

Instructions. Solve the following two exercises.

1 Integration of synaptic inputs by a leaky integrate and fire neuron

a. Implement the Matlab code for two alpha-function conductances representing AMPA and GABA synapses, respectively. Use the following parameter values:

1. Peak activation time: 1 msec (AMPA) and 7 msec (GABA).
2. Peak conductance: 1nS (AMPA) and 4 nS (GABA).
3. Reversal potential: 0mV (AMPA) and -70 mV (GABA).

Plot the time-course of each of these conductances, $g_{syn\ ex}$ and $g_{syn\ in}$.

Hints. The alpha function decays to less than 1 percent of its peak value within $8t_{peak}$. You therefore need only consider this interval of time.

b. Generate a 1 second sequence of excitatory synaptic conductance activation to be fed to the LIF neuron that you constructed during the previous exercise series. Assume $n_{syn} = 1000$ independent excitatory synapses activated at the same rate ρ_{syn} following a Poisson distribution. Plot the conductance activation for ρ_{syn} equal to 5.5, 6.5, 7.5 and 8.5 activations/sec.

Hints. Since the synapses are assumed to be independent, we can replace them by a single Poisson synapse activated at a rate $n_{syn} \cdot \rho_{syn}$. Generate a sequence of zeros and ones (sampled at 0.01 msec resolution with ones corresponding to an activation) as an homogeneous Poisson process, by using the `exprnd` function. If this sequence is called syn_{vect} , you can obtain the corresponding synaptic conductance activation by using the Matlab `conv` function, where the second parameter is set to the unitary synaptic conductance computed above ($g_{syn\ ex}$). Note that `conv` will generate a vector longer than your original 1 sec long syn_{vect} sequence. Truncate its tail to the appropriate length.

c. Feed this input to your LIF model for a 1sec long simulation. Compute the mean ISI and coefficient of variation of the ISI. Change the single synapse activation rate between 5.5 and 7.5 activations/sec in steps of 0.5 and plot the CV as a function of the mean ISI.

Hint. Modify your LIF model so that it accepts a synaptic conductance vector instead of a constant current as input. The corresponding current is then computed from the conductance and membrane potential at each time step as explained in the lecture notes. To make sure that your modified LIF model is working, compare its steady state potential output to the exact solution given in the lecture notes for a constant synaptic conductance.

d. Repeat in the case where 100 inhibitory conductances are also activated independently according to a Poisson process with constant rate of 1 activation/sec. Vary the range of excitatory synapses activation between 6 and 8 activations/sec in steps of 0.5. Compare the CV obtained in this case with the CV obtained when excitation is present alone.

Hint. In both c and d, your excitatory inputs should generate mean interspike intervals between 40 and 140 ms, approximately. In d, for the lowest excitatory input rate, the inhibitory conductance averaged over time should be about half the excitatory conductance, averaged over time.

e. Read the Shadlen and Newsome paper given on the Lecture web site. Answer the following questions:

1. How many inputs (typical range) do you expect a cortical neuron to receive?
2. How many of those do you expect to be inhibitory?
3. How many of those inputs are expected to come from neurons within a radius of 200 μm of the target cell?
4. Why would you expect neurons within a 100 μm radius of the target cell to respond to similar stimuli?
5. What is the typical impact of a single EPSP on the membrane potential of a cortical cell (i.e., typical depolarization as a percentage of action potential threshold)?

6. What are the arguments in favor of inhibitory inputs playing a relatively important role in determining the subthreshold behavior of the target cell (3 arguments)?

2 Retinal Ganglion Cell Receptive field

The contrast sensitivity function depicted in Fig. 15.4 belongs to an RGC neuron whose spatial receptive field is described by the following parameters: $r_c = 0.24$ deg, $r_s = 0.96$ deg, $k_s/k_c = 0.06$.

a. Plot the Fourier transform of the receptive field in the frequency domain using eq. 15.10. Scale the Fourier transform so as to have a peak value of 50, as in figure 15.4, left.

Hints. Use $\Delta f = 0.01$ cycles/deg in the frequency domain. Use the `loglog` function to plot in double logarithmic coordinates.

b. Plot the corresponding spatial receptive field using eq. 15.8 of the lecture notes and the scaling factor determined in a.

Hints. Use $\Delta x = 0.006$ deg in the space domain, $N = 2048$ points ($N/2 - 1$ negative spatial positions, $x = 0$ and $N/2$ positive spatial positions).

c. Fast Fourier transform the spatial receptive field and verify that it matches the theoretical result by plotting them together.

Hints. This is essentially similar to the exercise on the Fourier transform of the LIF, except for one additional complication: the function values at negative positions ($x < 0$) should be placed appropriately in *wrap-around order*. Let f_{-1} the value of $f(x)$ at the first negative spatial position ($x = -\Delta x$). Since the FFT assumes that f is periodic, we actually have $f_{-1} = f_{N-1}$ and similarly $f_{-2} = f_{N-2}$, etc... until $f_{-N/2+1} = f_{N/2+1}$. Rewrite first the spatial receptive field in this order (illustrate by a plot) and then Fourier transform. Plot the real part only to avoid small imaginary parts introduced by the finite precision of the calculation. Why can you ignore the imaginary part? Plot positive frequencies only.

d. Generate 3 1-dimensional cosine gratings (maximal contrast ± 1) with spatial frequencies $f_x = 0.1, 1, 2$ cycles/deg drifting across the receptive field

for 1000 msec (sampled at 1 msec resolution) at a temporal frequency $f_t = 3$ cycles/sec. Plot the drifting grating (contrast vs. position) at various times over the receptive field and show that it is moving in the right direction. Compute numerically the response of the LGN cell to the drifting grating from the spatial receptive field. Plot the time-varying firing rate and verify that the maximal amplitude modulation matches the theoretical prediction obtained from the Fourier transform of the receptive field obtained in **a**. What is the translation speed of the three gratings?

Hints. Generate the moving gratings by filling an array of 1000x2048 points (the first dimension is time and the second dimension is space). Use the MATLAB matrix multiplication to compute the response of the LGN cell.