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

Subject: NEURO-FUZZY AND EVOLUTIONARY COMPUTATION **Part: Part-I** **Full Marks: 50**

All parts of the same question must be answered at one place only
Answer any two questions. Each question carries 25 marks.

1. (a) With a neat schematic diagram briefly discuss the different components of an artificial neuron. How can you mathematically realize - i) a hard non-linearity, and ii) a soft non-linearity? 4+2

   (b) Differentiate among Unsupervised and Competitive learning strategies. Give an example of each of these two strategies. 2+2

   (c) What is a feed-forward connection topology? Consider a neural network with two layers having a feed-forward connection topology. The first (input) layer consists of two neurons and the second (output) layer contains one neuron. The top neuron in the first layer has inputs 6 and -2 with corresponding weights 3 and 2. The bottom neuron in the first layer has inputs 1, 3 and 4 with corresponding weights 2, 1 and -2. Assume all the three neurons have sigmoid type nonlinearity. Draw the network and find the final output. 1+6

   (d) What is a perceptron? Explain with an example function what is meant by a linearly separable problem. Show how a perceptron can realize your example function. 2+2+4

2. (a) Explain gradient descent learning. Name one algorithm which employs this learning strategy. 2+1

   (b) Show how the weights of neurons in the last and the penultimate layers can be updated in the back propagation algorithm. Can you justify the name "back propagation"? 6+1

   (c) Discuss any two strategies for improving the performance of the back propagation algorithm. 5

   (d) Distinguish between continuous and discrete Hopfield networks. Encode the four bipolar patterns $X_1 = [1\ -1]$, $X_2 = [-1\ 1]$, $X_3 = [-1\ 1]$ and $X_4 = [-1\ -1]$ using a discrete Hopfield Network. 2+5

   (e) Discuss how Hopfield networks can be used for pattern stage and recall. 3

3. (a) Explain Hebbian learning. 3

   (b) What do you mean by a Winner-Take-All network? Consider a Winner-Take-All network with three nodes A, B, C, and a learning rate of 0.5 for the first two iterations and that of 0.2 for the third iteration. The following three training patterns are shown successively to the above network: 2+8

   $i_1 = \{1.1, 1.7, 1.8\}$; $i_2 = \{0, 0, 0\}$; $i_3 = \{0, 0.5, 1.5\}$

   The initial connection strengths of the network with three input nodes and three output nodes are given by:

$$\begin{bmatrix} w_A & 0.2 & 0.7 & 0.3 \\ w_B & 0.1 & 0.1 & 0.9 \\ w_C & 1 & 1 & 1 \end{bmatrix}$$

   Further assume that the network has a linear topology of the form: B – A – C. Show the updated weight matrix for three iterations.

   (c) Explain the working principle of a Self-Organizing Feature Map (SOFM). State a similarity and a difference between a Winner-Take-All network and a SOFM. 6+2

   (d) Discuss one application of SOFM. 4

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

Subject: NEURO-FUZZY AND EVOLUTIONARY COMPUTATION Time: 3 Hours Full Marks: 100

Use Separate Answer Scripts for each Part.

PART-II

Module-I: Answer ANY TWO (2×20=40)

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 mixing composition of a chemical plant is governed according to a differential equation. But, to approximate this process, we know the following linguistic information:

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

$\mu_{HIGH}(concentration)$={0|100g/L, 0.2|150 g/L, 0.4|200 g/L, 0.7|250 g/L, 1|300g/L}
$\mu_{FAST}(drainage\text{-}rate)$ = {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 Lukasiewicz implication. 8

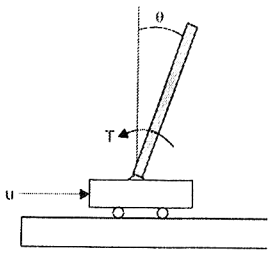
(ii) Suppose a new rule uses a different concentration, say "moderately high," and is expressed by the fuzzy membership function for "moderately high," or 7

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

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

2. (a) Define concentration and dilation operation in the context of fuzzy linguistic hedges. 5

(b) The linear differential equation of an inverted pendulum is given next.



$$\frac{4l}{3}\frac{4M+m}{4m}\ddot{\theta} - \frac{M+m}{m}g\theta = -\frac{u}{m}\frac{180}{\pi}$$

with $l = \frac{3(M+m)g}{4M+m}$ and $M = \frac{180}{\pi g} - m$

where m is the mass of the pole assumed to be concentrated at the center of the pendulum

M is mass of the cart

$2l$ is the length of the pendulum

θ is the deviation angle from vertical in the clockwise direction
T is the torque applied to the pole in the counterclockwise direction
U is the control on the cart acting from left to the right producing the counterclockwise torque T
t is time, and
g is the gravitational acceleration constant

(i) Define membership distributions of the state variables and the control output for $\theta(t) \in [-2 \text{ degree}, 2 \text{ degree}]$, $\dot{\theta}(t) \in [-4 \text{ dps}, 4 \text{ dps}]$ and $u(t) \in [-10, 10]$. 5

(ii) Design the production rules for balancing the inverted pendulum in the vertical position. 5

(iii) From the designed membership distributions and proposed production rules, determine $u(0)$, $\theta(1)$ and $\dot{\theta}(1)$ for $\theta(0) = 1$ degree and $\dot{\theta}(0) = 0$ dps using Mamdani implication. 5

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

(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. 9

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

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

(c) 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**. 5

Module-II: Answer ANY ONE (1×10=10)

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

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

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

5. (a) Why Pareto dominance is preferred over weighted sum approach for a multi-objective optimization? 4

(b) What is crowding distance? Explain its significance. 6