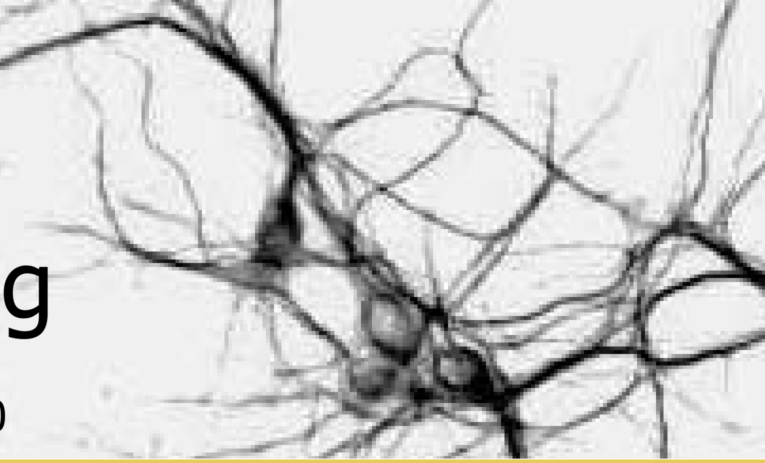
Center for Neuroengineering Newsletter

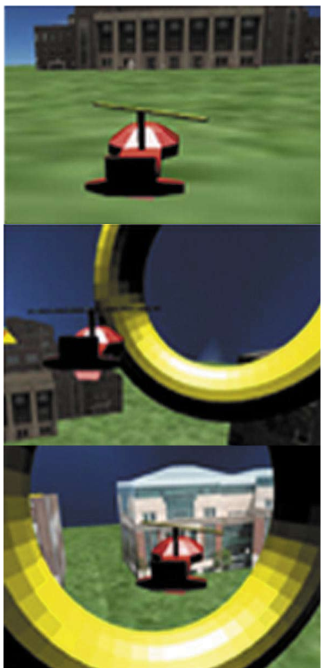
Fall 2010



University of Minnesota

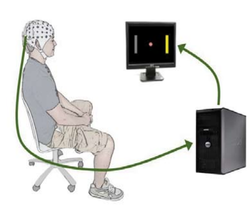
University of Minnesota Leads the Way in Brain-Computer Interface

Connecting Mind and Machine: CNE faculty member Bin He and laboratory advance methods in brain-computer interface



Controlling objects with the power of thought was once reserved for science fiction – but not anymore. Technological advancements in neuroengineering have paved the way for a new field called brain-computer interface (BCI), or the study of translating the "thought" of the brain into "action". Through BCI methods, scientists have recently allowed for the augmentation of human thought to move a computer cursor, type on a keyboard, or surf the internet. In other words, BCI can provide the brain with a new pathway of communication with the outside world that's independent from typical routes maintained by the central nervous system. Ultimately, this means that persons with diminished motor abilities, such as those suffering from with brainstem stroke, amyotrophic lateral sclerosis (ALS), or other paralyzing disorders, may be able to produce movement that, hitherto, has been impossible.

The University of Minnesota is one of the leading institutions for BCI research. The Biomedical Functional Imaging and Neuroengineering Laboratory, directed by CNE faculty Dr. Bin He (Biomedical Engineering), has been pushing the edge of BCI technologies. Recently, He and his students made a major advancement in BCI research with success in continuous 3-D control of a virtual helicopter from noninvasive electroencephalograms (EEG) collected over the scalp of subjects. Using this method, participants in this study were able to pilot a virtual helicopter through a simulation of the U of M campus. If the subject was prompted to steer the helicopter left toward a ring levitating over, for example, Coffman Union, he/she would merely imagine moving their left arm (see three-fold image). Concurrent with this "motor imagination" is the detection of underlying neuro-electrical activity of the brain by means of a "thinking cap", and the transmission of this information into a computer where it will be processed and displayed on a monitor (see image). This work was first presented on May 7, 2010 in the IEEE EMBS Forum on Grand Challenges in Neuroengineering, and e-published on September 27, 2010 in the leading neuroengineering journal – IEEE Transactions on Neural Systems and Rehabilitation Engineering, together with Audrey Royer, Alex Doud, Minn Rose.



Dr. He comments that, "The recent research we have produced on control of virtual helicopter flight in 3-D space represents an important advancement in noninvasive BCI. It demonstrates for the first time that one can control continuously an object in 3-D space in a virtual environment."

See INTERFACE on page 2.

Message from Director, Bin He

Faculty at the Center for Neuroengineering (CNE) have been pursuing cutting edge research in neuroengineering, bridging neuroscience and engineering sciences. From the news included here, you will find that CNE faculty members are making important contributions to advance the state of the art of the field, while also being recognized for their work by major federal grants, a NSF CAREER Award, and service to the field of neuroengineering.

Neural interfacing is one of several research focus areas of center faculty who have pioneered fundamental research and development of innovative brain machine interfaces. The recent advancement of 3-dimensional EEG-based brain computer interface illustrates the promise and power of interfacing and interacting with the brain. Neuromodulation is another focus area of center faculty research. The deep brain stimulation research conducted by multiple center faculty represents an important and exciting scientific exploration toward translation of neuroscience findings into clinical practice. Neural imaging represents yet another focus area of center faculty research, who continue to advance the state of the art of imaging brain functions from electrophysiological and hemodynamic measurements. Finally, of noteworthy mention is the recent NIH-led initiative on the Human Connectome Project, in which CNE faculty are playing an integral role.

We hope this newsletter will provide examples of exciting research CNE faculty are conducting. We look forward to working with you and together we will make the Center for Neuroengineering at the University of Minnesota a center of excellence in neuroengineering.

Interface

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The application of EEG holds many advantages to BCI research. For one, it's non-invasive, meaning that surgery is not required in order to measure changes in the electrical activity of the brain. This characteristic is also auspicious for clinical application. Dr. He remarks that, "As such, it [non-invasive BCI] has the merits to assist numerous people who may suffer from neurological disorders or healthy individuals by enhancing their capability to interact with the external world." However, one drawback of the EEG-based method is its limited spatial and temporal resolution in comparison to more invasive methods, such as intracranial EEG. Similar to these methods, EEG-based BCI also requires considerable training in order to properly isolate and record the correct neural activity in the brain for the purpose of controlling an external device. This means that subjects are not able to jump straight into the virtual helicopter's cockpit, but rather must progress incrementally from more rudimentary BCI systems. The most basic system employed by Dr. He's laboratory resembles the antiquated Atari video game – Pong. Contrary to this game, however, subjects must control the direction of the ball to one side or the other. After mastering this task over a series of sessions, subjects then incorporate up/down movement of the ball. Finally, after several sessions meant to refine their mental dexterity, subjects are then able to commandeer their own virtual helicopter.

While Dr. He and his laboratory continue to refine BCI techniques through virtual reality, their sights are set on real life applications of BCI. Further development of the BCI technology may lead to aiding disabled persons to control their environment through artificial limbs, or even for healthy subjects to enhance the capability to communicate with the external world through the additional channel of communication offered by a BCI.

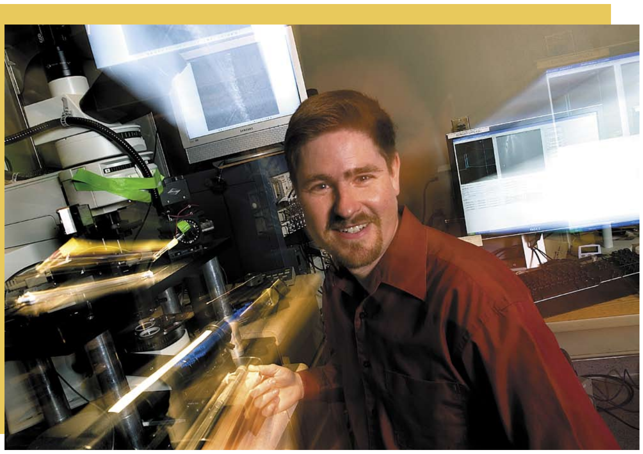
The work by Dr. He and his students has also been highlighted by the University's online news medium and can be found at:

* *www1.umn.edu/news/features/2010/UR_CONTENT_220013.html*
* *www.discover.umn.edu/featuredDiscoveries/harnessingBrainpower.php*

Center for Neuroengineering

FACULTY SPOTLIGHT: Tay Netoff Receives NSF CAREER Award

Dr. Tay Netoff, a CNE faculty member and Assistant Professor in the Department of Biomedical Engineering, has recently received the NSF CAREER Award for his ongoing research on the basic mechanisms of epilepsy, a neurological disease affecting roughly 50 million people worldwide. Dr. Netoff studies the mechanisms of epilepsy at the molecular level, including how many forms of genetically inherited epilepsy involve mutations in ion channels. His research seeks to bridge how these molecular scale changes affect the dynamics of individual neurons and in turn affects the ability of networks to synchronize. To do this, his research uses a combination of both modeling and experimentation. The modeling draws on nonlinear dynamical systems analysis to link neuronal dynamics to network synchrony. In the models, each neuron is treated as an oscillator. The effect of a synaptic input on a neuron's phase is measured; this results in a phase-response curve (PRC). From the PRC it is possible to predict whether a network of neurons will synchronize or not. By measuring how a neuron's PRC is affected by a drug or mutation it is then possible to predict whether the drug or mutation promotes or decreases synchrony. The theory is then tested by measuring PRC's from real neurons in brain slices using a computer interacting directly with a neuron in real-time. This type of closed loop experiment is called a dynamic clamp. The computer can be used to simulate synaptic inputs to the neuron or even introduce ion channel currents which can then be modified to simulate a mutation.



Dr. Tay Netoff has been a faculty member at the University of Minnesota for just over 4 years in the Department of Biomedical Engineering. He is also a senior member of the Graduate Program in Neuroscience and has been a member of the CNE since its inception in 2007. Dr. Netoff has a long pedigree working with numerous neuroscientists using nonlinear dynamical approaches to understand how the brain works. He completed his undergraduate degree in Psychology at University of California at Berkeley working in the laboratory of Walter Freeman, and his graduate degree in Neuroscience at George Washington University working with Steven Schiff. For his post-doctoral research he went to the Center for Biodynamics at Boston University where he collaborated with Nancy Kopell and John White.

Dr. Netoff has several collaborations at the University of Minnesota. He currently holds a seed grant from the Institute for Engineering and Medicine with Keshab Parhi (Electrical and Computer Engineering) and Tom Henry (Neurology) developing machine learning algorithms for detecting and predicting seizures from intracranial EEG electrodes. Dr. Netoff also collaborates with Duane Nykamp (Mathematics) developing methods to analyze changes in network topology that occurs following a seizure to interpret how these changes affect network synchrony.

Stephen Engel and Colleagues Further Perceptual Learning Research

CNE faculty member Dr. Stephen Engel, along with colleagues Dr. Min Bao, Lin Yang, Christina Rios, and Dr. Bin He, have recently published a noteworthy paper to the Journal of Neuroscience titled, "Perceptual learning increases the strength of the earliest signals in the visual cortex." In this paper, Dr. Engel and colleagues report that subjects trained on a simple visual detection task exhibited an increase in the amplitude of even the earliest EEG signal over time. This finding suggests that the first cortical stage of visual processing can be enhanced by practice. Moreover, since feedback from later processing stages would likely take some time to appear, this enhacement likely arises from local changes in cortical circuitry.

Wei Chen and Colleagues Advance Research on Brain Dynamics

CNE faculty member Dr. Wei Chen and colleagues (Drs. Xiao Liu, Xiao-Hong Zhu, and Yi Zhang) have recently published a paper in Cerebral Cortex examining the neural origin of spontaneous hemodynamic fluctuations under deep anesthesia states. In this study, epidural EEG and cerebral blow flow measures were recorded from the bilateral somatosensory cortical regions of rats with suppressed neural activity. Researchers observed a neurovascular coupling between these two measures, which was later corroborated with functional MRI-based BOLD imaging. These findings show that spontaneous CBF/BOLD fluctuations under anesthesia conditions originate primarily from underlying neural activity. Ultimately, such results provide insight into the use of hemodynamic-dependant imaging as a noninvasive method under various levels of consciousness.

CNE Co-sponsors Neuroengineering Grand Challenge Forum

On May 7-8th, 2010, the CNE co-sponsored IEEE Engineering in Medicine and Biology Society (EMBS) Forum on Grand Challenges in Neuroengineering, was held in Bethesda, MD. The Forum aimed to review the significant progress of neuroengineering in the past decade and identify opportunities and grand challenges facing the scientific community of neuroengineering in the next 10 years. The event was attended by ~150 participants including senior academic leaders and outstanding young faculty in neuroengineering, government officials from NIH, NSF, DARPA and the FDA, and senior executives from neurotechnology companies. Leading thinkers from the spheres of academia, government and industry were invited to present their visions, and all participants actively joined the interactive panel discussions and break-out sessions. Dr. Bin He, CNE Director, led the Grand Challenges on Functional Neuroimaging session with his keynote talk, "Toward high-resolution spatiotemporal functional brain imaging." Other invited speakers, including Miguel Nicolelis (Duke), Jon Wolpaw (Wadsworth Center), Emery Brown (MIT), Nitish Thakor (Hopkins), Todd Kuiken (RIC), Dominique Durand (Case Western), Ali Rezai (Ohio State), Ted Berger (USC), Christof Koch (Cal Tech), etc., discussed related work and its prospects.

Shown in the photo are Dr. Bin He (left), with Dr. Nitish Thakor (right), Professor and Director of NIH Neuroengineering Training Program at Johns Hopkins and Editor-in-Chief of IEEE Trans. Neural Systems & Rehabilitation Engineering, and Dr. Gert Cauwenberghs (middle), Professor and Co-Director of Institute for Neural Computation at UCSD and incoming Editor-in-Chief of IEEE Trans. Biomedical Circuits and Systems. Presentation slides of the talks from the Forum, and more general information can be found at the forum website: *www.gcbme10.org/*

John Ferguson Receives Doctoral Fellowship

PhD student John Ferguson (Biomedical Engineering) was awarded a University of Minnesota Interdisciplinary Doctoral Fellowship for 2010-2011, for his work in the lab of CNE faculty Dr. A. David Redish (Neuroscience). John is developing a novel type of nanoscale electrode for neural recording and stimulation. The nanoelectrodes, which are more than an order of magnitude smaller than traditional microelectrodes, are being designed to enable recording and stimulation of neurons with longer duration and higher spatial resolution than is currently available. He has also worked on carbon nanotube coatings for low-impedance electrodes and on miniature, wireless neural implants.

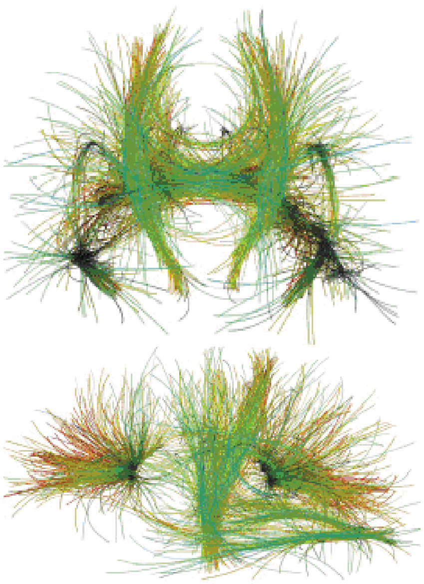
Center for Neuroengineering

University of Minnesota

Jerrold Vitek and Colleagues Advance DBS Research

CNE faculty member Dr. Jerrold Vitek was recently featured by the University of Minnesota News Service for his pioneering work in deep brain stimulation (DBS) treatment for Parkinson's disease. Dr. Vitek is the Chair of the Department of Neurology and a pioneer in the field of DBS research. In DBS treatment, an internal impulse generator, similar to a cardiac pacemaker, is implanted under the skin of the chest. This generator is then connected by wire leads to an electrode positioned in deep regions of the brain, most commonly in an area called the subthalamic nucleus. Although not considered a cure, DBS has been shown to reduce symptoms of Parkinson's disease, allowing doctors to lower a patient's medications, and ultimately improving patients' quality of life. Dr. Vitek collaborates with CNE faculty members Dr. Aviva Abosch (Neurosurgery) and Dr. Matt Johnson (Biomedical Engineering), among others. Read more about Dr. Vitek's work at *www1.umn.edu/news/features/2010/UR_CONTENT_258735.html*

CNE Faculty Receive NIH and NSF Grants



Population tractography from high angular resolution diffusion imaging. Courtesy of G. Sapiro, I Aganj et al.

CNE faculty Dr. Guillermo Sapiro (Electrical and Computer Engineering) and others are part of a $30 million NIH initiative called the Human Connectome Project, which aims to unravel the brain's neural connections. Dr. Kamil Ugurbil, Director of Center for Magnetic Resonance Research at the U of M, is a Principal Investigator of this major NIH grant, together with Washington University and other institutions.

CNE faculty Drs. Guillermo Sapiro and Kelvin Lim (Psychiatry) are among the team which recently was awarded a $3.1 million grant by NSF to study and develop tools that will assist with the early diagnosis of children at risk of developing psychiatric disorders. Dr. Nikos Papanikolopoulos (Computer Science and Engineering) is the Principal Investigator of this newly funded NSF project.

Seminar Series 2010

August 19, 2010
Dr. Pongkiat Kankirawatana, Associate Professor, University of Alabama at Birmingham
"Pediatric Epilepsy Surgery - In search for epileptogenic foci"

September 20, 2010
Dr. Warren M. Grill, Addy Professor of Biomedical Engineering, Duke University
"Cellular and Network Mechanisms of Deep Brain Stimulation"

October 7, 2010
Dr. Michael Lee, Professor of Neuroscience, University of Minnesota
"Engineering transgenic mouse models of human neurodegenerative disease"

November 4, 2010
Dr. Wim van Drongelen, Professor of Pediatrics, University of Chicago
"Intrinsic properties of the NMDA Receptor and Neural Oscillation: Modeling and Experimental Aspects"

December 2, 2010
Dr. Rajesh Rajamani, Professor of Mechanical Engineering, University of Minnesota
"Micro Sensors for Implants and In-Vivo Medical Applications"

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