additional projects, games and/or competition games, and demonstration purposes.
- Remote real experiments are efficient only when using suitable pilot plants. That means that they are robust, have corresponding (not too long) time constant and, if possible, the observation of the experiment can be informative for the user.
- Virtual experiments can be of great help, especially in the case of larger group of students. In such cases projects can be less time-consuming, different and yet similar enough, that they represent comparable burden for all students.

Regarding the importance and potential efficacy of project work we are adapting described technology also to a new version of E-CHO where prepared experiments (virtual and real) can be accessed now through defined url-adress which can be developed as one of the contents form inside E-CHO as was mentioned in the second section. This configuration is illustrated in figure 14.

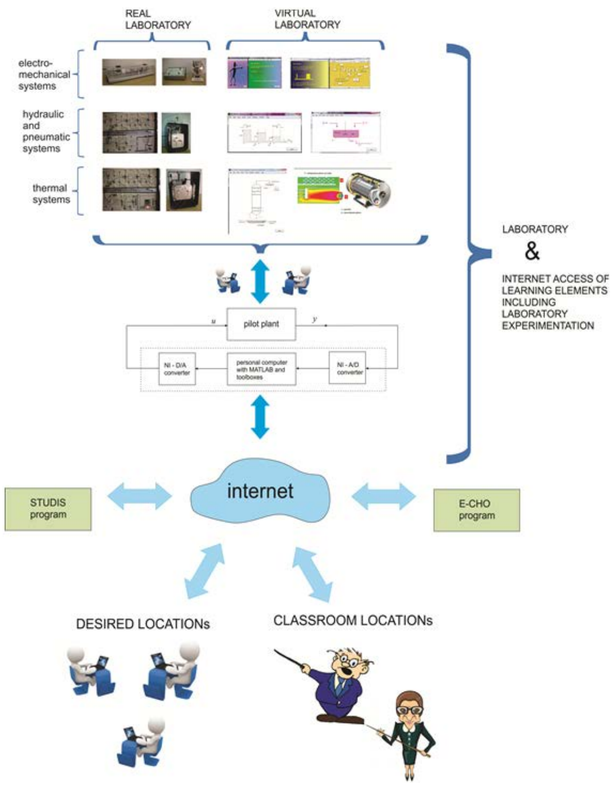

Figure 14: Extended laboratory work organization

For the next year the projects are prepared where the groups of students (each team will consist of two to three students) are instructed to:

- develop theoretical and/or experimental model of given problem,
- observe model responses in the whole operating range,
- choose five working points and develop corresponding linear approximations,
- analyze models' properties in all working conditions,
- and realize qualitative evaluation of models with measurements.
- Written reports and corresponding files are going to be uploaded into E-CHO regarding pre-defined timing.

Each project task realized correctly will be evaluated with corresponding number of points contributing to final mark, but also the evaluation of short tests will be taken into account.
On the basis of the evaluated efficacy of modified education and regarding numerous possibilities which are indicated in figure 14 further improvements will be designed.

One very important which will be realized as soon as possible is also realization of all content elements in English as each year we have a greater number of foreign students.

5. CONCLUSIONS

Through the last year we have introduced at the Faculty of Electrical Engineering, University of Ljubljana, Slovenia, a new program called E-CHO with which additional e-learning approaches have been opened for teaching staff as well as for students. The important question arises from this situation: how to take the optimal advantage of this new program and how to combine its capabilities with the established approaches in an efficient way? Some of the solutions are presented in the paper for the subject Modelling and simulation.

In the future we are planning

- to investigate the options which would enable the introduction of interdisciplinary students' projects,
- and projects which would represent the bridge to innovative enterprises,
- we will further develop remote experimentation with pilot plans,
- and with additional complex mathematical models presenting real processes, like is described in (Fathi et al. 2015),
- more attention will also be given to video contents where it is planned to activate especially students.

It is important to mention that some questions and problems are still not solved completely, like for example:

- which lectures or contents should be visible for the staff and/or students of the faculty,
- which contents should be made visible to everyone,
- should teachers have the possibility to develop additional courses, or only their lectures,
- can this additional equipment stimulate life-long learning,
- or activities which are not part of the regular study,
- etc..

These problems represent the challenge for our future endeavors.

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