Workshop for Middle and High School Students and Teachers

Wednesday, July 1, 2015
9:30 am – 2:30 pm
Red Lacquer Room, Hilton Palmer House*

The Power, Beauty and Excitement of Cross-Boundaries Nature of Control, a Field that Spans Science, Technology, Engineering & Mathematics (STEM)
15th Anniversary

This workshop is held in conjunction with the 2015 American Control Conference.
http://www.acc2015.a2c2.org

Organizers: Bozenna Pasik-Duncan (University of Kansas)
Ljubo Vlacic (Griffith University)
Linda Bushnell (University of Washington)

Sponsors: American Automatic Control Council (AACC) Technical Committee on Education
IEEE Control Systems Society (CSS) Technical Committee on Control Education

This outreach event is designed to increase the general awareness of the importance of systems and control technology and its cross-disciplinary nature among high school students and teachers. Control is used in many common devices and systems: cell phones, computer hard drives, automobiles, and aircraft, but is usually hidden from view. The control field spans science, technology, engineering and mathematics (STEM). The success of all STEM disciplines depends on attracting the most gifted young people to science and engineering professions. Early exposure to middle and high school students and their teachers is a key factor. The goal of these outreach efforts is to promote an increased awareness of the importance and cross-disciplinary nature of control and systems technology.

The workshop activities include presentations by control systems experts from our technical community, informal discussions, and the opportunity for teachers and students to meet passionate researchers and educators from academia and industry. The talks are designed to be educational, inspirational and entertaining showing the excitement of controls. Lunch will be provided. Participants will receive certificates of participation.

Welcome:

Bozenna Pasik-Duncan, Professor
Department of Mathematics
Courtesy Professor, Departments of Aerospace Engineering and Electrical Engineering and Computer Science
University of Kansas
Chair, AACC Committee on Education

Bozenna Pasik-Duncan received her Ph.D. and Habilitation doctorate degrees from the Mathematics Department of the Warsaw School of Economics in 1978 and 1986, respectively. She was a staff member of the Mathematics Department of Warsaw School of Economics from 1970 until 1984. In 1984 she moved to the University of Kansas, where she is currently a Professor of Mathematics, a Courtesy Professor of Electrical Engineering and Computer Science and a Courtesy Professor of Aerospace Engineering. Dr. Pasik-Duncan's current research interests are primarily in stochastic adaptive control, computational aspects of stochastic control, and stochastic analysis with its applications to mathematics of finance, medicine, and telecommunications. Her other current interests include mathematics education at K-12 schools, control engineering education, and mathematics education for women in science and engineering. She has received numerous awards in recognition of her teaching and service. Dr. Pasik-Duncan has been actively involved in the IEEE Control Systems Society (CSS) in a number of capacities. She is a Fellow of IEEE; was awarded the IEEE Third Millennium Medal and the IEEE Control Systems Society Distinguished Member Award; and is a Fellow of IFAC.

Richard Braatz, Edwin R. Gilliland Professor
Department of Chemical Engineering
Massachusetts Institute of Technology, Cambridge
General Chair, 2015 American Control Conference

Richard D. Braatz is the Edwin R. Gilliland Professor at the Massachusetts Institute of Technology (MIT) where he does research in control theory and its application to biomedical, pharmaceutical, energy, and nanotechnology systems. He received MS and PhD degrees from the California Institute of Technology and was the Millennium Chair and Professor at the University of Illinois at Urbana-Champaign and a Visiting Scholar at Harvard University before moving to MIT. He has consulted or collaborated with more than 20 companies including IBM, United Technologies Corporation, Novartis, and Abbott Laboratories. Honors include the Donald P. Eckman Award from the American Automatic Control Council, the Curtis W. McGraw Research Award from the Engineering Research Council, the Antonio Ruberti Young Researcher Prize, and the IEEE Control Systems Society Transition to Practice Award. He is a Fellow of IEEE, IFAC, and the American Association for the Advancement of Science.

Radhakishan S. Baheti, Program Director
National Science Foundation Engineering Division

Dr. Baheti received the B.S. and M.S. in Electrical Engineering in India from VRCE Nagpur, and from BITS Pilani, respectively. In 1970, he came to USA and received M.S. in Information and Computer Science from University of Oklahoma and Ph.D. in Electrical and Computer Engineering from Oregon State University. In 1976, Dr. Baheti joined the Control Engineering Laboratory of GE Corporate Research and Development Center in Schenectady, NY. His work focused on advanced multivariable control for jet engines, signal and image processing systems, computer- aided control system design, vision-based robots for precision welding, model-based fault identification and parallel implementation of Kalman filters. Dr. Baheti and his colleagues received IR-100 award for robotic welding vision system. He has organized a series of educational workshops for GE engineers that resulted in innovative product developments and contributed to enhance university collaborations with GE business divisions. In 1989, Dr.Baheti joined NSF as a Program Director in the Division of Electrical and Communications Systems. His contributions include the development of NSF initiatives on "Combined Research and Curriculum Development", "Semiconductor Manufacturing", and NSF/EPRI Initiative on "Intelligent Control". He was instrumental in the development of NSF Initiative on "Research Experience for Teachers" to involve middle and high school teachers in engineering research that can be transferred to pre-college classrooms. Recently he is involved in networked control systems, sensor and actuator networks, imaging and computational video, micro and nano systems, medical robotics, science of learning, and dynamics and control of biological and medical systems. He has served as associate editor for IEEE Transactions on Automatic Control, member of the Control Systems Board of Governors, chair for Public Information Committee, and awards chair for the American Automatic Control Council (AACC). He received "Distinguished Member Award" from the IEEE Control Systems Society. In 1997, he was elected a Fellow of IEEE.

Presentations include:

The Miracle of Stabilization
Dennis Bernstein, Professor
Department of Aerospace Engineering
University of Michigan, Ann Arbor
http://www.engin.umich.edu/aero/people/faculty/dennis-bernstein

I will explain what stabilization is, why it is important in daily life and advanced technology, and try to convey a sense of why stabilization is awesome and mysterious.

Professor Bernstein's interests include identification, estimation, and control for aerospace applications. His research has focused on active noise and vibration control, as well as attitude control for space applications. His current interests are in the theory and application of nonlinear system identification, large-scale state estimation for data assimilation, and adaptive control. He is director of the **Noise, Vibration, and Motion Control Laboratory**, which includes instrumentation and testbeds for control applications. A 6-degree-of-freedom electric shaker table under all-digital control is used for vibration and motion control applications. Facilities are available for implementing and testing algorithms for active noise and vibration control. Current research is focusing on adaptive command following and disturbance rejection algorithms for systems with uncertain dynamics and unknown disturbance spectra. He is co-director (with Ilya Kolmanovsky) of the **Attitude Dynamics and Control Laboratory**. In this laboratory, a triaxial air bearing is used to develop and implement adaptive control algorithms for spacecraft applications. He was Editor-in-Chief of the IEEE Control Systems Magazine from 2003 to 2011. Prof. Bernstein has authored more than 200 journal papers and 350 conference papers. He is the author of Matrix Mathematics, which is published by Princeton University Press.

How to Design a Self-Driving Car
Richard M. Murray, Everhart Professor
Department of Control and Dynamical Systems and Bioengineering
California Institute of Technology, Pasadena
www.cds.caltech.edu/~murray/

Building robots that can do things as well as humans has been the goal of scientists and engineers for decades. Despite what we see in the movies and on TV, getting a real robot to perform as well as a human can is still an challenge goal. Approximately ten years ago, the US has sponsored a competition to spur advances in robotics, called the DARPA Grand Challenge. This competition paved the way for the advances that we see today in the development of autonomous cars. In this talk I will explain how these cars work and some of the engineering challenges that remain.

Professor 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 the Thomas E. and Doris Everhart Professor of Control and Dynamical Systems. Murray's research is in the application of feedback and control to mechanical, information, and biological systems. Current projects include integration of control, communications, and computer science in multi-agent systems, information dynamics in networked feedback systems, analysis of insect flight control systems, and biological circuit design.

Molecular Robots

Elisa Franco, Assistant Professor
Department of Mechanical Engineering
University of California, Riverside
http://www.engr.ucr.edu/~efranco/Home.html

What is the smallest robot on earth? We, humans, can build pretty smart robots smaller than a penny, but nature is still better than us at making the tiniest machines. Think of bacteria, for example: they are microscopic robots constantly moving, finding food, adapting and surviving in many environments, and even capable of hibernating if needed. Cells can do many tasks better than any man-made robot, despite being one of the simplest life forms. Unlike the robots we can build, cells do not work with transistors, circuits and engines, but with biological materials: DNA, RNA and proteins. Can we learn from cells how to use these materials to make miniature molecular robots that grow, move, and perhaps perform tasks? For example, deliver drugs where and when needed in your body, clean up your arteries, or monitor the health of your organs. In my talk, I will describe how modern engineers think of DNA, RNA and proteins as a building materials to make artificial tiny motors, objects and robots, and how you can get involved!

Professor Franco received her B.S. and M.S. (Laurea Degree) in Power Systems Engineering from the University of Trieste (Italy) in 2002, summa cum laude. In 2007, she received her Ph. D. in Automation from the same institution. In 2011, she completed her second Ph. D. at the California Institute of Technology, Pasadena, in Control and Dynamical Systems. Dr. Franco's main interests are in the area of biological feedback systems. In particular, her research focuses on bottom-up approaches to the design and synthesis of controllers, sensors and actuators in biochemical reaction networks, using nucleic acids and proteins. She also works on robustness analysis of natural biochemical systems. In the past, Dr. Franco worked in the field of cooperative control and distributed estimation.

Micro-Hybrid Breathing Engines

Anna Stefanopoulou, Director Automotive Research Center and Professor
Departments of Mechanical Engineering and Naval Architecture and Marine Engineering
University of Michigan, Ann Arbor
http://www-personal.umich.edu/~annastef/

The Automotive Research Center's mission is to develop modeling and simulation environments for discovering and assessing critical ground vehicle technologies. We focus on problems associated with conversion and management of power and energy within vehicles, mobility and survivability of the complete vehicle system, including the human operator.

Professor Stefanopoulou obtained her Diploma (1991, Nat. Tech. Univ. of Athens, Greece) in Naval Architecture and Marine Engineering and her Ph.D. (1996, Univ. of Michigan) in Electrical Engineering and Computer Science. She is a professor of Mechanical Engineering at the Univ. of Michigan. She was an assistant professor (1998-2000) at the Univ. of California, Santa Barbara, a technical specialist (1996-1997) at Ford Motor Company and a visiting professor (2006) at ETH, Zurich. She is an ASME Fellow (08), and an IEEE Fellow (09), a member (2012-2015) of the National Research Council (NRC) Committee for Corporate Fuel Economy (CAFÉ) Standards in Light Duty Vehicles and the Founding Chair (2010-2014) of the ASME DSCC Energy Systems Committee. She was an elected member (2006-2009) of the IEEE Control Systems Society (CSS) Board of Governors, an Associate Editor (2002-2007) of the IEEE Transactions on Control System Technology, an Associate Editor (2009-2010) on the ASME Journal of Dynamic Systems Measurements and Control, and Chair (2001-1999) . She is a recipient of the 2009 Gustus L. Larson Memorial Award, a 2008 Univ. of Michigan Faculty Recognition award, the 2005 Outstanding Young Investigator by the ASME DSC division, a 2005 Henry Russel award, a 2002 Ralph Teetor SAE educational award, a 1997 NSF CAREER award and selected as one of the 2002 world's most promising innovators from the MIT Technology Review. She has a book on Control of Fuel Cell Power Systems, ten US patents, 4 best paper awards and more than 230 publications. Her current work addresses the control and automation issues associated with fuel cells, fuel processing, and internal combustion engines.

From Wright Brothers First Flight to Curiosity's Landing on Mars: What Makes Flight Control Challenging and How to Provide Guarantees of Performance

Naira Hovakimyan, Professor, University Scholar and Schaller Faculty Scholar
Department of Mechanical Science and Engineering
University of Illinois, Urbana-Champaign
http://naira.mechse.illinois.edu/naira-hovakimyan/

This talk will explain the role of feedback control in modern era. Some of the experiments conducted on subscale commercial jet at NASA and Learjet at Edwards AF base along with UAVs and drones will be used to illustrate the ideas.

Professor Hovakimyan received her MS degree in Theoretical Mechanics and Applied Mathematics in 1988 from Yerevan State University in Armenia. She got her Ph.D. in Physics and Mathematics in 1992, in Moscow, from the Institute of Applied Mathematics of Russian Academy of Sciences, majoring in optimal control and differential games. In 1997 she has been awarded a governmental postdoctoral scholarship to work in INRIA, France. In 1998 she was invited to the School of Aerospace Engineering of Georgia Tech, where she worked as a research faculty member until 2003. In 2003 she joined the Department of Aerospace and Ocean Engineering of Virginia Tech, and in 2008 she moved to University of Illinois at Urbana-Champaign, where she is a professor, university scholar and Schaller faculty scholar of Mechanical Science and Engineering. She has co-authored a book and more than 300 refereed publications. She is the recipient of the SICE International scholarship for the best paper of a young investigator in the VII ISDG Symposium (Japan, 1996), and also the 2011 recipient of AIAA Mechanics and Control of Flight award. In 2014 she was awarded the Humboldt prize for her lifetime achievements and was recognized as Hans Fischer senior fellow of Technical University of Munich. In 2015 she was recognized by Engineering Council award for Excellence in Advising. She is an associate fellow and life member of AIAA, a Senior Member of IEEE, and a member of SIAM, AMS and ISDG. Her research interests are in the theory of robust adaptive control and estimation, control in the presence of limited information, networks of autonomous systems, game theory and applications of those in safety-critical systems of aerospace, mechanical, electrical, petroleum and biomedical engineering.

Computational Thinking as the Link Between Recent Curriculum and Applied Mathematics

Andrew Bucki, Associate Professor
Department of Mathematics, Langston University
Faculty Member, Oklahoma School of Science and Mathematics, Oklahoma City

Two students' research projects based on presentations from 2000 ACC Workshop will be presented.

Professor Bucki received a PhD in pure mathematics and MEd degree from the Maria Sklodowska-Curie University, Lublin, Poland. His research interests include differential geometry and complex analysis in pure mathematics and application of ensemble based simulated annealing to intensity modulated radiotherapy planning and control theory in applied mathematics. Recently he has been working on a new educational program in mathematics based on computational thinking including programming approach for which he obtained the U.S. Presidential Scholars Program's Teaching Recognition Award. He is professor of mathematics at Langston University, OK, and mathematics education researcher at the Oklahoma School of Science and Mathematics.

Control of Complex Networks

Andrew Clark, Assistant Professor
Department of Electrical and Computer Engineering
Worcester Polytechnic Institute, Worcester, MA
https://www.wpi.edu/academics/facultydir/ac1.html

Networks are a useful model for describing interactions between people (social networks such as Facebook), technology (power grid, transportation network), and the natural world (gene regulation, neural networks). In this talk we will explore how control theory, together with network science, provides insights into how to control vast, complex networks with thousands to millions of individual nodes. Examples include synchronization in the brain, gene regulation, and influencing social networks. We will discuss unifying properties of these networks, and how those properties can provide insight into the structure, function, and control of complex systems.

Professor Clark received his PhD in electrical engineering at the University of Washington. His research interests include the performance and security of cyber-physical systems, adaptive and proactive network defenses, lightweight cryptography, and, vulnerability metrics. He was the co-author of a paper that received the 2010 IEEE/IGIP William C. Carter Award, and he also won the WiOpt Best Student Paper Award in 2012 and 2014. He earned a patent on privacy-preserving constant-time identification in RFID systems.

Think Mathematically Act Computationally

Alec Knutsen, B.S. Student in Math and Computer Science
Student Research Assistant, Information and Telecommunication Technology Center
University of Kansas

I will demonstrate how to program and use mathematical and statistical software.

Alex is an undergraduate student at the University of Kansas majoring in mathematics and computer science. He is working on an NSF sponsored undergraduate research project under the direction of Bozenna Pasik-Duncan.

Medically Inspired Engineering: Building an Artificial Pancreas

Francis J. Doyle III, Mellichamp Endowed Chair Professor in Process Control
University of California, Santa Barbara
Dean, Paulson School of Engineering and Applied Sciences (Beginning August 1)
Harvard University
http://tia.ucsb.edu/industry/inventors/frank-doyle/

Control system approaches are instrumental in the field of systems biology, which involves the application of theoretical approaches and the integration of experimental and computational research. Developing control systems for medical applications to treat diseases, such as diabetes, poses particular challenges. The dynamics vary from one individual to another, as well as within the same individual over time. No two people are alike, and this is especially true at the molecular scale in the body. For example, across the spectrum of subjects with diabetes, there are significant variations in how the cells respond to insulin, as well as other hormones in the body. It is also true that different individuals with Type 1 diabetes have varying severities of the disease, due to factors including age, exercise, diet, and stress.

Our research team has designed personalized control algorithms for the artificial pancreas (AP). The two key variables we aim to characterize are how the body responds to insulin, and the interaction of meals and insulin. These are the crucial 'gains' that affect how one designs a feedback controller for the AP, and how one tunes the controller to strike a compromise between over delivery of insulin (very dangerous) and under delivery of insulin (not therapeutic). However, there are no models that truly allow the prediction of how these quantities vary from individual to individual, so we are using a combination of prior knowledge, including the patient's medical history, which contains parameters like total daily insulin utilized, to build customized models that are the heart of the control algorithm.

In this talk I will share some of the basic ideas of feedback control that are harnessed to build an artificial pancreas, and will share some results of clinical trials with these algorithms.

Professor Doyle, a distinguished scholar in chemical engineering at the University of California, Santa Barbara (UCSB), has been appointed the next dean of the Harvard School of Engineering and Applied Sciences (SEAS) and will take the reins on Aug. 1. As a scholar, Doyle applies systems engineering principles to the analysis of regulatory mechanisms in biological systems. His work includes the design of drug-delivery devices for diabetes; modeling, analysis, and control of gene regulatory networks underlying circadian rhythms; and computational analysis for developing diagnostics for post-traumatic stress disorder. Doyle also applies control schemes to nonlinear, multivariable, constrained industrial processes such as particulate systems and pulp and paper operations, and works on control aspects of sheet/film processes. Doyle is currently the Duncan & Suzanne Mellichamp Endowed Chair Professor in Process Control at UCSB. He is also the Associate Director of the UCSB / MIT / CalTech Institute for Collaborative Technologies and a Guest Investigator at the Sansum Diabetes Research Center. He received his BS from Princeton University, his MS from Cambridge, and his PhD from the California Institute of Technology. Doyle has been named a fellow in the American Association for the Advancement of Science, the American Institute for Medical and Biological Engineering, the International Federation of Automatic Control, and the Institute of Electrical and Electronics Engineers.

Communicating Through Motion in Dance

John Baillieul, Dinstinguished Professor
Areospace and Mechanical Engineering
Boston University
http://www.bu.edu/me/people/faculty/ae/baillieul/

Kayan Ozcimder
Postdoctoral Research Associate
Princeton University

This study explores principles of motion based communication in human group behavior. It develops models of cooperative control that involve communication through actions aimed at a shared objective. In conducting a formal study of these problems, we investigate the leader-follower interaction in a dance performance. Here, the prototype model is salsa. Salsa is of interest because it is a structured interaction between a leader (usually a male dancer) and a follower (usually a female dancer). Success in a salsa performance depends on how effectively the dance partners communicate with each other using hand, arm and body motion. We construct a mathematical framework in terms of a Dance Motion Description Language (DMDL). This provides a way to specify control protocols for dance moves and to represent every performance as sequences of letters and corresponding motion signals. An enhanced form of salsa (intermediate level) is discussed in which the constraints on the motion transitions are described by simple rules suggested by topological knot theory. It is shown that the proficiency hierarchy in dance is effectively captured by proposed complexity metrics.

Professor Baillieul focuses on robotics, the control of mechanical systems, and mathematical system theory. His work in the late 1980's led to seminal papers on motion planning for kinematically redundant manipulators. Earlier work on nonlinear optimal control theory foreshadowed much of the current literature on singular Riemannian geometry. Current research focuses on extending and applying principles from nonlinear control theory to complex mechanical systems composed of interconnected rigid and elastic components. Dr. Baillieul has developed a laboratory system for experiments involving real-time control of mechanical systems, research fundamental to the design of lightweight, high-performance manipulator arms and other advanced robotic devices. He also investigates geometric effects in nonlinear rotational mechanics, with potential applications in stabilization and vibration suppression in rotating machinery, and the theory of control and motion planning for mechanical systems with relatively few actuators for the control of a large number of degrees of freedom. A Fellow of the IEEE, he is the former editor-in-chief of the IEEE Transactions on Automatic Control. He is also affiliated with Boston University's Center for Information and Systems Engineering (CISE).

H. Kayhan Ozcimder received is Ph.D. in mechanical engineering from Boston University and earned his B.S. degree (Mechanical Engineering) in Gazi University in Ankara/Turkey. He was a recipient of a scholarship from the Turkish Ministry of Education to start his academic career in the United States. He has been working on Control Communication Complexity of distributed control models and action based communication protocols for multi-agent autonomous systems. He is currently a postdoctoral research associate at Princeton University.