Characterizing complex, multi-scale neural phenomena using state-space models.

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In the past few decades, we have seen a massive expansion in our ability to record neural activity - from many more neurons, from multiple brain areas, and across multiple spatial and temporal scales. This has led to a concomitant increase in the complexity of neural coding and communication properties that neuroscientists have sought to explore. For example, ripple-replay events in the rat hippocampus comprise high frequency field oscillations, called ripples, behavioral periods with no active exploration, and the reactivation of sequences of spikes across a neural ensemble corresponding to previous experience.

Understanding the roles and mechanisms of such phenomena requires the ability to integrate information from multiple sources across neural ensembles, brain regions, and scales. Experimental neuroscientists are often limited in the statistical and data analysis tools available to deal with such multi-modal data. The state-space paradigm provides a natural statistical modeling approach for integrating information across multiple sources and scales, for discovering low dimensional representations of behavioral and cognitive states, and for expressing confidence about estimates and inferences.

In this talk, I will review the fundamental features of the state-space paradigm, discuss successful applications of the paradigm to various neural data analysis problems, and discuss a new extension of these methods to better understand the phenomenon of hippocampal replay. Specifically, I will discuss a semi-latent state-space model that combines information from a rats movement, LFP, and ensemble hippocampal spiking to simultaneously identify periods of replay and decode the replay content in real time.