NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II: 2019/2020)

EE4305 - **Fuzzy/Neural Systems for Intelligent Robotics**

April/May 2020 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This examination paper contains **TWENTY (20)** multiple choice questions (MCQ), and comprises **NINE (9)** pages.

2. For each multiple choice question, only **ONE** choice is accepted as the answer. If you select multiple choices, **ZERO** mark will be given.

3. The examination paper carries 100 marks in total. All questions are compulsory and carry equal marks. Answer **ALL** questions.

4. This is an **OPEN** book examination. You can refer to any references during the exam. But you are not allowed to communicate with any other person regarding the solutions to the questions during the examination period.

5. The hand phone cannot be used during the examination. If you are found using hand phone during the examination, you will receive **ZERO** marks as well as other possible disciplinary penalties.

6. Write all your answers in the table provided in the answer sheet. Upload ONLY the answer sheet file in PDF format to the submission folder in LumiNUS. You only need to write down the choice to each MCQ. DO NOT provide any explanations on your answers.

Q.1 In order to solve pattern recognition problem which is not linearly separable, which type of activation function should not be used for the hidden neurons in the multi-layer perceptron?

A) Logistic Function
B) Hyperbolic Tangent Function
C) Linear Function
D) Hard Limiter (step function)

Q.2 Data pre-processing is an important step for training the neural networks. Which of the following statements about normalization is NOT correct?

A) Normalizing the inputs are important to speed up the learning process.
B) Normalizing the outputs can also improve the efficiency.
C) Under certain conditions, it is not necessary to normalize the inputs.
D) Normalization can help to deal with overfitting problem.

Q.3 Rosenblatt's perceptron can be used to solve binary pattern classification problems. Which of the following statements regarding the Rosenblatt's perceptron is correct?

A) The weights will converge in finite time.
B) The weights will converge as the number of learning steps goes to infinity.
C) The weights may get stuck into local minima for some problems.
D) The learning rate is not a deciding factor for convergence of the weights.

Q.4 There are different ways to use the data to train neural networks. Considering the following four statements regarding the batch mode and sequential mode:
i. Training using batch mode is much faster than using sequential mode.
ii. Using sequential mode can help to alleviate the local minima problem.
iii. For the same training problem, the learning rates for batch mode and sequential mode should be different.
iv. Using sequential mode is better than batch mode in dealing with over-fitting problem.
Which one of the following answers is correct?

A) i, ii and iii
B) i, ii and iv.
C) iii and iv.
D) i, ii , iii and iv.

Q.5 Suppose that you are given the following input-output pairs:
{(1, 10.0), (2, 6.0), (3, 5), (4.0, 2), (5.0, 0)}.
Assume the data can be described by a linear model,

$$y = wx + b.$$

Find the parameters w and b using the standard linear least-squares (LLS) method. Which one of the following answers is correct?

A) w=-2.2, b=11.5
B) w=-2.5, b=11.6
C) w=-2.4, b=11.8
D) w=-2.8, b=11.4

Q.6 Given the same training data in **Q.5**. Suppose that the initial parameters are chosen as zero, and the learning rate is 0.1. Find the parameters of w and b using the least-mean-square (LMS) algorithm for two steps of updating using the first two samples from the training set. Which one of the following is the correct answer?

A) w=1.3, b=1.6
B) w=1.6, b= 1.3
C) w=1.4, b=1.2
D) w=1.2, b =1.4

Q.7 Consider the following two-dimensional pattern recognition problem. Class I contains eight points: (-1, -1), (0, -1), (1, -1), (-1, 0), (1, 0), (-1, 1), (0, 1), and (1, 1), while Class II contains only one point: (0, 0).
Construct a Multi-layer Perceptron (MLP) with two input nodes, one hidden layer, and one output neuron. The activation function of all the neurons is chosen as the threshold function (hard limiter). You need to determine the proper number of hidden neurons to solve this pattern recognition problem. How many hidden neurons are needed?

A) At least two
B) At least three
C) At least four
D) At least five

Q.8 The signal-flow graph of a feedforward neural network with x_1 and x_2 as the inputs, y as the corresponding output, φ(.) the activation function, and the values of the weights are as shown in Figure 1.

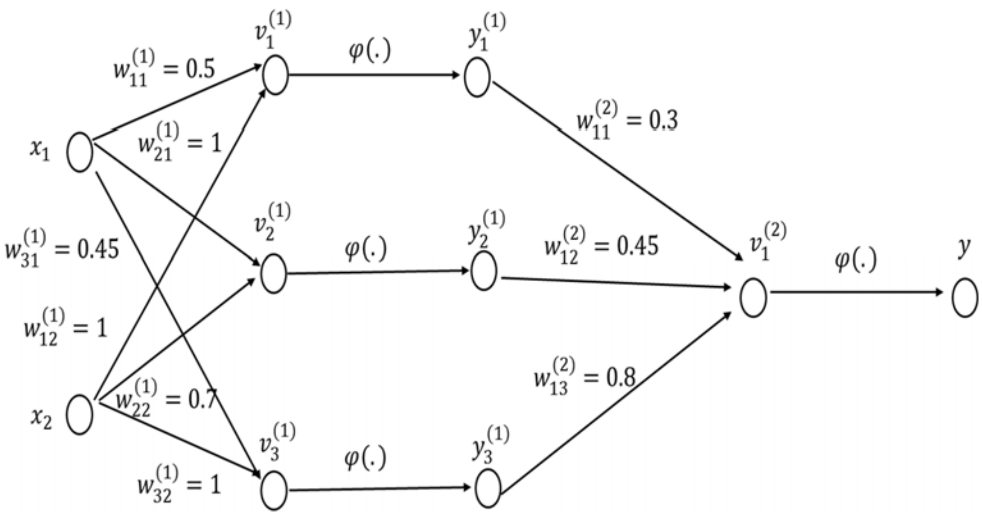

Figure 1

Which one of the following statements regarding the number of layers in the feedforward neural network is true?

A) There are two layers.
B) There are three layers.
C) There are four layers.
D) There is only one layer.

Q.9 Use the same feedforward network in Figure 1. Assume the activation functions for all the hidden neurons are hard limiter (step function), and the activation function for the output neuron is pure linear function φ(x)=x. All the biases of the neurons are assumed to be zero. Let the input signal be, $x_1 = 1$ and $x_2 = -1$. What is the output of the network?

A) y=1.1
B) y=0.75
C) y=0.45
D) y=0.8

Q.10 Use the same feedforward network in Figure 1. Assume the activation functions for all the neurons are pure linear function φ(x)=x. Let the input signal be, $x_1 = 1$ and $x_2 = -1$. The desired output corresponding to this input is *d*=0.545. All the biases of the neurons are assumed to be zero. Assume the learning rate is 0.1, and use the backpropagation algorithm to adjust the weights of the network for one step. Which one of the following numbers is the updated weight of $w_{11}^{(1)}$ after one step of learning?

A) 0.50
B) 0.53
C) 0.47
D) 0.15

Q.11 For all the functions listed below, the domain of the variable *a* is [0,1]. Which one of the following functions cannot be used as the fuzzy complement function?

A) $c(a) = 1 - a$
B) $c(a) = \frac{1-a}{1+a}$
C) $c(a) = \cos\frac{\pi a}{2}$
D) $c(a) = \sqrt{1 - a^2}$

Q.12 Find the equilibrium of the fuzzy complement

$$c(a) = \frac{\beta(1-a)}{a+\beta(1-a)}$$

where $a \in [0,1]$ and $\beta > 0$. Which one of the following is the correct answer?

A) $a = 0.5$
B) $a = \frac{\sqrt{\beta}}{1+\sqrt{\beta}}$
C) $a = \frac{\beta}{1+\beta}$
D) $a = \frac{1}{1+\beta}$

Q.13 The concepts of α-cuts play a principal role in the relationship between fuzzy sets and crisp sets. Consider the following statements regarding the properties of α-cuts. Which statement is NOT correct?

A) The α-cuts are crisp sets.
B) The α-cuts are fuzzy sets.
C) All the α-cuts of any fuzzy number must be closed intervals.
D) Any fuzzy set can be expressed as the union of its α-cuts.

Q.14 The fuzzy relations between the sets X, Y and Z are shown in the diagram in Figure 2.

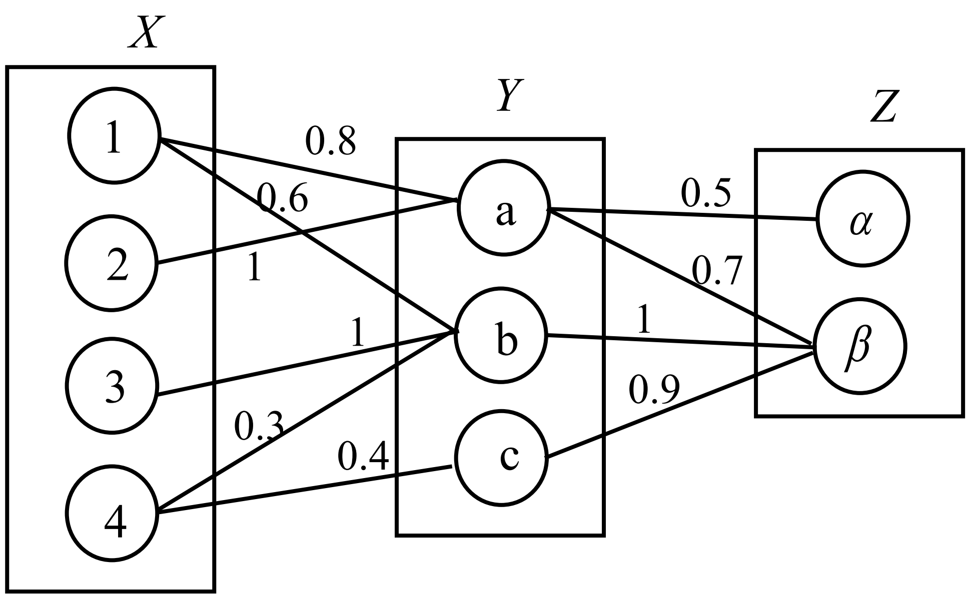

Figure 2

Which one of the following is the membership matrix of the fuzzy relation between *X* and *Y*?

A) $\begin{bmatrix} 0.8 & 1 & 0 & 0 \\ 0.6 & 0 & 1 & 0.3 \\ 0 & 0 & 0 & 0.4 \end{bmatrix}$

B) $\begin{bmatrix} 0.8 & 0.6 & 0 \\ 1 & 0 & 0 \\ 0 & 0.3 & 0.4 \\ 0 & 1 & 0 \end{bmatrix}$

C) $\begin{bmatrix} 0.8 & 0.6 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$

D) $\begin{bmatrix} 0.8 & 0.6 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0.3 & 0.4 \end{bmatrix}$

Q.15 Consider the same diagram in Figure 2. Which one of the following is the membership matrix of the fuzzy relation between *X* and *Z*?

A) $\begin{bmatrix} 0.5 & 0.7 \\ 0.5 & 0.7 \\ 0 & 1 \\ 0 & 0.4 \end{bmatrix}$

B) $\begin{bmatrix} 0.8 & 0.8 \\ 0.6 & 0.7 \\ 0 & 1 \\ 0 & 0.9 \end{bmatrix}$

C) $\begin{bmatrix} 0.4 & 0.6 \\ 0.5 & 0.7 \\ 0 & 1 \\ 0 & 0.36 \end{bmatrix}$

D) $\begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0.7 & 0.7 & 1 & 0.4 \end{bmatrix}$

Q.16 Let the fuzzy set $A(x) = 1/1 + 0.6/2 + 0.8/3 + 0.1/4$. Using the fuzzy relation between X and Z as expressed in Figure 2, compute the corresponding fuzzy set B(z). Which one of the following fuzzy sets is B(z)?

A) $B(z) = 0.5/1 + 0.8/2 + 0.8/3 + 0.1/4$
B) $B(z) = 0.5/\alpha + 0.8/\beta$
C) $B(z) = 0.5/\alpha + 0.7/\beta$
D) $B(z) = 0.5/\alpha + 0.4/\beta$

Q.17 Let the fuzzy set $A(x) = 0.2/-2 + 0.6/-1 + 1/0 + 0.5/1 + 0.3/2$.
Suppose $y = f(x) = x^2$. Use the extension principle to compute the fuzzy set $C = f(A)$. Which one of the following is the correct answer for C=f(A)?

A) $C(y) = 0.2/4 + 0.6/1 + 1/0 + 0.5/1 + 0.3/4$
B) $C(y) = 0.04/-2 + 0.36/-1 + 1/0 + 0.25/1 + 0.09/2$
C) $C(y) = 0.3/4 + 0.6/1 + 1/0$
D) $C(y) = 0.2/4 + 0.5/1 + 1/0$

Q.18 Consider the following two fuzzy numbers,

$$A(x) = \begin{cases} 0 & for\ x \le -1\ and\ x > 1 \\ x+1 & for -1 < x \le 0 \\ -x+1 & for\ 0 < x \le 1 \end{cases} \quad \text{and} \quad B(x) = \begin{cases} 0 & for\ x \le 0\ and\ x > 4 \\ \frac{x}{2} & for\ 0 < x \le 2 \\ \frac{4-x}{2} & for\ 2 < x \le 4 \end{cases}.$$

Use α-cuts method to compute the fuzzy number $D = B - A$. Which one of the following is the correct answer for D?

A) $$D(x) = \begin{cases} 0 & for\ x \le 0\ and\ x > 4 \\ \frac{x}{2} & for\ 0 < x \le 2 \\ \frac{4-x}{2} & for\ 2 < x \le 4 \end{cases}$$

B) $$D(x) = \begin{cases} 0 & for\ x \le 0\ and\ x > 5 \\ \frac{x+1}{3} & for\ 0 < x \le 2 \\ \frac{5-x}{3} & for\ 2 < x \le 5 \end{cases}$$

C) $$D(x) = \begin{cases} 0 & for\ x \le 0\ and\ x > 6 \\ \frac{x}{3} & for\ 0 < x \le 3 \\ \frac{6-x}{3} & for\ 3 < x \le 6 \end{cases}$$

D) $$D(x) = \begin{cases} 0 & for\ x \le -1\ and\ x > 5 \\ \frac{x+1}{3} & for -1 < x \le 2 \\ \frac{5-x}{3} & for\ 2 < x \le 5 \end{cases}$$

Q.19 Consider a Fuzzy Knowledge Based Control (FKBC) system in which the input $u(t)$ only depends upon the error signal, $e(t)$. Assume that the universe of discourse for the two variables are:

$$-2 \le e(t) \le 2 \quad \text{and} \quad -4 \le u(t) \le 4.$$

Let's design three types of linguistic variables for both the input and error signals as, positive (P), zero (Z) and negative (N).

The membership functions of the error signal are shown in Figure 3.

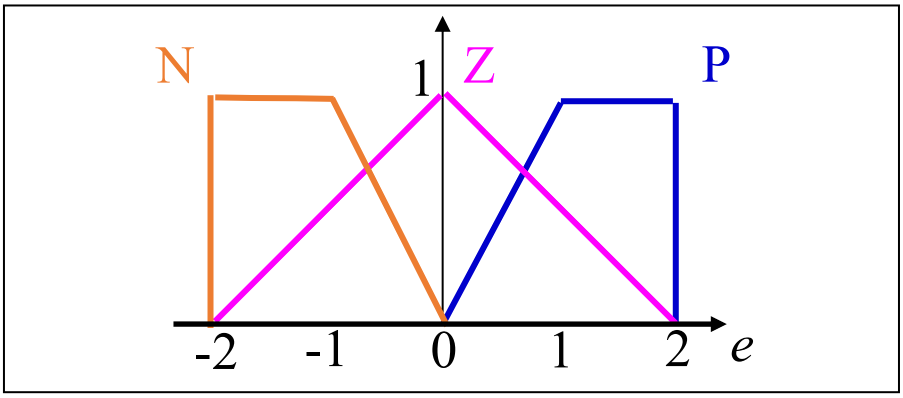

Figure 3

The membership functions of the input signal are shown in Figure 4.

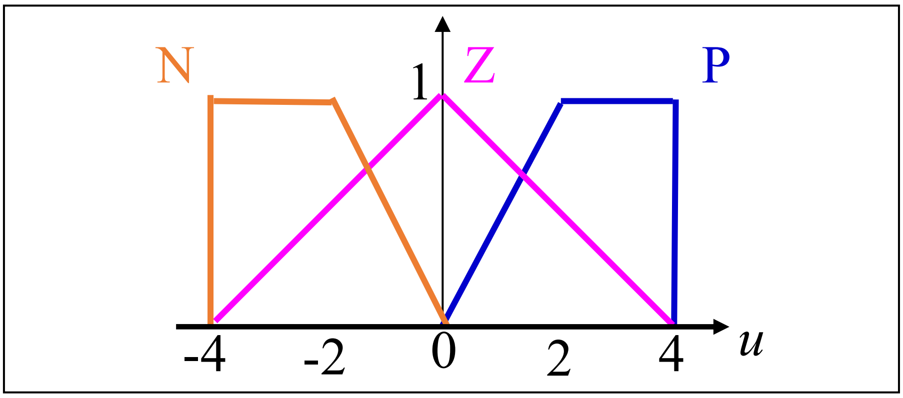

Figure 4

The fuzzy inference rules consist of the following three rules:

Rule 1: If the error is positive (P), then the input is also positive (P).
Rule 2: If the error is zero (Z), then the input is also zero (Z).
Rule 3: If the error is negative (N), then the input is also negative (N).

At time t, the measured error signal is given as e(t) = 1.0. Which one of following statements is true?

A) Rules 1 and 3 will be fired.
B) Rules 1 and 2 will be fired.
C) Rules 2 and 3 will be fired.
D) All the 3 rules will be fired.

Q.20 Consider the same Fuzzy Knowledge Based Control (FKBC) system designed in **Q.19**. At time t, the measured error signal is given as e(t) = 0.5. Use the fuzzy inference engine to compute the output from the inference engine, and then defuzzify it into a crisp number, which will be used as the input $u^*(t)$ to the plant. Which one of the following is the defuzzified input $u^*(t)$?

A) $u^*(t) = \frac{20}{51}$
B) $u^*(t) = \frac{10}{27}$
C) $u^*(t) = \frac{11}{27}$
D) $u^*(t) = \frac{25}{51}$

END OF PAPER