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Information Science & Technology Student/Postdoc Seminar

Valerio Mante and David Sussillo
Stanford University

"Integration and Gating of Sensory Information is Achieved by a Single Cortical Circuit with Orthogonal Mixed Representations"

Wednesday, November 30, 2011
2:00 - 4:00 PM
TA-3, Bldg. 1690, Room 102 (CNLS Conference Room)

Abstract: Computations in neural circuits are inherently flexible, allowing humans and animals to respond to sensory stimuli with actions that are appropriate in a given context. Fundamental to this flexibility is the ability to integrate only context-relevant sensory information while ignoring irrelevant, distracting information.

We studied the neural mechanisms underlying such context-dependent gating in monkeys performing two different sensory discriminations on the same set of visual stimuli. A contextual cue instructed the monkeys to report either the direction of motion or the color of a noisy visual stimulus. While the monkeys performed this task, we recorded neural responses from several cortical areas contributing to the monkeys' choices.

We found that the gating of relevant sensory signals, and their integration towards a choice, can be understood as two aspects of a single dynamical process reflected in the responses of populations of pre-frontal cortical neurons. Using linear regression, we identified a multitude of signals represented simultaneously in the responses of pre-frontal neurons, including the direction of motion and the color of the stimulus, the context, and the developing choice. While these different signals are mixed at the level of single neurons, by projecting the neuronal activity onto the regression vectors, these signals are separable at the level of the population.

In order to understand better the nature of the mixed signals in pre-frontal neurons, we trained a recurrent network model to solve a similar task, that of contextual integration of only one of two noisy input streams. The model reproduces the dynamic representations of the relevant signals, such as the motion and color stimulus, and the developing choice. Additionally, the model reveals previously unknown mechanisms for integrating the relevant input stream while ignoring the irrelevant one. We found that the network created two context-dependent, approximate line attractors to integrate the relevant sensory inputs. Surprisingly, the precise dynamics of integration are not simply based on a non-zero projection of the relevant input vector onto the relevant line attractor, but rather results from the transiently expanding, yet stable dynamics at each fixed point on the line attractor. Geometric reasoning suggests that this solution is highly likely given the observed orthogonality between the network input and output vectors.

Biographies: Valerio Mante received the B.S. and M.S. degrees in Physics from the Swiss Federal Institute of Technology in Zurich. Also in Zurich he received the Ph.D. degree in Neuroscience studying the encoding of natural stimuli by visual areas in the brain. He is currently a postdoctoral fellow with Bill Newsome at Stanford University where he records neural responses from monkeys engaged in well-controlled perceptual tasks. His goal is to understand how the brain combines sensory and contextual information to generate flexible, appropriate behaviors.

David Sussillo received his undergraduate degree in Computer Science from Carnegie Mellon University. For his PhD, he trained under Larry Abbott at Columbia University in the Center for Theoretical Neuroscience, studying the properties of chaotic neural networks. He is currently a postdoctoral fellow with Krishna Shenoy at Stanford University. David is interested in understanding how recurrent neural networks (RNNs) solve complex spatiotemporal tasks and also in novel algorithms to train RNNs. In particular he is interested in applying RNNs to neurophysiological data in an attempt to understand abstract circuit mechanisms that the cortex might use to solve related problems.

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