Examining Large-Scale Neural Data With Single-Trial Resolution

Alex Williams CSGF Program Review, 06/16/19

The size of neural datasets is growing exponentially



(Stevenson, 2019)

A simultaneous recording of ~3,000 neurons



min 1

mouse 1 mouse 2 mouse 3

These datasets contain structure over multiple time scales



		「
		in the second
500 ms		

Key challenge: Understanding circuit function across multiple timescales.



We propose to represent data as a threedimensional array (i.e., a *third-order tensor*)



dimensions ~ (1000 x 1000 x 1000)

Estimating firing rates on single trials is challenging



Amarasingham et al. (2015)

Key idea: single-trial dynamics don't vary arbitrarily, but exhibit systematic variability.

Gain / Amplitude Modulation









Changes in latency / duration





neuron 1



neuron 2



neuron 3





warping



template

single-trial estimates

Tensor decomposition can be viewed as a simple generalization of PCA

PCA / matrix decomposition



Williams et al. (2018). Neuron, 98(6): 1099-1115

Tensor decomposition can be viewed as a simple generalization of PCA



Williams et al. (2018). Neuron, 98(6): 1099-1115

Tensor decomposition can be viewed as a simple generalization of PCA



Unsupervised Discovery of Demixed, Low-Dimensional Neural Dynamics across Multiple Timescales through Tensor Component Analysis

Alex H. Williams,^{1,13,*} Tony Hyun Kim,² Forea Wang,¹ Saurabh Vyas,^{2,3} Stephen I. Ryu,^{2,11} Krishna V. Shenoy,^{2,3,6,7,8,9} Mark Schnitzer,^{4,5,7,9,10} Tamara G. Kolda,¹² and Surya Ganguli^{4,6,7,8,*}

Learning in Artificial RNNs



Motor learning in nonhuman primates



Navigational strategy switching in mice



Unsupervised Discovery of Demixed, Low-Dimensional Neural Dynamics across Multiple Timescales through Tensor Component Analysis

Alex H. Williams,^{1,13,*} Tony Hyun Kim,² Forea Wang,¹ Saurabh Vyas,^{2,3} Stephen I. Ryu,^{2,11} Krishna V. Shenoy,^{2,3,6,7,8,9} Mark Schnitzer,^{4,5,7,9,10} Tamara G. Kolda,¹² and Surya Ganguli^{4,6,7,8,*}





Are we missing key features in our data by looking at raw data?



(data collected by A. Dhawale, Harvard)

Temporal variability obscures structure in spike train data

raw data



trials

same data, re-sorted



(data collected by A. Dhawale, Harvard)













Time warping discovers oscillations in two different animal models



- Not aligned to motor actions
- Aligned to LFP
- In-phase across all multi-units



Tap 1





- Not aligned to motor actions
- Not aligned to LFP
- Not in-phase across units
- Related to whisking???
- Many un-answered questions.

<u>Summary</u> Tensor prob. of spike Decomposition neuron 1 neuron 2 neuron 3 prob. Time of spike Warping

neuron 1

neuron 2

neuron 3

<u>Summary</u> Tensor prob. of spike **Decomposition** neuron 1 neuron 2 neuron 3 prob. of spike Time Warping

neuron 1

neuron 2

neuron 3

across trials within trials gradual trends sharp events oscillations discrete events trials trials