Applied Machine Learning with Big Data "EE 6973"

Topic:
Convolution Neural Networks

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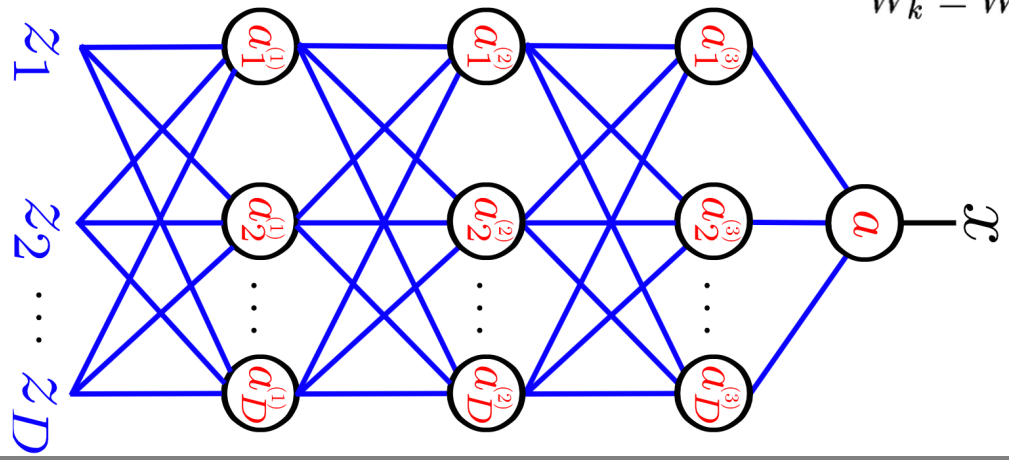
Stochastic Gradient Descent (SGD)

Loop:

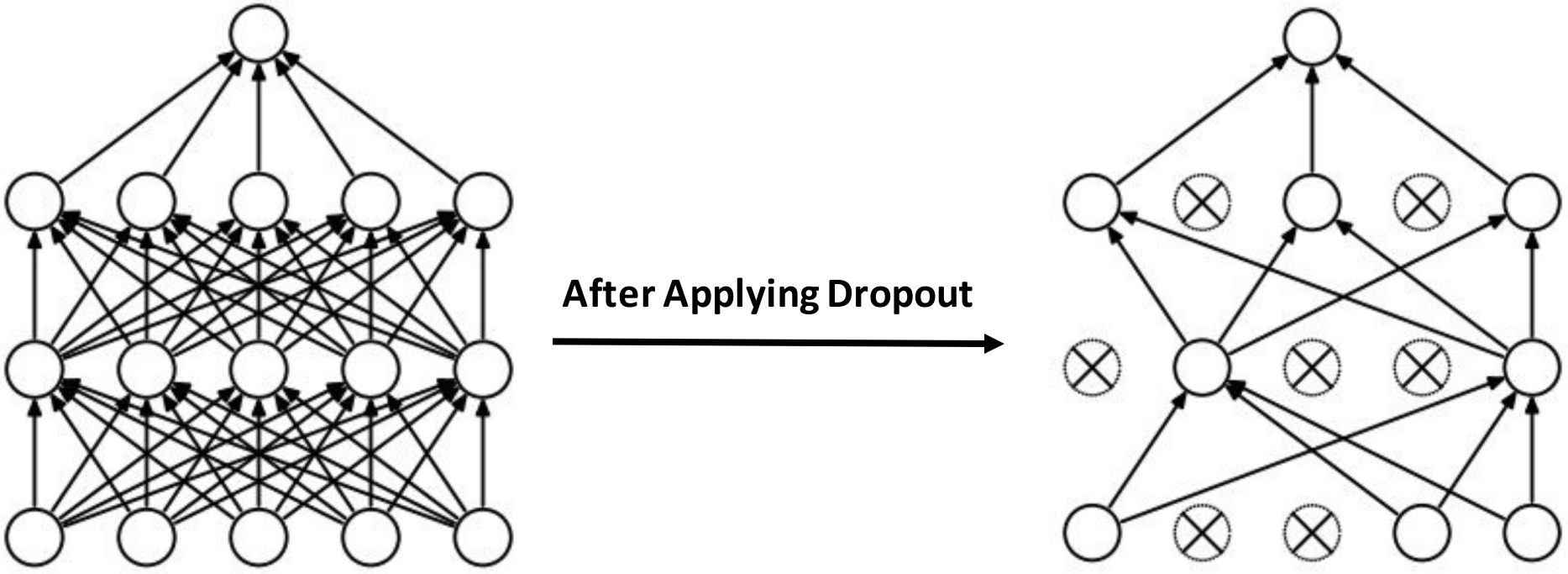
1. **Sample a batch of data with their labels**
2. **Forward Propagate it through the graph, calculate the error**
3. **Backpropagate to calculate the gradients**
4. **Update the parameters (weights) using the gradient**

$$W_k = W_{k-1} - \epsilon \frac{\partial E(W)}{\partial W}$$



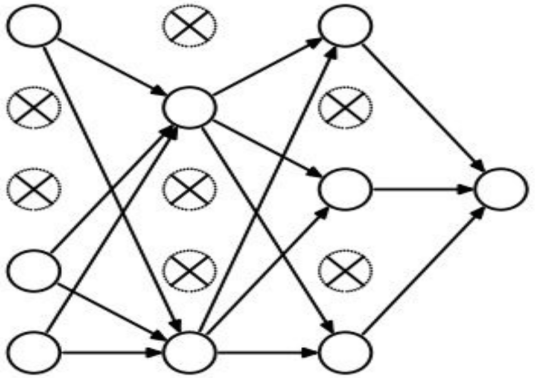
Dropout

Randomly set some neurons to zero in the forward pass

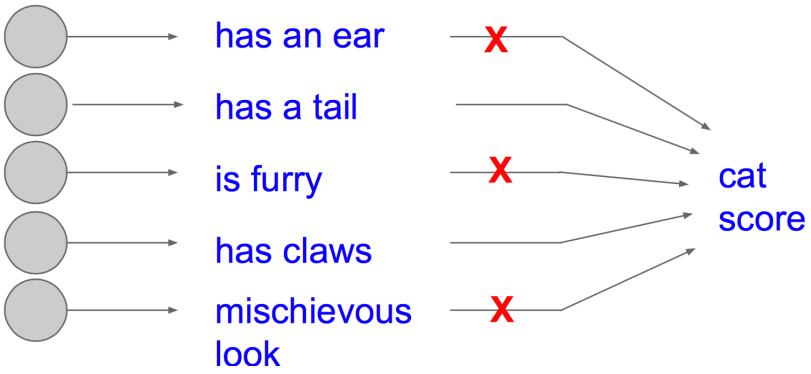


Srivastava et al., 2014, https://www.cs.toronto.edu/~hinton/absps/JMLRdropout.pdf

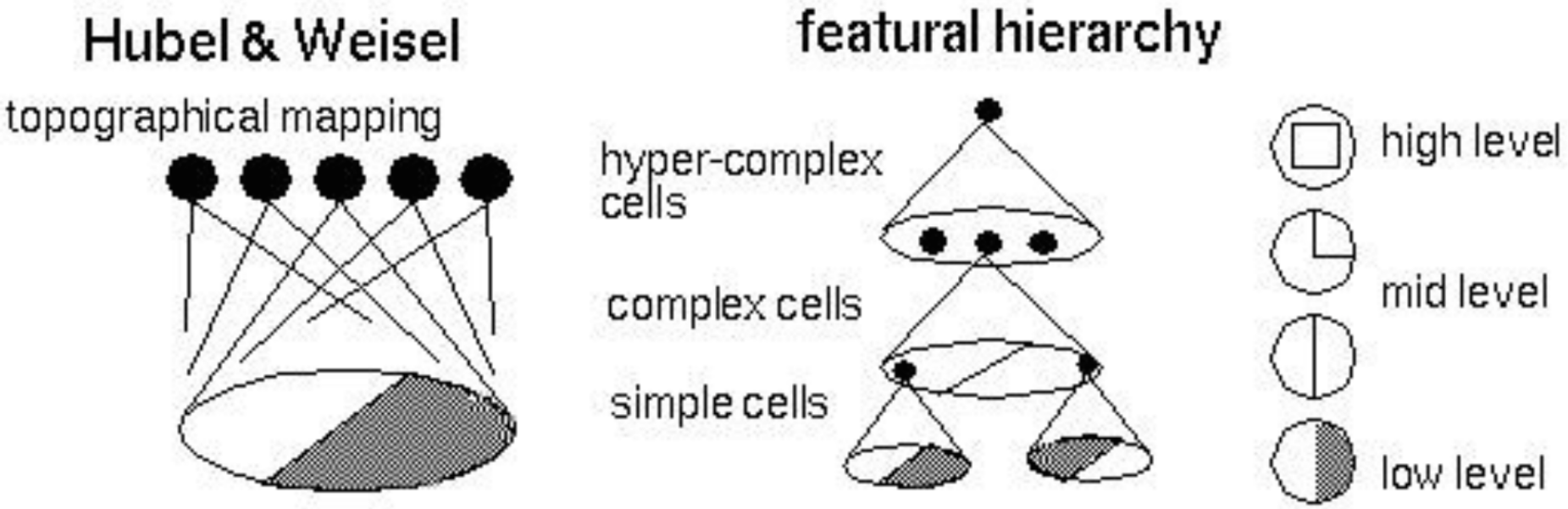
Dropout



Forces the network to have a redundant representation

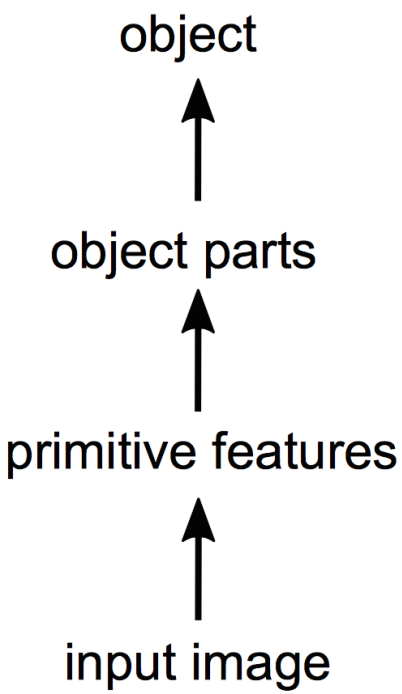


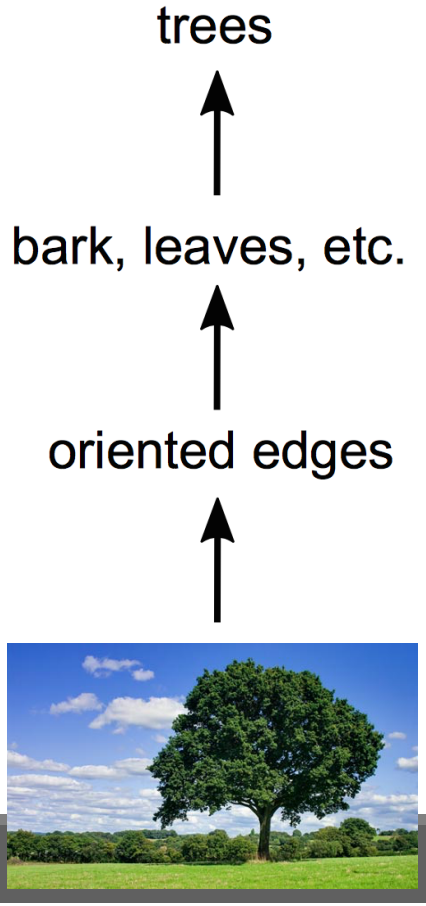
Vision: Hierarchical Organization (Year: 1962)

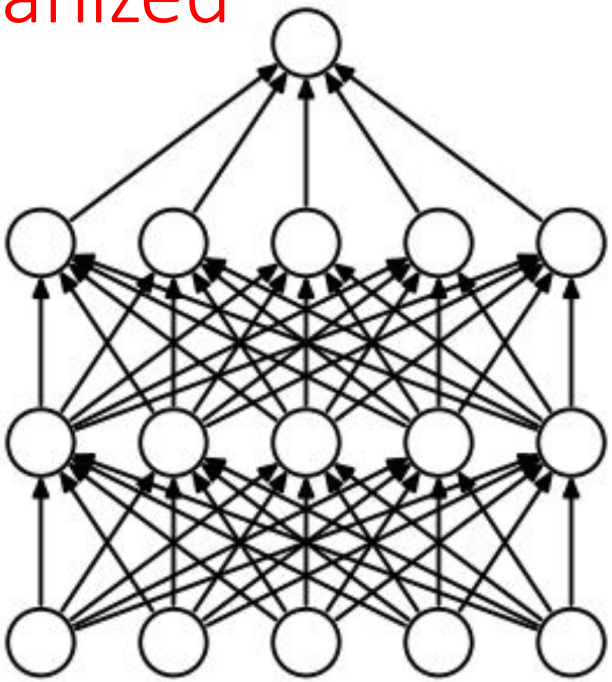


Why use hierarchical multi-layered models?

Biological vision is hierarchically organized







What's wrong with standard neural networks?

Hard to Train

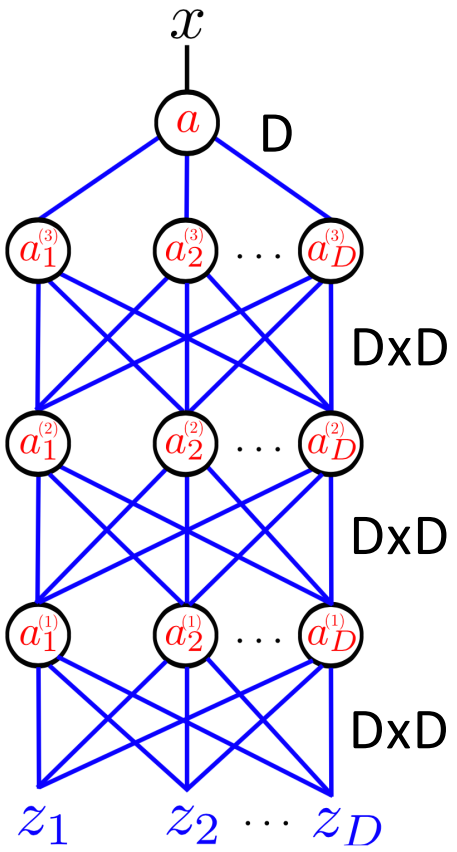
How many parameters does this network have?

Number of Parameters = 3 x (DxD) + D

For a small D = 32 x 32 = 1024 MNIST image:

Number of Parameters = 3 x (1024x1024) + 1024

~ 3×10^6



Architecture of LeNet-5, Convolution Neural Network

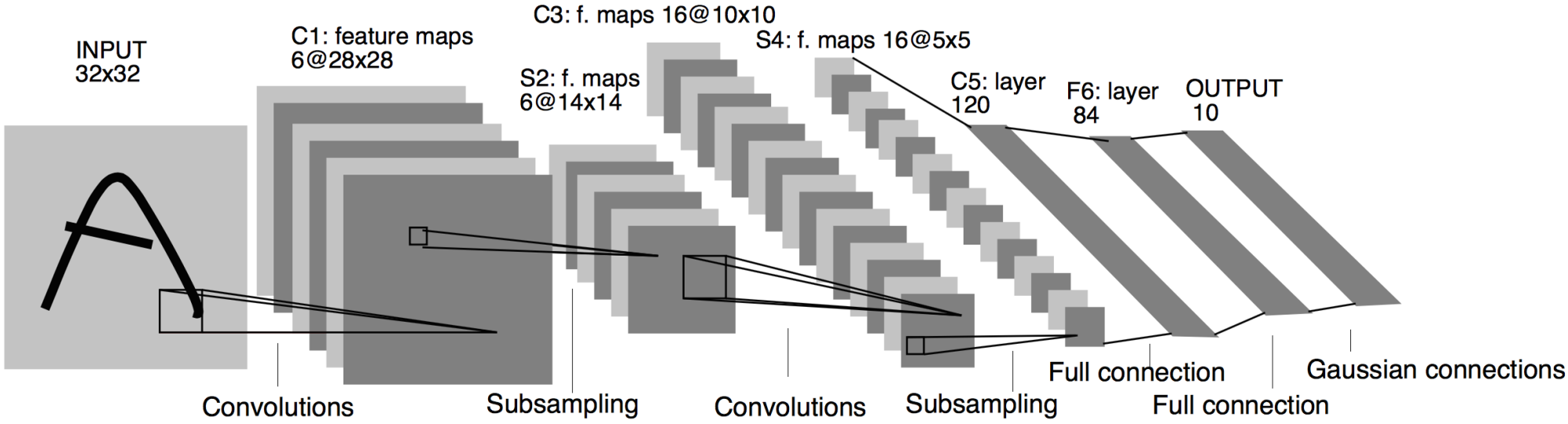
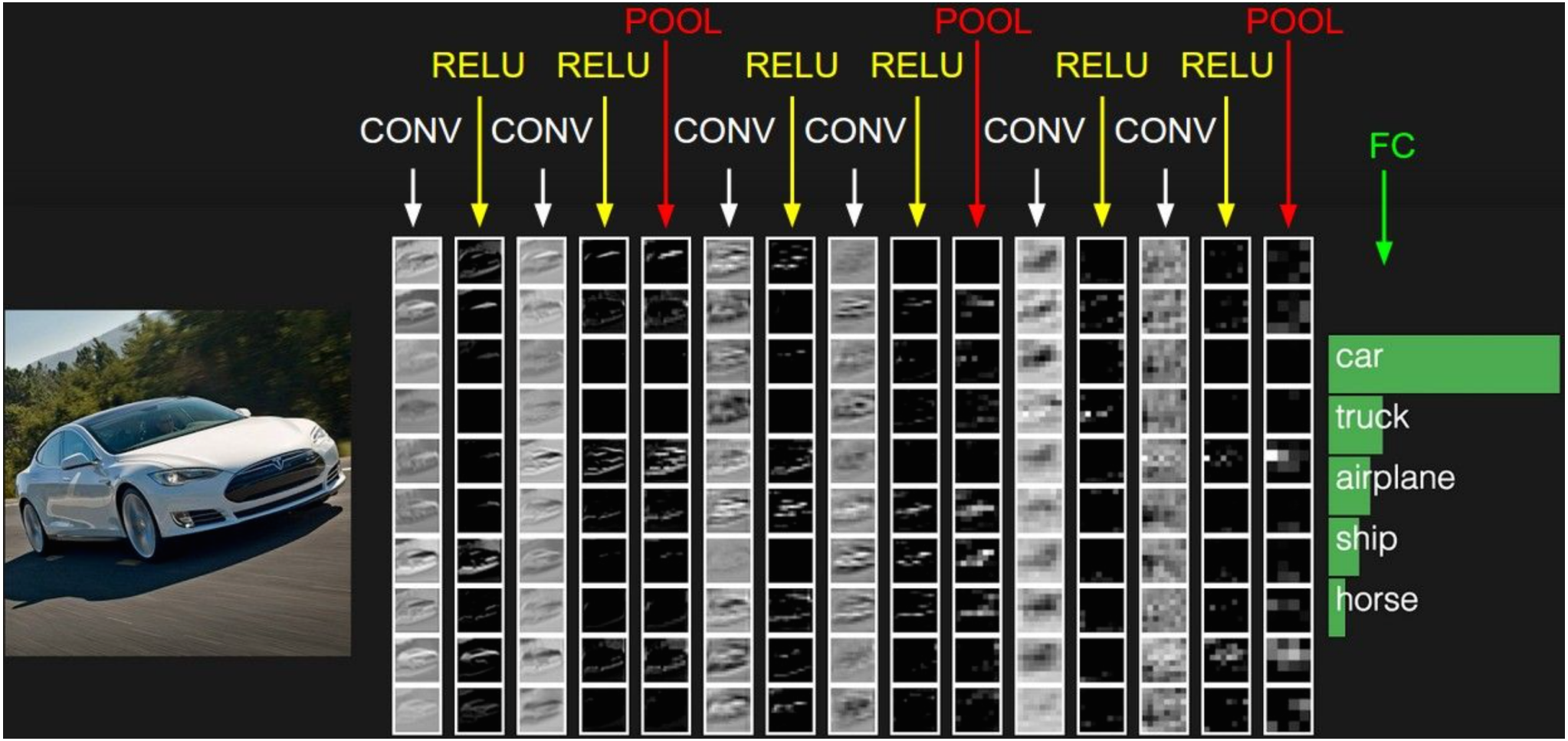


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

Proc. Of the IEEE, November 1998, "Gradient-Based Learning Applied to Document Recognition"


POOL
POOL
POOL
RELU
RELU
RELU
RELU
RELU
RELU
CONV
CONV
CONV
CONV
CONV
CONV
FC
car
truck
airplane
ship
horse

Review: What is convolution?

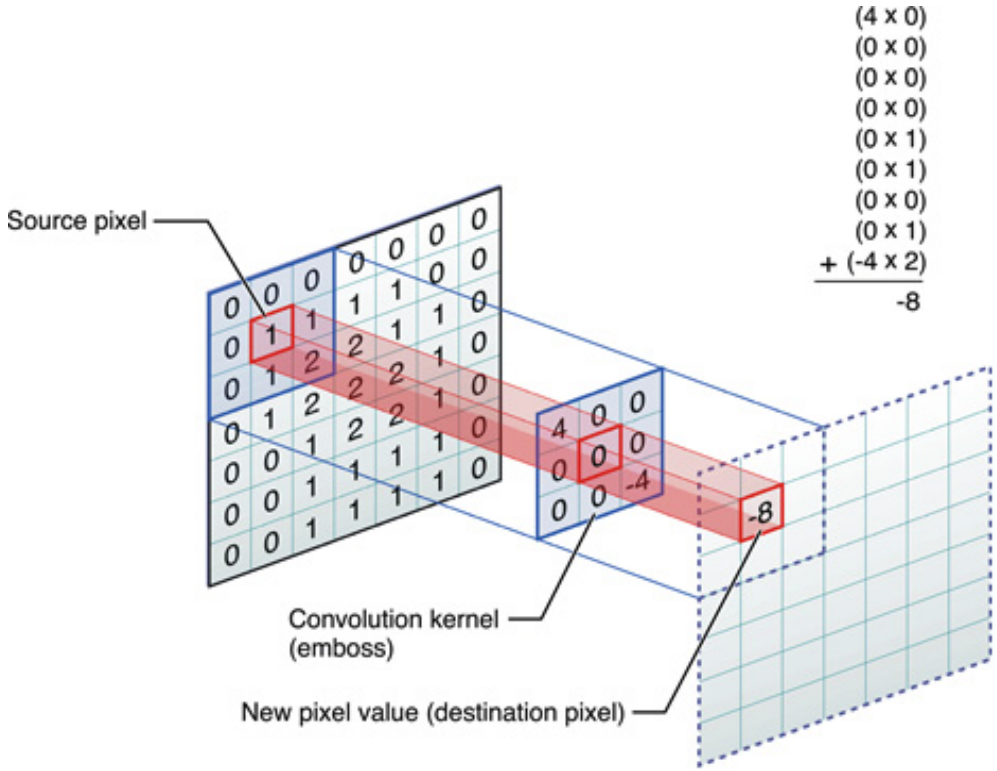
- Convolution is an important operation from signal processing
- A convolution is an integral that expresses the amount of overlap of one function as it is shifted over another function .

$$f * g = \int_{-\infty}^{\infty} f(\tau)\, g(t-\tau)\, d\tau = \int_{-\infty}^{\infty} g(\tau)\, f(t-\tau)\, d\tau$$

- 2 Dimensional Discrete Function (Image)

$$f[x,y] * g[x,y] = \sum_{n_1=-\infty}^{\infty} \sum_{n_2=-\infty}^{\infty} f[n_1,n_2] \cdot g[x-n_1, y-n_2]$$

2-Dimensional Convolution



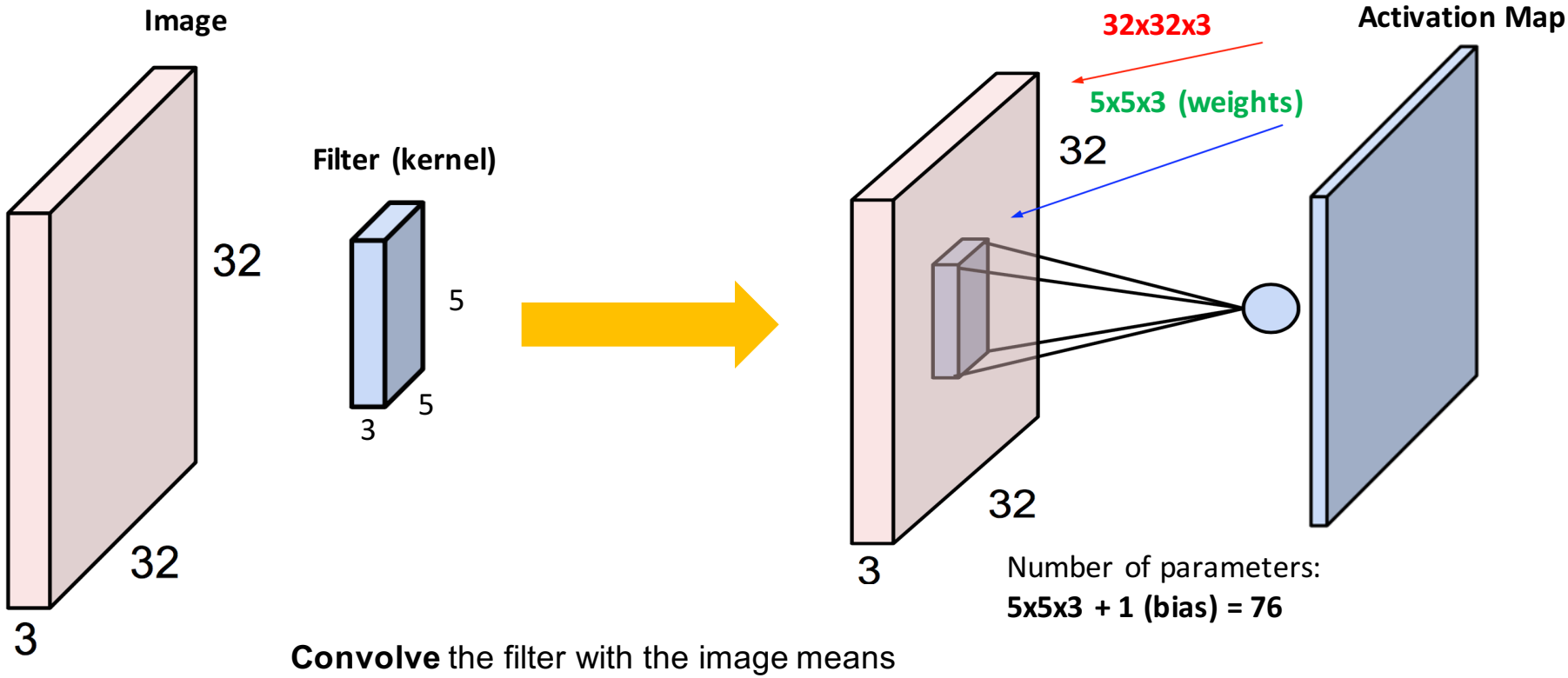
Example: 2-Dimensional Convolution

A convolution is an integral (discrete signals :Matrix Dot Product) that expresses the amount of overlap of one function as it is shifted over another function

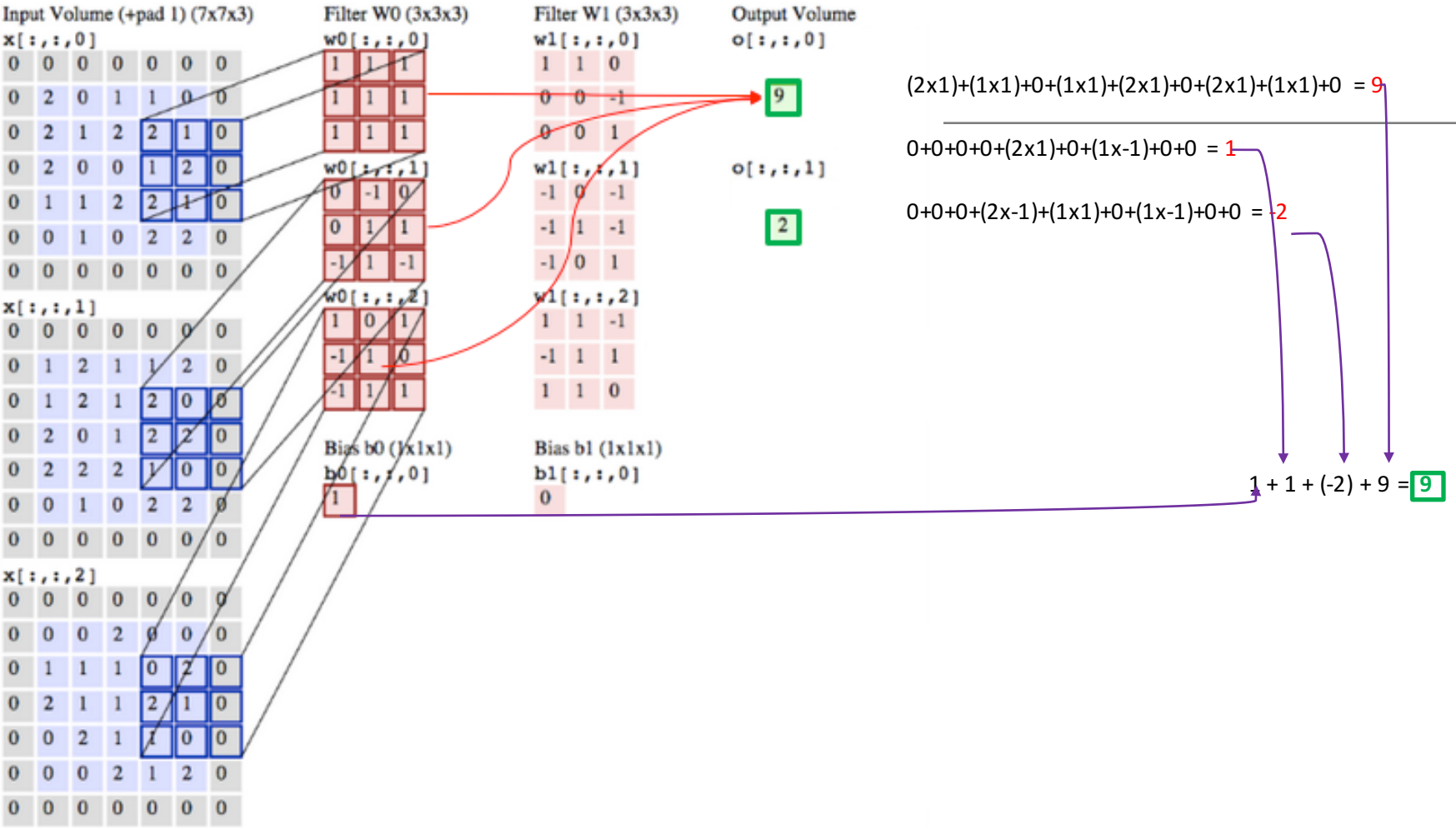
-1	-2	-1
0	0	0
1	2	1

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

Convolution Layer



Convolve the filter with the image means
"slide over the image spatially, compute dot products"


Input Volume (+pad 1) (7x7x3)
x[:,:,0]
0 0 0 0 0 0 0
0 2 0 1 1 0 0
0 2 1 2 2 1 0
0 2 0 0 1 2 0
0 1 1 2 2 1 0
0 0 1 0 2 2 0
0 0 0 0 0 0 0
x[:,:,1]
0 0 0 0 0 0 0
0 1 2 1 1 2 0
0 1 2 1 2 0 0
0 2 0 1 2 2 0
0 2 2 2 1 0 0
0 0 1 0 2 2 0
0 0 0 0 0 0 0
x[:,:,2]
0 0 0 0 0 0 0
0 0 0 2 0 0 0
0 1 1 1 0 2 0
0 2 1 1 2 1 0
0 0 2 1 1 0 0
0 0 0 2 1 2 0
0 0 0 0 0 0 0
Filter W0 (3x3x3)
w0[:,:,0]
1 1 1
1 1 1
1 1 1
w0[:,:,1]
0 -1 0
0 1 1
-1 1 -1
w0[:,:,2]
1 0 1
-1 1 0
-1 1 1
Bias b0 (1x1x1)
b0[:,:,0]
1
Filter W1 (3x3x3)
w1[:,:,0]
1 1 0
0 0 -1
0 0 1
w1[:,:,1]
-1 0 -1
-1 1 -1
-1 0 1
w1[:,:,2]
1 1 -1
-1 1 1
1 1 0
Bias b1 (1x1x1)
b1[:,:,0]
0
Output Volume
o[:,:,0]
9
o[:,:,1]
2
(2x1)+(1x1)+0+(1x1)+(2x1)+0+(2x1)+(1x1)+0 = 9
0+0+0+0+(2x1)+0+(1x-1)+0+0 = 1
0+0+0+(2x-1)+(1x1)+0+(1x-1)+0+0 = -2
1 + 1 + (-2) + 9 = 9

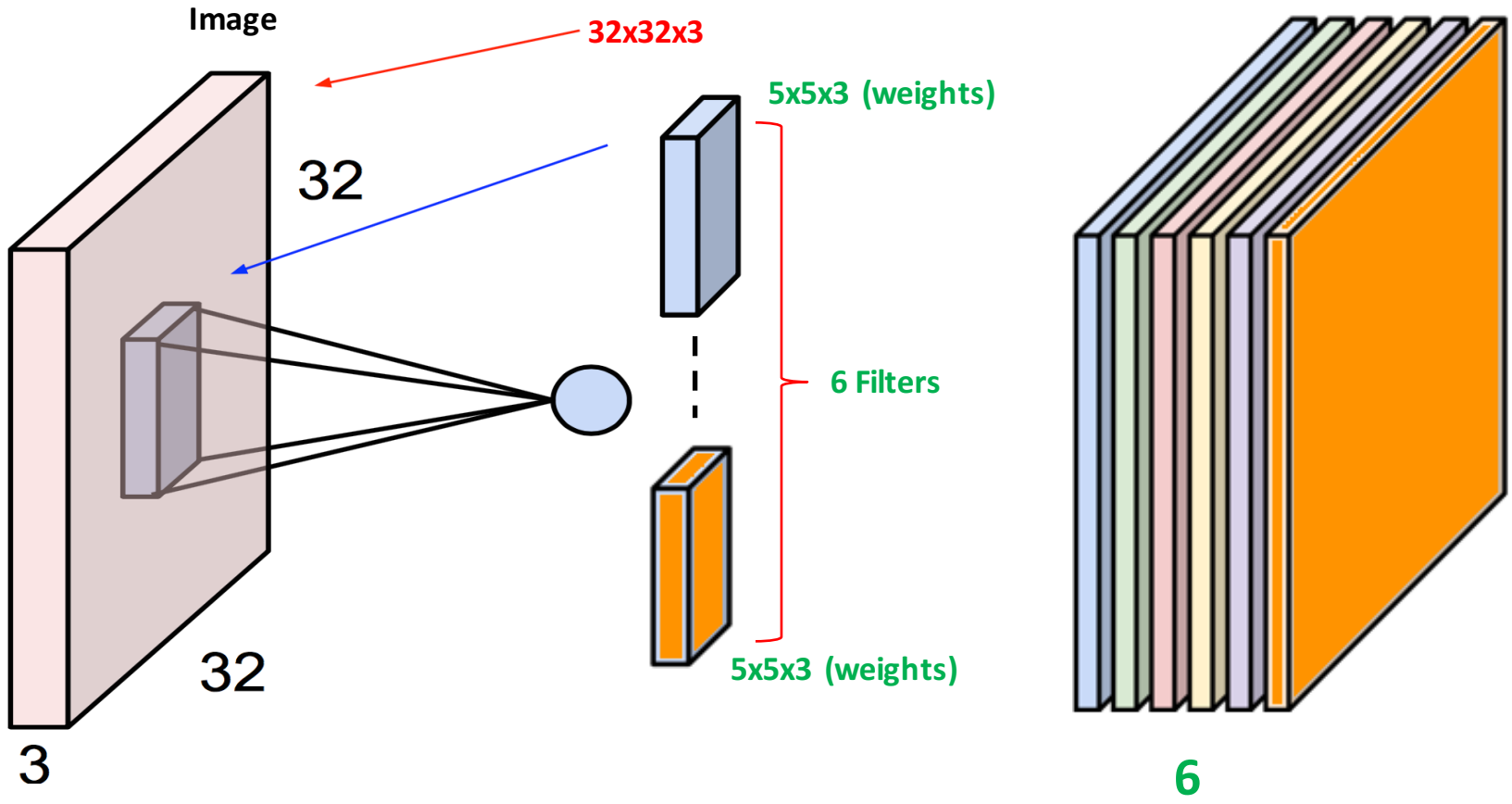
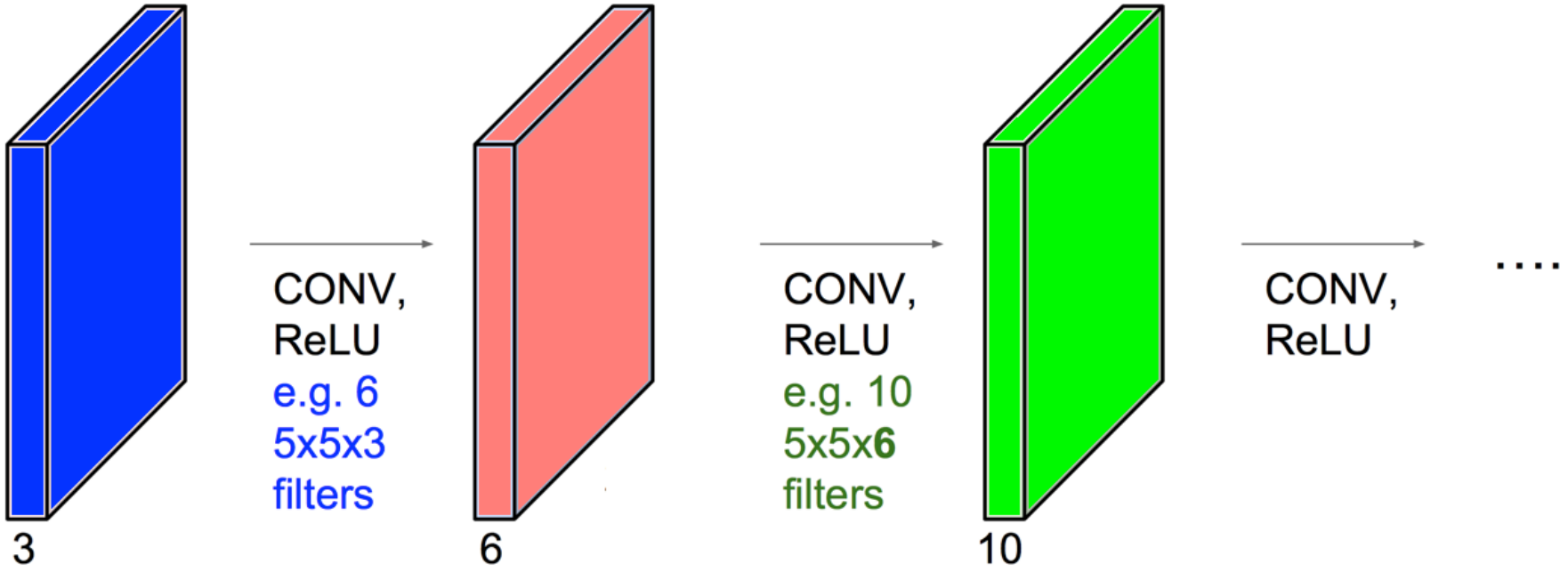
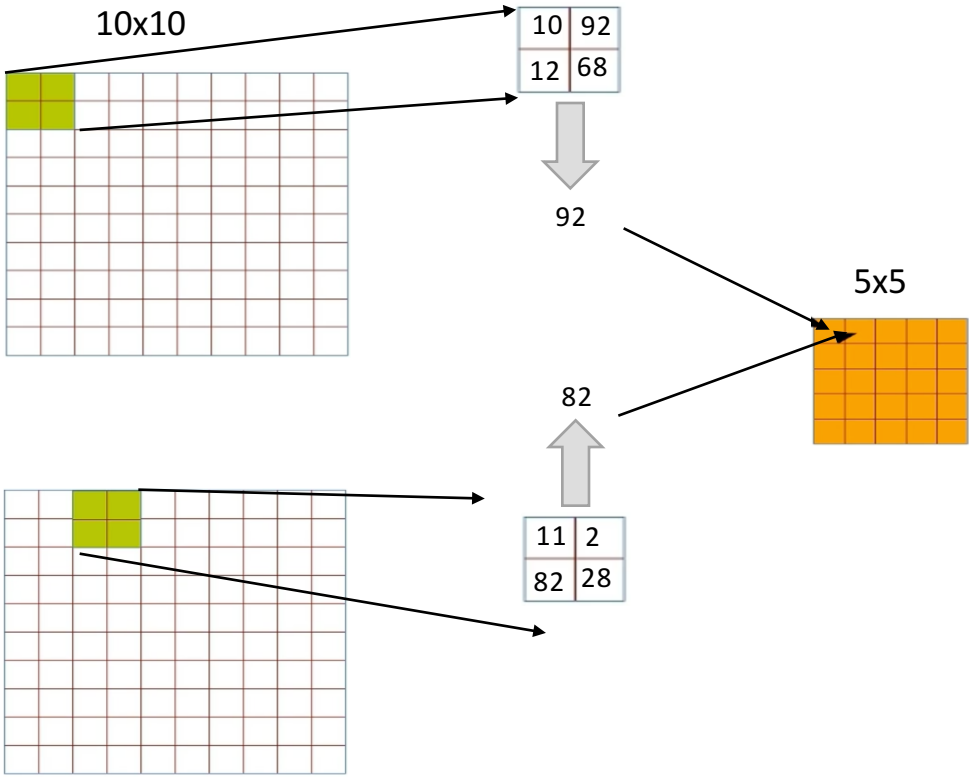


Image
32x32x3
5x5x3 (weights)
32
6 Filters
32
5x5x3 (weights)
3
6

Convolution Network



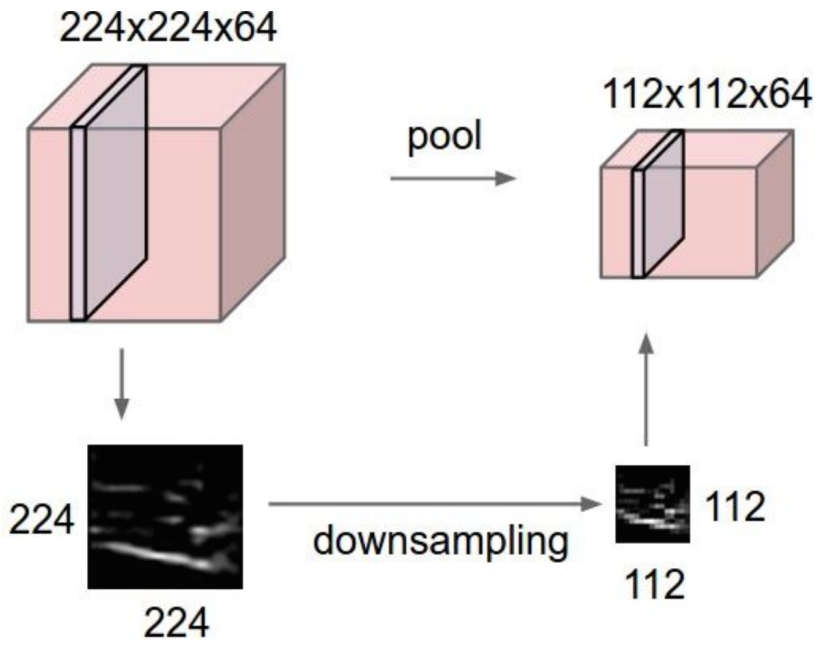
Downsampling = Max Pooling

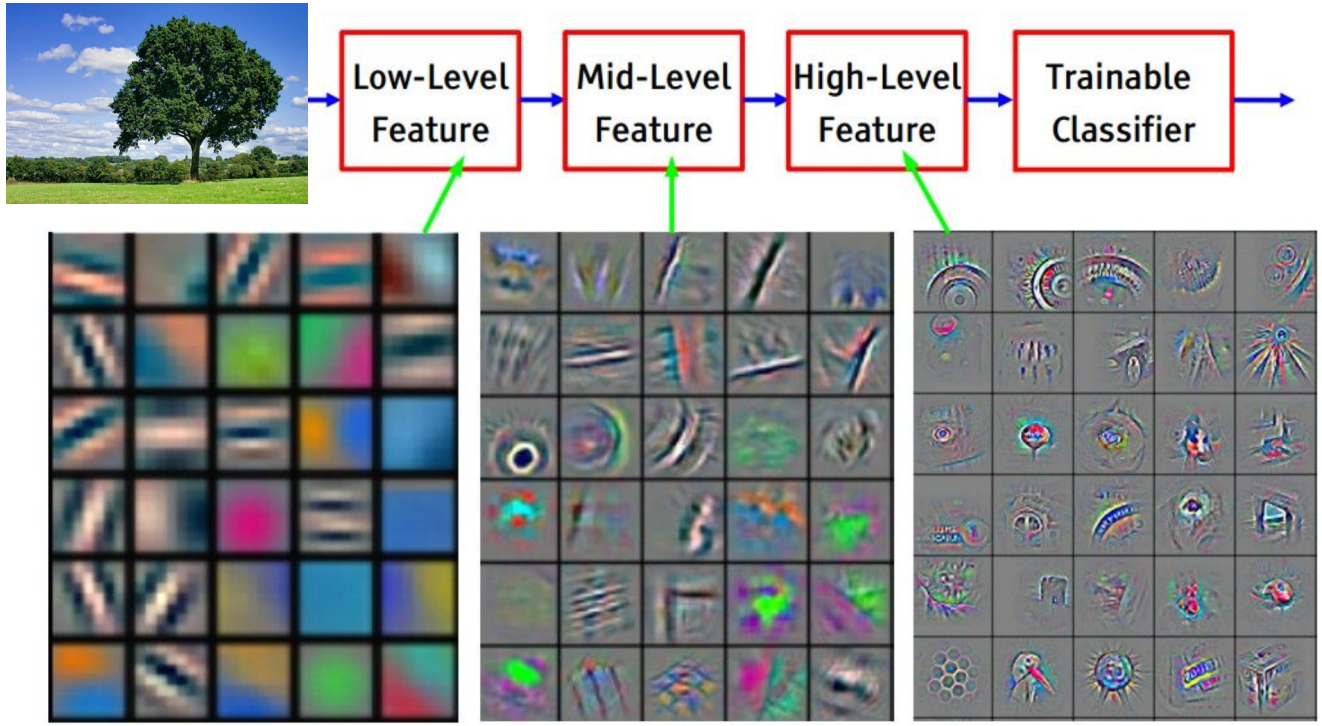


“Max Pooling” Layers to extract the “best” local feature

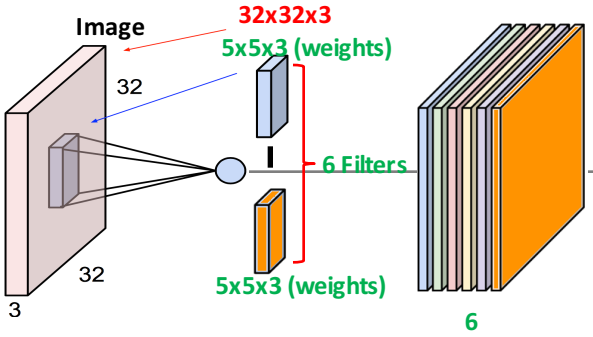
Pooling Layer

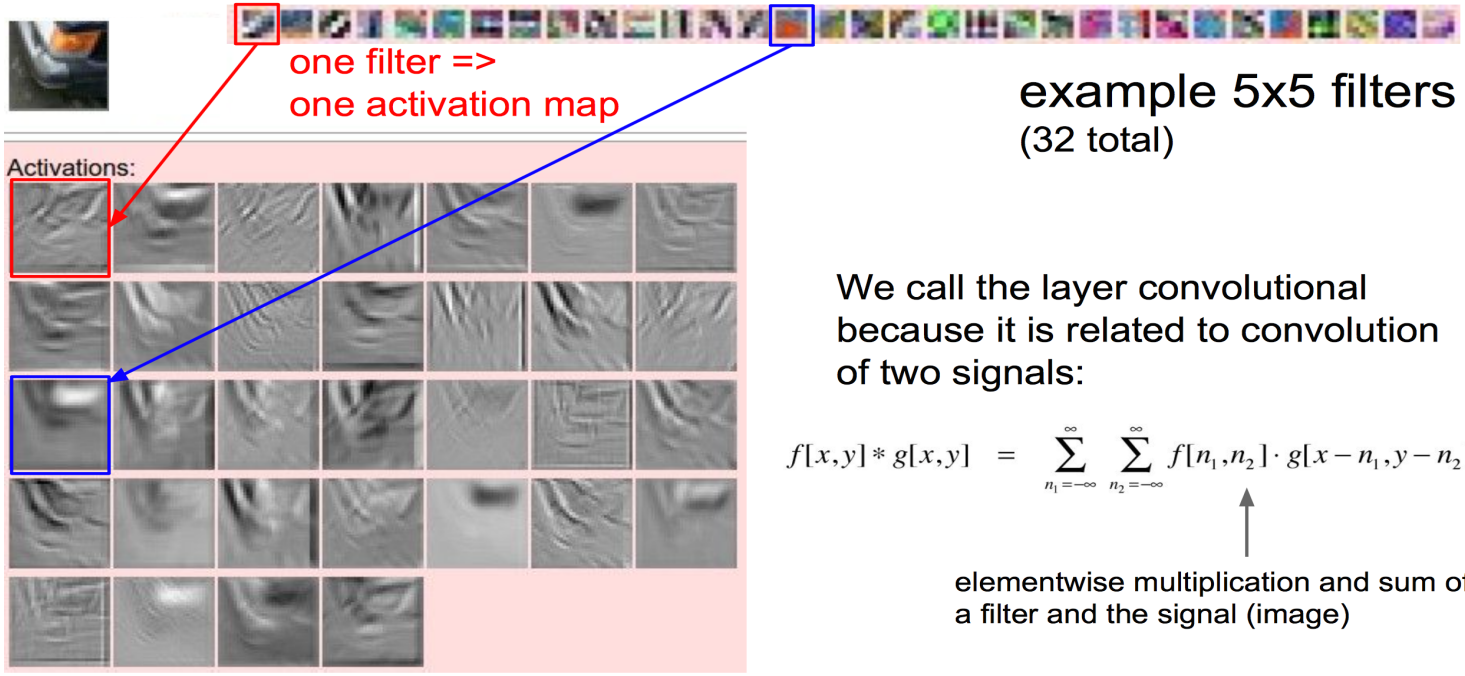
- Makes the representations smaller and more manageable
- Operates over each activation map independently





Feature visualization of convolution net trained on ImageNet from [Zeiler & Fergus 2013]





example 5x5 filters
(32 total)

We call the layer convolutional because it is related to convolution of two signals:

$$f[x,y] * g[x,y] = \sum_{n_1=-\infty}^{\infty} \sum_{n_2=-\infty}^{\infty} f[n_1,n_2] \cdot g[x-n_1, y-n_2]$$

elementwise multiplication and sum of a filter and the signal (image)