

2004-01-01

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Recommended Citation

O'Dwyer, Aidan :Using information technology to enhance control engineering education: some experiences. EdTech 2004: the 5th Annual Irish Educational Technology Users Conference, Institute of Technology, Tralee, June. doi:10.21427/3rt7-qh23

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Using Information Technology to Enhance Control Engineering Education: Some Experiences

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Abstract: In the past decade, the use of computer based design and analysis tools, such as MATLAB/SIMULINK, has revolutionised practice in Control Engineering. Concepts that were previously only understandable after sustained mathematical analysis or experimental work may now be readily simulated on the computer. Over the past four years, the author has experimented with the use of MATLAB/SIMULINK, in the lecture and laboratory environment, with degree and taught masters students in control engineering at Dublin Institute of Technology (DIT). It has been found that the tool helps to increase student understanding of challenging topics, to act as motivation to further exploration and to demystify important design ideas. The author has also explored the use of interactive computer based tools that automate much of the design iteration, and provide, on the computer screen, the appropriate images of the iteration process. Such tools further enhance the quality of the learning experience for the student (particularly in a self-learning mode).

1. Introduction:

Engineering is concerned with understanding and directing the materials and forces of nature for the use and convenience of humankind. *Control engineering* is concerned with the understanding and control of machines, processes and industrial automation systems to provide useful economic products for society. Control engineering is based on foundations of feedback theory and linear systems analysis. It is not limited to any engineering discipline but is equally applicable to aeronautical, chemical, mechanical, environmental, civil and electrical engineering [1].

A control engineering educator has the challenge of communicating a wide variety of concepts, ideas and techniques, to provide students of the discipline with both a strong theoretical base and good practical ability. In addition, the educator increasingly has the responsibility of providing students with the fundamental skills that are required for life long self-learning. Theoretical issues, which often involve mathematical and physical analysis, have tended to be taught in the classroom. Practical ability, which requires intuition and insight, has been traditionally conveyed through extensive laboratory work. However, time available for classroom and laboratory work has gradually been reduced, in response to pressure to reduce class contact hours and the increasing desire to facilitate student self-learning.

The use of computer aided design and analysis tools, which facilitate student self-learning and enhance theoretical understanding and practical ability, is one way to increase learning efficiency. In the past decade, the use of tools such as MATLAB/SIMULINK [2], sometimes with graphic user interface enhancement, has revolutionised practice in control engineering. Computer simulation has allowed the study of a greater range of problems than would be possible through either mathematical analysis or laboratory work.

2. Control Engineering at DIT

Automatic control is an integral part of degree and taught postgraduate programmes run by the School of Control Systems and Electrical Engineering at DIT, Kevin Street. The following programmes include modules in various facets of the subject:

B.E. in Electrical/Electronic Engineering (4 year honours degree, validated by the Institute of Engineers of Ireland).

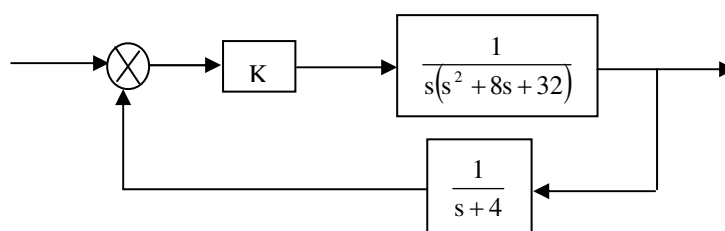
- Year 3: Control and Automation. This module is run over 14 weeks; it was taken by 60 students in the 2002-2003 academic year.
- Year 4: Control Engineering (Major). This module is run over 28 weeks; it was taken by 29 students in the 2003-2004 academic year.
- Year 4: Time Delay Systems (Elective). This module was run over 16 weeks; it was taken by 18 students in the 2003-2004 academic year.

M.E. in Advanced Engineering (1 year, taught masters course). Students choose five modules, followed by a dissertation. Each module has a yearly class contact time of 90 hours. Advanced Control Systems was one of the five modules, taken by 12 students, in the 2002-2003 academic year.

In addition, Control and Automation is offered on the part-time B.E. in Electrical Engineering as an option subject (this option ran in the period 2000-2002); it is also taught on the B.Tech. pass degree in Control and Automation Systems and the B.E. degree in Manufacturing Engineering.

The author is responsible for instruction on the Control Engineering (Major) and the Time Delay Systems (Elective) subjects in the B.E. in Electrical/Electronic Engineering, the Control and Automation subject in the part-time B.E. in Electrical Engineering and the Advanced Control Systems subject in the M.E. in Advanced Engineering. Typically, undergraduate courses would, after introducing basic ideas, explore the construction of time domain and frequency domain diagrams (e.g. root locus diagrams, Bode plots, Nichols charts), followed by controller design methods using these plots. Final year work would typically include process control ideas, adaptive control algorithms and the analysis of non-linear systems. The postgraduate taught course would place more detailed emphasis on, for example, process modelling and controller design.

Taking controller design methods as an example, significant time would be devoted to classical controller design (i.e. the design of PI, PID, phase-lead and phase lag controllers). The construction of the necessary time domain and frequency domain diagrams is greatly facilitated by MATLAB. In an example, the root locus of the feedback control system shown is developed, using the standard analytical technique, in the class.



The analytical development has eight subsections, and takes four A4 pages to complete for the example. In contrast, MATLAB will calculate and draw the root locus using three commands:

- num = [1];
- den = [1 12 64 128 0];
- rlocus(num,den);

The design of controllers also benefits from the use of MATLAB, as such methods involve significant computation; in addition, a number of iterations of the design often needs to be performed before the final design is satisfactory. SIMULINK, a block-diagram based offshoot of MATLAB, is particularly useful for the validation of the design.

Both traditional analytical design techniques, and computer aided design techniques, are covered in the lecture environment. The MATLAB/SIMULINK programmes are simultaneously placed on the student network so that students can access and interact with the simulations outside of the classroom; hundreds of such programmes, developed over four years, are available. The simulations are also used in the laboratory environment to allow the students to rapidly design and test controllers, prior to implementing the controllers on real processes.

Broadly, the objectives of using computer aided design techniques (i.e. to increase student understanding of challenging topics, to act as motivation to further exploration and to demystify important design ideas) have been achieved. The students have been introduced to MATLAB in previous years of their courses, though it is important to spend time with the students (typically over two two-hour laboratory sessions) in re-familiarising them with basic concepts in the use of the package. Student feedback has been broadly positive; however, only the more motivated students are interested in taking the simulations and experimenting themselves with different designs. Typically, it is the part-time students and the M.E. students that are willing to do this, perhaps because their maturity allows them to see that a little time invested in this activity has a disproportionate educational benefit.

3. Other tools

The MATLAB/SIMULINK software package, though very useful, does not completely dispel the confusing and laborious process often involved in design. To enhance the quality of the learning experience for the student (particularly in a self-learning mode), there is a real need for an interactive computer based tool that automates much of the iteration, and provides the appropriate images of the iteration process on the computer screen. Such interactive tools are a great stimulus for developing the students' engineering intuition. There has been a significant amount of work in recent years in the

development of these tools [3-7]. Some recent books also have an associated website, with interactive features [8-12]; the book by Messner and Tilbury [8] is particularly recommended. The development of virtual laboratories, in which experiments may be performed remotely over the internet, has also been the focus of attention (see, for example, [13-14]); other resources available on the internet include lecture notes ([15]-[16]).

4. Conclusions

The twin pressures of the need for students to learn a wider variety of concepts, ideally in a self-learning mode, and the reduction in class contact time has led to the use of increased levels of information technology in control engineering education. At DIT, work thus far has concentrated on the use of the MATLAB/SIMULINK computer aided design package to enhance student learning. Some work has also been carried out on the development of a graphic user interface to MATLAB/SIMULINK, to allow a more diagrammatic interface to the student [17]; some details of this work will be presented at the conference. It is anticipated that information technology, in all its manifestations, will have an accelerating impact on control engineering education.

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