

This exam counts for 20% of your final grade

Your exam grade will be two-thirds the number of points gained by answering all questions.

Answer in the space provided, continuing on the back of the sheet if necessary

NO collaboration is allowed on exams.

You **may** ask the TA for clarification of the questions.

CLOSED BOOK: You **may not** consult notes or textbooks.

You **must not** get any help with the answers, you must not cheat.

Your name: _____

Question 1. McCulloch & Pitts Neurons (8 pts)

a. Give the expression relating the output "y" of a McCulloch & Pitts neuron to the inputs " x_i " ($1 \leq i \leq n$) it receives through synaptic connections with weights " w_i " (1 pt).

b. Describe the general class of pattern classifications that such a neuron can perform. Motivate your answer using the expression from the previous question (1 pt).

c. Could you use gradient descent (possibly implemented using backpropagation) to train the weights of this neuron? Motivate your answer by a theoretical argument (1 pt).

d. You want to setup a McCulloch & Pitts network with three binary inputs (x_1 , x_2 and x_3) so that it fires if and only if two of its inputs are active.

d.1. To answer this question, start by writing down a table with the eight possible combinations of the three binary inputs along with the desired output for each combination (1 pt).

d.2. With help from your table, write the desired expression for the output as a logical function of the three binary inputs, using the logical operators AND, OR and NOT (Hint: start by spelling out the cases where the output is 1; then check whether the logical function you obtained would work for all cases, and add corrective terms to the function if necessary) (1 pt).

d.3. Write down the weights and thresholds for a single McCulloch & Pitts neuron with "n" inputs that implements: AND (i.e., fires if and only if all its inputs are 1), OR (fires if one or more input is 1), NOT AND (NAND), and NOT OR (NOR) (1pt)

d.4. Finally, draw a network of neurons from d.3. that implements the logical function found in d.2. (1 pt)

e. Looking at your answers from (d) and (b), what can you say about the logical function implemented in (d)? Is your implementation in (d) a proof of or rather a hint towards your answer to the present question? (1 pt)

Question 2. Optimization using Neural Networks (4 pts)

a. We saw in class several applications of neural networks to the extremization (i.e., minimization or maximization) of functions depending on many parameters. Briefly describe two of these applications and the underlying techniques used (type of neurons, method used to perform extremization). (2 pts)

b. If the function to extremize has many local extrema, can the techniques you just described avoid these local extrema and find the global extremum?

Suggest two ways in which these techniques can be enhanced such as to become more robust to local extrema. (2 pts)

Question 3. Hopfield Network for Speech Recognition (6 pts)

You want to build a Hopfield network to recognize the five digits ("one", "two", ... "five") in digitized speech. You asked your friends to help you by uttering the digits with various intonations several times, and obtained 10 recordings for each of the 5 digits. You apply some pre-processing to each recording, so that you can describe each sample by 3 characteristic parameters.

a. Describe the two general constraints on the design and simulation of Hopfield networks that make them different from McCulloch & Pitts networks (1 pt).

b. Draw a diagram of the Hopfield network you could design to store and later recall the digits. Do you want to store each sample or only an average of all the samples for a given digit? How many inputs do you want in your network? How many outputs? (2 pts).

c. Count the neurons in your network. Give a rough estimate of how many patterns you could reliably store in such network (1 pt). Do you think the network in (b) would do a good job at discriminating between the five digits? (1 pt). Suggest how we would need to modify the network's design to make the discrimination reliable (1 pt).

- c. Outline a coordinated control program for getting safely from one side of a busy street to another (no jay-walking allowed!). List the motor schemas necessary for this (don't forget action-oriented perception), and for each one list the perceptual schemas needed to initiate, parameterize and terminate the instantiation of that schema. (3 points)