520.735 Sensory Information Processing
Homework 2

Due date: April 2 2004

I. Integrate-and-fire model neuron

The following exercises are meant to help you develop an understanding of the integrate-and-fire model. Many questions are open ended - they are meant to provoke thought, not necessarily to evoke a closed-form answer.

1. Integrate-and-fire model neuron: Set up an integrate and fire model neuron with the following parameters: $\tau_m = 10$ ms, $R_m = 10\ M\Omega$, $V_{rest} = -70\ mV$, $V_\theta = -54\ mV$. When the membrane potential reaches V_θ, make the neuron fire a spike, and reset the potential to $V_{reset} = -80\ mV$. Choose a reasonable current $I(t)$, and observe the spikes produced in response to a 300 ms current pulse (What happens if you increase the duration?) The equation governing the sub-threshold activity is:

$$\tau_m \frac{dV}{dt} = V_{rest} - V + R_m I(t) \tag{1}$$

2. Compute the minimum current required to reach threshold.

3. Determine the firing rates of the model neuron for different magnitudes of the constant current I, and produce a firing rate versus current plot (called the f-I plot).

4. Add a constant voltage noise to the model. Plot the interspike interval distributions for a constant input current, for different values of voltage noise. Play around with different types of inputs, and see whether you can obtain a "poisson-like" (i.e., exponential) inter-spike interval distribution.

II. Reverse correlation

Setup a simple linear neuron model. Assume that the stimulus $\mathbf{S}$ is M dimensional and consists of n samples in time. Let the neuron's transfer function be $\mathbf{b}(i)$, $i = 1, 2, ..., N_d$ be the N_d "slices" of the spatiotemporal receptive field. Thus the response can be written in matrix form as (note that we can only compute the response from time N_d onwards)

$$\begin{bmatrix} r(N_d) \\ r(N_d+1) \\ .. \\ .. \\ r(N) \end{bmatrix} = \begin{pmatrix} \mathbf{S}^T(N_d) & \mathbf{S}^T(N_d-1) & ... & \mathbf{S}^T(1) \\ \mathbf{S}^T(N_d+1) & \mathbf{S}^T(N_d) & ... & \mathbf{S}^T(2) \\ .. & .. & ... & .. \\ \mathbf{S}^T(N) & \mathbf{S}^T(N-1) & ... & \mathbf{S}^T(N-N_d+1) \end{pmatrix} \begin{pmatrix} \mathbf{b}_1 \\ \mathbf{b}_2 \\ .. \\ ... \\ \mathbf{b}_{N_d} \end{pmatrix}$$

$$\mathbf{r} = \mathbf{X}\mathbf{b} \tag{2}$$

1. Generate a white noise stimulus with zero mean and unit variance using the `randn` function in Matlab. Use this to produce a response $\mathbf{r}$ from a sample RF (choose your own b). If the stimulus is specified in μm and response is in spikes per second (i.e., Hz), what are the units of the RF? Use $M = 2$, $n = 10000$ and $N_d = 5$. [In the somatosensory experiments we have $M = 400$, $n = 100000$ and $N_d = 50$.]

2. Using this response r, compute the reverse correlation estimate $X^T\mathbf{r}$. Then compute the least-squares estimate $(X^TX)^{-1}X^T\mathbf{r}$. Compare these values with the original RF values.

3. What causes the "error" in the reverse correlation estimate? Where does the noise come from? Check what happens when you increase or decrease n, the length of the stimulus.