CONFIDENTIAL

Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	INTELLIGENT CONTROL SYSTEMS
COURSE CODE	:	BEH 41803
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	DECEMBER 2018/ JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ALL QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

CONFIDENTIAL

Q1 For a fuzzy logic based air conditioner system that consists of two inputs (target temperature (*TT*), current temperature (*CT*)) and one output (temperature adjustment (*TA*)), we have the following nine fuzzy rules:

Rule 1: IF *TT* is *cold* AND *CT* is *cold* THEN *TA* is *maintain*
Rule 2: IF *TT* is *cold* AND *CT* is *medium* THEN *TA* is *low*
Rule 3: IF *TT* is *cold* AND *CT* is *warm* THEN *TA* is *low*
Rule 4: IF *TT* is *medium* AND *CT* is *cold* THEN *TA* is *high*
Rule 5: IF *TT* is *medium* AND *CT* is *medium* THEN *TA* is *maintain*
Rule 6: IF *TT* is *medium* AND *CT* is *warm* THEN *TA* is *high*
Rule 7: IF *TT* is *warm* AND *CT* is *cold* THEN *TA* is *maintain*
Rule 8: IF *TT* is *warm* AND *CT* is *medium* THEN *TA* is *high*
Rule 9: IF *TT* is *warm* AND *CT* is *warm* THEN *TA* is *maintain*

where *cold, medium, warm, maintain, low* and *high* is given by:

$$C = cold = \left\{ \frac{1}{15} + \frac{0.5}{19} + \frac{0}{23} \right\} \qquad L = low = \left\{ \frac{0}{-7} + \frac{1}{-4} + \frac{0}{0} \right\}$$

$$M = medium = \left\{ \frac{0}{20} + \frac{1}{23} + \frac{0}{26} \right\} \qquad Mt = maintain = \left\{ \frac{0}{-4} + \frac{1}{0} + \frac{0}{4} \right\}$$

$$W = warm = \left\{ \frac{0}{23} + \frac{0.5}{26} + \frac{1}{29} \right\} \qquad H = high = \left\{ \frac{0}{0} + \frac{1}{4} + \frac{1}{7} \right\}$$

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

(4.5 marks)

(b) If universe of discourse of the output is set from -7 to 7, *TT* = *24* and *CT* = *18*, investigate the model output before defuzzification using Mamdani implication relation and disjunctive aggregator.

(7.5 marks)

(c) Determine the crisp value of *TA* from the composed model in **Q1 (b)** using

(i) Bisector of Area (BOA) method. (5.5 marks)

(ii) Center of Area (COA) method.

(2.5 marks)

Q2 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 Q2**.
- 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 if *error = input - output* .

(5 marks)

(b) Based on the rules developed in **Q2 (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), $\mu_{\Delta U}$ = 0.2]. Also approximate your answer to the nearest 0.1 accuracy for the membership values.)

(i) $E = 60.0$ and $\Delta E = 80.0$

(2.5 marks)

(ii) $E = 10.0$ and $\Delta E = 40.0$

(4.5 marks)

(iii) $E = -10.0$ and $\Delta E = -30.0$

(8 marks)

Q3 (a) Let X={ Shah, Awie, Amy}, Y={ y_1, y_2, y_3, y_4 }={theory, application, hardware, programming}, and Z={Math (M), Science (S), History (H), Geography (G)}. Assume the student's interest is represented by fuzzy relation $P(X,Y)$:

$$P(X,Y) = \begin{array}{c} \\ \text{Shah} \\ \text{Awie} \\ \text{Amy} \end{array} \begin{array}{c} \begin{array}{cccc} y_1 & y_2 & y_3 & y_4 \end{array} \\ \begin{pmatrix} 0.2 & 1 & 0.8 & 0.1 \\ 1 & 0.1 & 0 & 0.5 \\ 0.5 & 0.9 & 0.5 & 1 \end{pmatrix} \end{array}$$

The properties of the courses are indicated by the fuzzy relation $Q(Y,Z)$:

$$Q(Y,Z) = \begin{array}{c} \\ y_1 \\ y_2 \\ y_3 \\ y_4 \end{array} \begin{array}{c} \begin{array}{cccc} M & S & H & G \end{array} \\ \begin{pmatrix} 1 & 0.5 & 0.6 & 0.1 \\ 0.2 & 1 & 0.8 & 0.8 \\ 0 & 0.3 & 0.7 & 0 \\ 0.1 & 0.5 & 0.8 & 1 \end{pmatrix} \end{array}$$

(i) Analyze the most favorite subject for Shah, Awie and Amy by using max-min composition.

(4 marks)

(i) Determine the least favorite subject for Shah, Awie and Amy by using max-product composition.

(4 marks)

(b) Suppose we have following two fuzzy sets of Torque (T) and speed (S). The Universe for $x = \{20, 40, 60, 80, 100\}$ and $y = \{250, 500, 750, 1000\}$. Construct the relation for the implication of **IF x is Torque THEN y is Speed** using :

$$T(x) = Torque = \left\{ {0.3}/{20} + {0.6}/{60} + {0.5}/{80} + {0.2}/{100} \right\}$$

$$S(y) = Speed = \left\{ {0.1}/{250} + {0.3}/{500} + {0.5}/{750} + {0.2}/{1000} \right\}$$

(i) Mamdani implication. (4 marks)

(ii) Zadeh implication. (4 marks)

(iii) Based on answer from **Q3(b)(ii)**, find the new consequent S'(y) if there is a new antecedent T'(x) as

$$T'(x) = \left\{ {0.4}/{20} + {1}/{80} + {0.6}/{100} \right\}$$

(4 marks)

Q4 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
1	1	1
1	0	1
0	1	1
0	0	0
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 learning algorithm in its first epoch (means that all the patterns have passed through once). Use learning rate, $\alpha = 0.1$ and the following table for the analysis.

Iter	X_1	X_2	T	S	Y	W_1	W_2	B
0						0.9	0.9	-0.1
1	1	1	1					
2	1	0	1					
3	0	1	1					
4	0	0	0					
5	0	-1	0					
6	-1	0	0					
7	-1	-1	0					

(14.5 marks)

(c) From **Q4 (b)**, construct the boundary decision function in the scatter plot of **Q4 (a)**.

(3.5 marks)

Q5 The Multi-layer Perceptron Neural Network (MLPNN) configuration which is to be trained using the backpropagation algorithm is shown in **Figure Q5**. All neurons in layers i have linear activation functions, and all neurons in layer j and layer k have tangent sigmoid and sigmoid activation functions respectively given by:

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

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

(2 marks)

(b) If C =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) You are required to construct a MLPNN controller for correcting the distorted depth reading of a wide field of view Kinect camera. To complete the process, you will be given 1800 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.

(4 marks)

-END OF QUESTIONS –

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2018/2019 PROGRAMME CODE : BEJ
COURSE NAME : INTELLIGENT CONTROL SYSTEMS COURSE CODE : BEH 41803

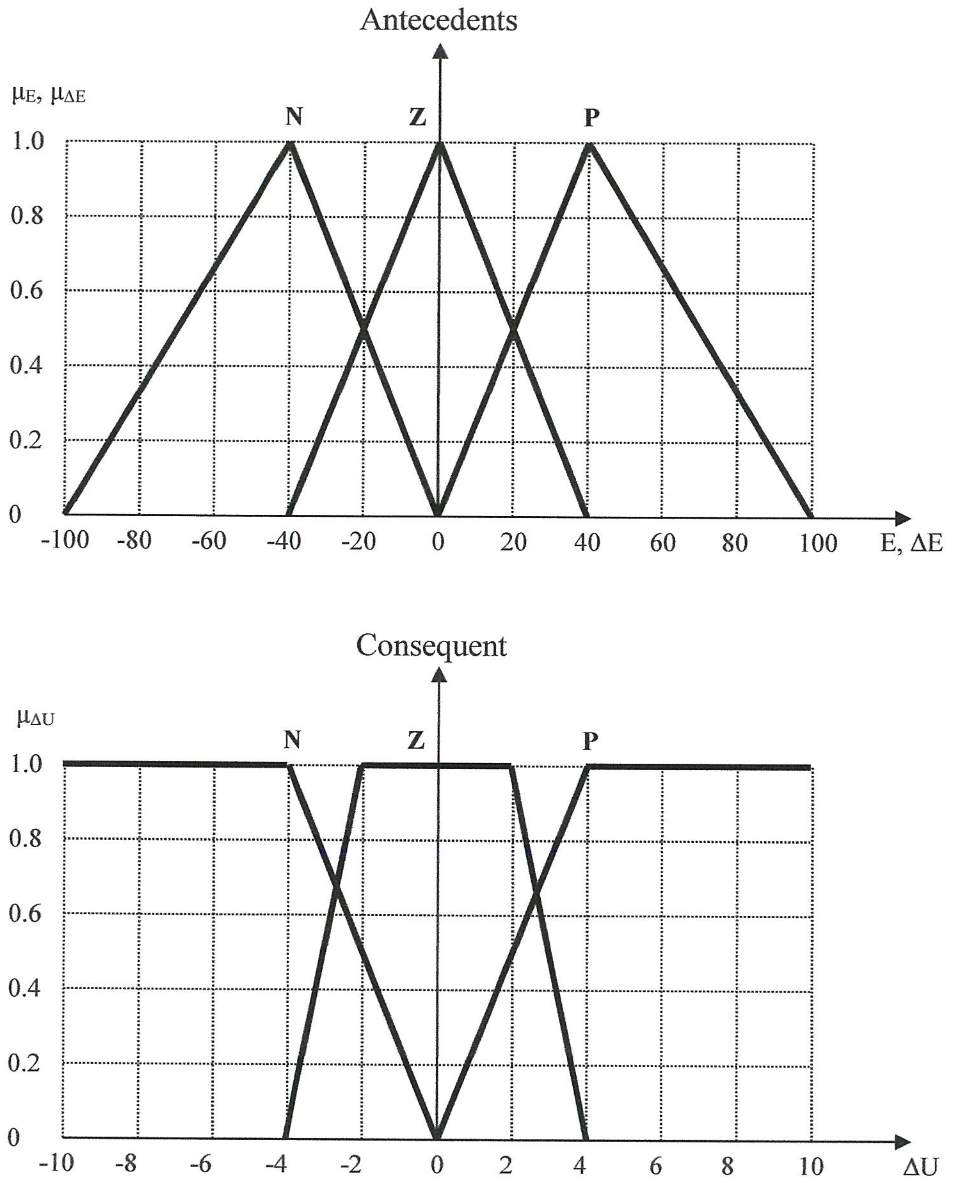

Figure Q2

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2018/2019 PROGRAMME CODE : BEJ
COURSE NAME : INTELLIGENT CONTROL,SYSTEMS COURSE CODE : BEH 41803

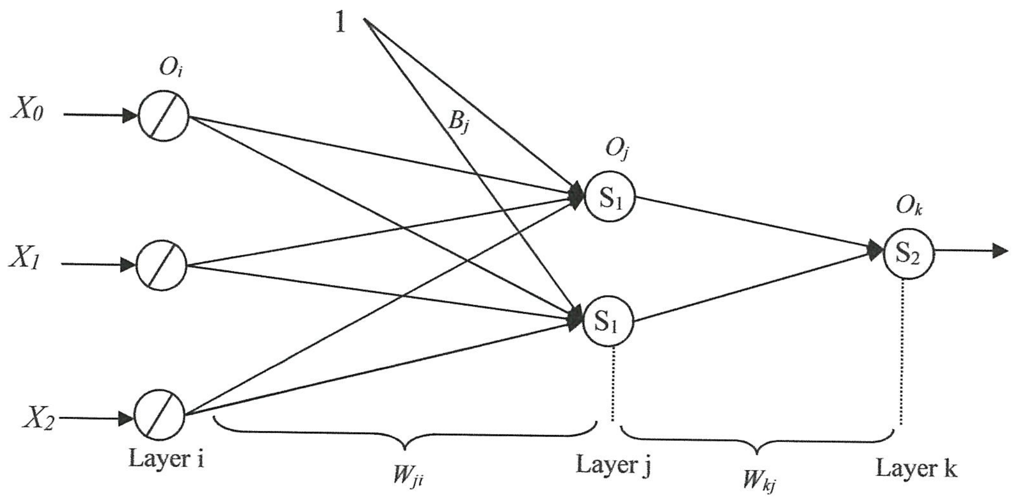

Figure Q5

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2018/2019
COURSE NAME : INTELLIGENT CONTROL SYSTEMS
PROGRAMME CODE : BEJ
COURSE CODE : BEH 41803

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) 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 Chain Rule

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

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

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

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