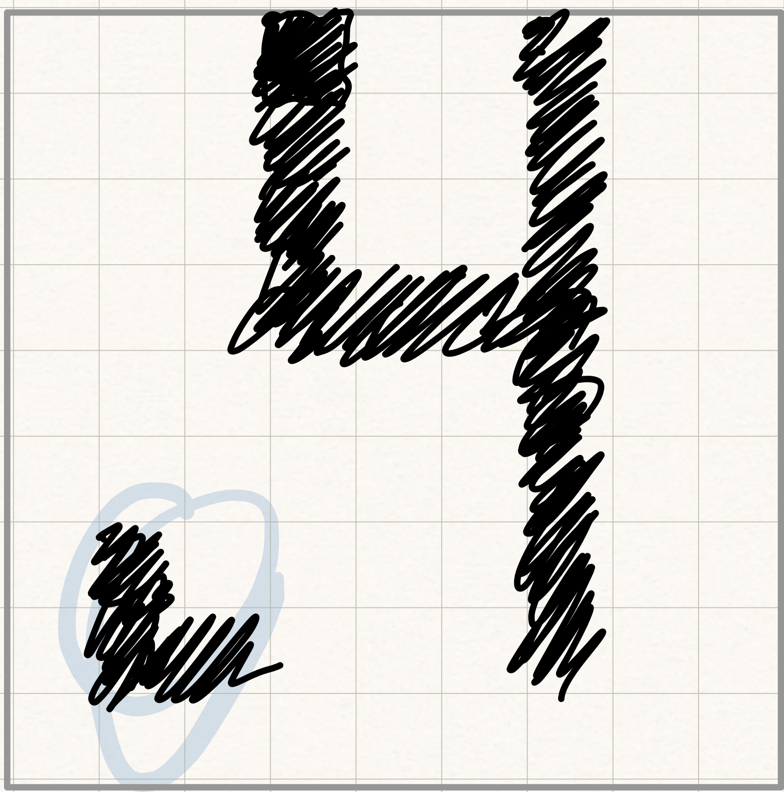


9x9

Vertical Edges

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

filter

■ = 1

□ = 0

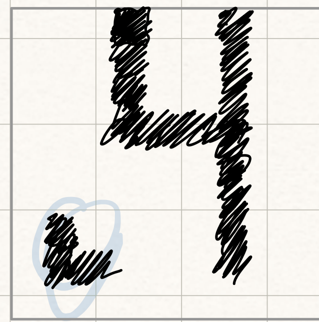
Vertical Edges

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

W

■ $= 1$

□ $= 0$



X

$$WX = ?$$

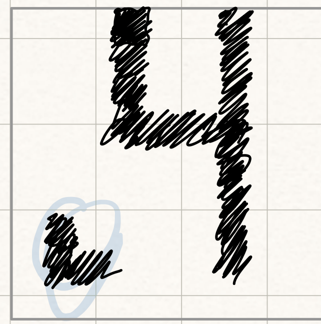
Vertical Edges

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

W

■ = 1

□ = 0



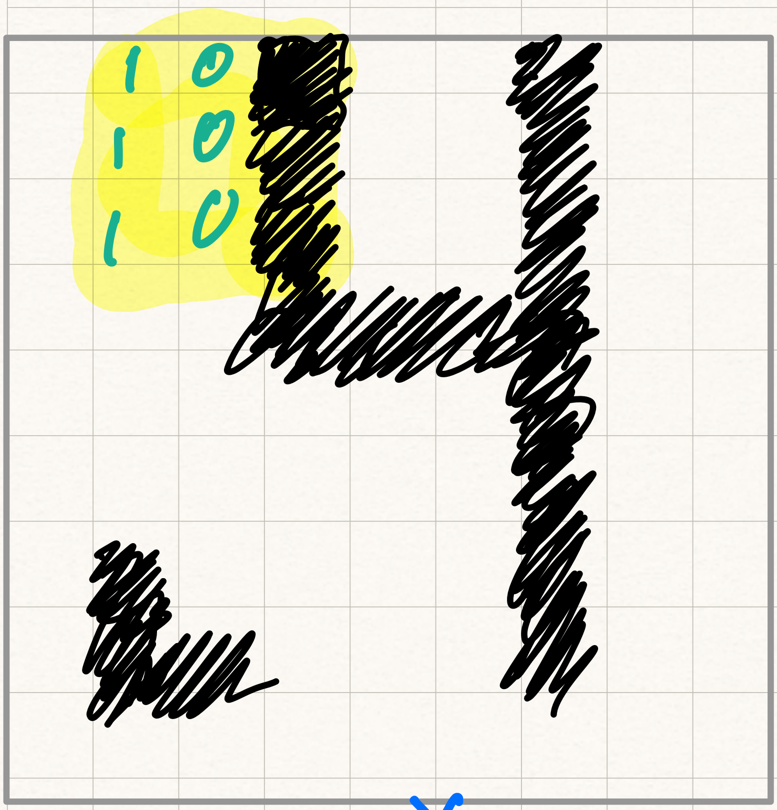
X

$$WX = ?$$

$$W = \begin{bmatrix} w_1 & w_2 & w_3\\ w_4 & w_5 & w_6\\ w_7 & w_8 & w_9\end{bmatrix} = \begin{bmatrix}1 & 0 & -1\\ 1 & 0 & -1\\ 1 & 0 & -1\end{bmatrix}$$

3x3 filter

Let's use no padding, stride 1
(padding + stride explained in lab 1)

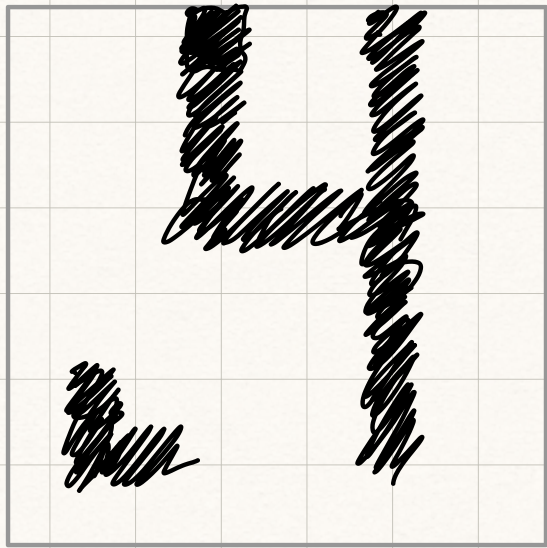


X

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

w

wx



X

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

w

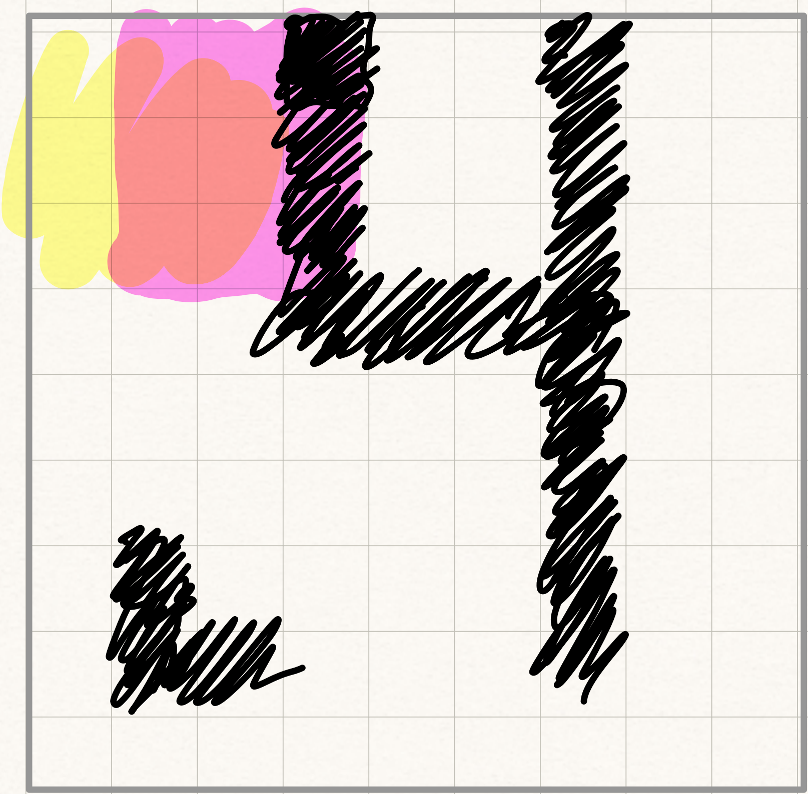
wx

$$wx = x_1 \cdot w_1 + x_2 \cdot w_2 + x_3 \cdot w_3 + x_4 \cdot w_4 + x_5 \cdot w_5 + x_6 \cdot w_6 + x_7 \cdot w_7 + x_8 \cdot w_8 + x_9 \cdot w_9$$

$$P_1 = WX_1 = x_1 \cdot w_1 + x_2 \cdot w_2 + x_3 \cdot w_3 + x_4 \cdot w_4 + x_5 \cdot w_5 + x_6 \cdot w_6 + x_7 \cdot w_7 + x_8 \cdot w_8 + x_9 \cdot w_9$$

$$\begin{matrix} x_1 & x_2 & x_3 \\ x_4 & x_5 & x_6 \\ x_7 & x_8 & x_9 \end{matrix} \times \begin{bmatrix} w_1 & w_2 & w_3 \\ w_4 & w_5 & w_6 \\ w_7 & w_8 & w_9 \end{bmatrix}$$

$$\begin{matrix} x_1 & x_2 & x_3 \\ x_4 & x_5 & x_6 \\ x_7 & x_8 & x_9 \end{matrix} \times \begin{bmatrix} w_1 & w_2 & w_3 \\ w_4 & w_5 & w_6 \\ w_7 & w_8 & w_9 \end{bmatrix}$$



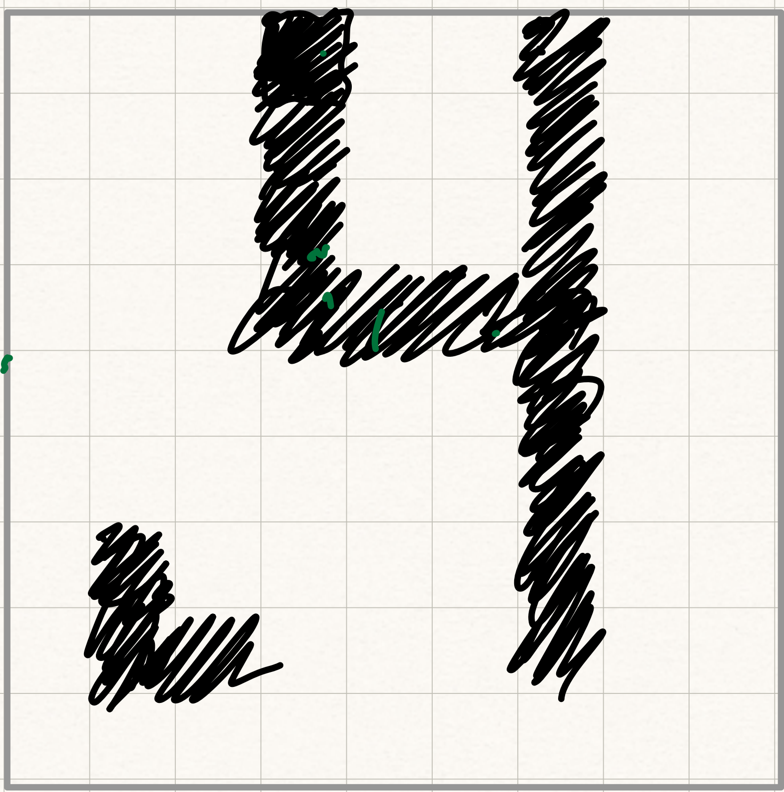
$$X \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

■ = 1
= 0

$= 0$

$= x_1 \cdot w_1 + x_2 \cdot w_2 + x_3 \cdot w_3 + x_4 \cdot w_4 + x_5 \cdot w_5 + x_6 \cdot w_6 + x_7 \cdot w_7 + x_8 \cdot w_8 + x_9 \cdot w_9$

$= 1 \cdot 0 + 0 \cdot 0 + -1 \cdot \cancel{0} + 1 \cdot 0 + 0 \cdot 0 + -1 \cdot 1 + 1 \cdot 0 + 0 \cdot 0 + -1 \cdot 1 = 3$



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

0	-3	0	3	-3	0	3
0	-3	-1	2	-2	0	3
0	-2	-1	1	-2	1	3
0	-1	-1	0	-2	1	3
0	1	0	0	-3	0	3
-1	2	1	0	-3	0	3
-1	2	1	0	-2	0	2

wx

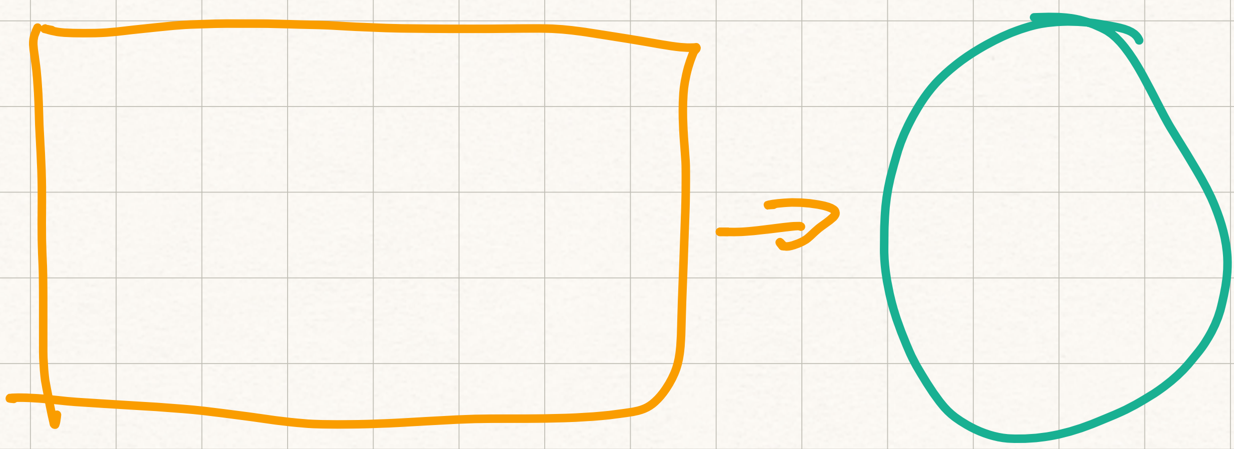
$$
\begin{bmatrix}
-2 & -5 & 0 & 3 & -3 & 0 & 3 \\
0 & -3 & -1 & 2 & -2 & 0 & 3 \\
0 & -2 & -1 & 1 & -2 & 1 & 3 \\
0 & -1 & -1 & 0 & -2 & 1 & 3 \\
0 & 1 & 0 & 0 & -3 & 0 & 3 \\
-1 & 2 & 1 & 0 & -3 & 0 & 3 \\
-1 & 2 & 1 & 0 & -2 & 0 & 2
\end{bmatrix}
$$

$wx \qquad + b$

$b = -2$

$$\boxed{\begin{matrix} -2 & -5 & -2 & 1 & -5 & -2 & 1 \\ -2 & -5 & -3 & 0 & -4 & -2 & 1 \\ -2 & -5 & -3 & -1 & 4 & -1 & 1 \\ -2 & -3 & -3 & -2 & -5 & -1 & 1 \\ -2 & -1 & -2 & -2 & -5 & -2 & 1 \\ -3 & 0 & -1 & -2 & -5 & -2 & 1 \\ -3 & 0 & -1 & -2 & -4 & -2 & 0 \end{matrix}}$$

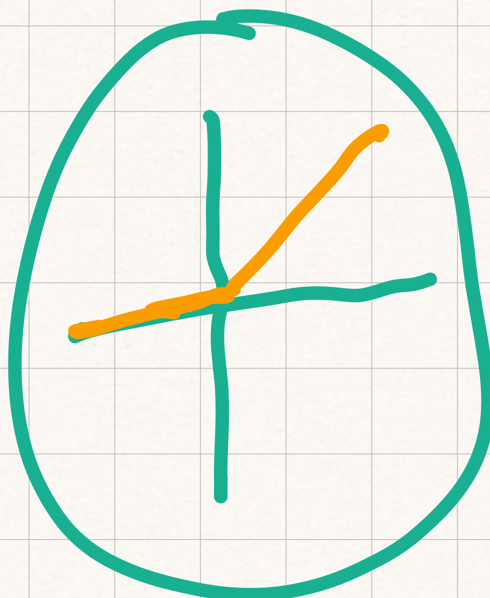
$$wx+b$$



activation function: relu

$$
\begin{bmatrix}
-2 & -5 & -2 & 1 & -5 & -2 & 1 \\
-2 & -5 & -3 & 0 & -4 & -2 & 1 \\
-2 & -5 & -3 & -1 & 4 & -1 & 1 \\
-2 & -3 & -3 & -2 & -5 & -1 & 1 \\
-2 & -1 & -2 & -2 & -5 & -2 & 1 \\
-3 & 0 & -1 & -2 & -5 & -2 & 1 \\
-3 & 0 & -1 & -2 & -4 & -2 & 0
\end{bmatrix}
$$

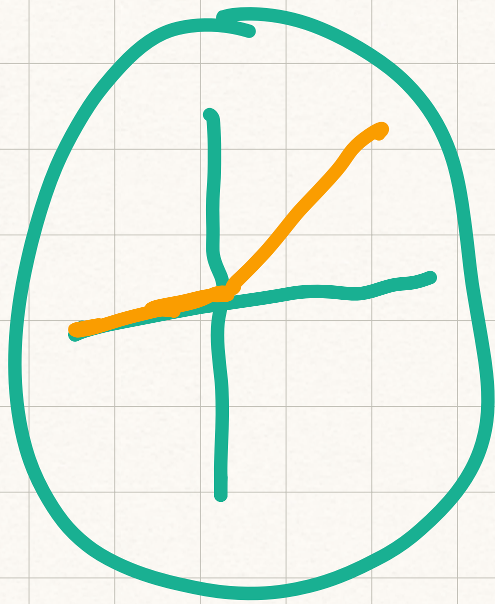
$wx+b$



-2	-5	-2	1	-5	-2	1
-2	-5	-3	0	-4	-2	1
-2	-5	-3	-1	4	-1	1
-2	-3	-3	-2	-5	-1	1
-2	-1	-2	-2	-5	-2	1
-3	0	-1	-2	-5	-2	1
-3	0	-1	-2	-4	-2	0

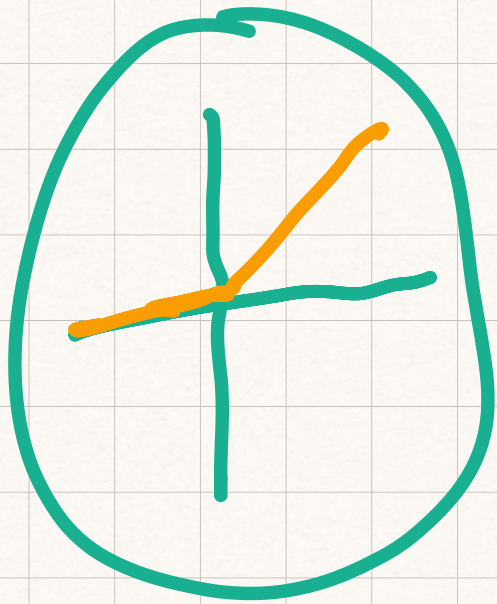
$wx + b$

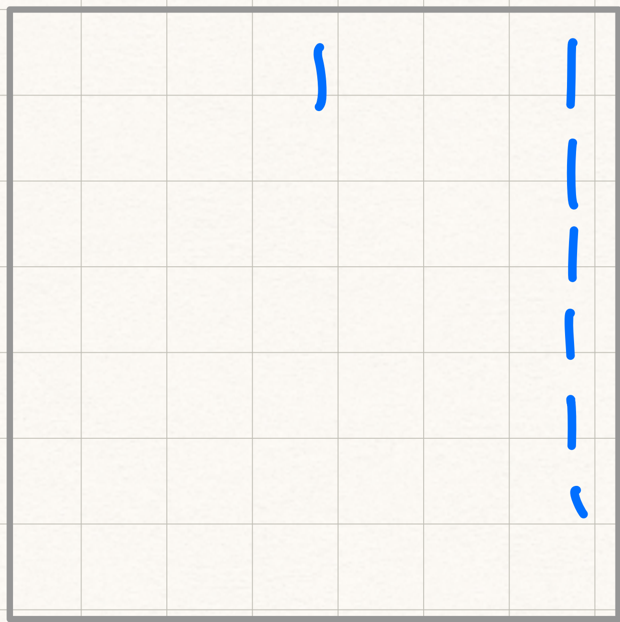
→

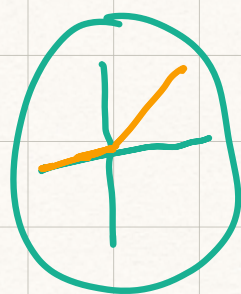


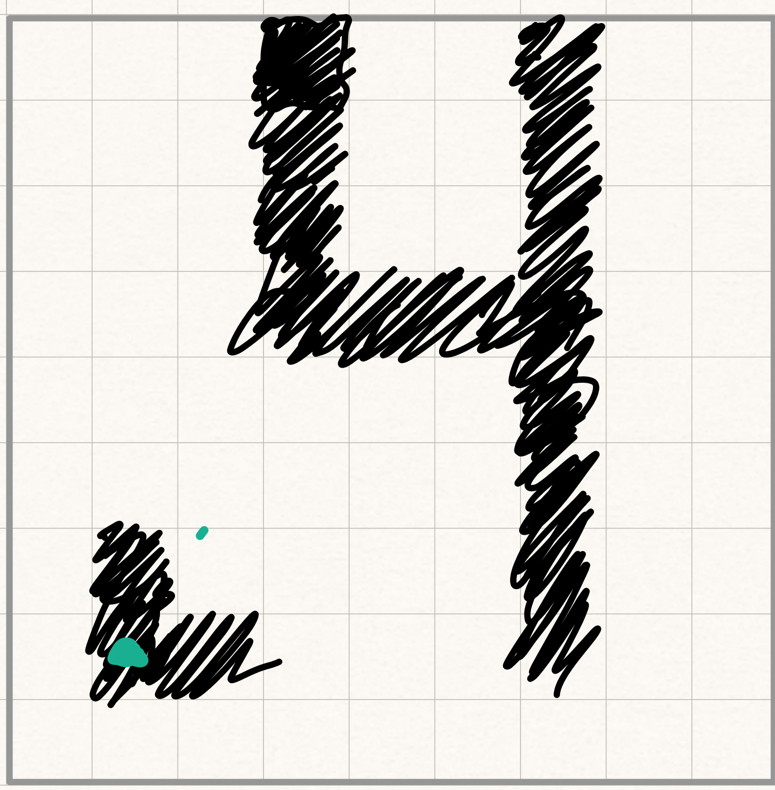
-2	-5	-2	1	-5	-2	1
-2	-5	-3	0	-4	-2	1
-2	-5	-3	-1	4	-1	1
-2	-3	-3	-2	-5	-1	1
-2	-1	-2	-2	-5	-2	1
-3	0	-1	-2	-5	-2	1
-3	0	-1	-2	-4	-2	0

$wx+b$





$wx+b \rightarrow$ 



Horizontal Edges

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

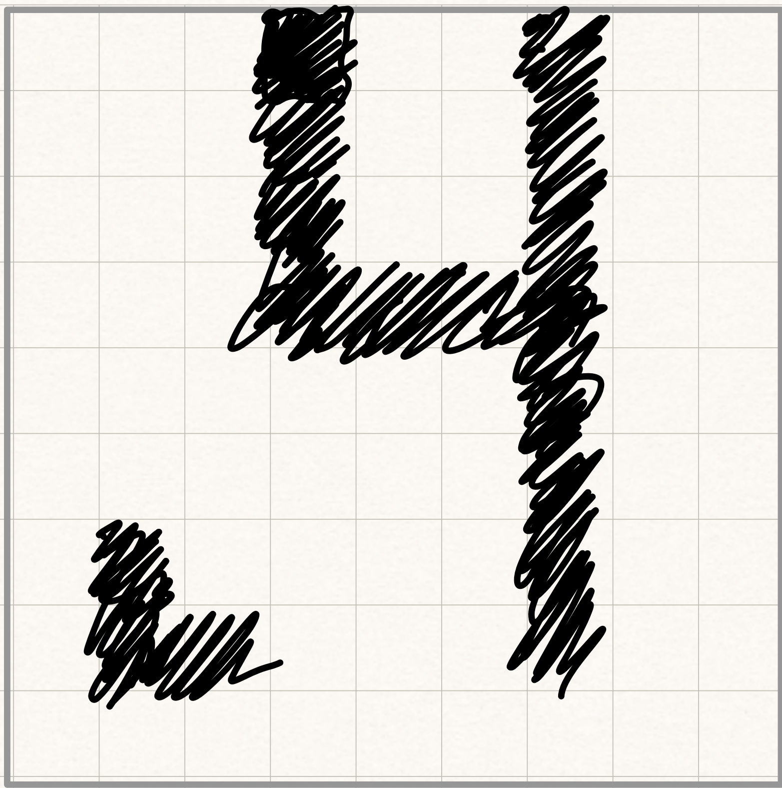
■ = 1

□ = 0

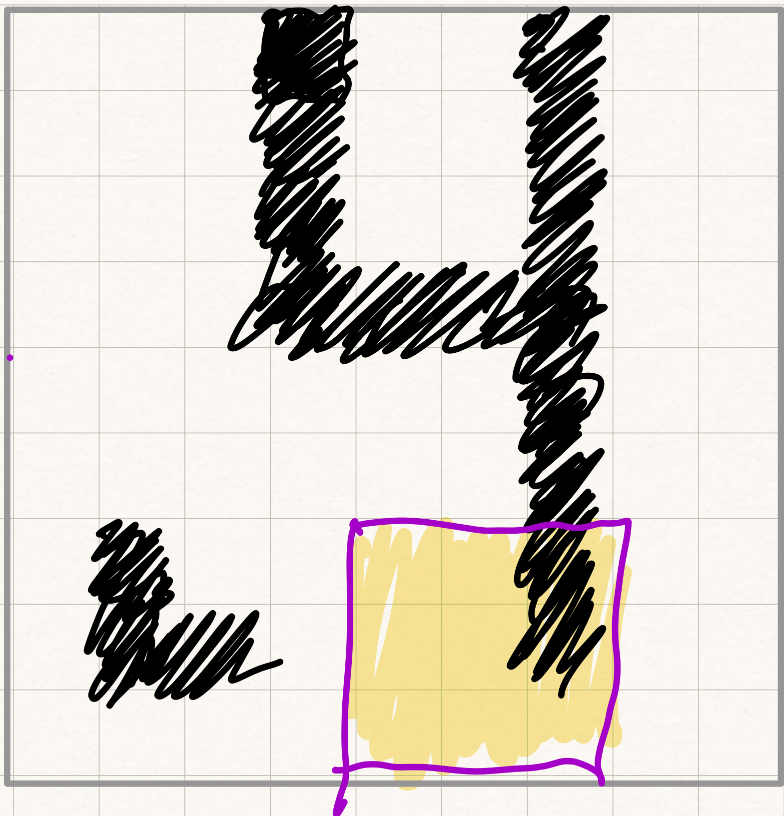
$$X \times W = ?$$

$$W = \begin{matrix} w_1 & w_2 & w_3 \\ w_4 & w_5 & w_6 \\ w_7 & w_8 & w_9 \end{matrix} = \begin{matrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{matrix}$$

3x3 filter



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



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

$$\begin{matrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & -1 & -1 & -1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 2 & 3 & 2 & 1 & 0 \\ -1 & -1 & 0 & 0 & 0 & 0 & 0 \\ -2 & -2 & -1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 1 & 1 \end{matrix}$$

So we have

$$Wx$$

What's next?

$$p = wx + b$$

$$z = f(p) = \mathrm{relu}(p)$$

$b_1 = -1$

$b_2 = -2$

$wx - b$

wx

$$P_1 = \begin{bmatrix} 0 & -3 & 0 & 3 & -3 & 0 & 3 \\ 0 & -3 & -1 & 2 & -2 & 0 & 3 \\ 0 & -2 & -1 & 1 & -2 & 1 & 3 \\ 0 & -1 & -1 & 0 & -2 & 1 & 3 \\ 0 & 1 & 0 & 0 & -3 & 0 & 3 \\ -1 & 2 & 1 & 0 & -3 & 0 & 3 \\ -1 & 2 & 1 & 0 & -2 & 0 & 2 \end{bmatrix}$$

$-1 \quad -4 \quad -1 \ \ldots$

$-1 \ \ldots -$

$-1 \ \ldots -$

$-1 \ \ldots$

$-1 \ \ldots$

$-2 - \ldots -$

$-2 - \ldots -$

$$P_1 = \begin{bmatrix} -1 & -4 & -1 & 2 & -4 & -1 & 2 \\ -1 & -4 & -2 & 1 & -3 & -1 & 2 \\ -1 & -3 & -2 & 0 & -1 & 0 & 2 \\ -1 & -2 & -2 & -1 & -3 & 0 & 2 \\ -1 & 0 & -1 & -1 & -4 & -1 & 2 \\ -3 & 1 & 0 & -1 & -4 & -1 & 2 \\ -2 & 1 & 0 & -1 & -3 & -1 & 1 \end{bmatrix}$$

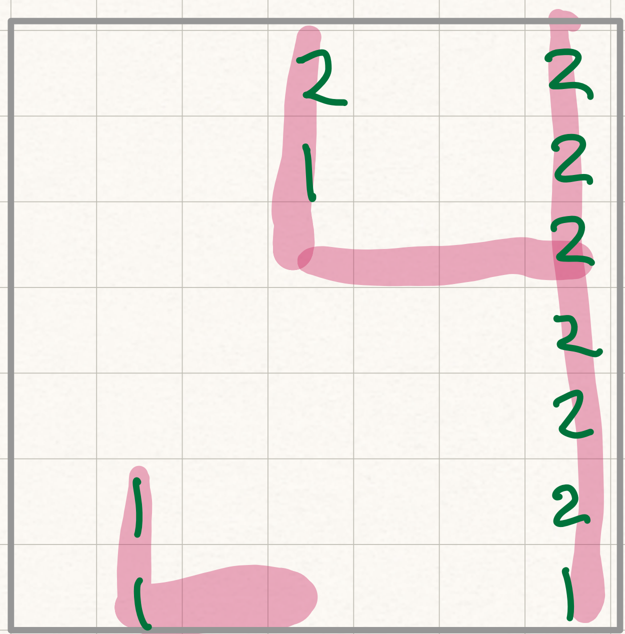
relu

$f(x) \begin{cases} x>0 \to x \\ x \le 0 \quad 0 \end{cases}$

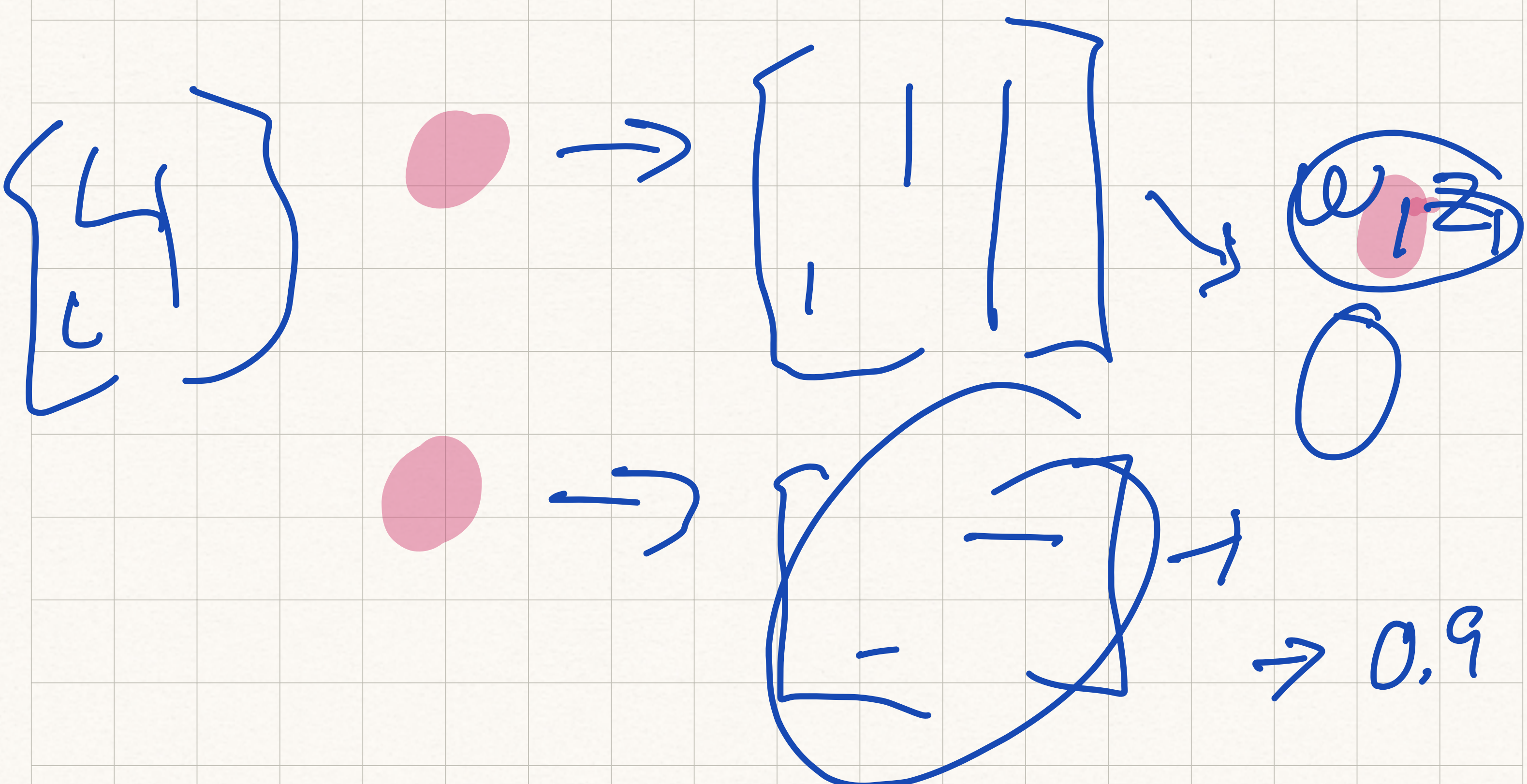
sigmoid

$Z_1 = f(p_1)$ $\quad$ $f = \text{relu}$

$Z_1 =$



$\square = 0$



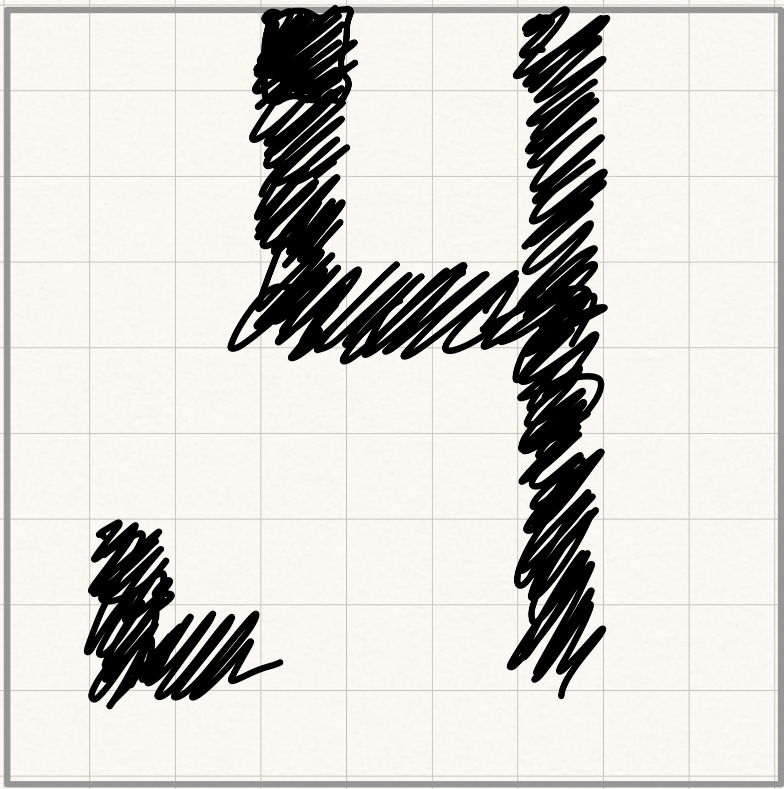
If you like
you can calculate

Zz

Clean

Pages to follow

4



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