A Distance Learning Course on Virtual-lab Implementation for High School Science Teachers

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Abstract

A distance course on the implementation of interactive, web-based virtual-labs is presented in this manuscript. This course is part of the Continuing Education Program offered by UNED, the National Open University of Spain. This 120-hour course is intended for high school science teachers who wish to make efficient use of the computer-based simulation in their classes. The simulation environment used to implement the virtual-labs is Easy Java Simulations (Ejs). Ejs is a freeware, open source, Java-based tool conceived to create web-based, interactive virtual-labs.

Course website: http://www.simulab-pfp.dia.uned.es

1. Introduction

Interactive, web-based virtual-labs are valuable educational tools. They allow students to design and perform their own simulation experiments. As a result, students themselves are active players in the learning process, which motivate them to learn.

A distance course on the implementation of interactive, web-based virtual-labs is presented. This course, intended for high school teachers, is part of the Continuing Education Program offered by UNED (Universidad Nacional de Educación a Distancia). UNED is the National Open University of Spain (www.uned.es).

The aim of this 120-hour course is to provide high school teachers the theoretical understanding and the practical skills required to design and implement virtual-labs useful for educational purposes.

The simulation environment used to implement the virtual-labs is Easy Java Simulations (abbreviated: Ejs). Ejs is a freeware, open source, Java-based tool intended to create web-based, interactive virtual-labs [1]. The top three reasons to choose Ejs are the following:

1. Ejs is easy to install and use. Ejs guides the user in the process of creating the virtual-lab. This process includes the definition of the mathematical model and the view (i.e., the user-to-model interface). This simplicity of use comes from the fact that Ejs was designed to be used by educators with a low programming level.
2. Ejs is free software (http://fem.um.es/Ejs/). It can be used and distributed for free.
3. Ejs automatically generates the virtual-lab as a Java application and as HTML pages containing the interactive simulation as a Java applet. Therefore, the virtual-lab can be run as an application and published on the Internet.

Due to Ejs’ simplicity of use, no specific programming skills are required to follow this course.

Due to the fact that Ejs is free software, this course can be offered at an affordable price. And once our students (i.e., high school teachers) have completed the course, they can continue using this very same software in their professional activity. They can use Ejs in their classes and distribute it to their students for free.

The course materials, its content and the procedure to evaluate the student performance are briefly discussed in the following sections. Finally, some virtual-labs implemented by the students during the course are shown.

2. Course materials

The course materials are sent to the students by postal mail. They include:

- A textbook, written by the course team [2]. This is a complete tutorial that covers from basics up to advanced virtual-lab programming. The implementation of several virtual-labs is described step-by-step by using Ejs.
- A CD-ROM, containing the Ejs software and manuals, and the source code of the virtual-labs described in the course textbook.

Students need to install and run Ejs in their own computers, in order to follow the textbook explanations and to develop their own virtual-labs.
3. Course content

The course has been structured into the following three parts (an estimation of the effort distribution percentage is given):

- **Part I.** Modeling & Simulation fundamentals (10%).
- **Part II.** Easy Java Simulations (30%).
- **Part III.** Case studies (60%).

Next, a overview of each of these three parts is provided. The course content is shown in Tab. 1.

### 3.1. Modeling and simulation fundamentals

Several fundamental concepts are explained in Lesson 1, such as “system”, “model”, “experiment” and “simulation”. Different types of models are described: verbal, mental, physical and mathematical models. Several classifications of the mathematical models are discussed [3]: (1) deterministic vs. stochastic; (2) dynamic vs. static; and (3) continuous time vs. discrete time vs. hybrid. Finally, the concept of “the experimental frame associated with a model” [4] is introduced.

Lesson 2 is devoted to the computer simulation of continuous-time models [4,5]. The concepts of “equation” and “variable” are introduced, and the model variables are classified into parameters, algebraic variables and state variables. An algorithm for simulating continuous-time models is described and its application is illustrated. Finally, a systematic method [5] to assign the computational causality of the model is explained and it is applied to several examples.

Lesson 2 provides a basis for understanding the Ejs simulation algorithm and the symbolic manipulations required to write the model in a form suited to Ejs. These two topics are discussed in Lesson 5.

### 3.2. Easy Java Simulations

Easy Java Simulations is introduced in Lessons 3 & 4. Its fundamentals (i.e., an original simplification of the “model-view-control” paradigm) are discussed. Also, its installation and how to run and publish on the internet a virtual-lab are explained.

Lesson 5 describes the Ejs’ procedure to define the mathematical model of the virtual-lab. This procedure is intimately related to the Ejs’ simulation algorithm: the algorithm for continuous-time models (described in Lesson 2) modified in order to support interactivity.

The purpose of Lesson 6 is to introduce the student to the use of the Ejs’ elements intended for composing the view.

### 3.3. Case studies

This third part of the course is a hands-on tutorial of virtual-lab implementation using Ejs. The concepts explained in Parts I & II are applied to the design and programming of virtual-labs with increasing complexity. New concepts are also introduced. Students are supposed to follow the lessons 7 to 15 sat in front of their computers, programming the virtual-labs by themselves. This course part is intended to represent the 60% of the total student’s workload.

The mathematical models of these virtual-labs cover most of the types described in Lesson 1. The models of “the Archimedes’ principle” and “the heat conduction in a wall” are static. On the contrary, the models of “the virtual oscilloscope”, “the limit cycle”, “the pendulum”, “the mechanical system” and “the ball & beam system” are dynamic.

Different types of dynamic models are discussed: (1) the model of “the virtual oscilloscope” is only composed of algebraic equations; (2) the model of “the limit cycle” is only composed of ordinary differential equations; (3) the model of “the simple pendulum” and “the aerostatic balloon” is composed of algebraic and differential equations (DAE); (4) the model of “the ball & beam system” is hybrid; and (5) the model of “the mechanical system” is a DAE-hybrid with a variable structure.

Finally, the “pi estimation” lab implements a stochastic technique: the Monte Carlo method.

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Four of these virtual-labs are shown in Fig. 1. The “multi-layered wall” virtual-lab is used to illustrate the steady-state heat conduction in three-layered walls (see Fig. 1a). The “aerostatic balloon” lab is a nice example of application of the Archimedes’ principle (see Fig. 1b). The atmospheric temperature and pressure, and the ballast weight can be interactively changed. The gas burner can be switched on and off.

The “mechanical system” lab (see Fig. 1c) simulates a system composed of a spring, a dumper and two contacting bodies with friction. Finally, the “ball & beam system” is composed of a beam attached to a motor, and a ball placed on the beam (see Fig. 1d). The ball is allowed to roll with one degree of freedom along the length of the beam. The control goal is to place the ball at certain position by changing the beam angle. This system can be controlled manually or with a PID.

4. Evaluation of the student performance

Students can receive a grade of “pass” or “fail”. The grade is not based on a exam (in fact, this course has not exams or tests). In order to pass the course, the student has to design and implement two virtual-labs: a simple one and other of a higher level of complexity. The student has to develop the virtual-labs in his own computer and to send then to the course team by e-mail. The virtual-lab topics are chosen by the students.

A selection of the virtual-labs implemented by our students is provided at the course website. It is intended to illustrate what students are able to do as a result of the course. Some of these virtual-labs are shown in Figs. 2 & 3, and they are briefly described next.
Fig. 2. Virtual-labs implemented by course students
Fig. 3. Virtual-labs implemented by course students
4.1. Emission spectrum of the hydrogen atom

This virtual-lab tries to explain how emission spectra are produced (see Fig. 2a). Bohr’s model is used to obtain the emission spectrum of the hydrogen atom. The initial (n2) and final (n1) energy levels of the transition can be selected. An schematic representation of the transition is automatically displayed on the right side window, and the emission spectrum is shown.

4.2. Electric circuit

The electric circuit is composed of a battery and four resistors (see Fig. 2b). The user is allowed to modify the resistance values and the battery voltage. The new values of the currents and voltages through/across the components are automatically calculated and shown in this virtual-lab.

4.3. Galton Box

This virtual-lab simulates a Galton Box used in the study of binomial probability distributions (see Fig. 2c). This device is a triangular board that contains several row of staggered but equally spaced pegs. Balls are dropped from the top, bounce off the pegs and stack up at the bottom of the triangle. The balls have equal probability to bounce left or right. The user is allowed to change the number of boxes and the number of throws.

4.4. Kinetic of chemical reactions

The kinetic of the following chemical reactions is calculated (see Fig. 3a):

\[ \text{A} \xrightleftharpoons[K_{\text{eq}}]{K_{\text{a}}} \text{B} \xrightarrow[K_{\text{c}}]{K_{\text{b}}} \text{C} \]

Three sliders allow changing the value of the rate coefficients (\( K_{\text{a}} \), \( K_{\text{b}} \) and \( K_{\text{c}} \)). Radio buttons allow selecting among the following three approximations: stationary state, fast pre-equilibrium and irreversible reactions. The concentration profiles obtained at the selected conditions are shown.

4.5. House heating

This virtual-lab shows the heat flow through the walls, doors, windows, roof and floor of a typical house (see Fig. 3b). The user is allowed to select: (1) the material and the thickness of the walls and the roof; (2) the thermal efficiency of the windows, the doors and the floor; and (3) the temperature inside and outside of the house.

In addition, the daily and monthly costs for four different heating systems (i.e. gas-oil heater, radiant heating, heat pump and electric thermal storage) are calculated. The external temperatures used for these calculations are the temperatures recorded in the city of Badajoz (Spain), during January 2005.

5. Conclusions

A distance course on the implementation of web-based virtual-labs has been presented. It is part of the Continuing Education Program offered by UNED, the National Open University of Spain. The course audience is high school teachers who wish to make efficient use of interactive simulation in their classes. As a result of this 120-hour course, they will have the skills to design and implement virtual-labs useful for educational purposes.

The course material is a textbook (written in Spanish) and a CD-ROM containing the virtual-labs discussed in the textbook. The software used is Easy Java Simulations (Ejs). It is a free, Java-based tool intended to create web-based, interactive virtual-labs (http://fem.um.es/Ejs/). An online, concise version of the course (written in English) is available for free on the course website (http://www.simulab-pfp.dia.uned.es).

6. Acknowledgements

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7. References


