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# E-TRAINING IN MECHATRONICS BY USING INNOVATIVE REMOTE LABORATORY

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**Abstract**. This paper describes e-training developed for teaching of the mechatronics. The training was developed within the frame of Leonardo da Vinci life long learning programs and MeRLab project (Innovative Remote Laboratory in the E-training of Mechatronics). The primary target group are the engineers or technicians who have already completed formal education in the field of mechanical, electrical engineering or other technical fields, but have no knowledge of mechatronics, although their job might require. For the training special e-learning platform was built in the user friendly environment which is based on combination of commercial eCampus platform and open-source Moodle platform. The complete materials with the animations, graphical presentations, tests and the utilities like discussion forums are offered. In addition to e-learning materials which present the theory, also the remote laboratory experiments are available. The training is divided to four modules: Introduction to mechatronics, Servo motor in mechatronics, Electrical circuits and Mechatronic devices. Each of the modules covers the important topics from the mechatronics and includes remote experiments on various mechatronic devices.

## 1 Introduction

Adult education is becoming increasingly important in the modern society, since it is of great importance to provide people with the opportunity to acquire new knowledge and skills throughout life, so that they are able to function well in society and keep up with the constantly changing demands of working life. However, the life-long learning programs developed for this purpose, bring many new challenges into education process. The participants in such programs are mostly employed persons with full time schedule and sometimes also widely geographically distributed. Therefore, the education process must be designed in the way to meet the constraints of time and distance and also offer high quality courses. A distance learning based educational approach can meet those requirements.

Introduction of the distance learning in the engineering education brings some additional educational challenges. Namely, for the engineering education it is especially important to give the participants a possibility to gain some practical skills by working on the real devices. In distance learning this can be achieved only by implementing remote laboratories where the user operates real devices trough the Web [1], [2], [3], [4], [5]. Only such distance courses in engineering, which include remote experiments with high quality study materials and sufficient online support of the teacher, can provide complete learning experience that can be compared to the conventional in-the-classroom education with laboratory exercises.

This paper present adult distance training of mechatronics, developed within Leonardo da Vinci MeRLab project (Innovative Remote Laboratory in the E-training of Mechatronics). The primary target group for the training are the engineers or technicians who have already completed their formal education in the field of mechanical, electrical engineering or other technical fields, but have no knowledge of mechatronics, although their job might require. Therefore, the training is developed for engineers and technicians from the related fields (electrical engineers, engineers, construction workers, etc) but it is also suitable for the teachers of the secondary schools who want to pass this knowledge to their pupils. As well it can be used for the education of regular students of mechatronics and automation in their first year. From the participants only the basics preliminary knowledge is required which includes introductory course in mechanics or some practical experience, introductory course in linear algebra and physics, everything at the secondary school level.

Paper is organised as follows. Second section describes E-learning Web portal and the remote laboratory. Third session presents the organization of the training and adopted educational approach. Fourth section describes the training topics. Forth section presents remote experiments and experimental setups. Last section gives a summary and some plans for the future work.

## 2 E-learning Web portal and remote laboratory

The theoretical part of training is performed within e-learning portal based on eCampus system. This system offers all functionalities that are required for execution of distance training. According to the usability testing of eCampus [6] it is in some aspects even better then Moodle, especially when it comes to the visual design of e-learning content. The home page of the ECampus learning portal is shown in 'Figure 1'. The materials which give the theory are presented in SCORM format.

Second, practical part of the training is executed in the innovative remote laboratory which is established at the Faculty of Electrical Engineering and Computer Science, University of Maribor [7]. The remote laboratory is built in the Moodle environment [8] and includes also the booking system for remote experiments. Home page of remote laboratory [9] is shown in ‘Figure 2’.

The users are, after finishing the study of theoretical part of each learning unit in eCampus portal, forwarded to the remote laboratory. The connection between the eCampus e-learning portal and the Moodle based remote laboratory is automatic and seamless and requires no additional registration or actions from the user.


**Figure 1**. MeRLab e-learning portal

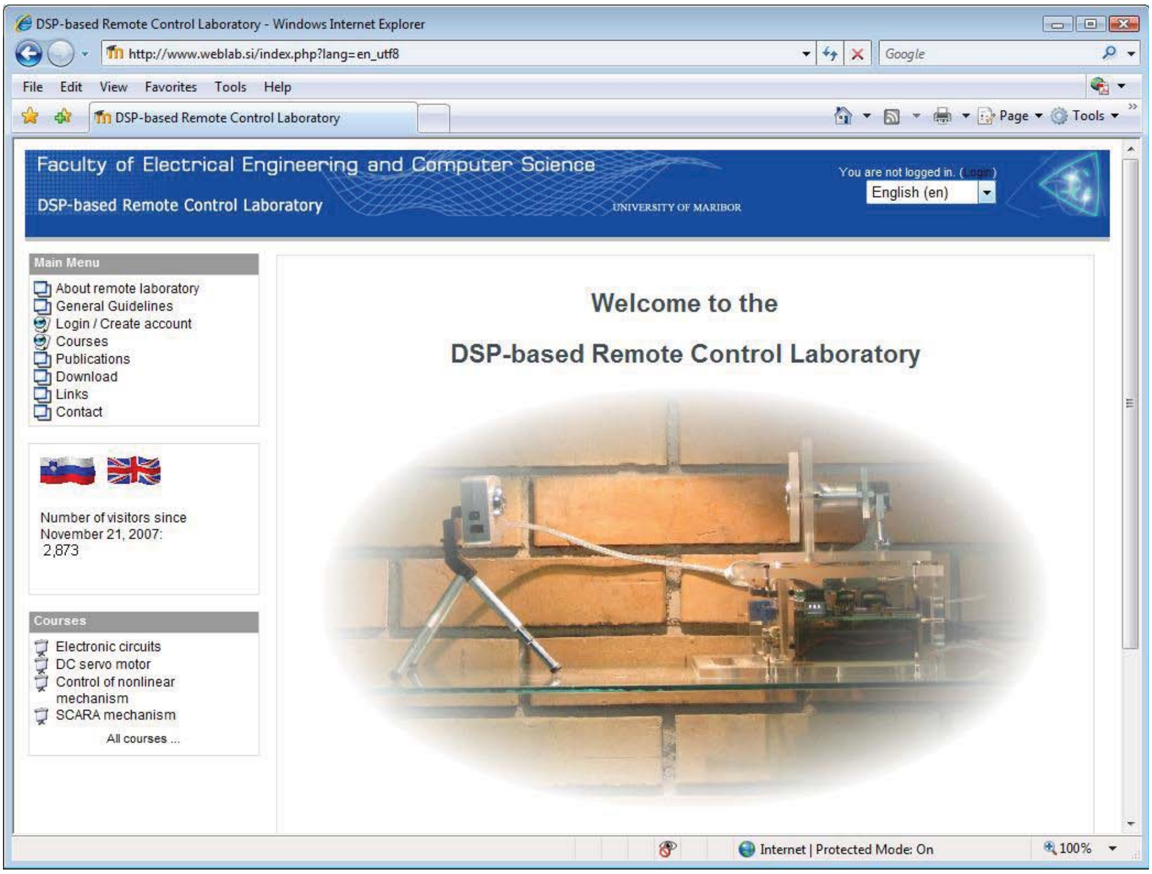


**Figure 2**. Remote laboratory

## 3 Organization of the training

The training can be divided in three parts as shown in 'Figure 3'. First part is introduction to the training which is organised as few hours long live meeting between the teachers and participants. The purpose of the live meeting is to introduce the participants with the organization of the training as well as with the e-learning portal and remote laboratory. At the meeting, the participants also create their user account. Then, each of the four modules in the training is briefly describes and few live experiments are shown.

Second part of the training is distance training. Here the students autonomously study materials for each of the modules, execute exercises, perform tests and also execute remote experiments. The discussion forums are introduced after each important learning unit. The participants also have to solve a task after each such unit and send the results to the teacher, who provides feedback.

Third part of the training is evaluation of the training success. Learners are asked to write few comments and to fill anonymous questionnaire concerning the training, e-learning portal with documentation and remote experiments. Based on those results the training and/or remote experiments are updated if necessary.

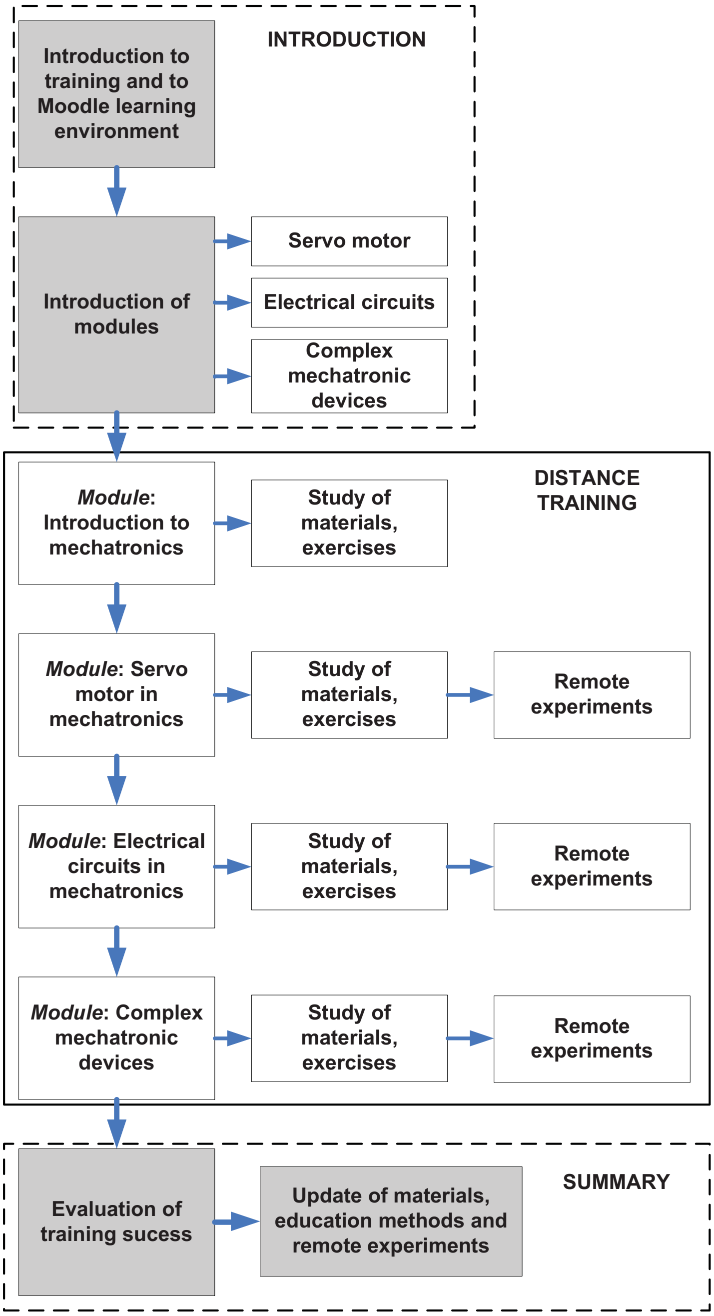


**Figure 3**. The organization of MeRLab training

## 4 Contents of the training

The training includes four modules. Modules can be studied in predetermined order. However, the participants with sufficient preliminary knowledge can also study only separate module(s). Each of the modules introduces one topic in mechatronics of mechatronics. In each module also a case study and some interesting details are discussed.

Modules are:

- Introduction to mechatronics,
- Servomotor in mechatronics,
- Electrical circuits,
- Mechatronic devices.

In the module 'introduction to mechatronics', the meaning of the term mechatronics and a short description of this new technical field is given. Then, the historical development from the pure mechanical systems to the state-of-the-art mechatronic devices is described. The structure of mechatronic systems and the role of each element of such a system are also discussed.

In the second module 'Servo motor in mechatronics' the role of actuators in mechatronics is described. Basic operational principles of direct current motor are presented, together with short description of construction of typical direct current motor. This is followed by defining the motion control problem in mechatronics and description of few simple controllers with the instruction how to set the controllers' parameters. Finally servo motor with velocity and position control is studied by execution of remote experiments. Users can tune the parameters of both controllers.

In third module 'Electrical circuits', first the fundamental elements of electrical circuits are presented. Beside resistor, capacitor and inductance, also a new fundamental element memristor in described. Next some electrical circuits are presented. This includes the operational amplifiers which are discussed in more details. Frequency characteristics and its graphical presentation in form of Bode plot is discussed next. Further filters are presented as one of frequently used electrical circuits in the mechatronics. Emphasis is put on the passive and active low-pass, high-pass and band pass filters. Switched capacitor filters and digital filters are also described. Basic operating principles and frequency characteristics of the filters are studied trough the remote experiments executed on the switched capacitor filters.

In the last module 'Mechatronic devices', the structure and operation principles of complex mechatronic devices are be described. First, mechanical elements, such as gears, belts and joints, are considered. As a simple mechatronic device and building block for more complex devices, a joint drive system is presented. Next, it is shown how joint drives are used to build a robot. The operation principles of the robots are explained in the case study. Finally, the real world problems in the control of complex mechatronic devices are demonstrated by executing the remote experiments with the SCARA robot.

The whole training requires around 40 hours. When learners finish this training they can also proceed with execution of additional course in the remote laboratory 'Control of nonlinear mechanism', which requires little higher knowledge level.

## 5 Remote experiments

Remote experiments are accessible at the remote laboratory described in [7]. Remote laboratory experiments are built with different experimental devices. 'Figure 4' shows two degree of freedom SCARA robot, which is implemented in the module 'Mechatronic devices'. 'Figure 5' shows direct current motor with flywheel, which is used in the module 'Servomotor in mechatronics'.

Very important feature of remote laboratory is booking system shown in 'Figure 6'. By using booking system learner can book in advance time when he or she wants to execute remote experiments. In booked time period nobody else can access remote experiment and therefore learner can perform experiments as he or she had planned. At the booked time, control window appears in the Web browser on learner's computer, and he can overtake the control of experiment. During execution of experiments learner can change number of different system parameters and observe system response in textual and graphical format. Further video transfer can be applied in order see experimental device and effects of remotely given commands on the operating or motion of the device.

As an example the remote experiment performed with SCARA robot will be described. User interface for operating the robot is shown in 'Figure 7'. In remote experiment following three controllers are implemented:

- PD controller with the position and velocity feedback loop. The controller is built for each robot joint separately.
- Computed torque controller. For realization of this controller, the derived dynamic model of SCARA robot is implemented. This is centralized controller, which means that there is only one controller for both joints, but it has two control outputs.
- Cascade controller. This a linear controller implemented in many commercially available controllers. It is composed from P position, PI velocity and PI current controller. The controller is built for each joint separately.

The user can change the controllers' parameters and observe position error and the motor current for both robot joints. Also it is possible to choose simultaneous motion of both joints, or just the motion of one joint. In the case when motion of only one joint is chosen, the second joint is held in the zero position by the controller in order to compensate the influences of the moving joint. In this way the user can see the effect of dynamic coupling i.e. interaction between the robot joints.

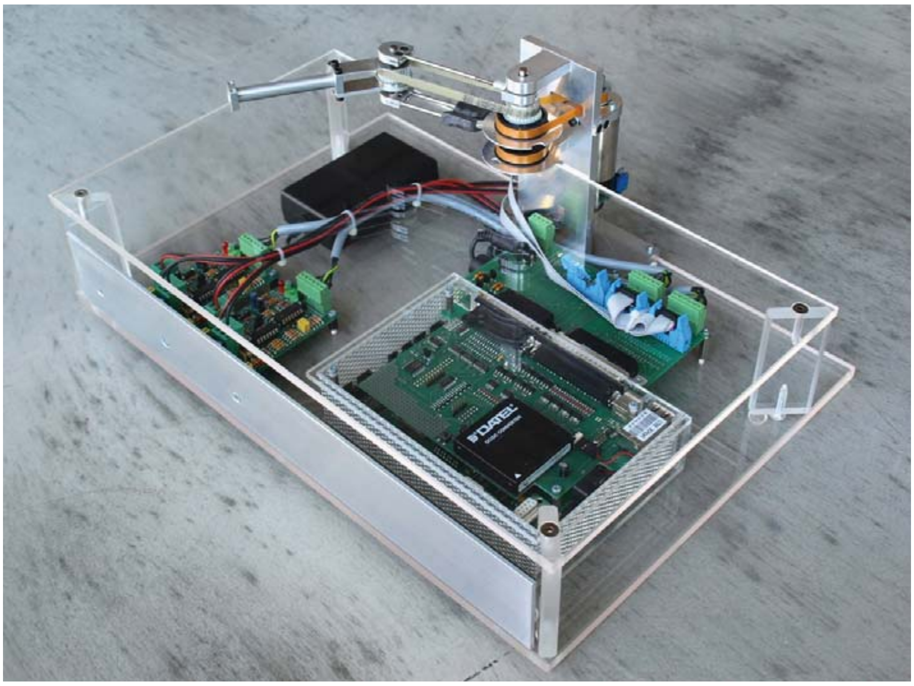

**Figure 4**. Experimental devices: SCARA robot

**Figure 5**. Experimental devices: Servomotor

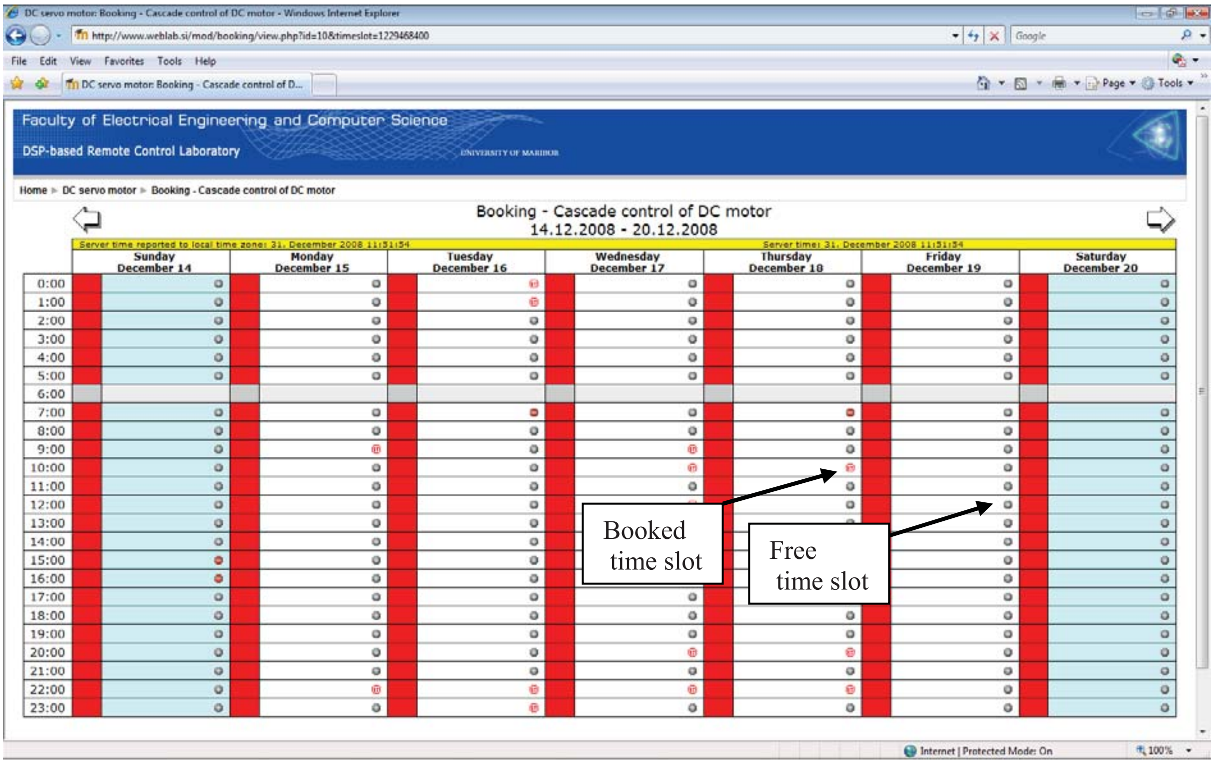


**Figure 6**. Booking of the remote experiments

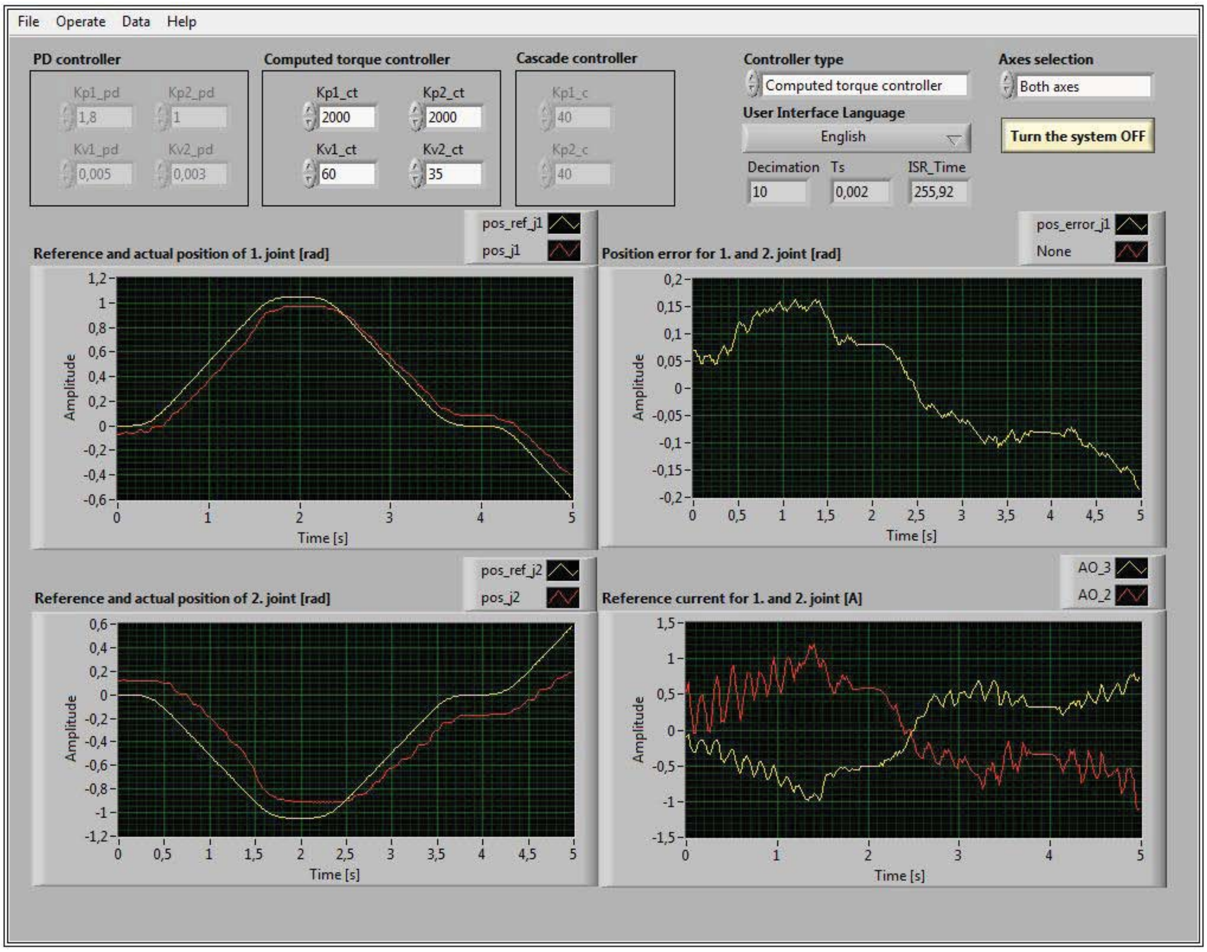


**Figure 7**. User interface for remote experiment with SCARA robot

## 6 Summary

In this paper a state-of-the-art approach to distance engineering education of adults is presented. The approach is implemented in the training of mechatronics which is aimed at the specialists from electrical and mechanical engineering that need also some mechatronics knowledge.

For the training, the web environment which combines two different learning platforms was developed. Within first, commercially available platform eCampus, e-learning materials are available. Second platform is Moodle based and serves for the implementation of remote laboratory with experiments that supplement the theory. In this way the best properties of both platforms are combined in order to obtain very efficient and user friendly learning environment and also to efficiently solve the technical problems that appear at the establishing of remote laboratory.

The training includes four modules, 'Introduction to mechatronics', 'Servo motor in mechatronics', 'Electrical circuits' and 'Mechatronic devices'. Each module is given with theory, tasks and remote experiments.

Some parts of the training were already tested by the local students and improved/updated according to their comments. For the complete training, a pilot testing with around 40 participants is planned. After the pilot testing and necessary updates, the training will be further offered to the potential users from industry and to the educational institutions.

**Acknowledgment**

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## 7 References

[1] P. Bauer, J. Dudak, D. Maga, V. Hajek; *Distance Practical Education for Power Electronics*, International Journal of Engineering Education, Vol. 23, No. 6., 2007, 1210-1218.
[2] D. Gillet, A. V. Nguyen Ngoc, Y. Rekik, *Collaborative web-based experimentation in flexible engineering education*, IEEE Transaction on Education, vol. 48, no. 4, 2005, 696-704.
[3] C. Lazar, S. Carari, *A Remote-Control Engineering Laboratory*, IEEE Transaction on Industrial electronics, Vol.55, No.5., 2008, 2368-2375.
[4] A. Rojko, D. Hercog, K. Jezernik, *Educational aspects of mechatronic control course design for collaborative remote laboratory*, 13th International Power Electronics and Motion Control Conference EPE-PEMC, 2008, 2380-2384.
[5] A. Rojko, D. Hercog, K. Jezernik, *Design of mechatronics course for international collaborative remote laboratory*, International Conference REV 2008, Remote Engineering & Virtual Instrumentation, Dusseldorf, Germany, 2008.
[6] M. Debevc, J. Lapuh Bele, *Usability testing of e-learning content as used in two learning management systems*. *EURODL (Oslo)*, 2008, also available online at: http://www.eurodl.org/materials/contrib/2008/Debevc_Bele.htm . Last accessed 01.01.2009.
[7] D. Hercog, B. Gergič, S. Uran, K. Jezernik, A *DSP-based Remote Control Laboratory*, IEEE Transactions on Industrial Electronics, vol. 54, no. 6, 2007, 3057-3068.
[8] K. Brandl, *Are you ready to Moodle?*, Language Learning & Technology, Vol. 9, Nr. 2, 2005, 16-23.
[9] Remote laboratory web page: *http://remotelab.ro.feri.uni-mb.si*. Last accessed 01.01.2009.