Ref. No.: **Ex/MECE 515/2024**

M.TECH. INTELLIGENT AUTOMATION AND ROBOTICS FIRST YEAR FIRST SEMESTER - 2024

Subject: COMPUTATIONAL INTELLIGENCE Time: 3 Hours Full Marks: 100

Answer any FIVE.
All parts of the same question must be answered at one place only

1. (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]

   (c) Define concentration and dilation operation in the context of fuzzy linguistic hedges. [5]

2. (a) Show that the Einstein product, given by [5]

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

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

   (b) 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
   $\mu_{HIGH}(conc)$={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 classical 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]
   $\mu_{MOD\_HIGH}'(conc)$={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.

3. (a) Explain the advantages of fuzzy C-means clustering (FCM). 3

   (b) Derive the expressions of the cluster centroids and the memberships of data points in FCM. 10

   (c) 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. 7

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

[Turn over

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

4. (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]

5. (a) State gradient descent learning algorithm. [4]

(b) Derive expressions for computing weights in the last layer and also in the penultimate layer in a feed-forward neural network by Back-Propagation algorithm. [10]

(c) Given a set of N input-output training instances, how will you train a feed-forward neural network by Back-Propagation algorithm? [6]

6. (a) Draw the circuit diagram illustrating a continuous dynamics proposed by J. J. Hopfield. [3]

(b) Derive the expression of the dynamics from the said network. [5]

(c) Suggest a suitable Lyapunov function to determine the condition for stability of the dynamics. [4]

(d) Also determine the condition for stability of the Hopfield Dynamics using the above Lyapunov function. What assumptions are used to determine the stability condition of the dynamics? [8]

7. (a) What is an ADALINE neuron? [2]

(b) Derive the condition for stability of an ADALINE neural dynamics. [3]

(c) How minimum disturbance principle is employed to train a 2-layered feed-forward neural network comprising ADALINES? [5]

(d) How translation and rotation – Invariant pattern recognition is possible using Widrow -Hoff's MADALINE networks? [10]

8. (a) What is SOFM neural network? [2]

(b) How similarity of patterns is encoded spatially on a 2-Dimensional SOFM topology? [3]

(c) Given the world map of a robot, how will you use the sonar-range data, describing distance of obstacles with respect to the position of the robot to train a SOFM neural network to generate speed and direction of the robot to reach a pre-defined target position? [8]

(d) In real time, how will you use the trained SOFM neural network to generate direction of motion and speed from the measured range data? [7]

9. Write short notes on any two of the followings. [10+10]

(a) Perception learning algorithm

(b) Lyapunov function and stability analysis of dynamics

(c) Jaya algorithm and its analysis