Brain-Machine Interfaces (BMI) is a young multidisciplinary field that has grown tremendously during the last decade. BMI has enormous potential as therapeutic technology that will improve the quality of life for the physically impaired.

BMI is about transforming thought into action, or conversely, sensation into perception. This novel paradigm contends that a user can perceive sensory information and enact voluntary motor actions through a direct interface between the brain and a prosthetic device in virtually the same way that we see, hear, walk or grab an object with our own natural limbs. Proficient control of the prosthetic device relies on the volitional modulation of neural ensemble activity, achieved through training with any combination of visual, tactile, or auditory feedback.

Interfaces exist at invasive and non-invasive levels. Examples of the former include cortical multielectrode array implants as well as cochlear implants, whereas the latter includes EEG recordings from the scalp (commonly referred as BCI).

Ultimately, research in BMI systems aims at achieving the milestones required to bring this technology to the clinical realm, and to explore and build real-world future applications of this technology. However, for this to occur, a systems perspective is required to develop real-world complex neuroprosthetics devices where man (human-in-the-loop, training) and modern cybernetics (feedback, learning) are pivotal components. To encourage this, the IEEE Systems, Man, and Cybernetics Society’s Technical Committee on BMI Systems was formed. This TC focuses on the integration within BMI systems of the three areas of SMC: Systems, Human-Machines Systems, and Cybernetics, which is required in order to develop and build real-world BMI systems.
Research in BMI strongly suggests that the "proof of concept" for the theoretical feasibility for building such working real-world BMI systems has moved from theory to the clinic. Using single unit recording, EEG and ECoG signals, human patients have already demonstrated simple real-time control. This progress is expected to greatly accelerate over the next 1-2 years, leading to direct control of various devices. Many researchers, who use ECoG signals, use them to "artificially" control simple devices, e.g., 2 degrees of movement, by having the patient think specific thoughts similar to "tapping" motions. Measuring the brain response to thinking about "taps", which can be detected via their ECoG signals, the researcher can then have the patient "control" simple devices. Other researchers have had success in not only having an animal control an artificial device via single cell recordings, but also having the animal create and learn new "neural" pathways in order to control an additional simple artificial limb in addition to their natural ones. However, promising new research now focuses on reading and decoding the actual ECoG signals of humans that are responsible for specific limb control. The goal is that these ECoG signals can then be used by the patient to control, naturally and in real-time, a complex prosthetic device similar to the actual limb that is controlled by the same signals. In fact, this approach has already recently been used by a patient to achieve simple control. Each approach has its use, with the last one being the most promising in achieving natural real-time control by a patient using more complex prosthetic devices (with more degrees of freedom than current devices) to replace missing limbs. Thus the direction of BMI will soon turn more and more to not "Can such a system ever be built?" to "How do we build it?"

SMC plans to host a series of workshops over the next 5 years to be held concurrently with its annual flagship conference each October. The goal of these workshops is to focus on the second question, how do we actually build a real-world BMI system?

Thus, instead of focusing only on narrow theoretical facets of BMI systems, these series of workshops plan to bring together all the stakeholders needed in order to initiate the process to actually build a real-world BMI system. The requirements, bottlenecks, resources, need, timeline, and funding necessary for developing and building real-world BMI systems will be addressed.

Hence this workshop, the first one in this series, aims to bring together experts on the different areas that will be required as part of any real-world BMI system, including system integration, sensors, integrated circuits, machine learning, control, robotics, systems neuroscience, and clinical studies. Workshop participants will include experts on research across different animal species as well as humans, with both invasive and non-invasive techniques for interfacing the brain. Participants will include neurologists, system engineers, cybernetic experts, and human-machine professionals.

BMI experts and experts in the above areas seriously interested in BMI are invited to participate in discussions about the future of BMI Systems research with respect to the scope of SMC, and the planning of future BMI workshops.
Agenda

Sunday, October 11th:

8:00-12:30  Tutorial:  Brain-Machine Interfaces
Jose M. Carmena
University of California
Berkeley, California, USA
Jose del R. Millan
Swiss Federal Institute of Technology
Lausanne, Switzerland

Abstract

In this tutorial we will introduce the exciting new field of brain-machine interfaces (BMI) and survey the main invasive and non-invasive techniques employed and their applications.

BMI is a young interdisciplinary field that has grown tremendously during the last decade. BMI is about transforming thought into action, or conversely, sensation into perception. This novel paradigm contends that a user can perceive sensory information and enact voluntary motor actions through a direct interface between the brain and a prosthetic device in virtually the same way that we see, hear, walk or grab an object with our own natural limbs. Proficient control of the prosthetic device relies on the volitional modulation of neural ensemble activity, achieved through training with any combination of visual, tactile, or auditory feedback. BMI has enormous potential as therapeutic technology that will improve the quality of life for the neurologically impaired.

Research in BMIs has flourished in the last decade with impressive demonstrations of nonhuman primates and humans controlling robots or cursors in real-time through singleunit, multiunit and field potential signals collected from the brain. These demonstrations can be divided largely into two categories: either continuous control of end-point kinematics, or discrete control of more abstract information such as intended targets, intended actions, and the onset of movements. In the first part of the tutorial, Dr. Carmena will cover cortical approaches to BMI with a focus on bidirectional techniques for decoding motor output and encoding sensory input. The techniques to be discussed include chronic microelectrode arrays in animal subjects as well as electrocorticography (ECoG) in human subjects. In the second part of the tutorial, Dr. Millan will cover non-invasive approaches to BMI with a focus on brain-controlled robots and neuroprosthetics. These approaches are based on electroencephalogram (EEG) signals. As illustrated by some working prototypes such a wheelchair, the success of these approaches rely on the use of asynchronous protocols for the analysis of EEG, machine learning techniques, and shared control for blending the human user’s intelligence with the intelligent behavior of a semi-autonomous robotics device.
Monday, October 12th:

AM: Keynote:  Oscillatory Dynamic and Brain Machine Interface Systems

Robert T. Knight, M.D.
University of California
Berkeley, California, USA

Understanding the neural basis of cortical processing promises to lead to advances in Human-Machine Systems with immense implications for both the normal population and patients with devastating neurological disorders. Our work shows that brain machine interface (BMI) is viable in humans using brain oscillations to control peripheral devices such as prosthetic limbs and potentially to generate language.

Studies to date reveal that every cognitive process examined including language, attention, memory and motor control generates high frequency oscillatory activity in the range of 70-250 Hz (high gamma, HG). Importantly, the HG band of the human ECoG has the most precise spatial localization and task specificity of any frequency we and others have examined. For instance, during language processing, HG precisely tracks the spatio-temporal evolution of language from comprehension in posterior temporal areas to production structures in frontal brain regions. Importantly, these HG changes track the subjects behavioral performance in real-time over the course of the 1200 milliseconds needed to comprehend the word, select a noun and articulate a response. Motor activity is also tracked by brain oscillations and studies will be discussed that use these brain oscillations to control peripheral devices in humans with implanted electrodes. Similarly, we have developed means to extract linguistic information from brain activity suggesting that thus approach may be useful for speech production.

The HG response is phase locked to the trough of theta rhythms (4-8 Hz) in the neocortex. This HG-theta coupling occurs in a task specific manner with different cognitive tasks eliciting unique distributed spatial patterns of HG-theta coupling. These results indicate that transient coupling between low- and high-frequency brain rhythms may provide a mechanism for effective communication in distributed neural networks engaged during cognitive, language and motor processing in humans.

Future BMI real-world applications will require the integration of all three areas of SMC: Human-Machine Systems, Cybernetics, and System Science and Engineering.

Noon:  Panel:

Brain Machine Interfaces – A new research avenue for cybernetics and system science
Brain-Machine Interfaces (BMI) is a young interdisciplinary field that has grown tremendously during the last decade. BMI is about transforming thought into action, or conversely, sensation into perception. This novel paradigm contends that a user can perceive sensory information and enact voluntary motor actions through a direct interface between the brain and a prosthetic device in virtually the same way that we see, hear, walk or grab an object with our own natural limbs. Proficient control of the prosthetic device relies on the volitional modulation of neural ensemble activity, achieved through training with any combination of visual, tactile, or auditory feedback. BMI has enormous potential as therapeutic technology that will improve the quality of life for the neurologically impaired.

The panel will consist of a team of experts in representative areas within BMI, including machine learning, control, robotics, systems neuroscience, and clinical psychology. Members of the panel will talk about invasive and non-invasive techniques for interfacing the brain, and will discuss ideas on how to bring this exciting interdisciplinary field to the SMC community.

Organizer/Moderator:
Jose M. Carmena – University of California at Berkeley, USA

Panelists:
Robert Knight – University of California at Berkeley, USA
Justin Sanchez – University of Florida, USA
Jose del R. Millan – Swiss Federal Institute of Technology, Switzerland
Daniel Repperger/Dr. Rodney Roberts – Wright-Patterson Air Force Base/Florida State University, USA
Michael Smith – University of California, Berkeley, USA

PM: Workshop Meeting: Planning and Technical and Meeting (3-4 hours)

BMI experts and experts in the above areas seriously interested in BMI are invited to participate in discussions about the future of BMI Systems research with respect to the scope of SMC, and the planning of future BMI workshops.

Evening: Reception for Workshop Participants (TBA)