BCS304 Theoretical Neuroscience Fall 2023

Midterm Exam: Due 10/22(Sun), 6:00 PM

Prepare your report as below and send it to: bcs304ta@gmail.com

- **Summarize your results including discussion and comments for each question, as a pdf file. Name it as "HW#_answer.pdf".**
- **Zip all the Matlab® codes and texts in one file**, 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 can use as many other sub-function files as you want.
- If you don't follow this direction you might get a penalty.

Comments In this problem set, detailed information is not given as it is in your research, often you need to decide what to do and what not to do based on your own reasoning and hypothesis. Thus, please provide explanations as specific as possible. You may get some extra points from demonstrating this successfully, regardless of whether it is true or not.

Problem 1

Build a Poisson spike generator, using the Poisson point process model (Δt=1ms).

a. Generate a spike train of a constant firing rate r = 10Hz for T = 0.1s for N = 100 trials. Calculate the average firing rate (μ) and the standard deviation (σ) in Hz.

b. Try the same estimation while you increase the length of spike trains for T = [0.1:0.1:1]s (Repeat the process for N = 100 for each T). Estimate the Fano factor for each T.

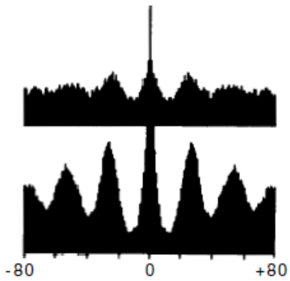
c. Repeat the process in **b** for a constant firing rate r = 100Hz. Discuss differences regarding the condition for reliable estimation of μ, σ, and the Fano factor.

d. Suppose that you need to estimate the average firing rate of spike trains achieved from an animal experiment. Discuss your strategy to decide the condition of the minimum length of spike trains and the number of trials you need, for two different average firing rates above.

Now build a different type of Poisson spike generator using the statistics of inter-spike-interval.

e. Repeat the spike generation process in **a**, and compare two results. Compare your "computation time" for achieving results in **a** and **e** (You can use Matlab functions *tic* and *toc*).

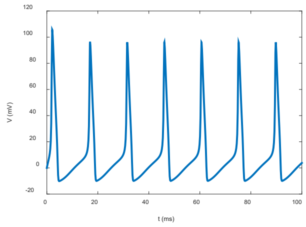
f. Generate a spike train of a constant firing rate r = 100Hz (You can generate a long spike train as needed). Calculate and show the autocorrelation of spikes as shown. Does the profile of the autocorrelogram look like what you expected?



Dayan and Abbott 2001

g. Try the same process in **f**, for a time varying firing rate r(t), as a cosine function of 0.1s period with 100Hz average and 150Hz peak firing rates. Discuss different patterns of spikes synchrony observed from the autocorrelograms in **f** and **g**.

Problem 2



Implement a Hodgkin-Huxley model neuron. You can choose any arbitrary value of membrane potential as long as it is properly scaled and normalized.

a. With a proper choice of model parameters, show that your neuron fires as shown in the figure for injected current of I = 10μA/cm^2 without any background noise.

b. Under this condition, estimate and plot the response function of this neuron (i.e. constant current injected vs. firing rate in Hz). Choose a proper range of the input current to find the "threshold" and "saturation" of the response function. Show how your threshold is estimated.

c. Now implement a time-varying current input as a sinusoidal function $\mathrm{I(t)} = A\sin(Bt) + C$. Find the values of constants A, B and C to achieve the input condition such that the period is 2s, the minimum input current is the threshold in **b**, and the maximum input current 10μA/cm^2.

d. Under this condition, plot the input current and the membrane potential of the neuron for t = [0, 2]s. Estimate each spike timings and plot this digitized spike train to compare with the continuous membrane potential above.

e. Apply an appropriate filter to the spike train in **d** and plot the instantaneous firing rate estimated. Can you predict the profile of input current, only using this firing rate?

f. Now choose a different value of the constant B so that the new period of input current becomes 0.2s. Repeat the process in **d** and **e**. Discuss your strategy to make a reliable estimation of rapidly-varying input profile, only using a spike train observed.

g. Plot the histogram of inter-spike-interval (ISI) using the spike trains in **c** and **f**. What is the minimum value you can observe in each condition? Discuss the refractory periods in the two conditions.

Problem 3 (Questions for questions)

Design a sub-question that can be added in Problem 1 or 2 and specify in which place you put it in. Provide your sample answer to the question, and explain what important issue can be discussed in the question.