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► **To cite this version:**

Christophe Gravier, Jacques Fayolle, Gérard Noyel, Arnaud Lelevé, Hcene Benmohamed. Distance learning: Closing the gap between remote labs and learning management systems. 2006 1st IEEE International Conference on E-Learning in Industrial Electronics, Dec 2006, Hammamet, Tunisia. pp.130-134, 10.1109/ICELIE.2006.347198 . hal-00187267

**HAL Id: hal-00187267**

**<https://hal.science/hal-00187267>**

Submitted on 1 Jun 2012

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# Distance Learning: Closing the Gap between Remote Labs and Learning Management Systems

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*Abstract—*

**In this paper, we discuss the leap distance learning has to make in the near future. We take it for granted that students need hands-on approaches in addition to annotated lectures and simulations in the distance learning process. For now, distance learning relies mostly on "top-bottom" teaching methods such as streaming lectures, but also on practical experiments that let students discover by themselves how appliances are to be used. Nevertheless, our purpose is that online laboratories suffer from the lack of coupling with Learning Management Systems (henceforth LMS). We state the gap between LMS and online laboratories platform has to be closed for the leverage of assistance to students, dynamic adaptation to user abilities, and assessments of hands-on approaches by teachers.**

## I. INTRODUCTION

Distance learning have brought to the Web a number of learning tools, making lectures possible where teachers and learners are in different places and/or at different time. Almost all those solutions can correspond any kind of lectures. They can be web based ([9]), dedicated rich clients (as annotations on slides or video) or even based on a MBone<sup>1</sup> toolset ([5]). Some also allow audio annotations ([7]). On the first hand, providing media requires advanced network protocols ([2]). On the other one, a geographically distributed classroom leads to create virtual environments, where we try to recreate the process of learning in a group ([3]). Those solutions, however, are inadequate when learners need hands-ons approaches in order to obtain the knowledge on how devices are supposed to be manipulated. In the process of learning, widely accepted works in cognitive science demonstrate that learners begin to compare situations to already known examples. Then and only then are they able to build cognitive rules regarding the learning experiences they had : this is principal means by which knowledge transitions from a declarative form (encoding of examples) to a procedural form (production rules) ([8]). We can only agree from our own experiences: see, hear, touch, and even smell help in remembering. Enhancement of information technologies for learning by practice has, of course, already been proven ([6]). Nevertheless, most universities provide distance learning through lectures but

fewer are able to put their hands-on approaches online ([4]).

Moreover, we think that hands-on approaches should not be put online independently from one another, even when answering a single punctual need. The major risk is to reinvent the wheel each time a device goes online. This is truly unsatisfactory, especially when the number of devices is large.

This is the reason why we consider remote laboratories as one of the most exciting issue in distance learning today. For example, it is obvious that learners needs to practice the measurement of frequency on dedicated appliances after being taught the theory on signal processing. This is due to students' need to make the link between theory and reality. Some e-lab solutions already cover the marriage between lectures and laboratories in distance learning ([7]). Our objectives is to offer a platform in order to put any hand-on approach online, in a collaborative manner, without reinventing the wheel for each hand-on approach. This is why our proposition goes some steps further from previous tries. We propose here a generic framework for remote laboratories.

We work in the fields of collaborative awareness, real-time, security and generic aspects for an industrial use. Moreover, as discussed before ([1]), using devices online makes it really difficult to bring the same level of tutorial assistance towards students, compared to "same place, same time" sessions. We argue Learning Management Systems (henceforth LMS) are a key tool for delivering a better service to students and teachers during their distance hands-on approaches as it already became one for other kinds of pedagogical approaches (virtual class, self-training, for instance).

This paper is organized as follows. First, our work on computer supported collaborative learning in the field of remote laboratories is presented. This includes the presentation of our remote laboratory platform. This is followed by remote laboratories challenges ahead, especially its marriage to LMS. Finally, main conclusions enlighten future works.

<sup>1</sup>Multicast Bone

## II. CURRENT EVOLUTION OF REMOTE LABORATORY: COMPUTER SUPPORTED COLLABORATIVE LEARNING

We started remote laboratory researches in 2000 with the need to put a network analyzer<sup>2</sup> online (see [10]).

A direct TCP/IP application was produced and the entire project (including the GUI<sup>3</sup>) was coded using C++ and CORBA<sup>4</sup>. The resulting application allowed the network analyzer to be remotely controlled over Internet. This gave us full satisfaction as it is still used in distance learning between students of different universities, as a remote laboratory. Nevertheless, we dropped this first implementation in favor of J2EE (see current implementation later in this section) due to firewall issues and lack of interoperability in heterogeneous information systems. This pedagogical experience encouraged us to put another device online: an antenna workbench. Of course, unlike the network analyzer, the antenna workbench involves mechanical movements (to orientate the antenna). However, the resulting GUI is close to the first one, because same kind of widgets are displayed to users, whatever the device is (square, rectangle, round or knob buttons, led, curves, moving objects, menus, etc.). Besides, we became aware we were about to reinvent the wheel each time we wanted another device online. This tends to prove dedicated solutions are short term answers but prevent reuse for other experiments involving other devices. Moreover, as we exploited this solution in our teaching, we understood how the authenticity of the displayed device is important. Indeed students mostly learn from hands-on approaches *how* to use appliances. As such, it is very important to be as realistic as possible, otherwise students tend to be lost when put later in front of the real appliance.

### A. Nobody wants to reinvent the wheel each time a device goes online

In order to enable reusability of online appliances, we missed a common mechanism for representing the User Interface of a device and its behavior (at least the command to be sent to the real appliance for it to work properly), whatever the device is. We then appealed to ontologies to solve this problem. To be short, an ontology is a description of nature and composition of something. Mainly, an ontology defines a vocabulary in the shape of classes (in the sense of Object Oriented Programming) and properties, according to their field of application, representing the elements populating this field of application. So, we established a generic ontology providing means (the vocabulary) of UI description for devices one could find in a laboratory.

A first ontology contains our vocabulary and is stored in a OWL<sup>5</sup> file. This is the file that formalize our perception of GUI of devices.

<sup>2</sup>A network analyzer allows the measurement of module and phase of reflected and transmitted signals of a device

<sup>3</sup>Graphical User Interface

<sup>4</sup>Common Object Request Broker Architecture

<sup>5</sup>Ontology Web Language

With such an ontology (see fig. 1), we are now able to dress the complete Graphic User Interface of any laboratory device.

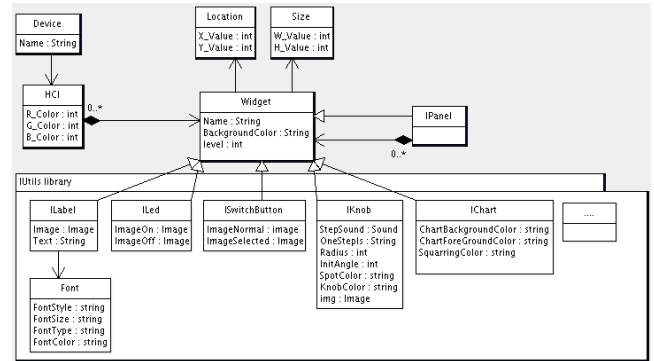


Fig. 1. Laboratory device ontology used for describing online appliances.

Then, a OWL file (one per device), is created. This file imports the OWL file that describes our vocabulary, and then list the individuals (based on the vocabulary) that correspond to our representation of the device. This is the step of specialization of the ontology for each device.

Using ontologies, we are able to describe in OWL format a network analyzer, an antenna workbench and we are about to write the OWL ontology corresponding to an optic fiber stretcher.

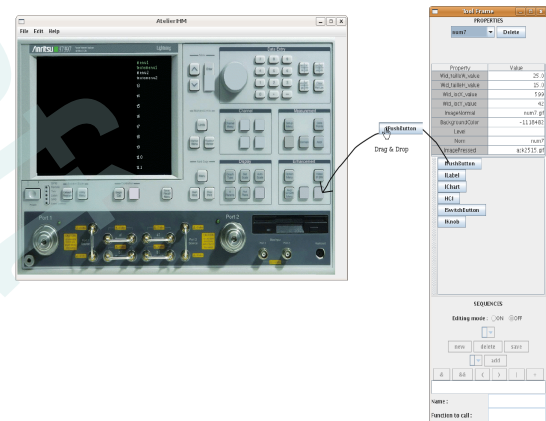


Fig. 2. Our tool for editing OWL files for devices, using our OWL vocabulary

We also developed a tool in order to edit device OWL files (named "GUI qualifier tool"). A caption is provided in the following figure 2. We believe its location must be within the backoffice of the learning architecture besides authoring tools for pedagogical content (Part of the LMS offers the backoffice, as it can assist pedagogical content production and the follow-up of students). The whole of this present work is implemented in our laboratory and being used. Figure 3 shows a screenshot of learner GUI.

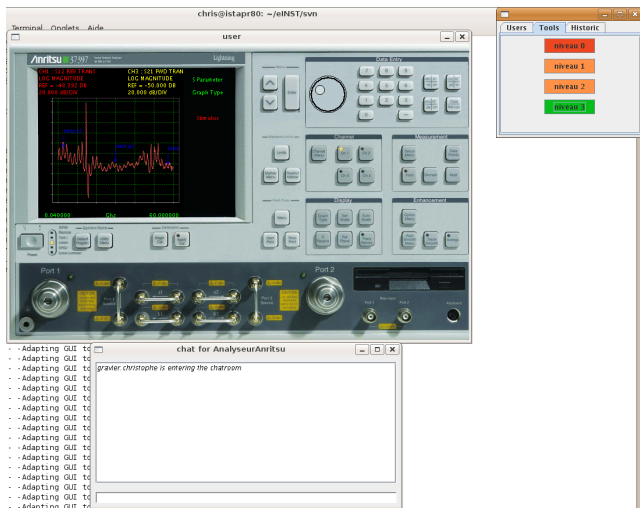


Fig. 3. High frequency analyzer being used via our application.  
Caption of our stand alone application, used by learners.

### B. Regulating access to devices: orchestrating CSCL experiences

One could argue about collaborative sharing of a single resource and how this pseudo-concurrent access (as it is collaboration) is managed. We present here our work currently being implemented. It aims at orchestrating CSCL experiences. Typically several learners try to gain access to an existing device plugged over Internet in real time and in a collaborative way. Hence we needed a layer being able to orchestrate accesses to the device. Our point of view is that this is not a complete concurrent and hostile environment. In fact, still from our point of view, Computer Supported Collaborative Work is defined as several users using a remote resource for a common objective. If the objective is not shared among all users, this is not a collaborative work any more. This explains why we cannot apply already well known current resource scheduling such as first in first out, round robin or any other rule used in complete concurrent environment (by analogy of CPU time sharing). This is mainly because the role the user plays in the collaboration is a factor of orchestration. Moreover, orchestrating rules are not supposed to be set forever, so they can be modified in time. For example, a common policy at the beginning of a hand-on session could be Let's give priority to students that were the first to connect, for a given amount of time (FIFO with a time-slice). Near the end of the session, learners that were the last to enter the remote lab would be late (less time to practice given the policy). Then, it could be interesting to switch to the policy Let's give priority to students that were the last to connect (LIFO).

Our aim is not to support every already known collaborative situation, but to supply the possibility to build our own collaborative strategies leading remote laboratory sessions, helped by learning scenario and context aware elements. We also chose to formally describe these strategies through ontologies (still in OWL format) which can be loaded from our gateway and associated to a given the device.

In order to achieve this, we appeal to a server-side ele-

ment which, in its turn, uses an ontology to set the strategy of collaboration model being used.

For example, it can feature such following statements : I give priority access to the learner that is the later in the learning scenario, or I give access to learners that have made the lesser number of actions, but the user which plays teacher role can make preemptive accesses. Our purpose is to get an orchestrating unit that can be parameterized using such an ontology (that describes the collaborative strategy to play in the learning experience). Ideally, every author should be able to write build his own collaborative strategy ontology to be used with the learning manipulation.

### III. INTEGRATING REMOTE LABORATORIES IN LMS

In our opinion, one path for the future of remote laboratories remains linked to IMS-LD engines, which are using IMS-LD file format (describing "units of learning" ([12]) in Learning Design.

#### A. Marrying online laboratories to IMS-LD engines.

In fact, we strongly believe that hands-on approaches must be seen as part of lectures (generally speaking) and not something that is put apart on dedicated structures. That is to say, there must be connectors between such online hands-on approaches and LMS. As for now, a LMS only provides tools for authoring, managing and playing of online pedagogical content. LCMS (Learning Content Management Systems) are another family of softwares which provides ease of use for pedagogical content exposition to authors (for reuse), tutors and students. Nevertheless, if content and management facilities are good to bring a full course online, they are not designed to feature hands-on functionalities !

This is the reason why IMS-LD language has been designed. IMS-LD goes further than providing learning content. It helps in describing a full strategy for a learning scenario, to build a complete lesson plan for a course. IMS-LD has been created by the Open University of the Netherlands (OUNL). It has to be noticed that it has been imagined to be a solution that would allow to describe a wide range of pedagogical approach. In fact, it doesn't stick to a specific pedagogical model. In fact, remote laboratories can only be coupled to pedagogical plans only if there are interoperable in the "Computer Supported Learning Architecture" (as it is described in figure 4). Loose coupling between LMS and remote laboratories must accompany such an approach. Fortunately, IMS-LD XML file format and message transportation using Web Services (SOAP<sup>6</sup> messages) participate to this interoperability.

Whereas IMS-LD aims at describing any lesson plan, as long as it is supported within a learning platform that renders the IMS-LD file, it is not widely used in online laboratories. As illustrated earlier (see II-A), online laboratory

<sup>6</sup>Simple Object Access Protocol

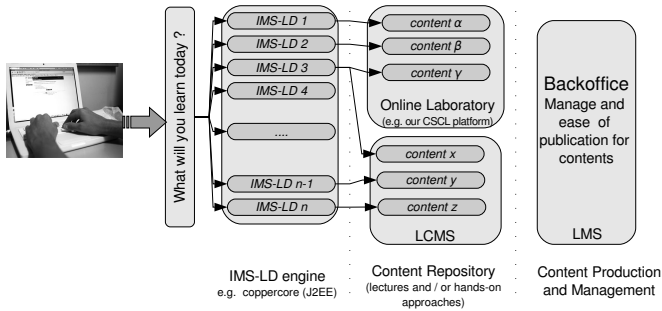


Fig. 4. Putting all pieces together: locating Online Laboratory in the Learning Architecture.

solutions are usually point-to-point and device specific solutions (and this is the reason why our platform proposal exposed in II-B is innovative). Being short-term and dedicated solutions, current online laboratories we know do not feature any "hands-on plans" as being a completion to already well known lesson plan as described in IMS-LD. Nevertheless, IMS-LD has been thought for interacting, and supporting widely accepted pedagogical learning models. Coupled with the fact that connectors must exist between online laboratories platform and "scenario players", we see in level C of IMS-LD (see [11]) the opportunity to build such a communication.

Indeed, level C of IMS-LD provides support for notification so that other IMS-LD engines can be informed of evolution (progress or regress) of students in the learning activity being played (for example using SOAP messages). This can be used to let online platforms that play an hands-on approach to inform the IMS-LD engines (that plays the associated hands-on plan), of all user actions. Then the IMS-LD file established for the given hands-on approach is held responsible to go forward (and why not backward !) in the scenario being played by the IMS-LD engine. The IMS-LD engine is the repository and the player of learning scenarios. This way, online laboratories will no longer be an isolated component in the distance learning architecture, but, as connected to IMS-LD aware systems, a natural completion to annotated lectures that a LCMS can already easily distribute.

### B. Illustrated Advantages.

There is a large amount of advantages in marrying online laboratories to IMS-LD engines, apart from bridging hands-on approach writers and lessons' authors. Firstly, as exposed earlier in this paper (II-B), hands-on approach platforms (whether they are device-specific or not) need to retrieve the progress already made by the learner in the current session, in order to be able to orchestrate the collaborative experience. This could help in solving the following collaborative strategy for example: "I always give the hand to the learner being late in the LD (i.e. in the learning scenario)". Of course, this will also allow to make the opposite statement : "I always give the hand to the

learner who is far beyond the other learners in the LD" (as he would most probably finish before the others and thus quit this hands-on approach earlier, freeing some device computation time for his colleagues).

In addition to this, this means that the online laboratory is able to response to IMS-LD engine solicitations (as they can communicate with one another). As such, the online laboratory can modify the Graphic User Interface (henceforth GUI) displayed to the user. For example, the IMS-LD scenario can state that the GUI must change when some actions are performed in the remote laboratory platform, or even when a certain level of clearance in the lesson plan has been reached.

Our ontology for devices allows to set a level for a widget, regarding its complexity of use and amount of skill needed to use it. With the IMS-LD being able to operate on the remote laboratory GUI, the level a user can have access to could be downgraded or upgraded regarding user progress in his learning scenario. This way, depending on the walkthrough of the user through the learning scenario, the GUI could be adapted to his abilities.

Another option could consist in switching the LD engine to another learning path in a given scenario (harder or softer, depending on the case, see [13]). Online laboratory are no longer static but adapt themselves to learners knowledge and cognitive skills (as long as it is supported by the original given learning scenario).

Back to the beginning: as long as online laboratories are not coupled to any scenario engine, online laboratory are just deported interfaces of a given device (learner and device being geographically distributed). This means there are no way of assessing learner's actions: the online laboratory unit does not make any distinction between each user actions.

And on the opposite side, *LD engine do not increment steps in the current learning scenario because of user asking to do so, but in response to user action in the hands-on approach* (use of level C of LD specifications).

If coupled to the LD, the online laboratory can compare the action made with the action(s) that awaits the current IMS-LD scenario. Furthermore, the learner's session can be stored to be further compared to the expected scenario. This way, the teacher receives a great tool for assessment. We can imagine that this comparator could be more evolved than simple boolean ones: instead of delivering a "true/false" evaluation for a session, it could deliver how much is the session near of what was expected in the scenario ?. This would be a nice objective tool for learner assessment in hands-on approaches.

There are, of course, other advantages for this coupling. For example, an online laboratory can just play a given scenario. Without any user input, step by step. Using such a tool, we can create "Scenarized Postponed Learning". This means learners could watch a replay, using the remote laboratory, of a scenarized hands-on approach that their teacher record earlier. We can easily imagine its impact for distance learning and auto formation. We can also imagine

that those scenarized hands-on approaches recorded could be linked to a lecture paragraph like "for illustration, play the attached IMS-LD file". The online laboratory client would take the hand and play the recorded manipulation. In this very case, this would not be simulation, but a postponed play of a learning experience that occurred in the past.

#### IV. CONCLUSION

This paper was divided in two distinct parts. At first, we pointed out the lack of available generic and collaborative online laboratory. In fact, almost all online laboratory solutions we found were whether device specific (one needs to reinvent the wheel each time you want another appliance available online), or not "synchrone collaborative" at all. This lack motivated us to propose an online laboratory that would not suffer from those drawbacks. In the second section of this paper, we argue that generic and collaborative online laboratories are not enough to support a real learning experience. This is the reason why we propose to marry online laboratories to Learning Design engines already working inside current LMS, in order to couple pedagogical materials to hands-on approaches. This is because, from our point of view, learners needs to manipulate appliances in order to remember how devices are to be used, whereas lectures tend to limit the delivered knowledge to understand "how things works". We illustrate this vision of learning architecture by taking a limited list of advantages that are offered from this marriage. Mostly, such a coupling helps in building remote device GUI adapted to learners' skills, but also lets a more complex collaborative strategy be described. Future works should consist in going some steps further, by exploring how one could write a IMS-LD scenario when the appliance is composed of several devices, because mostly hands-on approaches are workbenches of instruments (not reduced to a single nor isolated one).

#### Acknowledgments

This work is supported by the General Council of Loire.

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