==========

$$Y(N,C_2,H_2,W_2) := Conv2d\Big[X(N,C_1,H_1,W_1)\Big]$$

$$= \bigwedge_{c_2 \in C_2} \Big[ \sum_{c_1 \in C_1} \overbrace{\omega(c_2,c_1,K,K)}^{\text{weights}} * \overbrace{X(N,c_1,H_1,W_1)}^{data/features} + \overbrace{b(N,c_2,H_2,W_2)}^{bias} \Big]$$

$$= \bigwedge_{c_2 \in C_2} \Big[ \sum_{c_1 \in C_1} \omega_{c_2 c_1} * X_{c_1} + b_{c_2} \Big]$$

$$H_2 = \left\lfloor \frac{H_1 + 2p - d(K-1) - 1}{s} + 1 \right\rfloor$$
$$W_2 = \left\lfloor \frac{W_2 + 2p - d(K-1) - 1}{s} + 1 \right\rfloor$$

- N = batch size (GPU parallel computation)
- C = channels / num of filters / RGB(3)
- H = height (row indexs)
- W = width (column indexs)
- p = padding = 0
- d = dilation = 1
- s = stride = 1

==========

$$\omega(c_2,c_1,K,K) * X(N,c_1,H_1,W_1) = \bigwedge_{i_1 \in \hat{H_1}} \bigwedge_{j_1 \in \hat{W_1}} \Big[ \sum_{i' \in [i_1 \pm \frac{K-1}{2}]} \sum_{j' \in [j_1 \pm \frac{K-1}{2}]} \omega(c_2,c_1,i',j') \cdot X(N,c_1,i',j') \Big]$$

so we can have

$$Y(N,c_2,i_2,j_2) = \overset{filters\text{個數}}{\bigwedge_{c_2 \in C_2}} \bigwedge_{i_2 \in H_2} \bigwedge_{j_2 \in W_2} \Big[ \overset{\text{input-channels 加總}}{\sum_{c_1 \in C_1}} \sum_{i' \in [i_1(i_2) \pm \frac{K-1}{2}]} \sum_{j' \in [j_1(j_2) \pm \frac{K-1}{2}]} \omega(c_2,c_1,i',j') \cdot X(N,c_1,i',j') \Big]$$

$$\text{其中}：i_1(i_2) = i_2 + \frac{K-1}{2}, j_1(j_2) = j_2 + \frac{K-1}{2}$$

finally :

$$Y(N,C_2,H_2,W_2)$$
$$= \bigwedge_{c_2 \in C_2} \bigwedge_{i_2 \in H_2} \bigwedge_{j_2 \in W_2} \Big[ \sum_{c_1 \in C_1} \sum_{k \in [0,K-1]} \sum_{k \in [0,K-1]} \omega(c_2,c_1,i_2+k,j_2+k) \cdot X(N,c_1,i_2+k,j_2+k) \Big]$$