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Integration of an LMS, an IR and a Remote Lab

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Abstract. For over two decades an IR – Institutional Repository (at the time referred to as Digital Library) and an LMS – Learning Management System have been developed and integrated under the Maxwell System at Pontifícia Universidade Católica of Rio de Janeiro (PUC-Rio). It supports traditional face-to-face courses and offers distance and blended learning options. It is also a publishing platform. This model has proved very practical for many reasons mentioned in this work. To enhance the options for traditional, blended and distance learning, a Remote Lab was added to the Maxwell System. Adding a Remote Lab is an enhancement to the learning environment since it is a “real” equipment and not only a software for numerical computation.This work addresses this new integration and how it benefits from the original infrastructure of an IR and an LMS implemented as a single platform.

Keywords: Remote Labs; Learning Management Systems; Institutional Repositories; Digital Learning Resource; Learning Technologies.

1 Introduction

ICT – Information and Communication Technology has provided a large number and a wide variety of tools to support teaching and learning. Engineering Education has benefitted from these tools. Many software products have allowed students to simulate and/or solve problems. The same products help students get ready to go to the “real” lab by simulating experiments in advance. Videos, interactive courseware, animations, texts, etc also support learning and are the contents that help blended learning (b-learning) and distance learning (e-learning) to be accomplished.

Engineering Education requires experimentation. In Electrical Engineering, there are lab classes for Electric Circuits, Analog Electronics, Digital Electronics, Control Systems, Eletromechanical Energy Conversion, etc. They offer experiments with “real” equipment and components, and prepare future engineers to deal with “real” physical / technical problems. Remote Labs are a fairly new resource that is meant to be added to the options to be used in Engineering Education. Remote Labs are “real” labs that can remotely be used through computer networks, including the Internet. They can be used in addition to traditional labs to provide one more step of preparation before the traditional lab classes.

The use of ICT tools requires the management of multiple resources and different platforms. This is of paramount importance for the students and instructors to easily use them and commute among them in a seamless way. This integration – platforms, resources and users – is a task for the technical staff. The technical staff must work very closely with the users in order to provide solutions that suit their needs. This work addresses such an integration. It presents the results of integrating a Remote Lab to a systems that is at the same time an Institutional Repository and a Learning Management System.

Section 2 introduces some technical definitions. The context at the university is addressed in section 3 that is very important due to its long experience in using ICT for both digital resources management and as a learning support. Section 4 explains the integration of the Remote Lab to the local platform. The use of the Remote Lab is presented in section 5 and final remarks are in section 6.

2 Some Definitions

The title of this article contains two acronyms and an expression that must be defined so that their uses are made clear.

- LMS – Learning Management System

Wright et al. [1] defined a Learning Management System as **"An LMS is comprehensive, integrated software that supports the development, delivery, assessment, and administration of courses in traditional face-to-face, blended, or online learning environments."**

An LMS is a software environment to support different types of learning processes. There are many products available. Some are commercial solutions and others are free and open source products. There are also many "home grown" LMSs.

- IR – Institutional Repository

Lynch [2] created the expression Institutional Repository as **"A university-based institutional repository is a set of services that a university offers to the members of its community for the management and dissemination of digital materials created by the institution and its community members. It is most essentially an organizational commitment to the stewardship of these digital materials, including long-term preservation where appropriate, as well as organization and access or distribution."**

Currently it is used worldwide and has taken the place of the expression digital library that was very popular in the 1990s. It is very broad since it aims at digital materials created by the institution – this means that articles, ETDs (Electronic Theses and Dissertations), senior projects, monographs, etc can be included. But not only these – digital learning materials can be on the IR too.

An interesting aspect of this definition is that it addresses digital materials; this means that an IR is not a catalog of non-digital items. It hosts both the descriptions and the digital files of the documents that belong to the collection. Since digital learning materials were mentioned, it is necessary to present some definitions related to them. The first is LO – Learning Object, the second is SCO – Shareable Content Object and the third is Asset. They follow:

- LO – Learning Object

The definition of a Learning Object comes from IEEE LTSC – The Institute of Electrical and Electronics Engineers Learning Technology Standards Committee in page 1 of its IEEE Standard for Learning Object Metadata [3]: **"For this standard, a learning object is defined as any entity – digital or non-digital – that may be used for learning, education, or training."**

This definition is important in the context of Engineering Education because it allows non-digital artifacts to be classified as LOs.

- SCO – Shareable Content Object

SCORM – Shareable Content Object Reference Model is defined as: **“The Shareable Content Object Reference Model (SCORM) is a model that references and integrates a set of interrelated technical standards, specifications, and guidelines designed to meet high-level requirements for e-learning content and systems.”** in [4] page 3-3. The SCORM defines SCO as: **“SCOs are the smallest logical units of information you can deliver to your learners via an LMS.”** [4] page 11-4.

SCOs are always digital since they are to be delivered via an LMS. This is a difference they present when compared to LOs. At the same time, SCOs and LOs have two common characteristics – they are units with educational purposes and are “seen” by LMSs.

- Asset

Assets are defined by SCORM as: **“Assets are electronic representations of media, texts, images, sounds, HTML pages, assessment objects, and other pieces of data. They do not communicate with the LMS.”** [4] page 3-2.

In 2000, the terms reusable chuncks of instructional media, reusable instructional components, reusable digital resources, reusable learning objects (LO) were introduced by Wiley [5]. Later on, in 2009, the term Reusable Learning Object (RLO) was used by Alsubaie [6].

Except for Asset, SCO, LO, RLO, instructional media, reusable instructional components and reusable digital resources, have much in common and, therefore, fuzzy boundaries. At the same time, reusable digital resources can be used for Assets.

- Remote Lab

The expression Remote Lab is associated with VRLs – Virtual & Remote Labs. Virtual and Remote Labs are different from one another. Heradio et al [7] presented four possibilities of labs according to their physical natures and the ways they are accessed:

- Local Access – Real Resource
- Local Access – Simulated Resource
- Remote Access – Real Resource
- Remote Access – Simulated Resource

While Virtual Labs rely on Simulated Resources, Remote Labs use Real Resources, i.e., equipment and components found in traditional labs.

This work addresses the third case, i.e., a real resource that is remotely accessed using computer networks, including the Internet. This is the meaning of Remote Lab in this article.

3 The Context at the University

The context at the university is presented in three steps. The first is the system that is at the same time an IR and an LMS; it is a single platform that hosts both functionalities. The second is the first integration that was implemented with an external system. The third is the Remote Lab that was integrated with the System.

3.1 The Institutional Repository and the Learning Management System

The IR and the LMS are implemented on a single platform called The Maxwell System (http://www.maxwell.vrac.puc-rio.br/). It is also integrated with SciLab® (http://www.scilab.org/); this will be discussed later in this section.

The Maxwell System started being deployed in the middle of the 1990s as a digital library of courseware in Electrical Engineering. It is important to remark that courseware at that time was very simple since IT was quite limited. In 1999, the system was registered by the university at the Brazilian Patent Office.

As time went by, new functions were added and new versions of the system made available. The current version is 4.0 and it is accessible to the blind and the visually impaired. The main IR and LMS functions are presented in the following subsections.

- Institutional Repository Features

The Maxwell System hosts over 22 K titles of digital contents. There is a large variety of types/subtypes. ETDs (Electronic Theses and Dissertations) are the largest collection, with over 8,600 items. The second largest collection is that of Senior Projects with over 4,100 and the third largest is the articles collection with over 1,500 itens. The courseware collection (texts, videos, interactive modules, simulators, etc) has over 2,500 items. There are many other types/subtypes on the system.

In order to properly describe the items, the system is compliant with three metadata standards: DCMES – Dublin Core Metadata Element Set (ISO 15836) (http://www.dublincore.org/), ETD-ms – an Interoperability Metadata Standard for Electronic Theses and Dissertations (http://www.ndltd.org/standards/metadata) and MTD2-BR – Padrão Brasileiro de Metadados para Teses e Dissertações (http://oai.ibict.br/mtd2-br/MTD2_Fev2005.doc). The last two are specific for online theses and dissertations (ETD); one is international and the other is Brazilian. The description of courseware has many elements of the LOM Standard [3].

The IR characteristic of the system allowed the creation of a collection of Assets that are shared by different items of courseware [8]. The LMS does not manage Assets but the IR does. Assets are still images (block diagrams, schematic representations, photographs, graphics), interactive quizzes, MATLAB® code, SciLab® code, html pieces, videos, animations, etc. Currently there are over 700 Assets but a little overt 500 have been described and uploaded to the system so far. The Assets have a very high ratio of reuse since the courseware collection is focused on Electrical Engineering. The Assets collection has had additions due to the implementation of the Remote Lab; this will be discussed later in in this paper.

- Learning Management System Features

The Maxwell System started as a digital library of courseware in Electrical Engineering meant to be used by the students of the university; some access control functions began being implemented then. They grew in number and sophistication. Then, it was decided that the system could support the learning process of students in traditional face-to-face courses. As time went by, e-learning and b-learning courses started being offered from this platform with new added functions.

Currently, it supports traditional, b-learning and e-learning courses. It is integrated with the university administrative system.

It offers a “Classroom” (to support traditional courses) and a “Virtualroom” (for e- and b-learning). The last has more functions. Among the functions, the following can be mentioned: access to course materials, access to recommended bibliography, bulletin board, list of participants with photos & short bios (optional), discussion forums, chats, agenda, access to grades (individual grades and statistical data on the whole class), instructions on how to use the system and contacts. The first versions of online tests were implemented in the second term of 2016.

Since students and faculty are used to the system, the decision was to integrate the Remote Lab to this platform, so that they could have the functions of the Remote Lab available from a platform they feel comfortable.

One important feature must be mentioned at this point because it impacted the way the Remote Lab was integrated to the system – the scheduling of activities. Activities are scheduled and they have many attributes – initial time and date, final time and date, place (it can be the system), if grades are assigned and their types, etc. All this information is recorded on the database. Students are informed of the activities to participate through two different applications – *Atividades* (activities) that lists all activities of a given course and Agenda that has three options to see all the activities of all courses a student is enrolled plus office/tutoring hours; one of the options is a calendar. When the online tests were implemented, the *Atividades* application got a new function – it connects the student to the activity if it is in the scheduled time; the online tests are run from the Maxwell System.

- Institutional Repository + Learning Management System

This model has proved very practical for many reasons but the most important is that resources are course independent – they are independent items of the digital collection that are described with a detailed metadata set. The items can be: (1) courseware – resources developed to fulfill the needs of syllabi; (2) learning objects – self contained topics that can be used as references or to support other items; (3) simulators and interactive exercises – items that allow students to practice; and (4) texts of various natures (theses, dissertations, senior projects, monographs, articles) that are at the same time products of the educational process and inputs to it.

3.2 SciLab® – The First Integration

Simulation is an interesting tool in the learning process. In order to develop Learning Objects with this characteristic – Simulator Objects – the Maxwell System was integrated with SciLab®. Simulator Objects are created with some theoretical background and access to pages where users can choose parameters, functions and scales, and submit to SciLab®. The results (graphical and/or alphanumerical) are returned to the system and presented to the user. The user does not “see” SciLab® since its user is the Maxwell System. The SciLab® server was installed and the communication between the two systems was implemented.

The first object was made available in May 2015. Currently, there are 13 different objects with a total of 50 simulating modules and over 100 Assets with extension .sce. Additional Simulator Objects have been developed to support the Remote Lab experiments. They are related to the topics and circuits the students use in the course.

3.3 VISIR – The Remote Lab – The Second Integration

The LMS and the IR have been available for a long time and are solid tools for learning and teaching. Simulation was added in 2015. The number of learning materials can be counted by the hundreds and they are of various natures.

It was then necessary to add Remote Labs to enhance the ICT support to Engineering Education at the university. The objective of the faculty involved in the project was to have Remote Labs in addition to all other available tools to prepare for the traditional lab activities. The Remote Lab in the context of this work is defined as "Remote Access – Real Resource" [7].

Marques et al. [9] summarized the advantages of Remote Labs presented in the literature as: (1) accessibility; (2) availability; and (3) safety. The advantages are out of question even when e- and b-learning are not under consideration. Students in traditional courses can use a Remote Lab when they are not at the university or when the traditional labs are closed. This yields more opportunities to learn.

The Remote Lab that was integrated is VISIR – Virtual Instrument Systems in Reality, a Remote Lab for Electric and Electronic Circuits. Tawfik et al. [10] presented a good description of the main technical aspects of VISIR. Alves et al. [11] addressed the integration of VISIR with Moodle (http://www.moodle.org/), a free and open source LMS. It is important to remark that the focus of [11] is on the pedagogical aspects of the integration by assessing students performances. This is a big difference to this work which addresses the informational and technical aspects of the integration. VISIR is the available Remote Lab; if another Remote Lab equipment were used, the conceptual solution would be the same, though the informational and technical aspects would probably be different.

The next section presents the integration of VISIR and the Maxwell System.

4 The Integration of VISIR and the Maxwell System

The integration of VISIR and the Maxwell System had different aspects that are complementary. All of them are necessary to achieve the model of use.

The model of use is based on three premises: (1) the Remote Lab, as the Maxwell System, is an institutional resource that must be prepared to be used in different courses with different instructors; this has consequences on the integration of both systems; (2) the Remote Lab is part of the learning resources offered to students and faculty, and for this reason is to be integrated with the platform where all other resources are made available; and (3) digital materials are to be available for students to study and be prepared for the use of VISIR, and to afterwards go to the traditional lab. The three premises are discussed in the following subsections. Another subsection addresses the installation of VISIR and the communication with the Maxwell System.

4.1 VISIR as an Institutional Resource

VISIR requires many actions to be performed before it can be used for a set of experiments. The actions are a consequence of its architecture and implementation. It is not a "plug and play" resource. It is neither a software that one downloads and installs, and it is ready to use. This subsection is a little technical but it is necessary to understand the solution concerning the technical documentation required for the VISIR operation.

VISIR is made of a set of protoboards that host instruments (source, signal generator, multimeter and oscilloscope) and components that allow the experiments to be performed. In order to be ready to use, the components must be installed on the protoboards and the technical documentation uploaded on the VISIR server. The documentation is:

- Component List

The Component List is a text file that contains all the elements that are physically mounted on VISIR. Each element is described with attributes: type, number of the protoboard where it is mounted, number of the relay in which it is installed, names of the nodes it is connected and a description. Elements can be resistors, capacitors, inductors, diodes, transistors, integrated circuits and wires. Nodes are identified as 0, A, B, C, D, E, F, G and H.

The Component List is a result of all components that are installed on the protoboards, thus it is independent of the experiments. There is only one Component List for each VISIR installation at a time. This is an important characteristic of this file because it determines the Collection it belongs.

- Max Lists

VISIR uses Max Lists to "authorize" circuits that can be mounted. A circuit that belongs to a Max List is considered to be safe not to harm the equipment. A Max List is a text file describing:

- The sources that can be used in the corresponding experiment and their limits of voltage and current;
- The components that can be used in the corresponding experiments. They are subsets of the components listed in the Component List.

A Max List is associated with an experiment. Therefore, there is one Max List for each experiment to be performed.

- Equipment Configuration File

The Equipment Configuration File is a text file identified as filename.cir. It is generated by VISIR when used in the mode that allows experiments to be created. It contains the following information:

- Equipment and components to be used in the experiment related to the Equipment Configuration File;
- The components that can be used in the corresponding experiments. They are subsets of the components listed in the Component List.

An Equipment Configuration File is associated with an experiment. Therefore, there is one Equipment Configuration File for each experiment to be performed.

When an experiment is created in VISIR, the Equipment Configuration File is automatically generated. The person creating it must save it on the local computer. In the case addressed by this work, the creator must send it to the information processing staff for the file to be described, addeded to the corresponding Collection (next paragraphs) and stored on the system. The creator of the experiment can ask the satff to upload the file to the Maxwell System.

The Equipment Configuration File on the Maxwell System is of paramount importance in the integration process. This will be addressed in subsection 4.4.

It is clear the Component List is a document of VISIR. On the other hand, the Max Lists and the Equipment Configuration Files are documents that refer to experiments.

In order to store, make available and preserve these documents, the IR characteristic of the Maxwell System was used. The DCMES Standard classifies types of resources, one of the types is a "collection", which means a set of resources with specific characteristics. The Maxwell System uses two other attributes to classify resources – "subtype" and "nature". Subtype adds a more specific characterization of resources; for example, "text" is very wide and needs additional specification, such as article, manual, ETD, etc. "Nature" is used to specify a focus to the resource; two examples are "technical" and " educational". Combining the three possibilities – type / subtype / nature – two sets of collections were created:

- *Documentação Técnica do VISIR* – Virtual Instruments System in Reality (Collection / Technical Documentation / Technical)

This collection holds the Component List, photographs of the protoboards with the components, schematic representations of the components on the protoboards, the Data Sheet of VISIR provided by the manufacturer (with the necessary authorization) and the *Manual Técnico de Utilização do VISIR* [12] written by Barbosa.

Two remarks are important. The first is that the manual contains information about VISIR and its installation at PUC-Rio. The second is that all the documents, except the Data Sheet are updated along the time according to changes in the configuration. Changes in the configuration may occurr do to adding and/or deleting experiments.

- Name of the Experiment(*) (Collection / Remote Experiment / Educational)

There is one such collection for each experiment to be performed. Each one contains the Experiments Descriptions & Assignments (text), a set of support digital resources, the Max Lists for the experiments and the Equipment Configuration Files.

(*) An example of title for a collection is *Circuitos de Primera Ordem* (First Order Circuits).

Figures 1 and 2 show the catalog descriptions of two collections – the Technical Documentation Collection and a Remote Experiment Collection. There are as many of the second type collection as the number of experiments installed on VISIR.

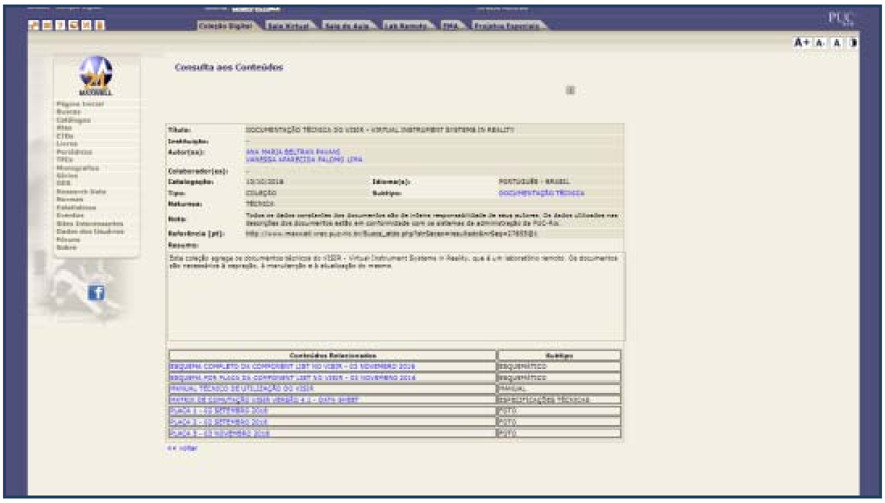


Fig. 1. Description of the Technical Documentation Collection.

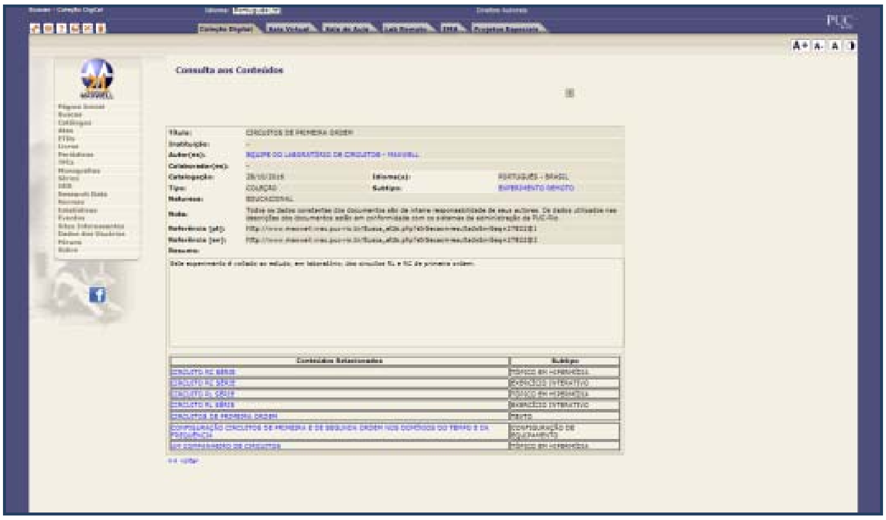


Fig. 2. Description of the First Order Experiment Collection.

A Remote Experiment Collection may hold all types of learning materials the instructor chooses from the ones available on the Maxwell System. More on this subject will be presented when the third premise is discussed.

At this point, there is a connection with the Assets that were presented in section 2. Some of the items of the collections do not have educational functions and have no meaning outside the collections they belong; some examples are the Max Lists, the Component List and the photos of the protoboards. For this reason, they were classified as Assets. On the other hand, there are many resources that are not Assets; some examples are the Experiments Descriptions & Assignements and the *Manual Técnico*.

4.2 VISIR is Another Learning Resource

The university has traditional labs for the engineering courses that require them. It also offers access to MATLAB® and CircuitLab® through licenses that students can use. The Maxwell System has a large collection of educational resources in Electrical Engineering. VISIR came as an additional resource to students.

Currently, there are two types of uses of VISIR: (1) laboratory classes of Electric and Electronic Circuits, which is a mandatory course in the curricula of the Computer, Control & Automation and Electrical Engineering careers; and (2) extracurricular activities for students who do not take Circuits.

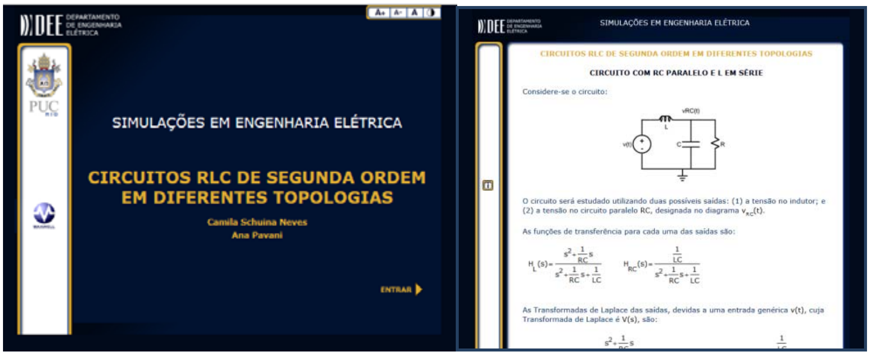
In the first case, VISIR is one of the resources to be used by students. This can be seen by examining the experiment description of First Order Circuits [13]. It clearly indicates that students are required to study the theory on the topic, simulate with CircuitLab®, use VISIR and then go to the traditional lab.

A similar situation is described in one of the cases analyzed by Marques et al. [9], i.e., VISIR as one of the resources available to students.

4.3 Digital Materials to be Used by Students

Abundant learning resources were available from the Maxwell System before VISIR was deployed. This happened because the system had been used to support traditional and b-learning courses. For example, 35 videos with the complete syllabus of the Electric and Electronic Circuits course [14] were published in 2013-2014, 51 Learning Objects in Electrical Engineering [15] were published in 2012-2017 and 15 Simulator Objects [16] were published in 2015-2016.

When VISIR started, a new series [17] started too. Its aim is to organize resources developed for the use of VISIR. Additional learning materials have been developed to support the experiments. The reason for this is that before VISIR, the lab classes used the Maxwell System only for support – hosting experiment descriptions, posting agendas, etc. One example of such new resource is the Simulator Object, developed using SciLab® *Circuitos RLC de Segunda Ordem em Diferentes Topologias* [18]. Figure 3 shows the opening screen of the object and figure 4 one of the configurations that the object supports.



Figs. 3. and 4. Opening Screen of a Simulator and an internal screen showing one of the configurations that the Simulator Object supports.

4.4 Installation of VISIR and Integration to the Maxwell System

Before VISIR was installed, the Maxwell System and NI LabVIEW® were integrated using another process to emulate VISIR. When NI PXI® and VISIR arrived, the installation was concluded. The challenge was to be able to command VISIR from the *Atividades* application presented in subsection

3.1. It had to be enhanced in order to be able to offer a "door" to enter VISIR. This was accomplished by creating a link to the Asset that is the Equipment Configuration File for the corresponding experiment. This Asset is on the IR feature of the system and during the process of creating the Activity (on the Maxwell System LMS feature) the program asks for an Asset of Type = Equipment / Subtype = Equipment Configuration. The user chooses the file corresponding to the experiment; it becomes a link as figure 5 shows. The link is active when the dates and times specified to perform the experiment are valid; the scheduling procedure is the same that has been used for discussion forums, chats and online tests. What is new is that it links to VISIR. This is possible because the technical documentation is on the system.

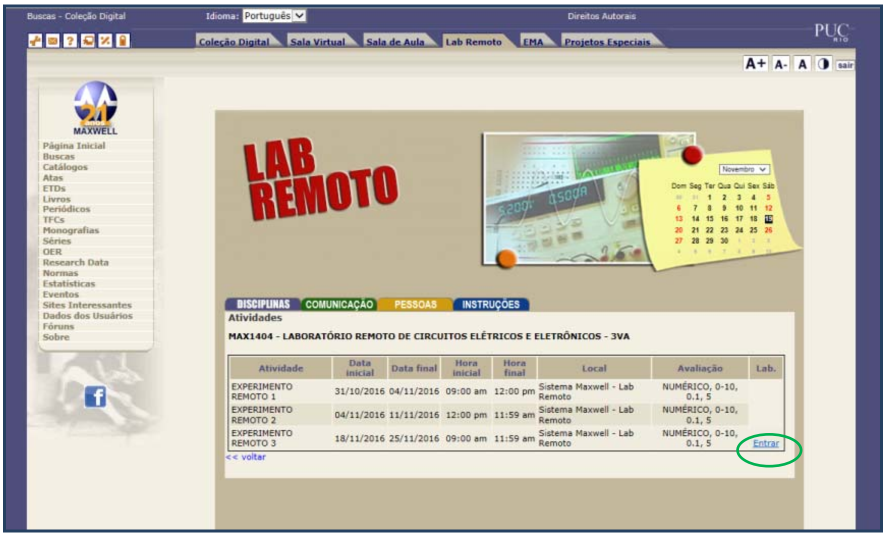


Fig. 5. Remote Lab environment on the Maxwell System showing the link to "*Entrar*" (Enter), in the ellipse, to perform Remote Experiment 3.

5 Using VISIR

VISIR is used by three different players – instructors, students and technical staff. Each has a particular and specialized set of functions and the system must support all of them. The Maxwell System has always been used by the same three players. Before the profiles of the users are presented, it is important to remark that the system has always identified persons by their roles and each role has a specific profile of functions and authorization levels. Thus, only new functions had to be created.

As mentioned in section 3, the decision to integrate the Remote Lab to the Maxwell System yielded the saving of a lot of work – all users are already identified and have profiles, information comes from the university administrative system, courseware with defined levels of access are on the IR, tables of courses and classes are on the LMS, etc. The players and the adjustments made to suit them follow.

- Technical Staff

The functions available to technical staff were not impacted since this set of users has been managing persons and resources for many years. The integration of VISIR and Maxwell was very comfortable for this group.

- Instructors

Some work has been devoted to add functions for instructors to use and manage VISIR from the System. Two were adjustments of functions already available for the use and management of the "Classroom" and/or the "Virtualroom": (1) configuration of the environment to suit the needs and/or preferences of the instructors; and (2) assessment of accesses by students. Two were new functions related to information on the IR: (1) browsing Remote Experiments Collections; and (2) browsing Technical Documentation collections. One was a completely new function that is performed from the system on the VISIR equipment – the Creation of a New Experiment. To perform this function VISIR has a feature that is not available to students – a button with a "+" sign that allows the inclusion of components. Figure 6 shows the VISIR interface when a remote experiment can be created – the "+" sign is in the ellipse.

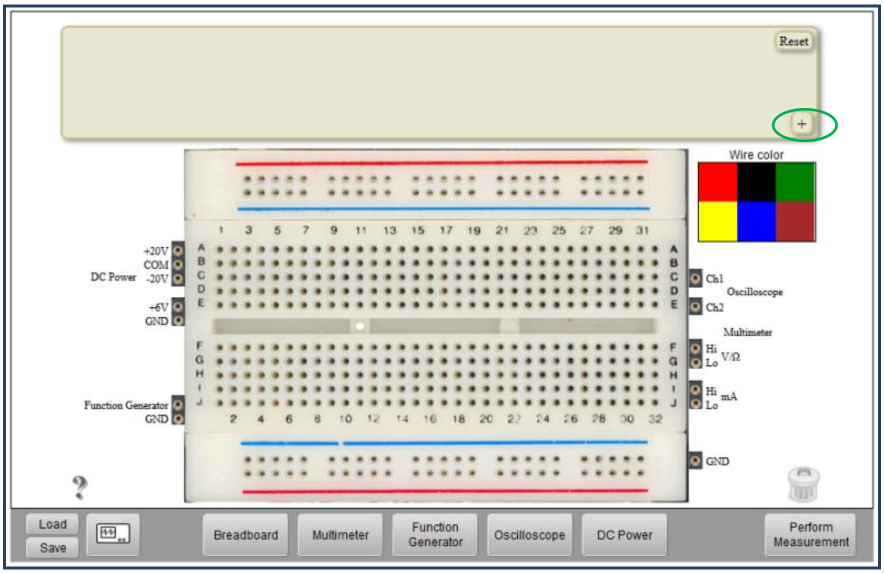


Fig. 6. VISIR interface available for instructors to create remote experiments.

The other functions – posting news on the bulletin board, mailing list, posting grades, assigning activities, posting bibliography, etc – were not affected. They are used as they have always been.

Figures 7 and 8 show, respectively, the instructors menu and an online accesses report (students' names were erased).

Fig. 7. Instructors' menu.

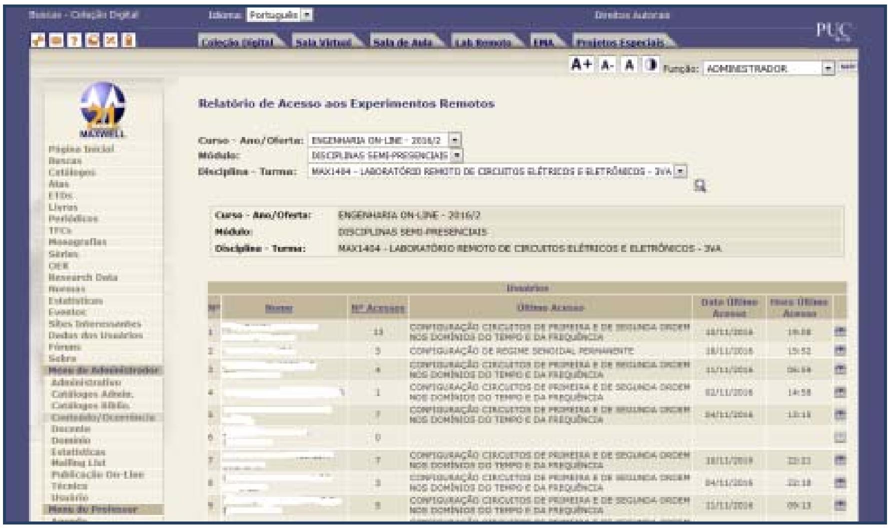


Fig. 8. Accesses report.

- Students

Students maintained the same functions they have always had and got a new one – access to VISIR. Figure 5 shows the list of remote experiments where only the last is available due to the scheduling defined by the instructors. Figure 9 shows the environment offered to students to get ready to experiments – the courseware is organized according to the configuration created using the function in the Instructors' menu. The upper part contains the Reference Resources and the lower part (partially shown) contains the Experiments Assignments.

Fig. 9. Materials available for the remote experiments.

6 Final Remarks

This is a project under way. The implementation is compliant with the premises that were stated.

The first run of VISIR at the university was in the second semester of 2016 which was the first semester of the integration. It may happen that new functions will be necessary and current functions will need enhancements.

At the end of the term, questionnaires were handed to students and are currently under analysis. Adjustments, new functions, etc can be implemented as consequence of the surveys.

Beginning next March the course of General Electricity will start using VISIR, thus new instructors and their students will be able to contribute with suggestions.

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