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VISIR State of the Art Report v2

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Platform Integration of Laboratories based on the Architecture of visiR – PILAR

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1.1. Overview

VISIR is an open remote laboratory dedicated to experiments with electrical and electronic circuits. It allows teachers and students to practice real-world experiments, remotely and in real-time mode, with test and measurement equipment relying on a user interface that replicates hands-on equipment and components.

The remote laboratory VISIR emerged from a feasibility study started in 1999, at the Blekinge Institute of Technology (BTH) in Sweden although it was launched just on 10 March 2004. VISIR is a combination of open source software packages and commercial equipment from National Instruments (NI), released under a GNU General Public License (GPL), for creating, wiring and measuring electronics circuits on a breadboard remotely, supporting a wide range of electronic circuit components [Claesson12]. Nonetheless the platform is not limited to electrical experiments - VISIR laboratories for acoustics and mechanical vibration experiments are on line in BTH [Gustavson14), [Tawfik13].

BTH, together with NI in the USA and Axiom EduTECH in Sweden launched the VISIR Project at the end of 2006, the project being financially supported by BTH and the Swedish Governmental Agency for Innovation Systems (VINNOVA) [Tawfik13].

In the VISIR lab, users can wire the desired circuit with the available components and use several instruments to analyze its behavior. **Figure 1** represents a VISIR system installed in ISEP/IPP, Porto and Figures 2 and 3 represent two parts of the VISIR interface, namely the virtual breadboard used for the experiment design and the interface panel of an instrument.

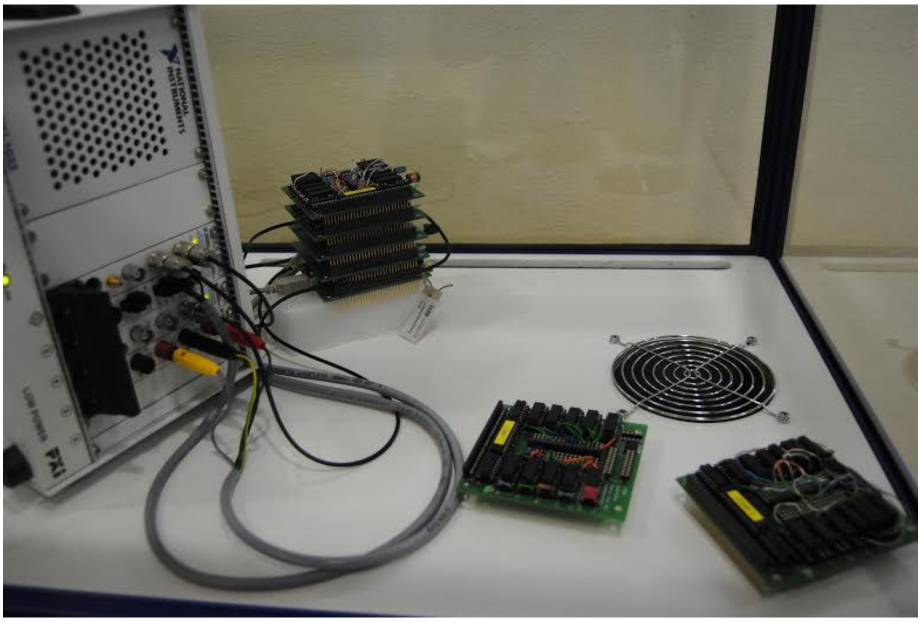

Figure 1 - VISIR at ISEP.

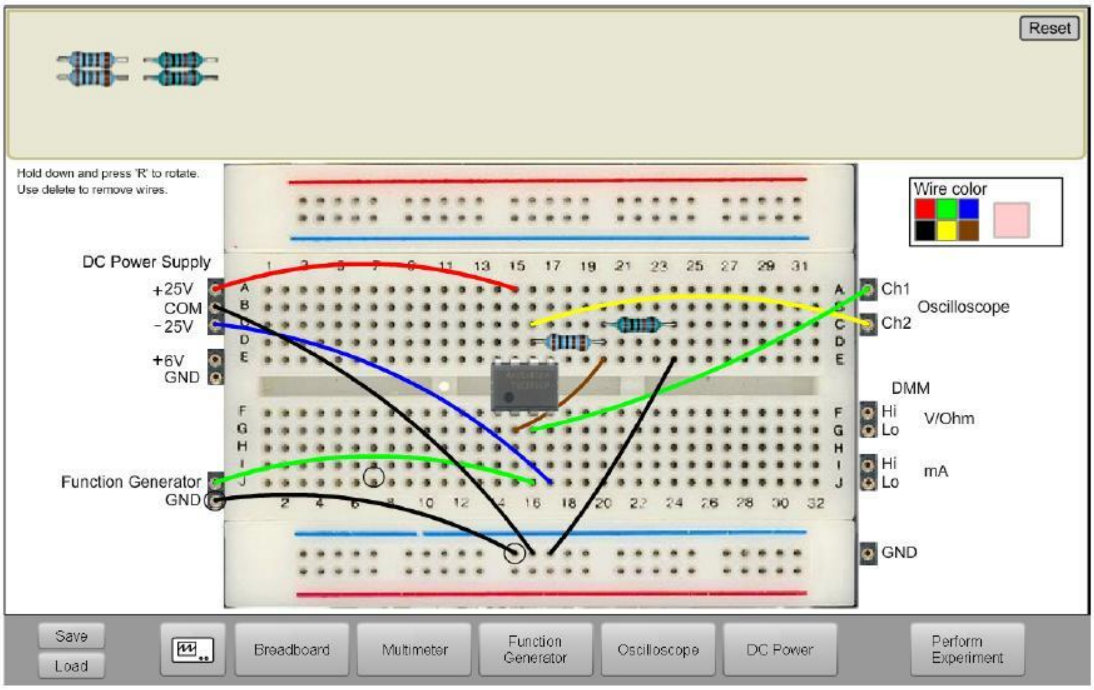

Figure 2 - VISIR Interface – Breadboard

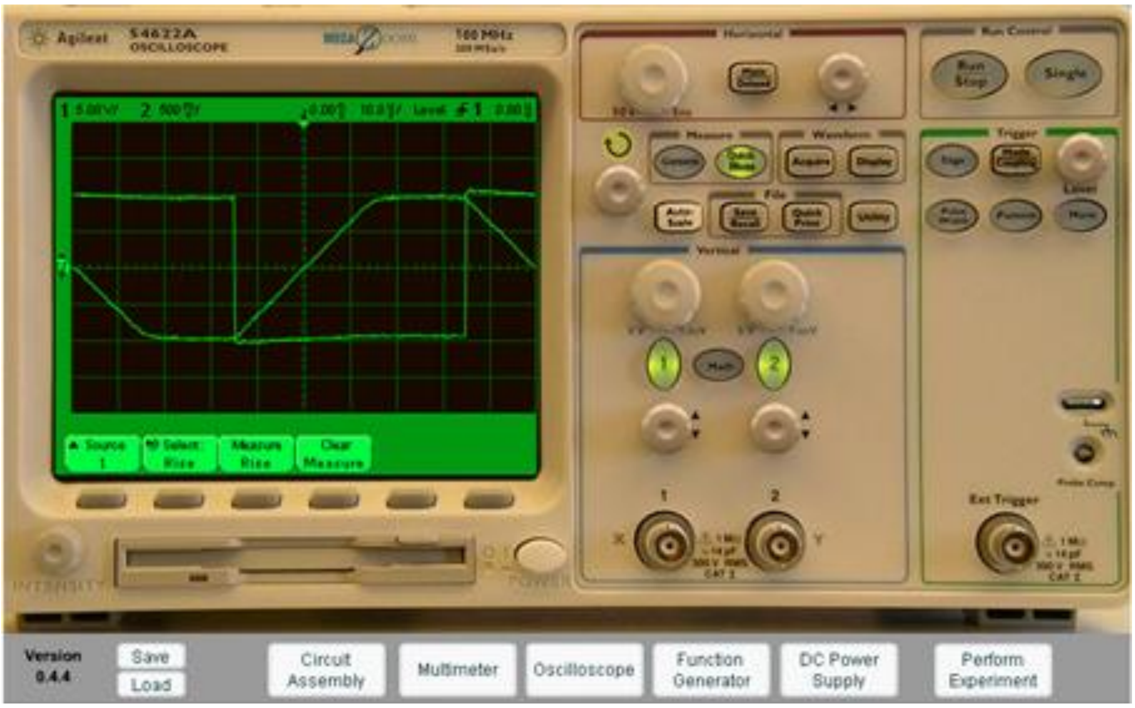

Figure 3 - VISIR Interface – Oscilloscope

I this case we have an example of an experience that uses an integrated circuit (741 OpAmp), a couple resistors a DC power supply while using an Oscilloscope for signal measurement. The interface was designed in order to replicate a real world breadboard, common digital and analogue components and connectors, allowing the use of different wire colors and customization of components graphics.

Figure 2 displays an Oscilloscope interface, replicating an Agilent 54622A device. Although the real oscilloscope used on the remote lab is probably different, as any remote accessible instrument can be installed (most VISIR based labs use PXI instruments), it is possible to use any front panel. The idea is for each institution to use as front panel the equipment used on its real laboratories and a considerable percentage of the device dials should be controllable by the user (the user can use the mouse cursor to operate buttons or rotate dials, for instance). On normal teaching environments, where the instruments are not pushed to their limits, the overall feel and results should replicate those obtained using the real lab equipment. In some cases, students are even encouraged to use the manuals from the emulated instrument.

Presently the interface provides five different components, namely:

The virtual breadboard, with connectors for DC power, function generator, digital multimeter and oscilloscope.

- A function generator, with HP33120A front panel
- An oscilloscope, with a Agilent 54622A front panel
- A digital multimeter, with a Fluke 23 front panel
- A triple output power supply, with a E3631A front panel

The real instruments used on the remote lab consists of plug-in PXI boards installed on a National Instruments PXI chassis. The basis of the experimental apparatus is the switching matrix, presented on Figure 4.

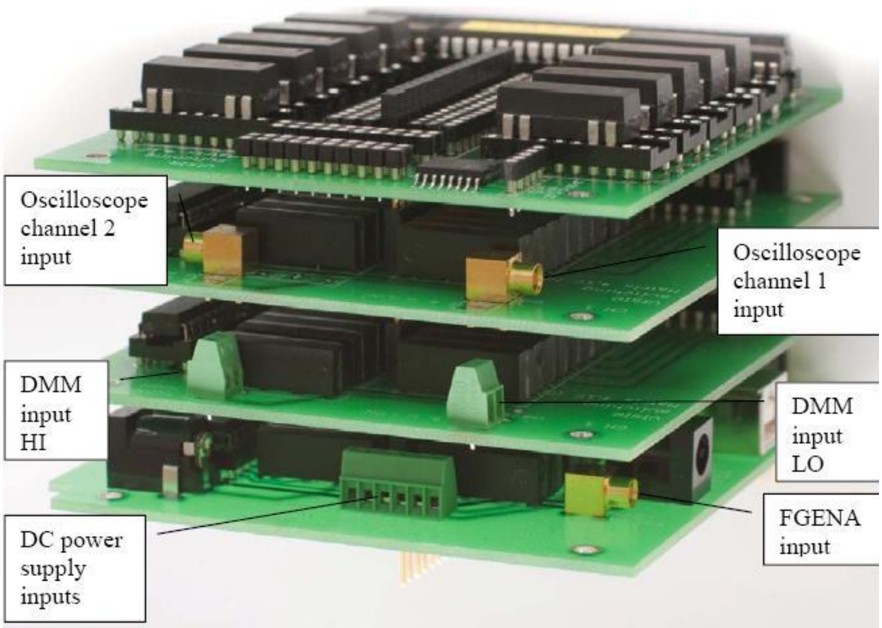

Figure 4 - Switching Matrix

The matrix displayed is the basic version, as it is possible to add boards and components. The circuit components are placed on the top boards, either on the boards themselves or mounted externally (but linked to the boards). The bottom three boards are used to connect the instruments and I/O signals, with a board used for the oscilloscope, another for the digital multimeter and the bottom one being used for the function generator and DC power. The matrix doesn't house any instruments, only the connections to external devices, but the component board (or boards) can house a reasonable number of components. **Figure 5** presents a simple navigation structure of VISIR interface software, divided in three levels.

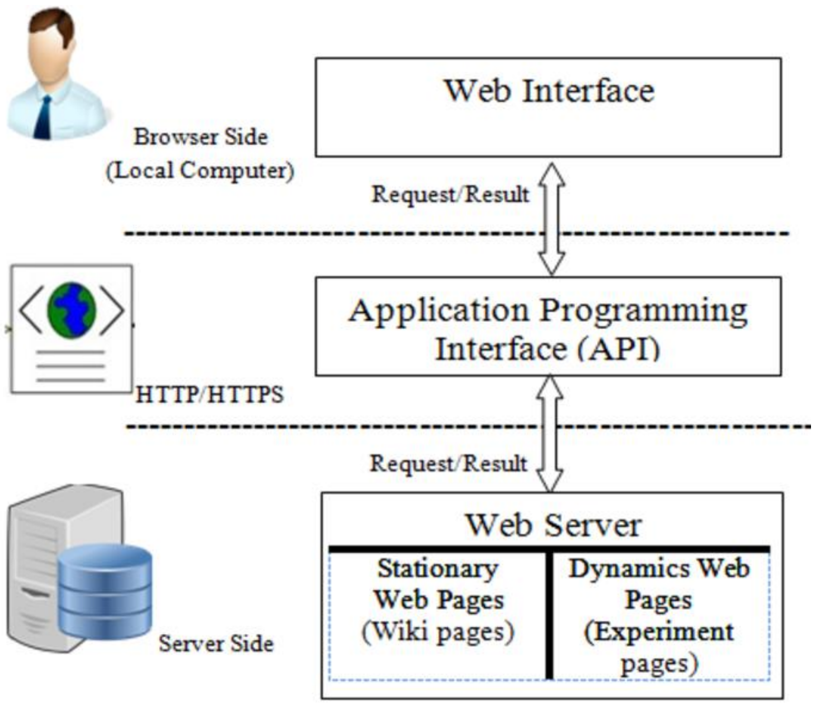

Figure 5 - VISIR Interface

The top level corresponds to the web interface, which allows users to interact with the software running on the web server. Between the web interface and the web server where is an application programming interface (API), which provide a set of routines, protocols and tools that are used for building the VISIR software application. This API specifies how software components should interact and be used for programming the Graphical User Interface (GUI) components. Through this API, the web site manager can easily access the VISIR system and change parameters or its functionality.

The complete VISIR platform consists of four main parts as presented in **Figure 6**, namely:

- **Equipment Server:** It comprises all the lab equipment including the PXI platform connected to the relay switching matrix. It receives the commands from the measurement server over TCP/IP to be executed on the real instruments. The commands are sent in form of XML-based protocol (experiment protocol) on HTTP. A "component list" file is inserted to the equipment server to define the components installed on the matrix.
- **Measurement Server:** It is a server written in Visual C++ for Microsoft. It acts as a virtual instructor that controls the commands passing from the web interface (and received over TCP/IP) to the equipment server.

- **Web Server:** It hosts the VISIR website and was designed for an Apache server and MySQL database.
- **Web Interface:** The actual VISIR website (written in PHP), with the experiment interface client (written in Flash) integrated inside. Access should be performed using the https secure protocol, after authentication.

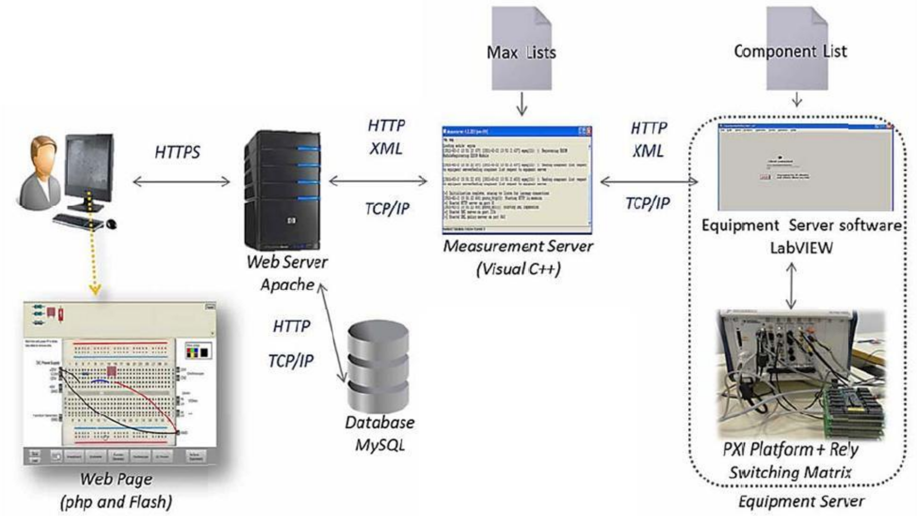

Figure 6 - VISIR Platform

VISIR includes also a Learning Management System (LMS) designed to control access to the remote laboratory resources, although several universities opted to integrate it into their own LMS systems.

VISIR may be considered as a remote workbench, equipped with the same instruments that exist in a hands-on laboratory for conducting experiments with electric and electronic circuits; these workbenches are similar to each other, every place in the world: usually in each, there is a breadboard and components, provided by the instructor, and the student uses them to mount the circuits and to connect the test probes, as determined in the lab instruction procedure. Using VISIR, an identical simulation of the real equipment and instruments appears (a virtual breadboard and photographs of the components) on the student PC screen. Students use the mouse, instead of their fingers, to adjust the instruments, to position components on the breadboard and to do the wiring to assemble the circuits. The corresponding real components are mounted in sockets in a switching matrix and the measurement results, through the instruments virtual front panels, are displayed in students´ PC screen. So, as long as the student as a PC or more recently a handheld device, such as a smartphone or tablet, he has the ability to access to this real electronic lab (which mimics a traditional workbench), at any location, by using the internet and a web-based user-interface using any web browser.

1.2. State of the Art Questionnaire

The work described on this document was prepared from two type of sources. Documentation produced by VISIR users since its initial deployment, with emphasis on partner publications, and an online questionnaire sent to each PILAR institution with VISIR installed. The documentation is referenced in the text and the published materials are listed in the references section. Authors were contacted for clarification when necessary. The questionnaire was sent to the person in charge of VISIR on each PILAR institution. After all information was compiled, there were an additional number of virtual and one final meeting to finish and validate the initial draft of document. The document will be updated regularly during the project execution, whenever necessary.

The questionnaire was designed to be:

- Comprehensive – in order to address all relevant VISIR features and usage information
- Direct – designed to allow straightforward answers (when possible) to avoid dispersion of information and allow a clear understanding of each institution specific issues and characteristics
- Expansible – the questionnaire questions were discussed ahead of its completion with the result that some points were added or edited after consultation with partners
- Online – Questionnaire performed online using Google Forms due to the known and documented ease of use, online access capabilities and data storage.
- Singular - One per institution in order to concentrate and simplify all communications and keep information clear and easy to standardize
- Clear - Subsequent request to partners were necessary as some points required clarification, being apparent that each partner interpreted some questions differently.

2. VISIR Institutions

Up to 2017 VISIR was installed in twelve different Higher Education Institutions (HEI), in seven different countries: Austria (Carinthia University of Applied Sciences and FH Campus Wien for Applied Sciences), Portugal (School of Engineering of Polytechnic of Porto (ISEP)), Spain (University of Deusto and the Spanish University for Distance Education), Georgia (Shota Rustaveli State University), India (Madras Institute of Technology), Brazil (PUC Rio, Universidade Federal de Santa Catarina, Instituto Federal de Santa Catarina) and Argentina (UNR e UNSE) and it has served well several thousands of students (Alves, et al., 2011), (Tawfik M. , et al., 2013), (Tawfik M. , et al., 2011), (Salah, Alves, Abdulazeez, Guerreiro, & Gustavsson, 2015).

Figure 7 – VISIR Institutions Map

BTH research group is still responsible for maintaining and updating the VISIR distribution that is available as open source. The International Association of Online Engineering (IAOE) created a Special Interest Group of VISIR (SIG VISIR) to foster the collaboration within the community and to foment the project dissemination. The existence of this community, which is quite wide and active is a major advantage: VISIR users, both teachers and students, frequently come up with different requirements and/or identify constraints and problems that were not predicted by VISIR developers. This feedback is often used to add new features and introduce improvements to the system interface and operation, promoting VISIR's evolution and improvement. In fact, in 2015, VISIR was recognized as the best remote controlled laboratory by the Executive Committee of Global Online Laboratory Consortium. VISIR is also the first remote lab in the world serving a Massive Open Online Course (MOOC) on industrial electronics.

Table 1 and

Table 2 present an overview of the VISIR System installations on the partner institutions. In **Table 1** we have the number of systems per partner, the software Releases being used both on the Measurement and Equipment Servers (updated in June 2017) and the Interface type being used.

Table 1 - VISIR Systems Configurations by Institution

Partner	# Sytems	Types	Release Measurement	Release Equipment	Interface
BTH	2	PXI	MS625	ES71	HTML5
UNED	1	PXI	MS625	ES71	HTML5
CUAS	1	PXI	MS625	ES71	HTML5
UDeusto	2	PXI LXI	MS625	ES68	HTML5
ISEP/IPP	2	PXI	MS407/625	ES71	HTML5 Flash

In

Table **2** we have the number of Boards operational on each partner. When two numbers are present, they are related to each individual VISIR system for partners with two separate systems.

Localization defines the languages used for the interface. For each installed system it is possible to replicate the interface webpages in different languages, while maintaining the graphical components, as these represent real equipment front panels.

Table 2 – VISIR System Boards by Institution

Partner	Instrument Boards	Component Boards	New 2C Boards
BTH	4/4	6	2/2
UNED	3	10	0
CUAS	3	6	0
UDeusto	3/3	8+6	0
ISEP/IPP	3/3	4	3

Table 3 – VISIR System Localization

Partner	EN	SV	ES	PT	DE	PL	NL	AR	Other
BTH	x	x					x		?
UNED	x		x	x	x	x	x	X	RO, SL, CZ, RU
CUAS	x				x				
UDeusto	x		x	x	x	x	x	x	RO, SL, CZ, RU
ISEP/IPP	x	x	x	x		x	x	x	EL, KU

Languages List:

EN – English; SV – Swedish; ES – Spanish; PT – Portuguese; DE – German; PL – Polish; NL – Dutch; AR – Arabic; RO – Romanian; SL – Slovakian; CZ – Czcech; RU – Russian; EL – Greek; KU - Kurdish

In terms of physical location of the hardware system, there are two different approaches. The two fundamental solutions would be a dedicated space on a research lab or in the institutional servers' room.

The research lab solution usually resorts to a room used by the research group responsible for VISIR contents and configuration. This solution allows easier access by the research team and a direct visualization of ongoing experiments when required, with expert support nearby.

The institutional servers room allows the VISIR system to be installed and maintained close to the remaining web and database servers, which should provide better and more timely support even if non-specialized.

In the PILAR consortium, three VISIR Systems are installed inside Research Lab while two Systems are on Institutional Servers Room. The end solution is more dependent on internal institutional policies than objective requirements, and both work adequately. Features that are much more relevant are the Network Access, the existence of a Mandatory External IP and adequate bandwidth that is desired within 100Mb to 1Gb.

3. VISIR Usage

3.1. Availability Metrics

Availability Metrics were designed in order to evaluate the VISIR systems availability over time. They are divided in two main categories, namely Operational Availability and System Availability, in order to better quantify and discriminate results.

Operational availability is used to measure the percentage of days the VISIR system was available to students, since installation on each institution.

This metric quantifies the actual number of days VISIR system was made available for usage on experiments as part of a planned course curricula.

System Availability is used to measure the ratio of time the system was up when it should be available and it quantifies the shortages due to technical or logistical issues.

These metrics were evaluated on all partners and both were rated as very high. Results are not based on factual metrics, as these are not recorded in the present system in none of the institutions. Available metrics are based on estimates by technical and management personnel.

The Operational Availability average was over 95%, with only UNED stating that some period there was a 50% availability due to courses being down for System reconfiguration, when it was not being used. In general, system was available when required on all institutions with no cases of unwanted unavailability.

As to System Availability, the average is over 90%, slightly lower as some issues did occur that required action. Usual issues were network constraints or electrical power outages, usually external to VISIR system. The problems were normally solved quickly, the reason for the lower estimate and consequent delays being the sometimes long time required for staff to be made aware of the problem.

3.2. User Authentication

User Authentication is different on all partner institutions. VISIR system has a built-in User Authentication system that can connect with external LMS systems.

The VISIR LMS provides a three level user access differentiating administrators, teachers and students accounts, and providing the following capabilities for each user type:

Administrators: They can add static web pages using the WIKI markup syntax, and also upload files including videos, archives and documents. They are also responsible for courses and user accounts creation and management.

Teachers: Their main task is designing and maintaining the experiments and also creating and managing student accounts. They can also administer the reservation system.

Student (or Instructor): Can only access and use experiments already designed and within their courses. They can schedule reservations and use the remote laboratory as needed.

In the VISIR user institutions, no two authentication systems are alike. In **Figure 8** we can see the standard login used on stand-alone VISIR installations, in this case the login at BTH Openlabs Electronics Laboratory in Sweden.

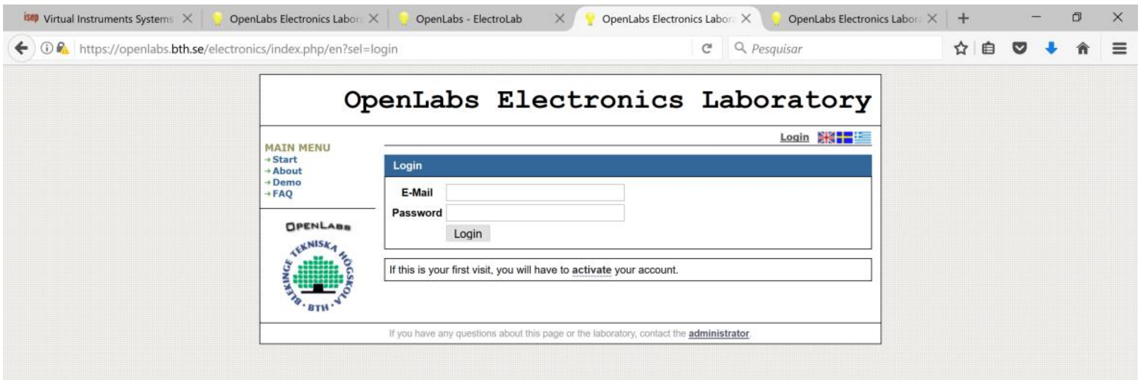

Figure 8 – VISIR Standard Login

Figure 9 and Figure 10 present the login and experiment selection sequence in UNED and Deusto. Those figures show the UNED LMS link to VISIR and the subsequent screen where the user can select the specific experiment he is interested in. In this case login into the VISIR is automated, assuming user was identified and authenticated when accessing the UNED LMS system. This procedure is transparent to the user.

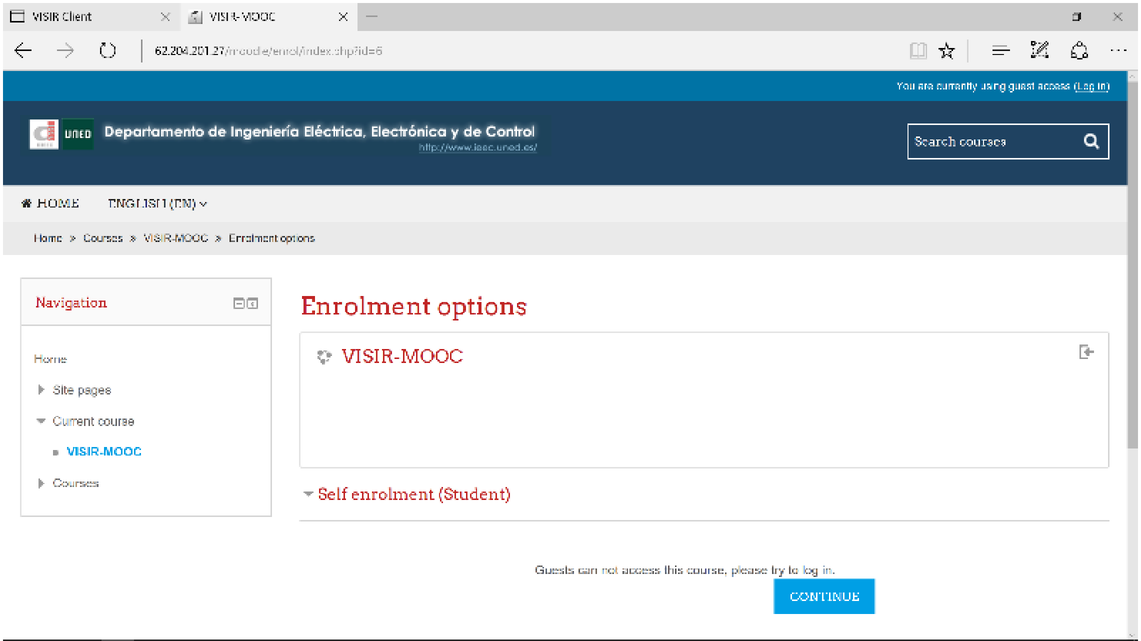

Figure 9 – VISIR Login at UNED

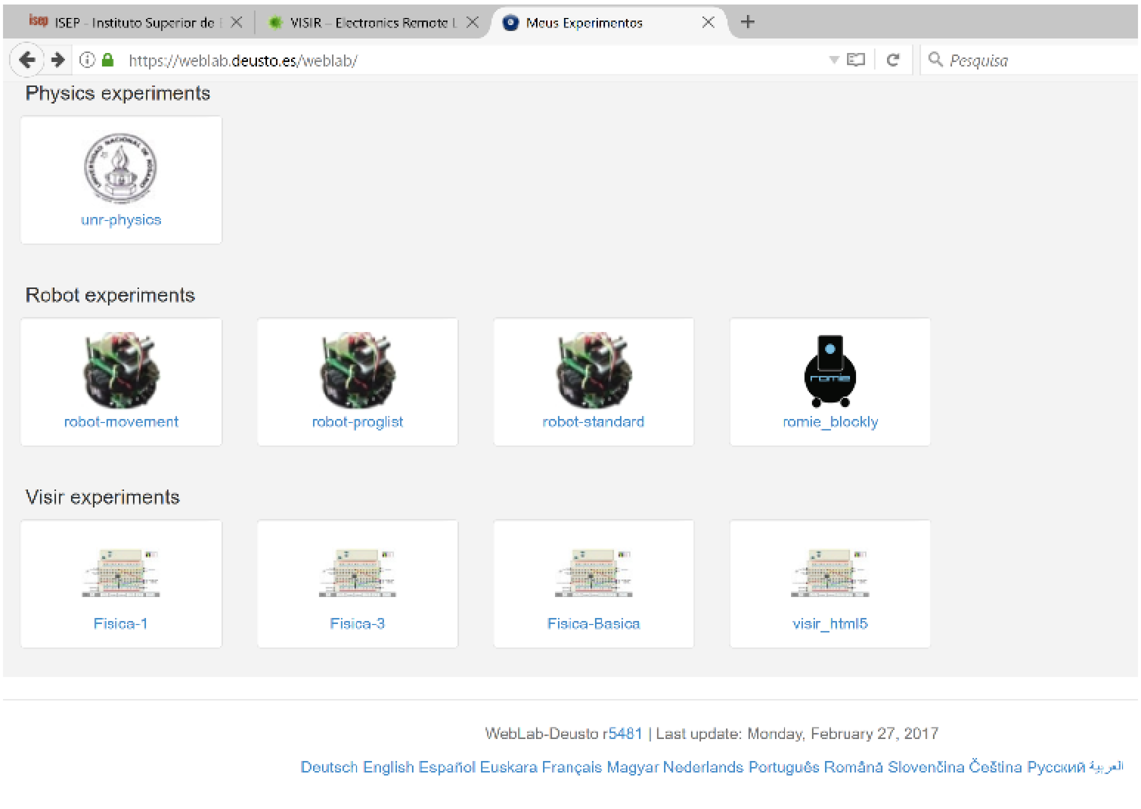

Figure 10 – Experiment Selection at VISIR UDeusto

Table 4 displays the user authentication alternatives used on each partner institutions. A survey of the login procedure allows to conclude that no two systems are alike. UNED, CUAS and UDeusto systems require the user to be enrolled in the LMS system for access to the VISIR experiments, although all but UNED will allow some type of limited experimental access to Guest users. Guest users are those that can use the system without ant enrolling being necessary and with immediate access. In some case an email address is required, but not verified, being used for statistical analysis purposes. In the performed survey it was also noted that available documentation on the login procedures and authentication is scarce in open access sites.

Table 4 – VISIR System User Authentication

Partner	Original	LDAP	Other	Guest Login
BTH	1	1	No	Yes
UNED	0	0	JSON	No
CUAS	0	0	GOLAB	Yes
UDeusto	0	2	No	Yes
ISEP/IPP	2	1	No	Yes

BTH and ISEP/IPP use the original interface, although there is some integration with existent LMS systems as it is possible to import user access information into the VISIR system. This is usually done by the technical staff at the teacher request, whenever a new course adds VISIR to its curricula. The remaining institutions integrated the VISIR experiments into their institutional LMS systems and/or remote laboratories systems.

3.3. System Data

To use VISIR system on any course it is usually necessary to provide the instruction manuals of all the experiment sessions of the course. Normal usage in VISIR includes at least the schematics of all the experiment circuits of the session and a list of the components of the set of components to be used. The VISIR online laboratory for electrical experiments is intended to be a replica of hands-on laboratories, however it is necessary to create a set of rules that will define what can and cannot be done with each experiment, which are designed as Virtual Instructor in the VISIR manuals.

The laboratory staff and the teachers create the rules of the Virtual Instructor together. These rules are associated with the available online components, which comprises at least the components of all the component sets of the experiment sessions of the courses that will be introduced in the course.

The purpose of the Virtual Instructor rules is preventing hazardous circuits from being activated. The rules are a number of net lists so called Max Lists describing all safe circuits. Circuits described by subsets of a Max List are also safe. It is only possible to activate circuits that are safe according to a Max List installed in the laboratory. Of course, the Max Lists must only contain components that are present in the online component store i.e. are installed in the switching matrix. The Max Lists may not list all safe circuit possible to create using the components of the store. Especially if the number of components is great, it is not likely that all circuits possible to create can be found in the Max Lists. The laboratory staff and the teachers create new Max Lists when needed.

The VISIR state of the art questionnaire requested samples of the available Maxlists, and those were subsequently analysed. Most were sent by email, as only the VISIR installation at ISEP/IPP provides a direct and updated access to the system Maxlists. All maxlists share a common structure as defined in the VISIR software manual, but several differences are visible in comments and component designations. The level of restrictions and variability allowed on the experiments is also flexible, depending on institution and experiment objectives. There is no identifiable common guideline, other than the VISIR implementation rules themselves.

From the analysis, it can be concluded that access to detailed information on the specific circuit implementations is necessary for experiment designers and teachers that wish to use them. This information can be shared through either maxlists or detailed documentation, probably a combination of both in order to allow maximum flexibility and details.

4. Users and Experiments

All institutions have a comprehensive log of VISIR systems usage. However, the extensive amount of available data and somewhat incomplete analysis tools do not allow for a very accurate quantification of overall system usage. **Table 5** and **Table 6** represent the questionnaire responses to present and past number of users. These were divided into users (mainly students), teachers using VISIR and Institutions officially using the system from a partner institution.

Table 5 – Present Number of Users

Partner	Users	Teachers	Institutions
BTH	less than 100	less than 10	less than 5
UNED	100 - 499	less than 10	less than 5
CUAS	less than 100	less than 10	less than 5
UDeusto	1000 or more	less than 10	20 or more
ISEP/IPP	100 - 499	10 - 49	5 to 9

Table 6 – Past Number of Users

Partner	Users	Teachers	Institutions
BTH	less than 100	less than 10	less than 5
UNED	1000 or more	less than 10	less than 5
CUAS	less than 100	less than 10	less than 5
UDeusto	1000 or more	less than 10	20 or more
ISEP/IPP	1000 or more	10 - 49	5 to 9

From the tables above, it can be verified that the number of users varies between partner institutions, but with all presenting a considerable number of evolved teachers and active users.

Table **7** and Table 8 present the specific experiments that are presently available (Active), or were available in the past (Past). Active experiments are those presently available for teachers to use, not necessarily experiments on use on active courses.

Table 7 – Electrical Experiments

Partner	Active Filters	Passive FIlters	Ohm and KCL (DC)	Ohm and KCL (AC)
BTH	Active	Active	Active	Active
UNED	Active	Active	Active	Active
CUAS	Past	Never	Active	Past
UDeusto	Never	Active	Active	Active
ISEP/IPP	Past	Active	Active	Past

Table 8 – Electronic Experiments

Partner	Diodes	Transistors	Ampops	Logic
BTH	Active	Active	Active	Past
UNED	Active	Active	Active	Active
CUAS	Active	Past	Past	Past
UDeusto	Active	Active	Active	Never
ISEP/IPP	Active	Active	Active	Never

Other experiments not included in the survey are Thevenin Equivalent circuits (as a “Black Box” component), RL time constant determination, Zener diodes, RCL circuits, DC-DC converters, Temperature Dependency and Power Dissipation Analysis.

5. Conclusions

This document is a brief overview of VISIR systems implementation as seen by the responsible persons on the institutions that use them. Its main purpose is to establish a base point for the development of a VISIR Federation.

It was possible to establish that implementation, documentation and policies are considerably variant between institutions. Several issues must be analysed in further detail, namely the Cross User Policies, System Data Sharing, Experiment Listing and Experiment Documentation. From this analysis, it will be possible to elaborate a better definition of a VISIR Federation Policies on Availability and the VISIR Federation Technical Specifications.

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