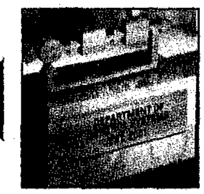

special section

Future Directions in Control Education

Bonnie S. Heck, Guest Editor

As the year 2000 quickly approaches, some pondering is in order on where we stand as a community and where we are headed. Control has a rich history dating back to applications in ancient times; however, most of the accomplishments are rooted in this century. Control emerged as a recognized specialty of engineering with development of the classical control methods in the 1930s and 1940s. The major applications initially were in the military arena, then extended quickly to manufacturing, aerospace, electromechanical devices, process control, and so on. Although the classical methods served the engineering community well for 50 years, newer engineering technologies and tighter performance and quality control specifications have stretched the capabilities of classical control to its limits. Rising to the challenge, researchers in academia and government and industrial labs began to develop more complex design methods suitable for meeting tight performance specifications, even for systems that might be large-scale, multiple-input/multiple-output, nonlinear, and might have uncertainty in the models. Although these methods initially existed only in the pages of conference proceedings and journals, they began to make their way into the graduate-level curriculum, starting with the optimal control methods being taught broadly in the 1970s. Currently, many graduate programs regularly teach cutting-edge control design techniques. Even many of the modern techniques such as optimization methods, nonlinear control, fuzzy logic, and neural networks are making their way into the undergraduate curriculum. As students trained in these techniques began to graduate and take on project-leader roles in industry, the infusion of these modern methods into the industrial setting began on a larger scale.

Concurrent with the evolution from classical to modern control, the whole of engineering has seen a revolution from "back-of-the-envelope calculations" and intuitive thought toward complex computer-aided design and analysis methods. Dramatic technological advances in semiconductor fabrication, VLSI design, computer architectures, materials, and communications have brought forth new challenges for educators to teach relevant engineering techniques and applications. As a result, many schools have had to revise their curricula dramatically in recent years. For example, the School of Electrical and Computer Engineering at Georgia Tech has had two major revisions within the last seven years. Even the title of the school has undergone transition (as have many others) from the old title of School of Electrical Engineering, reflecting the changing emphasis of the school and the changing orientation of the students. Currently, more than half our students are majoring in Computer Engineering. The computer has become dominant in virtually all fields of engineering. Where does this place traditional specialties within the teaching of engineering? Specifically, where does control education fit into this spectrum? And where should it be headed?

This special issue brings together articles that give a philosophical perspective on the future directions of control education. Most of the papers are based on opinions of well-respected educators (who are, by the way, also well-respected researchers). As noted in the articles, certain recent trends in control education can be identified. First is the already mentioned movement of modern control design techniques into the undergraduate curriculum. Second is the infusion of computer technology into the classroom, starting with out-of-class assignments (such as design and analysis using specialized software), extending to the use of the computers in the classroom (such as giving on-line demonstrations) and to making the computer an integral part of the educational process (such as the replacement of traditional laboratories with virtual or remote laboratories). A third trend in control education, which is seemingly at odds with the previous

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statements, is a return to the roots of the field; that is, a return to the more practical side of controls with a de-emphasis on the more mathematical methods that have dominated the educational process in recent years. This trend includes the desire to spend more class time on practical issues such as modeling and system identification, actuator/sensor selection, nonideal and nonlinear behavior, economic factors, report writing, and project/team work. A related trend is to broaden the basis of controls to relate it to various other specialties such as electronics, computers, and communications. Hopefully, a future issue of this magazine will delve into specific methodologies, both technological and pedagogical, that are the underpinnings of these trends. This particular issue deals with the philosophical issues: identifying the trends and determining where the discipline should be headed and what we might do to accomplish our goals.

The first article, written by Peter Dorato, discusses the need to cover more material in undergraduate control courses to ensure that graduates are competent. This is echoed in other engineering disciplines as an increasingly vast array of new technologies are developed—all vying for course coverage. Professor Dorato, winner of the 1998 John R. Ragazzini Education Award, makes a case for the first accredited degree being the Master of Engineering degree rather than the bachelor's degree to accommodate all that we are requiring of our engineering curriculum.

The second article, written by Dennis Bernstein, addresses the desire to include more practical issues in control education and to make the topic more concrete to students. The article offers a set of guidelines for educators on what topics to emphasize and how to incorporate practical issues and real examples into controls courses.

Chris Bissell, author of the third article, questions the basic foundations of control education as it is currently taught: the emphasis on theory and on mathematics at the expense of practical engineering issues, and the reliance on simplistic models and modeling methods. He strongly recommends a return to a more practical emphasis in control education as well as better use of information technology. In conjunction, he believes controls courses should be broadened in scope to encompass a variety of engineering as well as nonengineering applications.

Next is a case study showing how to introduce systems and controls concepts to freshmen and sophomores. Written by N. Harris McClamroch and Jack Fishstrom, the article outlines a new course specifically targeted to aerospace engineers; however, the lessons learned and the overall approach are applicable to all engineering disciplines. The authors propose a strategy to introduce the concept of control without using mathematical rigor (for example, introducing block diagram representation, including that of feedback, without the use of transfer function notation). Other engineering topics are introduced as well: very basic system modeling, economics, project/team work, and report writing. All of these topics are presented in the context of a real engineering application, so that students can see the "big picture" at an early stage in their academic careers.

The final article summarizes a report on the NSF/CSS Workshop on New Directions in Control Education held in October 1998 at the University of Illinois, Urbana-Champaign. Whereas the other articles in this issue express the thoughts and opinions of individuals in the field, this article represents a composite of the opinions of those who organized and attended the workshop. The article identifies the desired future directions in control education and makes specific recommendations on how to pursue the goals. Several of the authors of the other articles attended the workshop, which no doubt helped shape and clarify their thoughts.

As a final message, I would encourage anyone interested in control education to join the CSS Technical Committee on Control Education. More information can be found at http://www.ece.gatech.edu/users/bonnie/CSS.