Ref. No.: **Ex/ET/PE/B/T/414/B/2025**

B.E. ELECTRONICS AND TELE-COMMUNICATION ENGINEERING FOURTH YEAR FIRST SEMESTER - 2025

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) Show that the Einstein sum, given by 5

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

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. 6

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

μ_{MOD_HIGH}'(*concentration*)={0|100g/L, 0.3|150 g/L, 0.3|200 g/L, 1|250 g/L, 0.1|300g/L} 9

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

OR

2. (a) Explain the extension principle of fuzzy sets from n-dimensional product space to a single universe. 8

(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**. 12

3. 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 ft/s, 30 ft/s], the altitude $h(t) \in$ [0 ft, 1000 ft] and the exerted force $f(t) \in$ [−30 lbs, 30 lbs] and t is the time instant.

(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. 8

(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. 7

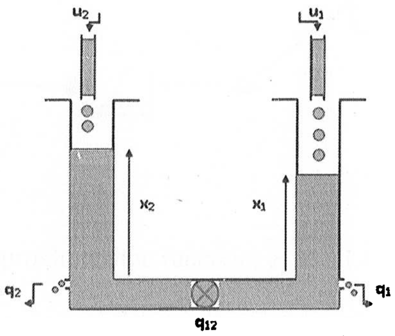
OR

4. (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 $x_2(t) \in [-1, 1]$. 10

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

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

(b) Design suitable fuzzy control system architecture of the following two-link tank system using Takagi-Sugeno model. 10



5. (a) Illustrate one iteration of DE with a population of 5 target vectors to optimize the following function with the true optima at (0,0). 10

$$f(\vec{X}) = 0.26\left(x_1^2 + x_2^2\right) - 0.48x_1x_2$$

(b) What is crossover ratio? Why it is usually set as a high value? 2

(c) Differentiate between evolutionary and swarm optimization techniques. 3

(d) How the global best of a swarm and the personal best of a particle help in improving its quality in PSO? 5

OR

6. (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 show how SVM handles non-separable classification problems. 10

7. (a) Show that the number of steps required by a perceptron to converge to a solution is always finite. 12

(b) Explain the limitation of a single perceptron to implement XOR operation. How could it be overcome? 8

OR

8. (a) Explain LMS and gradient descent search induced weight and bias adaptation strategy of an ADALINE neuron. 10

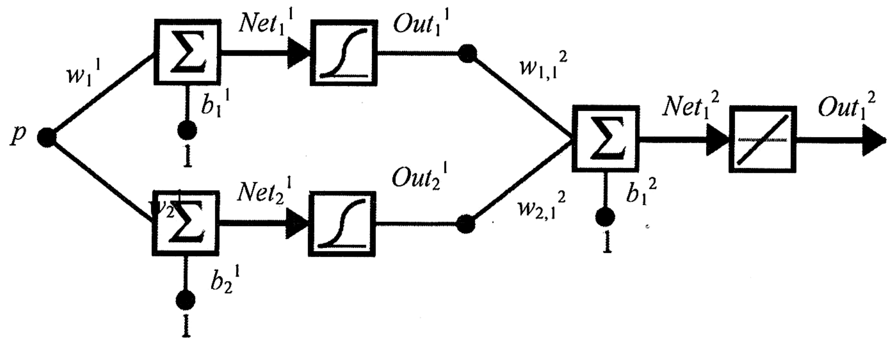
(b) How the learning rate influences the steady state of an ADALINE neuron? 10

9. Derive the expressions for adaptation of weights and biases in a multi-layer neural network using back-propagation learning algorithm. 20

OR

10. For the network shown below, the initial weights and biases are chosen to be 20

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



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