UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2010/11

COURSE	: FUZZY CONTROL SYSTEM
COURSE CODE	: BER4233
PROGRAMME	: 4 BEE
EXAMINATION DATE	: NOVEMBER/DECEMBER 2010
DURATION	: 3 HOURS
INSTRUCTION	: ANSWER ALL QUESTIONS

THIS PAPER CONSISTS OF SEVEN (7) PAGES

Q1 (a) Based on your knowledge, give definition for the following terms in fuzzy set.

(i) Membership Function,

(ii) Normalization.

(4 marks)

(b) Samples of new microprocessors IC chip are to be sent to several customers for beta testing. The chips are sorted to meet certain maximum electrical characteristics say frequency, and temperature rating, so that the "best" chips are distributed to preferred customer 1. Suppose that each sample chip is screened and all chips are found to have a maximum operating frequency in the range 7–15MHz at 20°C. Also the maximum operating temperature range (20°C± ΔT) at 8MHz is determined. Suppose there are eight sample chips with the following electrical characteristics:

Chip Number	1	2	3	4	5	6	7	8
f_{max} (MHz)	6	7	8	9	10	11	12	13
ΔT_{max} (°C)	0	0	20	40	30	50	40	60

The following fuzzy sets are defined.

Set of "Fast" chips = chips with $f_{max} \geq 12$ MHz

$$A = \left\{\frac{0}{1} + \frac{0}{2} + \frac{0.1}{3} + \frac{0.1}{4} + \frac{0.2}{5} + \frac{0.8}{6} + \frac{1}{7} + \frac{1}{8}\right\}$$

Set of "Fast" chips = chips with $f_{max} \geq 8$ MHz

$$B = \left\{\frac{0.1}{1} + \frac{0.5}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} + \frac{1}{6} + \frac{1}{7} + \frac{1}{8}\right\}$$

Set of "Fast" chips = chips with $T_{max} \geq 10$°C

$$C = \left\{\frac{0}{1} + \frac{0}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} + \frac{1}{6} + \frac{1}{7} + \frac{1}{8}\right\}$$

Set of "Fast" chips = chips with $T_{max} \geq 50$°C

$$D = \left\{\frac{0}{1} + \frac{0.6}{2} + \frac{0.1}{3} + \frac{0.2}{4} + \frac{0.5}{5} + \frac{0.1}{6} + \frac{1}{7} + \frac{1}{8}\right\}$$

Then find the following

(i) $(\overline{A} + D) \otimes \overline{A \oplus C}$

(ii) $CON(B) \cup DIL\,(D)$

(iii) $INT(CON(B) \cup DIL\,(D)) \Theta\,(B \cap C)$

(16 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

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

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

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

(a) Find the fuzzy Cartesian product
   (i) $P = V_{5\times1} \times I_{1\times5}$
   (ii) $T = I_{5\times1} \times C_{1\times3}$

(6 marks)

(b) Find $E = P_{5\times5} \circ T_{5\times3}$ using
   (i) max – min composition,
   (ii) max – algebraic sum composition.

(8 marks)

(c) Use a *Larsen implication* to find the relation IF x is $Voltage$, THEN y is $Cost$.

(6 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 ($v = 0\ to\ 100 km/h$), incline ($\theta = -10°\ to + 10°$), and throttle ($T = 0\ to\ 10$). The membership functions are shown in Figure Q3 and the correlation between v, θ, and T is 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 $v = 52\ km/h$ and $\theta = -1°$.
   (ii) Sketch the model output before defuzzification using *Mamdani implication* relation and *disjunctive* (∪) *aggregator*.

(8 marks)

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

(5 marks)

Q4 (a) Explain the steps in designing a simple fuzzy control sytem.

(5 marks)

(b) Sketch a simple fuzzy logic control system block diagram.

(5 marks)

(c) PD-like fuzzy controller is used to control a speed of DC motor.

(i) List the typical inputs and outputs of PD-like fuzzy controller.

(ii) Fill in empty places of Table Q4(c) for PD-like fuzzy controller rules.

(10 marks)

Q5 An electric kettle is controlled by fuzzy logic controller. It has a temperature sensor and a heater element.

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

(6 marks)

(b) Create a rules table for this system.

(4 marks)

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

(8 marks)

(d) Determine the crisp value of defuzzification using:

(i) Smallest of Maximum method (SOM).

(ii) Largest of Maximum method (LOM).

(2 marks)

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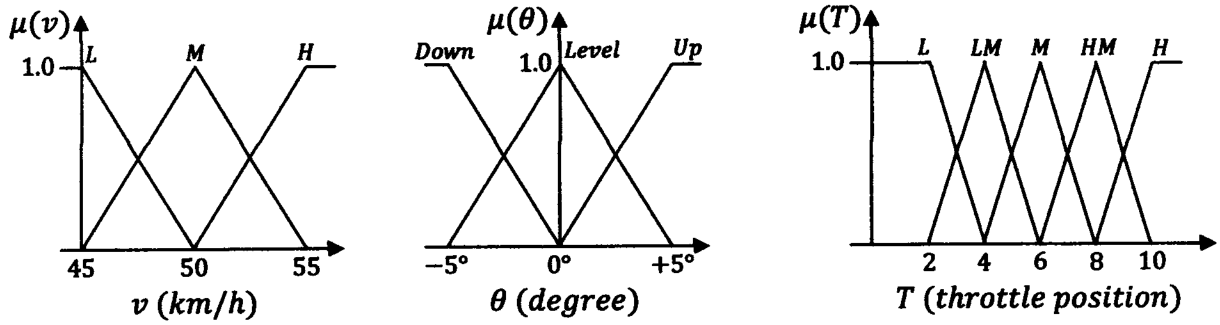

Figure Q3

Table Q3

[redacted]	[redacted]		
	Down	**Level**	**Up**
L	HM	HM	H
M	LM	M	HM
H	L	LM	LM

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

Table Q4(c)

Δe \ e	**NB**	**NM**	**NS**	**Z**	**PS**	**PM**	**PB**
NB		NB				NS	Z
NM							
NS	NS			Z			
Z					Z		
PS			Z				PS
PM		Z			PM		
PB	Z			PS			PB

APPENDIX 1

FUZZY OPERATORS

No	Operation	Membership Function
1	Union (Max)	$\mu_{A\cup B}(x) \equiv \mu_A(x) \vee \mu_B(x) \equiv max(\mu_A(x), \mu_B(x))$
2	Intersection (Min)	$\mu_{A\cap B}(x) \equiv \mu_A(x) \wedge \mu_B(x) \equiv min(\mu_A(x), \mu_B(x))$
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	$\mu_{A\oplus B}(x) \equiv min\left(1, (\mu_A(x) + \mu_B(x))\right)$
9	Drastic Product	$\mu_{A\otimes B}(x) \equiv \begin{cases} \mu_A(x), & for\ \mu_B(x) = 1 \\ \mu_B(x), & \text{for } \mu_A(x) = 1 \\ 0, & \text{for } \mu_A(x), \mu_B(x) < 1 \end{cases}$
10	Power	$\mu_{A^\alpha}(x) \equiv [\mu_A(x)]^\alpha$
11	Concentration	$\mu_{A^2}(x) \equiv \mu_{CON(A)}(x) \equiv [\mu_A(x)]^2$
12	Dilatation	$\mu_{A^{\frac{1}{2}}}(x) \equiv \mu_{DIL(A)}(x) \equiv \sqrt{\mu_A(x)}$
13	Contrast Intensification	$\mu_{INT(A)}(x) \equiv \begin{cases} 2[\mu_A(x)]^2, & \text{for } 0 \le \mu_A(x) \le 0.5 \\ 1 - 2[1 - \mu_A(x)]^2, & \text{for } 0.5 \le \mu_A(x) \le 1 \end{cases}$

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	$\mu_R(x,y) = \mu_{A\times B}(x,y) = min\left(\mu_A(x), \mu_B(y)\right)$
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\{fuzzy operator\}

FUZZY IMPLICATION OPERATORS

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