[ENG18]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSC SYSTEMS ENGINEERING AND ENGINEERING MANAGEMENT

SEMESTER ONE EXAMINATION 2021/2022

INTELLIGENT SYSTEMS

MODULE NO: EEM7010

Date: Monday 10th January 2022 **Time: 10:00 – 12:00**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer ANY THREE questions.

All questions carry equal marks.

Individual marks are shown within the question.

TOTAL MARKS = 75

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Question 1

a) Explain possible difficulties in using the basic back propagation algorithm on practical problems.

(5 marks)

b) 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 $-1 \leq p \leq 1$.

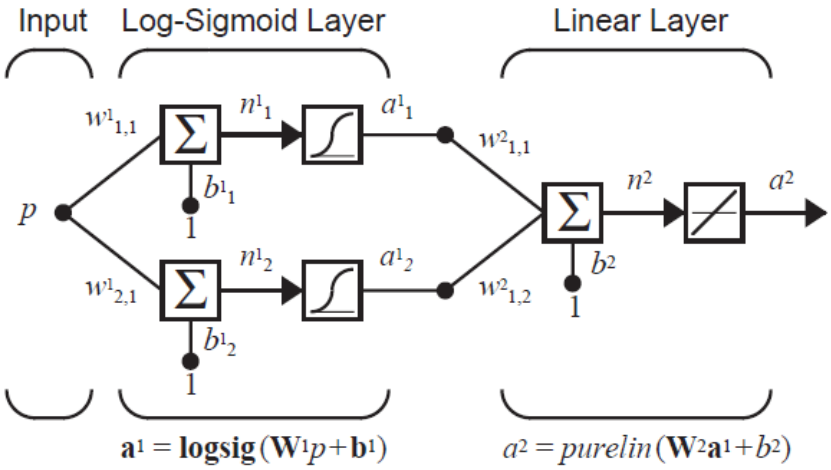

Figure Q1: 1-2-1 neural network.

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 $\alpha = 0.5$.
All the steps and calculations should be explained clearly.

(14 marks)

Total 25 marks

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Question 2

a) Identify the type of applications the perceptron network could be used and also discuss its limitations. Use diagrams appropriately to help in your discussion.

(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 4th iteration.

(12 marks)

Total 25 marks

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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 the four patterns.

(4 marks)

ii) Check if the input patterns are orthogonal.

(3 marks)

iii) Use Hebb supervised rule to design an Autoassociator 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)

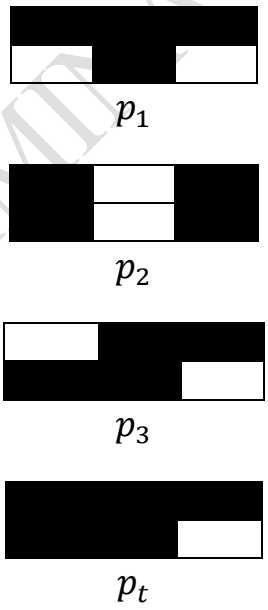

Figure Q3: Input and test patters.

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

$$W1 = \begin{bmatrix} 0.7 \\ 0.3 \\ -0.1 \\ -0.9 \end{bmatrix}, \quad W2 = \begin{bmatrix} 0.8 \\ -0.5 \\ 0.6 \\ -0.2 \end{bmatrix}, \quad W3 = \begin{bmatrix} 0.2 \\ 0.7 \\ -0.1 \\ 0.4 \end{bmatrix}, \quad W4 = \begin{bmatrix} -0.1 \\ 0.6 \\ 0.3 \\ -0.8 \end{bmatrix}$$

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

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Question 5

a) Discuss the following main aspects of the algorithm for the Kohonen self organising map (SOM):

i. the best matching node (BMN) *m*

(3 marks)

ii. the neighbourhood (Nm) of the BMN and its spatial extent as training progresses

(2 marks)

iii. the weight update rule for the SOM

(3 marks)

b) The details of a 1D mathematical model for self organisation in a system of 9 neurons are given in **Appendix 1 (on 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 (on page 7)**, for a system consisting of 9 neurons is shown below, in **Table Q5**. In **Table Q5**, the excitations of all the 9 neurons, for 10 time steps, are presented. Sketch a sequence of graphs, on the same axes, showing the spatial response at subsequent times, for time steps t = (1, 3, 10). Discuss how this model displays self organisation?

(7 marks)

Table Q5

Step	y1	y2	y3	y4	y5	y6	y7	y8	y9
1	0.06	0.21	0.39	0.54	0.60	0.54	0.39	0.21	0.06
2	0.00	0.19	0.60	0.95	1.08	0.95	0.60	0.19	0.00
3	0.00	0.00	0.87	1.74	2.10	1.74	0.87	0.00	0.00
4	0.00	0.00	1.02	3.32	4.00	3.32	1.02	0.00	0.00
5	0.00	0.00	0.89	4.00	4.00	4.00	0.89	0.00	0.00
6	0.00	0.00	0.00	4.00	4.00	4.00	0.00	0.00	0.00
7	0.00	0.00	0.00	4.00	4.00	4.00	0.00	0.00	0.00
8	0.00	0.00	0.00	4.00	4.00	4.00	0.00	0.00	0.00
9	0.00	0.00	0.00	4.00	4.00	4.00	0.00	0.00	0.00
10	0.00	0.00	0.00	4.00	4.00	4.00	0.00	0.00	0.00

Total 25 Marks

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Question 5 continued….

Appendix 1

A 1D Mathematical Model of Self Organisation

The response of the i[th] 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:

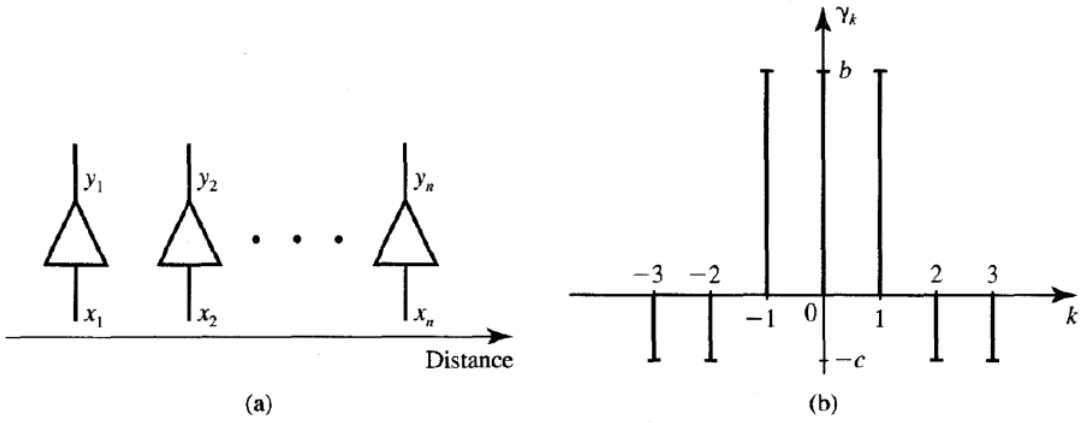
$$x_i(t) = 0.6\cos^2[\frac{\pi(i+5)}{10}], \text{ for } i = 1, 2, \ldots, 9$$

The neuron's activation function is given by:

$$f(net) \triangleq \begin{cases} 0, & net \le 0 \\ net, & 0 < net < 4 \\ 4, & net \ge 4 \end{cases}$$

b = 0.5, c = 0.3

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



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

END OF QUESTIONS