Project 4: Bayesian inference with population codes

1) Implement a population code for line orientation with a cosine tuning function, $f_d(s) = \phi(s)\exp[\cos(s - s_d^*)/\nu]$, where s is the line orientation, s_d^* is the preferred stimulus of neuron d, ν is the tuning width (fixed across the population), and $\phi(s)$ is the contrast (stimulus strength). Assume that spikes for each neuron are generated by a Poisson process (independent across neurons in the population) with rate given by the tuning function. Illustrate the behavior of this population using spike rasters and peristimulus-time histograms.

2) Construct a Bayesian decoder, $p(s|x) \propto p(s) \prod_d p(x_d|s)$, where x is the vector of spike counts for each neuron, $p(x_d|s) = Poisson(x_d; f_d(s))$, and $p(s)$ is the prior. Assume a uniform prior and illustrate how the posterior $p(s|x)$ changes with the choice of preferred orientations and tuning width. Based on the assumption that tuning width increases with stimulus distance (eccentricity) from the fovea, what happens to orientation discrimination for foveal vs. peripheral stimuli? To make predictions about discrimination tasks, assume that what matters is the relative posterior probability of the two orientations being discriminated. Discuss the model simulations in relation to experimental data on eccentricity-dependence of orientation discrimination (Paradiso & Carney, 1988; ignore the nasal/temporal asymmetry for present purposes).

3) How does changing the contrast affect both the population code and the posterior? Discuss the model simulations in relation to experimental data (Skottun et al., 1987).

References:

Paradiso, M. A., & Carney, T. (1988). Orientation discrimination as a function of stimulus eccentricity and size: Nasal/temporal retinal asymmetry. *Vision Research, 28*, 867-874.

Skottun, B. C., Bradley, A., Sclar, G., Ohzawa, I., & Freeman, R. D. (1987). The effects of contrast on visual orientation and spatial frequency discrimination: a comparison of single cells and behavior. *Journal of Neurophysiology, 57*, 773-786.