Award Abstract # 1054914

CAREER:Prediction of Synchrony and Phase-Locked Modes in Neural Networks based on Stimulus Time Resetting Curve

NSF Org:	IOS Division Of Integrative Organismal Systems
Awardee:	COLLEGE OF CHARLESTON
Initial Amendment Date:	March 25, 2011
Latest Amendment Date:	June 8, 2015
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Award Instrument:	Continuing Grant
Program Manager:	Sridhar Raghavachari sraghava@nsf.gov (703)292-4845

Special Conditions

Federal Demonstration Partnership

Policy Office Website

	IOS Division Of Integrative Organismal Systems BIO Direct For Biological Sciences
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Total Awarded Amount to Date:	$500,000.00
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History of Investigator:	Sorinel Oprisan (Principal Investigator) oprisans@cofc.edu
Awardee Sponsored Research Office:	College of Charleston 66 GEORGE ST CHARLESTON SC US 29424-0001 (843)953-4973
Sponsor Congressional District:	01

Primary Place of Performance:	College of Charleston 66 GEORGE ST CHARLESTON SC US 29424-0001
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ABSTRACT

Nervous systems are composed of complex networks of neurons, which involve chemical and electrical signal lines. These neural networks send signals within the brain and to muscles controlling bodily actions such as walking and breathing. Although each neuron is also complex, for the purpose of studying firing patterns in large neural networks a given cell can be modeled as a pacemaker that fires at regular intervals. When a neuron receives signals or inputs, from other neurons, it maps them into measurable changes of its firing activity or signaling rate, and passes this output to the next neuron. The focus of this research is to understand how the input-output, or resetting curve, of individual neurons and the coupling between them can generate complex firing patterns in large networks. New computer algorithms for classifying and storing resetting curves generated both by model and experimental neurons will be developed. The resetting curves will be used for predicting the spectrum of possible firing patterns of neural networks made of such neurons. The stability of numerically predicted firing patterns and the mechanisms leading to firing mode switch will be experimentally tested.

The broader impacts of this project include possible new solutions for predicting the emergent coherent firing pattern and its stability, at the network level, based on the resetting curves of individual neurons. Studying how the nervous system processes and responds to external stimuli will aid our understanding of how neural networks function, including the human nervous system and its related disorders. Educationally, the project will attract undergraduate students into the interdisciplinary field of computational neuroscience. A seminar in Computational Biology for incoming freshmen coupled with an upper-level class exploring computational models of neurons and their networks will offer a mentored pathway to related careers. Undergraduate students will also benefit from in-depth research experience throughout the project.

PUBLICATIONS PRODUCED AS A RESULT OF THIS RESEARCH

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PROJECT OUTCOMES REPORT

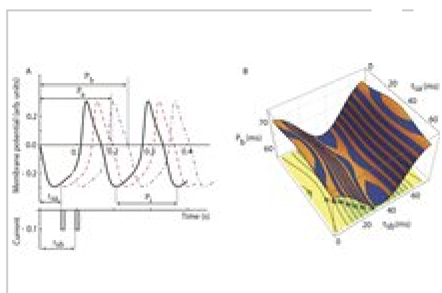
Disclaimer

CAREER awards are unique as they have two objectives: advance a research program and enhance the educational environment at the home institution. Computational neuroscience research, which is the focus of this award, is a relatively new - almost 20 years old - research field that uses computers and mathematical models to better understand how brains work. The research goal of this CAREER award has been advancing our understanding of the mechanisms used by neurons to communicate with each other. Neurons produce stereotypical spikes of electric activity called action potentials that travels down their axon and influence the activity of the neurons they project to. A spike of activity in one neuron can facilitate or inhibit the activity of a nearby neuron by changing, or resetting, the timing of its spike of activity. Depending on the strength and the number of connected neurons, a small perturbation of activity of one neuron can propagate through the entire network like a wave. Most of such waves of activity will die out, but some will reverberate throughout the entire network. We derived mathematical and computational tools for predicting which modes of activity of a neural network will be enhanced and propagate throughout the entire network. Such stable modes of activity are responses produced by organisms to environmental stimuli. For example, the neurons that control the flexor and extensor muscles must fire in a certain order to produce the correct pattern of locomotion. At first, while a baby still learns how to walk, the locomotor neural network will produce suboptimal responses. Over time, the brain resets its response with the help of environmental feedback until the organism learns the correct neural activity pattern for the desired outcome. Similarly, whenever we fly over multiple tome zones our internal biological clock finds itself suddenly out of phase with the local time. Among other solutions for such a jet lag, we can use pulses of light to stimulate our internal neural network responsible for keeping track of time. Carefully selected sequences of light stimuli can reset our internal clock and bring it quickly in synchrony with the local time. Resetting neural activity is the most fundamental mechanism involved in adaptation to the environment and learning. The education goal of this CAREER award has been the advance of neuroscience education by creating new opportunities for our undergraduate students. Computational neuroscience is an interdisciplinary research field at the crossroads between biology, psychology, physics, mathematics, and computer science. Through this grant we supported two new and unique interdisciplinary undergraduate courses on biophysical modeling of excitable cells and on signal and image processing with biomedical applications. They have been designed for and populated by biology/psychology majors, physics and math majors, and computer science undergraduates working together across multiple disciplines. With support from this grant, we created a new program of study - a concentration in computational neuroscience – to complement the strong neuroscience minor at the College of Charleston.

This CAREER award allowed Dr. Sorinel A. Oprisan advancing the research into computational neuroscience and, at the same time, training the next generation of researchers in this field. Over the life time of this CAREER award, we published 17 peer-reviewed papers with nine undergraduate co-authors in prestigious journals such as Philosophical Transactions of the Royal Society B: Biological Sciences, BMC Neuroscience, Neural Computation, Physical Review E, Journal of Theoretical Biology, etc. We published three book chapters with Springer and two peer-reviewed conference proceedings. Ten peer-reviewed extended abstracts have been published in BMC Neuroscience with seven undergraduate co-authors. The undergraduates gave over 30 presentations of their research results at national and international professional meetings, such as the Society for Neuroscience, the Organization for Computational Neuroscience, the International Conference on Mathematical Neuroscience, the American Physical society, etc. The students also presented to over 26 state and regional professional meetings plus over 44 local meetings. In recognition of their research achievements, the undergraduate students working on this CAREER project receive ten research awards from Sigma Xi - The Scientific Research Society, South Carolina Academy of Science, and Southern Atlantic Coast Section of the American Association of Physics Teachers. Some of students mentored with support from this award are working today towards their PhD in computational neuroscience, other work towards their MD, and some joined the growing workforce of professionals in biomedical research helping patients in clinics or creating new computer tools for faster and better data analysis. With support from this grant, we also contributed to outreach events that increased the awareness of the general public about the high quality and originality of computational neuroscience research done at the College of Charleston. Thorough outreach events, we also aimed at inspiring and attracting new students from middle and high schools around Charleston area into Science, Technology, Engineering and Math education.

Last Modified: 04/23/2018
Modified by: Sorinel A Oprisan

Images (1 of 6)





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