

The 2005 IFAC Congress Invited Panel Session: RETHINKING CONTROL EDUCATION IN THE MODERN WORLD

Organised by the IFAC TC on Control Education, this Session is aimed at provoking discussion on numerous challenging questions that will influence the ways in which we will teach control topics in the future.

In an effort to make the discipline of control more attractive to students we often introduce this subject as an enabling technology in the context of embedded electronic systems, intelligent robots, mechatronic systems, advanced communication systems, space technology, etc. While this approach works well in promoting the field of control, it however raises numerous questions such as:

- a) how much of the advanced computing technology do we need to use in presenting the basic control topics?
- b) are we going to fall into the trap of being technology driven and thus, in the long term, start to lose analytical problem solving skills?
- c) are we about to change the way we teach control?
- d) are all of these approaches going to change the profile of the control discipline?

Do we need to worry about these changes or, maybe, even strongly support them?

Here is what the invited panelists Christos G. Cassandras, Ted Djaferis, Sebastian Dormido, Stephen Kahne, Richard Murray and Mark Spong wish to say.

Statements by the Panelists:

Mark W. Spong

University of Illinois at Urbana Champaign, USA

The challenge of preparing students for lifelong learning.

We face the conflicting objectives of:

- a) preparing students for a 40 year career and
- b) providing them with real world skills needed to get good jobs and succeed as practicing engineers after graduation.

These objectives are somewhat conflicting for the following reasons:

- a) we have no idea what the world will look like in 10 years, let alone 40. Preparing students for lifelong learning requires that we teach strong fundamentals - mathematics, physics, as well as writing and communication skills.
- b) to prepare them to hit the ground running after graduation requires, first of all, that we keep them excited about engineering, and that the means

motivating them with fun projects, toys, competitions, etc. should include material on the latest technology in our courses - technology that will most certainly change in a few years. Also, companies are increasingly asking that students have experience in teamwork, leadership activities, as well as exposure to business topics.

It is increasingly hard to satisfy both a) and b) in an education period of 4 years. In many ways, I see this conflict being won in favour of b) at the expense of a loss of fundamentals - at least in the U.S.

Control for the liberal arts.

Control systems are so pervasive in modern society that every educated person, not just control engineers, needs to have a basic understanding of the technology behind control systems and how it will impact their lives. This is important for many reasons such as:

- a) privacy - the pervasive use of sensors (cameras, biometrics) in airports, etc., impacts on privacy and personal liberty.
- b) security - the creation of large interconnected networks of computer databases poses not only privacy concerns but also security concerns
- c) critical infrastructure - how do SCADA systems for power systems, etc. work and how can they fail.
- d) public policy - people need a knowledge of control technology to make basic policy decisions.

There are many other such issues. What would be the ideal course to teach to all college and university students?

Sebastián Dormido Bencomo

Universidad Nacional de Educación a Distancia, Spain

Interactivity and Virtual Labs in Control Education

- a) Many more people need control - How do we handle that?
- b) How do we deal with the rapidly increasing knowledge base in control both with respect to graduate and undergraduate education?
- c) How do we interface with communication and computing?
- d) How do we exploit technology? The role of interactivity, virtual and remote labs in control education.

Stephen Kahne

Embry-Riddle Aeronautical University, USA

MATLAB as the first programming language for control engineers

There is little doubt that computer programming is a necessary tool in the toolbox of a control engineer. However there is a tendency to think of this skill as being synonymous with "knowing how to use MATLAB". Our experience has been that the MATLAB language is, indeed, suitable as a first computer language for engineering

students but the way it is often taught, the exercise is more akin to training in MATLAB syntax than in the effective acquisition of programming skills using a language designed to be a particularly good match to the needs of engineers.

We have found that the hardest thing for students to learn when taking their first programming course is to think algorithmically. Their first tendency is to play rather than to think. One of beauties of computer programming for engineers is that the same sort of thought process needed to be an effective programmer is needed to solve engineering problems - a systematic and algorithmic approach to analysis and design.

In this talk we will explore some of the features of MATLAB that tend to emphasize good programming practice and to suggest the emphasis that is needed in textbooks and teaching aids when using MATLAB as a first programming language for engineers.

Christos G. Cassandras
Boston University, USA

The role of computer simulation in teaching systems and control theory.

While the hands-on laboratory experience is irreplaceable, laboratories are also expensive to build and maintain and involve a non-classroom setting which lacks the immediacy of teacher-student interaction and the value found in group discussions. Moreover, complexity and economies of scale do not allow us to have laboratories for the kinds of systems we build and need to control today. Computer simulation provides an "electronic laboratory" that is easily brought to the classroom. It can be used to illustrate basic concepts and methods (for analysis purposes), as well as let students build systems and explicit controllers (for synthesis purposes). Although simulation tools (e.g., Simulink) have reached a considerable level of maturity, they are not really part of the mainstream control theory classroom and one has to wonder why that is... One could argue that simulation tools are too "sanitized" to reflect reality. However, the capabilities of such tools, including graphics and visualization features, are now at a point where we can create convincing and exciting virtual reality.

Balancing the mathematical and technological components of control theory.

There is an indisputable and well-publicized dilemma we all face: Inevitably, control theory is a heavily mathematical subject that can turn off many otherwise smart and interested students; to compensate, we now often talk about "making control fun", using technology (including computer simulation that I advocate above...), inventing toy-like exercises, real-world projects, etc. It is hard to balance these two components and avoid either teaching control as essentially an applied mathematics course or going to the other extreme where control becomes a collection of "fun" problems playing with an inverted pendulum, controlling a toy plane, or simulating controllable manufacturing processes using canned hardware or software "black boxes". Is there a recipe for motivating the need for mathematical infrastructure through "fun" projects? Or for making the math come to life by leading directly to the solution of a real-world problem one can simply not solve with ad hoc or seat-of-the-pants basic engineering approaches?

Theodore Djaferis
University of Massachusetts

Control bridges

My comments here are relevant in a much broader context but here we focus on control. Control programs in engineering schools have been doing a great job at educating control engineers and scientists. Comprehensive programs exist that begin at the undergraduate level and lead to specialty technical areas in graduate school. Their goal is to prepare the next generation of control researchers and application engineers in established technical areas. Our impact on society can be significantly increased if we broaden our horizons and develop "bridges" (i.e., educational programs and material) for conveying control concepts, principles and practices to a much broader audience. These programs and material should be appropriately tailored to reach the intended audience. Specific material should be developed for the K-12 group that will improve their educational experience and motivate students for a career in systems and control. Programs should be established that reach outside engineering to undergraduate students in fields like biology, business, economics and the liberal arts. Courses and programs should be established at the graduate level to facilitate graduate education in multidisciplinary fields (e.g., bridges to biology, meteorology and medicine) and empower research. In fact, this process can be significantly enhanced if colleagues from these areas are encouraged to do the same from their end. There are many challenges in pursuing such a course of action the first of which is the realization that change is difficult. How do we pursue this agenda while at the same time preserving the successful programs that currently exist? Where will the support come from? Which is the best way to proceed? Should control organizations play a key role in this effort? These are important topics that warrant further discussion.

Richard Murray
Caltech CDS, USA

Eliminating the Laplace transform from undergraduate control courses

Virtually all introductory courses on control begin with a review of the Laplace transform and its use in modeling linear, time-invariant input/output systems. This is a natural (and rigorous) mechanism for introducing the transfer function and the key concepts in control, but it has many drawbacks that limit its applicability in teaching control at the undergraduate level and to a broad audience. First, in many disciplines it forces control courses to be taught in the 3rd or 4th year of undergraduate studies, after complex variables and the Laplace transform have been covered in pre-requisite mathematics courses. Second, it forces a frequency domain approach to control that is not necessarily the most natural for students in biology and computer science, where sinusoidal response is not necessarily the most natural input/output representation of a system. And finally, it crowds out more important and relevant topics such as Lyapunov functions and limit cycles that should be a central part of any first course in feedback systems. In this talk I will describe our experiences at Caltech in eliminating Laplace transforms from our first year course in control and argue that this approach be taken more broadly.