Efficient "shotgun" inference of neural connectivity from highly sub-sampled activity data

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Model-based connectivity

Calcium Traces  
Neural Activity  
Model Parameters

Spiking model (GLM) can infer synaptic connectivity:  
Gerhard et al. 2013  
Latimer et al. 2014  
Volgushev et al. 2015

... other methods (e.g. correlations) work less well

Mishchenko, Vogelstein & Paninski 2010

frame rate > 30Hz required!
Limited scanning speed – a fundamental barrier?

- The common input problem

Alleviating the common input problem with shotgun
Main Result

- Approximate loglikelihood and derivatives, so they only depend on the empiric second order statistics.
- Can now handle missing observations
- Faster than original likelihood – $O(TN^2 + N^3)$ instead of $O(TN^3)$
Inference quality maintained with approximations

- Regular MAP (red) does not improve (blue)
- Inferring missing spikes (pink+cyan) does not improve over ignoring them (blue)
Summary

Connectivity inference – main obstacles:

- Common input problem
- Low frame rate
- Experimental duration
- Inferring spikes from calcium traces
- Model Mismatch
- Comparing with “ground truth”

Shotgun - Scanning speed is not a fundamental limit

- Inference is computationally hard

New inference method: minutes, not $10^5$ hours [Zaytsev et al. 2015]
Thank you for listening!

Questions?
Network Simulation
GLM network $N=50$
LIF network N=50
GLM network $N=1000$
Estimation Quality – more details
Single Neuron – 10,000 inputs
Inference from Calcium data

(A) Inference from Calcium data over time [sec].

(B) Correlation with bin size [msec].

(C) Inferred weights for \( p_{\text{obs}} = 1 \).

(D) Inferred weights for \( p_{\text{obs}} = 0.2 \).

(E) Inferred weights for \( p_{\text{obs}} = 0.1 \).

(F) Quality distribution for different conditions: R, C, Z, S.
Logistic Function Approximation