M.E. ELECTRONICS AND TELE-COMMUNICATION ENGINEERING FIRST YEAR
FIRST SEMESTER - 2024

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

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

PART-I

Module-I: Answer ANY TWO (2×20=40)

1. (a) Show that the Einstein product, given by 5

$$ES(\mu_A(x), \mu_B(x)) = \frac{\mu_A(x)\mu_B(x}{2-(\mu_A(x)+\mu_B(x)-\mu_A(x)\mu_B(x))},$$

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

(b) In public transportation systems there often is a significant need for speed control. For subway systems, for example, the train speed cannot go too far beyond a certain target speed or the trains will have trouble stopping at a desired location in the station. Set up a fuzzy set

A = "speed way over target" = {0|T_0, 0.6|(T_0+5), 0.9|(T_0+10), 1|(T_0+15)}

on a universe of target speeds, say T = [T_0, T_0+15], where T_0 is a lower bound on speed. Define another fuzzy set

B = "apply brakes with high force" = {0.3|10, 0.8|20, 0.9|30, 1.0|40}

on a universe of braking pressures, say S = [10, 40].

(i) For the compound proposition, IF speed is "way over target," THEN "apply brakes with high force," find a fuzzy relation using classical implication. 8

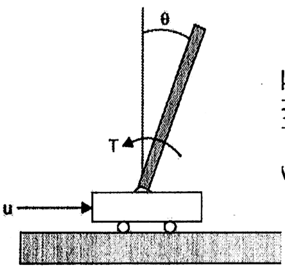
(ii) For a new antecedent, 7

A' = "speed moderately over target" = {0.2|T_0, 0.6|(T_0+5), 1.0|(T_0+10), 0.3|(T_0+15)}

find the fuzzy brake pressure using max–min composition.

2. (a) Explain the extension principle of fuzzy sets from n-dimensional product space to a single universe. 5

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



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

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

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. 10

(b) While designing CMOS inverter circuit, it is observed that the W/L ratio of both n-MOS and p-MOS must increase proportionally with an increase in the output load capacitance to maintain the same delay time.

(i) Design a suitable production rule to capture the design objective. 1

(ii) Find a fuzzy relation for the proposed rule using 4
$\mu_{LARGE}(capacitance)$= {0.2|0.5 pF, 0.6|2 pF, 1|8 pF} and $\mu_{HIGH}(W/L)$= {0.1|4, 0.8|16, 1|64}.

(iii) Find out the fuzzy membership distribution of W/L ratio if the designer is interested with VERY HIGH load capacitance. 5

Module-II: Answer ANY TWO (2×10=20)

4. Illustrate one iteration of particle swarm optimization with a population of 5 particles to optimize the following function with the true optima at (1, 1). 10

$$f(\vec{X}) = (1-x_1)^2 + 100\left(x_2 - x_1^2\right)^2$$

5. (a) How the global best of a swarm and the personal best of a particle help in improving its quality in particle swarm optimization? 4

(b) Differential evolution employs Darwin principle of the survival of the fittest to improve population over generations. Explain. 3

(c) What is the significance of the crossover ratio in differential evolution? 3

6. What is multi-objective optimization? 3
How does the non-dominated sorting helps in multi-criteria decision making? Explain with an example. 7

PART-II

Answer any two questions. Each question carries 20 marks.

7. (a) Differentiate among Supervised, Unsupervised and Competitive learnings. 3

(b) Mathematically discuss the importance of a differentiable function in the context of supervised learning. Give an example of such a function. 3+1

(c) What is a perceptron? Show how a perceptron can realize an AND function. Does realizing an AND function represent a linearly separable problem? 2+3+1

(d) State and prove the Perceptron Convergence Theorem. 2+5

8. (a) 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+4

(b) Mathematically show that - For a discrete Hopfield model having symmetric weights without self-feedback, the dynamics of the network for bipolar output functions using the asynchronous update always leads towards energy minima at equilibrium. 6

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

(d) Discuss the dynamics of a stochastic network with necessary mathematical details. Explain the objective of a stochastic network in improving the recall in 2(b). 3+2

9. (a) 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+6

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.

(b) 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. 4+2

(c) Show how a Back-propagation algorithm works using suitable expressions. You can assume a network in this context with the output layer containing appropriate synaptic non-linearity. Justify the name "Back-Propagation". 5+1