E2LP: A Unified Embedded Engineering Learning Platform

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Abstract—The main idea behind this project is to provide a unified platform which will cover a complete process for embedded systems learning. A modular approach is considered for skills practice through supporting individualization in learning. This platform shall facilitate a novel development of universal approach in creative learning environment and knowledge management that encourage use of ICT. New learning model is challenging the education of engineers in embedded systems design through real-time experiments that stimulate curiosity with ultimate goal to support students to understand and construct their personal conceptual knowledge based on experiments. In addition to the technological approach, the use of cognitive theories on how people learn will help students to achieve a stronger and smarter adaptation of the subject. Applied methodology will be evaluated from the scientific point of view in parallel with the implementation in order to feedback results to the R&D.

Keywords—technology enhanced learning, embedded systems, learning platform, engineering education

1. INTRODUCTION

Embedded systems are invisible electronics and corresponding software that bring intelligence to objects, processes and devices. The main challenge in engineering education for embedded systems is a complex interdisciplinary approach which includes: understanding of various systems based on different technologies and system solution optimizations.

The significance of laboratory work in electrical engineering education has been widely recognized. It provides engineering education personnel to transform passive listener’s students into active learners, thus stimulating students to actively participate in the learning process [1]. Moreover, knowledge obtained through laboratory hands-on experience has proven to be more profound and more lasting.

Increased role of computer based embedded systems in various industrial applications has produced a growing need for embedded system engineers. As of today, the job market is very competitive for highly qualified electronics systems engineers [2]. Furthermore, the European Centre for the Development of Vocational Training (Cedefop) in its publication "Skills supply and demand in Europe, Medium-term forecast up to 2020" [3] predicts that increase of 10.7% in new engineering positions across all disciplines in Europe will be reached up to 2020, compared to the 2010 level. Similar projections are available for USA by the Bureau of Labor Statistics, U.S. Department of Labor in "Employment Outlook Handbook, 2010-11 Edition" [4] and Asia given in "Employment Outlook Asia: Focus on China and India" written by Mary Anne Thompson [5]. Consequently, many technical faculties have put more emphasis on embedded systems learning by introducing a number of active learning laboratory-based courses [1].

A typical approach in the field of computer engineering education is to have a group of courses for a specific computer engineering topic. Usually, these courses comprise a set of laboratory assignments which are performed using different hardware platforms for each particular course, thus introducing high cost requirements for learning equipment. Further, the dynamics necessary to address industry needs have put teaching personnel under significant pressure to adequately design the laboratory environment for the courses, since updates of the learning environment in an embedded systems course are necessary on a regular basis to keep it relevant. Having this in mind, it is not hard to imagine technical faculties ending up with a set of different and often inconsistent laboratory setups and teaching platforms used throughout the curriculum. As a result, efficiency of laboratory work in embedded systems learning usually suffers from introduced overhead (30%) in both the time and the effort necessary to get students familiar with hardware platforms and software tools for each course.

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The approach in this project targets the lab education efficiency with the idea to use a single comprehensive platform for the complete curriculum. The main intention is to make the educational process more efficient and to introduce more interaction between the education and further embedded system research and development, which facilitates an optimal solution for a specific problem. The main E2LP objective is to efficiently educate future engineers capable of coping with current challenges in real-time embedded computer engineering field. It will further provide a learning environment that moves focus from hardware to software and encourages learning of the embedded systems, but without compromising a knowledge related to the hardware design. Additionally, by introducing a unified platform on a European level, easier interaction in collaborative-education between different scientific institutions will be enabled. Furthermore, the E2LP platform shall introduce a flexible and extendable learning environment for new-coming technologies in embedded systems, thus providing a long lasting educational solution for academia.

The rest of the paper is organized as follows: section 2 summarizes the requirements for the learning platform. Section 3 provides an overview of the concept of the unified platform. Section 4 discusses the central part of the platform – the Base Board. Finally, section 5 gives some concluding remarks.

II. EXPERIENCE-BASED EDUCATIONAL REQUIREMENTS FOR A LEARNING PLATFORM

The empirical evaluation of students’ and teachers’ perception of current courses in embedded computer engineering curriculum was done in the University of Zagreb and University of Novi Sad.

Below the results from the University of Zagreb, Faculty of Electrical Engineering and Computing and University of Novi Sad, Faculty of Technical Sciences are presented. At the University of Zagreb, the numbers of students who responded to the questionnaire were 80 for the Digital Logic and Computer Architecture 1 course, 15 for the Computer Architecture 2 course, and eight for the Multimedia Architecture and Systems course (a total of 183 answers). At the University of Novi Sad, the number of students who responded to the questionnaire was 30 for the Digital Logic and University of Novi Sad, Faculty of Technical Sciences, and eight for the Multimedia Engineering course. Additionally, 13 teachers responded to the teachers’ questionnaire in five course categories at the University of Novi Sad.

To summarize the students' answers, we calculated the percentage of students who marked ‘Very much’ or ‘Much’ for the six items for each of the five selected courses. The outcomes are presented in Fig. 1.

It may be seen in Fig. 1 that 71% of the students marked ‘Very much’ or ‘Much’ for the item “We deal with basic exercises, drills and practice,” which are basic assignments in the taxonomy (scale) we presented earlier in this document.

Further, 61.7% of the students marked that they “deal with solving open-ended small-scale problems or design tasks to meet given specifications and constraints,” which are mid-level assignments in the taxonomy; only 31.1% agreed that they “are engaged in challenging projects”; 44.2% marked that they “face difficulties”; only 3.3% answered that they “work in teams;” and 26.2% answered ‘Very much’ or ‘Much’ for the expression “we develop creativity.”

To summarize the teachers’ answers, we calculated the percentage of teachers who marked ‘Very much’ or ‘Much’ for the six items for each of the five course categories. The outcomes are presented in Fig. 1. It may be seen that 100% of the teachers marked ‘Very much’ or ‘Much’ for the item "The students deal with basic exercises, drills and practice," which are basic assignments in the taxonomy (scale) we presented earlier in this document; 92.3% marked that the students “deal with solving open-ended small-scale problems or design tasks to meet given specifications and constraints,” which are mid-level assignments in the taxonomy; however 0% think that the students "are engaged in challenging projects"; 61.5% marked that the students "face difficulties”; 30.7% answered that the students "work in teams;" and 76.9% answered 'Very much’ or ‘Much’ for the expression "the students develop creativity."

These results indicate that in learning computer engineering, the students deal merely with doing basic exercises and solving simple problems. Much work is required to shift the teaching and learning of embedded engineering and computer science towards enhancing students' higher-order cognitive skills such as problem solving and creativity, and fostering teamwork in the engineering class. These are among the major objectives of the E2LP project.
III. CONCEPT OF THE UNIFIED PLATFORM

The E2LP project concerns a novel development of a unified learning platform for embedded system design, which would serve as a general educational framework for future embedded system engineers. E2LP is supporting the following learning objectives:

1. embedded microprocessors & computer architectures programming (software aspects),
2. digital signal processing (audio, video and data) and its real-time implementation,
3. FPGA digital system design and verification,
4. FPGA accelerated computing,
5. networks & interfaces,
6. system integration.

A. Base Board with Extension Boards

In its essence, the E2LP platform consists of the Base Board and a set of extensions boards. The E2LP base board is supporting learning objectives (3) and (4). In order to support other learning objectives, at least 2 extension boards will be designed:

- microcontroller board, based on ARM-v7 with low power RF IC; supports learning objective (1), (4) and (5),
- DSP board based on Marvell ARMADA 1500; supports learning objective (2).

The E2LP base board and these 2 extension boards are together supporting learning objective (6).

The E2LP Learning Platform provides an advanced hardware platform that consists of a low cost Spartan-6 Platform FPGA surrounded by a comprehensive collection of peripheral components that can be used to create a complex embedded system.

B. Basic Set of Exercises

As embedded designs are becoming more complex, reconfigurable technology is now being seen as a viable option to speed up the embedded engineering design process. This evolution has not only increased the performance of the technology but also put before us the challenge of teaching this technology to computer engineering graduate students. Since this technology is very dynamic, it is essential to teach students the latest design methodologies, based on unified platform using FPGA technologies with advanced sets of exercise.

The basic set of exercises presents library of laboratory examples developed for the E2LP embedded engineering learning platform. It is part of the E2LP startup kit containing identified topics (objectives) in embedded systems: (1) digital system design, (2) computer system design, (3) digital signal and data processing (2D and 3D), (4) computer network and communications and (5) system integration (system software, android development). Library of exercises represents also some solved examples, removing entrance barrier into targeted learning objectives. Entrance barrier is often considered as a limiting factor for enabling students’ creativity in learning because they may be afraid of unknown.

Exercise logistics provides the methodological procedure for creation and implementation of application oriented exercise for embedded systems. It is an educational roadmap for practice for students and it is used for logistics for development of the optimal technical and systematic approach for embedded system application creativity.

At this point of the project we have specified E2LP startup kit describing laboratory examples for each learning objective. The intention is to have three categories of laboratory exercises: (1) basic exercise, (2) problem solving and (3) project solution, which will demand more learning effort through challenging exercises. A starting list of laboratory examples is collected online, by using online library assembling questionnaire, distributed through partners within the consortium, including all necessary information about exercises.

Complete set of laboratory exercises will define topics in digital design and for each exercise it will classify: (1) learning target in the area of the embedded system learning objectives, (2) theoretical background knowledge necessary to understand particular exercise and (3) instructions how to run it on the E2LP platform. Implementation of the Augmented Reality Interface will facilitate all these items for each particular exercise. E2LP start-up kit will be available online.

The developed set of laboratory exercises on E2LP platform will be included in the existing curriculum through academic partners within the consortium for the success evaluation purposes. Identified and recommended updates of the E2LP startup kit will be added to the existing exercise database. It is expected that E2LP courseware will have at least 60 open source laboratory exercises.

The main goals of the courseware are (1) to teach students the fundamental concepts in FPGA-based embedded system design within the preselected topics and (2) to illustrate clearly the way in which advanced FPGA-based embedded systems are designed today, using advanced unified platform and design methodologies and tools.

C. Augmented Reality Interface

The E2LP platform will integrate an Augmented Reality (AR) interface for visualizing, simulating and monitoring invisible principles and phenomena in the field of embedded electronics. This platform should also allow monitoring electronic/mechanical flows by changing a number of parameters. The unified learning platform and the AR interface will be complemented with interaction accessory to allow interaction between AR interface and the electronic board, as shown in fig. 2.
The augmented reality platform will consist of an articulated magnifying glass like usually used in electronics workshops. This articulated magnifying glass will be equipped with a display device allowing stacking virtual information over the real observed scene. For example, the pointer will indicate a complex digital component with numerous pins. Under normal circumstances, to know the affection of the component pins, it is necessary to consult the datasheet and to go through its numerous pages before finding the good figure.

Furthermore, usually, all the pins of the component are similar and it is very frequent to lose the sight of view of the interesting pin when the glance turns away towards the datasheet and comes back. Thanks to augmented reality and to interaction accessory, the articulated magnifying glass will display the map containing the component pins affectations under the real component. Consequently, the task will be perceived as more comfortable, more reliable and more attractive for electronics beginner like student.

D. Remote Laboratory

Laboratories, which are found in all engineering and science programs, are an essential part of the education experience. Not only do laboratories demonstrate course concepts and ideas, but they also bring the course theory into alive. In a traditional laboratory, the user interacts directly with the equipment by performing physical actions (e.g. manipulating with the hands, pressing buttons, turning knobs) and receiving sensory feedback (visual and audio). However, equipping a laboratory is a major expense and its maintenance can be difficult. [6]

Since the experiments are performed in a laboratory that contains expensive equipment, the students must be supervised which limits the time they have. This also requires a class with many groups performing the experiment at the same time, and thus many instruments are required to support each group. Laboratory experiments are also a serious problem for distance learning students who may not have access to the laboratory at all. [7]
experiment using computer commands (to control the experiment) and to see the evolution of the experiment using a webcam.

What makes E2LP platform innovative is that when students interact with the GUIs, they are actually operating real instruments that are set up in a laboratory in some remote location, controlling them via the internet. The output they see on the instrument’s display panels is not a simulation, but is actual data being read from the real instruments, in real time.

A high quality web camera with a very powerful zoom is mounted in the laboratory that allows the remote laboratory users to observe the real instruments as they operate them. The camera has motors which the users can operate to zoom in and read the real displays of each of the instruments, or zoom out and see the whole laboratory set up (Fig. 4).

The E2LP remote laboratory could be equipped with a function generator, which is a laboratory instrument capable of generating different shaped waveforms such as sine waves, square waves etc. at adjustable frequencies and amplitudes. With an input signal applied, students can observe the circuit response waveform on an oscilloscope. A digital multi-meter is also commonly used to measure voltages, currents and resistances.

E. Evaluation Methodology

It is widely agreed that a major objective of engineering education in the 21st century is fostering students’ higher-order thinking skills, such as the ability to analyze and interpret data, identify, formulate, and solve complex engineering problems, and think creatively. However, engineering educators also recognize that developing these skills can take place only if students also acquire basic knowledge and skills in their specialization area such as mechanical, electronic or computer engineering. In addition, engineering education has been increasingly influenced by learning theories such as constructivism and situated learning [8]-[9], according to which human beings construct new knowledge through activity and interaction with the real world, as well as through collaborative and social interaction. Therefore, the most important question in designing and evaluating an educational program is what are students’ activities, rather than what instructors do. With these thoughts in mind, we developed the evaluation methodology for E2LP based on the three-level task taxonomy (Fig. 5). We distinguish between:

- **Exercises**: basic closed-ended tasks in which the solution is known in advance and students can check their answers.
- **Problems**: open-ended small-scale tasks in which students might use different solution methods or arrive at different solutions.

IV. BASE BOARD FOR UNIFIED PLATFORM

The E2LP Base Board performs the following functions:

- based on FPGA, provides the central point of the E2LP platform on which all other parts are connected;
- supplies power for the whole E2LP platform;
- controls programming the FPGA and CPUs on extension boards;
- provides a basic user interface;
- provides storage, multimedia and communication interfaces for the platform;
- provides test points for debugging.

The key building modules of the E2LP Base Board (Fig. 6) are:

- Xilinx Spartan-6 FPGA,
- ARM-based control processor,
- Mezzanine connector to extension board,
- DDR2, flash and multimedia card memory,
- user interface (8 switches, 6 buttons, 8 LEDs, alphanumeric LCD screen),
- snapwire connector,
- CVBS video encoder and decoder,
- video output (VGA, HDMI),
- audio sub-system,
- communication interfaces (USB, Ethernet, RS232 and Infra-red).

V. CONCLUSIONS

This paper presented an Embedded Computer Engineering Learning Platform which aims to be used in the complete curriculum and reduce the overhead in engineering learning. It will ensure a sufficient number of educated future engineers in Europe, capable of designing complex systems and maintaining a leadership in the area of embedded systems, thereby ensuring that our strongholds in automotive, avionics, industrial automation, mobile communications, telecoms and medical systems are able to develop. In such a manner, the E2LP intends to increase European competitiveness in the learning process of embedded computer engineering, ensuring further technological and methodological development of the educational approach in this field.

REFERENCES