Data Visualization Techniques for Single and Multiple Spike Trains

Wanxin Li
Department of Computer Science
University of Waterloo

AMMCS 2019

Wilfrid Laurier University

August 2019

Overview

1. Interspike Interval Plot
2. (Joint) Peristimulus Time Histogram
3. Crosscorrelation Histogram
4. Correlation Grid
5. Gravity Transformation Plot
6. iRaster Plot
7. Snowflake Plot
8. Tunnel Plot

Motivation and Statement of the Problem

- Data visualization in "high-dimensional" spike trains is challenging.
- The very first step in modelling must be descriptive analysis and data visualization.
- We only discuss what the plots visualize, and theoretical details and how to generate them are left out.

The Data

- The main dataset discussed in this presentation is:
  - Retinal Ganglion (RGC) and Lateral Geniculate Nucleus (LGN) of generally anesthetized monkey,
  - The stimulus is a beam of light going through the centre of the eye filed, varying at 80Hz,
  - spike times of 4 pairs of physically connected neurons (repeated trials of 5 seconds each)

The Data (cont'd)

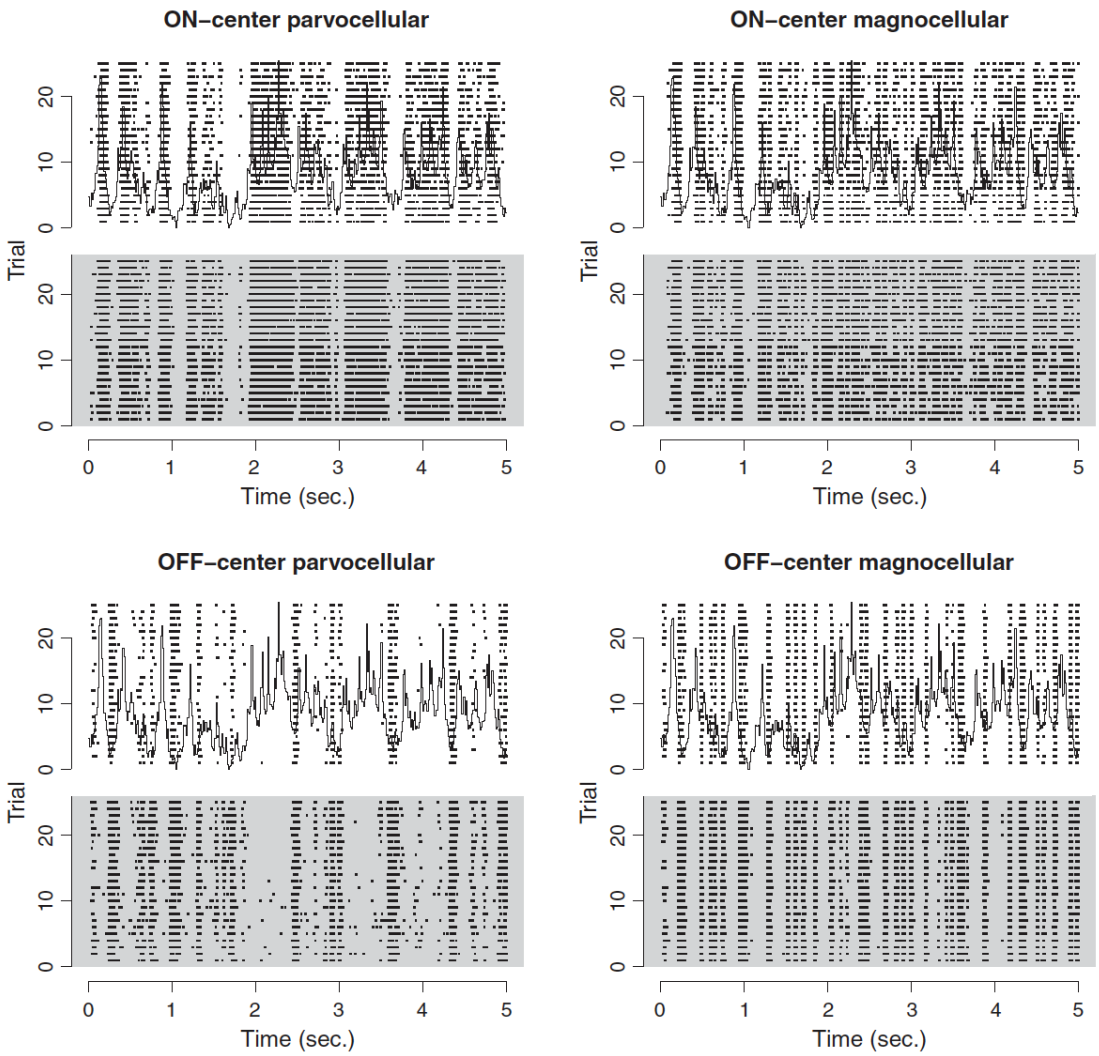
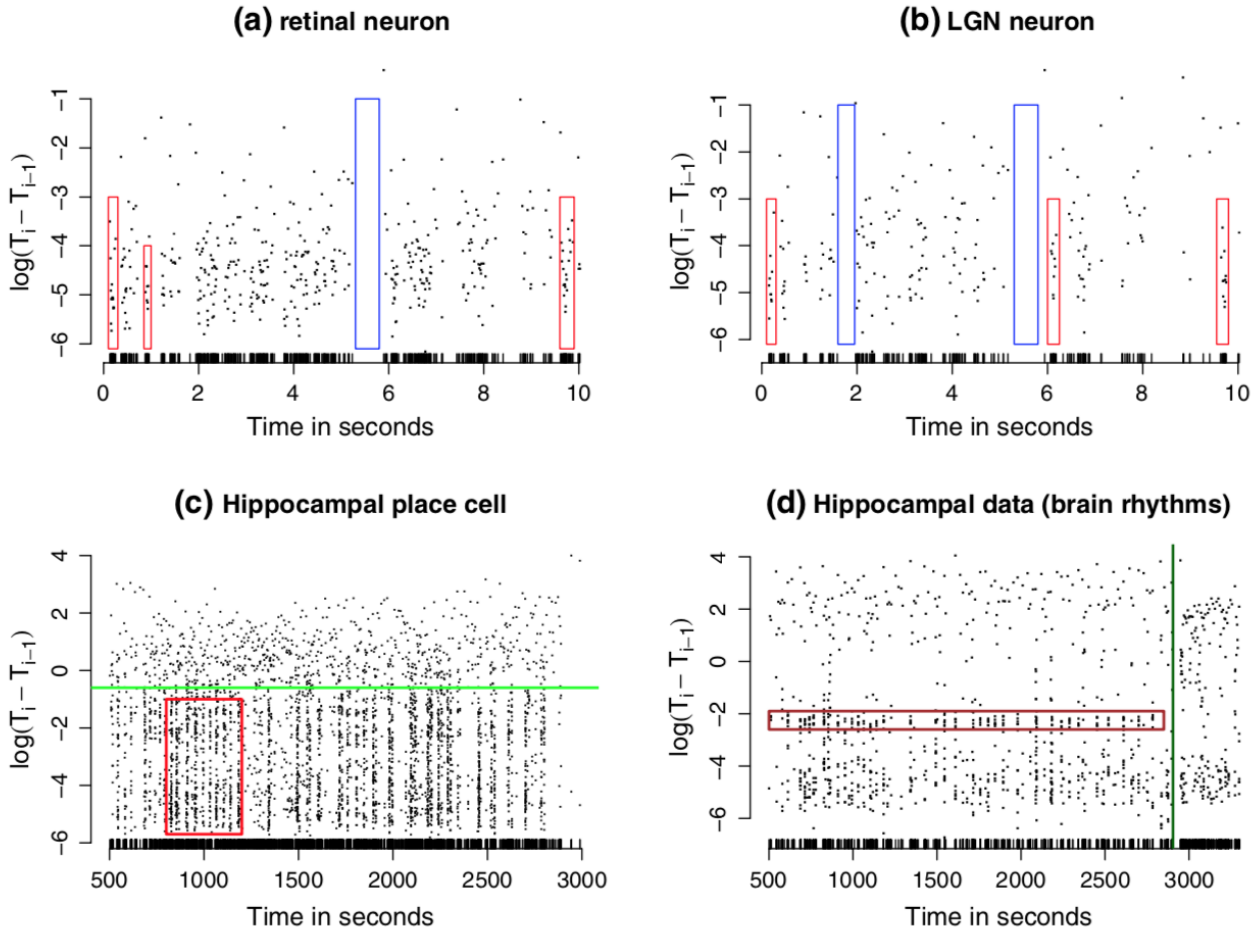


Figure: RGC-LGN Data: Sincich *et al.* (2007)

Interspike Interval Plot [1]

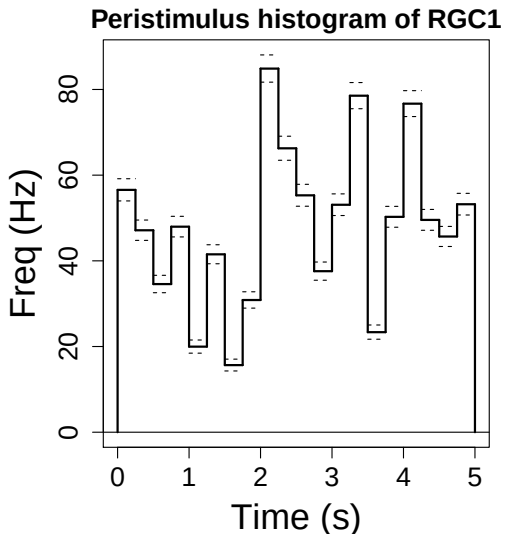
- Visualizes spike activities from large and small time scales
- Visualizes the departure from time homogeneity in the spiking activity



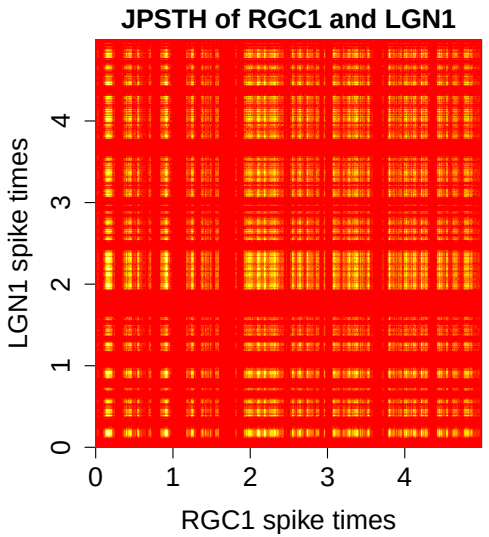
[1] Ramezan *et al.* (2014)

(Joint) Peristimulus Time Histogram

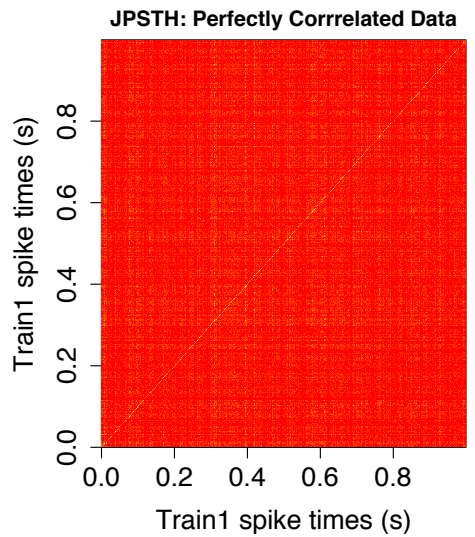
- Pulls data across trials/neurons to create a histogram
- Joint Peristimulus Time Histogram: Investigates the dynamics of correlation between two neurons over the course of the stimulus



(a) Peristim. Time Histogram



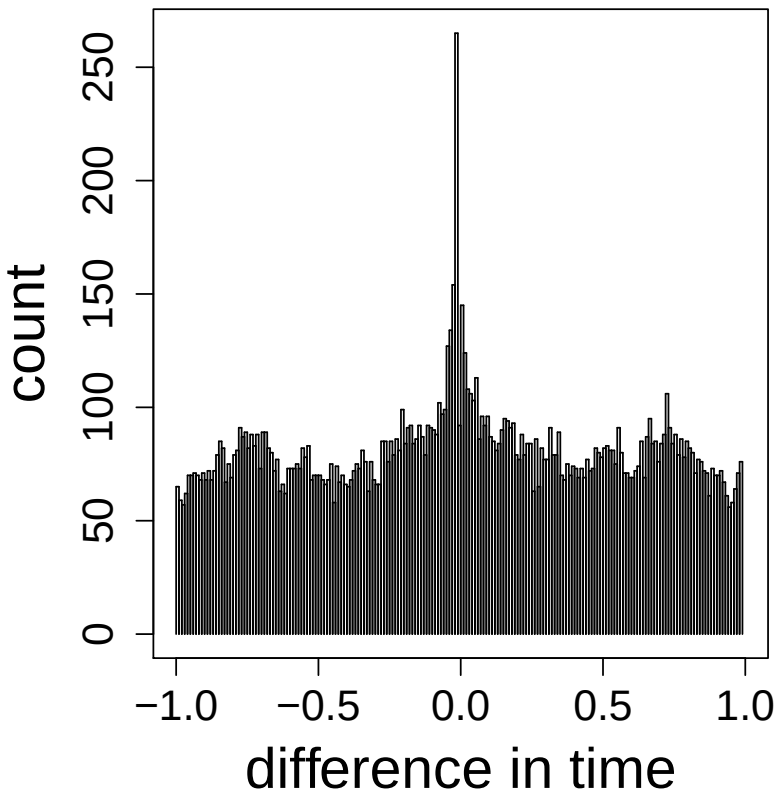
(b) Joint Peristim. Time Histogram (LGN-RGC)



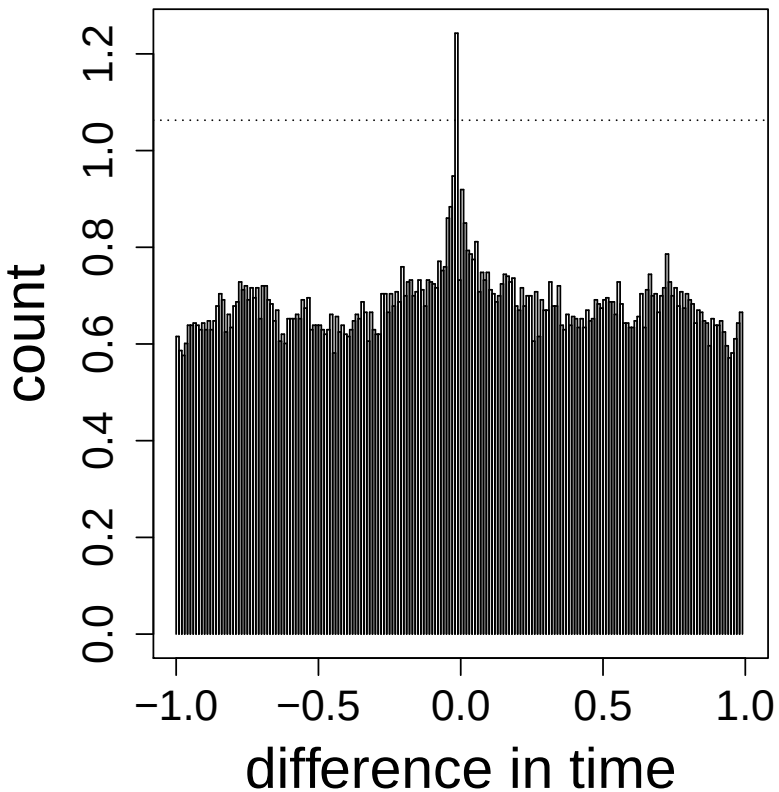
(c) Joint Peristim. Time Histogram (Simulated Data)

Crosscorrelation Histogram

- Indicates the firing rate of the target neuron versus the reference neuron
- Applies Brillinger Normalization to Crosscorrelation Histogram



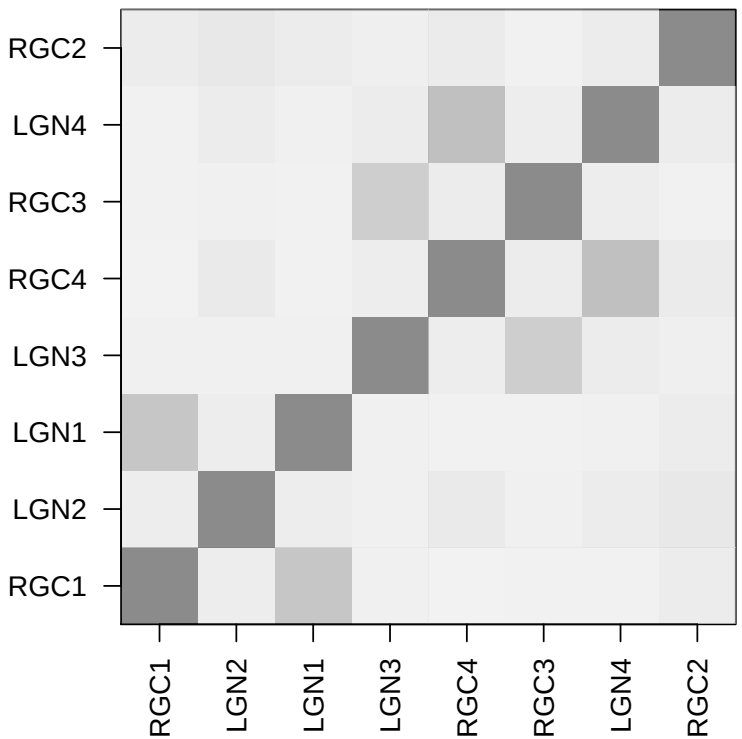
(a) CCH of Two Spike Trains



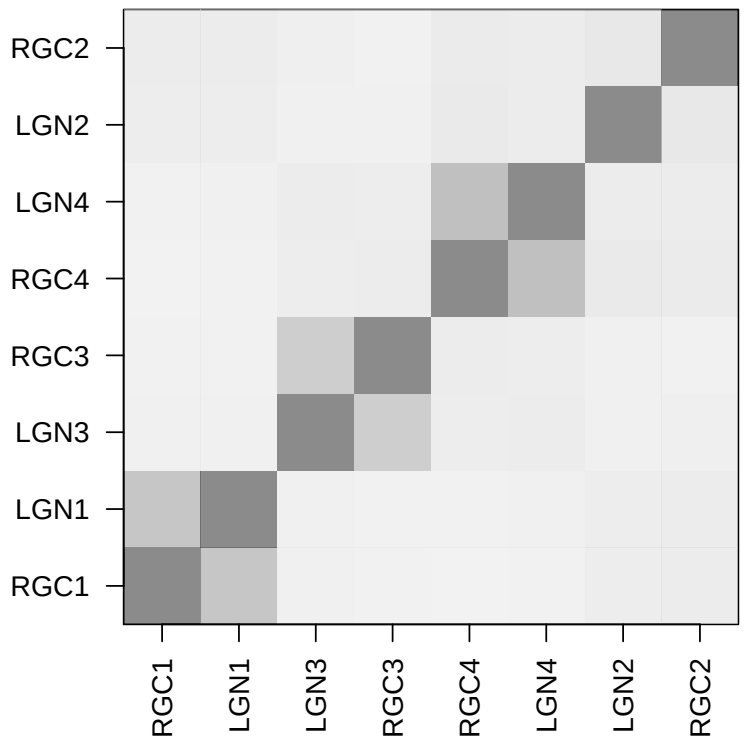
(b) After Brillinger Normalization

Correlation Grid [1]

- Visualizes the connection strength between pairs of neurons through several similarity measures
- Reorders neurons using hierarchical clustering



(a) Unsorted Correlation Grid



(b) Sorted by Coincidence Similarity

[1] Walter *et al.* (2003) & Stuart *et al.* (2005)

Gravity Transformation Plot [1]

- Measure sthe synchrony between pairs of spike trains dynamically over time by gravity transformation
- Visualizes the result by pairwise distance plots over time and iterative parallel coordinates
- Computationally expensive as it has to solve a system of differential equations

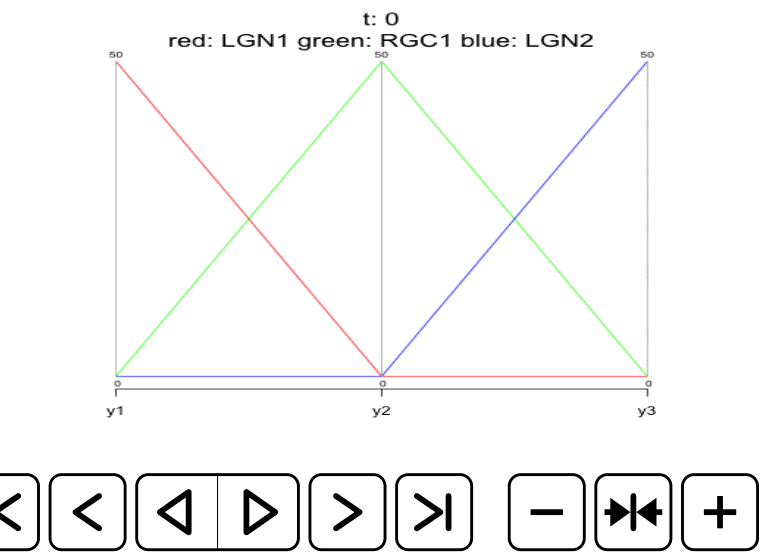


Figure: Parallel Coordinate Dynamic Plot

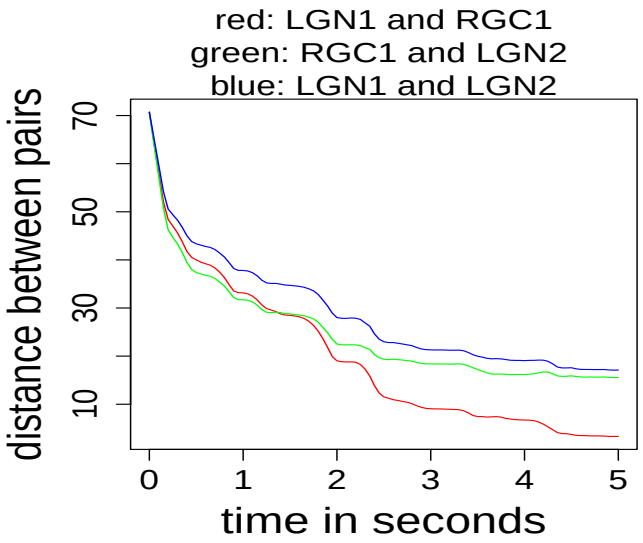
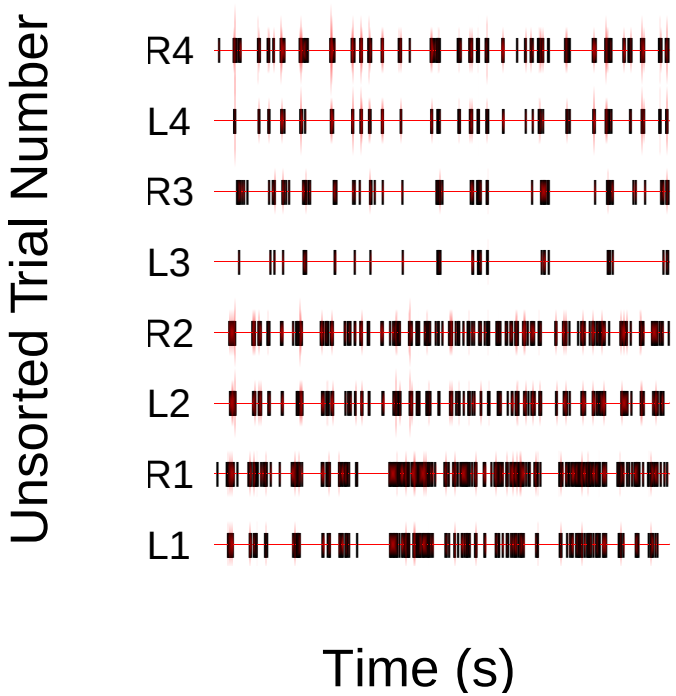


Figure: Distance Plot

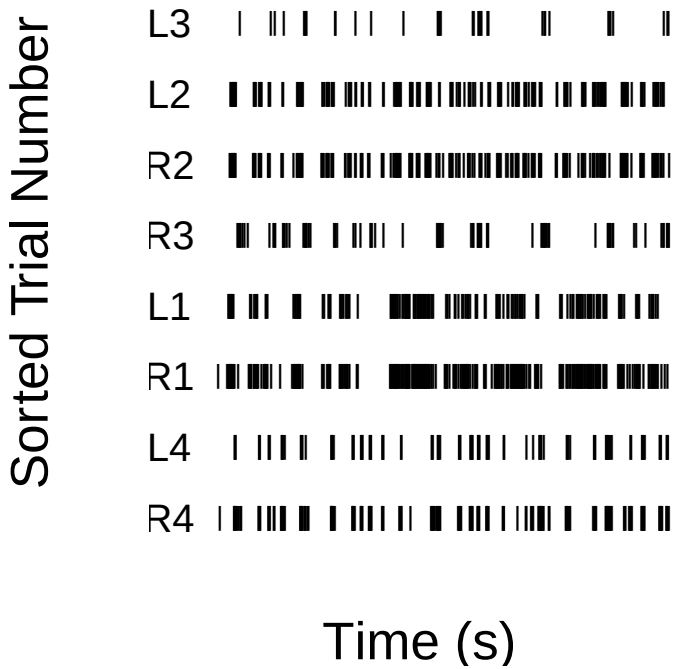
[1] Stuart *et al.* (2002)

iRaster Plot [1]

- Reorders Raster plot using 9 different similarity measures
- Superimposes firing rate onto Raster plot



(a) Estimated rates super imposed



(b) Rasters reordered by shortest ISI

[1] Somerville *et al.* (2010)

Snowflake Plot [1]

- Detects synchrony among three neurons
- Can be extended to more neurons, but the visualization is not as easy

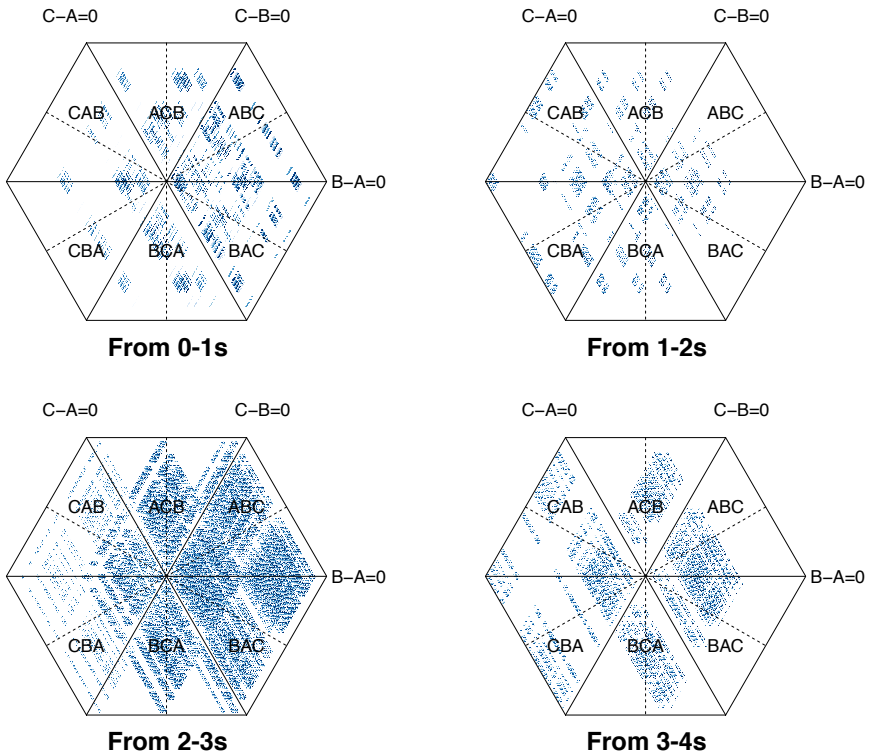
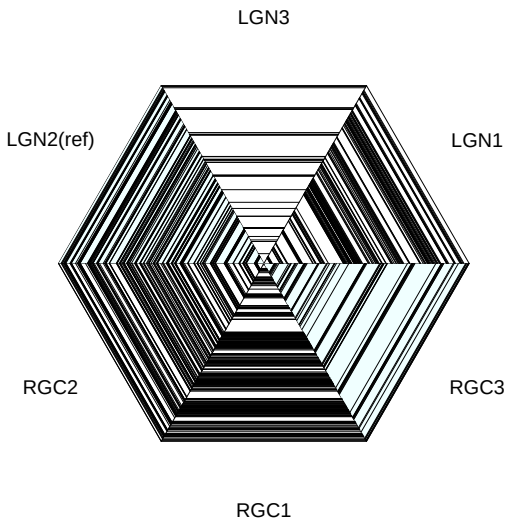


Figure: Snowflake plots of A: LGN1, B: RGC1, C: LGN3 recorded in 1s

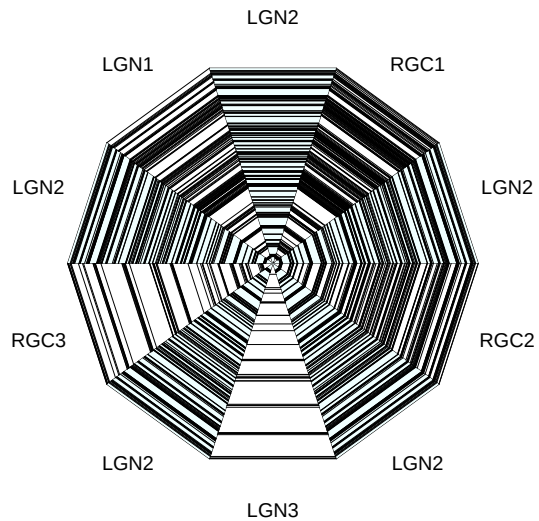
[1] Czanner *et al.* (2005)

Tunnel Plot [1]

- Discovers the dynamics of synchrony of neural activity over small ensembles
- Enables zooming, sorting, highlighting and clustering functionalities



(a) Tunnel Plot of 6 Neurons with Highlighting



(b) After Sorting against Reference

[1] Walter *et al.*(2004)

Questions