Electroactive Polymers (EAP's) as Artificial Muscles and Sensors: Fundamentals, Applications, and Control Problems

A one-day workshop at the 2007American Control Conference, New York, NY
July 10, 2007, Tuesday

Organizers:

Dr. Xiaobo Tan, Department of Electrical & Computer Engineering, Michigan State University
Dr. Kwang J. Kim, Department of Mechanical Engineering, University of Nevada, Reno

Instructors:

Dr. Kwang J. Kim, Department of Mechanical Engineering, University of Nevada, Reno
Dr. Benjamin Shapiro, Department of Aerospace Engineering, University of Maryland, College Park
Dr. Xiaobo Tan, Department of Electrical & Computer Engineering, Michigan State University
Dr. Woosoon Yim, Department of Mechanical Engineering, University of Nevada, Las Vegas

SUMMARY:

Electroactive polymers (EAP's), also known as *artificial muscles*, are a family of novel, attractive, smart materials characterized by large mechanical deformation upon electrical stimuli. These materials typically require low actuation voltage (under several volts), have high strain output, and are resilient and light-weight. They can be used as actuators, sensors, and energy harvesting devices, and have numerous potential applications in bio and micromanipulation, biomimetic robotics, prosthetics, and smart structures. The purposes of this one-day workshop are: 1) to expose the controls community to the basic principles and properties of several most promising EAP materials and their robotic, biomedical, and industrial applications, and 2) to explore the opportunities and challenges for the controls community in the modeling and control of EAP's. In particular, we will demonstrate how the control systems perspective (systems and control tools) can be taken to better understand the actuation and sensing mechanisms of EAPs, to develop effective and efficient real-time control and sensing strategies, and to build integrated, micro, autonomous systems enabled by EAP's.

WORKSHOP OUTLINE AND SCHEDULE:

8:00 – 8: 15 Overview [Tan**]**
Overview of electroactive polymers; workshop organization and schedule

8:15 – 9:45 Fundamentals and applications of ionic polymer-metal composites [Kim**]**
Fundamentals of Ionic polymer-metal composites (IPMC's); fabrication processes; working principles of IPMC actuators and sensors; biomedical, robotic, and industrial applications

9:45 – 10:00 Break

10:00 – 11:30 Fundamentals and applications of conjugated polymers [Shapiro]
Fundamentals of conjugate polymers; fabrication (including microfabrication) methods; biomedical and robotic applications; modeling of conjugated polymer actuators

11:30 – 12:00 Other important electroactive polymers [Kim]
Dielectric elastomers and carbon nanotubes as EAP's; working principles and applications

12:00 – 1:15 Lunch break

1:15 – 2:15 Case study: modeling and control of EAP-based robotic fish [Yim]
Undulatory motion of segmented IPMC actuator; modeling of actuation dynamics and hydrodynamics; neural oscillator-based controller for fish locomotion

2:15 – 2:45 Integrated sensory feedback for artificial muscles [Tan]
Need for integrated sensing in bio/micro/robotic applications; model-based compensation in integrated sensing; application to microinjection of Drosophila embryos

2:45 – 3:00 Break

3:00 – 4:30 A control-system perspective on EAP's [Tan]
Physics-based, control-oriented modeling; model reduction; model-based control design (robust adaptive control, H_∞ control) to handle uncertainty; experimental validation

4:30 – 5:00 Open discussion on challenges and opportunities [Kim, Shapiro, Tan, Yim]

WOKSHOP INSTRUCTORS:

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Kwang J. (Jin) Kim is Professor and Interim Chair of Mechanical Engineering Department and Director of Active Materials and Processing Laboratory (AMPL) and Advanced Energy Laboratory (AEL) at University of Nevada, Reno (UNR). He graduated from Yonsei University, Korea, in 1987 and received his MS and Ph.D. from Arizona State University in 1989 and 1992, respectively. Later, he completed a postdoctoral study at University of Maryland-College Park (1993-1995). His industrial experience includes Senior Research Engineer at Thermal Electric Devices, Inc. (1995-1997) and Chief Scientist at Environmental Robots, Inc. (1997-2001), Albuquerque NM. Also, he was an adjunct professor of University of New Mexico (1996-2001). His research interests are in Active Materials/Sensors and Energy Systems, that are currently sponsored by National Science Foundation, Navy, Army, Air Force, Department of Energy, NASA, Nevada Department of Transportation, and private industries. He has authored/co-authored over 200 technical papers (87 referred journal papers) including two books "Artificial Muscles: Applications of Advanced Polymeric Nano-Composites" and "Electroactive Polymers for Robotic Application: Artificial Muscles and Sensors" and holds one US patent. He is a recipient of the 2006 UNR Lemelson Award for Innovation and Entrepreneurship, the 2002 Ralph E. Powe Junior Faculty Enhancement Award from Oak Ridge Associated Universities, and the 1997 Best Paper Award of ASME/Advanced Energy Systems/HPTC.

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Dr. Benjamin Shapiro received his B.S. from Georgia Institute of Technology in 1995 in Aerospace Engineering, and his PhD from the California Institute of Technology in 1999 in the field of Control and Dynamical Systems. Currently he is an associate professor at the Aerospace Engineering department at the University of Maryland. He has a joint appointment with the Institute for Systems Research, and is affiliated with the Bio-Engineering graduate program and the Applied Math and Scientific Computation program. Dr. Shapiro's research interests are focused on modeling, design, and control of miniaturized system that involved complex fluid dynamics and bio-chemical phenomena. Current programs include: modeling and control of electrically actuated lab-on-a-chip systems, modeling and design of electrochemically driven conducting plastic actuators, fluid flow optimization for protein bio-chemical sensing, using living cells as low false positive bio-chemical sensors, computational fluid dynamics for complex 2-phase electrically driven flows, and modeling/optimization of iso-electric protein focusing in micro-channels. Dr. Shapiro is the recipient of the 2003 NSF Career award, for modeling and control of micro-fluidic systems, and is a member of the Small Smart Systems Center at the University of Maryland.

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Xiaobo Tan is an Assistant Professor in Electrical & Computer Engineering at Michigan State University. He received his B.S. and M.S. degrees in Automatic Control from Tsinghua University in 1995, 1998, and his Ph.D. in Electrical and Computer Engineering from University of Maryland in 2002. Prior to joining MSU in 2004, he was a Research Associate with the Institute for Systems Research at University of Maryland. He was an ISR Systems Fellow from 1998 to 2002, a finalist for the Best Student Paper Award at the 2002 IEEE Conference on Decision and Control, a co-recipient of the Best Poster Award at the MEMS Alliance Special Topics Symposium in April 2003, and a recipient of the NSF CAREER Award in 2006. His research interests include electroactive polymer sensors and actuators, modeling and control of smart materials, biomimetic robotics, and control of autonomous swarms.

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Woosoon Yim is a professor of Mechanical Engineering and Director of Intelligent Structures and Control Laboratory at University of Nevada, Las Vegas (UNLV). He received his B.S. degree in Mechanical Engineering from Hanyang University in Korea in 1981, and M.S. and Ph.D. degrees in Mechanical Engineering from University of Wisconsin-Madison in 1984 and 1987, respectively. Since 1987, he has been with the Mechanical Engineering Department in the University of Nevada, Las Vegas, and currently he is a professor and Graduate Program Director. He is a member of ASME and IEEE, and served as an organizing and program committee member for 2003 IEEE International Conference on Intelligent Robots and Systems (IROS) and a local arrangement chair for 2002 IEEE CDC and 2007 ASME IDETC. His research interests are in Intelligent Material and Control Systems Development, that is currently sponsored by National Science Foundation and Army Research Laboratory. He has authored/co-authored more than 100 technical papers.