NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2021-2022

EE7207 – NEURAL AND FUZZY SYSTEMS

November / December 2021 Time Allowed: 3 hours

INSTRUCTIONS

1. This paper contains 5 questions and comprises 6 pages.
2. Answer all 5 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. (a) Explain the rationale of using the Hopfield neural network and Bi-directional Associate Memory neural network for fundamental memory storage.

(4 Marks)

(b) There are three vectors as given below:

$$\mathbf{P}_1 = [1 \quad -1 \quad 1 \quad -1]$$

$$\mathbf{P}_2 = [-1 \quad -1 \quad 1 \quad -1]$$

$$\mathbf{P}_3 = [1 \quad -1 \quad -1 \quad -1]$$

If a Hopfield neural network is used to store the three vectors, sketch the architecture of the neural network, compute the weights, and check whether the Hopfield neural network designed could correctly retrieve the stored vectors. If the three vectors cannot be correctly retrieved, explain the reasons.

(8 Marks)

Note: Question No. 1 continues on page 2.

(c) If a bi-directional associative memory (BAM) neural network is used to store the three vectors, sketch the architecture of the neural network, compute the weights, and check whether the BAM neural network designed could correctly retrieve the stored vectors. If the three vectors cannot be correctly retrieved, explain the reasons.

(8 Marks)

2. (a) Briefly describe the 3 types of learning rules of neural networks. Give a few examples of neural networks where the three learning rules are applied.

(6 Marks)

(b) Describe the formulation of the primal problem of linear support vector machines (SVM) for non-separable data. Explain the rationale of the formulation.

(9 Marks)

(c) Assume a radial basis function (RBF) neural network and a kernel SVM are applied to solve the same classification problem. If a self-organizing neural network (SOM) is used to select centre vectors for the RBF neural network, discuss how the locations of the RBF centre vectors and the support vectors of the Kernel SVM differ in the input space.

(5 Marks)

3. (a) Consider the multilayer feedforward neural network shown in Figure 1 on page 3. The weight vectors for neurons 1, 2 and 3 are $\mathbf{w}_1$, $\mathbf{w}_2$ and $\mathbf{w}_3$, respectively,

$$\mathbf{w}_1 = [2 \quad 1 \quad -1]$$

$$\mathbf{w}_2 = [1 \quad 1 \quad 1]$$

$$\mathbf{w}_3 = [-1 \quad 1 \quad -1.5]$$

The activation function of neurons 1 and 2 is the rectified linear unit (ReLU), and the activation function of neuron 3 is the bi-polar binary function. Assume x_1 and x_2 are in the following range:

$$-1 < x_1 < 1$$

$$-1 < x_2 < 1$$

Find the regions where points (x_1, x_2) are mapped to 1 and -1 respectively by the neural network.

(8 Marks)

Note: Question No. 3 continues on page 3.

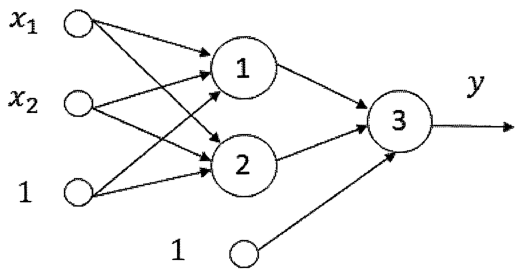

Figure 1

(b) Sketch a typical convolutional neural network for image classification, and describe the operations performed in each layer.

(6 Marks)

(c) In transfer learning for deep neural networks, models pre-trained on source domain data are often used to help target domain model training. Discuss how the pre-trained models should be used under the following scenarios:

(i) Target domain data is small and similar to source domain data
(ii) Target domain data is large and very different from source domain data
(iii) Target domain data is small and very different from source domain data

(6 Marks)

4. Assume there is an imprecise relationship between the temperature and pressure for efficient operation of a heat exchanger. Let A be a fuzzy set of the temperature (in ºCelsius) and B represents a fuzzy set of the pressure (in P) with the following membership functions:

$$A = \left\{ \frac{0.7}{50} + \frac{0.6}{60} + \frac{0.5}{80} + \frac{0.3}{90} + \frac{0.2}{95} \right\},$$

$$B = \left\{ \frac{0.5}{200} + \frac{0.7}{230} + \frac{1.0}{260} + \frac{0.2}{300} + \frac{0.1}{330} \right\}.$$

(a) Find the Cartesian product represented by the relation $R = A \times B$. What does the relation R represent?

(6 Marks)

Note: Question No. 4 continues on page 4.

(b) Suppose that we have another fuzzy set of temperature (in ºCelsius) given as

$$C = \left\{ \frac{0.3}{50} + \frac{0.4}{60} + \frac{0.7}{80} + \frac{0.9}{90} + \frac{1.0}{95} \right\}$$

(i) Use max-min composition, find $D = C \circ R$.

(4 Marks)

(ii) Use max-product composition, find $E = C \circ R$.

(4 Marks)

(c) Let S be a relation between the mass of steam (in kg) and the temperature (in º Celsius) in the heat exchanger given as:

$$S = \begin{bmatrix} 0.2 & 0.2 & 0.2 & 0.2 & 0.1 \\ 0.3 & 0.6 & 0.5 & 0.2 & 0.1 \\ 0.4 & 0.6 & 0.6 & 0.6 & 0.7 \\ 0.4 & 0.5 & 0.5 & 0.5 & 0.6 \\ 0.4 & 0.7 & 0.8 & 0.8 & 0.8 \end{bmatrix}.$$

Compute the fuzzy max-min composition $T = S \circ R$.

(6 Marks)

5. A fuzzy air conditioner (AC) controller which uses two inputs, namely the temperature difference (in ºC) and rate of temperature change (in ºC/s), is used to maintain the room temperature at a desired value. The AC will regulate the flow, U (in m^3/s), of the air into the room. The temperature difference is computed as $\Delta T = T - T_0$, where T_0 is the desired temperature and T is the current temperature. The rate of temperature change, D, is the derivative of ΔT with respect to time (in s). The fuzzy sets defined on the input parameters, ΔT and D, are Large Negative (*LN*), Medium Negative (*MN*), Zero (*ZE*), Medium Positive (*MP*) and Large Positive (*LP*). Figure 2 on page 5 shows the membership profiles of these fuzzy sets.

Note: Question No. 5 continues on page 5.

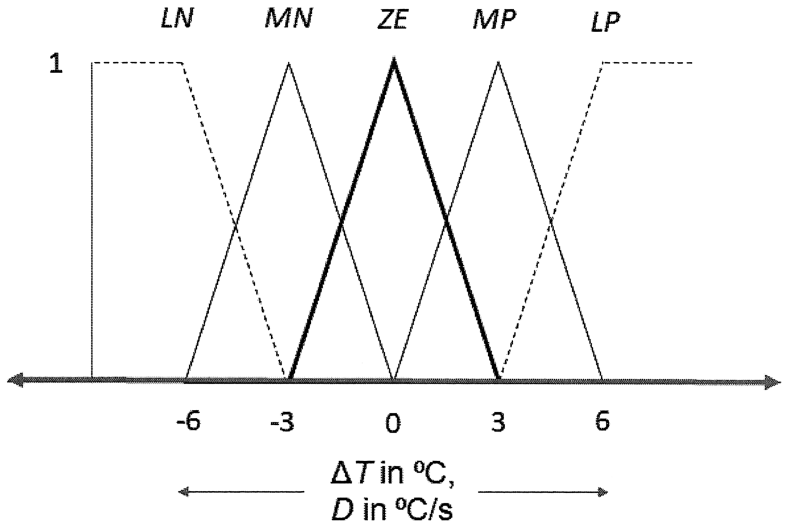

Figure 2 Fuzzy Membership Functions of ΔT and D

The output U is categorized by the fuzzy sets Zero (Z), Small (S), Medium (M) and Large (L) as shown in Figure 3.

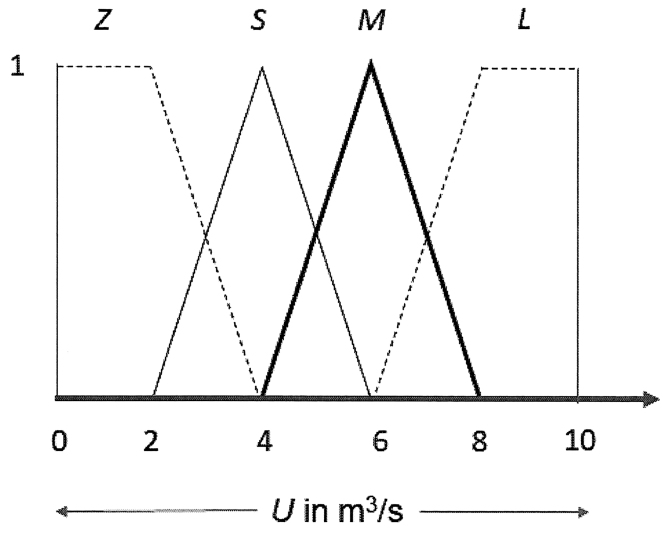

Figure 3 Fuzzy Membership Functions of U

The fuzzy rule base is tabulated in Table 1 on page 6.

Note: Question No. 5 continues on page 6.

ΔT / D	*LN*	*MN*	*ZE*	*MP*	*LP*
LN	*Z*	*Z*	*Z*	*Z*	*S*
MN	*Z*	*Z*	*Z*	*S*	*M*
ZE	*Z*	*Z*	*Z*	*M*	*M*
MP	*Z*	*Z*	*S*	*M*	*L*
LP	*Z*	*S*	*M*	*L*	*L*

Table 1 Fuzzy Rule Base

(a) Using a Mamdani fuzzy controller and the Weighted Average Method approximation to Centre of Gravity (COG) defuzzification, what is the defuzzified value of the control U when $\Delta T = 0.75$ °C and $D = 4.5$ °C/s?

(12 Marks)

(b) A Takagi-Sugeno fuzzy controller is proposed for the AC with the following four rules:

IF ΔT is ZE and D is ZE, THEN $f_1(\Delta T, D) = 2 \times (|\Delta T| + |D|) \div 3$.

IF ΔT is ZE and D is MP, THEN $f_2(\Delta T, D) = 2 + 2 \times (|\Delta T| + D) \div 3$.

IF ΔT is MP and D is ZE, THEN $f_3(\Delta T, D) = 4 + 2 \times (\Delta T + |D|) \div 5$.

IF ΔT is MP and D is MP, THEN $f_4(\Delta T, D) = 4 + (\Delta T + D) \div 3$.

Using *min* T-norm operator to compute the firing strength, what is the new value of the control U when $\Delta T = 0.75$ °C and $D = 1.5$ °C/s?

(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.