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# LABOREM - A NETWORK OF OPEN SOURCE REMOTE LABORATORIES FOR LEARNING

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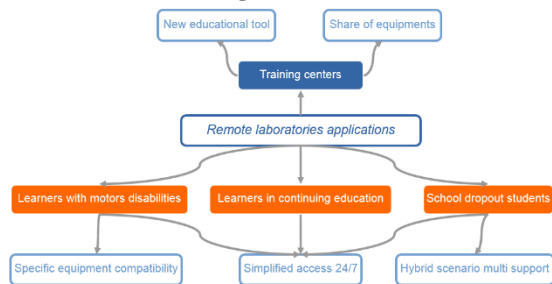
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**Abstract:** The increase in numerical technologies development makes possible the emergence of new pedagogical tools as remote laboratories. The instrumentation of technological systems and distant interfaces offers new possibility for a distant learner. The LaboREM platform, designed with this objective, is running and evolving since 2009. In this paper, we present the evolution from a local solution to a network of remote laboratories. To deploy remote laboratories informatics and electronics development are needed. Based on these objectives, a novel approach using Python as unique programming language is used. A generic PCB (Printed Circuit Board) approach has been designed to answer robustness and adaptive needs. These developments will help to spread LaboREM to other education remote laboratories.

**Keywords:** e-learning, game-based learning, industrial engineering, labwork, student motivation, online education, virtual instruments, remote laboratory, SCADA.

## 1. INTRODUCTION

Distance education is growing easier and faster with the widespread use of computers and internet. Moreover as shown in [1] the “massification” of higher education leads to a diversification in post-secondary student profile. To answer this issue, it appears to be decisive to create new tools for teachers and learners as remote laboratories and game-like scenarios. The perspectives of applications with this new teaching format are various (**Fig.1**).



**Fig.1. Applications of LaboREM in education**

From one side, training centers can share equipment through a network of distant laboratories and can offer a new educational tool. This tool is not designed to replace traditional practical works in classroom, but its objective is to offer a combined learning process: on-site courses, simulation, online courses.

On the other side, online technologies erase time and transfer constraints. This functionality gives good perspectives to learners with motor disabilities and learners in continuing education. Remote laboratories allow teachers to show live experiments in a lecture to apply directly theoretical knowledge. Another advantage is to

provide to the students a new way to deal with in depth revision to prepare for an exam.

The innovative character is the set-up of a learning scenario that allows connecting in real-time to a platform with the integration of the lesson in the LMS (Learning Management System) [2]. The lesson adopts a game-like scenario.

Creating a network of remote laboratories can be very useful to share expensive experiments, to mutualize equipment between training institutes which have the same learning program. This kind of network was developed in the project WebLab Deusto [3]. As, since 2009, we have developed and deployed a remote laboratory for 40 undergraduate students, we get some interesting feedback of their feeling to use this kind of lab [4]. Main important things that emerge from their perception are listed below:

- Feeling of immersion (video, robot)
- Real-time process
- Integration in the LMS of the university (interaction with tutor)
- Work on the same equipment as it was during hands-on labworks.

For this reasons, our approach is quite different from the approach chosen by the authors of [3] who are working on remote lab network which is not linked with a game-like pedagogical scenario in a LMS.

## 2. METHODOLOGY AND ISSUES

The actual prototype of LaboREM evolving since 2009 is facing several issues to develop a network of remote laboratories sharing resources between various scientific centers and universities (**Fig.2**).

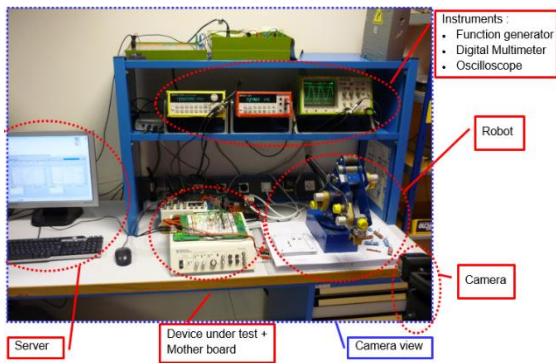


Fig.2. LaboREM hardware resources on server side

To describe the set-up of a generic platform, it is necessary to list the issues and transpose them to each part of the system (Fig.3).

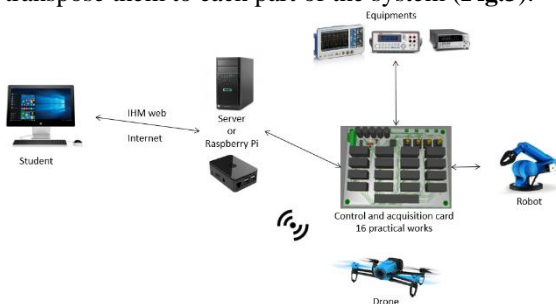


Fig.3. Diagram of LaboREM 2018

The methodology we choose to create an e-lab network is a low-cost solution, easy to deploy and open source. To have an immersion of the learner, we design experiences embedded in a game-like scenario. To have high availability and easy access to the platform, we use a web HMI (human machine interface) with 24/7 or scheduling access. To carry out various equipment compatibility, we would like to develop an open community to easily share practical works.

### 2.1. Server and software

LaboREM uses a supervisory control and data acquisition (SCADA) system. The initial prototype of LaboREM uses a technically advanced solution running on Windows Server operating system, and using the proprietary LabVIEW software from National Instruments© to program and create the web remote access, which allows to control the instruments (Fig.4) and exploit data results. The cost of the software, the powerful server needed and the non-standard protocol used by LabVIEW to communicate data through the internet lead us to develop an entirely new IT system for migration to an open source and light software (Fig.5). Similar issues exist for low and medium size industries [5].

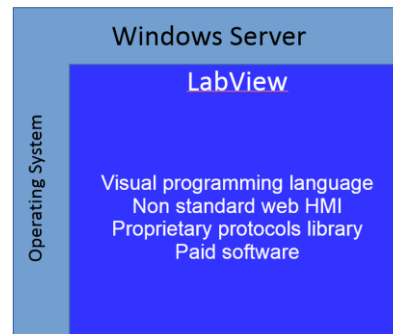


Fig.4. Diagram of the proprietary structure

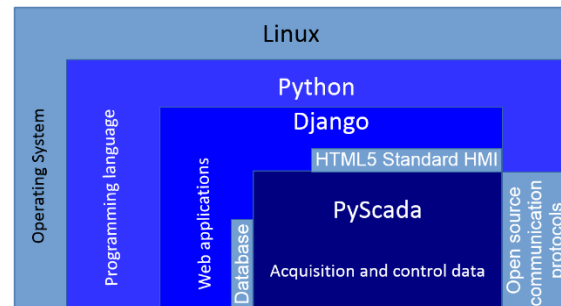


Fig.5. Diagram of the open source structure

Linux (Debian) is used as operating system for the stability. The programming language used is Python. This language enables clear programming, in addition of the Django framework which eases the creation of complex, database-driven websites. To communicate with the instruments, we used the Django application of PyScada [6] and other Python open source applications. One advantage of this solution is to provide an HTML5 interface compatible with every client (computer, smartphone...). Another advantage on the server side is to develop with a light and open software solution which enables to use as a server a single-board computer (SBC). These choices require additional developments in comparison with the solution with LabVIEW© but it ensures that the deployment will be robust on client-side (HMI) and on server-side (open-source applications)

### 2.2. Data acquisition and control

The deployment of the instrumentation and the server system needs the design of an electronic box. The “LaboREM Box” will store the electronic part designed in our laboratory in University of Pau. The approximate size for practical works in electronics is 20x15x10cm<sup>3</sup>. The box is composed of several printed circuit boards (PCB): a motherboard (Fig.6) where we can place 16 different plugs and a robot extension board. The robot extension-board interconnects the movable elements. The robot extension will be optional to adapt the box to all the university’s needs.

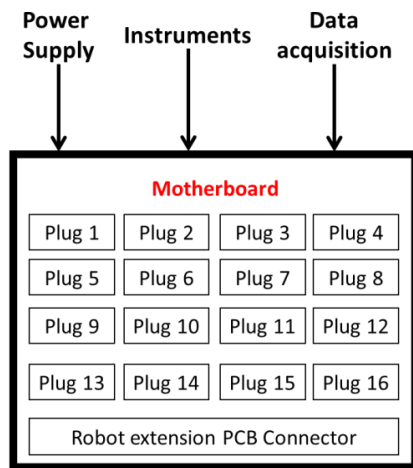


Fig.6. Block schematics of the modular motherboard

The motherboard receives and manages all the information of the experiment that the learner wants to work on. Each plug is a device under test (DUT) and can be easily replaced by the teacher to adapt the scenario to the learners. The learners will have access to 16 DUT to achieve their work. The generic plug schematics is illustrated in Fig.7.

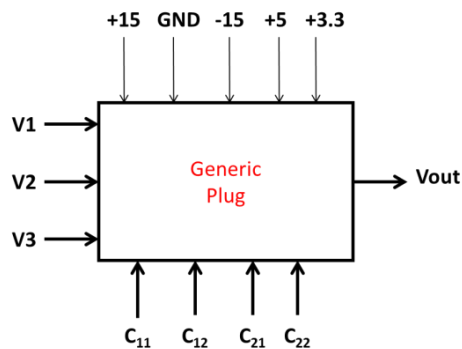


Fig.7. Pin mapping of the generic plug

Each plug is supplied with different voltages in order to deal with CMOS or TTL circuits and also circuits with symmetric supply. Three input voltages and one output voltage are present.  $C_{ij}$  interconnect the external components placed by the robot.

### 2.3. Instruments communication

The data acquisition system has to be compatible with several protocols (VISA, Modbus, BACnet...) and connections (USB, Serial, Ethernet). To fulfill these requirements, we take profits to use an open source solution in Python and we can easily find in the Python community usefull applications: PyUSB, PySerial, PyVISA, PyModbus. As shown in Fig.8, we have to develop the instrument commands part called by PyScada. The idea is to provide a list of experiments scripts available in a bank of instruments selected by PyScada after the teacher has informed the experiment he wants to set-up.

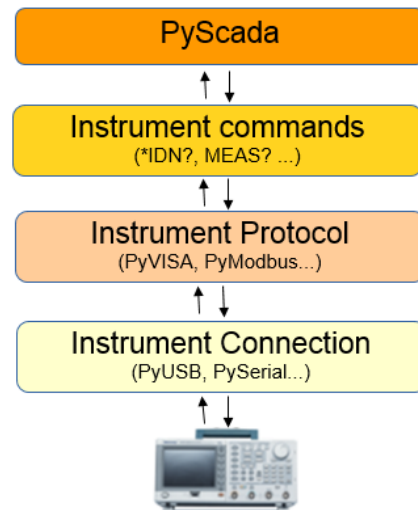


Fig.8. Instrument communication

### 2.4. Interaction between learner and laboratory

Improving motivation and immersion of the learner is a priority to have a good learning process. To ensure these issues, it is necessary to use some digital tools to bring immersion feeling to the student. A live video coming from a simple camera and/or a drone replaces the eye of the learner (Fig.9). It allows to focus on the experiment and move around. Image processing techniques allow to work on facial expression recognition to detect the emotion of the learner, and give him the feeling that he is not alone: this mimics the eye of the teacher [7]. Live call will be possible between the teacher and the student.



Fig.9. Drone flying above the LaboREM measurement instruments

Implementation of the robotic arm on server side permits to interact directly on the experiment via some controls available on the web interface: this mimics the arm of the student.

### 2.5. Integration of the pedagogical scenario in the LMS

An adaptive scenario for the learner will improve his immersion and his motivation in the

learning process. To interact in real-time with the scenario and the remote lab, a bidirectional communication between the laboratory (instrument drivers database, HMI) and the LMS (user database, game-like scenario, SCORM database) is required. A typical game-like scenario contains video presentations, quizzes, online lessons, remote laboratories, online simulators. The game-like scenario designed in the LMS plans some different paths depending on student's results during the sequence of the scenario, allowing teachers or students to adapt it or to redo one step as described in Fig.10.

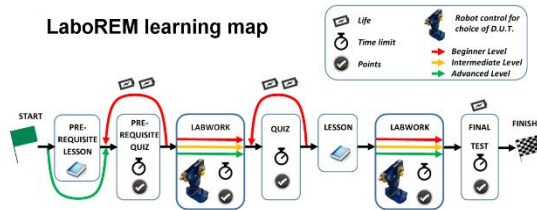


Fig.10. Learning map as a treasure hunt with various steps

### 3. TECHNICAL RESULTS AND PROGRESS

The actual HMI version of LaboREM is directly accessible from the learning management system (LMS) of the University of Pau. The remote laboratory activity is embedded into a game-like scenario which gives an access to practical works in analog electronics, to the list of connected users and a “TOP 10” ranking which offers the opportunity to the students to compare their experimental results with other classmates, and to compete for best measurements

#### 3.1. Open source SCADA development

The SCADA system was developed and validated, the web HMI allows to enter the values to control function generator, digital multimeter and oscilloscope (Fig.11). An algorithm which computes the frequency response of any filter was validated. Fig.12 and Fig.13 present a Bode plot of a simple RC low-pass filter.

Ve	10	Vpp
Fmin	100	Hz
Fmax	100000	Hz
Nombre de points	15	

BODE

- Position de la souris : (152571, 15.61)
- Points tracés : 15.00 sur 15.00

Fig.11. Input Controls and plot information

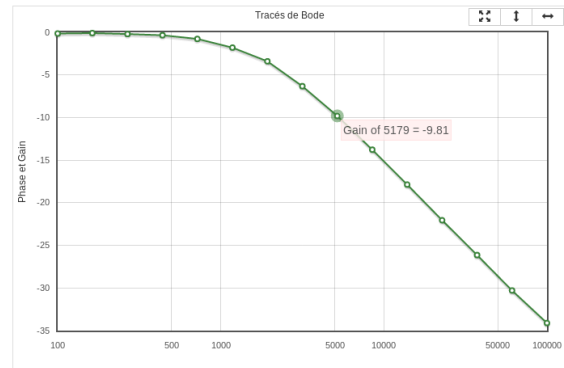


Fig.12. Magnitude Bode plot

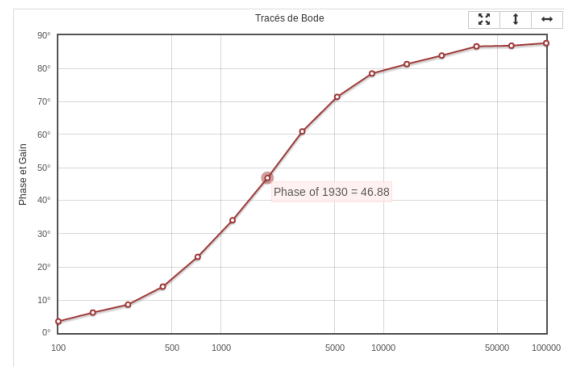


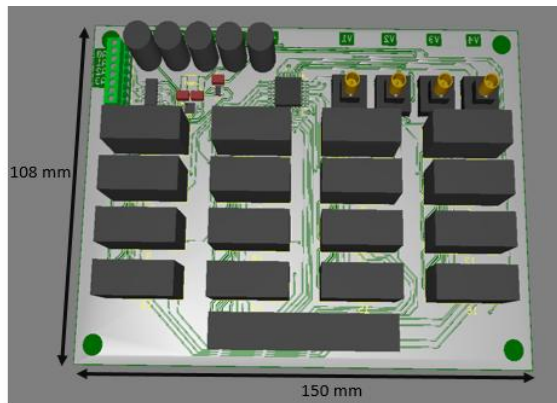
Fig.13. Phase Bode plot

Based on our first results, we are currently working towards three major improvements and developments:

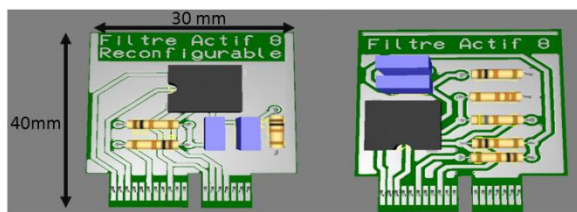
- Improve the graphic part of the HMI to be more attractive,
- Create a library to permit to SCADA system to communicate with different instruments brands (Tektronix, Agilent, Rigol, etc.),
- Migrate to Moodle to be compliant with the most used LMS in higher education.

#### 3.2. PCB design

A PCB design software - called Ultiboard - was used to design PCBs. Connectors and plugs are designed in PCI Express logic because this is a well-known electronic standard. It simplifies PCB design, reduces the cost thanks to widely used connector types and assures a mechanical resistance that allows the teacher to change easily the plug on the motherboard. 3D views of the designed PCB are visible in Fig.14 and Fig.15.



**Fig.14.** 3D view of the “LaboREM Box” motherboard; grey rectangles represent connectors to interconnect plugs and robot extension board



**Fig.15.** Plugs examples of two active filters: one configurable remotely by the robotic arm, and a second one with fixed components

All the PCB designs will be available as open hardware permitting community to create new DUT and to share it with the LaboREM network.

## CONCLUSION

We have shown in this article all the topics which refer to the deployment of LaboREM in some universities. Development with open-source applications, standardized protocols and low-cost hardware set-up allows to design a solution easy to duplicate and favors interconnection of the remote labs to create a network. The use of opensource applications on the server-side allows to embed the remote lab into a blended learning scenario in the LMS of the university.

As generic motherboard were designed, new practical DUT can be imagine in other fields in applied sciences like mechanics, optics and renewable energies.

Further developments are currently conducted toward a full design of the “LaboREM Box” and a transfer to universities in Senegal, Burkina Faso and Germany. The impact of LaboREM for learners and teachers will be measured in all partner universities to improve the pedagogical approach, the immersion of the learner in the practical work, and the interaction with the professor.

This pedagogical tool will be a new pillar for blended learning approach and thus the frontier

between theoretical and practical studies becomes more porous.

## ACKNOWLEDGMENTS

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