

# A TEACHING AND LEARNING ENVIRONMENT FOR INTEGRATING VIRTUAL LABORATORIES

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**Abstract** — In this work, a teaching and learning environment to support different virtual engineering laboratories is described, allowing remote access via Internet. Such environment integrates virtual laboratories on linear systems, signal processing, control engineering, and neural processing and it is designed to be used in continuous learning and regular undergraduate courses, both in the frameworks of presential and distance learning programmes. As the laboratories are designed in a modular structure and using accessing layers of different depths of the didactic material, extensions to accommodate other virtual laboratories can be easily accomplished. The environment also supports implementation in firmware, using digital signal processor technology. A set of tools integrated to the environment also supports the automatic introduction of new modules by the teachers and communication among students and between students and instructors.

**Index Terms** — Distance learning, engineering education, remote and virtual laboratories.

## INTRODUCTION

The Internet and recent computing resources offer many possibilities for disseminating educational material to students, both locally and as part of remote programmes. Traditional courses offer classes driven by professors, and supported by libraries, exercising lists and hours dedicated to the clarification of misunderstandings and doubts. Uncertainties of previous years can remain the same for new students. Therefore, the answers of earlier doubts can be helpful for novices as well and accomplished projects can serve as a base for new developments. Failed experiences can be analyzed and understood to avoid undesired outcomes. Graduated students can access stored materials to improve the way a task is planned, designed, implemented, tested, adapted, expanded and so on. Furthermore, one working team can make use of all information and acquired knowledge of other groups, not necessarily in the same domain area.

Within a worldwide scenario, the Internet is a powerful tool to provide access to any data independently of its location and of person's background. So, knowledge databases are becoming increasingly popular as a method to catalog the best practices of several categories of projects and keeping, in this way, the main resource that an enterprise has, it means, its experience.

Engineering projects are becoming more and more complex because they are involving interdisciplinary and cooperative activities and some working group members are geographically distributed, placed at different locations. Another arising necessity is that laboratory experiments are a vital part of engineering education [1]. Recent advances in Internet/Web technologies and computer-controlled instrumentation presently permit net-based techniques to be utilized for setting up environments that respect the previous requirements. In this context, teaching and learning activities have been requesting urgent reviews on traditional educational systems, in order to match the needs of modern communication models [2].

In this paper, we present an Internet teaching and learning environment to support different engineering virtual laboratories. It integrates hypertext pages on linear systems, signal processing, control engineering, and neural processing. The laboratories are designed for either continuous learning or regular undergraduate courses. Their modularity facilitates the integration of diverse virtual building blocks and allows the aggregation of new material. The environment also supports implementation in firmware, using digital signal processor (DSP) technology. A set of tools integrated to the environment also supports the various aspects of engineering classes and learning processes, such as, for instance, the communication among students and between students and teachers.

## VIRTUAL ENGINEERING LABORATORIES

The Federal University of Rio de Janeiro has been developing the Papoula Project, envisaging the interconnection of virtual laboratories. The project aims at furnishing a learning environment that integrates a set of virtual hypertext labs, in a way to explore new teaching approaches and to introduce sophisticated technologies. One of the fundamentals of the proposed environment is the hardware and software amalgamation, which is in fact a strong observed tendency in engineering nowadays. It is important to realize that such concept of fuzzy limits between hardware and software emphasizes how broad is the knowledge required in the conception and elaboration of modern engineering projects.

More specifically, the integration of virtual laboratories is achieved by hypertext links that are set among the contents of each individual module belonging to the interconnection net. Three development layers

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compose the elaboration method of the contents of each module of each virtual lab. The first layer aims at facilitating the knowledge acquisition by the student of fundamental topics of each module. The second layer is dedicated to the simulation of the topics that will be further codified into hardware (firmware), in a way that the student can explore a practical implementation. Thus, the last layer, provides the virtual access to hardware implementation over programmable devices, in this case, using the digital signal processing (DSP) technology. The layers are implemented through commercial and widely used software packages, which allows students to easily enter into the lab environment.

The implementation of the hardware layer is performed by experiments built over a computer net, using testbench equipments (generators, power-supplies, oscilloscopes, multimeters), which are remotely commanded through the Web. The equipments are interconnected by a GPIB interface, which allows the communication with the server computer of the environment. A virtual instrument for each piece of equipment is thus available to the users for control and display of the experiments. In the server, a DSP development layer is installed, which makes it remotely accessible. This proposal gives priority to a fast, easy and dynamical communication through a suitable language at each interaction level in order to stimulate the students [3].

This model for the learning and teaching environment can support both regular and distance learning programs. It also integrates available information technology in order to facilitate not only who accesses the didactic material but also who creates the virtual laboratories. The distinction of the Papoula Project, comparing it to other distance learning developing environments, is the grouping of diverse engineering subjects and tools within a cooperative environment, offering a remote execution of resources and allowing their sharing. It is interesting to notice that this model can also be applied in other contexts, such as cooperative work, resources training and experiments through virtual instruments.

Before initiating the construction of a distance learning environment, as the initial investment is quite high, even when having the supporting tools available, it is important to validate its real need, since a traditional class or a presential training can be less expensive. The first step is to validate whether the content will have some stability. Evidently, the content of a distance learning course can be updated, but it is necessary to consider the costs of its maintenance. A remote course can be synchronous with a specific date to start with and predefined length, offering discussion means, hardware access (the technical responsible or even a sort of robot has to turn it on and off) and cooperative tasks. A registering tool is essential in such cases. On the other hand, a distance learning course can also be asynchronous and, in these cases, the students must have in mind that arising doubts sent by email may not be answered immediately [4].

In order to make the developing process of distance learning environments easier, some steps must be respected: define who are the main users, study the need of

different access form for all types of users, define the fundamental requirements to provide ways of using the learning tool, inform the whole contents of the material to alert users before initiating the course, define a plan of a suitable navigation to avoid that wrong choices influence the learning process.

The development of a Web-based learning tool must give priority to the interactivity and to the communication among students and between an educator and students. Pointing towards this goal, the environment should dispose some services such as forums, notes about the course, main topics and bibliographic references used. The user registration tool is a powerful tool, since it enables the information exchange among users and serves as a base for the environment that can provide a suitable configuration according to students' background. A student register helps on determining the user profile through an analysis of his/her data stored into a database. In conjunction with other tools, a distance learning course may personalize the page navigation, automatically switching the contents to the needs or to the skills of its users. It is important to take into consideration that everybody, including those with no Web experience, has to be able to use the tools and the learning environment itself. In this way, the environment could offer Web tutorials in order that more complex functionalities could be used in the advanced modules.

## DISTANCE LEARNING TOOLS

At the beginning of the developing process of a supporting tool for a distance learning environment, some steps should be followed as describing its goal, defining the input and output data, classifying its functionalities, identifying the development strategy, restrictions and improvements for a next version. This specification guides programmers as it delineates the tool scope and target.

Within the Papoula Project, the tool organization follows the classification proposed by Malluhi [5]:

- **System administration tools:** belong to this group the tools that make the user interface to work, including its facilities such as password protection, user's files access, user profile characterization, dynamic menu automatically generated, contents listing in a linear format (not in a hypertext format), user registration including access levels based on the student knowledge, mechanisms that allow access level change, localization in the hypertext map, specialization, map of the site, automatically update of the references, and verification of not existing hypertext links.
- **Authorizing supporting tools:** any implementation that supports the structuring of a distance learning course can be classified in this category: selection of course components from a complete list, contents publishing based on certain criteria, multimedia contents, test and examination creation, graphical page design, personalized icons, course outline elaboration support, last updates, glossary access, mechanism for searching and inserting hypertext

links, sensitive figure generation, cooperative authoring, references list, working team (titles, background and positions) and general information about the course.

- **Collaboration and communication tools:** belong to this group the tools that assist the instructors on controlling ongoing courses as visualization of the entire course by instructors, visit counting, statistics of the time spent in each module, activities registry, frequency control, examination and listing databases, test generators, automatic correction of tests, creation of groups, advertisements, and administration of users.
- **Students tools:** implementations that support users to visualize the contents and to obtain information about its performance such as grade visualization, comparison between a certain grade and the class average, creation of lesson guides, abstract database, searching for a specific data within a course, presentation of the latest modifications, and glossary of terms.
- **Virtual and remote laboratory tools:** this category groups all tools that support simulations (virtual labs) or the remote execution of resources as software and hardware supporting mechanisms and mathematical function programs.

In the context of the proposed environment, the tool development is directly related to the technological needs of the virtual laboratories.

### PAPOULA: AN IMPLEMENTATION OF THE PROPOSED MODEL

The PAPOULA<sup>5</sup> environment corresponds to a practical accomplishment of the proposed model. It runs on the Web and its main goal is the delivery of a set of laboratories on the Internet that supports the learning of some of the main subjects in electronics engineering. PAPOULA offers to the users three levels of contents and exercises, both theoretical and practical, as well as a virtual practice of experiments with the support of a specific software for either a simulation of a device or a real hardware test through remote mechanisms. The current laboratories already implemented and linked are:

- **PATROL:** supporting pages to the learning of control systems, including aspects of both classical and modern control engineering.
- **PAPROS:** supporting pages to the learning of signal processing, presenting the main topics in signal processing, discrete and continuous.
- **PANN:** supporting pages to the learning of neural networks under supervised and unsupervised learning.
- **PALAS:** supporting pages to the learning of linear systems, including both time and frequency analysis.

<sup>5</sup> The acronym comes from the original in Portuguese, which translation means “supporting pages to presential and distance learning courses”.

Besides the contents of the above pages, the Web environment also integrates some of the tools cited in the previous section with the assistance of the “Tools Module”, which contains pages to support the technical development of learning systems in the Internet. This module also provides mechanisms to help on the construction of virtual and remote experiences, linked to devices that are shared among several users. In addition, two labs are under development, linking engineering and basic science:

- **PACUS:** supporting pages to the learning of Calculus.
- **PALIN:** supporting pages to the learning of linear algebra.

Figure 1 presents the HomePage of the PAPOULA Web environment. The right frame provides access to the laboratories. The left frame presents the menu, where the main functionality and links are. All pages follow this design, in order to provide the same navigation structure among the accessible laboratories.

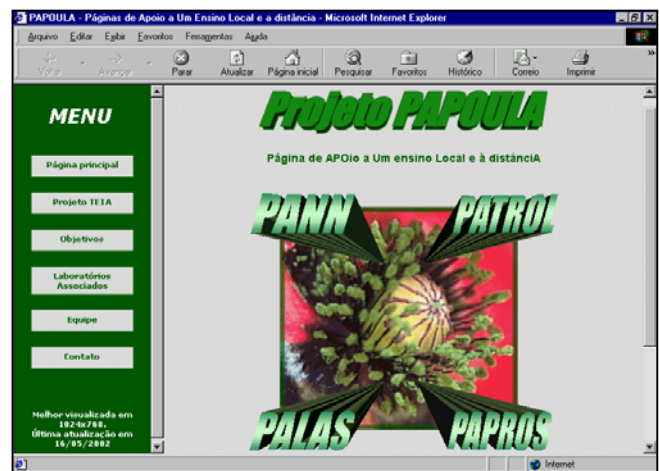


FIGURE. 1

THE PAPOULA HOMEPAGE.

The linked pages through the PAPOULA HomePage have the objective of providing information, via a simple and informal way, of the subjects discussed inside a classroom. In order to achieve the target of presenting a colloquial text, the students themselves read, understand a specific topic and write the contents with the orientation and supervision of full professors.

The laboratories have to work mainly as an extra helping source to clarify eventual doubts. The practical examples evolve through three stages. In the first stage, exercises are suggested to practice the theory. Succeeding, simulated experiences are proposed. Finally, real experiments are remotely performed with the support of instructors and current technologies. For example, regarding the linear systems theory, the PALAS laboratory integrates simulation techniques of circuits and systems with simple hardware modules. Besides simulation, students can experimentally practice through experimental kits located in one physical laboratory.

As part of the theoretical material, supporting tools to the learning process are accessible by the environment. On each module of a given laboratory, students are invited to face a challenge. A complex problem referred to the current module is presented and, in this way, the subject can be deeper discussed based on the student ability. The challenging section is also useful to test the contents assimilation by students and the creative capacity of a student, as the problem is not directly argued within the module. Obviously, electronic mail supports the communication among students and offers an efficient way to clarify eventual doubts with the assistance of instructors.

Within this environment, the students can access several static data related to the subject (as reading a book) and also interactive contents. The importance of the Web technology in the learning process is the possibility to offer a high degree of interactivity to an user, independently of the working place. It is not demanded to install software or to have a specific hardware. A browser and an Internet connection are enough to start acquiring knowledge and expertise. Though an environment like this, it is possible to perform experiences on numeric simulation through the Web and get the results immediately afterwards. Moreover, the student can choose the parameters that will be used in the simulation.

The pages run over an HTTP Apache server in a Linux platform. The HTML language is used on the static parts of the laboratories and CGI programs, implemented in C or C++ language, correspond to the dynamic part. Graphical results as well as all kinds of images are presented together with the text, contributing to a better understanding of the users through multimedia facilities.

Respecting the informal way of learning, a laboratory can provide "tips" on how using the features, devices and software packages. Another feature is the reference page with hypertext links to other Web sites related to the main subject of the module.

### **FUTURE IMPROVEMENTS**

The working group is developing a Web environment to support the automatic creation of distance learning sites. This feature integrates the contents with only some of the distance learning tools as registry, search by keyword, communication features, latest updates, self-scoring, multiple-choice tests. The Web environment also guides instructors on the requirements of a distance learning environment. It means that the environment asks for important data to be displayed as the author background, the summary of the whole contents, terminology, creation date, objective of the course, an email for contact and so on. Contents and tools are automatically integrated through a database without requiring from instructors knowledge about HTML, JavaScript or Web programming.

Our next step is to develop more pages within PAPOULA by using the Web environment and, in this way, guaranteeing standard interfaces. We also plan to construct other distance learning tools according to the classification presented in this paper. Other important

feature is related to evaluative criteria for Web sites that would check aspects related to authority, accuracy, currency, navigation, design, quality of writing and so one [6]. At last, we notice that it is very important to produce a variety of mechanisms to facilitate the creation of virtual and remote experiences.

Regarding the concepts of the proposed model, it is necessary to improve the connectivity method that links the laboratories. Nowadays, the authors have to set each link between two pages. Nevertheless, a certain level of procedure automatizing can be achieved by, for example, the glossary tool, where the terminology of all modules is placed. It could also be very useful to provide a database of content links among various pages and, moreover, a database of experience links among different laboratories.

The idea is to offer a technological "factory" of distance learning pages and to make the construction the most automatic as possible. Professors would concentrate on the contents while the Web environment automatically publishes an already integrated learning material of software, hardware, theory and practice in the Internet.

### **CONCLUSIONS**

The information technology and the intense use of the Internet are becoming very interesting for educators in several knowledge areas. Different conceptions of learning environment on the Web were developed. Nevertheless, the need of creating educational tools that facilitates a fast and easy access to a stored knowledge is increasing, mainly due to the necessity of a constant intellectual update.

Generally, the available time that professionals can dedicate to the update of new methods and techniques is quite restricting. Thus, offering conditions to acquire information through a fast and efficient way is essential to either enterprises that need to keep themselves market competitive or qualified people that constantly need to keep informed.

Recent researches pointed out the potentiality of distance learning through computational support. That is the main reason a specialized distance learning model can contribute to the increasingly grow of new learning methods based on modern technologies applied to engineering courses.

The research project presented in this article intends to construct a multidisciplinary network of virtual laboratories. The network integrates hardware and software to support students in the learning process of different subjects from electronics engineering and basic sciences.

The hypertext pages aim at presenting, through a clear and objective way, material and mechanisms for an effective learning. The Web environment assists instructors within classrooms and not only, as the learning process can be continued out of teaching hours and anywhere. The focus of our proposal is on interconnectivity of data from several domain areas, high interactivity and stimulating the cooperation among users. The PAPOULA environment demonstrates that the proposed model for the interconnection network of virtual

laboratories feasible and that students can get more involved with interactive and dynamic learning material.

The integration of tools, contents and devices to connect different virtual laboratories aims at enlarging the navigability about the didactical material gathered by hypertext links constructing a huge net of knowledge.

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