CISC 3250
Systems Neuroscience
Spring 2020

Midterm

Prof. Daniel Leeds

This is a closed book exam. A four-function or scientific calculator is allowed but not required. It is useful for you to show your work for math questions.

Name: ____________________________

Date: ____________________________
1. (5 Points) Assume we have a model neuron with $v(0)=-65$, $E_L=-60$, $v_{reset}=-65$, $\tau=0.1$, and $v_{thresh}=-35$. We observe the following voltage output:

![Voltage Output Graph](image)

- **a)** Draw $R_I(t)$ given the $v(t)$ shown below. (Estimate $R_I(t)$ voltages to the nearest 5mV – if you think the input should be 37mV, you would label the input as 35mV.)

![Input Graph](image)

- **b)** How does the spiking of the simulated neuron differ from that of a real biological neuron?

  *Simulated neuron auto-reset after reaching threshold, biological neuron voltage rises even higher first.*
2. (8 Points) Presume the output of each neuron is found by computing the weighted sum of the inputs \( h \), and applying the function \( g \) shown below, i.e., \( r_{\text{out}} = g(h) \).

\[
\begin{align*}
\text{N1: 0} & \quad \text{N2: 0.5} \\
\text{OR}
\end{align*}
\]

(a) Compute the output of the two neurons above.

(b) Presume the maximum value for each of the four inputs is 3. Provide new weights for the neuron so that it is a template recognizer, where the template requires a value of at least 2.7 for inputs \( r_1, r_2, \) and \( r_4 \). (Specifically, \( r_1 > 2.7, r_2 > 2.7, r_3 > 2.7 \)) \( r_3 \) is ignored for the template. We say the neuron “recognizes” the template if its output is above 0.6 (\( r_{\text{out}} > 0.6 \)).
3. (8 points)
   a) List a function of the hippocampus.

   Memory

   b) Circle and label the following:
   (A) the superior temporal gyrus
   (B) the pre-central gyrus
   (C) the “temporal-parietal junction”
   (make an educated guess based on the vocabulary)

4. (5 Points) Below is a picture of your instructor’s brain.

   a) What type of imaging technology produces this picture?

   MRI (Magnetic Resonance Imaging)

   b) What plane of view is this slice of brain? E.g., is it coronal?

   Saggital
5. (16 Points) We have a neuron, called neuron 4, that takes input from 3 pre-synaptic neurons. We define \( h = \sum_j w_{4j} r_{4j} \) and establish the output of neuron 4, \( r_4 = \begin{cases} 0 & h < 1.2 \\ 1 & h \geq 1.2 \end{cases} \) (\( r_4 \) is 1 if \( h \geq 2 \), otherwise it is 0).

a) What sort of activation function is used by neuron 4?

Step

b) Use the Willshaw learning rule discussed in class to determine the new weights and new outputs of neuron 4 after each of the 2 learning steps below. (The inputs from each pre-synaptic neuron vary at each learning step, as depicted.)

This question was a lot easier than intended. The output was always 0, so the weights never change.
c) Now, let us presume the weights for each learning step are learned according to

Hebbian learning with \( (w) = \begin{cases} \frac{1}{1+w} & w \geq 0 \\ \frac{1}{1+w} & w < 0 \end{cases} \). There is no normalization in this question. You may estimate the weights up to 1 decimal place, e.g., .2.

This question was a lot easier than intended. The output was always 0, so the weights never change.

6. (3 Points) Presuming we implement fully distributed coding with 6 binary neurons (they each fire at 30 Hz or 100 Hz only). How many distinct concepts can be represented across these 6 neurons?

\[ 2^6 = 64 \]
7. (9 Points) Consider the following variables in Matlab:
\[ V1=\[4, 5, -10, 2, 13, 15, -10, -82, 34\]; \]
\[ V2=\[12, 12, 10, 10, -5, -8, -7, 5, 4\]; \]

a) Write a command to store the locations (indices) of the negative numbers in \( V1 \) into the variable \( \text{negIndsV1} \). (Do NOT simply write \( \text{var}=[3, 7, 8]; \))

\[ \text{negIndsV1} = \text{find}(V1<0); \]

b) Write a command to store the locations (indices) of the negative numbers in \( V2 \) into the variable \( \text{negIndsV2} \). This command should be identical to your answer to a) except for 2-4 letters/numbers.

\[ \text{negIndsV2} = \text{find}(V2<0); \]

c) Write a command to create a vector \( \text{negNums} \) that contains all the negative numbers in \( V1 \) and \( V2 \). This command must use the variables \( \text{negIndsV1} \) and \( \text{negIndsV2} \). At the end, \( \text{negNums} \) will contain \([-10, -10, -82, -5, -8, -7] \)

\[ \text{negNums} = V1(\text{negIndsV1}); \]
\[ \text{negNums}(\text{end}+[1:\text{length(negIndsV2)}])=V2(\text{negIndsV2}); \]
8. (5 Points) We discussed local inhibition as a representational mechanism in neuroscience.
   a) Using Marr’s three levels of modeling, provide an example of inhibition at the “hardware implementation” level. One sentence should be sufficient.
   **Inhibitor interneuron from Olfactory Bulb for first smell inhibits firing of mitral cell in Bulb for second smell.**

   b) Provide an example of inhibition at the “theory” level (i.e., the level of human/animal behavior). One sentence should be sufficient.
   **Alternate between seeing vase and two faces looking at each other.**

9. (3 Points) Show how the spike pattern below would need to change to be a synchronous code:
10. (7 points) At a job interview, the interviewer must determine whether the applicant possesses qualities desirable in a future employee. As the interviewer listens to the applicant’s responses, she forms an opinion of the applicant’s intelligence, confidence, and friendliness. Each quality can be marked on a scale from 0 (minimum) to 1 (maximum). A pattern of neural responses in the interviewer’s brain will reflect her opinion of the applicant. Let us say four neurons encode the interviewer’s opinion, and the table below shows the maximum response for each of the three possible qualities in the applicant.

<table>
<thead>
<tr>
<th>Neuron 1</th>
<th>50 Hz</th>
<th>- Hz</th>
<th>25 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuron 2</td>
<td>25 Hz</td>
<td>25 Hz</td>
<td>- Hz</td>
</tr>
<tr>
<td>Neuron 3</td>
<td>- Hz</td>
<td>- Hz</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Neuron 4</td>
<td>- Hz</td>
<td>25 Hz</td>
<td>25 Hz</td>
</tr>
<tr>
<td></td>
<td>Friendliness</td>
<td>Confidence</td>
<td>Intelligence</td>
</tr>
</tbody>
</table>

(a) What is the neural response for an applicant who is not very friendly (0.2), very unconfident (0), and fairly intelligent (0.6)?

N1 N2 N3 N4
25 5 30 15

(b) We find another applicant produces the neuron responses below. What are the qualities of the applicant (amount friendly, confident, intelligent)?

Neur 1: 20
Neur 2: 25
Neur 3: 40
Neur 4: 45

0 Friendly 0.8 Intelligent 1.0 Confident
11. (8 Points) Write the numbers contained by the vectors $a_1$, $a_2$, and $a_3$ after they are defined below.
(a) $a_1 = [4:2:10]$; 
\[ [4, 6, 8, 10] \]
(b) $a_2 = [8:-1:4]$; 
\[ [8, 7, 6, 5, 4] \]
(c) $\text{vec} = [3, 6, 8, 1, 4, 2]$; $a_3 = \text{vec}(4:\text{end})$; 
\[ [1, 4, 2] \]

12. (8 Points) Presume we have brain data recorded from an EEG array, where electrodes are spread on a 5x5 grid across the skull as shown to the right. Note, the first and last row only have 2 active electrodes. We record data over 10,000 ms and store the result in a matrix $\text{EEGdata}$ with size $[5, 5, 10000]$.

(a) Provide Matlab code to plot the voltage across time for the electrode at location $(x=3, y=5)$.
\[
\text{plot(squeeze(EEGdata(3,5,:)))}
\]

(b) Several of the locations in $\text{EEGdata}$ are not assigned to actual electrodes. These locations have zeros at all time points. Provide Matlab code to determine at least one electrode location that is not assigned to an electrode. Explain your answer in a sentence. (There are multiple valid ways to answer this question!!)

Use plot command from above, changing $x$ and $y$
\[
\text{plot(squeeze(EEGdata(x,y,:)))}
\]
See if all 0's
Could also use $\text{sum}(\text{EEGdata}(x,y,:))$
(c) We would like to “zero-center” the EEGdata matrix so that the activity in every electrode varies evenly around zero. For example, if the activity initially were \[2, 4, 3, 5, 8, 3, 3\] (average value in this vector is 4), the zero-centered version would be: \[-2, 0, -1, 1, 4, -1, -1\] (obtained by subtracting the average value from all the values in the original vector).

Provide Matlab code to create EEGdataZeroCent where the data at each electrode is converted to have a mean of zero.

```matlab
for x=1:5,
    for y=1:5,
        EEGdataZeroCent(x,y,:) = EEGdata(x,y,:) - mean(EEGdata(x,y,:));
    end;
end;
```

13. (2 Points) Explain how retinotopy can be modeled with lateral connectivity.

Neurons sensing information in one location in the visual field will laterally excite neurons sensing information in a neighboring location in the visual field. These neurons will be next to one another in the brain.

(In class we focused on lateral inhibition for spatially neighboring regions in the visual field; I gave credit for that as well)
14. (2 Points) Presume we would like to model the axon voltage/spiking of a neuron using the differential equation and voltage reset rule we used in class.

Let us assume the variable values for the model neuron are:

- $E_L = ??$
- $v_{\text{reset}} = E_L$
- $v_{\text{thresh}} = -40mV$
- $\tau = 1$
- $RI(t) = 25mV$ (for all time)
- $v(0ms) = -60mV$

How low does the resting state $E_L$ have to be to prevent spiking?

$E_L < -65\, \text{mv}$