CISC 3250: Systems Neuroscience
Homework 4
due April 12

1. If it is attached to the right layer 3 “neurons,” a single neuron in layer 4 of HMAX will be able to detect the letter “A” centered at various locations in the visual field, and also the letter “A” rotated at different angles. (This neuron will remain silent – output 0 – when pictures of other letters are shown at any rotation.)

   a) What is the operation/computation performed on the inputs to this neuron? (For example, is it a weighted sum?)

   b) Describe the types of features (visual information) being represented by the layer 3 neurons that serve as input to this layer 4 neuron. (For example, would you expect each layer 3 neuron to represent a single edge centered at a single location?)

2. Identify what patterns – e.g., the pattern in picture a or the pattern in picture d – activate the following model neurons, given the specified inputs and the specified HMAX-inspired computation. Note, each input will be 1 if the depicted feature is seen and 0 if the feature is not seen. For this question, the neuron is considered “activated” if it’s output is 0.85 or higher.

Here as an example problem, with answers at the bottom right:

Which activate the neuron?

(a) Produces response 0.2+0.2=0.4 – not above 0.85 activation

(b) Produces response 0.7+0.7=1.4 – above 0.85 activation
3. Below (next page) are three spectrograms (time-frequency plots) for three spoken-word recordings, with the corresponding word recorded above each spectrogram. Unlike the other two words, the word “clock” contains an additional 500ms of background noise at the end.

For each vowel in each word answer the following questions:

a. What is the time interval during which the vowel is spoken?
   ("trees" has one vowel sound “ee”; “clock” has one vowel sound “ah”; “neuro” has two vowel sounds “oo” and “oh”)

b. What are the frequencies for formant 1 and formant 2? (Note the formant 1, “F1”, is between 400 and 1200 Hz. Review the extra slide I posted online for lecture 5.)

c. Identify one example of a frequency glide for one of the words provided.
d. The word “clock” was recorded while a lawn-mower was running in the background. Using the Sigma-Pi Node attention implementation, suggest an assignment of weights $a$ to decrease the influence of the lawnmower.

4. We hear a dog start to bark. The barking reaches the right ear at time $t_1$ and the left ear at time $t_2$, defined in each example below. For each example, compute the angular location of the dog.

   a. $t_1=7.02\text{ms}$ $t_2=6.85\text{ms}$
   b. $t_1=12.03\text{ms}$ $t_2=12.00\text{ms}$
   c. $t_1=5.62\text{ms}$ $t_2=6.01\text{ms}$

5. What are the results of the following matrix operations:

   a. \[
   \begin{bmatrix}
   2 & -1 & 5 \\
   3 & 4 & -5 \\
   \end{bmatrix}
   \begin{bmatrix}
   1 \\
   0 \\
   2 \\
   \end{bmatrix}
   =
   \]

   b. \[
   \begin{bmatrix}
   4 & 4 & 0 \\
   -2 & 0 & -5 \\
   3 & 3 & 3 \\
   \end{bmatrix}
   \begin{bmatrix}
   0 \\
   -3 \\
   -2 \\
   \end{bmatrix}
   =
   \]
6. Let us revisit the S1pic.mat data using Matlab. We have a $60 \times 5 \times 96 \times 96 \times 31$ matrix BrainMatS1 (60 pictures viewed, 5 time points of brain response, 96$\times$96$\times$31 X-Y-Z grid of the brain).

As discussed in class, an object-detecting region is in the “Lateral Occipital Cortex” (LOC). In the present data matrix, this region is around the location $x=65$, $y=77$, $z=12$.

Please note you can visualize any of these results using plot and/or imagesc. It will be educational (and a good sanity-check) for you to do so. For example, you can visualize the original brain slices of BrainMatS1 using:

```matlab
for slice=1:30
    subplot(5,6,slice),
    image(squeeze(BrainMatS1(5,3,:,:,:,slice)+1)*30)
end;
```

a. First: we are interested to identify the “hemodynamic response function” in LOC. Provide code to create a matrix `cubeTime` containing the 5-time point time-responses for the cube of voxels centered around $x,y,z=(65,77,12)$. Specifically, we want the information from voxels at $(63,73,10)$, $(67,77,14)$ and all voxels in between – this is a $5\times5\times5$ voxel cube, containing $125$ voxels in total. `cubeTime` should have the dimensions $60\times5\times5\times5\times5$ ( # images x # time points x X x Y x Z).

b. Provide code to find the average response across all voxels in `cubeTime`. Store the average response in the vector: `aveResponse`. (Note for example, the average of the two vectors $[0, 2, 2, 1, 0]$ and $[1, 2, 3, 0, 1]$ would be $[0.5, 2, 2.5, 0.5, 0.5]$.)

c. Provide code to compute the response of each voxel in `BrainMatS1` as the weighted sum of responses from the 5 time points, using `aveResponse` as the weights. Store the results in the matrix `BrainWSum`. (For example, if `BrainMatS1(10,:,20,20,15) = [0.3, 0.7, -1.2, -2.1, 0.3]` and `aveResponse = [0, 0, 1, 1, 0.5]` the weighted sum would be: $-3.15$.)

d. We would like to identify any voxels in the brain outside of LOC that respond similarly to the pictures shown during our study. Provide code to compute the correlation of the response of each voxel – e.g., `BrainWSum(:,x,y,z)` – with the LOC reference voxel `BrainWSum(:,65,77,12)`. Store the result in `BrainCorr`, a $96\times96\times31$ matrix.

e. Are there any voxels not immediately adjacent to $65\times77\times12$ that have high correlation?