COMPUTER ENGINEERING DEPARTMENT

AI&SC Assignment 2

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Sr. No.	Questions
1	An engineer is testing the properties, strength and weight of steel. Suppose he has two fuzzy sets, A defined on the universe of discourse (s1,s2,s3} and B defined on a universe of discourse {w1,w2,w3). The membership of A and B are given by uA={(s1,1),(s2,0.5),(s3,0.2); and uB={(w1,1),(w2,0.5),(w3,0.3) A. Find the Cartesian product of A and B i.e R = A X B. B. Suppose C={(s1,0.1),(s2,0.6),(s3,1)}. Find S =C X B. C. Find C o R using Max-min composition. D. Find C . R using max-product composition.
2	Design a fuzzy logic controller stem for a tipping example. Consider service and food quality rated between 0 and 10. Use this to leave a tip of 25%.
3	Use perceptron learning rule for computing weights after one iteration for the data given below: X1=[1 -2 0-1]T; X2=[0 1.5 -0.5 - 1]T; X3=(-1 10.5 -1]T. Initial weight W1=[1 - 1 0 0.5]. The learning constant is given by c=0.1. The teacher's desired responses for X1, X2, X3 are [-1,-1,1] respectively.
4	Discuss EBPTA algorithm with the help of flowchart.
5	Write a short note on ANFIS.
6	Explain genetic algorithm steps with the help of a flowchart.

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Signature of Student

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Q1.

Ans:

(a)

$R = A \times B$ (Cartesion Product)

$\rightarrow \mu A = \{(s_1, 1), (s_2, 0.5), (s_3, 0.2)\}$

$\mu B = \{(w_1, 1), (w_2, 0.5), (w_3, 0.3)\}$

$$R = \begin{array}{cc} & \text{B} \\ & \begin{array}{ccc} w_1 & w_2 & w_3 \end{array} \\ \text{A} \begin{array}{c} s_1 \\ s_2 \\ s_3 \end{array} & \begin{bmatrix} 1 & 0.5 & 0.3 \\ 0.5 & 0.5 & 0.3 \\ 0.2 & 0.2 & 0.2 \end{bmatrix} \end{array}$$

(b)

$S = C \times B$ (Cartesion Product)

$\rightarrow C = \{(s_1, 0.1)\ (s_2, 0.6)\ (s_3, 1)\}$

$\rightarrow B = \{(w_1, 1), (w_2, 0.5)\ (w_3, 0.3)\}$

$$S = \begin{array}{cc} & \text{B} \\ & \begin{array}{ccc} w_1 & w_2 & w_3 \end{array} \\ \text{C} \begin{array}{c} s_1 \\ s_2 \\ s_3 \end{array} & \begin{bmatrix} 0.1 & 0.1 & 0.1 \\ 0.6 & 0.5 & 0.3 \\ 1 & 0.5 & 0.3 \end{bmatrix} \end{array}$$

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(c) C ∘ R [max - min composition]

R ∘ C

$$\begin{bmatrix} 1 & 0.5 & 0.3 \\ 0.5 & 0.5 & 0.3 \\ 0.2 & 0.2 & 0.2 \end{bmatrix} \begin{bmatrix} 0.1 \\ 0.6 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} \max(0.1, 0.5, 0.3) \\ \max(0.1, 0.5, 0.3) \\ \max(0.1, 0.2, 0.2) \end{bmatrix} = \begin{bmatrix} 0.5 \\ 0.5 \\ 0.2 \end{bmatrix}$$

(D) C · R [Max Product Composition

R ∘ C

$$\begin{bmatrix} 1 & 0.5 & 0.3 \\ 0.5 & 0.5 & 0.3 \\ 0.2 & 0.2 & 0.2 \end{bmatrix} \begin{bmatrix} 0.1 \\ 0.6 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} \max(0.1, 0.3, 0.3) \\ \max(0.05, 0.3, 0.3) \\ \max(0.02, 0.12, 0.2) \end{bmatrix} = \begin{bmatrix} 0.3 \\ 0.3 \\ 0.2 \end{bmatrix}$$

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Q2.

Ans:

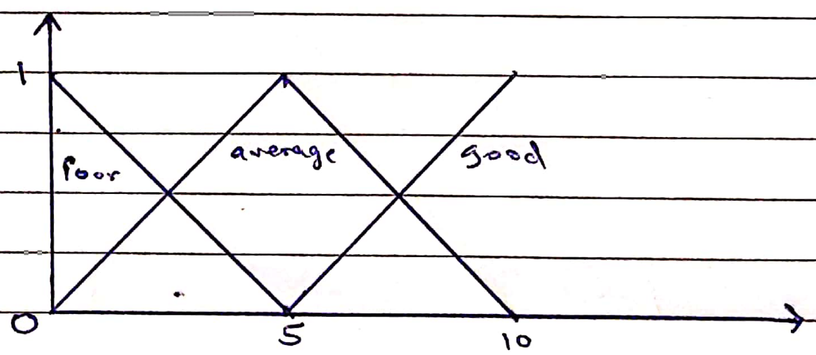
Step 1: Modelling Control Parameters

→ Service { Poor (SP), average (SA), good (SG) }
→ Food Quality { Poor (FP), average (FA), good (FG) }
→ tip { Low (L), Medium (M), High (H) }

Step 2: Input Parameters

① Service : $\mu_s(x)$:

$$\mu_s(x) = \begin{cases} \mu_{SP}(x) = \dfrac{5-x}{5} & 0 \le x \le 5 \\ \mu_{SA}(x) = \dfrac{x-0}{5} & 0 \le x \le 5 \\ \qquad\qquad \dfrac{10-x}{5} & 5 \ge x \le 10 \\ \mu_{SG}(x) = \dfrac{x-5}{5} & 5 \le x \le 10 \end{cases}$$



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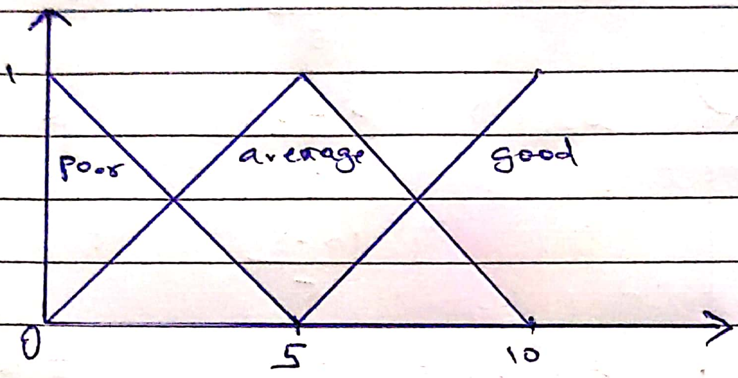
② Food Quality.

$$\mu_R(y) = \begin{cases} \mu_{FP}(y) = \dfrac{5-y}{5} & 0 \le y \le 5 \\ \mu_{FA}(y) = \dfrac{y-0}{5} & 0 \le y \le 5 \\ \quad = \dfrac{10-y}{5} & 5 \le y \le 10 \\ \mu_{FG}(y) = \dfrac{y-5}{5} & 5 \le y \le 10 \end{cases}$$



③ Tip

$$\mu_T(z) = \begin{cases} \mu_L(z) = \dfrac{12.5-z}{12.5} & 0 \le z \le 12.5 \\ \mu_m(z) = \dfrac{z-0}{12.5} & 0 \le z \le 12.5 \\ \quad = \dfrac{25-z}{12.5} & 12.5 \le z \le 25 \\ \mu_H(z) = \dfrac{z-12.5}{12.5} & 12.5 \le z \le 25 \end{cases}$$

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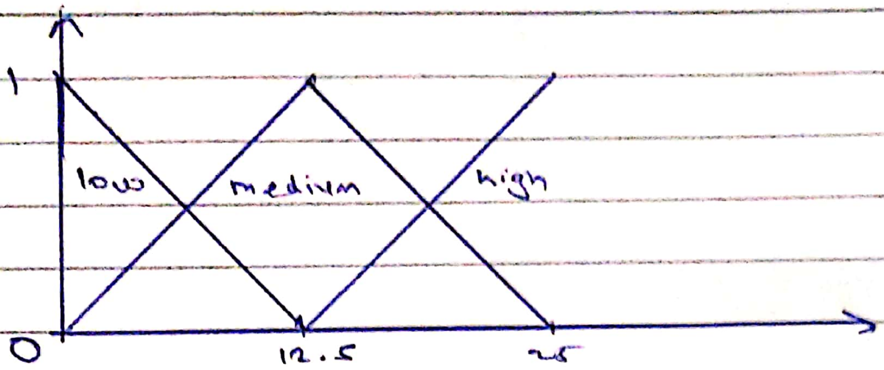

Step 3: Deterministic Rules

S \ F	FP	FA	FG
SP	L	M	H
SA	M	M	H
SG	H	H	H

→ Poor service with poor food quality then tip = low
→ Average service with average food quality then tip = medium
→ Good service with good food quality then tip = high

Step 4: Defuzzification

Consider, service : $x = 7$

food quality : $y = 9$

For service $x = 7$

$$\mu_{SA} = \frac{10 - x}{5} = \frac{10 - 7}{5} = \frac{3}{5}$$

$$\mu_{SG} = \frac{x - 5}{5} = \frac{7 - 5}{5} = \frac{2}{5}$$

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For food service, $y = 9$

$$\mu_{FA} = \frac{10-y}{5} = \frac{10-9}{5} = \frac{1}{5}$$

$$\mu_{FG} = \frac{y-5}{5} = \frac{9-5}{5} = \frac{4}{5}$$

Applying max - min

S \ F	FP	FA	FG
SP	0	0	0
SA	0	1/5	3/5
SG	0	1/5	2/5

$$\max\left\{\frac{1}{5}, \frac{3}{5}, \frac{1}{5}, \frac{2}{5}\right\} = \frac{3}{5}$$

$$\mu_{TM}(z) = \frac{25 - z_1}{12.5}$$

$$\Rightarrow \frac{3}{5} = \frac{25 - z_1}{12.5}$$

$$z_1 = 17.5$$

$$\mu_{TM}(z) = \frac{z_2 - 12.5}{12.5}$$

$$\frac{2}{5} = \frac{z_2 - 12.5}{12.5}$$

$$z_2 = 20$$

$$z = z_1 + z_2/2 = (17.5 + 20)/2 = \underline{18.75\%\ \text{Hp}}$$

Q3.

Ans:

For perceptron learning rule,

$net_i = w_i \cdot x$

$O_i = sign(net_i)$

$\Delta w_i = c(d - O_i)x$

Step 1: Take first training pair $x = x_1$; $d = d_1$

$$x = \begin{bmatrix} 1 \\ -2 \\ 0 \\ -1 \end{bmatrix} \qquad d = 1$$

$$net_1 = w_1 x = \begin{bmatrix} 1 & -1 & 0 & 0.5 \end{bmatrix} \begin{bmatrix} 1 \\ -2 \\ 0 \\ -1 \end{bmatrix} = 2.5$$

$O_1 = sign(net_1) = sign(2.5) = 1$

$$\Delta w_1 = c(d - O_1)x$$

$$= 0.1(-1-1)\begin{bmatrix} 1 \\ -2 \\ 0 \\ -1 \end{bmatrix}$$

$$= \begin{bmatrix} -0.2 \\ 0.4 \\ 0 \\ 0.2 \end{bmatrix}$$

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$W_2 = W_1 + \Delta W_1$

$$= \begin{bmatrix} 1 \\ -1 \\ 0 \\ 0.5 \end{bmatrix} + \begin{bmatrix} -0.2 \\ 0.4 \\ 0 \\ 0.2 \end{bmatrix} = \begin{bmatrix} 0.8 \\ -0.6 \\ 0 \\ 0.7 \end{bmatrix}$$

Step 2: Take second training pair, $x = x_2$, $d = d_2$

$$x = \begin{bmatrix} 0 \\ 1.5 \\ -0.5 \\ -1 \end{bmatrix} \qquad d = -1$$

$$net_2 = W_1 x = \begin{bmatrix} 0.8 & -0.6 & 0 & 0.7 \end{bmatrix} \begin{bmatrix} 0 \\ 1.5 \\ -0.5 \\ -1 \end{bmatrix} = -1.6$$

$\cdot O_2 = \text{sign}(net_2) = \text{sign}(1.6) = -1$

Here,

$d = -1$ & $O_2 = -1$

So,

$(d - O_2) = 0$

Hence,

$\Delta W_2 = 0$

$$\therefore W_3 = W_2 = \begin{bmatrix} 0.8 \\ -0.6 \\ 0 \\ 0.7 \end{bmatrix}$$

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Step 3: Take third training pair, $x = x_3$, $d = d_3$

$$x = \begin{bmatrix} -1 \\ 1 \\ 0.5 \\ -1 \end{bmatrix} \quad d = 1$$

$$net_3 = w_3 x = \begin{bmatrix} 0.8 & -0.6 & 0 & 0.7 \end{bmatrix} \begin{bmatrix} -1 \\ 1 \\ 0.5 \\ -1 \end{bmatrix} = -2.1$$

$$o_3 = sign(net3) = sign(-2.1) = -1$$

$$\Delta w_3 = c(d - o_3)x$$

$$= (0.1)(1-(-1)) \begin{bmatrix} -1 \\ 1 \\ 0.5 \\ -1 \end{bmatrix} = \begin{bmatrix} -0.2 \\ 0.2 \\ 0.1 \\ -0.2 \end{bmatrix}$$

$$w4 = w3 + \Delta w3$$

$$= \begin{bmatrix} 0.8 \\ -0.6 \\ 0 \\ 0.7 \end{bmatrix} + \begin{bmatrix} -0.2 \\ 0.2 \\ 0.1 \\ -0.2 \end{bmatrix} = \begin{bmatrix} 0.6 \\ -0.4 \\ 0.1 \\ 0.5 \end{bmatrix}$$

Weights after one iteration: $\begin{bmatrix} 0.6 & -0.4 & 0.1 & 0.5 \end{bmatrix}$

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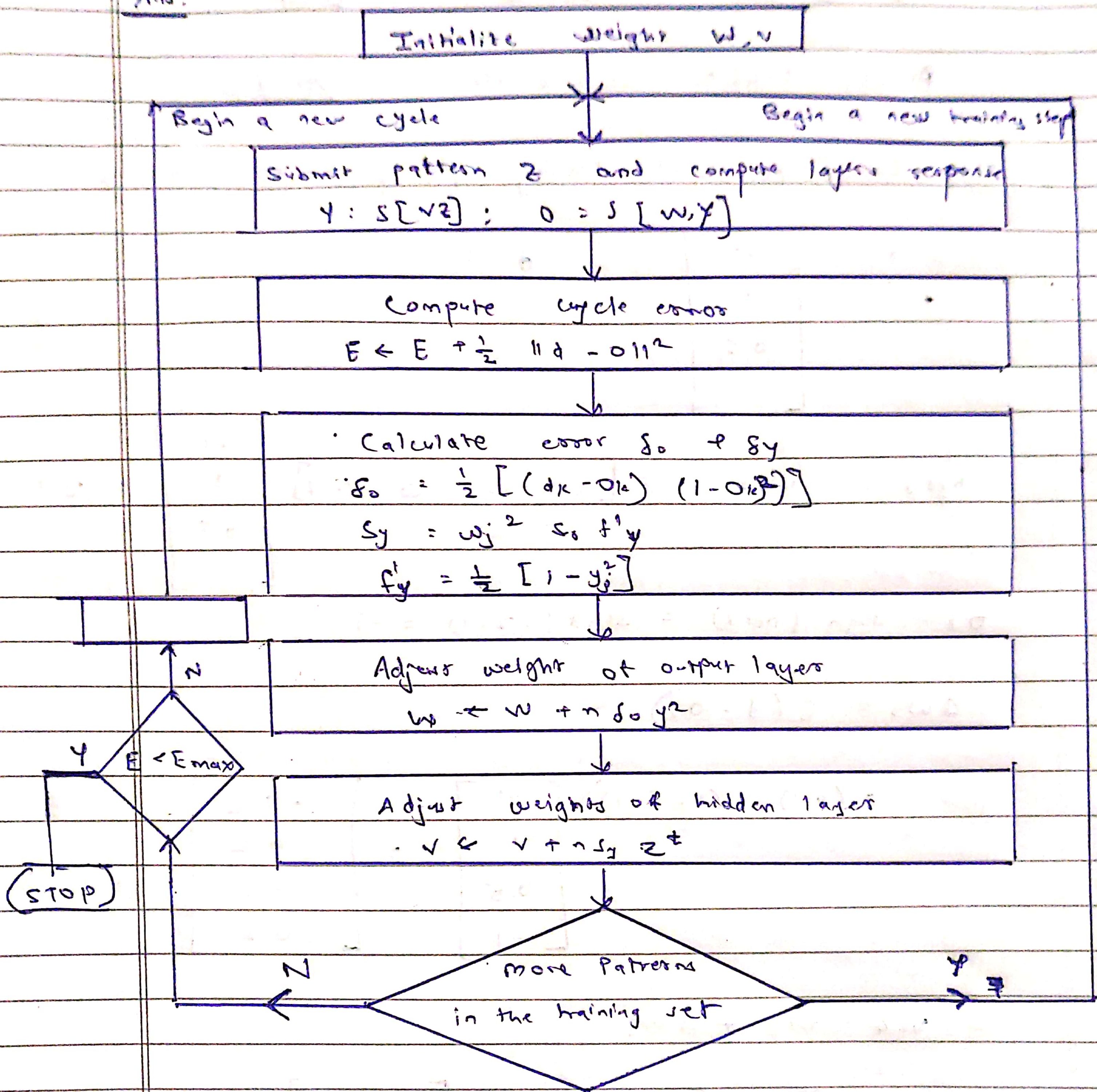
Q4

Ans:



Error Back Propogation Flowchart

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- The back propogation algorithm is one of the most important developments in neural networks. This learning algorithm is applied to multilayer feed forward network consists of processing elements with continuous differentiable activation function.
- Back propogation algorithm is different from the other networks in respect to the process by which the weights are calculated during learning process.
- For the multilayer perceptron calculation of weights of hidden layer in an efficient way that would result in a very small or zero output error is a challenging task
- We can easily measure error between the actual and desired output at the output layer, but at the hidden layer there is no direct information of the error available. Therefore, adjusting the weights of hidden layer perception is difficult.
- The back propogation algorithm solves this problem by providing the equation for updating the weights of hidden layer along with weight update formula at output layers such overall output ~~[illegible]~~ error is minimized
- The back propogation algorithm contains two phases:
  1. Feedforward recall
  2. Feedback phase that calculates the back propogation of the error.

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Q5.

Ans:

→ ANFIS - Adaptive Neuro - Fuzzy Inference System is based on Takagi - Sugeno Fuzzy inference system Developed in 1990s.

- Since it integrates both Neural network and fuzzy logic, it has the potential to capture the benefits of both in a single framework

ANFIS Architecture

- Assume that the fuzzy inference system under consideration has two inputs x and y & one output.
- For first order Sugeno Fuzzy model, a common rule set with two fuzzy rules is

Rule 1: If x is A_1 & y is B_1 then $f_1 = p_1 x + q_1 y + r_1$

Rule 2: If x is A_2 & y is B_2 then $f_2 = p_2 x + q_2 y + r_2$

- The architecture contains five layers.

① Layer 1 - Fuzzification layer.

- Neuron in fuzzification layer receives a crisp input and determines the degree to which this input belongs to the neuron's fuzzy set.
- Any membership function can be used such as Generalized bal function : $\mu_A(x) = \dfrac{1}{1 + \left|\dfrac{x - c_i}{a_i}\right|^{2b}}$

- Parameters in this layer are called Premised parameters.

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② Layer 2 - Fuzzy rule layer.
- Every node in this layer is fixed node
- Output of ith node is product of all incoming signal
$O_{2i} = W_i = \mu_{Ai}(x)\ \mu_{Bi}(y)$, $i = 1, 2$
- No of neurons in this layer will be equal to no of rules.

③ Layer 3 - Normalization layer
- The ith node of the layer calculates the ratio of the ith rule's firing strength to the sum of all rules firing strengths.
$O_{3i} = \overline{W_i} = (w_i / w_1 + w_2)$ $i = 1, 2$
- Output of this layer is normalized firing strength.

④ Layer 4 - Output membership layer,
- Every node in this layer is an adaptive node represented as $O_{4,i} = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r_i)$ $i = 1, 2$
- Parameters in this layer are referred to as consequent parameters.

⑤ Layer 5 - Defuzzification layer.
- Nodes in this layer is fixed node
- Output of this node can be represented as.
$$O_{5,i} = \sum \overline{w_i} f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}, \quad i = 1, 2$$
- The structure of this adaptive network is not unique.

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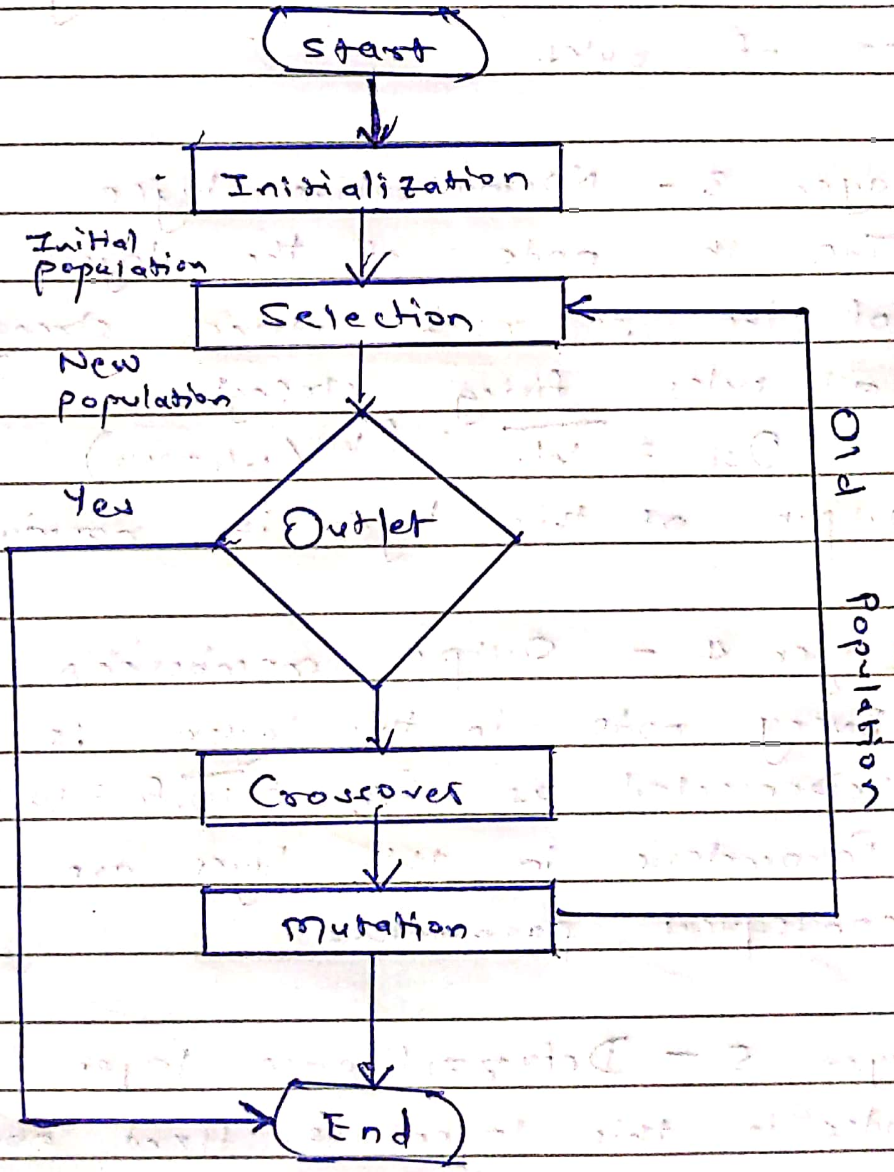
Q6.

Ans:

- A genetic algorithm is a search heuristic that is inspired by Charles Darwin's theory of natural evolution.
- This algorithm reflects the process of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation.



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Phases of Genetic algorithm:

① Initial Population

- Process begins with set of individuals called population.
- An individual is characterized by set of parameters known as Genes. Genes joined together into a string from chromosomes.

② Fitness Function.

- It determines how fit an individual is. to select the fittest individual. Probability that an individual will be selected for reproduction is based on the fitness score

③ Selection.

- The idea of selection phase is to select the fittest individuals and let them pass their genes to the next generation. Two pairs of individuals are selected based on their fitness score

④ Crossover:

- Crossover is the most significant phase in a genetic algorithm. For each pair of parents to be mated, a crossover point is chosen at random from within the genes.

⑤ Mutation

- In certain new ~~string~~ offspring formed, some of their genes can be subjected to a mutation with a low random probability. This implies that some of the bits in the bit string can be flipped.