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CHALMERS | Anonymous code / Anonym kod: FFR135-0152-PXZ | Points for question (to be filled in by teacher) / Poäng på uppgiften (ifylles av lärare) | Consecutive page no. / Löpande sid nr: 1 | Question no. / Uppgift nr: 1

1. a) Given,

$$H = -\left(\frac{w_{12}+w_{21}}{2}\right) s_1 s_2$$

$\because$ $w_{12} = 2$ and $w_{21} = -1$

$$\Rightarrow H = -0.5\, s_1 s_2$$

When we update s_2 asynchronously,

$$H' = -0.5\, s_1 s_2'$$

$$\therefore \Delta H = H' - H = -0.5\, s_1 (s_2' - s_2)$$

$$= -0.5\, s_1 (\operatorname{sgn}(-s_1) - s_2)$$

$$= -0.5\, s_1 (-s_1 - s_2)$$

$$= 0.5\, s_1 (s_1 + s_2) = 0.5\, s_1^2 + 0.5\, s_1 s_2$$

$$= 0.5(1 + s_1 s_2) \quad \because (s_1^2 = 1)$$

$$\geq 0 \quad (\because s_1 s_2 = \pm 1)$$

$\therefore$ $\Delta H \geq 0$

$\Rightarrow$ Energy can increase. ✓

When we update s_1 asynchronously,

$$H' = -0.5\, s_1' s_2$$

$$\therefore \Delta H = -0.5\, s_2 (s_1' - s_1)$$

$$= -0.5\, s_2 (\operatorname{sgn}(2 s_2) - s_1)$$

$$= -0.5\, s_2 (s_2 - s_1)$$

$$= 0.5(s_1 s_2 - s_2^2)$$

$$= 0.5(s_1 s_2 - 1) \leq 0$$ ✓

$\therefore$ $\Delta H \leq 0$ 0,5

$\Rightarrow$ Energy cannot increase. ✓

(b) $$H = -\left(\frac{w_{12}+w_{21}}{2}\right) s_1 s_2$$

$$= -0.5\, s_1 s_2$$

After update, $H' = -0.5\, s_1' s_2'$

$$\therefore \Delta H = -0.5(s_1' s_2' - s_1 s_2)$$ ✓

1

$$\Delta H = -0.5\left[\operatorname{sgn}(2S_2)\operatorname{sgn}(-S_1) - S_1S_2\right]$$
$$= -0.5\left[-S_2S_1 - S_1S_2\right]$$
$$= S_1S_2 \quad \checkmark$$

$\because$ S_1 and S_2 can take values ± 1 only.

So, S_1S_2 can be ± 1 only.

So, $\Delta H \neq 0$ 0.5

$\Rightarrow$ Energy can't stay constant after synchronous update. ✓

(c)

$$H = -\frac{1}{2}\sum_{i,j}^{N} w_{ij} n_i n_j + \sum_{i=1}^{N} \mu_i n_i$$

Update m^{th} neuron:

$$n'_m = \theta_H(b_m), \quad b_m = \sum_{j=1}^{N} W_{mj} n_j - \mu_m$$

$$\therefore H' = -\frac{1}{2}\sum_{\substack{i=1\\ i\neq m}}^{N}\sum_{\substack{j=1\\ j\neq m}}^{N} w_{ij} n_i n_j - \frac{1}{2}\sum_{\substack{j=1\\ j\neq m}}^{N} W_{mj} n'_m n_j - \frac{1}{2}\sum_{\substack{i=1\\ i\neq m}}^{N} W_{im} n_i n'_m$$
$$- \frac{1}{2} W_{mm} n'_m n'_m + \sum_{\substack{i=1\\ i\neq m}}^{N} \mu_i n_i + \mu_m n'_m$$

$$\therefore \Delta H = H' - H$$
$$= -\frac{1}{2}\sum_{\substack{i=1\\ i\neq m}}^{N} (W_{mi} + W_{im})(n_i n'_m - n_i n_m) - \frac{1}{2} W_{mm}(n'^2_m - n^2_m) + \mu_m(n'_m - n_m)$$ ✓

$[\because$ First term in H' gets cancelled as it remains same as in $H]$ 0.5

Now $\because$ $w_{ij} = w_{ji}$

$$\Rightarrow \Delta H = -\sum_{\substack{i=1\\ i\neq m}}^{N} W_{im} n_i n'_m - \frac{1}{2} W_{mm}(n'_m n'_m - n_m n_m) + \mu_m(n'_m - n_m)$$

$$= -n'_m\left[\sum_{i=1}^{N} W_{im} n_i - \mu_m\right] + W_{mm} n_m n'_m - \frac{1}{2} W_{mm}(n'_m n'_m - n_m n_m) - \mu_m n_m$$

$$= -b_m n'_m - \frac{W_{mm}}{2}\left(n'_m n'_m - n_m n_m + 2 n_m n'_m\right) - \mu_m n_m$$

If $n_m' = n_m \Rightarrow \Delta H = 0$ ✓

Now if $n_m = 0$ and $n_m' = 1 \Rightarrow b_m > 0$

$$\Rightarrow \Delta H = -b_m - \frac{W_{mm}}{2}(1 - 0 + 0) - \mu_m(0)$$

$$= -b_m - \frac{W_{mm}}{2}$$ ✓

$\because b_m > 0$ and $W_{mm} > 0$ ✓

$\Rightarrow \Delta H < 0$ ✓

If $n_m = 1$ and $n_m' = 0 \Rightarrow b_m < 0$

$$\Rightarrow \Delta H = -\frac{W_{mm}}{2}(-1) - \mu_m$$

$$= \frac{W_{mm}}{2} - \mu_m < 0 \quad (\because b_m < 0)$$

$\therefore \Delta H \leq 0$

$\Rightarrow$ H cannot increase under this dynamics. ✓ 0.5

2/2

2. (a) Let $H_{\mu\nu}$ denote Hamming distance between patern μ and ν.

Let $Q_{\mu\nu} = \sum_{j=1}^{N} x_j^{\mu} x_j^{\nu}$

So, $Q_{\mu\nu} = N - 2H_{\mu\nu} = 35 - 2H_{\mu\nu}$

$\therefore$ For $\mu=1$, $H_{11} = 0 \Rightarrow Q_{11} = 35$

$H_{12} = 10 \Rightarrow Q_{12} = 15$

$H_{13} = 8 \Rightarrow Q_{13} = 19$

$H_{14} = 11 \Rightarrow Q_{14} = 13$

$H_{15} = 35 \Rightarrow Q_{15} = -35$

For $\mu=2$, $H_{21} = 10 \Rightarrow Q_{21} = 15$

$H_{22} = 0 \Rightarrow Q_{22} = 35$

$H_{23} = 14 \Rightarrow Q_{23} = 7$

$H_{24} = 3 \Rightarrow Q_{24} = 29$

$H_{25} = 25 \Rightarrow Q_{25} = -15$

(b)
$$b_i^{(\nu)} = \sum_{j=1}^{N} W_{ij} x_j^{(\nu)}$$
$$= \sum_{j=1}^{N} \left(\frac{1}{35} \sum_{\mu=1}^{2} x_i^{(\mu)} x_j^{(\mu)} \right) x_j^{(\nu)}$$
$$= \frac{1}{35} \left[\sum_{j=1}^{N} x_i^{(1)} x_j^{(1)} x_j^{(\nu)} + \sum_{j=1}^{N} x_i^{(2)} x_j^{(2)} x_j^{(\nu)} \right]$$
$$= \frac{1}{35} \left[x_i^{(1)} Q_{1\nu} + x_i^{(2)} Q_{2\nu} \right]$$
$$\therefore b_i^{(1)} = \frac{1}{35} \left[35 x_i^{(1)} + 15 x_i^{(2)} \right] = x_i^{(1)} + \frac{3}{7} x_i^{(2)}$$
$$b_i^{(2)} = \frac{1}{35} \left[15 x_i^{(1)} + 35 x_i^{(2)} \right] = \frac{3}{7} x_i^{(1)} + x_i^{(2)}$$

$$b_i^{(3)} = \frac{1}{35}\left(19\, x_i^{(1)} + 7\, x_i^{(2)}\right) = \frac{19}{35} x_i^{(1)} + \frac{1}{5} x_i^{(2)}$$ ✓

$$b_i^{(4)} = \frac{1}{35}\left(13\, x_i^{(1)} + 29\, x_i^{(2)}\right) = \frac{13}{35} x_i^{(1)} + \frac{29}{35} x_i^{(2)}$$ ✓

$$b_i^{(5)} = \frac{1}{35}\left(-35\, x_i^{(1)} - 15\, x_i^{(2)}\right) = -x_i^{(1)} - \frac{3}{7} x_i^{(2)}$$ ✓

(c)

If $\operatorname{sgn}(b_i^{(\nu)}) = x_i^{(\nu)}$ then pattern remains same.

$\Rightarrow \nu=1,\ \operatorname{sgn}(b_i^{(1)}) = \operatorname{sgn}\left(x_i^{(1)} + \frac{3}{7} x_i^{(2)}\right) = x_i^{(1)}$ ✓

$\nu=2,\ \operatorname{sgn}(b_i^{(2)}) = \operatorname{sgn}\left(\frac{3}{7} x_i^{(1)} + x_i^{(2)}\right) = x_i^{(2)}$ ✓

$\nu=3,\ \operatorname{sgn}(b_i^{(3)}) = \operatorname{sgn}\left(\frac{19}{35} x_i^{(1)} + \frac{1}{5} x_i^{(2)}\right) = x_i^{(1)}$ ✓

$\nu=4,\ \operatorname{sgn}(b_i^{(4)}) = \operatorname{sgn}\left(\frac{13}{35} x_i^{(1)} + \frac{29}{35} x_i^{(2)}\right) = x_i^{(2)}$ ✓

$\nu=5,\ \operatorname{sgn}(b_i^{(5)}) = \operatorname{sgn}\left(-x_i^{(1)} - \frac{3}{7} x_i^{(2)}\right) = -x_i^{(1)} = x_i^{(5)}$ ✓

$\because\ x^{(5)} = -x^{(1)}$

$\Rightarrow$ Only pattern 1,2 and 5 remain same. ✓

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Points for question (to be filled in by teacher) / Poäng på uppgiften (ifylles av lärare)

Consecutive page no. / Löpande sid nr: 6

Question no. / Uppgift nr: 3

3. (a) Take points $(-2,1)$, $(0,1)$, $(-1,-2)$, $(-1,3)$

o $(-1,3) \rightarrow -1$

$+1 \leftarrow (-2,1)$ •   • $(0,1) \rightarrow +1$

o $(-1,-2) \rightarrow -1$

We cannot construct a line (decision boundary) that separates the points mentioned above. Thus problem's not linearly separable.

OK

(b) On decision boundary the argument of signum function is zero.

Thus, $w_{11} x_1 + w_{12} x_2 - \theta_1 = 0$

$(-1,-1)$ and $(-3,2)$ lie on this line $\Rightarrow$

$$-w_{11} - w_{12} = \theta_1$$

& $$-3w_{11} + 2w_{12} = \theta_1$$

Take $w_{11} = 1$ $\qquad \Rightarrow 2w_{11} - 3w_{12} = 0$

$\Rightarrow w_{12} = 2/3$ & $\theta_1 = -5/3$ OK

And, $w_{21} x_1 + w_{22} x_2 = \theta_2$

$(-3,2)$ & $(2,3)$ lie on this line $\Rightarrow$

$$-3w_{21} + 2w_{22} = \theta_2$$

$$2w_{21} + 3w_{22} = \theta_2$$

$$\Rightarrow 5w_{21} + w_{22} = 0$$

Take $w_{22} = 1 \Rightarrow w_{21} = -1/5$ & $\theta_2 = 13/5$ OK

And $w_{31} x_1 + w_{32} x_2 = \theta_3$

$(2,3)$ & $(-1,-1)$ lie on this line $\Rightarrow$

$2w_{31} + 3w_{32} = \theta_3$

$-w_{31} - w_{32} = \theta_3$ $\qquad \Rightarrow 3w_{31} + 4w_{32} = 0$ OK

Take $w_{31} = +1 \Rightarrow w_{32} = -3/4$ & $\theta_3 = -1/4$

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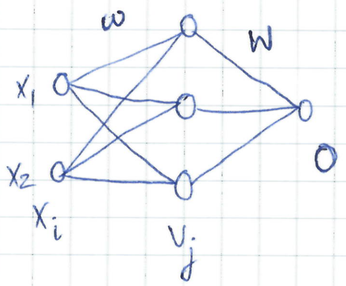
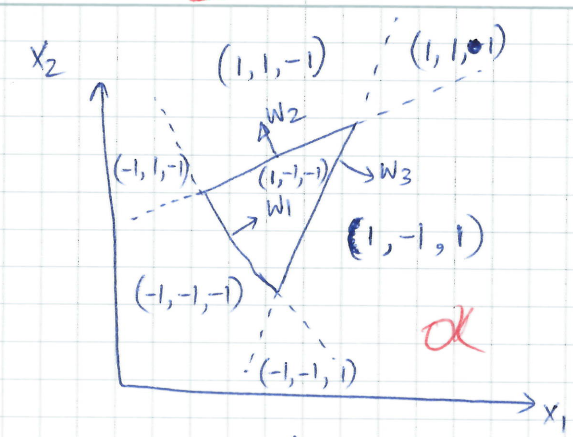
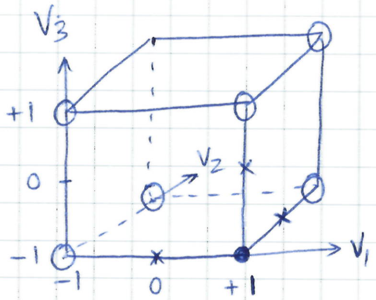
3(c)







Regions denoting different values of (V_1, V_2, V_3) OK

We can draw a plane passing through the (x) marks above.

i.e. $P_1(0,-1,-1)$, $P_2(1,0,-1)$, $P_3(1,-1,0)$

V_1	V_2	V_3	O
-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	-1	-1
+1	+1	+1	-1

$\Rightarrow \quad W_1V_1 + W_2V_2 + W_3V_3 = \theta$

$P_1 \Rightarrow \quad -W_2 - W_3 = \theta \quad \text{—— } ①$

$P_2 \Rightarrow \quad W_1 - W_3 = \theta \quad \text{—— } ②$

$P_3 \Rightarrow \quad W_1 - W_2 = \theta \quad \text{—— } ③$

$② - ③ \Rightarrow W_2 - W_3 = 0 \Rightarrow W_2 = W_3 = -\theta/2$ or $\theta = -2W_3$

Take $W_1 = 1$

$\therefore ② \Rightarrow W_1 - W_3 = -2W_3$

$\Rightarrow W_3 = -1 = W_2$

$\therefore \theta = \underline{\underline{2}}$

So, $W = \begin{bmatrix} 1 \\ -1 \\ -1 \end{bmatrix}$ and $\theta = 2$ OK (Output layer)

& $w = \begin{bmatrix} 1 & 2/3 \\ -1/5 & 1 \\ 1 & -3/4 \end{bmatrix}$ & $\theta = \begin{bmatrix} -5/3 \\ 13/5 \\ -1/4 \end{bmatrix}$ (Hidden layer) OK

1

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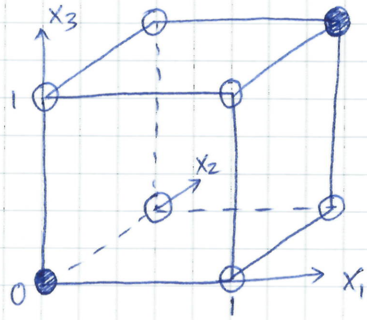
4(a)



● = +1
o = −1

Simple perceptron cannot solve this problem as the problem is linearly not separable and simple perceptrons can only solve linearly separable problems. OK

(b)

1.

μ	x_1^μ	x_2^μ	x_3^μ	t^μ	g_1^μ	g_2^μ
1	0	1	0	−1	e^{-1}	e^{-2}
2	1	0	1	−1	e^{-2}	e^{-1}
3	0	0	0	+1	1	e^{-3}
4	1	0	0	−1	e^{-1}	e^{-2}
5	1	1	0	−1	e^{-2}	e^{-1}
6	0	0	1	−1	e^{-1}	e^{-2}
7	0	1	1	−1	e^{-2}	e^{-1}
8	1	1	1	+1	e^{-3}	1

$w_1 = (0,0,0)$

$w_2 = (1,1,1)$

OK

$\mu=1$, $g_1^{(1)} = \exp(-|(0,1,0)^T|^2) = \exp(-1)$

$g_2^{(1)} = \exp(-|(1,0,1)^T|^2) = \exp(-2)$

$\mu=2$, $g_1^{(2)} = \exp(-|(1,0,1)|^2) = \exp(-2)$ OK

$g_2^{(2)} = \exp(-|(0,1,0)|^2) = \exp(-1)$

$\mu=3$, $g_1^{(3)} = \exp(-|(0,0,0)|^2) = 1$

$g_2^{(3)} = \exp(-|(1,1,1)|^2) = \exp(-3)$

$\mu = 4$, $g_1^{(4)} = \exp(-|(1,0,0)|^2) = \exp(-1)$

$g_2^{(4)} = \exp(-|(0,1,1)|^2) = \exp(-2)$

$\mu = 5$, $g_1^{(5)} = \exp(-|(1,1,0)|^2) = \exp(-2)$

$g_2^{(5)} = \exp(-|(0,0,1)|^2) = \exp(-1)$

$\mu = 6$, $g_1^{(6)} = \exp(-|(0,0,1)|^2) = \exp(-1)$

$g_2^{(6)} = \exp(-|(1,1,0)|^2) = \exp(-2)$

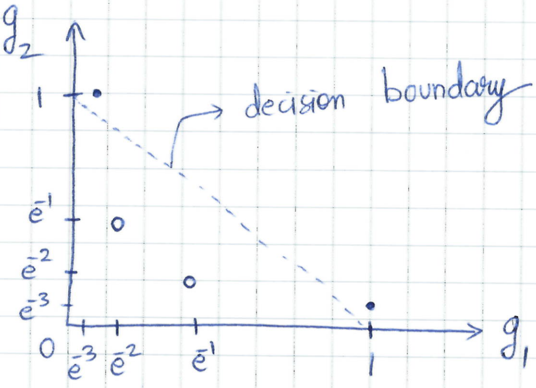
OK

$\mu = 7$, $g_1^{(7)} = \exp(-|(0,1,1)|^2) = \exp(-2)$

$g_2^{(7)} = \exp(-|(1,0,0)|^2) = \exp(-1)$

$\mu = 8$, $g_1^{(8)} = \exp(-|(1,1,1)|^2) = \exp(-3)$

$g_2^{(8)} = \exp(-|0,0,0|^2) = 1$

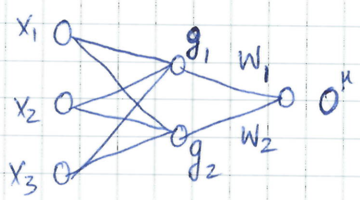


Here

$\bullet \to +1$, $\circ \to -1$ $\}$ t^{μ}

OK

Let weight vector be $(w_1, w_2)^T$ and threshold θ.



$\therefore$ On decision boundary arguement of signum function should be zero.

$\therefore$ $O^{(\mu)} = \mathrm{sgn}(w_1 g_1^{(\mu)} + w_2 g_2^{(\mu)} - \theta)$

$\Rightarrow$ $w_1 g_1 + w_2 g_2 = \theta$ on decision boundary!

Points $(1,0)$ and $(0,1)$ lie on this line.

1

$(g_1, g_2) = (1, 0) \Rightarrow \quad w_1 = \theta$

$(g_1, g_2) = (0, 1) \Rightarrow \quad w_2 = \theta$

Choose $w_1 = 1 \Rightarrow w_2 = 1 = \theta$

Thus $w = (1, 1)^T$ and $\theta = 1$. OK

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5)

$$V_j^{(\mu)} = g\left(\sum_{k=1}^{3} w_{jk} x_k^{(\mu)} - \theta_j\right) \quad \& \quad b_j^{\mu} = \sum_{k=1}^{3} w_{jk} x_k^{\mu} - \theta_j$$

$$O_1^{(\mu)} = g\left(\sum_{j=1}^{5} W_{ij} V_j^{(\mu)} - \theta_1\right) \quad \& \quad B_1^{\mu} = \sum_{j=1}^{5} W_{ij} V_j^{(\mu)} - \theta_1$$

$$H = \frac{1}{2} \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right)^2$$

ok

Now,

$$\delta W_{1m} = -\eta \frac{\partial H}{\partial W_{1m}}$$

OK

$$= +\eta \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right) \frac{\partial O_1^{(\mu)}}{\partial W_{1m}}$$

$$= \eta \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right) \frac{\partial O_1^{(\mu)}}{\partial B_1^{(\mu)}} \cdot \frac{\partial B_1^{(\mu)}}{\partial W_{1m}}$$

$$= \eta \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right) g'\left(B_1^{(\mu)}\right) \left[\sum_{j=1}^{5} \delta_{mj} V_j^{(\mu)}\right]$$

OK

$$\delta W_{1m} = \eta \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right) g'\left(B_1^{(\mu)}\right) V_m^{(\mu)}$$

We get update rule for θ_1 if we replace $V_j^{(\mu)}$ by -1.

$$\Rightarrow \delta \theta_1 = -\eta \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right) g'\left(B_1^{(\mu)}\right)$$

OK

Now for the hidden layer:

$$\delta w_{mn} = -\eta \frac{\partial H}{\partial w_{mn}} \cancel{= -\eta \partial}$$

$$= \eta \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right) \frac{\partial O_1^{(\mu)}}{\partial w_{mn}}$$

$$= \eta \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right) \frac{\partial O_1^{(\mu)}}{\partial B_1^{(\mu)}} \cdot \frac{\partial B_1^{(\mu)}}{\partial w_{mn}}$$

ok

$$= \eta \sum_{\mu=1}^{p} \left(t_1^{(\mu)} - O_1^{(\mu)}\right) g'\left(B_1^{(\mu)}\right) \left[\sum_{j=1}^{5} W_{1j} \frac{\partial V_j^{(\mu)}}{\partial w_{mn}}\right]$$

Now, $\dfrac{\partial v_j^\mu}{\partial w_{mn}} = \dfrac{\partial v_j^\mu}{\partial b_j^\mu} \cdot \dfrac{\partial b_j^\mu}{\partial w_{mn}}$

$$= g'(b_j^\mu) \cdot \left(\sum_{k=1}^{3} \delta_{jm}\delta_{kn} x_k^\mu \right)$$ OK

$$= g'(b_j^\mu)\, x_n^\mu \,\delta_{jm}$$ OK

So, $\delta w_{mn} = \eta \sum_{\mu=1}^{p} (t_1^{(\mu)} - o_1^{(\mu)})\, g'(B_1^{(\mu)})\, W_{1m}\, g'(b_m^{(\mu)})\, x_n^{(\mu)}$

$$= \eta \sum_{\mu=1}^{p} (t_1^{(\mu)} - o_1^{(\mu)})\, g'(B_1^{(\mu)})\, g'(b_m^{(\mu)})\, W_{1m}\, x_n^{(\mu)}$$ OK

For thresholds update rule simply replace $x_n^\mu \rightarrow -1$

$$\Rightarrow \delta\theta_m = -\eta \sum_{\mu=1}^{p} (t_1^{(\mu)} - o_1^{(\mu)})\, g'(B_1^{(\mu)})\, g'(b_m^{(\mu)})\, W_{1m}$$

OK

Sequential training?

6. Input layer – This layer feeds the input image in all channels into the neural network.

Convolution layer – This layer performs convolution operation with kernels on the input layer to get feature maps which capture features of images. ✓

Max-pooling layer – This layer takes maximum value in a receptive area thus summarizing the feature maps or the output of previous layer. ✓

Fully-connected: This layer takes the output from max-pooling layer and acts as buffer layer before feeding its own output to the output layer. ✓

Output layer: This layer produces the final output of the network. (classes or real values). ✓

→ $x_1 = 31$, $y_1 = 31$, $z_1 = 3$ ✓

→ If j is the number of strides, 's' step size then

$1 + js = x_1 - (3-1)$ ∵ 3x3 is field size.

$\Rightarrow j = \dfrac{x_1 - 3}{s}$

$\Rightarrow x_2 = j+1$ (∵ one more than the no. of strides)

$= \dfrac{x_1-3}{s} + 1$

$= \dfrac{31-3}{2} + 1 = 15$

$\Rightarrow x_2 = 15$ ✓, $y_2 = 15$ ✓ (∵ similar calculation), $z_2 = 10$

→ $x_3 = x_2/5$ (∵ max-pooling layer)

$x_3 = 3$ ✓

Thus, $y_3 = 3$ ✓ and $z_3 = 10$ ✓ (same as z_2).

Also, $y_4 = 10$ ✓ and $y_5 = 5$ ✓

→ Now for convolution layer, no. of weights = $(3 \times 3 \times 3) = 27$
& each feature map has one threshold
⇒ total parameters = $(27+1) \times 10$
$= 280$ ✓

→ No trainable parameters between convolution layer & max-pooling layer. ✓

→ Between max-pooling & fully connected layer:
No. of weights = ~~$(3\times3)\times z_{3}$~~ $(x_3 \times y_3) \times z_3 \times y_4$
$= 3 \times 3 \times 10 \times 10$
$= 900$ ✓

~~Also~~, No. of thresholds = 10 $(= y_4)$
⇒ total = 910 ✓

→ In between output layer & fully connected layer
No. of weights = $y_5 \times y_4 = 50$ ✓
No. of thresholds = $y_5 = 5$ ✓
∴ total = 55 ✓

2/2

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Rough Work

$4 \to 6$

$\frac{4 \cdot 60}{6} = 40$

$n'n' - nn + 2nn'$

$n'n' + nn' + nn' - nn$

$n'(n'+n) + n(n'-n)$

35 - 16

35 - 22

4, 15

8, 5

$b_m = \sum_{i \neq m} w_{mi} n_i + w_{mm} n_m - \mu_m n_m$

$n = 0 \quad n' = 1 \quad \to 1$

$n = 1 \quad n' = 0 \quad \to -1$

$\sum_{i \neq m} w_{mi} n_i + w_{mm} < \mu_m$

$\frac{w_{mm}}{2} - \mu_m =$

$b_m n_m' \quad b_m \theta_H(b_m)$

$\underbrace{b_m n_m'}_{>0}$

$\cancel{b_m - w_{mm} - \mu}$

$n \quad n'$

$0 \to 1 \Rightarrow \boxed{-b_m - \frac{w}{2}} < 0$

$1 \to 0 \Rightarrow \frac{w}{2} - \mu_m$

$b_m < 0$

35 - 28

35 - 6

35 - 50

-15

$\sum < \mu_m$

$(\ ) + w < \mu_m$

$9 \times 3 = 27 + 1 \times 10$

$x_1 = 31, y_1 = 31, z_1 = 3$

$x_2 = 15, y_2 = 15, z_2 = 10$

$x_3 = 3, y_3 = 3, z_3 = 10$

$\frac{4 \cdot 60}{6} = 40$

120

$y_4 = 10$

$y_5 = 5$

$-\frac{2}{5} + 3.$

$\frac{13}{5}$

$5 - \frac{(3-1)}{2}$

$7 -$

$1 + s x$

$\frac{5-3-1}{2}$

$1 \to 1+s \to 1+2s$

$\frac{31-3}{2}$

$14+1$

15

$1 + js = N - (n-1) \quad js = \frac{(n-1)}{s}$

$1 + sj = \frac{N - l - 1}{s}$

$\frac{N-n}{s} + 1$