UNIVERSITY OF LIVERPOOL

COMP 532
Machine Learning and BioInspired Optimization

Lecture 12: Deep Learning

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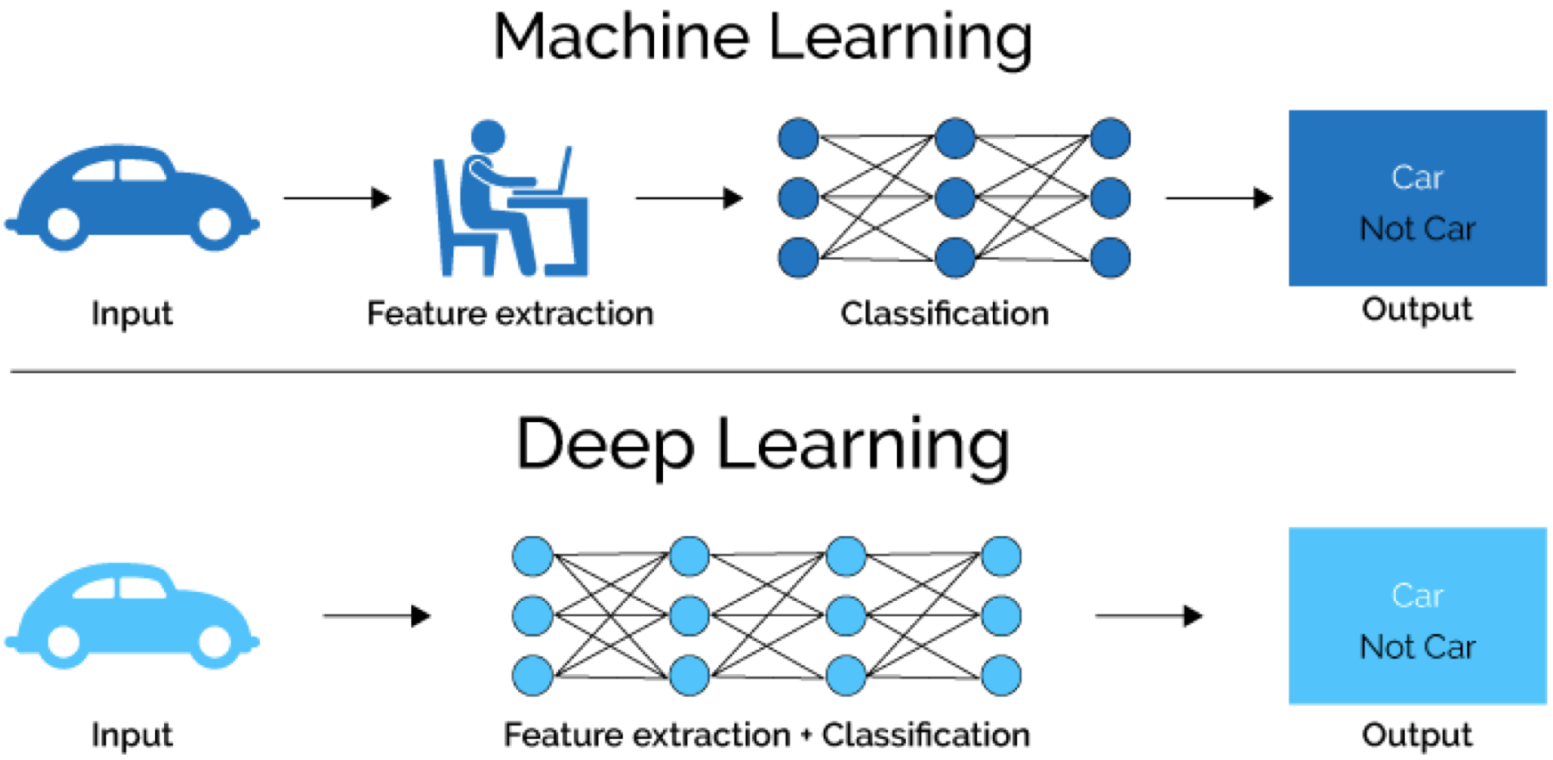
Recap

- What is Deep Learning?

Deep Learning is a family of methods that use deep architectures to learn high-level feature representations.



Recap

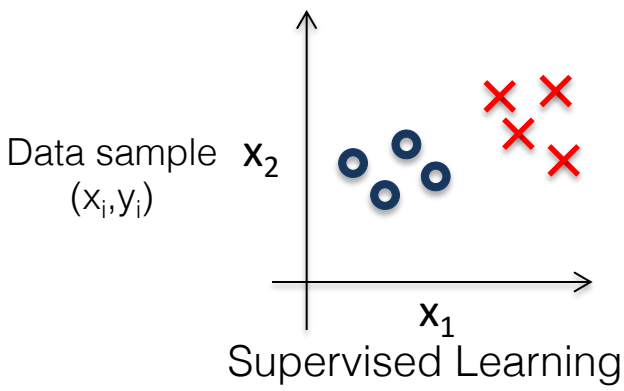
- What is Deep Learning?

➢ Composition of non-linear transformation of the data.

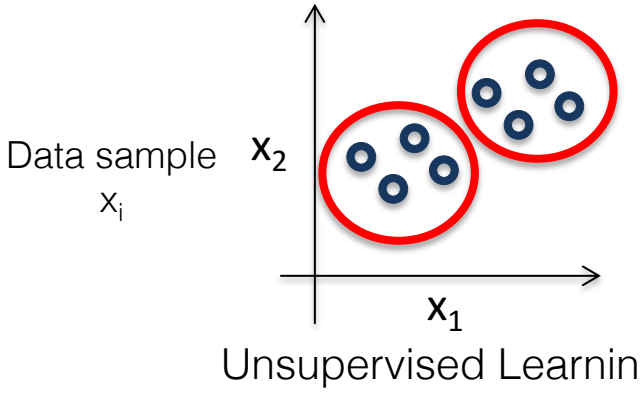
➢ Goal: Learn useful representations, a.k.a., features, directly from data.

➢ Many varieties, can be supervised (e.g., CNNs, and unsupervised (e.g., autoencoders, sparse coding).

➢ Today is about ConvNets, which is supervised learning.



Supervised Learning



Unsupervised Learning

Overview (2 lectures)

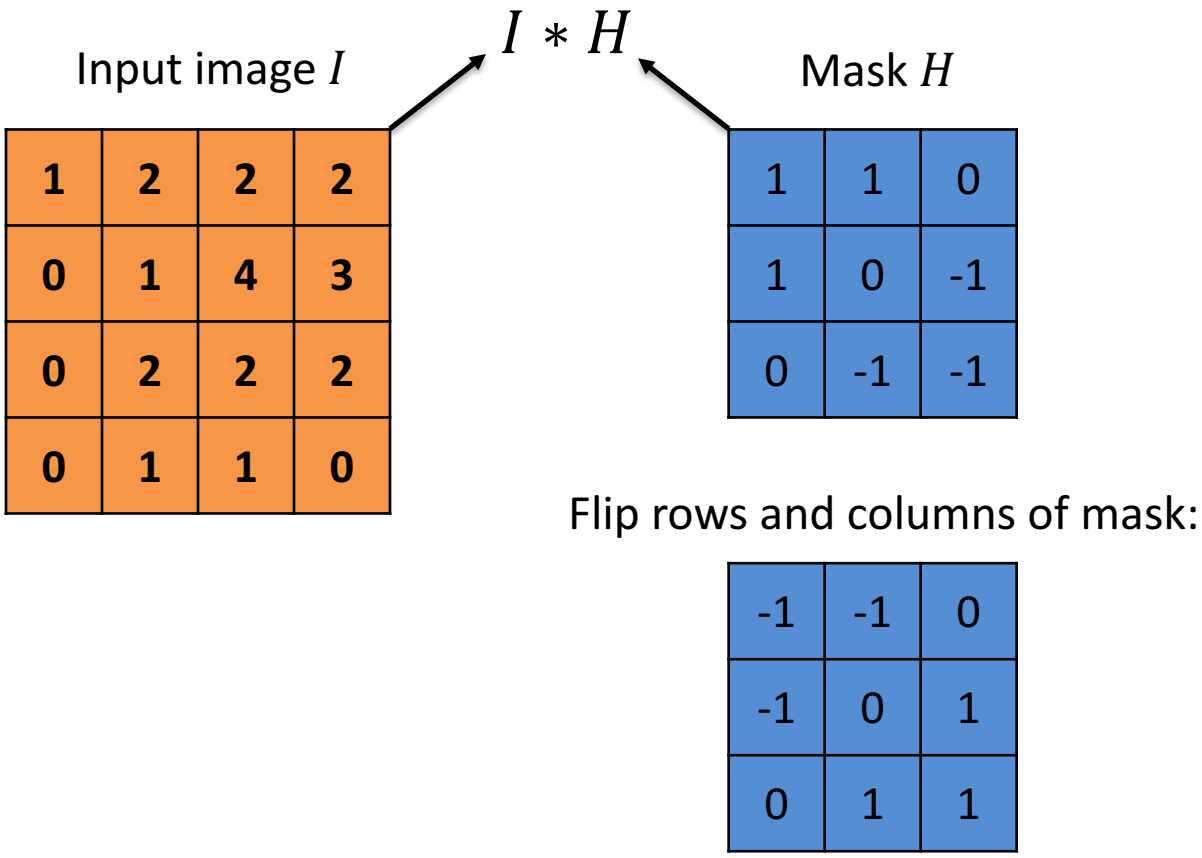
- Why Deep Learning?

- Convolutional Neural Networks
  - What are they?
  - Why are they useful?

- Technicalities of ConvNets
  - Convolution and Pooling
  - Typical architecture

Convolution

- $I'(i,j) = I * H = \sum_{k,l} I(i-k, j-l)H(k,l)$



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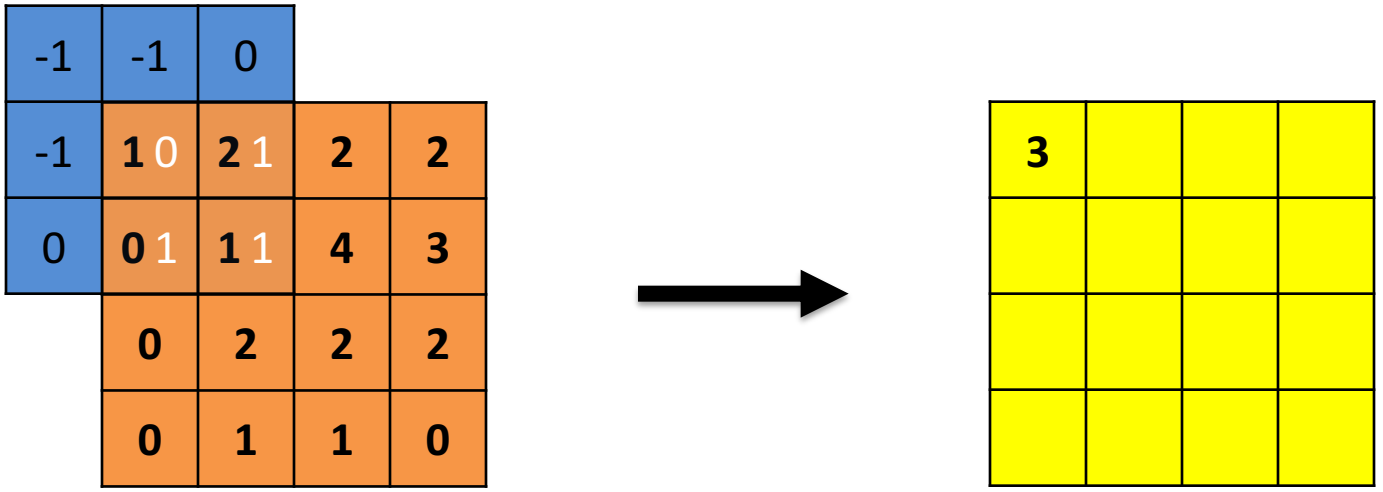

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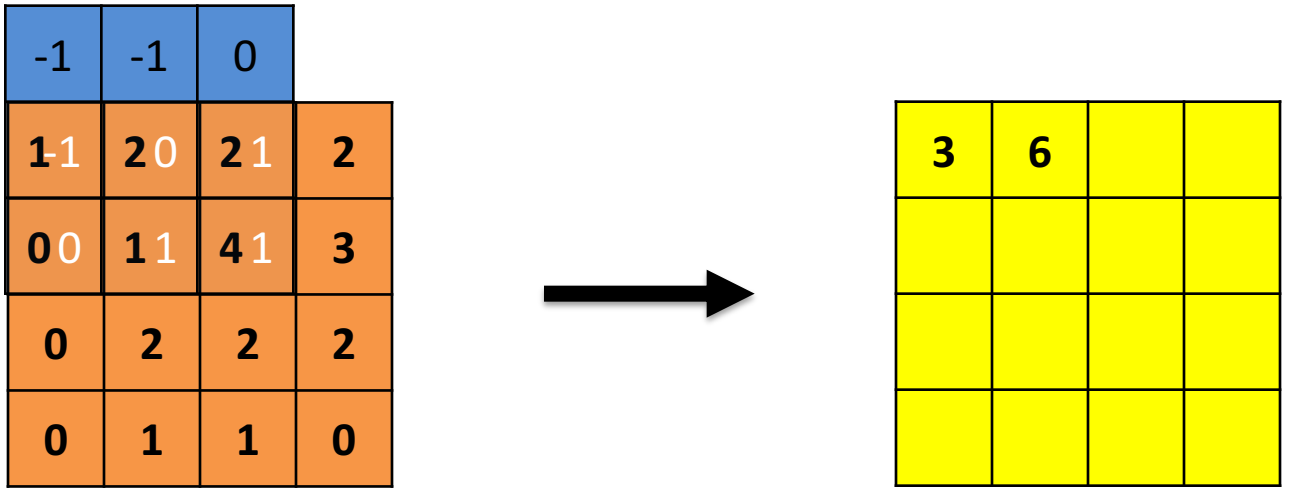

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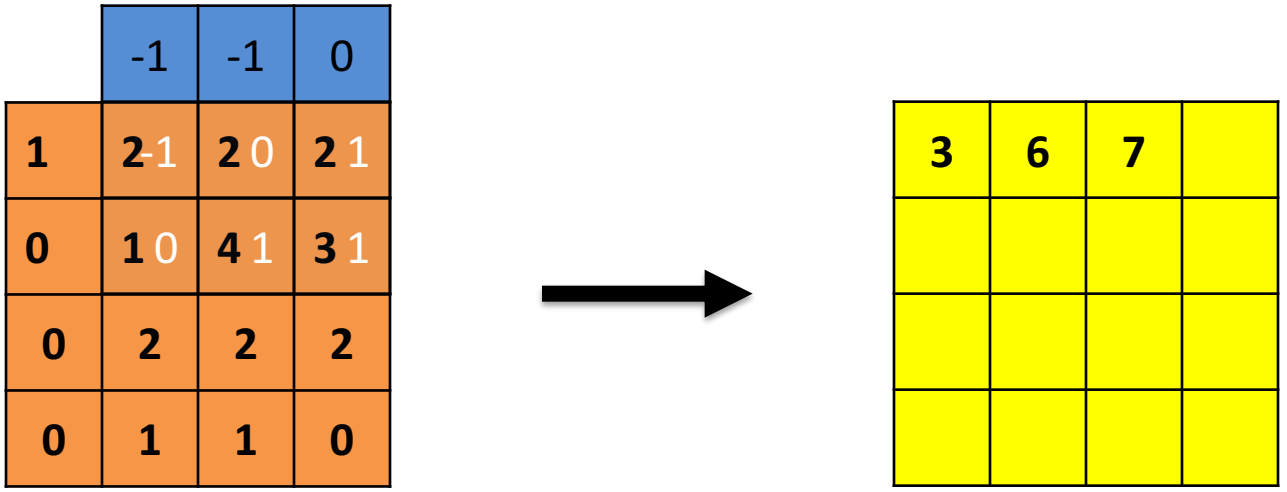

Convolution

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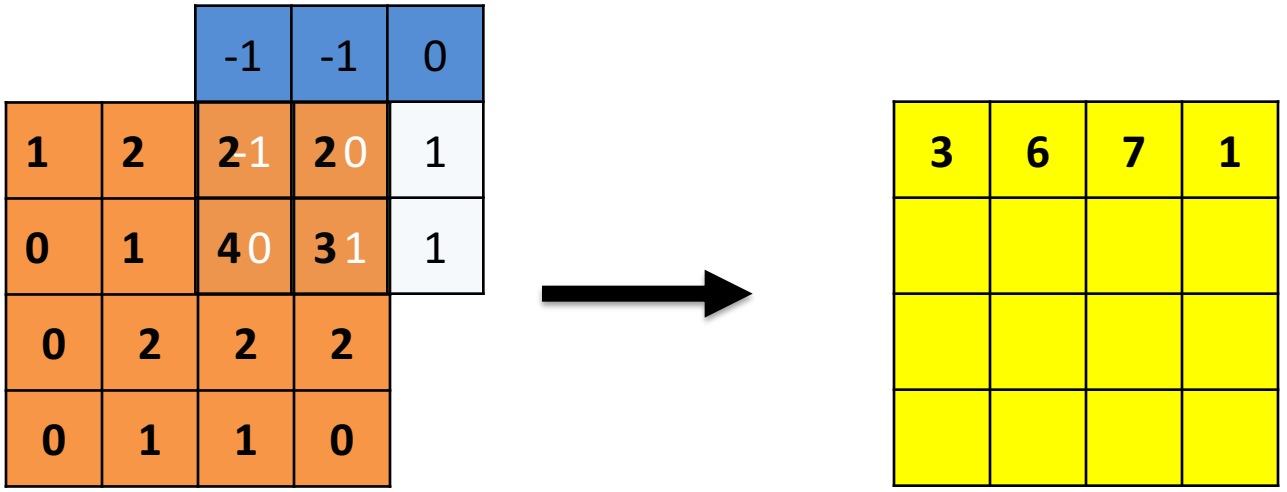

Convolution

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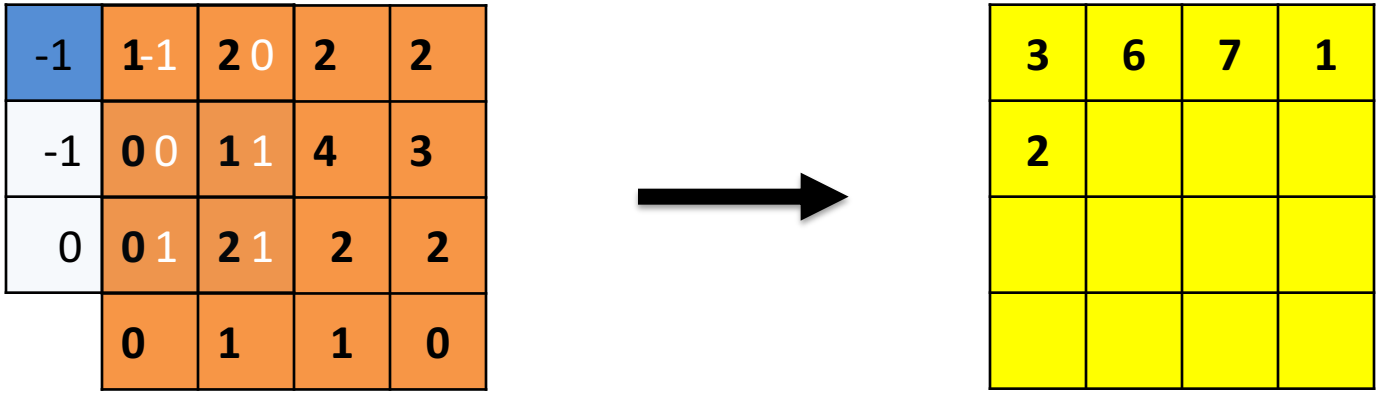

Convolution

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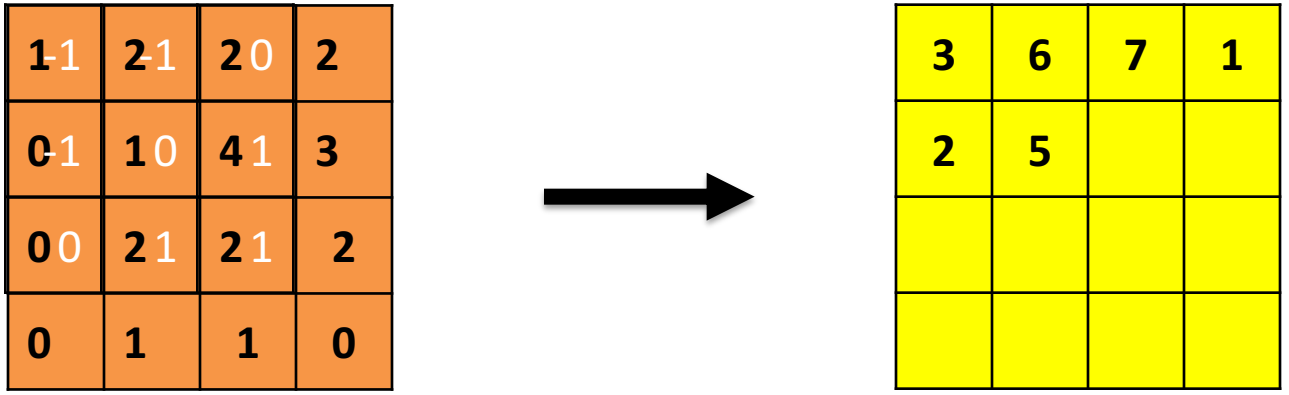

Convolution

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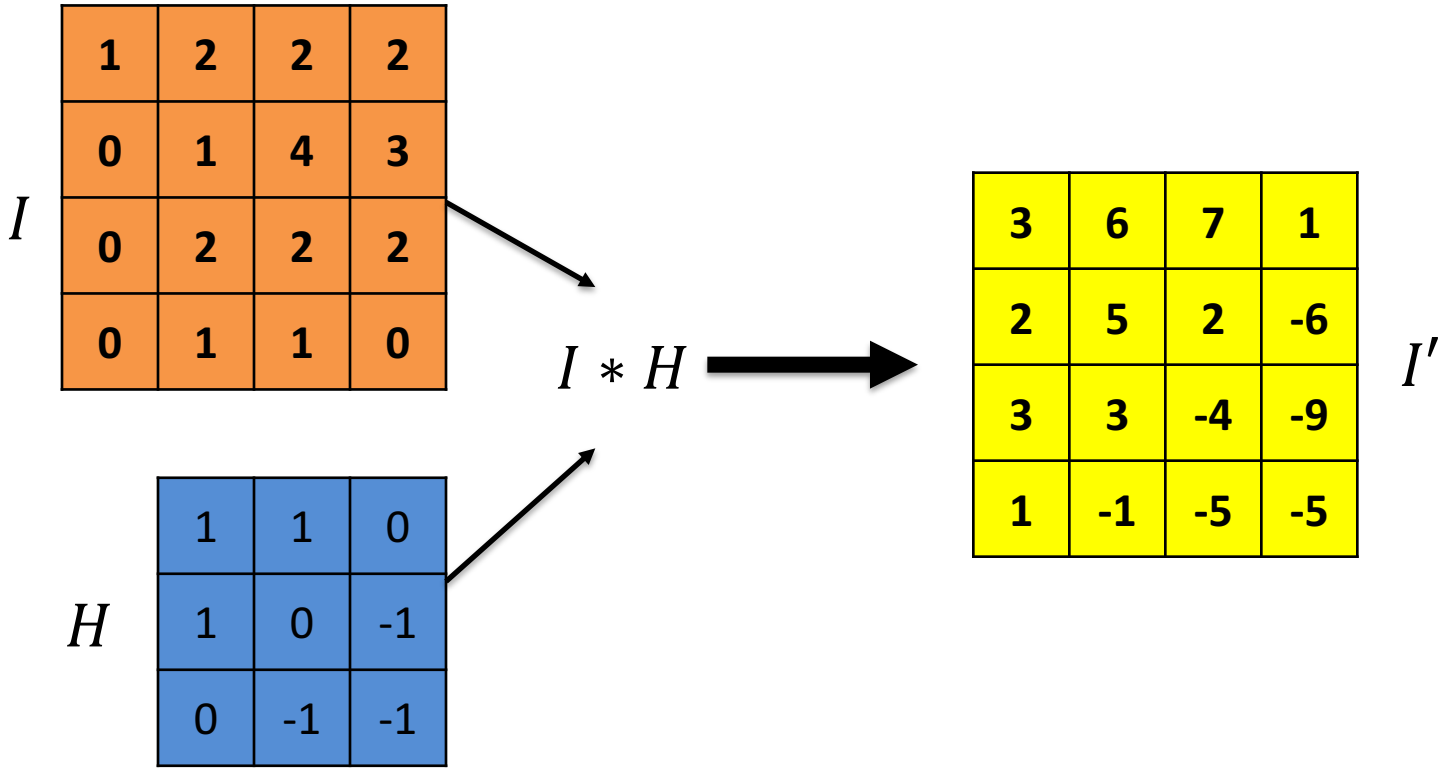
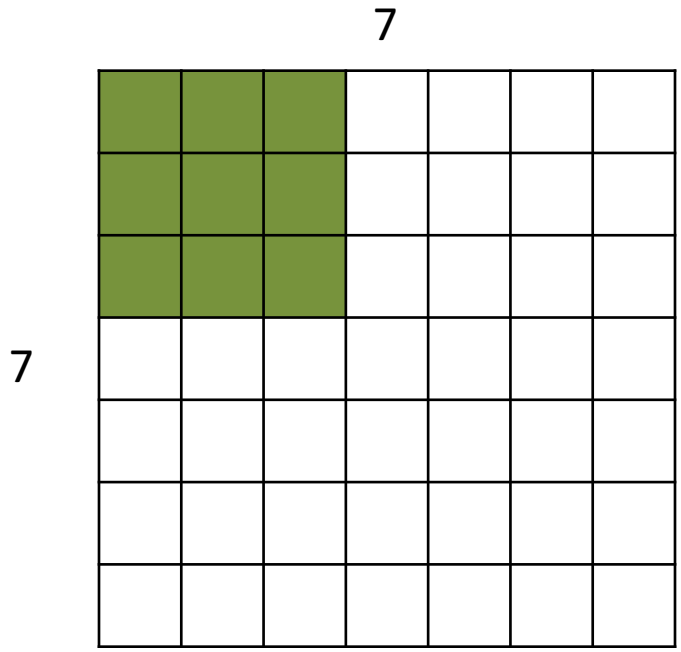


Convolution

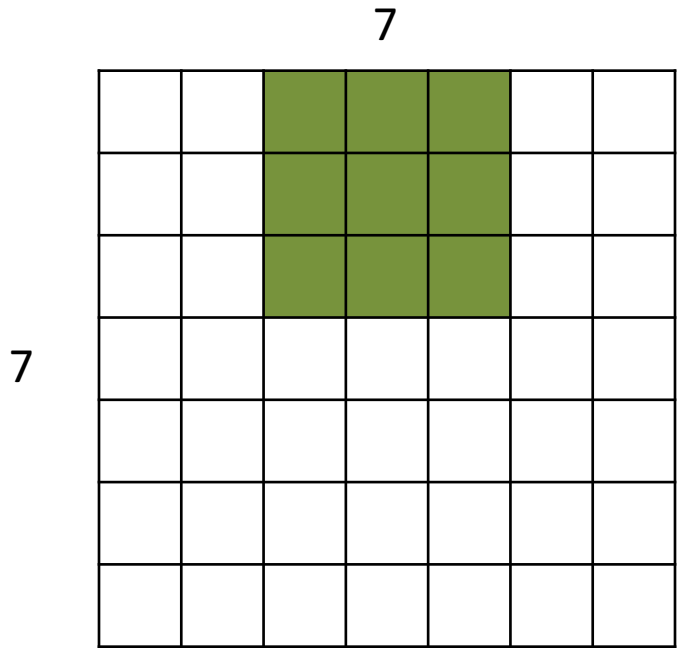
- Stride



7x7 input
assume 3x3 filter
applied with **stride 2**

Convolution

- Stride



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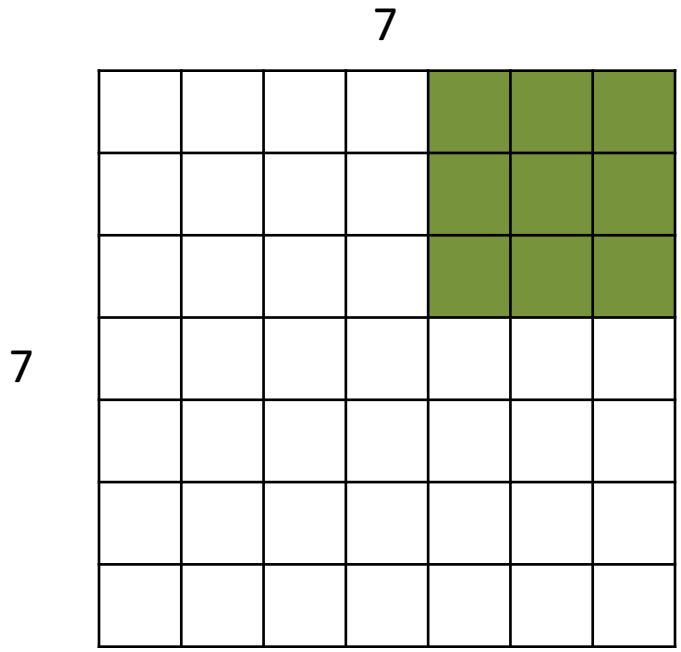
Convolution

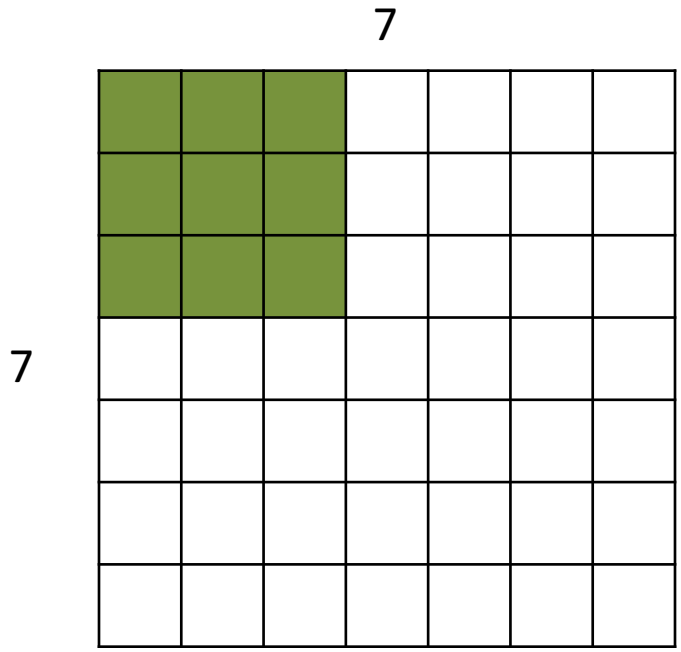
- Stride



7x7 input
assume 3x3 filter
applied with **stride 2**
=> 3x3 output

Convolution

- Stride

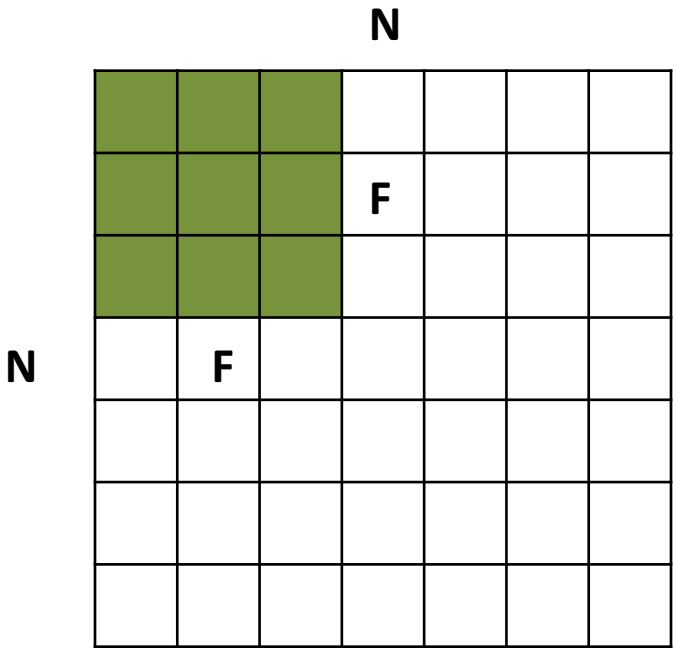


7x7 input
assume 3x3 filter
applied with **stride 3?**

doesn't fit
cannot apply 3x3 filter on 7x7 input with stride 3

Convolution

- Stride

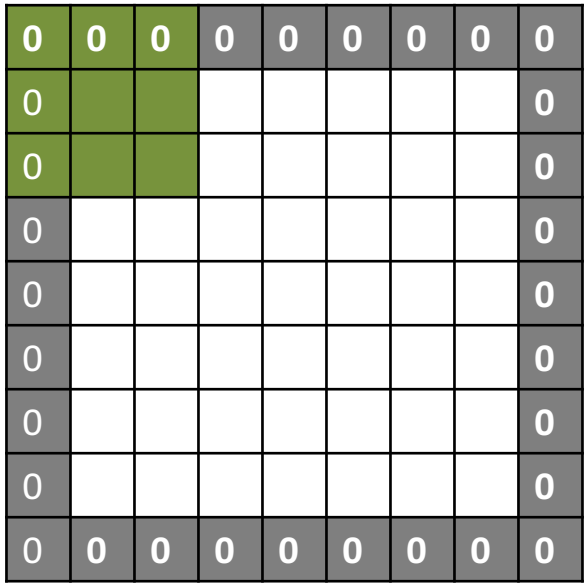


Output size:
(N - F) / stride +1

e.g., N=7, F=3:
stride 1 => (7 - 3) / 1 + 1 = 5
stride 2 => (7 - 3) / 2 + 1 = 3
stride 3 => (7 - 3) / 3 + 1 = 2.33

Convolution

- Padding



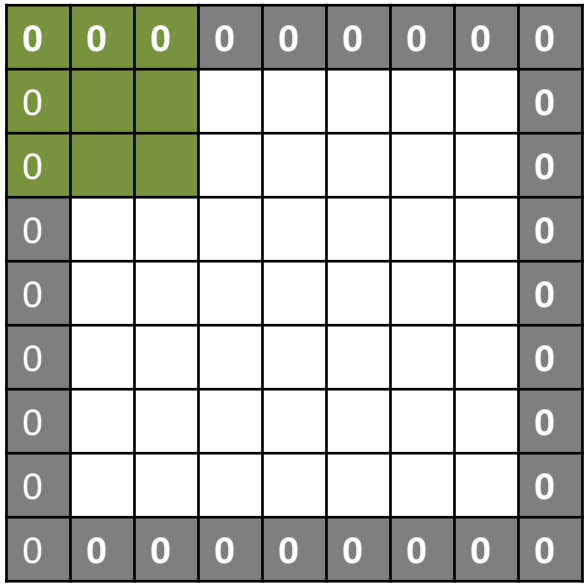
In practice, it is common to zero pad the border

e.g., input 7x7
3x3 filter, applied with stride 1
pad with 1 pixel border => what is the output?

Recall: (N - F) / stride + 1

Convolution

- Padding



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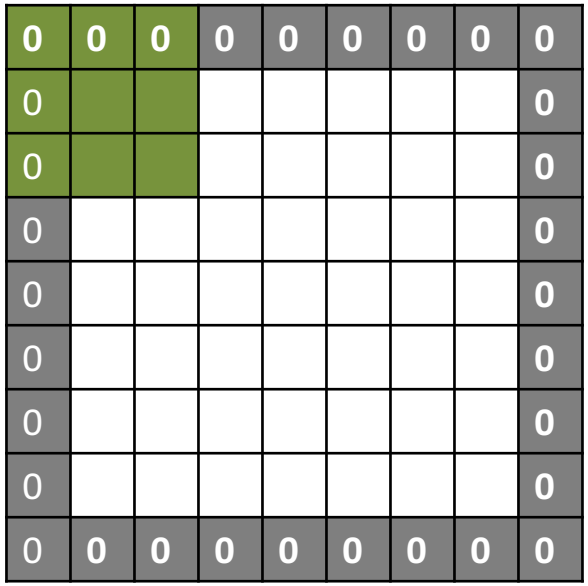
7x7 output!

Convolution

- Padding



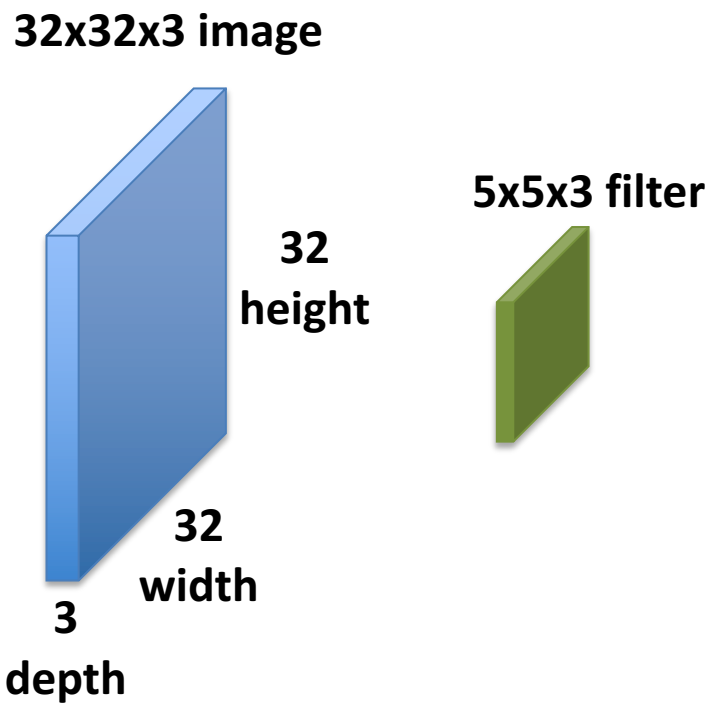
In practice, it is common to zero pad the border

e.g., input 7x7
3x3 filter, applied with stride 1
pad with 1 pixel border => what is the output?

7x7 output!

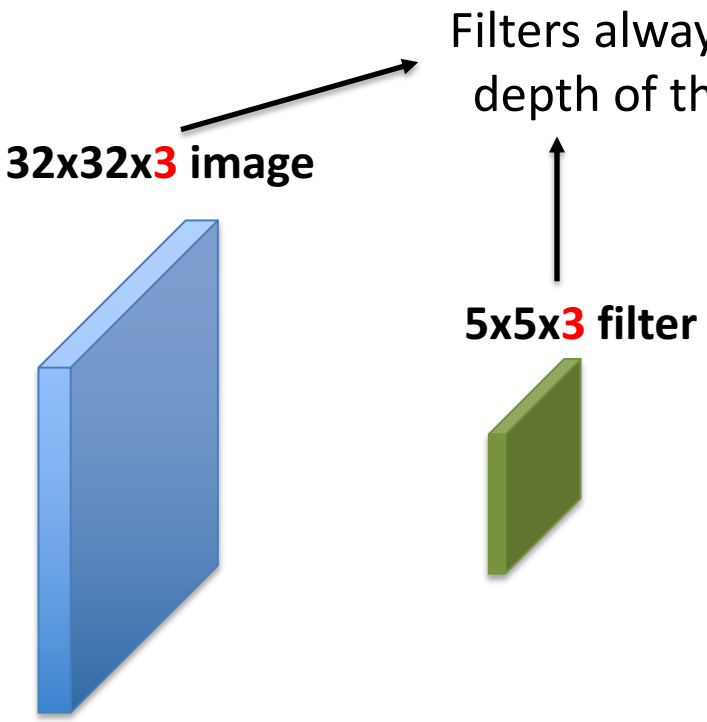
In general, common to see CONV layers with stride 1, filters of size FxF, and zero-padding with (F-1)/2. (will preserve size spatially)
e.g., F=3 => zero pad with 1
F=5 => zero pad with 2
F=7 => zero pad with 3

Convolution layer



Convolve the filter with the image, i.e., “slide over the image spatially, computing dot products”

Convolution layer



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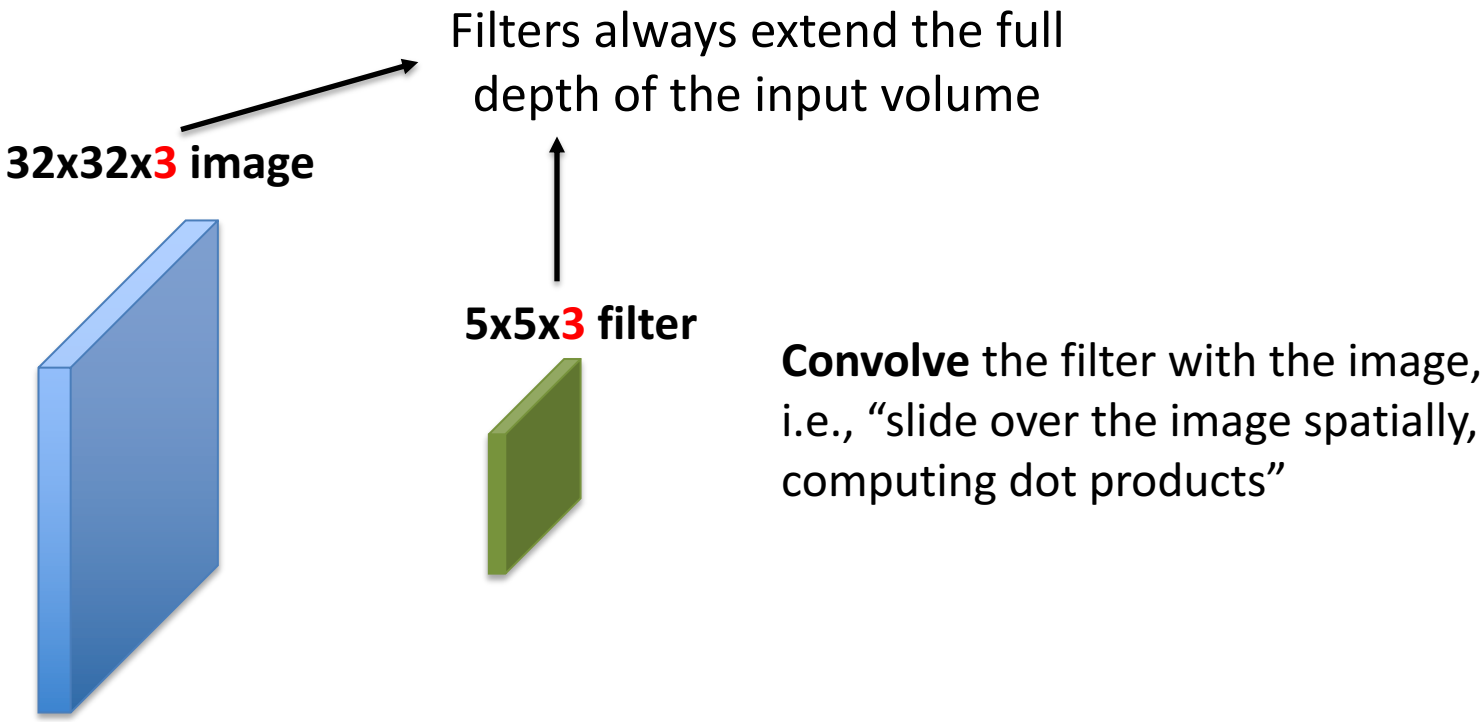

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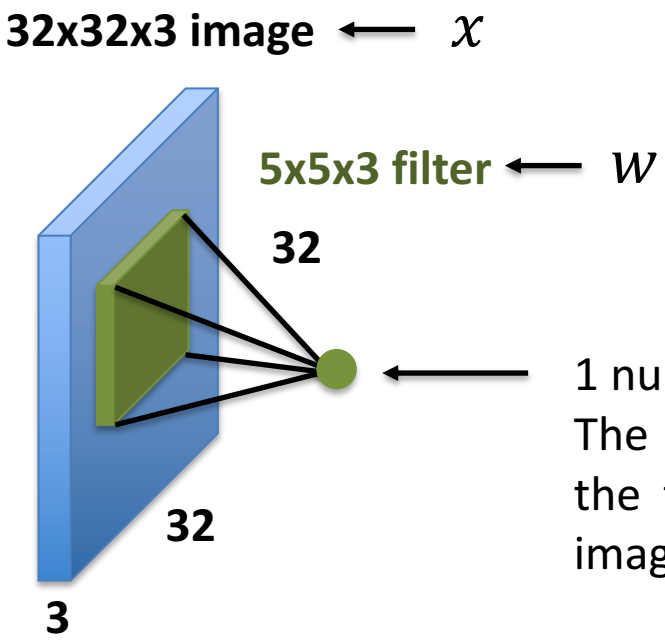
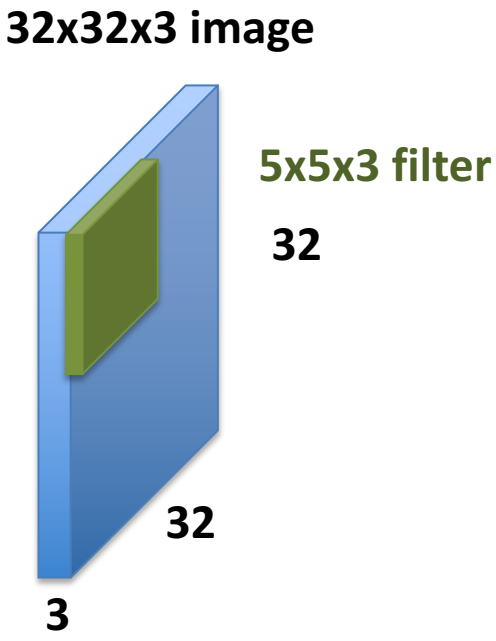
Convolution layer



1 number:
The result of taking a dot product between the filter and a small 5x5x3 patch of the image (i.e., 5*5*3 = 75-d dot product +bias)

$$w^T x + b$$

Convolution layer



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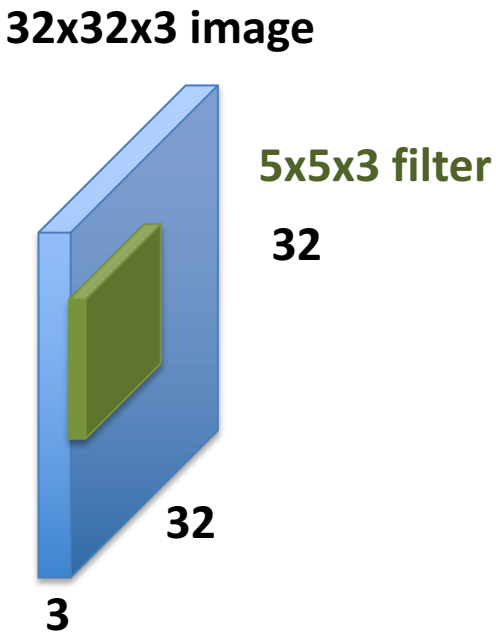

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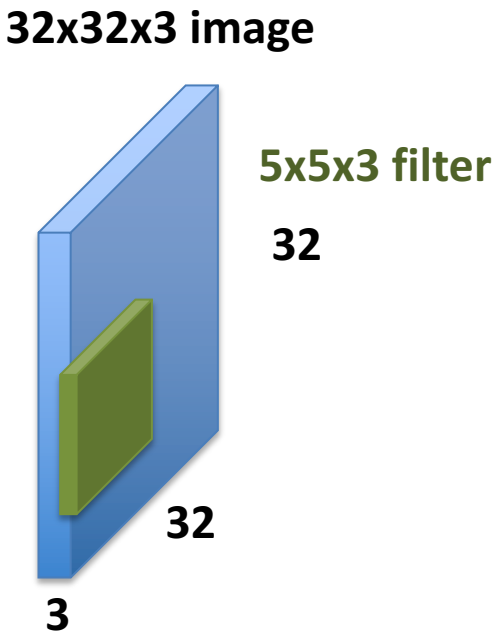
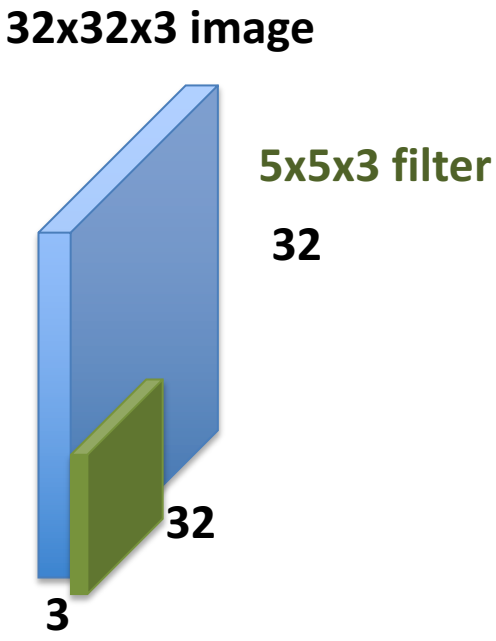
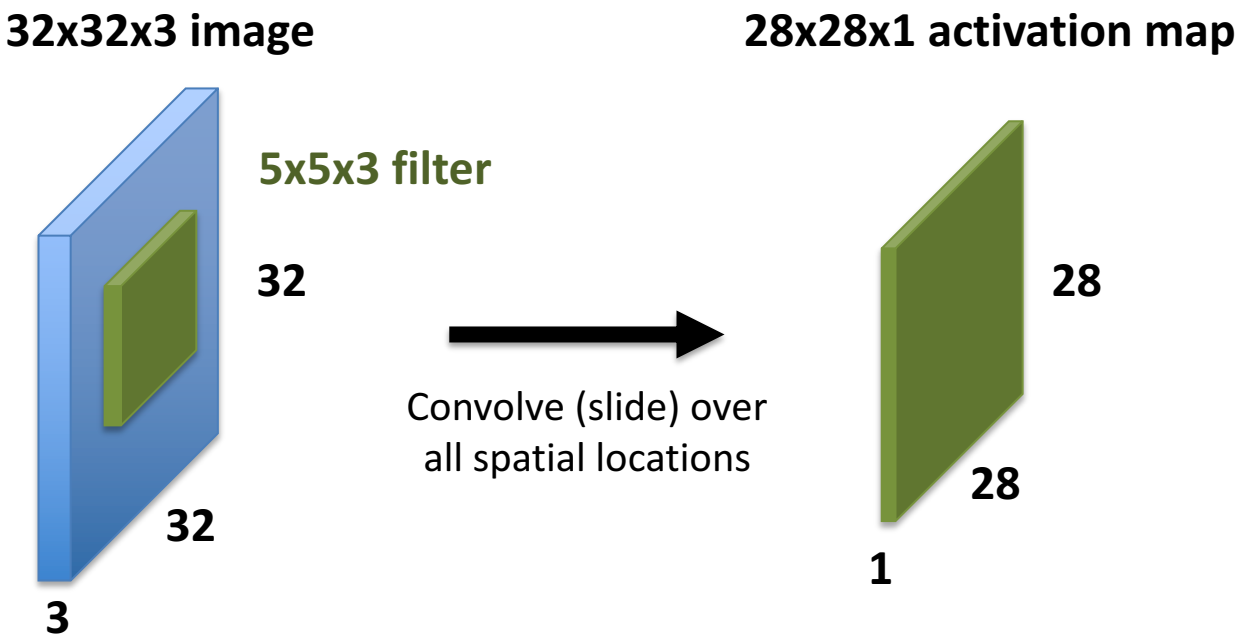


Convolution layer

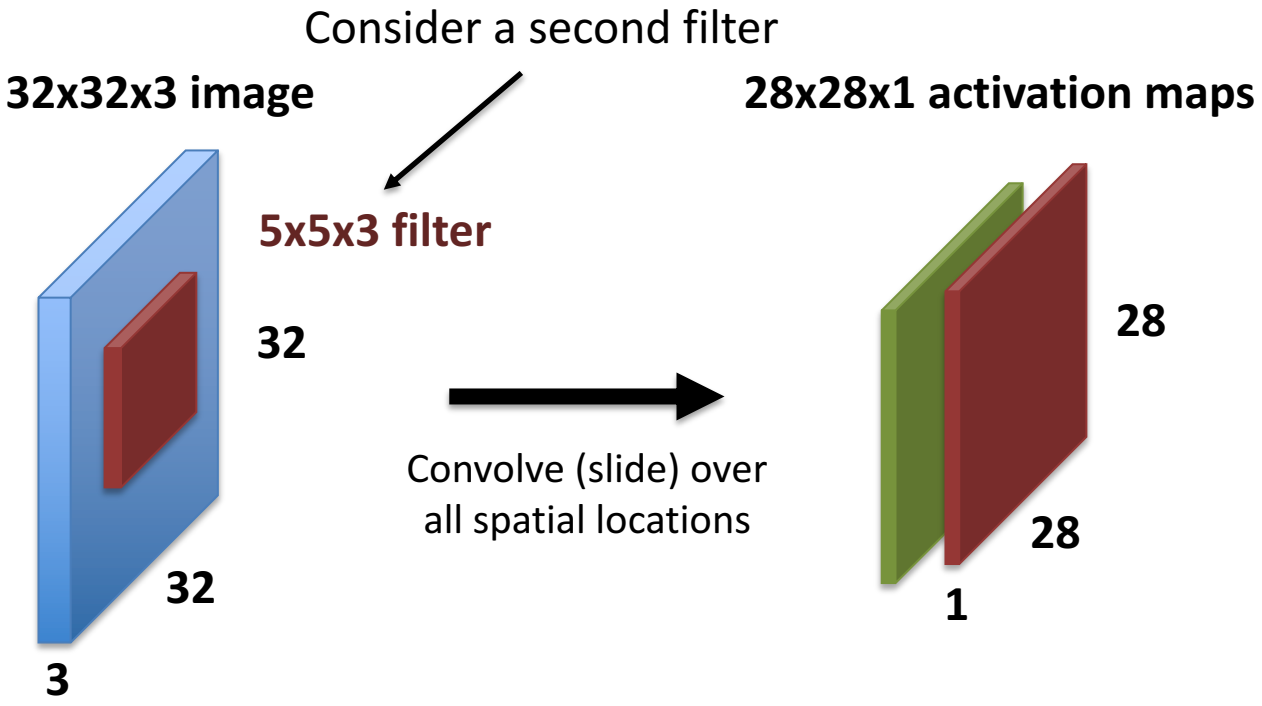


Convolution layer



Recall: (N - F) / stride + 1

Convolution layer



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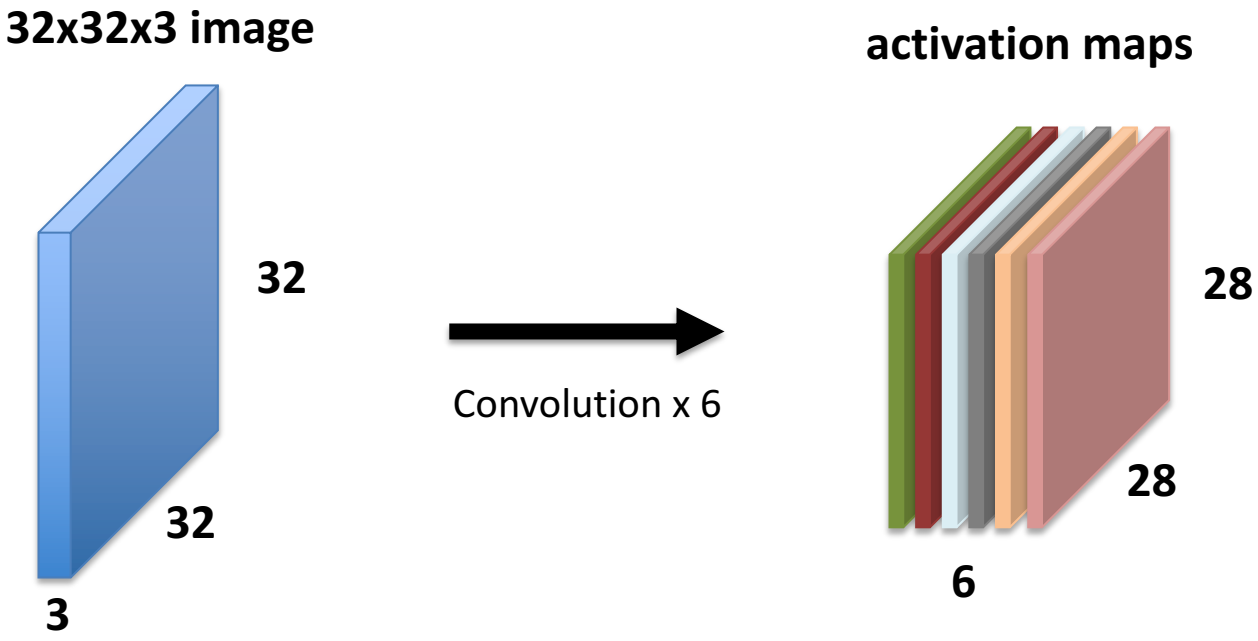
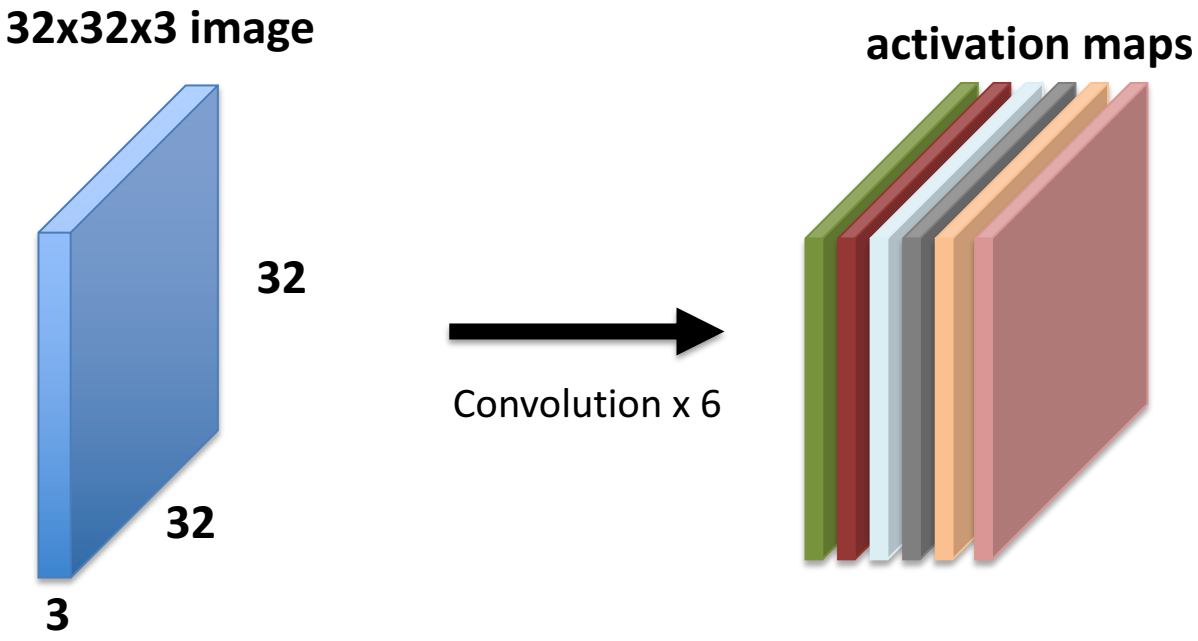
Convolution layer



If we have 6 5x5x3 filters, we get 6 separate activation maps.

And we stack these up to get a ”new image” of size 28x28x6.

Convolution layer



If we have 6 5x5x3 filters with stride 1, pad 2, output volume size?

Spatially, (32 + 2x2 - 5)/1 +1 =32, so output volume size: 32x32x6

Convolution layer

- Previous layer: a volume of size $W_1 \times H_1 \times D_1$
- Four hyperparameters are required:
  - Number of filters K
  - Filter size F
  - The stride S
  - The amount of zero padding P
- Next layer: a volume of size $W_2 \times H_2 \times D_2$
  - $W_2 = (W_1 - F + 2P) / S + 1$
  - $H_2 = (H_1 - F + 2P) / S + 1$
  - $D_2 = K$

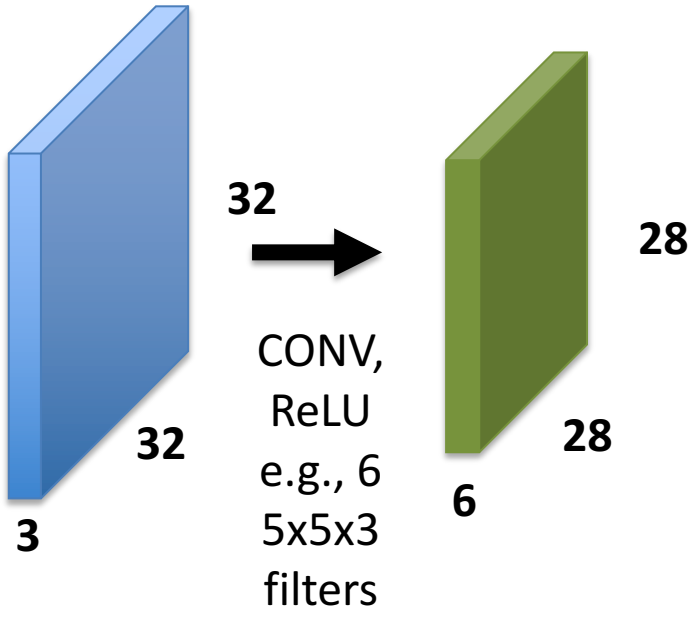
Common settings:

K = (powers of 2, e.g., 32, 64, 128, 512)

- F =3, S=1, P=1
- F =5, S=1, P=2
- F =1, S=1, P=0

ConvNet

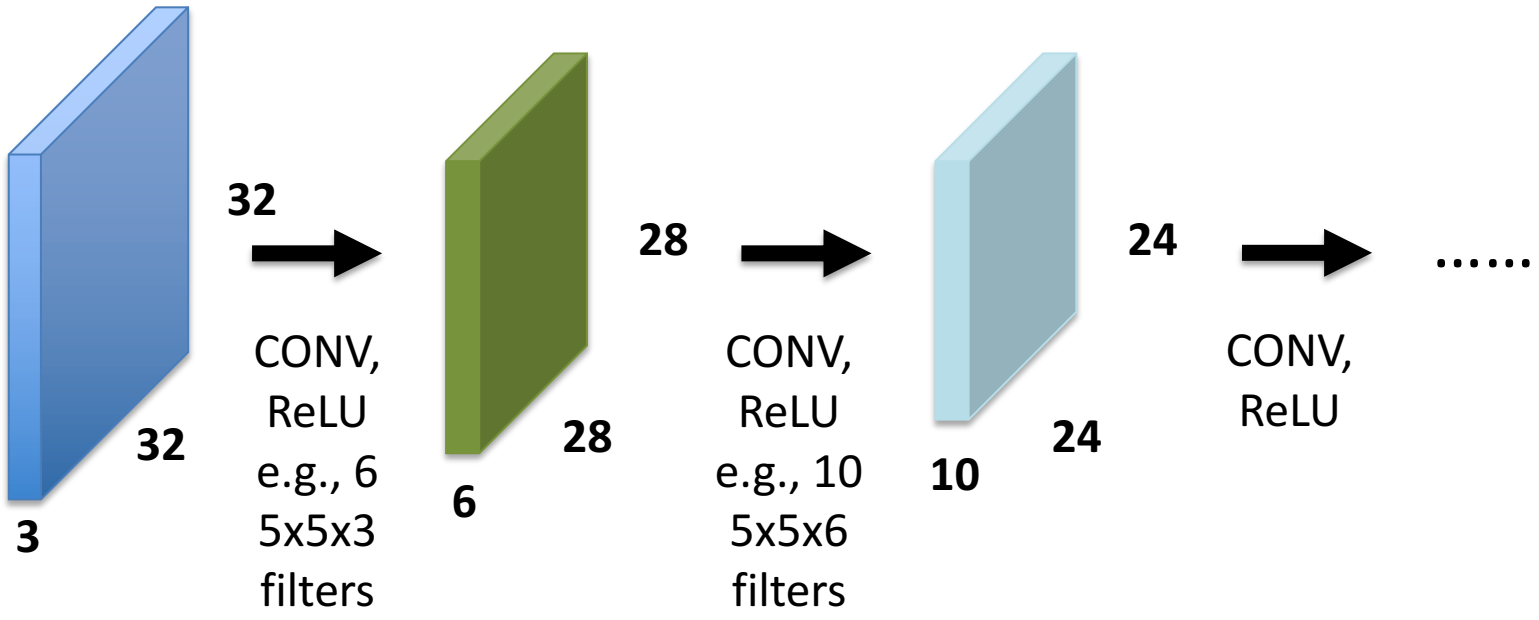
(*Convolutional Nuerual Networks*)



ConvNet is a sequence of convolution layers, interspersed with activation functions

ConvNet

(*Convolutional Nuerual Networks*)



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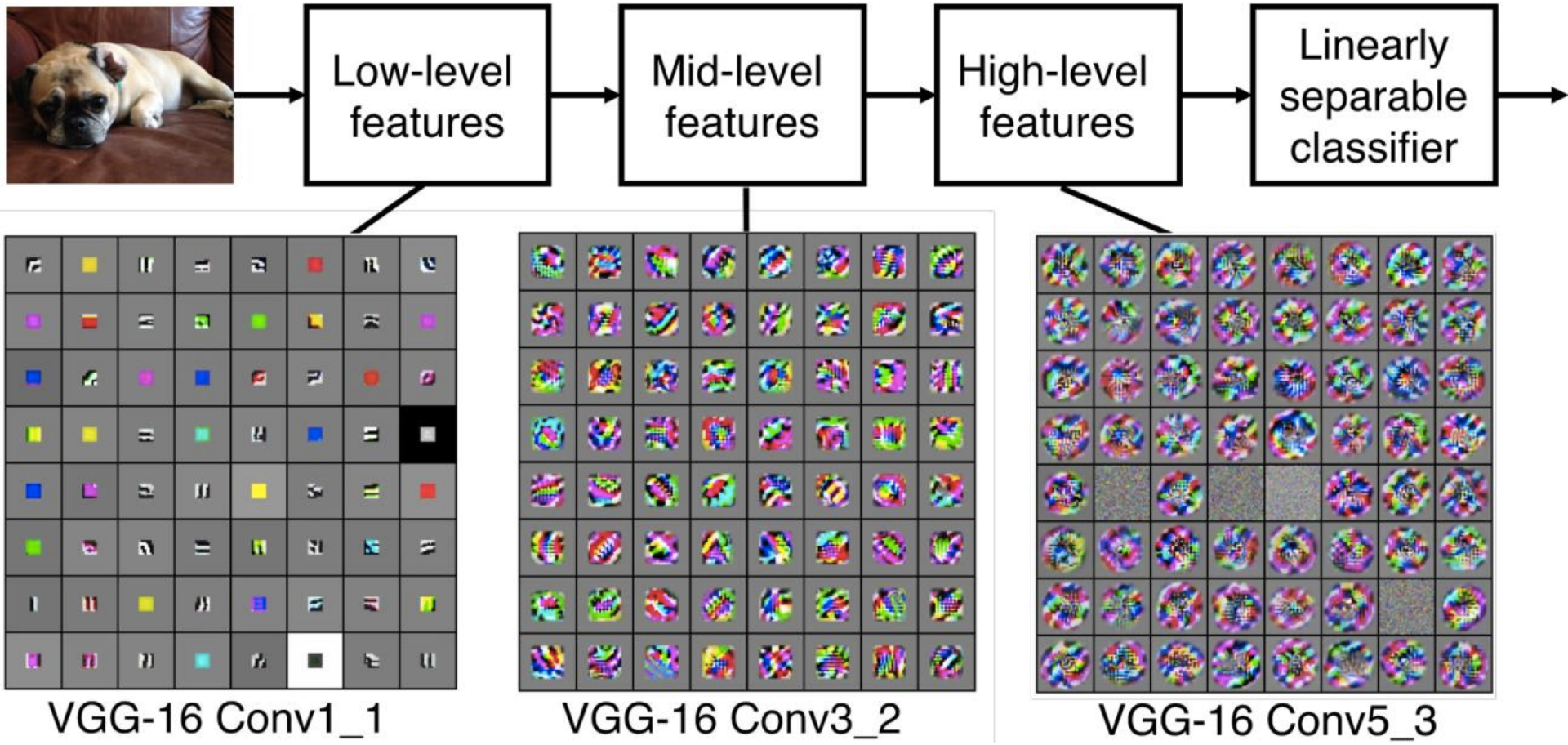
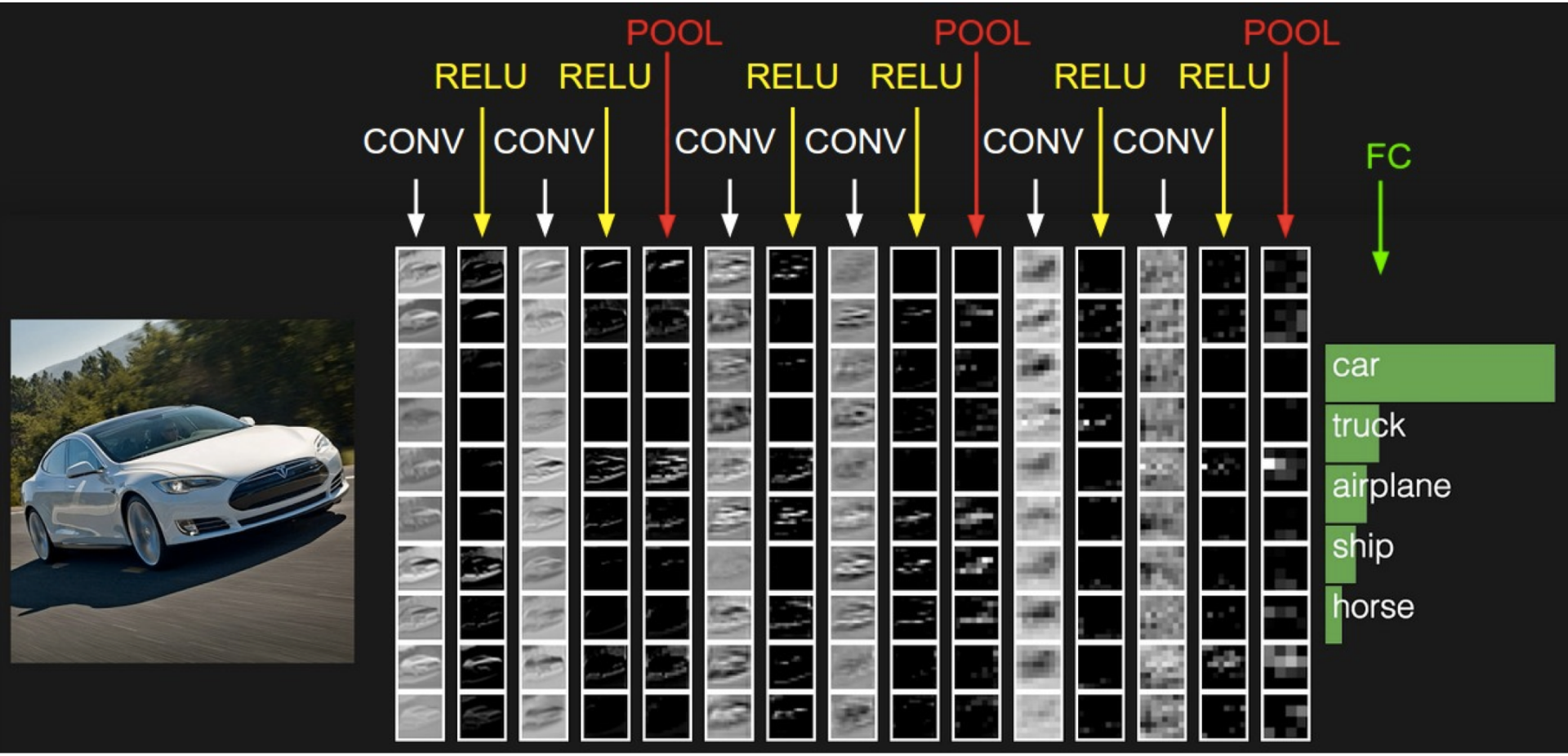
ConvNet



Zeiler and Fergus. “Visualizing and understanding convolutional networks.” *ECCV,* 2014.

ConvNet

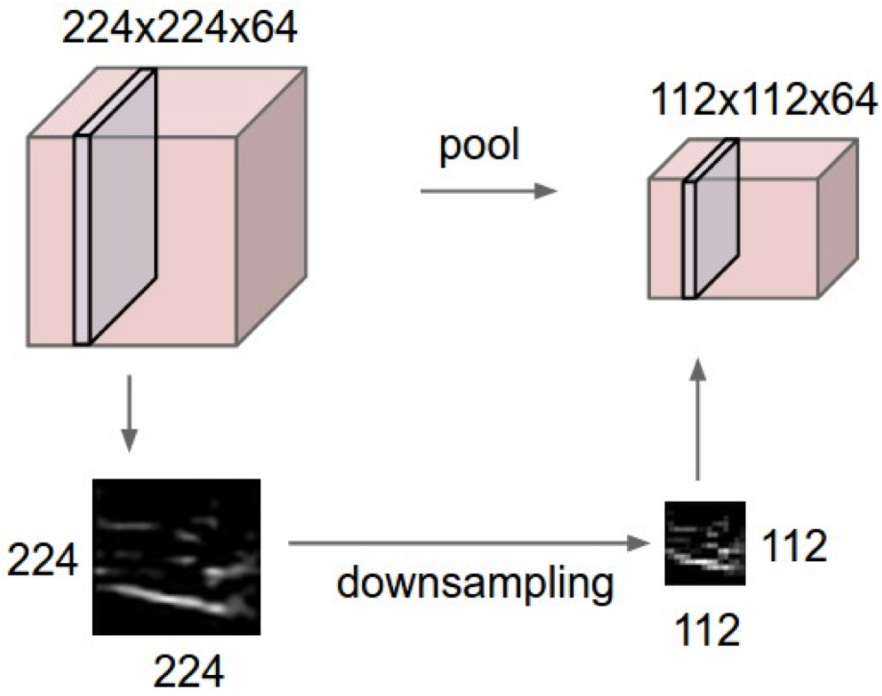
Two more types of layers: pooling and fully connected (FC)



ConvNet

Pooling layer

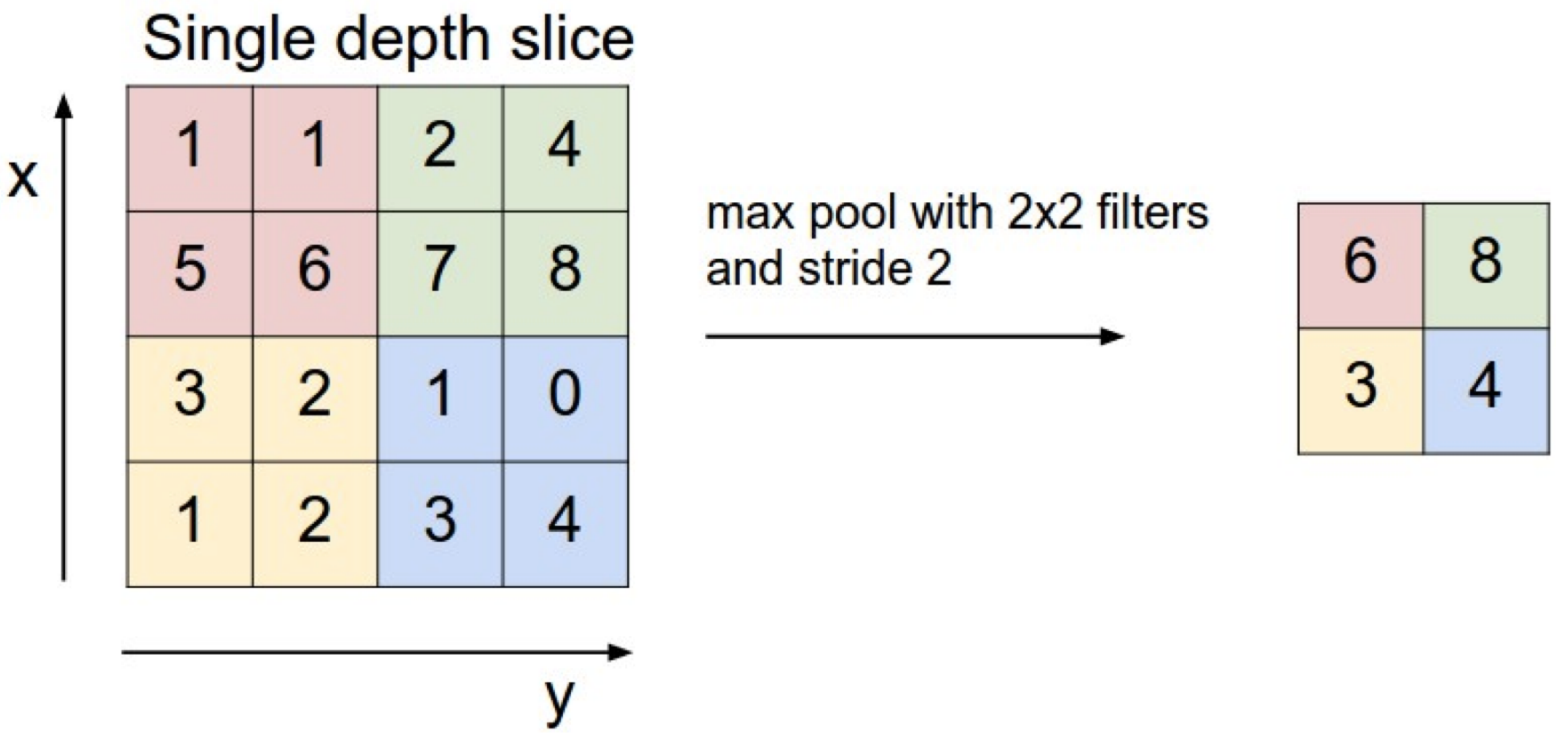
- Make the representations smaller and more manageable
- Operates over each activation map independently



ConvNet

Pooling layer

- Max pooling



ConvNet

Pooling layer

- Previous layer: a volume of size W_1 x H_1 x D_1
- Two hyperparameters are required:
  - Filter size F
  - The stride S
- Next layer: a volume of size W_2 x H_2 x D_2
  - $W_2 = (W_1 - F) / S + 1$
  - $H_2 = (H_1 - F) / S + 1$
  - $D_2 = D_1$

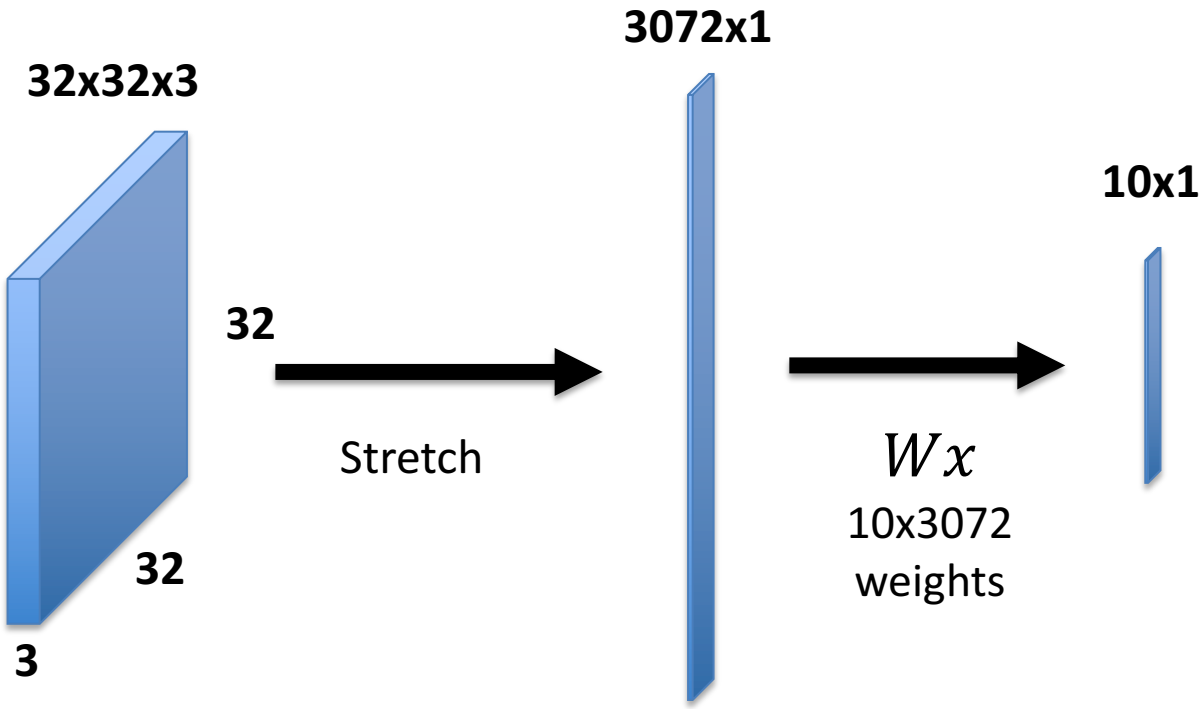
Common settings:
- F =2, S=2
- F =3, S=2

It is not common to use zero-padding for Pooling layers

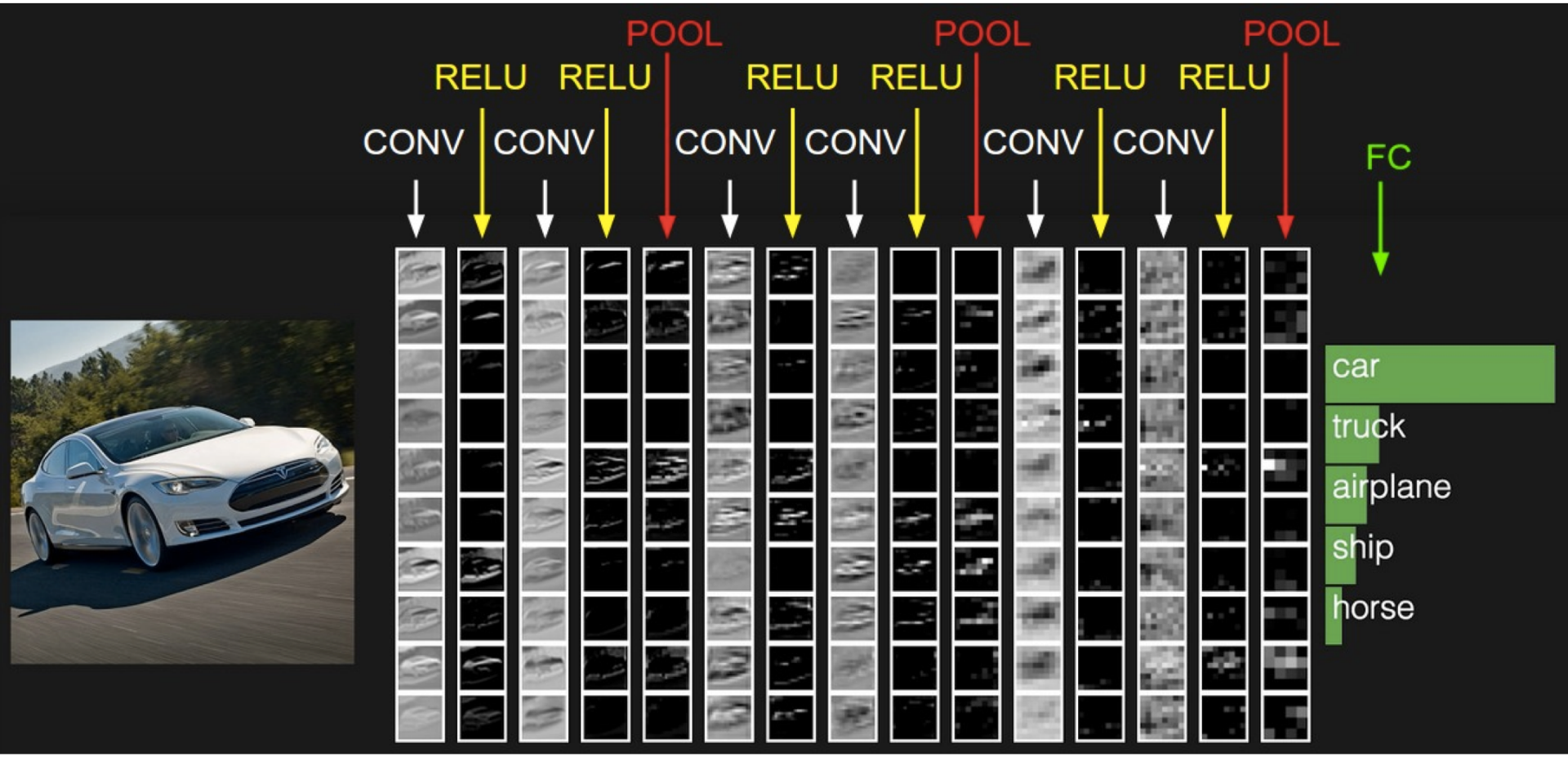
ConvNet

Fully Connected (FC) layer

- Contains neurons that connect to the entire input volume, as in ordinary neural networks



ConvNet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