Perceptron but supervised hai, iska test le sakte

⇒ α can never be any 0. α is learning rate. अगर α 0 हो गया then learning stop. $\therefore \alpha \neq 0$.

15 Feb 2022

ADALINE N/W

→ Delta learning rule ← another name

→ Adaline n/w = Delta learning rule
= Gradient Descent learning rule
= Widrow Hoff " "

→ Why called Delta L.R.?
→ " " Gradient Descent?

→ In perceptron we were checking only that y & t are same or not.
$t = y \rightarrow$ no updet
$t \neq y \rightarrow$ updet

We were not checking how close t & y are there.
Also we were always initialize with weights & bias 0.
What if kahin aur se

→ In Delta learning Rule, we can initialize weights & bias by any value other than 0.

But take as small value as possible to initialise wts & bias.
I/p ke hisaab se weights की value

→ In Delta LR, α is will (NOT) be equal to 1
It has to less than 1.

$\alpha < 1$

→ In Perceptron we didn't calc. any error.

→ In Delta LR we find LMS (Least Mean Square Error)

$$\boxed{E = \frac{1}{2}(t - y_{in})^2}$$

LMS

y_{in} ही लेना

book में y होगा यहाँ पर But हम y_{in} ही लेंगे & bcoz Sirunandem में y_{in} है

$\frac{1}{2}$ से सिर्फ ye significance is differentiate में then 2 cancel.

→ ~~The learning signal in Delta~~

→ so $\frac{1}{2}$ with this sqrt & here this sqrt ~~you keep~~ $\frac{1}{2}$.

$\theta = 0$ then we use $y = f(y_{in}) = \begin{cases} 1, & y_{in} > 0 \\ -1, & y_{in} \leq 0 \end{cases}$

→ The learning signal r

$$\boxed{r = (t - y_{in})}$$

t = target o/p

→ Delta LR will work with bipolar i/ps & o/ps.

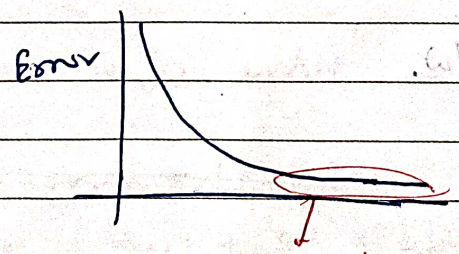
→ In Delta LR activation f. is used as (Discrete Binary A.f.)

$$y = f(y_{in}) = \begin{cases} 1, & y_{in} \geq \theta \\ -1, & y_{in} < \theta \end{cases} \rightarrow \text{when } \theta \neq 0$$

#

→ What adv. have over Perceptron?
यहाँ initial wt's 0 नहीं होंगे.
If we plot error error v/s inputs or
" v/s o/ps

Then asymptotic graph bnega.



it will be // to x axis, not touch it.
∴ its called Gradient

→ When to stop the training in Delta LR?

Sol) यहाँ तो कभी error 0 होगा नहीं i.e. t never equal to y.

So we set a Epoch Error E_s. (given in ques.)

If not given, for practical purposes we can take $E_s = 0.0001$

Basically जब हमारा error E_s ~~से~~ $\boxed{\text{close}}$ हो जाएगा then stop.

हमारा Error कभी भी E_s के Equal नहीं आएगा

~~d) AND gate using Delta LR~~

→ Why called Adaline?

Adaptive linear n/w.

If we related it to ~~so~~

?

Linear ~~so~~ because Activation function taken is linear

$y_{in\,i}$ = y_{in} for i^{th} training pair

Q) Apply Delta LR to AND gate. Do for 1 epoch.

$w_1 = w_2 = b = 0.1$

~~$\alpha = 0.1$~~.

A)

x_0	x_1	x_2	t		
1	1	1	1	E_1	$y_{in\,1}$
1	1	-1	-1	E_2	$y_{in\,2}$
1	-1	1	-1	E_3	$y_{in\,3}$
1	-1	-1	-1	E_4	$y_{in\,4}$

Taking $\alpha = 0.1$ (Easy calc.)

1) For I T.P. $[x_0 \;\; x_1 \;\; x_2] = [1 \;\; 1 \;\; 1]$, $t = 1$

$y_{in1} = b + \sum_{i=1}^{2} w_i x_i = 0.1 + 0.1 + 0.1 = 0.3$

(No need to find y as LMS ~~t~~ formula for y_{in} $\sum$)

$\Delta w_1 = \gamma x \alpha = (t - y_{in_1}) x_1 \alpha = (1 - 0.3)(1)(0.1)$
$= 0.07$

$w_{1\,new} = w_{1\,old} + \Delta w_1 = 0.1 + 0.07 = 0.17$

~~$\Delta w_2 = \gamma x \alpha = (t - y_{in}$~~

$w_{2\,new} = w_{2\,old} + \Delta w_2 = 0.1 + (t - y_{in1}) x_2 \alpha = 0.1 + (1 - 0.3)(1)(0.1)$
$= 0.1 + 0.07 = 0.17$

$b_{new} = 0.1 + (1 - 0.3)(1)(0.1) = 0.17$.

for every T.P. we have to calculate error
→ E_1, E_2, E_3 ——.

~~Find~~ finally we have to find Epoch error E_p.

E_p = sum of Errors of all Training pairs in an Epoch

→ $E_1 = (t - y_{in1})^2 = (1 - 0.3)^2 = 0.49$.

अगर Mam ने कोई E_s दी या होता
then we see E_p or E_s पास होता या नहीं।
अगर Close हो होगा, then we say Convergence होगयी & stop

अगर पास नहीं होगा Then we do another epoch.

'पास' का Meaning → 2 decimal places तक
diff. हो ≤ then पास

But यहाँ Mam ने E_s diya दी होगी. Bata diya कि 11 epoch + 1 sum करना

→ यहाँ हमें activation function की No need as y_{in} से ही काम हो रहा

→ In all these decimal values को 2 decimal plces तक round off

2) for second T.P, $[x_0 \ x_1 \ x_2] = [1 \ 1 \ -1]$, $t = -1$

$y_{in_2} = 0.17 + 0.17(1) + 0.17(-1) = 0.17$

$w_{new} = w_{old} + (t - y_{in_2}) x \alpha = w_{old} + (-1 - 0.17) x (0.1)$

$= w_{old} + (-0.117) x$

$= w_{old} - 0.117 x$

$b_{1\,new} = 0.17 - 0.117(1) = 0.053 \simeq 0.05$

$w_{1\,new} = 0.17 - 0.117(1) = 0.053 \simeq 0.05$

$w_{2\,new} = 0.17 - 0.117(-1) = 0.287 \simeq 0.29$

$E_2 = (t - y_{in_2})^2 = (-1 - 0.17)^2 = 1.368 \simeq 1.37$

3) For 3rd T.P. $[x_0 \ x_1 \ x_2] = [1 \ -1 \ 1]$ $t = -1$

$y_{in_3} = 0.05 + 0.05(-1) + 0.29(1) = 0.29$

$W_{new} = w_{old} + (t - y_{in_3}) x \alpha = w_{old} + (-1 - 0.29) x (0.1)$

$= w_{old} - 0.129 x$

$b_{1\,new} = 0.05 - 0.129(1) = -0.079 \simeq 0.08$

$w_{1\,new} = 0.05 - 0.129(-1) = 0.179 \simeq 0.18$

$w_{2\,new} = 0.29 - 0.129(1) = 0.161 \simeq 0.16$

$E_3 = (t - y_{in_3})^2 = (-1 - 0.29)^2 = 1.664 \simeq 1.66$

$E_p = E_1 + E_2 + E_3 + E_4$.

In Midsem, 3rd Q, logic gate fit Ques follow the below sequence

x_1	x_2
1	1
1	-1
-1	1
-1	-1

~~Think in b~~

Think like

	x_1	x_2	
	1	1	1
	1	-1	-1
	-1	1	-1
	-1	-1	1

4) For 4th T.P, $[x_0\ x_1\ x_2] = [1\ -1\ -1]$, $t = -1$

$y_{in4} = 0.08 + 0.18(-1) + 0.16(-1) = -0.26$

$w_{new} = w_{old} + (t - y_{in4}) \times \alpha = w_{old} + (-1 - (-0.26)) \times (0.1)$

$= w_{old} + (-0.74) \times (0.1)$

$= w_{old} - 0.074 \times (1)$

$b_{1new} = 0.08 - 0.074(1) = 6 \times 10^{-3} = 0.006 \simeq 0.01$

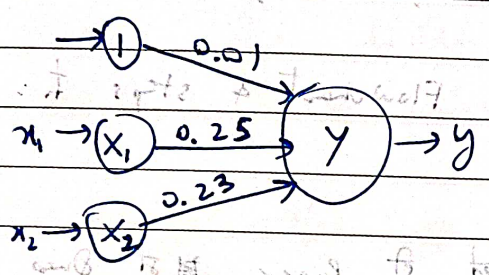
$w_{1new} = 0.18 - 0.074(-1) = 0.254 \simeq 0.25$

$w_{2new} = 0.16 - 0.074(-1) = 0.234 \simeq 0.23$

अभी तक Mem. के Single layer Arch. के Ques. ही करा है except XOR. वैसे ही Ques आएंगे in Midsem.

$$E_4 = (t - y_{in4})^2 = (-1-(-0.26))^2 = 0.5476$$
$$\simeq 0.55$$

Now, $E_p = E_1 + E_2 + E_3 + E_4 = 0.49 + 1.37 + 1.66 + 0.55$
$= 4.07$ (Ans)



(Ans)

VIP ??

MADALINE

Multi Adaptive Neurons. We have many neurons which are adapting themselves!

It has multiple layers.

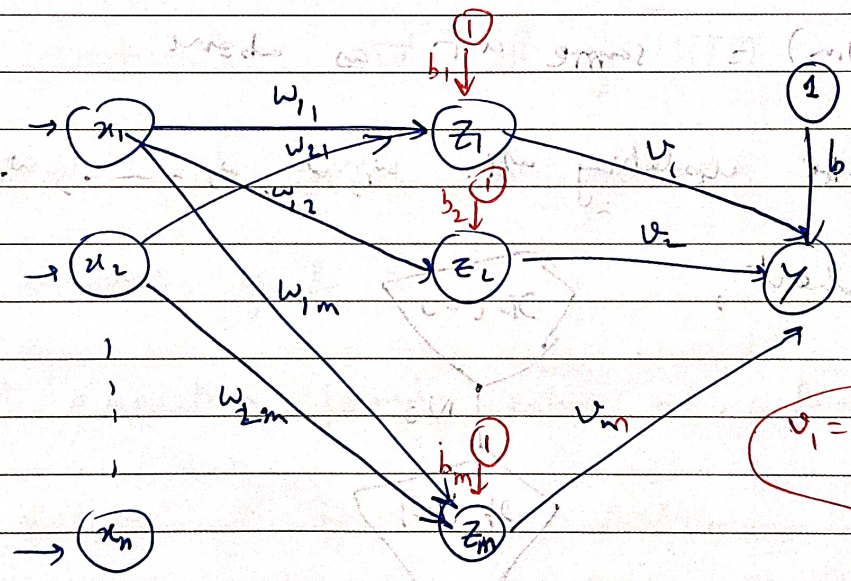
Output layer only has 1 neuron.

We introduce a hidden layer. Complexity ↑ much.

To ↓ complexity

weights b/w hidden layer & o/p layer are fixed. Fixed value is 0.5.

The weights b/w i/p layer are adaptive (can be changed)



$v_1 = v_2 = \dots v_m = \frac{1}{2}$

~~Every thing belongs to class 1~~

~~In Madaline, t is always 1~~

Madaline uses Delta L.R. its output is 1 or −1

$v_1 = v_1 = v_3 \text{ ——— } = v_m = 0.5$

Steps

① Calc. net input at all neurons in hidden layer.

② $z_{1,in} = w_{11} x_1 + w_{21} x_2 + \text{ — — } w_{m1} x_m$

$$z_1 = f(z_{1,in}) = \begin{cases} 1, & z_{in} > 0 \\ -1, & z_{in} \leq 0 \end{cases}$$

~~f(z)~~

Do this for all z_2, z_3 — — —

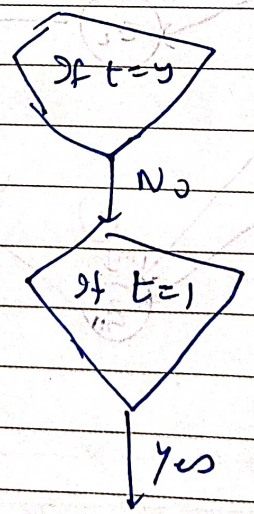
at step ① it

② $y_{in} = z_1 v_1 + z_2 v_2 + \text{———} + z_m v_m$.

$y = f(y_{in})$ = same a.f as above

③ We'll be updating wts. w_1, w_2, w_3 — —, w_m.

④ In flowchart,



Update wts among $w_1, w_2, \ldots w_m$ which are close to 0

$w_{new} = w_{old} + \alpha \boxed{(1 - z_n)} x$

b_{new}

* Madaline का Numerical V. big ∴ Not in exam
But Madaline की theory aa sktu.

* In a madaline, any no. of neurons in input layer & hidden layer.
O/p layer only 1 neuron.

* Delta learning rule में o/p always 1 or -1 bcoz Bipolar a.f. is used.

* Hidden layer में हर Node का एक bias होगा।

⇒ $y = f(y_{in})$ करके से y आया

Now a t given to us.

Compare y & t.

⇒ wt. updation formula same as Adaline.

⇒ $\alpha \neq 1$ α is a small value

⇒ wt. updation w_1, w_2, w_3 — — करते ∴ $z_{1,in}$, $z_{2,in}$

— — etc us

target output मेरा O/P Node पर आता है।

target Node ~~पर~~ Hidden layer से No मतलब।

Target value से y से compare करेंगे।

Wts initial value given in ques.
And not given, then 0 से भी initialize भी करते।

~~Basically mean~~

Madaline n/w will have a single hidden layer

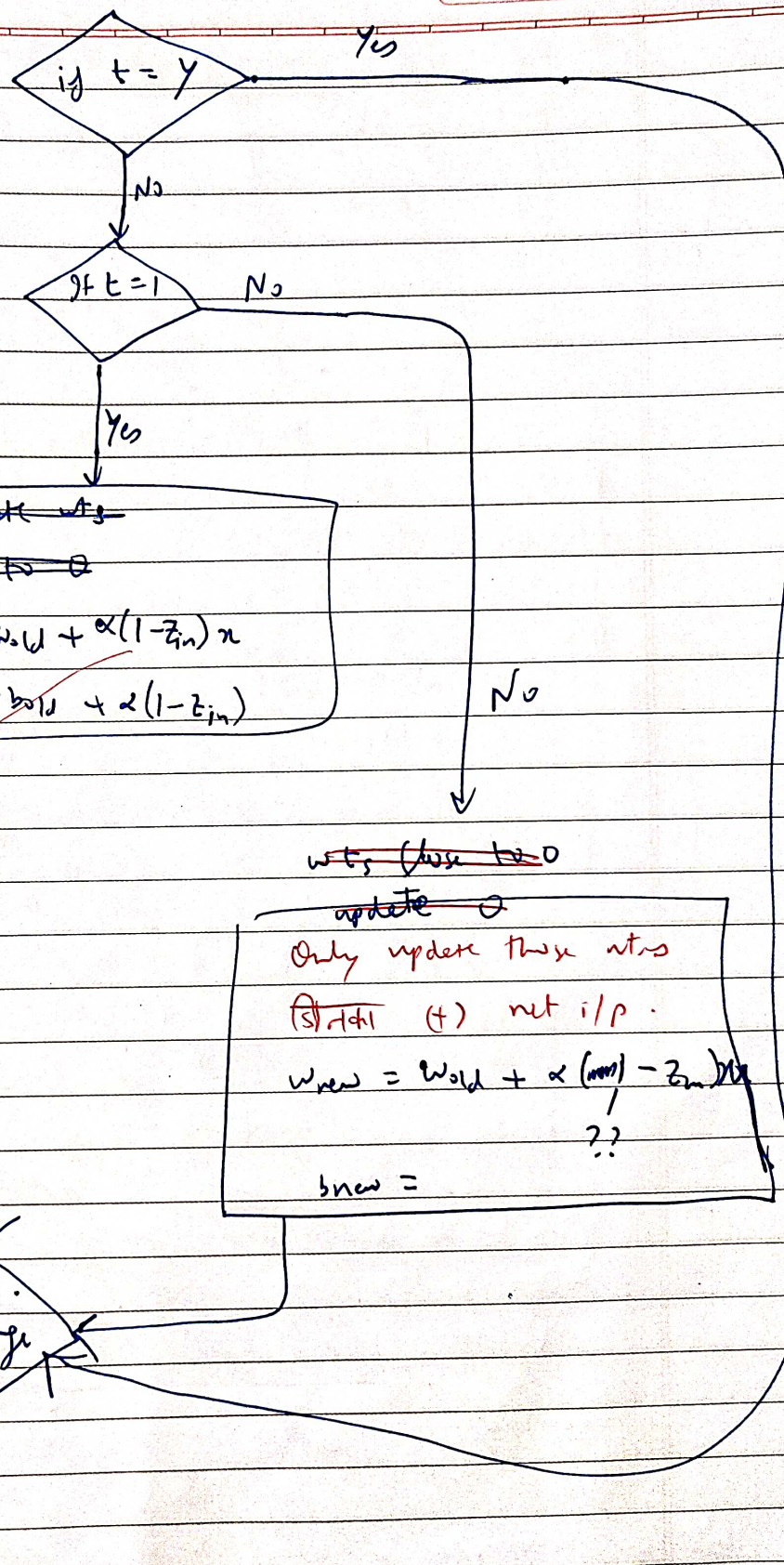
यह a Multilayer feed fwd n/w with single hidden layer

Basically mean t दिया use y compare ~~comp~~ करेंगे and go through flowchart

~~formula~~ Bas formula से ~~t - y~~ alag से learn

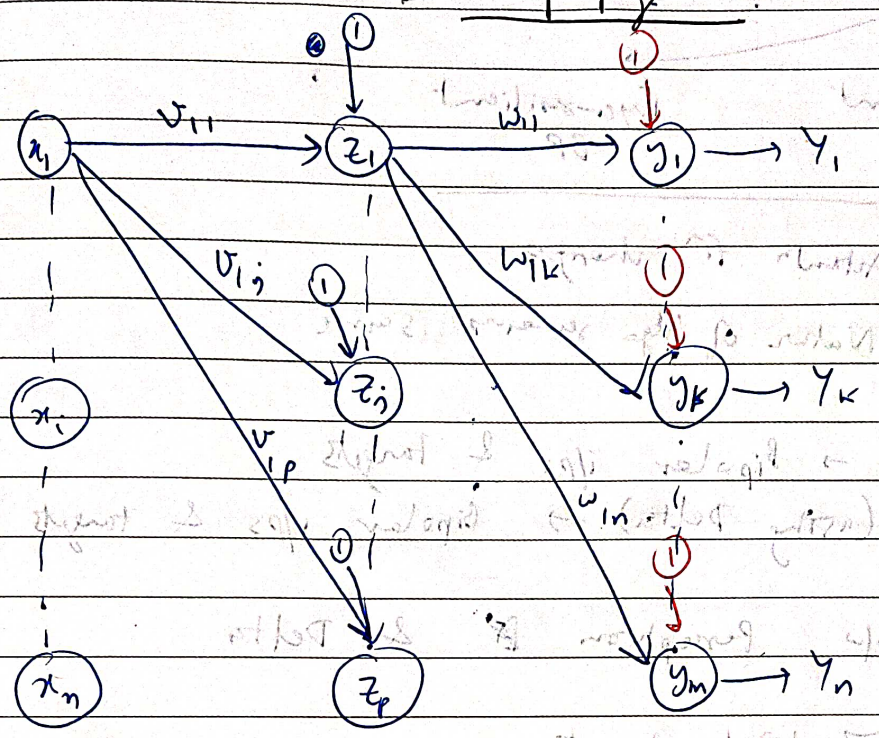
$\delta = t - y_{in}$

⇒


if t = y
Yes
No
If t = 1
No
Yes
~~Only update wts~~
~~close to 0~~
$w_{new} = w_{old} + \alpha(1 - z_{in})x$
$b_{new} = b_{old} + \alpha(1 - z_{in})$
Only update those wts
Net input close to 0
Put t = 1
y = t - y_{in}
No
~~wts close to 0~~
~~update 0~~
Only update those wts
(+) net i/p.
$w_{new} = w_{old} + \alpha(\ - z_{in})x$
??
b_{new} =
No wt. change
Stop

~~10th~~ 29 Mar 2022

Back propagation



$$z_{in_j} = v_{0j} + \sum_{i=1}^{n} x_i v_{ij}$$

Phase (1) $z_j = f(z_{in_j})$

Now, $y_{in_k} = w_{0k} + \sum_{j=1}^{k} z_j w_{jk}$.

$y_k = f(y_{in_k})$

$\cancel{\delta_k (H-o/p) = (t_k - y_k) f'(y_{in_k})}$

$\cancel{\Delta w_{jk} = \alpha \delta_k z_j}$, $\cancel{\Delta w_{0k} = \alpha \delta_k}$

Backpropation (BP)

↓ Resilient BP

→ Every-resilient BP

Activation fn changes.

Nature of Algo remains same

⇒ Perceptron → Bipolar i/ps & Targets

Adaline (using Delta) → Bipolar i/ps & targets

⇒ Diff. b/w Perceptron & Delta

↳ kinds of wts we are using

In Perceptron → initializing wts with 0

In Adaline → " " with small value

⇒ In Backprop., we can take a small value of weights

In Backprop, 0 mat lo.

In backprop., ~~start~~.

↓

Data has larger discrete values

↓

W start with 0.5

~~Data has smaller smaller than 1.~~

⇒ kisi bhi ~~data~~ weight se initialise karlo. Ek range set karlo. उसमें initialise.

⇒ Hidden layer also working layer.

⇒ In BP, never start with 0 weights

⇒ BP does (not) work on a feedback network.

⇒ BP works on Multi-layer feed fwd Architecture

जो fig. में दिखा उसमें multiple working layers,

⇒ BP works in 3 phases or 2 phases
both correct

⇒ Working
Whatever i/p given at i/p layer → propagate it to hidden layer → whatever got in hidden layer → propagate it to output layer.

→ Phase 1 (Feed forward phase)

which a.f.?
Sigmoidal a.f. (Binary or Bipolar)

Why sigmoidal?
Bcz jab signal propagate ~~होगा~~ then we need to differentiate. Discrete ~~fit~~ differentiate nhi kr skte

=) Target is always for the o/p layer.

In Exam, ek hi a.f. diya hoga wohi hidden layer & o/p layer pr use karna.

In implementation
hidden → non-sigmoidal
o/p layer → sigmoidal

→ We can use diff. a.f. in each ~~activation~~ hidden layer. That's hit & Trial.

=) $\Delta w = \alpha . \delta . x$

seems constant

δ changes
Since its BP, instead of δ we calc error signal (δ)

$\therefore \Delta w = \alpha \delta Z$

→ Error signal generation

Phase ② Only error signal is being propagated in back direction.
~~Then~~ पीछे की connection नहीं होगे.

$$\boxed{\delta_k (\text{H-o/p}) = (t_k - y_k) f'(y_{in_k})}$$

Pehle δ output layer पर निकालो

$\Delta w_{jk} = \alpha \delta_k Z_j$, $\Delta w_{0k} = \alpha \delta_k$

~~Once error signal~~

Once error signal is calculated then find Δw.

Abhi Δw ही निकाली है | wt. update नहीं करनी | 3rd phase.

Now in hidden layer, पुरानी wt. use करनी

$$\boxed{\delta_{in_j} = \sum_{k=1}^{m} \delta_k w_{jk}}$$

?

$$\boxed{\delta_j = \delta_{in_j} \boxed{f'(z_{in_j})}}$$

$$\Delta v_{ij} = \alpha \delta_j x_i$$

$$\Delta_{0j} = \alpha \delta_j$$

Phase (3) Wt. updation Phase

$$w_{new} = w_{old} + \Delta w$$

$$v_{new} = v_{old} + \Delta v$$

Type of Ques → Solve complete ques. (All 3 phases)
→ find error signal of all nodes in O/P layer.

$$\delta_k(\text{for o/p}) = (t_k - y_k) f'(y_{in_k})$$

$$\Delta w_{jk} = \alpha \delta_k z_j, \quad \Delta w_{0k} = \alpha \delta_k$$

और iteration करो

→ एक बार Phase ①, Phase ②, Phase ③ करना is 1 epoch.

→ Calculate Least mean Square error

$$= \frac{1}{2}(t - y)^2$$

Do this for all o/p layer

सारे o/p layer के nodes का add → epoch error

~~Table o/p In Phase ①, 2, table सारे~~

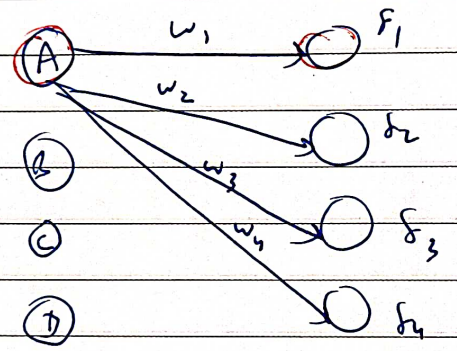
→ UCI rep → से classified की Dataset (

→ ~~Sec BP v/s Resilient P.~~

☆ In Phase 2, Pehle sare nodes in o/p layer पर δ initialize.

$\delta_1, \delta_2, \delta_3$ ———

Then उसके just ~~Peche~~ Peche wali layer पर सीधे ~~की~~ हर node पर δ find.



↳ already calculated.

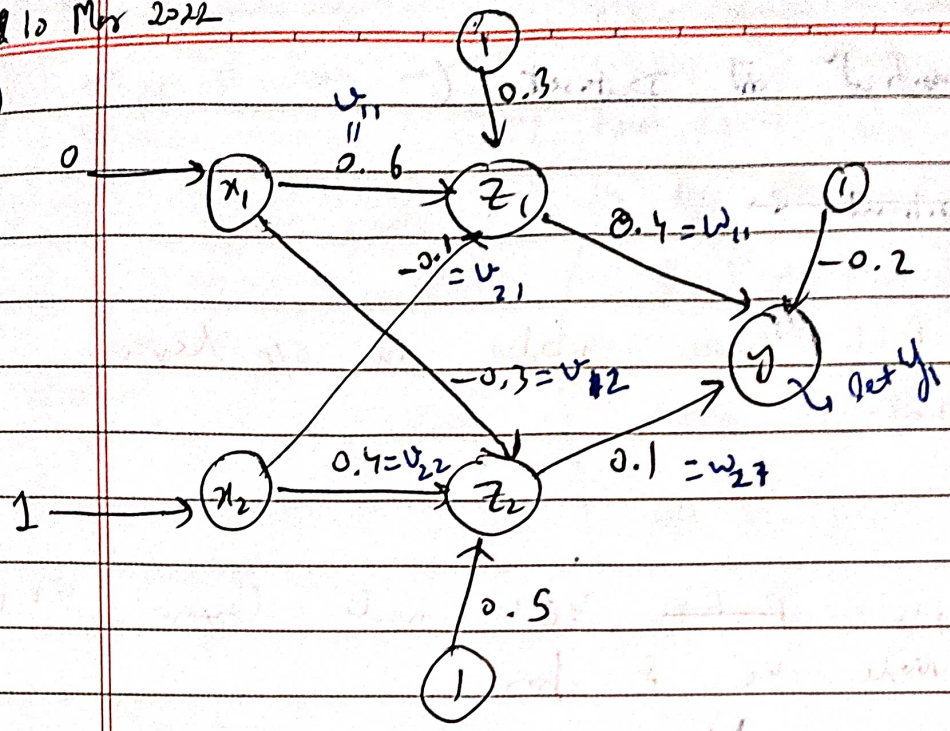
$\delta_A = w_1\delta_1 + w_2\delta_2 + w_3\delta_3 + w_4\delta_4$.

Similarly (A), (B), (C), (D), में से δ find.

Then अगर एक से अधिक hidden layers होंगी तो उनमें भी similar process.

10 Mar 2022

Q)



$\alpha = 0.25$, $\lambda = 1$, $t = 1$

$f(x) = \dfrac{1}{1+e^{-\lambda x}}$

$f'(x) = \lambda f(x)\,[1 - f(x)]$

} In exam, its given "Use Unary Sigmoidal function"

Only 1 o/p neuron → ∴ output layer पर एक ही δ.

Make clear notations

δ_{y_1} → output layer

δ_{z_1}

δ_{z_2}

forward direction → & calculate → Δweight calc.

As these are decimal. So round off upto 2 decimal places.

If small ques. in exam, then pure solve ~~direct~~ it de skte.

[But if big ques, then ~~&~~ only a single phase calc. may be asked]

Sol:) ~~$z_{1,in}$~~ Phase 1

$z_{1,in} = 0 + (-0.1) \cancel{= -0.1} + 0.3 = 0.2$

$\cancel{z_1 = f(z_{1,in}) = \frac{1}{1+e^{-(-0.1)}} = \frac{1}{1+e^{0.1}}}$

$z_1 = f(z_{1,in}) = \frac{1}{1+e^{-(1)(0.2)}} = \frac{1}{1+e^{-0.2}} = 0.55$

$\cancel{z_2 = f(z}$

$z_{2,in} = 0.4 + 0.5 = 0.9$

$z_2 = \frac{1}{1+e^{-0.9}} = 0.71 = f(z_{2,in})$

$\alpha = 0.25$

$y_{in} = (0.55)(0.4) + (0.71)(0.1) + (-0.2)$
$= 0.091$
$\simeq 0.09$

$y = f(y_{in}) = 0.522 \simeq 0.52$

Phase 2

$\delta_{y_1} = (t_1 - y_1) f'(y_{in_1})$

$= (1 - 0.52)(1)(0.52)(1 - 0.52)$
$= 0.1198$
$\simeq 0.12$

$\Delta w_{11} = \alpha \delta_{y_1} z_1 = (0.25)(0.12)(0.55) = 0.0165 \simeq 0.02$

$\Delta w_{21} = \alpha \delta_{y_1} z_2 = (0.25)(0.12)(0.71) = 0.0213 \simeq 0.02$

And now hidden layer ~~ki~~ δ find

$\delta_{in,1} = (0.4)(0.12) = 0.048$

$\delta_{in,2} = (0.1)(0.12) = 0.012$

$\delta_1 = \delta_{in,1} f'(z_{in,1}) = 0.048 \times (1)(0.55)(1 - 0.55)$
$= 0.0118$
$\simeq 0.01$

(δ_2 nikla hai bs)

$$\delta_2 = \delta_{in,2} f'(z_{in,2}) = 0.012 \times 1 (0.71) \times (1 - 0.71)$$

$$= \cancel{0.0116}$$

$$= 0.0024$$

$$= 0.002$$

Pehle Poore n/w में δ निकालना, सबका Δw nikal lo, then सब hone ke baad finally पूरे n/w में एक साथ weights update

Now find Δ of weights b/w i/p layer & hidden layer

$$\Delta w_{11} = \alpha \delta_1 x_1 = (0.25)(0.012)(0) = 0$$

$$\Delta w_{12} = \alpha \delta_2 x_1 = 0$$

$$\Delta w_{21} = \alpha \delta_1 x_2 = (0.25)(0.01)(1) = 0.0025$$

$$\Delta w_{22} = \alpha \delta_2 x_2 = (0.25)(0.002)(1) = 0.005$$

~~Hidden & o'~~

सारी hidden layers & o/p layer पर δ find karna hota.

I/p layer par δ find nhi krne

~~Phen~~

Phase 3

$w_{11(new)} = 0.4 + 0.02 = 0.42$ ✓

$w_{21(new)} = 0.1 + 0.02 = 0.12$ ✓

$v_{11(new)} = 0.6 + 0 = 0.6$ ✓

$v_{12(new)} = -0.3 + 0 = -0.3$ ✓

$v_{21(new)} = -0.1 + 0.0025 = -0.0975$ ✓

$v_{22(new)} = 0.4 + 0.005 = 0.405$. ✓

(Ans)

15 Mar 2022

Associative Memories

~~Main app.~~

One of the main app. of NN is Memorizing.

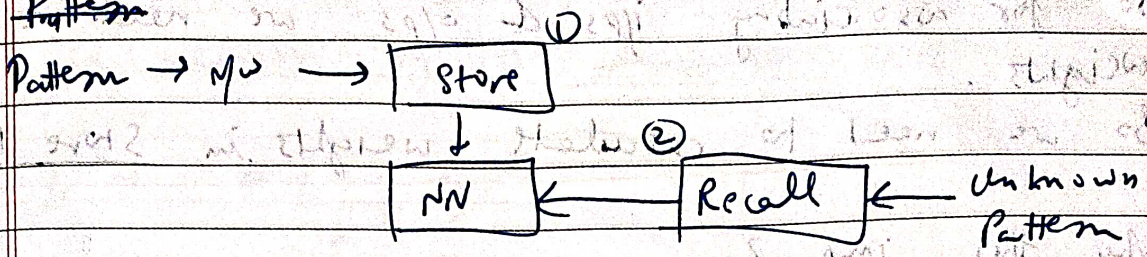
Pattern → N/W → (1) $\boxed{\text{Store}}$ that pattern

~~sit~~ ~~all~~ Pattern given in n/w → its Stored

When we ~~give~~ give unknown pattern to NN

Then (2) $\boxed{\text{Recall}}$ phase

~~Pattern~~



~~So means~~ So 2 phases.

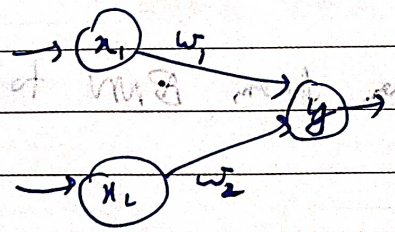
Example

we study before mid sems. We learn it, store it in our brain.

Then in exam, we read the ques. associate it and try to recall

① Store phase

We are storing connections



Animal, pet animal, starts with D, eats bone ⇒ Dog

" " " " C, drinks milk → Cat.

In storage phase, we have i/p's & o/p's.

So for associating i/ps & o/ps we need ~~we~~ weights.
So we need to calculate weights in Store Phase.

Why this imp. ?
Bcoz in Recall phase, we know i/p but not o/p. And we know weights now.
So we can now find o/p in the Recall phase

In Recall phase, ~~a~~ test pattern given.

$$y_{in} = b + w_1 x_1 + w_2 x_2 + \text{———}$$

$$y = f(y_{in})$$

⇒ ~~The~~ Association is very imp. bcoz ~~a~~ we are able to create links b/w patterns

→ The ANN has taken inspiration from BNN to ~~associate~~ ~~ass~~ associate & memorize.

→ Classification of Memories

Associative Memory

CAM
(Content addressable memory)

AAM
(Address Addressable Memory)

22. CAM ~~F~~ ~~content~~ file ~~ki~~ Naam nhi pata. content ~~ki~~ file Dhundhe.

(1) CAM → We are looking out for a particular item (file) in memory by its ~~address~~ content

Eg → $\boxed{5}$ xxx
a

~~Assuming~~ Every memory block has an address.
When we as

(2) *p

(2) AAM →

Eg → go into a society, searching ~~for~~ for a house no. (AAM)

Eg → $\boxed{5}$
a → address 789

int *p = &a

∴ we access this by *p.

II) 2nd classificatn

AM (Associative Memory)

Auto AM — Hetero AM

① Auto AM → whenever your i/ps & o/ps are of the same nature & of same no.

$n \longrightarrow n$

i/p → o/p

② Hetero AM → ~~there~~ Here the no. of i/ps & o/ps are different. And the nature of i/ps & o/ps are different.

$n \longrightarrow m$

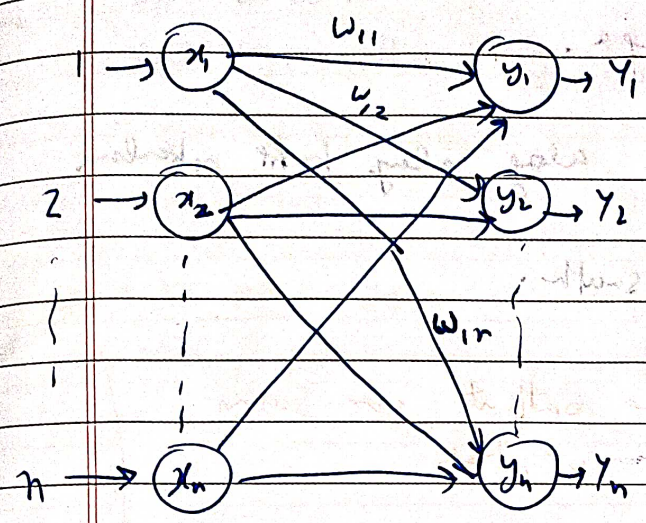
i/p $\not\rightarrow$ o/p (different)

In both cases, we can work with binary or bipolar data

① Auto AM → As same nature,
name linked with name
no. " " "

② Hetero AM → Eg. Phone book
Name → Phone No. (Name is associated with phone no.)

(*) Auto AM



This is an Auto ~~Ass~~ AM network.

no. of i/ps = no. of o/ps.

Its a full n/w.

Whenever I will calculate the weight matrix, the principal diagonal is ~~ben~~ always 0, i.e. all 0 in it.

$$W = \begin{bmatrix} & & \\ & \ddots & \\ & & \end{bmatrix}$$

When calculating weights, we'll use 2 ways - Hebb or Outer product rule.

As no bias given, I'll consider no bias.

$$\Rightarrow \quad y = f(y_{in}) = \begin{cases} 1, & y_{in} > 0 \\ -1, & y_{in} \le 0 \end{cases}$$ Activation function

Hebb rule

$\Delta w = y x \alpha$ → 1

$\boxed{\Delta w = y x}$

$w_{new} = w_{old} + \Delta w$

Outer product rule

$\boxed{w = S^T t}$

S = input matrix

t = target "

In exam if its not given then we can use any way.
Ans dono se same aayega.

In Hebb, same weights alag alag karke nikalne pdte.
2nd way में सब weight एक साथ.

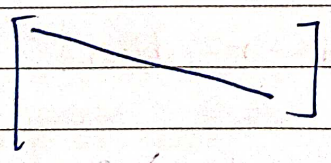
☆ In Auto AM, as i/ps are outputs are same so i/p vector = o/p vector

⇒ Method

① Store
First weights.

w_{ij} = x_i से y_j का weight

If $w_{ij} = 0$, then x_i से y_j तक NO wt., No link.



As i/p and o/p are same so in actually सिर्फ एक layer है in Auto AM,
so again if $w_{KK} = 0$ then no self loop on nodes.
Isliye diagonal को zero करते।

* In all memory ques, Make sure to Diagonal to all 0, in Hopf-field N/w.

② Recall → a test pattern given.

I/p matrix ✓, wt matrix already found.

Find y_{in}. Then $y = f(y_{in})$.

$Y_{in} = X \cdot W \longrightarrow Y = f(y_{in})$
(Matrices)

⇒ Auto AM does NOT work with Binary Data.

So if Auto AM asks binary data given, convert it into Bipolar data.

Q) Train an auto Associative n/w for pattern $\begin{array}{cccc} x1 & x2 & x3 & x4 \\ [-1 & 1 & 1 & 1] \end{array}$.

Test the n/w for Same i/p vector

Sol) ① Store ∴ calculate weight matrix

② Recall.

As auto associative ∴ i/p = o/p.

Using outer product rule

No bias given ∴ No bias

$S = [-1 \quad 1 \quad 1 \quad 1]$

$t = S = [-1 \quad 1 \quad 1 \quad 1]$

$$W = S^T t = \begin{bmatrix} -1 \\ 1 \\ 1 \\ 1 \end{bmatrix}_{4\times1} [-1 \quad 1 \quad 1 \quad 1]_{1\times4}$$

$$= \begin{bmatrix} 1 & -1 & -1 & -1 \\ -1 & 1 & 1 & 1 \\ -1 & 1 & 1 & 1 \\ -1 & 1 & 1 & 1 \end{bmatrix}_{4\times4}$$

~~Now~~ ~~as~~ ~~digo~~ ~~digo~~ ~~di~~ Now diagonal पर 0 set ~~kA~~ kr state whi bhi my choice.

~~Mai~~ ~~Age~~ ~~kon~~ Mai koke dekh sk. Simply diagonal पर 0 करदो

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

(2) Recall phase

Test i/p $= [-1 \quad 1 \quad 1 \quad 1] = X$

$$Y_{in} = X.W = [-1 \quad 1 \quad 1 \quad 1]_{1\times4} \begin{bmatrix} 0 & -1 & -1 & -1 \\ -1 & 0 & 1 & 1 \\ -1 & 1 & 0 & 1 \\ -1 & 1 & 1 & 0 \end{bmatrix}_{4\times4}$$

$$= [-3 \quad 3 \quad 3 \quad 3]_{1\times4}$$

$\downarrow f() \quad \downarrow f() \quad \downarrow f() \quad \downarrow f()$

$$Y = f(Y_{in}) = [-1 \quad 1 \quad 1 \quad 1]$$ (हर किसी पर alag से apply f())

This o/p is correct. As this is auto AM so o/p is ~~coming~~ coming equal to i/p ∴ its correct.

∴ Weights sahi calculate kiye the

16 Mar 2022

Q) [-1 1 1 1] → I/p pattern.

a) Test ~~the~~ with one missing entry

b) Test with one mistaken entry

c) Test with two missing entries

d) " " " mistaken "

Sol^n) Same i/p pattern as prev. ques.
We trained our n/w with this i/p pattern.

Missing v/s Mistaken

Missing → out of these 4, one entry is not available

Eg → [0 1 1 1], [-1 0 1 1]

→ 0 denotes missing entry.

(~~bipolar~~ ~~case~~ were using bipolar data)
That's why

~~Mistaken~~ Unless & Unless its specified की कोनसी bit missed we can take any bit as 0.

Mistaken → 1 की जगह -1 copied OR
-1 " " 1 "

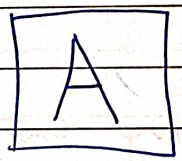
Eg → [-1 -1 1 1]
mistaken

Similar here, सिर्फ एक वाला (नहीं) कोनसी bit mistaken we can take any.

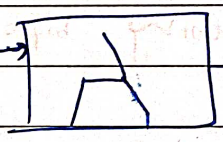
Sol^n) ~~⇒~~ ~~tde~~ From prev. qns, $W = \begin{bmatrix} 0 & -1 & -1 & -1 \\ -1 & 0 & 1 & 1 \\ -1 & 1 & 0 & 1 \\ -1 & 1 & 1 & 0 \end{bmatrix}$

Now we ~~are~~ have different test patterns.
Find $Y_{in} = X.W$, Then Y.
अगर Y equal to I/p pattern आता that means ~~fa~~ our ~~N~~ N/w is able to correctly identify the pattern with ~~maistal~~ those no. of mistakes / missing data.

eg I/p →



Test pattern →



→ इसमें भी N/w बता देगा कि 'A' होगा

a) 1 missing entry → $[-1 \quad 0 \quad 1 \quad 1] \Rightarrow X$

$$Y_{in} = X.W = \underset{1\times4}{[-1 \quad 0 \quad 1 \quad 1]} \underset{4\times4}{\begin{bmatrix} 0 & -1 & -1 & -1 \\ -1 & 0 & 1 & 1 \\ -1 & 1 & 0 & 1 \\ -1 & 1 & 1 & 0 \end{bmatrix}}$$

$$= \underset{1\times4}{[-2 \quad 3 \quad 2 \quad 2]}$$

$$Y = f(Y_{in}) = [-1 \quad 1 \quad 1 \quad 1]$$

so Y = I/p pattern ⇒ Pattern correctly identified even with 1 missing entry.

b) 1 mistaken → $[-1 \quad -1 \quad 1 \quad 1] = X$

$Y_{in} = X.W = [-1 \quad 3 \quad 1 \quad 1]$

$Y = f(Y_{in}) = [-1 \quad 1 \quad 1 \quad 1]$

So $Y =$ i/p pattern

→ किन्ही भी 2 bit पर missing करदो

c) 2 missing → $[-1 \quad 0 \quad 1 \quad 0] = X$

$Y_{in} = X.W = [-1 \quad 2 \quad 1 \quad 2]$

$Y = f(Y_{in}) = [-1 \quad 1 \quad 1 \quad 1]$

So, $Y =$ i/p pattern

→ किन्ही भी 2 bit पर Mistake करदो।

d) 2 mistaken → $[1 \quad -1 \quad 1 \quad 1] = X$

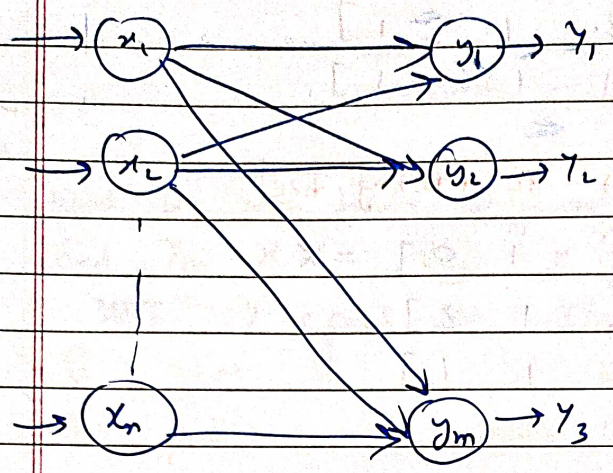
$Y_{in} = X.W = [-1 \quad 1 \quad -1 \quad 1]$

$Y = f(Y_{in}) = [-1 \quad 1 \quad -1 \quad 1]$

Here $Y \neq$ I/p pattern ∴ N/w not able to identify the pattern, so in this case n/w gives either incorrect o/p or not identified

22 Mar 2022

Heteroassociative Memory



we are considering fully connected n/w.

$$\cancel{Y = f(y_{in}) = \begin{cases} 1, & y_{in} > 0 \\ 0, & y_{in} = 0 \\ -1, & y_{in} < 0 \end{cases}}$$

$Y = f(y_{in})$

For Bipolar i/ps, use

$$Y = \begin{cases} 1, & y_{in} > 0 \\ 0, & y_{in} = 0 \\ -1, & y_{in} < 0 \end{cases}$$

For Binary I/ps use

$$Y = \begin{cases} 1, & \cancel{y_{in} < 0}\ y_{in} > 0 \\ 0 & y_{in} \cancel{<0} \le 0 \end{cases}$$

⇒ In Auto AM, only 1 A.f.
But here in Hetero, which A.f. to use it depends on i/p.

⇒ In A.M, we were doing 2 phases
① Storage → finding connections. finding wt. matrix
② Recall.

⇒ Actually Outerproduct Rule is simpler form of Hebb.

⇒ In Hebb, अगर binary I/p there was confusion b/w 0 & −1. ∴ In Hebb we use Bipolar.

⇒ In Bi.

⇒ In Hetero associative Memory, we can find wt.s either by:

① Hebb Rule, or [

② Delta learning Rule

→ we could also use Outerproduct Rule as its nothing but a simpler version of Hebb.

PTO

Q)

	s_1	s_2	s_3	s_4	t_1	t_2
①	1	0	1	0	1	0
②	1	0	0	1	1	0
③	1	1	0	0	0	1
④	0	0	1	1	0	1

Find the weight matrix for this particular network

Sol) As size of I/p ≠ size of o/p. ∴ its ques. of Hetero.

First 2 i/ps का same o/p ∴ they are in 1 class

Last " " . . . . . another class.

Now, अगर किसी I/p का 1 bit change then still उसका सही classification

But अगर 2 bits change → misclassification

Sol) Solving it with Hebb

We have 4 i/ps.

$W = S^T t$

Have i/p के लिए do $S^T t$ & add.

$$\begin{bmatrix} \\ \\ \end{bmatrix}\begin{bmatrix} \\ \end{bmatrix} + \begin{bmatrix} \\ \\ \end{bmatrix}\begin{bmatrix} \\ \end{bmatrix} + \begin{bmatrix} \\ \\ \end{bmatrix}\begin{bmatrix} \\ \end{bmatrix} + \begin{bmatrix} \\ \\ \end{bmatrix}\begin{bmatrix} \\ \end{bmatrix}$$

① output

① input

② input

$$\Rightarrow \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \end{bmatrix}_{4\times1} \begin{bmatrix} 1 & 0 \end{bmatrix}_{1\times2} + \begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \end{bmatrix} \begin{bmatrix} 0 & 1 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \\ 1 \end{bmatrix} \begin{bmatrix} 0 & 1 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 1 & 0 \\ \cdot & \cdot \end{bmatrix}_{4\times2}$$

This is lengthy way.

Use below matrix way

$W = S^T t$

Now, $S = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix}$, $t = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$

$$W = S^T t = \begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{bmatrix}_{4\times4} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}_{4\times2}$$

$$= \begin{bmatrix} 2 & 1 \\ 0 & 1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}_{4\times2}$$

As binary data hai, ∴ missing wale ques ban hi nhi sakta as missing ki ~~ki~~ agar 0 ki likhenge then confusion.

a) 1 mistaken.

Yaani koi ek i/p ki 1 bit ki change karda.

I^st ~~input~~ i/p ki I'st bit switch

$$S = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix} = X, \quad \cancel{t} \begin{bmatrix} \\ \\ \\ \end{bmatrix}$$

Recall, $y_{in} = X.W = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix}_{4\times4} \begin{bmatrix} 2 & 1 \\ 0 & 1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}_{4\times2}$

$$= \begin{bmatrix} 1 & 1 \\ 3 & 2 \\ 2 & 2 \\ 2 & 2 \end{bmatrix}$$

~~$y = f(y_{in})$~~ As binary $\Rightarrow y = \begin{cases} 1 & y_{in} > 0 \\ 0 & , y_{in} \le 0 \end{cases}$

$$\therefore y = \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}$$

→ not matching with ~~ki~~ o/p of given i/p. ∴ Cannot classify 1 bit mistaken.

classmate

Date
Page

* So Hebb ka Outer product rule is not working on Binary Data.

Q) Check the auto associative n/w for i/p vector
[1 1 -1]

Find out the weight vector with no self connection and test whether the network is able to recognise i/p pattern with 1 missing & 1 mistaken entry

2 seperate cases

no self connect^n ⇒ diagonal 0.
missing में 0 से सीखा
mistaken में switch

Ans) $\begin{array}{ccc} x_1 & x_2 & x_3 \\ [1 & 1 & -1] \end{array}$

As Auto. ∴ I/p = o/p
∴ ~~s = t = f~~

$$s = t = \begin{array}{ccc} x_1 & x_2 & x_3 \\ [1 & 1 & -1] \end{array}$$

$$W = s^T t = \begin{bmatrix} 1 \\ 1 \\ -1 \end{bmatrix}_{3\times1} \begin{bmatrix} 1 & 1 & -1 \end{bmatrix}_{1\times3} = \begin{bmatrix} 1 & 1 & -1 \\ 1 & 1 & -1 \\ -1 & -1 & 1 \end{bmatrix}_{3\times3}$$

As no self connection ∴ make wt. matrix में diagonal 0

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

As ~~[illegible]~~ ques. में दिया ∴ this step necessary.

Auto A.f. => $y = f(y_{in}) = \begin{cases} 1, & y_{in} > 0 \\ -1, & y_{in} \le 0 \end{cases}$

a) 1 missing

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

missing

Do Recall Phase

Test I/p = $\begin{bmatrix} 0 & 1 & -1 \end{bmatrix} = X$

$$Y_{in} = X.W = \begin{bmatrix} 0 & 1 & -1 \end{bmatrix}_{1\times3} \begin{bmatrix} 0 & 1 & -1 \\ 1 & 0 & -1 \\ -1 & -1 & 0 \end{bmatrix}_{3\times3}$$

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

$$y = f(y_{in}) = \begin{bmatrix} 1 & 1 & -1 \end{bmatrix}$$

This o/p is correct as it matches with the original i/p fn o/p. Can classify 1 missing

b) 1 mistaken

$$\begin{array}{ccc} x_1 & x_2 & x_3 \\ \end{array}$$
$$\begin{bmatrix} -1 & 1 & -1 \end{bmatrix} = X$$

Recall

$$Y_{in} = X.W = \begin{bmatrix} -1 & 1 & -1 \end{bmatrix}_{1\times3} \begin{bmatrix} 0 & 1 & -1 \\ 1 & 0 & -1 \\ -1 & -1 & 0 \end{bmatrix}_{3\times3}$$

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

$$y = f(y_{in}) = \begin{bmatrix} 1 & 1 & -1 \end{bmatrix}$$

This o/p is not matching with [1 1 -1]
∴ Cannot classify. 1 mistaken

* Hetero Associative,

Binary I/p

$$y = \begin{cases} 1, & y_{in} > 0 \\ 0, & y_{in} \leq 0 \end{cases}$$

⇒ Only Delta L.R. applicable

Bipolar I/p

$$y = \begin{cases} 1, & y_{in} > 0 \\ 0, & y_{in} = 0 \\ -1, & y_{in} < 0 \end{cases}$$

⇒ Both Hebb & Delta L.R. applicable. But Hebb use krna bcoz its easier then Delta.

23 Mar.

Q)

s_1	s_2	s_3	s_4	t_1	t_2
1	0	0	0	1	0
1	1	0	0	1	0
0	0	0	1	0	1
0	0	1	1	0	1

Given this i/p & o/p in binary, store it in a neural n/w (Hetero Associat).
Then test all 4 i/ps

Sol) Store ⇒ 1st phase ⇒ ~~wt~~ wt. calc.

$$W = S^T T = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix}_{4\times 2} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}_{4\times 2} = \begin{bmatrix} 2 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 2 \end{bmatrix}_{4\times 2}$$

Now testing.

① 1st i/p $X = [1 \quad 0 \quad 0 \quad 0]$

$$Y_{in} = X.W = [1 \quad 0 \quad 0 \quad 0]_{1\times 4} \cdot W = [2 \quad 0]$$

$$Y = [1 \quad 0]$$

(Matched ✓)

Classified ✓

b) IInd i/p $X = [1 \quad 1 \quad 0 \quad 0]$

$Y_{in} = X.W = [1 \quad 1 \quad 0 \quad 0].W = [3 \quad 0]$

$Y = [1 \quad 0]$ → same

Matched ✓

c) IIIrd i/p $X = [0 \quad 0 \quad 0 \quad 1 \quad 1]$

$Y_{in} = X.W = [0 \quad 2]$

$Y = [0 \quad 1]$ → Same

~~the~~ classificat^n

d) IV i/p $X = [0 \quad 0 \quad 1 \quad 1 \quad 1]$

$Y_{in} = X.W = [0 \quad 3]$

$Y = [0 \quad 1]$ → same

classificat^n ✓

& All 4 i/ps पर ~~Match~~ classify हो गया

in this test case

* यदि given i/ps में से कोई भी ले लो & उसमें

sirf 1 bit को change ~~kr~~ karle then that's

a similar pattern

Date
Page

☆ ~~When there are difference~~

☆ std difference in 2 or more bits ⇒ mistaken entry or dissimilar pattern

a) Test with pattern [0 1 0 0]

This pattern is similar to 2nd i/p ∴ ~~ग~~ o/p [1 0] dega

☆ Dissimilar pattern ~~को~~ classify nhi kr pate in binary

☆ ☆ To identify / classify dissimilar ~~data~~ patterns,

~~Both~~

WAY 1) Use ~~both~~ bipolar data instead of binary data in both testing pattern & given i/p, o/p

0 → −1

And for testing, use Bipolar A.f.

~~WAY 2)~~

WAY 2) Convert i/p ~~patter~~ & o/p to Bipolar

0 → −1

Test pattern ~~को~~ ~~&~~ Binary Rehn do

Q-1

Then calculate wt.

$$W = [2(S) - 1]^T [2(t) - 1]$$

$\underbrace{\quad}_{I}$

$\xi 2$ entry ~~it~~ it.

ξt minus 1

for testing use Binary A.f.

~~A.f. ki~~

A.f ki use hoga it depends on the nature of Test pattern.

If Testing pattern Binary then Binary A.f.

" " Bipolar " Bipolar "

Q) Same as prev. ques.

Using way 2.

S_1	S_2	S_3	S_4	t_1	t_2
1	-1	-1	-1	1	-1
1	1	-1	-1	1	-1
-1	-1	-1	1	-1	1
-1	-1	1	1	-1	1

Date
Page

$$W = [2(S)-1]^T [2(t)-1]$$

$$= \left(\begin{bmatrix} 2 & -2 & -2 & -2 \\ 2 & 2 & -2 & -2 \\ -2 & -2 & -2 & 2 \\ -2 & -2 & 2 & 2 \end{bmatrix} - 1 \right)^T \left(\begin{bmatrix} 2 & -2 \\ 2 & -2 \\ -2 & 2 \\ -2 & 2 \end{bmatrix} - 1 \right)$$

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

$$= \begin{bmatrix} 20 & -12 \\ 16 & 0 \\ 0 & 16 \\ -12 & 20 \end{bmatrix}$$

similar to 2nd I/P
∴ o/p [1 0] आना चाहिए

Now test by $[0 \quad 1 \quad 0 \quad 0]$

As way & 2 ∴ testing pattern ~~tt~~ Binary schn do.

$$Y_{in} = X.W = \underset{1\times4}{[0 \quad 1 \quad 0 \quad 0]} \underset{4\times2}{\begin{bmatrix} 20 & -12 \\ 16 & 0 \\ 0 & 16 \\ -12 & 20 \end{bmatrix}}$$

$$= [16 \quad 0]$$

* In Hetero in Bipolar, data. classification of Testing Patterns is easier.

Now use Binary A.f.

$Y = [1, \quad 0]$

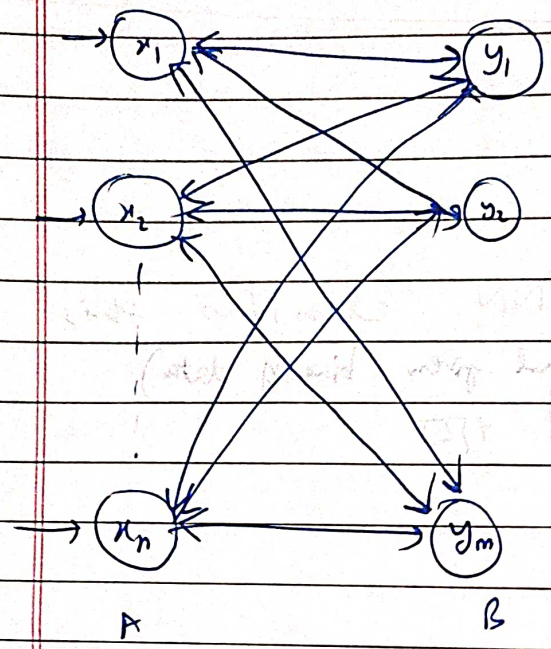
[1 0] आएगा ∴ NN classifies this as 2nd I/p. (Matching with original given binary data)

∴ Classificat^n ✓ ई. ५२१

CLASSMATE
Date
Page

5 April 2022

BAM (Bidirectional Associative Memory)



~~Binary~~ Bipolar

$W = S^T t$

~~Bipolar~~
~~Bipolar~~ Binary

$$W = \sum_{p=1}^{P} [2S_{(p)} - 1][2t_{(p)} - 1]$$

⇒ In BAM, flow of info is in both directions

first go from i/p to o/p layer & from o/p layer to i/p layer

⇒ BAM can be both Auto AM or Hetero AM

⇒ for Auto Ass. BAM, no. of i/ps = no. of o/ps

$n = n$

Bidirectional Auto Associative network

→ In the diagram, no. of i/ps = n
" o/ps = m } → different
⇓
Hetero Associative BAM.

→ अब तक only discrete A.f. used.

→ BAM can be used with both discrete & continuous ~~A.f.~~ data

(I) from I/p layer (A) to O/p layer (B)

a) When binary, a.f. is $(\theta = 0)$

$$y = \begin{cases} 1 & , y_{in} > 0 \\ y_{in} & , y_{in} = 0 \\ 0 & , y_{in} < 0 \end{cases}$$

means 0

अगर $\theta \neq 0$

$$y = \begin{cases} 1 & , y_{in} > \theta \\ y_{in} & , y_{in} = \theta \\ 0 & , y_{in} < \theta \end{cases}$$

b) for bipolar, (θ anything)

$$y = \begin{cases} 1 & y_{in} > \theta \\ y_{in}, & y_{in} = \theta \\ -1, & y_{in} < \theta \end{cases}$$

(II) from o/p layer to i/p layer, (we calculate X)

a) Binary

$$X = \begin{cases} 1 & , x_{in} > \theta \\ x_{in} & , x_{in} = \theta \\ 0 & , x_{in} < \theta \end{cases}$$

b) Bipolar

$$X = \begin{cases} 1 & , x_{in} > \theta \\ x_{in} & , x_{in} = \theta \\ -1 & , x_{in} < \theta \end{cases}$$

Above all things we use discrete ~~BAM~~ data
i.e. its discrete BAM

⇒ In case of continuous data, continuous BAM, we'll be using sigmoidal A.f.

(In qs its given konsa a.f. lagana)

⇒ When A ⟵ B then, multiply W with Y & find X_{in}. Then apply a.f. to find X.

PTO

⇒ BAM works like linear associator.
In BAM we can go in both directions

⇒ In Auto BAM, ~~no. of i/p =~~ i/p = o/p.

⇒ In Hetero Ass BAM, i/p ≠ o/p B, A & B layer different

PTO

Date
Page

Q)

x_1	x_2	x_3	x_4	y_1	y_2
1	0	0	0	1	0
1	0	0	1	1	0
0	1	0	0	0	1
0	1	1	0	0	1

As binary में ~~Mistaken~~ Missing में confusion,

∴ Convert the given data to bipolar to find wt.

whole data में convert to bipolar

x_1	x_2	x_3	x_4	y_1	y_2
1	-1	-1	-1	1	-1
1	-1	-1	1	1	-1
-1	1	-1	-1	-1	1
-1	1	1	-1	-1	1

Test the response on every input.
यानी सभी i/ps given हैं और Test patterns भी हैं।

If ~~to said~~ ~~said~~ test for [1 -1] This matches with o/p की structure ∴ we'll go from o/p layer to i/p layer
(B) (A)

→ easy to find his direction me jaana.

Std भी Testing perform करते the set given था ques. में उसी से करना।
Converted Bipolar से नहीं करना

For Bipolar, $W = S^T T$

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

$$= \underbrace{\begin{bmatrix} 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 \\ -1 & -1 & -1 & 1 \\ -1 & 1 & -1 & -1 \end{bmatrix}}_{4\times4} \underbrace{\begin{bmatrix} 1 & -1 \\ 1 & -1 \\ -1 & 1 \\ -1 & 1 \end{bmatrix}}_{4\times2}$$

$$= \begin{bmatrix} 4 & -4 \\ -4 & 4 \\ -2 & 2 \\ 2 & -2 \end{bmatrix}$$

~~Now to~~

Now testing i.e. ~~to~~ i as all i/ps that check that it go from i/p to o/p

Testing original data से करना

Assume $\theta = 0$

Date
Page

~~a) $X = [1 \quad -1 \quad -1 \quad -1]$~~

~~$Y_{in} = X.W = [1 \quad -1 \quad -1 \quad -1]$~~

a) $X = [1 \quad 0 \quad 0 \quad 0]$

$$Y_{in} = X.W = \underset{1\times4}{[1 \quad 0 \quad 0 \quad 0]} \underset{4\times2}{\begin{bmatrix} 4 & -4 \\ -4 & 4 \\ -2 & 2 \\ 2 & -2 \end{bmatrix}}$$

$$= [4 \quad -4]$$

As original data is binary so use compare कर पाए इसलिए binary a.f. use करो

$Y = [1 \quad 0]$ → matches with 1st i/p का o/p ∴ classified ✓

Similarly all other 3 i/ps के liye do

Alt) A shortcut is that jitne bhi i/ps को test करना, उन सबको club करके एक Matrix बनादो & इसपर $Y_{in} = X.W$ लगादो → Combined data

Then step a.f. apply.

$\therefore$ final Y आएगा जिसका i^{th} row corresponds to i^{th} testing pattern.

$$\therefore X = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 \end{bmatrix} \begin{matrix} \rightarrow \text{I i/p} \\ \rightarrow \text{II} \quad " \\ \rightarrow \text{III} \quad " \\ \rightarrow \text{IV} \quad " \end{matrix}$$

$$\therefore Y_{in} = X.W = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 \end{bmatrix}_{4\times4} \begin{bmatrix} 4 & -4 \\ -4 & 4 \\ -2 & 2 \\ 2 & -2 \end{bmatrix}_{4\times2}$$

$$= \begin{bmatrix} 4 & -4 \\ 6 & -6 \\ -4 & 4 \\ -6 & 6 \end{bmatrix}_{4\times2} \begin{matrix} \rightarrow Y_{in} \text{ for I i/p} \\ \rightarrow \text{" " II "} \\ \rightarrow \text{" " III "} \\ \rightarrow \text{" " IV "} \end{matrix}$$

Now Binary a.f. apply,

$$Y = f(Y_{in}) = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} \begin{matrix} \rightarrow \text{matches with o/p of I i/p} \\ \rightarrow \text{" " " " II "} \\ \rightarrow \text{" " " " III "} \\ \rightarrow \text{" " " " IV "} \end{matrix}$$

$\therefore$ all the i/ps can be classified

☆ As given data (i/p & o/p) binary hain. So testing ke liye bhi binary pattern hi diye jayenge. But missing ki question bar sake isliye wo binary data ki ki bipolar ki convert karke dete. $\therefore$ Next Page ☆ पर ही examples hain

b) Test the n/w for following data points

I/P O/P

(i) [1, 0, -1, -1] → resembles with i/p layer ⇒ A → B

(ii) [-1, 0, 0, -1] ⇒ " " " " → A → B

(iii) [1, 1] ⇒ " " o/p " ⇒ A ← B

These are examples of missing & mistaken entries

actually in binary

Sol) (i) [1 0 -1 -1] = X = [1 missing 0 0]

missing

either same as I input or similar to I input ∴ [1 0] o/p आना चाहिए।

$$Y_{in} = X.W = \underset{1\times4}{[1 \quad 0 \quad -1 \quad -1]} \begin{bmatrix} 4 & -4 \\ -4 & 4 \\ -2 & 2 \\ 2 & -2 \end{bmatrix}_{4\times2}$$

$$= \begin{bmatrix} 4 & -4 \end{bmatrix}$$

~~Y = [1 -1] → matches with~~

As original data is binary, तो उससे match करे पाए, ~~then~~ isliye hum usko acc a.f. lagayenge

∴ Binary a.f. lagayenge

Y = [1 0]

Given data point में -1 है इसलिए No मिलेगा। Hum hamesha जो given i/p o/p होते उनसे compare

A to B & B to A के लिए Hetero associative होना Necessary.

Auto में ये होता same ही है।

करना होता ∴ उसी के हिसाब से hum a.f. लगाते

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* ~~B~~ o/p layer (B) to i/p layer (A) के लिए

wt matrix का Transpose करके & use it

As $Y = [1 \quad 0]$ ∴ $[1 \quad 0 \quad -1 \quad -1]$ is

classified as I^{st} i/p [See ques के table]

(ii) $[-1 \quad 0 \quad 0 \quad -1] = X$ = [0 missing missing 0]

↳ either 2nd or 4th i/p

or similar to 3rd or similar to 4th i/p

$Y_{in} = X.W = [-6 \quad 6]$

$Y = [0 \quad 1]$

∴ ans [0 1] आना चाहिए

∴ $[-1 \quad 0 \quad 0 \quad -1]$ is classified as III pattern

?

What to write ?

(iii) $[1 \quad 1] = \cancel{X}\ Y = [1 \quad 1]$ → similar with all ∴ ~~confusion~~

∴ ~~$X_{in} = Y.W =$~~

for this transpose wt. matrix

$$W^T = \begin{bmatrix} 4 & -4 & -2 & 2 \\ -4 & 4 & 2 & -2 \end{bmatrix}$$

I'll use this as my wt.

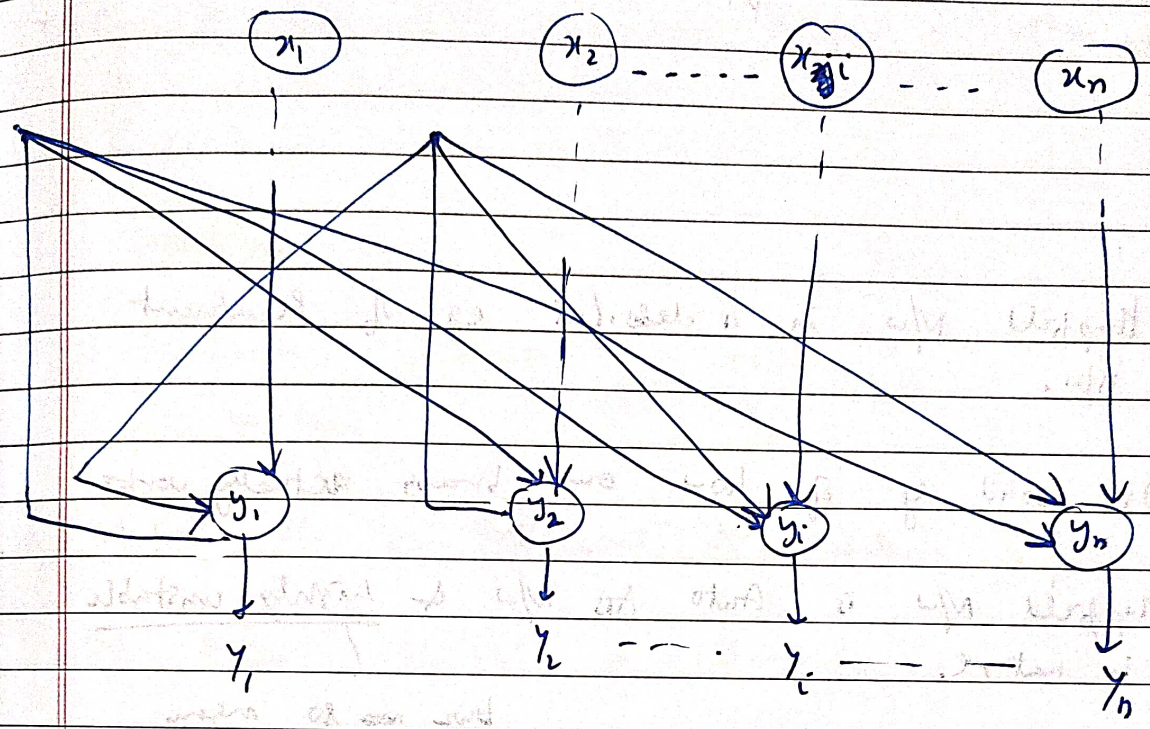
$$\boxed{X_{in} = Y.W^T} = [1 \quad 1]_{1\times 2} \begin{bmatrix} 4 & -4 & -2 & 2 \\ -4 & 4 & 2 & -2 \end{bmatrix}_{2\times 4}$$

$$= [0 \quad 0 \quad 0 \quad 0]$$

This does not match with any of the input so its not classified.

6 April 2022

Hopfield Networks



$w_{ij} = w_{ji}$

$w_{ii} = 0$

$w_{ij} = \sum S_{(p)}^T S_{(p)}$

$y_{in_j} = x_i + \sum y_i w_{ji}$

$Y = [1 \ 1 \ 1 \ -1 \ 1]$

$y_{in_j} = -1 +$

$[1 \ 1 \ 1 \ -1 \ 1]$

$E = -\frac{1}{2}\left[x_i W^T \cdot x_i^T \right]$

Date
Page

pT

⇒ Hopfield N/w is a classical eg of Recurrent n/w.

⇒ Its solid eg of how our brain actually works

⇒ Hopfield N/w is Auto Ass N/w & highly unstable in nature.

but ~~no~~ so many i/ps

⇒

⇒ Its stabilised by using Lagrangy Energy funct (E)

⇒ As its Auto Ass ; ∴ i/p = o/p.

⇒ Here there's an extra i/p like bias

⇒ ~~∴ Every y n~~

→ ET Node ET o/p is fed to all other nodes but not to itself.

⇒ wt. matrix is symmetric.

→ External i/ps (Extra) denoted by x_i.

→ As ~~हर~~ किसी Node का o/p feeded to other ~~other~~ nodes,
∴

∴ ~~We train~~

∴ To prevent unstability we train one node at a time.

→ Hop field N/w is both cont" & Discrete.

Only Discrete Hopfield in course

→ We can have either Binary or Bipolar

(a) Binary

$$y_i = \begin{cases} 1 & y_{in} > \theta \\ y_i & y_{in} = \theta \\ 0 & y_{in} < \theta \end{cases}$$

(b) Bipolar

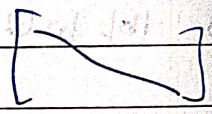
upar $0 \rightarrow -1$

Date
Page

⇒ As its Auto Ass, = only 1 pattern given
its both i/p & o/p.

PTO

⇒ After calculating wt. matrix we have to make
~~the di~~.
its diagonal 0 bcz $w_{ii} = 0$



Also it has (no) self loop

⇒ Whenever we require to use NN to store informat
then we use Hopfield.

⇒ As its asynchronous in nature its like brain

⇒ Wt. matrix calculated ⇒ Store

⇒ Recall phase

a Test pattern given.

⇒ अगर ques. में given Train 1st unit
then सिर्फ 1st $\frac{d(0)}{d(2-1)}$

⇒ Recall

External i/p

$$y_{in_j} = x_i + \sum y_i w_{ji}$$

Sig of node i^{th}

wt. matrix

⇒ Eg → [1 1 1 1 1 1] = x

Say 1st unit update ⇒ y_1

→ If θ not given then take it 0

Q) Construct an auto associative n/w to store the following patterns

~~The~~

There are 3 patterns. Each pattern has 5 bits

$x_1 = (1, 1, 1, 1, 1)$

$x_2 = (1, -1, -1, 1, -1)$

$x_3 = (-1, 1, -1, -1, -1)$

Find the wt. matrix and use the test pattern $(1, 1, 1, -1, 1)$

Hop field

पहला Transpose है

$$W = X_1^T X_1 + X_2^T X_2 + X_3^T X_3$$

Diagonal का 0 करना

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

A(t)

→ जो Testing के लिए 1 test pattern दिया होगा, तो जिससे similar होगा (i.e. only 1 bit different) then सिर्फ वाली bit वाले को update करना

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

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

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

-1 -1

Ans) Shortcut ~~से~~ ~~Ip~~ I/p's ~~को~~ Row by row join करदो to make an i/p. matrix

$$X = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 \\ -1 & 1 & -1 & -1 & -1 \end{bmatrix}_{3\times5}$$

$$W = X^T X$$

$w_{ij} = w_{ji}$

Make diagonal 0

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

Now Test

$$\begin{array}{ccccc} x_1 & x_2 & x_3 & x_4 & x_5 \\ \end{array}$$
$$\begin{bmatrix} 1 & 1 & 1 & -1 & 1 \end{bmatrix}$$

similar to I i/p
diff at 4th position

$\therefore$ sirf 4th वाली update करनी $\Rightarrow i=4$

Plus sirf wt. matrix की 4th col use करनी

$$\cancel{y_{in_j} = x_i + \sum y_i w_i}$$

$$y_{in_j} = \underset{\substack{\Downarrow \\ i=4}}{x_i} + \underbrace{\sum y_i \cdot w_j}_{\text{denoted Matrix}}$$

$$\left(\begin{array}{c}\text{testing pattern} \\ \text{row matrix}\end{array}\right) \times \left(\begin{array}{c}i^{th} \text{ position की} \\ \text{column matrix}\end{array}\right)$$

$$y_{in_j} = -1 + \underset{1\times 5}{\begin{bmatrix} 1 & 1 & 1 & -1 & 1 \end{bmatrix}} \underset{5\times 1}{\begin{bmatrix} 3 \\ -1 \\ 1 \\ 0 \\ 1 \end{bmatrix}}$$

$$= -1 + [4] = [3]$$

Now apply a.f. to it $\therefore y = 1$ (Bipolar.

Now testing pattern of ith position पर यह

२२वां)

$[1 \quad 1 \quad 1 \quad 1 \quad 1] \rightarrow$ (Ans)