Exploring the Effectiveness of Interactive On-line Exercises in Project Accomplishing in the Course: Intelligent Control Systems*

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This paper presents the experiences with web-based interactive exercises in fuzzy logic teaching. In addition to theoretical lectures, laboratory exercises and a project-based learning environment in 2010, at the College of Applied Sciences in Subotica, web-based interactive laboratory exercises were introduced into the Intelligent Control Systems course in the sixth semester. A set of MATLAB on-line exercises was developed as well as an on-line tool for student assessments and for the formative evaluation of the new web-based learning environment. The effects of the interactive on-line exercises on the success of the project-based learning were examined. The results show the benefit of giving students the opportunity to learn by exploring at any time and from any location. The results of the questionnaire on student satisfaction are also given.

Keywords: interactive learning; project-based learning; formative evaluation; on-line experiments; intelligent systems

1. Introduction

The rapid development of technologies produces an ever-increasing demand for the education of future engineers. Learning is most effective when it involves the learner in an activity, and when it motivates learners to get ahead. Much effort has been put into achieving excellent educational tools for engineers [1], but there are many difficulties in obtaining such learning materials and researchers need to deliver time- and cost-effective engineering education [2]. With this in mind, we have developed a set of on-line interactive exercises to improve engineering education. Laboratory classes are an integral part of almost every educational program, especially in engineering education. The purpose of laboratory exercises is to bring the students closer to real life situations in their area of study, to help them obtain a deeper understanding of the topic under study and to enlarge their knowledge. Applying this knowledge to their laboratory work raises it to a higher level.

Learning by exploring is more exciting and attractive to students than simple reading about a topic as was reported in [3]. Understanding the basics of fuzzy logic can be time consuming. MATLAB has been used in laboratory exercises in control classes as described in [4, 5]. An educational tool has been presented for a fuzzy logic controller in [6]. The Fuzzy Logic E-Book is presented in [7]; it aids self-learning by offering interactive facilities such as animations and demonstrations of application examples. In this paper web-based exercises on fuzzy logic basics are introduced to supplement the laboratory project to design a fuzzy controller for an inverted pendulum. Some of the goals of the development of the interactive exercises were to enhance students learning, and to reinforce student interest in the laboratory classes. Interactive exercises offer an active way of learning, hence our expectation was an increase of student motivation and more success in finishing the laboratory project.

The aim of this paper is to describe the on-line learning material with interactive exercises, and its development process, aided by feedback information from the users, as well as to present the results of the improvement of the learning outcome when the exercises are included.

Distance learning has often been criticized for being no more than content delivery through the Internet. Here a set of exercises is presented that can be used both in distance learning and also within a college as a supplement to lessons and laboratory exercises. Considering that the need for cost-effectiveness in education is especially important, a learning system is created where students just need an Internet connection and a browser to access the exercises. The system was first used for the topic 'linear prediction in speech coding', and later it was extended to other themes. Further topics in which it was used were digital audio signal processing, digital signal processing and fuzzy logic.

The learning material was first tested out at the University of Technical Sciences in Budapest, Hungary and in the Faculty of Technical Sciences at the University in Novi Sad, Serbia; it is in the process of being introduced in the Technical College in Subotica, Serbia. Fuzzy logic is a topic in 'Intelligent Control Systems', which is a compulsory subject in the sixth semester in the Internet Technologies and in the Informatics Engineering courses. Intelligent Control Systems appears as an optional subject in the Mechatronics, Thermotechnics and Ecology, Automatics and Energetics courses, as well as in the Electronics and Telecommunications course. Evaluation of the developed learning material taking into account both the students' satisfaction and the learning outcomes took place in the summer semester of 2010, and will be presented here.

The paper is organized as follows. In Section 2 the architecture of the e-learning system is shown. Section 3 deals with the topics of the course through an illustrative example of the evaluated interactive exercises. A description of the evaluation method is given in Section 4. Section 5 contains the results and a discussion of the evaluation of the learning material.

2. Architecture of the system

MATLAB has been used in creating web based laboratories as described in [8–11]. Figure 1 represents the core of the established architecture described here. MATLAB has its own server, and it also has a built-in common gateway interface that supports communication with the other web-server, connected to the Internet. Several educators from various colleges and faculties can share one server and take advantage of the on-line learning system.

A number of users can carry out the exercises at the same time. The system is configured to run with an Apache web-server to carry out communication with the users' browsers. PHP scripting language is used to create the on-line tasks and the on-line questionnaire. A PHP engine and a MySQL database are used to achieve the registration and login system to the learning object. Students can change specific parameters in each simulation in order to explore the behavior of the model set up by the exercise. They can repeat the experiments with various parameters, submitting them on the website. By modifying the input parameters, students can more easily understand the impact of those parameters on the resulting output, hence the behavior of the explored system. Every topic is associated with a set of questions. Students are given several tasks, which lead them step by step through the topic in question. After finishing these tasks, they should be able to answer the questions in the questionnaire. Registration and logging in became necessary in the implementation phase of the project, when students began to be graded and personal data such as an index number had to be entered. Logging in is requested before filling out the questionnaire and carrying out tasks concerning the selected topics, which demand the completion of the exercises with various, sometimes pre-defined parameters. In addition to the tasks and the questions about them, there is also a survey to collect information about the students' opinions of each exercise and they also have the chance to make comments. The use of the exercises is not conditional on registration, anybody can carry out the experiments as many time as they wish. Students can submit input parameters from the .html file to the MATLAB application. The graphical user interface of an exercise from the set about fuzzy logic is shown in Fig. 2. After carrying out the exercise, the appli-
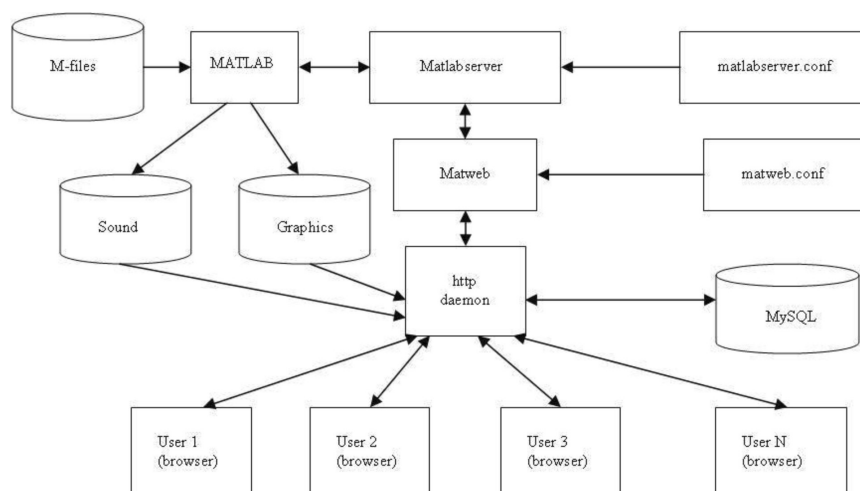

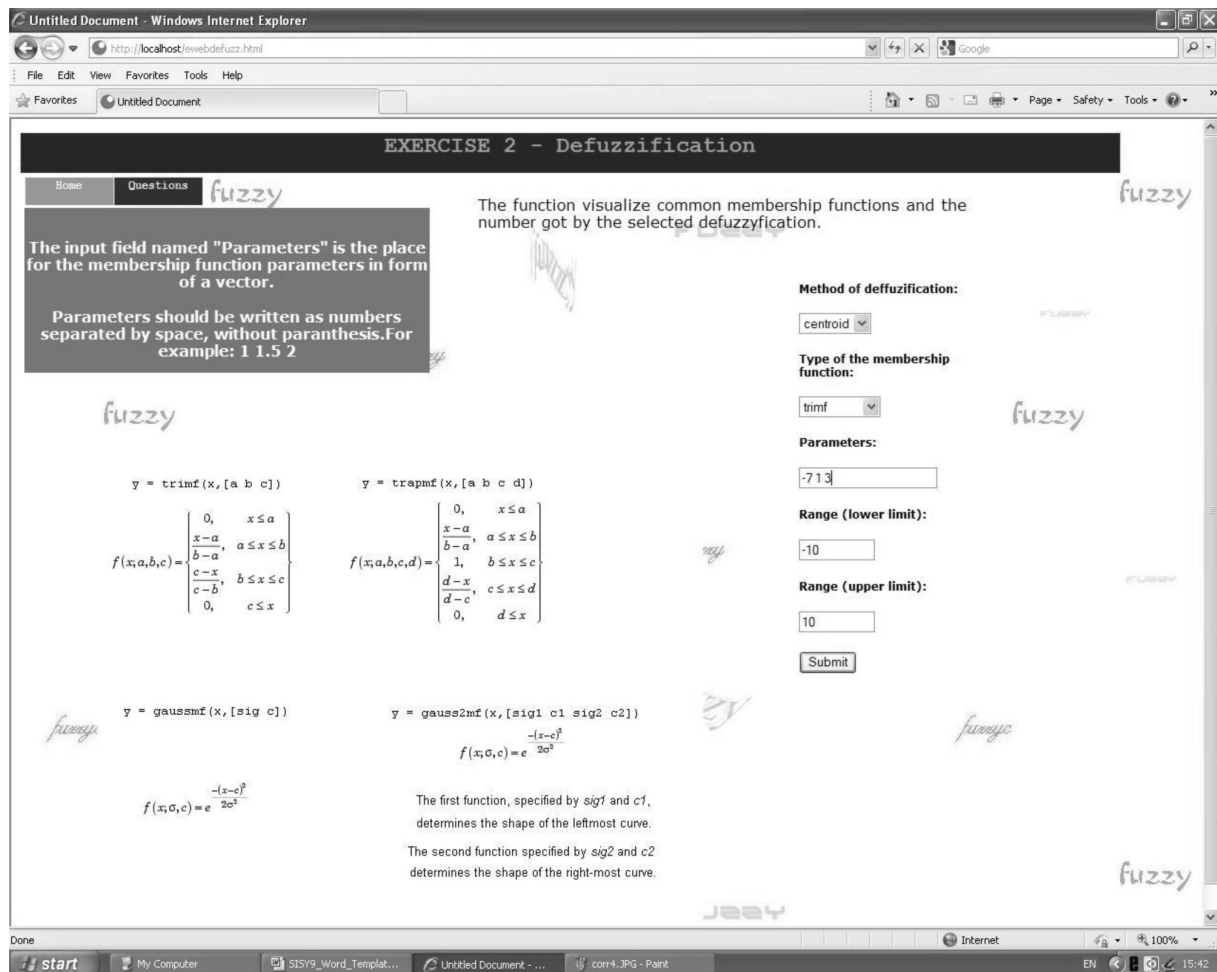**Fig. 1.** Architecture of the system.

Fig. 2. Interactive exercise on defuzzification method GUI.

cation generates the results in the form of graphics and variables.

In the case of the digital audio signal processing topic, the MATLAB applications also generate sound in the form of WAVE files, so outputting the processed speech or music signal [12]. The created sound files can be obtained by the user through a link. The link address is the name of the file generated as a variable in the same application and presented in the output HTML file, where the user can see it, and hear the sound. Every result is delivered to the corresponding user by Apache in a particular .html file.

When too many students use the server simultaneously, Internet bandwidth dependency and possible server overload can become a drawback for the described on-line system as its response time can become large.

3. Example of the evaluated set of exercises

On-line exercises, grouped into five topics, membership functions types, membership function para-

meters, defuzzification methods, fuzzy inference system creation, rules creation and aggregation methods, are developed [13]. The aim of offering such web-based exercises was to supplement the project-based learning, as well as to facilitate learning and improving the students' theoretical knowledge of fuzzy logic. An illustrative example will be given on the topic of defuzzification methods.

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The function itself can be an arbitrary curve whose shape can be defined as a function that suits one from the point of view of simplicity, convenience, speed, and efficiency. $\mu A(x)$ is called the membership function (or MF) of x in A. The membership function maps each element of X to a membership value between 0 and 1. In the exercises students can choose a triangular, trapezoidal, Gaussian or two-sided Gaussian function, and they can specify their parameters. A fuzzy set is a set containing elements that have varying degrees of membership in the set. The membership function $\mu A(x)$ describes the membership of the elements x of
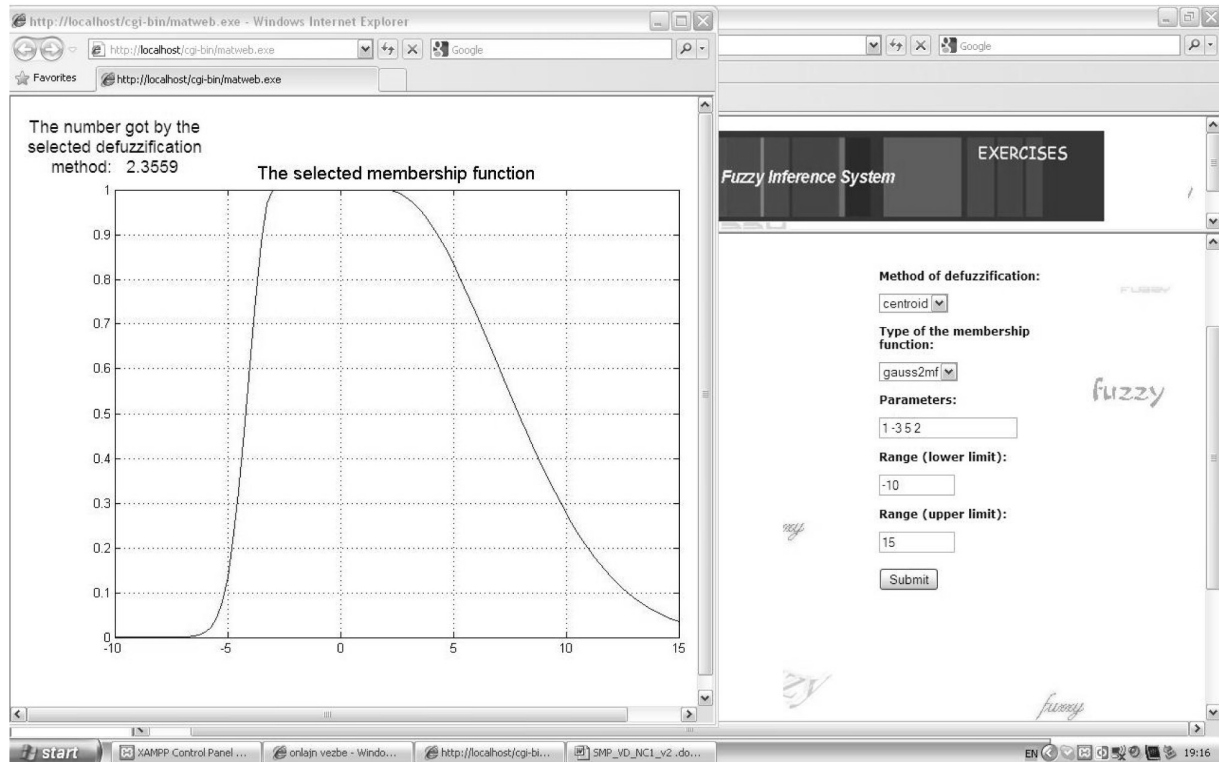
Fig. 3. Result of exercise on defuzzification. After the submission of the selected parameters, the students obtain a single value after defuzzification and a graph of the membership function.

the base set X in the fuzzy set A. The grade of membership $\mu A(x_0)$ of a membership function $\mu A(x)$ describes it for the special element $x = x_0$, to which grade it belongs to the fuzzy set A. This value is in the unit interval [0, 1]. Larger values denote higher degrees of set membership. Membership functions represent the degree of truth. A large class of functions can be taken. Elements of a fuzzy set can be members of other fuzzy sets on the same universe. The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set [14].

Centroid defuzzification is the most widely used method. This can be called the center of gravity or center of area method and it returns the center of the area under the curve. It can be defined by the algebraic expression:

$$C = \int x\mu(x)/\mu(x)dx \qquad (1)$$

The bisector defuzzification method computes the bisector, which is the vertical line that divides the region into two sub-regions of equal area. It is sometimes, but not always, coincident with the centroid line.

The mean of the maximum defuzzification technique takes the output distribution and finds the mean of its maxima to come up with one crisp number. This is computed as follows:

$$z = \sum_{j=1}^{l} z_j/l \qquad (2)$$

where z is the mean of the maximum, z_j is the point at which the membership function has a maximum, and l is the number of times the output distribution reaches the maximum level. The defuzzification methods supported in MATLAB are MOM, SOM, and LOM, which stand for Mean, Smallest, and Largest of Maximum, respectively.

The graphical user interface for the exercise about defuzzification can be seen in Fig. 3. The users can select the type of membership function from those described. The parameters and range of the membership function can be chosen arbitrarily. In the presented case in Fig. 3, a two-sided Gaussian membership function is selected with parameters 1, –3, 5, 2 and a range [–10 10]. The selected defuzzification method is the centroid. The result of the exercise is also shown in Fig. 3. The shape of

the membership function is presented and the crisp value obtained by defuzzification is given.

4. Evaluation method

Evaluating a product such as an educational game or some general learning material is a task that is neither easy nor simple. This is because there are many factors that influence the learning process and the learning outcome. It is difficult to separate the impact of a new learning technology from that of other existing factors.

The European Foundation for Quality Management divides the outcomes of an organization into four categories, and this division is adopted in [15] for the evaluation of educational organizations: (1) student satisfaction, (2) applicability, (3) social impact, (4) results of learning according to the strategic and operational planning, that is, according to the wishes and goals of the educational organization. Student satisfaction is selected as an outcome-variable to describe the effectiveness of virtual learning environments in [15]. Student satisfaction is selected to be one of the parameters in the evaluation of the effectiveness of the interactive on-line exercises that we have developed. The other parameter of effectiveness is estimated from the learning outcome in a project-based learning environment enriched with the on-line exercises.

Modifications to the designs are easier in the first stage of the development. Feedback from representatives of the potential users can serve as guidelines to improve the project. As the technology is improving and the environment is changing rapidly, a formative evaluation needs to be made, even when the project development phase is finished and underway. Often modifications are necessary to enhance the learning objects to keep in step with the growing expectations of the users. Formative evaluation improves a project during the development and implementation phases and it provides feedback during the program development and implementation. Students' voices provide a valuable dimension to the program-enhancement process in education [16]. However, caution is needed when introducing new methods: learners' reactions have to be observed, as well as the effectiveness of the methods in terms of learning outcomes.

The survey applied to evaluate the learning material presented in this work is time-effective as it is in the form of an on-line questionnaire. The students were asked to fill in a questionnaire containing two types of questions. The first part of the questionnaire is a set of tasks and questions about the explored topic. The second type of question is related to the students' opinions about the usefulness of the exercise on a scale from 1 (the least) to 5

(the most). The limitation of a query is the limited spectrum of the possible answers. This problem was overcome by asking the participants to give comments on the learning object or on part of it [3]. In this way, the students express in their own words their perceptions, opinion, and expectations regarding the e-learning material. The qualitative data from the comment entries of the questionnaires can serve to obtain a deeper insight into the students' perceptions and can be used as complementary data to the quantitative data [17]. Our experience is that notes collected in this way are even more useful than the results of the survey in which answers were pre-defined or where the users graded parts of the learning material. Students have mainly interesting and useful ideas about the possible enhancement of the content. At the end of the set of exercises, the students were asked to answer the questions in a final, summarized on-line survey. Data obtained from the final survey were analyzed to obtain insight into the students' points of view of the whole created system and the on-line method of education in question. The results of the survey not only helped to enhance the project, but showed that the interactive exercises were useful, motivating and interesting for the students.

Most of the young people spend several hours a day in front of a computer screen and, while studying, they retrieve most of the information they need from the Internet rather than from a library. Their perception abilities are predominantly audio-visual: they learn more easily from images than from text. Their multitasking capability in their activities is outstanding: they can focus on multiple parallel objects, and they are able to quickly switch between activities. Young people today prefer to learn by exploring, discovering and doing rather than by being told facts and given instructions. They seek interactivity in every segment of learning [17].

The complementary way in which the lecture and lab enhance each other's validity to the students' understanding of the engineering topics is undeniable and is of utmost importance as reported in [18]. Elements of modern teaching and learning environments such as Active Collaborative Learning (ACL) and Project-based Learning (PBL) are being widely adopted in universities as powerful teaching tools. By design, these tools require the actual immersion of students in learning activities [19]. While formative evaluation consisted of the evaluation based on student satisfaction in the early stage of the development, in the stage described here, in addition to student satisfaction, the effect of the on-line system on the learning outcome in a laboratory project was evaluated. In the Intelligent Control Systems course, students had to carry out a project on the topic of a fuzzy logic based control system. The task
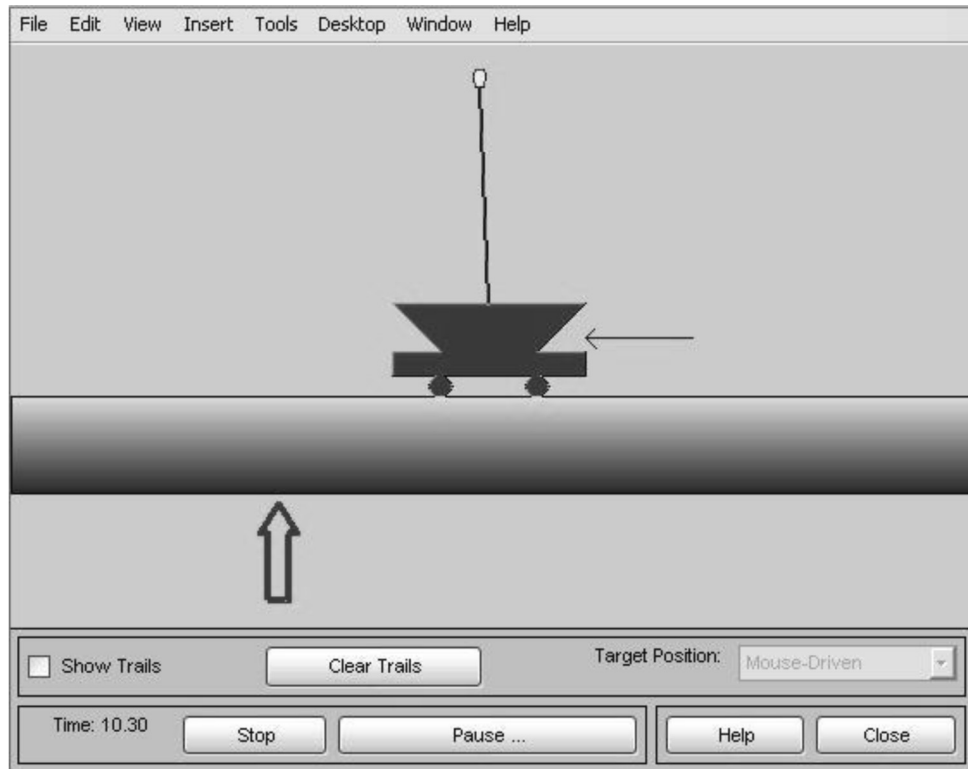
Fig. 4. Animation of the inverted pendulum in the project. Students have to establish the fuzzy rules to bring the inverted pendulum to any selected position.

was to realize an inverted pendulum balanced by a fuzzy controller in the MATLAB environment. The inverted pendulum has to be lead to the target position pointed at by the mouse in the simulation (Fig. 4).

The fuzzy rules of one of the possible solutions are shown in Fig. 5. Every student had a similar task, but they had to solve the problem using different types and numbers of membership functions, as well as using different kinds of fuzzy operators. Students
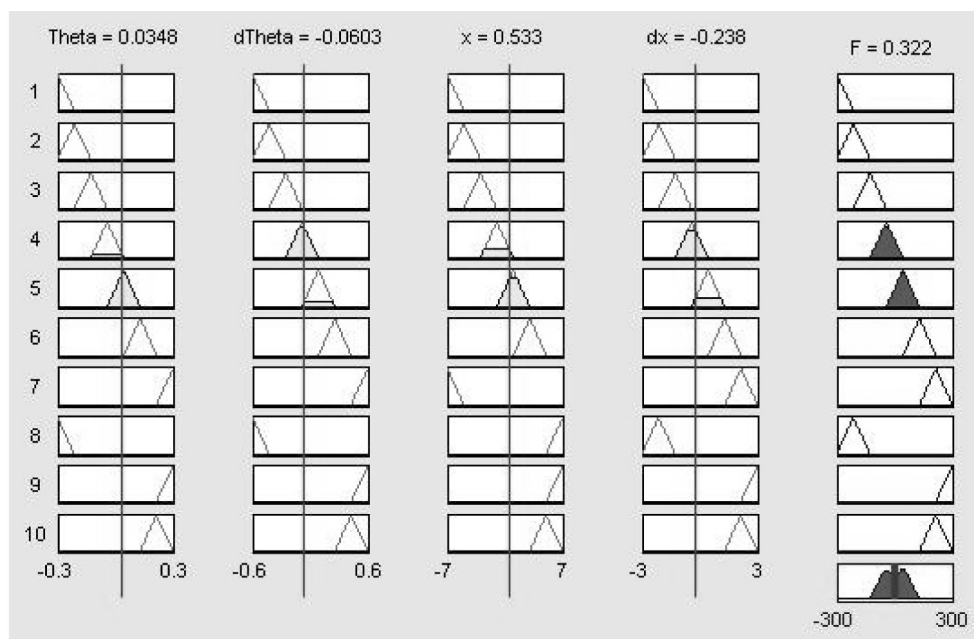

Fig. 5. Ruleviewer of the fuzzy controller in the project during simulation. Ten rules with seven triangular membership functions are acting to create the output force that will push the inverted pendulum to the desired point.
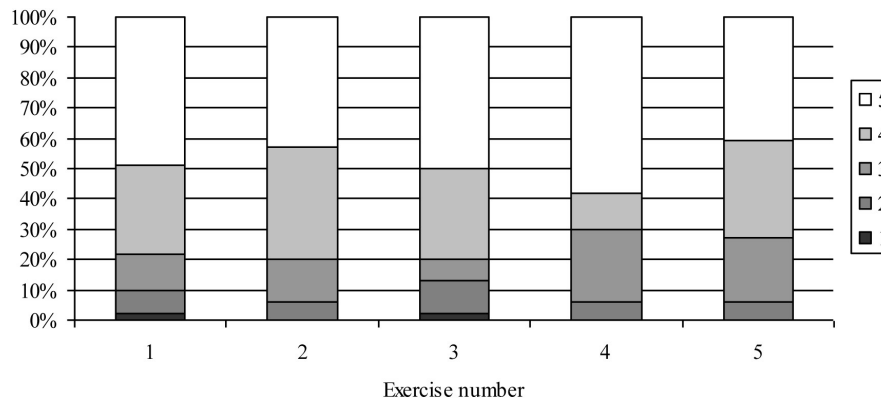
Fig. 6. Distribution of grades given to each particular exercise on the Likert scale.

collaborated in solving the problem during the laboratory classes. The project was supposed to be finished and defended by the end of the period of the laboratory classes in the semester, i.e. the beginning of the exam period in June. The success of completing and defending the project was measured in the group of 107 students who had not had the chance to do on-line exercises about fuzzy logic, as well as in the group of 89 students who were offered the chance to do them. All other student activities and obligations were the same. Theoretical lessons were taught by the same professor and laboratory exercises as well as auditorium exercises were lead by the same lecturer.

5. Results and discussion

Of a total number of 89 students who were offered access to the on-line exercises, 67 of them took up the opportunity. They also correctly answered the question posed in the tasks, except for one single exercise, where most of them commented that they didn't understand the question, which was useful information for the content creators who could correct the question. It also gave an indication that more theoretical explanations were needed and more help items needed to be created on the web-site in the future.

Sixty-seven of the students graded the exercises according to their own opinions. Statistics regarding the students' opinions, comments and statistics about the project's success regarding the students' engagement in the exercises created are given below.

5.1 Assessment of the particular exercises

The students' opinion about the set of exercises was assessed. They graded each particular exercise on the Likert scale (Fig. 6). The results are intended to serve as feedback to the creators of the on-line exercises to show which of the topics need further enhancement or if the students find that any are inadequate.

5.2 Assessment of the final questionnaire

The final questionnaire was filled in by 34 students. It contained the following questions:

Q1: Do you like the idea of on-line exercises?
Q2: Are the on-line exercises easy to use?
Q3: Are the on-line exercises fun?
Q4: Do the on-line exercises make understanding the theory easier?
Q5: Would you like to have the possibility of accessing such learning material in the future?

The results of the final questionnaire based on the Likert scale are given in Fig. 7.

5.3 Final results of the project

Figure 8 and 9 show the distribution of grades given to the project. Grade 0 means that the student did not manage to complete the project before the given term end (deadline). Grades 6 to 10—meaning sufficient to excellent—are for the students who completed their project.

The group of students who finished the interactive on-line exercises as an additional task during the semester was much more successful in carrying out the project to solve the inverted pendulum problem with a fuzzy logic controller. The percentage of students who failed to finish the project in time was halved. The greatest increase can be seen in the percentage of students who achieved the best grade.

A Student's t-test was performed to examine whether the additional tasks increased the success of the project with the null hypothesis that there is no significant difference between the achievements of the two groups of students with a significance level of 0.05. Satterthwaite's approximation for the effective degrees of freedom was used. The test resulted in the rejection of the hypothesis with a significance of $1.9139e-5$.

Of the second group of the students who had been asked to complete the on-line exercises, 21 students
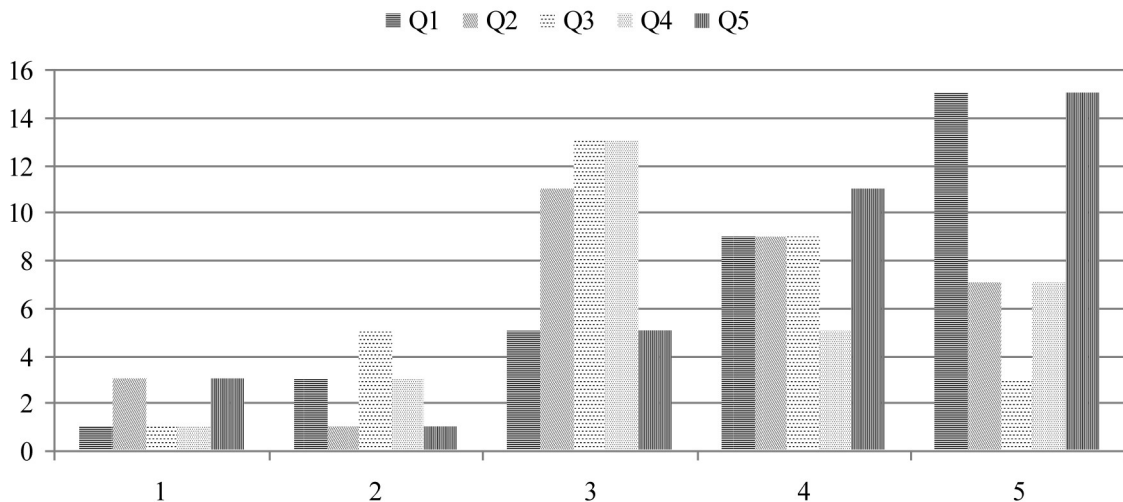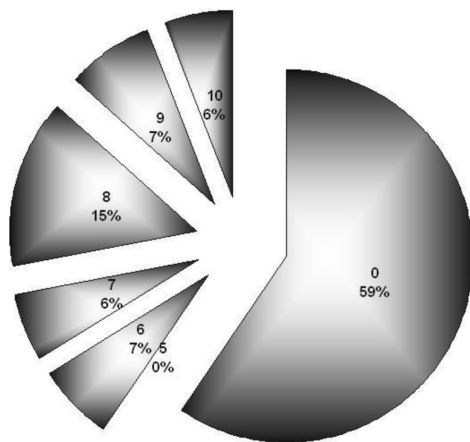
Fig. 7. Students' answers to questions Q1–Q5.

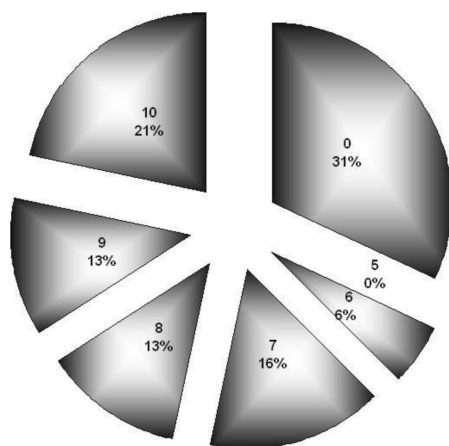

Fig. 8. Success of the project.

Fig. 9. Success of the project when on-line exercises used.

(23%) did not, while 68 (77%) of the students did complete the on-line exercises. Only 28% of the students who did not do exercises finished the project, and 80% of those students who participated in on-line education finished the project.

With regard to the results of the learning enhancement, it can be stated that the enrichment of the learning material that was offered had a positive influence on the students' success in the education topic. The increase in the students' success was not only the result of the students' deeper understanding of the topic under study, but also the result of their increased motivation, as the results of the survey about their opinion on the on-line system showed.

5.4 Students' written feedback

All of the students who participated in the evaluation had an Internet connection at home.

One of the students criticized the appearance of the user interface in the mean of aesthetics. The Internet generation accepts novelty very fast, but it also has high expectations. The learning materials have to be supported by high quality design, because it seems that attractive design can be crucial for taking complete advantage of what on-line education can offer; hence it can have a significant impact on the sustainability of a learning environment. Some of the students stated in the questionnaire that they preferred short exercises. They seem to be impatient, as they expect immediate answers to their questions. Some of the students had creative and interesting ideas about possible supplementary questions and new tasks.

6. Conclusion

The impact of the implementation of on-line interactive exercises on the success of the students' projects is explored. Data about students' satisfaction as an outcome-variable of the effectiveness of the learning environment is assessed for formative evaluation. It was proved that the evaluated interactive exercises enhanced the learning outcome of

project-based learning as well as improving the students' motivation to further explore the studied topic. The examination of the results indicates that web-based exercises could also improve project-based learning environments in other learning topics. The results obtained from a continuous evaluation of the learning environment help the exercise creators to specify future directions for the created system's further development. On-line sets of exercises are not limited in time or space; hence they can bridge the gap between lectures and laboratory exercises. They also can bridge the time gap between laboratory classes as it is always available.

References

1. F. L. Tan and S. C. Fok, Development of a computer-aided educational tool incorporating MATLAB in Engineering Measurements, *Computer Applications in Engineering Education*, **17**(2), 2009, pp. 206–213.
2. D. Gurkan, A. Mickelson and D. Benhaddou, Remote laboratories for optical circuits, *IEEE Transactions on Education*, **51**(1), 2008, pp. 53–60.
3. P. Stanic Molcer and V. Delic, On-line Matlab gyakorlatok formatív evaluációja, *Proceedings of 13th Conference on Multimedia in Education*, Budapest, Hungary, 2007, http://uni-obuda.hu/conferences/multimedia2007/20_StanicDelic.pdf, Accessed 2 June 2010.
4. S Alcántara, C. Pedret, R. Vilanova and R. Moreno, An undergraduate laboratory course on fuzzy controller implementation in FPGAs, *Proceedings of the 16th Mediterranean Conference on Control & Automation*, T10–004, Athens, Greece, July 27–28, 2007.
5. F. Jurado, M. Castrop, J. Carpio and I. Rivilla, Experience with neural networks and fuzzy logic in an electrical engineering control course, *31st ASEE/IEEE Frontiers in Education Conference*, October 10–13 2001, Reno, NV, S1E, pp. 8–13.
6. M. A. Akcayol, C. Elmas, O. A. Erdem, M. Kurt, An educational tool for fuzzy logic controller and classical controllers, *Computer Applications in Engineering Education*, **12**(2), 2004, pp. 126–135.
7. A. Bermúdez, A. Barriga, I. Baturone, S. Sánchez-Solano, FLEB: A fuzzy logic e-book, *European Symposium on Intelligent Technologies, Hybrid Systems and their implementation on Smart Adaptive Systems (EUNITE-2001)*, Tenerife, December 2001, pp. 549–554.
8. M. de Magistris, A MATLAB-based virtual laboratory for teaching introductory quasi-stationary electromagnetics, *IEEE Transactions on Education*, **48**(1), 2005, pp. 81–88.
9. P. Yan, M. Valkama and M. Renfors, Distance learning in communications signal processing using MATLAB web server, *Proceedings of the 6th Nordic Signal Processing Symposium—NORSIG 2004*, Espoo, Finland, June 2004.
10. A. Asif, Multimedia and cooperative learning in signal processing techniques in communications, *IEEE Signal Processing Letters*, **11**(2), 2004, pp. 278–281.
11. W. Chen, A model for assessing web-based simulations in engineering education, *International Journal of Engineering Education*, **25**(2), 2009, pp. 318–323.
12. P. Stanic Molcer and V. Delic, Case study of a cost-effective on-line learning environment development for laboratory class enhancement, *Electronics and Electrical Engineering*, accepted in 2010.
13. P. Stanic Molcer and V. Delic, Web-based exercises for teaching basis of fuzzy logic. *Proceedings of the 7th International Symposium on Intelligent Systems and Informatics*, Subotica, Serbia, 2009, pp. 103–107.
14. T. J. Ross, *Fuzzy Logic with Engineering Applications*, J. Wiley & Sons Ltd, 2004.
15. Ch. Katsidis, P. Anastasiades and V. Zacharopoulos, Assessing student satisfaction in an asynchronous e-learning environment, *Proceedings of 5th WSEAS / IASME International Conference on Engineering Education*, Heraklion, Greece, July 2008, pp. 292–298.
16. E. Ralph, K. Walker and R. Wimmer, Practicum-education experiences: Post-interns' views, *International Journal of Engineering Education*, **25** (1), 2008, pp. 122–130.
17. Gy. Mester, P. Stanic Molcer and V. Delic, Educational games, in *Business, Technological and Social Dimensions of Computer Games: Multidisciplinary Developments*, IGI Global, 2011, in press.
18. R. S. Turner, J. Boone Jr., Z. Ye, and P. Bhattacharya, The importance of lecture and lab configured courses to enhance interests in engineering education, *Proceedings of the 2006 ASEE Gulf-Southwest Section, Patrick Carriere*, Southern University and A&M College, Baton Rouge, Louisiana, March 2006.
19. U. R. Abeyratne, Learning how to learn medical signal processing: A case study, *International Journal of Engineering Education*, **24**(6), 2008, pp. 1084–1090.

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