# Adaptive Follow-Up of Online Engineering Laboratories Activities.

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***Abstract*—In this paper, we are providing a study on the issue of interoperating Learning Management Systems (LMS) and Remote Laboratories, in a seamless integration. This study emphasizes the need to make Remote Laboratories seen as a pedagogical material within the LMS. We are presenting a novel and original approach to make these two kind of platforms (LMS and Remote Laboratory) to communicate under a loose coupling relationship. The main purpose of this work is to bring a better follow-up of students to the tutor and the students themselves, and therefore to lead to an enhanced learning experience.**

***Index Terms*—Remote Laboratories, Distance Learning, Learning Management System, Interoperability, Learning experience, Hands-on Approaches, Personalized Learning, IMS-LD, SCORM.**

## I. INTRODUCTION

Remote training services exploded with the growth of the Internet. Information Technologies and Telecommunications appeared therefore as a keystone for the leverage of Remote Laboratories (RLabs) in Distance Learning curriculum. Before the last few years, ongoing research in Distance Learning primarily focused on conceptual teaching or case studies, in the form of remote courses, works directed remotely or remote projects, but without possibility of real practical activities.

Hands-on approaches however are mandatory in scientific and technical education, especially in engineering curriculum [1]. Mainly, this study emphasizes that hands-on approaches help the students in making the link between theory and real problems, in supporting motivation and curiosity, in contributing to their personal development, in building socials networks. Because heavy and expensive laboratories facilities can neither be moved nor easily duplicated, a lot of efforts were made for the development of platforms, which now allow remote interactions between geographically distributed users and a pedagogical materials hosted in the school [2,3,4,5], laboratory [6] or company walls [7]. In these publications, all researchers accord to observe that it is not enough to create an interactive Web Site: it is compulsory that the conditions of experiments are realistic, productive and protected. In Distance Learning, one could add that interoperability is another mandatory characteristic, as Learning Management Systems (LMS) are the containers of remote learning activities and student's follow-up, and they are not yet able to include remote hands-on activities, while they already host lectures, tests, etc. Remote practical works are therefore ignored, because excluded since of their low interoperability, from the LMS. This paper addresses the problem.

In this paper, we are primarily interested in the interoperability between any Learning Management System and any Remote Laboratory. We identify the LMS as the element in the Information System that endorses the role of exposing the teaching contents on line while ensuring the follow-up of the user learning throughout his course of study. The purpose of this article is therefore to propose new models of interactions between these two types of platforms (LMS and Remote Laboratory) for a better follow-up of students, and therefore an enhanced learning experience.

The paper is organized as follows. Section 2 introduces a presentation of LMS in the light of relevant elements for integration with Remote Laboratories. Section 3 presents some elements of today's architecture for most common Remote Laboratories. Section 4 presents our approaches to make the two previously exposed architectures interoperate. Section 5 concludes.

## II. LEARNING MANAGEMENT SYSTEM (LMS)

### A. *Motivations of LMS*

In order to face problems in Education and life-long learning, such as the fast evolution of pedagogical materials and contents, many institutions and companies have turned towards e-learning, which makes it possible to learners, to acquire knowledge and competences without having to move of their place where they live or work. This calls the citation from Jesus del Alamo: “"If you can't come to the lab, the lab will come to you” [8]. In order to facilitate the organization and the success of these new ways of learning, software solutions appeared, known as “Learning Management Systems” (LMS). LMS are platforms created for managing remote curriculum and teaching through the Internet, while also proposing an electronic follow-up of the students throughout their learning experience.

They are Web-based systems hosting:

- Pedagogical materials (content)
  - o Hosting and harvesting: SCORM, LOM, IMS-LD metadata, Dublin Core, OAI-PHM, ... (meta data in general)
- Pedagogical scenarios
  - o Usually IMS-LD-based (planning the learning experience)

### B. *Follow-ups of students within the LMS*

A main feature of LMS is that they enable the follow-ups of students during lectures, tests, online exercises, etc. As for now, Online Laboratories are dedicated platform that ran outside the LMS, which means that no follow-ups

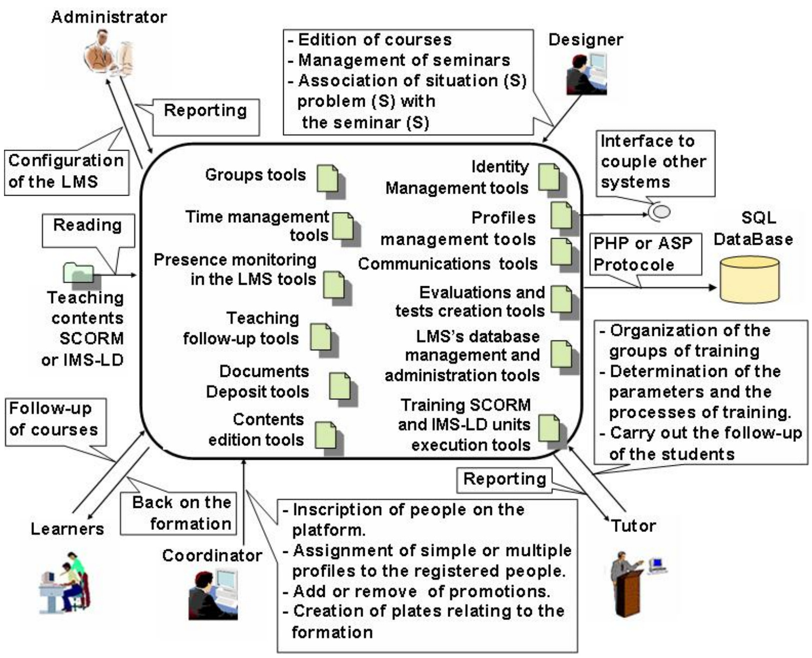


Figure 1. LMS's components and Functioning principle

of the student during their practical activities can be expected from such architectures.

In addition, Engineering Education is known to let students learn knowledge, know-how, and social skills. Without labs in the LMS, do the follow-ups of students in Distance Engineering Learning can possibly happen? How can we be sure they have developed such skills in a given module?

The aim of this work is therefore to propose solution in order to cope with the lack of Online Laboratories activities performed outside the LMS.

### C. *LMS functionalites*

The LMS are Web applications, which provide to their users (designer, tutor, learner, coordinator, and system administrator or super user), a set of tools ([9], [10], [11], [12]), or services allowing especially for:

a) The designer:
   a. To build and maintain his/her pedagogical materials by integrating resources and activities of any type according to a hierarchical structure carried out according to the standards, mainly at the SCORM (Sharable Content Object Reference Model [13] or IMS-LD (Instructional Management Systems-Learning Design [14]).

b) The tutor:
   a. To organize the groups of training and to determine the parameters and the processes of the training sessions.
   b. To carry out the follow-up of the students.

c) The learner:
   a. To reach and follow courses according to their own rhythm, auto-evaluation using tests constructed and carried out according to IMS-QTI specifications.

d) Both the tutor and learners:
   a. To communicate in a synchronous way (chat) or asynchronous (mails, forum, shared documents).

e) The coordinator:
   a. To register people on the platform.
   b. To assign simple or multiple profiles with the registered people.
   c. To add or remove of promotions.
   d. To create areas relating to a module of training.

f) The administrator:
   a. To configure the platform according to the desired organization.

The Figure 1 shows the common most frequent components, which can be met, in a given LMS, as well as the functioning principle of this last one.

## III. REMOTE LABORATORIES

The remote laboratories are referring to practical works carried out remotely on real devices under the assumption of a learning experience. Learners, tutors as well as devices to be handled are not in the same place. A typical architecture for the remote laboratories is given on fig. 2.

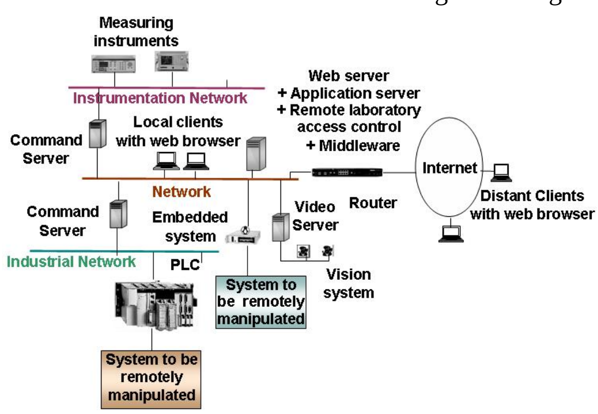


Figure 2. Typical Remote laboratory structure

The common software architecture is composed as follows (figure 3): the device itself, a local computer connected to the device, which plays the role of a gateway between the device and the remote computer of the user, and the associated middleware, through which information is exchanged between the local and the remote computers. There is, of course, a reason why this architecture is so widespread. In fact, a computer must locally handle most of devices in order to be remotely controlled over the Internet. There is no denying that some device directly embed an Internet connection, but this is only because they embed a modern operating system inside the device, which therefore does not require a dedicated local computer; yet it does not make much difference in the presented architecture: local computer (would it be embedded in the device itself or as a separate computer linked to the device, middleware, and remote Graphic User Interface (GUI)).

As a result, remote laboratories architects have no choice but to build a middleware allowing remote clients to connect to the local computer that handle the device. That is the reason why the first remote laboratories were using software solutions such a VNC[1], as it provided them the remote control over the local computer connected to the corresponding device. Nonetheless, those solutions were given up as they lack security and they require a lot of bandwidth, in favor to software development following the Distributed Architectures paradigms, such as Service-Oriented Architecture.

This evolution was mandatory to open the Remote Laboratory middleware to the other services in the Information Systems, and especially to Learning Management Systems, as we will study it under the following section. The connection between LMS middleware and RLabs middleware is at the core of our approach.

## II. A NEW APPROACH TO COUPLE A LMS AND A RLABS.

As already evoked in section 2, many institutes have already included remote formations in their curriculums. However, these platforms, largely used today, are not designed to integrate remote practical works, whereas remote practical works propose to put the theoretical teaching into practice, they are found excluded from the LMS, for lack of sufficient software technologies. The fact that the RLabs session is unlinkable to a Learning Object in the LMS at the moment comes with strong drawbacks:

- all the situations of training are hardly proposed online, and especially,
- no follow-up of students can be proposed during remote hands-on approaches,
- no authoring tool for setting-up the associated learning scenario,
- no possibility for the student to easily confront experimental results towards his/her theoretical exercises conducted in his/her LMS session.

It has to be noticed that especially the latter one (decreasing the learning enhancement by putting technological barriers between theoretical and practical learning experiences) strongly violate the first principle of laboratories in general, which are designed to let the students making theory and practice meet during the same learning session.

[1] Virtual Network Computing

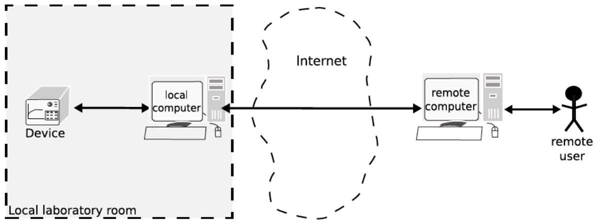


Figure 3. The widespread software chain of remote laboratories.

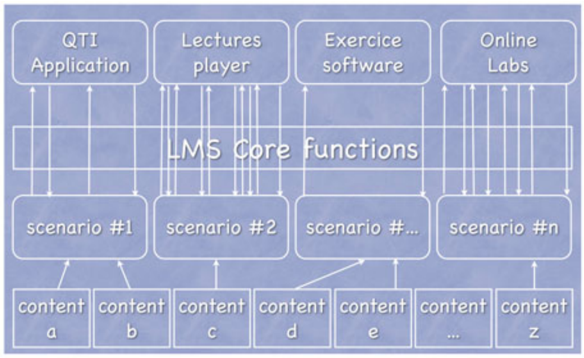


Figure 4. Core idea and motivation of the presented work.

We therefore think that part of ongoing research in RLabs should focus on making RLabs and LMS converge. The gap [13] between platform of remote practical works and the LMS is due to the fact that remote practical works require specific developments. They are thus stored in platforms' owners, while no standard exist for RLabs. As for LMS standards, such as SCORM [14] or IMS-LD [15], nothing is designed for RLabs, because so far those standards did not excepted the pedagogical content to be hosted outside the L(C)MS[2]. Moreover, it is difficult to imagine to host all the remote practical works in a LMS, in the same way that lectures or directed works, which requires much less interactivity between learners and educational contents.

### A. *Methodology*

This said, a pragmatic solution to integrate RLabs within an LMS, would be to carry out a loose coupling, between these two platforms through an interface in the forms of modules or "plug-ins", allowing to connect any RLab to any LMS, as long as the shared vocabulary and data exchange protocol (the module of the LMS, and its correspondent for the RLabs) is available on both parties.

The expectation of our research is provided at figure 4.

What is expected is to have Online Labs seen as a learning resource in the LMS in the same way lectures, QTI, exercise, etc. This is a two-steps process to match these expectations:

1. The Online Laboratory should be integrated in the LMS as a content (content z in figure 4). This con-

[2] Usually the difference is made between the LMS, which expose pedagogical content to the students and tutors, and the LCMS, meaning Learning *Content* Management Systems, which is held responsible for providing authoring tools and scenarii engines. In this paper, we are using the stretch of language where LMS denotes both the LMS and the LCMS.

tent should be described using common standards such as SCORM.

2. Above the content, the Online Laboratory is expected to be delivered as a scenario to the user.

The main issues lies in the 2nd step. Actually, would an Online Laboratory be integrated as a whole as learning content using SCORM metadata for instance, the follow-ups of the students, whatever the above scenario, would not be efficient. Indeed, that would mean that the scenario would be based on a single content. The only information we could expect is therefore to know when the student accesses the lab, and when he/she disconnects. This is by far insufficient would the teacher want to promote a better understanding of what the student's errors or skills are.

We believe that a solution is to apprehend the GUI of the online lab not as a single content, but to partition the GUI in several widgets, based on functionality. In other words, we would gather significant GUI elements for the same functionality in the same widget.

Several widgets therefore compose the GUI of a online lab. This enables fine-grained follow-ups of students, as every widget that composed the GUI could be integrated in the LMS as a learning content. This way, this means the scenario could deal with the user using each widget (and therefore build learning scenarios according to the sequence of actions of the user), while it was only possible previously to know when the user had launched the online laboratory.

Figure 5 illustrates this thought with 12 widgets we choose for partition the GUI of a Vector Network Analyzer (a device involved in OCELOT Online Laboratories framework).

### *B. Widgets as cornerstone of fine-grained follow-ups of students*

Our research tasks thus initially concentrated to make a research on the platforms of LMS having a plug-in system. After a long bibliographical search we discovered that there do not exist academic documents covering this kind of subject. In practice existing LMS (e.g: Moodle, Claroline, etc.) allow the use of third parties libraries through a plug-in system.

One can afterwards recover information on the set of "widgets" W = {w1, w2, …, wn} used in the remote GUI of a RLab (whatever the technology of the RLabs). It is therefore possible to store the set of widgets of each RLab in a repository, which could be queried afterwards, so that the remote GUI could be instance on the fly, after the set of widgets delivery. If this set of widgets is hosted in the LMS and seen as usable resource in learning scenario in LMS, the connection between LMS and RLabs become effective. Indeed, the LMS have the knowledge and comprehension of the widgets, and the RLabs are built upon instantiation from the widgets retrieved within the LMS. The widgets are therefore the keystone for interoperability between LMS and RLabs.

### *C. Implementation details*

In this study, the aim was not to reinvent the wheel as for a widget repository for RLabs. [16], [17], and [18] proposed an architecture which make it possible to display a set of "widgets" by making an entry from a Unit Of Learning (UOL) in the IMS-LD standard. Thus while proceeding to small improvements of this architecture, we think that it is possible realizing the development of some modules and "plug-ins" of extensions, to use it as bridge or interface to couple in loose manner, an LMS and a remote "Widgets Laboratories". There is a natural choice for connecting HCI and LMS, which is W3C Widgets. In W3C Widgets ongoing standardization, a widget is a local HTML/CSS/JavaScript web application. A PC/mobile user downloads a widget once, and then he/she adds the widget on his/her device. W3C Widgets is an ongoing standardization effort for describing a widget as a set of graphic elements in a Web-based HCI.

Thus, this is the approach, which we try in this research project, to realize by proposing a new architecture allowing to remotely controlling a system via its deported GUI, made up by a set of "widgets".

A study of the functioning of "Wookie" [18], an implementation of a W3C Widgets server, showed us that it is possible to make this coupling while making:

- An entry from a UOL (Unit Of Learning) IMS-LD according to the architecture of figure 6.
- A simple entry (i.e. not from an IMS-LD scenario) from the LMS according to the architecture of fig. 7.

The Plug-In, in these two architectures carries out the two following principal operations:

- Request "Wookie" to have an instance of the "Widgets" to deploy in the LMS to command the instrument or the system,
- Parse the response sent by "Wookie" to create a GUI of the command of the instrument or system in the LMS.

Figure 5. each area can be seen as a widget stored on a Widget server and retrieved by a plug-in within the LMS when the user instantiate a Online Laboratory.

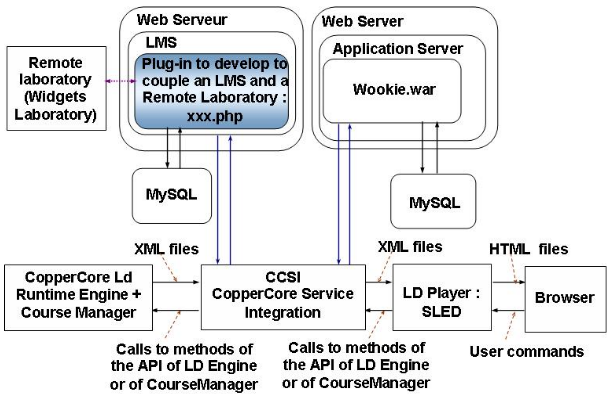


Figure 6. LMS Remote Laboratory Coupling with an entry from an UOL IMS-LD

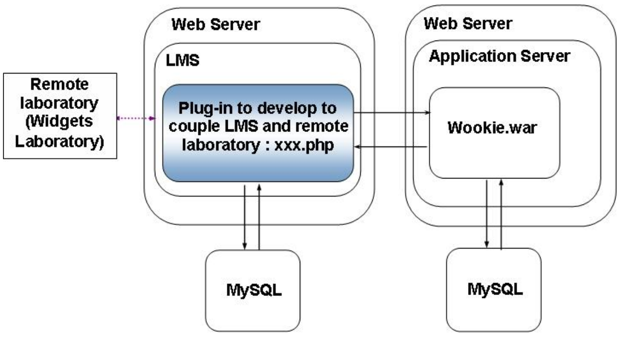


Figure 7. LMS Remote Laboratory Coupling with a simple entry from the LMS

We chose in a first step to work within second architecture assumption, by leaving an entry from a IMS-LD scenario in second step, as it lead us to use all the chain composed by: SLED, CopperCore, and CCSI ([19], [20], [21]).

Wookie responds to request (GET request for a widget/set of widgets instance) by sending a response in XML form, about information relating to the “widget” or the whole of the “widgets” for which it was requested.

As for authoring of the RLabs possibly connected to a LMS, the process is to describe a set of widgets in the Wookie fashion, setting a package for “Wookie” [23], and then to used it as a UOL in the learning scenario hosted by a LMS compliant with IMS-LD. This also means that the RLabs is reusable through different LMS, as long as it supports IMS-LD standard (loose coupling).

However, while processing in this way, there is not enough loose coupling, in our opinion. The main issue is that Wookie repository of widgets is populated from its config file describing the widgets (a set of widgets according to the W3C standard with its file config.xml, containing the URI of the start page as well as metadata, and loaded in “Wookie” via the its admin pages of this last one [21]). This is however compulsory if we want to connect an existing RLab to Wookie without having to reengineer its widgets. In order to solve this problem, we think that it is possible to modify the source code of “Wookie”, so that it could import these information from the RLabs itself. A first simple solution consists in introducing this information directly into the database of “Wookie”. Another solution is under study as we are conducting research in this matter, and especially using the Web 3.0 (ontologies) to represent the GUI of a RLabs in our RLabs framework (called OCELOT [23]). Such ontologies could be aligned with the concepts and relationships proposed by Wookie so that the widgets issued by such a framework could automatically be populated in the associated wookie meta-widget representing the RLabs, and allowing the connection with the LMS thanks to IMS-LD.

## III. CONCLUSION

In this paper, we tried to a new approach, which tries to close the gap between LMS and RLabs. The main issue is to find a solution to use the Rlabs in the UOL (Unit Of Learning), conform to standard IMS-LD, so that the walkthrough of the student during RLabs session could participate to the LMS follow-up of the student.

The main result is a loosely-coupled approach based on existing software which allows the follow-up of students during RLabs sessions through their use of predefined widgets expressed in a Wookie server, which are themselves usable in a UOL in IMS-LD standard. The biggest open issue is the provisioning of the Wookie server. Several means are under study, from standard insertion in database, to automatic provisioning through ongoing research in ontologies alignment, but each of these should still be tested in a real experiment in a broader audience in order to gather data on their scalability.

We have presented a solution for enhanced scenarios in the learning activities of online laboratories, as the presented system can enable to show/hide widgets depending on the user’s pending activity during the online laboratory. Future work will consist in a more Personalized Learning architecture where widgets would be on the shelf (teacher and users could be prosumers of online laboratories, by definition of Personalized Learning).

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