Assignment 2

Computational Neuroscience

Computer problem 1 (2pts)

Generate spike trains using both a Bernoulli process, and an exponential spike interval distribution (ISI). Compare spike counts for both to a Poisson distribution of equivalent mean.

Suggested approach:

1. Decide on reasonable physical parameters, e.g. simulate 100 seconds long spike train with 10 spikes per second.
2. Bernoulli process: Assume each time bin is 1ms long. This means the output will be a vector that contains 100.000 elements containing either a zero or a one. (Helpful Matlab command: binornd.)
3. Exponential ISI. Generate as many random numbers (exprnd) as necessary to fill 100s with spikes, i.e. their sum of all ISIs should be larger than 100.
4. Comparison to Poisson distribution (spike *counts* are well described by Poisson distributions).
   (a) Convert spike trains to spike counts: Think of your 100s long spike train as 100 trials of length 1s each. (These are arbitrary numbers, try different ones!)
   (b) Count the number of spikes in each trial. Then plot a histogram (hist) over all spike counts. Superimpose the expected histogram for a Poisson distribution (use poissrnd, or poisspdf).
   (c) Compute mean and variance for your spike counts. Is the ratio approximately 1 as expected from a Poisson distribution?

Computer problem 2: (8pts)

a) Implement a simple cell with a vertical RF and a half-wave squaring output nonlinearity. As RF use a 2D Gabor function:

$$RF(x,y) = \frac{1}{2\pi\sigma_x\sigma y}\exp\left(-\frac{x^2}{2\sigma_x^2} - \frac{y^2}{2\sigma_y^2}\right)\cos(kx-\phi) \tag{1}$$

where the image size should be ± 5 degrees along each boundary. Discretize the image such that 1 pixel corresponds to $0.2\,\text{deg} \times 0.2\,\text{deg}$, i.e. using a 50x50 image. σ_x=1 degrees, σ_y=2 degrees, $1/k$=0.56 degrees and $\phi = \pi/2$. Plot the RF both as a 2D image and as a cross section along the $x-$axis. (1pts)

b) Plot the mean spike rate in response to a vertical grating image $I(x,y) = \sin(kx-\alpha)$ as a function of the phase of the grating, α. Scale the output of your neuron such that the peak firing rate is 50Hz. (1pts)

c) Implement a complex cell by appropriately combining the outputs of two RFs, one of which is identical to the one above. The other RF is identical up to the phase, which is $\phi = 0$. Replace the half-wave squaring, $|\cdot|_+^2$ with a full-wave squaring $(\cdot)^2$. Plot the mean spike rate in response to a vertical grating image $I(x,y) = \sin(kx-\alpha)$ as a function of the phase of the grating, α, as above. Next, plot the tuning curve with respect to the orientation of the grating image, i.e. change the orientation of the grating from vertical to horizontal back to vertical. (2pts)

d) Perform reverse correlation on your simple and your complex cell model neurons. Generate a sequence of white noise images and simulate spiking responses to them. Assume a Poisson model. Scale your model such that the average spike count per image is 0.2spikes. Compute the average over all images that generated at least 1 spike. Compare it to the RF of the model neuron. Quantify the match of true RF and STA by computing the correlation coefficient between both. How does the quality of the match depend on the number of spikes that enter your calculation? (2pts)

e) Graduate level: Perform a spike-triggered covariance analysis on the same model neurons. How many eigenvectors are significantly different from 1 (by visual inspection)? What filters (eigenvectors) correspond to them? Describe the differences in your results from the STA analysis. Hint: Use a coarser grid, e.g. 10x10. (2pts)

Note:

Please combine code, output and verbal answers into one compact pdf document. Please comment your code.