UNIVERSITY OF LONDON

GOLDSMITHS COLLEGE

B.Sc. Examination 2015

DEPARTMENT OF COMPUTING

IS53002A Neural Networks

Duration: 2 hours 15 minutes

Date and time:

There are five questions on this paper. You should answer no more that THREE questions. Full marks will be awarded for complete answers to a total of THREE questions. Each question carries 25 marks. The marks for each part of a question are indicated at the end of the part in [.] brackets.

There are 75 marks available on this paper.

Electronic calculators must not be programmed prior to the examination. Calculators which display graphics, text or algebraic equations are not allowed.

THIS PAPER MUST NOT BE REMOVED FROM THE EXAMINATION ROOM

Question 1.

a) Describe briefly how a batch training algorithm for neural networks operates. What is the alternative kind of training algorithm for neural networks and how does this alternative algorithm process the training examples? **[7]**

b) Define the two most commonly used activation functions in multilayer Perceptron networks. **[4]**

c) Give the expression for calculating the total number of weights and thresholds in a two-layer multilayer Perceptron (MLP) network with z inputs, H hidden nodes and k outputs. **[4]**

d) Consider a Radial-basis function (RBF) network with 4 neurons each having Gaussian basis functions. Assume that the initial weight vector is: $\boldsymbol{w}$=(0.1,–0.3,0.2,–0.15), the basis function variances are: $\boldsymbol{s}^2$=(0.22,0.33,0.44,0.11), and the corresponding centres are as follows: $\boldsymbol{c}_1$=(0,1,0,1), $\boldsymbol{c}_2$=(1,0,1,1), $\boldsymbol{c}$ =(1,1,0,0) and $\boldsymbol{c}_4$=(1,0,0,1).

i) Show the analytical formula for computing the output of this RBF network including the calculations performed in each network node. **[6]**

ii) Compute the RBF network output with the following training input vector **x**=(1,1,0,1), with precision up to and including the fourth digit after the decimal point. **[4]**

Question 2.

a) Explain how classification into K (K>2) classes can be performed using a single-layer Perceptron network which infers a linear function? **[4]**

b) Give the formula for offline (batch) gradient descent training of unthresholded Perceptron networks. Explain each term in the training formula. **[5]**

c) Consider a single-layer Perceptron neural network with five inputs and no threshold. This Perceptron computes the sum: $s=w_1\, x_1+w_2\, x_2+w_3\, x_3+w_4\, x_4+w_5\, x_5$, and passes it next through the discrete activation function: *Threshold* (s) = 1 if $s > 0$. Assume that the learning rate is one. Demonstrate one cycle of training this Perceptron using the following example vectors, provided sequentially:

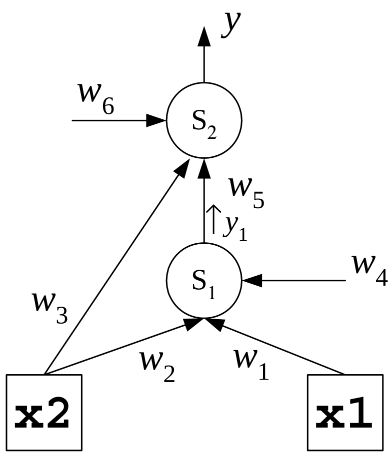
x_1	x_2	x_3	x_4	x_5	y
1	1	0	1	0	0
1	0	1	0	1	1
0	1	1	1	0	0
1	1	0	0	1	1

Begin with the following initial weights: $(w_1, w_2, w_3, w_4, w_5)$=(0,0,0,1,1). Show the network output and compute the weights changes after each example. **[16]**

Question 3.

a) Define the gradient descent training rule for multilayer networks with weight decay regularization. Explain the main components of the rule. **[5]**

b) Consider a multilayer neural network with two nodes: one hidden and one output using sigmoidal activations (that is, S_1 and S_2 denote sigmoidal activation functions) given in the figure below. There are two inputs passed to the network: (x_1, x_2), and six weights: $(w_1, w_2, w_3, w_4, w_5, w_6)$. Both of the hidden neurons have bias connections w_4 and w_6 which are fixed at 1.



Demonstrate the operation of the backpropagation training algorithm on this network including:

i) Develop the expressions for computing the error and weight updates w'_3, w'_5 and w'_6 for the connections entering the output node. Explain the meaning of each term in the expressions. **[10]**

ii) Develop the expressions for computing the backpropagated errors and weight updates w'_1, w'_2, and w'_4 for the connections entering the hidden node. Explain the meaning of each term in the expressions. **[10]**

Question 4.

a) Explain briefly what operations are performed in each of the three main phases of the training algorithm for self-organizing Kohonen networks. **[9]**

b) Draw a picture of a self-organizing Kohonen network with three neurons. **[6]**

c) Let a self-organizing Kohonen neural network with two neurons be given. There are four inputs passed to each neuron. Assume that the initial weight vectors are: $\boldsymbol{w}_1$=(0.15,0.2,-0.33,0.4), and $\boldsymbol{w}_2$=(0.25,-0.1,0.44,-0.33).

i) Compute the summation block using the input vector: (x_1, x_2, x_3, x_4)=(0.1,0.4,0.3,0.2) and determine the index of the largest component (neuron) in the summation block. **[4]**

ii) Train the neuron computed in part (i) and show the weight updates using learning rate η=0.25. **[6]**

Question 5.

a) i) Describe what operations are involved in the retrieval phase of the Hopfield neural networks. **[5]**

ii) Define the formula for updating of the state in Hopfield neural networks after a testing probe vector is presented to the network during the retrieval phase. **[5]**

c) Consider a Hopfield neural network with 4 neurons and 4 inputs: x_1, x_2, x_3, x_4. The initial weights are given by the following matrix:

$$\mathbf{W} = \begin{matrix} 0 & -0.1 & 0.2 & 0.4 \\ -0.1 & 0 & -0.15 & 0.3 \\ 0.2 & -0.15 & 0 & -0.2 \\ 0.4 & 0.3 & -0.2 & 0 \end{matrix}$$

i) Using the state [0,1,0,1] compute the new state after neuron 1 fires. **[4]**

ii) Assuming that the network operates in synchronous mode, that is starting from the updated state, compute the next state after neuron 2 fires. **[4]**

iii) Starting from state [1,0,1,1] the output of neuron 2 is 1 while it should be 0. Using the Widrow-Hoff rule train the weights of the network to correct the situation. **[7]**