Theoretical and Computational Neuroscience 2018

Problem Set 5: Direction and Coherence Sensitivity in Area MT

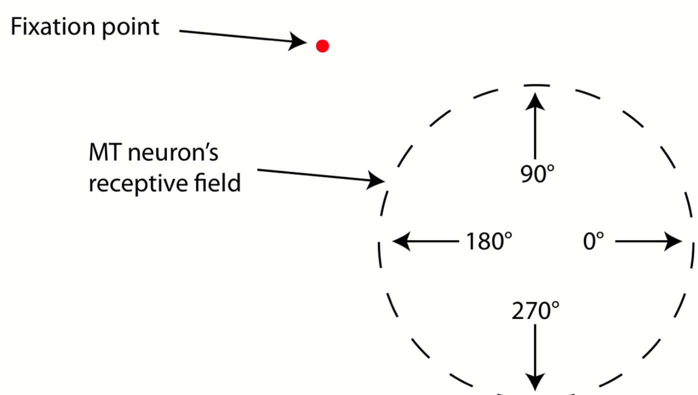
Due date: Thursday, March 22, 2018

1 Introduction

In this homework set we are going to analyze data recorded from a monkey (kindly provided by Prof. Joshua Gold, Neuroscience Department, University of Pennsylvania). The single-cell recordings are done in the visual area MT (medial temporal), an area that is known to be sensitive to coherent large-field motion. Single cells can be found that are tuned to a certain direction of motion. These cells are sensitive to a large visual field and respond even if the motion is not completely coherent. We will assume that, in an experimental setting, the monkey uses these cells to make decisions based on the motion direction. The monkey is tested on its ability to identify the direction of motion of a stimulus. We will extract the neurometric and psychometric data from this experiment to see if a single neuron contains enough information to let the monkey make this decision.

2 The Data

The data file `HW5_data.mat` contains a cell array called `cellArrayOfCells` with data from 5 individual MT cells. Recordings were made while the monkey was awake and fixating on a central spot, while a random-dot stimulus was shown in the neuron's receptive field. The stimulus consisted of motion at a fixed speed in one of several possible directions and one of several possible coherences (the percentage of dots moving in the given direction), as shown:



Rows of the cell array correspond to individual cells. The first column includes data to be used in problem 1 (direction tuning). The second column includes data to be used in problem 2 (coherence dependence).

Each entry of the cell array `cellArrayOfCells` is a structure with the following fields:

`header`:		Information about the recording session (e.g. date)
`ecodes`:		Another structure, with two fields:
`ecodes.name`:		Labels for the columns in `ecodes.data`
`ecodes.data`:		The data. Rows are trials. Columns are:
	dot_on:	Onset time of motion stimulus (msec, relative to fixation onset)
	dot_off:	Offset time of motion stimulus (msec, relative to fixation onset)
	dot_dir:	Motion direction, in degrees
	dot_coh:	Motion coherence (percent)
	task:	Code for the task the monkey is doing (not important for us)
	correct:	0=error, 1=correct
`spikes`:		Cell array of spike data. Rows are trials. Each cell is an array of spike times (msec, relative to fixation onset).

3 Direction Tuning

Problem 1:

Determine the direction tuning of the five cells, using the data from the first column.

(**a**) Compute and plot (in polar coordinates, MATLAB command: `polar`) the mean spike rates measured during stimulus presentation as a function of motion direction. For each trial, compute the spike rate over the entire motion-viewing interval. The mean spike rate should be measured across all trials with the same motion direction. Do not forget to normalize by the total viewing time for each direction. Produce separate plots for each cell.

(**b**) Fit the relationship between mean spike rate M and motion direction θ using a von Mises function:

$$M(\theta) = A \exp\Big(k\,[\cos(\theta - \phi) - 1]\,\Big) \tag{1}$$

A is the value of the function at the preferred orientation ϕ, and k is a width parameter. Plot the original data and the tuning curves for all cells. Report the preferred direction for all cells.

To do the fitting you will need the `Curve Fitting Toolbox` of MATLAB. For our purposes there is also a free fitting toolbox for one-dimensional fits available on the internet called `EzyFit`:

http://www.fast.u-psud.fr/ezyfit/

This toolbox is very comfortable and easy to use (maybe even easier than the `Curve Fitting Toolbox`). It integrates itself into the menu of figures such that custom fits can be done on the fly. Adding this toolbox to MATLAB is very easy and is described on the webpage. You essentially have to download the files and add the folder to the MATLAB path (MATLAB → File → Set Path...). After running the demonstration (MATLAB → Start → Toolboxes → EzyFit → Plot Sample), you should get an extra menu entry called `EzyFit` in every new figure. From there you can access the fitting tools graphically. The toolbox also contains a help file.

(**c**) **(Extra Credit)** How does the direction tuning in the first 200 ms of the response compare to the tuning later in the response?

4 Coherence Dependence

Problem 2:

Use an ROC-based ideal-observer analysis (Dayan and Abbott pages 89 - 95) to compute a neurometric function for each neuron, using data from the second column of `cellArrayOfCells`. This data is from the same cells as the data from the first column, but now mainly two different motion directions are displayed for each cell: the preferred direction and the opposite (null) direction. At the same time, the monkey is now performing a task which will indicate if it recognizes the direction correctly. The directions used are:

cell	preferred direction	opposite direction
1	180	0
2	315	135
3	180	0
4	180	0
5	200	20

(**a**) Compute ROC curves (one for each cell during presentation of each coherence level) based on firing rates corresponding to motion in the preferred and opposite directions. For each cell, plot the ROC curves for all the different coherences in one graph, as in figure 3.3 in the textbook. Make a separate graph for each cell, and find the area under each ROC curve. A routine `rocN.m` to compute ROC curves and the ROC area can be downloaded from Blackboard. A short description of the routine is given at the beginning of the file.

(**b**) Fit the neurometric function (probability correct p, computed as the ROC area, versus coherence c, see Dayan and Abbott, figure 3.2) with a cumulative Weibull function of the form

$$p(c) = 1 - 0.5\exp(-(c/\alpha)^{\beta}), \tag{2}$$

with free parameters α and β. To make it easier for the fitting algorithm to converge, divide the given c by 100 to get a value between zero and one (not a percent value as given in the data). Plot the data and the fits.

(**c**) Fit the behavioral data (percent correct versus coherence) with cumulative Weibull functions and plot them.

(**d**) **(Extra Credit)** How do the neurometric and psychometric functions change when considering only short- or long-duration trials? Choose a threshold for what you want to call short- or long-duration trials because the speed of the monkey's response is a continuous distribution.

5 Group Project

Do the literature search and background reading for your project. Write a two page project proposal describing the idea in detail and including a preliminary bibliography. Be concrete about exactly what you plan to do. One proposal is sufficient for each group.

Turning in the homework: Please upload the following files to the Canvas Assignment Homework 5:

1) Your legible and commented code. If you have multiple files (for example, for different problems), please indicate which can be run to reproduce the output for each problem in file name. Please be sure that your code runs! If it does not, it partial credit may not be awarded for incorrect outputs.

2) A word document containing your answers to each question, with your MATLAB output figures embedded where necessary. Please include a caption accompanying each figure describing the relevant content. Be sure to label your axes, and make sure all relevant dynamics are clearly visible in the figures you make. Legibility is key!

Turn in the Group Project portion of the assignment to Canvas Assignment Homework 5 - Group Project. Please be sure to list all members of your group. Only one submission per group is necessary (but make sure someone does it)!