NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2016-2017

EE7207 – NEURAL AND FUZZY SYSTEMS

November/December 2016 Time Allowed: 3 hours

INSTRUCTIONS

1. This paper contains 5 questions and comprises 5 pages.
2. Answer all 5 questions.
3. All questions carry equal marks.
4. This is a closed-book examination.

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1. (a) There are two vectors:

$$P_1 = [1 \quad -1 \quad 1]^T \text{ and } P_2 = [-1 \quad 1 \quad -1]^T.$$

Design a bi-directional associative memory (BAM) neural network to store P_1 and P_2. Sketch the architecture of the BAM neural network designed, compute the weights on the links between neurons, and test whether the designed BAM works.

(8 Marks)

(b) There are two vectors:

$$Q_1 = [1 \quad -1 \quad -1]^T \text{ and } Q_2 = [1 \quad 1 \quad 1]^T.$$

Design a Gaussian radial basis function (RBF) neural network to map Q_1 and Q_2 to 1 and -1, respectively. Sketch the RBF neural network architecture, determine centre vectors of hidden layer neurons and the weights on the links between neurons, and test whether the designed RBF neural network works.

(8 Marks)

Note: Question No. 1 continues on page 2

(c) In an application, it was found that the trained RBF neural network fitted the training data perfectly, but generalized badly on the unseen testing data. Discuss the causes of the above problem and ways to deal with the problem.

(4 Marks)

2. Self-organizing map (SOM) neural network is a powerful tool in data analysis.

(a) Describe the 3 ingredients of the SOM neural network learning.

(6 Marks)

(b) Describe SOM neural network learning procedure, and discuss parameter settings in different learning phases of the SOM neural network.

(9 Marks)

(c) Discuss the potentials of SOM neural networks in data visualization.

(5 Marks)

3. Support vector machine (SVM) is widely used in pattern classification.

(a) Describe the optimal separating hyperplane of linear SVM for linearly separable 2-class patterns, and formulate the solution of the optimal hyperplane as an optimization problem.

(7 Marks)

(b) Describe the optimal separating hyperplane of linear SVM for linearly non-separable 2-class patterns, and formulate the solution of the optimal hyperplane as an optimization problem.

(7 Marks)

(c) SVM is inherently formulated for solving 2-class pattern classification problems. Discuss how to extend SVM to solve multi-class pattern classification problems.

(6 Marks)

4. (a) Consider the membership functions $\mu_{X_1}(x)$ and $\mu_{X_2}(x)$ in Figure 1, where $X_1 = [0, \infty)$ and $X_2 = [0, \infty)$.

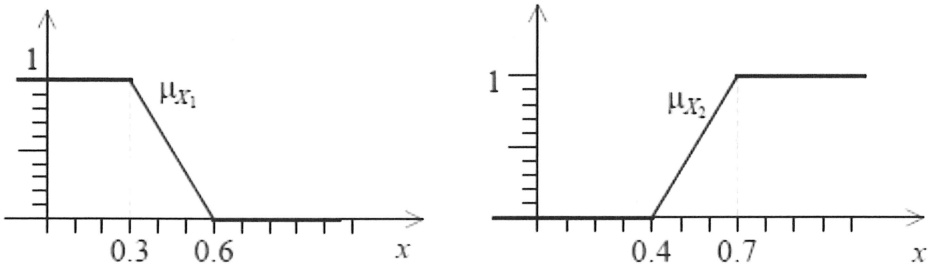

Figure 1

Determine their analytical expressions.

(4 Marks)

(b) Suppose that an unknown system with input x and output y is modelled by the following fuzzy rules:

R1: IF x is X_1 THEN $y = a_{11} + a_{12}x$
R2: IF x is X_2 THEN $y = a_{21} + a_{22}x$

where X_1 and X_2 are fuzzy sets with membership functions $\mu_{X_1}(x)$ and $\mu_{X_2}(x)$ in Figure 1, a_{11}, a_{12}, a_{21} and a_{22} are unknown parameters.

Some experiments are carried out on the unknown system and N pairs of input output data in Table 1 are obtained.

Table 1 Input-Output Data

Input x	x_1	x_2	.....	x_N
Output y	y_1	y_2		y_N

Based on the data, a system of linear equations is obtained as follows:

$$\Lambda\theta = b.$$

What is θ? Determine Λ and b using the given data.

(10 Marks)

(c) Suppose that the optimal estimate of θ in part 4(b) is θ^* based on the least-squares parameter identification scheme. Find θ^* in terms of Λ and b.

(6 Marks)

5. (a) Consider the fuzzy relation R: $X \times Y \rightarrow [0, 1]$.

$R =$

	y_1	y_2	y_3
x_1	0.7	0.3	0.1
x_2	0.4	0.8	0.2
x_3	0.1	0.2	0.9

and a fuzzy set A defined on X:

$$A = \{0.1/x_1, 0.8/x_2, 0.4/x_3\}.$$

Compute fuzzy set $B = A$ o R, where o is the sup-min composition operator.

(6 Marks)

(b) Consider an air-conditioner with five control switches: ***COLD, COOL, PLEASANT, WARM*** and ***HOT*** with input temperature x in degrees Celsius (°C). The corresponding speeds of the motor controlling the fan speed y revolutions per minute (rpm) on the air-conditioner are ***MINIMUM, SLOW, MEDIUM, FAST*** and ***BLAST.***

The rules governing the air-conditioner are as follows:

- RULE 1:

IF TEMP is COLD
THEN SPEED is MINIMUM

- RULE 2:

IF TEMP is COOL
THEN SPEED is SLOW

- RULE 3:

IF TEMP is PLEASANT
THEN SPEED is MEDIUM

- RULE 4:

IF TEMP is WARM
THEN SPEED is FAST

- RULE 5:

IF TEMP is HOT
THEN SPEED is BLAST

Note: Question No. 5 continues on page 5

The membership functions for the fuzzy sets are respectively given as follows:

$\mu_{COLD}(x) = \begin{cases} -0.1x + 1 & 0 \le x \le 10 \\ 0 & otherwise \end{cases}$	$\mu_{COOL}(x) = \begin{cases} 0.08x & 0 \le x < 12.5 \\ 3.5 - 0.2x & 12.5 \le x < 17.5 \\ 0 & otherwise \end{cases}$
$\mu_{PLESANT}(x) = \begin{cases} 0.4x - 6 & 15 \le x < 17.5 \\ 8 - 0.4x & 17.5 \le x < 20 \\ 0 & otherwise \end{cases}$	$\mu_{WARM}(x) = \begin{cases} 0.2x - 3.5 & 17.5 \le x < 22.5 \\ 5.5 - 0.2x & 22.5 \le x < 27.5 \\ 0 & otherwise \end{cases}$
$\mu_{HOT}(x) = \begin{cases} 0.2x - 5 & 25 \le x < 30 \\ 1 & 30 \le x \\ 0 & otherwise \end{cases}$	$\mu_{MINIMUM}(y) = \begin{cases} -\frac{1}{30}y + 1 & 0 \le y \le 30 \\ 0 & otherwise \end{cases}$
$\mu_{SLOW}(y) = \begin{cases} 0.05y - 0.5 & 10 \le y < 30 \\ 2.5 - 0.05y & 30 \le y < 50 \\ 0 & otherwise \end{cases}$	$\mu_{MEDIUM}(y) = \begin{cases} 0.1y - 4 & 40 \le y < 50 \\ 6 - 0.1y & 50 \le y < 60 \\ 0 & otherwise \end{cases}$
$\mu_{FAST}(y) = \begin{cases} 0.05y - 2.5 & 50 \le y < 70 \\ 4.5 - 0.05y & 70 \le y < 90 \\ 0 & otherwise \end{cases}$	$\mu_{BLAST}(y) = \begin{cases} \frac{1}{30}y - \frac{7}{3} & 70 \le y \le 100 \\ 0 & otherwise \end{cases}$

For a temperature of 22.5°C, determine the fan speed using the centre of gravity (COG) method.

(7 Marks)

(c) If the temperature is 20°C in part 5(b), what is the fan speed determined by using the mean-of-maxima (MOM) method?

(7 Marks)

END OF PAPER

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Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.