OUTCOME OF AN ONLINE LABORATORY TO SUPPORT A MASTER PROGRAM IN REMOTE ENGINEERING

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Abstract

Active learning or working by means of online laboratories is especially valuable for distance working or education. The fact that users in the workplace can access remote laboratories without having to travel makes their flexibility one of the main characteristics of remote engineering. This flexibility is important for teleworking, education, and lifelong learning. As part of a European Union funded SOCRATES project, different universities have developed a Joint European Master Program in Remote Engineering (MARE) which includes a course of "Rapid Prototyping of Digital Systems" in its curriculum, designed by the Technical University Ilmenau, Germany. Implementing the laboratory part of this course as an Online Lab turned out to be a good solution to obtain better learning outcomes. The overall development and evaluation of the online solution was realized at Carinthia University of Applied Sciences, Villach Austria.

Introduction

Active learning or working by means of online laboratories is especially valuable for distance working or education. Users in the workplace can access remote laboratories without having to travel. This flexibility is important for teleworking, education, and lifelong learning. In spite of the well-known benefits of online laboratories, we observed a lack of specialists in this field and the number of needed specialists will dramatically increase in the coming years. As part of a European Union (EU) funded SOCRATES project, universities from Austria, Germany, Ireland, Romania, and Slovenia developed a Joint European Master Program in Remote Engineering (MARE). Remote Engineering can be defined as combination of engineering and telematics, where specific engineering activities like programming, designing, controlling, measuring, sensoring, maintenance, etc. are provided in an interactive manner over a distributed network (Internet, Intranet etc.). It is a special network technology with remote and virtual laboratories as its core. Also, grid technologies are of high interest for Remote Engineering.

Remote Engineering (or more common Online Engineering) is one of the future directions for advanced teleworking/e-working environments, not only in engineering, science, economics, and informatics, but also in almost all other areas of society. In the last few years, in Europe, many projects related to the design and development of remote and virtual labs have been carried out. We can see the same trend overseas. This is related to the growing technical possibilities of the Internet (availability, bandwidth, etc.) and new models of e-learning and e-work. The forerunners in this area are engineering disciplines and natural sciences.

Remote Engineering and Virtual Instrumentation are very future trends in engineering and science for the following reasons:

- The growing complexity of engineering tasks
- The increasingly specialized and expensive equipment, software tools, and simulators required to carry out experiments
- The necessary use of expensive equipment and software tools/simulators in short-term projects
- The application of high tech equipment in Small and Medium Enterprises (SMEs),
- The need of highly qualified staff to control new, specialized equipment
- The demands of globalization and division of labor

all of which make it not only increasingly necessary to allow and organize the shared use of equipment, but also the specialized software employed, for example, in simulators.

This also would benefit people with special needs and people working from their home. Employees working at their company facilities can use remote specialized equipment at another affiliate or company, reducing the need to travel. This may provide new opportunities and benefit SMEs who might not otherwise have access to such equipment.

On the negative side, however, there is currently a worldwide shortage of specialists in this field while the number of needed specialists is expected to dramatically increase in the next few years.

The MARE master study program promotes [1]:

- Basics, applications, and experience in remote engineering
- Design and application of virtual and remote working environments
- Advanced teleworking solutions like online laboratories
- Remote Technologies for complex engineering tasks
- Use of hardware and software, as well as simulators in networks
- New ways for SMEs to access and apply high-tech equipment

The master study program provides the opportunity:

- To use equipment and software tools distributed in the Internet or company intranet
- To organize, implement, serve, and maintain remote solutions
- To let people with special requirements actively participate in labor work

The multidisciplinary structure of the program is shown through the different competencies the participants acquire concerning remote engineering technology and enhanced learning, which accompanies the collaboration among the different partner countries.

The students learn in a dual mode manner (each module is available in traditional and e-learning modes). The study program is a collaboration involving four European universities. The student has the possibility to spend one semester (3 modules) in one of the partner institutions. Parts of this MARE program are also summer-schools. The enrolled students of all partner-universities participate in two TARET (Training in Advanced Remote Technologies) summer-schools. This has a great impact on the internationalization of the study program and for the further development of groups of specialists in this area.

The curriculum of MARE offers a course titled “Rapid Prototyping of Digital Systems”, developed by the Technical University Ilmenau, Germany. Students attending this course learn different methods and concepts to create, implement, and validate digital systems to solve complex design tasks. The goal is to introduce methods and technologies needed for rapid prototyping of digital (embedded) control systems, especially the hardware oriented part of these systems. Students learn to handle modern CAD tools, logic simulation, and logic synthesis using hardware description languages (e.g. Very High Speed Integrated Circuit Hardware Description Language - VHDL), design hierarchy, and current generation field programmable gate array (FPGA) technology. With modern logic synthesis tools and large FPGAs, more advanced designs are needed to present challenging laboratory projects. The course “Rapid Prototyping of Digital Systems” is held during the third semester of the Master Program and includes one-day lectures in which the students are introduced to the course goals and objectives and are informed about how the course will unfold during the semester. The other lectures are carried out in a distance learning mode via the Moodle platform where all the learning materials are available. The necessary support to accomplish the different tasks is given via E-mail or Skype meetings.

The assignments mentioned are composed mainly of lab work where students have to perform some exercises with a “CPLD Board”, a prototyping board developed by the Technical University of Ilmenau, Germany; CPLD stands for

Complex Programmable Logic Device. This board is shown in Figure 1.

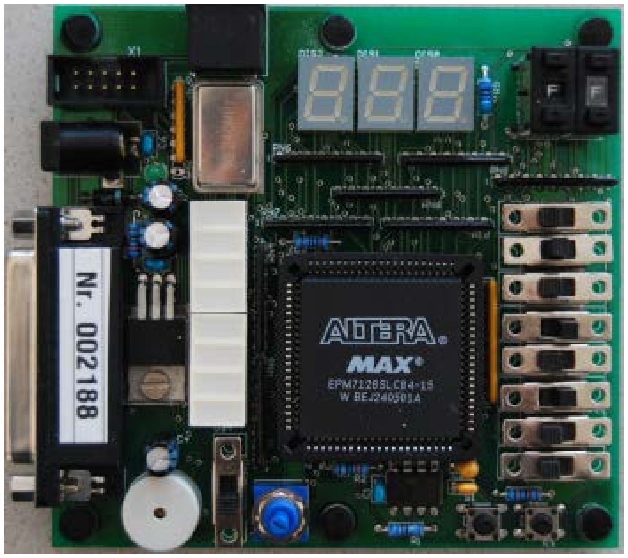

Figure 1. The CPLD Prototyping Board.

Because of the special conceptual design of this board, students are able to test all the topics covered by the given lectures, e.g. basics of Boolean algebra, combinational logic and simple sequential circuits, etc. Furthermore, they can apply and compare different functional specification techniques (e.g. logical equation, truth table, schematic diagram) with both local and Web-based remote access. By using common design tools (e.g. MaxPlus+, QuartusII from Altera[2]), students are able to specify their designs via:

- Text based design methods - students can enter their design by means of logical equations, truth tables or hardware description languages (Altera Hardware Description Language - AHDL, VHDL or Verilog);
- Graphically based design methods - students can use block or schematic diagrams to input their designs;
- Integrated Finite State Machine Editor (FSM editors) – students can directly enter the derived automaton graph (or graphs of parallel automata) with the built in FSME in the case of sequential design tasks.

The editor itself generates VHDL code for the further design steps.

Another use of the rapid prototyping board is to identify the function of a given design (black box). The FPGA (Field Programmable Gate Array) is programmed by the teacher – students cannot reprogram the device. By manipulating the inputs of the design (e.g. to enter all the input sets of a truth table or special input test vectors), students analyze the response (the output signals) to evaluate the function of the given design.

During the course, students have a prototyping system at their disposal. Because the course was taught at a distance, the hardware had to be transported between the partner institutions. This situation led to the idea of developing an online laboratory with the already used prototyping board, where students could carry out exactly the same experiments as in the hands-on version of the platform. Design, construction, implementation, and testing of the online laboratory were done at Carinthia University of Applied Sciences, Villach, Austria and the online laboratory was included in the Massachusetts Institute of Technology (MIT) iLab Shared Architecture (ISA) so it could be used worldwide.

The iLab Shared Architecture

MIT's iLab Shared Architecture is used by Carinthia University of Applied Sciences (CUAS) in Villach, Austria, as a solution to deliver online laboratories to students, researchers and teachers from all over the world.

Our institution is using ISA because it has some important advantages in contrast to other solutions. For example, it offers online laboratory developers and users a common framework to use and share online laboratories and facilities, manage laboratories, and user accounts in a scalable manner.

This architecture started as an attempt to address the technical problem of sharing and managing online laboratories and became part of a broader initiative, together with other technologies that aim to create standardized interfaces and establish a global community of online laboratories[3].

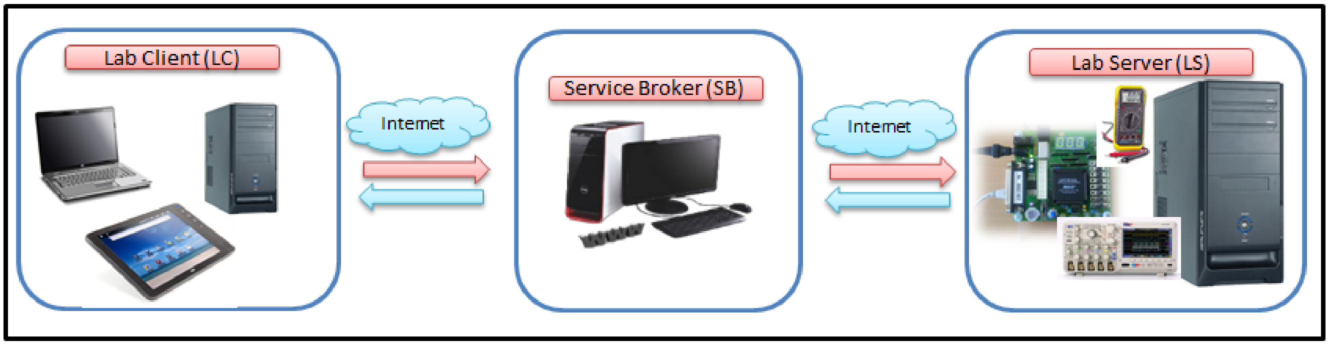

Figure 2. MIT's iLab Shared Architecture Components.

As can be seen in Figure 2, the iLab Shared Architecture divides the online laboratory into three distinct parts: the Lab Client, the Service Broker, and the Lab Server. The Lab Client, which is, in fact, the student's client application, usually runs as a downloaded application or applet on the user's computer and the service broker provides the shared services. The Lab Client communicates with the service broker, which then forwards experiment specifications to the Lab Server, including the lab equipment, while, at the same time, the Lab Server notifies the Service Broker when the results are ready to be retrieved[4].

The CPLD Online Laboratory

The work presented in this paper is based on a student evaluation of a system for rapid prototyping and testing of digital systems which allows users to remotely perform tests on real devices over the Internet, as well as design digital systems with the Altera Max + Plus II development environment.

The CPLD used is based on the Altera's MAX® architecture and supports in-system programmability (ISP), making it easily reconfigurable in the field. The MAX II CPLD family is based on a groundbreaking architecture that delivers the lowest power of any CPLD Family[5].

The device is hosted by an evaluation board containing the interface needed to program the CPLD and other peripherals like LEDs, push buttons, 7 segment displays, and hexadecimal and on-off switches connected to I/O lines of the device (see Figure 1). Students, like in the traditional hands-on laboratories, can program the device to interact with these peripherals and test the functionalities and the real behavior of the programmed functions.

The CPLD Online Laboratory was developed as a plug and play remote solution, and communications with the real device were made via a communication board, based on one PIC18F4550 microcontroller and two MCP23S17 Port Expanders from Microchip.

LabView remote panel technology was used to deliver the remote clients. LabView Software provides a built-in Web server that is used to publish the Web pages, including the embedded interfaces (front panels). A LabView run time engine is necessary to allow Web browsers to run the remote panel. It contains a plug-in that enables the remote panel to work on the client's Web browser, while the virtual instrument actually runs on the server side[6].

The MAX+PLUS II software was not eliminated from the online solution because it was the only way that the students could realize the course assignments. In this implementation it was delivered to remote users via a Citrix Presentation Server, which allowed them to access the desired application that ran on the server. By a mouse click, screen-updates and keyboard controls were transmitted in a 128bit encrypted connection over the internet and the users had the feeling of running the application locally on their machines[7].

Figure 3 shows the steps through which users have to pass in order to work with the CPLD online laboratory.

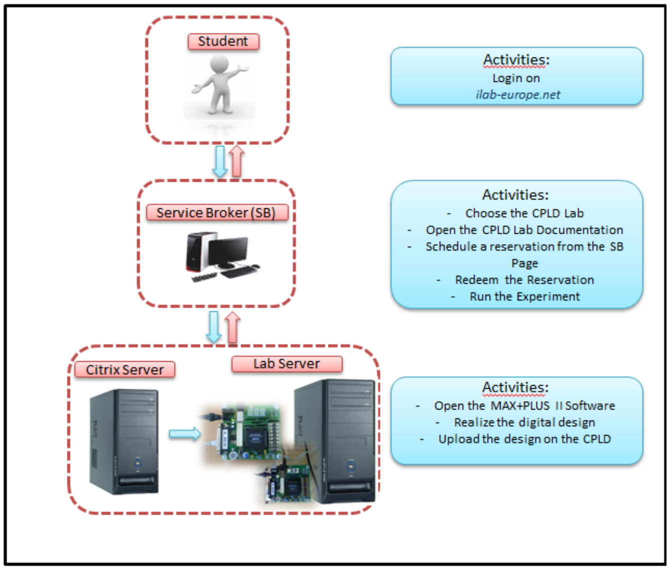

Figure 3. CPLD Online Labs Steps.

Every student has to have an account on the www.ilab-europe.net page, where all CUAS online laboratories are hosted. With a simple login they are able to see laboratories available on the network. After accessing the CPLD Online Lab, they are sent to a new page where they can choose to realize different activities: to open the user interface, the Webcam which shows the real device, the documentation of the CPLD Online Lab, the MAX+PLUS II development environment, or the exercises to be realized.

After the login process is realized and the CPLD Online Lab is chosen, the students have to open the documentation, assignment documents, and the MAX+PLUSII Software. They have to realize the digital design, upload it on the real board, and afterwards pass to the next step, which is to access the user interface. On this platform, they are able to run the experiment as if they were next to the real prototyping board. For a double check of the laboratory, the students can, at any time, see how the real device is reacting through a Web cam placed on top of the real device with a direct link to the service broker.

Results of a Student Survey

Taking in consideration that this process of using the CPLD laboratory online is a new strategy for the MARE program, and that our objective was, in part, to evaluate if remote laboratories can totally replace the local ones, we decided that the first group of students to attend this course were to work with both solutions.

At the end of the course, each student was asked to fill in a short questionnaire which was used later to analyze the acceptance and usability of the remote solution.

Pilot testing of the laboratory was performed with students enrolled in the remote engineering specialization program at the Carinthia University of Applied Sciences, Villach, Austria. For all students, this was their first experience working with a remote laboratory.

There were 25 students enrolled in the System Design Master Program when the survey was realized.

This evaluation used several types of questions to obtain its statistical results, including open-ended, matrix, and graded questions. The open-ended questions offered students the possibility of personally expressing their opinions. The matrix questions allowed students to assess certain specific aspects of their experience and provide their feelings about them.

A final gradient question was used to determine the students' degree of global satisfaction when using the online solution of the CPLD laboratory. As part of their response, students had to score the laboratory according to their opinions.

Figure 4 shows that more than 80% of the students already used the local solution of the laboratory while only approximately 11% had not.

As Figure 5 shows, 78% of the students answered "YES" and 22% answered "NO" to the question "Do you have at home all the necessary equipment for the execution of the CPLD Remote Experiment?" Further conversations with the 22%

of the students who answered NO to this question made us realize that the question had not been carefully read, as they had understood that it was in reference to the local experiment. For the local experiment, the students would need a serial communication connector at home.

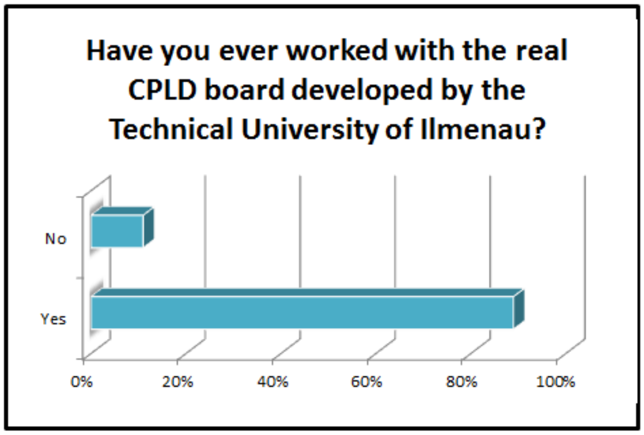

Figure 4. Was the local CPLD Board ever used?

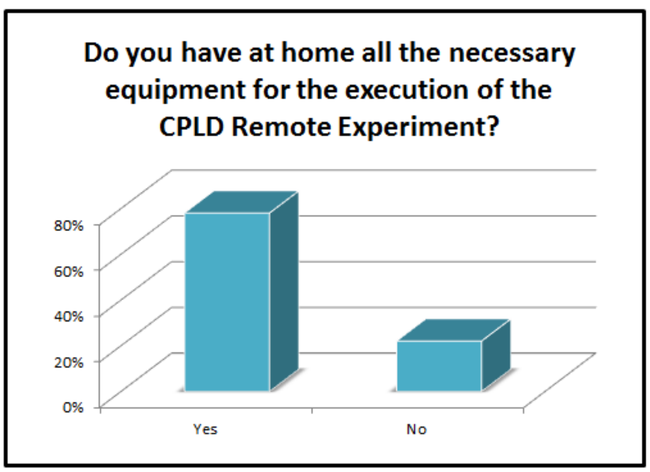

Figure 5. Possessing the necessary equipment for the execution of the online laboratory.

When analyzing the results regarding the question of whether or not CPLD Online Laboratory was suitable, we discovered that more than half of the students (56%) could not decide if the remote solution is more suitable than the local one, while 22% of them answered "YES" or "NO". This clear separation of the user responses can be seen in Figure 6.

As Figure 7 shows, 78% of the students agreed that the CPLD Online Laboratory could totally replace the local experiment, while 11% could not decide or said that this would not be a good idea.

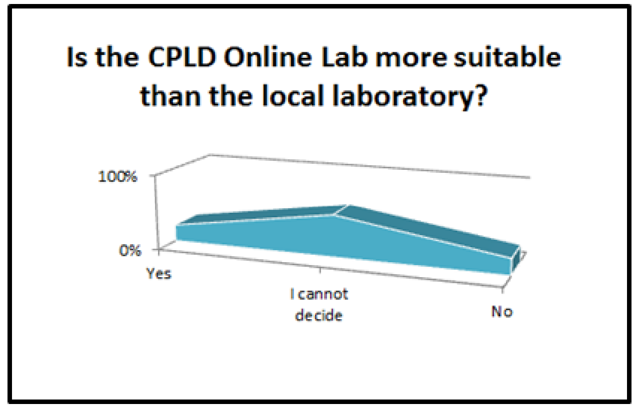

Figure 6. Suitability of the CPLD Online Laboratory.

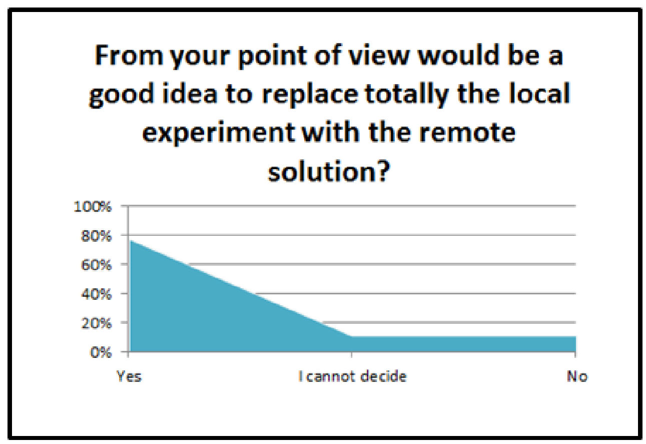

Figure 7. How good is the idea of replacing the local experiment with the remote laboratory?

The question: "Being far from the prototype, have you felt yourself to be in control?" was asked to discover whether or not students felt in control. The answer was positive as 89% of the students said "YES", while only 11% of the respondents did not feel they were sufficiently in control and answered "NO".

To the question: "While working with the CPLD Online Lab, have you learned more than if you performed the real experiment?", 56% of the students answered that they could not see any difference between the two solutions, while 22% of the students answered “YES” and 11% replied “NOT REALLY” or “NO”.

All of the students agreed that the CPLD Online Laboratory has a friendly user interface. To the question: “Do you think the CPLD Online Laboratory has a friendly user interface?” all of the users answered “YES”.

Because our interest was to discover the problems that can occur during the use of the online laboratory, the following question was asked: “Have you had problems using the MAX+PLUS II Software Online?” This question was an open question to give students the freedom to express themselves. The answers will help us to improve future implementations with the MAX+PLUS II Software. Even though a significant number of respondents reported they had no problems using the software online, others reported some difficulties. The most important difficulty is that if a preceding user had not disconnected from the Citrix Server after the end of the session, subsequent users could not connect to the MAX+PLUS II software anymore.

Conclusions

We conclude that replacing the traditional hands-on laboratory with a remote laboratory practice did not hinder the learning process. As far as global satisfaction with the CPLD online laboratory is concerned, the results help us to strengthen our claim that the remote solution has the same effect on student satisfaction as the local one.

Using both online tool support and laboratories has the potential of removing the obstacles of cost, time-inefficient use of facilities, inadequate technical support, and limited access to design and laboratory resources. This also benefits students and researchers with specialized needs and students/researchers working from their homes so that they do not have the need to travel to their company facilities. Even students/researchers working at their university facilities can use remote specialized equipment at another university without having to travel.

Students learn more about the limitations and possibilities of remote control and observation via Internet by practical examples. The prerequisites students need for this are only a Web browser and an access slot, which they can obtain from the brokerage software (time reservation). By working in a distributed lab environment, students can also use experiments developed at other universities, which users may not be able to find in their home universities.

Last but not least, the use of online experiments in online engineering learning environments enhances learning activities. In engineering education, the experimental part (and not only simulations) of courses should be increased. What students need is a plan for testing the experiment under various conditions. Because of the need to repeat experiments, laboratory time in traditional labs is often quite limited. However, students can work in remote labs 24 hours a day and seven days a week, so the opportunity to gain access is greater than in traditional hands-on labs.

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Biographical Information

Since 1995, Michael Auer has been professor of electrical engineering at the Systems Engineering Department of the Carinthia University of Applied Sciences, Villach, Austria, and has also held teaching positions at the universities of Klagenfurt (Austria), Amman (Jordan), Brasov (Romania), and Patras (Greece). He was invited for guest lectures at MIT Boston, Columbia University, and the technical universities of Moscow, Athens, and others. He is a senior member of IEEE and a member of VDE, IGIP, etc., author or co-author of more than 180 publications, and a leading member of numerous national and international organizations in the field of online technologies. He is Founder and Chair of the annual international ICL and REV conferences and Chair or member of the program committees of several international conferences and workshops. He is editor-in-chief of the International Journals of Online Engineering (iJOE, http://www.i-joe.org/), Emerging Technologies in Learning (iJET, http://www.i-jet.org/), and Interactive Mobile Technolgies (iJIM, http://www.i-jim.org/). Auer is Founding-President and CEO of the International Association of Online Engineering (IAOE) since 2006, a non-governmental organization that promotes the vision of new engineering working environments worldwide. In Sept. 2010, he was elected as President of the International Society of Engineering Education (IGIP). Furthermore, he is a member of the Advisory Board of the European Learning Industry Group (ELIG).

Diana Vasilica Pop graduated in technological engineering at Transylvania University of Brasov, Romania, and obtained her Master degree in System Design (Remote Systems specialization) at Carinthia University of Applied Sciences in Villach, Austria. Her research interests are in the field of remote technologies and online labs services oriented architectures. Diana was Graduate Researcher at Carinthia University of Applied Sciences (CUAS), Villach, Austria where she was engaged in a Europeean Project together with UNINIVA-Instituto de Desenvolvimiento de Novas Technologias from Portugal and the work performed was related to the development of online laboratories. She is now with Infineon Technologies Corp. Austria and holds a position as software engineer.

Danilo Garbi Zutin graduated in electrical engineering at the State University of Sao Paulo (UNESP), Bauru, Sao Paulo, Brazil, and obtained his master’s degree in systems design (specialization in remote systems) at the Carinthia University of Applied Sciences in Villach, Austria. His research interests are in the field of remote engineering, online labs, remote control of devices, and software development for online labs. Garbi Zutin is currently a Senior Researcher and team member of the Center of Competence in Online Laboratories and Open Learning (CCOL) at the Carinthia University of Applied Sciences (CUAS), Villach, Austria, where he has been engaged in projects for the development of online laboratories. In Jan. 2010, Garbi Zutin was appointed Secretary General of the International Association of Online Engineering and, in the following year, Secretary General of IGIP (International Society for Engineering Education). Garbi Zutin is author or co-author of more than 30 scientific papers published in international journals, magazines, and conferences. Most of these papers are in the field of online laboratories and issues associated with their dissemination and usage.