A Federation of Remote Laboratory OERs

Grid of VISIR systems through PILAR Project

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Abstract—Today's educational needs require tools with neither geographical nor temporal restrictions. These tools also have to help students to reach the knowledge and provide them with the skills that the labor market demands. To achieve this goal, the technical areas rely on the contribution that laboratory practices provide. However, traditional laboratory practices, carried out in person at the institution, are limited due to the requirements of both their exploitation and their provision. For this reason, educational institutions have opted for remote laboratories (RLs) as the educational tool to provide the benefits of experimentation in real environments, either as an accompaniment to face-to-face activities or as the only mean of experimentation in real environments. Although RLs provide exclusive benefits <<24/7 availability, integration of Information and Communication Technologies (ITCs), etc.>>, they also present limitations derived from the technology involved <<hardware and software>>; PILAR project << Platform Integration of Laboratories based on the Architecture of VISIR>> was conceived under this premise. PILAR proposes a federation of 5 Virtual Instrument Systems in Reality (VISIR) systems. VISIR is a RL for wiring and measuring electrical and electronics circuits in a simulated workbench. PILAR aims to create a grid of laboratories shared and accessed by all participants, expanding and empowering the existing systems to a new level of service and capacity.

Keywords—Federation, remote laboratory, RLMS, VISIR, PILAR

1 Introduction

Current educational strategies adopted by institutions are strongly based on the existing needs of their students and potential students. Regardless of whether it is <<face-to-face education, distance education or a blended combination of both>>; instruction, learning, and training processes are fostered by a high ductility, lack of restrictions, and self-managed processes [1]. As a result, educational trends are highly influenced by friendly-availability learning scenarios [2], [3] because, basically, educational consumers are looking for on-demand training, not only in content but also in how and when to access it.

The challenge for educational institutions is to provide access to enriched learning environments with a broad repository of educational tools and contents. These educational resources must, not only cover the key educational aspects but must also be compact, i.e. not involving an enormous amount of content that may overwhelm students [4]. ITCs help us to make available these learning environments.

Today's society presents an unprecedented number of educational challenges which are very fickle as time goes by; In other words, the training currently required by the labor market may vary in a very short period of time: workers with dynamic competencies and skills are required. Even students accustomed to use ICT tools face challenges when using them, and they also value the opportunity to learn new skills [5]. Therefore, educational institutions have to provide tools and contents which also must be sufficiently flexible for each student profile: allowing self-learning strategies, and adaptable to the particular background of each student and not the other way around. The goal is not only to suit the contents to the backgrounds of students, but also to generate the required capacities that make possible the apparition of metacognitive processes: learn to learn.

Some topics are more complex to be customized for this demanding learning society. This is the case of experimentation environments. Software-based solutions like simulators and/or virtual laboratories are a first approach to alleviate distance. However, in order to provide interaction with the real world, analyze physical limitations or which variables can be controlled and which measured; these computer-generated solutions are still a little bit far from providing a comprehensive scenario [6]. The benefits provided by experimentation are based on a scenario intended for discovering. Thus, the interaction with the real world should be an important component in any field which requires experimentation. Traditionally, hands-on labs have served these goals, providing the additional value that only experimentation within the real-world is able to. But, the involved adaptation for the ubiquitous and temporal needs requires a solution far from physical institutions. Nowadays, RLs <<Real laboratories accessible and controllable remotely [7]>> are, not only, the alternative to provide experimenting environments to students when hands-on labs are not an option to interact with the real world [8], [9], they also are used by institutions providing RLs blended with hands-on labs [6], [10].

As aforementioned, RLs provide several and unique educational advantages. However, there are also inherent limitations due to operation boundaries and the design of the laboratory. This article describes a unique solution, under the Erasmus+ PILAR project, to alleviate the limitations presented by the isolated operation of a VISIR system. The federation resulting from PILAR project counts with 5 VISIR systems from 5 Higher Education Institutions (HEI). The result of the federation not only increases the number of experiments but also improves them by making the possibilities more flexible.

2 PILAR project

PILAR Erasmus Plus project <<Platform Integration of Laboratories based on the Architecture of visiR; 2016-1-ES01-KA203-025327>> aims to interconnect VISIR nodes into a common platform in order to make use of the individual services provided by each node and create federated laboratory services only possible through the framework established within the federation.

PILAR contributes to open the classrooms to ICT technologies opening a new window to the interaction with real laboratories. PILAR also holds a connection with the 2013 action plan “Communication on Opening Up Education” [11], with the aim of providing a high-quality education by creating opportunities to innovate and fostering the digital skills that future jobs will demand.

2.1 VISIR RL

A RL is a real laboratory which is controlled and monitored remotely through the Internet. The promotion of online experimentation is strengthening due to social needs and students/user demands based on accessible educational resources without temporal or geographical restrictions through the Internet. This educational approach also promotes lifelong learning and may support any educational strategy.

VISIR is a RL intended for analog electronics [12]. It has been successfully integrated from secondary school courses [13] to advanced postgraduate courses [14], [15]. The key feature in VISIR lays in the practical experience powered by the simulated workbench and the trustworthy results obtained. VISIR stands out because of its concurrent access (up to 60 users), flexible circuit design, quick response and reliability of the results provided [16], [17].

2.2 PILAR alliance

PILAR project aims for the federation of five of the existing VISIR nodes, for sharing analog electronics experiments and empowering the capacity and the resources of each VISIR provider within the federation, as well as providing access to other educational institutions to a VISIR RL through the PILAR consortium.

The VISIR nodes at the PILAR consortium are from Blekinge Tekniska Högskola (BTH) from Sweden, Universidad Nacional de Educación a Distancia (UNED) and Universidad Católica de Deusto (UDeusto) from Spain, Instituto Politécnico do Porto (IPP) from Portugal and Fachhochschule Kärnten (CUAS) from Austria. All of them have vast experience in designing experiments in the VISIR platform and integrating practical contents.

The alliance of these VISIR systems not only provides direct benefits to each node of the federation (i.e. size of the repository of experiments or system availability), but it also provides transversal benefits: i.e. the immediate use and evaluation for any institution within the federation of the latest hardware developments of the VISIR system, the access and exploitation to learning analytics tools [18], self-assessment tools [19] or the integration of a booking system [20].

2.3 Federation of RLs

The federation is a feature that Remote Laboratory Management System (RLMS) weblabdeusto supports. RLMSs provide APIs, management tools <<manage users, permissions, user tracking, scheduling, etc.>>, federation protocols, and manage common services for RLs [21], [22]. RLMSs also provide the required mechanisms to establish a service level agreement for consumer institutions: An institution <<provider institution>> may provide credentials to the users from another institution <<called consumer institution>> so the users from the consumer institution, once authenticated in platform, will have access to the RLs resources from the provider institution thanks to the federation protocols, and at the levels agreed with the provider institution. Each consumer institution might have different permissions/agreements for each laboratory resource [21].

2.4 Architecture

Typically, RLs have been developed in order to cover some particular needs and, therefore, designed focusing on these needs defined by the teaching staff [21]. Depending on the architecture, these laboratories may provide from recipe experiments to open experimental environments. Thus, similar RLs have been developed but designed with different technologies and provided with different interfaces. In the area of electronics, the aforementioned influence can be trusted through developed RLs such as NetLab [23], MOSTALAB [24], eLab3D [25], the BJT Amplifier lab described in [26], the matrix-based solution reported in [27], or VISIR [12].

This pool of specific purpose RLs does not allow to develop shareable resources. Furthermore, any desired improvement facing a constraint usually requires the redesign of the RL. However, due to the number of existing systems, the VISIR RL represents an exception that allows a different approach: A federation of RLs based on a common architecture.

To refer to PILAR federation as the federation of VISIR replicas is not completely correct since each entity may have, and actually has, different components installed and, therefore, different experiments available. Therefore, the basis of the federation is the common architecture among all VISIR providers. So, we can speak of a federation of experiments, which allows two ways of federating practice-based resources through VISIR architecture:

- **Transitive federation → transitive experiments:** Sharing experiments, as if they were different laboratories but using the same architecture and provided by the same interface.
- **Redundant federation → Distributed load balance experiments:** Balancing the load of users among the different replicated instances of experiments in an automatic way.

In figure 1 the architecture of the federation is represented: Red arrows represent how teachers can interact and exploit OERs within PILAR; Light-blue arrows represent the communications between entities: communications between weblabdeusto entities (transitive federation in order to balance load of users) are not represented; Broad yellow arrows represent student ways of interaction with PILAR. The OERs, represented in figure 1, are not only composed of laboratory services (accesses to VISIR-based experiments), but practice scripts, videos, additional documents (datasheets, complementary docs, etc.). OERs also contain the required information to validate the inter-communication protocol for the "symbiotic" integration of the platforms. This protocol is based on the IMS Learning Tool Interoperability standard (LTI), used for supporting single-sign-on and preserving the learning context and user roles. We can distinguish 3 types of teachers:

- **Consumer teacher:** This profile is intended for teachers who do not belong to a VISIR-provider institution and who do not have the technical knowledge of the internal functioning of VISIR.
- **Developer teacher:** This profile is intended for teachers who, belonging or not to a VISIR-provider institution, have the technical knowledge of the internal functioning of VISIR.
- **Management teacher:** This profile is intended for teachers from VISIR-provider institutions who are in charge of the VISIR-system.

Institutions and, by extension, teachers who are part of the federation can make use of the VISIR-based OERs, provided through PILAR LTI credentials (key and secret), regardless of their profile. The way OERs are provided to end-users (students) varies depending on the existence of an educational platform, i.e. LMS or CMS, outside the PILAR architecture:

- **Teachers managing an external platform:**
  - Figure 1, red arrows A-A1: teachers may create their own VISIR-based courses by picking up the desired OERs provided in the repository.
  - Figure 1, red arrow B: teachers may create a link to the PILAR open course; or, existing a previous agreement with the owner, to any course hosted in PILAR-moodle.
- **Teachers not controlling an external platform, figure 1, red arrows A-A2:** Teachers may request a space (course) in the PILAR-moodle. In it, teachers may create their own VISIR-based course by picking up the desired OERs provided in the repository.

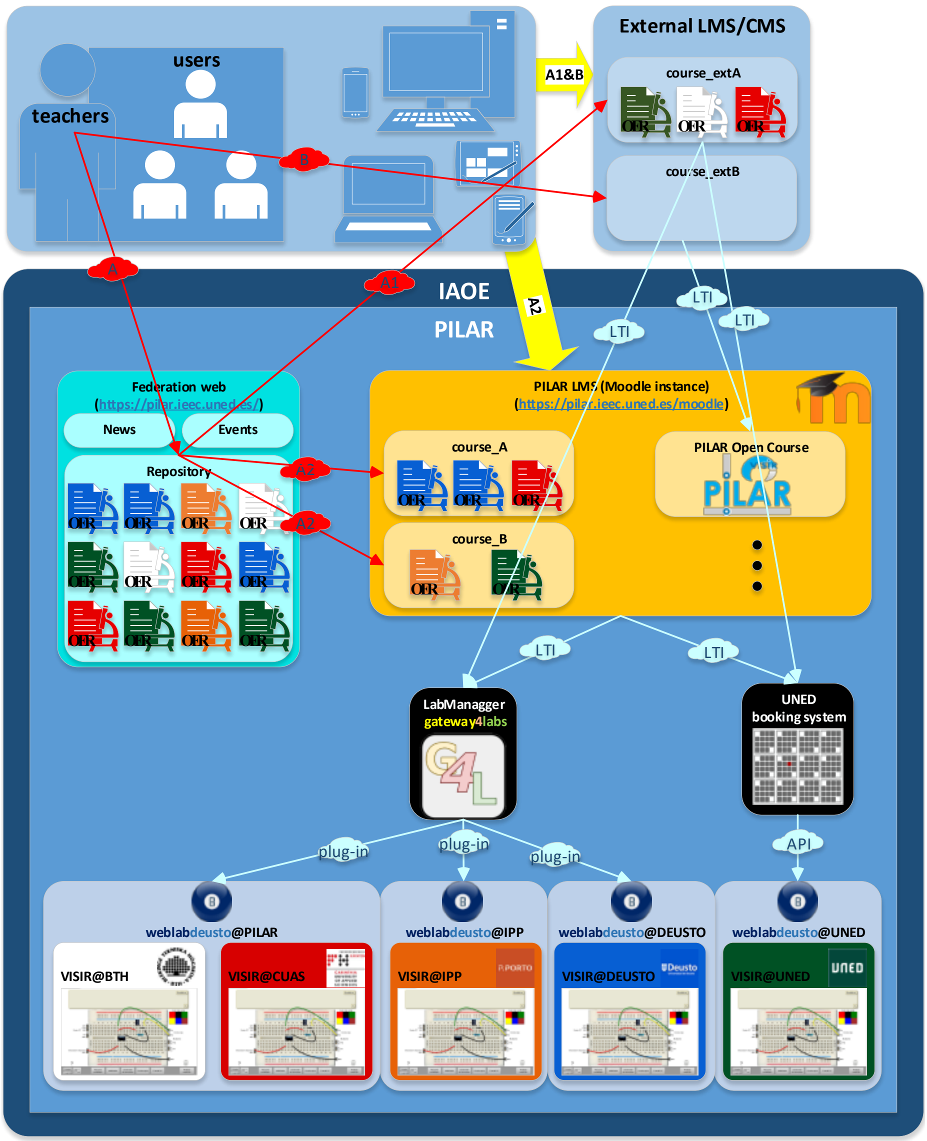

Fig. 1. Architecture for the federation.

3 Results and Future of the Federation

The benefits of the resulting federation from the PILAR project are evident for consumer institutions. By joining the federation, these institutions take advantage of the exploitation of the OERs provided by all the nodes integrated into the federation. However, the benefits for VISIR providers are also relevant: the established architecture fosters the relationship and communication between providers institutions (institutions with a VISIR system). Once the federation was formally established <SLA, platform, communication protocols, federation protocols, policies, etc.>>, the different nodes have reported different benefits of the exploitation of the federation:

- **UNED system**: Due to the particular needs of some experiments which require the private use of the laboratory <<this is the reason for the existence of the reservation system [28] >>, frequently has disabled concurrent access. Therefore, the ability to balance students between the rest of nodes is essential to provide a better service.
- **Before the federation:** Those HEIs with few component boards had to redesign the matrix each semester in order to cover the demanded/required experiments. The federation has allowed these HEIs to focus their resources on particular topics and make use of the federation shareability.
- **UDeusto system**: Is designed aiming to provide a wide flexibility of interconnection among the installed components. This strategy, although indicated to provide a sandbox laboratory, requires a high number of slots of the component cards, thus limiting the number of components available.

The resulting federation provides a technology-enhanced educational tool to serve a large student population that could not be covered by the 5 systems working in a standalone scheme. Besides, the available repository of experiments covers a broad spectrum of topics, accessible for all partners through the stipulated protocols. The fact that there are 20 VISIR RLs installed in 17 HEIs from 12 different countries (Argentina, Austria, Brazil, Costa Rica, Georgia, Germany, India, Morocco, Portugal, Spain, Sweden, and the USA) gives an idea of the and relevance of the VISIR RL and the potential of the federation. Several of these HEIs VISIR providers have declared their interest to join the federation as VISIR providers in the near future.

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