Ref. No.: **Ex/ET/T/415B/2019**

B.E. ELECTRONICS AND TELE-COMMUNICATION ENGINEERING FOURTH YEAR FIRST SEMESTER - 2019

Subject: NEURO-FUZZY CONTROL Time: 3 Hours Full Marks: 100

All parts of the same question must be answered at one place only

1. (a) Briefly explain different defuzzification methods. 5
   (b) What is the advantage of Takagi-Sugeno fuzzy control system over Mamdani control system? 5
   (c) How FCM overcomes limitations of *k*-means clustering? 5
   (d) What is the significance of a kernel function in the context of non-linear classification using SVM? 5
   (e) Explain LMS and gradient descent search induced weight and bias adaptation strategy of an ADALINE neuron. 5

2. (a) Show that the Einstein sum, given by 4

$$ES(\mu_A(x), \mu_B(x)) = \frac{\mu_A(x) + \mu_B(x)}{1 + \mu_A(x)\mu_B(x)},$$

   for any two fuzzy sets A and B under a common universe X is a typical S-norm function.

   (b) The following linguistic information approximates the differential equation governing the process of mixing composition of a chemical plant.

   IF the concentration within the tank is "high",
   THEN the tank should drain at a "fast" rate.

   The fuzzy sets for a "high" concentration and a "fast" drainage rate can be

   μ_{HIGH}(*concentration*)={0|100g/L, 0.2|150 g/L, 0.4|200 g/L, 0.7|250 g/L, 1|300g/L}
   μ_{FAST}(*drainage-rate*) = {0|0 LPM, 0.3|2 LPM, 0.6|4 LPM, 1|6 LPM, 0.8|8 LPM}

   (i) From these two fuzzy sets construct a relation for the rule using classical implication. 4

   (ii) Suppose a new rule uses a different concentration, say "moderately high," and is expressed by the fuzzy membership function for "moderately high," or

   $\mu_{MOD\_HIGH}{}'$(*concentration*)={0|100g/L, 0.3|150 g/L, 0.3|200 g/L, 1|250 g/L, 0.1|300g/L} 7

   Using max–product composition, find the resulting drainage rate.

OR

3. (a) Explain the extension principle of fuzzy sets from n-dimensional product space to a single universe. 5
   (b) Find the fuzzy set **B** obtained by mapping from fuzzy sets $\mathbf{A}_1$ = {0.2/-1, 0.4/0, 0.6/1} and $\mathbf{A}_2$ = {0.8/-1, 0.6/0, 0.7/1} with $f(x_1, x_2) = x_1 + x_2$ where $x_1 \in \mathbf{X}_1$ and $x_2 \in \mathbf{X}_2$. Here $\mathbf{A}_1$ and $\mathbf{A}_2$ are respective subsets of fuzzy universal sets $\mathbf{X}_1$ and $\mathbf{X}_2$ and **B** is a subset of universal fuzzy set **Y**. 10

[Turn over

4. The force to be applied to an aircraft while descending is controlled by its altitude and downward velocity. The applied force must ensure that the aircraft will descend promptly from high altitude but will touch the ground very gently to avoid damage. The dynamics of the system is given by

$$v(t+1) = v(t) + F(t) \text{ and } h(t+1) = h(t) + v(t),$$

where the downward velocity $v(t) \in [-30 \text{ ft/s}, 30 \text{ ft/s}]$, the altitude $h(t) \in [0 \text{ ft}, 1000 \text{ ft}]$ and the exerted force $f(t) \in [-30 \text{ lbs}, 30 \text{ lbs}]$ and t is the time inst ınt.

(a) Define membership distributions of the state variables and the control output. 5

(b) Design the production rules satisfying the desired objective of aircraft landing. 5

(c) From the designed membership distributions and proposed production rules, determine $F(0)$, $v(1)$ and $h(1)$ for $v(0) = -20$ ft/s and $h(0) = 1000$ ft. 5

OR

5. (a) Design suitable fuzzy control system architecture of a system described by the following state-model using Takagi-Sugeno model for $x_1(t) \in [-1, 1]$ and $x_2(t) \in [-1, 1]$. 7

$$\frac{dx_1(t)}{dt} = -x_1(t) + x_1(t)x_2^3(t)$$

$$\frac{dx_2(t)}{dt} = -x_2(t) + (3 + x_2(t))x_1^3(t)$$

(b) State the Lyapunov stability criteria for a Takagi-Sugeno fuzzy control system with n production rules. Prove the theorem for $n = 2$. 8

6. (a) Derive the expressions of the cluster centroids and the memberships of data points in FCM. 7

(b) A civil engineer wants to classify five rivers into two classes based on flow Q (in cfs) and Manning's roughness coefficient n as given below. 8

Rivers	x_1	x_2	x_3	x_4	x_5
Q	500	250	100	800	750
n	12	50	85	10	21

Find the fuzzy memberships of these five rivers to belong to two classes using FCM algorithm after two iterations with the initial memberships given as

$$\mu_{A1} = \{1|x_1, 1|x_2, 1|x_3, 0|x_4, 0|x_5\} \text{ and } \mu_{A2} = \{0|x_1, 0|x_2, 0|x_3, 1|x_4, 1|x_5\}.$$

OR

7. (a) How the goal of a SVM classifier can be formulated as an optimization problem with inequality constraints? 10

(b) Modify the objective function obtained in the last step to handle non-separable classes. 5

8. (a) Show that the number of steps required by a perceptron to converge to a solution is always finite. 10

(b) Explain the limitation of a single perceptron to implement XOR operation. How could it be overcome? 5

OR

9. (a) How the learning rate influences the steady state of an ADALINE neuron? 9

(b) Determine the maximum value of the learning rate of an ADALINE neuron with the following input data (generated randomly with equal probability` and target pairs. 6

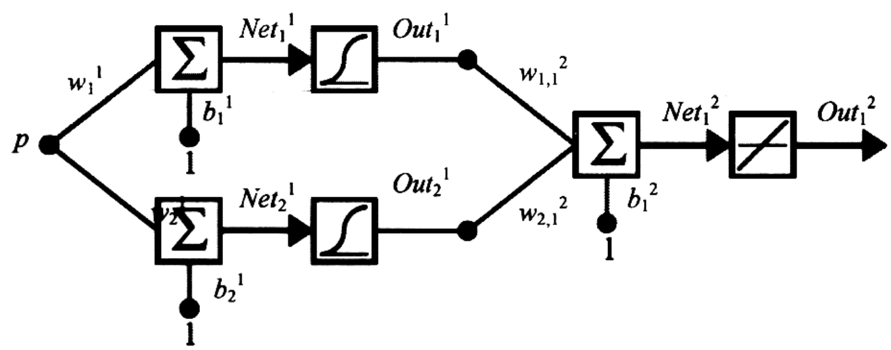
$$\left\{\vec{p}_1=[1,-1,-1]^T, t_1=-1\right\}, \left\{\vec{p}_2=[1,1,-1]^T, t_2=1\right\}$$

10. Derive the expressions for adaptation of weights and biases in a multi-layer neural network using back-propagation learning algorithm. 15

OR

11. For the network shown below, the initial weights and biases are chosen to be 15

$$\vec{W}^1(0)=\begin{bmatrix}-0.27\\-0.41\end{bmatrix},\ \vec{b}^1(0)=\begin{bmatrix}-0.48\\-0.13\end{bmatrix},\ \vec{W}^2(0)=\begin{bmatrix}0.09\\-0.17\end{bmatrix},\ b^2(0)=0.48.$$



The network is used to approximate the function: $g(p)=1+\sin\left(\frac{\pi p}{4}\right)$.