



K. K. Wagh Institute of Engineering Education & Research, Nashik
(An Autonomous Institute From A.Y. 2022-23)

WINTER-2025	
Exam Seat No.:	
Academic Year:2025-2026	Semester:IV
Class:SY	Program:B.Tech
Branch Code:ROB	Pattern:2023
Name of Course:Artificial Neural Networks and fuzzy systems	Course Code:2312216
Max. Marks:60	Duration:2.30 Hrs.

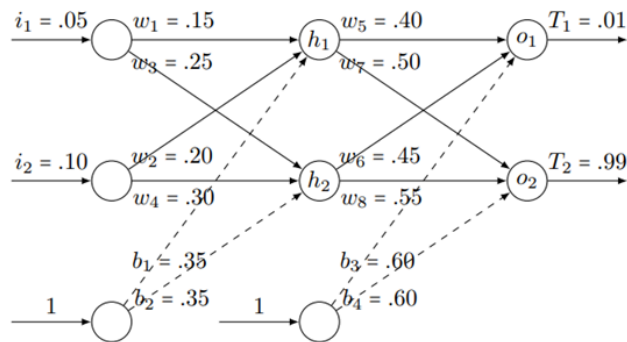
Instructions: Candidates should read carefully the instructions printed on the Question Paper and on the cover page of the Answer Book, which is provided for their use.

1. This question paper contains 8 pages.
2. Answer to each new question is to be started on a new page.
3. Assume suitable data wherever required, but justify it.
4. Draw the neat labelled diagrams, wherever necessary.
5. The last columns indicates the Course Outcome and level of Blooms Taxonomy of the Question/sub-question.

Marks CO

Question No. 1

- 1a) Given the following network, compute the outputs from o1 and o2 (assume that the activation function is the sigmoid function). Also calculate mean squared error (MSE). (6) CO1



Question No. 2

- 2a) A robot is programmed to choose one of three possible tasks based on a neural network's output scores. The scores (logits) for the tasks are as follows: (6) CO2

- Task A (Object Picking): 2.0
- Task B (Path Navigation): 1.0
- Task C (Obstacle Detection): 0.1

Use the softmax function to compute the probability that the robot selects each task.

$$z = [2.0, 1.0, 0.1]$$

Calculate the softmax probabilities

Question No. 3

- 3a) In an automated inspection system, two intelligent agents monitor equipment inside a smart factory: (8) CO3

- Aerial Drone (D) – flies above and scans for issues.
- Ground Inspection Robot (G) – moves along the floor and inspects equipment closely.

Their fuzzy detection sets (membership values) for different objects are:

Aerial Drone Detection Set (D):

$$D = \{ 0.3(\text{pipe}) + 0.7(\text{crack}) + 0.4(\text{robot}) + 0.1(\text{human}) + 0.6(\text{valve}) \}$$

Ground Robot Detection Set (G):

$$G = \{ 0.8(\text{pipe}) + 0.5(\text{crack}) + 0.2(\text{robot}) + 0.9(\text{human}) + 0.3(\text{valve}) \}$$

1. Find the combined detection capability of both systems (the union of D and G).
2. Find the objects that are commonly detected by both systems (the intersection of D and G).
3. Find the objects that the aerial drone does not detect (the complement of D).
4. Find the objects that the ground robot does not detect (the complement of G).

OR

- 3b) In an automated inspection system, a robotic vision system checks transistors for defects (μ_T), and a (8) CO3 sensor system assesses resistor reliability (μ_R).

Given the membership functions μ_T and μ_R :

Membership Functions:

$$\mu_T = \left\{ 0 + \frac{0.2}{1} + \frac{0.7}{2} + \frac{0.8}{3} + \frac{0.9}{4} + \frac{1}{5} \right\}$$

$$\mu_R = \left\{ 0 + \frac{0.1}{1} + \frac{0.3}{2} + \frac{0.2}{3} + \frac{0.4}{4} + \frac{0.5}{5} \right\}$$

Find using fuzzy set operations:

1. Algebraic Sum – Overall likelihood of successful detection.
2. Algebraic Product – Joint probability of both systems working.
3. Bounded Sum – Maximum combined success without overestimation.
4. Bounded Difference – Difference between vision accuracy and sensor reliability.

- 3c) An articulated robot uses fuzzy logic to select arm speed based on task complexity. (8) CO3

- Set A (Task Complexity Requirement): $A = \{(\text{Low}, 0.3), (\text{Medium}, 0.5), (\text{High}, 0.8)\}$
- Set B (Arm Speed Options): $B = \{(\text{Slow}, 0.7), (\text{Moderate}, 0.4), (\text{Fast}, 0.2)\}$

1. Compute the fuzzy relation matrix using the min operation.
2. Compute the fuzzy relation matrix using the max-product operation.
3. Based on your result, which speed is best suited for high-complexity tasks?

OR

3d) Consider three sets in the context of robotic arms performing tasks in an automated manufacturing system: (8) CO3

$S = \{ R_1, R_2, R_3, R_4 \}$ is a set of robotic arms.

$T = \{ T_1, T_2, T_3 \}$ is a set of tasks performed by robotic arms (welding, assembly, painting).

$E = \{ E_1, E_2, E_3, E_4 \}$ denotes a set of efficiency levels of the performed tasks.

Two relations are given below:

Relation 1: R_α (Robotic Arm to Task Assignment)

	T ₁	T ₂	T ₃
R ₁	0	0	0
R ₂	1	0	0
R ₃	0	0	1
R ₄	0	0	0

Relation 2: R_β (Task to Efficiency Level)

	E ₁	E ₂	E ₃	E ₄
T ₁	1	0	0	1
T ₂	0	1	1	1
T ₃	0	0	1	1

Find $R_\alpha \circ R_\beta$, which represents the degree of association between robotic arms and efficiency levels.

Question No. 4

4a) Given the following rules for evaluating the load handling performance of a robot arm: (8) CO4

- Rule 1: IF Load is Light OR Arm Stability is Low THEN Load Handling Performance is Poor
- Rule 2: IF Load is Heavy OR Arm Stability is High THEN Load Handling Performance is Good

The input variables (Load and Stability) are modelled using Gaussian membership functions.

Input Variables and Parameters

Linguistic Variable: Load [1,10]

Fuzzy Value	c	σ
Light	1	5
Heavy	10	5

Linguistic Variable: Stability [1,10]

Fuzzy Value	c	σ
Low	1	5
High	10	5

The fuzzy values and corresponding parameters for Stability are:

Output Variable: Load Handling Performance [1,5]

The membership function for Load Handling Performance is defined as follows:

- **Poor:**
 - $\mu_{\text{Poor}}(1) = 1, \mu_{\text{Poor}}(2) = 0.75, \mu_{\text{Poor}}(3) = 0.5, \mu_{\text{Poor}}(4) = 0.25$
- **Good:**
 - $\mu_{\text{Good}}(2) = 0.25, \mu_{\text{Good}}(3) = 0.5, \mu_{\text{Good}}(4) = 0.75, \mu_{\text{Good}}(5) = 1$

Let the Load = 7.3 and Stability = 3.2, Compute the fuzzy output for the robot arm's load handling performance using the disjunctive aggregation method (max for OR and weighted average for defuzzification).

OR

Consider a universe of discourse [0 ... 100] in a continuous domain.

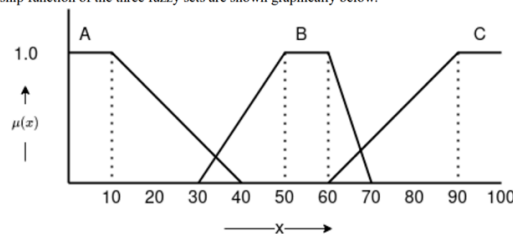
Three fuzzy sets are defined over the above universe of discourse:

- A: Score is Poor
- B: Score is Average
- C: Score is Good

4b)

(8) CO4

The membership function of the three fuzzy sets are shown graphically below.



(a) Express the μ -functions for $\mu_A(x)$, $\mu_B(x)$ and $\mu_C(x)$ mathematically.

(b) Find the defuzzified value of the **fuzzy set B** using COG method

4c) A mobile robot adjusts its speed z based on:

(8) CO4

- x : Terrain smoothness (0–10 scale; low = rough, high = smooth)
- y : Obstacle distance (0–10 scale; low = near, high = far)

Fuzzy Rules:

- **Rule 1:** If terrain is SMALL and obstacle distance is BIG, then $z=1+2x+3y$
- **Rule 2:** If terrain is BIG or obstacle distance is SMALL, then $z=1+2x-3y$

Membership functions:

$$\mu_{SMALL}(s) = \begin{cases} 1 & s \leq 1 \\ 1 - \frac{s-1}{4} & 1 < s \leq 5 \\ 0 & \text{otherwise} \end{cases} \quad \mu_{BIG}(s) = \begin{cases} 0 & s \leq 1 \\ \frac{s-1}{4} & 1 < s \leq 5 \\ 1 & s \geq 5 \end{cases}$$

Let the system inputs be $x=3, y=1$

Use Sugeno inference to compute the robot's speed output z .

OR

- 4d) A 2-DOF robotic arm is designed to maintain stability during precise pick-and-place operations. (8) CO4
The fuzzy logic controller uses two inputs. Each input has three triangular membership functions:

- Joint Angle Error (degrees) : Negative, Zero, Positive
- End-Effector Velocity (mm/s) : Low, Medium, High

Let the Joint Angle Error = -2° and End-Effector Velocity = 45 mm/s

Fuzzy Rules:

Joint Error	Velocity	Rule Output Function
Negative	Low	$z = -0.3E - 0.2V + 10$
Negative	Medium	$z = -0.4E - 0.1V + 8$
Negative	High	$z = -0.2E - 0.3V + 6$
Zero	Low	$z = -0.1E - 0.1V + 5$
Zero	Medium	$z = 0.0E + 0.0V + 0$
Zero	High	$z = 0.1E + 0.2V - 2$
Positive	Low	$z = 0.2E + 0.1V - 5$
Positive	Medium	$z = 0.3E + 0.1V - 7$
Positive	High	$z = 0.4E + 0.2V - 10$

Perform fuzzification of the inputs using triangular membership functions:

- For Joint Angle Error: Negative $(-10, -5, 0)$, Zero $(-2, 0, 2)$, Positive $(0, 5, 10)$
- For Velocity: Low $(0, 0, 50)$, Medium $(30, 50, 70)$, High $(60, 100, 100)$

Use the Sugeno weighted average formula to compute the final crisp Z-axis correction output

Question No. 5

- 5a) Design a convolutional neural network for a robot equipped with a grayscale camera, using an input (8) CO4
image size of $32 \times 32 \times 1$ for object detection. The initial convolutional layer in its vision pipeline has the following parameters:

- Filter (kernel) size: $7 \times 7 \times X$
- Stride: 1
- No zero-padding

Answer the following:

- What must be the value of X to ensure the filter can process the input image correctly?
- After convolution, what will be the dimensions of a single output feature map (activation map)?
- If the robot uses 32 different filters in this layer, how many feature maps will be generated?
- Which nonlinear activation function is commonly applied after convolution in robot vision systems?
 - Sketch its graph and explain why it's useful for detecting edges/objects.
- Suggest a filter size for the next convolutional layer (justify briefly).
- Perform max pooling (2×2 filter, stride 2) on the given feature map below. Given Feature Map (4×6):

$$\begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 5 & 1 & 0 & 4 & 10 & 3 \\ 4 & 7 & 2 & 1 & 10 & 2 \\ 1 & 2 & 3 & 4 & 9 & 7 \end{bmatrix}$$

OR

- 5b) A robotic arm performs visual inspection of components on an assembly line. It uses sequential data (8) CO4 from 4 image-processing sensors (Input Dim = 4) to decide whether a component passes or fails the quality check (Output Dim = 1). The decision is made using a Recurrent Neural Network (RNN) with a hidden state size of 3. The inspection occurs over 4 time steps for each component.

Given:

- Initial Hidden State:

$$H_0 = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

- Input Sequence from sensors over 4 inspection stages:

$$X_1 = \begin{bmatrix} 2 \\ -1 \\ 0 \\ 1 \end{bmatrix}, X_2 = \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \end{bmatrix}, X_3 = \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \end{bmatrix}, X_4 = \begin{bmatrix} 1 \\ 2 \\ -1 \\ 2 \end{bmatrix}$$

- RNN Parameters:

$$W_x = \begin{bmatrix} 1 & 0 & -1 & 1 \\ 0 & 2 & 1 & 0 \\ 1 & 2 & 1 & 0 \end{bmatrix}, W_h = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & -1 \\ 0 & 1 & -1 \end{bmatrix}, b_h = \begin{bmatrix} 1 \\ -1 \\ -1 \end{bmatrix}$$

$$W_y = [3 \ 0 \ -1], b_y = 3$$

Provide the predicted outcomes Y1, Y2, Y3, Y4, indicating probability of passing the quality check at each stage.

- 5c) A Stewart Platform is used for precision motion control in a robotic system. A Mamdani-type fuzzy logic controller is designed to adjust the vertical displacement (Z-axis) of the platform based on the following two input variables: (8) CO4

- Force Applied on Platform (N)
- Tilt Angle of Platform (degrees)

The output of the system is the Z-axis Correction (mm) to stabilize the platform. All input and output variables are represented using triangular membership functions.

Fuzzy Sets and Membership Functions (Triangular):

Input 1: Force Applied (N)

Fuzzy Term	Membership Function
Low	(0, 0, 50)
Medium	(30, 50, 70)
High	(60, 100, 100)

Input 2: Tilt Angle (degrees)

Fuzzy Term	Membership Function
Negative	(-10, -5, 0)
Zero	(-2, 0, 2)
Positive	(0, 5, 10)

Output: Z-axis Correction (mm)

Fuzzy Term	Membership Function
Move Down	(-20, -10, 0)
No Correction	(-2, 0, 2)
Move Up	(0, 10, 20)

Fuzzy Rule Base:

Force \ Angle	Negative	Zero	Positive
Low	Move Up	Move Up	No Correction
Medium	Move Up	No Correction	Move Down
High	No Correction	Move Down	Move Down

Let the Force Applied = 40 N and Tilt Angle = -3 degrees

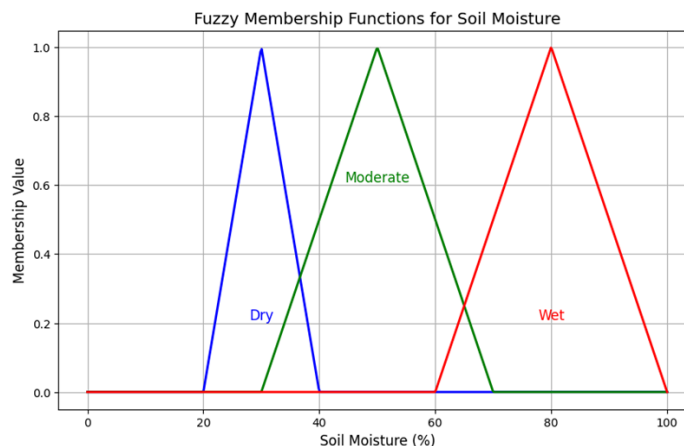
1. Determine the degree of membership of each input in its respective fuzzy sets.
2. Identify and evaluate the active rules based on the fuzzy inputs using the minimum (min) operator.
3. Aggregate the fuzzy outputs of the active rules using Mamdani inference.
4. Apply the Centroid Method to calculate the crisp Z-axis correction

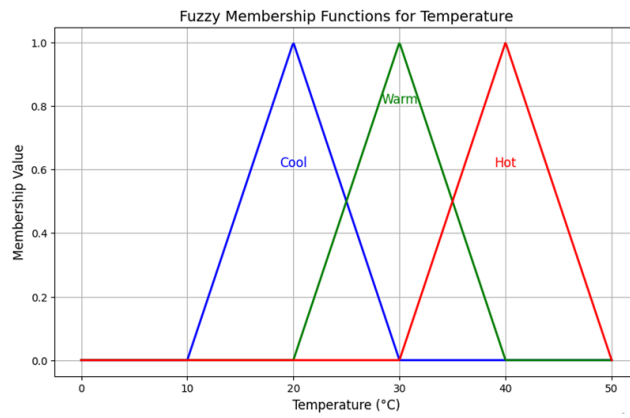
OR

5d) A smart irrigation system adjusts its water flow rate based on two sensor inputs:

(8) CO4

- Soil Moisture (M) in percentage
- Temperature (T) in °C





Fuzzy Rule Base (Sugeno Type):

Rule	IF (Soil Moisture) is...	AND (Temperature) is...	THEN Water Flow Rate =
1	Dry	Warm	Flow = $M + 2 \times T$
2	Dry	Hot	Flow = $M + 3 \times T$
3	Moderate	Warm	Flow = $2 \times M + 2 \times T$
4	Moderate	Hot	Flow = $2 \times M + 3 \times T$

Calculate the output water flow rate using the Sugeno weighted average method when $M = 40\%$ and $T = 30^\circ\text{C}$.

..... End of question paper.....