NEURON SPIKE ENCODING OF STIMULUS

21CS10021
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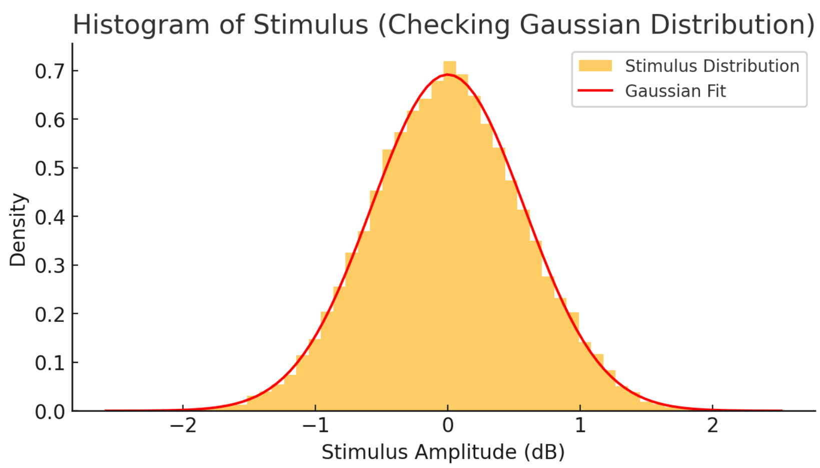
1) Stimulus nature

As you have learned to apply spike triggered average correctly the stimulus must be Gaussian distributed (white noise). Is it true? What is the autocorrelation function of the stimulus R( ) for tau = -50 to 50 ms in steps of 1 ms (make necessary assumption about the stimulus)?

Sol:

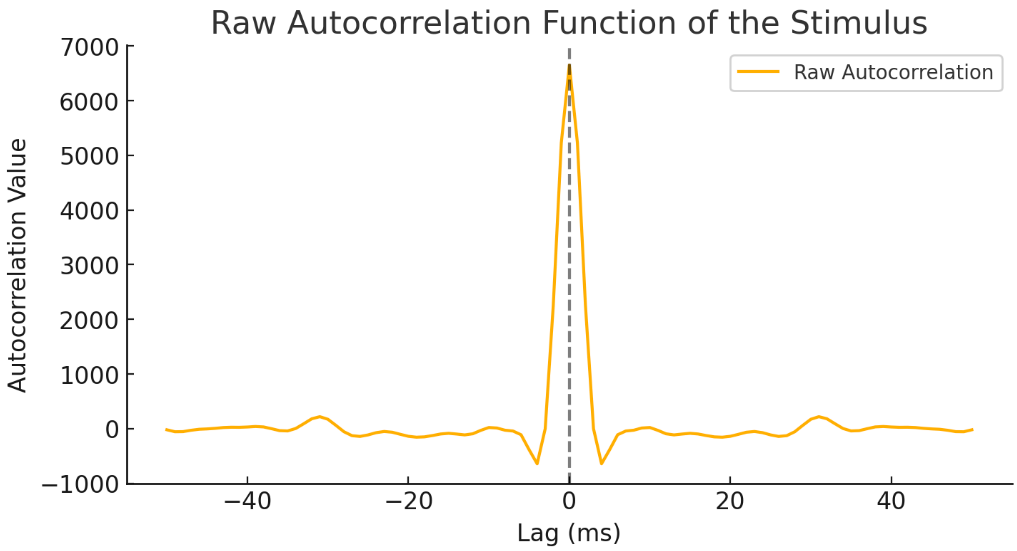
To test this let us plot stimulus(from mat file) and check weather it follows Gaussian distribution:



Above plot is approximately equal to the gaussian distribution.
Yes, stimulus is gaussian distributed. We can apply spike triggered average without any problem.

$$\rho(\tau) = \frac{cov(x_t, x_{t-1})}{\sigma(x_t)\sigma(x_{t-1})}$$

Again plotting the autocorrelation function we get:



Note that this resembles autocorrelation of white noise, which is an impulse at 0.

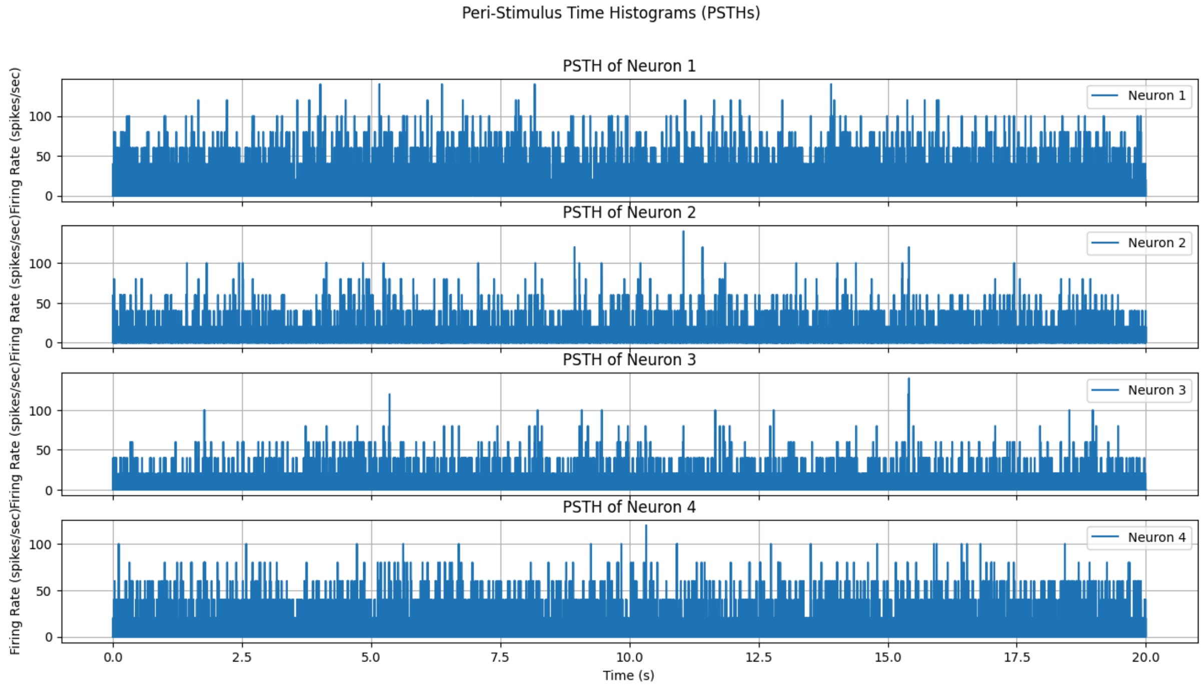
2) PSTH and mean firing rate

Obtain the PSTHs of the neurons (in spikes/sec) in response to the stimulus and plot them.You should be getting rates in 1 ms bins from the 50 repetitions of the stimulus. The firing rates should be of the order of 10s of spikes/sec (up to approximately 100). So you should have 4 plots, 1 each for each neuron, x-axis is time (0-20s) and y-axis is rate is spikes/sec showing the firing rate r(t) – where t is at a temporal resolution of 1 ms. Keep the r(t) of each neuron for the last 5 seconds separately, which will used for prediction performance of the models you estimate.

Sol:

Steps

1. Given data All_Spike_Times (4 neuron X 50 repetitions).
   All_Spike_Times[i,j] (1,344) time at which spike happens, there are 344 spike times.
2. We create spike_counts(1,20000) and initialize it with 0.
3. Convert spike time into ms, and add 1 for each time bin when spike occurs.
4. Calculate mean firing rate by $spike\_count/repetitions\ *\ time\ bin$

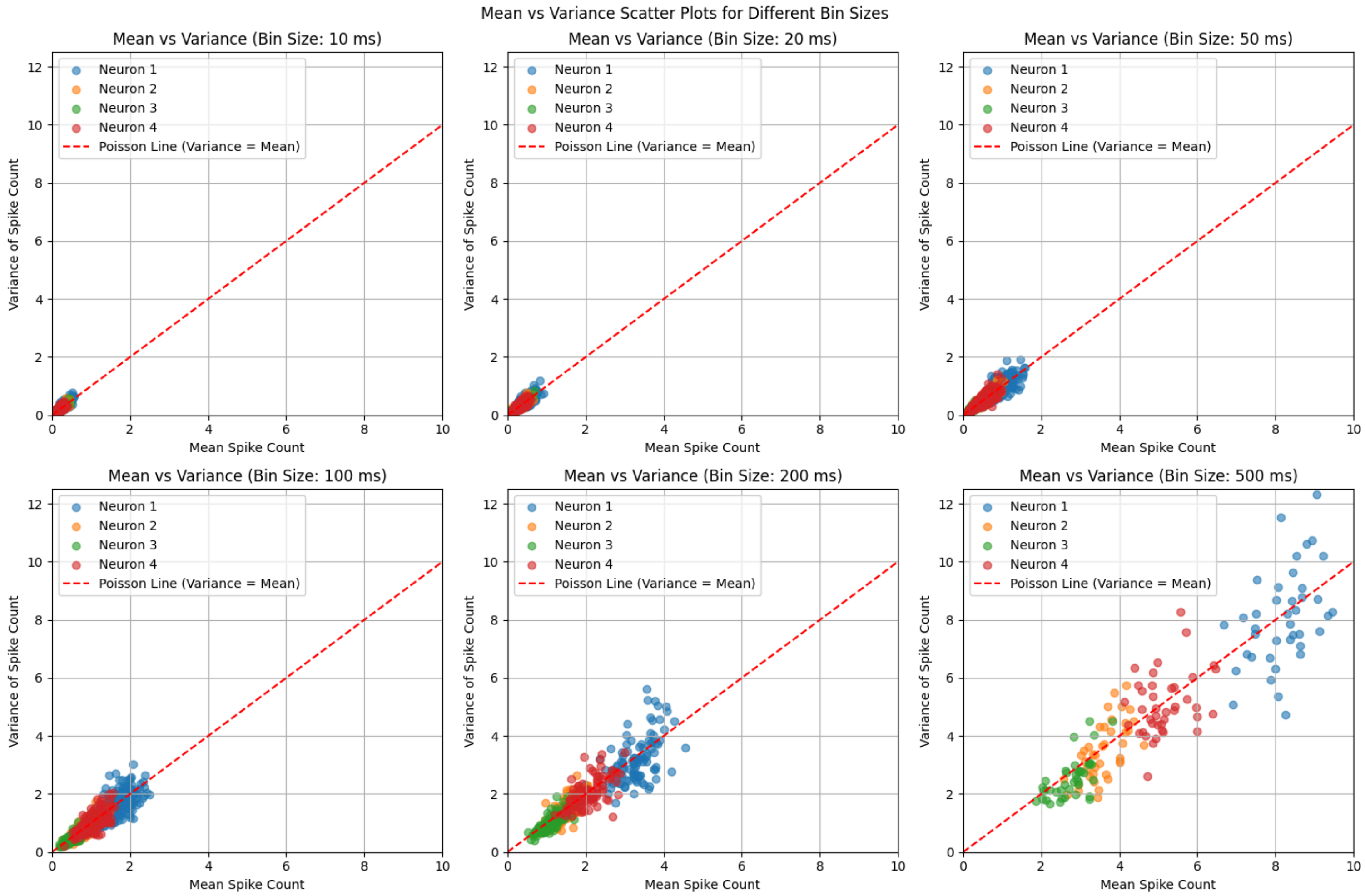


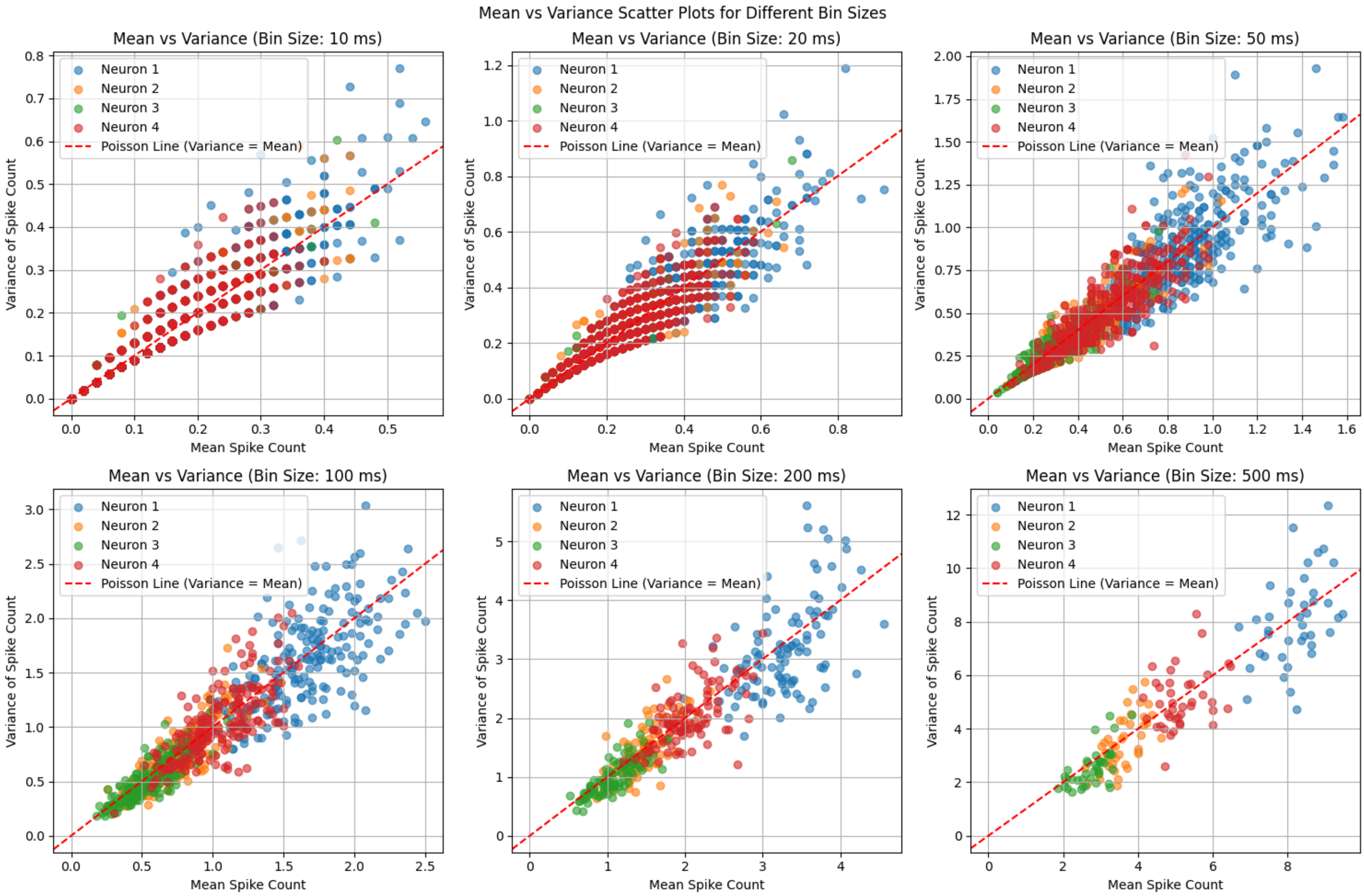
3) Poisson or non-Poisson

For each neuron consider time bins of 10 ms, 20 ms, 50 ms, 100 ms, 200 ms and 500 ms. Get number spikes in each bin for every repetition. For example, in the 100 ms case for each repetition you will have 200 (20s/100ms) spike count values. Now with 50 repetitions you will get 50 samples of each spike count. From a scatter plot of mean and variance (obtained from 50 repeats) comment on the Poisson or non-Poisson nature of the spiking for each neuron at each time scale (10 ms to 500 ms).

Sol:

Visually, we can see that the spiking is poisson like for bin size of 50ms,100ms.
We observe that many bins of size 10ms and 20ms have 0 spike count. Thus mean and variance are not meaningfully defined.
Fano-Factor = $variance/mean$


Mean vs Variance Scatter Plots for Different Bin Sizes
Mean vs Variance (Bin Size: 10 ms)
Mean vs Variance (Bin Size: 20 ms)
Mean vs Variance (Bin Size: 50 ms)
Mean vs Variance (Bin Size: 100 ms)
Mean vs Variance (Bin Size: 200 ms)
Mean vs Variance (Bin Size: 500 ms)
Neuron 1
Neuron 2
Neuron 3
Neuron 4
Poisson Line (Variance = Mean)
Variance of Spike Count
Mean Spike Count



4) Spike triggered average (STA) [and correction for non-Gaussianity?]

Now, as taught in class, obtain an estimate of the linear filter, h(t) (left), that may represent each of the neurons, using the first 15 seconds of the data (spike times and stimulus). Assume a 100 ms length of the filter (ie assume spiking depends only on the previous 100 ms of the stimulus). Comment on the kind of filtering that such filters would be performing for each neuron. Based on your results in 1), make any correction(s) necessary.

Sol:

Steps:

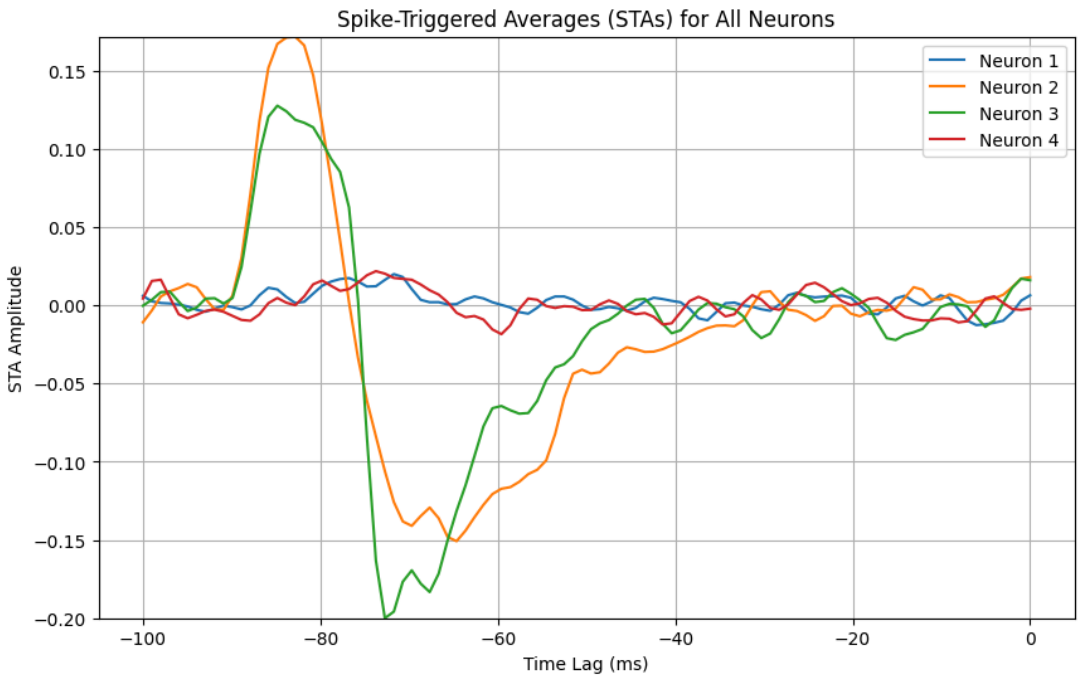
We have,

STA : $h(\tau) = \frac{1}{N}\sum_{i=1}^{N} s(t_i - \tau)$

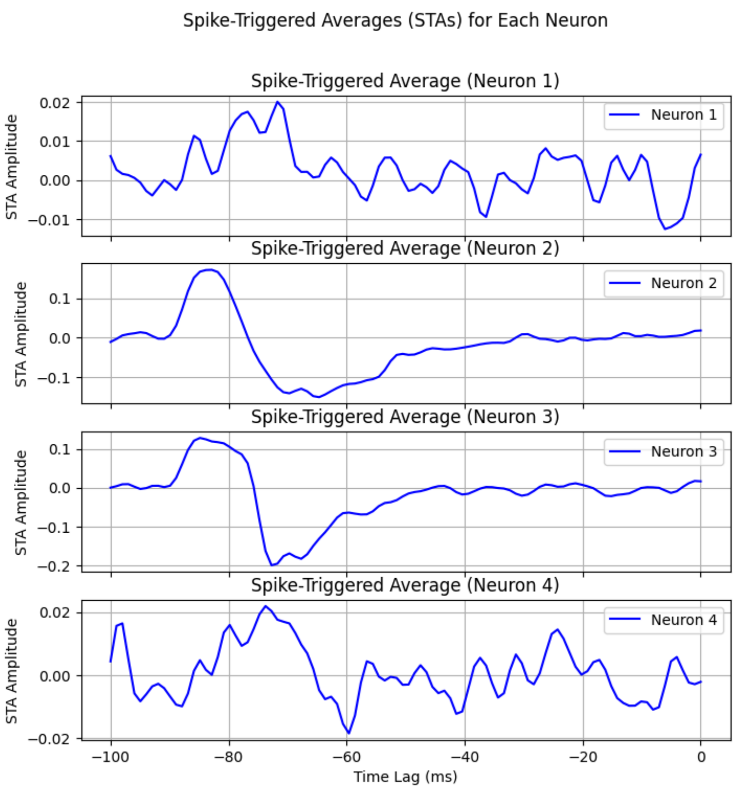
s(t) be stimulus.

T_i time of ith spike, N total #spikes, h() be STA filter.

On the same time scale:



On different time scale:



As we can see from above plots, neuron 1 and 4 responses appear noisy.

And for neuron 2, neuron 3 have a significant peak and a valley, showing selectivity towards change of stimulus features.
Neuron 2,3 behaves like a band-pass filter, meaning it is sensitive to specific frequencies in the envelope.
Neurons 1, 4 do not show strong linear selectivity, they might be non-linear in nature.

No Correction Needed, since $|\text{skew}|<0.1$ and $|\text{kurtosis}|<0.1$, the stimulus is Gaussian for STA computation. (provided in code)

5) Determining the output nonlinearity