The Ideas and Technology of Control Systems
Maui, HI
December 12, 2012
Organizer: Bozenna Pasik-Duncan

The Ideas and Technology Control Systems Workshop was held in conjunction with the 51st IEEE Conference on Decision and Control (CDC 2012) at the Grand Wailea Hotel in Maui, HI, on December 12, 2012.

The website for the workshop (http://www.math.ku.edu/ksacg/workshops/CDC_2012/cdc2012workshop.html) contains details of the proceedings, including additional photos and a short video.

The purpose of this outreach event is 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 fields depends on attracting the most gifted young people to science and engineering profession. 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.

150 middle and high school students and teachers from three Hawaii schools participated in workshop activities that included 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 the STEM fields.

The workshop was sponsored by IEEE CDC 2012, IEEE CSS Technical Board, AACC, IEEE CSS Outreach Fund, the University of Kansas, and the University of Hawaii. The Organizer was Bozenna Pasik-Duncan (University of Kansas), who was assisted by Linda Bushnell (University of Washington), Monique Chyba (University of Hawaii), Cody Clifton (University of Kansas), and Dominique Duncan (Yale University). The Organizing and Program Committee consisted of members of the IEEE CSS Technical Committee on Control Education and AACC Technical Committee on Education.




List of Speakers and Abstracts

Daniel Y. Abramovitch, Agilent Labs

WHAT IS A CONTROL SYSTEM AND WHY SHOULD I CARE

After years of teaching coaching little league trying to explain control systems to biologist and computer scientist friends, I will try the ultimate test of explaining the topic to a group of bright and easily bored high school kids. We will go through examples of feedback in everyday life, and then tease out what is common to all these examples. We will talk about how the "control" is computed, even when we don't have a computer. And we will talk about the dreaded math of control systems, and explain why we use it and what it tells us. The talk will finish with some general lessons about science and engineering, and why anyone might want to learn these intense subjects.

John Baillieul, Professor, Mechanical Engineering, Electrical and Computer Engineering, Boston University

ANIMAL FLYERS---AND HOW THEY DO IT

From bats, to birds, to insects, animal flyers exhibit phenomenal speed, grace, and agility. Upwards of several million bats emerge from each of several well known bat caves in Texas every night; peregrine falcons swoop toward their prey at close to 200 miles per hours, and goshawks fly through forest clutter at speeds approaching 40 miles per hour. Researchers have recently become interested in finding out how they do it, whether their flight behaviors can be replicated in engineered flight vehicles, and what fundamental physical performance limits can be determined. This talk will give a very high level overview of some of this research.

Christos G. Cassandras, Head, Division of Systems Engineering, Professor of Electrical and Computer Engineering, Center for Information and Systems Engineering (CISE), Boston University, President, IEEE CSS

JOYS AND PERILS OF AUTOMATION: "SMART PARKING" FOR ALL

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 or the Internet to crash. 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. An application motivated by the trend towards creating "smart cities" is that of "smart parking" which will be described and illustrated through movies from laboratory experiments involving miniaturized cities and wireless robots, as well as a real deployment in Boston.

Monique Chyba, Professor, Department of Mathematics, University of Hawaii-Manoa
Geoff Patterson, Graduate Student, Department of Mathematics, University of Hawaii-Manoa

DESIGNING SPACE MISSIONS TO RENDEZVOUS WITH TEMPORARILY-CAPTURED NATURAL EARTH SATELLITES

1) Presentation:

Designing and executing any space mission is extremely ambitious. However, history has proved that the challenge can be met successfully. As of 2012, there are eight active missions involving spacecraft navigation beyond Mars but within our solar system, with goals to advance our understanding of the universe; work toward even more exciting missions is already taking place. For instance, NASA ran in August 2012 a 10 days simulated asteroid mission for potential human-flight in 2025. Our era is witnessing an expansion in the complexity of endeavors beyond the earth's orbit. It is therefore natural to study the possibility of spacecraft missions meeting with temporarily-captured natural Earth satellites. The benefits would be tremendous in many ways.

Rendezvous missions with asteroids, comets or temporarily-captured natural Earth satellites present even greater challenges for the spacecraft than exploring the outer planets. Indeed, the effect of the mass of these objects on the gravitational field is minimal and cannot be used in the design of the trajectory for the spacecraft. As a consequence the mission has to rely heavily on years of orbit adjustment to match position and velocity with these objects of negligible mass.

Near earth asteroid rendezvous (NEAR) and Hayabusa (formerly known as MUSES-C) are completed missions that involved a rendezvous with an asteroid. The dimensions of the target were respectively measured in kilometers for Eros (the NEAR asteroid) and in hundreds of meters for Itokawa (the Hayabusa asteroid). Safe landing on the asteroid was a major success for both missions. Eros and Itokawa are Mars-Crosser asteroids, and while we still refer to them as Near Earth asteroids, their distance from the Earth is such that it took 4 years for NEAR from launch to landing, and a little over 2 years for MUSES-C. Both Eros and Itokawa are S-type (stony composition) asteroids.

Rendezvous missions to temporarily-captured natural Earth satellites differs from NEAR and Hayabusa in several ways. Indeed, temporarily-captured natural Earth satellites are called irregular satellites. After their capture, they orbit the Earth for a finite time that typically amount to a few months to eventually escape from Earth's gravity. As a consequence, tight time constraints become a major criterion when designing a mission to reach a temporarily-captured natural Earth satellite. Moreover, launch vehicles have very limited power and therefore transfers must rely heavily on the gravitational field of the solar system to minimize energy consumption. On the other hand, a rendezvous mission with a temporarily-captured natural Earth satellite has to be designed when the satellite is captured by Earth's gravity. The satellite is therefore much closer to Earth than for instance Eros or Itokawa were, and we expect to be able to design a mission within the time frame of the capture from the time it has been detected. Reaching temporarily-captured natural Earth satellites can be a solution to more complex missions that require large gravity assists needed for the spacecraft to gain momentum to reach asteroids beyond the asteroid belt, and that as a consequence impose lengthly circuitous paths that amount to years of navigation. A major difficulty however is to take into account the complexity of the orbit along which temporarily-captured natural Earth satellites typically travel. Both Eros and Itokawa's orbits are elliptic around the Sun. The orbit influences the selection of the rendezvous location as well as the design of the mission once the rendezvous between the satellite and the spacecraft has been established. An important fact to be taken into account during mission design is that temporarily-captured natural Earth satellites are objects whose average diameter is of a few meters, a size that do not permit landing approach.

2) Demonstration:

During this activity the students will build their own paper rocket and launch it. The paper rocket will be build using PVC pipes, paper and tape. One of the main goal of this activity is to construct a simple air pressure launcher for paper rockets. The main interest in such launcher is that it doesn't require an air source other than the student himself. Students stomp or jump on an empty 2-liter soft drink ("pop") bottle and force the air inside through connected plastic pipes to propel a paper rocket. The launch platform can be aimed at different angles by tilting to one side or another. Rotating the entire launcher horizontally changes its direction. The students will then explore how changing the attack angle changes the trajectory and will try to come out with mathematical strategies to solve a precise mission.

Theodore E. Djaferis, Dean, College of Engineering, University of Massachusetts Amhers

THE POWER OF FEEDBACK

The field of engineering is very exciting as it allows engineers to have jobs and work on projects with an immediate impact on society. Engineers are problem solvers who can work on "clean water," "alternative fuels," "medical imaging systems," "health-care systems," "medical instruments" and engineering degrees have many advantages including the following: 1) Engineers with BS degrees can begin to make a contribution to society and advanced degrees in engineering offer additional opportunities; 2) It is very satisfying to be able to say that you are working on something that makes a difference in peoples' lives; 3) In many cases one is able to construct devices, develop software or systems that can be relatively easy to prototype and test, so that in a very short time one can be gratified with the fruit of their labors; 4) Designing, creating or constructing something completely new allows one to express their entrepreneurial spirit and be innovative.

In solving problems engineers frequently use basic engineering principles and practices. Systems and Automatic Control Engineers frequently use the concept of "feedback," which is the focus of this talk. Feedback is found everywhere in nature and on a daily basis we encounter it in a multitude of situations. 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, many of them operating automatically keeping us alive and well. Systems and Control engineers regularly employ feedback strategies for the solution of engineering problems. These problems can have characteristics that are electrical, mechanical, chemical, hydraulic, financial, environmental or biological, to name a few. Some can be very simple problems and others can be quite complicated. In this talk we will discuss the notion of feedback, explore its use in the solution of various problems and in the process show why Systems and Automatic Control is a fascinating field of study.

Francis J. Doyle III, Associate Dean for Research, College of Engineering, Dept. of Chemical Engineering, University of California, Santa Barbara

MEDICALLY INSPIRED ENGINEERING: BUILDING AN ARTIFICIAL PANCREAS

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.

Sebastián Dormido, Prof., Dpt. Informática y Automática, Universidad Nacional de Educación a Distancia, Juan del Rosal 16, 28040 Madrid, Spain

INTERACTIVITY IN AUTOMATIC CONTROL: FOUNDATIONS AND EXPERIENCES

The first part of this talk presents the concepts of interactivity and visualization and its essential role in learning the fundamentals and techniques of automatic control. More than 10 years experience in the development and design of interactive tools dedicated to the study of automatic control concepts are also exposed. The second part summarizes the main features of the "Automatic Control with Interactive Tools" text that has been recently published by Pearson and whose aim is to provide a series of auto-contained tools allowing to learn different basic concepts related to the automatic control.

Crystal Fantry, Senior Educational Outreach Specialist, Wolfram Research Inc

DEMONSTRATING SYSTEMS WITH WOLFRAM TECHNOLOGIES

Join us to see a demonstration of modeling physical systems, designing controllers and creating simulations. Find out how Wolfram|Alpha, SystemModeler and Mathematica make modeling and control of dynamic systems - like bungee jumpers and quadrocopters - accessible to students and educators.

Elisa Franco, Assistant Professor, Mechanical Engineering, University of California, Riverside

MOLECULAR ROBOTS

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!

Philipp Reist, Institute for Dynamic Systems and Control, ETH Zurich, Switzerland

HOW TO BUILD A BLIND JUGGLING ROBOT

The Blind Juggler is a robot that is able to juggle a ball on a paddle without any sensing; there are no cameras, no microphones, or any other sensors that could tell the robot where the ball is. Imagine yourself juggling a ball blindfolded. Try it: itís no easy task! I will talk about how we built the Blind Juggler. Specifically, I will explain the concept of stability, which is important to the design of the robot. Finally, I will show some of the cool tricks that the Blind Juggler can do, such as juggling multiple balls in patterns and making the balls bounce chaotically. For more information on the Blind Juggler, please visit www.blindjuggler.org.

Mark W. Spong, Lars Magnus Ericsson Chair and Dean, Erik Jonsson School of Engineering and Computer Science, The University of Texas at Dallas, Richardson, Texas

THE FUTURE OF ROBOTICS

In the past robots were heavy, slow, dangerous and expensive and used mostly in factory automation jobs like welding and painting automobiles. In the future, robots will be more friendly, less expensive, and available everywhere. In this talk, we will discuss three important ways that robotics will impact our lives in the future – namely, networked robots, human-robot interaction, and Telepresence

Anna G. Stefanopoulou, Professor of Mechanical Engineering, Director, Automotive Research Center, University of Michigan, Ann Arbor

CONTROLLING BATTERIES AND FUEL CELLS: MASTERING THE MYSTERIOUS WORLD OF IONS

I use mathematics and physics to discover the inner workings of devices that generate power and store energy such as batteries, capacitors, and fuel cells. Then I create virtual models and codes that feed control signals to these devices so that they can be operated safely.

When my models and control codes work well, nobody notices and even my daughter thinks that I deal with pretty boring stuff.

So I am going to show you what happens when my control magic fails. Special "neutron vision goggles" will let us look inside these mysterious chemical devices. Watch what happens to the lithium ions inside a battery's electrodes as it starts to swell when my controls go haywire. And see how fuel cell channels flood with water, causing rapid corrosion when my hydrogen controller misbehaves. I promise that the show is safe and no explosions will occur.

After this experience, I bet you will appreciate my Math and Control tools for Mastering and Commanding these powerful devices!

Supported by Ford, US Army, NSF, NIST, A123.

Sebastian Trimpe, Institute for Dynamic Systems and Control, ETH Zurich, Switzerland

A CUBE THAT BALANCES ITSELF ON A CORNER

When you put an ordinary cube on one of its corners and let it go, it will fall. The Balancing Cube is different - you can put it on any of its corners, and it will balance. Six rotating arms located on each of the cube's faces make balancing possible. Multiple times every second, the arms sense the cube's motion, compute corrections based on these measurements, and rotate accordingly. It is through this continual feedback process of sensing, computing, and adjusting that the system as a whole is able to balance. The fundamental concept of feedback control is illustrated in this presentation by discussing how the Balancing Cube works. For more information on the Balancing Cube, see www.cube.ethz.ch.

Quanyan Zhu, Coordinated Science Laboratory, Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign

GAME THEORY: FROM ECONOMICS TO ENGINEERING

This talk is a multidisciplinary introduction to game theory and its applications in multiple disciplines such as social science, economics, and engineering. Developed in 1960's, game theory has been widely used in economics to explain the strategic interactions among different players in competitive or cooperative environment. Recently, it has just been introduced into engineering to analyze and design complex systems such as wireless sensor networks, energy markets and cyber security. The purpose of this talk is to introduce multi-agent control systems from a game theory perspective. The talk discusses the importance of game and control theory from a conceptual level, incorporating examples of lottery, biology, social media and networks, popular culture, etc. We address the question why game theory is relevant in our lives, and how it is related to engineering disciplines and research. Students are strongly encouraged to participate actively in the thought experiments in the talk.