Contribution ID: **109**

Type: **Oral Presentation**

Networks of Spiking Neurons for the Control of Movement

Monday, 11 July 2016 14:00 (20 minutes)

Abstract content
   (Max 300 words)
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The human brain has about 85 billion neurons, of which about 15 billion are in the cortex. These cortical neurons fire action potentials (spikes) at a rate of about 10 Hz – about 150 billion spikes per second. This activity underlies our sensory perceptions, thoughts, decisions, and actions. One of the central problems of systems neuroscience is that of decoding these spatial and temporal patterns of neural activity, to interpret them and assign meaning to them. In recent years much progress has been made in decoding activity of neurons in the motor cortex, an output area of the brain that controls movement through its projection to muscles via the spinal cord. Recent and continuing increases in the experimental ability to simultaneously track the dynamics of many constituent elements within these networks present a challenge to theorists: to provide conceptual frameworks and develop mathematical and numerical tools for the analysis of such vast data. The subject poses great challenges, as the systems are noisy and the available information is incomplete.

Theoretical efforts to construct models that capture the underlying relationship between neural activity and movement have exploited Generalized Linear Models based on the exponential family of probability distributions; the Bernoulli and Poisson distributions are relevant to the case of networks of elements that communicate via pulses, such as neurons. From a theoretical point of view, we continue to make progress in our understanding of the neural code. From a practical point of view, our increasing ability to extract motor information from these signals has allowed us to translate neural activity into commands to control computer cursors and robotic manipulators. The potential of this approach to restore motor behavior in severely handicapped patients motivates pioneering interdisciplinary research in Brain Machine Interfaces (BMIs), an area at the frontier of systems neuroscience.

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Session Classification: Parallel Track B

Track Classification: Computational Biology