Putting Logic in Modeling of Biological Neuron – A New Framework

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ABSTRACT

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In this paper and the accompanying presentation, we discuss various frameworks used for modeling communications among biological neurons and their networks. Following the framework discussion, we highlight various modeling attempts made in the past, their strengths and limitations. Along the way, we present the role of technological advancements in making headways in quantitative modeling, and the state-of-the-art in such techniques. We also present a novel framework in which a neural processing unit is viewed as a node in a heterogeneous network of clusters of neural processing units. Neural processing units are scalable as appropriate for various levels of modeling in the central nervous system (CNS). We believe this scalability is feasible from the neuron and sub-neuron level all the way up to major tissue systems encompassing millions of neurons. The approach has similarities to the one presented by Cohen and Grossberg (Human Neurobiology 1986 5:1-22) in explaining speech and Damasio (Cognition 33(1989) 25-62) in explaining neural basis of memory and recognition. In the proposed framework, we view a neural processing unit ("neuron") as consisting of interconnected smaller units ("organelles") that together generate a composite signal ("activity") consisting of physiological and logical groups of signals. These groups are responsible for specific tasks, such as physiological signaling, signal routing and mental function coding (neural code) with ‘standard’ interfaces between signal groups. We contend that despite the variety of signals processed in the CNS, the interfaces between same signal groups are in some sense "standardized" for all communications. In our framework, we define an organelle as source of a distinct signal group. Thus it does not have to be the sub-somal organelle delimited by its own membrane. The benefits of such a framework are that (i) it assumes that the mental function is topologically coded in only a subset of the neuronal signals that gives the possibility of restricting research on mental functions on certain parts of neuronal signals (Malsburg, Handbook of Brain Theory and Neural Networks, 2003, pp. 365-8), and (ii) it assume standardized interfaces between logical signal groups that makes it possible to have common models of different mental functions, such as cognition, memory, neuro-muscular and audio-visual functions. We will present various experimental set ups possible for deriving quantitative models under this framework.

Dr. Aftab Ahmad (D.Sc. George Washington University) is an associate professor in the computer science department of Norfolk State University. He has been a Senior Member of IEEE from 2005-2011, is a Member ACM, and a member of New York Academy of Sciences. Dr. Ahmad’s research interests are in modeling of biological neuron, resource management in wireless networks, and network security assessment. He holds Certified Ethical Hacking (CEHv6) certification for 2012. He also has certifications of Opnet modeler (advance level). He’s authored two book, Data Communications Principles: For Fixed and Wireless Networks published by Springer-Verlag (2002) and Wireless and Mobile Data Networks published by John Wiley and Sons (2005). He has also authored a book chapter titled Security Assessment of Networked Systems in Network Security, Administration and Management: Advancing Technologies and Practice published by IGI Global (2011). In this chapter, he has made original contribution on assessing security of a networked system according to the ITU X.805 framework. He’s published over 50 peer reviewed papers in peer-reviewed professional journals and conferences. Dr. Ahmad has

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Dr. Wells is founder and director of the Wells Laboratory for Computational Neuroscience and Technology Research. He is past director of the Graduate Program in Neuroscience and past associate director of the Microelectronics Research and Communication Institute, both at the University of Idaho. He is currently associate chair of Electrical and Computer Engineering. Dr. Wells serves on the University Curriculum Committee, is chair of the College of Engineering Curriculum Committee, chair of the Electrical and Computer Engineering Curriculum Committee, and member of the Neuroscience Curriculum Committee. He has in the past served on the University of Idaho Research Council, the University Wide Programs Committee, and the University Selection Committee for the Department of Defense Experimental Program to Stimulate Competitive Research (DoD-EPSCoR). He has served as an External Reviewer for the National Science Foundation and as a National Science Foundation Review Panelist for the Professional Science Masters Program, a part of the American Recovery and Reinvestment Act.

He has served as Major Professor for more than fifty graduate students and as a member of more than seventy other graduate student committees for students studying in various disciplines. He annually serves as academic advisor for fifteen to twenty-five undergraduate students. His Laboratory Website, containing numerous electronic books, tutorial articles and papers, currently receives a quarter of a million hits per year coming from every continent except Antarctica.