NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester I: 2017/2018)

EE4305 INTRODUCTION TO FUZZY/NEURAL SYSTEMS

November/December 2017 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **FOUR** (4) questions and comprises **FIVE** (5) printed pages.

2. All questions are compulsory. Answer **ALL** questions.

3. This is a **CLOSED BOOK** examination.

4. Show all your working clearly.

Q.1 (a) Consider fuzzy sets A and B, and a continuous function $c(\alpha)$ defined as follows,

$$A = 1/\{0.7\} + 0.5/\{0.5\} + 0/\{0.1\},$$

$$B = 0/\{1\} + 0.5/\{0.7\} + 1/\{0.5\} + 0.5/\{0.3\} + 0.1/\{0.2\}, \text{ and}$$

$$c_\lambda(a) = \frac{1-a}{1+\lambda a},\ \lambda \in (-1, \infty).$$

(i) Compute the fuzzy union $A \cup B$,

(3 marks)

(ii) Compute the fuzzy intersection $A \cap B$, and

(3 marks)

(iii) Find the equilibrium of fuzzy complement $c(\alpha) = 1 - \alpha$.

(2 marks)

(b) A Voltage amplifier circuit is shown in Fig. 1.1, where the membership functions of the two resistors and input voltage are given by

$$R_f = 0.5/\{12\} + 0.8/\{6\},\ \mathrm{R} = 0.3/\{2\} + 0.7/\{3\}, \text{ and}$$

$$V_{in} = 0.5/\{4\} + 0.6/\{6\}.$$

The fuzzy output voltage is described as $V_{out} = V_{in} * \frac{R_f}{R}$. Using the extension principle, find the fuzzy voltage V_{out}.

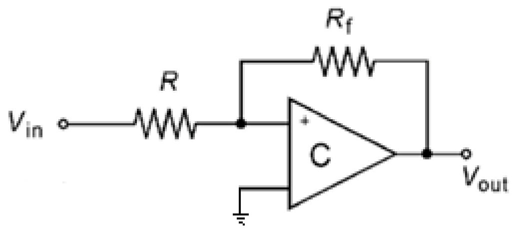

Fig. 1.1: Voltage amplifier Circuit

(10 marks)

(c) As an engineer, you are to design a Fuzzy Knowledge Based Control (FKBC) system for an autonomous driving vehicle as shown in Figure 1.2 where r, e, u, and y are the command, tracking error, control input and system output, respectively. Describe the basic concepts of fuzzy membership function, and practical considerations.

(7 marks)

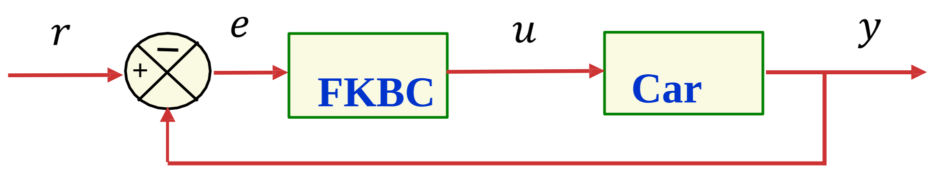

Fig. 1.2: FKBC system

Q.2 (a) Let $U = \{x_1, x_2, x_3\}$ and $V = \{y_1, y_2\}$, and a fuzzy IF-THEN rule given by "IF x is A, THEN y is B",

where $A = 0.8/\{x_1\} + 1/\{x_2\} + 0.7/\{x_3\}$ and $B = 0.2/\{y_1\} + 0.1/\{y_2\}$.

It is given that "x is A'," where $A' = 1/\{x_1\} + 0.8/\{x_2\} + 0.9/\{x_3\}$.

Derive a conclusion in the form "y is B'," with the fuzzy relation $A \to B$ interpreted by

(i) Mamdani implication, and

(5 marks)

(ii) Lukasiewicz implication.

(5 marks)

(b) A fuzzy XOR logic consists of four rules

R1: If x is about-1 and y is about-1, then z is about-0,
R2: If x is about-0 and y is about-0, then z is about-0,
R3: If x is about-1 and y is about-0, then z is about-1,
R4: If x is about-0 and y is about-1, then z is about-1,

where the fuzzy numbers about-0 and about-1 are defined in Fig. 2.1.
Assume that the actual inputs are x = 0.75 and $y = -0.5$.

(i) Sketch the output fuzzy set using the Mamdani inference, and

(5 marks)

(ii) Derive the weights (firing strength) for the 2 output fuzzy numbers about-0 and about-1.

(10 marks)

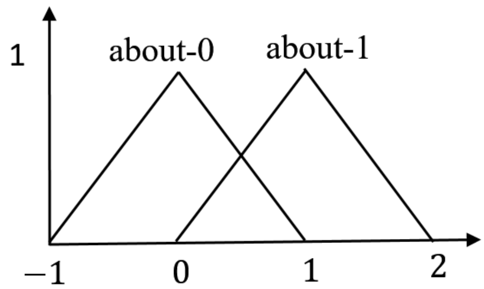

Figure 2.1 Membership functions about-0 and about-1

Q.3 (a) Given two linear separable classes C_1 and C_2 defined as

$$C_1(d = 1): x = -0.8, -2.0$$

$$C_2(d = 0): x = 1.0, 2.0$$

Suppose that we want to separate these two classes by using a perceptron with one input, a bias and one output. Assume that the learning rate, initial weight and bias of the perceptron are

$$\eta = 2; \qquad w = 2; \qquad b = 1,$$

and the activation function is

$$\varphi(v) = \begin{cases} 1 & v \geq 0 \\ 0 & otherwise \end{cases}$$

Using the Perceptron Learning Algorithm for learning,

(i) Calculate the final weights after 4 iterations, and

(10 marks)

(ii) Explain how the learning rate η and bias b affect the perceptron convergence.

(10 marks)

(b) Explain the differences and similarities among (i) Single-layer linear network, (ii) Single hidden layer, and (iii) Multi-layer perceptrons in function approximation.

(5 marks)

Q. 4 Consider a multilayer feedforward network as shown in Fig. 4. Suppose that initially all the weights of the hidden layer are 0.2, all the weights of the output layer are 0.6, the activation function used in the hidden and output layers is sigmoidal function, $\varphi(v) = \frac{1}{1+\exp(-v)}$, and the learning rate is $\eta = 1$.

For a training pattern $x = [2 \quad 0.5]$ and $d = 1$, using the backpropagation method,

i) Determine the output and output error of the network before learning,

(5 marks)

ii) Compute the network weights for one iteration, and

(5 marks)

iii) Determine the output error of the network after learning, and describe your observations about the output errors before and after learning.

(10 marks)

iv) Explain the advantages and disadvantages of the backpropagation method.

(5 marks)

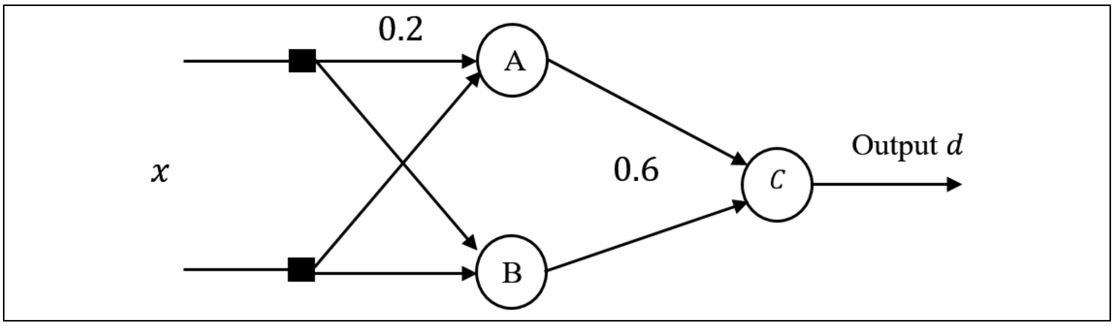

Fig. 4 Multilayer feedforward network

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