Modeling, Estimation and Control Across Scales in Neuroscience
Jason Ritt, ShiNung Ching, Sridevi Sarma

In this workshop, an array of speakers will present the state of current research in neurocontrol, and outline the key challenges and future directions for applications in research and clinical settings. An organizing principle for the workshop is the question of scale; a central goal is to bridge the gaps in methods typically employed from single neurons to macroscopice brain regions. The workshop will introduce models of single neurons and neural ensembles commonly used in computational neuroscience. We will cover biophysical-based models of neurons, mean field models of populations of neurons, and hybrid models of neural networks. We will discuss algorithms to estimate parameters of these models and describe their use in various applications, including characterization of neurons in diseased networks (e.g. Parkinson's disease, epilepsy), and the effect of deep brain stimulation control. We will conclude with a moderated discussion on outstanding control problems in neuroscience.

	Start Time	Name	Affiliation	Expertise
Introduction	9:45	Jason Ritt; ShiNung Ching; Sridevi Sarma	Boston University; Washington U., St. Louis; Johns Hopkins University	
Cellular	10:00	Uri Eden	Boston University	Statistical Modeling, Neuroscience
	10:45	Rodolphe Sepulchre	Cambridge University	Nonlinear Control, Neuroscience
	11:30	Sabatino Santaniello	University of Connecticut	Modeling and Estimation, Brain Computer Interfaces
Lunch	12:15			
Ensemble	1:15	Antoine Chaillet	Supelec - Universite Paris Sud	Network Control Systems, Stabilization
	2:00	Demba Ba	Harvard University	Network Science, Computational Neuroscience
	2:45	Jr-Shin Li	Washington U., St. Louis	State Estimation, Optimal Control
Break	3:15			
Macroscopic/ Fields	3:30	Michael Westover	Massachusetts General Hospital	Epilepsy Diagnosis and Treatment, Clinical Neuroscience
	4:15	Sujith Vijayan	Boston University	Brain State Estimation, Epilepsy Detection
	5:00	Fabio Pasqualetti	U. C. Riverside	Network Identification
Wrap Up Discussion	5:45-6:30	Jason Ritt; ShiNung Ching; Sridevi Sarma	Boston University; Washington U., St. Louis; Johns Hopkins University	

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Biographies of Speakers

- **Uri Eden (Boston University):** received his PhD in 2005 from Harvard University. His research focuses on developing mathematical and statistical methods to analyze neural spiking activity. This research can be divided into two categories; first, a methodological component, focused on developing a statistical framework for relating neural activity to biological and behavioral signals and developing estimation algorithms, goodness-of-fit analyses, and mathematical theory that can be applied to any neural spiking system; second, an application component, wherein these methods are applied to point process observations in real neural systems to dynamically model the spiking properties of individual neurons, to characterize how ensembles maintain representations of associated biological and behavioral signals, and to reconstruct these signals in real time.
- **Rodolphe Sepulchre (University of Cambridge):** received an engineering degree (1990) and a PhD (1994), both in mathematical engineering, from the Université catholique de Louvain, Belgium. He was a BAEF fellow in 1994 and held a postdoctoral position at the University of California, Santa Barbara from 1994 to 1996. He was a research associate of the FNRS at the Université catholique de Louvain from 1995 to 1997. He moved in 1997 to the Université de Liège, where he is currently professor in the department of Electrical Engineering and Computer Science. He was department chair from 2009 to 2011. He held a visiting position at Princeton University in 2002-2003, and at the Ecole des Mines de Paris in 2009-2010. Since October 2012, he has a part-time appointment with INRIA (Lille) as director of a project in neurodynamics (Orchestron). His other current research interests are in control and coordination problems on nonlinear spaces, optimization on manifolds, analysis and synthesis of networks of oscillators and rhythmic systems. He co-authored the monographs "Constructive Nonlinear Control" (Springer-Verlag, 1997) and "Optimization on Matrix Manifolds" (Princeton University Press, 2008). He is currently Editor-in-Chief of Systems and Control Letters and an Associate Editor for SIAM Journal of Control and Optimization, the Journal of Nonlinear Science, and Mathematics for Control, Signals, and Systems. In 2008, he was awarded the IEEE Control Systems Society Antonio Ruberti Young Researcher Prize. He is an IEEE fellow and an IEEE CSS distinguished lecturer since 2010.
- **Sabatino Santaniello (University of Connecticut):** is Assistant Professor in the Biomedical Engineering Department, University of Connecticut. He received a Ph.D. in Systems and Control Engineering from University of Sannio (Italy). He was a postdoctoral fellow (2009-2013) and a research scientist (2013-2014) in Neural Engineering and Computational Neuroscience in the Institute for Computational Medicine, Johns Hopkins University. His research interests include modeling, estimation, and control of neural systems, biomedical signal processing, and neural stimulation, with applications to movement disorders, epilepsy, and brain-computer interface.
- **Antoine Chaillet (Supelec – Universite Paris Sud):** is an associate professor at L2S-Univ. Paris Sud 11-Supélec-EECI. In 2002, he received his B.Sc. degree from ESIEE Amiens, France, and his M.Sc. degree in Control Engineering from Univ. Paris Sud 11 in 2003. He was an undergraduate visiting scholar at the University of Twente, The Netherlands, and a graduate visiting scholar at the INRIA Sophia Antipolis, France. In July 2006, he received his Ph.D. degree *cum laude* in Control Theory from Universite Paris Sud 11-L2S. In 2004, he was recipient of a Marie-Curie Scholarship to visit Università degli Studi di Firenze, Italy. In 2006–2007, he served as a postdoctoral fellow at Centro di Ricerca Piaggio, Pisa, Italy. He has been at L2S-Univ. Paris Sud 11-Supélec-EECI since September, 2007. His research interests include synchronization analysis for

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neuroscience applications, stability analysis and stabilization of nonlinear systems, control of mechanical systems, and network controlled systems.

- **Demba Ba (Harvard):** is an Assistant Professor of Electrical Engineering and Bioengineering at Harvard University. Professor Ba's interests lie at the intersection of theory, computing, and data, with diverse applications that range from computational neuroscience, multimedia signal processing, and network science. He received the B.Sc. degree in Electrical Engineering from the University of Maryland, College Park, in 2004 and the M.Sci. and Ph.D. degrees in Electrical Engineering and Computer Science with a minor in Mathematics from the Massachusetts Institute of Technology, Cambridge, MA in 2006 and 2011, respectively. He went on to work as a postdoctoral associate with the MIT/Harvard Neuroscience Statistics Research Laboratory, where he developed theory and efficient algorithms to assess synchrony among large assemblies of neurons.
- **Jr-Shin Li (WUSTL):** received his S.M. and Ph.D. from Harvard University in 2004 and 2006, respectively. In fall 2006, Professor Li joined the Department of Electrical & Systems Engineering at Washington University in St. Louis. Previously, he worked as a graduate student in the Harvard Robotics Lab. The focus of Professor Li's laboratory is on the area of mathematical control and systems science. In particular, he is interested in studying the control systems arising from quantum mechanical phenomenon that lead to an interdisciplinary research crossing the boundaries of physics, biology, medicine, applied math and engineering.
- **Brandon Michael Westover (Massachusetts General Hospital):** received his MD/PhD from Washington University School of Medicine St. Louis. He did his Residency at Brigham and Women's Hospital, and a Fellowship at the Massachusetts General Hospital in Boston. He is in the department of Neurology at MGH.
- **Sujith Vijayan (Boston University):** is a postdoctoral fellow at Boston University. He received a B.A. (Cognitive Science and Psychology) from Amherst College in 1998, and a Ph.D. (Neuroscience) from Harvard University in 2007, and an M.A. (Mathematics) from Boston University in 2009. His research employs mathematics and electrophysiology in the study of sleep, sensory processing, and mental imagery, using behavioral studies with human subjects in conjunction with ECoG/EEG/MEG recordings, signal processing techniques, and computational modeling. He uses the basic science knowledge gained from these investigations to understand how “off-line” states like sleep play a role in the consolidation of memories, to develop pharmacological and stimulation therapies for diseases (with an emphasis on disorders that are marked by abnormal sleep rhythms), and to improve brain machine interface (BMI) algorithms.
- **Fabio Pasqualetti (U.C. Riverside):** is an Assistant Professor in the Department of Mechanical Engineering at the University of California, Riverside. He was a Postdoctoral Researcher in the Department of Mechanical Engineering at the University of California, Santa Barbara. He completed a Doctor of Philosophy degree in Mechanical Engineering at the University of California, Santa Barbara, in 2012, a Laurea Magistrale degree (M.Sc. equivalent) in Automation Engineering at the University of Pisa, Italy, in 2007, and a Laurea degree (B.Sc. equivalent) in Computer Engineering at the University of Pisa, in 2004. Dr. Pasqualetti’s research interests are in the area of multi-agent, large-scale, and networked systems, such as power grids, water distribution networks, and cooperative robotic systems.
- **Jason Ritt (Boston University):** is an Assistant Professor in Biomedical Engineering. He received a B.Mus. in Jazz Studies from the Oberlin Conservatory in 1994, a B.S. in Mathematics from Boston University in 1997, and an M.S. in Mathematics and a Ph.D. in Neuroscience from Boston University in 2003. From 1997 to 2000 he was a Center for BioDynamics Graduate Fellow, and was a Program in Mathematical and Computational

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Biology Fellow from from 2001 to 2002. He was a postdoctoral fellow at the Massachusetts Institute of Technology from 2003 to 2009, where he held a NIH Ruth Kirschstein NRSA fellowship from 2004-2006. In 2007, he received a Career Award at the Scientific Interface from the Burroughs Wellcome Fund, for work on the neuroscience of active sensing. In 2010 he joined the faculty of the Boston University Department of Biomedical Engineering. He held a two year appointment as a Junior Faculty Fellow in the Hariri Institute for Computing and Computational Science and Engineering from 2011-2013. His research concentrates on how organisms gather and use information from their environment, using model-driven, real-time neural feedback in animal models to test the neural basis of active sensing, and develop control strategies that could guide future sensory prostheses.

- **Shinung Ching (WUSTL):** received the B. Eng. (Hons.) and M.A.Sc in Electrical and Computer Engineering from McGill University and the University of Toronto in 2003 and 2005, respectively. He completed his Ph.D. in Electrical Engineering at the University of Michigan in 2009. Starting 2009 he was a Research Fellow at the Massachusetts General Hospital, Harvard Medical School, and the Massachusetts Institute of Technology. He joined the faculty of Electrical and Systems Engineering at Washington University in St. Louis in 2013. His research interests are in using systems theoretic approaches to study mechanisms of neuroactive pharmacology, and new methods to regulate pathological brain dynamics. He is the lead author of the textbook "Quasilinear Control" (Cambridge University Press, 2011), and is a recipient of a Career Award at the Scientific Interface from the Burroughs Wellcome Fund.
- **Sridevi Sarma (Johns Hopkins University):** received the B.S. degree in electrical engineering from Cornell University, Ithaca NY, in 1994; and M.S. and Ph.D. degrees in Electrical Engineering and Computer Science from Massachusetts Institute of Technology in 1997 and 2006, respectively. She was a postdoctoral fellow in the Brain and Cognitive Sciences Department at the Massachusetts Institute of Technology from 2006-2009. She is now an assistant professor in the Institute for Computational Medicine, Department of Biomedical Engineering, at Johns Hopkins University, Baltimore MD. Her research interests include modeling, estimation and control of neural systems using electrical stimulation. She is a recipient of the GE faculty for the future scholarship, a National Science Foundation graduate research fellow, a L'Oreal For Women in Science fellow, the Burroughs Wellcome Fund Careers at the Scientific Interface Award, the Krishna Kumar New Investigator Award from the North American Neuromodulation Society, and a recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE).

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