Systems Bioengineering II

Exam 3

May 14th, 2014

Dr. Bastian:	20 points
Dr. Zhang:	50 points
Dr. Farrah:	10 points
Dr. Wang:	20 points
General:	45 points

Dr. Bastian:	**Q1____/10**	**Dr. Farrah:**	**Q1____/10**
	Q2____/10	**Dr. Wang:**	**Q1____/12**
Dr. Zhang:	**Q1____/6**		**Q2____/8**
	Q2____/6	**General:**	**Q1____/15**
	Q3____/10		**Q2____/15**
	Q4____/10		**Q3____/15**
	Q5____/10		
	Q6____/8	**Total:**	

You are reminded that you are under an Honor Code at Johns Hopkins. You are not permitted to use any of your own electronic equipment during the exam. All work on this exam must be entirely your own.

Print Name: ____

Signature: ____

Please write your name on every page of the exam.

Name___________________________________

Exam 3 Questions by Prof. Bastian

Question 1 (10 pts total)
Compare and contrast the medial (i.e. vermis) versus lateral cerebellum (i.e. lateral zone) in terms of anatomy (layers, cell types, deep nuclei), and output (where these parts of the cerebellum project to). Would you expect walking deficits from damage to the medial or damage to the lateral cerebellum?

Question 2 (10 pts total)
Where are the lesions in the basal ganglia that cause Parkinson's disease versus hemiballismus? Which condition causes increased activity in the globus pallidus internal segment and which causes decreased activity? What are the major symptoms of these two conditions?

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Exam 3 Questions by Prof. Zhang

Question 1 (6 pts total)
Please give an example of a computational problem that can be solved by a multilayer perceptron but not by a simple perceptron with a single layer. Explain why a simple perceptron fails in this example.

Question 2 (6 pts total)
Suppose we want to store a set of input patterns as auto-associative memories in a feedforward network. We write the input patterns, $\mathbf{x}_1, \cdots, \mathbf{x}_n$, as a column vectors, and define the input matrix as $\mathbf{X} = [\mathbf{x}_1, \cdots, \mathbf{x}_n]$. We want to have $\mathbf{WX} = \mathbf{X}$. The weight matrix should be given by which of the following formulas?

(1) $\mathbf{W} = \mathbf{X}\left(\mathbf{X}^{\mathbf{T}}\mathbf{X}\right)^{-\mathbf{1}}\mathbf{X}^{\mathbf{T}}$, assuming that the matrix inverse exists.
(2) $\mathbf{W} = \left(\mathbf{X}^{\mathbf{T}}\mathbf{X}\right)^{-\mathbf{1}}$, assuming that the matrix inverse exists.
(3) $\mathbf{W} = \mathbf{X}^{\mathrm{T}}\mathbf{X}$
(4) $\mathbf{W} = \mathbf{I}$ (the identity matrix).

Question 3 (10 pts total)

Suppose we want to store three independent random patterns $\mathbf{a} = (a_1, \cdots, a_N)$, $\mathbf{b} = (b_1, \cdots, b_N)$, and $\mathbf{c} = (c_1, \cdots, c_N)$ in a Hopfield network with N units. Here each entry in the pattern vectors is either +1 or -1 with equal probability.

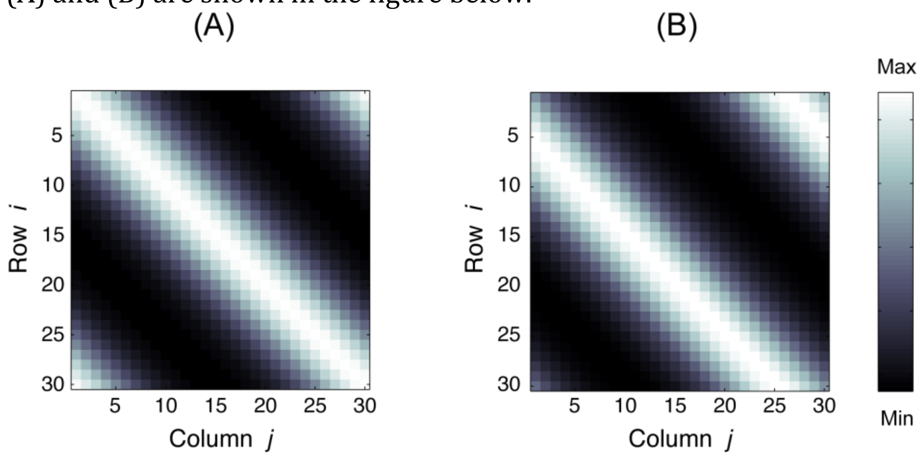
(1) How should the weights w_{ij} of the network be set up?

(2) Suppose we want to store the complementary patterns $\mathbf{a}' = (-a_1, \cdots, -a_N)$, $\mathbf{b}' = (-b_1, \cdots, -b_N)$, and $\mathbf{c}' = (-c_1, \cdots, -c_N)$ rather than patterns $\mathbf{a}$, $\mathbf{b}$, and $\mathbf{c}$. Show that the weight matrix is the same.

(3) Show that the weights are always symmetric $w_{ij} = w_{ji}$ regardless of what patterns are stored.

Question 4 (10 pts total)

Consider a recurrent network with 30 units that are connected as a ring. The weight matrix w_{ij} specifies the strength of synaptic connection from unit j to unit i. Two cases of the weight matrix (A) and (B) are shown in the figure below.



Please answer the following questions by picking only one choice.
Choices: (i) A only, (ii) B only, (iii) both A and B, (iv) None.

(1) Which weight patterns are symmetric (that is, $w_{ij} = w_{ji}$)?

(2) Which weight patterns are shift-invariant (that is, the weight between two units depend only on their relative position but not their absolute positions on the ring)?

(3) Which weight patterns may generate traveling wave of activity?

Question 5 (10 pts total)

In Kohonen self-organizing map, each neuron is described by a weight vector $\mathbf{w}_\mathbf{r}$, where $\mathbf{r}$ indicates the location of the neuron on the two-dimensional map. The response of the neuron is given by the dot product $y_\mathbf{r} = \mathbf{w}_\mathbf{r} \cdot \mathbf{x}$, where the input vector $\mathbf{x}$ is the same for all neurons. The weights are updated by $\Delta\mathbf{w}_\mathbf{r} = H(|\mathbf{r} - \mathbf{r}^*|)(\mathbf{x} - \mathbf{w}_\mathbf{r})$, where $H(|\mathbf{r} - \mathbf{r}^*|) = Aexp(-|\boldsymbol{r} - \boldsymbol{r}^*|^2/s^2)$ is a Gaussian neighborhood function with | | indicating vector length (Euclidean distance).

(1) What does $\mathbf{r}^*$ stand for?

(2) Given a specific input pattern **x** and 0< A < 1, what would the $\mathbf{W}_{\mathbf{r}^*}$ approach to?

(3) If the width *s* of the neighborhood function is reduced greatly, how would the final map be affected after the same number of learning steps?

Question 6 (8 pts total)

Consider a population of *N* motor cortical neurons with preferred directions given by the vectors $\mathbf{p}_1,\cdots,\mathbf{p}_N$. Let the activities of these neurons be $a_1,\cdots,a_N$.

(1) What is the population vector for this neuronal population?

(2) Suppose a drug can double the activities $a_1,\cdots,a_N$ of all the neurons in the population. How would this drug affect the direction and the length of the population vector?

Exam 3 Questions by Prof. Farrah

Question 1 (10 pts)

Peripheral nerves like sciatic nerve contain myelinated and unmyelinated axons. These two populations carry information to and from the central nervous system. Generally unmyelinated axons have less than 1 um diameters and myelinated axons have diameters greater than 1 um. Peripheral neuropathies affect these two populations of axons differently

1. (2 points) What controls whether or not a peripheral axon will be myelinated during development? Which cell provides myelin to peripheral axons?

2. (3 points) Describe three salient features of painful small caliber peripheral neuropathy?

3. (2 points) Describe the differences in propensity for functional regeneration between myelinated axons and unmyelinated axons.

4. (3 points) Describe what happens to the proximal and distal segments of a single injured axon cut at a midpoint?

Exam 3 Questions by Prof. Wang

Question 1 (12 pts total)

a) (3 points) What are the three acoustic cues used in determining the location of a sound by a human subject? Explain under what conditions these cues are used by the auditory system in localizing sounds.

b) (3 points) Please identify the key neural structures and mechanisms involved in extracting these cues.

c) (2 points) If a 10,000 Hz tone is played from a loudspeaker located 30 degrees to the right of a subject, which cue(s) can be used by the auditory system to localize it, and which cue(s) cannot? Explain why.

d) (2 points) If a broadband noise is played from a loudspeaker located 30 degrees to the right of a subject, which cue(s) can be used by the auditory system to localize it, and which cue(s) cannot? Explain why.

e) (2 points) If a 1,000 Hz tone is played from a loudspeaker on the horizontal plane behind a subject, can the subject tell whether the sound is coming from the front or back? Explain why.

Question 2 (8 pts total)

a) (4 points) Explain how human vocal apparatus produces an English vowel.

b) (2 points) Explain why a vowel produced by a male sounds differently than the same vowel produced by a female?

c) (2 points) When two persons say the same vowel, they sound different ("accent"). Explain which component of the human vocal apparatus generates the accent.

Name___________________________________

Exam 3 General Questions

Question 1 (15 pts total)
Most cochlear implant users can understand speech in conversations. However, it has been reported that cochlear implant users have difficulties in understanding tonal languages and music. Cochlear implant users also have difficulties in correclty pronouncing speech with accurate pitch contours, though their vocal production apparatus is generally normal.

a) (6 points) Why can cochlear implant users understand speech, but not perceive tonal languages and music normally? Answer this question by (i) identifying which components of speech are extracted or processed by cochlear implants and which components are not and (ii) explaining why.

b) (4 points) If you image the brain of a cochlear implant user when he/she listen to a tonal language and compare that with the image obtained from the brain of a normal hearing subject listening to the same tonal language, would you expect any differences in brain activity patterns in auditory cortex? Why?

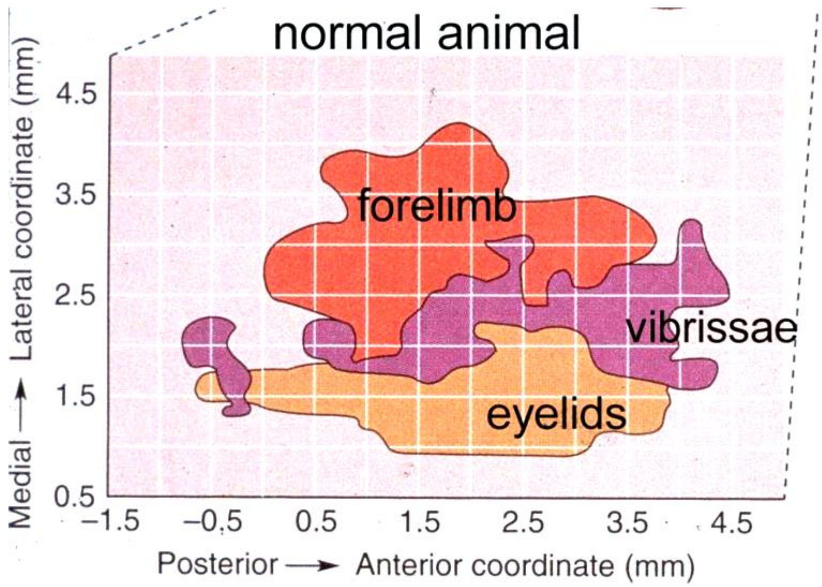
c) (5 points) Why can't a cochlear implant user correctly pronounce speech with accurate pitch contours? You may answer this question with text and a diagram of components involved in producing and maintaining speech.

Question 2 (15 pts total)
Based on what you know about cochlear implants and visual neurophysiology, sketch out a design for a visual implant. This is a device that would electrically stimulate retinal ganglion cells directly to produce visual perception in a person with no photoreceptors. Assume that the problems of building such a device, powering it, surgically implanting it, and successfully stimulating retinal ganglion cells have been solved. You should deal with issues of acquiring sensory data (i.e. the visual scenes) and converting them to a format for successful stimulation. These include: (1) How many electrodes should it have? (2) How should they be arranged on the retina? (3) What part of the retina would be best? Explain why. (4) How does it capture the visual scene and transform into appropriate electrical stimulation? (5) How fast should the implant sample the visual scene?

a. (10 points) Describe your design, and answer the questions above.

b. (5 points) What aspects of vision will your design not provide?

Question 3 (15 pts total)
The figure below shows the motor map in the motor cortex of an adult rat. Draw the map that you expect to see if the motor nerve to the vibrissae muscles is cut. Then, describe how the circuitry in the motor cortex would have changed in order to produce this new map.



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