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A Toolkit to Facilitate the Development and Use of Educational Online Laboratories in Secondary Schools

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Abstract - Online laboratories have gained motion during the last decade, mainly due to the increase of online education programs. Online labs provide pedagogical values in some circumstances and fill in some gaps left open by traditional hands-on experiments. It is however a challenge to develop and deploy such laboratories for lecturing staff, as special software development skills are needed for such a task. In this research, we propose a novel approach for the deployment of new experimentation equipment. This system is not tailored to any specific type of laboratory. It can rather be understood as general purpose service, or lab as a service (LaaS). It is different from the approaches to deliver lab as a service implemented to date because the intended consumers of our service are lab owners, and not lab users (students, teachers and lab instructors). It shifts the complexity of a lab server to a central location (cloud) and ensures that the consumer (lab owner) has only to implement a tiny piece of software to deploy an online laboratory.

Introduction

Online Laboratories started gradually to gain motion after undergraduate distance education programs appeared. At first, the initial approaches were to send students to spend a period of time on the campus where they took concentrated hours of laboratory experiment lessons or to provide the students with experiment kits that allowed them to perform the required exercises at home. Meanwhile the delivery methods of distance education has undergone major changes as soon as new technologies appeared (mail, telephone, radio, television, tape recording, computers), however this did not impact the way laboratory experiment was carried out in distance undergraduate education. This impact came later with the introduction of the Internet[1]. The Internet changed the way distance education has been carried out so far. The enhanced delivery of educational services through technological innovations and socio-economic factors, like the need for part-time study programs and continuing education have completely redefined the physical and temporal boundaries that education and laboratory experimentation have been subjected to[1]. Furthermore, this new scenario placed Online Laboratories as part of a much larger picture with the potential to deliver education at any time and place, not only to students who could not not come to the campus, but also as a tool that could potentially enhance laboratory experience of on-campus students as well[1]. Despite the proven additional value added by online laboratories, it is a difficult task for teachers at all educational levels to include interactive online experiments in their courses.

Overview on Remote Lab Management Systems and iLab Shared Architecture

During the past years, considerable advances have been made concerning the design and development of educational Online Laboratories. These advances have contributed to improve their efficacy in different learning scenarios. It has been shown that Online Laboratories can potentially fill in gaps left open by traditional hands-on laboratories, in addition to serving as a tool for distance education. As pointed out in[3], if used in the right context, online laboratories can provide significant advantages over conventional hands-on labs. Several factors contribute to this, such as their ability to cross institutional barriers and foster collaboration and sharing of lab equipment. Hands-on and remote labs have been compared in several studies[11, 12, 13]. In this section the technical context for this work will be examined.

Given the immense variety of Online Laboratories available today, a common framework providing support for the framing and maintenance of a lab session turns out to be of extreme importance, but in the other hand a paradigm raises as usually different lab developers are likely to adopt different software strategies to implement their solutions. In addition, there are several software packages available today that provide low level control of devices via industrial standard protocols. LabView, from National Instruments, for example, provides support for visualization and easy to use APIs for dealing with low level libraries for data acquisition and network communication protocols, but these tools usually do not provide support for integration with different types of learning management systems (LMS) or other platforms that universities use to manage courses[5].

Developing an online laboratory from scratch can be an arduous task, especially if the developer is a specialist in the laboratory domain and not a software engineer. Several aspects have to be considered, like user management, scheduling of lab sessions, single sign-on with university authentication systems, management of experiment data, etc. To address these issues, during the last decade several developers began to identify and to group common functionalities to every online laboratory system around a single system. These systems were later on named Remote Laboratory Management Systems (RLMS). Some examples of RLMSs are WebLab Deusto[2], Labshare Sahara[3], Labicom.net[4] and the iLab Shared Architecture (ISA)[5]. The latter serves as the basis for this work. The next paragraphs will describe the ISA and its main features. Fig. 01 shows the typical topology of the ISA network.

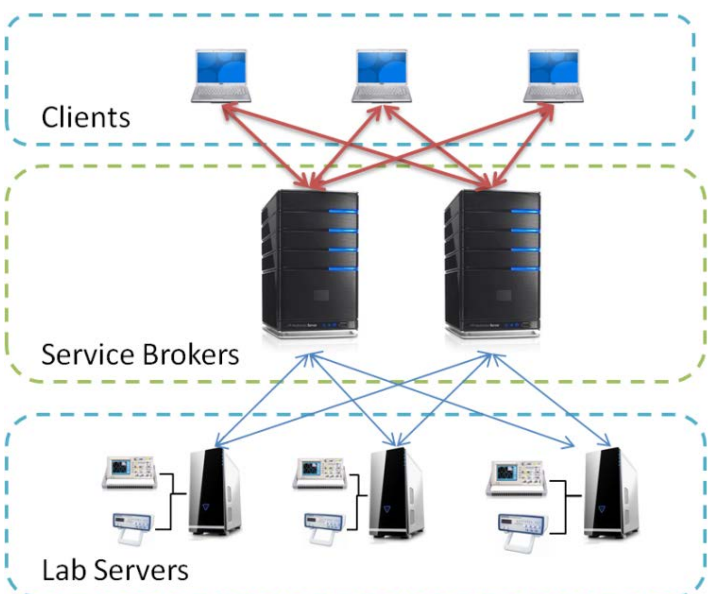

Fig. 01 – The iLab Shared Architecture

The iLab Shared Architecture is a Remote Laboratory Management Systems and a software architecture developed at the MIT (Massachusetts Institute of Technology) that facilitates a cross institution sharing and management of online labs. ISA provides a framework for the maintenance of a lab session, lab users' management and experiment data storage. It establishes clear rules governing the communication between clients and lab servers by means of a Web services based API[6, 7]. The choice for Web services was favored due to their platform independence and standardization by W3C (World Wide Web Consortium). ISA distinguishes the tasks of using a specific lab that comprises an experiment from the tasks of managing users' accounts, user authentication and other tasks that follow a lab session. This clear separation of roles is a fundamental of several RLMSs and one of the main advantages of this software architecture. ISA does not focus in a specific type of laboratory but provides a set of general purpose functions for lab developers. ISA is divided into three tiers that provide different services as depicted in Fig. 01. These tiers are client, Service Broker and lab server. The Service Broker is the core of the architecture and provides user authentication, authorization, experiment data storage and access to scheduling services. Beyond these functionalities, the architecture supports the use of a diverse number of laboratory hardware and software and does not tie client and server platforms[8].

Online Laboratories developers are used to different types of labs. Not all labs have the same technical requirements in terms of bandwidth, number of users and not always their behaviour and control can be modelled with a single model. Therefore ISA foresees two different types of experiments: Interactive and batched. Interactive Experiments are those experiments that require "real time" control and visualization of the laboratory hardware and results during the experiment execution. Interactive experiments usually require a higher bandwidth for the communication between client and Lab Server. Batched Experiments, on the other hand, are those experiments that can have their entire course specified before execution. The task of performing a batched experiment can be summarized in submitting an experiment protocol, executing the experiment, retrieving and analysing the results. This type of experiment requires very low bandwidth and run relatively fast, therefore scheduling of lab session is not necessary. Batched experiments are usually queued prior to processing by Lab Server. Additionally batched labs are designed to maximize throughput; all experiments are queued before execution and are dequeued at the lab server in a first in first out basis. Typically, the execution of a batched experiment can last from a few seconds up to a few minutes and the user requesting the experiment execution can be offline while the experiment runs. Batched experiments are the focus of this work and because they are well suited (due to the reasons previously mentioned) for a large scale use of online laboratories in education.

The Proposed Solution

As previously mentioned, developing an online laboratory around an RLMS decreases substantially the efforts employed to create such a system. All common functionalities, like user management, lab data storage, queuing of lab execution requests, etc, can and should be reused. However, it is still not a trivial task for future lab owners to deploy their systems if they are not software engineers or computer scientists. In the specific case of ISA, they

should be able to develop, deploy and consume SOAP Web services to develop client and server applications.
The aim of this work is the development of a toolkit that helps lab developers to deploy their lab experiments in an easier and faster way. The ultimate aim of this toolkit is an authoring tool that should allow domain specialists to deploy and lab, assuming it was developed according to the batched execution model previously explained.
The initial implementation and prototype of the proposed toolkit was developed in LabVIEW. This platform was chosen due to its broad usage in several different fields in engineering, physics, chemistry, etc and for being a broadly used tool for easily creating applications involving virtual instrumentation and data acquisition. It provides also interfaces for several commercial hardware equipment.
As a starting point for the initial prototype development, the following requirements were set:

- The toolkit will not be tailored for one specific type of lab.
- It should (at least initially) support only batched laboratories
- Users should have available a Web based configuration interface where they should be able to configure the parameters that will be needed govern the experiment execution (batched parameters)
- Parameters should be converted to their proper data types
- XML should be initially used to exchange the experiment data

The diagram of Fig. 03 depicts the initial implementation of the prototype. In this diagram, the lab server generic modules implement the Web services interface to communicate with the other tiers of ISA (Fig. 01). This module also queues experiments for execution and stores them in the database. The toolkit acts as an experiment engine by dequeuing experiments, parsing the parameters and passing them on the Lab specific VIs, where it will be executed.

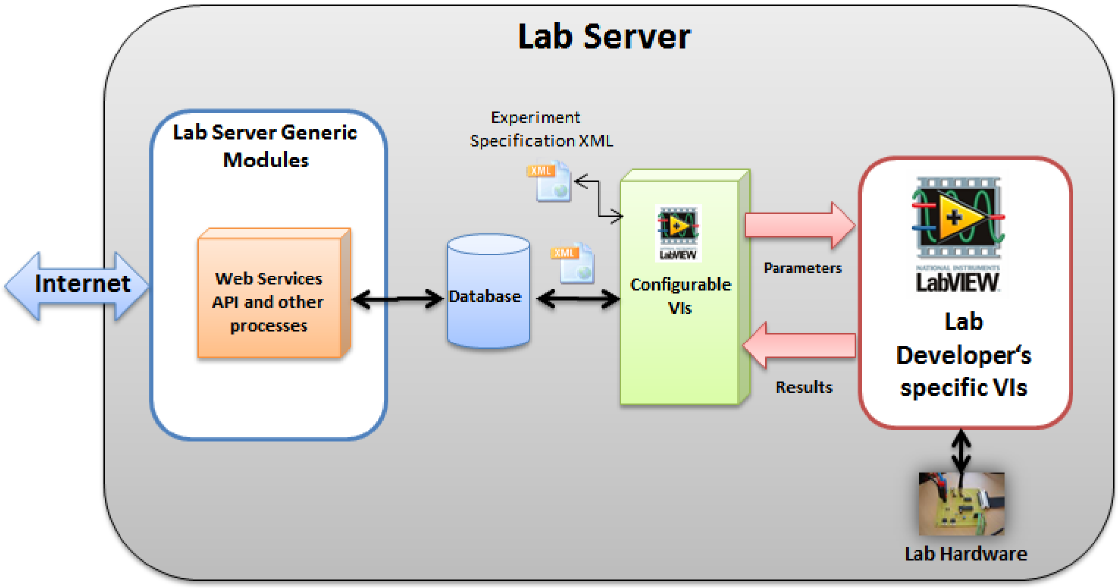

Fig. 03 – The Lab Server and the proposed toolkit.

The lab specific part (Lab developer's specific VIs) shall be the only component of the lab server developed by the lab owner. All the interfaces that will communicate this component with the remaining parts of ISA are ready to use and are implemented by the toolkit. LabVIEW was the first choice due to reasons previously explained, but implementations of the interfaces in other platforms will also be offered.
As previously mentioned, for the initial prototype we require the use of XML as the vehicle to transport the lab parameters and experiment results. This is, however, not a requirement of ISA, but rather a lab developer's choice. Since XML is well suited for this purpose it was decide to support it. In the future, support for JSON will also be included.

Preliminary Results

The outcome of this work is a product that includes a configurable experiment engine (called the toolkit) that can be utilized at any place for any type of laboratory.
The direct beneficiaries of the proposed Framework are online lab developers and lab owners in general. In this work we aim to create guidelines on how interfaces between lab equipment and client can be simplified, so that the software programming skills required to develop a new online laboratory are minimal. The developed prototype has been used to successfully deploy one online laboratory that allows students to perform experiments to study the properties of light by measuring the intensity of radiation emitted by a blackbody[9]. Fig. 04 shows a screenshot of the lab client user interface of the Blackbody radiation lab which is deployed with the toolkit. This client is a JavaScript application and the requests are processed by the configurable experiment engine (or toolkit).

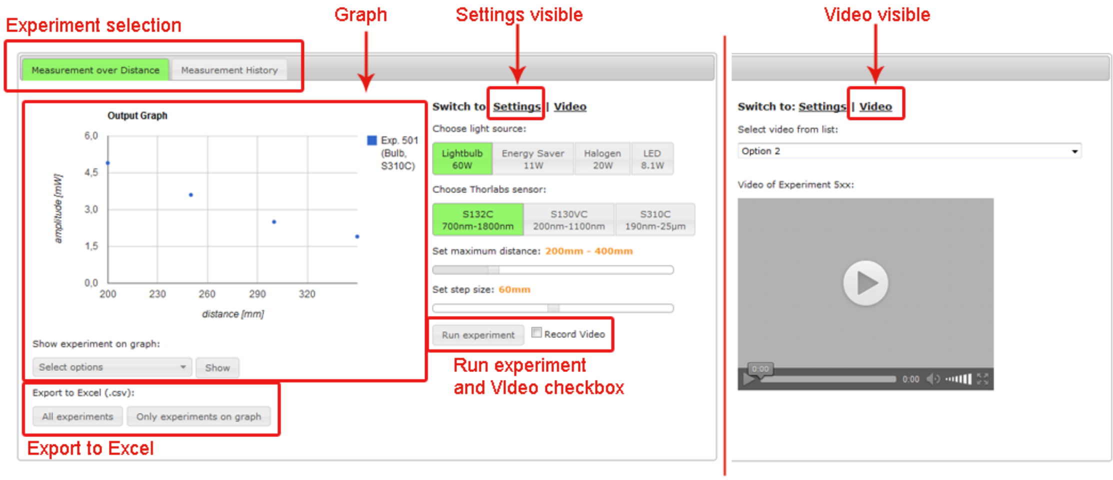

Fig. 04 – User interface of a lab deployed with the prototype toolkit

In this way including online experiments in in a variety of educational forms will be much easier. It is important to notice, however, that the proposed solution aims at the server-side development only.

Conclusion and Future Work

In a second stage, the toolkit will be extended to support other programming environments and some of its functionalities shall be centralized and provided as a service. This new paradigm is introduced in the OnlineLabs4All project (www.onlinelabs4all.org), a research project that is being carried out under the Sparkling Science Program, funded by the Austrian Federal Ministry of Science, Research and Economy. In this new approach, queuing, lab data storage and deployment will be offered as a service for lab owners, allowing the lab specific part to be loosely coupled with the RLMS and lab server. This is depicted in Fig. 05.

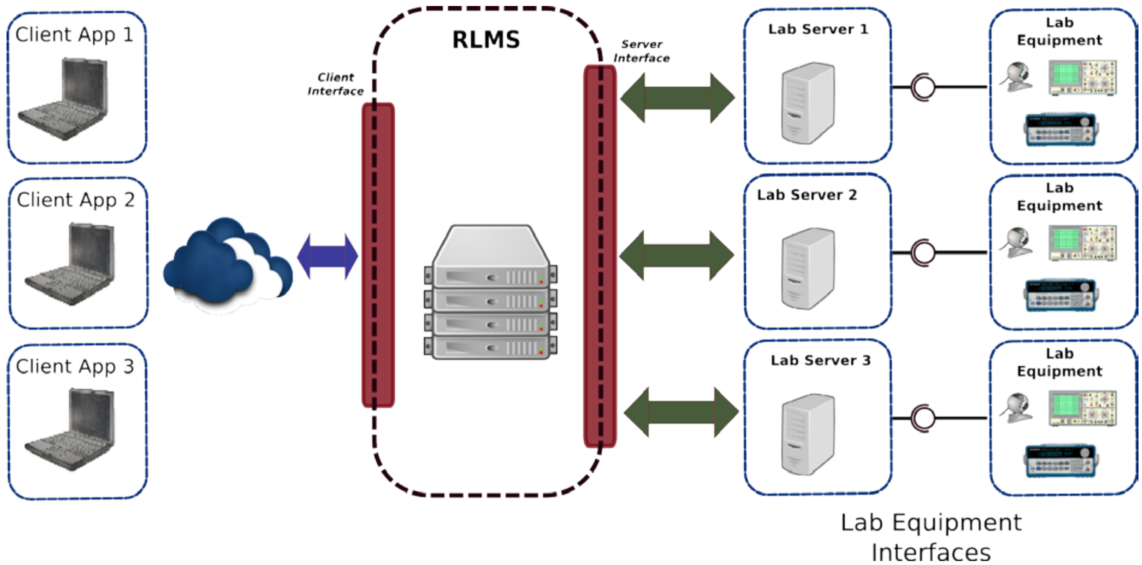

Fig. 05 – Lab server functionalities provided as a service

In this project, together with international partners we will involve secondary school students in the developing process of online laboratories and potentially achieve valuable scientific results as well as provide insights for students into scientific research. We therefore target to strongly involve young learners in the research process as well as to gain age appropriate insights into the requirements of these students.

In addition, we anticipate better understanding of the age-appropriate student preferences for the use of the laboratory experiments. As a result of this research, we expect to gain a better understanding of the requirements design and implement interfaces that facilitate the attachment of new laboratory equipment to the Internet.

REFERENCES

1. L. D. Feisel and A. J. Rosa, "The role of the laboratory in undergraduate engineering education," *Journal of Engineering Education*, vol. 94, no. 1, pp. 121–130, 2005.
2. Ordua, Pablo and Irurzun, Jaime and Rodriguez-Gil, Luis and Garcia-Zubia, Javier and Gazzola, Fabricio and Lpez-de-Ipia, Diego. Adding New Features to New and Existing Remote Experiments through their Integration in WebLab-Deusto. International Journal of Online Engineering (iJOE), vol. 7, no. S2, Oct. 2011.
3. Lowe, S. Murray, E. Lindsay, and D. Liu, Evolving remote laboratory architectures to leverage emerging internet technologies. Learning Technologies, IEEE Transactions on, vol. 2, no. 4, pp. 289294, 2009.

4. I. Titov and E. Smirnova, “Network architectures of remote laboratories: Proposal of a new solution and comparative analysis with existing ones,” *International Journal of Online Engineering (iJOE)*, vol. 9, no. 6, p. 41, Nov. 2013.
5. V. J. Harward, J. A. del Alamo, S. R. Lerman P. H. Bailey, J. Carpenter, et. al., "The iLab Shared Architecture: A Web Services Infrastructure to Build Communities of Internet Accessible Laboratories," Proceedings of the IEEE , vol.96, no.6, pp.931-950, June 2008.
6. Harward, J. V. 2005. Service Broker to Lab Server API, 2005, MIT iCampus, Cambridge MA, USA.
7. Zych, D. 2005. Client to Service Broker API, 2005, MIT iCampus, Cambridge MA, USA.
8. Soumare, H., Schroff, R., Hardison, J. L., et al. (2009). A Versatile Internet-Accessible Electronics Workbench with Troubleshooting Capabilities. Paper presented at the REV 2009 Conference, Bridgeport, CT.
9. Kreiter, C., Oros, R.G., Pester, A., 2014. Black body radiation for students and secondary schools. Demonstration presented at the REV 2014 Conference, Porto, Portugal. IEEE, pp. 401–402. doi:10.1109/REV.2014.6784202
10. Zutin, D.G., Auer, M., 2014. A LabVIEW based experiment execution engine to ease the development of ISA batch lab servers. IEEE, pp. 1089–1092. doi:10.1109/EDUCON.2014.6826244
11. J.E. Corter, J.V. Nickerson, S.K. Esche, C. Chassapis, S. Im, and J. Ma, “Constructing Reality: A Study of Remote, Hands-On and Simulated Laboratories,” ACM Trans. Computer-Human Interaction, vol. 14, pp. 1-27, 2007.
12. E.D. Lindsay and M.C. Good, “Effects of Laboratory Access Modes upon Learning Outcomes,” IEEE Trans. Education, vol. 48, no. 4, pp. 619-631, Nov. 2005.
13. J. E. Corter, J.V. Nickerson, S.K. Esche, and C. Chassapis, “Remote versus Hands-On Labs: A Comparative Study,” Proc. 34th Am. Soc. for Eng. Education (ASEE)/IEEE Frontiers in Education Conf., 2005.