GILABVIR: Virtual Laboratories and Remote Laboratories in Engineering.
A Teaching Innovation Group of Interest.

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Abstract— GILABVIR (Grup d’Interès en Laboratoris Virtuals i Remots) is a recently created Virtual and Remote Laboratory Group of Interest at the UPC (Universitat Politècnica de Catalunya) and it is integrated in a more general teaching innovation project: RIMA [1], [2]. RIMA has been developed to promote research on the use of innovative learning methodologies applied to engineering education and it was specially created to assess in the new European higher education adaptation process.

Keywords- Generic skill, digital campus, software platform, laboratory experiment.

I. INTRODUCTION

The GILABVIR Group is formed by high education faculty members who are involved within different laboratory courses, all of them characterized by the use of real and simulated experiments accessed through the Moodle based UPC digital campus platform (ATENEA). The experiments in the different laboratory courses usually follow the next three steps sequence: 1.- The student designs the experiments and configures the output parameters. The configuration parameters are displayed and optionally recorded at the ATENEA server. 2.- The experiment is executed. 3.- The different software monitoring platform starts the simulator program models some real environment, producing output signals, graphs and/or data when a set of input parameters is configured by the user.

These data are used to evaluate the students. For most of these experiments, taken into account the design of the learning activities in the course context, when a student executes an experiment at a remote laboratory, the virtual and remote GILABVIR laboratories are described. The design and functionalities of the monitoring tool: Moodle_LAB are described in section III. In section IV innovative teaching methodologies based on these laboratories are presented and related to a generic skill list. Finally, the conclusions are described in section V.

II. VIRTUAL AND REMOTE LABORATORIES

The university education environment is becoming more diversified and interdisciplinary in the type of activities offered to students. Virtual and remote laboratories have been developed by combining experimentation, homework and use of information and communication technologies. In this context, when a student executes an experiment at a distance, two different modalities must be distinguished: Virtual Laboratories and Remote Laboratories.

A Virtual Laboratory is defined as an interactive environment for designing and conducting simulated experiments. The experiment execution considers running a program loaded in a remote server machine. To start this program the user accesses the server through a user interface. A software monitoring platform starts the simulator program. The program models some real experimental behavior, producing output signals, graphs and/or data when a set of input parameters is configured by the user.

A Remotely Accessible Laboratory is defined as an interactive environment designed to allow users to remotely control real laboratories. A monitoring platform is installed in a remote server machine. To start the experiment the user accesses the monitoring application through a user interface and configures an input parameter set. After the experiment, measured data or

The first goal is related to the implementation of a software application to join all the virtual and remote laboratories of the UPC digital campus platform (Moodle_LAB) and allows students to access, conduct and evaluate experiments in the virtual and remote laboratories. The software platform starts the simulator program. The user proposes monitor and evaluate the experiments conducted and obtains the results of the experiments conducted, individually for each student, about the timing, the configuration parameters of the experiment.

Keywords- Generic skill, digital campus, software platform, laboratory experiment.

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signals are obtained and returned to the user through the monitoring application.

As it can be deduced from previous definitions, virtual laboratories and remote laboratories are extremely similar in the sequence of steps to follow when a practice is executed. Teaching methodologies based on these two kinds of laboratories are also very similar.

Remote laboratories and Virtual Laboratories are connected to the server through a software platform: Java or Labview. Atenea is the user interface (UPC Digital Campus).

Figure 1 shows a functional diagram including the elements that at have a main role in the environment. Some advantages and disadvantages when comparing virtual and remote laboratories are displayed on Table I.

TABLE I. ADVANTAGES AND DISADVANTAGES

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Virtual</th>
<th>Remote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimentation with real signals</td>
<td>NO Y</td>
<td>ES</td>
</tr>
<tr>
<td>Flexibility and configurability level</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>System registers user activity</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Number of users simultaneously running the experiment.</td>
<td>Unlimited user</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Virtual</th>
<th>Remote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workstation booking system is necessary.</td>
<td>NO Y</td>
<td>ES</td>
</tr>
<tr>
<td>Software update is eventually necessary</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Expensive</td>
<td>NO Y</td>
<td>ES</td>
</tr>
</tbody>
</table>

The GILABVIR group has been formed by faculty members who use virtual or remote laboratories in their teaching courses. Nine different projects directly related to nine different laboratories are currently grouped.

Virtual and remote laboratories that joined the GILABVIR initiative are described in the following list.

A. Remote and virtual laboratories for mechatronics and enertronics students.

Different platforms have been designed to allow students to access the remote laboratory virtually to complement the local laboratory sessions. The platforms are used in electrical engineering courses related to automation, mechatronics, motor control, renewable energy generation and power systems. Students program and supervise real systems as if they were working with real in stallations. The method is done by users for examples standard PLC (Programmable Logic Controller) programming software provided by the PLC manufacturers.

Remote laboratories include: Automation and motor control laboratory [5], Flexible manufacturing cell [6], Power Quality laboratory, measurements of harmonics for different loads, power system laboratory, protection, fault detection and restoration of electrical power systems.

Virtual laboratories include: DC motor control laboratory, Hotel automation laboratory, Chemical process automation [7].

B. LAVICAD

The virtual laboratory of analog and digital communication systems is a useful tool to verify the performance of different communication systems and simulate signal techniques, topics that typically are integrated in the derived courses of the curriculum of telecommunications engineering. The communication systems have been implemented and designed as Java applets and are free available. They can be run at the e-learning platform: comweb.upc.edu. The different communication systems present different levels of user interactivity and when students execute a system integrated in a course, the obtained results can be supervised by the professor as an evaluation tool. From a pedagogical point of view, this laboratory has been created to facilitate the learning of certain matters, acting as a connection between the model of knowledge based on concepts and theories, and their practical understanding and experimentation.

C. Project: 62, an interactive tool to study discrete time signals and systems.

62 is an interactive tool written in JAVA that allows, first, to define discrete time signals and systems, and then to work with them. Signals, systems and operations are specified by means of menus or dialog windows without the need of knowledge of any programming language. One of these menus is devoted to specifying digital filters (FIR and IIR) both in the frequency and in time domain. The tool includes a graphic interface to show the sequences, their Fourier transform and the characterization of linear invariant systems (frequency response, impulse response). The tool uses the A/D and D/A converters of the PC sound card. Thereby, the tool can generate and filter an analog signal in real time. 62 is part of the experimental framework designed for students of different levels of knowledge in circuit and systems. The tool is freely available in [4].

D. iLabRS: Remote laboratory for Secondary Education.

iLabRS is built over a Modular platform to perform remote experiments in sensors and signal conditioning. It uses two experiment boards, which together with three additional boards

The group is supported by the ICE (Institut de Ciencies de l'Educació) UPC including a financial aid from the 2009 - Educational Projects Budget.
allow doing currently 13 different practices. This remote Laboratory is aimed to secondary education students, to allow them to perform online real experiments, with remote access through Internet. The aim is triple: giving a tool to increase experimentation in scientific and technological subjects, demonstrating the IC T’s use and establishing a bridge between the second dary school and the university.

E. LEARN-SQL

LEARN-SQL is a system conforming to the IMS QTI specification that allows online learning and assessment of students. It does not affect the sql l i nes in an automatic, interactive, informative, scalable and extensible manner.

This tool facilitates the definition of virtual laboratories or remote quiz questions that are used by students of subjects to learn design and use of relational databases in the UPC. More specific goals are to:

- Provide the possibility to define virtual laboratories or remote quest innaires that be solved by the students at class or at home.
- Facilitate the participation of the students in its self-learning of database subjects.
- Provide students with valuable feedback, so that they can learn from their mistakes.
- Automatically evaluate the correctness of any SQL statement (queries, updates, stored procedures, triggers etc.) and other relational databases related exercises (Relational Algebra) with independence of the student solution.
- Help teachers define the questions or items in the remote questionnaires as well as allow them to review the solutions provided by the students.
- Adapt the subjects where it is used to European Higher Education Area (EHKA) and innovative education methodologies.

F. Circuit and Communications Systems Simulators

This virtual laboratory is still in construction.

The aim is to develop monitoring tools for homework based on running software simulators or remote laboratory experiments. The monitoring tool will allow systematically send a report to a Moodle platform. It will be based on a Python module with functions to write ascii text, formatted text, results tables and figures in the report to gather with the answers to questions asked by the student.

This project is to be implemented in the following activities of the UPC “European Master of Research on Information and Communication Technologies”:

Course: “Antennas for Communications” and “Waves and Systems”. Activity: Modeling a WiFi system with intermediate repeater, including modulations and RF.

Course: “Electromagnetics Engineering”. Activity: Analysis of a transmission line with impedance discontinuities using different numerical methods in frequency or time domains. The results of different methods are compared in terms of accuracy and computational efficiency.

Course: “Design and Analysis of RF and Microwave Systems for Communication”. Activity: Remote control of a network analyzer using the high-frequency circuit simulator ADS.

G. Modular platform to perform remote experiments in sensors and signal conditioning [8].

It is based on a custom acquisition board which includes a Ethernet capable microprocessor, so that every board has its own IP address. The connection of multiple boards to a switch allows the access to multiple experiments and/or to multiple replica of an experiment. Every board gives power supply and control signals to specific experiment boards that are connected to the control board in a sand which structure. The signals are 4 A/D channels (16 bits), 2 D/A channels (14 bits), 8 control bits and a SPI bus. The experiment server runs specific applications made in LabView that control the experiments. Every application generates a remote panel that allows the use with a web browser. The link with the remote panel is placed among the course materials in the digital campus Atenea. This platform gives a certain degree of security, the user authentication and a basic record of the user activity. Four different experiment boards have been developed up to now, which allow performing 6 different laboratory activities around the sensor characterization and the setup of conditioning and acquisition circuits. The use of the remote laboratory is focused as a complementary to ol to ad flex ibility to the lab oratory courses, mainly with the semi-distance students.

H. VirtuaLab: remote workbench for instrumentation and sensors [9].

Remote laboratory based on a web server and a VXI modular instrumentation system connect ed to a clickboard with experiments and to a weather station. The access is made through a website (virtualab.upc.es) using a password. It only admits a single simultaneous user, who can use the resource during 20 minutes. Seven different laboratory activities can be carried out, from a system identification and control, sensor calibration and remote control of instrumentation. In operation from 2003, the user interface was designed with the criterion of minimizing the data exchange and ensuring the system robustness. Because of this, the control applications in LabView that control the experiments are running in the server and they just exchange parameters and the results with the user dialogues in the web pages.

I. rWLaB-Remote WaveLab

The goal of this laboratory is to convert an experimental setup (wave channel) into a platform for teaching, research and dissemination of knowledge using all the advantages offered by today’s information technologies. Thus, we propose the creation of a new knowledge portal based on per experiment with small-scale physical models with in the field of Maritime Engineering. The purpose of this portal will serve as the container of the remote and virtual laboratories that can be
developed from this initiative. It is envisaged to provide the necessary content to the portal in order to either through simulation, experimentation or study, achieve varying knowledge levels of methods and technologies employed in the experimental scale.

III. CONNECTING GILABVIR PROJECTS TO MOODLE.

One of the main technical aims of the GILABVIR group is the connection of all the projects to the UPC digital campus. The UPC digital campus is a based moodle platform and it is called Atenea. In [3] some guidelines are proposed in order to connect virtual and remote laboratories to an educational platform.

Moodle LAB is the application designed to connect all the at distance lab oratories to the UPC digital campus. It is integrated by the connection module JLab and by the booking module.

A. Moodle Connection Module

The connection functionality allows the different at distance offered experiments can be run from a Moodle site. When an on-line experiment is invoked through the moodle platform there are some tasks that are identified to be performed in order to communicate the virtual and remote laboratories with the Moodle database to store practice results and then allow teachers view them.

The application that has been implemented is a new module for Moodle called JLab. JLab:

1. Centralize the management of the simulators that can be used in practices.
2. Allow laboratories to send the results to the server in order to be stored in the Moodle database.
3. Enable teachers to see the results of the practices from the portal and download them in Excel format.

The user enters in to the main portal using any browser. Then the user enters in a JLab practice of any of his courses.

On the last page of the applet figure 3 shows the simulator applet using javascript embedded in view.php. This is a communication protocol for a virtual laboratory based on XML and Java platform. The user enters in a JLab practice of any of his courses.

The user enters in the main portal using any browser. Then the user enters in a JLab practice of any of his courses.

It shows the simulator applet using javascript embedded in view.php.

View.php obtains the id of the user connected, the id of the practice selected and a parameter that indicates if it is necessary to send the results to the server.

Applet is loaded.

5. Each stage of the applet, upon completion, generates an XML with the results.

Joel also implements the report.php file which will show all users results of each practice.

Figure 2. shows the system architecture for at distance laboratories.

JLab module has been currently finished and is being tested with a virtual laboratory (II.B) and with a remote laboratory (II.D). It is expected to connect all GILABVIR laboratories to Atenea campus on June 2010.

B. Moodle Booking Module

If the experiment is performed in a remote laboratory and the number of local workplaces is limited, a booking planning strategy becomes necessary. A dedicated moodle module is being designed to allow booking functionality and JLab module coordinate work. The booking strategy defined for ours laboratories integrate:

- Students and teachers can book a workplace session some days in advance.
- A booked session can be modified or canceled
- The occupation time per session is configured by a laboratory administrator
- The dedicated moodle application assigns workplaces to the booked sessions.
- A workplace inactivity detector releases the inactive workplaces and these are automatically available for other booked sessions.
- Teachers can supervise if a booked session is occupied by its owner.
- Laboratory resesponsible and teachers can periodically check the statistical books and the statistical use of the workplaces in the laboratory.

The Moodle booking module is currently being tested with a remote laboratory (II.D).
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The authors wish to acknowledge all GILABVIR members for their aid and support provided throughout each activity and meeting, the enrolled students who have implemented most of platforms and applications and the RIMA management team for their institutional support.

REFERENCES


IV. ACADEMIC USE OF VIRTUAL AND REMOTE LABORATORIES

One of the main goals of the interest group is to share and improve the academic activities related with the use of virtual and remote laboratories. Two different aspects have been identified: the in situ or remote use and the interaction within our groups and with the learning methodologies (what to do, evaluation, incidence in specific and generic skills, …).

After a survey within the group members, we can conclude that the virtual and remote labs are used both in classroom and remote activities. In addition to its use by the students, that the virtual and remote laboratories are used both in classroom and laboratory. Two different aspects have been addressed as a substitute of current academic activities, all others are used as complementary activities. Concerning the assessment, one half of the subjects including virtual or remote laboratories use them as voluntary issues while the other half specifies a given percentage of the mark. To perform a formal assessment, two of the involved subjects perform an automatic harvesting of results, a third one performed an automatic evaluation of the work with a third one performing an automatic evaluation of the performance and a fourth one performing a classic off-line gathering of reports.

Concerning the learning outcomes, the virtual and remote laboratories should contribute to improve the specific and generic knowledge of the topics in the respective subjects, but also to boost several generic skills. Among the mandatory skills defined by our university, the survey has shown that the use of virtual and remote laboratories can contribute to acquire the following skills: self-learning, effective use of learning resources, teamwork, innovation and entrepreneurship, and use of a foreign language. Additionally, the different school levels can define other generic skills like “experimental behavior or an independent instrumentation knowledge” or “engineering problems identification, modeling, formulating and solving”. Most of these are also identified as targets of virtual and remote labs.

Several virtual and remote laboratories have been with a higher stress in their technical aspects than in their didactical aspects. An outcome of the Interest Group activity has been the recommendation of the use of virtual and remote laboratories as standard academic activities. That is, with a lifecycle that starts at the subject goals, defined a given learning activity, includes a deliverable that can be aessed and closes the cycle with an evaluation of the performance on the laboratory activities. The learning activity should incorporate a form which, in addition to the technical content of the activity, gives information about the steps taken and the results obtained. This includes the objectives and assessment criteria of the generic skills to be handled. As an example, Table II describes the goals at three depth levels of the generic skill “engineering problems identification, modeling, formulation and solving”. Each row in the table represents a different virtual or remote laboratory activity that can be proposed to acquire the skill. Levels 1 and 2 are suitable for first and second years of an engineering degree and level 3 is proposed for third and fourth years. Goals at level 3 usually also serve to acquire more generic skills, as for instance “Cooperative Learning” and “Autonomous Learning”.

V. CONCLUSIONS

The main aims of the GILABVIR group can be divided into two lines. As a result of detecting common needs of the technical solution of the different laboratories, the first line is related to the implementation of a software application to join all the virtual and remote laboratories in the UPC digital campus Atenea (moodle pl atform) and all low students execute experiments and teachers propose monitor and evaluate these experiments. The second main line is related to the design of new educational methodologies that use virtual and remote laboratories as educational activities. That is, with a recommendation of planning virtual and remote laboratories that use them as voluntary issues while the other half is used as complementary activities. Concerning the learning outcomes, both specific and generic skills.

Concerning the learning effectiveness of virtual and remote laboratories, the authors wish to acknowledge all the GILABVIR members for their aid and support provided throughout each activity and meeting, the enrolled students who have implemented most of platforms and applications and the RIMA management team for their institutional support.

Concerning the learning effectiveness of web based on experiments, in [10] a study is presented where the authors conclude that learning performance using dynamic media is significantly higher when the subject of the experiment is text-based lesson, especially if the dynamic media can support or enhance learning when cognitive load is reduced by the mental representations. Furthermore, based on our experience, we can assume that the learning effectiveness of dynamic resources doesn’t depend on if they are offered by internet or in a laboratory classroom, but it is highly correlated with the teacher ability to choose the appropriate experiments to be made to work each subject or sequence of subjects in the program.

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Figure 3. JLab – Module to communicate Moodle with simulators: Functional Diagram.

Table II: goals of the activities that should develop the generic skill “engineering problems identification, modeling, formulation and solving”

<table>
<thead>
<tr>
<th>Virtual and remote laboratory uses</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 1</strong> To perform a guided activity</td>
<td><strong>Level 2</strong> To perform an open solution activity which includes a partial system or sub-system design</td>
</tr>
<tr>
<td><strong>As a complementary activity of a theoretical exercise</strong> To solve a guided theoretical exercise with the aid of a virtual or remote lab as a verification tool. Their configuration parameters are given by the exercise statement.</td>
<td><strong>As a complementary activity of a laboratory practice</strong> Use of the virtual or remote lab to help knowing the instrumentation, preparing a given in-situ practice or confirming their results.</td>
</tr>
<tr>
<td><strong>As an independent, remote activity (e.g. remote access to a singular resource)</strong> To perform a guided activity using a virtual or remote laboratory as a demonstrator.</td>
<td><strong>Use of the virtual or remote lab to perform non-guided activities that reinforce the in-situ lab activities and help analyzing their results.</strong></td>
</tr>
<tr>
<td><strong>As an independent, remote activity (e.g. remote access to a singular resource)</strong> To interact with a virtual or remote laboratory with modification of parameters.</td>
<td><strong>Design of a new building block for a virtual or remote laboratory.</strong></td>
</tr>
</tbody>
</table>

References:
