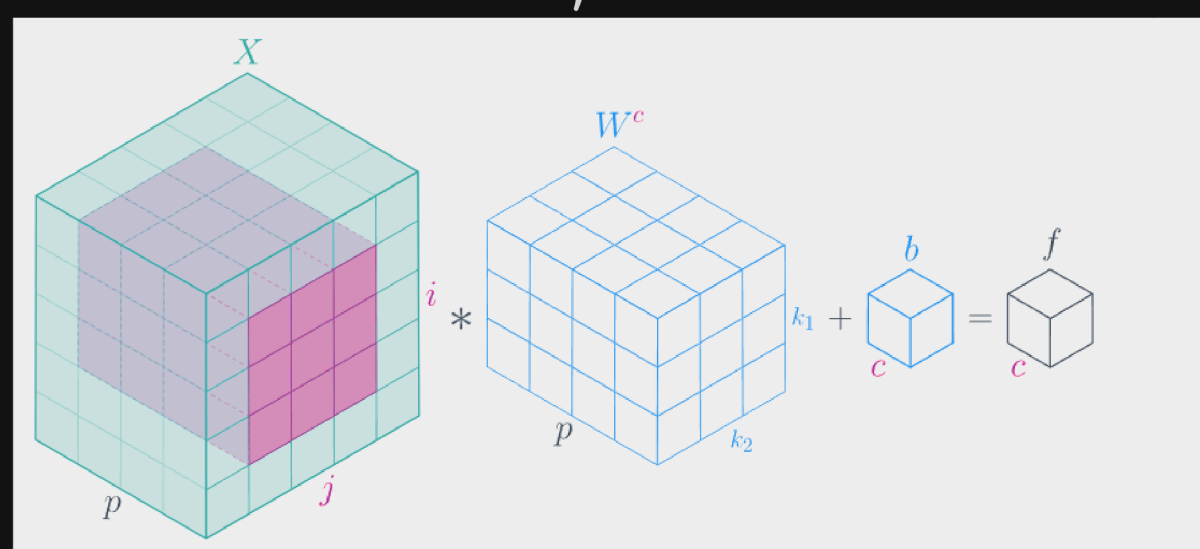


input feature map \downarrow output feature map

k - kernel size, X - $M \times W \times C_{in}$, f - $M \times W \times C_{out}$



b - bias

$$f_{ijc} =$$

$$\sum_{p=1}^{C_{in}} \sum_{k_1=\lfloor \frac{k}{2} \rfloor}^{\lfloor \frac{k}{2} \rfloor} \sum_{k_2=\lfloor \frac{k}{2} \rfloor}^{\lfloor \frac{k}{2} \rfloor} W^c_{\lfloor \frac{k}{2} \rfloor + 1 + k_1, \lfloor \frac{k}{2} \rfloor + 1 + k_2, p} \odot$$

$$\odot X_{i+k_1, j+k_2, p} + b_c$$

Thinking Question.

Suppose we have a tensor of shape $H \times W \times C_{in}$, to which C_{out} convolutional filters are applied simultaneously, each with a window size of $k \times k$.

1. Compute the number of trainable parameters.
2. How does the formula change if a bias is added to each convolution?
3. By how much does the number of parameters change if the window size is doubled?
4. What if the number of input and output channels (C_{in} and C_{out}) is doubled?
5. What if the input tensor's height and width are doubled?

$$1. k \cdot k \cdot C_{in} \cdot C_{out}$$

$$2. k \cdot k \cdot C_{in} \cdot C_{out} + C_{out}$$

$$3. \text{By } 4$$

$$4. \text{Increase by } 1$$

$$5. \text{Count of parameters won't change}$$

Thinking Question.

Estimate the number of multiply-add operations for the previous exercise.

How does it change if you double the window size?

The number of channels?

The input tensor size?

$$1. O(M W C_{out} \cdot C_{in} \cdot k^2)$$

slide

$$2. \text{Increase by } 4 \text{ (but } C_{out} \text{ decrease if don't change padding)}$$

$$3. \text{Increase by } 4 \text{ (} C_{in} \rightarrow 2C_{in}, C_{out} \rightarrow 2C_{out} \text{)}$$

$$4. \text{by } 4 \times 100 \text{ (} W \rightarrow 2W, M \rightarrow 2M \text{)}$$

Thinking Question.

Suppose N convolutional layers with $k \times k$ kernels are applied sequentially.

Compute the receptive field size of the last layer.

let a is side of receptive field

$$a_1 = k$$

$$a_2 = a_1 + (k-1) = 2k-1$$

$$a_3 = a_2 + (k-1) = 3k-2$$

$$a_N = N \cdot (k-1) + 1$$