UNIVERSITY OF LONDON

B.Sc. Examination 2005

COMPUTING AND INFORMATION SYSTEMS

CIS311 Neural Networks [Western]

Duration: 2 hours 15 minutes

Date and time:

- *Full marks will be awarded for complete answers to FOUR questions. Do not attempt more than FOUR questions on this paper.*
- *Electronic calculators may be used. The make and model should be specified on the script. The calculator must not be programmed prior to the examination. Calculators which display graphics, text or algebraic equations are not allowed.*

THIS EXAMINATION PAPER MUST NOT BE REMOVED FROM THE EXAMINATION ROOM

Question 1.

a) Describe briefly the four main characteristics that determine the computational potential of artificial neural networks. **[8]**

b) Suppose that a single layer network is given. This network has a neuron with two incoming inputs and weights initialised as follows: $w_1 = -0.15$, $w_2 = 0.4$. Determine the output of this neuron using the training vector $(-1.2, -0.5)$ for each of the following activation functions:

i) linear activation function with threshold. **[3]**

ii) thresholded activation function using threshold $u=0.3$. **[4]**

iii) sigmoidal activation function. **[6]**

c) Discuss which of the following four Boolean functions: AND, OR, XOR and NOT can not be modelled by single layer feedforward neural networks. **[4]**

Question 2.

a) Develop a neural network with 2 layers having the following components: 3 neurons in the hidden layer, 1output neuron, 2 inputs and a discrete activation function in every neuron. Let the network be made so that it generates 1 when the inputs pass some point from the triangle with vertices: (-0.4, -0.4), (0, 0), and (0, -0.4).

i) Draw on the two-dimensional plane the lines modelled by the three neurons which enclose the given triangle. **[9]**

ii) Determine the weight matrix for the input to hidden connections of the three neurons. **[6]**

b) Let a single layer from a neural network with two neurons and two inputs be given. Both neurons use a discrete activation function. Suppose that the weights on connections entering the first node are: $w_{11} = -2$, $w_{12} = 1$, $u_1 = 4$, and respectively the weights on connections entering the second node are: $w_{21} = -1$, $w_{22} = 2$, $u_2 = 3$.

i) Derive the equations that determine the space including the point: $(y_1, y_2) = (2/5, -1/5)$. **[5]**

ii) Derive the equations that determine the space including the point: $(y_1, y_2) = (-1/5, 2/5)$. **[5]**

Question 3.

Consider a single layer neural network with 1 sigmoidal neuron and 4 inputs. The training vector is: $\mathbf{x} = (x_1, x_2, x_3, x_4)$, where x_4 is always clamped at $x_4 = 1$. The weights on the connections feeding the neuron are: $\mathbf{w} = (w_1, w_2, w_3, w_4)$. Assume that the learning rate is 0.15.

i) Give the Widrow-Hoff rule for training this sigmoidal neuron and explain each component in it. **[7]**

ii) Perform incremental training of this sigmoidal neuron with the following three training input vectors, and show how the weights are updated after each of them, starting with the following initial weight vector: $\mathbf{w} = (-0.1, 0.2, -0.3, 0.4)$. **[18]**

x_1	x_2	x_3	x_4	y
0.25	-1.2	1.5	1	0
0.5	1.5	-0.4	1	1
0.3	-1	1.3	1	0

Question 4.

a) The training of counterpropagation neural networks involves normalization of the input vectors and the weights. The normalization of a vector $\mathbf{x} = (x_1, x_2, \ldots, x_n)$ is made by multiplying its components with a positive number c.

i) Show the formula for computing the positive normalizer c. **[3]**

ii) Perform normalization of the vector: $\mathbf{x}$ = (1.2, -2.3, 3.4, -4.55, 5.6). **[3]**

b) Let a self-organizing neural network with two neurons in the Kohonen layer be given. Each neuron has 4 inputs. The initial weight vectors are: $\mathbf{w}_1$=(-0.4,1.2,2,1.3), and $\mathbf{w}_2$=(-1.5,2,-0.8,1).

i) Prepare these initial weights for training by normalization. **[6]**

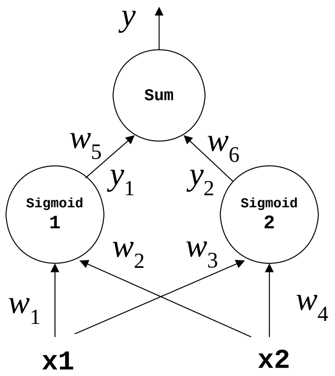
ii) Using the input vector: (x_1, x_2, x_3, x_4)=(0.4, 0.3, 0.2, 0.1) compute the summation block and determine the index of the largest component in sum. **[4]**

iii) Perform training of the two neurons in the Kohonen layer and show the weight updates, using learning rate η=0.15. **[6]**

iv) Explain what is the problem of having too many neurons in such self-organizing networks. **[3]**

Question 5.

A two layer feedforward neural network with two neurons in the first layer and one neuron in the second layer is given. As shown in the figure below the network has two inputs (x_1, x_2). The weights on the input to hidden connections are w_1, w_2, w_3, and w_4. The weights feeding the hidden signals y_1 and y_2 into the output neuron are: w_5 and w_6. Assume that the two hidden neurons use sigmoidal activation functions, while the output neuron is linear. Explain how training of this multiplayer network is carried out according to the backpropagation algorithm by answering the following questions:



i) What are the formulae that generate the signals y_1, y_2 and y during the forward pass? **[2x2=4]**

ii) What are the formulae for updating the hidden to output weights w_3 and w_4 during the backward pass? Explain each component of these formulae. **[3+2x2=7]**

ii) What are the formulae for updating the input to hidden weights w_1, w_2, w_3, and w_4 during the backward pass? Explain each component of these formulae. **[2x3+4x2=14]**

Question 6.

a) Describe the main difference between synchronous and asynchronous mode of training Hopfield networks. **[4]**

b) Assume that a Hopfield network with four neurons: N_0, N_1, N_2, and N_3 is given. This network has three inputs: x_1, x_2, x_3 and neuron N_0 has a clamped output: x_0=1. The initial weight matrix is:

$$\mathbf{W} = \begin{vmatrix} 0 & 0.2 & 0 & 0 \\ 0.2 & 0 & 0 & -0.6 \\ 0 & 0 & 0 & -0.1 \\ 0 & -0.6 & -0.1 & 0 \end{vmatrix}$$

i) Given the pattern: [1 0 1] the output of neuron N_1 is negative while it is required to be positive. Train the network weights: w_{10}, w_{12} and w_{13} with the Widrow-Hoff rule to correct it. **[5]**

ii) Demonstrate that the updated network is unstable for N_2 and retrain it. **[5]**

iii) Demonstrate that the updated network is unstable for N_3 and retrain it. **[5]**

iv) Suppose that the state is: [0 1 1]. Determine the next three states when each neuron fires assuming the most recently learned weight vector. **[6]**