Center for Neuroengineering Newsletter

Spring 2010

David Redish explains advances in mathematical analysis techniques

Of Rats and Math: CNE Professor David Redish explains how advances in mathematical analysis techniques are helping us better understand cognition.

CNE Faculty member A. David Redish studies rodent spatial cognition and its corresponding neurophysiology. Specifically, his lab uses implanted electrode recordings from the rodent hippocampus to understand spatial navigation and decision-making. Thanks to recent advances in mathematical analysis techniques, the understanding of the rodent navigation system is shedding light on behavior, decision making, and has the potential to change how we approach addiction and more.

David Redish, PhD

In the March 2010 issue of Neuron, Dr. Redish, along with Dr. Matthijs van der Meer from the U of M, and collaborators Anoopum Gupta and Dr. David S. Touretzky of Carnegie Mellon University, published results suggesting that a phenomenon known as “hippocampal replay” is much more complex that previously recognized. The hippocampus contains what are known as “place fields,” which are neurons active in small portions of an environment, so that the population of “place cells” correspond to the animal’s location in space, creating a neural representation of a physical environment. “Hippocampal replay” entails these same cells activating with a representation of a different location, for example representing the maze run while sleeping afterwards. For years these networks have been accepted within the neuroscience community as primarily a function of memory consolidation — place fields “replay” trajectories the animal has already navigated. In their study, however, Dr. Redish and his colleagues found that the hippocampus can actually “replay” routes the animal had never experienced, challenging decades of accepted theory.

These results built upon research published in the Journal of Neuroscience by Dr. Redish and Dr. Adam Johnson in 2007, in which they reported their discovery that when rats come to choice points and pause to look back and forth, as if they were ‘considering the possibilities,’ the neural representation in the hippocampus swept forward ahead of the animal, literally showing a representation of those possibilities.

Dr. Redish says that his findings would have been impossible without newly developed analytical techniques that allowed his team to decode representations that occur at very fast time scales — faster that the animal’s behavior — and to “identify when a representation of another location on the maze is actually a representation of that non-local position and not just noise.” These developments are significant because “cognition happens faster than behavior, and it allows the explicit identification of non-local cognitive information.” These results helped elucidate processes that have been highly sought in the field of cognitive neuroscience for decades.

Dr. Redish explains the importance in recognizing that “these new mathematical analytical techniques really are a form of technology development that really do change what we can do with our data.” In particular, Dr. Redish explains that “We normally think of new technologies as just devices, and mathematics as just analysis, however, these advancements allow for new discoveries to be made from the same recording devices and techniques used in the past.”

So the next real question, according to Dr. Redish, is “how does the animal make a decision?” Currently, scientists have no accepted answer to that question, but these new analysis techniques are paving the way toward a better understanding. Dr. Redish describes how these analyses could apply to addiction studies, “Addiction is really about bad decision making, so now we have the potential to build models of addiction based on this engineering. Like any engineering system, there are failure modes— in this case the failure mode is the wrong decision. In the future, if we could potentially identify these failure modes correctly and assign the right treatment to the right people, it would have a big impact on the treatment of addiction.” Dr. Redish admits “That’s a long way in the future,” but says that “This is an important first step.” Thanks to these new techniques we will be able to explain data we previously couldn’t. “These new analysis techniques are completely general and can be applied to any system,” says Dr. Redish. The possibilities seem limitless from here.

Learn more about Dr. Redish’s research at: *http://redishlab.neuroscience.umn.edu/*

University of Minnesota

Center for Neuroengineering

Message from Director, Bin He

DIrector, Bin He, PhD

The Center for Neuroengineering (CNE) was established by University leadership to enhance neuroengineering research at the University of Minnesota as part of the Institute for Translational Neuroscience. Bridging neuroscience and engineering, neuroengineering is an emerging field that translates research discoveries into neurotechnologies, which provide powerful new tools for basic and clinical neuroscience and lead to enhanced patient care. The CNE was later also affiliated with the Institute for Engineering in Medicine.

The University of Minnesota has strong, highly recognized research groups in both engineering and neuroscience that provide the underpinning for an initiative in neuroengineering. Coupled with the strong medical device industry in Minnesota, the University is uniquely positioned to seize this opportunity to enhance neuroengineering research and translate findings into new technologies and products. The CNE brings together and builds upon the rich strengths existing at the University to address the unique opportunity in the emerging field of neuroengineering.

The CNE has identified the following thrust areas for collaborative research: neural interfacing and modulation, neural imaging, and neural computation. To enhance the faculty expertise in neuromodulation, we have recruited two outstanding young faculty members, Drs. Lim and Johnson. It is our goal to make the CNE a center of excellence for interdisciplinary research and training in the emerging field of neuroengineering, bridging faculty in the basic sciences, engineering, and clinical departments as well as collaborations with the neuro-technology industry.

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.

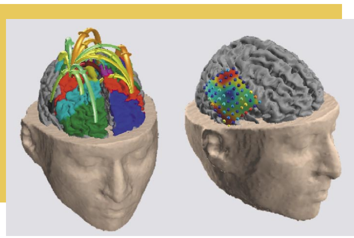
Release of eConnectome for functional brain connectivity mapping

March 15, 2010 saw the release of the eConnectome (Electrophysiological Connectome), a new open-source MATLAB software package designed for user-friendly imaging of functional brain connectivity. The software was developed by the Biomedical Functional Imaging and Neuroengineering Lab, directed by Dr. Bin He, a center faculty, in conjunction with Drs. Fabio Babiloni and Laura Astolfi at the University of Rome "La Sapienza." It is designed for research use in neuroscience, neurology, psychology, cognitive science and related fields to image functional brain connectivity from EEG and ECoG signals. It provides investigators with tools for EEG/ECoG preprocessing, source estimation, connectivity analysis and visualization.

As part of the efforts of the Human Connectome project, which shall be aimed at mapping and imaging structural and functional neural circuits and networks, eConnectome provides a tool for investigators to map and image brain functional connectivity from electrophysiological signals, at both the scalp and cortex level. The current release allows functional connectivity imaging from electroencephalogram (EEG) and electrocorticogram (ECoG) over the sensor and source domains.

eConnectome was developed with support from NIH/NIBIB under grants RO1 EB006433 and RO1 EB007920 to Bin He.

For more information, visit the eConnectome website at: *http://econnectome.umn.edu/*



Sapiro selected for Department of Defense Fellowship

Professor Guillermo Sapiro is one of 11 distinguished University faculty scientists and engineers selected for the 2010 Department of Defense's National Security Science and Engineering Faculty Fellowship (NSSEFF) program. From a field of 800 nominations, of which 670 white papers were reviewed, 21 semi-finalists were invited to submit full proposals outlining research plans.

Center for Neuroengineering

Faculty Spotlight

Matthew Johnson

Disorders that limit our capacity for making precise and timely movements can have a huge impact on our quality of life. Professor Matthew Johnson and his team are working on the next generation of therapies for movement disorders in which implanted devices smartly control the expression of motor symptoms by direct stimulation of brain tissue.

Professor Johnson's group studies the physiological mechanisms of Deep Brain Stimulation, a therapy currently approved for treating essential tremor, dystonia, and Parkinson's disease, by coupling computational modeling with multi-channel neurophysiological and behavioral recordings in animal models of movement disorders. His group is investigating how the encoding of sensorimotor information changes during stimulation, how stimulation at different therapeutic efficacies influences neuronal network activity, and how neuronal firing patterns adapt during chronic stimulation.

The computational and experimental studies provide a basis for his group's research on developing new electrode designs and stimulation algorithms tailored to a patient's motor symptoms with the goal of the therapy's improving efficacy, efficiency, and sustainability in individuals with movement disorders.

Hubert Lim

The University of Minnesota has initiated the Institute for Translational Neuroscience (ITN) with the goal of fusing the University's strengths in basic neuroscience, imaging, and other interdisciplinary resources to push new discoveries into clinical application. Professor Hubert H. Lim was hired in 2009 into the ITN as part of the Center for Neuroengineering.

The general goal of Professor Lim's research group is to push the development and translation of neural interfaces and prosthetics from scientific concept into clinical application with close collaboration with clinicians and industry. Brain-machine interfaces span a broad array of applications and consist of either direct connection of a device to neurons within the brain or neural communication through noninvasive techniques, such as surface neural recordings and transcranial magnetic stimulation. The initial focus of his lab is to develop and improve implantable neural prostheses for restoring auditory function in deaf or hearing-impaired patients as well as those experiencing severe tinnitus.

Professor Lim hopes that his animal and human studies provides a clearer understanding of how the brain codes for sound information and in what ways they can successfully implement these neural devices. These studies will be performed in collaboration with leading engineers, scientists, clinicians, and companies linked to the University as well as institutions worldwide.

New UMN - Mayo Grant to investigate minimally invasive treatment of epilepsy and stroke

CNE faculty, Bin He, Aviva Abosch, and Steven Rothhman, with other University Faculty members Edward E. Patterson and Adnan I. Quireshi, have been awarded a new grant from the Minnesota Partnership for Biotechnology and Medical Genomics. Mayo Clinic physician Samuel J. Asirvatham and Bin He are the PI and Co-PI of this project. The grant joins the University of Minnesota and the Mayo Clinic in a partnership to investigate a novel noninvasive approach to treatment of epilepsy and stroke.

Currently, individuals diagnosed with intractable epilepsy are faced with lifestyle altering and often disabling symptoms. When pharmacotherapy fails the only remaining option is highly invasive neurosurgery. These procedures involve craniotomy, high morbidity risk, time-intensive hospital visits (about 1~2 weeks in an intensive care unit) and are prohibitively expensive. For these reasons, many patients choose to live with the condition, resulting in a $12.5 billion burden on the health care system, due to the costs of long-term management.

In an attempt to reduce the need for invasive surgery, the researchers on this grant have proposed a novel system designed to identify abnormal brain activity and ablate seizure-causing tissue—in a minimally invasive fashion. It works by using electrode-fitted catheters inserted and directed through systemic veins. Once in the central nervous system, the electrodes can transmit radio-frequency energy to produce localized ablation lesions to seizure generating locations. The technology utilized in this project is similar to widely used cardiac catheter ablation approach treating cardiac arrhythmias. The technologies, if successful, are hoped reach beyond epilepsy and have applications in treatment of stroke.

IEEE EMBS Forum on Grand Challenges in Neuroengineering

Coming up in May, the CNE is co-sponsoring the IEEE EMBS Forum on Grand Challenges in Neuroengineering, being held in Bethesda, MD. This forum is the first of a new series of forums launched by the IEEE Engineering in Medicine and Biology Society (EMBS) addressing grand challenges in biomedical engineering. The forum series will review the significant progress we have made in the past decade, and identify grand challenges facing the scientific community in a specific discipline within the biomedical engineering field in the next 10 years. Leading thinkers from academia, government and industry will be invited to present their visions. All presentations will be invitation only, and all participants will be encouraged to join the interactive panel discussions that will follow the invited presentations.

Bridging engineering and neuroscience, neuroengineering is an emerging field that translates research discoveries into neuro-technologies that provide new and powerful tools for basic and clinical neuroscience research and lead to enhanced patient care. Exploration of neural systems has long focused on understanding how neural systems work at the molecular, cellular, circuitry and system levels. Engineering methodologies have always played an important role in the study of neural systems, providing tools needed to detect, process and model neural signals. Recently, tremendous progress has been made in the field of neuroengineering, both in the application of engineering concepts and methodologies to the study of neural systems, and in interfacing neural systems with external devices for restoration of lost neural function. The rapid progress and tremendous translational potential of neuroengineering has been well recognized in the past several years.

Dr. Bin He, CNE Director, is chairing the Steering Committee of the Grand Challenges Forum. More information can be found at the forum's website: *http://www.gcbme10.org/*

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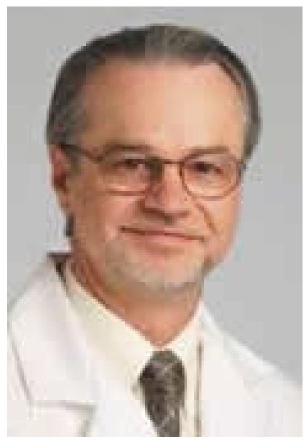
Grant awarded to develop hardware for seizure prediction

Keshab Parhi (Electrical and Computer Engineering), Tay Netoff (Biomedical Engineering), Thomas Henry (Neurology), and Gregory Worrell (Mayo Clinic) were awarded a grant by the University of Minnesota's Institute for Engineering in Medicine (IEM). The grant, entitled "Seizure Prediction Classifier Algorithms and Architectures," was awarded for Fiscal Year 2010 (July 1, 2010 – June 30, 2011).

150 attend Symposium for Neuroengineering

The Center for Neuroengineering presented a special Symposium on February 12, 2010 in Coffman Union. Over 150 people attended this event, which featured 23 speakers. The keynote speaker, and incoming head of Dept of Neurology at UMN, Jerry Vitek, Director of the Neuromodulation Research Center of the Cleveland Clinic, spoke on "Deep Brain Stimulation: Now and the Future." The third annual Symposium on Neuroengineering is planned for February 2011.



Jerry Vitek, M.D, Ph.D.

Altered Reality Systems paper published in Current Biology

Center faculty members, Stephen Engel and Sheng He, and their collaborators Peng Zhang, Min Bao, and Miyoung Kwon had a paper on altered reality systems published in Current Biology in December 2009. The paper was entitled "Effects of Orientation-Specific Visual Deprivation Induced with Altered Reality."

Seminar Series 2010

March 23, 2010
The Neuroengineering Seminar on March 23, 2010 featured Dr. Thomas R. Henry, Director of the Epilepsy Center and Professor of Neurology from University of Minnesota. He presented on Anatomical-Physiological Strategies for Deep Brain Stimulation in Epilepsy.

March 5, 2010
This seminar presentation featured Dr. Rosalind Sadleir, a Research Assistant Scientist at the University of Florida, who spoke about "Fresh approaches to modeling and imaging neural activity."

March 1, 2010
With the Department of Biomedical Engineering, the CNE co-sponsored the seminar on "Functional molecular imaging in the brain", presented by Dr. Alan Pradip Jasanoff, Associate Professor of Biological Engineering at MIT.

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