PLENARY LECTURES

Plenary 1: Wednesday, June 8, 2005

Control Challenges for the Next Century of Flight

Colonel Michael B. Leahy
Director, Air Vehicles Directorate
Air Force Research Laboratory

Abstract:

The previous century witnessed remarkable advances in the science and technology of flight. We were so successful, that many now view us as masters of the aerospace domain and the supporting science and technology are mature or even sunset. Nothing could be further from the truth. There are many game changing aerospace system concepts within our collective reach as we begin our journey into the second century of flight.

One of the primary missions of the Air Force Research Laboratory is to define our future air forces. We envision alternative futures and then lead the process of discovery, development and transition into war winning solutions. Increasingly those solutions can not be achieved by a single technical advance, but rather by integrating a set of science and technology activities toward enabling a system level capability. As the director responsible for integrated solutions across the air domain, my talk will introduce the future capability vectors we are focused on. Within each of those I will discuss some of the specific controls challenges this community needs to solve to have a game changing impact. Topics range from “traditional” adaptive flight control to flights of intelligent unmanned systems operating in unison with their manned counterparts with applications from micro air vehicles to “airplane like” access to space.

By definition my list of challenges will be incomplete but hopefully stimulating enough to encourage at least a few of the creative minds in the audience to take up the challenge of bringing the next century of flight from vision to reality.

Biography:

Colonel Michael B. Leahy Jr. is currently director of the Air Vehicles Directorate, Air Force Research Laboratory and Commander of the Wright Research Site. He leads the $195 million science and technology development of air vehicles for the United States Air Force. This program is executed by 550 Air Force civilian, military, and contractors comprising three technical divisions in aeronautical sciences, control sciences, and advanced structures as well as an operations and integration division. Colonel Leahy is responsible for planning, programming, and executing programs to sustain the current fleet of aircraft, enable the evolution of unmanned air vehicles into combat roles, and to provide affordable access to space and high speed operations. In addition, Colonel Leahy manages the infrastructure including high performance computing, modeling and simulation facilities, and structural test facility required to support this program.

Colonel Leahy entered the United States Air Force in 1980 as a distinguished graduate of the Stevens Institute of Technology Reserve Officer Training Corps program. His assignments include tours in the laboratory, logistics and product centers, headquarters, and OSD. He began his AF career as an instrumentation engineer on the Airborne Laser Laboratory, was a senior command sponsored civilian institute candidate for his PhD, rose to the rank of associated professor of electrical engineering at the Air Force Institute of Technology, lead the Air Force Material Command Robotics and Automation Center of Excellence, served on the headquarters staff of the Air Force Research Laboratory and was the deputy director for Combat UAVs at the Aeronautical Systems Center before serving at the Defense Advanced Research Projects Agency (DARPA) as the director of the joint DARPA/USAF Unmanned Combat Air Vehicle program. During that time he has published over 50 papers in archival journals and conferences and is the founding editor of the IEEE Robotics and Automation Society Magazine.

Colonel Leahy received his BS from Stevens Institute of Technology in 1980, MS from University of New Mexico in 1983, and Ph.D. from Rensselaer Polytechnic Institute in 1986 all in Electrical Engineering. He is the recipient of numerous awards that include the Defense Superior Service Medal, Meritorious Service Medal with three oak leaf clusters, Air Medal, Air Force Achievement Medal with oak leaf cluster, Air Force Institute of Technology Outstanding Professor of the Year, Air Force Material Command, General (Ret) James Ferguson Engineering Award, Department of the Air Force Federal Engineer of the Year, and Association for Unmanned Systems International Pioneer Award

Plenary 2: Thursday, June 9, 2005

Autonomous Machines: Racing to Win the DARPA Grand Challenge

Richard M. Murray
Control and Dynamical Systems
California Institute of Technology

Abstract:

The DARPA Grand Challenge is a desert road race from Los Angeles to Las Vegas that will take place for the second time on 8 October 2005, with a grand prize of $2 million. Competing teams must build a vehicle that can operate autonomously and drive itself along a 175-mile course -- including dirt roads, trails, open desert and man-made obstacles -- in 10 hours or less. The competition provides a unique setting for testing ideas in perception, decision making, systems integration and autonomy.

The results from last year's race provide important lessons for information-rich, networked control systems and autonomy in highly uncertain environments. This year's race will feature teams from around the country who are bringing new research approaches to develop machines with human-like capabilities. Particular emphasis will be given to future directions in control, dynamics and systems motivated by this class of applications.

Biography:

Richard M. Murray received the B.S. degree in Electrical Engineering from California Institute of Technology in 1985 and the M.S. and Ph.D. degrees in Electrical Engineering and Computer Sciences from the University of California, Berkeley, in 1988 and 1991, respectively. He is currently a Professor of Control and Dynamical Systems at the California Institute of Technology, Pasadena. Professor Murray's research is in the application of feedback and control to mechanical, information, and biological systems. Current projects include information dynamics in networked feedback systems, analysis of insect flight control systems, autonomous desert racing for fun and profit, and synthetic biology using genetically-encoded finite state machines. Professor Murray is currently developing a new course at Caltech that is aimed at teaching the principles and tools of control to a broader audience of scientists and engineers, with particular emphasis on applications in biology and computer science.

Plenary 3: Friday, June 10, 2005

Control of Nonlinear Distributed Process Systems

Panagiotis D. Christofides
University of California, Los Angeles

Abstract:

Over the last ten years, key technological needs in growth areas such as semiconductor manufacturing, nanotechnology and biotechnology have motivated extensive research on analysis and control of complex distributed processes. Examples include film spatial uniformity and microstructure control in the chemical vapor deposition of thin films, temperature profile control in the Czochralski crystallization of high-purity crystals, as well as control of size distribution in the crystallization of proteins and the aerosol-based production of nanoparticles. From a control point of view, the distinguishing feature of complex distributed processes is that they give rise to nonlinear control problems that involve the regulation of highly distributed control variables by using a finite number of spatially-distributed control actuators and measurement sensors. Thus, complex distributed processes cannot be effectively controlled with control methods which assume that the state, manipulated and to-be-controlled variables exhibit lumped behavior or with linear control algorithms derived on the basis of linear/linearized distributed models.

We have developed a general and practical framework for the synthesis of practically implementable nonlinear feedback controllers for complex distributed processes based on fundamental models that accurately predict their behavior. The key difficulty in developing model-based control methods for distributed processes lies in the infinite-dimensional nature of the process models, which prohibits their direct use for control system synthesis. We have developed nonlinear order reduction techniques for deriving low-dimensional approximations that accurately reproduce the dynamics and solutions of distributed process models. We have used these approximate models for the synthesis of nonlinear feedback controllers via geometric, predictive and Lyapunov-based control methods. The controllers can be readily implemented in practice and enforce the desired control objectives in the infinite-dimensional closed-loop system. We will present applications of the theoretical results to: a) temperature profile control in rapid thermal chemical vapor deposition and crystal growth, b) control of microstructure and composition in thin film growth including an experimental implementation, and c) control of size distribution in crystallization.

Biography:

Panagiotis D. Christofides was born in Athens, Greece, in 1970. He received the Diploma in Chemical Engineering degree in 1992 from the University of Patras, Greece, the M.S. degrees in Electrical Engineering and Mathematics, in 1995 and 1996, respectively, and the Ph.D. degree in Chemical Engineering in 1996 all from the University of Minnesota.

Since July 1996 he has been with the Department of Chemical Engineering at the University of California, Los Angeles, where he is currently Professor. His theoretical research interests include nonlinear control, singular perturbations, and analysis and control of distributed parameter systems, multiscale systems and hybrid systems, with applications to advanced materials processing, particulate processes, biological systems and fluid flows. His research work has resulted in a large number of articles in leading scientific journals and conferences and two books entitled *Nonlinear and Robust Control of PDE Systems: Methods and Applications to Transport-Reaction Processes* (Birkhäuser, 2001) and *Model-Based Control of Particulate Processes* (Kluwer Academic, 2002). He has also co-authored (with N. H. El-Farra) the forthcoming book *Control of Nonlinear and Hybrid Process Systems: Designs for Uncertainty, Constraints and Time-Delays* (Springer, 2005).

A description of his research interests and a list of his publications can be found at http://www.chemeng.ucla.edu/pchristo/index.html.

Professor Christofides has been a member of the Control Systems Society Conference Editorial Board, the 2004 Program Coordinator of the Applied Mathematics and Numerical Analysis Area of AIChE and the Program Vice-Chair for Invited Sessions for the 2004 American Control Conference. He is currently an Associate Editor of IEEE Transactions on Automatic Control.

Professor Christofides has received the Teaching Award from the AIChE Student Chapter of UCLA in 1997, a Research Initiation Award from the ACS-Petroleum Research Fund in 1998, a CAREER award from the National Science Foundation in 1998, the Ted Peterson Student Paper Award from the Computing and Systems Technology Division of AIChE in 1999 and a Young Investigator Award from the Office of Naval Research in 2001. He has also received twice the O. Hugo Schuck Best Paper Award in 2000 (with A. Armaou) and 2004 (with D. Ni, Y. Lou, L. Sha, S. Lao and J. P. Chang), and the Donald P. Eckman Award in 2004, all from the American Automatic Control Council.