Future Trends in Control Engineering Education

Afef Fekih

Electrical and Computer Engineering Department
University of Louisiana at Lafayette

Abstract

This paper investigates the challenges faced by the control community in education to meet the technological advances in the field. The adjustments needed in the curriculum and in the research directions to better prepare the next century's engineering students.

The field of control engineering is poised to enter a golden age of opportunities. These opportunities are being made possible by incredible advances in computer technology, sensor and actuator technology, as well as in the theoretical foundations of dynamical systems and intelligent control.

Applications of control are expanding and this is placing new demands on education. Moreover, because of the wide range of applications that involve control engineering, the student's technical background is expected to change which will require new approaches to control education.

Future generations of engineering students will have to be broadly educated to cope with cross-disciplinary applications and rapidly changing technology. With this, come many questions: How should we adjust our curriculum to meet those needs? How can we prepare our students to take over the technology developments? How can we make control engineering accessible to students with a wide variety of background?

This paper is intended to present some of the current trends in control engineering and provide some possible answers to those questions. Possible solutions at both the undergraduate and graduate level are given.

Introduction

Dynamic Systems and Control is a fast growing and pervasive engineering field. There is rarely an engineering endeavor that does not involve the careful control, analysis, and/or synthesis of physical, dynamic systems. Be it fluids, thermodynamics, heat transfer, machine design, or materials engineering, systems and control contributions are essential.

The field of control engineering is poised to enter a golden age of opportunity and unprecedented growth that will likely dwarf the advancements that were stimulated by the space program in the 1960's. These opportunities are being made possible by incredible advances in computer technology, sensor and actuator technology, as well as in the theoretical foundations of dynamical systems and intelligent control. Many of the opportunities for future growth are at the boundaries of traditional disciplines, particularly at the boundary of computer science with other engineering disciplines. Control engineering is the cornerstone of the new “mechatronics revolution”, that is resulting in the ever increasing use of microprocessor based feedback control in such diverse areas as household appliances, consumer electronics, automotive and aerospace systems, manufacturing systems, chemical processes, civil and environmental systems, even biological systems [3].

Control engineering has made possible space travel and communication satellites, has assisted in the design of safe and efficient aircraft, ships, trains and cars, has helped in developing cleaner chemical processes while addressing environmental concerns. Automatic control constantly improves the quality of human life.

Future generations of engineering students will have to be broadly educated to cope with cross-disciplinary applications and rapidly changing technology. The time is ripe for major changes in how control engineering is taught in most universities. The needs of industry for well trained control engineers are changing, due to marketplace pressures and advances in technology. At the same time, the background of students is changing. Many come from nontraditional backgrounds; they often are less well prepared in mathematics and science while being better prepared to work with modern computing technologies [1],[2].

The truly exciting developments in automatic control will occur where there is a confluence of application drivers and disciplinary development of the subject. Changes in control education, adjustments in research directions, and more emphasis on implementation may provide the foundations and tools to meet the challenge of the next century and keep automatic control a dynamic and fascinating field.

Background of control engineering

Control refers to the use of algorithms and feedback in engineered systems. Control engineering systems traces its roots to the eighteens century with the first significant work of James Watt's centrifugal governor for the speed control of a steam engine. In that device, a flyball mechanism was used to sense the rotational speed of a speed turbine and adjust the flow of steam into the machine using a series of linkages [4],[5].

Control theory and engineering have witnessed dramatic achievements throughout this century. Recall the stability theory of Lyapunov from the beginning of the century, the conception of three-term or PID controllers in the 1910s, electronic and pneumatic feedback amplifiers in the 1920s, Nyquist and Bode charts of the 1930s, and Wiener's cybernetics of the 1940s. Then came the 1950s and Bellman's principle of optimality, Kalman filter of the 1960s, adaptive control in the 1970s, robust control in the 1980s, and the hybrid control systems of the current decade [4],[5].

The milestones of this development were the introduction of negative feedback amplifiers, field adjustable PID controllers, and especially digital computers. These technologies have had a tremendous impact on control theory and its application. The origin of classical control theory dates back to the conception of negative feedback and the subsequent development of frequency domain techniques, while modern control theory coincides with the introduction of state space methods related to the use of computers in space applications.

Today, as a result of this evolution, it is possible to implement advanced control methodologies. We have smart sensors and smart actuators. The most dramatic impact of electronic processing occurs in controllers. In times past, computational demands of adaptive, optimal and robust control techniques could not be easily performed. With modern electronics, such operations are possible. Modern electronic implementations are also more immune to aging effects, system noise and disturbances.

Control theory, on the other hand, is looking for new solutions. There is a strong influence of computer science and engineering. Analytic methods are giving way to synthetic ones. A search for closed-form solutions was typical in the classical era. The modern control theory considers a problem solved when it is reduced to an equation; an algorithmic solution is left to a computer. This trend will continue. The control of complex systems, or systems of systems, will be formulated as a mathematical program. Much of the analysis will be replaced by interactive, computer-aided design procedures. The solution will have to address the issues of hierarchy, interaction and the possibility of system evolution.

New Approaches to Control Education

Control is traditionally taught within the various engineering disciplines that make use of its tools, allowing a tight coupling between the methods of control and their applications in a given domain. It is also taught almost exclusively within engineering departments, especially at the undergraduate level. At the graduate level, courses are often shared between various departments or in some places they are part of the curriculum in applied mathematics or operations research. This approach has served the field well for many decades.

Increasingly, control is being applied outside of its traditional domains in aeronautics, chemical, electrical and mechanical engineering. Biologists are using ideas from control to model and analyze cells and animals, computer scientists are applying control to the design of rooters and embedded software, physicists are using control to measure and modify the behavior of quantum systems, and economists are exploring the applications of feedback to markets and commerce [1].

As a result, future generations of engineering students will have to be broadly educated to cope with cross-disciplinary applications and rapidly changing technology. This change in the control applications presents a challenge to the control education community. In order to meet those challenges, a reviewed academic program must be developed [1]'[2].

Some possible solutions at both the undergraduate and graduate level are listed below [1]:

Undergraduate level

- Introduce new approaches to education in order to make the courses more accessible to a broad range of potential users such as physicists, medical researchers, biologists. This can be achieved by emphasizing on the principles of control rather than simply providing tools that can be used in a given domain,
- The extensive use of experiments and laboratory experiments in order to expose the students to the real life applications of control theory [9],
- Provision of the students with cross disciplinary skills
- Very close interaction with industry
- Arranging tours of nearby technical facilities, such as manufacturing and electric power plants, satellite ground stations, and telecommunications facilities. Those tours will help them become enthusiastic about the different fields where control engineering can be applied

- Encourage them to sign up for summer internships in order to give them an insight about the real word applications
- Feed their curiosity and try to answer their expectations by assigning extra credit research topics where they do a search about topics related to emerging technologies, such as nanotechnology, hybrid vehicles, wireless technology….
- Present current knowledge in a more compact way by creating new books and courses that emphasize feedback concepts and their applications to a wide range of fields.
- Increase exposure to feedback in math and science education at all levels

Graduate level:

- Organization of inter-institutional graduate seminars in order to provide another form of sharing ideas in addition to the national and international conferences. This will provide opportunities for students and fellows from different institutions to meet and discuss mutual research and career interests. Moreover, this will provide networking opportunities and exposure to multiple perspectives by the collaboration of different institutions.
- Establishment of a cross-disciplinary research center, where there is a large critical mass of control researchers. These centers coordinate research activities, organize workshops and seminars, and provide mechanisms for continuing interactions between control students and faculty in different departments.
- Establishment of shared courses between the disciplines. These shared courses encourage a broader view of control since the students come from varying backgrounds. They also provide an opportunity for the large control community at the university to establish action dialogs and provide a mechanism for sharing students and building and joint research activities.
- Creation of regional control alliances that build critical mass by linking together multiple universities in a geographic region.

But one key solution to meet those challenges and to be able to modify the curriculum is to improve the student's education in math and science at the high school level. Moreover, the early introduction of some concepts related to control systems, such as signals, systems, and control into primary and secondary education will promote their diffusion throughout the academic disciplines and better prepare the students to deal with more complex topics [7].

Conclusion

This paper investigated some possible solutions regarding new strategies in control education to meet the emerging technologies in the control engineering field.

The solutions presented here, can extend beyond the control engineering field to all engineering disciplines where future career opportunities are expected to be created. In the coming decades, revolutionized technology will create exciting career opportunities in automotive and aerospace industries, medicine and biomedical industries, robotics and automated manufacturing, computer hardware and software industries, telecommunication industries…

In order to take advantage of the exciting career opportunities, we clearly need broadly educated engineers trained in multidisciplinary systems engineering to meet the challenge.

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Dr. Fekih is an assistant Professor of Electrical Engineering at the University of Louisiana at Lafayette. Her research interests include, control theory and applications, nonlinear and robust control, dynamic system modeling, fault-tolerant control, Neural networks, applications to dynamic systems, applications to aircraft systems, education.