Manhattan Distance:

↳ No. of moves to achieve goal.

Goal

eg:

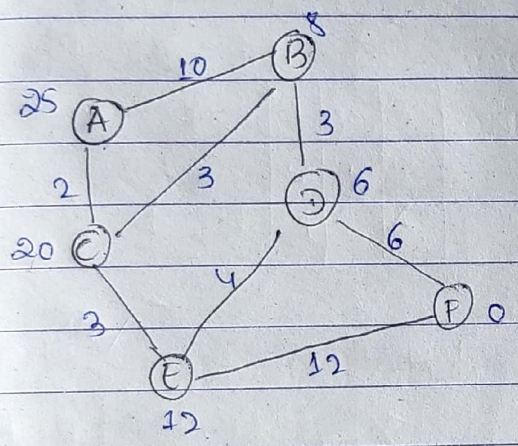
1	2	3
4	5	6
7	8	

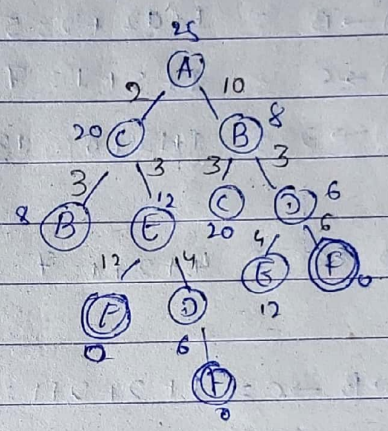
1	2	3
4	8	5
7	6	

$1+2+1 = \boxed{4}$

Hill climbing:

3)





Soln) steepest ~~Checkpoint~~ Hill climbing

Open	closed	
[A]	[ ]	
[B, C]	[A]	(∵ C discarded)
DC	[A, B]	
FEC	[A, B, D]	
	[A, B, DF] ✓	

Simple Hill Climbing

A C E D F

A C E F

A B D F

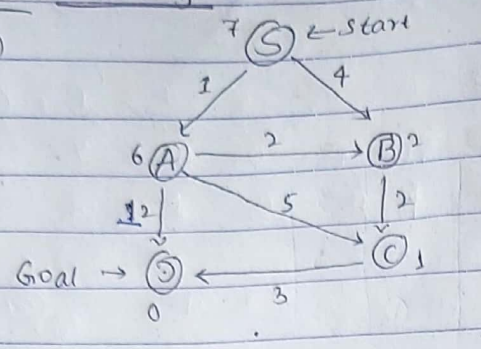
edge values or depth

$$\boxed{f(n) = g(n) + h(n)}$$

heurastic value of child

A Star Algo :-

Q)



Soln)

$S \to A = 1+6 = 7$

$S \to B = 4+2 = 6$

$S \to A \to B = 1+2+2 = 5$

$S \to A \to C = 1+5+1 = 7$

✓ $S \to A \to D = 1+12+0 = 13$

$S \to B \to C = 4+2+1 = 7$

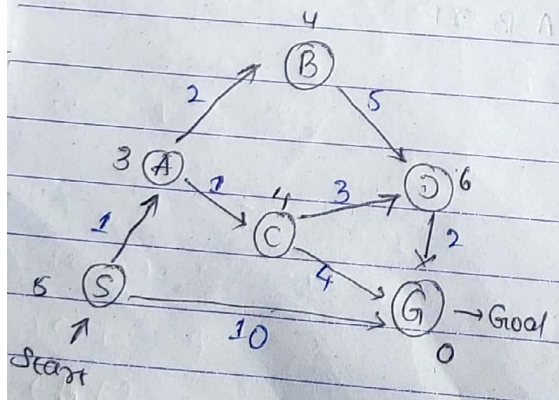
$S \to A \to B \to C = 1+2+2+1 = 6$

✓ $S \to A \to C \to D = 1+5+3+0 = 9$

✓ $S \to B \to C \to D = 4+2+3+0 = 9$

✓ $S \to A \to B \to C \to D = 1+2+2+3+0 = 8$

Q)



$S \to A \to C \to G = 1+1+4+10 = 6$

$S \to A \to C \to D \to G = 1+1+3+2+10 = 7$

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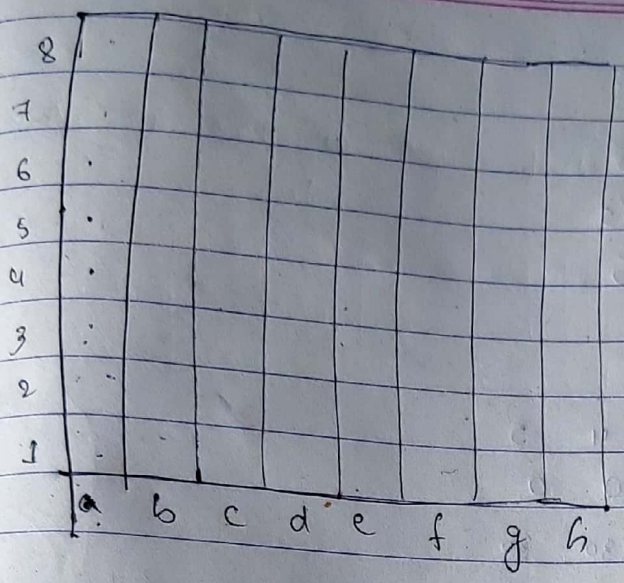
zero knapsack problem to fractional knapsack



I	1	2	3	4
V	3	4	5	6
W	2	3	4	5
V/W	1.5	1.33	1.2	1.2

$W = 5$

=> already in descending

$\{x_1, x_2, x_3, x_4\}$
1 1 0 0

$C = 5 - 2 = 3$

$P = (1) \times 3 = 3$

$C = 3 - 3$

$P = (1) \times 4 = 4$

Total profit : $3 + 4 = 7$

Total weight : $2 + 3 = 5$

$C_0 = 1$

$C_1 = 2$

$C_2 = 3$

$C_3 = 4$

$C_4 = 5$

Total capacity $= 5$

Scanned with CamScanner

0/1 Knapsack problem

Q)

I	1	2	3	4	5
V	30	40	90	57	45
W	2	2	3	4	5

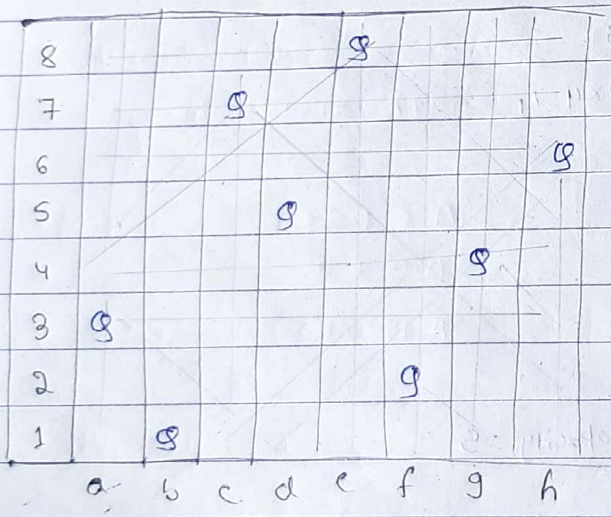
Soln)

W = 5

	0	1	2	3	4	5
0	0	0	0	0	0	0
1	0	30	30	30	30	30
2	0	30	40	70	70	70
3	0	30	40	90	120	130
4	0	30	40	90	120	130
5	0	30	40	90	120	130

Solution set 2, 3

8 Queen Problem: (Constraint Specification Problem)



⇒ Forward checking

⇒ Chronological backtracking

(e, 8) = Q → 1st

(c, 7) = Q → 2nd

(h, 6)

(d, 5)

(g, 4)

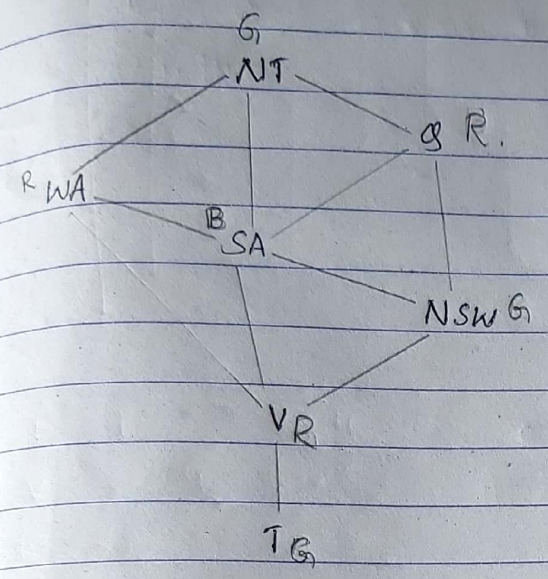
(a, 3)

(f, 2)

(b, 1)

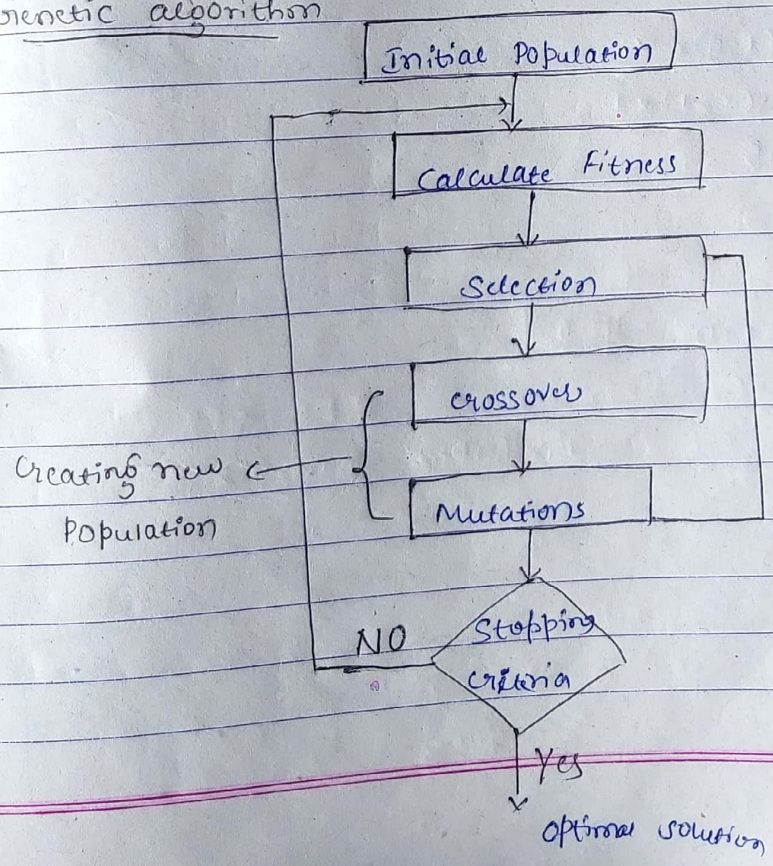
(e,8), (c,7), (f,6), (d,5), (g,4), (a,3), (b,2) & (h,1)

Graph coloring:



Simulated Annealing

Genetic algorithm



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Bi-directional Search:

Time complexity: $b^{d/2} + b^{d/2}$

$= \underline{2b^{d/2}}$

Space complexity: $\underline{b \times d}$

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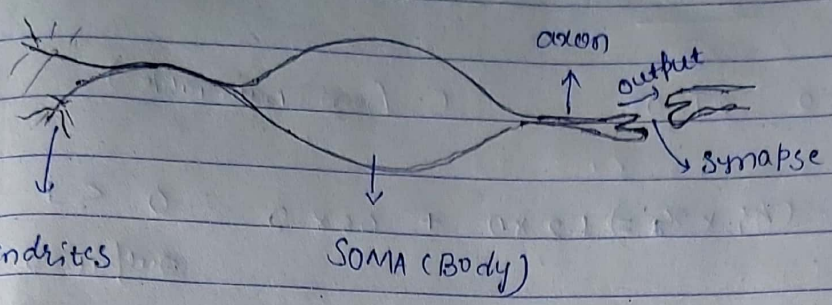
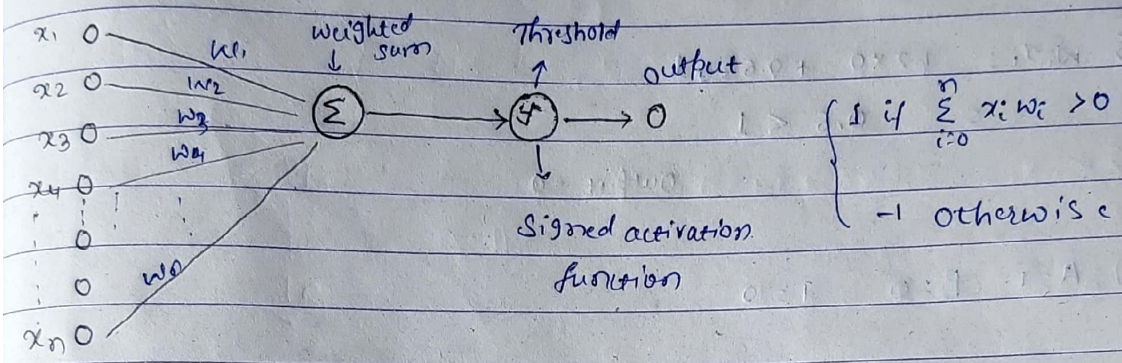
Unit-3

Biological Neuron:





1) Step Function
2) Linear Function
3) Sigmoid function

→ Perspetron training rule → to adjust the weights

Perspetron Training Rule:

$$W_i = W_i + \alpha \times e \times x_i$$

(α → Learning rate)

(New weight)

e → error rate

$$e = (t - o)$$

(t → Target, o → output)

AND gate (Step function)

A	B	A.B
0	0	0
0	1	0
1	0	0
		1

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$W_1 = 1.2$, $W_2 = 0.6$, threshold $= 1$ & $a = 0.5$ (learning rate)

i) $A = 0$; $B = 0$ $T = 0$ (∵ from Truth Table).

$\sum_{i=0}^{2} w_i x_i = (W_1 \times x_1) = 1.2 \times 0 + 0.6 \times 0 = 0 < 1$

Output $= 0$

(ii) $A = 0$ $B = 1$ $T = 0$

$\sum w_i x_i = 1.2 \times 0 + 0.6 \times 1$

$= 0.6 < 1$

Output $= 0$

(iii) $A = 1$, $B = 0$ $T = 0$

$\sum w_i x_i = 1 \times 1.2 + 0.6 \times 0$

$= 1.2 \nless 1$

Output $= 1$

$W_i = W_i + a \times (t - o) \times x_i$

$= 1.2 + 0.5 \times (0 - 1) \times 1$

$= 1.2 - 0.5$

$\boxed{W_1 = 0.7}$

$W_2 = 0.6 + 0.5 (0 - 1) 0 = \boxed{0.6}$

Now, $W_1 = 0.7$, $W_2 = 0.6$ Threshold $= 1$ & $a = 0.5$

(i) $A = 0$, $B = 0$ $T = 0$

$\sum w_i x_i = 0.7 \times 0 + 0 \times 0.6 = 0 < 1$

Output 0

(ii) $A = 0$, $B = 1$ $T = 0$

$\sum w_i x_i = 0 \times 0.7 + 1 \times 0.6 = 0.6 < 1$

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H/W1 $w_1 = -0.2$ & $w_3 = 0.4$ $t = 0$ & $a = 0.2$

using OR gate

(iii) $A = 1$, $B = 0$ $T = 0$

$\Sigma w_i x_i = 1 \times 0.7 + 0 \times 0.6$

$= 0.7 < 1 \rightarrow$ Threshold

Output 0

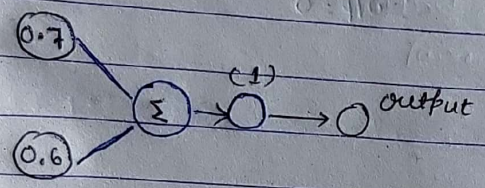
(iv) $A = 1$, $B = 1$ $T = 1$

$\Sigma w_i x_i = 1 \times 0.7 + 1 \times 0.6$

$= 0.7 + 0.6$

$= 1.3 \nless 1$

Output 1



OR gate

A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

$w_1 = 0.6$, $w_2 = 0.6$, $t = 1$ & $a = 0.5$

i) $A = 0$, $B = 0$, $T = 0$

$\Sigma w_i x_i = 0.6 \times 0 + 0.6 \times 0 = 0 < 1$

$\therefore o/p = 0$

ii) $A = 0$ & $B = 1$, $T = 1$

$\Sigma w_i x_i = 0.6 \times 0 + 0.6 \times 1$

$= 0.6 < 1$ $\therefore o/p = 0$

Scanned with CamScanner

$W_1 = 0.6 + 0.5(1-0) \times 0$

$= 0.6$

$W_2 = 0.6 + 0.5(1-0) \times 1$

$= 0.6 + 0.5$

$W_2 = 1.1$

Now, $W_1 = 0.6$ & $W_2 = 1.1$

(i) $A=0$, $B=0$ $T=0$

$\Sigma w_i x_i = 0.6 \times 0 + 1.1 \times 0 = 0$

$\therefore o/p = 0$

(ii) $A=0$, $B=1$, $T=1$

$\Sigma w_i x_i = 0.6 \times 0 + 1 \times 1.1$

$= 1.1 > 1$

$\therefore o/p = 1$

(iii) $A=1$, $B=0$, $T=1$

$\Sigma w_i x_i = 0.6 \times 1 + 0 \times 1.1$

$= 0.6 < 1$

$\therefore o/p = 0$

$W_1 = 0.6 + 0.5 \times (1-0) \times 1$

$= 0.6 + 0.5$

$W_1 = 1.1$

$W_2 = 1.1 + 0.5(0-0) \times 0$

$W_2 = 1.1$

Now, $W_1 = 1.1$ & $W_2 = 1.1$

(i) $A=0$, $B=0$, $T=0$

$\Sigma W_i x_i = 1.1 \times 0 + 1.1 \times 0 = 0 < 1$

$\therefore o/p = 0$

Scanned with CamScanner

Learning rate a range 0 to 1.

(ii) $A=0$, $B=1$ $T=1$,

$\Sigma W_i X_i = 0 \times 1.1 + 1 \times 1.1$
$= 1.1 > 1$

$\therefore o/p = 1$,

(iii) $A=1$, $B=0$ $T=1$

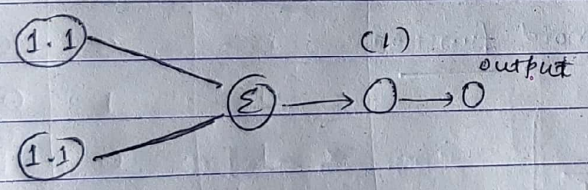
$\Sigma W_i X_i = 1 \times 1.1 + 0 \times 1.1$
$= 1.1 > 1$

$\therefore o/p = 1$

(iv) $A=1$, $B=1$, $T=1$

$\Sigma W_i X_i = 1 \times 1.1 + 1 \times 1.1$
$= 1.1 + 1.1$
$= 2.2 > 1$

$\therefore o/p = 1$



NOT Gate :

A	$\bar{A}$
0	1
1	0

Scanned with CamScanner

$$X = \sum_{i=1}^{n} w_i x_i$$

$$y = \begin{cases} +1 & \text{for } X > t \\ 0 & \text{for } X \leq t \end{cases}$$ → Threshold

$$\text{Step}(X) = \sum_{i=1}^{n} w_i x_i$$

$$\text{Step}(Y) = \text{Step} \begin{cases} +1 & \text{for } X > t \\ 0 & \text{for } X \leq t \end{cases}$$

$$y = \text{Step}\left(\sum_{i=1}^{n} w_i x_i\right)$$

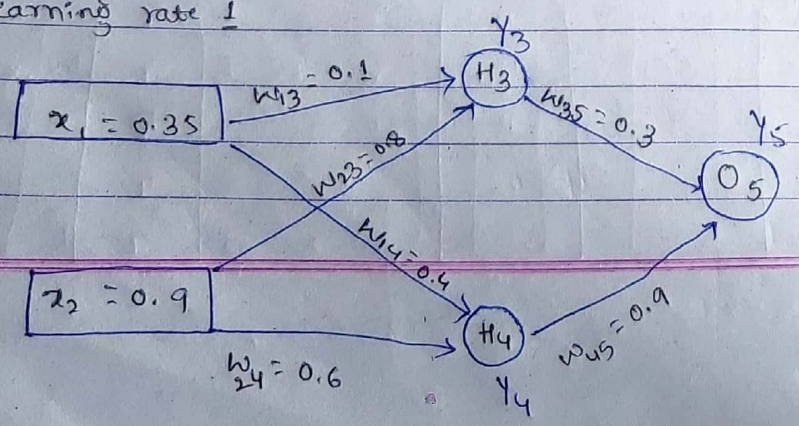
Multi-layer Neural networks:

→ Most real-world problems are not linearly seperable. so all the perceptron have interesting model something more powerful is needed. Thus we shall learnt about the multi-layer neural networks.

→ Activation f^n → Sigmoid function.

$$\boxed{\sigma(x) = \frac{1}{1 + e^{-x}}}$$

Q) using Sigmoid activation f^n forward pass is being performed & backward pass on the network. Assume that actual o/p of Y is 0.5 and learning rate 1



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0.035
0.72
0.755

Soln) $A_j = \sum_j (W_{ij} \cdot x_i)$

$A_1 = 0.1 \times 0.35 + 0.8 \times 0.9$ $\quad (x_1 \times W_{13}) + (x_2 \times W_{23})$

$= 0.035 + 0.72$

$A_1 = 0.755 = X_3$

$$Y_3 = \frac{1}{1+e^{-x_3}} = \frac{1}{1+e^{-0.75}} = 0.679$$

$A_2 = 0.4 \times 0.35 + 0.6 \times 0.9$

$= 0.14 + 0.54$

$A_2 = 0.68 = X_4$

$$Y_4 = \frac{1}{1+e^{-x_4}} = \frac{1}{1+e^{-0.68}} = 0.663$$

$A_3 = 0.679 \times 0.3 + 0.68 \times 0.9$

$= 0.2037 + 0.612$

$A_3 = 0.8157 = X_5$

$$Y_5 = \frac{1}{1+e^{-x_5}} = \frac{1}{1+e^{-0.8157}} = 0.69$$

Actual o/p - Obtained o/p

$0.5 - 0.69 = -0.19$ (Error rate)

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→ Common method to improve performance of back propagation is include Momentum.

$$\Delta w_{ij}(t) = \alpha . x_i . \delta_i + \beta \Delta w_{ij}(t-1)$$

(bias) $$\Delta w_{jk}(t) = \alpha . y_j . \delta_j + \beta \Delta w_{jk}(t-1)$$

→ An alternate method of speeding up backpropagation is used hyperbolic tangent function.

$$\boxed{\tanh(x) = \frac{2a}{1+e^{-bx}} - a}$$

→ Last method is adjust the learning rate

Recurrent Networks:

Field Network - invented by John (1989)

→ Sign activation function

$$\text{Sign}(x) = \begin{cases} +1 & \text{for } x \geq 0 \\ -1 & \text{for } x < 1 \end{cases}$$

$$\boxed{W = \sum_{i=1}^{N} X_i . X_i^t - NI}$$

where X_i → input

X_i^t → Transpose input

I → Identity matrix

N → No. of inputs, vectors

***

Q)

$$X_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}_{5\times 1} \quad X_2 = \begin{bmatrix} -1 \\ -1 \\ -1 \\ -1 \\ -1 \end{bmatrix} \quad X_3 = \begin{bmatrix} 1 \\ -1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$$

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Soln)

$N = 3$

$x_1^t = [1 \quad 1 \quad 1 \quad 1 \quad 1]_{1\times5}$

$x_2^t = [-1 \quad -1 \quad -1 \quad -1 \quad -1]$

$x_3^t = [1 \quad -1 \quad 1 \quad 1 \quad -1]$

$$W = \sum_{i=1}^{N} x_i x_i^t - NI$$

$$W = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \cdot [1 \quad 1 \quad 1 \quad 1 \quad 1] + \begin{bmatrix} -1 \\ -1 \\ -1 \\ -1 \\ -1 \end{bmatrix} \cdot [-1 \quad -1 \quad -1 \quad -1 \quad -1] + \begin{bmatrix} 1 \\ -1 \\ 1 \\ 1 \\ -1 \end{bmatrix} \cdot [1 \quad -1 \quad 1 \quad 1 \quad -1]$$

$$- 3 \cdot \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$W = \cancel{5 + 5 + 5} - \cancel{\begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 & 0 \\ 0 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 0 & 3 \end{bmatrix}}$$

$\cancel{W = 15}$

$$W = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} + \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} + \begin{bmatrix} 1 & -1 & 1 & 1 & -1 \\ -1 & 1 & 1 & -1 & 1 \\ 1 & -1 & 1 & 1 & -1 \\ 1 & 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & -1 & 1 \end{bmatrix}$$

$$- \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 & 0 \\ 0 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 0 & 3 \end{bmatrix}$$

$$W = \begin{bmatrix} 3 & 1 & 3 & 3 & 1 \\ 1 & 3 & 1 & 1 & 3 \\ 3 & 1 & 3 & 3 & 1 \\ 3 & 1 & 3 & 3 & 1 \\ 1 & 3 & 1 & 1 & 3 \end{bmatrix} - \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 & 0 \\ 0 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 0 & 3 \end{bmatrix}$$

$$W = \begin{bmatrix} 0 & 1 & 3 & 3 & 1 \\ 1 & 0 & 1 & 1 & 3 \\ 3 & 1 & 0 & 3 & 1 \\ 3 & 1 & 3 & 0 & 1 \\ 1 & 3 & 1 & 1 & 0 \end{bmatrix}$$

$y_i = \text{sign}(WX_i - \theta)$

$\theta \rightarrow$ threshold

$y_i \rightarrow$ Output vector

$$y_1 = \begin{bmatrix} 0 & 1 & 3 & 3 & 1 \\ 1 & 0 & 1 & 1 & 3 \\ 3 & 1 & 0 & 3 & 1 \\ 3 & 1 & 3 & 0 & 1 \\ 1 & 3 & 1 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

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$$y_1 = \begin{bmatrix} 0+1+3+3+1 \\ 1+0+1+1+3 \\ 3+1+0+3+1 \\ 3+1+3+0+1 \\ 1+3+1+1+0 \end{bmatrix}_{5\times 1}$$

$$y_1 = \text{sign}\begin{bmatrix} 8 \\ 6 \\ 8 \\ 8 \\ 6 \end{bmatrix}$$

$$\therefore y_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = x_1$$

Similarly y_2 & y_3

if $x_5 = \begin{bmatrix} -1 \\ 1 \\ -1 \\ 1 \\ 1 \end{bmatrix}$

$$y_5 = \text{sign}\begin{bmatrix} 0 & 1 & 3 & 3 & 1 \\ 1 & 0 & 1 & 1 & 3 \\ 3 & 1 & 0 & 3 & 1 \\ 3 & 1 & 3 & 0 & 1 \\ 1 & 3 & 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} -1 \\ 1 \\ -1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} 0+1-3+3+1 \\ -1+0-1+1+3 \\ -3+1-0+3+1 \\ -3+1-3+0+1 \\ -1+3-1+1+0 \end{bmatrix} = \text{sign}\begin{bmatrix} 2 \\ 2 \\ 2 \\ -4 \\ 2 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$$

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$$y = \text{sign}\begin{bmatrix} 0 & 1 & 3 & 3 & 1 \\ 1 & 0 & 1 & 1 & 3 \\ 3 & 1 & 0 & 3 & 1 \\ 3 & 1 & 3 & 0 & 1 \\ 1 & 3 & 1 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$$

$$y = \text{sign}\begin{bmatrix} 0+1+3-3+1 \\ 1+0+1-1+3 \\ 3+1+0-3+1 \\ 3+1+3-0+1 \\ 1+3+1-1+0 \end{bmatrix}$$

$$y = \text{sign}\begin{bmatrix} 2 \\ 4 \\ 2 \\ 8 \\ 4 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = X_1$$

(8) On Paper calculate weight matrix for a field network i.e to learn the following two input vector (N)

$$X_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}_{4\times1} \qquad X_2 = \begin{bmatrix} -1 \\ -1 \\ -1 \\ -1 \end{bmatrix}_{4\times1}$$

now, calculate the behaviour of (Network matrix) when it presented X_1 as i/p, how does it behave when it present at with following i/p

$$X_3 = \begin{bmatrix} -1 \\ -1 \\ 1 \\ -1 \end{bmatrix}_{4\times1}$$

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(Soln)

$N = 2$

$x_1^t = [1 \ 1 \ 1 \ 1]_{1\times4}$

$x_2^t = [-1 \ -1 \ -1 \ -1]_{1\times4}$

$$W = \sum_{N=1}^{N} x_i x_i^t - NI$$

$$W = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \cdot [1 \ 1 \ 1 \ 1] + \begin{bmatrix} -1 \\ -1 \\ -1 \\ -1 \end{bmatrix} \cdot [-1 \ -1 \ -1 \ -1] - 2 \cdot \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\cancel{W = \begin{bmatrix} 1+1+1+1 \\ 1+1+1+1 \\ 1+1+1+1 \\ 1+1+1+1 \end{bmatrix} + \begin{bmatrix} 1+1+1+1 \\ 1+1+1+1 \\ 1+1+1+1 \\ 1+1+1+1 \end{bmatrix} - \begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 2 \end{bmatrix}}$$

$$W = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix} + \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix} - \begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 2 \end{bmatrix}$$

$$W = \begin{bmatrix} 0 & 2 & 2 & 2 \\ 2 & 0 & 2 & 2 \\ 2 & 2 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix}$$

$y_i = \text{sign}(Wx_i - \theta)$

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$$y_1 = \text{sign}\begin{bmatrix} 0 & 2 & 2 & 2 \\ 2 & 0 & 2 & 2 \\ 2 & 2 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix}_{4\times4} \cdot \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}_{4\times1} - \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$y_1 = \text{sign}\begin{bmatrix} 0+2+2+2 \\ 2+0+2+2 \\ 2+2+0+2 \\ 2+2+2+0 \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$y_1 = \text{sign}\begin{bmatrix} 6 \\ 6 \\ 6 \\ 6 \end{bmatrix}$$

$$y_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = x_1$$

Given:

$$x_3 = \begin{bmatrix} -1 \\ -1 \\ 1 \\ -1 \end{bmatrix}$$

$$y_3 = \text{sign}\begin{bmatrix} 0 & 2 & 2 & 2 \\ 2 & 0 & 2 & 2 \\ 2 & 2 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix} \begin{bmatrix} -1 \\ -1 \\ 1 \\ -1 \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$y_3 = \text{sign}\begin{bmatrix} 0-2+2-2 \\ -2+0+2-2 \\ -2-2+0-2 \\ -2-2+2-0 \end{bmatrix} = \text{sign}\begin{bmatrix} 2 \\ -2 \\ -6 \\ -2 \end{bmatrix} = \begin{bmatrix} 1 \\ -1 \\ -1 \\ -1 \end{bmatrix}$$

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$$y_4 = \text{sign}\begin{bmatrix} 0 & 2 & 2 & 2 \\ 2 & 0 & 2 & 2 \\ 2 & 2 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{bmatrix}\begin{bmatrix} 1 \\ -1 \\ -1 \\ -1 \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$= \text{sign}\begin{bmatrix} 0-2-2-2 \\ 2+0-2-2 \\ 2-2+0-2 \\ 2-2-2-0 \end{bmatrix}$$

$$y_4 = \text{sign}\begin{bmatrix} -6 \\ -2 \\ -2 \\ -2 \end{bmatrix} = \begin{bmatrix} -1 \\ -1 \\ -1 \\ -1 \end{bmatrix} = x_2$$

Bi-directional Association Memory [BAMP]

→ It is a neural network (bart-kosko 1980) i.e similar to network of Hopfield, that can be used to associate items from one set to another set of items.

$$\boxed{W = \sum_{i}^{h} x_i y_i^t} \qquad \boxed{y_i = \text{sign}(w^t x_i)}$$

Eg) $x_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ $\quad x_2 = \begin{bmatrix} -1 \\ -1 \end{bmatrix}$

$y_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$ $\quad y_2 = \begin{bmatrix} -1 \\ -1 \\ -1 \end{bmatrix}$

Soln) $W = x_1 y_1^t + x_2 y_2^t$

$$= \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{2\times1} \cdot \begin{bmatrix} 1 & 1 & 1 \end{bmatrix}_{1\times3} + \begin{bmatrix} -1 \\ -1 \end{bmatrix} \begin{bmatrix} -1 & -1 & -1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}_{2\times3} + \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}_{2\times3}$$

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$$W = \begin{bmatrix} 2 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix}_{2\times 3}$$

$$y = \text{sign}\begin{bmatrix} 2 & 2 \\ 2 & 2 \\ 2 & 2 \end{bmatrix}_{3\times 2} \cdot \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{2\times 1}$$

$$= \text{sign}\begin{bmatrix} 2+2 \\ 2+2 \\ 2+2 \end{bmatrix}$$

$$= \text{sign}\begin{bmatrix} 4 \\ 4 \\ 4 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = Y_1$$

$$Y = \text{sign}\begin{bmatrix} 2 & 2 \\ 2 & 2 \\ 2 & 2 \end{bmatrix} \cdot \begin{bmatrix} -1 \\ -1 \end{bmatrix}$$

$$= \text{sign}\begin{bmatrix} -2-2 \\ -2-2 \\ -2-2 \end{bmatrix}$$

$$= \text{sign}\begin{bmatrix} -4 \\ -4 \\ -4 \end{bmatrix} = \begin{bmatrix} -1 \\ -1 \\ -1 \end{bmatrix} = Y_2$$

To find x' $\boxed{X_i = \text{sign}(W Y_i)}$

$$X_1 = \text{sign}\begin{bmatrix} 2 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix}\begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

$$= \text{sign}\begin{bmatrix} 6 \\ 6 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix} = X_1$$

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Pattern classification

Q) using Hebb rule find weight require to perform the following classification of given i/p pattern '+' symbol that represent value 1 & empty squares 'N' minus 1. consider 'I' belongs to members of class, so that target value will be 1 & 'O' does not belong to members of class i.e [-1]

Soln)

+	+	+
	+	
+	+	+

I

Y = 1

+	+	+
+		+
+	+	+

O

Y = -1

pattern	input									Test o/p
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	Y
I =	1	1	1	-1	1	-1	1	1	1	1
O =	1	1	1	1	-1	1	1	1	1	-1

$$\boxed{\begin{aligned} W_{new} &= W_{old} + x_i y \\ b_{new} &= b_{old} + y \end{aligned}}$$

$x_i \rightarrow$ i/p vector

$Y \rightarrow$ Test o/p

$\boxed{\text{Change in } W \quad \Delta W = x_i y}$

Initial $W = 0$ (all) Initial $b = 0$

Now,

$W_1 = 0 + 1 \times 1 = 1$ $W_4 = 0 + (-1)(1) = -1$ $W_7 = 0 + 1 \times 1 = 1$

$W_2 = 0 + 1 \times 1 = 1$ $W_5 = 0 + (1)(1) = 1$ $W_8 = 1$

$W_3 = 0 + 1 \times 1 = 1$ $W_6 = 0 + (-1)(1) = -1$ $W_9 = 1$

$W_{new} = [1 \ 1 \ 1 \ -1 \ 1 \ -1 \ 1 \ 1 \ 1]$

New weight i.e W_{new} becomes W_{old} for 'O'

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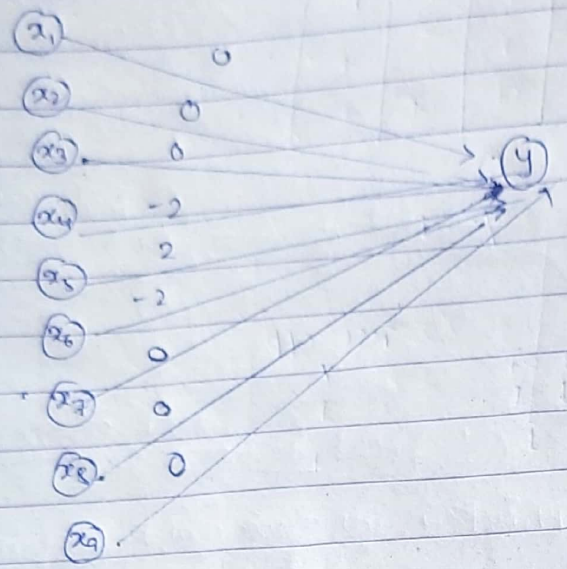
$W_1 = 1 + 1(-1) = 0$ $\quad W_4 = -1 + (1)(-1) = -2$ $\quad W_7 = 0$

$W_2 = 1 + 1(-1) = 0$ $\quad W_5 = 1 + (1)(-1) = 2$ $\quad W_8 = 0$

$W_3 = 1 + 1(-1) = 0$ $\quad W_6 = -1 + (1)(-1) = -2$ $\quad W_9 = 0$

for 'o':

$W_{new} = [\,0 \;\; 0 \;\; 0 \;\; -2 \;\; 2 \;\; -2 \;\; 0 \;\; 0 \;\; 0\,]$



General hypothesis $\{?\ ?\ ?\ ?\ ?\ ?\}$

Specific " $\{\phi\ \phi\ \phi\ \phi\ \}$

Candidate Elimination Algorithm

Example	Sky	Air Temp	Humidity	Wind	Water	Forecast	Enjoyspor
1	Sunny	Warm	Normal	Strong	Warm	Same	Yes
2	Sunny	Warm	High	"	"	"	Yes
3	Rainy	Cold	High	"	"	Change	No
4	Sunny	Warm	High	"	Cool	"	Yes

soln) S_0 : $\langle \phi\ \phi\ \phi\ \phi\ \phi\ \phi \rangle$

S_1 : <Sunny, Warm, Normal, Strong, Warm, Same>

S_2 : <Sunny, Warm, ?, Strong, Warm, Same>

S_3 : <Sunny, Warm, ?, Strong, Warm, Same>

S_4 : <Sunny, Warm, ?, Strong, ?, ?>

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G0 : < ? ? ? ? ? ? >

G1 : < ? ? ? ? ? ? >

G2 : < ? ? ? ? ? ? >

G3 : <Sunny, ?, ?, ?, ?, ?> <?, warm, ?, ?, ?, ?> <?, ?, Normal, ?, ?>
<?, ?, ?, ?, cool, ?> <?, ?, ?, ?, ?, same>

G4 : <sunny, ?, ?, ?, ?, ?> <?, warm, ?, ?, ?, ?>

eliminate normal, cool, same

To write ~~two~~ few more hypothesis towards the learn origin space by candidate elimination, we consider one from general & one from specific hypothesis.

S4 : <sunny, warm, ?, strong, ?, ?>

G4 : <Sunny, ?, ?, ?, ?, ?> <?, warm, ?, ?, ?, ?>

<Sunny, warm, ?, ~~strong~~ ?, ?, ?> <Sunny, ?, ?, strong, ?, ?>
<?, warm, ?, strong, ?, ?>

8)

	Size	color	shape	class/label
1	Big	Red	circle	NO
2	Small	Red	Δle	NO
3	Small	Red	circle	Yes
4	Big	Blue	Circle	No
5	Small	Blue	circle	yes

Soln) S0 = < ϕ ϕ ϕ >

S1 : ~~Big Red circle~~ < ϕ ϕ ϕ >

S2 : < ϕ ϕ ϕ >

S3 : <Small, Red, circle>

S4 : < Small, Red, Circle >

S5 : < Small, ?, circle > { if negative retain old previous data

G_0 = < ? ? ? >

G_1 : < Small, ?, ? > < ?, Blue, ? > < ?, ?, Δle >

G_2 : < Small, Blue, ? > < Small, ?, circle >

< ?, Blue, ? > < ?, Blue, triangle > < Big, ?, Triangle >

G_3 : < Small, ?, circle >

G_4 : < Small, ?, circle >

G_5 : < Small, ?, Circle >

final hypothesis

S_5 : < Small, ?, circle >

G_5 : < Small, ?, circles >

Decision Tree:

→ Entropy - Eliminate the impurity from dataset.

→ Information Gain

$$\boxed{\text{Entropy}(S) = -P_1 \log_2 P_1 - P_0 \log_2 P_0}$$

P_1 → Probabality of +ve value

P_0 → Probabality of -ve

Information gain

$$\boxed{\text{Gain}(S,A) = \text{Entropy}(S) - \sum_{V \in \text{values}(A)} \frac{|S_v|}{|S|} \text{Entropy}(S_v)}$$

if equal no. of positive values & -ve values then $\boxed{\text{Entropy}(S) = 1}$

only +ve values then $\boxed{\text{Entropy}(S) = 0}$

only -ve values then $\boxed{E(S) = 0}$

NOTE:

If Gain is more make it as root node

Film	Country of origin	Big star	Genre	Success
1	U.S.A	Yes	Sci-fic	True
2	U.S.A	NO	comedy	False
3	U.S.A	Yes	"	True
4	Europe	NO	"	True
5	Europe	Yes	Sci-fic	False
6	Europe	Yes	Romance	False
7	rest of the World	Yes	comedy	False
8	"	NO	Sci-fic	False
9	Europe	Yes	comedy	True
10	U.S.A	Yes	comedy.	True

Soln)

$$H(U.S.A) = -\underbrace{\frac{3}{4}}_{True}\log_2\frac{3}{4} - \underbrace{\frac{1}{4}}_{False}\log_2\frac{1}{4}$$

$$= 0.811$$

$H(Europe) = 1$ ($\because$ no. True = no. False)

$H(rest_of_the_world) = 0$ ($\because$ all negative i.e False)

Gain of entire attribute dataset

$$= H(CO) - \left[\left(\frac{4}{10}\right)\cdot(0.811) + \left(\frac{4}{10}\right)(1) + \left(\frac{2}{10}\right)\cdot(0)\right]$$

$$= 1 - \left[\frac{2}{5}\cdot 0.811 + \frac{2}{5} + 0\right]$$

{ $H(CO) = 1$ $\because$ equal no. of True & False }

Gain $= \underline{0.2756}$

For Big star

$$H(Yes) = -\frac{4}{7}\log_2\left(\frac{4}{7}\right) - \frac{3}{7}\log_2(3/7)$$

$$= \underline{0.985}$$

$$H(NO) = -\frac{1}{3}\log_2\left(\frac{1}{3}\right) - \frac{2}{3}\log_2(2/3) = \underline{0.918}$$

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$H(\text{Big Mon}) = \frac{1}{2}$

Now,

$$\text{Gain} = 1 - \left[\frac{7}{10}(0.985) + \frac{3}{10}(0.918) \right]$$

Gain $= 0.035$

For Genre:

$$H(\text{Sci-fi}) = -\frac{1}{3}\log_2\left(\frac{1}{3}\right) - \frac{2}{3}\log_2\left(\frac{2}{3}\right)$$

$$= 0.918$$

$$H(\text{Comedy}) = -\frac{4}{6}\log_2\left(\frac{4}{6}\right) - \frac{2}{6}\log_2\left(\frac{2}{6}\right)$$

$$= 0.918$$

$H(\text{Romance}) = 0$

Now,

$$\text{Gain} = 1 - \left[\frac{3}{10}(0.918) + \frac{6}{10}(0.918) + 0 \right]$$

Gain $= 0.1738$

Since Gain (Country origin) is more compare to other

Country of origin is root node

For U.S.A.

Film	Big Star	Genre	Success
1	Yes	Sci-fic	True
2	No	Comedy	False
3	Yes	Comedy	True
10	Yes	Comedy	True

$H(S)_{\text{Big Star}} = -\frac{3}{4}\log_2\left(\frac{1}{4}\right) - \frac{1}{4}\log_2\left(\frac{1}{4}\right) = 0.811$

$H(\text{Yes}) = 0$

$H(\text{NO}) = 0$

Gain = 0.811

For genre

$H(\text{Sci-fic}) = 0$

$H(\text{Comedy}) = -\frac{2}{3}\log_2\left(\frac{2}{3}\right) - \frac{1}{3}\log_2\left(\frac{1}{3}\right)$

$= 0.918$

$H(\text{Genre}) = -\frac{1}{4}\log_2\left(\frac{1}{4}\right) - \frac{3}{4}\log_2\left(\frac{3}{4}\right) = 0.811$

Gain $= 0.811 - \left[\frac{1}{4} \times 0 + \frac{3}{4} \times 0.918\right]$

Gain $= 0.1225$

Big Star is root node

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For Europe:

Film	Bigstar	Genre	Success
4	No	Comedy	True
5	Yes	Sci-fi	False
6	Yes	Romance	False
9	yes	comedy	True

Bigstar

$$H(Yes) = -\frac{1}{3}\log_2(1/3) - \frac{2}{3}\log_2(2/3)$$

$$= 0.918$$

$H(NO) = 0$

$H(Bigstar) = 1$

$$Gain = 1 - \left(\frac{3}{4} \times 0.918 + 0\right) = \underline{0.3115}$$

Genre

$H(comedy) = 0$

$H(Sci\text{-}fi) = 0$

$H(Romance) = 0$

$H(Genre) = 1$ ∵ no. of True = no. of False

$Gain = 1 - (0 + 0 + 0)$

$= \underline{1}$

$Gain_{(genre)} > Gain_{(Bigstar)}$

Genre root node

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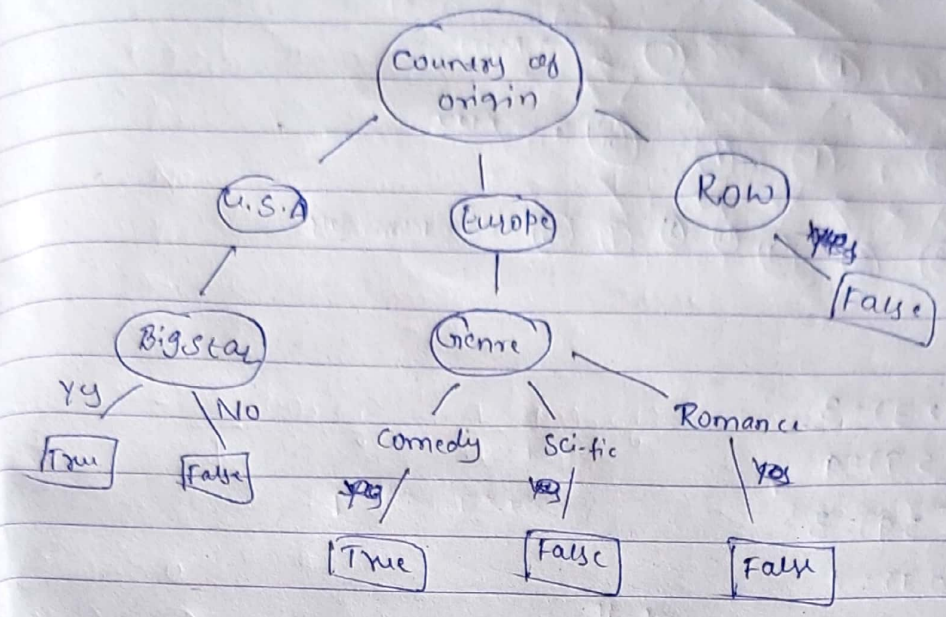
Final decision tree



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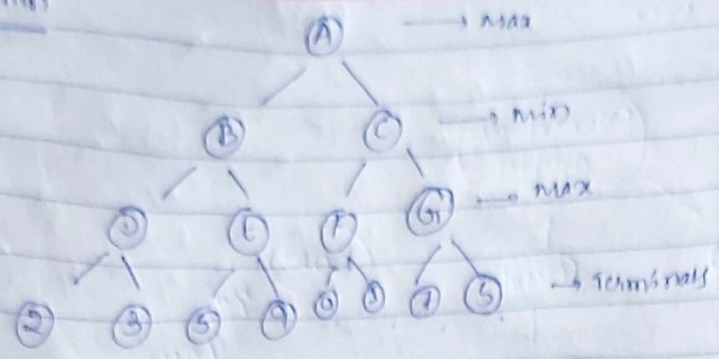
Game Playing

Max → α
Min → β

Max-min

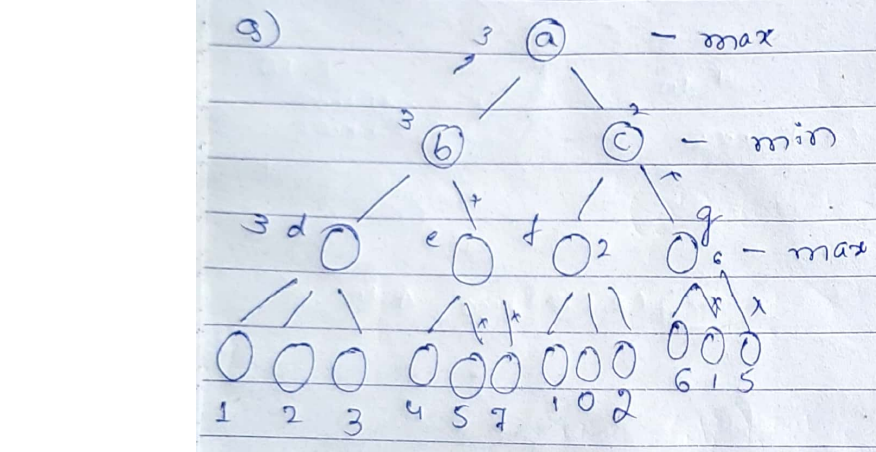


At D max (2,3) = 3
at E max (5,9) = 9
at B min (3,9) = 3
at F max (0,1) = 1
at G max (7,5) = 7
at C min (1,7) = 1

at A max (3,1) = 3

(α - β)

α → -∞
β → ∞



Soln) at d

max (1, -∞) = 1
max (1,2) = 2
max (2,3) = 3
∴ at d max ( ) = 3

at e

max (4, -∞) = 4
max (4,5) = 5 x
max (6,7) = 7 x
∴ max ( ) = 7

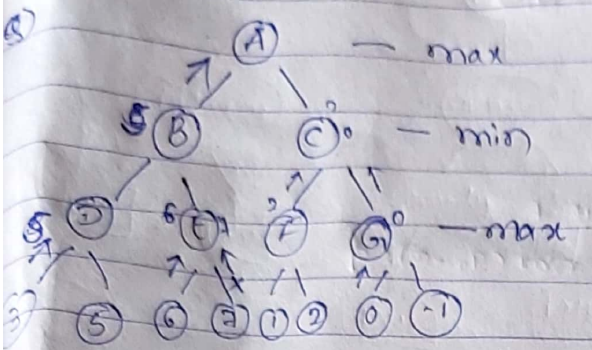
Hence at b

min (3,7) = 3

at f

max (1, -∞) = 1
max (1, 0) = 1
max (1, 2) = 2
∴ max () = 2

(5)



(Ans) At D
max (3, 5) = 5

At F
max (1, 2) = 2

At E max (6, 7) = 7

At G
max (0, -1) = 0

∴ at B min (5, 7) = 5

∴ at C = min (2, 0) = 0

Hence at a max (5, 0) = 5

Function alpha-beta (cur-node)
{
if is_leaf (cur-node)
then return static-Evaluation (cur-node)

if is_maxnode (cur-node) and alphaval (cur-node) >= betaval (min-ancestor of (cur-node))
then cut-off-search-below (cur-node);

if is-midnode (cur-node) and betavalue (cur-node) <= alphavalue (max-ancestor of (cur-node))
then cut-off-search-below (cur-node);
}

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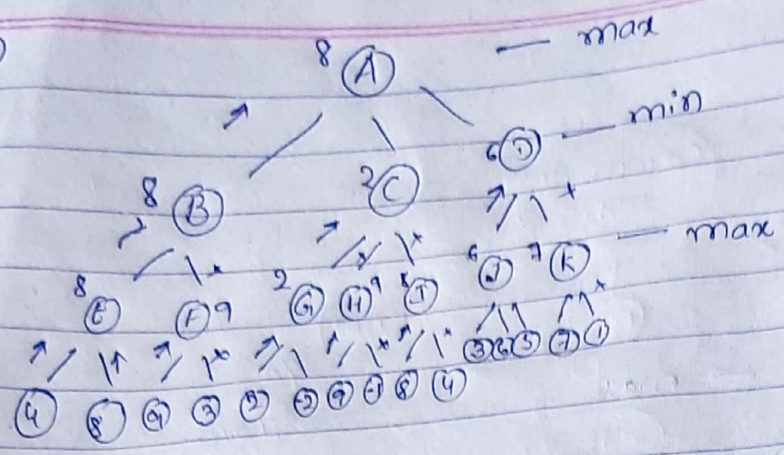
8)



(Soln)

at E
max(4, -∞) = 4
max(4, 8) = 8

at F
max(9, -∞) = 9

at G
max(2, -∞) = 2
max(2, -2) = 2

at H
max(9, -∞) = 9

at I
max(8, 4) = 8

at J
max(3, -∞) = 3
max(3, 6) = 6

at K
max(7, -∞) = 7

at A max(8, 2, 6) = 8