Neurodesign
Using computational modeling for the design of neurotechnology

CNS*2010 workshop
July 30, 2010

Engineered systems are increasingly being integrated with the nervous system and a concerted effort is being made to make them adaptive. This workshop will link Computational Neuroscience with development of Neurotechnology for interfacing with the spinal cord and the peripheral nervous system. Interfacing with the spinal cord and the peripheral nervous system offers the opportunity to provide directed engineering control of end organs whose natural control has been lost or compromised, to tap the nervous system for control of external devices while taking advantage of the dynamic and adaptive integrative computational properties of having the "person in the loop" and to use neurotechnology to promote plasticity in the nervous system through patterned afferent stimulation.

The workshop will explore and discuss the use of neuromorphic models in the design of algorithms and spinal and peripheral neural interfaces for electrical stimulation control of different biological systems. Examples of the use of such systems for promoting plasticity in the nervous system will also be examined.

Organizers:

Doug Weber (djw50@pitt.edu), University of Pittsburgh
Ranu Jung (ranu.jung@asu.edu), Arizona State University

Format: Invited talks: 35 minutes + 10 minutes q/a
Student/postdoc/participant talks: 5 slides/10 minutes

Program

8:00-8:15 Introduction to the Workshop

8:15-9:00 James Abbas (Arizona State U)
Title: Neural oscillators and cyclic movements
When cyclic processes such as locomotion or breathing are impaired by injury or disease, neural interface technology can sometimes be used to restore function. These engineered systems must interact with the biological system in a coordinated manner in order to accomplish the task at hand. Computational models of neural oscillators can be embedded into the engineered systems to endow the technology with capabilities that are at least reminiscent of their biological inspiration and possibly to facilitate integration with the biological system. This talk will review the intent, implementation and outcomes of approaches that use models of neural oscillators to control cyclic processes using neurotechnology.

9:00- 9:45 Vivian Mushawar (U Alberta)
Title: Computational models of walking: Necessary features for the production of robust over-ground locomotion
This talk will focus on aspects of locomotion that are necessary for incorporation within a neuroprosthetic device in order to restore functional walking following spinal cord injury, head trauma or stroke. Principles pertaining to the interaction of feed-forward and feedback control emulating the central pattern generator for locomotion and sensory modulation, respectively, will be discussed. The importance of the natural recruitment order of motor units for resistance to muscle fatigue and the activation of spinal circuits for the production of coordinated movement synergies will be highlighted. Results from computer simulations and in vivo experimentation demonstrating the effects of various principles of locomotion on walking patterns produced through neuroprosthetic devices will be shown.

9:45- 10:00 Break

10:00 -10:45 Matt Schiefer (Case Western Reserve U)
Title: Optimized Design of Lower Extremity Neural Interfaces: Anatomically-Based Model-Driven Design and Intraoperative Evaluation
Realistic computer models of a Flat Interface Nerve Electrode (FINE) on the proximal femoral nerve were created and analyzed for their potential to restore knee extension and hip flexion while meeting the competing constraints of simultaneously maximizing selectivity while minimizing stimulus channels. Simulations suggested that an 8-contact FINE could selectively recruit muscles to restore standing and facilitate stepping. Based on these results, a clinical-grade FINE was manufactured and placed around the femoral nerve in a series of intraoperative experiments. The efficacy of the FINE to selectively recruit muscles was determined using electromyograms (EMGs). At least four of the six muscles innervated by the femoral nerve were selectively recruited in all subjects. Normalized EMGs and biomechanical simulations were used to estimate joint moments and functional efficacy. Intraoperative results and computer model predictions were found to be correlated.

10:45-11:30 Douglas Weber (U Pittsburgh)
Title: Recruitment of dorsal root ganglion neurons by intraneural stimulation
Primary afferent microstimulation (PAMS) can be used to selectively activate somatosensory fibers, such as the muscle and cutaneous neurons that mediate proprioception and tactile sensations. Computational models are being developed to gain insight into the number and types of fibers recruited by PAMS, so as to facilitate development of a somatosensory neural interface to provide haptic and proprioceptive feedback for prosthetic limbs.

11:30 - 12:30 Mini Talks (3-5 students/postdocs/other participants)
Student #1 Tsvi Achler, Los Alamos National Labs. USA.
Title: Role of Top-Down Feedback in Processing Simultaneous Patterns

Humans and other animals exhibit a remarkable ability to process simultaneous patterns in parallel, an ability that has been difficult to capture in tradition, feed forward computer vision algorithms. Our experimental findings show that both backward and simultaneously presented visual masks display nearly identical similarity and asymmetry phenomena, suggesting a common underlying mechanism. Our simulations indicate that massive output-to-input "top-down" re-entrant feedback pathways, such as are found throughout sensory processing regions of the brain, can account for the similarity and asymmetry properties observed in both types of tasks. Such feedback connections may have evolved to promote efficient simultaneous pattern processing.

If you would like to be considered for the Mini Talks, please contact Ranu Jung (ranu.jung@asu.edu) by email or sign up with Name/Title/Affiliation.

Lunch: 12:30 – 1:30

1:30-2:15 Sliman Bensmaia (U Chicago)
Title: Predicting the timing of spikes evoked by tactile stimulation of the hand

What does the hand tell the brain? Tactile stimulation of the hand evokes remarkably precise patterns of neural activity, suggesting that the timing of individual spikes may convey information. However, many aspects of the transformation of mechanical deformations of the skin into spike trains remain unknown. Here, we describe an integrate-and-fire model that accurately predicts the timing of individual spikes evoked by arbitrary mechanical vibrations in three types of mechanoreceptive afferent fibers that innervate the hand. The model accounts for most known properties of the three fiber types, including rectification, frequency-sensitivity, and patterns of spike entrainment as a function of stimulus frequency. These results not only elucidate the process of mechanotransduction but can be used to provide realistic tactile feedback in upper-limb neuroprostheses.

2:15-3:00 Ken Horch (Arizona State U)
Title: This Hand is my Hand.
The advantages of electrical stimulation of nerve stumps in amputees for providing tactile and proprioceptive sensations referred to the missing limb and hand will be presented. However, peripheral sensory receptors exhibit non-linear properties, such as adaptation, which need to be better modeled in order to provide a more realistic substitute for normal sensation.

3:00-3:15 Break

3:15-4:00: Michel Lemay (Drexel U)
Title: Neurotrophins and sensory afferent stimulation for promoting neuroplasticity
Neurotrophins producing transplants can be used to promote locomotor recovery in spinalized animals through their actions on the locomotor spinal circuitry. However, the locomotion obtained through neurotrophins producing transplants still suffer from a number of deficits, such as reduced step length, which may be addressed through the use of phase-dependent activation of the hindlimb sensory afferents.

4:00-4:45: Ranu Jung (Arizona State U)
Title: Promoting neuroplasticity through neuromuscular electrical stimulation
The first talk discussed neuromorphic oscillators for controlling cyclic processes for adaptive control of movement while the previous talk discusses the role of afferent stimulation in promoting neuroplasticity after incomplete spinal cord injury. Here we will describe the use of adaptive electrical stimulation to provide repetitive movement therapy and activation of sensory afferents to promote recovery of function.

4:45-5:30pm: Group Discussion Chalk-Talks