ENG34

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSC SYSTEMS ENGINEERING AND ENGINEERING MANAGEMENT

SEMESTER 1 EXAMINATION 2023/2024

INTELLIGENT SYSTEMS

MODULE NO: EEM7010

Date: Monday 8th January 2024 **Time: 10:00 – 12:00pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer ANY THREE questions.

All questions carry equal marks.

This examination paper carries a total of 75 marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

For your reference, appendices of formulae follow the questions.

Question 1

a) Using back propagation algorithm, to design the network shown in **Figure Q1** to approximate the function:

$$f(p) = \frac{p}{2} + \sin(\pi p)$$

in the range $-1 \leq p \leq 1$.

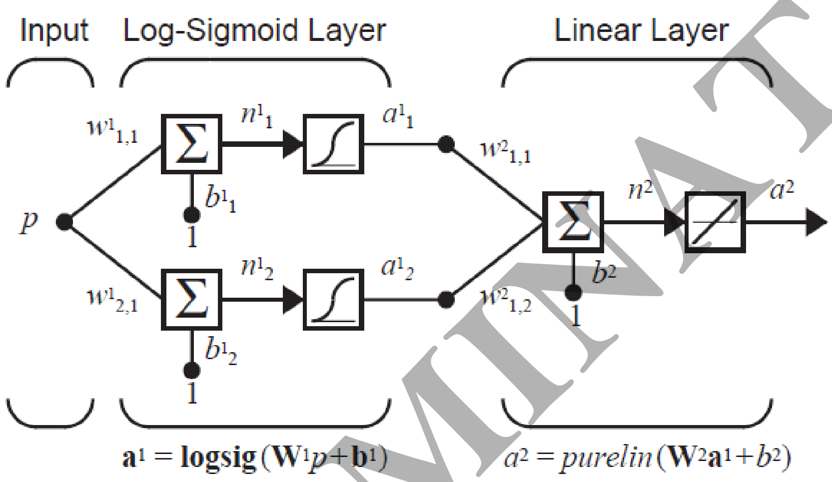

Figure Q1: 1-2-1 Neural Network.

i. Write down the important equations for updating the weights and bias using the backpropagation algorithm.

(6 marks)

ii. If the initial values for the network weights and biases have been chosen as

$$W^1(0) = \begin{bmatrix} -0.2 \\ 0.2 \end{bmatrix}; \qquad b^1(0) = \begin{bmatrix} -0.5 \\ -0.5 \end{bmatrix};$$

$$W^2(0) = [0.2 \quad 0.6]; \qquad b^2(0) = [0.7];$$

Perform one iteration of back propagation algorithm with input $p = 0.5$ and learning rate $\alpha = 0.4$.
All the steps and calculations should be explained clearly.

(19 marks)

Total 25 Marks

Question 2

a) Critically identify the similarities and differences between the perceptron learning rule and the backpropagation algorithm.

(6 marks)

b) Considering the classification problem defined below in terms the input vectors (**p**) and their corresponding targets (**t**).

Input 1: $\left\{p_1 = \begin{bmatrix} -1 \\ 1 \end{bmatrix},\ t_1 = 1\right\}$

Input 2: $\left\{p_2 = \begin{bmatrix} -1 \\ -1 \end{bmatrix},\ t_2 = 1\right\}$

Input 3: $\left\{p_3 = \begin{bmatrix} 0 \\ 0 \end{bmatrix},\ t_3 = 0\right\}$

Input 4: $\left\{p_4 = \begin{bmatrix} 1 \\ 0 \end{bmatrix},\ t_4 = 0\right\}$

i) Design a perceptron network to solve this problem. Determine the minimum number of neurons required and draw the network with all its ingredients and their annotations.

(4 marks)

ii) Define the learning rules for the perceptron neural network designed.

(3 marks)

iii) Assuming that the initial values for the weights and biases as

$$W(0) = [0.2 \quad -0.1]; \quad b(0) = [-0.3]$$

Apply each input vector in order to complete 4 iterations to generate values of weights **W**(4) and biases **b**(4) at the end of 4^{th} iteration.

(12 marks)

Total 25 marks

Question 3

a) Describe Hebb's and Pseudoinverse learning rules for a perceptron neural network. Discuss their relative advantages, disadvantages and limitations.
(6 marks)

b) Consider the three prototype patterns and a test pattern shown in **Figure Q3**.

i) Normalise all input patterns.
(4 marks)

ii) Check if P_1 and P_2 input patterns are orthogonal.
(3 marks)

iii) Use Hebb supervised rule to design an Auto-associator network that will recognise these three patterns. You may use original input patterns.
(8 marks)

iv) Find the response of the network to the pattern p_t and check if the response is correct. Discuss the results.
(4 marks)

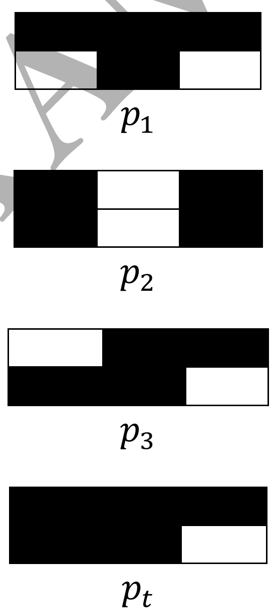

Figure Q3: Input and test patters.

Total 25 Marks

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Question 4

a) What in general terms is unsupervised learning?

(3 marks)

b) Define using formulae and explain two similarity measures for clustered data.

(5 marks)

c) Draw the principal architecture of the Kohonen Network and explain its working principles.

(8 marks)

d) A Kohonen network receives the input pattern P.

$$P = \begin{bmatrix} 0.4 \\ 0.2 \\ 0.8 \\ 0.5 \end{bmatrix}$$

and with four neurons in the network which have weights

$$W_1 = \begin{bmatrix} 0.7 \\ 0.3 \\ -0.1 \\ -0.9 \end{bmatrix}, \quad W_2 = \begin{bmatrix} 0.8 \\ -0.5 \\ 0.6 \\ -0.2 \end{bmatrix}, \quad W_3 = \begin{bmatrix} 0.2 \\ 0.7 \\ -0.1 \\ 0.4 \end{bmatrix}, \quad W_4 = \begin{bmatrix} -0.1 \\ 0.6 \\ 0.3 \\ -0.8 \end{bmatrix}$$

Using the “winner-takes-all” learning algorithm, determine

i. the neuron that will have its weights adjusted.

(5 marks)

ii. the new values of the weights, suppose that the learning coefficient is 0.5.

(4 marks)

Total 25 Marks

Question 5

Consider the linear associator with the following input and output vectors:

$$p_1 = \begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \end{bmatrix} \quad , \quad t_1 = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

$$p_2 = \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \end{bmatrix} \quad , \quad t_2 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

i. Utilize Hebb's rule to ascertain the approximate weight matrix for this linear associator. Employ the pseudo-inverse method to determine the approximate weight matrix for this linear associator.

(10 marks)

ii. Apply input vector p_1 to the linear associator using the weight matrices obtained through Hebb's and pseudo-inverse rule, and subsequently, validate the outcomes.

(15 marks)

Total 25 Marks

END OF QUESTIONS

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Formula Sheet

Name	Input/Output Relation	Icon	MATLAB Function
Hard Limit	$a = 0 \quad n < 0$ $a = 1 \quad n \geq 0$		hardlim
Symmetrical Hard Limit	$a = -1 \quad n < 0$ $a = +1 \quad n \geq 0$		hardlims
Linear	$a = n$		purelin
Saturating Linear	$a = 0 \quad n < 0$ $a = n \quad 0 \leq n \leq 1$ $a = 1 \quad n > 1$		satlin
Symmetric Saturating Linear	$a = -1 \quad n < -1$ $a = n \quad -1 \leq n \leq 1$ $a = 1 \quad n > 1$		satlins
Log-Sigmoid	$a = \frac{1}{1 + e^{-n}}$		logsig
Hyperbolic Tangent Sigmoid	$a = \frac{e^{n} - e^{-n}}{e^{n} + e^{-n}}$		tansig
Positive Linear	$a = 0 \quad n < 0$ $a = n \quad 0 \leq n$		poslin
Competitive	$a = 1$ neuron with max n $a = 0$ all other neurons	C	compet

Table 2.1 Transfer Functions

$$\boldsymbol{s}^2 = -2\,\dot{\boldsymbol{F}}^2(\boldsymbol{n}^2)(\boldsymbol{t} - \boldsymbol{a})$$

$$\boldsymbol{s}^1 = \dot{\boldsymbol{F}}^1(\boldsymbol{n}^1)(\boldsymbol{W}^2)^T\boldsymbol{s}^2$$

$$\boldsymbol{W} = \boldsymbol{T}\,\boldsymbol{P}^T$$

$$\boldsymbol{W} = \boldsymbol{T}\,\boldsymbol{P}^+$$

$$\boldsymbol{P}^+ = (\boldsymbol{P}^T\boldsymbol{P})^{-1}\boldsymbol{P}^T$$

END OF PAPER