Decoding Upsampled Limb Trajectories of a Running Mouse from 2-Photon Calcium Imaging Using a Recurrent Neural Network Encoder-Decoder

Seungbin Park, Megan Lipton, Maria Dadarlat
Weldon School of Biomedical Engineering, Purdue University

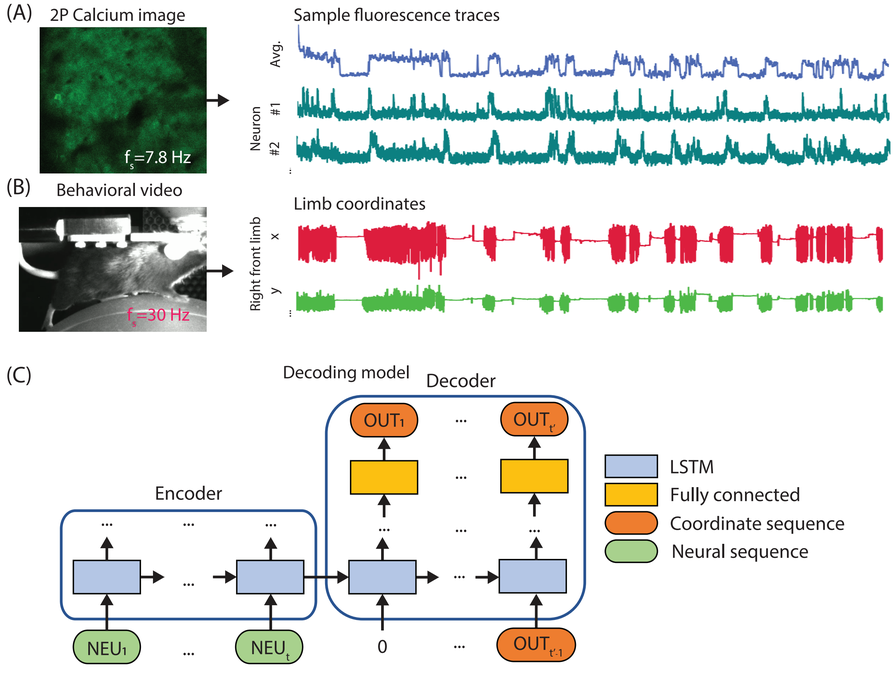
PURDUE UNIVERSITY

DADARLAT LAB

1. Introduction

- Neural decoding predicts behavior from brain signals, which helps us understand brain function and develop technologies for patients with neurological injury and disease.
- To improve neural decoding, recording and analyzing large populations of neurons is crucial, as behavior results from interactions among many neurons in various brain areas.
- Two-photon (2P) calcium imaging is a promising technique for recording activity from thousands of neurons; however, decoding it is challenging because the calcium signal: 1) indirectly and non-linearly relates to action potentials, 2) has low sampling rates, and 3) has slow kinetics including a long decay time.
- Here, we present an approach that uses a neural network to decode limb positions of a running mouse from 2P calcium images.

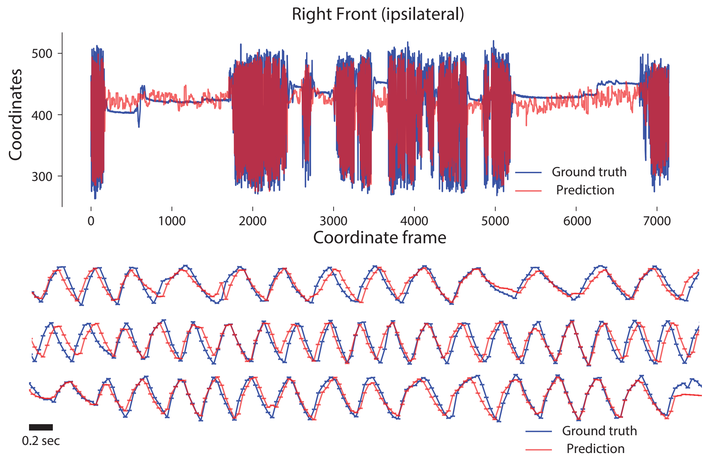
2. Methods



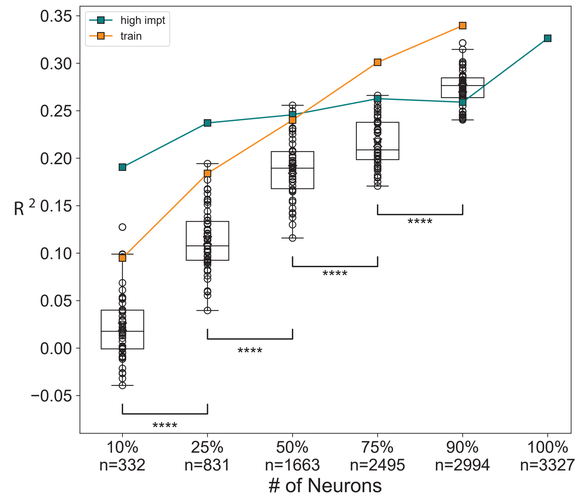
- The experiment setup: While a TRE-GCaMP6s x CAMK2-tTa mouse was running on a ball freely, the neural activity and the behavior of the mouse was recorded simultaneously with a 2P microscope (Neurolabware) and cameras, respectively.
(A) An example of 2P calcium image and the calcium fluorescence traces extracted from the 2P images using Suite2p [1]. The sampling rate is 7.8 Hz. The size of the field of view is 1.9 mm by 1.2 mm. The area of imaging includes the motor cortex and the primary somatosensory cortex in layer 2/3.
(B) An example of a frame in behavior video and the limb coordinates extracted from the behavior videos using Deeplabcut [2]. The sampling rate is 30 Hz. The size of the video frame is 540 pixels by 400 pixels of which 1 pixel equals to 0.15 mm.
(C) The recurrent neural network encoder-decoder. The deconvolved fluorescent traces were used as inputs to the network and the x and y coordinates of eight limbs were used as target outputs. The network was designed after the sequence-to-sequence learning model for machine translation [3], which allows different length inputs and outputs. The model was modified for the dataset being used here, where neural data was mapped to higher-sampling rate behavioral data.

3. Results

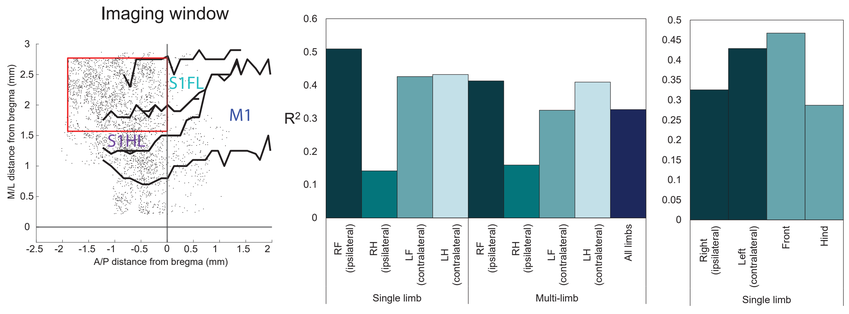
Continuous limb trajectories of a single limb can be decoded from calcium fluorescence traces.



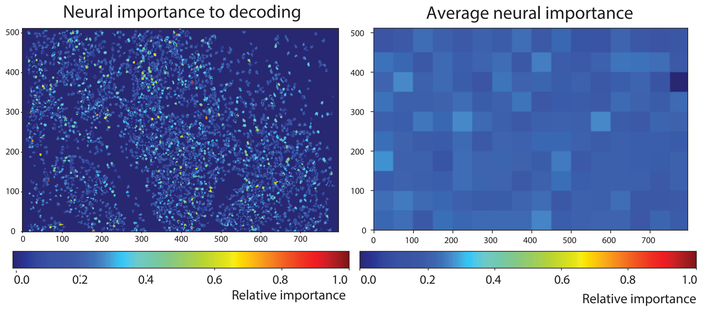
Informative neurons yield higher accuracy decoding than randomly-sampled neurons.



Trajectories of limbs can be decoded both seperately and simultaneously.



Informative neurons are sparsely distributed across cortical areas including M1/S1.



4. Conclusions

- Our approach can decode behavior from 2P calcium images with a lower sampling rate, overcoming perceived limitations of 2P calcium imaging as a technique to record behaviorally-relevant neural data.
- We found that information about all four limbs (contralateral and ipsilateral front and hind limbs) could be decoded from a single cortical hemisphere.
- A fraction of the most informative neurons yielded higher decoding accuracy than randomly-sampled neurons.
- Accuracy was directly proportional to the number of neurons used to decode.
- Our results validate the use of calcium imaging for decoding continuous behavioral variables to better understand brain function and for application in brain-machine interfaces.

5. References

[1] M. Pachitariu, C. Stringer, M. Dipoppa, S. Schröder, L. F. Rossi, H. Dalgleish, M. Carandini, and K. D. Harris, "Suite2p: Beyond 10,000 neurons with standard two-photon microscopy," 2016.
[2] Mathis, A. et al. (2018) "Deeplabcut: Markerless pose estimation of user-defined body parts with deep learning," Nature Neuroscience, 21(9), pp. 1281–1289. Available at: https://doi.org/10.1038/s41593-018-0209-y.
[3] I. Sutskever, O. Vinyals, and Q. V. Le, "Sequence to sequence learning with neural networks." Advances in neural information processing

Contacts
Seungbin Park: park1377@purdue.edu
Megan Lipton: liptonm@purdue.edu
Dr. Maria Dadarlat: mdadarla@purdue.edu