NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester I: 2018/2019)

EE4305 - INTRODUCTION TO FUZZY/NEURAL SYSTEMS

November/December 2018 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES:

1. Please write your student number only. Do not write your name.
2. This examination paper contains **FOUR (4)** questions and comprises **FIVE (5)** pages.
3. Answer all **FOUR** questions.
4. All questions carry equal marks.
5. Students are allowed to bring 1 page A4 size Data sheet.
6. This is a **CLOSED BOOK** examination.

Q.1 (a) A fuzzy relationship R (if-then rule) is: If x is A, then y is B, where fuzzy sets A and B are given by,

$$A = 0.3/\{1\} + 0.6/\{2\} + 1/\{3\} + 0.7/\{4\} + 0.5/\{5\}, \text{ and}$$

$$B = 0.8/\{-2\} + 1/\{0\} + 0.2/\{2\}.$$

(i) Compute the fuzzy relation R using the Mamdani implication.

(5 marks)

(ii) Compute the domain and range of the fuzzy relation R.

(5 marks)

(b) Consider a fuzzy set,

$$A(x)=30^{-x}$$

Use the extension principle to derive $f(A)$, where $f(x) = x^3$ for all $x \in X = [0, 20]$.

(5 Marks)

(c) A fuzzy rule is: IF x is A THEN y is B, where the fuzzy sets are defined as,

A=0.9/{1}+0.7/{2}+0.3/{3}, and
B = 0.2/{2}+0.4/{3}+0.6/{4}.

Compute the fuzzy relation using Lukasiewicz implication,

$$\mu_R(x, y) = min\{1,\ 1 - \mu_A(x) + \mu_B(y)\}$$

When the input fuzzy set is $A' = 0.5/\{1\} + 1/\{2\} + 0.6/\{3\}$, conduct the fuzzy inference to obtain the fuzzy output using the Lukasiewicz implication.

(10 Marks)

Q.2 (a) Gyros are calibrated for axis biases with temperature, and we can have a relation of a gyro bias (GB) vs temperature (T). Suppose that we have fuzzy sets for a given gyro bias and a given temperature as follows,

GB = 0.5/3 + 0.7/4 + 1/5 + 0.7/6 + 0.5/7, and
T = 0.3/66 + 0.8/68 + 1/70 + 0.8/72 + 0.3/74

(i) Use the Mamdani implication to find the relation: IF gyro is GB, THEN temperature is T.

(5 Marks)

(ii) Suppose that we are given a new gyro bias (GB') as follows,

GB' = 0.3/{3} + 0.5/{4} + 0.7/{5}+1/{6} + 0.8/{7}

Using max-min composition, find the new temperature associated with the new bias.

(5 Marks)

(b) For Mamdani, Lukasiewicz, **K**leene-**D**ienes, and Zadeh Implications, explain their common properties, and differences which are designed for various possible applications.

(5 Marks)

(c) As an engineer, you are to design a Fuzzy Knowledge Based Control (FKBC) system for a rice cooker 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.

(10 marks)

Q.3 (a) The multi-layer neural network shown in Fig. 3.1 has two inputs and one output. The network has two neurons in a hidden layer. The network is to be trained with backpropagation algorithm. Each neuron has a sigmoid activation function:

$$\varphi(v) = \frac{1}{1+e^{-v}}.$$

Assume that the biases to the neurons is +1 and the learning rate is 1.

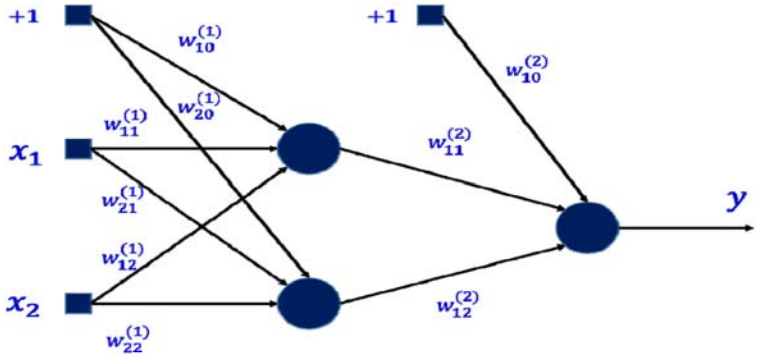

Fig. 3.1

The network has the following initial weights:

$$\left\{w_{10}^{(1)}, w_{20}^{(1)}, w_{10}^{(2)}\right\}=\{0.05, -0.15,\ 0.2\}$$
$$\left\{w_{11}^{(1)}, w_{12}^{(1)}, w_{11}^{(2)}\right\}=\{0.1, 0.2,\ 0.3\}$$
$$\left\{w_{21}^{(1)}, w_{22}^{(1)}, w_{12}^{(2)}\right\}=\{-0.2,\ -0.3,\ -0.1\}$$

Perform the training with the following training vectors:

x_1	x_2	d
0	0	0
0	1	1

Determine the modified weights, after one iteration of the backpropagation algorithm with the first training sample.

(15 Marks)

(b) Explain the associated problems for the back propagation algorithm, and possible remedies.

(10 Marks)

Q.4 The signal-flow graph of a feedforward neural network with x_1 and x_2 as the inputs, y as the corresponding output, $\varphi(.)$ the activation function, and the values of the weights are as shown in Figure 4.1.

(a) How many layers are there in the network? Can this network be used to solve 2 class classification problems that are not linearly separable? Explain your answer. State any assumption(s) made.

(7 Marks)

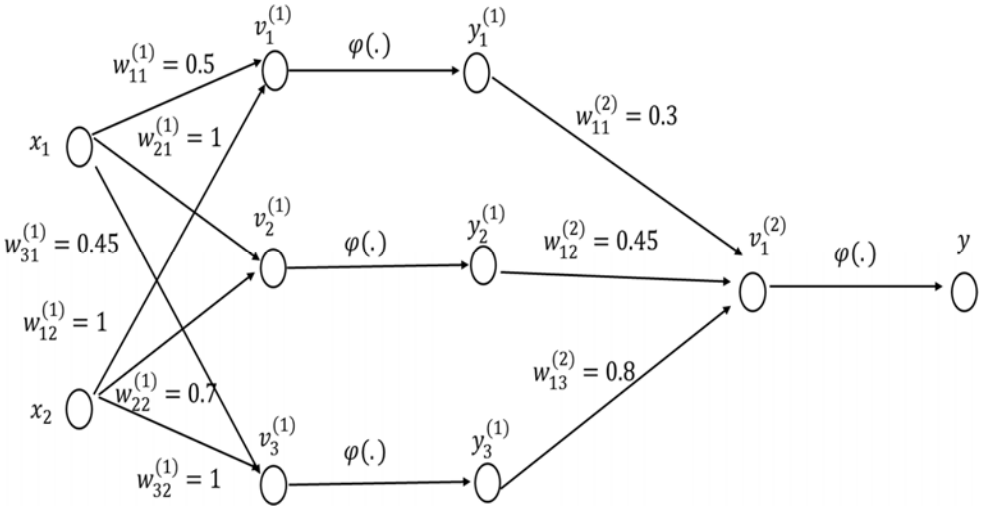

Figure 4.1

(b) A neuron with a sigmoid activation function, $\varphi(v) = \frac{1}{1+\exp(-2v)}$, has two input weights, $w_1 = 0.5$ and $w_2 = 0.5$. For an input $X = (x_1, x_2) = (-1, 0.5)$, find the value of the bias weight such that the neuron output y is 0.2.

(8 Marks)

(c) Describe your own understanding of the RBF network in terms of function approximation, computational advantages, structure complexity, and training, among others.

(10 Marks)

END OF PAPER