Statistical Analysis of Brain Activity

Carla Pinkney

@CarlaPinkney_ c.pinkney@lancaster.ac.uk pinkney19

STOR-i

excellence with impact

1. Measuring Brain Activity

Electrical activity in the brain can be measured in a variety of ways. Traditional approaches measure the coordinated activity of neurons.

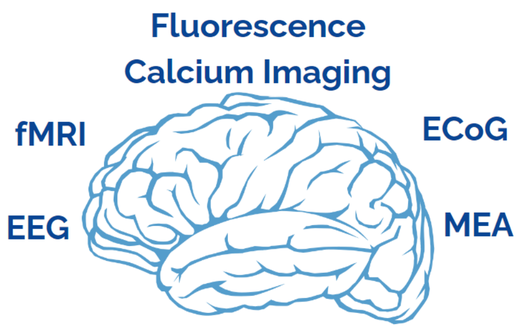


Figure 1. Commonly used methods for measuring brain activity.

Advances in technology have enabled scientists to measure the activity of individual neurons. New mathematical techniques are required to analyse brain activity at this refined level.

2. Neuron Level Data

The activity of individual neurons can be measured via multi-electrode arrays.

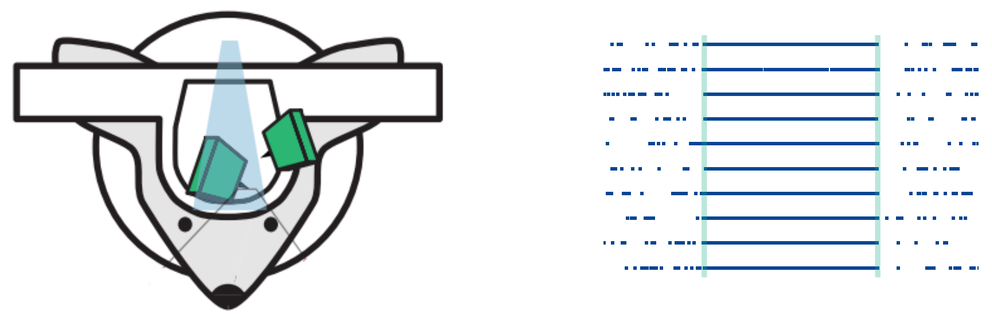
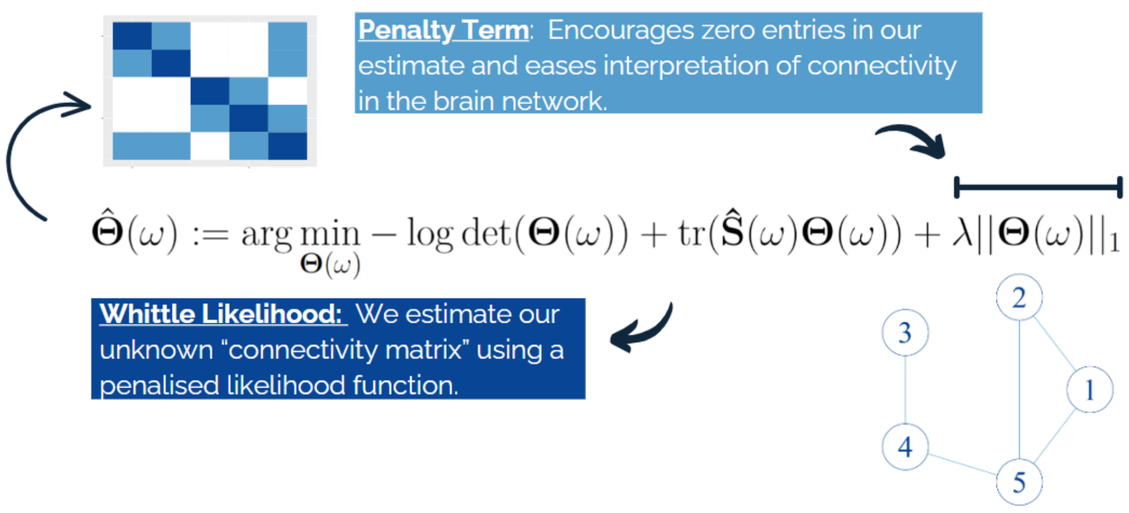


Figure 2. Experimental procedure and neuroscience spike train data from Bolding and Franks (2018).

Spike train data represent the firing times of individual neurons. Statistically, these data can be thought of as observations from a marked multivariate point process $\mathbf{N}(t) := \{N_1(t), \ldots, N_p(t)\}$.

3. Estimating Neuronal Connectivity

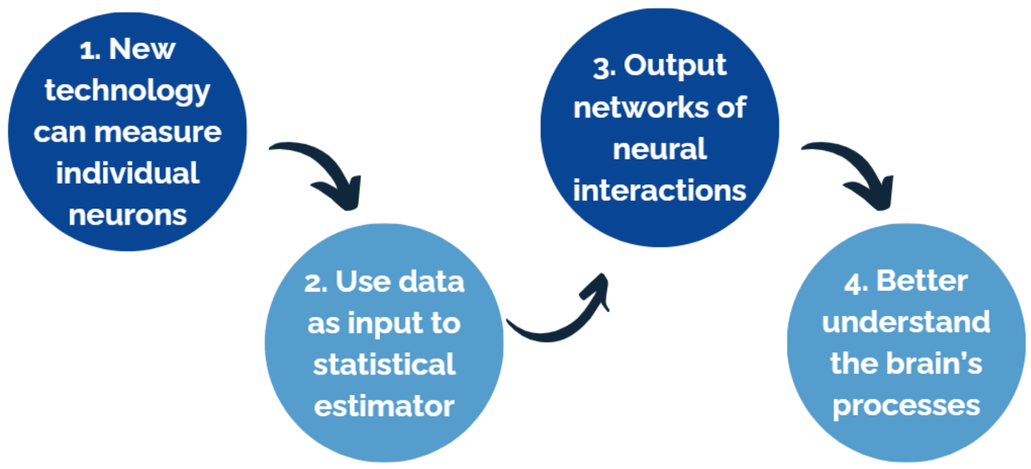
Interactions between neurons at a given frequency are encoded in the matrix $\boldsymbol{\Theta}(\omega)$. We propose the following estimator:



Neurological conditions can be characterised by the activity detected at certain frequency bands.

4. The Research Impact

Existing statistical techniques can capture the activity of a small number of neurons.



We have developed a tool which can be used to visualise interactions between large populations of neurons.

5. A Neuroscience Case Study

We use data from an experiment where an optogenetic approach is used to directly stimulate a particular region of the mouse brain.

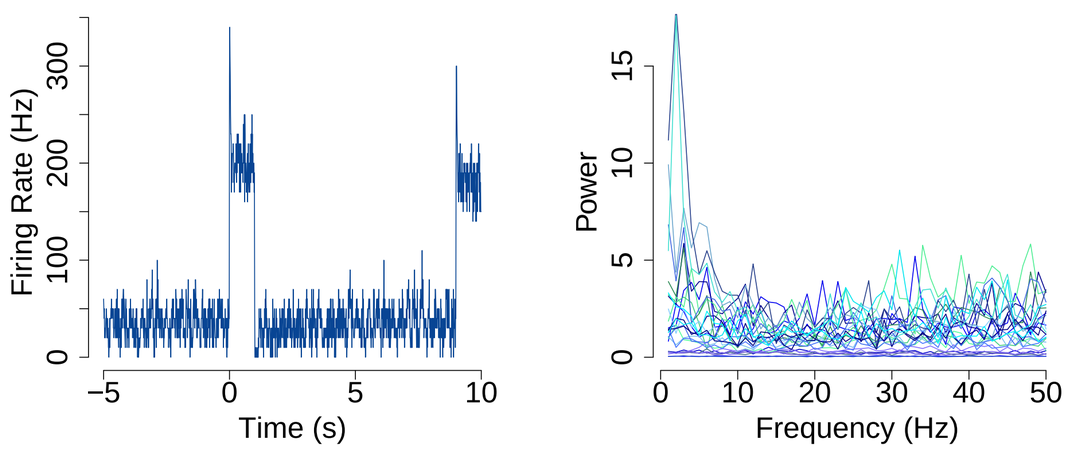


Figure 3. Firing rate and estimated spectra for spike train data.

The neural processes are driven by lower frequencies in the spectrum. In neuroscience, this corresponds to frequencies in the delta or theta bands.

6. Our Method in Action

Our method can be used to determine if and how estimates of neuronal connectivity differ in response to changing stimuli.

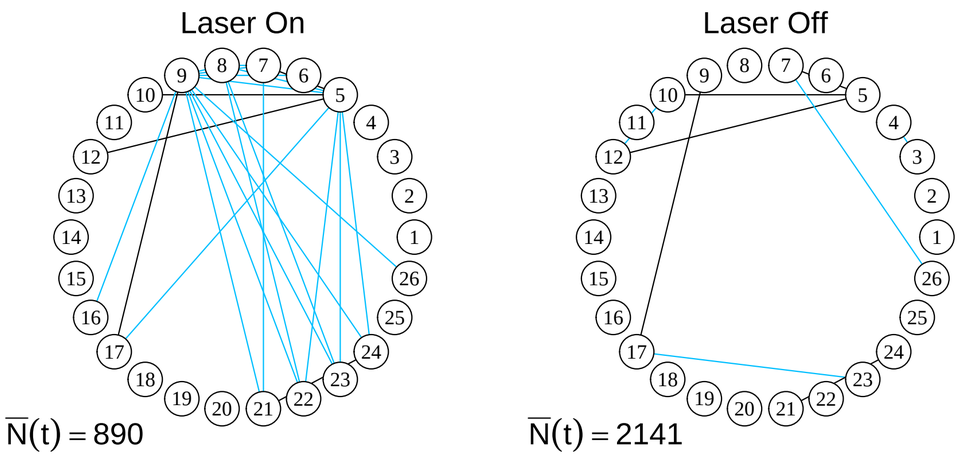


Figure 4. Estimated networks of neural interactions on the delta band.

We observe that more edges are detected when the laser is applied, indicating that the network structure changes in response to external stimuli.

7. Further Work

- We will apply our method to Neuropixel data recorded in experiments conducted by the International Brain Laboratory.
- We will develop methods to quantify uncertainty around our graph estimators.

8. References

- Bolding KA, Franks KM. Recurrent cortical circuits implement concentration-invariant odor coding. *Science*. 2018 Sep 14;361(6407):eaat6904.
- Jung A, Hannak G, Goertz N. Graphical lasso based model selection for time series. *IEEE Signal Processing Letters*. 2015 Apr 22;22(10):1781-5.

Supervisors: Carolina Euán[1], Alex Gibberd[1] and Ali Shojaie[2]

[1]STOR-i CDT Lancaster University,[2] University of Washington

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Lancaster University

University of Washington