Neural Computation : Exercise Sheet 1

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The following questions are of the kind that may come up in the exam this year. They are designed to help you monitor your progress – try to answer the questions without your notes, and then use your notes to check whether your answers are correct. The percentages indicate the corresponding fraction of a 1.5 hour exam.

Question 1

(a) Outline the main reasons why artificial neural networks are worth studying. **[5%]**

(b) Draw diagrams of a biological neuron and the artificial equivalent, with the key components labelled. **[6%]**

(c) What are the principal differences between the artificial neuron and the biological equivalent? **[4%]**

(d) The human brain contains around 10^{10} neurons, whereas a large computational model may have only 10^4. Give reasons why the large difference in number may matter, and reasons why it may not. **[4%]**

(e) It is clear that the human brain is able to generalize. Can artificial neural networks generalize? Discuss the importance of that question. **[6%]**

Question 2

(a) What is a *neuron action potential*? **[4%]**

(b) What factors affect the magnitude of such an action potential? **[6%]**

(c) Explain what is meant by the terms *spike time coding* and *rate coding*, and the main differences between them. **[8%]**

(d) What are the advantages and disadvantages of using *spike time coding* rather than *rate coding* for artificial neural networks? **[7%]**

Question 3

(a) Outline the basic structure and components of a simple biological neuron. **[6%]**

(b) Discuss how this is related to a McCulloch-Pitts neuron. **[6%]**

(c) Design networks of McCulloch-Pitts neurons that implement logical NOT, AND and OR gates. Draw each network and label all the weight and threshold values. **[8%]**

(d) In what way is XOR more difficult? **[5%]**

Question 4

(a) With the aid of labelled diagrams, describe the relationship between a *Biological Neuron* and a *McCulloch-Pitts Neuron*. **[7%]**

(b) Write down the equation for the output of a McCulloch-Pitts neuron in terms of its two inputs, its connection weights and its threshold. Derive inequalities that specify the weights and threshold for the logic gates NOT, AND, OR, and XOR. **[13%]**

(c) What do those inequalities tell us about the computational power and limitations of networks of McCulloch-Pitts neurons? **[5%]**

Question 5

(a) Describe what a *McCulloch-Pitts Neuron* is and what a *Perceptron* is, and explain their relation to biological neurons. **[10%]**

(b) Derive expressions for the weights and thresholds that would be required for a single McCulloch-Pitts neuron to perform the following input-output mapping:

in1	*in2*	*out*
0	0	1
0	1	0
1	0	0
1	1	0

State in words what ranges of values each weight and threshold can take, and provide an example of particular numerical values. **[8%]**

(c) There is a limited class of input-output mappings that can be performed by *Single Layer Perceptrons*. What is that class called? Explain how one can determine whether a given mapping is a member of that class. Give one simple example of a problem within that class, and one simple example from outside that class. **[7%]**

Question 6

(a) Write down the equation for the output of a *McCulloch-Pitts Neuron* with n inputs. For the case of two inputs, derive the equation for the decision boundary that it computes in the input space, and explain what it means. **[6%]**

(b) In terms of such decision boundaries, describe with the aid of diagrams which logical functions can be computed by a *McCulloch-Pitts Neuron* and which cannot. **[5%]**

(c) Explain what the *Perceptron Learning Rule* is, and discuss its advantages and disadvantages over attempting to compute decision boundaries analytically. **[8%]**

(d) Outline two ways of overcoming the computational limitations of *Single Layer Perceptrons* built from *McCulloch-Pitts Neurons*. **[6%]**