

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.
-

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 = # of counts

n = expected # 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:

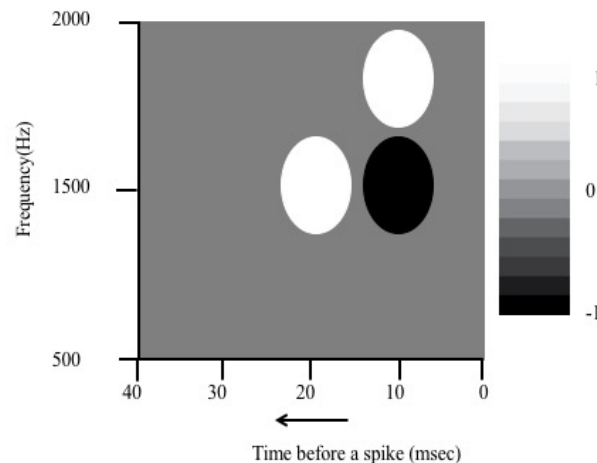
- 1 spike within a time window of 50 msec?
- 2 spikes within a time window of 5 msec?

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:



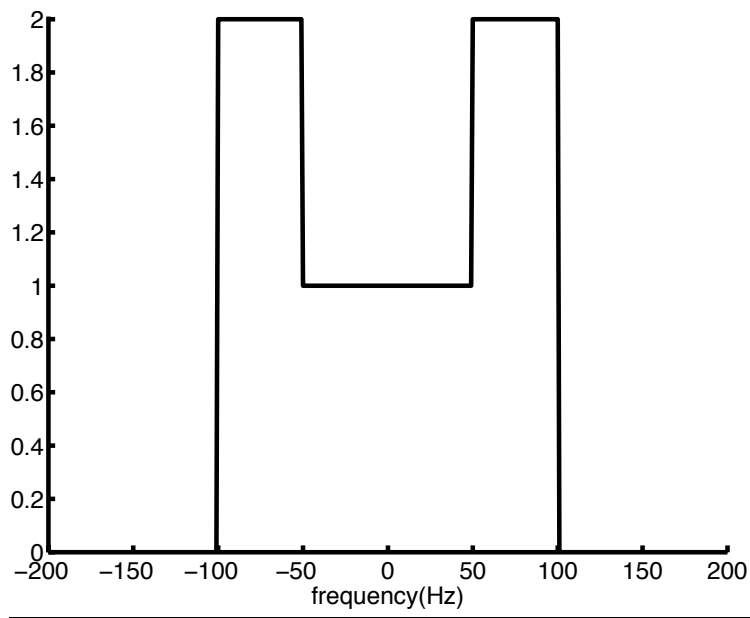
- Describe a stimulus that would excite this cell maximally.
- Describe two stimuli that will excite this cell with responses below the maximum.
- Describe three stimuli, different than playing no sound, that will not elicit spiking activity for this cell.

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 $y(t) = x(t) \sin(2\pi f_0 t)$, $f_0 = 800$ 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?