Thesis Proposal

Machine Learning Department

The influence of trial-to-trial variability on downstream readout in the brain

Abstract:

To understand how the brain represents incoming sensory stimuli, one must study the interplay between signal and noise. The signal might be thought of as the variation in neuronal responses due to different sensory stimuli, whereas the noise might be thought of as the trial-to-trial variation in responses to repetitions of the same stimulus. The trial-to-trial variability of neural activity can limit the fidelity of information encoded about a sensory stimulus, but only if that variability lies along the same axes by which a downstream area reads out the sensory stimulus (i.e., stimulus-encoding dimensions). One might expect that most of the trial-to-trial shared variability (i.e., variability shared across neurons) resides in dimensions orthogonal to the stimulus-encoding dimensions, simply because two low-dimensional subspaces comprising randomly-chosen dimensions are likely to be close to orthogonal in a high-dimensional space. This would allow for a high-fidelity readout by a downstream area. However, this interplay between signal and noise has not been empirically tested.

In this proposed work, we use dimensionality reduction techniques to identify stimulus-encoding dimensions within a high-dimensional population activity space, and to identify dimensions that capture the shared variability (i.e., shared-noise dimensions). For a population of recorded neurons in visual cortical area V4, we find that the stimulus-encoding and shared-noise dimensions are remarkably similar, which presents substantial problems for stimulus readout by downstream areas. We also find that the shared-noise dimensions largely comprise shared activity that slowly drifts across an experimental session, on the order of minutes. In order to understand how a downstream area deals with this "slow drift," we simultaneously recorded populations of neurons from V4 and prefrontal cortex (PFC), a downstream area known to receive input from V4. We find that V4 and PFC neurons have access to the same slow drift, effectively canceling the slow drift's interference with the stimulus encoding dimensions to preserve sensory stimulus information. Overall, these results provide an avenue for understanding how the brain deals with noise in a rapidly fluctuating sensory environment.

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Link to draft document:
http://www.cs.cmu.edu/~bcowley/bcowley_proposal.pdf.