NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2022-2023

EE7207 – NEURAL AND FUZZY SYSTEMS

November / December 2022 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.
5. Unless specifically stated, all symbols have their usual meanings.

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1. There are three vectors as given below:

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

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

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

(a) If a Hopfield neural network with a bi-polar binary activation function 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.

(7 Marks)

Note: Question No. 1 continues on page 2.

(b) If a bi-directional associative memory (BAM) neural network with a bi-polar binary activation function is used to store the three vectors, sketch the architecture of the BAM neural network, compute the weights, and check whether the BAM neural network designed could correctly retrieve the stored vectors.

(7 Marks)

(c) Compare and discuss the storage capability of the Hopfield neural network in part (a) and the BAM neural network in part (b).

(6 Marks)

2. A Bank has one million customers. In a direct marketing study, 2500 customers are to be selected as the representatives of the one million customers.

(a) Sam suggested that the self-organizing map (SOM) neural network be used for the selection of the 2500 customers. Discuss the rationale of Sam's suggestion.

(5 Marks)

(b) Discuss how to design and train the SOM neural network for selecting the 2500 customers.

(10 Marks)

(c) SOM neural networks are often used for clustering. Discuss any other applications of SOM neural networks.

(5 Marks)

3. (a) Consider the single-layer feedforward neural network shown in Figure 1 on page 3, where $x_1, x_2, \cdots, x_p$ are the inputs, $w_1, w_2, \cdots, w_p$ are the weights. The activation function of the output layer neuron is a sigmoid function. Assume the sequential learning is adopted, and the following loss function is used:

$$J = \frac{1}{2}[y(k) - d(k)]^2$$

where $y(k)$ and $d(k)$ are the output of the neural network and target value for the k^{th} sample. Derive the back-propagation weight updating rule.

(7 Marks)

(b) Figure 2 on page 3 shows a cell of the typical long-short-term-memory (LSTM) neural network. Identify the gates and describe the functions and operations of each gate.

(7 Marks)

Note: Question No. 3 continues on page 3.

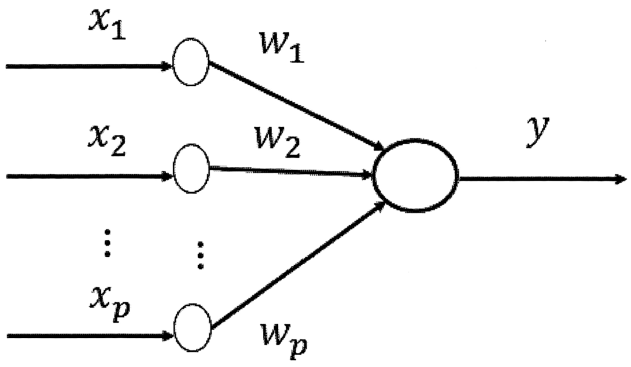

Figure 1

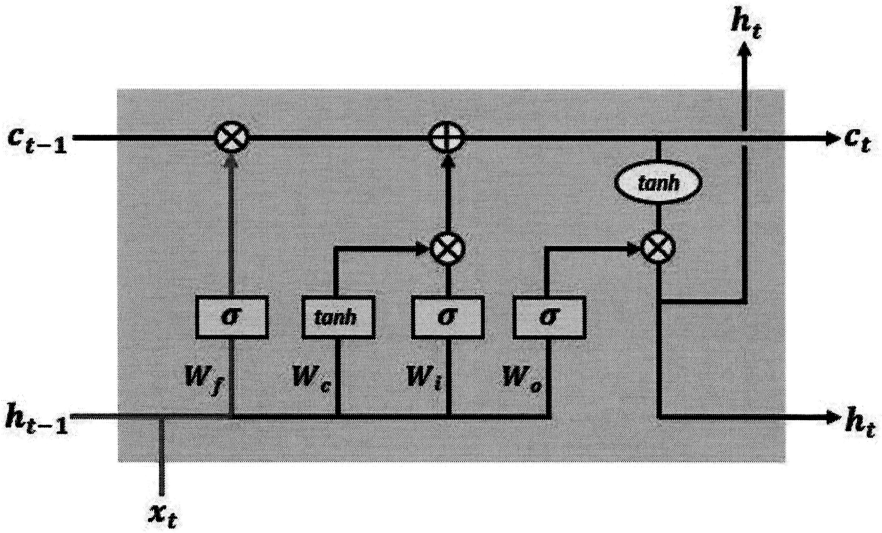

Figure 2

(c) In deep neural network training, one frequently encountered problem is gradient vanishing. Discuss its impact and suggest solutions to the problem.

(6 Marks)

4. (a) The membership function for fuzzy binary relation $R(x,y)$ on X x Y, a Cartesian product of real numbers, is defined as follows

$$\mu_R(x,y) = \exp\left[-\left(\frac{x-7}{3}\right)^2 - \left(\frac{y-1}{9}\right)^2\right] \quad .$$

Determine the projections of R onto X and Y. What does the relation R represent?

(5 Marks)

Note: Question No. 4 continues on page 4.

(b) Let $X=[2,5]$ and $Y=[3,8]$ with respective fuzzy membership functions

$$\mu_X(x)=\begin{cases}x-2, & 2\le x\le 3\\ (5-x)/2, & 3\le x\le 5\end{cases}$$

and

$$\mu_Y(y)=\begin{cases}(y-3)/2, & 3\le y\le 5\\ (8-y)/3, & 5\le y\le 8\end{cases}$$

Let $z=F(x,y)=x-y$. Compute the fuzzy interval Z and fuzzy membership function $\mu_Z(z)$.

(10 Marks)

(c) Identify 2 characteristics of problems where fuzzy logic controller is most suitable. Describe the 3-step design procedure for a direct fuzzy logic controller.

(5 Marks)

5. (a) Consider the following fuzzy rule : **If '*x* is *A*' Then '*y* is *B*',** where A and B are fuzzy sets in the Universes X and Y, respectively. Let

$X=\{500,1000,3000,5000,10000\}$,

$Y=\{10,15,20,25\}$.

(i) The fuzzy sets A and B are given below:

$$A=\left\{\frac{0.3}{500}+\frac{0.4}{1000}+\frac{0.7}{3000}+\frac{0.9}{5000}+\frac{1.0}{10000}\right\},$$

$$B=\left\{\frac{0.1}{10}+\frac{0.4}{15}+\frac{0.7}{20}+\frac{0.9}{25}\right\}.$$

Using Mamdani implication rule (min operator), compute the fuzzy implication relation $R_m=A\times B$. Given the fact that x is A', where

$$A'=\left\{\frac{0.9}{500}+\frac{0.7}{1000}+\frac{0.5}{3000}+\frac{0.3}{5000}+\frac{0.1}{10000}\right\},$$

derive the conclusion y using max-min composition.

(5 Marks)

(ii) The fuzzy rule is modified to be: **If '*x* is *A*' Then '*y* is *B*' Else '*y* is *C*',** where C is another fuzzy set in the Universe Y defined as

Note: Question No. 5 continues on page 5

$$C = \left\{ \frac{0.3}{10} + \frac{0.6}{15} + \frac{0.5}{20} + \frac{0.2}{25} \right\} .$$

Use Larsen implication rule (algebraic product operator) to compute the fuzzy implication relation $R_p = (A \times B) \cup (\bar{A} \times C)$ for the modified fuzzy rule.

(3 Marks)

(b) Give two advantages of Neuro Fuzzy Hybrid Systems and list two examples of Neuro Fuzzy Hybrid Systems.

(4 Marks)

(c) In an Adaptive Neuro Fuzzy Inference System (ANFIS), the computed output $z(k)$ to the k-th input pattern, $x(k)$, is given by the following bell function

$$z(k) = \frac{1}{1 + \left| \frac{x(k) - c}{a} \right|^{2b}} .$$

Derive the partial derivatives of $z(k)$ with respect to the membership function parameters a, b and c and show how the shape of the membership function is adjusted using the following steepest descent equations

$$a(k+1) = a(k) - \eta \left(z(k) - y(k) \right) \frac{\partial z(k)}{\partial a} ,$$

$$b(k+1) = b(k) - \eta \left(z(k) - y(k) \right) \frac{\partial z(k)}{\partial b} ,$$

$$c(k+1) = c(k) - \eta \left(z(k) - y(k) \right) \frac{\partial z(k)}{\partial c} ,$$

where η is a learning parameter and $y(k)$ is the desired output for $x(k)$.

(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.