CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2017/2018

COURSE NAME	:	INTELLIGENT CONTROL SYSTEM
COURSE CODE	:	BEH 41803
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JUNE/JULY 2018
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS

TERBUKA

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

Q1 The output equation for single layer Neural Network with two inputs (X_1 and X_2), a bias (B) and an output (Y) is given below:

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

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 the following sample:

X_2	X_1	Y
0	0	0
1	1	0
2	3	0
1	-1	0
-2	0	1
-1	-1	1
0	-2	1

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

(2 marks)

(b) By using Adaptive Linear Element (*ADALINE*) training framework, analyze the optimal linear decision boundary model after the sample been trained in its first epoch (means that all the patterns have passed through once). Use learning rate, α = 0.5 and the following table for analysis.

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

(21 marks)

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

(2 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 given by:

$$f(net_k) = f(net_j) = \frac{1}{1+e^{-Cnet}}$$

(a) If $C=1$, T_k is the target, n is learning rate, and *net* is the summed input of neuron, derive the equations of weights adaptation (ΔW_{25}, ΔW_{45}, ΔW_{14}, ΔW_{12}, ΔW_{32}, ΔW_{34}) and bias adaptation (ΔB_5, ΔB_2, ΔB_4) between layer if the MLPNN's error model is given by $E=0.5\,(T_k - O_k)^2$. [Note: Ignore the given values during derivation]

(17.5 marks)

(b) If the control input value and target is shown below, analyze the sum square error of the model.

X_1	X_3	T_k
1	1	1
1	-1	1

(7.5 marks)

Q3 (a) In the field of hydrology, the study of rainfall patterns is most important. The rate of rainfall, in units of mm/hour, falling in a particular geographic region could be described linguistically. Defining membership functions for linguistic variables 'heavy' and 'light' as follows:

$$'heavy' = \left\{ \frac{0.2}{5} + \frac{0.4}{8} + \frac{0.6}{12} + \frac{0.8}{20} + \frac{1.0}{30} \right\}$$

$$'light' = \left\{ \frac{1.0}{5} + \frac{0.8}{8} + \frac{0.5}{12} + \frac{0.1}{20} \right\}$$

Analyze the final membership function for the following linguistic phrases:

(i) Plus *light* and not (very *light*).

(4 marks)

(ii) Slightly *light* and not (very *heavy*)

(4 marks)

(iii) (*heavy* + *light*)(*light light*)

(3 marks)

(b) Membership function for *Normal Speed (NS)-km/h* and *Normal Temperature (NT) - ℃* is given in **FigureQ3 (b)** and equation below respectively where x is x is temperature and y is speed.

$$NT(x)=\begin{cases} 0 & \dashrightarrow \text{for } x<0 \\ \dfrac{x}{20} & \dashrightarrow \text{for } 0<x<20 \\ 1 & \dashrightarrow \text{for } 20\le x\le 100 \\ \dfrac{140-x}{40} & \dashrightarrow \text{for } 100<x<140 \\ 0 & \dashrightarrow \text{for } x\ge 140 \end{cases}$$

(i) Determine $M=NT\times NS$ for a values of $x=\{15, 90, 130\}$ and $y=\{25, 60, 115, 125\}$.

(5 marks)

(ii) Determine projection values of M (M^1 and M^2)

(1 mark)

(iii) If the relationship between *NS* and Gear Ration (*GR*) is given in below, analyze the relationship between Normal Temperature (*NT*) and Gear Ratio (*GR*) by using *Max-Min* compositional operator.

NS \ *GR*	1	2	3	4
25	1	0	0	0
60	0	1	0	0
115	0	0	1	0
125	0	0	0	1

(7 marks)

(iv) Determine $M=NT\times$ NS for a values of x = {15, 90, 130} and y = {25, 60, 115, 125}.

(1 mark)

Q4 An engineer needs to design a fuzzy position control system using the following specifications:

- Each antecedent (for E which is error and ΔE which is change in error) and consequent (ΔU which is change in control output) 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 in **Figure Q4**.
- Use the Mamdani rule base and disjunctive aggregator.

(a) With reference to the under damped transient response, design the most appropriate fuzzy control rules in matrix form to solve the positioning problem with minimum of overshoot if *error = input - output*. Give justification for each of the designed rules.

(7 marks)

(b) Based on the rules developed in **Q4(a)**, analyze model of output before Deffuzzification for E=-15.0 and ΔE = 1.0 case.

(8 marks)

(c) Based on answer from **Q4(b)**, determine the crisp value of ΔU using Bisector of Area (BOA) method.

(10 marks)

-END OF QUESTIONS -

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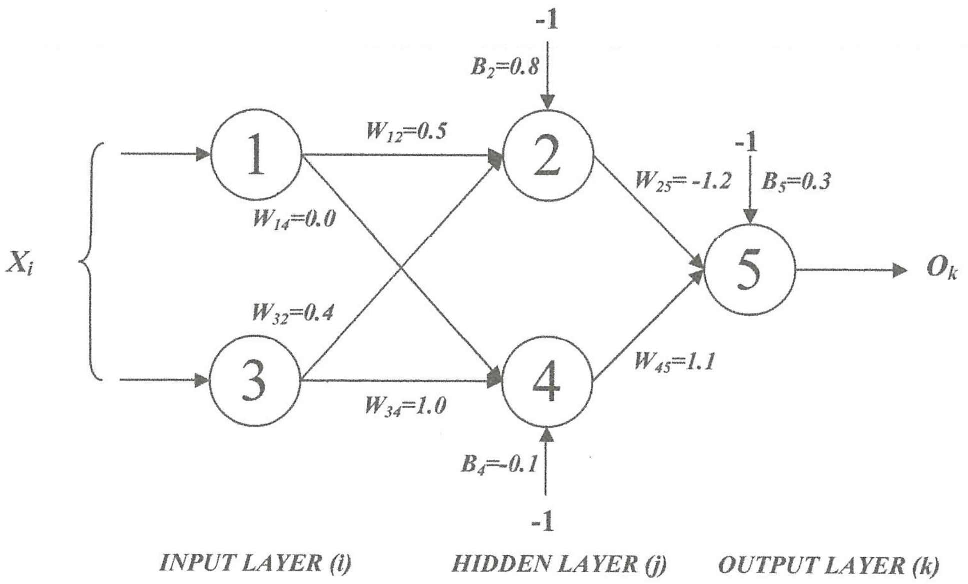

Figure Q2

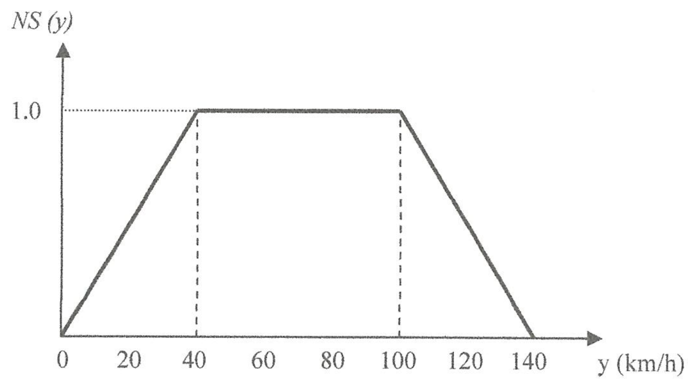

Figure Q3 (b)

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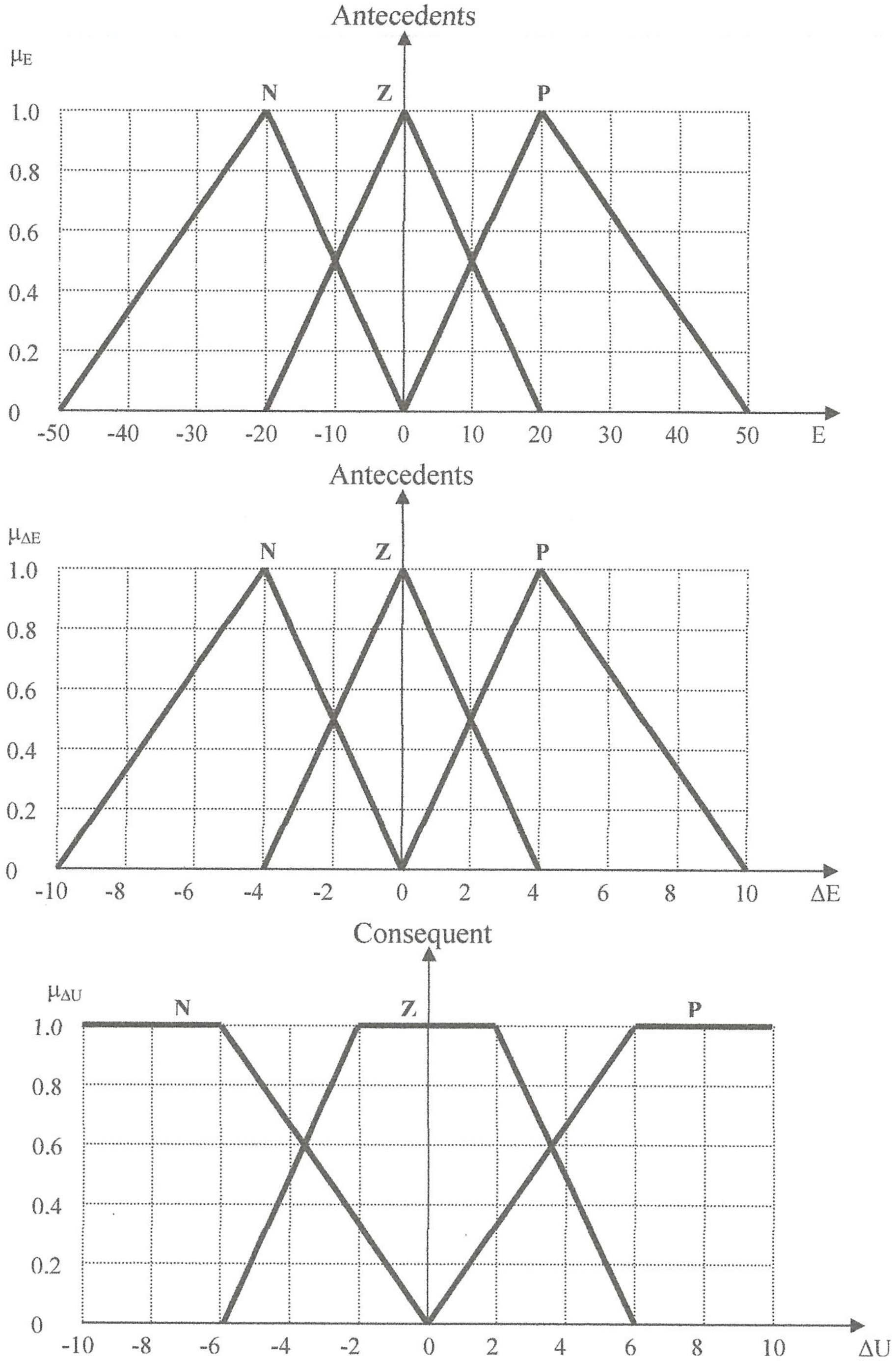

Figure Q4

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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) **Disjunctive Aggregrator**

$$\mu_y(y) = max\left[\mu_{y^1}(y), \mu_{y^2}(y), \cdots, \mu_{y^r}(y)\right]$$

4) **Mamdani Implication Operator**

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

5) **Backpropogation Chain Rule**

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

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

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

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