UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2015/2016

COURSE NAME	:	INTELLIGENT CONTROL SYSTEM
COURSE CODE	:	BEH 41803
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JUNE / JULY 2016
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS ALL QUESTIONS

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

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

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

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	1
0	1	1
1	0	1
1	1	1
0	-1	0
-1	0	0
-1	-1	0

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

(2 marks)

(b) Analyze the network performance after the sample been trained using Perceptron 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**	**S**	**T**	**Y**	**W_1**	**W_2**	**B**
0						1	1	-1
1	0	0		1				
2	0	1		1				
3	1	0		1				
4	1	1		1				
5	0	-1		0				
6	-1	0		0				
7	-1	-1		0				

(14 marks)

(c) From **Q1 (b)**, determine the boundary decision function.

(2 marks)

(d) Three more samples consist of {X_1=2 X_2 = 1 T = 0 ; X_1=1 X_2 = 2 T = 0 ; X_1= -2 X_2 = -1 T = 1 } will be trained together with the previous sample. Analyze either it is possible to train the new sample using the Perceptron algorithm.

(2 marks)

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

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

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

(2 marks)

(b) 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.

(13 marks)

(c) You are required to use a MLPNN model for correcting the distorted depth reading of a wide field of view Kinect camera. To complete the process, you will be given 800 set of data consist of laser and kinect reading from field of view of 57° to 135° obtained from both devices. The laser will be use as the benchmark for correcting the Kinect reading and the error between Kinect and laser is highly nonlinear. Design a procedure to optimally configure the MLPNN for solving the problem with verification by V-fold cross validation framework.

(5 marks)

Q3 (a) Describe the function of relation and projection in fuzzy operation.

(2 marks)

(b) By referring **Figure Q3 (b)**:

(i) Determine membership functions for A, B, and C.

(6 marks)

(ii) If $G = A \cup B \cup C$, construct the membership function of G.

(6 marks)

(c) Suppose we have following two fuzzy sets of Torque (T) and speed (S):

$$T(x) = Torque = \left\{ \,0.3/20 + 0.5/40 + 1.0/60 + 0.8/80 + 0.2/100\, \right\}$$

$$S(y) = Speed = \left\{ \,0.1/250 + 0.3/500 + 0.5/1000 + 1.0/2000\, \right\}$$

(i) Construct the relation for the implication of **IF x is Torque THEN y is Speed** using Mamdani implication.

(4 marks)

(ii) Determine all projection values of the relation constructed in **Q3 (c) (i)**.

(2 marks)

Q4 For a given fuzzy logic system, we have the following nine fuzzy rules:

Rule 1: IF X is *small*	AND Y is *small*	THEN Z is *small*
Rule 2: IF X is *small*	AND Y is *medium*	THEN Z is *small*
Rule 3: IF X is *small*	AND Y is *large*	THEN Z is *medium*
Rule 4: IF X is *medium*	AND Y is *small*	THEN Z is *small*
Rule 5: IF X is *medium*	AND Y is *medium*	THEN Z is *medium*
Rule 6: IF X is *medium*	AND Y is *large*	THEN Z is *medium*
Rule 7: IF X is *large*	AND Y is *small*	THEN Z is *medium*
Rule 8: IF X is *large*	AND Y is *medium*	THEN Z is *medium*
Rule 9: IF X is *large*	AND Y is *large*	THEN Z is *large*

where *small*, *medium* and *large* are fuzzy sets define by:

$$S = small = \left\{ \frac{1}{0} + \frac{1}{1} + \frac{1}{2} + \frac{0.5}{3} + \frac{0}{4} \right\}$$

$$M = medium = \left\{ \frac{0}{2} + \frac{0.5}{3} + \frac{1.0}{4} + \frac{0.5}{5} + \frac{0}{6} \right\}$$

$$L = large = \left\{ \frac{0}{4} + \frac{0.5}{5} + \frac{1.0}{6} + \frac{1.0}{7} \right\}$$

(a) Sketch all the fuzzy sets in one universe of discourse axis.

(2 marks)

(b) If X = 3.5 and Y = 4.5, compose the model output before defuzzification using Mamdani implication relation and disjunctive aggregator.

(10 marks)

(c) Compare the obtained crisp value of Y if it was calculated using Bisector of Area (BOA) method and discrete Centroid of Area (COA) with sample only integer universe of discourse values for **Q4 (b)**.

(8 marks)

Q5 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 already given in **Figure Q5**.

- Use the Mamdani rule base, disjunctive aggregator and discrete centroid of area (COA) defuzzyfication procedure.

(a) Using engineering common sense, design the most appropriate fuzzy control rules in matrix form to solve the positioning problem with minimum of overshoot.

(4 marks)

(b) Based on the rules developed in **Q5 (a)**, analyze all the rules that would be fired by computing the consequent firing angle using triangulation for the following cases. (Note: Your answer should be in triple form as follows [for example (*N, N; Z*), $\mu_{\Delta U}$ = 0.3]. Also approximate your answer to the nearest 0.1 accuracy for the membership values.)

(i). E = 30.0 and ΔE = 40.0

(2.5 marks)

(ii). E = 10.0 and ΔE = 20.0

(4 marks)

(iii). E = -5.0 and ΔE = -10.0

(6 marks)

(c) For the case of **Q5 (b) (iii)**, sketch the resultant waveform of the consequents and calculate the actual output of the fuzzy controller using a discrete sample of 1 for the universe of discourse.

(3.5 marks)

-END OF QUESTIONS –

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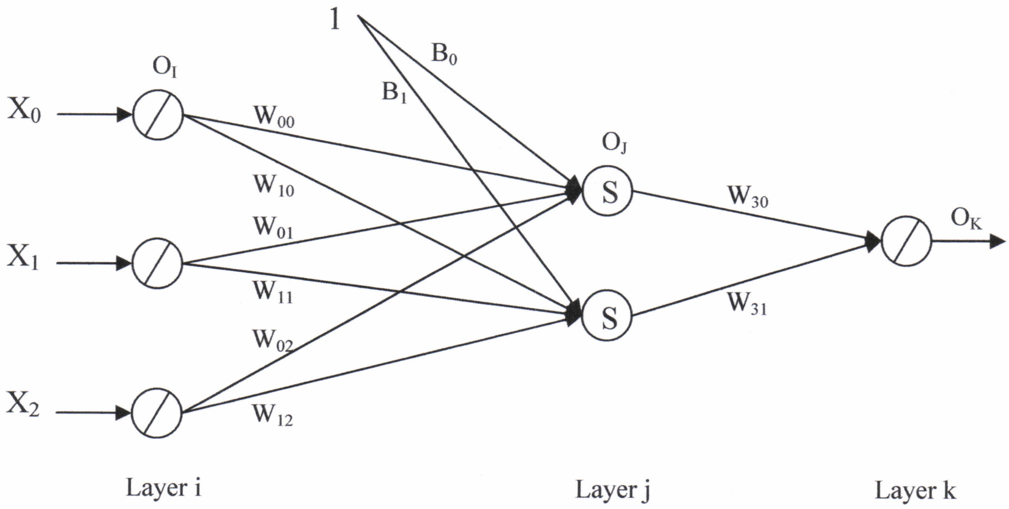

Figure Q2

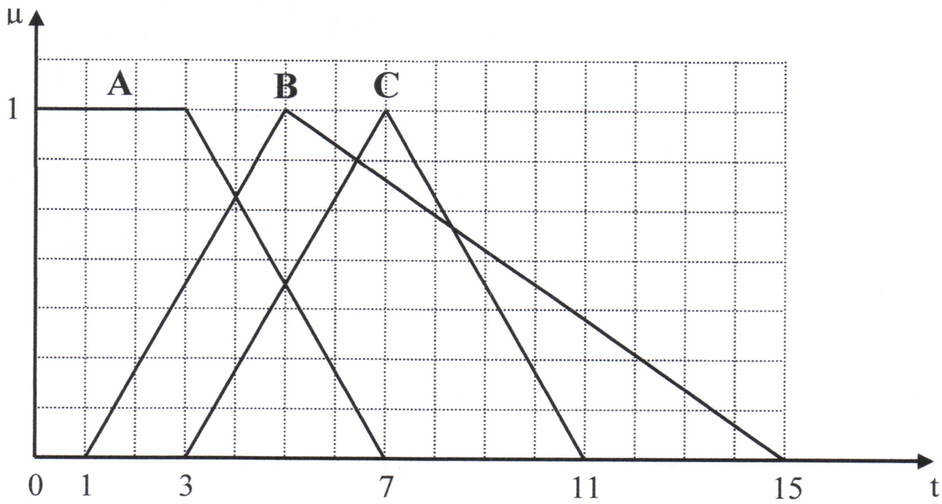

Figure Q3(b)

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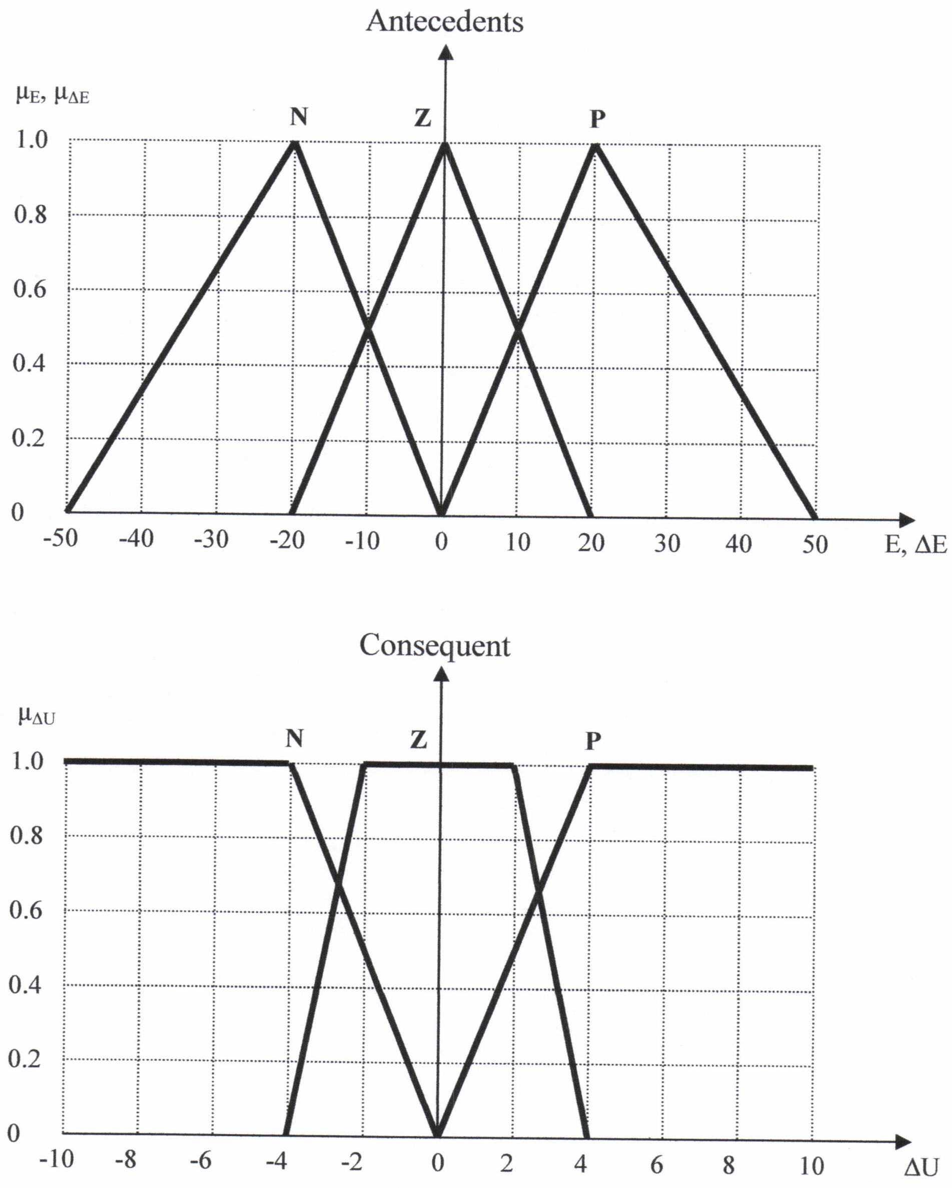

Figure Q5

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FORMULAS

1) Cartesian product

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

2) Mamdani Implication

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

3) Disjunctive Aggregrator

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

4) Discrete Centroid of Area Method (COA)

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

5) Mamdani Implication Operator

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

6) Backpropogation Derivation Chain Rule

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

$$\Delta B_K = -n \frac{\partial E}{\partial B_K}$$

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

$$\frac{\partial E}{\partial B_K} = \frac{\partial E}{\partial NET_K} \frac{\partial NET_K}{\partial B_K}$$

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

$$\Delta BJ = -n \frac{\partial E}{\partial B_J}$$

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

$$\frac{\partial E}{\partial B_J} = \frac{\partial E}{\partial NET_J} \frac{\partial NET_J}{\partial B_J}$$