Achieving interoperability among educational remote laboratories

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Abstract. An educational remote laboratory is a software and hardware tool that enables students to remotely access real equipment located in the university as if they were in a hands-on-lab session. Since the equipment used by students is real, it has associated costs: laboratory development, hardware used and maintenance costs. Given the remote nature of the remote laboratories, institutions can share these costs by sharing the access to the laboratories. In order to reduce the associated development and maintenance costs, as well as to reduce the overall costs by managing the sharing of laboratories in different institutions, software infrastructures and toolkits have arisen, such as the MIT iLab project, the Labshare Sahara project, or WebLab-Deusto. While these toolkits have been designed to be decoupled of the particular laboratory (so they can be used to create different laboratories), various factors and influences have led to different approaches and solutions. Making different systems collaborate at infrastructure level is therefore highly desirable to share laboratories with different characteristics. The focus of this contribution is to show the integration of WebLab-Deusto laboratories inside the iLab Shared Architecture (ISA), as well as the integration of iLab batch laboratories inside WebLab-Deusto, detailing the limitations and advantages of both integrations.

1 Introduction

Remote laboratories enable the access to laboratories located in the host institution. The equipment does not usually need human attention to work, being available in a 24-hour basis. Students can access it during winter breaks, weekends, etc. at any time from anywhere connected to the Internet. This increases the chances of decreasing the number of required equipment: in electronics, if 20 boards are required for 40 students when the boards are available few hours a week, 10 boards might be enough if they can access anytime. The Labshare project survey [1], made on all 34 Australian universities offering undergraduate engineering programs, suggests that remote labs offer superior features in terms of flexibility, utilization, space saving, and safety issues.

However, a characteristic generally present in both remote and traditional laboratories is that they are long time unused. In the case of remote laboratories, they can be easily shared with other institutions, regardless the city, country or continent where the student is. The sharing of remote laboratories through the federation of institutions makes sharing the costs of laboratories possible, either by paying for the access or by providing different laboratories. If two institutions each have a remote laboratory, they can exchange them so students would in fact have two laboratories for the same price. This way, federating remote laboratories would make it possible to increase the use made of the investment on laboratories, as well as pedagogically add more types of practices to the curricula of students.

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 cited above 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 going to spend 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.

In order to exploit such a federation of remote laboratories, a software infrastructure that makes it possible to develop, deploy, manage and share remote laboratories is required. Targeting this, different remote laboratory systems have arised: MIT iLabs [4] [2], Labshare Sahara [5] [3], WebLab-Deusto [6] [4], LiLa [7] [5] or VLCAP [6].

The approaches taken by these systems are different, and even key features of some of them are not supported on the rest. This is common given the wide background differences in remote labs in terms of technologies and approaches to create the labs. In order to build an ecology of remote labs [7], 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 labs designed for other audience.

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[4] http://ilab.mit.edu

[5] http://www.labshare.edu.au

[6] http://www.weblab.deusto.es

[7] http://www.lila-project.org/

In this line, [8] proposed the LabConnector application protocol interface (API) as a bridge between iLabs and Labshare Sahara focused at protocol level, evaluating it with an iLab labs 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 lab systems.

2 Bridging WebLab-Deusto labs in MIT iLabs

The iLab Shared Architecture (ISA) only supports scheduling through booking in the case of interactive labs, while WebLab-Deusto only supports queuing.

In order to handle this issue, the "no scheduling" option was selected in the ISA for the integration. Using this option, the ISA relies completely on the Lab Server, sending all the users that attempt to use the lab to the Lab Server. A Lab Server was implemented that uses this scheme to rely the scheduling on WebLab-Deusto. Being WebLab-Deusto labs presented as regular iLab labs, the authentication and authorization can be managed through the iLab tools. Furthermore, if the particular host institution desires to share the labs with other universities, it is possible using the ISA.

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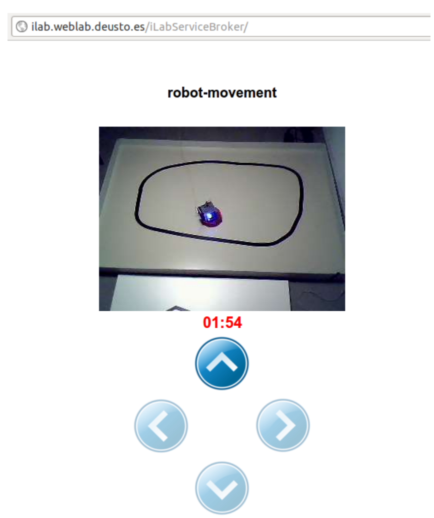
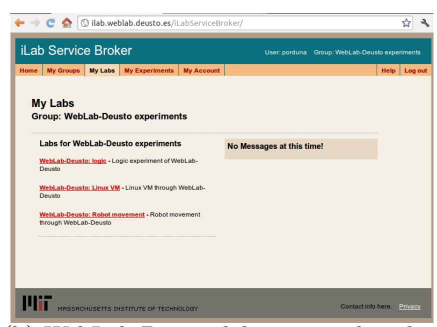


(a) WebLab-Deusto robot laboratory running through an iLab system



(b) WebLab-Deusto laboratories listed in iLab

Fig. 1. WebLab-Deusto integrated on iLab

3 Bridging MIT batch iLabs labs in WebLab-Deusto

An experimental bridge of batch iLab labs into WebLab-Deusto has been implemented. This way, it becomes possible to consume iLab labs from WebLab-Deusto instances. So as to process the requests sent by iLab Lab Clients, a translator of a subset of the possible requests to their corresponding request type in WebLab-Deusto was developed. Once they have become WebLab-Deusto requests, WebLab-Deusto uses its pluggable scheduling system to handle the requests with a new scheduling plug-in for the iLab integration. This plug-in will convert the requests again and forward them to an external iLab Lab Server, therefore acting WebLab-Deusto as a Service Broker.

Given that it has been implemented as a plug-in in the core of the scheduling system of WebLab-Deusto, all the messages are automatically stored so educators can track the usage performed by students. The authentication and authorization is managed by WebLab-Deusto, and since it supports creating accounts and being authenticated through OAuth 2.0 with Facebook, iLab expermients can be used through it (fig 2).

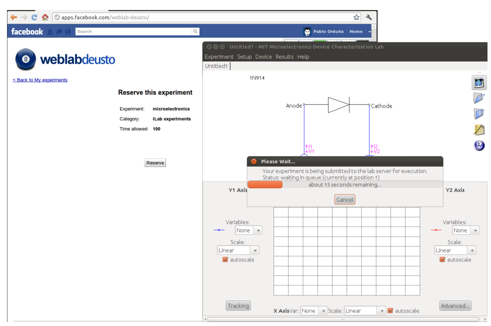


Fig. 2. MIT Microelectronics WebLab through WebLab-Deusto in Facebook

Finally, being implemented as a plug-in also allows WebLab-Deusto to use other plug-ins of WebLab-Deusto, so inter-institutional chains can be built. As described in figure 3, students can access WebLab-Deusto in their institution (Institution A in the example), and through the plug-in resolver they can use an iLab plug-in contacting an iLab Lab Server in the same institution. Furthermore, through the federation plug-in, it is possible to connect WebLab-Deusto with other WebLab-Deusto in the Institution B, which has also set up the iLab plug-in with yet another institution (Institution C). More complex chains, even supporting distributed load balance, can be built with this approach.

However, this bridge is experimental since only those request types required to validate, submit, wait and retrieve the results. Those request types required to store user information in their session have not been implemented, since WebLab-Deusto lacks of this interesting feature, it could not be implemented in the bridge.

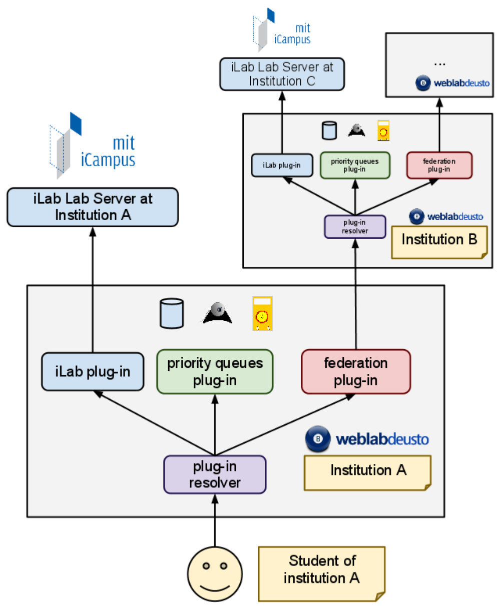


Fig. 3. Architectural overview of the iLab on WebLab-Deusto integration

4 Conclusions

The contribution has presented two bridges between WebLab-Deusto and the iLab Shared Architecture. While this work might not be directly extrapolated to other systems, it draws the potential advantages, drawbacks and the motivation for exploring this area. These bridges show that these TEL solutions can automatically federate laboratories that might not fit in one of the two systems or that would require a notable amount of work.

In both bridges, the major advantage is that students already used to one system can consume laboratories of the other using the solution they know and for which they already have credentials. Students and educators of one institution who are using one system with the laboratories developed on it for different classes can start using laboratories developed in the other, which will appear in the same menus.

In the case of WebLab-Deusto being consumed by the iLab Shared Architecture, it enables the use of WebLab-Deusto using the iLab federation model. This means that if an iLab Service Broker has a number of WebLab-Deusto laboratories included, it can share these to other iLab Service Broker. For instance, the Service Broker at the University of Deusto can share WebLab-Deusto laboratories through the iLab system to the iLab-Europe Service Broker [8], so users there will automatically be able to consume those laboratories. Given the size of the

[8] http://www.ilab-europe.net/

network of iLabs, this is a considerable benefit for WebLab-Deusto laboratories. Additionally, the iLab Shared Architecture benefits from three features provided by WebLab-Deusto: a) consuming other federation model, so users of an iLab Service Broker bound to a WebLab-Deusto instance will be able to use laboratories of other WebLab-Deusto instance if the two WebLab-Deusto instances are federated; b) support of queue based interactive laboratories; c) load balancing of laboratories among different copies -i.e. if there are two copies of one WebLab-Deusto laboratory, it will manage the queues so the load of users will be balanced in a transparent way for the iLab system-.

Regarding future work, the WebLab-Deusto laboratories consumed by the iLab Shared Architecture does not store the results in the iLab system, so educators can see that a particular student used the system but not what was done. The iLab Shared Architecture consumed by WebLab-Deusto also presents problems, since the interactive version -which requires booking- is not supported, as well as some features of the batch version such as storing information of each student. This is mainly due to limitations of the WebLab-Deusto system.

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