Integrated Systems & NeuroImaging Lab

Predicting Behavior from Cortical Activity Recorded through Widefield Transcranial Imaging

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Overview

- Widefield imaging of newly developed genetically encoded calcium indicators, such as GCaMP6, when expressed in transgenic reporter mouse, offers several advantages including improved sensitivity and brightness, ability to record large numbers of spatially distributed neurons, and high temporal resolution [1].
- In this study, using visibility graph (VG) and machine learning, we aim at inferring behavior from brain data obtained through widefield imaging. Our goal is to understand the relationship between the brain function and behavior to eventually identify biomarkers of brain-related disorders.
- For the behavior, we focus on whisker movement. VG is used to extract features from imaging data. Topological measures of VGs are then used to find the best models capable of predicting active whisking (AW) and no whisking (NW) behavioral conditions. Results show that the proposed method can be used for decoding the behavior from imaging data.

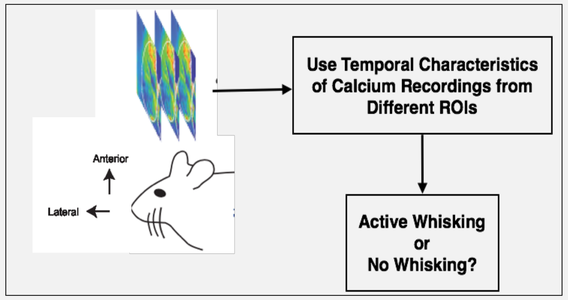


Fig. 1: An overview of the study. Features from calcium recordings are used to predict active whisking or no whisking conditions.

Visibility Graph

Construction:

Mapping time series $\{x(i)\}_{i=1}^{N}$ into networks [2]:

- Each time point is considered as a node in graph.
- Two nodes h and l are connected if for any point p $(h < p < l)$, the following condition holds:

$$x(p) < x(l) + [x(h) - x(l)][\frac{t_l - t_p}{t_l - t_h}]$$

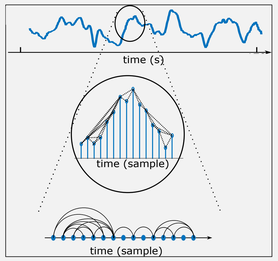
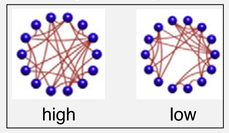


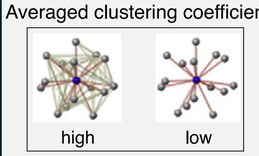
Fig. 5: Construction of VG.

Graph Measures:

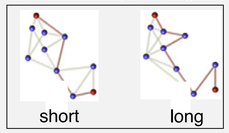
Edge density (D)



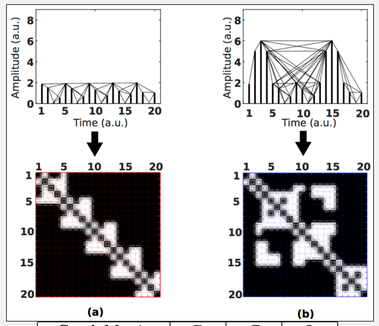
Averaged clustering coefficient (C)



Characteristic pathlength (L)



Example: VGs of Two Time Series



Graph Metric	D	C	L
Time Series (a)	0.10	0.77	2.72
Time Series (b)	0.15	0.70	2.33

Fig. 6: Two time series and their corresponding VG adjacency matrices and measures. (a) A sinusoidal time series with added drift. (b) A time series consisting of irregular peaks with added drift.

Sample Recordings

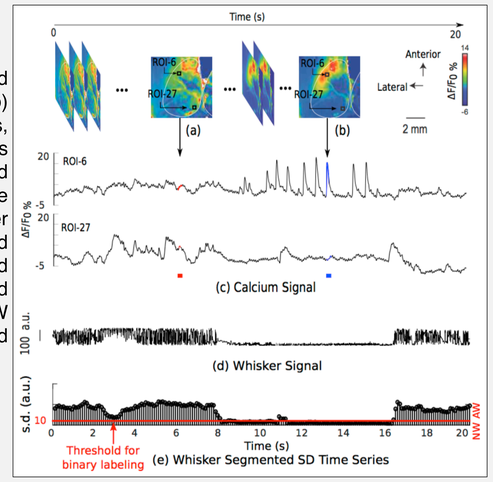


Fig. 8: Sample images and time series recorded. (a)-(b) baseline-corrected images, (c) time series corresponding to ROI-6 and ROI-27, (d) measured angle corresponding to whisker movement signal recorded from the same block, and (e) the threshold level used for labeling AW and NW conditions is shown as a red line.

Classification Results

- Classification performance across subjects and classifiers.

Classifier	Subject ID	1	2	3	4	5	6	Mean	SD
kNN	AC (%)	88.26	90.76	85.09	83.27	84.12	87.76	**86.54**	2.86
	SE (%)	66.93	82.87	62.91	75.83	59.96	50.04	**66.42**	11.68
	SP (%)	93.85	94.71	90.94	87.39	89.71	93.42	**91.67**	2.82
LR	AC (%)	90.37	91.28	88.14	83.95	88.35	90.46	**88.76**	2.67
	SE (%)	70.31	87.52	64.37	73.67	64.42	51.59	**68.65**	11.93
	SP (%)	95.30	93.12	94.45	89.60	94.04	96.37	**93.81**	2.34
RF	AC (%)	87.08	90.24	86.83	84.71	86.15	89.87	**87.48**	2.16
	SE (%)	57.65	86.30	59.37	72.29	61.48	49.13	**64.37**	13.07
	SP (%)	94.30	92.12	94.07	91.45	91.89	96.02	**93.31**	1.78

- Classification performance comparison with other approaches:
  - **All ROIs VG-based**: the proposed approach.
  - Spike-based: classification is done based on the number of spikes.
  - primary somatosensory cortex (ROI-20) VG-based: classification is done based on VGs from ROI associated with only primary somatosensory cortex.

Subject	1	2	3	4	5	6
AC (All ROIs VG-based)	0.90	0.91	0.89	0.85	0.88	0.90
AC (Spike-based)	0.87	0.87	0.84	0.83	0.86	0.90
AC (ROI-20 VG-based)	0.79	0.89	0.80	0.84	0.85	0.87
SE (All ROIs VG-based)	0.69	0.88	0.63	0.75	0.62	0.50
SE (Spike-based)	0.58	0.77	0.44	0.71	0.55	0.34
SE (ROI-20 VG-based)	0.17	0.86	0.23	0.70	0.47	0.29
SP (All ROIs VG-based)	0.95	0.93	0.96	0.91	0.94	0.96
SP (Spike-based)	0.95	0.91	0.94	0.89	0.94	0.98
SP (ROI-20 VG-based)	0.95	0.91	0.96	0.91	0.93	0.96

Experimental Setup

Widefield Calcium Imaging

- six head-fixed GCaMP6f mice
- entire L & medial portion of the R hemispheres
- 100 x 100 pixels per frame
- sampling rate at 100 frames per second
- 30 ROI locations (5x5 pixels) were selected

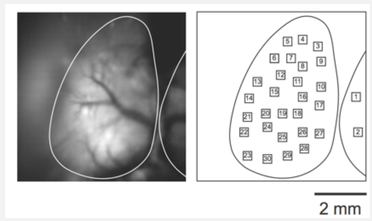


Fig. 2: Raw image of neocortical surface (left) and placement of ROIs (right).

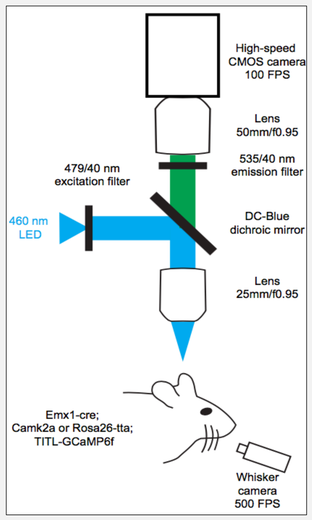


Fig. 3: Experimental setup.

Whisker Movement Recoding

- simultaneously recorded at 500 f/sec.

Task Paradigm

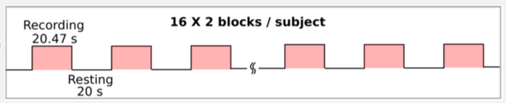


Fig. 4: 32 blocks with 20 sec rest in between.

FrameWork

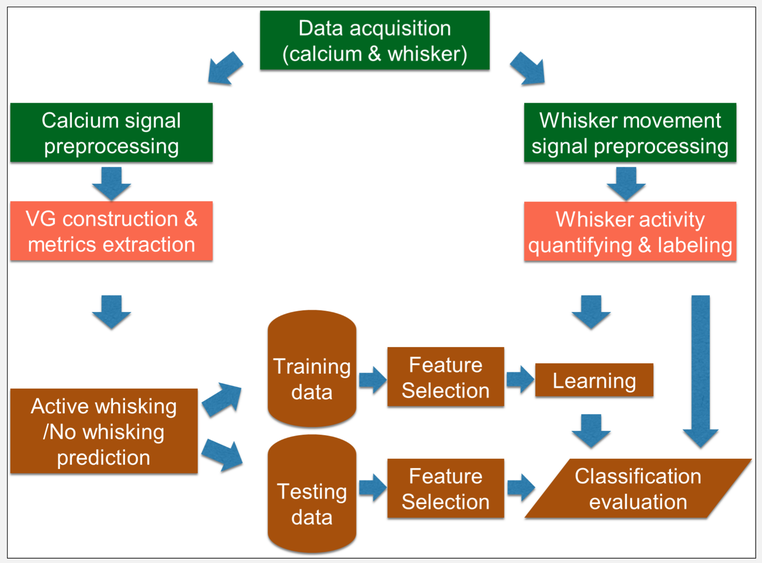


Fig. 7: Summary of the proposed framework.

Conclusion

- Widefield imaging was used to record cortical activity in six GCaMP6f mice during active whisking and no whisking.
- A VG-based approach was proposed for predicting the behavior from recorded calcium signals.
- We demonstrated that temporal characteristics of calcium recordings can be utilized to predict behavior and it outperforms spike-based methods.
- Future work include considering a more diverse range of behavior.

References

[1] Steinmetz, Nicholas A., et al. "Aberrant cortical activity in multiple GCaMP6-expressing transgenic mouse lines." bioRxiv (2017): 138511.

[2] Sannino, Speranza, et al. "Visibility graphs for fMRI data: multiplex temporal graphs and their modulations across resting state networks." Network Neuroscience (2017).

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