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Towards federated interoperable bridges for sharing educational remote laboratories

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ABSTRACT

Educational remote laboratories are software and hardware tools that allow students to remotely access real equipment located in the university as if they were in a hands-on-lab session. Different initiatives have existed during the last two decades, and indeed toolkits (e.g. iLabs, WebLab-Deusto or Labshare Sahara) have been developed to ease their development by providing common management features (e.g. authentication or scheduling). Each of these systems was developed aiming particular constraints, so it could be difficult to migrate the labs built on top of one system to other. While there is certainly some overlap among these systems, with bridges among them they become complimentary. Given that these systems support web services based federation protocols for sharing labs, it is possible to achieve this goal, and share labs among different universities through different systems. The impact of this goal is that different institutions can increase the experiential activities of their students, potentially improving their learning goals. The focus is the integration of WebLab-Deusto labs inside the iLab Shared Architecture, as well as the integration of iLab batch labs inside WebLab-Deusto, detailing limitations and advantages of both integrations and showing particular cases.

1. Introduction

Remote laboratories enable the access to laboratories located in the host institution. These laboratories are physically located in the institution and comprehend many areas: physics (Gustavsson, Zackrisson, Håkansson, Claesson, & Lagö, 2007), chemistry (Coble et al., 2010), robotics (Dziabenko, García-Zubia, & Angulo, 2012), or even nuclear reactors (Hardison, DeLong, Bailey, & Harward, 2008).

As a straightforward example, WebLab-Deusto provides a mobile robot shown in Fig. 1, which is controlled by a Microchip PIC microcontroller. Students learn how to program in PIC assembler, so the real robot is provided, as well as the instructions on what inputs and outputs are available. Students program the code, and while doing this, they can log in the WebLab-Deusto system through the Internet, submit the program to a real robot located in the University of Deusto. Then, for a small slot of time, they can exclusively see the effects of the program in the real robot. Other students attempting to use the laboratory will be queued until the current user finishes (in a matter of minutes). Finally, instructors can later check the usage of the laboratory, which programs have been sent, and gather statistics.

While remote laboratories cannot be used in all type of experiential learning (for instance, the laboratory would not be suitable for a lesson where students must learn how to build a robot), in those fields where it is suitable (e.g. learning how to program in assembler), it adds flexibility, since students can learn experimenting at night or during weekends without being in the university. Effectiveness of this type of laboratory has been already addressed in the literature (Lang et al., 2007; Corter, Esche, Chassapis, Ma, & Nickerson, 2011; Garcia-Zubia et al., 2011), which is outside the focus of this contribution. The focus of this contribution is on how to maximize the type of laboratories available for a particular institution, increasing the available experiential learning among its students. The effectiveness of this learning will depend on the particular laboratories shared among institutions.

So as to develop a remote laboratory, certain features can be shared with other remote laboratories. From the example presented, students (a) log in the system – authentication, (b) use a scheduling mechanism – a queue – to guarantee exclusive access, (c) communicate with the remote system, (d) do something particular of the laboratory – send the program, see the results – and (e) enable user tracking by the instructor. Except for the particular code, the rest of the features could be shared with a different type

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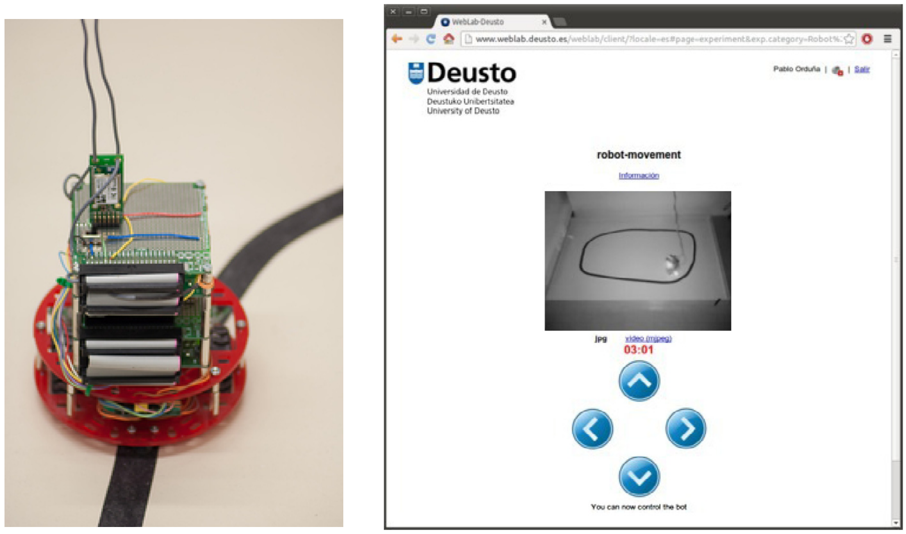

(a) Azkar robot (b) Robot controlled through a web interface

Fig. 1. Response times measured in different embedded devices.

of remote laboratory. So as to do this, remote laboratory management systems (RLMSs) were developed. They provide APIs (Application Programming Interfaces) to develop new remote laboratories, authentication and authorization mechanisms, scheduling systems, management tools (to add/remove users, laboratories, etc.), and user tracking tools. A laboratory developer can use these systems to create new laboratories easily, since the RLMS already provides these features. Additionally, upgrades of these RLMSs will provide the laboratory developer with more features.

Additionally, the creators of these laboratories found that, once students of a particular institutions can access through the Internet to a particular laboratory, it can also be accessed by students of other universities. This way, these systems supported federation. This means that these systems enable that two independent deployments of the management system in two institutions can share their laboratories automatically, under a service level agreement (SLA), such as "students of this university can access 10,000 a year this laboratory".

The interest on this unique characteristic of remote laboratories – federating them to increase the types of practices and reduce costs – is growing. The Labshare project survey (Kotulski & Murray, 2010), made on all 34 – Australian universities offering undergraduate engineering programs, reflects that interviewed executives were more interested in getting involved for the pedagogic merits of the remote laboratories, and were more inclined on initially being laboratory consumers than providers. Indeed, the European Union Commission is investing 60 million euro in research actions, projects and network of excellences in Technology-enhanced Learning (TEL), under the objective ICT-2011.8.1 of the call FP7-ICT-2011-8. One of the target outcomes is precisely supporting a European-wide federation and use of remote laboratories and virtual experimentations for learning and teaching purposes.

Three major RLMSs can be found in the literature: MIT iLabs[2] (Harward et al., 2008b), WebLab-Deusto[3] (Orduña et al., 2011) and Labshare Sahara[4] (Diponio, Lowe, & de la Villefromoy, 2012). However, while these systems share the motivation, rationale and are essentially equivalent, technically each of them has been focused on a type of laboratory and have certain differences. For example, WebLab-Deusto has always been used with short session laboratories (i.e. students access often but in 3–10 min sessions), and therefore its main scheduling system is queueing, while MIT iLabs in its interactive version will rely on calendar-based booking for supporting long session laboratories. This is common given the wide background differences in remote laboratories in terms of technologies (Gravier, Fayolle, Bayard, Ates, & Lardon, 2008) and approaches to create the laboratories. In order to build an ecology of remote laboratories (Harward et al., 2008a), not only a software infrastructure is required, but also a deep understanding of the student audiences. Since each system has been influenced by different student audiences, building bridges between two systems, when feasible, make it possible for each system to consume laboratories designed for other audience.

In this line, (Yeung, Lowe, & Murray, 2010) proposed the LabConnector application protocol interface (API) as a bridge between iLabs and Labshare Sahara focused at protocol level, evaluating it with an iLab laboratory located in the University of Queensland being consumed by Labshare Sahara. While the bridge itself might have technical difficulties in becoming adopted by other systems, it represented a clear step forward in the interoperability of remote laboratory management systems.

In this contribution, a bridge to consume WebLab-Deusto laboratories by the iLab Shared Architecture (Harward et al., 2008b), as well as an experimental bridge to consume iLab batch laboratories from WebLab-Deusto is presented. This type of bridge make it possible that institutions can wide the number of supported remote laboratories, increasing the student audiences and supporting more laboratories. In order to achieve a global solution, an interface defined by the Global Online Laboratory Consortium (GOLC[5]) would be required.

2. Remote laboratory management systems

This section provides a brief summary of the architectures of MIT iLabs and WebLab-Deusto, focusing only on the most relevant parts for the contribution. Other remote laboratory management systems are outside the scope of this contribution.

2 http://ilab.mit.edu.
3 http://www.weblab.deusto.es.
4 http://www.lila-project.org/.
5 http://www.online-lab.org/.