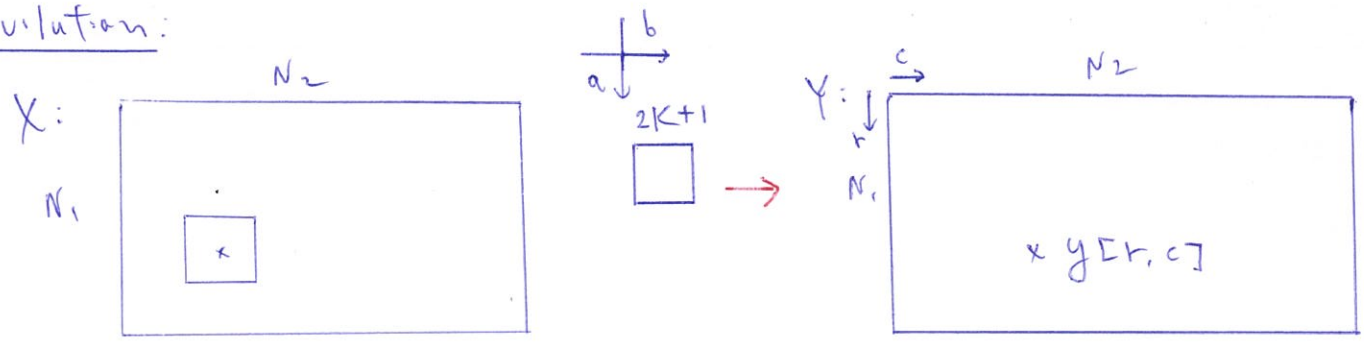
Convolution:

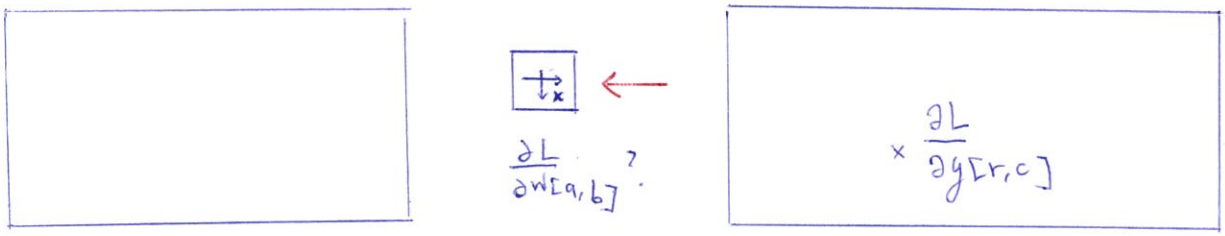


Forward:

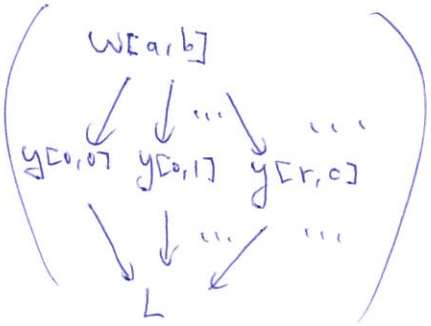
$$y[r,c] = \sum_{b=-k}^{k} \sum_{a=-k}^{k} X[r+a, c+b]\, w[a,b] \qquad (1)$$

(r, c): anchor

Backward:



$$\frac{\partial L}{\partial w[a,b]} = \sum_{c=0}^{N_2-1} \sum_{r=0}^{N_1-1} \frac{\partial L}{\partial y[r,c]} \frac{\partial y[r,c]}{\partial w[a,b]}$$



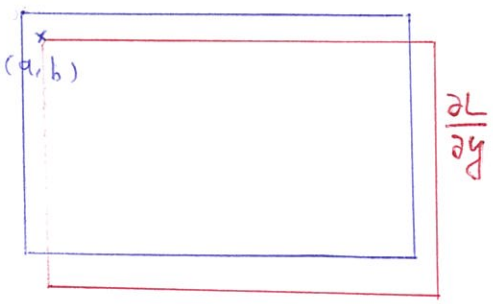
$$= \sum_{c=0}^{N_2-1} \sum_{r=0}^{N_1-1} \frac{\partial L}{\partial y[r,c]} X[r+a, c+b]$$

(from (1))

$$= \sum_{c=0}^{N_2-1} \sum_{r=0}^{N_1-1} X[a+r, b+c] \frac{\partial L}{\partial y[r,c]}$$

(a, b): anchor

X:



$\rightarrow \frac{\partial L}{\partial w[a,b]}$

Convolution of X by $\frac{\partial L}{\partial y}$ as filter mask

$\rightarrow \frac{\partial L}{\partial w}$

Note: ① X should be padded → Valid

② only need: $-k \le a \le k$, $-k \le b \le k$