DEPARTAMENTO DE ENGENHARIA ELÉTRICA

Internal Research Reports

ISSN

Number 47 | June 2016

Interactive Digital Resources for a Blended Learning Controls Course

Ana Maria Beltran Pavani

William de Souza Barbosa

PUC RIO

Internal Research Reports

Number 47 | June 2016

Interactive Digital Resources for a Blended Learning Controls Course

Ana Maria Beltran Pavani

William de Souza Barbosa

CREDITS

Publisher:
MAXWELL / LAMBDA/CCPA/VRAc
Sistema Maxwell / Laboratório de Automação de Museus, Bibliotecas Digitais e Arquivos
http://www.maxwell.vrac.puc-rio.br/

Organizers:
Alexandre Street de Aguiar
Delberis Araújo Lima
Cover:
Ana Cristina Costa Ribeiro

Interactive Digital Resources for a Blended Learning Controls Course

Ana M. B. Pavani*, *Member IEEE*. William S. Barbosa**

Pontifícia Universidade Católica do Rio de Janeiro, Rio de Janeiro, RJ, 22451-900
Brazil
**(e-mail: apavani@puc-rio.br). **(e-mail: wsbarbosa@ele.puc-rio.br)*

Abstract: This paper presents the digital resources used in an undergraduate blended learning Controls course that is mandatory in the curricula of both Controls and Automation Engineering and Electrical Engineering. It briefly describes available items – texts, videos, online exercises, simulators and other assorted types of contents that substitute for class hours. The objective of blended learning and of the use of online resources is to stimulate self learning so that the sessions are used for discussion and problem solving.

Keywords: b-learning; learning objects; simulators; interactive learning; control systems

1. INTRODUCTION

The faculty of Electrical Engineering of Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio) has been very active in using ICT – Information and Communication Technology tools to support traditional face-to-face courses. This has been going on for two decades. In the first semester of 2014, two courses started being taught in the blended learning mode (b-learning) – Signals & Systems and Electric & Electronic Circuits. In the second semester, the Controls & Servomechanisms course was switched to this mode. Even before adopting b-learning, abundant online courseware was available from the Maxwell System (http://www.maxwell.vrac.puc-rio.br/), the integration an Institutional Repository (IR) with a Learning Management System (LMS); part of the courseware was interactive. The introduction of b-learning was a motivation to keep developing contents of the same types and to add new interactive resources. The new resources for the b-learning courses were introduced in the first semester of 2015.

Controls & Servomechanisms is a mandatory course in the curricula of Controls and Automation, and Electrical Engineering. It is taught every term with an average of 15 students per term. Before switching to b-learning, it had 8 hour per week of traditional face-to-face classes – 6 lecture and 2 laboratory hours. The b-learning option substituted computer mediated activities and home assignments for 2 lecture hours.

This work presents the courseware that has been developed for b-learning. It also mentions other resources that have been in use since ICT supported learning was introduced to enhance the traditional face-to-face mode.

Section 2 addresses the initial digital resources while section 3 deals with the new interactive courseware. Section 4 presents the b-learning mode and the use of the new resources for the first time (second semester of 2015). Section 5 comments the results, current activities and actions to be taken in the near future. Finally, section 6 outlines the demo and access numbers.

2. COURSEWARE DEVELOPED AND USED BEFORE 2015

At the very beginning, due to the technological limitations in the second half of the 1990s, courseware was made up of two sets of resources – hypertext files with some images and the corresponding text files for linear navigation.

In the early 2000s, small videos, animations and simulators were introduced. The simulators allowed some interactivity. At the same time, online exercises started being developed – each had, at least, three parameters and/or functions sets and one was randomly selected every time the exercise was used; online check and suggested solutions were available too. Exercises were in Electric & Electronic Circuits, Control Systems and Signals & Systems.

In 2008, the numbers of exercises in the three topics had grown a lot and some organization was necessary. The exercises were organized in three interactive books, one for each subject; they are offered as a collection entitled *Exercícios Interativos em Engenharia Elétrica* (Interactive Exercises in Electrical Engineering).

The books do not contain texts, only interactive exercises. They maintain the characteristic of having at least three options of parameters and/or functions that are randomly selected each time the exercise is used. They also offer online checking and suggested solutions. The exercises are grouped in chapters that are the usual in text books in each area. The total numbers of exercises are: Electric & Electronic Circuits – 281; Controls & Servomechanisms – 237; and Signals & Systems – 167. They are in open access and can be found at http://www.maxwell.vrac.puc-rio.br/livros/index.html. Figure 1 shows screen shots of the interactive books.

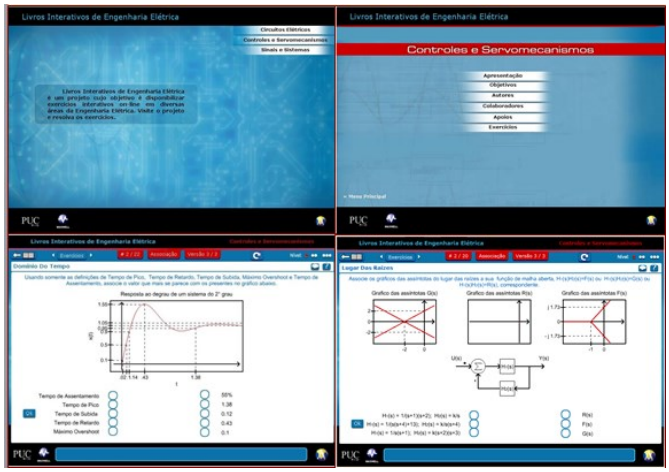

Fig. 1. Interactive books in Electrical Engineering cover, interactive book in Controls & Servomechanisms cover and two exercises.

In parallel, a set of class notes (5 volumes), a study guide and lists of assignments have been created. These are text files.

In 2012, a series of resources was started – *Objetos Educacionais em Engenharia Elétrica* (Learning Objects in Electrical Engineering). Each one is a stand alone content; they are in different areas of EE. They are of varied nature – simulators, animations, small videos and other hypermedia. Currently, there are 44 such objects. Among them, 28 are related to Controls, though they can be used in other courses too. The Learning Objects in EE can be found at http://www.maxwell.vrac.puc-rio.br/series.php?tipBusca=dados&nrseqser=5. Figure 2 shows screen shots of some Learning Objects in EE.

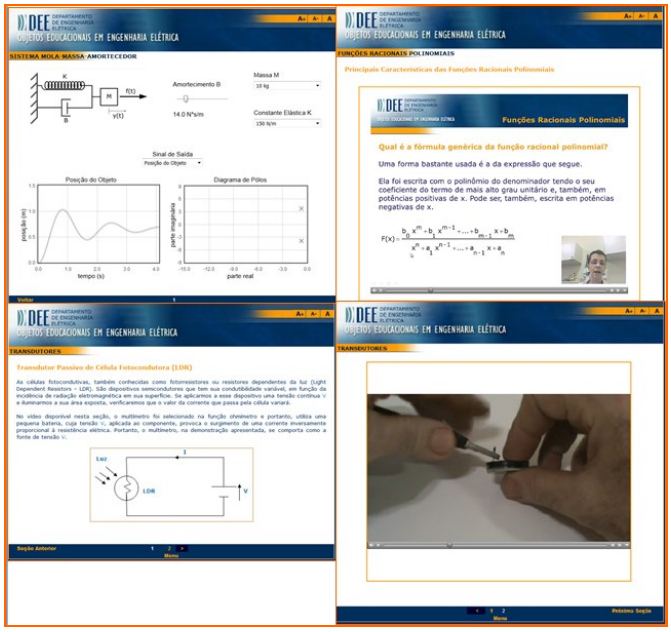

Fig. 2. Learning Objects with a a small simulator, videos and hypermedia.

When the course was switched to b-learning it was necessary to have a resource to guide the student from one topic to the other, to suggest activities, to link to other contents (internal and external links) and to present the main topics. This resource is called *Roteiro* (Course Guide) and also offers 23 short videos that address specific topics. The presentation materials used in the videos are available for students too. Figures 3 shows screen shots of the *Roteiro*. The *Roteiro* allows students a preliminary study of the topic before class so that it is used for discussions and questions on the subject, and also freeing time to solve problems.

Fig. 3. *Roteiro* – table of contents, a definition, a video and an activity.

These resources started being developed before 2015 but they were not discontinued; new items are added every semester.

3. A NEW TYPE OF COURSEWARE DEVELOPED IN AND AFTER 2015

In 2013, Costa-Castello, Guzman, Berenguel and Dormido wrote: "Many concepts have complex visual representations which can not sufficiently be explored through the normal classroom experience. For these reasons, a need arises for a set of applications which provide students the opportunity to visually and interactively explore the classroom concepts without use of pen and paper." (Costa-Castello, 2013). Options of interactive tools have been presented by many authors, as for example the use of Augmented Reality (Restivo, 2014). Ariza (2015) introduced an interactive platform that integrates hardware and software to teach control systems. An interesting use of low cost technology is the implementation of an artifact that each student may have and take to home to experiment with control systems (Taylor at al., 2013). These works are based on the knowledge that experimentation, even if virtual or numerical, leads to a better understanding of concepts.

Engineering courses have been users of MATLAB® for many years. The Electrical Engineering Department of PUC-Rio has this software installed in its labs. Students are proficient

in the use of this product. But to use it students must be at one of the labs during office hours.

Scilab (http://www.scilab.org/) is a free and open source software for numerical computations that can be used to solve problems the same way MATLAB® can. Scilab was used to solve electronics problems (Campos, 2010) in an undergraduate course and was integrated to Moodle, the free and open LMS – Learning Management System.

In order to enhance the interactivity of the online resources for the b-learning course, a decision was made to develop learning objects using Scilab and make them available from the Maxwell System. This new set is called *Simulações em Engenharia Elétrica* (Simulations in Electrical Engineeering) and can be found at http://www.maxwell.vrac.puc-rio.br/series.php?tipBusca=dados&nrseqser=12. The following subsections address this new set.

3.1 Development Strategy

The decision was to focus on Control Systems, though there is a plan to develop for Signals & Systems and Electric & Electronic Circuits too. The development steps were:

- Objects to support topics of the syllabus:
  - Nyquist Stability Criterium – one object with 7 exercises and one simulator was developed. In the simulator the user can define the transfer functions and in the exercises only the parameters.
  - Root Locus Plot – one object with 8 exercises and one simulator was developed. In the simulator the user can define the transfer functions and in the exercises only the parameters.
  - Bode Plot – one object with the RL, RC and RLC circuits, and the spring-mass-damper system.
- Objects with systems that are analyzed and/or controlled by different methods:
  - Inverted Pendulum – one object with the computation of the transfer function and the state-space model, the stabilization using the PID controller, the adjustment of the controller using the Root Locus Plot and control using the State Feedback Controller.
  - DC Motor – one object with the computation of the transfer function and the state-space model, the stabilization using the PID controller, the adjustment of the controller using the Root Locus Plot and control using the State Feedback Controller.
  - Analysis of the RLC Circuit – one object with the Root Locus Plot, the Bode Diagram, the Nyquist Stability Criterium and transient responses due to the impulse, the step and the ramp functions; R is the variable parameter.

There are situations in which the students must practice the methods they are studying – for this need, step one implemented objects for specific methods. For each, transfer functions were presented and the students could change the parameters to observe the differences in the results. For the Nyquist Stability Criterium and the Root Locus Plot an option for the studeents to choose the transfer functions themselves is available. The second step focused a systemic approach to analyze and control a system.

Currently, three systems are under development: spring-mass-damper systems with 1, 2 and 4 degrees of freedom. This work is being supervised by a faculty of Mechanical Engineering.

Figure 4 shows some screen shots of the Inverted Pendulum object.

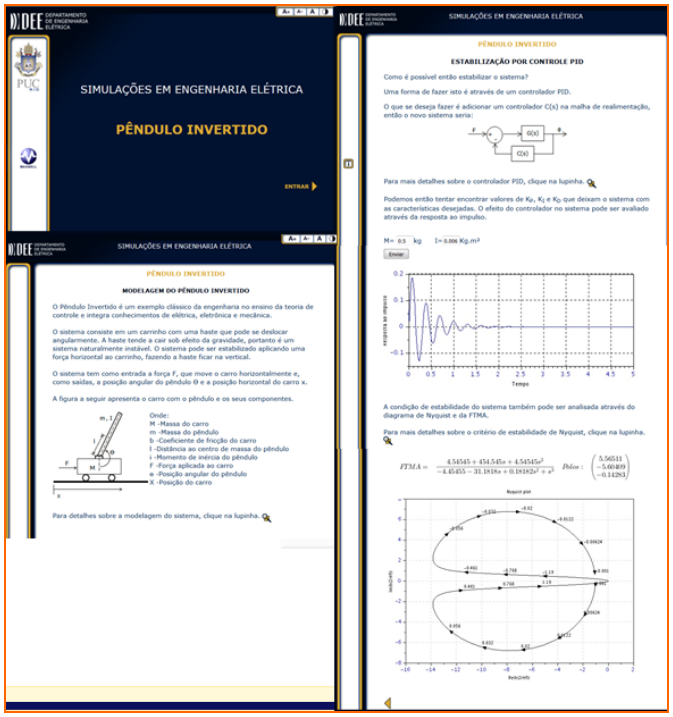

Fig. 4. Inverted pendulum.

3.2 The Integration of Scilab with the Maxwell System

Scilab was installed on a server that communicates with the Maxwell System. This communication works as follows:

- The developers create the Scilab programs (.sci) that implement the systems/methods of each object and also the textual and image files (.doc) that "wrap" the object.
- The two sets of digital files are sent to the Maxwell System technical staff that integrate the Scilab code and the text into a .php program. The interfaces are in html.
- This new object is sent to the information staff to describe and upload into the system. This .php program is stored on the objects server of the system.
- When a user accesses one of the objects, the .php program places a request to the Scilab server that executes the code.

- Once the code is executed, the result is turned into an image and returned to the .php program.
- The .php program displays the result to the user.

Some objects execute multiple functions and so send multiple requests to Scilab generating multiple return images.

3.3 The Developers of the Scilab Modules

The Scilab modules have been developed by undergraduate students of Controls and Automation, and Electrical Engineering – they propose the problems, define the systems and generate the Scilab code. They also write the theoretical explanations that introduce the problems. The programming of the objects , i.e., the integration of all parts, is done by the technical staff. Faculty guide and supervise the students.

4. THE USE OF THE SIMULATORS IN THE B-LEARNING COURSE IN 2015

The Controls & Servomechanisms course is taught in the b-learning mode, so students use the Course Guide to prepare for the traditional face-to-face sessions – they use the text book, online courseware and/or other resources too.

The traditional face-to-face sessions start with doubts and discussions; it is supposed that students previously got to know the topics. Next, students are encouraged to use the ICT resources developed for the course. Faculty assign homework that requires the use of simulators. They are used in class too. The simulations play an important role, since students can modify the system parameters and/or models and/or input functions and see what happens with the system behavior. This allows the students to understand the impacts of the changes. They yield graphic results and are very fast.

In addition to being an important tool for learning, simulators are also handy to the teacher since time consuming blackboard drawings are not necessary anymore. Time can be spent discussing and/or solving additional problems.

The simulators stimulate the students curiosity and present a more "real world" application, linking theoretical aspects to application. An example is the inverted pendulum simulator that allows the visualization the concepts of stability and of two types of classic controllers, verifying their limitations and differences in mathematical modeling.

Simulators were used for the first time in the second semester of 2015. So far there is not a formal evaluation on how students react to them. Informal interaction with students yielded the information that they enjoy using them and think that a better understanding of system behavior is achieved.

An important aspect of the use of the simulators can be observed from the system usage statistics – the uses of specific simulators increased along the semester according to the weeks when the topics were addressed. This happened not only during the traditional sessions but in other days of the week, indicating individual study.

At last, the use of simulators stimulates the students to search several values for the simulation, observing the system behavior and the differences of performance for each controller and the difficulties in tuning each controller.

5. COMMENTS AND NEXT STEPS

The first impression on the use of the simulators by the students was quite positive. This was observed by the faculty who taught the course (the second author). The other resources had been around for a long time and students had been using them. This is an encouragement to follow the next steps which are divided in two groups:

- Resource development

Concerning the simulators, the next steps are to keep developing new objects using Scilab. Besides the three that are under implementation, an airplane system and a watercraft system are planned. The objective is to keep this collection growing the same way the collection of Learning Objects in Electrical Engineering is. Concerning the Interactive Books, currently implemented in Adobe Flash, the plan is to convert all to html 5.

Though the focus of this work is Control Systems, it is important to mention that simulations will be developed to support the Signals & Systems and the Electric & Electronic Circuits courses too. Many objects can be shared due to the common concepts and methods that these courses have.

All learning resources are created in Portuguese and the simulator objects are currently being translated into English. They are in open access and this will be useful.

In order to bring the "real world feel" to the ICT supported tools set, a Remote Lab in Control Systems is planned too. It will allow students to work when and where they can.

- Resource usage

Currently, there is a wide variety of online resources available to support the b-learning course. In the first semester of 2016, a questionnaire will be submitted to students so they can rate different aspects of each and also guide enhancements and future developments.

6. THIS DEMO

This demo has two complementary objectives:

- Present the integrated set of resources that support the b-learning mode of the Control Systems course

Controls & Servomechanisms has been taught in the b-learning mode since 2014.2 – this means for three semesters. To switch to this mode it was necessary not only to have many digital resources but also on integrate them. This mission is a function of the *Roteiro* and also of *Sala Virtual* (Virtual Room). *Sala Virtual* is the environment of the LMS side of the Maxwell System used to deploy distance and b-learning courses. *Sala Virtual* yields access to the course agenda, to grades, the communication tools (chat, discussion

forum, bulletin board) and to the persons in the course (students, faculty, TAs). The integration covers:

- *Notas de Aula* (Class Notes) – 4 volumes of topics on the syllabus and one annex with complementary topics. The annex was written by 9 students as a contribution to the course. All are in .pdf format for linear reading and serve to complement the text book.
- *Estudo Orientado* (Study Guide) – one volume with suggested exercises on all the topics of the syllabus grouped by topic; each has an introduction. It is in .pdf format for linear reading.
- Files with the presentations in the 23 videos of the *Roteiro*. All are in .pdf format for linear reading.
- *Livro Interativo de Controles e Servomecanismos* – this book was presented in section 2.
- *Objetos Educacionais em EE* – this set LOs was presented in section 2.
- *Simulações em Engenharia Elétrica* – this set of LOs was presented in section 3.

During the demo, access to the *Sala Virtual* and the *Roteiro* will be available. They are all in Brazilian Portuguese.

- Present each type of interactive resource

This is the main part of the demo since the session is on Interactive Demonstrations. It is important to remark that all the interactive resources are in open access. They are:

- *Livro Interativo de Controles e Servomecanismos* – the title specifies that the book is interactive. All exercises are interactive and have the objective of allowing students to check the understanding and the mastering of the methods by themselves. The book, as the other two, is in Brazilian Portuguese but it has had accesses from 22 countries since it was launched in Jan.2010 (until Feb.2016). The total number of accesses in 6 years was over 13,000 and over 1,600 came from countries that do not have Portuguese as an official language.
- *Objetos Educacionais em EE* – this set of 44 LOs contains 7 items that are interactive, 3 that have very simple quizzes and 11 with videos. All LOs are in Brazilian Portuguese and have had accesses from 28 since the series started in Aug.2012 (until Feb.2016). The total number of accesses (to the whole collection) in 3.5 years was over 6,700 and over 1,500 came from countries that do not have Portuguese as an official language.
- *Simulações em Engenharia Elétrica* – this set contains 6 items (33 simulating options) in Control Systems and one in Signals & Systems, all of that are interactive. Three additional objects (planned 12 simulations options) are under development. As mentioned, all objects are originally implemented in Brazilian Portuguese and are currently being translated into English. The accesses to these objects deserve a special comment. Early in the project, the months of May to Jul.15, the system had counted 967 accesses coming from Brazil and 36 accesses coming from other countries (USA, Panama, Croatia and others). After the inclusion of this resource in the classroom activities, from Aug to Dec.2015, there were 4,811 accesses from Brazil only (which shows the interest of students in the use of the objects) and 154 accesses coming from other countries (USA, Portugal, Panama, Croatia and others). The simulations have widely been used by students after made available. These data confirm the success of the project and stimulate the team to keep adding objects to the collection. But it also indicates that accesses have grown because more objects have been made available and that the school term runs from Aug to Dec. Other interesting fact is that accesses from other countries are still logged by the system; this is the motivation behind translating the objects to English so that more international students can use them. Access statistics can be seen at http://www.maxwell.vrac.puc-rio.br/Esta_serie_anopais.php.

REFERENCES

Ariza, J. A. (2015). Controlly: Open source platform for learning and teaching control systems, *Proceedings of the 2nd Colombian Conference on Automatic Control,* pp. 1-6, IEEEXplore. DOI: 10.1109/CCAC.2015.7345194.

Campos, D., Dias, N., Dias, A. and Ferreira, H. (2010). Introducing Numerical Analysis Tools in Engineering. A Scilab User Case in Electronics Course. Proceedings of ICERI 2010 – The 3rd International Conference of Education, Research and Innovation, pp. 5178-5184. Available https://www.researchgate.net/publication/235997651_INTRODUCING_NUMERICAL_ANALYSIS_TOOLS_IN_ENGINEERING_A_SCILAB_USER_CASE_IN_ELECTRONICS_COURSE.

Costa-Castello, R., Guzman, J.L. Berenguel, M. and Dormido, S. (2013). An Advanced CAD Tool to Teach and Learn Nyquist Criterion. In S. Dormido (ed), *Proceedings of the 10th IFAC Symposium on Advances on Control Education*, pp. 55-60, IFAC Papers onLine. DOI: 10.3182/20130828-3-UK-2039.00049.

Restivo, T., Chouzal, F., Rodrigues, J., Menezes, P. and Lopes, J.B. (2014). Augmented Reality to Improve STEM Motivation. Proceedings of EDUCON 2014 – IEEE Global Engineering Education Conference, pp. 803-806. DOI: 10.1109/EDUCON.2014.6826187.

Taylor, B. P., Eastwood, P. and Bryn, L. I. (2013). Development of a low cost, portable hardware platform for teaching control and systems theory. In S. Dormido (ed), *Proceedings of the 10th IFAC Symposium on Advances on Control Education*, pp. 208-213, IFAC Papers onLine. DOI: 10.3182/20130828-3-UK-2039.00009.