Thinking on Future Web Laboratory Services

Application to the VISIR Remote Laboratory Environment

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ABSTRACT

Educational institutions have to train the next-generation workforce. Unfortunately, it is not easy for educational institutions and educators to adapt to this unpredictable and volatile labor world. Besides, students have become more demanding adopting a role close to a consumer. They also have embraced a lifelong learning strategy in «skills learning» through professional development as a common occupational norm. Remote laboratories have emerged as an educational tool in order to provide flexibility to practical training. However, they are going to turn into core elements in future educational approaches due to students' demands and technological advances.[1]

CCS CONCEPTS

• **Hardware → Communication hardware, interfaces and storage →** Sensors and actuators. **Applied computing → Education →** Interactive learning environments, E-learning Computer-assisted instruction

KEYWORDS

Analog electronics, central server, education, federation remote laboratory, VISIR, remote laboratory net.

ACM Reference format:

F. Garcia-Loro, S. Martin, M. Castro and J. Marquez-Barja. 2020. SIG Proceedings. *6th EAI International Conference on Smart Objects and Technologies for Social Good September 14-16, 2020.N/A, Antwerp, Belgium, September 2020*, 5 pages.
DOI: 10.1145/3411170.3411266

1 INTRODUCTION

Current societal demands concerning educational provision require wide flexibility in the application of educational approaches. Since a few years ago, educational authorities around the world are promoting a switch from the traditional teacher-centered model to a student-centered model [1]-[4]. This strategy implies more autonomy and responsibility of the student in the process compared to the traditional model [5]. Students must assume an active role in the process of building their knowledge. Furthermore, educational process must not only provide to the individual with knowledge but also with the required skills beyond the academic scope.

The labor market is strongly shaken by the 4th industrial revolution [6][7]. Although this effect has affected all areas, its effects are even greater in the engineering and technological-based sectors. Education is not an exception in this revolution since it has to train the next-generation workforce [8][9]. Unfortunately, it is not easy for educational institutions and educators to adapt to this unpredictable and in constantly-changing labor world [10]. Besides, the core skills that will be required in the short term are not yet shaped and that most of the

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ones that are considered core today may not be tomorrow or will be subject of accelerated changes [11][12].

On the other hand, students of any course have certain common characteristics such as theoretical background, usually similar age, usually focused on certain goals, a certain set of academic skills, etc., however, when facing any new open learning process, they interact with different elements from other students and in a different way with the same elements than other students. Therefore, personalization of the learning processes occurs [13]. Students require flexible learning scenarios in which they want to be able to self-regulate their learning processes, design their learning paths and be assisted when they request. That is, through their learning strategies they are more comfortable and motivated, favoring in this way meaningful learning [14][15]. In addition, students have become more demanding adopting a role close to a consumer. They require anywhere anytime access to education in order to integrate learning into their daily lives, and not the other way around as was the custom a few years ago. They also have embraced a lifelong learning strategy in "skills learning" through professional development as a common occupational norm.

There is an obvious exception in the aforementioned “sterile” quasi-homogeneity of student profiles within a course: Massive Open Online Courses (MOOCs) or similar approaches. These types of courses are far from having a homogeneous population of students. Generally, the strategy used when designing these courses is based on the premise that a solid educational background is not necessary to cope with the course contents.

With all these actors, ingredients and changing factors, and due to the unfeasibility of providing a permanent educational background with effective qualifications and competences enough for the whole working life of students, it is obvious that the current educational scenario must be focused on providing students with the ability of learn to learn, helping them to acquire learning strategies and the critical thinking to apply them correctly through their life.

This approach, required for educational institutions, is challenging in technological-based programs. Most of the ideas and paradigms that have to be introduced are de facto hardwired into the education system; however, they are not adapted to self-regulated contexts, anywhere/anytime premise or to the flexibility desired. Although these methodological limitations, some interesting solutions have emerged to provide a more comprehensive learning scenario. This is the case of remote laboratories: learning tools, based on real systems, designed to provide 24/7 access to interactive experiments remotely.

Remote labs make available unique advantages to students with educational difficulties and geographical obstacles: it allows such students to carry out experiments the number of times they need, without having to be in the lab. In this paper, we explore the current and future potential of one of these tools: Virtual Instruments System in Reality (VISIR), an analog electronics remote laboratory.

2 VISIR REMOTE LABORATORY

The VISIR remote laboratory is the result of a research project carried out by the Department of Signal Processing of the Blekinge Tekniska Högskola (BTH, Blekinge Institute of Technology), from Karlskrona, Sweden [16].

Currently, there are more than 20 VISIR systems deployed and their use has been integrated as a curricular educational tool from primary school students [17] to highly specialized training courses [18] and in all types of educational modalities satisfactorily: 100% distance, blended, classroom, moocs, continuing education courses, etc. [19]-[21].

The hardware of the VISIR system is based on a PXI platform from National Instruments for the equipment and instruments, and a stack of PC/104 sized boards for the components and acts as a breadboard (Fig 1).

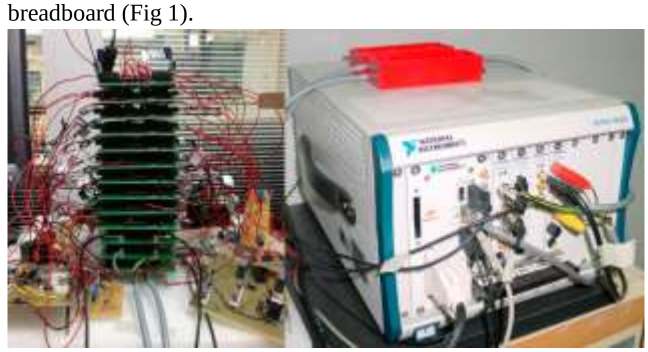

Figure 1: Hardware of the VISIR system installed at UNED: PXI chassis in which the instruments and equipment cards from National Instruments are installed; and a relay switching matrix in which the components are plugged.

The software in VISIR consists of 3 elements:

a) Experiment client: it consists of a simulated workbench (Fig. 2) in which users may interact with the laboratory elements and design experiments.
b) Measurement server: it is responsible of receiving the access requests, of managing the FIFO queue, of validating the experiment and acting as a bridge between experiment client and equipment server.
c) Equipment server: It is responsible of setting up the equipment and instruments and wiring physically the circuit according to the validated request provided by the measurement server.

Despite the advantages of VISIR [16]-[21], there are, logically, disadvantages associated with its hardware architecture [22][23]. These can be centralized in the rigidity of the connections of the components to the node matrix [22]. While the closing/opening relays allow the connection/disconnection of the components to the matrix of nodes and the equipment and instruments, all of them are rigidly connected to the nodes. This means that two components located in different locations of the relay switching matrix which are plugged to the same nodes, cannot be connected in series.

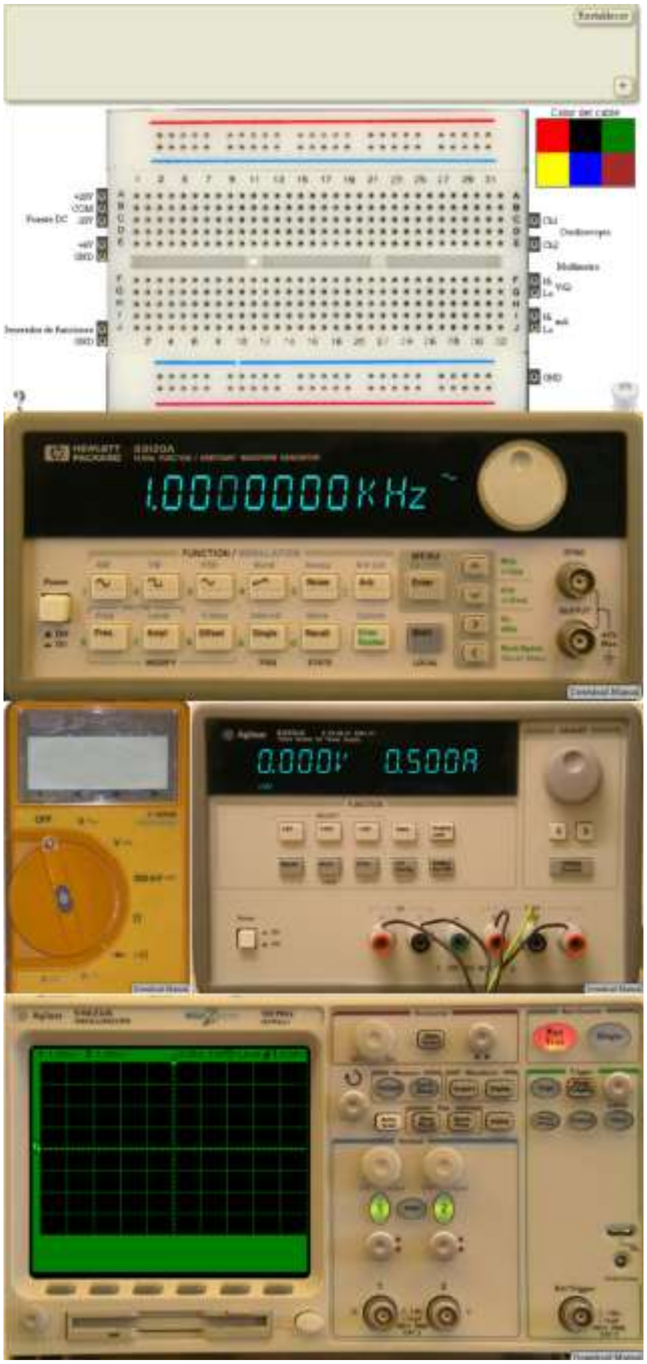

Figure 2: Equipment and instruments interfaces in VISIR, from top to bottom: Components tray and breadboard, function generator, digital multimeter (left) and power supply (right) and oscilloscope.

Therefore, to provide a flexible practical environment and the desired design freedom available in hands-on labs, the matrix must use more component slots: to generate more short circuits or replicating components, in order to make possible more circuits using the same subset of components [23].

3 POTENTIAL FUTURE SCENARIOS

In this section, we are going to outline the potential scenarios for VISIR remote laboratory as a learning tool as well as a researching instrument based on its hardware and software development.

The main differentiating feature in VISIR is its multi-user availability. VISIR simultaneously allows 60 students to interact with its equipment, instruments and installed components. These 60 simultaneous users can interact with the same or different components, setting up diverse configurations for equipment and instruments. This is possible thanks to 3 reasons:

1. The implemented FIFO queue (first in first out) managed by the measurement server to handle the accessing requests.
2. The fast response of the equipment server in validating the user's authentication and requests.
3. The fast transients of electronic components and circuits.

This limitation of 60 simultaneous users in VISIR is imposed by the measurement server: the FIFO queue cannot handle more than 60 requests. For this reason, the booking systems and Remote Laboratory Management Systems (RLMSs), which are one layer above the remote laboratory, set the limitation of users connected to the laboratory on that value. Also, the bigger the queue size the worse the response times on the client are (increasing time request- response in the client). In most cases in which only one user is accessing the hardware, the response takes less than 100 ms; On the other side, more than 2 seconds with 30 requests simultaneously.

However, if we think about the prototypical interaction in an analogical electronics laboratory, the use of the equipment and instruments is limited at most to 5% of the time of the sessions. The remaining time, at least 95%, is devoted to reading the practice script, calculations, designing tasks, assembly of components on the protoboard, setting up the instruments, data analysis and/or discussion of conclusions. Therefore, the fact that the user has access to the client does not mean that he is using the laboratory, so the possibility that the system handles a large queue of simultaneous requests (e.g. 30 requests) is very remote. Even with all this, this limitation of the measurement server can be modified and extend the capacity of managing the FIFO queue, platforms like the one proposed by LabsLand [24] have established this limit at 120 to allow a greater number of connected users without running the risk of overflow.

In any of the potential scenarios, the result is an interaction over a real system. It virtually happens in real-time and supports a high number of users daily with high reliability of the system and truthfulness results.

3.1 Stand-alone

One potential option is to use it as a stand-alone system. This approach has been the one used up to 2016/2017 for all VISIR systems and it remains as the exploitation option in several ones [27][28].

3.1.1 Obsolescence. A potential future for each VISIR system is the obsolescence of the system. It may be caused by hardware obsolescence and/or software deprecated or by the emerging of an alternative and improved solution.

2.4.2 Isolated mode. The VISIR remote laboratory has a high level of customization. This has been revealed in the PILAR project [22],[25],[26], with 5 European VISIR systems deployed, with more than 5 years of usage and customized developments according to the needs of each HEI: ad-hoc web applications, completely different strategies in terms of the booking management, usage of different Remote Laboratory Management Systems (RLMSs), diverse approaches of integration into Learning Management Systems (LMSs), etc. The federation has been implemented, however, these particularities have been a challenge for its establishment [22][23].

The efforts carried out by each HEI in order to update and improve the VISIR system according to the particular needs at each HEI would cause an individualization of the system over the years. Therefore, the same remote laboratory may be implemented using different architectures, so they must be considered as different laboratories.

3.2 Federation

The PILAR project (Platform Integration of Laboratories based on the Architecture of visiR) aimed for a common platform and a shareability of the educational resources based on 5 VISIR systems deployed at the Higher Educational Institutions (HEIs) involved in the project. The VISIR nodes at the PILAR consortium are from Blekinge Tekniska Högskola from Sweden, Universidad Nacional de Educación a Distancia and Universidad Católica de Deusto from Spain, Instituto Politécnico do Porto from Portugal and Fachhochschule Kärnten from Austria.

For its part, LabsLand [24], a commercial solution spin-off of WebLab-Deusto, is also using a federated solution. The approach is based on the reliability of the service by providing redundant experiments only. So, in case one VISIR is out of service for any reason, the system redirects the incoming traffic to the node in which redundant experiment has been deployed.

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The aim of federated solutions may be summarized as:

a) A reliable and highly available system based on sharing services and resources.
b) The formal definition of federation.
c) The provision of protocols to allow more systems to join the federation.
d) An increasing variety of the repository.
e) Optimized design of experiments to make more flexible and real experimentation experience.
f) Efficient and effective use of practical resources based on the LR VISIR
g) It provides the infrastructure for the exploitation of Open Educational Resources (OERs) based on LR VISIR.
h) The platform provides tools for the analysis of the learning process.
i) Standardization of the services and architectures.
j) The development of hardware and software improvements according to the needs of all avoiding particularization.
k) Any system update, improvement, or auxiliary tool is available for any federated systems immediately.

l) 3.3 Central server

An interesting option in terms of system performance is based on the design of a central measurement server. In this way, the end-user accesses the client's experiment, designs the experiment and requests access in a conventional way. However, the access requests are analyzed in this central measurement server and directed to the VISIR system that supports and admits the experiment implied in the request.

4 DISCUSSION AND CONCLUSIONS

In this paper, we have outlined the potentials future scenarios for VISIR remote lab. However, they may be extrapolated to any other remote lab, by adapting solutions to the particular specifications and requirements of each laboratory.

None of the described scenarios is superior to each other, but they may be complementary solutions. However, given the numerous community of VISIR systems, it would accelerate and improve future developments if the efforts are defined as a community aim instead of single systems. In this sense, the federation is the first step to provide a fully flexible, reliable and trustworthy analog electronics laboratory.

The experience reported in PILAR project highlighted the high level of customization shown by the 5 VISIR systems involved, hindering the development of common solutions for the same problems. In this sense, it is clear that federated solutions may help the whole community and accelerate improvements. Therefore, architectures allowing redundancy model, based on transitive VISIR systems, make this approach highly reliable in providing laboratory services.

The development of a central measurement server may be combined with the federated solution. By combining both, the synergies of both solutions are exploited.

On the other hand, the development of a solution that solves the rigidity of the connections in the relay switching matrix may be considered as a key issue in VISIR hardware. However, solutions based on dynamic connections of the components to the nodes require a parallel development of the software.

ACKNOWLEDGMENTS

This work was supported by the Madrid Regional Government and Structural Funds (FSE and FEDER) through the Project e-Madrid- CM under Grant P2018/TCS-4307, by the Industrial Engineering School of UNED as well as from the Innovation and Digitalization Vicerrectorate of UNED under Project “Laboratorios de STEM y robótica educativa para la mejora de la experiencia del estudiante – STEM-SEC”.

And partially supported by e-LIVES Project, e-Learning Innovative Engineering Solutions under Grant 2017-585938-EPP-

12017-1-FR-EPPKA2-CBHE-J; I4EU Project, Key Competences for an European Model of Industry 4.0 - nº 2019-1-FR01-KA202-062965; IoE-EQ Project, Internet of Energy-Education and Qualification, under Grant 2017-1-IT01- KA202-006251, and finally by the PILAR Project, Platform Integration of Laboratories based on the Architecture of visiR, under Grant 2016-1-ES01-KA203-025327.

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