Federated Electronic Practical Resources using PILAR as VISIR Integrated Tool

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Abstract

Practical training is a pillar in technical education. Traditionally, these benefits have been acquired through hands-on laboratory sessions. However, at present, the educational models tend to rely on distance education tools either totally (e-learning, m-learning, etc.) or partially (b-learning). To provide practical training in those educational scenarios is challenging. Remote laboratories —real laboratories, working on real systems and under real conditions, controlled remotely— can play a fundamental role. Nevertheless, remote laboratories not only provide advantages but disadvantages of both environments involved in the process: real laboratories and remote communications. Furthermore, remote laboratories add new limitations due to constructive constraints. VISIR (Virtual Instruments System In Reality) is a remote laboratory on top of the state of the art for wiring and measuring electrical and electronics circuits, but VISIR system has his own particular restrictions like any other remote lab. In this context, PILAR (Platform Integration of Laboratories based on the Architecture of visiR) Erasmus Plus project development aims for a federation of five of the existing VISIR nodes in Europe: Blekinge Institute of Technology (BTH), Spanish University for Distance Education (UNED), University of Deusto (UDEUSTO), Carinthia University of Applied Sciences (CUAS), School of Engineering of Polytechnic of Porto (ISEP). This paper describes the benefits that PILAR project will provide to the consortium, and how these physical constraints of the VISIR system can be compensated through the federation, after one year and a half of the project development and having the first draft of the federation and website running.

Keywords: Remote Laboratories, Federation; Practical Competences, General Electronics Practical Environment, Open Educational Resources, VISIR, PILAR.

1 Introduction

Distance education has become widespread in the last decade and has fostered lifelong learning and continuing education patterns, allowing access to learning resources at any time and from anywhere. It has been possible thanks to the internet development and technologies associated with learning tools for a new teaching pedagogy. To support life-long learning and students' autonomous learning activities, remote experimentation has become a challenge in electronics courses. The way the universities and educational organizations or institutions deliver remote experimentation to students in distance learning environments has become a challenge.

Nowadays, there is an extensive variety for providing theoretical contents in distance learning (videos, documents, tutorials, scaffolding activities, peer-to-peer reviews, forums, etc.) to students. These tools, by an efficient and appropriate selection from professors and use from students, can complement or replace successfully in-person education, even they can reach some aspects that in-person education cannot achieve. Unfortunately, practical issues are not as developed as theoretical ones are. A first approach to this problem is clearly the use of simulators and virtual labs. Although, they are still a bit far from providing to the students the real performance and features of equipment under real-life operating conditions. The major challenge is the provision of laboratory working online along with the theoretical contents in a massive context.

The essential difference between remote laboratories and in-person laboratories results from how the interaction between student and workbench is performed. Therefore, remote laboratories have very limited ability to provide manual skills; However, physical presence is only a subjective mental reality (Sheridan, 1999), (Biocca, 2001). The possibility of a direct comparison between the different alternatives is constrained by a lack of uniform criteria with which to evaluate the effectiveness of laboratory. Therefore, it is impossible to conclude that any type of laboratory is superior to another objectively, but also each one provides different learning outcomes (Ma & Nickerson, 2006; Naef, 2006; Nedic, Machotka & Nafalski, 2003).

A review of the current literature shows a great number of universities or organizations that have created their own virtual and remote laboratories to support life-long learning and students' autonomous learning activities (Jara et al., 2011; Rojko, Hercog & Jezernik, 2010).Remote labs provide flexibility to learning scenarios, "the concept is about providing new possibilities for students to do laboratory work and become experimenters by adding a remote operation option to traditional instructional laboratories to make them more accessible for students, irrespective of whether they are on campus or mainly off-campus" (Gustavsson et al, 2007).

Remote laboratories also provide controlled and safe scenarios at the expense of flexibility. This loss of flexibility when experimenting is due to the protections and constraints established by teachers in the design stage of the experiments and limitations established by remote lab operation. For example, destructive experiments that students may be carried out erroneously in in-person laboratories, cannot be allowed in remote labs. But sometimes, this loss of flexibility in the interest of safety also limits the students' freedom, thus limiting students' options to explore. Some of these limitations cannot be overcomed. However, a federation of VISIR, systems such as the one proposed in PILAR, establish a new scene for electronics remote experimentation. PILAR is an Erasmus+ PILAR project that aims to interconnect the partners' VISIR remote laboratories, creating a grid of shared VISIRs in order to expand and empower the circuit repository of all participants: each institution may design certain experiments and their students perform these experiments and others installed at other institutions, and vice versa. But PILAR project is not only for institutions with a VISIR remote lab installed, it would be also possible for an organization without VISIR to participate. This paper aims to describe the PILAR project: the need and reason of PILAR, its goals and challenges.

2 VISIR remote laboratory

VISIR is a remote lab for electric and electronic circuits experiments developed at Blekinge Institute of Technology (BTH) in Sweden and in use in several universities all around the world (Garcia-Loro et al., 2018). In VISIR the traditional equipment (DC-power source, function generator, multimeter and oscilloscope) are replaced with an equipment platform, which is suited for remote control such as PXI (PCI eXtensions for Instrumentation), LXI (LAN eXtensions for Instrumentation) and GPIB (General Purpose Interface Bus) (Gustavsson et al, 2007). Therefore, VISIR is a real laboratory as hands-on laboratories are, but designed for remote control interaction.

The VISIR project started in 2006 at the Department of Signal Processing, BTH, in cooperation with National Instruments and Axiom EduTech and with financial support from VINNOVA (Swedish Governmental Agency for Innovation Systems). However, VISIR origin is in 1999 "to ascertain that it is feasible to design a remote electronics laboratory comprising standard equipment to supplement local instructional laboratories and provide free access to the experimental equipment to students enrolled in circuit analysis and electronics courses" (Gustavsson et al, 2007).

VISIR remote laboratory can be divided into two blocks: The hardware block —instrumentation platform and relay switching matrix— and the software block —experiment client, measurement server and equipment server—.

2.1 Hardware description

The instrumentation platform of VISIR is based on PCI eXtensions for Instrumentation (PXI) from NI. The NI PXI platform consists of a controller card (embedded/external PC), instrument module cards (DC power supply, digital multimeter, oscilloscope, and function generator), and a chassis into which all the cards are plugged. The terminals of the NI PXI-modules are connected to a relay switching matrix. The matrix communicates with the controller through a USB cable. All the equipment described is shown in Figure 1.

The relay switching matrix is a stack of "PCI/104" sized boards. The matrix installed at UNED consists of three instrument boards and 10 component boards. The matrix can house up to 15 component boards at maximum. Each component board comprises 10 sockets and each socket is connected to a Double-Pole Single-Throw (DPST) relay, four of these sockets can be connected instead to 2 Single-Pole Single-Throw (SPST) relays. So, each component card can accommodate 6 two-leads components (6 DPST relays), and 8 single pole connection which is used to allocate any type of component and provide flexibility in order to optimize sockets. The circuits are constructed in the matrix by opening/closing relays with regard to the received circuit design from the controller. The connection of the NI PXI-modules' terminals through the instruments cards and the components' leads on a common 10 nodes (A-I, 0) propagating through all the boards of the matrix.

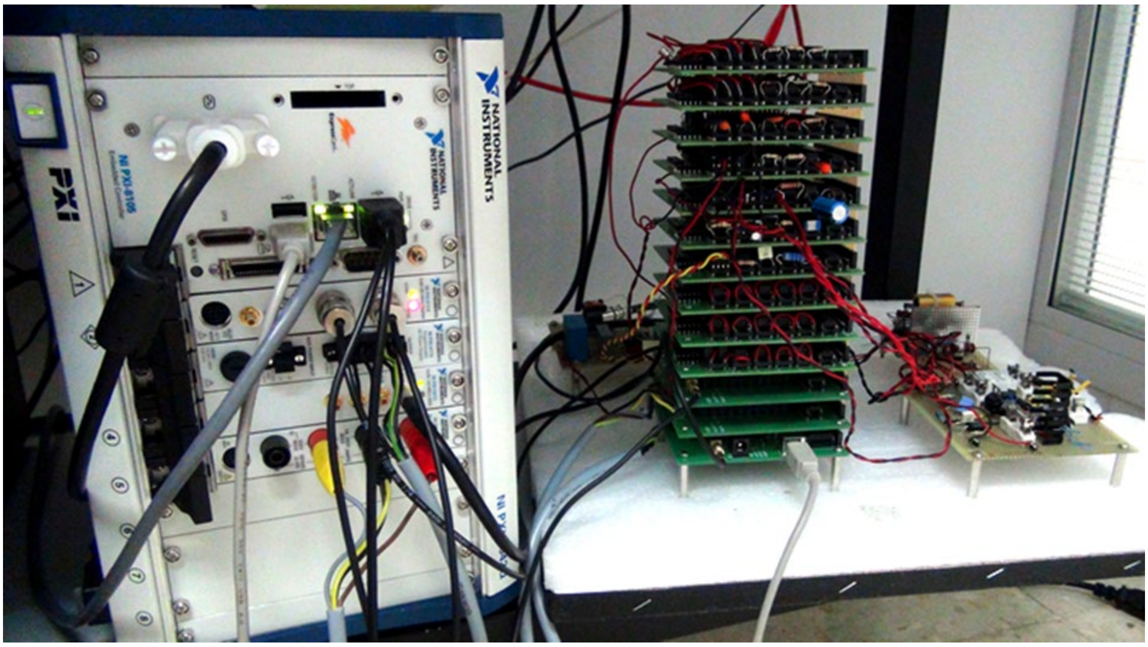

Figure 1. VISIR hardware at UNED.

2.2 Software description

The VISIR software is an open-source that is released under GNU General Public License (GPL):

- Experiment Client: It is the Graphical User Interface (GUI) and the simulated workbench of VISIR as shown in Figure 2. The user drags the selected components to the virtual breadboard, wires his/her circuit, and configures the instruments. When the user wants to experiment with his/her designed circuit, presses the “perform experiment” button. The designed circuit created by the user is transferred first to the “Measurement Server” in form of an XML-based protocol, called “Experiment Protocol”.
- Measurement Server: It is a software application written in Microsoft Visual C++. It is responsible for the periodical authentication versus database during sessions for more security, queuing simultaneous requests, and verifying designed circuits created by users versus maximum allowed parameter values listed in the “maxlists” (i.e. these lists are configured by the teacher depending on the specification of the available components) in order to avoid hazardous circuits. After validating and sequentially arranging the requests, it starts to send them in order to the “Equipment Server”.
- Equipment Server: It is a software application for instrumentation control developed by LabVIEW and hosted in the NI PXI controller. It receives users’ verified circuit designs from the “Measurement Server” in “Experiment Protocol” format and executes them through the physical equipment. Eventually, the results return back to the users on their PC-screen (i.e. in the instrument interfaces) with the same sequence.

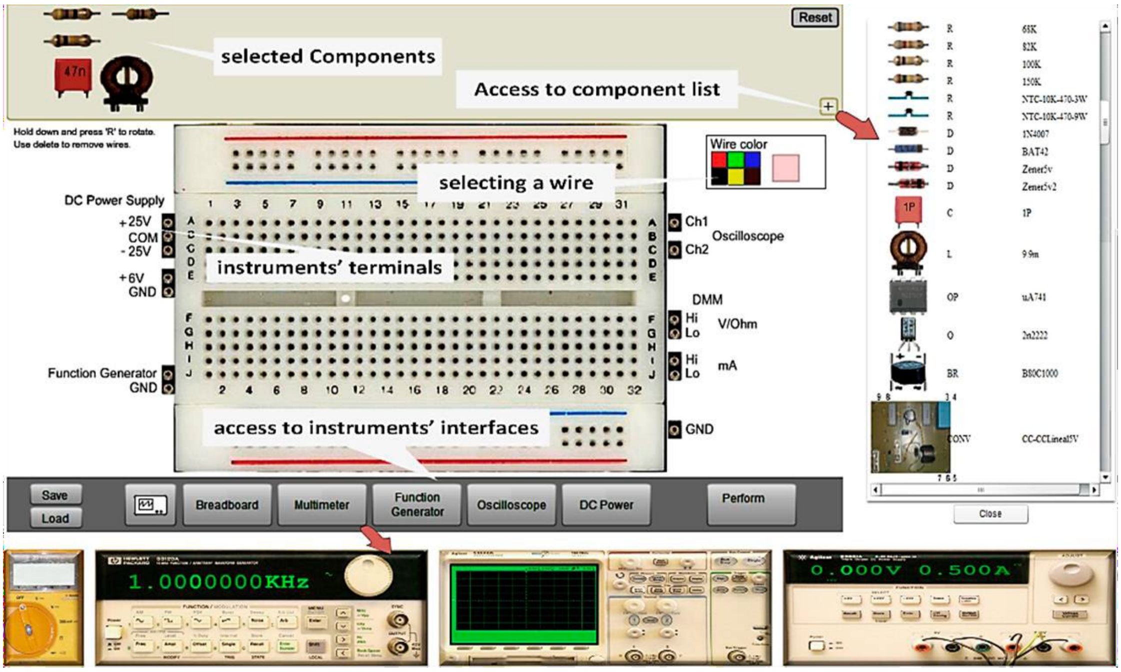

Figure 2. Simulated workbench of VISIR.

2.3 VISIR reliability

So far, VISIR remote lab units are installed in thirteen different Higher Education Institutions (HEI) from eight different countries: in Argentina at National University of Rosario (UNR) and National University of Santiago del Estero (UNSE); in Austria at CUAS and FH Campus Wien for Applied Sciences; in Brazil at Federal University of Santa Catarina (UFSC), Federal Institute of Santa Catarina (IFSC) and Pontifical Catholic University of Rio de Janeiro (PUC); in Georgia at Batumi Shota Rustaveli State University (BSU); in India at Madras Institute of Technology (MIT); in Portugal at ISEP; in Spain at UDEUSTO and UNED and in Sweden at BTH. VISIR remote lab has served well several thousands of students and has been incorporated at different educational levels and types of courses: lower secondary (Blazquez-Merino et al., 2018), upper secondary (Claesson et al., 2013), undergraduate (Marques et al., 2014), postgraduate (Tawfik et al, 2015), MOOCs (Massive Open Online Courses) (Garcia-Loro et al, 2016), life-long learning or professional development (Garcia-Loro et al., 2016).

In Intellectual Output 3 (IO3) some metrics have been analyzed from the VISIR nodes: the operational availability (in order to measure the percentage of days (of planned ones) which VISIR was available for students, and the system availability (in order to measure the percentage of days which VISIR was available). The results were satisfactory: an operational availability over 95% on average and a system availability over 90% on average. Since its origin VISIR has been improved continuously (both, hardware and software); new versions of component and instrument boards have been released, and the software layer has been upgraded several times. This continuous improvement, together with the measured results, confirm that VISIR is a robust and reliable system.

3 PILAR project

PILAR partnership is composed by 8 participants: BTH, the origin of VISIR; UNED, CUAS, IPP and UDEUSTO, four institutions with VISIR experiences, some of them shared, and finally, the IAOE (International Association of Online Engineering), an international non-profit organization with the objective of encouraging the wider development, distribution and application of Online Engineering. EVM has wide experience in EU projects and will colead and coordinate the dissemination activities. OMNIA is a multi-sector education provider that will colead the training activities.

3.1 Goals

PILAR is a project that addresses the following needs:

- Need of real, extensive and intensive, online, cheap practices for building and interacting with electrical and electronics circuits in engineering subjects of university level, and also as a lifelong learning activity (industry oriented) and at a school and high school level.
- Need of reliable, highly available, remote laboratory services offered through the Internet by a robust remote labs service provider, that will enhance a stronger digital integration for learning and teaching
- Need of having these practices available at any time and from anywhere, in a timely and controlled manner, helping to increase the number of graduates at the university that cannot easily access these practices

The main objectives pursued by PILAR are:

1. Based in the different implementations of VISIR in several of the partners in the project (BTH, CUAS, UDEUSTO, IPP, UNED), the first objective is building a reliable, highly available, unique international VISIR platform federation, that integrates all the different resources used by VISIR in each of the partners.
2. Once established, this federation will be completely opened to other partners in Europe, through easy gateways to the federation, allowing to extend the capabilities of PILAR to much more interested educational institutions.
3. Building a set of remote practices, based in this new platform, for electrical and electronics circuits, at school, grade and master level, and also as a lifelong learning activity, that will be offered as remote lab services, to students in all the partners institutions and, as a second step, to anyone interested. The results will bring added value at EU level because the activities cannot be attained in a single country.
4. Those new remote lab VISIR Internet services must allow, in a transparent way, the use of the best set of remote learning services of each partner in each moment.

3.2 Federation aspects

Four different aspects can be faced using a federation of the existing VISIR nodes:

1. Scalability. The VISIR system is designed to support around 50 users at the same time because the hardware is multiplexed. But if a huge amount of users are expected we need to scale the VISIR using a federation. If the circuits are replicated in different VISIR nodes, more users can access the platform and experiment through the federation.

2. Reliability and availability. Redundancy. If one node is not available for any reason, its effort can be supported by other nodes. That is: if one user is accessing the VISIR in his institution but it is down he will be automatically redirected to another available VISIR node (in other institution). This process will be transparent for the user. In this case, the federation mechanism must know what circuits are available in what VISIR nodes.

3. Set of experiments. VISIR is a REAL remote lab, it is like in the classical lab. There you can construct any circuit, but it is not true because in the lab we do not have all the components, we have a set of them (some resistors, some capacitors, some…). In VISIR is the same, we can offer any circuit, but not all of them at the same time. In this situation the federation is very interesting because each VISIR node can implement a set of circuits (DC circuits, AC circuits, Operational Amplifiers circuits, etc.) but the user will not access only to the set of experiments of his institution, but also to the total set of experiments of all the VISIR nodes.

4. Tracking system. The federation must be able to know how many users are accessing each VISIR node, to balance the use of the VISIR federation. The federation software layer must have a system to assure the balance of the nodes and to control the accessing priorities of the different users

3.3 Partners

The partnership and the federation will act as a resource multiplier at EU level, allowing all partners to introduce their best resources and efforts into the project and have the results evaluated globally. The PILAR project will combine the partners' capabilities to develop the technical solution, create contents and deliver these experimental solutions to courses and technical workshops.

UNED

UNED has been part of the VISIR consortium for the last 6 years. During these years VISIR has been used routinely by hundreds of students each year. In this case, due to the "at distance" nature of UNED, these students have taken particular advantage of VISIR practices. VISIR has also been used twice as the practical part of the first completely free MOOC dedicated to learn how building electrical and electronics circuits (6.000 enrolled students). UNED will coordinate the whole project, leading project management, serving as a large provider of pilots for PILAR, leading evaluation and organizing one of the multiplier events and one of the training sessions.

BTH

BTH is the institution where VISIR was born and is the inspiring institution for many of the new approaches in VISIR. BTH will coordinate all the work related with VISIR's state of art and integration in PILAR official documentation. BTH also will organize one of the multiplier events and will be a pilot site.

UDEUSTO

The University of Deusto is part of the VISIR consortium for the last 8 years. Thanks to the knowledge acquired during these years. More than 150 students have been using the platform every academic year due to its integration as a learning tool used by professors and learners. Furthermore, UDEUSTO has offered access to its VISIR platform to high schools in the framework of Olarex project ("OLAREX", 2018). UDEUSTO will lead the building and maintaining of the Project Management Center, will colead and coordinate the dissemination effort and will coordinate the training sessions with high schools, besides being also a pilot site.

ISEP-IPP

The Polytechnic of Porto (IPP) is a public higher education institution created in 1985. With over 18500 students, IPP is the largest Polytechnic of Portugal. The School of Engineering (ISEP) hosts about 6500 students enrolled in the 11 bachelors and 11 master degrees in engineering. The educational approach is designed using logic of applied knowledge, which favours "hands-on" approaches and an entrepreneurial mindset. ISEP has already tested its VISIR system with more than 1000 students accessing it, during a single semester. ISEP will lead the coordination of all the project reports, will lead the building of the set of new remote VISIR services, federated and balanced through PILAR federation mechanisms and will lead the coordination of one of the multiplier events.

CUAS

CUAS Is also part of the VISIR consortium and their VISIR implementation is used routinely as part of subjects in different matters in engineering grades. CUAS will coordinate all the jobs related to federation policies and will organize one of the multiplier events.

IAOE

The International Association of Online Engineering (IAOE) is an international non-profit organization with the objective of encouraging the wider development, distribution and application of Online Engineering (OE) technologies and it's influence to the society. As can be seen in http://online-engineering.org/, the association seeks to foster practices in education and research in universities, higher education institutions and the industry on OE. IAOE will coordinate the analysis of all the results, will help especially with the dissemination through different associations and journals related with remote engineering and will lead the building of a VISIR alliance.

EVM

EVM has a wide experience with different Erasmus + projects, adding specialized skills to the knowledge and experience of its customers and partners to optimize revenue with the lowest request of operating resources from them. EVM has vast experience in providing training and consultancy services to various types of organizations, both public and private (higher education institutions, VET Providers, schools...). EVM has wide experience in EU projects and will colead and coordinate the dissemination activities. with UDEUSTO.

OMNIA

OMNIA is a multi-sector education provider that offers upper secondary vocational education and training as well as apprenticeship training for young people and adults, general upper secondary education, youth workshop training as well as non-formal education courses. Omnia offers flexibility to combine study and leisure activities into meaningful entities for different learners of all ages. Omnia has an important role in developing vocational education and training on regional, national and international level through its wide partner networks. OMNIA will colead and coordinate WP4 with UDEUSTO.

3.4 Workplan (2016-2019)

The methodology and work plan applied for PILAR are based on a structure of work packages (Figure 3), in order to clearly define what activities should take place when and relate them to the outputs presented. The intellectual outputs are directly related to the different work packages. The intellectual outputs of the project are the following:

- IO1- VISIR Alliance (01/03/2017-30/08/2019)
- IO2- Advances in VISIR's state of the art (02/01/2017-31/07/2017)
- IO3- VISIR federation policies (10/07/2017-30/11/2017)
- IO4- Results on PILAR pilot (02/10/2017-30/04/2018)
- IO5- Set of open remote VISIR electrical and electronics practices (01/02/2018-30/09/2018)
- IO6- PILAR set of technical and methodological documentation (02/04/2018-30/11/2018)
- IO7- Evaluation plan and evaluation results analysis (02/07/2018- 29/03/2019)
- IO8- Dissemination outcomes (03/04/2017-30/08/2019)

Work packages:

- WP1: Project management and global coordination.
- WP2: Building PILAR federation. (Intellectual Outputs related: IO1, IO2, IO3, IO5 y IO6)
- WP3: Using PILAR in academic institutions: university level. (Intellectual Outputs related: IO4, IO5, IO6)
- WP4: Using PILAR in academic institutions: VET, high schools. (Intellectual Outputs related: IO4, IO5, IO6)
- WP5: PILAR Evaluation. (Intellectual Outputs related: IO7)
- WP6: Dissemination, impact and sustainability. (Intellectual Outputs related: IO8)

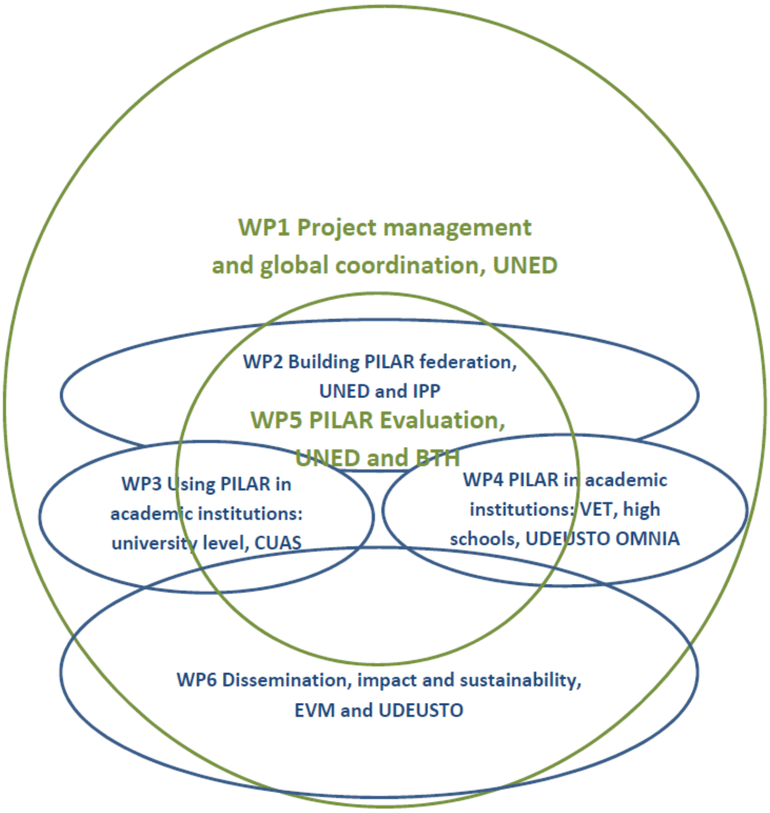

Figure 3. PILAR Workpackages structure.

3.5 PILAR challenges

There is a constraint imposed by the VISIR system on the number of concurrent requests that a VISIR system is able to manage (60). Therefore, this is the number of maximum concurrent users connected. However, for a good immersion feeling, a quick response of the system is required. Figure 4 to Figure 6 show how an increasing number of concurrent users slow down system time response. A federation of VISIR systems allows a balanced design between the nodes for the more demanding practices.

All VISIR nodes have a limitation on the available components and feasible circuits. This limitation derives from the number of component boards installed —the maximum allowable of component boards installed at each VISIR system is 15— and the number of components installed.

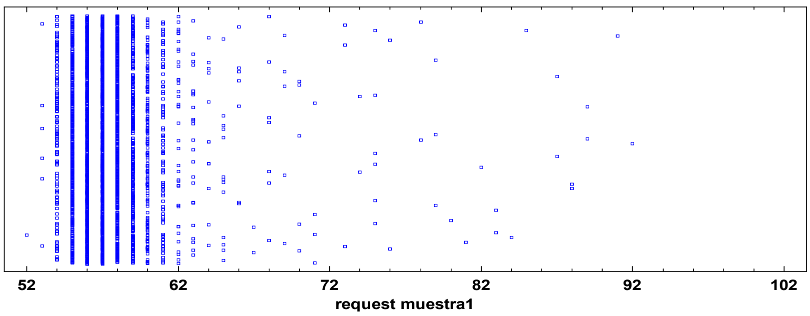

Figure 4. A unique user, time response in milliseconds; 5 minutes in continuous mode.

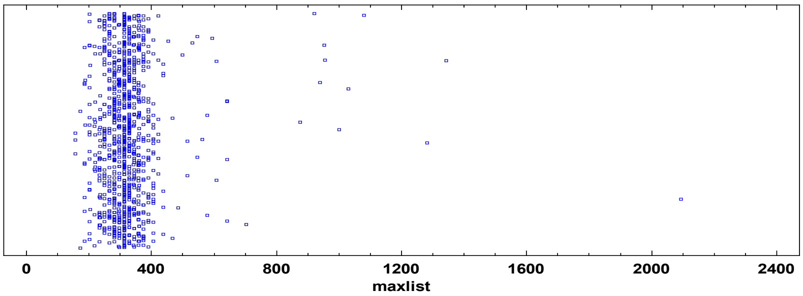

Figure 5. 5 users simultaneously measuring, sample time response in milliseconds; 5 minutes in continuous mode.

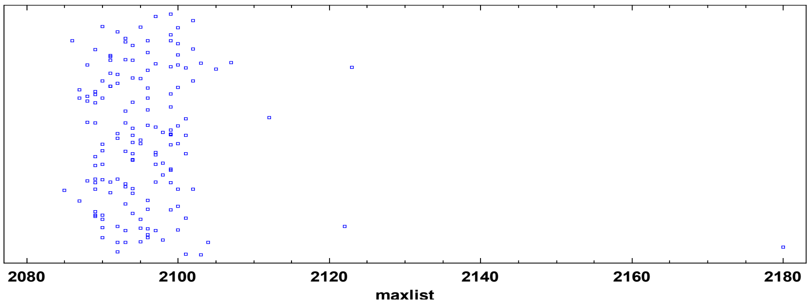

Figure 6. Over 20 users simultaneously measuring, sample time response in milliseconds; 5 minutes in continuous mode.

The more complex is a circuit, the more slots it will need at the relay switching matrix. Obviously, these components and short-circuits can be reused for other experiments but they will be always connected to the nodes wired at the relay switching matrix; e.g. a 3.01 kΩ resistor wired to nodes E and F, and a 10 kΩ resistor wired to nodes E and F as well, can be connected in parallel (nodes E and F) but clearly it is impossible to connect them in series. So, the number of feasible circuits is a strong limitation for an isolated system. Furthermore, even a federation will have problems in offering all possible constructible circuits based on a relatively large set of components. However, most of these constructible circuits are worthless learning circuits or hazardous circuits for components and/or electronic equipment/instruments. A federation of VISIR systems will not only provide a substantial circuit repository and variations based on their components but also an optimization of component and time resources at each node.

4 Conclusions and future work

PILAR partnership will enhance the learning, teaching and practical training at university and high school levels, by allowing to develop many different electronic practices through a newer and richer level of digital integration. The possibility of real practices for many different student profiles will help to develop basic and transversal skills all through the involved countries and, as a second step, all through any interested country. This new VISIR labs federation will also help to address low achievement in basic skills through more effective teaching methods, in a totally new dimension. Only with a federation of existing VISIR nodes will be possible to serve the large student population that may benefit from this technology-enhanced educational tool. This larger impact will also increase the efficiency of public expenditure and the investment in education and training, which could be identified as yet another horizontal or sectoral priority addressed by PILAR. STEM needs of improvement and practical competencies that must be addressed in schools, high schools and colleges, as well as might be used in industry for the capacitance and relocation of personnel might be obtained through the proposed federation of remote laboratories resources allowing a self-sustainable environment and incrementing the synergies as well as empowering the level of sharing open resources for the whole community.

It is palpable that partners feel the need to develop experiments concerning topics which are already available on other partners systems. The main finding underlines, even more, the need for a VISIR federation and the idea of sharing experiments.

Any of the approaches suggested for the experiments federation in PILAR will improve the efficiency of each VISIR system already built and will allow partners to share their learnings and capabilities of their respective VISIR systems and experiences with the rest of the academic community.

As future work, the architecture of the Federation will be established soon, as it is being technically planned nowadays. Once it will be defined, a pilot experience will be released as part of Work Package 2. The main challenge is derived from the different architectures implemented at each node. BTH and ISEP use OpenLabs platform, CUAS have iLabs as RLMS, whereas WebLab-Deusto is the RLMS at UNED and UDEUSTO. This pilot federation and the results obtained from it will be applied in a “Plan-Do-Check-Act” Deming cycle.

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