The Power, Beauty and Excitement of the Cross-Boundary Nature of Control

National Science Foundation
Middle and High School
Students & Teachers Workshop

December 13, 2006
Manchester Grand Hyatt Hotel
San Diego, California

in conjunction with the
2006 Conference on Decision and Control

Sponsored by:
National Science Foundation

Co-Sponsors:
IEEE Control Systems Society
University of Kansas
College of Liberal Arts & Sciences
Department of Mathematics
Electrical Engineering and Computer Science
Information & Telecommunications Technology Center

The purpose of this workshop is to enhance the cooperation among various control groups and middle and high school students and teachers throughout the United States and the world, to give attention to control and systems ideas and technology, and to increase the general awareness of the importance of control and systems technology and its cross-boundary nature among students and teachers.

Organizing and Program Committee

Bozenna Pasik-Duncan (Chair)
Department of Mathematics
University of Kansas

Patricia Winter (San Diego Co-Chair)
Education Outreach Consultant
General Atomics Sciences Education Foundation

Dominique Duncan (Student Assistant)
University of Chicago

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Technical Committee on Control Education
Control Systems Society

Technical Committee on Education
International Federation of Automatic Control

Technical Committee on Control Education
American Automatic Control Council

Contact:
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Program

Morning

9:00 Welcome
Bozenna Pasik-Duncan, Chair, CSS Committee on Control Education and AACC Committee on Control Education
Pradeep Misra, General Chair, Organizing Committee, 45th IEEE Conference on Decision and Control
John Baillieul, President, Control Systems Society
Kishan Baheti, Program Director, Engineering Systems Program, National Science Foundation

9:30 *The Next Phase of the Information Technology Revolution*
P.R. Kumar, University of Illinois, Urbana-Champaign

9:50 *When Computers Control: Joys and Perils of Automation* **Christos Cassandras**, Boston University

10:10 *From Hundreds of Warehouse Robots to Self-assembling Chairs: How Automation is Helping to Rewrite What is Possible* **Raffaello D'Andrea**, Cornell University

10:30 Short Break

10:40 *The Power of Feedback*
Theodore Djaferis, University of Massachusetts, Amherst

11:00 *Control in Mechatronics and Robotics*
Mark Spong, University of Illinois, Urbana-Champaign

11:20 *How to Design a Self-Driving Car: The DARPA Grand Challenge*
Richard Murray, California Institute of Technology

11:40 Lunch Break (served in Douglas Ballroom)

Afternoon

12:40 *Understanding Phenomena through Real Physical Objects—Controlling Petroleum*
Katsuhisa Furuta, Tokyo Denki University

1:00 *Using Mathematics to Help Understand How Organisms Develop*
Claire Tomlin, University of California, Berkeley and Stanford University

1:20 *Application of Control Theory to the Problem of Epilepsy*
Ivan Osorio, Kansas University Medical Center, and **Mark Frei**, Flint Hills Scientific, L.L.C.

1:50 Meet industry representatives and university graduate and undergraduate students.

2:10 Evaluation of Workshop

2:30 Farewell

Acknowledgement

The Organizing and Program Committee would like to express their gratitude to Dr. Kishan Baheti, Program Director, National Science Foundation, for lending his support and advice. It is through him that these workshops are made possible.

Speakers

Christos Cassandras
Professor
Manufacturing Engineering and
Center for Information and Systems Engineering
Boxton University
http://vita.bu.edu/cgc/

When Computers Control: Joys and Perils of Automation

One of the definitions of the word "control" is "to govern or direct according to rule" (Merriam-Webster dictionary). In science and engineering, these "rules" have traditionally been dictated by the laws of nature—such as gravity or conservation of mass. Computer technology, however, has enabled us to build complex systems that have become essential to our daily life, from automated factories to computer networks, with intelligent highways and autonomous vehicles just around the corner. The "rules" that these systems must obey are as arbitrary as human imagination can make them (as in designing a video game where one may create a virtual world where anything goes). While this is exciting, it is also dangerous—it takes but one minor "bug" or "virus" to bring a multimillion factory to a standstill, the Internet to crash, or the Mars exploration vehicle to erroneously "think" that its landing legs were deployed, effectively forcing it to commit electronic suicide. Many of the dangers of automation stem from the lack of designers and engineers with appropriate skills that are cultivated through an understanding of what a "system" is and how to evaluate the effectiveness of a controller before deployment. This presentation will illustrate the difference between physical processes subject to the laws of nature and human-made processes that must satisfy human-made rules. We will then show how "automatic control" can be used and demonstrate both its benefits and risks. Short movies will be included to show how teams of small wireless autonomous robots can cooperate as a system to accomplish various "missions".

Raffaello D'Andrea
Associate Professor
Sibley School of Mechanical and Aerospace Engineering
Cornell University
http://www.mae.cornell.edu/Raff/

From Hundreds of Warehouse Robots to Self-assembling Chairs: How Automation is Helping to Rewrite What is Possible

www.kivasystems.com
Kiva Systems, Inc. uses breakthrough automation technology to help companies reduce cost and increase flexibility in their distribution centers. Using autonomous mobile robots, storage pods, and sophisticated control software, the Kiva Mobile Fulfillment System enables a smooth flow of materials through the facility, from receiving to picking to shipping - all without conveyor. The result is a building that is quick and low-cost to set up, cheap to operate, and easy to change.

http://www.mae.cornell.edu/raff/RoboticChair/RoboticChair.htm

The Robotic Chair is an apparently generic-looking wooden chair with the capacity to fall apart and put itself back together. The Chair is reminiscent of those used to furnish schoolrooms and waiting rooms. The Robotic Chair however, is not at all generic as it collapses, falls to the floor and then proceeds to seek itself out and reassemble itself. The Chair's seat houses a custom mechanical robot designed to locate its various other chair components: legs and back; dock with each element and then restore itself to the upright position. The Robotic Chair's custom mechanical joints are specially designed to meet the challenging task of securing the chair legs to the chair seat and up righting the sprawled assembly. The Robotic Chair acts autonomously and is not dependent on viewer presence or interaction to perform. The Robotic Chair distinguishes itself as a life-like object in that it defines its own state of being.

Theodore Djaferis
Professor
Department of Electrical and Computer Engineering
Associate Dean, College of Engineering
University of Massachusetts, Amherst
http://eeexplore.ieee.org/iel5/37/29513/01337855.pdf

The Power of Feedback

One can find "feedback" everywhere in nature and we encounter it in a multitude of situations on a daily basis. One can argue that life as we know it would not be possible without feedback. We are so used to it that in most cases we do not even notice its presence. Consider how humans walk. It would be impossible to walk without sensing our surroundings and using this information to take the next step. The human body includes a multitude of functions that employ feedback and operate automatically keeping us alive and well. The concept of feedback is also used to solve a great variety of engineering problems. Take cruise-control in automobiles as an example. It would be impossible to maintain a desired speed without measuring the actual vehicle speed and using this information to adjust the accelerator pedal. It is said that "information is power" and this is because new data can be "fed-back" and used to affect future decisions.

Systems and Control engineers regularly employ feedback strategies for the solution of engineering problems in service to humanity. These problems can have characteristics that are electrical, mechanical, chemical, hydraulic, financial, environmental or biological, to name a few. Some involve many disciplines making automatic control a fascinating field of study. In this talk we will explore the use of feedback in the solution of problems. To illustrate the concepts we will focus on a specific collision avoidance problem and demonstrate automatic control of a Computer Intelligent Model Car (CIMCAR). We will then discuss other "new" engineering problems whose solutions can benefit from the use of feedback.

Katsuhisa Furuta
Professor
Department of Computers and Systems Engineering
Tokyo Denki University, Japan
http://furutalab.k.dendai.ac.jp/

Understanding Phenomena through Real Physical Objects -Controlling Pendulum

A pendulum is one of the simple examples of nonlinear and unstable mechanical systems and is a pedagogical example to show the effect of control. The control of a single pendulum is said to be analogous to the rocket launch. In this talk, at first two videos show the experimental results on the stabilization of an inverted pendulum in the spherical space by vision measurement and the swing-up control of Furuta pendulum, respectively. Then the dynamics of a single pendulum is derived. A swing-up control algorithm is discussed. The stabilization of a double pendulum is explained. Finally, Furuta pendulum is presented and its model is described.

P.R. Kumar
Professor
Department of Electrical and Computer Engineering
University of Illinois, Urbana-Champaign
http://decision.csl.uiuc.edu/~prkumar/

The Next Phase of the Information Technology Revolution

Over the past twenty years we have seen the growth of the Internet that connects computers all over the world together. Over the next twenty years we expect to increasingly see computer networks getting information automatically from sensors and automatically controlling various objects like the cars we drive or the buildings we live or work in. This talk will show movies of some of these possibilities and the challenges that lie ahead. Movies can be seen at http://decision.csl.uiuc.edu/~testbed/?x=multimedia%2Fvideoclips.html&t=Multimedia

Richard Murray
Professor
Department of Control and Dynamical Systems
California Institute of Technology
http://www.cds.caltech.edu/~murray

How to Design a Self-Driving Car: The DARPA Grand Challenge

Building robots that can do things as well as humans h as 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 elusive goal. Over the last three years, the US has sponsored an interesting competition to spur advances in robotics, called the DARPA Grand Challenge. The first two grand challenges were desert road races, using cars that were completely controlled by computers. In October 2005, five autonomous vehicles demonstrated their ability to drive over 100 miles along desert roads and trails, with no human intervention. The next grand challenge, scheduled for November 2007, will involve designing a car that can drive itself around in cities. This includes driving on the proper side of the road and obeying other basic traffic laws, detecting and avoiding other static or moving vehicles, and reasoning about how to drive at intersections and in parking lots, with other cars present. Ideas from control are at the center of many of the behaviors that must be implemented to design robots of this sort and in this talk I will describe some of the ways that feedback and control have been and will be used in the DARPA Grand Challenge.

Ivan Osorio, M.D.
Director

Comprehensive Epilepsy Center
University of Kansas Medical Center

Mark Frei, Ph.D.
Operating Manager/Technical Director
Flint Hills Scientific, L.L.C.
http://www.fhs.lawrence.ku.us

Application of Control Theory to the Problem of Epilepsy
Epilepsy is the most serious, prevalent neurological disorder spanning all age groups. In this talk, we describe how signal processing and control theory have played an invaluable role in the detection and automatic treatment of epileptic seizures.

Mark Spong
Donald Biggar Willett Professor
Department of Electrical and Computer Engineering
University of Illinois, Urbana-Champaign
http://decision.csl.uiuc.edu/~spong/

Control in Mechatronics and Robotics
Mechatronics is the synergistic integration of precision mechanics, electronics, computer science and control. In this talk we will give an overview of applications of mechatronics in the design of smart systems of all kinds, especially robots, which are the ultimate mechatronic systems. We will discuss the development of an air hockey playing robot, autonomous mobile robots, and a Segway riding robot.

Claire Tomlin
Associate Professor
Department of Electrical Engineering and
Computer Science
University of California, Berkeley
Associate Professor
Departmentn of Aeronatics and Astronautics
Standford University
http://www.eecs.berkeley.edu/~tomlin/

Using Mathematics to Help Understand How Organisms Develop
Mathematics provides a way of encoding and testing hypotheses about biological systems. This talk will demonstrate how designing, coding up, and simulating a mathematical model of biological cell development can help to understand how the cell is developing.

Participants

Chabad Hebrew Academy
Pat Paluso
San Diego, California

Chet Harrit Middle School
Dave Massey
Santee, California

Christian Family Schools
Ceclia Chafin
Escondido, California

Clairemont High School
Larry Engelbrecht
David Marceleno
San Diego, California

Hidden Valley Academy
Maria Wong
Escondido, California

Jefferson Middle School
Sharon Strathman
Oceanside, California

Lake Elsinore High School
Barbara Christopher
Temecula, California

Lakeside Middle School
Tricia Digenan
Lakeside, California

Mac Queen Middle School
Brendan Casey
Alpine, California

Mann Middle School
Zamaria Rocio
San Diego, California

Moutain Empire Junior and High Schools
Roger Wynn
Pine Valley, California

Morse High School
Shirley Miranda
San Diego, Calfornia

Poway High School
Lisa Casey-O'Brien
Poway, California

San Marcos Middle School
Debra Brice
San Marcos, California

Serra High School
Guillermina von Borstel
San Diego, California

Spring Valley Middle School
Claudette Wear
Spring Valley, California