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9.35 Sensation And Perception
Spring 2009

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Problem Set #1: 100 Points

Please turn in all results and source code in a single document (hint: try the ‘publish’ functions in Matlab), preferably a PDF or hard copy. Please document your source code appropriately. Submissions may be made online, to the TA’s. Be sure to label all figures appropriately. Collaboration is encouraged, but each student must turn in a unique report.

1. Light from a bright star falls on the receptive field of an ON midget retinal ganglion cell.

1.a) Describe, in two or three sentences, the steps and circuitry involved in transducing the light from the star into an electrical potential on the RGC. (15 Points)

1.b) Sometimes the light will hit only the center of the receptive field, sometimes it will hit only the surround, and sometimes it will hit both. For each case, compared to when no star is in the receptive field, is the RGC more or less likely to create an action potential? Why? (15 Points)

2. As an ON midget retinal ganglion cell, you do not see the star itself, but only ‘see’ input from upstream neurons. Each processing step between the physical light and the final input introduces noise. Thus, your center and surround inputs are noisy. Let’s say that this noise is Gaussian.

2.a) We can simulate the center and surround inputs to this RGC by drawing two vectors of 1000 samples each from a normal distribution, using the syntax `randn(1000, 1)`. By default this returns Gaussian noise with mean 0 and variance 1. Name these vectors Ci_n and Si_n . These are random samples from the center and surround inputs in the absence of any signal (that is, just noise). Let each sample represent the total input to the RGC on a single trial, so that $Ci_n(i)$ and $Si_n(i)$ can be used as inputs from the same trial.

Now, create two more vectors representing the center and surround inputs if the starlight were to fall exclusively in that subregion of the receptive field. Assume that the signal increases the input by a mean of 4 from baseline – so, simply add 4 to two *new* vectors drawn from `randn`. Call these vectors Ci_s and Si_s .

Plot and label the distribution of input magnitudes from all four vectors over the range $[-10, 10]$ in the *same figure* (use syntax like `distr_Ci_s = hist(Ci_s, linspace(-10, 10))`), and functions like `plot`, `hold`, and `xlim`). (5 Points)

2.b) An RGC soma does not know whether input is coming from the center or the surround, but only its final membrane potential. What simple, arithmetic rule does an ON midget RGC use to combine center and surround input? Use this rule to combine

your input vectors above into four new vectors, representing the final RGC membrane potential response under each input condition:

- 1) V_n in the absence of any signal (using Ci_n and Si_n)
- 2) V_c for signal in the center, but noise in surround (Ci_s and Si_n)
- 3) V_s for signal in the surround, but noise in the center (Si_s and Ci_n), and
- 4) V_b for signal in both the center and surround (Ci_s and Si_s).

Each of these vectors should still be 1000 random samples representing the response for 1000 different trials.

Create a second figure plotting the histograms of each of these vectors. Provide a legend to indicate which ‘bump’ corresponds to which condition. (15 Points)

2.c) This RGC will fire an action potential whenever its membrane potential exceeds some threshold. An action potential counts as a ‘hit’ when it is caused by a signal in the center and not in the surround. An action potential in any other condition is a ‘false-alarm.’

Considering the four vectors in 2.b, if the threshold for this RGC were 3, how many hits (of the possible 1000) would this cell get? How many ‘false alarms’ (of the possible 3000)? (Hint: try using logical operators like ‘>’, and ‘sum’) (5 Points)

2.d) Define a vector of 100 different threshold levels in the range [-5, 5] (e.g., $thr = \text{linspace}(-5, 5)$). Use a ‘for’ loop to repeat the computation in 2.c for each threshold value in your vector. In other words, for each threshold value, count the number of hits and false alarms your cell would make given the four ‘membrane potential’ vectors you created above.

Plot the number of hits (y axis) as a function of the number of false alarms (x axis). Each data point will correspond to a particular threshold value. This is an ROC curve. (20 Points)

2.e) If the input to this cell was much more noisy, what would the curve look like? If the input to this cell was not noisy at all, what would the ROC curve look like? Sensitivity is limited by noise. With this in mind, in general, what is the relationship between the ROC curve and the sensitivity of the cell? (10 Points)

2.f) Let’s pretend that your grade on this assignment depends on how well this RGC can detect starlight. You get 1 point for every 10 hits the cell makes and lose one point for every 30 false alarms. Write a simple equation that describes your grade as a function of the cell’s threshold using the hits and false alarms counted in 2.d. Plot this ‘reward’ function, and find the threshold that gives you the best grade. Where is this point on the ROC curve? Where is it on the histogram in 2.b? What grade do you deserve? (15 Points)