Towards the integration of Remote Laboratories into Learning Management Systems.

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Abstract

The inherent limitations imposed by time and space boundaries to the use of laboratories in experimental disciplines can be overcome by using the tools provided by the communications technologies.

In this work different approaches to the design and implementation of a remote laboratory are presented. The remote laboratory is integrated into an open source e-learning platform.

1. Introduction

One of the most important factors in achieving the engineering graduate competencies is the experimental component of the engineering curriculum. The employers of future engineering professionals expect that graduate students have acquired and developed a set of practical skills during their undergraduate education. These skills, provided through the work into an engineering laboratory, are: experiential learning, development of team work abilities, interaction with real industrial equipment, and capacity to work with experimental data.

The work in a real laboratory imposes time and physical limitations both for students and teachers. It requires an important financial investment to buy the required equipment. The rational use of the laboratory resources requires also a significant scheduling effort because usually the number of students is greater than the available experimental equipment.

Modern education encourages the use of new methods such as open-learning, flexible learning, and interactive multimedia. All these methodologies are supported by the use of Information and Communication Technologies (ICT), mainly the Internet. Recently in the European countries, mainly due to the process of convergence to a common educative space, the universities are strongly advocating for the introduction of these technologies in the learning process and the adoption of online delivery of courses.

This mixture of face-to-face teaching with on-line learning activities is known as “blended learning” [1] that could be defined more formally as “... learning that is facilitated by the effective combination of different modes of delivery, models of teaching and styles of learning, and founded on transparent communication amongst all parties involved with a course.” [2].

In this context, the time and place constraints that impose the use of laboratories could be dismissed by the introduction of ICT in the access mechanism to physical equipment. This result in two main approaches: virtual laboratories and remote access to real laboratories. In the first approach the cost and availability constraints are alleviated by using simulated experiments. In the second, communication technologies, mainly Internet, are used to provide access to real laboratory experiments from anywhere at anytime. Several models of remote laboratories have been reported in the literature, for instance, the control of a servo drive and a DC motor [3], access to an oscilloscope [4], etc.

In this paper we will focus in this last approach and we will present the main steps towards the integration of a remote experimentation environment into a Learning Management System (LMS).

The paper is structured as follows. The next section introduces the application context of the current virtual laboratory architecture. Section 3 describes the structure and components of a traditional microcontroller laboratory. The subsequent section introduces the open remote access framework to the real devices. Section 5 presents the basic steps in the integration of the remote laboratory into a standard open source LMS called Moodle. Finally some
conclusions concerning the proposed model are discussed.

2. Context

The Universitat Rovira i Virgili (URV) is immersed in the transformation process necessary to adapt its graduate and postgraduate programs towards the European Higher Education Area defined by the Bologna Process in 2004 and to be realized by 2010. This adaptation process relies heavily in the use of ICT to introduce open and flexible learning models at the higher education level. From the point of view of the curriculum of a computer engineer, the experimental component is one of the strongest elements in their competency profile. The successful implementation of these student-centred models will have a strong influence in the way that laboratory work is done.

In this study we propose a set of changes to improve a traditional laboratory introducing a high level of flexibility and openness in the way that students perform their experiments. The laboratory selected to assess these new models is related to computer architecture subjects and corresponds to a course on Microcontrollers. The number of students per course fluctuates from 20 to 25.

One of the key points in the computer engineer curriculum is the concept of the architecture of a microprocessor. With the advent of VLSI technology, microcontrollers serve as an embedded controller and could be found within a range of household, industrial and commercial products; such as engine control, washing machines, microwave ovens, and other industrial automation products. Every day, microcontrollers are more powerful and reliable, they have become a low-cost alternative to solve a great range of industrial problems, not only for data acquisition and processing but also to solve monitoring and control problems. Microcontrollers have additional functions such as digital and analog input/output and timing systems, which make them suitable for solving a high range of monitoring and control problems instead of using a general-purpose microprocessor.

Furthermore, microcontrollers can be used as a fundamental paradigm to teach and demonstrate the basic architecture of a basic microprocessor. Microcontrollers have a simple architecture and allow direct access to memory, input/output and interrupt systems. Moreover, they offer facilities to program and debug code using assembler as well as high-level languages such as C.

In the microcontrollers laboratory the project proposed to students is to use a microcontroller to monitor and control the rotation speed of a DC motor. To complete this project, they must discover how to sense and measure the speed of the motor, how control the rotation speed and, finally, how to interface with users to allow interaction. Moreover, they must interconnect the microcontroller with other devices such as sensors, keypads, motors, and LCD displays.

During their laboratory work students learn the different functions of the microcontroller and develop small blocks of code as laboratory exercises that will be used later to solve the overall project.

In this way, students not only learn about microcontroller characteristics but also learn how to apply a microcontroller to solve real-world problems. These kinds of problems are very challenging to students and improve their motivation in this subject matter [5].

3. Description of The traditional Microcontroller Laboratory

Usually, in the design of a microcontroller laboratory, the only decision we have to deal with is the selection of the microcontroller chip. In our laboratory we selected a widely used microcontroller, the Intel 80C196KC because it offers a great range of tools to help students in the development of applications. The laboratory holds several workplaces equipped with an EV80C196KC evaluation board (see figure 1).

![Figure 1. Schematic of the EV80C196KC evaluation board.](image)

Each workplace has two additional target boards. The first one is connected to a keypad and a LCD display (LCD MC16201). The other is attached to a sensor (TFR223) and a DC motor.

Figure 2 shows the basic arrangement corresponding to a typical control experiment. This settlement provides the real-world like application that students must handle during their experimental sessions.
Each workplace also includes an oscilloscope; a function generator and a power supply that can be used to develop specific blocks of code that are focused towards the learning of special functions of the microcontroller such as pulse width modulator (PWM) or analog inputs. The students will need these blocks later in order to implement their final assignments.

The interaction with the microcontroller is handled by the computer using some specific software. The evaluation board used in the laboratory provides the following software:

- **Reduced Instruction Set Monitor (RISM-96).** Provides a set of instructions that allow the microcontroller to communicate with another device using a standard RS232 serial port.
- **Embedded Controller Monitor (ECM-96).** It is a MS-DOS program that allows users to interact with the microcontroller. This program interprets the user commands and encodes them into RISM instructions.
- **ASM compiler and linker.** This is a set of free software to develop low level programming projects using assembler.

In addition, another set of higher level tools is available to help the students during the process of design and implementation of their programming projects:

- **Tasking Embedded Development Environment (EDE 196/296).** This is a project management tool which provides editing, building and debugging capabilities for several microcontroller of the MCS96 family.

- **Project Builder 196 (ApBUILDER. Intel).** It is an Integrated Development Environment (IDE) that allows the graphical development of applications without prior knowledge of the 196 microprocessor architecture. This application builder generates both C and assembler code.

All these software and tools are in a laboratory with restricted access that remains open only when the teacher is present. This access restriction is a major difficulty for students that are unable to finish their assignments on-time. An increase in the lab accessibility would probably allow these students to finish properly their experiments but this would require more teacher or laboratory staff time that is not always available. An alternative solution would be to transform the laboratory into an open remote facility.

4. Open Remote Access to the Microcontroller Laboratory

Remote Laboratories [6] are a new development concept but the rapid development of the Internet and the availability of tools for its design and implementation have produced an important increase in their number.

This approach represents the best alternative to working in a real laboratory because if properly designed they can offer students:

- to perform experiments on real equipment
- to collaborate with other students
- to learn by experimenting
- to perform analysis on real experimental data

And additionally they also offer (i) flexibility in choosing time and place for performing the experiments, and (ii) some sense of tele-presence in the laboratory.

4.1. Main Components of the Remote Laboratory

Our main objective is the development of a system that would allow several users to perform experiments remotely simultaneously. The basic idea is that students could be able to control remote instruments over the Internet using a simple web browser.

Figure 3 depicts the main functional components of our model. Students are able to access the laboratory devices through their Internet connection.

The main components of the proposed framework are (i) the remote access server, and (ii) the real device gateway. The functional separation of these two components allows for a better uncoupling between the management interface and the physical access to the real device so that changes in the low level layer will have low impact in the overall architecture.
Figure 3. Main components of the remote laboratory facility.

The remote access server receives user’s commands and resends the appropriate instructions to the microcontroller through the device gateway. The server can retrieve data from the equipment and send them back to the client interface when requested by the user. In addition, a video camera would allow users to see the equipment and monitor in real-time the execution of their commands.

4.2. The TINI-board based Approach

The first approach to the implementation of the previously proposed model was through the use of a java processor with an embedded web server. The selected system was the TINI board from Dallas Semiconductor [7].

The TINI platform (figure 4) is a microcontroller-based development platform that executes code for embedded web servers. The platform is a combination of broad-based I/O, a full TCP/IP stack, and an extensible Java runtime environment.

By using this approach both components, the remote access server and the device gateway, were implanted into one single element. The main advantages of this solution are twofold. First, we have a low cost component that can be used to connect the microcontrollers to the Internet world providing universal access to the laboratory. Second, the component is fully programmable using the Java language and supports its own web server as well as the servlet programming model so it is very easy to implement the management interface into each TINI board (booking system, program uploading, memory inspection, etc.). Figure 5 shows the microcontroller connected to the TINI through and E10 evaluation board.

The major drawbacks of this approach are that only a very simple servlet engine could be used due to memory restrictions in the board. Furthermore, as the processor uses a reduced set of the java language corresponding to the J2ME specification it is very difficult to integrate high level services as for instance database access and a robust user control and authentication.

4.3. Improving the I/O capability

The previous implementation allows students to interact remotely with the laboratory equipment avoiding the problems related to openness. However, it presents some limitations for the use of input/output devices mainly because inputs are fixed and students couldn’t change them.

In order to solve these restrictions, we have extended the functionality of the remote laboratory including the generation of input/output signals that can be controlled remotely using a web interface.

The first step was to replace the TINI board by an enhanced board, the Taylec’s TutorIO [8]. This board has better IO capabilities. It provides 8-bit digital IO to
connect to external devices along with the interrupt, DAC and ADC. Also the board includes a high range of peripherals: LCD, external buses (CAN bus, I2C and 1-wire), two serial ports, led, etc. (see figure 6).

The Tutor IO allows the developer to experiment with real time java applications. Moreover, it includes the DS80C390 microcontroller that can be programmed in assembler to implement some low-level functions.

![Figure 6. View of the Taylec TutorIO board](image)

Some of the typical assignments that students must complete in the real laboratory are:
- Control of the keypad and the LCD display.
- Calculate the frequency of an input signal.
- Use the analog-digital converter.

In order to make the remote experiment as similar as possible to the real one we have developed two additional modules: the virtual keypad and the function generator.

### 4.3.1. The Virtual Keypad

The virtual keypad module uses the digital input/outputs of the board to act as a keypad physically connected to the microcontroller.

The user executes an applet on its internet browser that offers the same behavior as a keypad, even the switches bounce. This user interface offers also some additional control functions such as execute/stop code, show result, etc. When the user presses any key on the virtual keypad the TutorIO board generates the appropriate digital signals to microcontroller.

### 4.3.2. Function generator module

The function generator applet is able to generate analog and frequency signals.

The analog signal varies in a range from 0V to +5V. This signal generator has been developed using the DAC output placed in the board and the API included to access from java the low level TINI components.

The frequency signal has a range from 0 to 500Hz with an error of 1.56Hz. The main challenge in the signal generation was its accuracy. In order to achieve the desired precision a native method using the timer and the interrupts of DS80C390 microcontroller has been developed.

The board outputs are connected to EV80C196KC’s inputs. The user interface is implemented using an applet with a slider to change the analog or frequency output. Each event change in the slider will produce a physical change in the board output.

### 5. Integration into an open source LMS

The use of Learning Management Systems (LMS) becomes more and more common in most Universities. It would be very useful to achieve the complete integration of the remote laboratory facilities into an e-learning environment. In fact, the LMS could provide all the management services that in our framework are handled by the remote access component.

#### 5.1. An open source LMS: Moodle

In order to test the integration of the virtual laboratory into a LMS we used Moodle [9] as the e-learning platform. Moodle is an open source e-learning platform implemented using PHP that includes support for a database backend (usually MySQL or Postgres) and uses the Apache web server as its remote access mechanism.

The main reason to make this choice is that moodle is an open source LMS. Also it has been taken into consideration its extensibility capabilities. It is possible to add new functionalities using PHP code.

It is also important to note that there exist a broad community of users and developers of free components for this platform.

#### 5.2. The Remote Laboratory as a Moodle Task

To implement a new moodle task we must follow a set of strict development rules. To implement a new task module we need to write some PHP files as well as HTML forms. The structure of a module is as follows.

Each task contains a file called `mod.html` that implements its management interface. Also a file named `version.php` is used to control the automatic versioning of the code. A folder named `db` that contains all the SQL files related to the database management. The user interface is implemented in a file that must be called `view.php`, and finally a file called `lib.php` that contains all the application logic. The entry point to the application is done through a file called `index.php`.

To implement the remote laboratory three distinct roles are considered: administrator, teacher and student. The administrator is the responsible of setting-up real devices into the environment and connecting them to the remote laboratory. The teacher is in charge of the design of all the activities into an existing laboratory and also is able to assess the student’s work. It is also capable of limiting the microcontroller
commands that are available to students. This functionality allows for a great flexibility in the design of the experiments. Finally students can book a time slot into some real microcontroller and perform their experiments.

Each microcontroller is attached to a device gateway that encodes the protocol neutral queries received from the LMS into the specific protocol of the microcontroller. The device gateway is implemented in Java and uses the serial port API to communicate with the microcontroller. The communication between the LMS and the gateway is performed using a socket based layer (using PHP sockets in the moodle side and Java sockets in the device gateway).

5.2.1. The Management interface

Using this interface the administrator is able to create an instance of a virtual laboratory.

Once the virtual laboratory is created the administrator is able to modify the number of microcontrollers allocated to the laboratory. The application is designed to perform a load balancing procedure to distribute the reservations from students among all the microcontrollers configured in the laboratory. From this interface the administrator is also capable of resetting the microcontrollers or mark as temporarily unavailable certain devices.

5.2.2. The Teacher interface

From this interface the teacher is able to configure the main characteristics of an experiment. Among other parameters, a teacher can define the maximum number of hours/week allowed to be booked by a student, the maximum duration of the time slots allocated to each student. It can also configure the reporting mechanism (i.e. whether the student must upload a report of its work). The teacher is also able to assess the work of the students and to publish their achieved marks.

From the teacher point of view the integration of the remote laboratory within the components of the LMS facilitates the assessment task because it has access to the whole record of student’s activities as well as to all their exercises and progress information.

5.2.3. The student interface

The student interface has a twofold functionality. First allows the booking of certain time slots to perform a remote experiment.

Also from this interface the students will be able to access all the microcontroller commands configured by the teacher to perform the remote experiment.
6. Summary and Conclusions

In the new teaching and learning strategies, for instance in blended learning, the remote access to real laboratories opens a new perspective in the teaching of experimental disciplines.

Three different approaches to the design and implementation of a remote access mechanism to a microcontroller laboratory have been implemented and tested. The proposed component framework for the design of remote laboratories has been used in all the three implementation models.

Without doubt the experimentation in a real laboratory is irreplaceable as a learning experience but in some circumstances the access to the real laboratory is restricted by distance and time concerns. In these situations the remote laboratory approach would be a valuable alternative. The experience presented in this paper corresponds to a first step towards the integration of remote access to laboratories into the ordinary curricula of computer science students. The remote access facility is now in an assessment period and is only used as a prototype implementation to evaluate its functionalities. The full deployment is expected for the second semester of 2006.

The integration of the remote laboratory into e-learning platforms allows the integration of all the services provided by the LMS into the laboratory. In addition, the use of an open source LMS facilitates the development of remote access gateways to real laboratories.

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References
