Homework 4

Instructions:

- Due Sunday Oct 18 end of day.
- You may communicate with each other about the course material, but collaborating on homework assignments is not allowed. NYU's Academic Integrity Policies, as referenced in the syllabus, apply.
- Please submit your written answers and plots as a single, typed PDF, and attach your code as a single separate file. When I ask for a single numerical answer, give it in the PDF document. Do not put any matrices or code in the PDF document.
- When I ask you to explain something, don't write too much. Usually, your explanation can stay under 50 words. Explanations go into your PDF, not into the code.
- Comments in your code are optional. They are mainly to help yourself. I will not review them.
- Please make sure that your code runs as is; I will deduct points if I have to debug your code to make it work.
- Make plots look good. Besides axis labels (mandatory) and a legend (if necessary), I recommend thicker-than-default axes and lines, larger-than-default font size, `box off`, and no unnecessary color. Use your sense of aesthetics. If you don't know how to do something, just Google it.
- For editing equations, I recommend LaTeX, a typesetting software that displays equations beautifully. Many free LaTeX editors are available, e.g. TeXShop. There is a bit of a learning curve. Alternatively, Equation Editor for Word (comes built in) or MathType for Word (if you happen to have this) is also fine.

Good luck!

In this homework, we will compare different decoding methods on simulated population patterns of activity. We consider any real-valued stimulus variable s (such as position on a horizontal line). We assume a population of 51 neurons with Gaussian tuning curves

$$f_i(s) = g\, e^{-\frac{\left(s-s_i^{\text{pref}}\right)^2}{2\sigma_{\text{tc}}^2}} + b, \tag{1}$$

with $g = 0.5$, $b = 0.1$, $\sigma_{\text{tc}} = 5$, and the preferred stimuli s_i^{pref} linearly spaced between -20 and 20 (use `linspace`).

a) Plot these tuning curves. Follow the plotting guidelines in the instructions.

b) A stimulus $s = 0$ is presented to this population. Assume that the neurons are conditionally independent and Poisson. Using `poissrnd`, generate 1000 population patterns of activity. Suppress the output, since this is a lot of numbers.

c) For each pattern of activity, apply the winner-take-all decoder, the center-of-mass decoder, and the maximum-likelihood decoder. Save the result into one array for each decoder, so three arrays of length 1000 in total.

d) For each of the three decoders, estimate the bias and the variance of the decoder from the 1000 numbers. Give the numerical output (3×2 numbers) in your text file.

e) Repeat parts (b)-(d) for different true stimuli, namely from -5 in steps of 0.5 to 5. No need for numerical output (it would be too much).

f) In a single plot, plot bias as a function of the true stimulus for each of the three decoders (use three colors).

g) In a second single plot, plot variance as a function of the true stimulus for each of the three decoders (use the same three colors).

h) Interpret your results: How do the decoders compare? Which one is best according to your plots, and which one is worst? Explain why that one would be worst. Write a total of 100-150 words.

i) Why did I ask you to go from -5 to 5 in part (e), and not for example from -20 to 20? What would happen if you were to go too far from the central stimulus value ($s = 0$), and why?

j) (Extra credit:) Suppose s had been a circular variable such as motion direction, instead of real-valued variable. Then parts of this homework would have to be modified. Which parts and how? You will need to do some independent research for this. I'm only looking for the modified questions - you don't actually need to do those questions. Write your new questions in a way that is detailed enough that a student in our class can understand them (e.g. don't introduce an unfamiliar term without explanation).