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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	INTELLIGENT CONTROL SYSTEM
COURSE CODE	:	BEH 41803
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	DECEMBER 2019/ JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

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Q1 The output equation for single layer two inputs, one bias and one output artificial neural networks is given below:

$$Y = \begin{cases} 1 & \text{if } W_1X_1 + W_2X_2 + B \geq \theta \\ 0 & \text{elsewhere} \end{cases}$$

where W_1 and W_2 are weights, X_1 and X_2 are inputs, B is bias, Y is output and θ is threshold value. This network will be used to train sample below:

X_1	X_2	Y
0	0	0
0	1	0
1	0	0
1	1	0
0	-1	1
-1	0	1
-1	-1	1

(a) Plot all the samples in a scatter plot of X_1 versus X_2.

(3 marks)

(b) Analyze the network performance after the sample been trained using Hebb learning algorithm in its first epoch (means that all the patterns have passed through once). Use learning rate, $\alpha = 0.5$, threshold $\theta = -1$ and the following table for the analysis.

Iter	X_1	X_2	T	Y	W_1	W_2	B
0					2	2	-1
1	0	0	0				
2	0	1	0				
3	1	0	0				
4	1	1	0				
5	0	-1	1				
6	-1	0	1				
7	-1	-1	1				

(14 marks)

(c) From **Q1 (b)**, construct the boundary decision function in the scatter plot of **Q1 (a)**.

(3 marks)

Q2 The Multi-layer Perceptron Neural Network (MLPNN) configuration which is to be trained using the backpropagation algorithm is shown in **Figure Q2**. All neurons in layers i have linear activation functions, and all neurons in layer j and layer k have sigmoid activation functions respectively given by:

$$S_1 = f(net_j) = \frac{1}{1+e^{-Cnet_j}} \; ; \; S_2 = f(net_k) = \frac{1}{1+e^{-Cnet_k}}$$

(a) Explain the performance of the MLPPNN model in term of training and accuracy for a C_{net} value of lower and higher than 1.

(2 marks)

(b) If C_{net} =1, derive the equations of weights and bias adaptation between layer k to j and layer j to i if the MLPNN's error model is given by E=0.5 (Target – output)^2.

(14 marks)

(c) Explain the basic idea of the backpropagation learning algorithm and the role of the learning rate. What effect has it when the learning rate is increased and decrease.

(4 marks)

Q3 (a) A fully connected feedforward network has 10 sources nodes, 2 hidden layers, one with 4 neurons and the other with 3 neurons, and a single output neurons. Construct an architecture graph of this network.

(4 marks)

(b) Explain the difference between Supervised and Unsupervised Learning.

(6 marks)

(c) Two fuzzy sets for small and fast, which the universe of discourse are between 0 and 5, have the following formulas :

$$\mu_{small}(x) = \begin{cases} 0.125(x+1) & \text{for } 0 \le x \le 4 \\ 0.75 & \text{for } x > 4 \end{cases}$$

$$\mu_{fast}(x) = \begin{cases} \dfrac{x}{2} & \text{for } 0 \le x \le 2 \\ -0.5x+2 & \text{for } 2 < x \le 4 \\ 0 & \text{for } x > 4 \end{cases}$$

(i) Construct the membership functions for "less small but very fast".

(5 marks)

(ii) Construct the relation for the implication of IF x is small THEN y is fast using Zadeh implication

(5 marks)

Q4 A fuzzy logic based washing machine system has been simplified by using only two inputs and one output. The input variables are degree-of-dirt (DD) and type-of-dirt (TD); the output variable is washing-time (WT). The fuzzy rule-base consist of:

Rule 1 : IF DD is *Large*	AND TD is *Greasy*	THEN WT is *Long*
Rule 2: IF DD is *Medium*	AND TD is *Greasy*	THEN WT is *Long*
Rule 3: IF DD is *Small*	AND TD is *Greasy*	THEN WT is *Short*
Rule 4 : IF DD is *Large*	AND TD is *Medium*	THEN WT is *Long*
Rule 5 : IF DD is *Medium*	AND TD is *Medium*	THEN WT is *Short*
Rule 6 : IF DD is *Small*	AND TD is *Medium*	THEN WT is *Short*
Rule 7 : IF DD is *Large*	AND TD is *Not Greasy*	THEN WT is *Short*
Rule 8 : IF DD is *Medium*	AND TD is *Not Greasy*	THEN WT is *Very Short*
Rule 9 : IF DD is *Small*	AND TD is *Not Greasy*	THEN WT is *Very Short*

The DD and TD having the same universe of discourse [0 - 100], Meanwhile the WT is represented in the universe [0 - 60]. The membership functions for each variable are as follows:

$$Small = \left\{ \frac{1}{0} + \frac{1}{20} + \frac{0}{40} \right\} \qquad Long = \left\{ \frac{0}{30} + \frac{1}{50} + \frac{1}{60} \right\}$$

$$Medium = \left\{ \frac{0}{20} + \frac{1}{40} + \frac{1}{60} + \frac{0}{80} \right\} \qquad Short = \left\{ \frac{0}{20} + \frac{1}{30} + \frac{0}{40} \right\}$$

$$Large = \left\{ \frac{0}{60} + \frac{1}{80} \right\} \qquad Very\ Short = \left\{ \frac{0}{10} + \frac{1}{20} + \frac{0}{30} \right\}$$

$$Greasy = \left\{ \frac{0}{60} + \frac{1}{80} + \frac{0}{100} \right\}$$

$$Not\ Greasy = \left\{ \frac{0}{0} + \frac{1}{20} + \frac{0}{40} \right\}$$

(a) Sketch the input and output of the fuzzy membership function respectively.

(6 marks)

(b) Investigate the model output before defuzzification using Mamdani implication relation and disjunctive aggregator when DD is 35 and TD is 88.

(7 marks)

(c) Determine the crisp value of *WT* from the composed model in **Q4 (b)** using Bisector of Area (BOA) method. (7 marks)

Q5 Design a fuzzy logic controller for a control system using the following specifications:

- Each antecedent (for E which is error and DE which is change in error) and consequent (DU) which is change in control input) must have only 3 fuzzy sets: Negative (N), Zero (Z) and Positive (P).
- The membership functions for the two antecedents and one consequent are given as in **Figure 5.**
- Use the Mamdani rule base and discrete Centroid of area (COA) defuzzyfication procedure.

(a) Using engineering common sense, design the most appropriate fuzzy control rules in matrix form for this system.

(3 marks)

(b) Based on the rules developed in **Q5 (a)**, analyze all the rules that would be fired by computing the consequent firing angle for the following cases. Approximate your answer to the nearest 0.1 accuracy for the membership values.

(i) E = -7.0 and DE = 10.0

(5 marks)

(ii) E = -2.0 and DE = 5.0

(8 marks)

(c) Sketch the resultant waveform of the consequenses for **Q5(b)(ii)**

(2 marks)

(d) Calculate the actual output of the fuzzy logic controller based on answer from **Q5(b)(ii)** and **Q5(c)**.

(2 marks)

-END OF QUESTIONS -

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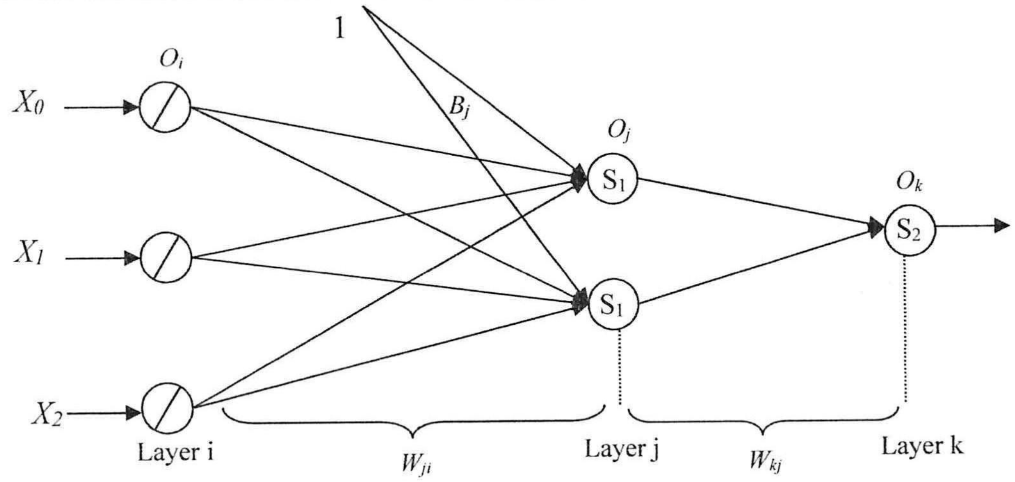
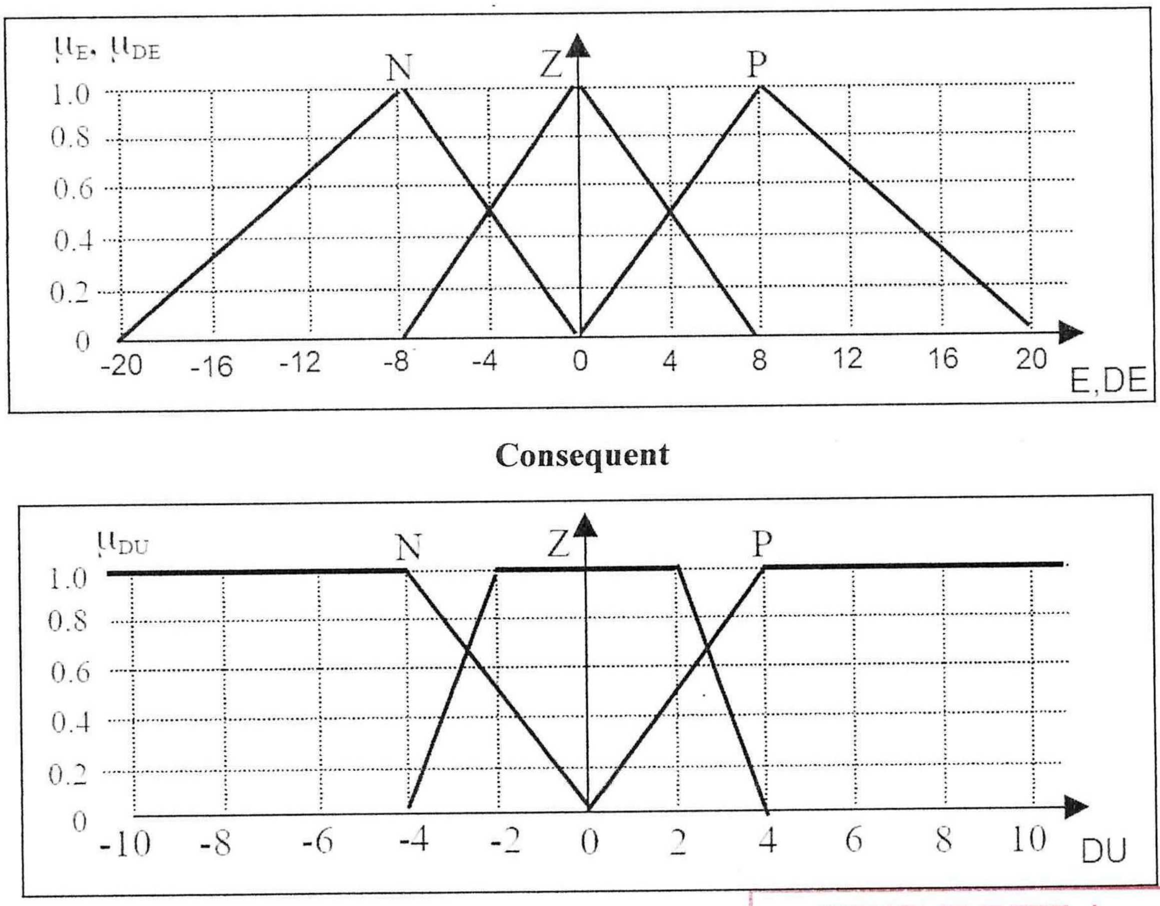


Figure Q2

Antecedents



Consequent

Figure Q5

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FORMULAS

1) Cartesian product

$$\mu_{A_1 x A_2 x A_3 \ldots\ldots An}(x_1, x_2, x_n) = min[\mu_{A_1}(x_1), \mu_{A_2}(x_2), \ldots \mu_{A_n}(x_n)],$$

2) Mamdani Implication

$$(\mu_A(x) \Lambda \mu_B(x))$$

3) Discrete Centroid of Area Method (COA)

$$z_{COA} = \frac{\sum_{j=1}^{n} \mu_A(z_j) z_j}{\sum_{j=1}^{n} \mu_A(z_j)}$$

4) Mamdani Implication Operator

$$\Phi_c[\mu_A(x), \mu_B(y)] \equiv \mu_A(x) \wedge \mu_B(y)$$

5) Backpropogation Chain Rule

$$\Delta W_{KJ} = -n \frac{\partial E}{\partial W_{KJ}}$$

$$\frac{\partial E}{\partial W_{KJ}} = \frac{\partial E}{\partial O_K} \frac{\partial O_K}{\partial NET_K} \frac{\partial NET_K}{\partial W_{KJ}} \text{ Where } \delta_K = \frac{\partial E}{\partial NET_K}$$

$$\Delta W_{JI} = -n \frac{\partial E}{\partial W_{JI}}$$

$$\frac{\partial E}{\partial W_{JI}} = \frac{\partial E}{\partial NET_K} \frac{\partial NET_K}{\partial O_J} \frac{\partial O_J}{\partial NET_J} \frac{\partial NET_J}{\partial W_{JI}} \text{ Where } \delta_J = \frac{\partial E}{\partial NET_J}$$