

# Convolutional Neural Network

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January 2019

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# 1 Introduction

Convolutional neural network (CNN or ConvNet) is a type of neural network used in artificial intelligence that is commonly applied to analyzing images.

They can be considered a pre-processing compared to image classification algorithms. They have applications in image and video recognition, recommender systems, image classification, natural language processing, etc.

# 2 Notation

$f^l$  : filter size.

$p^l$  : padding.

$s^l$  : stride.

$n_H^{l-1} \times n_W^{l-1} \times n_C^{l-1}$ : input.

$n_H^l \times n_W^l \times n_C^l$ : output.

$n^l = \left\lfloor \frac{n^{l-1} + 2p^l - f^l}{s^l} + 1 \right\rfloor$ .

$f^l \times f^l \times n_c^l$  : filter.

$a^l$  : activation function.

$n_c^l$  : bias.

# 3 Layers

0	0	0	0	0	0	0
0	1	1	0	0	0	0
0	1	1	1	0	1	0
0	1	0	0	1	1	0
0	1	0	1	0	1	0
0	0	1	1	1	1	0
0	0	0	0	0	0	0

Figure 1: Matrix example:  $p = 1$ ,  $n_H = 5$ ,  $n_W = 5$ ,  $n_C = 1$

### 3.1 Convolutional

The convolution operation is the most representative. The convolutional operation is the Hadamard/Element-wise product.

$$A' = A \circ B$$

We can rewrite our operation using the Hadamard product:

$$A_{ij}^l = \sum_{i=1}^{f^l} \sum_{j=1}^{f^l} A_{ij}^{l-1} B_{ij}^l$$

where  $B$  is the matrix output and  $A$  is a subset of the input matrix which first element is  $ij$  and the same size of  $B$ , the filter.

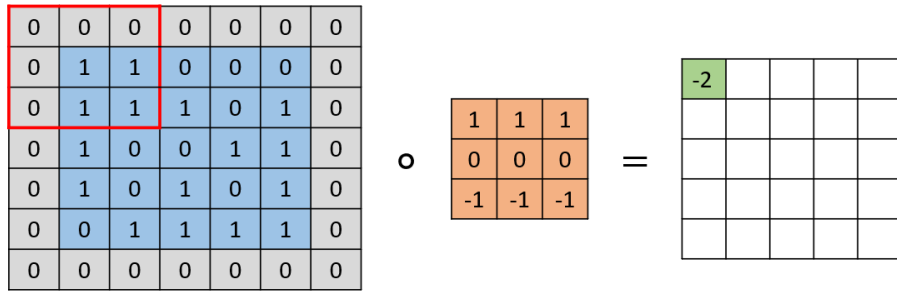


Figure 2:  $A \circ B = C$

### 3.2 Pooling

Pooling layer combines the output of neuron clusters at one single neuron, it is used to reduce the size of the image. Pooling layer needs two hyper-parameter: stride and filter size. There are two kind of pooling layers: *max pooling* and *average pooling*.

#### Max pooling

Outputs the highest value of the cluster.

#### Average pooling

Outputs the average of the cluster.

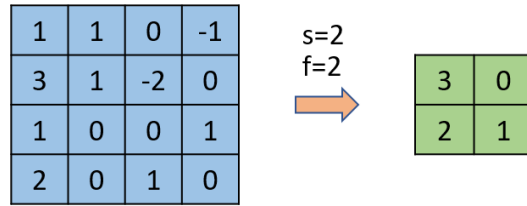


Figure 3:  $Pool(A) \rightarrow C$ , using stride=2 and  $2 \times 2$  filters

### 3.3 ReLU

ReLU is the abbreviation of rectified linear unit.  $f(x) = \max(0, x)$ . It removes the negative values.

### 3.4 Residual

This neural network is based on the cerebral cortex. Its characteristic feature is that it jumps over some layers.

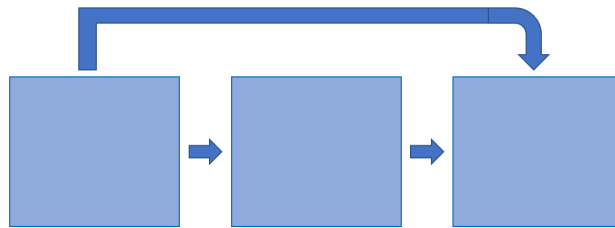


Figure 4: Residual layer with step 2

### 3.5 Fully connected

Fully connected layers connect every neuron in one layer to every neuron in another layer. It is in principle the same as the traditional multilayer perceptron neural network (MLP).