Implementation of Cloud-Based Smart Adaptive Remote Laboratories for Education

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Abstract— **Remote Laboratories are used in educational settings as tools to give students access to experiments that are not physically available to them at their institutions. During implementation, problems such as: bandwidth, security or limitations in terms of the usability, have been identified. This paper proposes an approach that integrates, what we call, a Smart Adaptive Remote Laboratory (SARL) with Virtual Learning Environments (VLE) to improve the students' experience by automatically adapting the experiments according to the student's current level of knowledge and experience. For this purpose, the laboratory experiment is connected with the VLE to access the student profile and academic information. This information is used by the SARL to adapt the educational content and the experimental interfaces accordingly. All students access the same set of equipment, but the adaptive system shows a variation of the graphic user interface with different controls and activities. The VLE provides the assessment component, completing the learning experience. The results of the experiments are stored in the remote laboratory system and sent back to the VLE to update the student information. A Raspberry Pi microcontroller and a web camera are used as hardware of the remote interface. The prototype software platform was implemented using Python and JavaScript languages and HTML 5 interface. The paper presents the design of the remote laboratory, the software integration model, and describes the details about the implementation of the prototype using this SARL strategy.**

Keywords—Remote Laboratories; Adapted Interfaces; VLE; LMS; Remote Laboratories Management System

I. INTRODUCTION

Advances in software, communication protocol and standards, provide an excellent scenario for the implementation of Smart Adaptive Remote Laboratories (SARL) to be applied in education. This configuration of remote laboratories includes two main components. The Remote Laboratories Management System (RLMS)[1], which is responsible of the management of the remote experiments, the wrapping of those as a laboratory learning objects and the generation of user adaptive interfaces. The second component which is the Virtual Learning Environments (VLE) [2], it is the system from where the academic information is gathered and is the place from where the users interacts with the laboratory learning objects [3], which include the access to the remote experiments. The interaction of

those two elements, and with the support of communication and educational standards, it is possible to have a complete smart adaptive remote lab experience.

The system works by providing the user an individualized experience. Followed by processing the user information stored in the VLE along with wrapping the educational content and the remote laboratories with the adapted interface. Everything is wrapped in a learning object for laboratory experience. In this sense, different students will have access to different versions of the same experiments, exhibiting different levels of complexity in their interactions and requiring different levels of knowledge to perform them. An example of this is a skilled student will have a more challenging experiment and activities, while less skilled students will see a simpler version of the experiment with different activities that evaluate more basic concepts.

The VLE provides the academic content and the assessment component, providing a complete learning experience. The results of the experiments are sent back to the VLE to update the students' academic information. This paper presents the design of SARL, the software integration model, and describes the details about the prototype implementation, using the SARL architecture.

II. RELATED WORK IN REMOTE LABORATORIES PLATFORMS

Three of the most recognized projects in the field of remote laboratories platforms are; the iLab-ISA project from Massachusetts Institute of technology (MIT) developed in United States [4, 5], the Global Online Laboratory Consortium (GOLC) [6] and LabShare developed in Australia [7]. This section gives a brief description of each project. It is important mention two other projects that will not be detailed in this article, those are: WebLab-Deusto [8] and Virtual Labs (India) [9].

The iLab-ISA project provides a networked infrastructure for the deployment of remote laboratories. They have worked for the enrichment of science and engineering education, impacting student learning. The iLab project objective has been for the last decade, the creation of a wide set of experiment resources that facilitates the sharing of experiments using the internet [4, 5].

The iLab system is composed by three components. First is the computer that controls the experimental setup. The second component is the user interface. Finally, the service broker, which act as a link between the other two, scheduling access to different iLab equipment around the world [10].
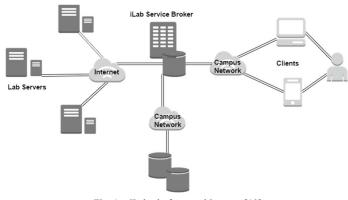

Fig. 1. iLab platform architecture [10].

Taking into account the increasing interest of the education community, about the use of remote experiments. The Global Online Laboratory Consortium is focused on promoting the development, sharing and research into remotely accessible laboratories for educational use. GOLC has a goal for the establishment of a unified architecture that turns the online experimentation into a more efficient and economically viable technology, making it interoperable and widely spread [6].

Some lines of interest of GOLC involves topics such as: online labs, curricular materials, lab sharing mechanisms, infrastructure to allow shareable experiments, support for communities of scholars working with online experimentation and standard architectures for online laboratories.

Lastly the Australian government funded the project LabShare, whose mission is: "To create a nationally shared network of remote laboratories that will result in higher quality labs". LabShare has developed, during the last decade, initiatives to develop remote laboratories in diverse topics and provide centralized access to their network to Australian universities.

LabShare was created under the premise that there is not enough capacity for an individual institution to afford the most advance and complex infrastructure of laboratories. Instead it is more feasible to create a network in which every institution can share their laboratory infrastructure with each other. LabShare received, for the period 2009 – 2011, the amount of 3.8 million USD for its operation [7].

III. SMART ADAPTIVE REMOTE LABORATORIES (SARL)

We define Smart Adaptive Remote Laboratories (SARL) [11] as a strategy in which the remote laboratory is aware of the users information; offering the necessary tools to allow the remote laboratories to gather information from the virtual learning environment, information such as: the student mastery level in certain topic, the current level of progress in the course and the accumulated experience with that specific experiment. Based on this information and the values of the variables of the lab, parameterized by the teacher, it can adapt the activities and

complexity of the experiment. For this purpose, the laboratory interface asks the student to do specific activities and will change the controls, restricting the access to some commands or blocking the choice of configuring others.

This way, students can start using a simplified version of the remote laboratories experiment based on the difficulty level and their knowledge. With the increase of their knowledge, experience and mastery level, the remote laboratory will turn on more controls, increasing the complexity of the experiment. Information must flow in both directions, from the student profile in the VLE to the remote laboratory and vice versa, keeping updated both the student progress and the remote laboratory interface.

The figure 2 shows the back end support of both the VLE and the RLMS in the adaptation of interface (view 1, view 2, view n) each interface is generated based on the student information retrieved from the VLE or stored in the same remote laboratory management system.
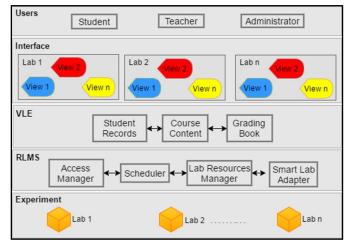

Fig. 2. Different user interfaces and the integration of Smart Adaptive Remote Laboratories with the VLE [12].

A. Integration of the RLMS with the VLE

Two standards were used for the integration of the RLMS with the VLE; the first one is the Learning Tools Interoperability (LTI) [13] that makes possible the integration of the educational laboratory learning objects with the VLE. This learning objects are created by the user (teacher or lab content responsible) inside the Smart Lab Adapter module, part of the RLMS component of the SARL system. LTI standard provides options to pass information to the VLE such as: session id, role of the user, status of the activity, difficulty level among others. The second standard is Tin Can API (xAPI) [14], using this standard the system will continuously stores the teachers, administrators and students interactions with the system , allowing the VLE and the RLMS to manage the student information defined for the laboratory experience. The integration model is aligned to the model that is being proposed in the development of the IEEE P1876 Networked Smart Learning Objects for Online Laboratories Standard [15] in terms of layers and interfaces, that will generate a unified view about the meaning of the laboratory learning objects totally compatible and integrated with the VLE's such as LMS's or educational content repositories.
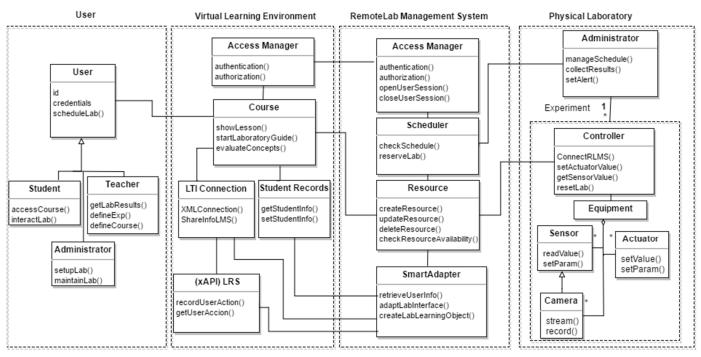
Fig. 3. Different user interfaces and the integration of Smart Adaptive Laboratories Management system with the VLE [12].

B. Model of the SARL System

The figure 3 presents the high-level design of the SARL System with its components and interfaces [12]. The first is the user component, which in this case defines the educational basic roles: the student, teachers and administrators, all of them will have their credentials to access the system and will have different rights according to their role. The second component is the VLE which commonly is a Learning Management System (LMS) which it objective is to support the courses content and students activities management, the third component is the RMLS which will control all the activities related with the laboratories, scheduling, resources management, interfaces adapting parametrization, laboratories activities customization and content inclusion. Finally, the fourth component is the remote labs experiments, that include all the hardware equipment and administration and communication interfaces with the RMLS.
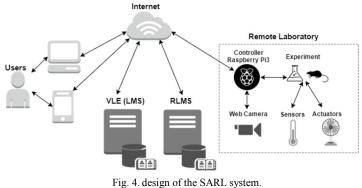
IV. IMPLEMENTATION OF THE SARL SYSTEM PROTOTYPE

The configuration of the prototype includes the use of a basic set of electronic components: LEDs, resistors, switches and servo motors, to make experiments in topics related with digital electronics. A Raspberry Pi microcontroller and a web camera are used as hardware of the remote interface. The software for the prototype was implemented using Python and JavaScript languages and HTML 5 interface.

The software architecture style was based in a client server cloud computing based, in which the SARL is a PHP based application running over a Linux Ubuntu operating system cloud server, running Apache web application server and MySQL database engine. The platform also needed some other services such as: Python interpreter, and some other libraries for the interface deployment process.

To be part of a remote laboratory setup, laboratory experiments need to be adapted to support the remote access and control, for that purpose an architecture based on the use of the raspberry Pi 3 (RPi3) hardware was used. The WebIOPi [16] service has been installed in the RPi3 to expose the General Purpose Input Output (GPIO) communication ports to the web and the service package called Motion [17] was used as a video streaming server, this allows the experiment visualization through the camera. With the controller running all the services for communication and the video streaming, the process will be completed with the connection of the experiment to the controller.

The RMLS Includes four modules: user manager, scheduler, resources manager and the smart adapter. User manager gives the user two services: the login interface, to authenticate the user into the system, and the registration interface for new users. The user credentials can be provided directly by the user if he is accessing the RLMS directly, or passed directly the VLE Through the implementation of a single sign on scheme. The scheduler gives to the teachers the possibility to reserve the experiments in windows of time for groups of students, the teacher can choose different remote laboratories related with his course, those labs will be blocked for another users. The students can schedule slots of time inside the windows reserved by their teacher. The resource manager contains all the remote labs available in the system, from there is possible to configure the labs setting and basic operation such as: connect new labs, update, remove etc. Finally the smart adapter provides to the teachers a complete designer mode in which the professor defines the activities and different checkpoints in which the lab change the difficulty, in this module the teacher parameterize the variables of the lab such as: difficulty level of every activity of the lab, experience requirements and prerequisites (another labs or activities inside the same lab). The figure 4 shows the design

of the implemented SARL system. The Remote Laboratory component can be one or many labs and can be distributed in different locations.

Fig. 4. design of the SARL system.

The prototype implementation included: the RLMS user manager, the resource manager and a simplified version of the future smart adapter, which currently is an adaptation of the interface of a remote laboratory according with the student grades and topics reviewed in the class, two of the variable defined as input for the smart adapter in the design, this adaptation is performed automatically by the system but the final version of the system will provide the teacher designer mode.

The integration with the VLE was implemented using LTI to give access to the student to the lab through the VLE. The platform chosen for the prototype was the LMS Moodle, this open source platform allows the configuration of the LTI connection between the RLMS and the LMS, the teacher can easily integrate the labs in the course and define the parameters for the Smart Adapter directly from the LMS. The Figure 5 shows an experiment composed by a set of LEDs that controls a servo-motor, simulating a traffic signal. This experiment is integrated in the LMS Moodle.
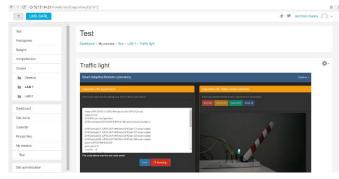

Fig. 5. SARL Registration and login interface.

The next two figures 6 and 7, show adapted views for the same experiment. In the first screenshot shows the authentication interface in which two students (A and B) see different version of the same remote experiment according with their own information, Student A is asked to do two activities the first one is a simple led blinking task and the second requires programing the LED's to do a sequence red, yellow and green during ten times. In the case of the student B the activity asks the student to create a dimmer light sequence, for that the student needs to know the concept of Pulse Width Modulation (PWM),

the student must make the program using Python language, the code is saved, validated and executed in the remote experiment in real time.
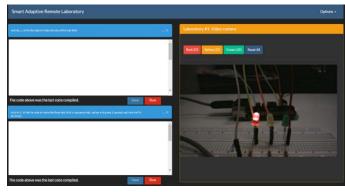

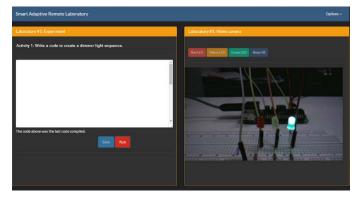Fig. 6. SARL- Remote lab for a LED's experiment adapted to student A.

Fig. 7. SARL- Remote lab for a LED's experiment adapted to student B.

V. CONCLUSIONS AND FUTURE WORK

The Smart Adaptive Remote Laboratories through the use of adapted interfaces, will create a more meaningful laboratory experience for the students, guiding them in the learning process and providing different learning scenarios, this creates a whole new learning experience in which the teacher and administrators will be participants of the students learning process.

The early stage of the prototype does not allow us to see all the possible interactions proposed in the original design. More implementation is needed to have a more usable and reliable system, additionally, the integration process is a big challenge due the variety of VLE's and their poor development of standards capabilities for integration with other system. The next stage in the development of the prototype will include the full implementation of the xAPI standard and the double direction information flow between the two platforms, additionally a more complete scheduling and smart adapter modules will be included.

Depending of the type of activities proposed in the remote lab experiment, the lab activities' validation may need a specific software implementation to generate the automatic result for the student, otherwise the activities must still on hold until the teacher validates de results.

REFERENCES

[1] Remote Laboratory Management Systems and the iLab Shared Architecture (ISA) [Online]. Available: http://tempus-desire.eu/meetings/2015-04_summerschool-ilmenau/downloads/presentations/Introduction%20to%20RLMS%20and%20ISA.pdf

[2] Y. Matsubara; S. Toihara; Y. Tsukinari. Virtual learning environment for discovery learning and its application on operator training. IEICE Transactions on Information and Systems, 02/1997, Volume E80D, Issue 2

[3] M. A. Bochicchio; A. Longo Learning objects and online labs: The micronet experience. 2012 9th International Conference on Remote Engineering and Virtual Instrumentation (REV)

[4] iLab Service Broker [Online]. Available: Platform http://ilab.mit.edu/iLabServiceBroker/

[5] V. J. Harward et al., "The iLab Shared Architecture: A Web Services Infrastructure to Build Communities of Internet Accessible Laboratories," in Proceedings of the IEEE, vol. 96, no. 6, pp. 931-950, June 2008. doi: 10.1109/JPROC.2008.921607

[6] Global Online Laboratory Consortium [Online]. Available: http://www.online-lab.org/

[7] Remote Labs - Enriching digital education [Online]. Available: http://www.labshare.edu.au/

[8] Weblab-Deusto, University of Deusto [Online]. Available: http://weblab.deusto.es

[9] Virtual Labs India [Online]. Available: http://vlab.co.in/

[10] iLab Acrchitecture Description [Online]. Available: https://www.technologyreview.com/s/418515/online-labs/

[11] L. F. Zapata Rivera, M. M. Larrondo Petrie, "Models of Collaborative Remote Laboratories and Integration with Learning Environments," International Journal of Online Engineering, Vol. 12, No. 9, International Association of Online Engineering, Austria, 2016, pp 14-21.

[12] L. F. Zapata Rivera, M. M. Larrondo Petrie, "Models and Smart Adaptive Interfaces for the Improvement of the Remote Laboratories User Experience in Education," in proceedings of the 13th International Conference on Remote Engineering and Virtual instrumentation (rev 2017), New York, USA, IEEE, Mar. 2017.

[13] EduApps Center (online) https://www.eduappcenter.com/ Learning Tools Interoperability (LTI) is a trademark of the IMS Global Learning Consortium, Inc. (www.imsglobal.org).

[14] Experience API – TinCanAPI. [Online]. Available: http://tincanapi.com/

[15] H. Saliah-Hassane; "IEEE Education Society Standards Committee Report," presented at The Frontiers in Education Conference, El Paso, Texas, USA, 20-23 October 2015. [Online] Available: http://ieee-edusociety.org/sites/ieee-edusociety.org/files/Standards%20 Committee %20-%20EdSocStandardsReport1015.pdf

[16] WebIOPi. GPIO API for Raspberry Pi [Online]. Available: http://webiopi.trouch.com/

[17] Motion – Motion detection Web Camera service [Online]. Available:
http://www.lavrsen.dk/foswiki/bin/view/Motion/WebHome