Center Directors:
James Abbas
Ranu Jung

Program Coordinator:
Betsy Arnold
betsy.arnold@asu.edu

Contact:
Tel: (480) 414-2626
Fax:(480) 727-8395

jabbas@asu.edu
Tel: (480) 965-9521

rjung@asu.edu
Tel: (480) 965-9052

www.biodesign.asu.edu/centers/ans/

The Center for Adaptive Neural Systems presents a symposium on

"Adaptation and Learning in Neuro-Biomechatronic Systems"

Supported by National Science Foundation ***SBE-0518697***

Location: Biodesign Auditorium
The Biodesign Institute at Arizona State University
March 22-23, 2007
Tempe, Arizona

Symposium Objective:

This symposium will explore key issues regarding co-adaptation of engineered systems with biological systems. The symposium will bring together life scientists, engineers, mathematicians, and clinician-scientists. It will create a forum for interaction to identify key limitations and opportunities for anticipated advances in enabling technologies that promote adaptation and learning. A diverse set of experts will lead seminars and discussions towards integration of adaptive engineered systems with the inherent learning and plastic capabilities of living systems. The symposium will work towards developing strategies for cohabitation in advanced rehabilitation systems.

Thursday, March 22, 2007

1:00 - 1:30 pm Introduction and Overview:
Ranu Jung, Co-Director Center for Adaptive Neural Systems
Associate Professor of Bioengineering

1:30 - 2:30 pm Apostolos P. Georgopoulos
"Noninvasive Neural Engineering"
Regents Professor
University of Minnesota
http://www.neurosci.umn.edu/faculty/georgopoulos.html

2:30 - 3:30 pm Scott Frey
"Neural representations of technology: Implications for rehabilitation"
Professor of Psychology
Director, Lewis Center for Neuroimaging
University of Oregon
http://freylab.uoregon.edu; http://lcni.uoregon.edu

3:30 - 4:00 pm **Break**

4:00 - 5:00 pm David Fuller
"Neuroplasticity in biological systems"
Assistant Professor
Department of Physical Therapy
McKnight Brain Institute
University of Florida
http://www.phhp.ufl.edu/pt/fuller.shtml

CENTER FOR ADAPTIVE NEURAL SYSTEMS

Friday, March 23, 2007

8:45 - 9:00 am	Introduction
9:00 - 10:00 am	Arunava Majumdar **"Replicating the sense of smell in a miniature device"** Professor and Member of National Academy of Engineering Departments of Mechanical Engineering & Materials Science & Engineering University of California, Berkeley http://www.me.berkeley.edu/faculty/majumdar/
10:00 - 11:00 am	Thomas Stieglitz **"How can neural microimplants adapt to a changing biological system?"** Professor Director, Laboratory of Biomedical Microtechnology Institute for Microsystem Technology University of Freiburg (Germany). http://www.imtek.de/bmt/
11:00 - 11:30 am	Break
11:30 - 12:30 pm	Ralph Etienne-Cummings **"Dynamic Generation and Control of Spinal Locomotion Signals and Its Application to Neural Prosthetic Devices"** Associate Professor Department of Electrical and Computer Engineering Johns Hopkins University Director, Institute of Neuromorphic Engineering, University of Maryland http://etienne.ece.jhu.edu/labweb/info.html http://www.ine-web.org/

Participating Units

IRA A. FULTON SCHOOL OF ENGINEERING
- Harrington Department of Bioengineering
- Department of Chemical Engineering
- Department of Electrical Engineering
- WINTech/Connection One
- Imaging and 3D Data Exploitation and Analysis Lab

COLLEGE OF LIBERAL ARTS AND SCIENCES
- Department of Kinesiology
- Department of Mathematics and Statistics
- School of Life Sciences

BARROW NEUROLOGICAL INSTITUTE
- Division of Neurobiology

Catalyst: Center of Excellence in Adaptive Neuro-Biomechatronic Systems (CEANS)

A Planning Grant for a National Science Foundation Science of Learning Center

Summary

When using a tool or a device, a person must learn to interact with it appropriately in order to accomplish the task at hand. We learn to swing a hammer in a manner that strikes the nail accurately; we learn to press the brake with an appropriate level of force to decelerate the car smoothly; and we learn to move a computer mouse in order to proficiently utilize software. As technology becomes increasingly complex in its operations, its functionality, and its degree of interaction with the user, there is a growing need to embed adaptability and intelligence into the device itself. In this situation, the device and the user simultaneously learn in an attempt to optimize their interactions. The degree of success in this sensorimotor learning process depends strongly on the interaction between the person and the engineered system.

The focus of the Center of Excellence in Adaptive and Neuro-Biomechatronic Systems (CEANS) will be to understand and to optimize the learning that occurs as humans interact with adaptive technology. The Center will focus its efforts on addressing a few broad questions: What are the biological processes that occur as a person learns to interact with a device? How do the properties of the device affect the learning process? How can we design engineering devices to maximize the effectiveness of the learning process?

CEANS will use advanced prosthetic systems as a research platform to address these questions regarding the nature of the sensorimotor learning process and to develop strategies for the design of adaptive systems to achieve specific learning outcomes. After a traumatic injury such as limb loss or spinal cord injury, technology can assist in tasks such as stepping, reaching or grasping. Several intelligent robotic devices and electrical stimulation systems with adaptive capabilities that are either on the market or on the horizon require that the person learn to use the device as the device adapts to meet the needs of the person. CEANS will use these types of co-adaptive prosthetic systems to investigate the molecular, cellular and systems-level dynamics of sensorimotor learning.

Our goal for this Catalyst project is to lay the foundation for a Science of Learning Center that addresses key issues regarding learning in the integration of adaptive biological systems with adaptive engineered systems. In the planning period, we will develop a proposal for a Center that integrates interdisciplinary research and development with educational and outreach programs. Our research agenda will be at the intersection of molecular biology, neuroscience, mathematics, bioengineering, and rehabilitation. CEANS will draw upon a wide range of expertise to discover the principles that govern activity-dependent learning in living systems, to develop novel approaches to sense dynamic changes in adaptive living systems, and to deliver new adaptive technology for sensorimotor learning. The scope of activities will include experimental biological investigation, design and development of new technology to maximize learning outcomes, the evaluation of the effects of the technology on biological learning processes, and the transfer of these techniques to biomedical industry and clinical practice.

TITLES & ABSTRACTS FOR SPEAKERS

1. Apostolos P. Georgopoulos

TITLE: "Noninvasive Neural Engineering"

ABSTRACT: TBD

2. Scott Frey

TITLE: "Neural representations of technology: Implications for rehabilitation"

ABSTRACT: The ability to manufacture and use technology to augment existing behavioral abilities is a hallmark of the human species. Understanding the neural mechanisms that support these behaviors and how they are affected by experience is critical for the development and optimization of rehabilitation protocols, as well as assistive and prosthetic devices. In this talk I will discuss research from the field of cognitive neuroscience concerning the neural bases of tool use behaviors in humans and other primates, and discuss the implications of these findings for 'neuro-biomechatronics.'

3. David Fuller

TITLE: "Neuroplasticity in biological systems"

ABSTRACT:

[1]**D.D. Fuller**, [1]N.J. Doperalski, [2]M. Lane, [1]K. Qiu, [1]M. Sandhu, [1,3] L.R. DeRuisseau, [3]B.J. Byrne, and [2]P.J. Reier. Depts. of [1]Physical Therapy, [2]Neuroscience, and [3]Pediatrics. University of Florida. Gainesville, FL. 32610.

Neural plasticity can be defined as a persistent change in the structure and/or function of neurons or neural networks due to experience. Thus plasticity is a fundamental property of neural systems, and occurs in both health and disease. An understanding of how to promote and harness plasticity is of paramount importance to rehabilitation following injuries to the central nervous system (CNS). For example, both experimental and currently accepted therapeutic strategies after CNS injury (*e.g.* cell transplant, physical therapy, brain-machine interface) should compliment endogenous neural plasticity and any associated natural repair mechanisms. My colleagues and I study plasticity in the neurons and networks that control breathing. Using data from our group at the University of Florida, and select examples from the literature, I will provide an overview of plasticity in neural systems, and will attempt to synthesize several general rules that relate to plasticity in the context of neural rehabilitation and repair. Topics to be addressed include: 1) stimulation paradigms to optimally induce plasticity, 2) gene therapy and plasticity, 3) enhancing endogenous mechanisms of neuroplasticity, and 4) sex hormones and plasticity. The intent is to stimulate thought and discussion regarding the mechanisms by which neural plasticity occurs, and how plasticity can be interfaced with emerging biotechnologies.

Funding: NIH 1R01HD052682-01A1 (DDF), NIH RO3 NS050684-01A1 (DDF), 1 R01 NS054025-01 (PJR)

4. Arunava Majumdar

TITLE: **"**Replicating the Sense of Smell in a Miniature Device"

ABSTRACT: The only human senses that have not been replicated in a miniaturized device are the senses of smell and taste. Devices and systems that are most amenable to miniaturization are based on ligand-receptor binding and subsequent transduction to an optical or an electronic signal. Current sensor systems that rely on receptor-based chemical sensing have inadequate performance. The key technical challenge has remained the selectivity of the receptors, since most systems in the past have used arrays of polymers. Polymers have marginal differences in affinity to gas molecules, making them susceptible to non-specific binding, especially of water vapor, with grossly inadequate selectivity to specific target gas molecules. To address this critical issue, we propose a new approach whereby we mimic the principles of molecular recognition in biology to achieve highly selective binding to gas molecules. Molecular recognition is achieved through multivalent binding of a molecular recognition element (MRE) to a target molecule that can occur through the complementary structure and chemistry of the MRE. We have developed a comprehensive program where we are combinatorially screen large libraries of MREs against specific target analyte molecules in the presence of a realistic background mixture of other molecules. So far, we have identified MREs against explosives-related molecules and the process is now being expanded to other volatile organics. Once these MREs are identified, they are integrated into a coating that is then placed on microelectromechanical MEMS devices. In particular, our group has developed membrane-based devices that deform in the presence of ligand-receptor binding on one surface, which can be detected electronically through capacitive measurements. The combination of selectivity of the MRE-embedded coatings and the sensitivity of the MEMS sensor yields desirable receiver operating characteristics.

5. Thomas Stieglitz

TITLE: "How can neural microimplants adapt to a changing biological system?"

ABSTRACT: Information exchange between an implant and a neural system takes place at the neuro-technical interface. Electrodes have to record bioelectrical signals or deliver charge to electrically stimulate axons or somata of excitable cells nearby. The implantation of any monitoring and intervention system severely disturbs the biological system: inflammation, foreign body reaction and material-tissue interaction with respect to surface and structural biocompatibility occur. Peripheral nerves form oedema due to manipulation during implantation. Even though miniaturization delivered arrays with large numbers of electrode sites in dimensions of cell bodies, the precision during implantation is limited for chronic implants. Stereotactic insertion delivers fascinating precision in the brain but physiologic movements might shift microimplants over time. Thus, anticipating biological reactions in the design of neural microimplants is a challenging task. Several aspects how biological changes might be compensated with engineering solutions will be discussed: Adequate material selection with respect to cytocompatibility and long term stability is mandatory. A proper design with respect to mechanical (structural) biocompatibility might prevent strong tissue growth and thereby displacement of the implant from the target tissue. Mechanical flexible systems may follow tissue movements due to ventilation or heart beat and do not lead to increased pressure peaks at the material-tissue-interface. If the exact target structure is unknown prior to implantation or the orientation of the implant can hardly be altered during the intervention, technical systems may have redundant electrode sites that will be selected to a later point of time. The Utah array is an excellent example of this design paradigm. Even though equipped with 100 channels, only eight channels have been used in a human trial to control an interface for communication. If signal to noise ratio is not sufficient in this "passive" adaptation, several research groups proposed active electrode control to optimize the electrode nerve position by actuators. Approaches include precision mechanics drives for stereotactic needle placement, micromachined gears that have been integrated into the top of a silicon needle electrode, and latest shape memory polymers. For peripheral nerve interfaces, the two way effect of shape memory metals has been proposed. Advantages and disadvantages of the different engineering solutions to adapt to a changing biological system will be discussed and compared to chemical and biological approaches.

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ARIZONA STATE UNIVERSITY

6. Ralph Etienne-Cummings

TITLE: "Dynamic Generation and Control of Spinal Locomotion Signals and Its Application to Neural Prosthetic Devices"

ABSTRACT: For normal locomotion, the brain initiates and modulates the activity of spinal cord circuits that generate the basic motor pattern, called the central pattern generator (CPG). After severe spinal cord injury, patients are unable to walk because they cannot activate or control the CPG, although the local circuits may still be intact. One approach to restoring locomotion is to use phase-dependent electrical stimulations of the spinal cord or muscles, relative to either the underlining activity in the cord or sensory feedback, is required. Hence, work focuses on understanding how to generate signals required for locomotion and/or control the existing locomotion circuits in the spinal cord. We approach this problem from an instrumentation and neural signal processing by developing neuromorphic chips that may become implantable neural prosthetic devices. Ultimately, such a neuroprosthesis, which could be used in combination with regeneration or training methods and functional electrical stimulation, would have to initiate activity and dynamically modulate the rhythm of the CPG according to parameters or commands supplied by the user.

In this talk, I will show how CPGs spinal circuits from a lamprey are modeled mathematically and in silicon. I will then show these silicon CPGs being used to adaptively control walking/running in robotic biped.
The ideas gleaned from the robotics experiments lead us to conducting neuroscience experiments using lamprey spinal cords, to investigate how to interact with the biological locomotion controllers. Finally, I will show how we can use these neuroscience results and /neuromorphic/ VLSI chips to "replace" the spinal cord and brain signals in an anesthetized cat, and how this may lead to the development of the next generation controllers for prosthetic limbs for humans.