UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2010/11

COURSE	: FUZZY CONTROL SYSTEM
COURSE CODE	: BER4233
PROGRAMME	: 4 BER
EXAMINATION DATE	: APRIL/ MEI 2011
DURATION	: 2 HOURS 30 MINUTES
INSTRUCTION	: ANSWER **FOUR (4)** QUESTIONS ONLY

THIS PAPER CONSISTS OF NINE (9) PAGES

Q1 (a) Give definition for the following terms.

(i) Fuzzy singleton
(ii) Normalization.

(2 marks)

(b) (i) Draw the fuzzy control system block diagram
(ii) Explain each element of fuzzy control system block diagram

(12 marks)

(c) Develop the reasonable membership function for fuzzy sets and draw the following sets based on measurement in centimetres based on Table Q1(c)

(i) "Tall"
(ii) "Slightly Tall"
(iii) " Average"
(iv) "Short"
(v) " Not Short"

(11 marks)

Q2 The three variables of interest in the MOSFET are the amount of current that can be switched, the voltage that can be switched and the cost. The following membership function for the transistor was developed

$$\text{Current} = \text{I} = \left\{\frac{0.4}{0.8}+\frac{0.7}{0.9}+\frac{1}{1}+\frac{0.8}{1.1}+\frac{0.6}{1.2}\right\}$$

$$\text{Voltage} = \text{V} = \left\{\frac{0.2}{30}+\frac{0.8}{45}+\frac{1}{60}+\frac{0.9}{75}+\frac{0.7}{90}\right\}$$

$$\text{Cost} = \text{C} = \left\{\frac{0.4}{0.5}+\frac{1}{0.6}+\frac{0.5}{0.7}\right\}$$

(a) Find the fuzzy Cartesian product

(i) $P = V_{5x1} \;\; X \;\; I_{1x5}$
(ii) $T = I_{5x1} \;\; X \;\; C_{1x3}$

(6 marks)

(b) Find $E = P_{5x5} \circ T_{5x3}$ using

(i) max – min composition,
(ii) max – product composition.

(8 marks)

(c) Use a boolean implication to find the relation IF x is Voltage, THEN y is Cost.
(6 marks)

(d) Use a Larsen implication to find the relation IF x is Voltage, THEN y is Cost
(5 marks)

Q3 An automobile cruise control system contains of two input variables and one output variable. The input variables are speed and angle of inclination of the road, and the output variable is the throttle position. Let speed $\upsilon = 0\ to \dfrac{100km}{h}$, incline $(\theta = -10^o\ to + 10^o)$, and throttle $(T = 0\ to + 10)$. The membership functions are shown in Figure Q3 and the correlation between $\upsilon, \theta\ and\ T$ are given in Table Q3.

(a) Determine membership functions for input and output parameters are shown in Figure Q3.
(7 marks)

(b) By referring to Figure Q3 and Table Q3,

(i) Produce the possible firing rule when $\upsilon = 52\dfrac{km}{h}$ and $(\theta = -1^o)$

(ii) Sketch the model output before defuzzification using Mandani implication relation and disjunctive $\cup$ aggregator.
(8 marks)

(c) Calculate the crisp value of T for Q3(b) by using mean of maximum (MOM) method.
(4 marks)

(d) Calculate the crisp value of T for Q3(b) by using Discrete Centroid of Area (COA) method.
(4 marks)

(e) Evaluate which method giving the best result for the systems
(2 marks)

Q4 Design a system using a fuzzy control system for an electric kettle where this system is equipped with a temperature sensor and a heater element.

(a) Propose appropriate fuzzy set and their membership function.
(6 marks)

(b) Propose a rules table for this system.
(4 marks)

(c) Explain each of the propose rules
(3 marks)

(d) By selecting a possible firing value, sketch the model output using Larsen implication relation and disjunctive aggregator before defuzzification.

(8 marks)

(e) Determine the crisp value of defuzzification using:
(i) Mean of Maximum method (MOM).
(ii) Largest of Maximum method (LOM).

(4 marks)

Q5 For a given fuzzy logic system, the following three fuzzy rules are applied:

Rule 1: IF X is *A1 and Y is B1* THEN Z is *C1*

Rule 2: IF X is *A2 and Y is B2* THEN Z is *C2*

Rule 3: IF X is *A3 and Y is B3* THEN Z is *C3*

Suppose X_0 and Y_0 are the sensor readings for fuzzy variables X and Y and the following input and output membership functions are given:

$$\mu_{A1}(x)=\begin{cases}\dfrac{3+x}{3} & -3\le x\le 0\\ 1 & 0\le x\le 3\\ \dfrac{6-x}{3} & 3\le x\le 6\end{cases}\quad \mu_{A2}(x)=\begin{cases}\dfrac{x-2}{3} & 2\le x\le 5\\ \dfrac{9-x}{4} & 5\le x\le 9\end{cases}\quad \mu_{A3}(x)=\begin{cases}\dfrac{x-6}{4} & 6\le x\le 10\\ \dfrac{13-x}{3} & 10\le x\le 13\end{cases}$$

$$\mu_{B1}(y)=\begin{cases}\dfrac{y-1}{4} & 1\le y\le 5\\ \dfrac{7-y}{2} & 5\le y\le 7\end{cases}\quad \mu_{B2}(y)=\begin{cases}\dfrac{y-5}{3} & 5\le y\le 8\\ \dfrac{12-y}{4} & 8\le y\le 12\end{cases}\quad \mu_{B3}(y)=\begin{cases}\dfrac{y-8}{4} & 8\le y\le 12\\ \dfrac{15-y}{3} & 12\le y\le 15\end{cases}$$

$$\mu_{c1}(z)=\begin{cases}\dfrac{3+z}{2} & -3\le z\le -1\\ 1 & -1\le z\le 1\\ \dfrac{3-z}{2} & 1\le z\le 3\end{cases}\quad \mu_{c2}(z)=\begin{cases}\dfrac{z-1}{3} & 1\le x\le 4\\ \dfrac{7-z}{3} & 4\le z\le 7\end{cases}\quad \mu_{c3}(z)=\begin{cases}\dfrac{z-5}{2} & 5\le z\le 7\\ 1 & 7\le z\le 9\\ \dfrac{11-z}{2} & 9\le z\le 11\end{cases}$$

Assume that X,Y and Z are discrete fuzzy sets, that is x,y,z = 1,2,3,….If the sensor output values are $X_0 = 7$ and $Y_0 = 10$, do the following:

(a) By using Mamdani operator, determine the resultant control action

(4 marks)

(b) Produce a sketch of resultant output for the membership function

(11 marks)

(c) Determine the crisp value of defuzzification using
(i) Mean of maximum (MOM) (5 marks)
(ii) Centre of area (COA) (5 marks)

Q6 A transient response of a fuzzy position control system with step input is shown in Figure Q6. The system consist of two antecedents (E which is error and ΔE which is the change in error) and one consequent (ΔU which is change in control output) and each of these parameters only have 3 fuzzy sets which are Negative (N), Zero(Z) and Positive (P).

(a) By referring to Figure Q6, label region that meet the following condition and give explanation why the region is choosen.

(i) E=P and ΔE=P
(ii) E=P and ΔE=N
(iii) E=N and ΔE=P
(iv) E=N and ΔE=N

(6 marks)

(b) By using engineering common sense, recommend nine rules for controlling ΔU with respect to the E and ΔE. Use region labeled in Q6(a) as a reference. Please give a clear justification for each of the develop rule.

(13.5 marks)

(c) If the membership function for E consist of trapezoid shape for N and P , and Triangle shape for Z.

(i) Produce suitable universe of discourse values for 100% membership of N,Z and P.
(ii) Explain why do you select the values.

(2.5 marks)

(d) By assuming the membership functions of ΔE and ΔU have the same shape with E. Produce a sketch of membership function if universe discourse value of ΔE and ΔU is 10% and 30% from universe discourse of E.

(3 marks)

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TABLE Q1(c)

Name	Height,cm
Boon Yong	208
Chia yeak	205
Afif	198
Saiful	181
Eric	179
Rui Jia	172
Wei Pin	167
Maryam	158
Shazanee	155
Zulhilmi	152

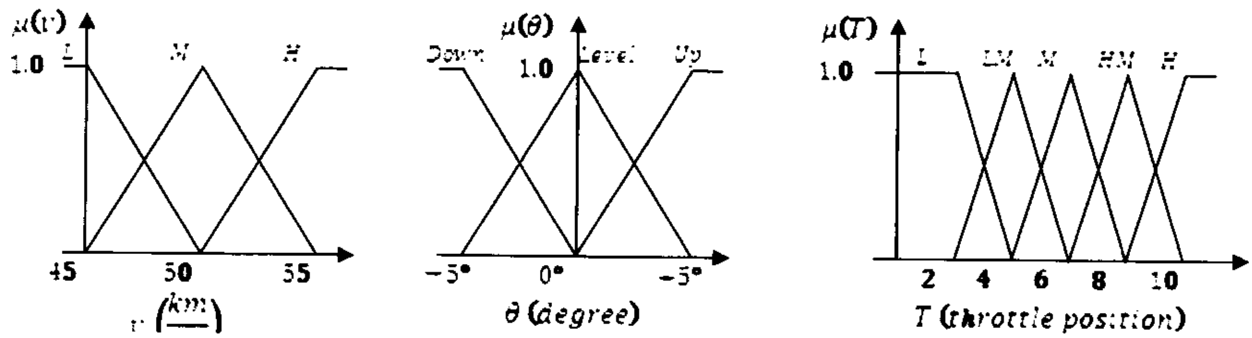

FIGURE Q3

TABLE Q3

	Inclination of the road		
Speed	Down	Level	Up
L	HM	HM	H
M	LM	M	HM
H	L	LM	LM

note: L (low), M (Medium), H (High)

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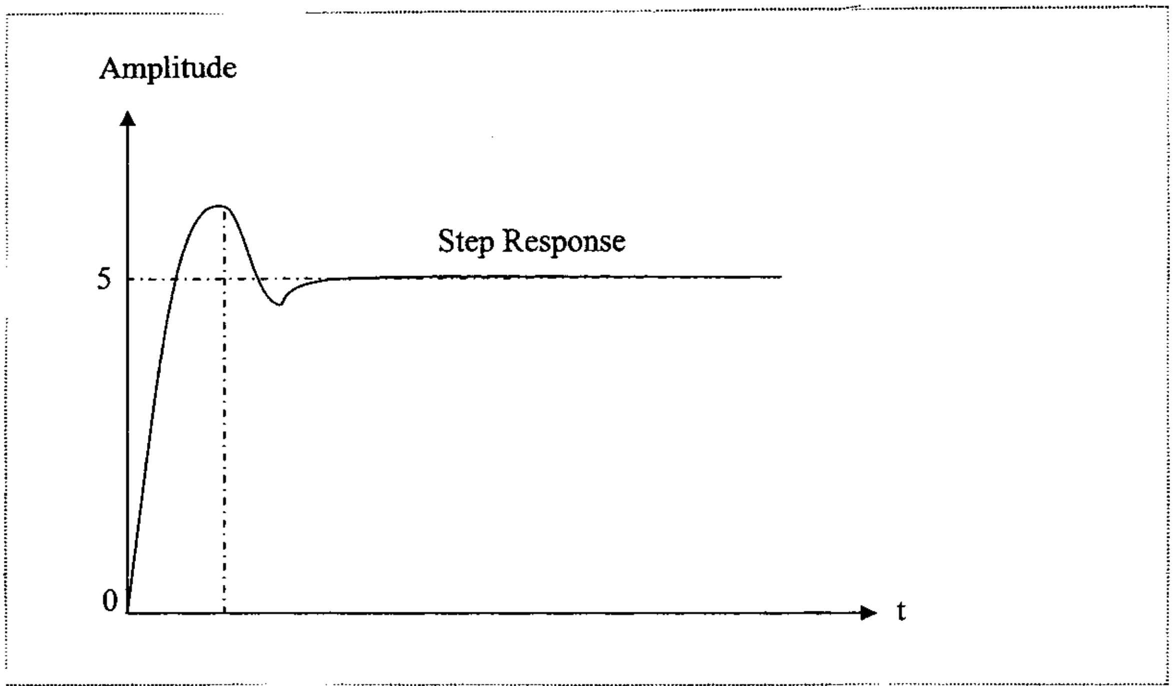

FIGURE Q6

APPENDIX 1

FUZZY OPERATORS

No	Operation	Membership Function
1	Union (Max)	$\mu_{A\cup B}(x) \equiv \mu_A(x) \vee \mu_B(x) = max(\mu_A(x), \mu_B(x))$
2	Intersection (Min)	$\mu_{A\cap B}(x) \equiv \mu_A(x) \wedge \mu_B(x) = min(\mu_A(x), \mu_B(x))$
3	Complement	$\mu_{\bar{A}}(x) \equiv 1 - \mu_A(x)$
4	Algebraic Product	$\mu_{A\cdot B}(x) \equiv \mu_A(x) \cdot \mu_B(x)$
5	Multiplying by a Crisp Number	$\mu_{a\cdot A}(x) \equiv a \cdot \mu_A(x)$
6	Algebraic Sum	$\mu_{A+B}(x) \equiv \mu_A(x) + \mu_B(x) - (\mu_A(x) \cdot \mu_B(x))$
7	Bounded Product	$\mu_{A\ominus B}(x) \equiv max(0, (\mu_A(x) + \mu_B(x) - 1))$
8	Bounded Sum	$\mu_{A\oplus B}(x) \equiv min(1, (\mu_A(x) + \mu_B(x)))$
9	Drastic Product	$\mu_{A\bullet B}(x) = \begin{cases} \mu_A(x), & for\ \mu_B(x) = 1 \\ \mu_B(x), & \mathbf{for}\ \mu_A(x) = 1 \\ 0, & \mathbf{for}\ \mu_A(x), \mu_B(x) < 1 \end{cases}$
10	Power	$\mu_{A^\alpha}(x) \equiv [\mu_A(x)]^\alpha$
11	Concentration	$\mu_{A^2}(x) \equiv \mu_{CON(A)}(x) = [\mu_A(x)]^2$
12	Dilatation	$\mu_{A^{\frac{1}{2}}}(x) \equiv \mu_{DIL(A)}(x) = \sqrt{\mu_A(x)}$
13	Contrast Intensification	$\mu_{INT(A)}(x) = \begin{cases} 2[\mu_A(x)]^2, & \mathbf{for}\ 0 \le \mu_A(x) \le 0.5 \\ 1 - 2[1 - \mu_A(x)]^2, & \mathbf{for}\ 0.5 \le \mu_A(x) \le 1 \end{cases}$

LINGUISTIC HEDGES AND OPERATORS

No	Hedge	Operator Definition
1	Very F	$CON = F^2$
2	More or Less F	$DIL = F^{0.5}$
3	Plus F	$F^{1.25}$
4	Not F	$1 - F$
5	Not Very F	$1 - F^2$
6	Slightly F	$INT[Plus\ F\ AND\ Not\ Very\ F]$

APPENDIX 2

FUZZY RELATIONS

No	Operation	Membership Function
1	Cartesian Product	$\mu_R(x,y) = \mu_{A \times B}(x,y) = \min(\mu_A(x), \mu_B(y))$
2	Union	$\mu_{R_1 \cup R_2}(x,y) \equiv \mu_{R_1}(x,y) \vee \mu_{R_2}(x,y)$
3	Intersection	$\mu_{R_1 \cap R_2}(x,y) \equiv \mu_{R_1}(x,y) \wedge \mu_{R_2}(x,y)$
4	First Projection	$\mu_{R^1}(x) \equiv \bigvee_y [\mu_R(x,y)]$
5	Second Projection	$\mu_{R^2}(y) \equiv \bigvee_x [\mu_R(x,y)]$
6	Total Projection	$\mu_{R^T}(x) \equiv \bigvee_y \bigvee_y [\mu_R(x,y)]$
7	Compositional max – fuzzy operator	$\max\{\textbf{fuzzy operator}\}$

FUZZY IMPLICATION OPERATORS

No	Operation	Relation and Membership Function Operation
1	Zadeh	$R = (A \times B) \cup (\bar{A} \times Y)$ $\Phi_m[\mu_A(x), \mu_B(y)] \equiv (\mu_A(x) \wedge \mu_B(y)) \vee (1 - \mu_A(x))$
2	Mamdani	$R = (A \times B)$ $\Phi_c[\mu_A(x), \mu_B(y)] \equiv \mu_A(x) \wedge \mu_B(y)$
3	Larsen	$R = (A \times B)$ $\Phi_p[\mu_A(x), \mu_B(y)] \equiv \mu_A(x) \cdot \mu_B(y)$
4.	Boolean	$\Phi_b[\mu_A(x), \mu_B(y)] \equiv (1 - \mu_A(x)) \wedge \mu_B(y)$