Using Xcos as a Teaching Tool in a Simulation course

A. LEROS $^{1,2}$ and A. ANDREATOS $^{2}$

1) Department of Automation  
School of Technological Applications  
Technological Educational Institute of Chalkis  
34400 Psachna, Evia  
GREECE  
lerosapostolos@gmail.com

2) Div. of Computer Engineering & Information Science  
Hellenic Air Force Academy  
Dekeleia Air Force Base  
Dekeleia, Attica, TGA-1010  
GREECE  
aandreatos@gmail.com
Topics

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2 Basic concepts of Simulation
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Abbreviations:
HAFA = Hellenic Air Force Academy
FOSS = Free & Open-Source Software
Xcos = the Visual programming tool of Scilab.
Abstract

Simulation is a powerful tool for understanding and assessing the operation of systems, as well as, natural phenomena. At the Hellenic Air Force Academy a Simulation course is offered to engineering cadets during the 2\textsuperscript{nd} year of studies; it is a fundamental and prerequisite course for future specialisation courses.

The ability to model systems --either existing or under design-- in order to better understand their operation under various conditions is mandatory for Engineers.

Simulation is a very important learning process because it enables learners to easily experiment with natural concepts, phenomena and systems. This paper proposes Xcos as a teaching tool in our Simulation course.
1/ Introduction

- Simulation is a powerful tool for understanding and assessing the operation of systems.
- At the HAFA, Simulation is offered as a background course and a prerequisite for specialisation courses to the specialisation of Telecommunications and Electronics Engineers.
- Such courses include: Signal Processing, Radar Systems, Telecommunications, Antennas and Propagation, Queuing Theory and Computer Networks, etc.
2 Basic concepts of Simulation

1. **System** is an object or a collection of organically inter-connected objects, whose properties we would like to study.

2. **Experiment** is the process of applying signals at the inputs of a system in order to extract information by studying its outputs or by observing and measuring its behaviour.

3. **Model** of a system is an abstract mathematical or simplified physical construct which we consider that it represents the system, i.e. behaves like it under specific circumstances or conditions. The use of a model is to give us relatively easy indications of the behaviour of the real system. The study of the behaviour of a system is achieved by controlling specific parameters. The creation of models is simplified significantly with the use of special modelling software. The mathematical models and the simulation techniques are presented in the following Fig. 1:
Fig. 1: Models and simulation techniques

- **Mathematical Models of Systems and Simulation Techniques**
  - **Deterministic**
    - **Static**
    - **Continuous Time**
      - Optimization Solutions
  - **Dynamic**
    - **Discrete Time**
      - Monte Carlo Simulation
  - **Stochastic**
    - **Static**
      - **Continuous Time**
    - **Dynamic**
      - **Discrete Time**
      - Discrete-Event Simulation
Why study systems?

a) To understand the physical world and to build our knowledge.

b) To satisfy our scientific curiosity, i.e. understand better the nature (natural science viewpoint).

c) To build or to improve our own systems (engineering point of view).
Reasons for performing a simulation

a) Pedagogical reasons: Effective learning through the “construction of knowledge”. The simulation gives us the ability to experiment with the model of a system in the classroom and/or at home, in order to understand better the physical meanings.

b) Economic reasons: The experiment is economically very expensive. Example: The determination of the endurance of airplanes or spacecrafts by constructing them and then by crashing them through experimentation is an uneconomical method to obtain information.

c) Security reasons: The experiment sometimes is dangerous: The training of nuclear plants operators for crisis management by driving the nuclear reactor in risky operating conditions is not a safe method.

d) Design of new systems: The system in need for experiments might not yet exist: This is part of the process to design new systems yet under construction.
Reasons for performing a simulation

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b) Economic reasons: The experiment is economically very expensive. Example: airplanes.

c) Security reasons: The experiment sometimes is dangerous: The training of nuclear plants operators.

d) Design of new systems: The system in need for experiments might not yet exist.
Example: simulation of nuclear fission
Reasons for performing a simulation (2)

e) Suppression of disturbances: In a simulation of a model it is possible to suppress the disturbances which might not be avoided in measurements in the real system.

f) Simulation for redesign and validation of analytical models of systems (Fig. 2): Using the results of simulation it is possible to modify a model of the system in order to incorporate in it details which originally were not included. It is also possible to conduct various types of analyses.

g) Validation of analytic modelling: The analytic modelling of systems often demands assumptions for simplification which make the results suspicious until these have been verified by other techniques, such as simulation. Fig. 3 shows the role of simulation to the validation of an analytical model.
Fig. 2: The role of simulation in redesign
Fig. 3: Simulation for validating analytical models
Examples of experiments or simulations

a) Simulation of the behaviour of vehicles, e.g., an airplane or automobile, for the purpose of operator training.

b) Simulation of a manufacturing process, such as metal or paper, for learning the behaviour of the process under various operating conditions and for its improvement.

c) Simulation of a simplified model of a computer network, for studying its behaviour of performance under different demanding loads.
Example from Computer Networking

No mobile station can hear the other mobile stations.

There is one access point and three mobile stations. The mobile stations cannot hear each other’s transmissions. To operate the applet, first click on “Start”. Then click on a station button whenever you want that station to emit a frame.

<table>
<thead>
<tr>
<th>Emit Frame</th>
<th>Queue</th>
<th>BackOff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station 1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Station 2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Station 3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Access Point</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend
- **Frame type**:
  - RTS
  - CTS
  - Data frame
  - ACK
- **Carrier sensing**:
  - Medium free
  - Medium busy
  - NAV: Medium considered busy
Pedagogical value of Simulation

The pedagogical value of Simulation is its ability to implement modern learning theories in education such as constructivism, collaborative learning, social learning, and learning by discovery.
8.2 Conservation of energy in a roller coaster

<table>
<thead>
<tr>
<th>Cart height</th>
<th>m</th>
<th>Potential energy</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cart speed</td>
<td>m/sec</td>
<td>Kinetic energy</td>
<td>J</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total mechanical energy</td>
<td>J</td>
</tr>
</tbody>
</table>

Gravity = 9.8 \text{ m/sec}^2

Mass of cart = 150 \text{ kg}

Cart speed at bottom = \_ \_ \_ m/sec
3/ Simulation software and selection criteria

- Full coverage of the Simulation course syllabus.
- Existence of specific toolboxes supporting specialisation courses.
- Operation on Windows as well as Linux platforms. Most courses of the Computer Engineering and Information Science Division are offered on Linux platform.
- The power of the programming language. All Matlab-like languages share this advantage. Thus, high Matlab compatibility matters.
- Wide user community and technical support.
- Steep learning curve.
Specifications (2)

- Compliance with software compatibility rules.
- User-friendly Graphical User Interface (GUI).
- Existence of bibliography in Greek and English.
- Cost effectiveness.

- Taking all of the above into account, as well as, the existing instructor's asset, we have chosen GNU Octave as the best software for our needs.
4/ Educational policy of the Computer Engineering Division

- Introducing FOSS in an effort to cover educational and infrastructural needs;
- Maximise student learning experience with different software tools and programming styles;
- Independence of specific products and suppliers;
- Use many different software products in our courses, and FOSS is a convenient option.
The migration from Matlab to Octave

Starting from the fall 2008 semester, we began using both Matlab and Octave in the simulation course. This way we could achieve at least three things:

a) compare their possibilities and features in relation to the course syllabus;

b) check their compatibility;

c) check student acceptance.

Plan was successfully implemented.
However, a small gap remained:

- we had no substitute for Matlab's companion, Simulink, a powerful graphical simulation environment.
- Simulink is based on the “G” visual programming language which enables the user to easily and quickly design a system without the knowledge of a typical programming language.
- The gap was small because there was very little time left at the end of the course.
- However, a graphical simulation tool might prove useful in coming courses as well as, the thesis, and is a great teaching tool.
Discovering the Xcos tool of Scilab

After further research we discovered that the Xcos tool of Scilab (another FOSS alternative to Matlab), could nicely substitute Simulink.

So the new educational plan of the Simulation course which we are running this semester (fall 2011) is:

a) to teach the basic theory in Octave/ QtOctave on Linux platform and then:

b) jump to the Xcos tool of Scilab by the end of the course.
Scilab

Scilab Console

scilab-5.3.3

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Startup execution:
loading initial environment
Xcos (1)
Many common systems are represented by a linear differential equation of second order. Examples:

a) An electrical circuit consisting of an inductor, a resistance, and a capacitor in series.

b) A sphere tied to a spring on a level (plane) with friction, on which a force is applied to.

c) A locomotive (kinetic) system of a motor engine.
The equations of all the above systems can finally be presented by the equation:

\[
\frac{d^2 y(t)}{dt^2} + 2\zeta \omega_n \frac{dy(t)}{dt} + \omega_n^2 y(t) = \omega_n^2 u(t)
\]

- where the variables \( y(t) \) and \( u(t) \) represent the output and the input of the system respectively, \( \omega_n \) is its natural frequency and \( \zeta \) is the damping coefficient.
Fig. 4: Model of a second order linear differential equation in Xcos
Where:

- In the above figure, with reference the mechanical system, $y(t)$ is the displacement, $dy(t)/dt$ is its velocity and $dy^2(t)/dt$ is its acceleration.
- Choosing $\zeta = 0.2$ and $\omega_n = 1$ and placing scopes at appropriate points (see Fig. 4) we obtain the following results (Fig. 5, 6 and 7):
Fig. 5a: Position versus time
Fig. 6a: Velocity versus time
Fig. 7a: Acceleration versus time
The major advantages of simulating such systems with Xcos are:

a) The design of the model in Xcos is easy (visual) and does not require programming knowledge.

b) As soon as the trainees acquire the model, they can very easily experiment with it, to build their personal knowledge.

Thus, a visual simulation tool such as Xcos or Simulink constitutes a great learning and teaching tool, according to modern learning theories used in education, such as constructivism and learning by discovery.
Example

• Indeed, the regulation of the two Gain components in Figure 4 above is equivalent to changing the coefficients $2\zeta \omega_n$ and $\omega_n^2$ of equation (1).

• Double-clicking the gain blocks, the gain coefficient appears and we can easily enter any value. Consequently, the possibility is provided to the trainee to experiment and study the impact of the coefficients of the system on the position, the velocity and the acceleration of the object.

• According to the theory of oscillations, when $\zeta$ approaches 0, the system falls in oscillations. For pedagogical purposes, we give the position of the object for two more (small) values of $\zeta$, specifically: 0.05 and 0.01 in Figure 8:
Fig. 8a: Making $\zeta$ smaller drives the system to oscillations
Conclusions

- **3-year migration plan succeeded:**
- The transition from Matlab to Octave presented no difficulties for the HAFA students. Octave was a good alternative because of its toolboxes, high programming language compatibility and the QtOctave GUI.
- An evaluation questionnaire verified student acceptance (refs).
The next step is the substitution of Simulink with the Xcos tool of Scilab

Evaluation results presented here show that this migration will also be successful because of the high compatibility of Simulink – Xcos function and libraries.

Neither Octave nor Scilab can fully substitute Matlab with Simulink, because:

a) Octave language is highly compatible to that of Matlab and this was considered an advantage for the reasons explained in (Andreatos & Leros, 2010a; 2010b), Octave has a huge set of toolboxes but no tool like Simulink.

b) Scilab has a good visual programming tool, namely Xcos, which can successfully substitute Simulink, although less “polished”.
Xcos-Simulink comparison (1)
Comparison (2)

Simulink ==>

<= Xcos
The tutorial has shown that:

- not only Xcos suffices for our purposes, but also, it constitutes a great teaching and learning tool, for the following reasons:
- it uses visual programming, hence it does not require advanced programming skills;
- it enables the design and simulation of systems in a few minutes;
- we can easily test the effect of various parameters on system behaviour and performance.
The use of more than one software products in a single course

... is not considered a problem but rather an advantage, which, according to our educational policy, makes future engineers eager to test and adopt new tools, instead of being stuck to only what they have used during their studies.
END of the PRESENTATION

• Thanks for listening.
  – Any questions?

• More:
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To contact us: aandreatos @ gmail.com