NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2020-2021

EE7207 – NEURAL AND FUZZY SYSTEMS

November / December 2020 Time Allowed: 2 hours

INSTRUCTIONS

1. This paper contains 4 questions and comprises 5 pages.
2. Answer all 4 questions.
3. All questions carry equal marks.
4. This is a closed book examination.
5. Unless specifically stated, all symbols have their usual meanings.

---

1. Sam wants to use barcodes to label products of his company. Assume that the barcodes shown in Figure 1 are used to label Products A, B, and C, respectively.

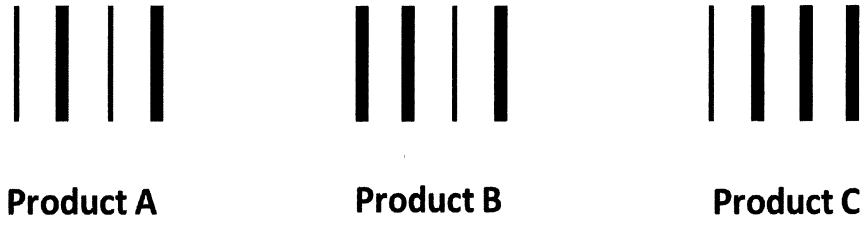

Figure 1

(a) Assume that the thin lines and thick lines are encoded as 1 and -1, respectively. If a bi-directional associative memory (BAM) neural network is used to store the three barcodes, sketch the architecture of the neural network, compute the weights, and check whether the BAM neural network designed could correctly retrieve the stored barcodes.

(9 Marks)

Note: Question No. 1 continues on page 2.

(b) If a Hopfield neural network is used to store the three barcodes, sketch the architecture of the neural network, compute the weights, and check whether the Hopfield neural network designed could correctly retrieve the stored barcodes.

(9 Marks)

(c) If the Hopfield neural network cannot correctly retrieve all barcodes, analyse causes of the problem, and suggest possible solutions.

(7 Marks)

2. (a) If Gaussian basis function (kernel) is used in radial basis function (RBF) neural networks and kernel support vector machines (SVM), discuss the similarity and difference of the architectures and learning algorithms of the two methods.

(9 Marks)

(b) List the three types of commonly used layers in the convolutional neural networks (CNN), and describe the operations performed in each of the three types of layers.

(9 Marks)

(c) In the backpropagation-based training of deep neural networks, one problem encountered is the gradient vanishing problem. Analyse causes of the problem, and suggest solutions.

(7 Marks)

3. A certain strain of virus can be examined using a microscope. Digital image processing can be applied to generate 2 variables: the first variable, A, is related to grey spot quantity (grey pixels) and the second variable, B, is related to the shape of the grey spots. Suppose that we have 2 fuzzy sets: $\hat{A}$ that represents the quantity of grey pixels in the virus and $\hat{B}$ that represents the shape of the grey pixel clusters defined as follows:

$$\hat{A} = \left\{ \frac{0.2}{a_1} + \frac{0.6}{a_2} + \frac{0.9}{a_3} \right\} \text{ and } \hat{B} = \left\{ \frac{0.4}{b_1} + \frac{0.8}{b_2} + \frac{1.0}{b_3} \right\}$$

(a) Determine the relationship $R = \hat{A} \times \hat{B}$ between quantity of grey pixels in the virus and the shape of the grey pixel clusters.

(6 Marks)

Note: Question No. 3 continues on page 3.

(b) Suppose that another image is taken and the quantity of black pixels is slightly different and represented by a fuzzy set $\hat{A}'$:

$$\hat{A}' = \left\{ \frac{0.4}{a_1} + \frac{0.7}{a_2} + \frac{0.8}{a_3} \right\}$$

Use the max-min composition $S = \hat{A}' \circ R$ to determine a new value for the fuzzy set $\hat{B}'$ of grey pixel cluster shapes that are associated with the new black pixel quantity. Is the fuzzy composition $S = R \circ \hat{A}'$?

(6 Marks)

(c) Let $S[a,b,c]$ denote the triangular set determined by the points $(a,0)$, $(b,1)$, $(c,0)$. In general, the triangular set $S[a,b,c]$ can be defined mathematically as follows:

$$S[a,b,c] = \begin{cases} \dfrac{x-a}{b-a} & \text{if } a \le x \le b \\ \dfrac{x-c}{b-c} & \text{if } b \le x \le c \\ 0 & \text{otherwise} \end{cases}$$

The fuzzy sets $A_1[1,4,7]$ and $A_2[3,6,9]$ are depicted in Figure 2. Fuzzy sets $B_1[1,4,6]$ and $B_2[4,8,9]$ are in Figure 3 on page 4. Fuzzy sets $C_1[2,4,6]$ and $C_2[4,6,8]$ are shown in Figure 4 on page 4.

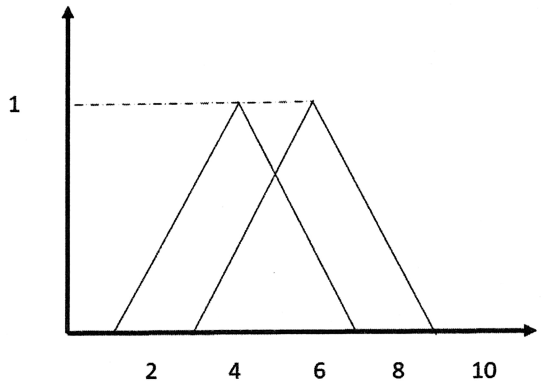

Figure 2

Note: Question No. 3 continues on page 4.

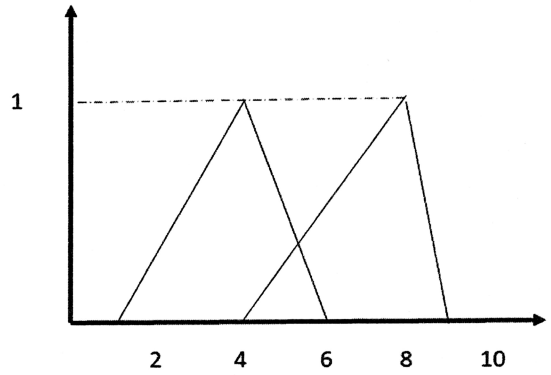

Figure 3

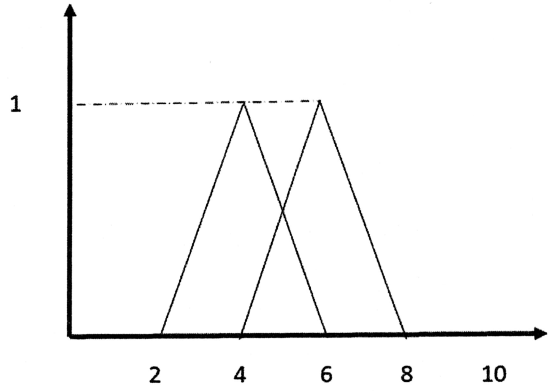

Figure 4

(i) Using Figures 2 to 4, graph the aggregated fuzzy set realised by the Mamdani method

$$O_{(4,4)}(z) = \left(A_1(4) \wedge B_1(4) \wedge C_1(z)\right) \vee \left(A_2(4) \wedge B_2(4) \wedge C_2(z)\right).$$

(ii) Using Figures 2 to 4, defuzzify $O_{(4,4)}(z)$ by the "Centre of Gravity" (CoG) method.

(13 Marks)

4. (a) Let U and V be the set of real numbers, that is, $U = V = \mathbb{R}$. A fuzzy relation "x is much larger than y," denoted by ML, may be defined by the following membership function:

$$\mu_{ML}(x, y) = \frac{1}{1 + e^{-(x-y)}}.$$

Determine the projection of ML on U and V.

(7 Marks)

Note: Question No. 4 continues on page 5.

(b) Consider the following Takagi-Sugeno model-based control method with the following rules:

$$\begin{aligned} R_1 &: If\ z\ is\ C_1\ then\ \dot{x}_1 = A_1 x_1 + B_1 u_1 \\ R_2 &: If\ z\ is\ C_2\ then\ \dot{x}_2 = A_2 x_1 + B_2 u_2 \end{aligned} \tag{4.1}$$

where $A_1 = -1, B_1 = 2, A_2 = -2, B_2 = 1$ and the fuzzy sets C_1 and C_2 are given by

$$C_1(z) = \begin{cases} 1 & \text{if } z \le -1 \\ \dfrac{1-z}{2} & \text{if } -1 \le z \le 1 \\ 0 & \text{if } 1 \le z \end{cases} \tag{4.2}$$

and

$$C_2(z) = \begin{cases} 0 & \text{if } z \le -1 \\ \dfrac{1+z}{2} & \text{if } -1 \le z \le 1 \\ 1 & \text{if } 1 \le z \end{cases}. \tag{4.3}$$

The output of the Takagi-Sugeno fuzzy system is given by

$$\dot{x}(t) = \frac{\sum_{i=1}^{2} A_i . C_i(z)}{\sum_{i=1}^{2} C_i(z)} x(t) + \frac{\sum_{i=1}^{2} B_i . C_i(z)}{\sum_{i=1}^{2} C_i(z)} u(t). \tag{4.4}$$

Using expressions (4.1) to (4.3), compute the explicit form of the output in Equation (4.4).

(10 Marks)

(c) Given the following two fuzzy sets R and S,

$$R = \left\{ \frac{0.1}{20} + \frac{0.6}{40} + \frac{0.4}{60} + \frac{0.3}{80} + \frac{0.9}{100} \right\},$$
$$S = \left\{ \frac{0.3}{20} + \frac{0.4}{40} + \frac{0.7}{60} + \frac{0.4}{80} + \frac{0.2}{100} \right\},$$

determine the $\alpha-$cut sets for the following fuzzy set operations:

(i) $R \cup \bar{S}$ using α=0.5

(ii) $\bar{R} \cap S$ using α=0.3

(8 Marks)

END OF PAPER

EE7207 NEURAL & FUZZY SYSTEMS

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.