BCS304 Theoretical Neuroscience Spring 2025

Homework set #3: Due 5/12(Mon), 6:00 PM

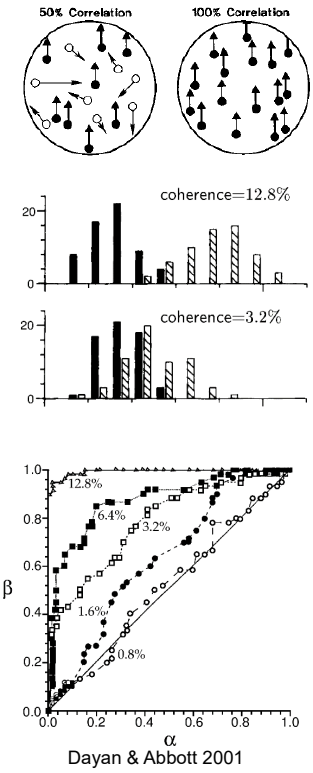
Please prepare your report as outlined below and send it to: **bcs304ta@gmail.com**

- Summarize your results, including discussions and comments for each question, in a PDF file. Name the file as: **"HW#_answer.pdf"**.
- Zip all the MATLAB® codes and text files into one compressed folder, named as: **"HW#_YourSID_YourName.zip"**.
- For each problem, clearly indicate which file to run by naming them as: **"Prob1a.m"**, **"Prob1b.m"**, etc. You may also include as many sub-function files as necessary.
- Failure to follow these instructions may result in a penalty.

Comments: In this problem set, detailed instructions are not provided, as it mirrors your own research. You'll need to use your reasoning and hypothesis to determine the necessary steps. Be as specific as possible in your explanations. Successfully demonstrating this may earn you extra points, regardless of the outcome.

Problem 1

The activity of a neuron in MT is selective to the direction of stimulus motion, such as upward(+) or downward(-) movement. The neuron's firing rate is modeled as a Gaussian distribution, characterized by parameters (μ_+, σ_+) and (μ_-, σ_-) in Hz, where μ_x and σ_x represent the mean and standard deviation of the firing rate in response to stimulus direction x.



Dayan & Abbott 2001

a. For an "easy" task (i.e. with high stimulus motion coherence), the neural response is selective, with (μ_+, σ_+) = (30, 3) and (μ_-, σ_-) = (10, 3). Model this condition and simulate the neuron's response across 100 trials, assuming a equal probability for upward and downward motion stimuli. Plot the histogram of firing rates as shown in the figure.

b. Implement a simple decision-making model that mimics a go (for +) / no-go (for -) task. Set a threshold z = 20Hz for decoding the stimulus direction. Using the data from part **a**, estimate the "hit rate" β and "false alarm rate" α, as discussed in the lecture. Report your estimates for α, β and the probability of correct answer p = (β+1- α)/2.

c. Gradually decrease the threshold z from the value used in **b** and describe in detail how α and β change. Discuss why a high hit rate may not guarantee a high correct rate. Using the profile of the Gaussian distribution, qualitatively explain how β-α decreases as the threshold shifts below the optimal value.

d. Repeat the process in part **a**, but only for 10 trials. Using this data, calculate the probability of correct answer for each value of varying threshold z=[0:3:45]. Plot your ROC curve as shown.

e. Determine the optimal threshold z based on the result in **d**. Discuss potential issues with estimating the optimal value of z using only a small number of trials. Propose a strategy to determine the minimum number of experimental observations required to ensure a reliable result.

f. Implement models for the “hard” and “moderate” task conditions, using the parameters: $(\mu_+, \sigma_+) = (20, 5)$ and $(\mu_-, \sigma_-) = (18, 5)$ and $(\mu_+, \sigma_+) = (26, 4)$ and $(\mu_-, \sigma_-) = (15, 4)$, respectively. Follow the same analysis steps as in previous parts to generate and plot the ROC curves of all three conditions (easy, moderate, and hard) together. Estimate the optimal value of z and the decoding accuracy for each case.