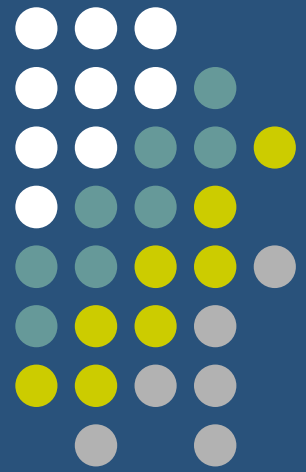
Peri-event Cross-Correlation over Time for Analysis of Interactions in Neuronal Firing

Antonio R.C. Paiva, Il Park, Justin C. Sanchez and Jose C. Principe

{arpaiva, memming, principe}@cnel.ufl.edu
jcs77@ufl.edu

Computational NeuroEngineering Laboratory
Neuroprosthetics Research Group
University of Florida, Gainesville, FL32611



Outline

- Motivation
- Generalized cross-correlation
- Peri-event cross-correlation over time (PECCOT)
- Results

Analysis problem

- We want to analyze interactions among neurons over time.
  - Need to assess and measure the temporal dynamics of neural couplings.
- This is important, for example, for studies on the role of populations in information encoding and/or processing.

Current approaches

- Cross-correlation, JPSTH, unitary events, partial directed coherence, etc.
- To deal with non-stationarity, most methods operate over time windows, thereby limiting the temporal resolution of the analysis.
- Also, most methods are meant to analyze pairs of neurons. Thus, analysis of a large number of neurons with these methods is cumbersome or impractical.

We propose...

- ... the Peri-Event Cross-Correlation Over Time (PECCOT) because:
  - It measures the coupling of neuron couplings over time with high temporal resolution.
  - Scales easily for a large number of neurons.
  - Is applicable regardless of coupling feature (that is, firing rate or synchrony).
  - Results are easy to visualize.

Cross-Correlation as usual

- Cross-correlation of two spike trains is typically expressed in term of their binned counterparts,

$$C_{AB}^{bin}[l] = \frac{1}{M} \sum_{n=1}^{M} N_A[n] N_B[n+l]$$

- Two main limitations of this perspective:
  - Binning imposes a time quantization
  - Averaging over time further reduces the temporal resolution of the analysis

Generalized Cross-Correlation

- Binning is an intensity estimator!
- Hence, using the intensity functions of the underlying point processes we can write a generalized cross-correlation (GCC),

$$C_{AB}(t) = E\left[\lambda_A(t)\lambda_B(t)\right]$$

- Instead of averaging over time, the time resolution can be preserved by approximating the expectation as an average over trials.

PECCOT algorithm

1. For each trial,
   - Estimate intensity function of each neuron around, the event onset
   - Compute the instantaneous cross-correlation for the k-th trial as,

$$c_{ij}^{(k)}(t) = \hat{\lambda}_k^i(t)\hat{\lambda}_k^j(t),$$

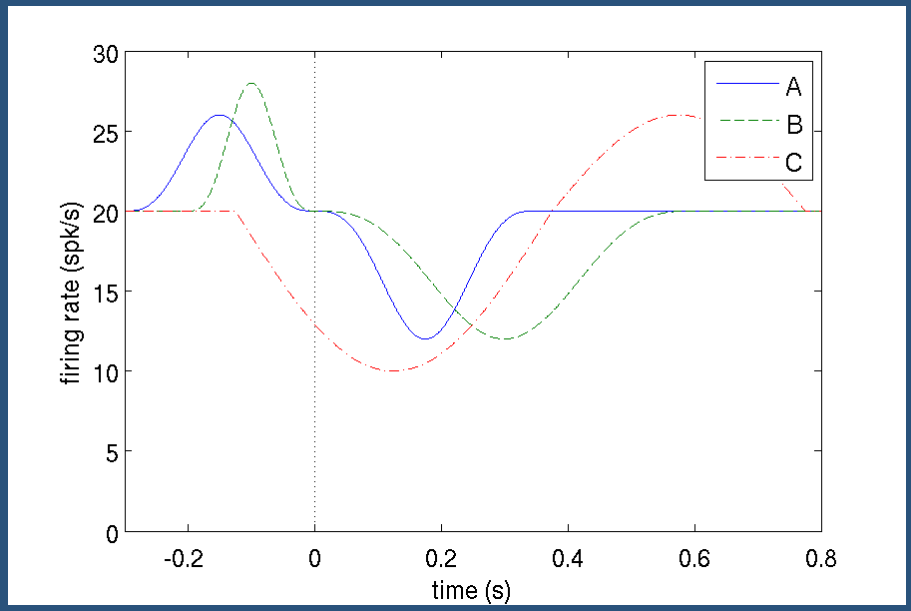
   between neurons i and j.

4. Average the instantaneous cross-correlation for each pair of neurons across trials.

Results

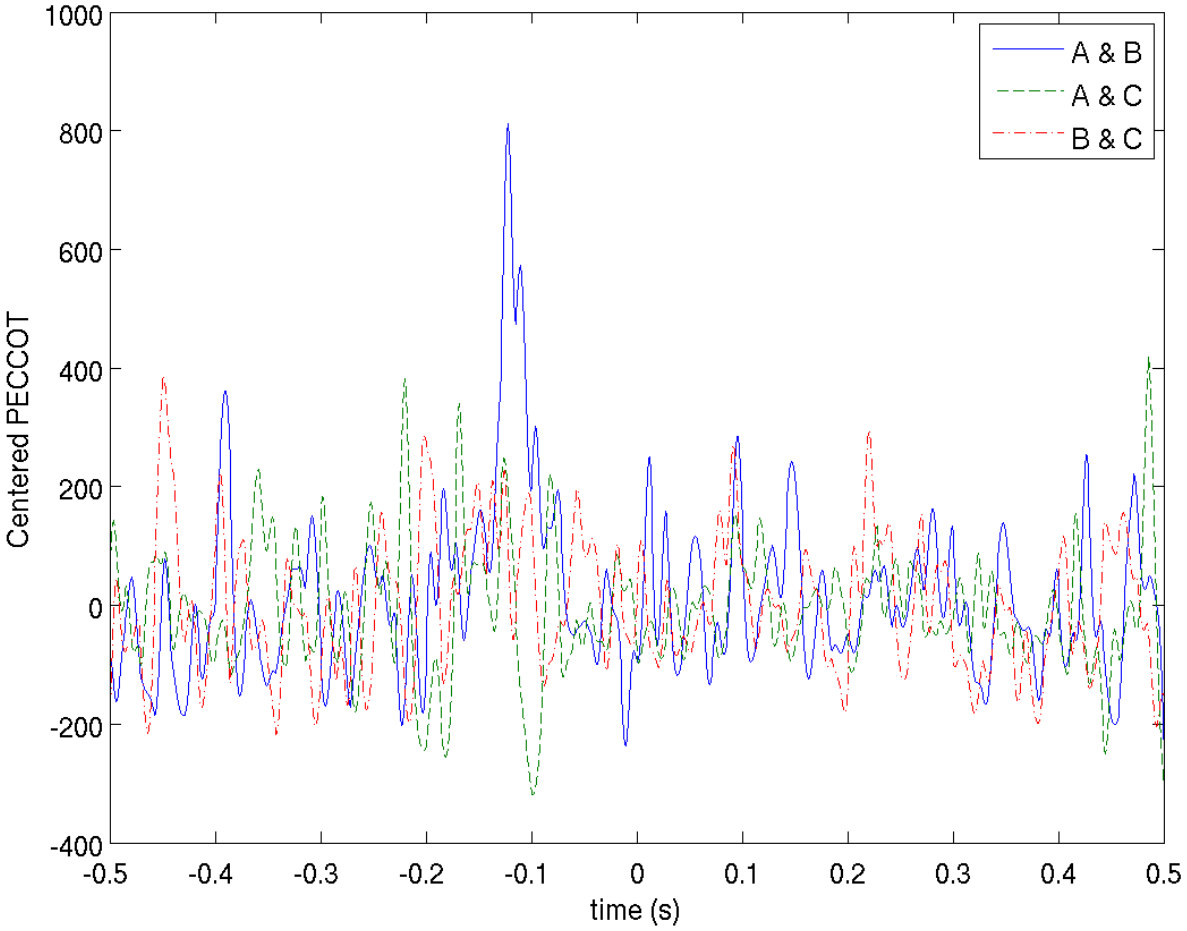
Simulated experiment: dataset

- Dataset with 3 neurons modulating in response to an event.
- Introduced stochastic synchrony between neurons A&B, 0.12s before event onset.



Results

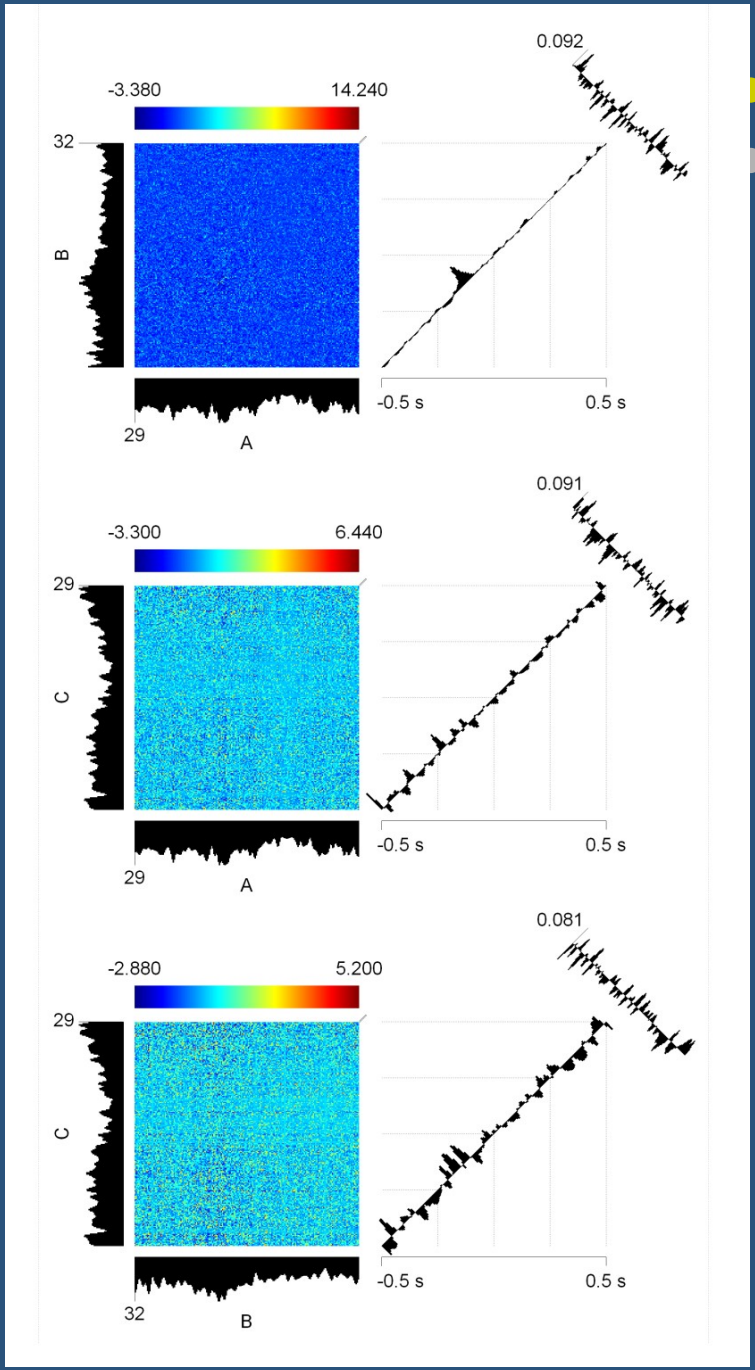
Simulated experiment: PECCOT



Results

Simulated experiment: JPSTH

- Conceptually, PECCOT expresses the same information as the main diagonal of the JPSTH.
- By focusing on only this dimension, it shows the interactions over time, but it is much easier to visualize and analyze.



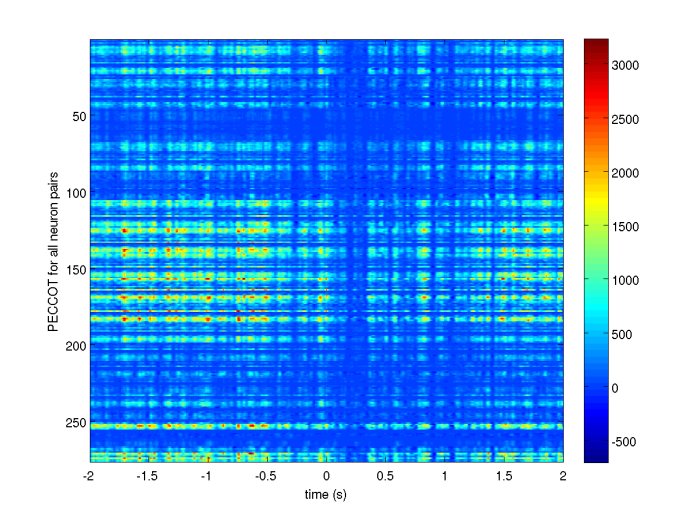
Results

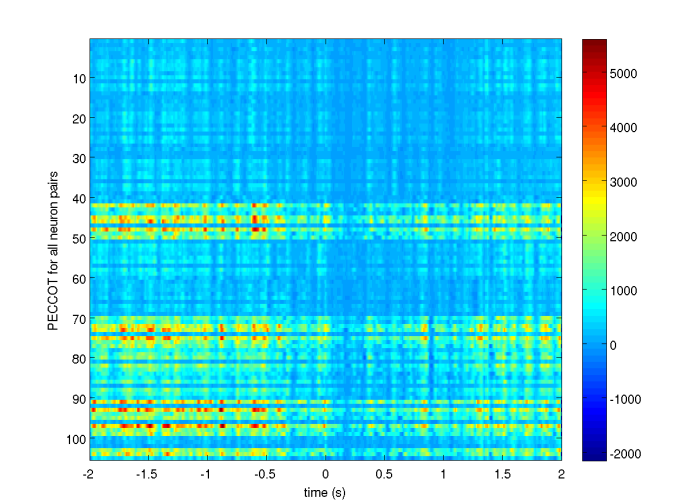
Behavioral experiment: dataset

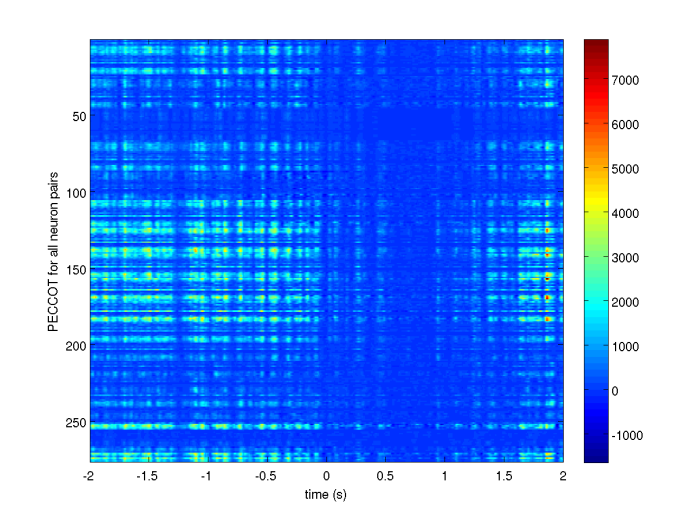
- Used multielectrode array recordings collected from male Sprague-Dawley rats performing a go-no go lever pressing task.
- 2×8 electrode array configurations, chronically implanted in the forelimb region of M1.
- Utilized 39 spike trains (24 left hemisphere, 19 right hemisphere).
- Averaging was done over 93 left lever presses and 45 right lever presses.

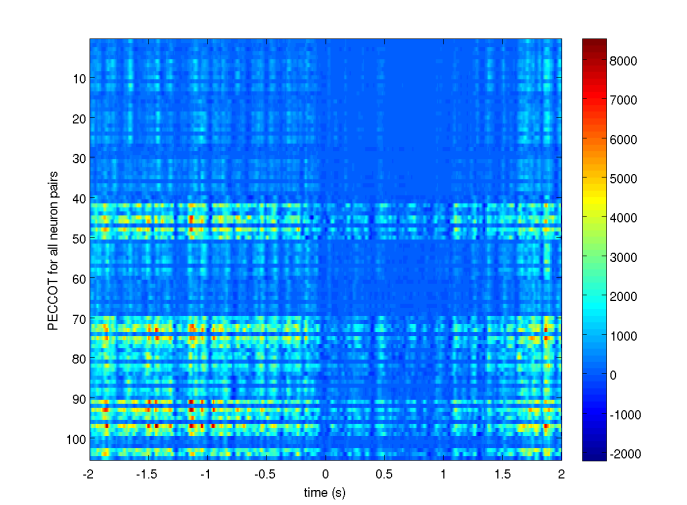
Results

Behavioral experiment: PECCOT









Conclusion

- Presented PECCOT as a simpler and more effective tool to study interactions over time among neurons.
- Exchanges averaging over time by averaging over realizations to achieve high temporal resolution.
- Formulation is general and applicable to either the coupling feature is synchrony or rate modulation.

Future work

- Interesting phenomena was observed in analysis of rat's motor cortex data.
  - Application of PECCOT to track the evolution of interactions across regions of the brain.
  - PECCOT may be an effective tool to relate meso- and macroscopic recordings (such as LFPs and EEG) to correlated single neuron activity.