NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2018-2019

EE7207 – NEURAL AND FUZZY SYSTEMS

November/December 2018 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) Design a bi-directional associative memory (BAM) neural network to store the following two vectors:

$$Q_1 = [1 \quad -1 \quad -1]^T$$

$$Q_2 = [-1 \quad 1 \quad 1]^T$$

Sketch the architecture of the BAM neural network designed, compute the weights on the links between neurons, and test whether the designed BAM works.

(6 Marks)

(b) Train a multilayer perceptron (MLP) neural network with one hidden layer to map the following two input vectors to 1 and 0, respectively:

$$Q_3 = [0.8 \quad 0.9 \quad 0.8]^T$$

$$Q_4 = [-0.9 \quad -0.7 \quad -0.95]^T$$

Assume that the logistic sigmoid activation function is used in both the hidden layer and the output layer. Sketch the MLP neural network architecture, and describe the training process and weight updating rules.

(9 Marks)

Note: Question No. 1 continues on page 2

(c) The back propagation (BP) algorithm is a commonly used gradient-based algorithm for MLP neural network training. It is discovered that the gradients of the network's output with respect to the weights in the early layers become extremely small when multiple hidden layers are used. Discuss the cause of the problem, the impacts, and solution to the problem.

(5 Marks)

2. (a) Describe the self-organizing phase training procedure of the self-organizing map (SOM) neural network.

(5 Marks)

(b) Assume that the following samples are used to train an SOM neural network with two neurons:

$$\boldsymbol{x}_1 = [0.235 \quad -0.081 \quad 0.264]$$

$$\boldsymbol{x}_2 = [1.994 \quad 2.195 \quad 2.083]$$

$$\boldsymbol{x}_3 = [0.169 \quad 0.156 \quad 0.301]$$

$$\boldsymbol{x}_4 = [2.211 \quad 1.909 \quad 2.161]$$

$$\boldsymbol{x}_5 = [-0.006 \quad 0.297 \quad 0.083]$$

$$\boldsymbol{x}_6 = [2.096 \quad 2.052 \quad 2.101]$$

At the end of the self-organizing phase, the weight vectors of the two neurons are obtained as follows:

$$\boldsymbol{w}_1 = [0.136 \quad 0.211 \quad 0.216]$$

$$\boldsymbol{w}_2 = [2.16 \quad 1.98 \quad 2.051]$$

If $\boldsymbol{x}_1$ and $\boldsymbol{x}_2$ are used in the first and the second iterations respectively, what are the weight vectors of the two neurons after 2 iterations of the convergence phase? Assume that the learning rate is fixed to 0.01, and only the weight vector of the winning neuron is updated at each step of the convergence phase.

(9 Marks)

(c) Discuss the setting of the number of neurons in SOM neural networks.

(6 Marks)

3. Let two fuzzy variables x and y have the sets $\mathrm{X}=[-10,5]$ and $\mathrm{Y}=[0,10]$ with the membership functions:

$$\mu_X = \begin{cases} 0 & -10 \le x \le -5 \\ \frac{x}{4}+\frac{5}{4} & -5 \le x \le -1 \\ -\frac{x}{6}+\frac{5}{6} & -1 \le x \le 5 \end{cases}$$

$$\mu_Y = \begin{cases} 0 & -2 \le y \le -1 \\ \frac{y}{6}+\frac{1}{6} & -1 \le y \le 5 \\ -\frac{y}{7}+\frac{12}{7} & 5 \le x \le 10 \end{cases}$$

Use the α cut method to solve the following problems:

(a) Derive and sketch $\mu_Z(z) = \underset{Z=X+Y}{\vee}\{\mu_X(x) \wedge \mu_Y(y)\}$.

(7 Marks)

(b) Derive and sketch $\mu_Z(z) = \underset{Z=X-Y}{\vee}\{\mu_X(x) \wedge \mu_Y(y)\}$.

(7 Marks)

(c) Derive a mathematical representation of $(Z)_\alpha = (X)_\alpha \cdot (Y)_\alpha$.

(6 Marks)

4. Two discrete variables are given as:

$$X = \{20 \quad 22 \quad 24 \quad 26 \quad 28 \quad 30 \quad 32\};\ Y = \{15 \quad 20 \quad 25 \quad 30 \quad 35 \quad 40\}$$

with the respective fuzzy membership functions:

$$\mu_A(x) = [0 \quad 0.6 \quad 0.4 \quad 0.1 \quad 0 \quad 0.5 \quad 0.1];\ \mu_B(y) = [0.6 \quad 0.2 \quad 0 \quad 0.5 \quad 0 \quad 0.5 \quad 0].$$

Assume that when the fuzzy reasoning is "if x in A then y is B", then a generalized membership function is given as $\mu_{A1}(x) = [0 \quad 0 \quad 0.1 \quad 0.5 \quad 0.2 \quad 0.6 \quad 0.1]$.

(a) If x is A1, what is membership function of y in B1?

(7 Marks)

(b) Give a sample graphic representation of the fuzzy set relationship among A, A1, B and B1 based on Question 4(a).

(7 Marks)

(c) Based on Mamdani's fuzzy implication function $C1 = (A1 \times B1) \circ (A \times B \rightarrow C)$, show the fuzzy membership function $\mu_{C1}(z)$.

(6 Marks)

5. A fuzzy car control system has two inputs: steering wheel angle θ and steering wheel angular speed $\dot{\theta}$ and one output: car directional angle θ_c. The membership functions of fuzzy sets for both θ and $\dot{\theta}$ are given in Figure 1 and the fuzzy membership functions of output θ_c are given in Figure 2 on page 5.

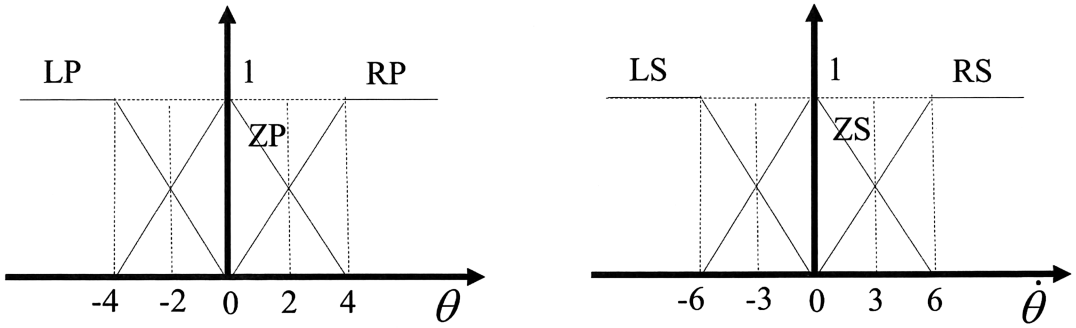

Figure 1

Note: Question No. 5 continues on page 5

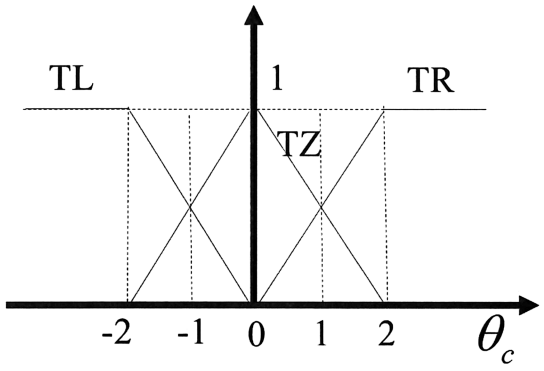

Figure 2

(a) Write a set of linguistic rules according to Table 1 in which LP, ZP and RP represent fuzzy inputs of steering angles; SL, ZS and RS represent steering angular speeds.

(5 Marks)

(b) The control inputs $\theta = 1.2$ and $\dot{\theta} = 2.5$ are applied to the linguistic rules derived in Question 5(a). Assuming that we are using the conjunction operator (FUZZY AND) in the antecedents of the rules based on Mamdani's minimum, calculate the corresponding rule firing levels.

Table 1

	LP	ZP	RP
LS	Turn Right	Turn Right	Turn Left
ZS	Turn Right	No Change	Turn Left
RS	Turn Right	Turn Left	Turn Left

(10 Marks)

(c) Use the center of gravity defuzzification method to calculate the car directional angle θ_c with the given crisp inputs in Question 5(b).

(5 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.