Study guide for Midterm 2

Introduction to Neural Computation (9.40)

Spring 2018

Below is a list of all the things you should **be able** to do for each of the topic areas covered in the midterm.

Convolution:

- Obtain the post-synaptic voltage response to a spike train by convolving a spike train with the postsynaptic response to a single presynaptic spike. This assumes that postsynaptic potentials superimpose linearly.

Exercise:

The following kernel in units of millivolt gives the post-synaptic voltage response of a cell: $K(t) = e^{-t/\tau}$, where $\tau = 10$ msec. This cell receives a burst of three presynaptic spikes with a firing rate of 200Hz.

a. Plot the presynaptic spike train and carefully label the inter-spike interval.
b. Qualitatively plot the post-synaptic response to this presynaptic spike train.
c. Calculate the peak (maximum) voltage response to this burst. Assume the membrane potential response to presynaptic spikes is linear with the given kernel.

Extracellular Potentials:

- Identify current sinks and sources and draw patterns of current flow in and around a neuron during an action potential or synaptic input on a dendrite.
- Plot the extracellular membrane potential during an action potential or during a brief synaptic input.
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Poisson process:

- Explain and understand the distribution of spike counts and inter-spike intervals for a Poisson process.
- Plot the inter-spike interval (ISI) distribution for a Poisson spike train.
- Relate the mean firing rate of this process to the statistics of the ISI distribution.

- Compute the probability that a Poisson neuron will generate *n* spikes in a given time window for a specified firing rate.

Exercise:

The distribution of spike counts for a Poisson process is given by the following formula:

$$P_k(n) = \frac{(n)^k e^{-n}}{k!}$$

$$k = \#\,\text{of counts}$$

$$\text{n=expected } \# \text{ of counts}$$

If a Poisson process has a constant mean firing rate of 15 Hz, what is the exact probability that this neuron would fire:

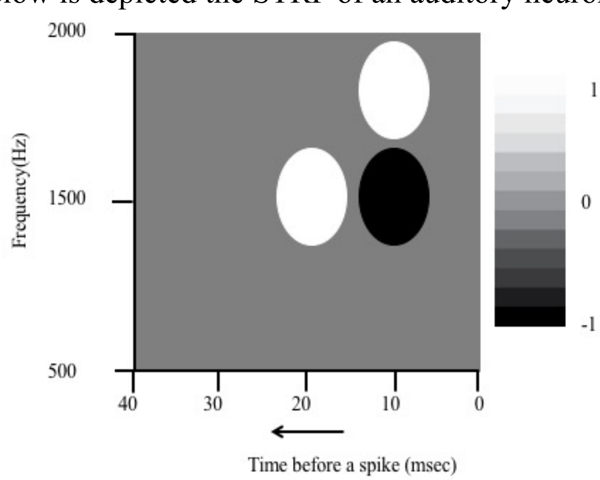
a. 1 spike within a time window of 50 msec?
b. 2 spikes within a time window of 5 msec?

Receptive fields:

- Write down the integral representing the time-dependent firing rate of a neuron in terms of a linear receptive field and a time-dependent stimulus. (Use one or two spatial stimulus dimensions.)
- Be able to explain the terms and mathematical operations involved in this equation.
- Be able to describe in words, which stimuli would excite a cell by looking at a picture of a spatio-temporal or spectro-temporal receptive field.
- State for what kinds of stimuli the spike-triggered average will reliably estimate the linear response of a neuron.

Exercise:

Below is depicted the STRF of an auditory neuron:



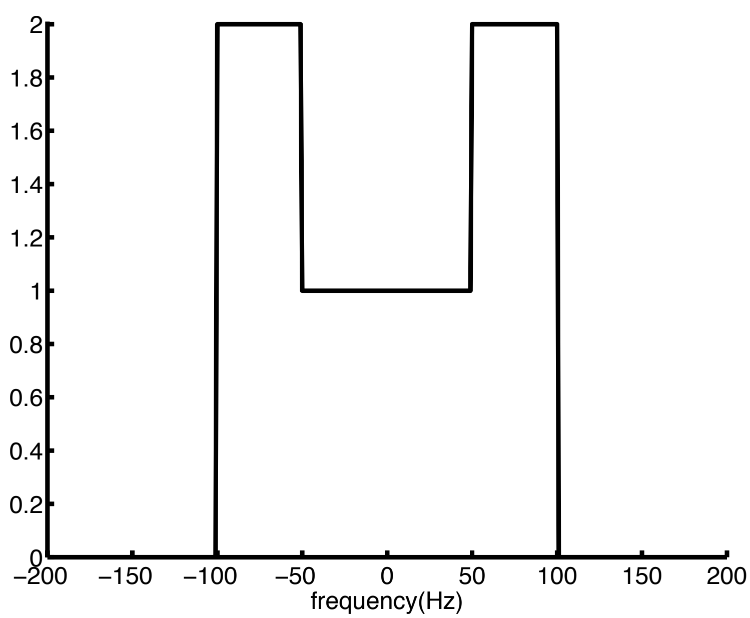
a. Describe a stimulus that would excite this cell maximally.
b. Describe two stimuli that will excite this cell with responses below the maximum.
c. Describe three stimuli, different than playing no sound, that will not elicit spiking activity for this cell.

Fourier series and Fourier Transform:

- Write the Fourier series for odd and even periodic functions with period T.
- Plot the Fourier transform (real and imaginary parts) of simple functions such as: sine, cosine, single delta function, train of delta functions (delta comb), Gaussian and square pulse.
- Use the convolution theorem to find the Fourier transform of different combinations of these functions.

Exercises:

1) Draw the Fourier transform of a square pulse of width T. Express the relation between the width of the Fourier transform and the width of the square pulse in the time domain.
2) Plot the convolution of a square pulse of width T with itself. What is the resulting shape of this convolution?
3) Using the convolution theorem, compute the Fourier transform of the function obtained in 2).
4) A function *x(t)* has a purely-real Fourier transform depicted below



Draw the Fourier transform of $y(t) = x(t)\sin(2\pi f_0 t),\ f_0 = 800\text{ Hz}$. Draw the power spectrum of *y(t)* on a linear scale.

White Noise:

- Plot the autocorrelation and average power spectrum on a linear scale, of a white noise signal.
- You smooth this signal with a Gaussian kernel with a full width at half maximum of 50 ms. Plot the autocorrelation of the smoothed noise. Plot the average power spectrum of the smoothed noise on a linear scale. Make sure to correctly label your time and frequency axes with appropriate numerical scales.
- State how the autocorrelation is related to the power spectrum of a given signal.

Filtering:

Plot the kernel *g(t)* in the time domain, and the filter $\tilde{G}(f)$ in the frequency domain, for low-pass, high-pass and band-pass filters. Explain why they work.

Signal Processing:

- Calculate the ratio of power and amplitude between two signals given their power in decibels units (dB).
- Explain the significance of the Nyquist frequency.
- Calculate the number of statistically independent estimates you can extract from a signal for a given signal duration (T) and desired frequency resolution (bandwidth, 2W).
- Explain what a spectrogram is and how it is computed.
- Explain the trade-off between frequency and temporal resolution when doing spectral analysis.
- Explain the uses of zero-padding when doing spectral analysis.

Exercise:

You are considering buying a system for presenting auditory stimuli for your lab and you are comparing two options: the first choice has a maximum power of 80 dB, the second option has a maximum power of 120 dB. By what factor in acoustic power is the second system louder than the first one?