

# Platform for Virtual Problem-Based Learning in Control Engineering Education

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**Abstract**—This document describes the development of a platform for virtual Problem-Based Learning in control engineering education. Four tools are proposed for it: experimentation, mathematical analysis, dynamic simulation and hypertext for the contents. They form a rich environment for learning through Internet, in which students solve control engineering problems using only a computer with Internet accessibility.

**Index Terms**—Engineering Education, analysis and simulation through Internet, teaching methodologies, active learning, problem-based learning.

## I. INTRODUCTION

In the last years the education in engineering has experienced multiple changes, as a consequence of the technological advances in different study fields. This has generated the necessity to restructure the academic programs and to look for new teaching models. The current curricular tendencies include many pedagogic focuses for which technological tools of support have been developed.

In this article the development of a supporting tool for education in control engineering is presented. A problem in control education resides in the lack of tools to support the technological education or in the necessity to integrate these tools in a friendly and comprehensible environment. Another problem is the educational methodology used in the area of the control systems which due to their multidisciplinary nature, requires different way of learning.

In the second section of this document a brief glance to the problem-based methodology and to some applications in the control engineering education is given. In the third part the education platform is presented and its tools are described. Finally, some conclusions and further works are carried out.

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## II. PROBLEM-BASED LEARNING IN CONTROL SYSTEMS EDUCATION

During the last few years the education in engineering and mainly the control engineering, it has suffered multiple changes due to the fast technological development and the current demands of the field. This situation has prompted the academic programs to implement new pedagogic models and to design teaching-learning strategies that use technological tools to optimize their results. This is evidenced in the efforts carried out by the universities [1], [2], [3] and [4].

The new pedagogic models have prepared engineers for fulfilling the current necessities of the work in multidisciplinary teams where the professional should contribute to the group with his specialty in the solution of practical problems which requires increasingly more communicative and cooperative skill. In the problem-based learning (or PBL) methodology, several technological and pedagogic tools allow the students to solve real problems, in a self-study approach. PBL has demonstrated to be very effective in interdisciplinary areas due to the capacity to associate different concepts in a single problem, that makes of PBL an ideal methodology for the learning of control systems, which is a horizontal area in all the engineering curricula [5] [6].

The technological tools that support the educational process have the potential to increase the communicative possibilities among a bigger quantity of actors, simulating scenarios where the student requires to show abilities in the solution of engineering problems. The current technological developments have arisen from other areas of engineering and have been applied to the teaching of the control systems with good results, but the costs of acquisition of these, they pose a major difficulty for their diffusion, what requires the development of new designed tools thinking of the specific necessities of the education in control [7] [8].

The main inconvenience of the current learning systems, resides in the low interaction among the different tools, forcing the student to move among different environments, hindering its concentration. Additionally, these systems tend to be expensive and to require dedicated computational systems. The main objective of the developed project, is to generate an integrated learning environment for the engineering education, looking for low costs and access facilities through Internet.

### III. PLATFORM STRUCTURE

In order to develop the problem-based education strategy, four basic aspects has been considered: theoretical concepts, mathematical analysis tools, simulation tools and experimentation tools.

The theoretical concepts were organized in concept maps, which guide the student to acquire the knowledge in a consequent order with the solution of diverse outlined problems. The tools of mathematical analysis and simulation were developed using HTML and Javascript language to allow their execution from the World Wide Web. The data processing is carried out using MATLAB© through the Web Server Toolbox.

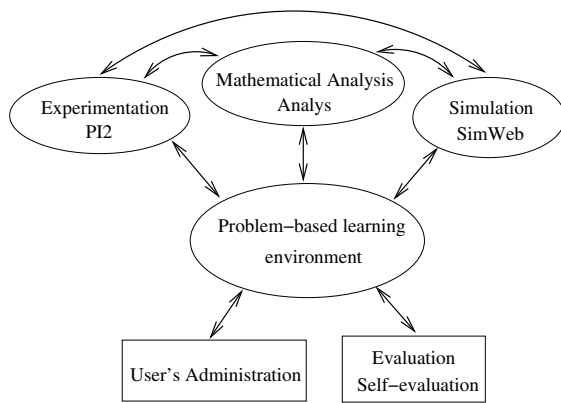


Fig. 1. Platform Diagram.

In Figure 1, a schematic diagram of the platform is presented with its components.

#### A. Learning environment

For the problem-based methodology, the concepts were organized according to its use in the solution of problems and practical projects. For instance, for mathematical modeling of dynamical systems, the proposed learning activities were:

- Problem statement.
- Problem interpretation and search of preliminary information.
- Basic concepts for approaching the problem.
- Identification of physical laws that govern the studied phenomenon.
- Analysis and simulation of some typical cases for better understanding of the theoretical concepts.
- Mathematical modeling of the phenomenon through the studied physical laws.
- Mathematical analysis of the model.
- Simulation of the mathematical model, results analysis and fitting.
- Experimentation and validation.

The concepts are organized in hypertext; the students are able to move among the different topics using connections

and links to the mathematical manipulation tools and remote experiments.

#### B. Analysis Tool - *Analys*

**Analys** is an analysis tool of multivariable linear systems, in which the student can define a mathematical model in space state, transfer function or pole-zero representation. The linear system can be continuous or discrete and it is possible to carry out the following operations and analysis:

- Time analysis.
  - Step response.
  - Impulse response.
  - Initial states response.
  - User signal response.
- Frequency analysis.
  - Bode diagram.
  - Nyquist diagram.
  - Nichols chart.
  - Stability margins.
- Space state analysis.
  - Transformation to the canonical forms.
  - Similarity transformations.
  - Observability and controlability Matrix.
- Root locus analysis.
- Model conversion.
  - Continuous model to discrete.
  - Discrete model to continuous.
  - Resampling of a discrete model.
- Dynamics of the system.
  - Bandwidth.
  - Poles and zeros.
  - DC gain.

### Analys - Sistemas de Control

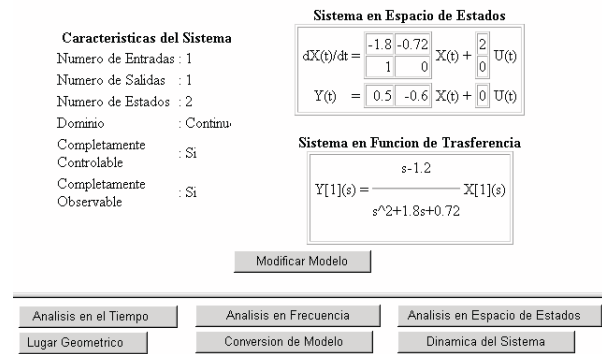


Fig. 2. Analys user interface.

In Figure 2, user interface is presented, where the execution of the actions are carried out through buttons and Web forms. The answer from the different analysis are submitted as Web form page and Jpeg graphics. In Figure 3, the step response of a SISO system is observed and in Figure 4 the corresponding Nyquist diagram is given.

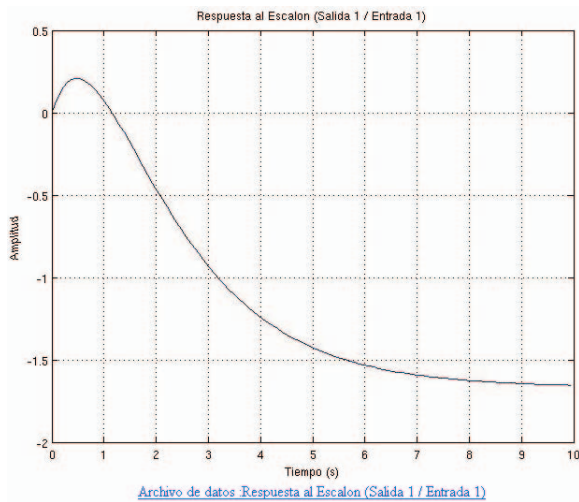


Fig. 3. Step response - Analys.

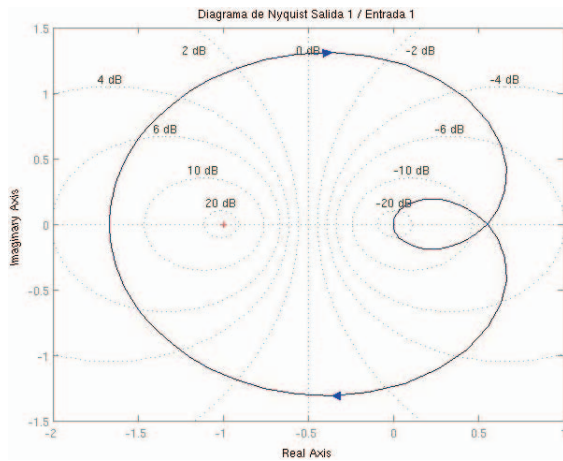


Fig. 4. Nyquist Diagram - Analys.

The analysis tool has also a general purpose command line that allows the students to execute MATLAB commands including graphic manipulation tools and toolbox functions, see an example in Figures 5 and 6. The general architecture of the tool is presented a little later on.

### C. Simulation tool - SimWeb

**SimWeb** is a web environment that allows to design block diagrams through *easy to use* user interface. **SimWeb** supports the technology "drag and drop" standard for this type of applications (such as Simulink from MATLAB [9] or Scicos of Scilab [10]). **SimWeb** allows to carry out simulations through Internet of linear systems, non-linear, continuous, discrete or a mixture of them.

In Figure 7 the user interface of **SimWeb** is presented, which is divided in three areas: blocks area, where the function blocks are placed; workspace, where the blocks diagram is developed; finally, the configuration area, where the parameters of the functional blocks are defined.

## Analys - Linea de Comandos

```

syms s;
G1=(s+0.5)/((s+1)*(s+2));
G2=1/s;
G3=G1*G2;
g=ilaplace(G3);
ezplot(g)
Ejecutar
Volver
Operacion =
Ejecutando ...
G3 =
(s+1/2)/(s+1)/(s+2)/s
g =
1/2*exp(-t)+1/4-3/4*exp(-2*t)
Content-type: text/html

```

Fig. 5. Command Line - Analys.

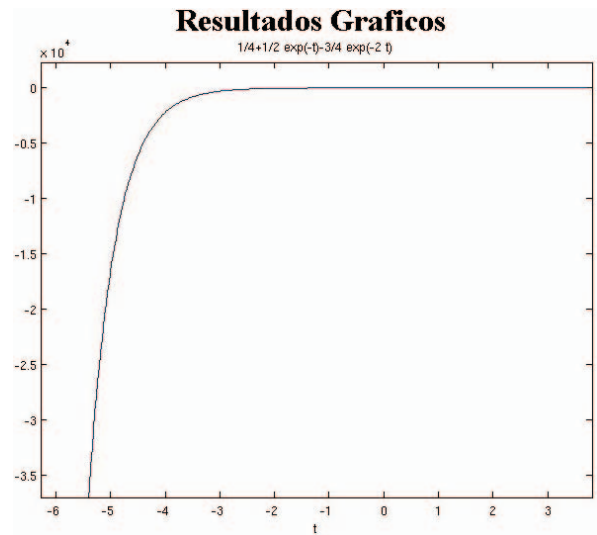


Fig. 6. Command Line (graphics results) - Analys.

The block position in the workspace is carried out dragging and dropping; the parameters are defined in the configuration area and the blocks connections are carried out by the connections utility (Figure 8).

In the connections utility is possible to assign connections to the different inputs from the blocks that conform the blocks diagrams; the system presents the names designated by the user to facilitate their identification.

Figure 9 shows the simulation of a block diagram, which allows the visualization through a Jpeg image and downloading the data files.

### D. Analysis and simulation Web tools structure

The structure of the analysis and simulation tools through the World Wide Web (**Analys** and **SimWeb**) can be observed in Figure 10. The clients access the applications from web navigators through Internet, which reside in a server with Linux operating system and the MATLAB software which include the Web Server ToolBox that allows to receive data

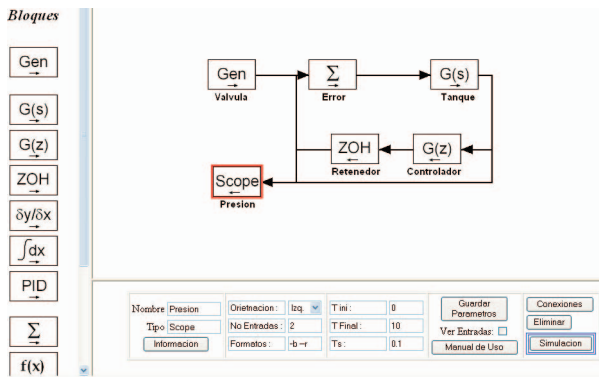


Fig. 7. SimWeb user interface.

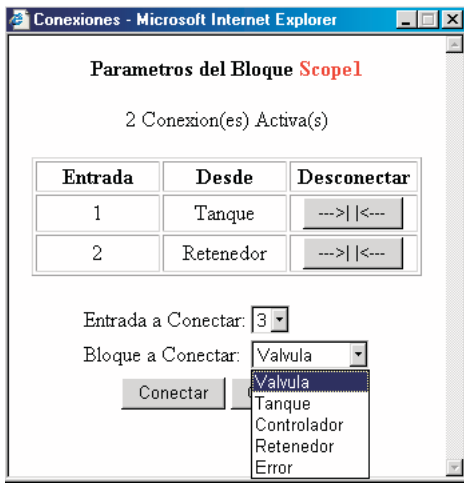


Fig. 8. Utility of connections - SimWeb.

and give back variables and graphics, through the TCP-IP.

The applications are developed using HTML, Javascript, and MATLAB language. The first two allow to build the graphic interfaces and the result pages. The third one is used to develop the algorithms of data processing for the analysis and simulations using MATLAB. The use of MATLAB as a tool of mathematical manipulation is justified due to its diffusion in the scientific community and great calculation precision, besides having ToolBox for different applications. This system presents the following characteristics:

- The mathematical models are coded in HTML forms and the results are given in Web pages and Jpeg graphics which allows low bandwidth for information transmission.
- The updating of the tools is carried out directly in the server and thus the new version is available immediately for all the users of the system.
- The number of simultaneous users of **Analys** and **SimWeb** is determined by the capacity of the server where MATLAB resides and not by the number of licenses available, which implies an important economic saving.

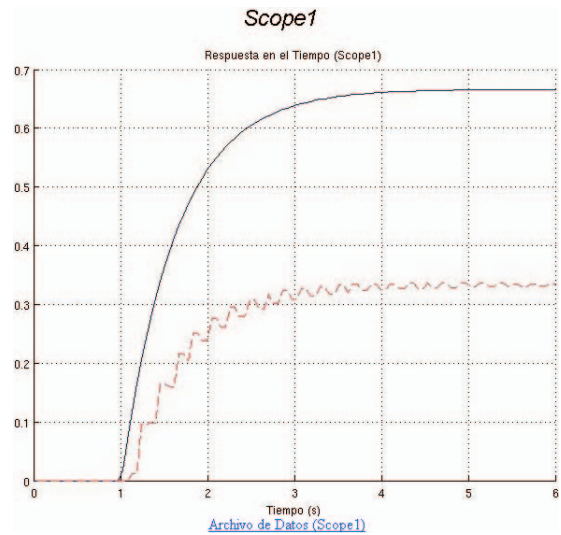


Fig. 9. Simulation - SimWeb.

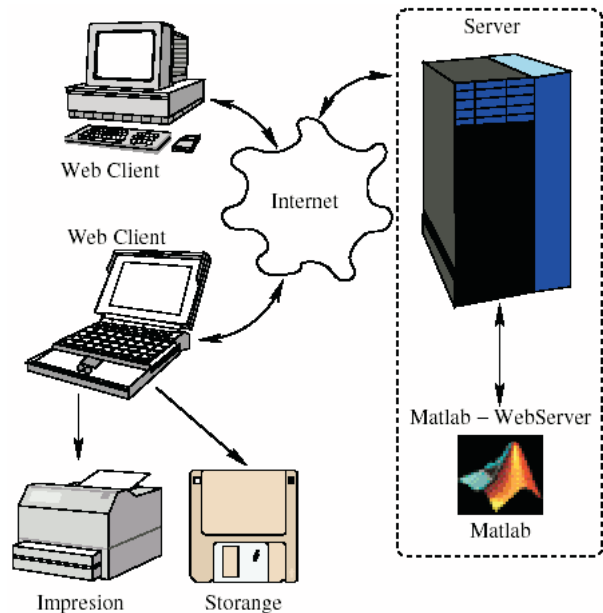


Fig. 10. Web tools structure - Analys, SimWeb.

### E. Experimentation tool - PI2

The experimentation tool through Internet was developed inside the project **PI2** financed by Colciencias [11], the government entity of Science and Technology in Colombia.

**PI2** is an experimentation platform that has multiple sensors and operators to form different control links. A diagram is presented in Figure 11.

It consists of a reactor process, which allows several class of experiments of heat transfer, fluid mechanics and process control.

Manual and proportional valves, solenoids, resistance heating, hydraulic pumps, an agitator, signal transmitters and

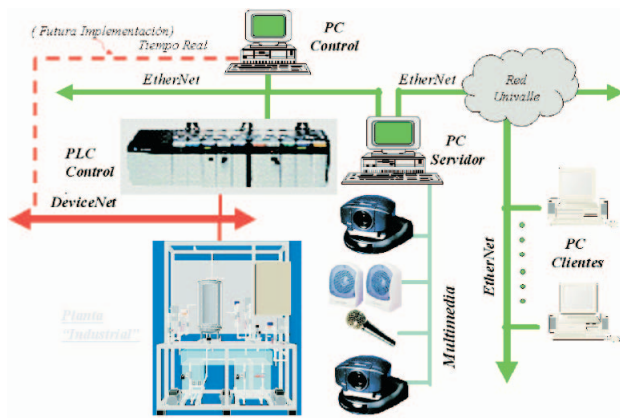


Fig. 11. Platform of Experimentation PI2.

sensors of level, temperature, flow and pressure, constitute the actuators and measuring instruments, that allow to know the plant state, configurate the experiment and conduct it. The measuring instruments and the actuators interact with a PLC, which implements the control law.

**PI2** has a remote execution environment and a multimedia acquisition system that allows interactive experimentation through Internet.

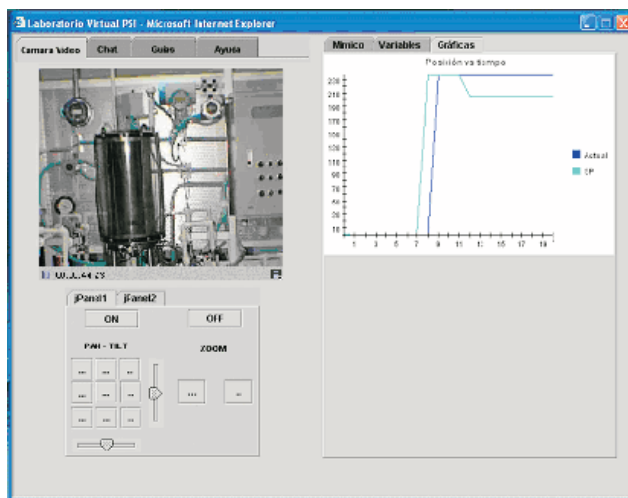


Fig. 12. Remote User Interface - PI2.

Figure 12 shows the Remote User Interface of **PI2**; there are real-time video, variables of the process and a control interface. For further information see the reference [12].

#### IV. ADVANTAGES FOR THE STUDENTS AND PROFESSORS

The integrated learning environment developed, offers different benefits to the students as to the professors:

- *Students*: The students have a wide range of pedagogic, methodological and mathematical tools, which allow to

approach different thematic from a remote work-station (through Internet). These access facilities to the tools and theoretical concepts, combine with the capacity of remote communication with the professor, allow the student to approach complex problems looking for the skills in the resolution of practical problems.

- *Professors*: The professors have tools to know the performance of the students in the questionnaires, equally they have tools for communication and exchange of files with their students. These advantages allow the professors to assist a group of students individually, being focused in the individual and collective development. In the same way, the system allows the professors to define work methodologies and group projects.

Additionally, it is possible to define multiple use forms for the integrated learning system, obtaining an applicable tool for different education and learning methodologies.

#### V. CONCLUSIONS AND FUTURE WORKS

The platform for virtual problem-based learning allows the students to be educated in control engineering, giving them tools of analysis, simulation and remote accessible experimentation through Internet. This development allows to multiple users, access the resources of MATLAB, through an intuitive and powerful user interface.

The problem-based learning environment, lead the student through concepts, procedures and experiments necessary to acquire the control systems knowledge in an autonomous way, in presence or distance (through Internet) form, enlarging in this way the covering of the superior education.

At the present, the platform debugging in made by using it in the control systems courses. It is expected to expand the platform to other areas, such as digital signals processing and mathematical basic courses. It is also expected to expand the analysis and simulation tools to supply the necessities of these new areas.

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