

# Motivic analysis of neuronal signals

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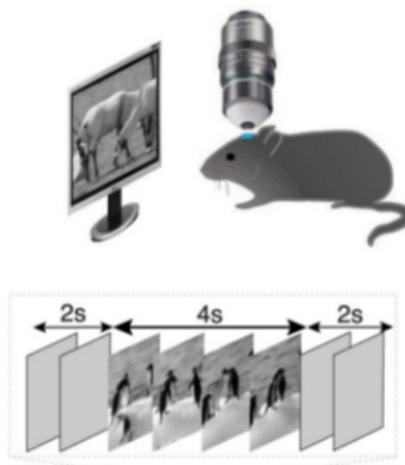
April 25, 2016

# Overview

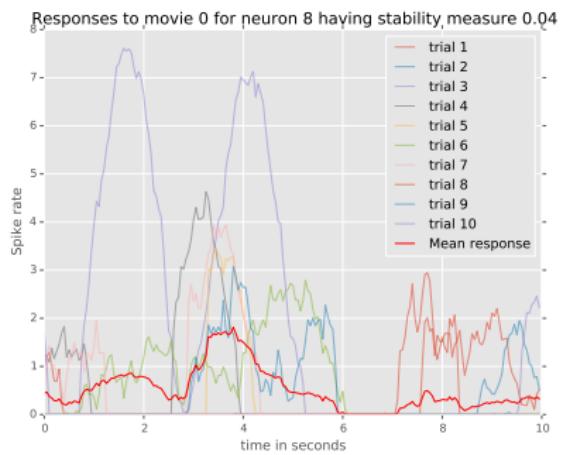
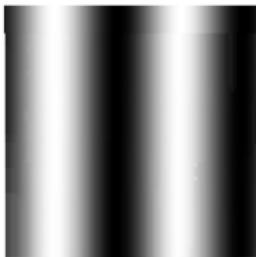
- How does neurons in Primary Visual Cortex (V1) behave?
- Motifs here refer to recurring patterns in the time-series response of neurons. Are there motifs in neuronal responses?
- What is similar in responses of two different neurons in a same mice?
- What is similar in responses of two neurons in different mice?
- What does these similarities mean?

# Experiment

Virus expressing GCaMP6f was injected into the V1 of mice. mice were imaged under a 2-photon microscope while sinusoidal drifting gratings/video were presented on a computer screen placed 3 inches from the mouse (1 degree of visual space  $\sim$  21.3 pixels on the screen).



# Data



# Background

## Orientation and Directional selectivity of neurons in V1

- Cells which respond to orientation of a contrasting visual stimuli. - simple cells
- Among the orientation selective cells, some cells are also sensitive to motion of the stimuli in a particular direction. - complex cells
- Orientation insensitive cells.

## Quantifying selectivity

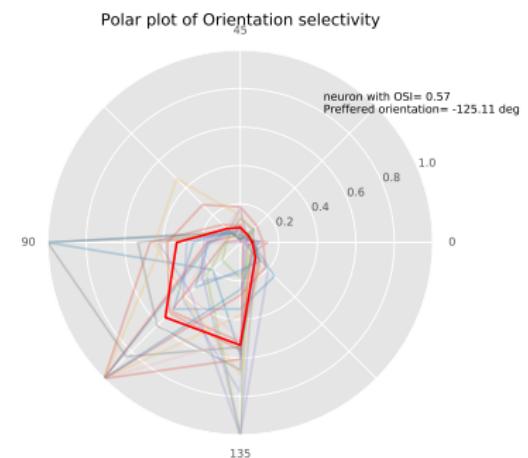
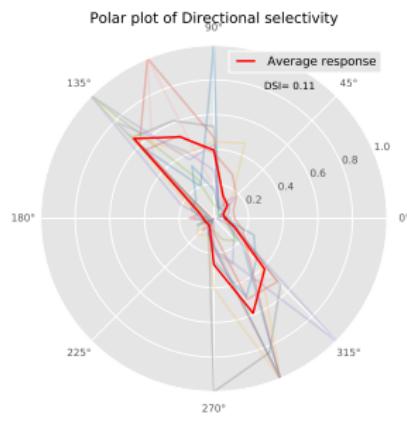
### Orientation selectivity index

$$L_{ori} = \frac{\sum_k R(\theta_k) \exp(2\theta_k)}{\sum_k R(\theta_k)}$$

### Directional selectivity index

$$L_{dir} = \frac{\sum_k R(\theta_k) \exp(\theta_k)}{\sum_k R(\theta_k)}$$

# Background



# Reliability and correlation

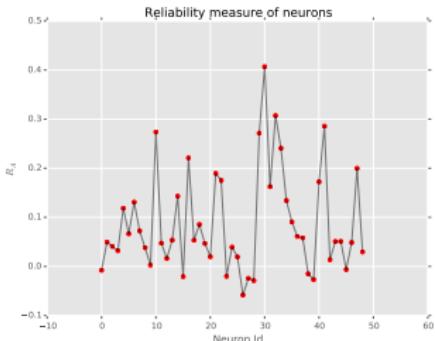
Response reliability to movie A ( $R_A$ ) is

## Reliability Measure

$$R_A = \frac{2}{T^2 - T} \sum_{i=1}^T \sum_{j=i+1}^T \rho(f_{i,A}, f_{j,A})$$

where  $f_{i,A}$  is the response of neuron to  $i^{th}$  trial of movie A and  $\rho$  is the Pearson correlation.

**Reliability measure is very low (~ 0.15) for most of the neurons.**



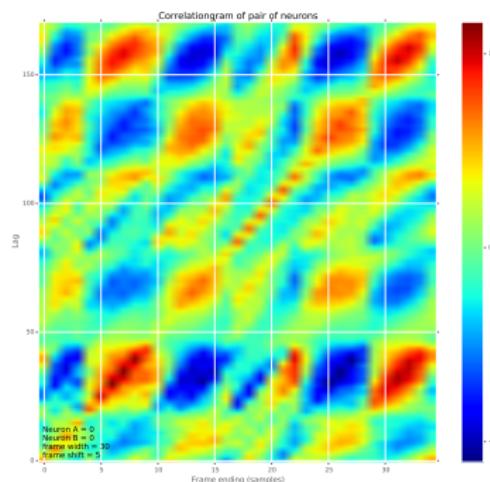
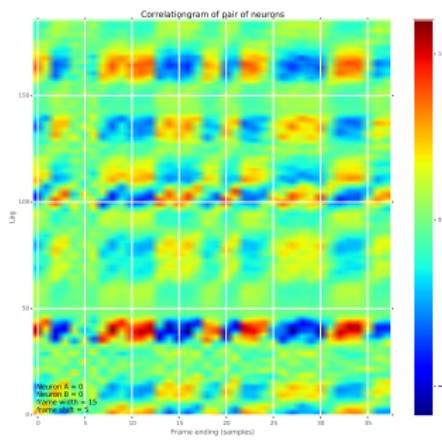
## ACF analysis

Having realized full time-series is not well correlated, We look for similar subsequences. We do this by taking a frame from template signal and finding ACVF with target signal at various lags.

- Heatmap of the ACF - a time vs lag vs ACF is created for analysis.
- For small window length ( $\approx 15$ ), the template is small. Such a small template does not satisfy as a motif. Also as the samples are less, estimate of sample correlation will be poor.
- For window lengths  $\approx 30$  we see patterns. These shows that there are repeating subsequences in the response.
- **Common subsequences across different neurons are found.**

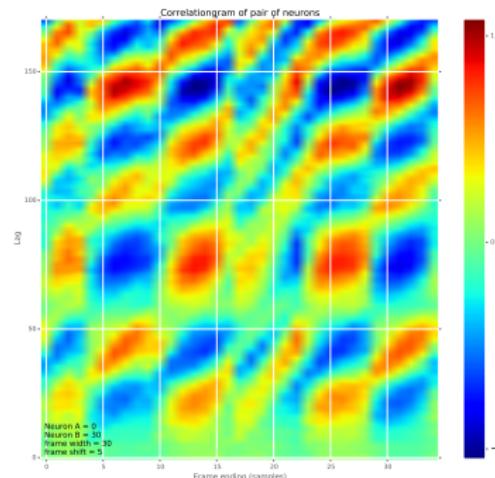
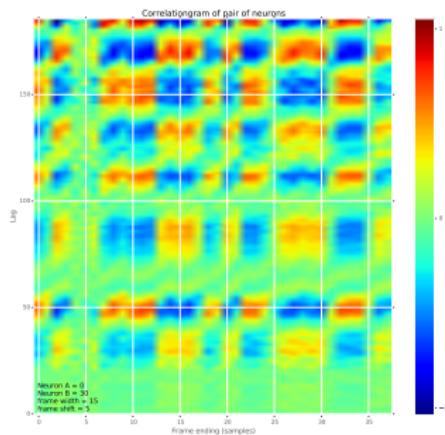
# ACFGram

Same neuron, different trials.



# ACFGram

Different Neurons.



# Subsequence detection using RLCS

## RLCS

Let  $\mathbf{X} = \langle x_1, x_2, \dots, x_n; x_i \in R \rangle$  be template signal and  $\mathbf{Y} = \langle y_1, y_2, \dots, y_m; y_m \in R \rangle$  be the target signal.

Distance between sample  $x_i$  and  $y_j$  is

$$dist(x_i, y_j) = (x_i - y_j)^2$$

and RLCS problem is

$$R(X_i, Y_j) = \begin{cases} \emptyset & \text{if } i = 0 \text{ or } j = 0 \\ LCS(X_{i-1}, Y_{j-1}) \cup x_i & \text{if } dist(x_i, y_j) < \tau_{dist} \\ \max(LCS(X_i, Y_{j-1}), LCS(X_{i-1}, Y_j)) & \text{if } dist(x_i, y_j) > \tau_{dist} \end{cases}$$

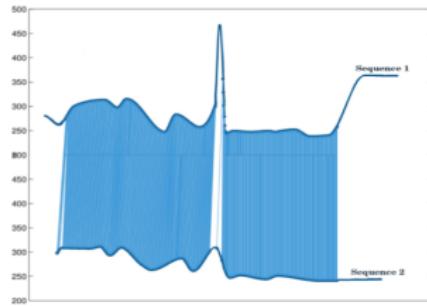
## Score updates

- For a sample match

$$\text{cost}(i, j) = \text{cost}(i - 1, j - 1) + \left(1 - \frac{\text{dist}(x_i, y_j)}{\tau_{\text{dist}}}\right)$$

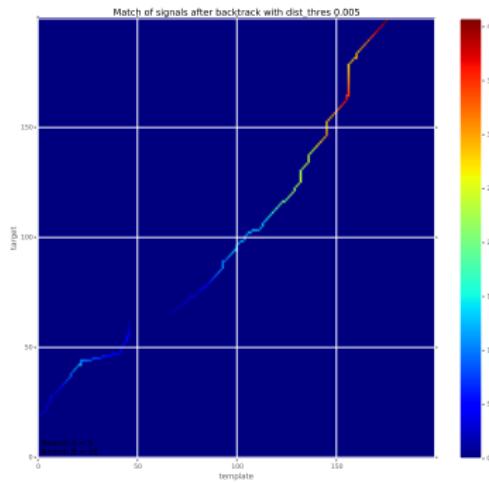
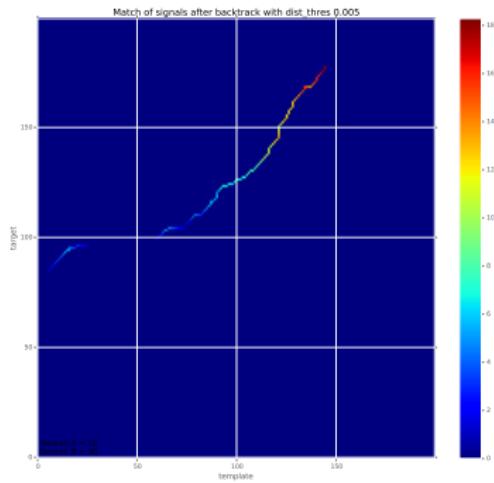
- For a sample mismatch/ gap

$$\text{cost}(i, j) = \text{cost}(i - 1, j - 1) - \delta$$



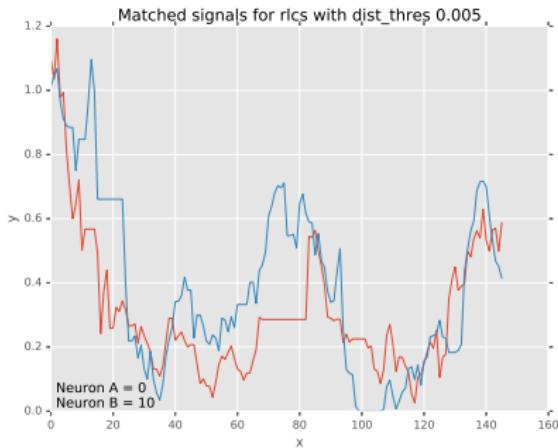
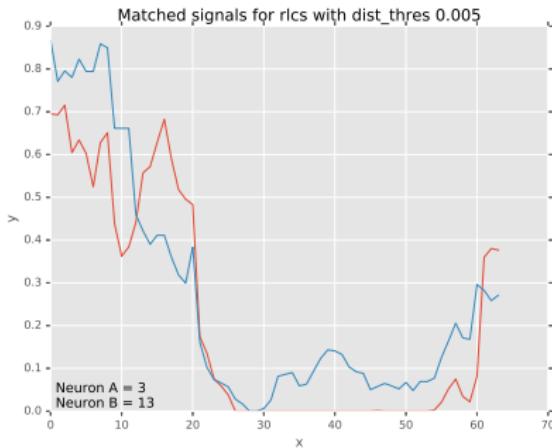
# Results

## Score matrix for same mice, different neurons



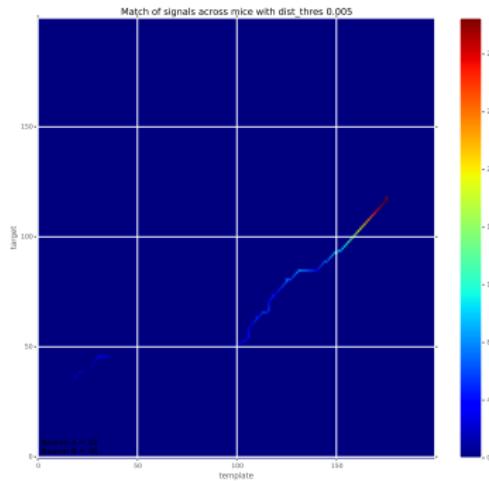
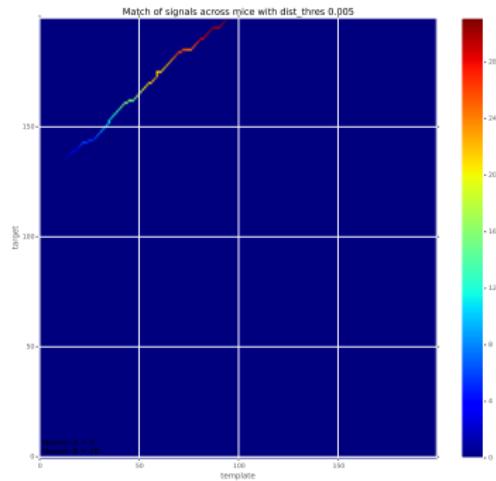
# Results

## Longest common subsequence extracted from two neurons in same mice.



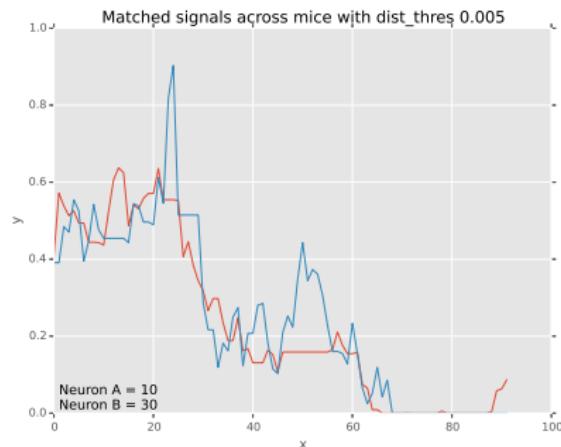
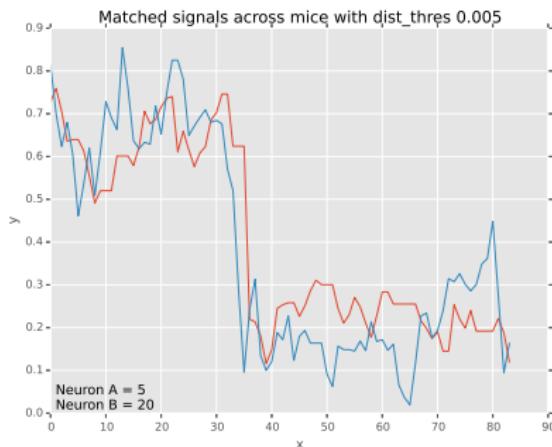
# Results

## Score matrix for Different mice



# Results

## Longest common subsequence extracted from two neurons in different mice.



## Inferences

- Neuronal responses contain motifs/subsequences. The chemical process under every neuron's activation is same.
- Same neuron's response for different trial has a long subsequence. In every trial, receptive field of neuron stays approximately same.
- More or less any two neurons in the same mice contain motifs. On top of activation mechanism, neuronal interconnections could contribute to motifs.
- Motifs exist across neurons as well. But less frequent or motifs are shorter. As there are no neuronal connections, motifs across neurons are due to similar chemical activation process.

# References

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