UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSC SYSTEMS ENGINEERING AND ENGINEERING MANAGEMENT ALL PATHWAYS

SEMESTER ONE EXAMINATIONS 2022/2023

INTELLIGENT SYSTEMS

MODULE NO: EEM7010

Date: Monday 9th January 2023 **Time: 10:00 – 12:00**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer ANY THREE questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

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.

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1. (a) Critically identify the similarities and differences between the perceptron learning rule and the backpropagation algorithm. (8 marks)

(b) A classification problem with five classes of input vectors **p** and corresponds to their targets **t** is shown below:

Class 1: {p1 = $\begin{bmatrix} -1 \\ 1 \end{bmatrix}$, t1 = 1},

Class 2: {p2 = $\begin{bmatrix} 0 \\ 0 \end{bmatrix}$, t2 = 1},

Class 3: {p3 = $\begin{bmatrix} 1 \\ -1 \end{bmatrix}$, t3 = 1},

Class 4: {p4 = $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$, t4 = 0},

Class 5: {p5 = $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$, t5 = 0},

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

W(0) = [0 0.5] b(0) = [0]

Apply each input vector in order to complete 5 repetitions to generate values of weights W(5) and biases b(5) for the problem.

(12 marks)

ii) Using the values of weights W(5) and biases b(5) generated to check whether the problem has been solved or not.

(5 marks)

Total 25 marks

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2. (a) Describe supervised Hebb rule and Pseudoinverse rule. (4 marks)

(b) Use performance index to explain why Hebb rule, under certain condition, would be replaced by Pseudoinverse rule. (4 marks)

(c) Consider three input prototype patterns P1, P2 and P3, one test pattern Pt shown in Figure Q3(c) below:

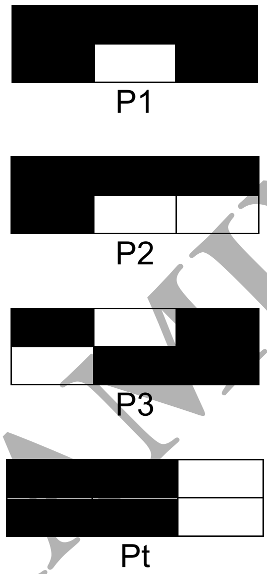

Figure Q3 (c) Inputs and Test Patterns

i) Normalise all input patterns. (3 marks)

ii) Check if P1 and P2 input patterns are orthogonal. (2 marks)

iii) Use the Hebb supervised rule to design an autoassociator network that will recognise these three input patterns. (7 marks)

iv) Find the response of the network to the test pattern Pt and check if the response is correct. Discuss the results. (5 marks)

Total 25 marks

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3. (a) Using back propagation algorithm to approximate the function:

$$f(x) = x + \cos(\frac{\pi}{2}x) \text{ for } -1 \leq x \leq +1$$

A 1 – 2 – 1 network architecture with transfer functions in the first layer are Log-Sigmoid and second layer is Linear shown in Figure Q3 below:

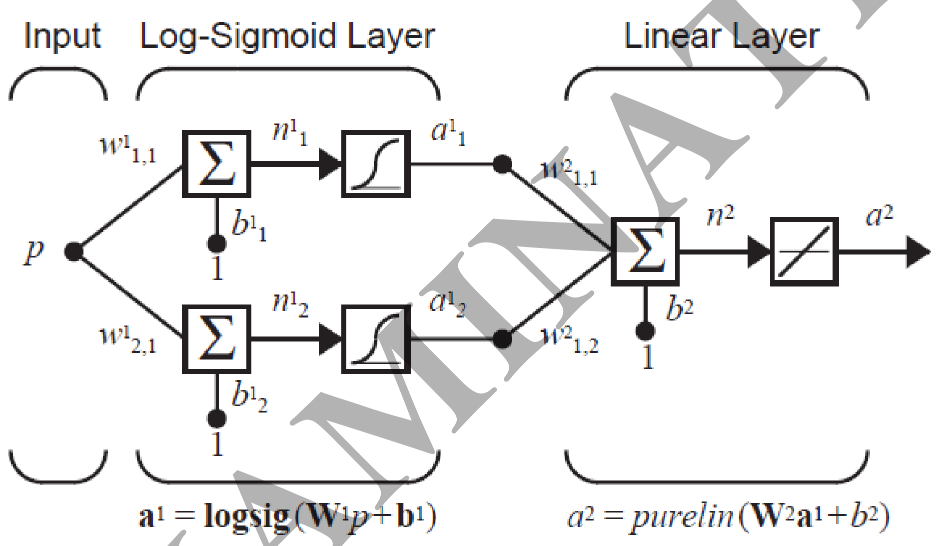

Figure Q3

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

$$W^1(0) = \begin{bmatrix} -0.3 \\ 0.2 \end{bmatrix} \qquad b^1(0) = \begin{bmatrix} 0.4 \\ 0.1 \end{bmatrix}$$

$$W^2(0) = \begin{bmatrix} -0.3 & -0.2 \end{bmatrix} \qquad b^2(0) = \begin{bmatrix} -0.4 \end{bmatrix}$$

Perform one iteration of back propagation with input $a^0 = p = 1.0$ and learning rate α = 0.8.

(20 marks)

(b) Comment on major issues that would impact on the practical implementation of back propagation algorithm.

(5 marks)

Total 25 marks

Please turn the page…

4. (a) Critically compare and analyse the competitive learning (winner-take-all) algorithm with self-organising feature map (SOFM). (8 marks)

(b) A competitive neural network has three-neuron outputs with four input vectors p1, p2, p3 and p4, and two initial weight vectors W^1, and W^2, where

p1 = $\begin{bmatrix}0.8660\\0.5000\end{bmatrix}$, p2 = $\begin{bmatrix}0.5000\\0.8660\end{bmatrix}$, p3 = $\begin{bmatrix}-0.9659\\-0.2588\end{bmatrix}$, p4 = $\begin{bmatrix}-0.9397\\0.3420\end{bmatrix}$

W^1= $\begin{bmatrix}0.0000\\1.0000\end{bmatrix}$, W^2= $\begin{bmatrix}0.0000\\-1.0000\end{bmatrix}$

i) Draw a diagram to show these input vectors and weight vectors. (3 marks)

ii) Calculate the resulting weights found after training the competitive layer with Kohonen rule and use a learning rate α of 0.7, on the series of inputs: p1, p2, p3 and p4. (14 marks)

Total 25 marks

5. (a) Critically explain the differences between a pattern space and a feature space Why is it important to map pattern space into feature space? (6 marks)

(b) The details of a 1D mathematical model for self organisation in a system of 8 neurons are given in Appendix 1 Page 7. Plot by hand the output of neuron's activation function versus the input (*net*) and discuss the mathematical form for the recursive equations. (10 marks)

(c) The resulting response for the 1D mathematical model of self organisation in Appendix 1, for a system consisting of 8 neurons is shown in Table Q5 (c). In Table Q5 (c), the excitations of all the 8 neurons, for 12 time steps, are presented. Sketch a sequence of graphs, on the same axes, showing the spatial response at subsequent times, for time steps *t* = (0, 4, 12). Discuss how this model displays self organisation? (9 marks)

Question 5 continues over the page….

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…Question 5 continued

Table Q5 (c)

Step	y1	y2	y3	y4	y5	y6	y7	y8
0	0.21	0.32	0.43	0.49	0.49	0.43	0.32	0.21
1	0.29	0.61	0.83	0.94	0.94	0.83	0.61	0.29
2	0.30	0.81	1.21	1.38	1.38	1.21	0.81	0.30
3	0.24	0.93	1.55	1.85	1.85	1.55	0.93	0.24
4	0.11	0.94	1.87	2.39	2.39	1.87	0.94	0.11
5	0.00	0.83	2.16	3.00	3.00	2.16	0.83	0.00
6	0.00	0.62	2.39	3.00	3.00	2.39	0.62	0.00
7	0.00	0.63	2.36	3.00	3.00	2.36	0.63	0.00
8	0.00	0.62	2.35	3.00	3.00	2.35	0.62	0.00
9	0.00	0.61	2.35	3.00	3.00	2.35	0.61	0.00
10	0.00	0.60	2.34	3.00	3.00	2.34	0.60	0.00
11	0.00	0.60	2.33	3.00	3.00	2.33	0.60	0.00
12	0.00	0.59	2.33	3.00	3.00	2.33	0.59	0.00

Total 25 Marks

END OF QUESTIONS

Appendices of formulae follow on the next page

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Appendix 1

<u>A 1D Mathematical Model of Self Organisation</u>

The response of the ith neuron is given by recursive equation:

$$y_i(t+1) = f(x_i(t+1) + \sum_{k=-k0}^{k0} y_{i+k}(t)\gamma_k)$$

The initial excitation is given by:

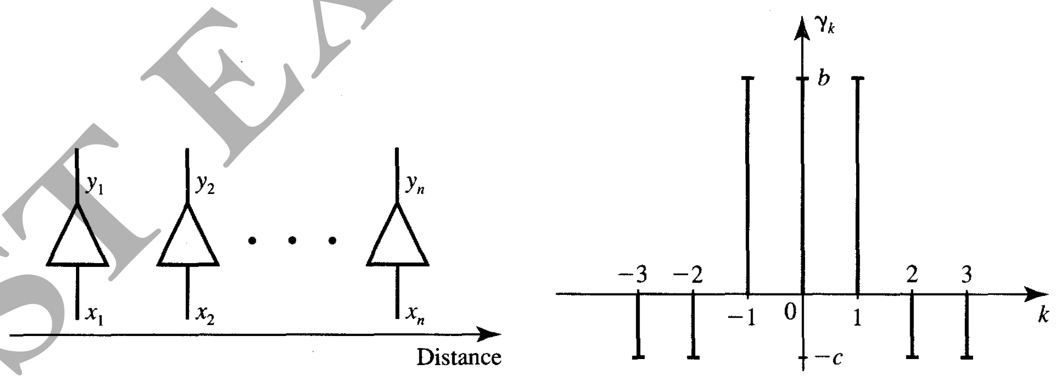
$$x_i(t) = 0.5\sin^3[\frac{\pi(i+3)}{15}],$$ for *i* = 1, 2, …, 8

The neuron's activation function is given by:

$$\text{f(net)} \triangleq \begin{cases} 0, & net \le 0 \\ net, & 0 < net < 3 \\ 3, & net \ge 3 \end{cases}$$

b = 0.6, c = 0.2

The 1D neural network architecture is shown below and a discretised Mexican top hat function form for the feedback coefficients γ_k.

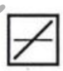


(a) (b)

(a) The 1D array of neurons. (b) The feedback coefficients γ_k are shown as a function of inter neuronal distance.

Appendix 2

Transfer Functions

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

END OF PAPER