PLENARY PANEL DISCUSSION

Challenges and Opportunities for the Future of Control

Moderator: John Doyle
Panelists: Jean Carlson, Christos Cassandras, P. R. Kumar, Naomi Leonard, Hideo Mabuchi

Thursday, December 16
8:30 – 9:30am
Atlantis Grand Ballroom D

This panel reflects the scope and diversity of the unprecedented challenges and opportunities for the systems and controls community that has been created by several research themes from the basic sciences to advanced technologies. Connecting physical processes at multiple time and space scales in quantum, statistical, fluid, and solid mechanics, remains not only a central scientific challenge but also one with increasing technological implications. This is particular so in highly organized and nonequilibrium systems as in biology and nanotechnology, where interconnection, feedback, and dynamics are playing an increasingly central role.

Molecular biology has provided a detailed description of much of the componentry of biological networks, and the organizational principles of these networks are becoming increasingly apparent. It is now clear that much of the complexity in biology is driven by its control systems, however poorly understood these remain. At higher levels of organization, the feedback between humans and their ecosystems raise questions of both public health and technological sustainability. In addition, advanced technology is creating engineering examples of networks with complexity approaching that of biology. While the components are entirely different, there is striking convergence at the network level of the architecture and the role of protocols, control, and feedback in structuring complex system modularity.

Finally, there are new mathematical frameworks for the study of complex networks that suggest that this apparent network-level evolutionary convergence both within biology and between biology and technology is not accidental, but follows necessarily from the requirements that both be efficient, robust, and evolvable. Through combinations of evolution and natural selection or engineering design, such systems exhibit highly symbiotic interactions of extremely heterogeneous components to create functional hierarchies, with massive use of control and feedback throughout.

The next wave of the Information technology revolution, may well see the convergence of control with communication and computation. Much attention is currently directed at sensor networks, with the emergence of nodes that can sense, wirelessly communicate, and compute. Actuation is but the next step, leading to their full fledged use in both small-scale and broader cooperative control settings. With wireless networks possibly on the cusp of a take-off, and the growth of embedded processors, the future may see large collections of sensors and actuators orchestrated over the ether or inside the human body. Large systems with a variety of time, space, and energy saving usages can result.

Promising, popular, as well as specious theories of complex systems, deterministic or stochastic, all now coexist and compete for both research funding and the attention of the brightest young minds. In this context, the systems and controls community offers a unique perspective, combining rigor and practical relevance with a critical combination of dynamics, feedback, robustness, nonlinearity, design, and optimization. With the concepts of control and feedback at the heart of so many emerging multidisciplinary challenges, the controls community is poised to be a central enabler in the future of both basic scientific research and sustainable technology.

John Doyle (moderator) has a BS and MS, EE, MIT (1977), and a PhD, Mathematics, UC Berkeley (1984). He has been a Professor at Caltech since 1986, in the departments of Control and Dynamical Systems, Electrical Engineering, and BioEngineering. Early work was in the mathematics of robust control, LQG robustness, (structured) singular value analysis, H∞ and various more recent extensions. Current research interests are in theoretical foundations for complex networks in engineering and biology, as well as multiscale physics. Prize papers include the IEEE Baker, the IEEE AC Transactions Axelby (twice), and the AACC Schuck. Individual awards include the IEEE Control Systems Field Award, and the IEEE Centennial Outstanding Young Engineer. He has held national and world records and championships in various sports.

Jean M. Carlson is a professor of physics at the University of California, Santa Barbara. She received a B.S.E. in Electrical Engineering and Computer Science and Engineering Physics from Princeton University in 1984, an M.S.E. in Applied and Engineering Physics from Cornell University in 1987, and a Ph.D. in Theoretical Condensed Matter Physics from Cornell in 1988. She is a recipient of fellowship awards from the Sloan Foundation, the David and Lucile Packard Foundation, and the McDonnell Foundation. Carlson leads a research team working on a broad selection of interdisciplinary topics, including dynamics of earthquake faults, friction, and material deformation, optimization in networks and ecosystems, and fundamentals of statistical physics and mechanisms for scaling.

Christos G. Cassandras is Professor of Manufacturing Engineering and Professor of Electrical and Computer Engineering at Boston University. He received degrees from Yale University (B.S., 1977), Stanford University (M.S.E.E., 1978), and Harvard University (S.M., 1979; Ph.D., 1982). He specializes in the areas of discrete event and hybrid systems, stochastic optimization, and computer simulation, with applications to computer and sensor networks, manufacturing systems, transportation systems, and command-control systems. He has published over 200 refereed papers in these areas, and two textbooks. He is currently Editor-in-Chief of the *IEEE Transactions on Automatic Control*. He is a member of the IEEE CSS Board of Governors, chaired the CSS Technical Committee on Control Theory, and served as Chair of several conferences, including the 43rd IEEE CDC. He has been a plenary speaker at various international conferences, including the ACC in 2001 and the IEEE CDC in 2002. He is the recipient of several awards, including the 1999 Harold Chestnut Prize (IFAC Best Control Engineering Textbook) for *Discrete Event Systems: Modeling and Performance Analysis* and a 1991 Lilly Fellowship. He is an IEEE Fellow.

P. R. Kumar obtained his B. Tech. degree from IIT Madras in 1973, and the M.S. and D.Sc. degrees from Washington University, St. Louis in 1975 and 1977, respectively. Since 1985 he has been at the University of Illinois Urbana-Champaign, where he is currently Franklin Woeltge Professor of Electrical and Computer Engineering, and a Research Professor in the Coordinated Science Laboratory. Prof. Kumar was the recipient of the Donald P. Eckman Award of the American Automatic Control Council in 1985. He has presented plenary lectures at IEEE TENCON', WiOpt, the Mediterranean Conf. on Control and Automation, German Open Conf. on Probability and Statistics, SIAM Annual Meetings, Institute of Mathematical Statistics Workshop on Applied Probability, Brazilian Automatic Control Congress, IEEE/IAS International Conf. on Industrial Automation and Control, IEEE CDC, SIAM Conf. on Optimization, SIAM Conference on Control in the 90's, etc. His current research interests include wireless networks, protocol development, sensor networks, the convergence of control with communication and computing, wafer fabrication plants, manufacturing systems, and machine learning.

Naomi Ehrich Leonard is Professor of Mechanical and Aerospace Engineering at Princeton University and Associated Faculty Member of the Program in Applied and Computational Mathematics at Princeton. Her research focuses on the dynamics and control of mechanical systems using nonlinear and geometric methods. Current interests include underwater vehicles, mobile sensor networks, adaptive sampling and application to observing and predicting physical processes and biological dynamics in the oceans. She received the B.S.E. degree in mechanical engineering from Princeton University in 1985, and the M.S. and Ph.D. degrees in electrical engineering from the University of Maryland, College Park, in 1991 and 1994. She is the recipient of a National Science Foundation CAREER award, an ONR Young Investigator Award, and an Automatica Prize Paper Award. She has delivered plenary lectures at NOLCOS and SIAM Conf. on Applications of Dynamical Systems, and won a 2004 MacArthur Fellowship.

Hideo Mabuchi has worked in optical and atomic physics, using a combination of experimental and theoretical approaches to study the behavior of quantum-mechanical systems under continuous observation. His continuing research focuses on the use of real-time feedback for active control of quantum systems, and on clarifying the transition from quantum to classical behavior. Developing new interests include the application of mathematical methods from control theory to analyze and design complex physical systems, quantum optics with nanostructures, molecular biophysics, translating quantum mechanics, and the role of information technology in higher education. Mabuchi is currently an Associate Professor of Physics and Control & Dynamical Systems at the California Institute of Technology. Mabuchi received his A.B. (1992) from Princeton University and Ph.D. (1998) from Caltech. Selected honors include an Office of Naval Research Young Investigator Award, and A. P. Sloan Research Fellowship, and a John D. and Catherine T. MacArthur Foundation Fellowship. He has been named among MIT Technology Review Magazine's "Top 100 Young Innovators," and Discover Magazine's "Twenty Scientists to Watch in the Next Twenty Years."