Remote Laboratories for Renewable Energy courses
Courses at Jordan Universities

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Abstract—In the field of Engineering Education, performing practical experiments is essential, as an accompaniment to magisterial classes, in order to enforce theoretical and practical concepts. This task is much more difficult in distance education since students attend mainly to virtual classes. Therefore, the use of remote laboratories can help minimize this inconvenient. In addition, remote laboratories may help teachers to prepare suitable evaluation on-line experiments, in similar conditions if students were physically in the real laboratory, on the other hand, remote laboratories can be a good complement to real experimentation, as a preparatory step, preparing them to face similar tasks in the immediate future.

Accordingly, the principal objective of the European TEMPUS project entitled “Modernizing Undergraduate Renewable Energy Education: EU Experience for Jordan”, which supports this work, is the development, integration, accreditation, and evaluation of a renewable energy course in the context of engineering degrees from several universities in Jordan. This project follows the guidelines proposed in the Bologna process, and considers the previous experimentation with low-cost renewable energy equipment in order to allow us to study the best approximation of remote laboratories. This is a previous step before addresssing this task with complex and expensive equipment.

Keywords—low-cost remote laboratories; renewable energy

I. INTRODUCTION

A remote laboratory is a software and hardware instrument which allows students to use real tools through the Internet [1]. In this sense, distance education students are able to perform on-line experiments from anywhere and at any time as if they were physically at the local institution. Additionally, the remote laboratory can be available all time; 24 hours a day, 365 days per year, except during maintenance task. On the other hand, remote laboratories can be a good complement to real experimentation, as a previous step, preparing them to tackle similar tasks in the immediate future.

What is more, institutions can desire to share their laboratories by means of the federation of laboratories, avoiding the need to reproduce the same deployment in each institution. The sharing of laboratories, not only reduces cost, but also allows students to have a wider offer of laboratories. Several studies are found in the literature ([2], [3], [4]) which detail how well remote laboratories can help teachers in the learning/teaching process.

However, regarding with the task of designing and implementing a remote laboratory, we can find two different approaches: the use of low-cost simple devices to permit the easy replication of them in other institutions, or the utilization of expensive systems with a complex deployment, but with a higher amount of sensors and actuators.

In 2013 the MUREE, [5], Modernizing Undergraduate Renewable Energy Education: EU Experience for Jordan, Tempus project started. The wider objective of MUREE is to develop, integrate, accredit and evaluate a quality bachelor degree program in Renewable Energy (RE) in Jordan with an appropriate laboratory component jointly taught by universities in Jordan, in accordance with the Bologna process.

Since the economic resources are reduced, the Muree project also take into account the idea of federation of the educational resources among the Jordan Universities, allowing, specifically, the use of a set of renewable remote laboratories.

Hence, this paper proposes the hardware and software implementation of low-cost remote laboratories using Lego Mindstorms NXT v2.0, for solar and wind renewable energy in the frame work of a resource federation in the MUREE Project as a previous step before dealing this task with complex and expensive equipment. These remote laboratories have been developed, following the philosophy of Laboratories as a Service (Laas) ([6], [7]), an original approach that allows teachers to design multiplatform laboratories

II. MUREE Project

A. Brief description of MUREE goals

The MUREE project, [5], foresees the development and implementation of a new national undergraduate degree programme in renewable energy (RE) in the Jordanian
universities, according with EU practices and Bologna process. Bologna Process aims to create the European higher education area by harmonizing academic degree standards and quality assurance standards throughout Europe for each faculty and its development by the end of 2010. The objectives are the introduction of undergraduate and postgraduate levels in all countries, with first degrees no shorter than 3 years; a European Credit Transfer System; the elimination of remaining obstacles to the mobility of students and teachers.

The main goal of the project is to update, improve and deliver the content of 6 state-of-the art renewable energy courses and adapt to add value to existing programs at universities in Jordan, therefore the program will provide a high quality education for Jordanian students in the key aspects of Renewable Energy, enabling them to take responsible, creative, challenging and stimulating posts in industry or research in this exciting field.

To achieve this goal, different activities have been programmed as follows:

- Conducting desk research and field study of the status of renewable energy education in Jordan and producing a report on current situation on need of the country.
- Promoting the Bologna Process in Jordan
- Elaboration of didactic materials for selected courses on renewable energies adapted to EU Bologna Process
- Federation of renewable remote laboratories according to the new contents.

B. First steps in MUREE Project

The undergraduate degree has been elaborated following the suggestions of European partners involve in the project, but also evaluating the internal potential of Jordanian universities in term of state-of-art of courses on renewable energies, laboratories and internal didactic proposals, and the needs of the renewable energy Jordan Market.

In this sense, a workshop was held at TUG particularly to update the curricula and study plans and select the pilot courses on the basis of a report on the needs of Jordan for renewable energy education carried out prior to the workshop. As a result has been defined the different syllabus of six renewable energy courses.

Regarding RE market analysis, a total of 23 companies in various regions of Jordan were targeted with a total number of employees exceeding 1500. The following needs emerged:

1. The concentration of business activities of companies working in RE in Jordan is within sales/installations, with majority of employees working in sales and marketing of RE systems.
2. Companies declare difficulties in finding qualified persons with skills related to technical aspects and to general knowledge of RE.
3. About 80% of the companies that have participated into the previously referred market analysis indicated the need to hire technicians in RE.
4. Companies indicated that although there is a clear need for qualified engineers, engineers with multidisciplinary skills (knowledge of finance, marketing, or economics) are also needed.

On the base of the results of analysis needs, the design of the following six courses have been defined:

- Energy Conversion.
- Solar-Thermal Energy.
- Wind Energy.
- Drives and Machines
- Photovoltaic Systems.

These courses should eventually have a technological impact on renewable energy education in Jordan. The course design has already been submitted to university authorities for approval and implementation. Local professors will be responsible for teaching the programme and will be assisted in the first run by EU professors, who will participate in teaching both face to face and virtually. The pedagogical approach (teaching, learning and assessment strategy) will include lectures, seminars, case studies, group work, report writing and independent research. This will provide an example of a Bologna process, paving the way for the adoption this process.

C. Next steps in MUREE project

The next activity of the course development is to have the courses approved by partner university authorities, incorporate in the appropriate study plans and then offer and deliver to students during the fall semester of the 2014/2015 academic year. The next immediate activities will then be concerned with the effective provision of the courses to students and the monitoring of students’ course evaluation at the end of the semester to ensure quality.

Admission of students to the Renewable Energy programmes in the 5 partner universities will follow the national procedures and guidelines. Usually, students of a score of a minimum of 90% in the Secondary School Final Examination (Tawjihi) will be admitted to Engineering programmes (mechanical engineer, electronic, electric, architect, etc), particularly at state universities. Only students, who follow the scientific stream with good background in mathematics, physics, chemistry, will be selected. They are also expected to have a good command of English, the language of teaching and learning at Jordanian universities.

III. REMOTE LABORATORIES

A. Description of the used hardware

One of the activities to achieved MUREE goal is the implementation of a real federation of renewable energy remote laboratories. For this purpose and as concept test, a robotic kit s Lego Mindstorms NXT v2.0 [7] has been used to
develop two different laboratories: eolic and solar. These kits allow the modular design of laboratory components by a wide set of pieces, sensors, and actuators. With a NXT v2.0, a robot can be linked to a PC by means of USB or Bluetooth, so interacting with sensors (sound, distance, light...) and motors. There are many free and commercial programming libraries in a wide range of programming languages (Java, Python, C...) to develop control applications of the experiment/robot.

Since the robotic kit can be assembled and disassembled as many times as needed, the educational activities may easily be changed or modified. So, the eolian laboratory can be transformed into a solar laboratory using the same pieces. Also, it is possible to modify the laboratory design without purchasing new hardware components. The maintenance is simple, since any broken or lost piece is easily replaceable, being also cheap. For all these reasons, the two laboratories (eolian and solar) have been designed with Lego Mindstorms NXT v2.0, and its renewable energy kit [8]. Each robot/experiment represents an investment of up to five hundred euros.

The laboratory deployment also includes video images from an IP webcam placed next to the robots. This IP webcam provides students with a visual feedback of what happens in the laboratory.

The remote laboratory is made of the following elements from the software point of view:

- A remote control server, based on RESTful web services.
- A web-client, so that laboratory access is multiplatform.

To develop this architecture, multiple solutions can be found for other remote laboratories [9]. Error! Reference source not found.1, shows the proposed architecture for this work, following the concept of Laboratories as a Service (LassS) Next, the software design made for the selected laboratory, made of two parts, the lab server and the web client interface will be described.

B. Laboratory Server

The remote control server handles all client requests and transmits them to the actuators of the experiment, as well as reading the values of the experiment sensors to be reported to the web clients. It is the responsible for sending requests in order to modify the values of the actuators and represent the sensor data in an understandable way. As detailed in the next section, it is a web interface which guides the experiment, and allows students to obtain the data experiment to be processed later as homework.

The selection of different technologies for the development of a remote laboratory may have different impacts on its performance. In this case, the selected technology must be a universal technology, cross-platform, non-intrusive, and low bandwidth usage. According to [9], the web services technologies offer all these features.

As a first approach to the creation of the laboratory, the use of LabVIEW software from National Instruments (NI) is considered as the only technology for the laboratory. Within this suite, it is allowed to create graphics panels for remote control that can be easily integrated into a Web page, by using the "iframe" tag. This way, both components of the laboratory, the remote server and the web client would be organized in only one application. However, LabVIEW remote panels, despite its simple creation, are unsuitable for the objectives for several reasons. First, it is necessary to install a LabVIEW Runtime Engine plug-in in each web browser, in order to correctly visualize the remote panel in it. In addition to this, the plug-in must work in all browsers. This means that the access to the laboratory would need a particular configuration depending on the type of device. In this sense, many students are already used to employing tablets or mobile devices for their distance education. Moreover, it is too complex to use monitor services during the experiment sessions to analyze the students’ behavior through the remote panel. Another problem is that loading this remote panel into the web site is very slow.

To solve these drawbacks, RESTful web services are developed through LabVIEW 2013. In particular, three simple web services are designed: one of them dedicated to the laboratory actuator, another one dedicated to transmit the reading data from the laboratory sensors, and the last one indicates the laboratory status.

The use of RESTful web services, instead of using a TCP or UDP socket, allows requesting by using the AJAX technology from any website or programming language, which support this type of technology (actually, a great variety). This way, any user could create its own client application with the desired adaptations over the laboratory. As inconvenient, using the HTTP protocol introduces a slight delay between the client call and the execution of the particular request. In our tests, this delay much less than one second, so it is not perceived by the end user. Data is formatted using JSON instead of XML to reduce the required bandwidth during the transmission of information. That is because the coding information is more compact.

Another question related to these types of services is that the client has to keep the requests associated to the current session, since our architecture relies on the HTTP protocol— it does not implement the concept of session. Therefore, it is planned to include our remote laboratory into some federation management platform (such as WebLab Deusto [10], RELATED [11], etc.) to ease the management of user sessions,
resource scheduling, and control access. Thanks to the modular development of our remote laboratory, it will not be complex to perform this integration.

C. Web-client Interface

Once the real laboratory is built, our hardware must be communicated with a web-client, which is accessible for the students. In this particular case, a web site has been accessible (see Error! Reference source not found.), based on HTML5, jQuery, and the Bootstrap library. This approach allows us the usage of the laboratory with a wide range of devices and operating systems. The functionality of the laboratories have been tested with the Firefox and Chrome browsers, and Windows, Linux, Android (mobile and tablet), and iOS for iPad devices.

This website is the responsible for starting and ending the experiments, temporarily store the generated data, and export the data to be processed by the student in CSV format. Also, it includes a graphical plot from the data captured by the Energy Meter sensor, in order to show the values of each of the possible variables. The actuator of the laboratories can be controlled by using a slider located at the left side of the web.

This site also includes video images from the previously mentioned webcam placed next to the robots, providing students with a visual feedback of what happens in the laboratory, whereas the parameters of the actuators are modified. In order to assist students during an experiment session, several aid messages have been included in the website, when they pass the mouse over the controls and web elements. These aids attempt to explain the meaning and operation of the laboratory.

IV. CONCLUSIONS AND FUTURE WORK

This work has presented the MUREE, work plan to develop and implement a new national undergraduate degree program in renewable energy (RE) in the Jordanian universities. Among the different activities to foster the project goals is the development and implementation of RE remote laboratories. Regarding the remote labs, two low-cost remote laboratories for the study of renewable energy have been developed. The presented laboratories are very flexible with regard to their design and cost, as well as their integration into a large amount of educational platforms and web-sites. The programming of these laboratories has been performed by using RESTful web services with LabVIEW, which is a novel approach that allows users to easily create multiplatform laboratories.

As these laboratories are prototypes, associated management services are not created for them so probably it’s not ready for a real environment with some users accessing at the same time. As future work, in a first phase, we plan to create management additional services. A second phase will be focused to develop an extension LMS module for including these laboratories into a real course. Afterwards, the laboratory impact into students’ learning can be evaluated through several methodologies.

Finally, the learned outcomes with these laboratories will be applied to the creation of more complex remote laboratories in the field of renewable energy.

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REFERENCES


