AIP-Primeca RAO Remote Laboratories in Automation

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***Abstract*—During last decade, Internet and related web technology development enabled the arising of e-learning services and made distant learning a reality. As traditional face to face classroom became virtual classroom through Internet, traditional laboratories found their image in Electronic Laboratories (ELABs). These ones enable learners to train themselves on remote real or virtual systems. They represent essential components in e-learning environments, especially in scientific and technical disciplines.**

In this context, AIP-Primeca RAO is a pool of resources and competencies about industrial topics for many universities in Rhône-Alpes french Region. Due to the constraints inherent in using heavy and shared industrial resources, AIP is setting up new laboratories related to automation as both local and distant resources. After recalling the global context of e-laboratories, this paper describes this platform. It evokes first returns of use and it details evolutions to come.

***Index Terms*—Education, Laboratories, Manufacturing automation, Remote handling**

I. INTRODUCTION

For a few years, numerous educational institutions have incorporated tools based on Information and Communication Sciences and Technologies into their educative systems. These new tools contribute to a continuous improvement of educational practices. So, e-learning solutions, which were at first essentially based on “abstract” education (online courses, virtual classrooms, e-projects, role-playing, ...), gradually spread to real hands-on activities through Electronic Laboratories (ELABs) [1]. ELABs are laboratory activities performed with the help of computers: to catch every variant of ELABs, Ref. [2] offers an inventory of situations where ELABs occur, from local to distant learning, with or without tutor, with a real or a virtual appliance. This recent trend answers to a recognized need for such activities and enables real experimentation, more particularly in engineering, scientific and technical disciplines.

In this context, *AIP-Primeca-RAO* has been a pool of resources and competencies since 1987. It continually has made industrial equipment available to many high schools in french Rhône-Alpes Region and it has been playing the role of support for thorough trainings in industrial engineering. The eight partner universities are also its main users, in Lyon (*INSA*, *Ecole Centrale*, *Université Claude Bernard Lyon 1*, *ECAM*, *IUT Lumière of University Lyon 2*) and in Saint-Etienne (*ENI*, *Ecole des Mines*, *Université Jean Monnet Saint-Etienne*). The resources at users' disposal are mainly composed of :

- industrial equipment (such as CNC machine-tool, conveyors, assembly automation systems, robots, ...);
- computer systems featuring industrial software (Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Manufacturing Execution System (MES), process simulation, shop control, ...);
- communication and cooperation systems (LAN, WAN access, video-communication, Computer Supported Cooperative Work (CSCW), ...).

AIP has been studying solutions to promote laboratories to ELABs since 2000 [3, 4]. Since 2006, a growing need for laboratories about automation technologies (Programmable Logic Controller (PLC), Human Machine Interface (HMI) programming, Field Network (FN) setting, motion control, ...) from different institutions and from *Schneider Electric* has led to build an offer of ELABs (ARI[1] project) to its partners. The reasons and the main concepts of this project are described in section III.A To sum up, it consists of providing both local and distant access to sets of appliances (PLC+HMI+FN+Motion control). The means to teleoperate these appliances are currently available on-line from the *AIP* portal. The corresponding architecture is detailed in following sections of III. First use returns are commented out in section III.E.

In a near future, this platform will be completed with e-learning software developed by LIESP e-learning team (former ICTT), to provide fully functional local and remote laboratories. This evolution is given in IV.

II. ELECTRONIC LABORATORIES

Electronic Laboratories can be divided in two main categories: Remote Laboratories (RLABs) and Virtual Laboratories (VLABs):

- RLABs (sometimes called “web-based control”), offer remote access to real laboratory equipment and instruments in real time [5, 6]. We include in this category situations where laboratories are local but enhanced with e-learning software. In this last case,

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[1] ARI is a french acronym for Automation and Field Networks

laboratories are not remote any longer but reuse RLAB technology to provide a controlled access (mainly in terms of security) to local appliances. Main advantages of RLABs are the realness of systems learners work on. Their main drawbacks are based on a loss of observability (no direct system view : only through a webcam) and commandability (keyboard, mouse or joystick tools to drive remote system).
- VLABs are based on simulations of real systems or phenomena such as for Ref. [7] and [8]. These simulations can be run directly on client host (learner computer) such as with *Easy Java Simulation* [9] but we could envisage server-side simulations when specific software or calculus power are required and not easily available on client side. Their main advantages are their scalability (no direct limitation of concurrent users) and their main drawback is that it is not a real system : it is a relatively realistic model of a real system.

Notice that some RLABs may include Virtual Reality techniques such as in [10]. One could suggest a third ELAB category: Hybrid Laboratories (HLABS), which combines advantages of both previous categories. In this sample, virtual system representation is offered to compensate for low quality video feedback : user can zoom and move around the virtual system which is synchronized with the real system in real time. Another aspect of HLABs is depicted in [11] where the evolution of the virtual system is compared to the one of the real system in order to focus on limitations of modeling.

More precise differences, advantages and drawbacks of RLABs versus VLABs have already been discussed in literature and more precisely in [12].

Applications of RLABs deal with electronics [13], automatic control [14], robotics [15], ... but fewer with automation systems : [16] (CAN fieldbus), [10] (vertical store), [11] (conveyor) and [5] (flexible manufacturing cell) who covered solutions for these kinds of systems.

Concerning engineering process of ELABs, we distinguish two software approaches for ELAB Human Machine Interfaces :

- reusing commercial software such as LabView ® [2] or Matlab+Simulink ® [17]. These softwares now enable teleoperation of laboratory systems but this was not the case in the first times of ELABs;
- specifically designing one's own software such as for Ref. [18].

Current generation of research about ELABs is no more based uniquely on teleoperation of devices but it also takes care of actors (authors, tutors and learners) educational goals, from scenario authoring to experimental result reporting and evaluation, as for Ref. [19] and [13]. In this context, works on linking traditional Learning Management Systems (LMS) with ELAB Management Systems (ELaMS) are on way at LIESP and DIOM laboratories [1]. Another need for efficient RLABs has been explored in Ref. [20]: collaborative group working and tutor driven experiences on a single remote system as for traditional on-campus based laboratories.

III. ARI PROJECT

A. Initial need

AIP has already studied collaborative means to help people to work together and at distance, more particularly on production systems. In this context, *AIP* launched in 2006 the *ARI* project in collaboration with 3 departments of *INSA* (Electrical Engineering, Industrial Engineering and Mechanical Engineering and Design), long life education center *INSACAST* and *Schneider Electric*. This project consists in building a technological platform featuring modern controllers and industrial networks with the aim to illustrate the concept of the “Transparent Factory”*:* Internet-based technologies that provide seamless communication between plant-floor and business systems and improve collaborative management.

This shared and centralized platform has been designed to be accessible at distance by every member educative institution and other socio-economic actors (partners and clients) in the frame of initial and long-life learning. This design is set up on the experience acquired during previous projects, more particularly with nomadic students working with *CNED*[2] institute.

Needs from different partners are summed up here:

- for initial learning (*INSA*, *ECAM*, ...):
  - development of student autonomy for self education;
  - experience of industrial software engineering (functional analysis, design, programming, control);
- for long-life learning (alternate or continuous education: *CNAM*[3], *ITII*[4]):
  - supply (to students alternatively in their enterprise and at school) of access to software and hardware resources, outside office schedules (night and week-end);
  - training cost optimization:
    - decrease of time when employees are away from their enterprise;
    - validation of prerequisites and check of appropriateness between trainee competences and training program before training periods;
    - access to the appliance after training periods to increase trainee acquisition of knowledge or to enable a preparation for an exam or a certification;
- for partners:
  - supply of distant access to shared equipment;
  - development of a competent team federating the actors of education in the different institutes;
  - providing of a technological showcase to train experts and industrial managers about concepts of the “digital enterprise”;
- common needs:
  - decreasing of time spent in transports for far users;
  - raising of appliance busy rate.

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2 Distance Learning Institute; see http://www.cned.fr/en/

3 Lifelong Learning Inst.: http://www.cnam.fr/42394825/0/fiche___pagelibre/

4 Lifelong Learning Inst.: http://www.uimm.fr/fr/reseau/contenu_ITII.html

B. *Concept*

This platform enables control of automation devices such as motors, motion drives, pneumatic actuators, ... by Programmable Logic Controllers through standard Field Networks. It has been designed into a modular architecture. Every module illustrates a common set-up including a PLC, a motion drive and remote I/O distributed on a standard field network (*Modbus/RTU*, *Modbus/TCP*, *CanOpen*, *Profibus*, *Ethernet TCP/IP* and *ASi*).

Every module (depicted on Fig. 1) is made up of :

- a power supply area (circuit breaker, AC/DC converter and a safety monitor for *Asi-Safe* module);
- a control area containing a PLC fitted with, in one hand, an Ethernet coupler featuring a web server to gain access from the web and, in the other hand, a field network adapter to communicate with distributed sensors and actuators. The whole is completed with a touch panel HMI;
- a field part containing distributed I/O with pre-actuators, sensors, position encoders, ... , a motor starter, a motion drive and future equipments.

Each module features at least an Altivar for motion control, an AC motor and distributed I/O. Modules are fitted with Schneider Electric Premium or M340 PLCs.

Nowadays, eight modules are locally available at *AIP*:

- two prototype modules (*Modbus* and *Profibus* (see Fig. 2).
- six modules of second generation:
  - 1 *Modbus* (see Fig. 3) featuring also a motor starter and a gateway between *Modbus/TCP* and *Modbus/RTU*;
  - 1 *Profibus*, with a touch panel*;*
  - 1 *Ethernet*, with a touch panel;
  - 1 *Asi* with *Asi Safe* equipment for “safety at work” management;
  - 2 *CanOpen* with a motor starter and an HMI.

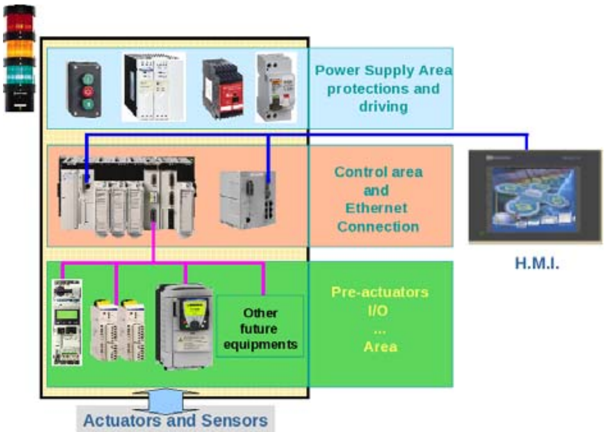

Figure 1. Module generic architecture

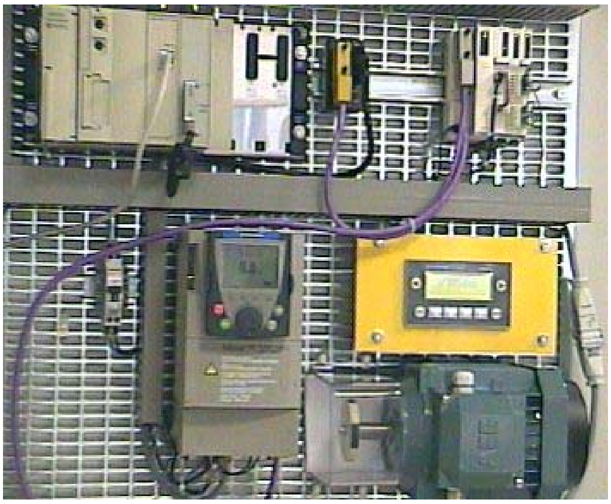

Figure 2. Profibus prototype module

Moreover, two modules featuring *ASi* field network on a surface treatment application are available at Electrical Engineering Department of INSA (on the same campus).

Thanks to Ethernet adapters, all the modules can be connected and synchronized together through the campus LAN, in order to create more complex architectures.

This platform is now partially available on line but, at term, every module will be available on line. Distant users gain access through *AIP* web portal[5]. Specific web services have been developed to manage and schedule access to these modules.

Global architecture is detailed in next section.

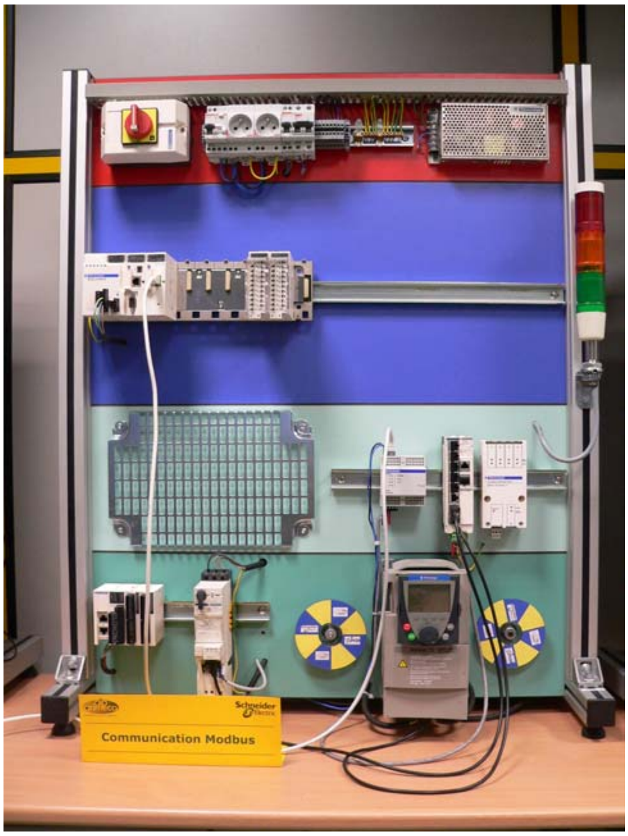

Figure 3. Modbus module

[5] See http://aipportail.insa-lyon.fr:8085/aiprao

Figure 4. Main room with 6 modules

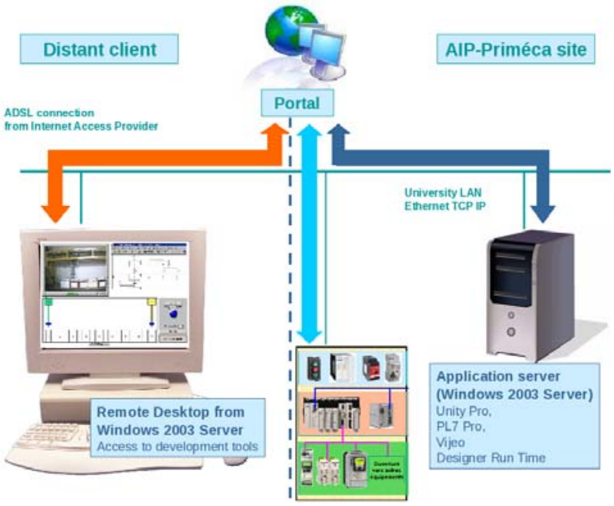

Figure 5. Platform architecture

C. *In Situ accessibility*

A main room has been equipped with six new generation modules (see Fig. 4). Eight desktop PC are available to users. Every necessary software is freely available (*Unity*, *Citect Scada*, *Vijeo Designer*, *Open Office*, ...). A projector is available to tutors to display information on a collapsing projection wall screen.

D. *Web functionalities*

Access to the *ARI* platform is provided through *AIP* web portal (see Fig. 5) according to the user profile (visitor, student, tutor, administrator). Users such as tutors and administrators must be registered in *AIP* LDAP repository, while visitors and students must not. The portal is based on *TomCat* application server technology.

Visitors must type in their name and email in order to have access to a set of demonstration resources (whenever they are not previously booked). More precisely, they gain access to a limited amount of time (60 minutes max) to a limited number of functionalities of the platform.

Once connected into the intranet, tutors can book some modules for their laboratories. They are provided:

- the list of existing resources and their status;
- a prioritized access to a module, provided the resource is neither in use nor booked;
- booking forms to fill for one or more modules, out of the available ones and according to a time period;
- a personal schedule summing up their own bookings;
- the necessary documentation to help them in using available software and material

Tutors can choose to set the mandatory password which will be used by their students to log into the laboratory intranet or use the automatically generated one. They may also add online documentation for their students (demonstration programs, complementary documentation, to-do lists, ...).

Students have to provide the password given by their tutor to gain access to a specifically booked module at a scheduled time. Their access is limited to the booked period.

Once the user is connected to a resource, whatever profile he might have, he is led to a single screen shared between tree main frames :

- a webcam view;
- a help view (including documents, links, ...) and
- a main applicative view.

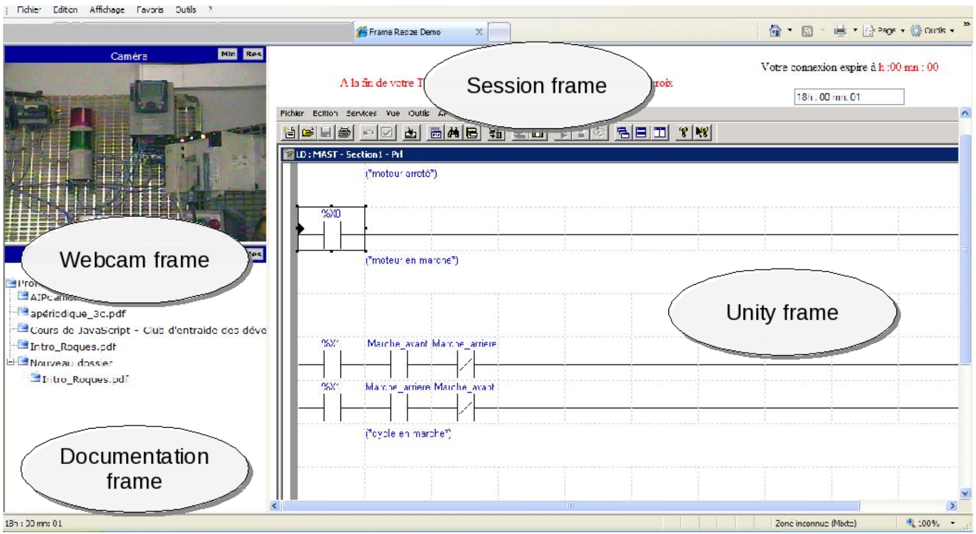

Figure 6. Screenshot of current student interface to program a module

Inside a unique browser window, these frames can easily be minimized and resumed, in order to work with a unique maximized view, as soon as the need is being felt. Obviously, the main view automatically includes all the necessary laboratory software and remote widgets permitting to remotely test programs (see Fig. 6).

The documents (programs, reports, ...) produced during the session are either stored on the web server or downloaded on the local desktop.

PLC programming is performed with the help of *Schneider Electric PL7-Pro* (for prototypes and surface treatment modules) and *Unity Pro* (for other ones) programming software. This latter is compliant with IEC 61131-3 standard and it enables *component based engineering*. This software is installed on a *Terminal Server Edition* (TSE) on a *Windows 2003 Server* host, which permits distant users to use it remotely without having to install it on their own PC. This software also features a PLC simulator. The whole module can be simulated when Unity PLC simulator is run with a program which simulates operative parts. It then can be used to preventively test one's program before uploading it on the real PLC, through Ethernet LAN.

Once a program is uploaded, real time handling of each module is performed through a local touch panel HMI and also through a web version of the same HMI for distant users. These HMI are designed with the help of supervision software *Vijeo Designer* or *Citect Scada.*

A motorized web cam is set up on the ceiling of the main room. It enables a global view of modules or a single user to zoom on its own module.

The whole web architecture is based on *J2EE* technology. Web services enable a modular architecture able to be extended without having to redesign the whole web site from scratch. *Active X* components are used to gain web remote access to the *Terminal Server* in order to offer distant use of different softwares. This constrains every user to use *Microsoft Internet Explorer*.

E. Distant usage returns

2006-2007 academic year enabled to begin the deployment of prototypes for local and distant use with *ASi*, *Modbus* and *Profibus* field networks. 36 students (of Licence level) from Electric Engineering Department at University Lyon 1 (on the same campus) remotely used this platform. This first experimentation enabled us to validate first laboratory scenarios and led to make adjustments about distant means. For example, for laboratories open out of business hours, it is necessary to drive the surrounding lighting to be able to use efficiently the web cam... Tests at greater distances, from Nantes (650km) and Seville in Spain 1630km) showed us that such distances do not constrain the ergonomy in nomadic usages.

IV. EVOLUTION

A. Appliances

Some new modules will be developed to complete this set so that an entire class of students will be able to simultaneously perform their laboratory work. Moreover, modules are currently available only as single devices but the platform will provide the mean to book and use several linked modules.

B. Distant access

From technical point of view, we remarked that *Active X* components could be a constraint on student and tutor accessibility. A new version based on *Web 2.0* technologies is under development to enhance accessibility.

C. E-Learning environment

At now, means to teleoperate modules are available but minimal learning support is provided to users (as tutors as learners).

We are going to implement works on generic ELAB scenarios from Ref. [21] to provide an ELAB Learning Management System (LMS).

1) Objectives

The aim of this evolution is to provide a way for authors and tutors, in one hand, to edit ELAB scenarios without requiring to be computer science specialists, and, in the other hand to avoid rewriting scenarios written for similar appliances (for instance, two optical benches with different control hardware but with same functionalities). *AIP* experience where many tutors from different universities use the same appliances but do not efficiently reuse previous common works, clearly demonstrates the need for a mean to reuse scenarios used with the same pool of appliances for different audiences.

2) Working

To do so, they will be provided an environment to edit scenarios for ELABs with the particularity that these scenarios will not be dependent of a particular appliance, but of a same class of similar appliances. These "generic" scenarios will then have to be automatically adapted into appliance specific scenarios to be used with a specific real appliance.

This automated adaptation will be performed by a middleware: an ELAB Management System (ELaMS) which is also used to route different users with their scenarios towards compatible appliances. This working is similar to the one of a printing service one can find in modern operating systems, delivering efficient printing through printer drivers.

Users will gain access to the platform through a standard LMS which will run scenarios. In this way, learners will be more finely guided during their lab work and tutors will be able to follow at distance how far learners have made headway. LMS can be also used to help in assessment.

Fig. 7, 8 and 9 illustrate the life cycle of an ELAB scenario. It consists of four main steps, illustrated here with robotic appliances:

1. installation (see Fig. 7), by the ELAB manager, of a new appliance on the ELaMS platform; this new one belongs to an appliance class represented here by a robotic arm template.
2. Creation (see Fig. 8) by authors of generic training scenarios on an authoring tool; each scenario is linked to an appliance class. In actual fact, scenarios include an URL which link them towards the corresponding template and every appliance related actions (here : initialization, linear move, pick and place, ...) and data (status, position, ...) are targeted towards generic items of this template.

3. Adaptation (see Fig. 8), asked by a tutor and performed by ELaMS middleware, of a generic training scenario to a specific set of same appliances : from now on, every action and data are targeted towards real web services which will later deal requests to the right appliance in this set.

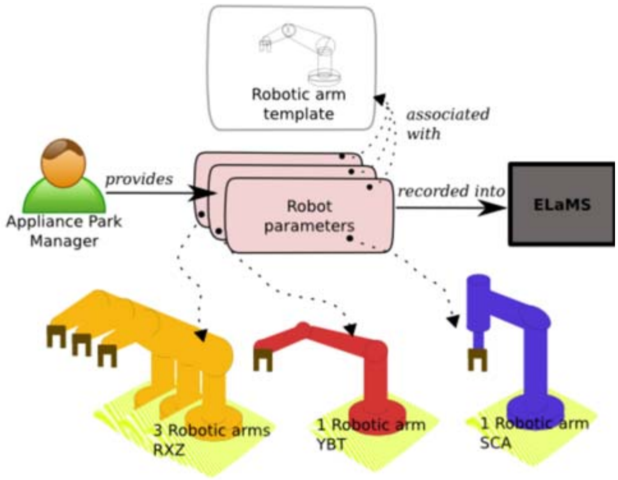

Figure 7. First step: appliance installation

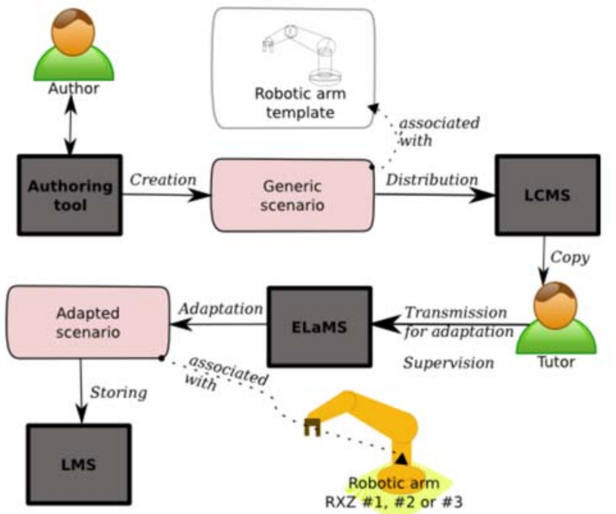

Figure 8. Steps 2 and 3: creation and adaptation of a scenario

4. Use (see Fig. 9), by tutors and learners, through their LMS, of this scenario. Each group of learners is routed to one different appliance out of available ones.

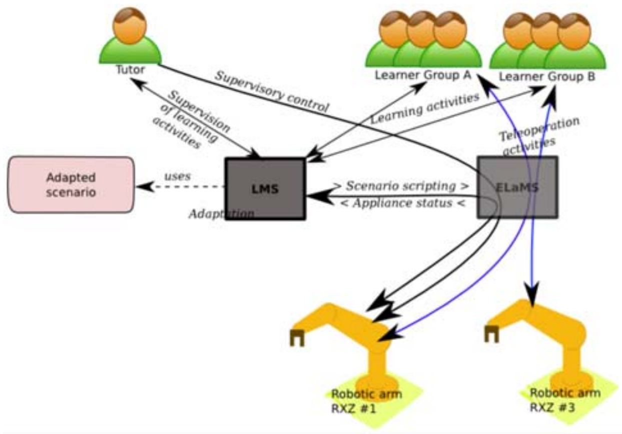

Figure 9. Step #4 : use of a scenario by several users

3) *Technology*

Concerning software technologies, scenario edition and running will make use of open source IMS-LD compliant software. *Reload6* (A, B and C level compliant) will be used for scenario editing in a first approach but we are thinking of a web-based authoring tool such as the one of LAMS7 (which is currently not IMS-LD compliant). Selection of available data and actions for a given template is now manually made but should be included in the scenario editor for efficiency reasons in the long term. Scenario player is *Coppercore8* engine (A, B and C level compliant).

The middleware initially written in Java for template management and PHP for its Human Machine Interface will be provided as web services to form a global homogeneous application. Templates are coded in *OWL*[9] Web Ontology language. *Protégé*[10] software is used to edit templates.

Fig. 10 sums up the integration of ELaMS model in ARI platform : the LMS and ELaMS layers come on top of existing teleoperation one to bring didactic functions as for any distant learning environment.

V. CONCLUSION

This paper outlines ARI project at *AIP-Primeca RAO* where a platform including modular appliances featuring PLC and field networks is being built. These appliances are to be used *in situ* and at distance. The global architecture from client to PLC was depicted and evolutions to come were exposed. This architecture which now covers teleoperation layer will lead to a complete e-learning platform enabling hands-on distant learning.

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6 See http://www.reload.ac.uk/ldeditor.html
7 See http://www.lamsinternational.com/
8 See http://coppercore.sourceforge.net/
9 See http://www.w3.org/TR/owl-features/
10 See http://protege.stanford.edu/

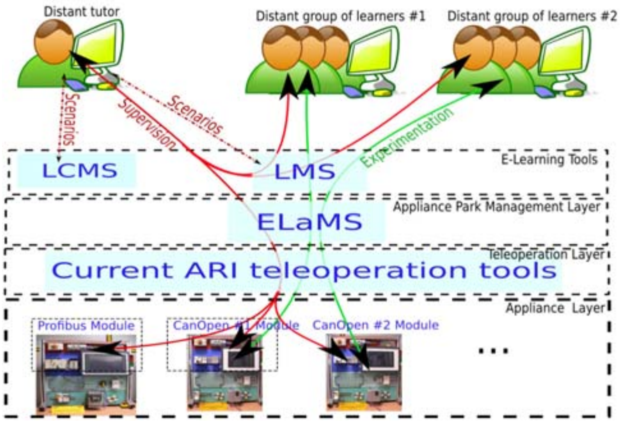

Figure 10. Final platform architecture

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