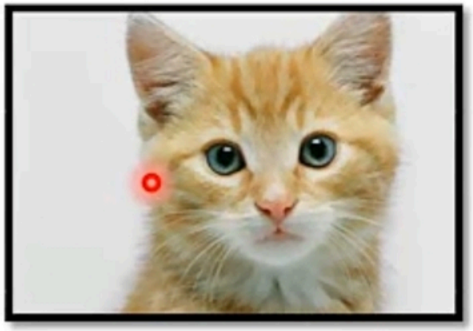
Convolutional Neural Network

Hung-yi Lee

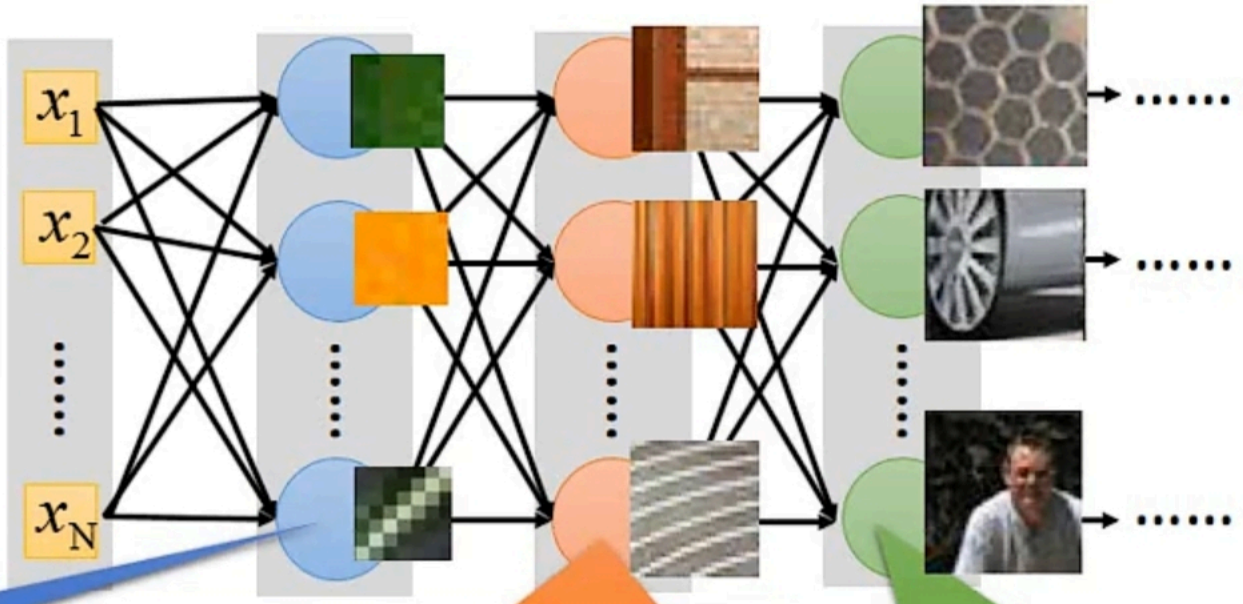
Can the network be simplified by considering the properties of images?

Why CNN for Image?

[Zeiler, M. D., *ECCV 2014*]



Represented as pixels



The most basic classifiers

Use 1st layer as module to build classifiers

Use 2nd layer as module .....

Can the network be simplified by considering the properties of images?

Why CNN for Image

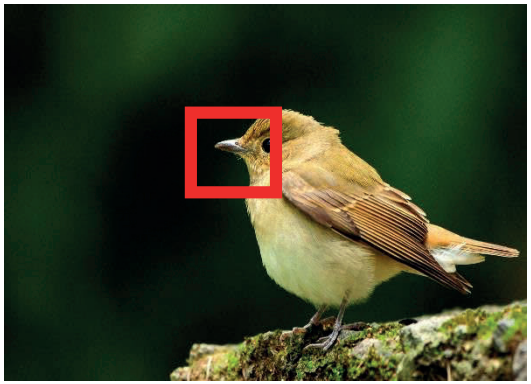
- Some patterns are much smaller than the whole image

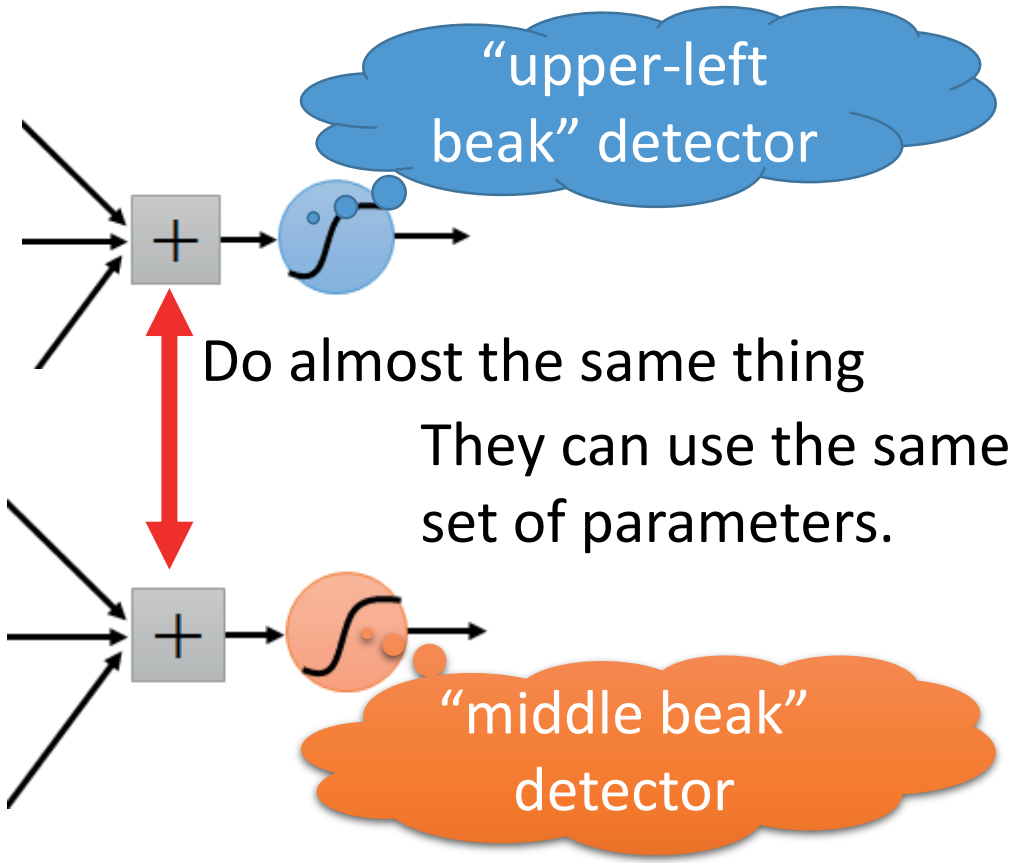
A neuron does not have to see the whole image to discover the pattern.

Connecting to small region with less parameters

Why CNN for Image

- The same patterns appear in different regions.





Why CNN for Image

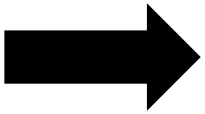
- Subsampling the pixels will not change the object

bird

subsampling

bird

We can subsample the pixels to make image smaller



Less parameters for the network to process the image

The whole CNN

Convolution

Max Pooling

Convolution

Max Pooling

Can repeat many times

Flatten

Fully Connected Feedforward network

cat dog ……

The whole CNN

Property 1

- Some patterns are much smaller than the whole image

Property 2

- The same patterns appear in different regions.

Property 3

- Subsampling the pixels will not change the object

Convolution

Max Pooling

Convolution

Max Pooling

Can repeat many times

Flatten

The whole CNN

Convolution

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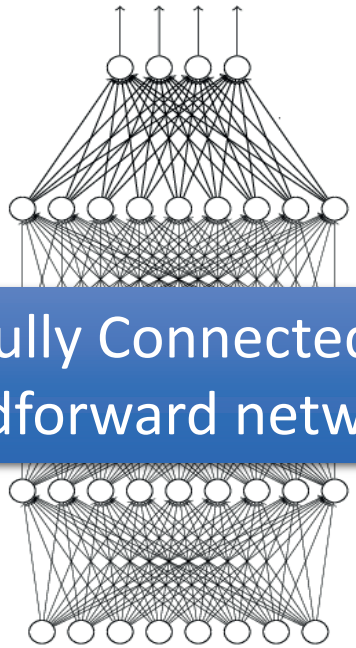
Can repeat many times

Flatten

cat dog ……



Fully Connected Feedforward network

CNN – Convolution

Those are the network parameters to be learned.

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

6 x 6 image

1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

Matrix

-1	1	-1
-1	1	-1
-1	1	-1

Filter 2

Matrix

⋮

Property 1

Each filter detects a small pattern (3 x 3).

CNN – Convolution

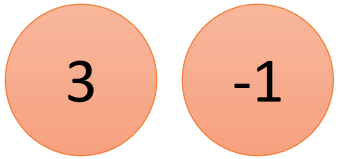
1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

stride=1

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

6 x 6 image



CNN – Convolution

1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

If stride=2

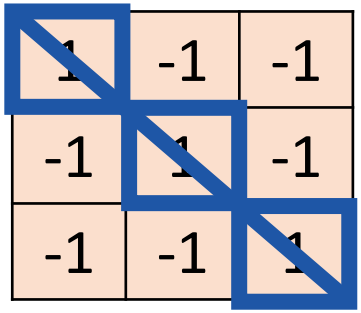
1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

3 -3

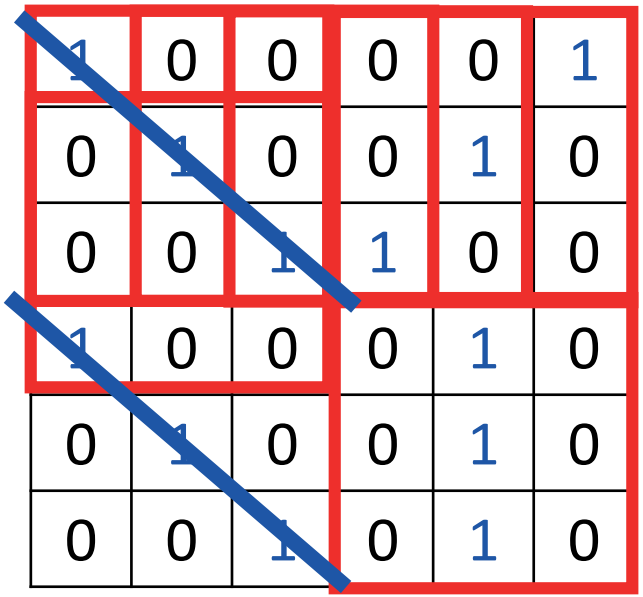
We set stride=1 below

CNN – Convolution

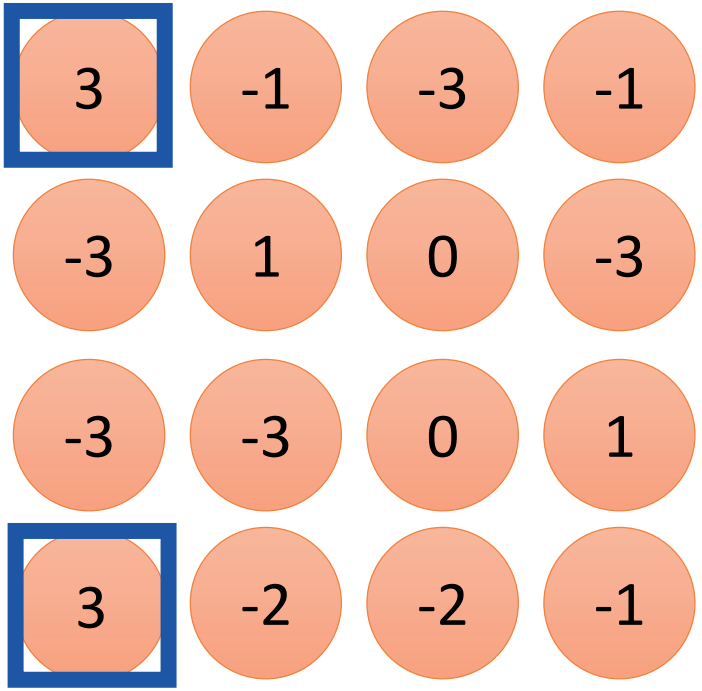


Filter 1

stride=1



6 x 6 image



Property 2

CNN – Convolution

-1	1	-1
-1	1	-1
-1	1	-1

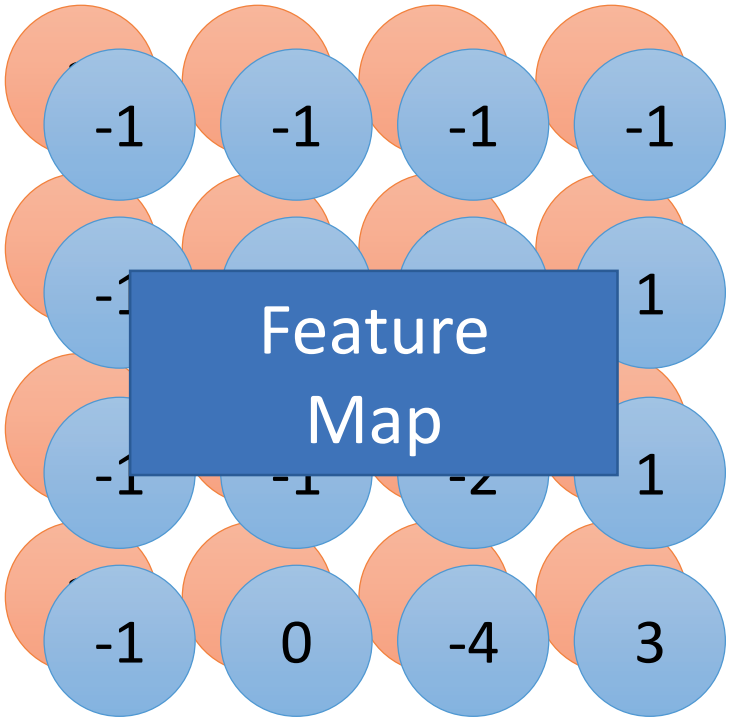
Filter 2

stride=1

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

6 x 6 image

Do the same process for every filter



4 x 4 image

CNN – Colorful image

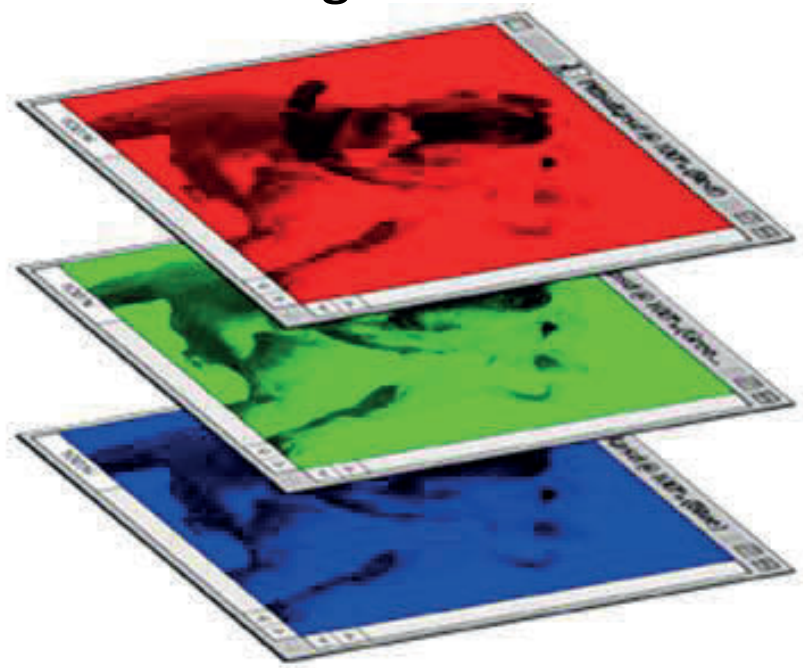
1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

-1	1	-1
-1	1	-1
-1	1	-1

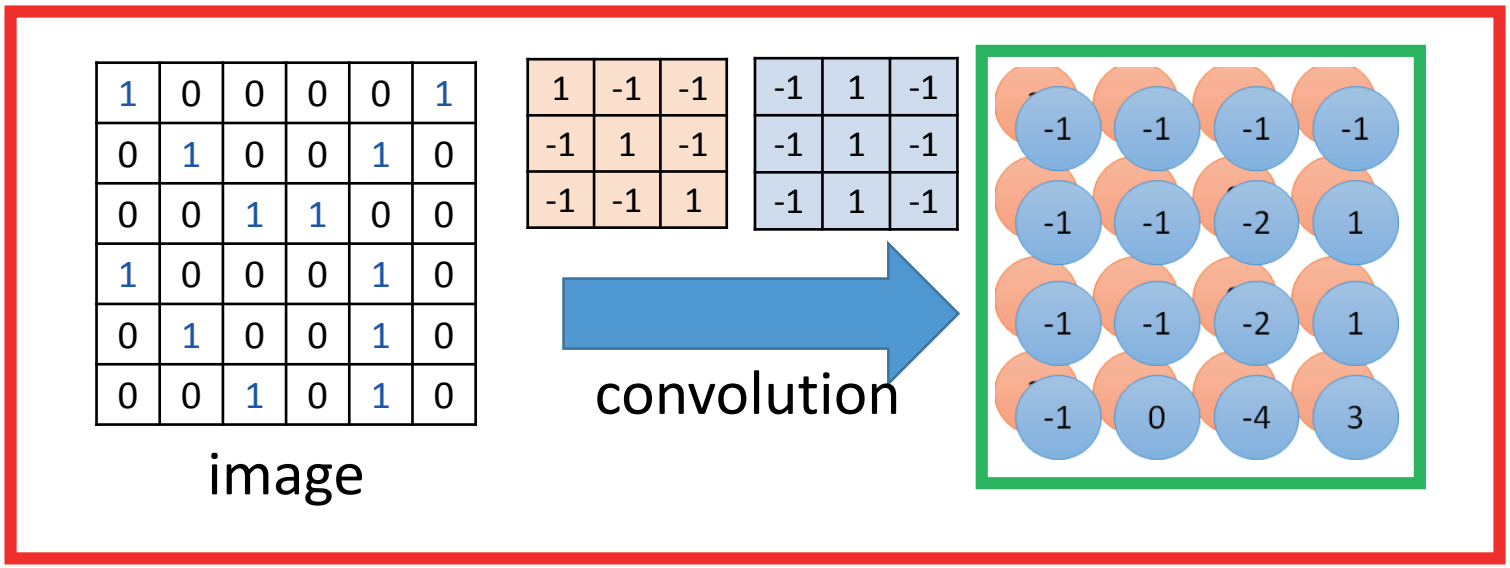
Filter 2

Colorful image



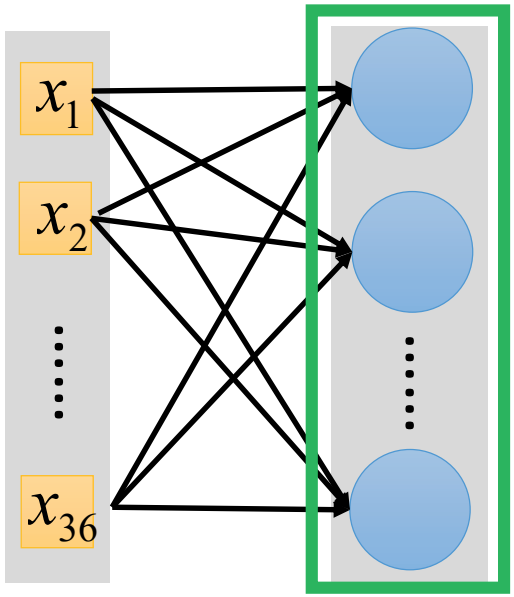
1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

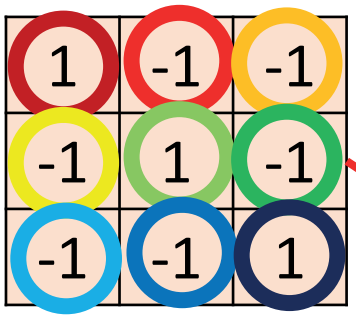
Convolution v.s. Fully Connected



Fully-connected

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

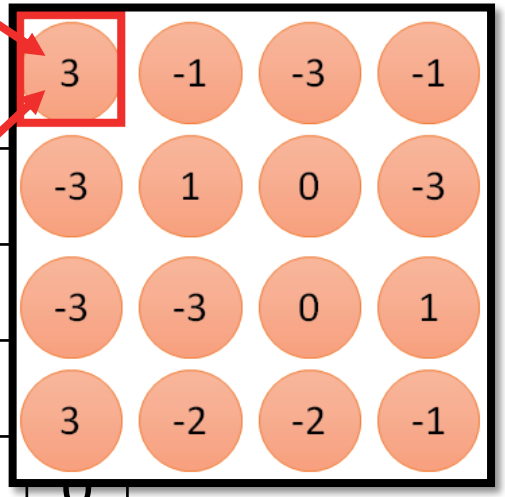




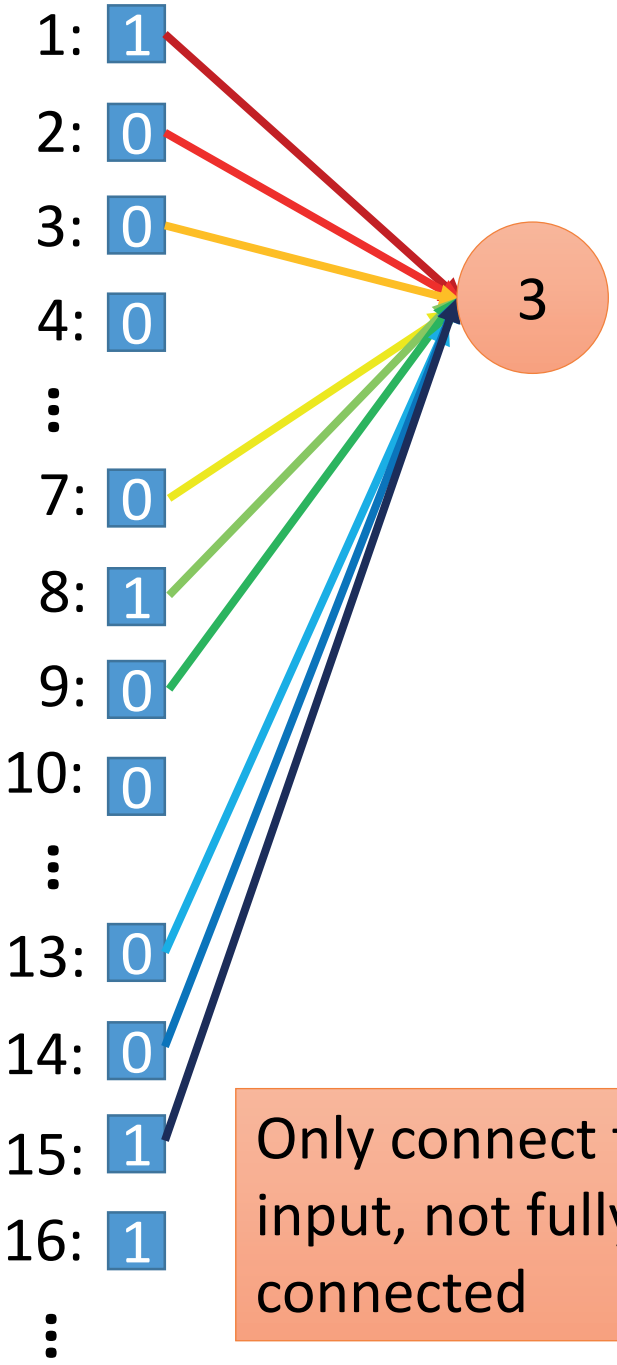
Filter 1

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

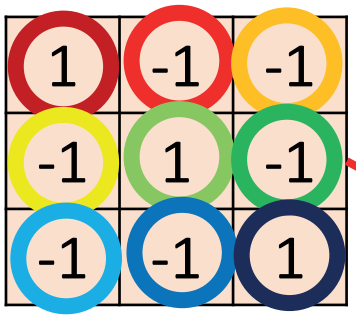
6 x 6 image



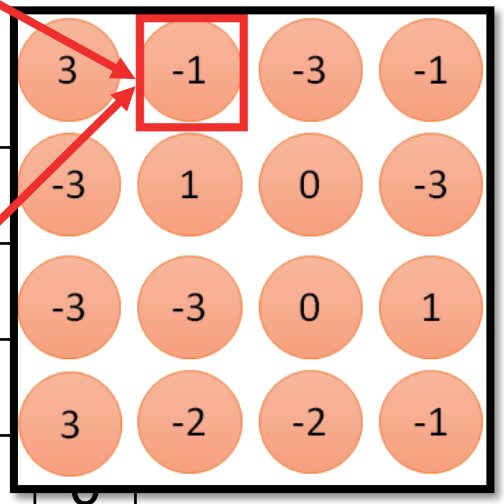
Less parameters!



Only connect to 9 input, not fully connected



Filter 1

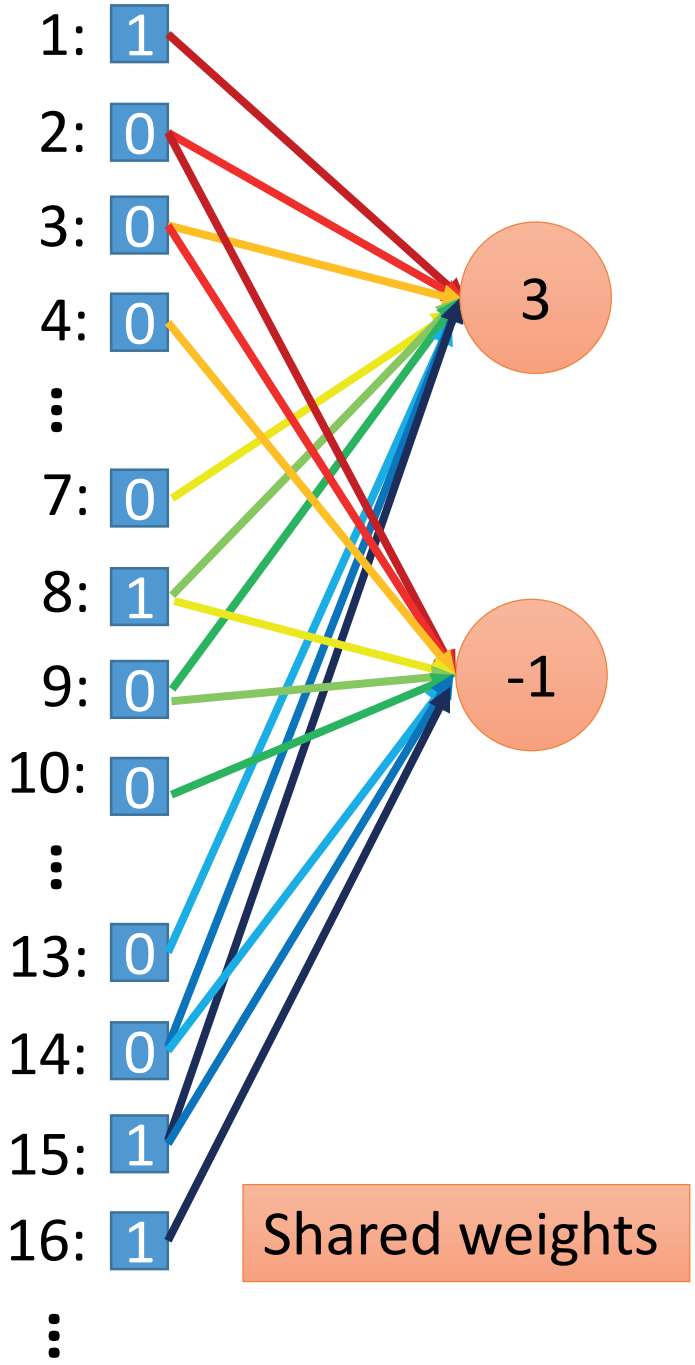


1	0	0	0	0	
0	1	0	0	1	
0	0	1	1	0	
1	0	0	0	1	
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

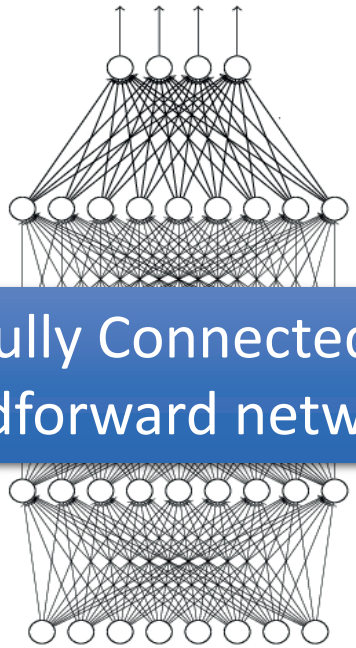
Less parameters!

Even less parameters!



The whole CNN

cat dog ……



Fully Connected Feedforward network

Convolution

Max Pooling

Convolution

Max Pooling

Can repeat many times

Flatten

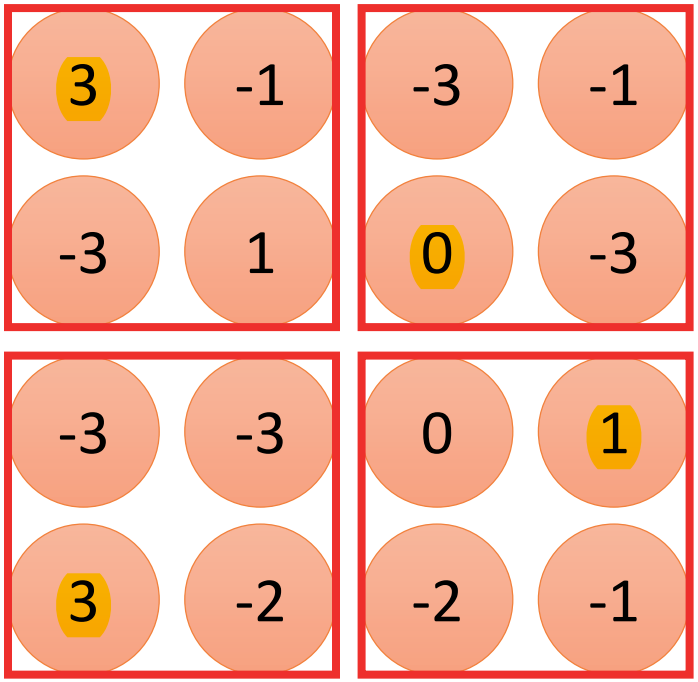
CNN – Max Pooling

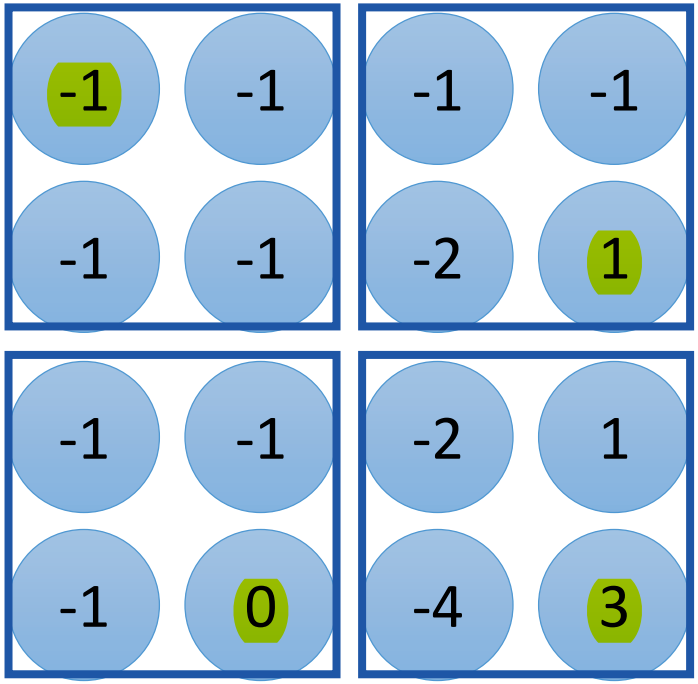
1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

-1	1	-1
-1	1	-1
-1	1	-1

Filter 2

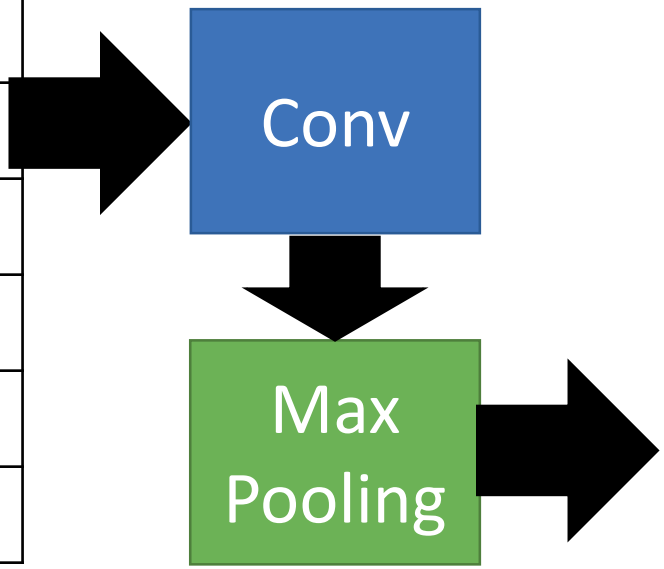




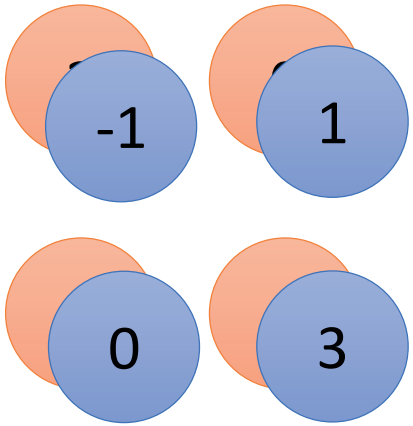
CNN – Max Pooling

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

6 x 6 image



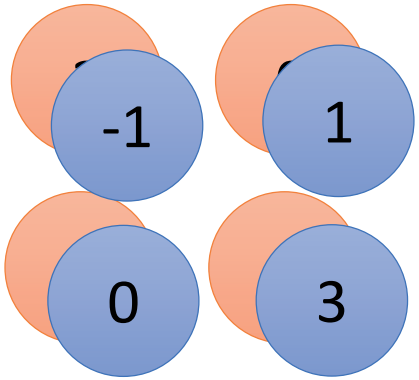
New image but smaller



2 x 2 image

Each filter is a channel

The whole CNN



A new image

Convolution

Max Pooling

Convolution

Max Pooling

Can repeat many times

Smaller than the original image

The number of the channel is the number of filters

The whole CNN

cat dog ……

Convolution

Max Pooling

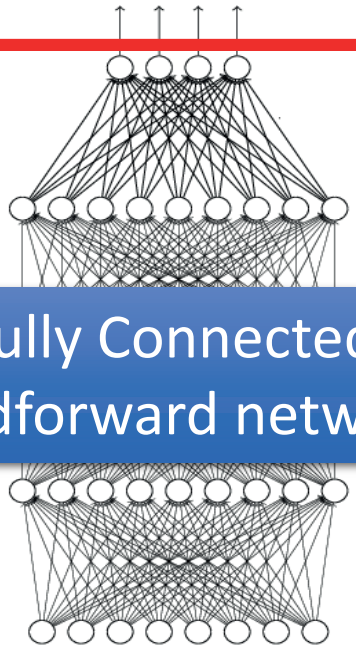
A new image

Convolution

Max Pooling

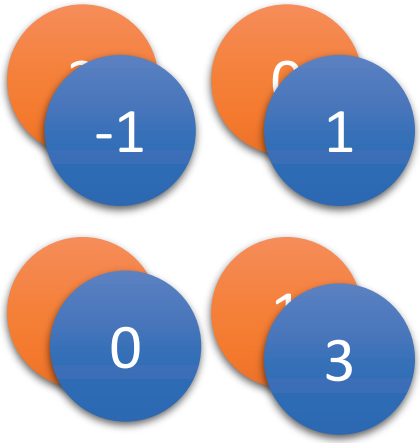
A new image

Flatten

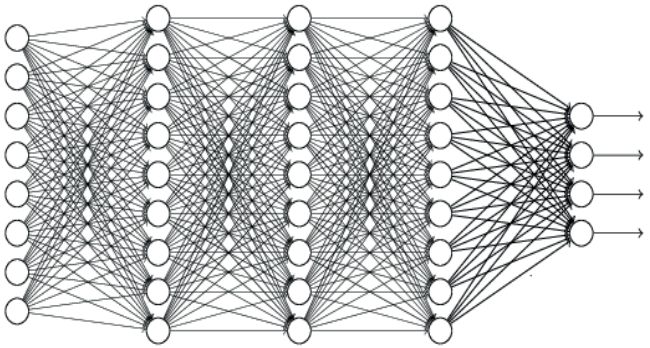


Fully Connected Feedforward network

Flatten



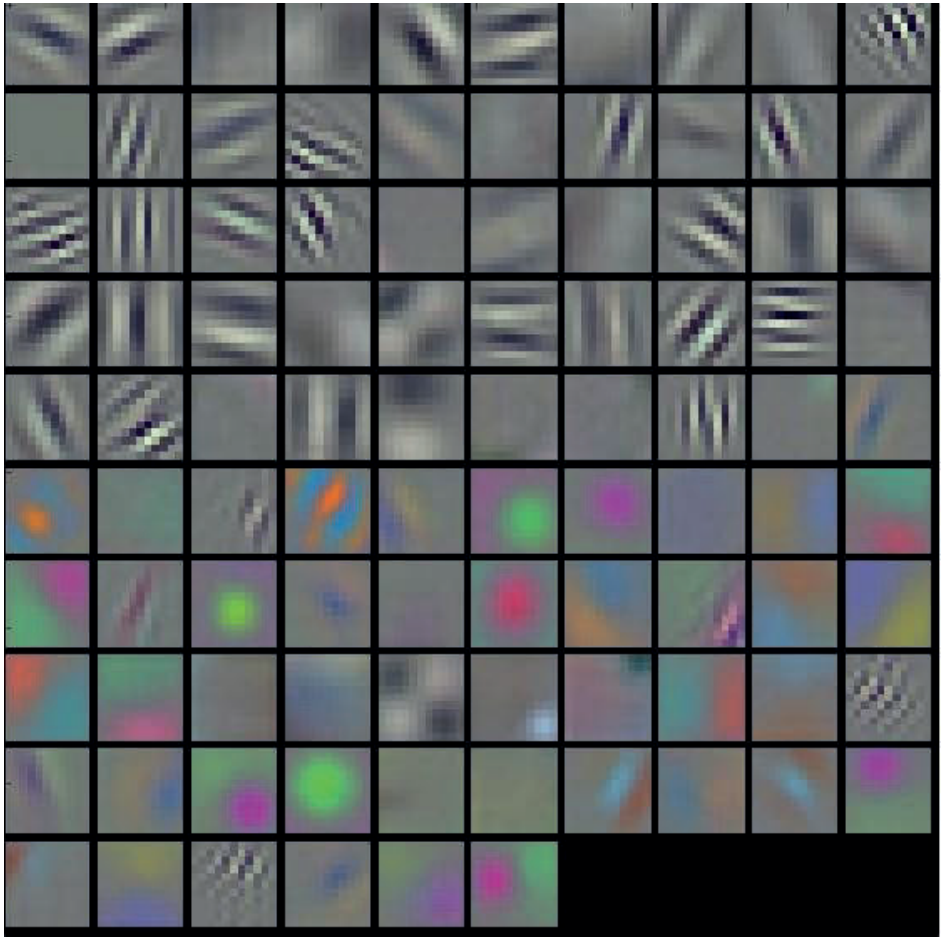
Flatten



Fully Connected Feedforward network

First Convolution Layer

- Typical-looking filters on the trained first layer



11 x 11
(AlexNet)

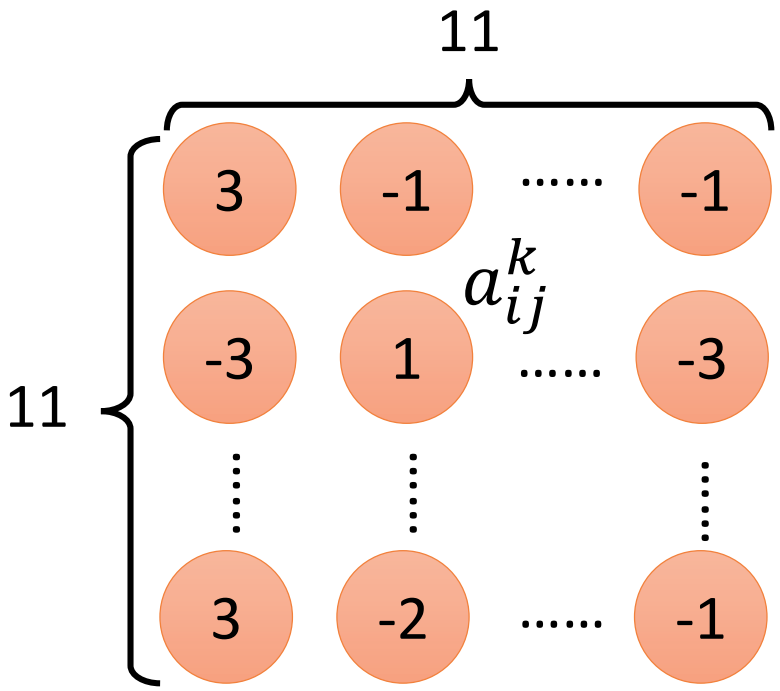
http://cs231n.github.io/understanding-cnn/

What does CNN learn?

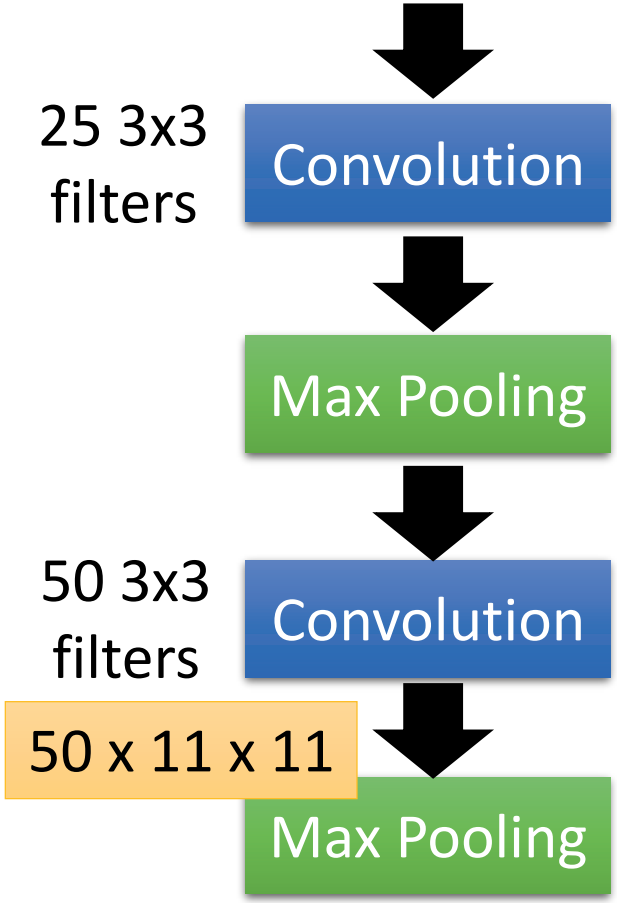
The output of the k-th filter is a 11 x 11 matrix.

Degree of the activation of the k-th filter: $a^k = \sum_{i=1}^{11} \sum_{j=1}^{11} a_{ij}^k$

$x^* = arg \max_x a^k$ (gradient ascent)



$\frac{\partial a^k}{\partial x_{ij}}$ x input



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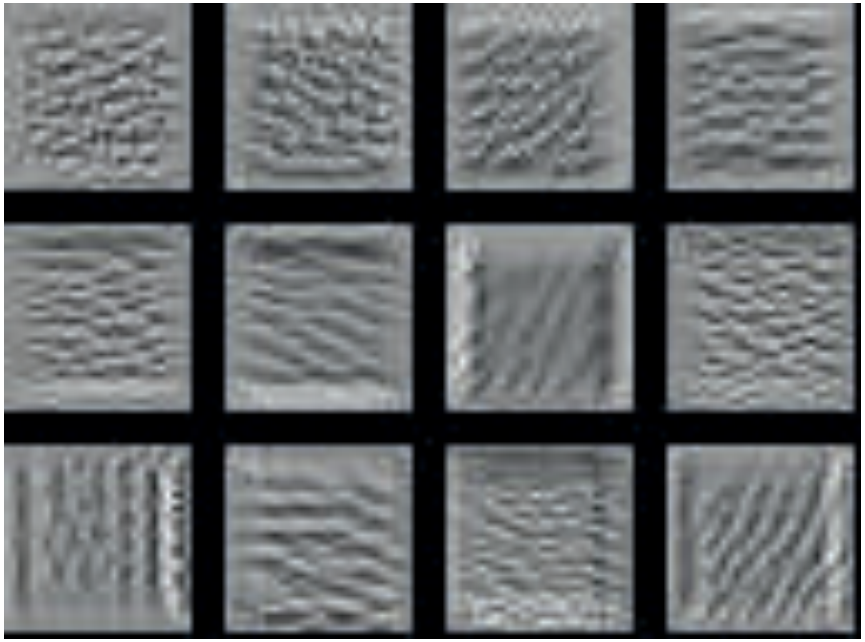
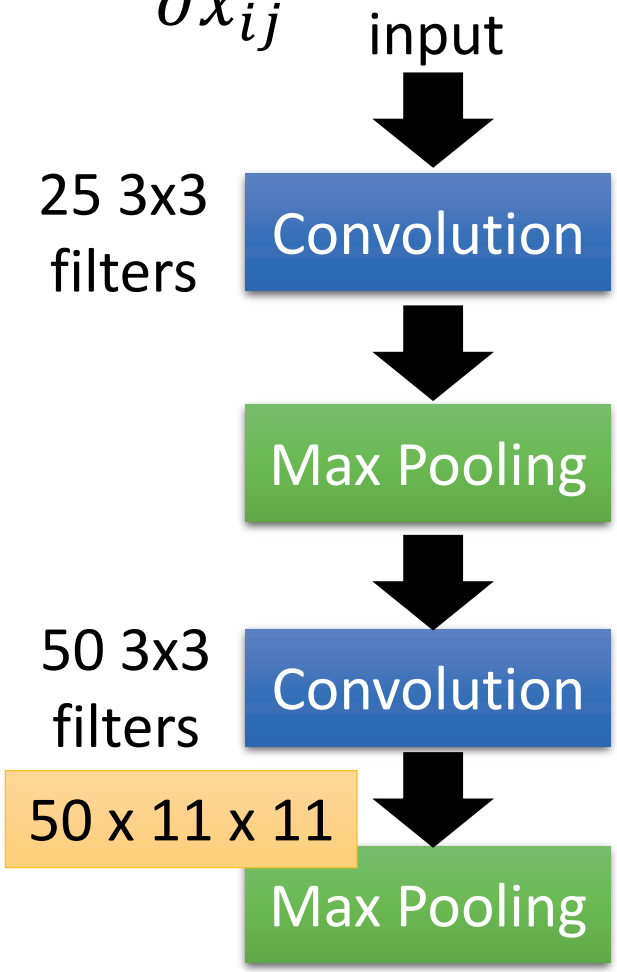


$\frac{\partial a^k}{\partial x_{ij}}$

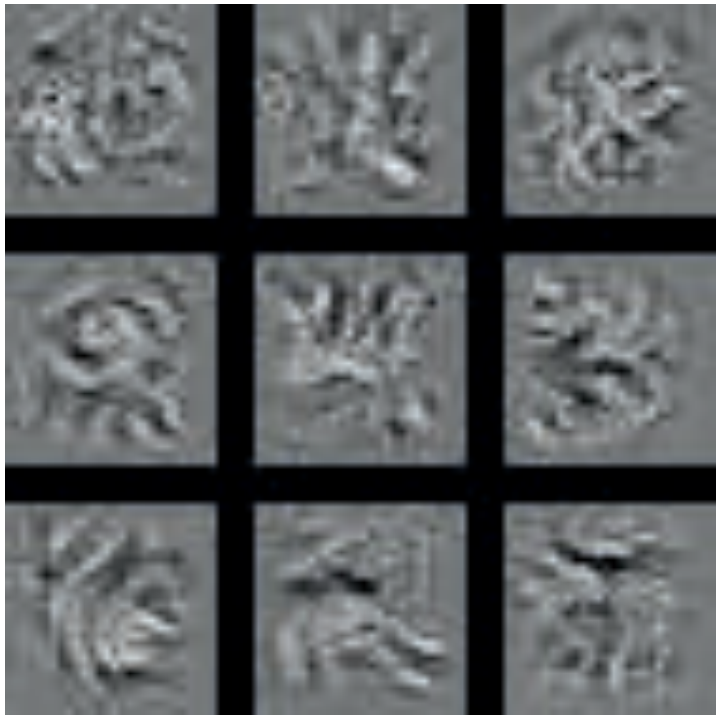


For each filter

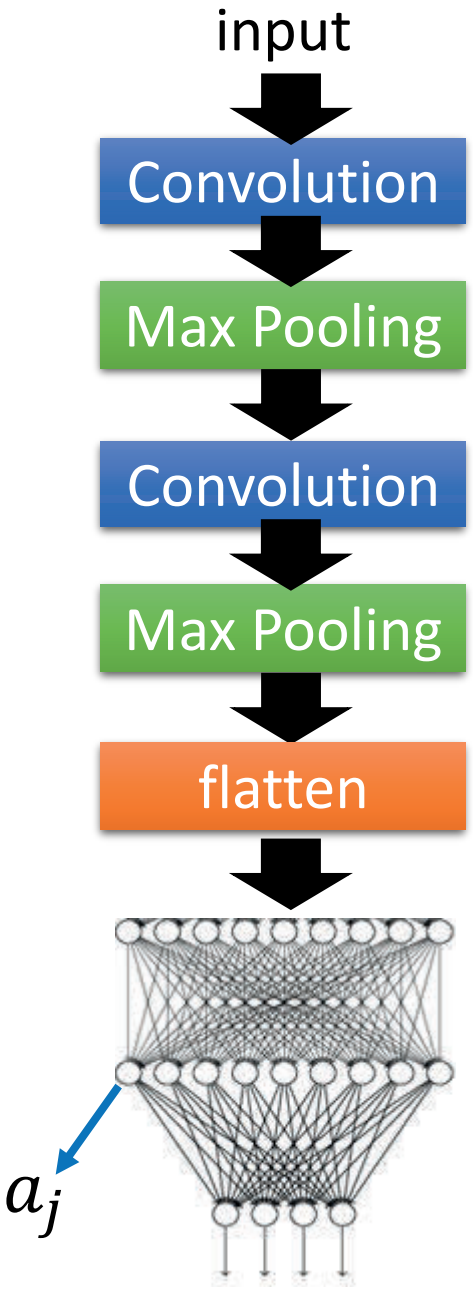
What does CNN learn?

Find an image maximizing the output of neuron:

$$x^* = arg \max_x a^j$$



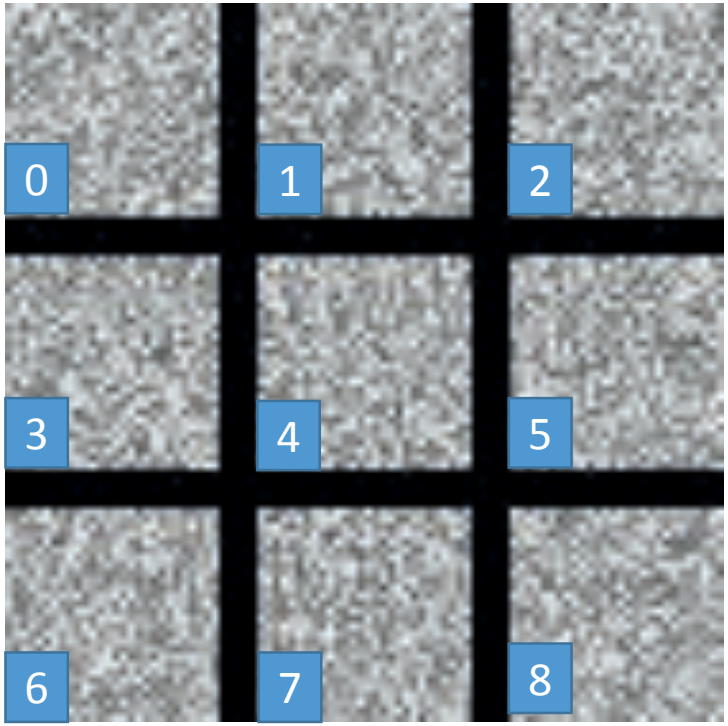
Each figure corresponds to a neuron



What does CNN learn?

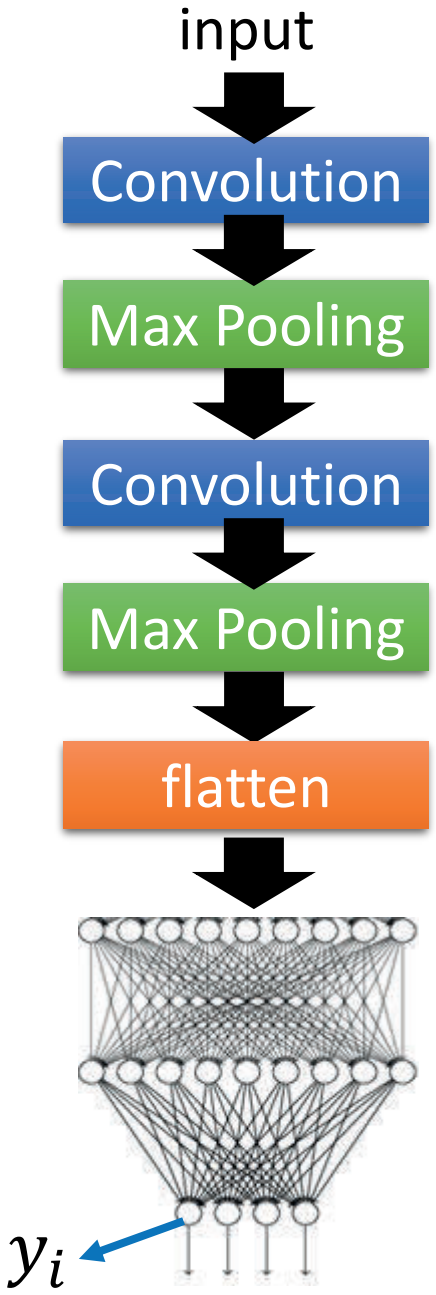
$$x^* = arg \max_x y^i$$

Can we see digits?



Deep Neural Networks are Easily Fooled

https://www.youtube.com/watch?v=M2IebCN9Ht4

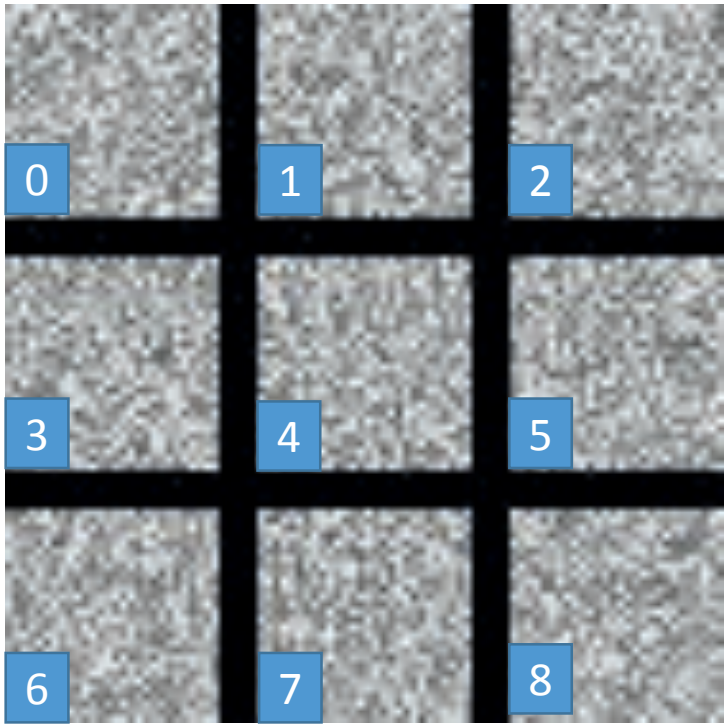


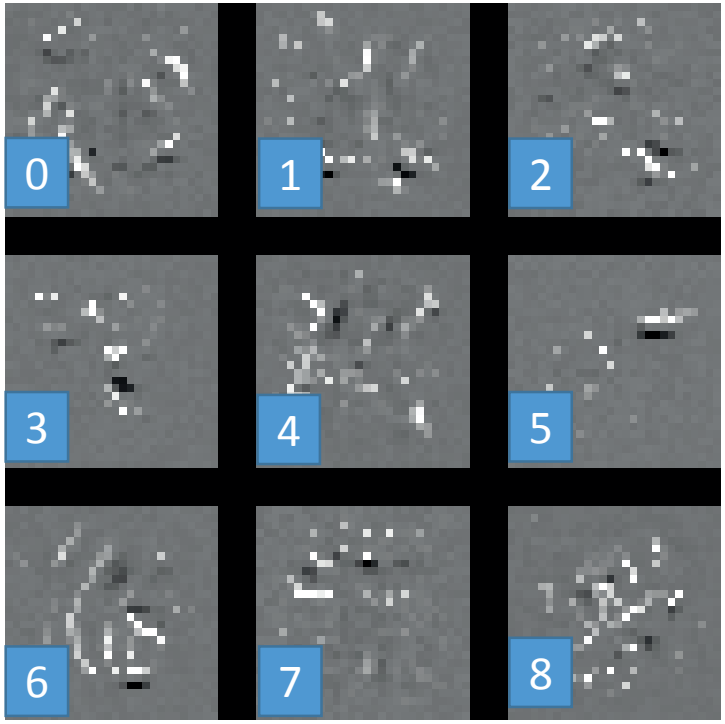
What does CNN learn?

$$x^* = arg\max_x y^i$$

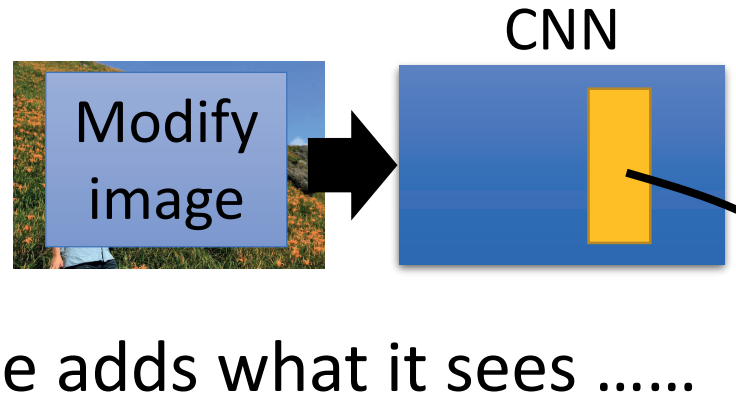
Over all pixel values

$$x^* = arg\max_x \left(y^i - \sum_{i,j} |x_{ij}| \right)$$

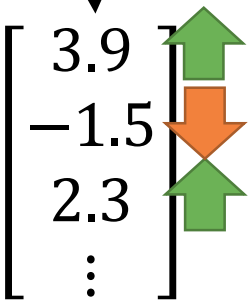




Deep Dream



- Given a photo, machine adds what it sees ……



http://deepdreamgenerator.com/

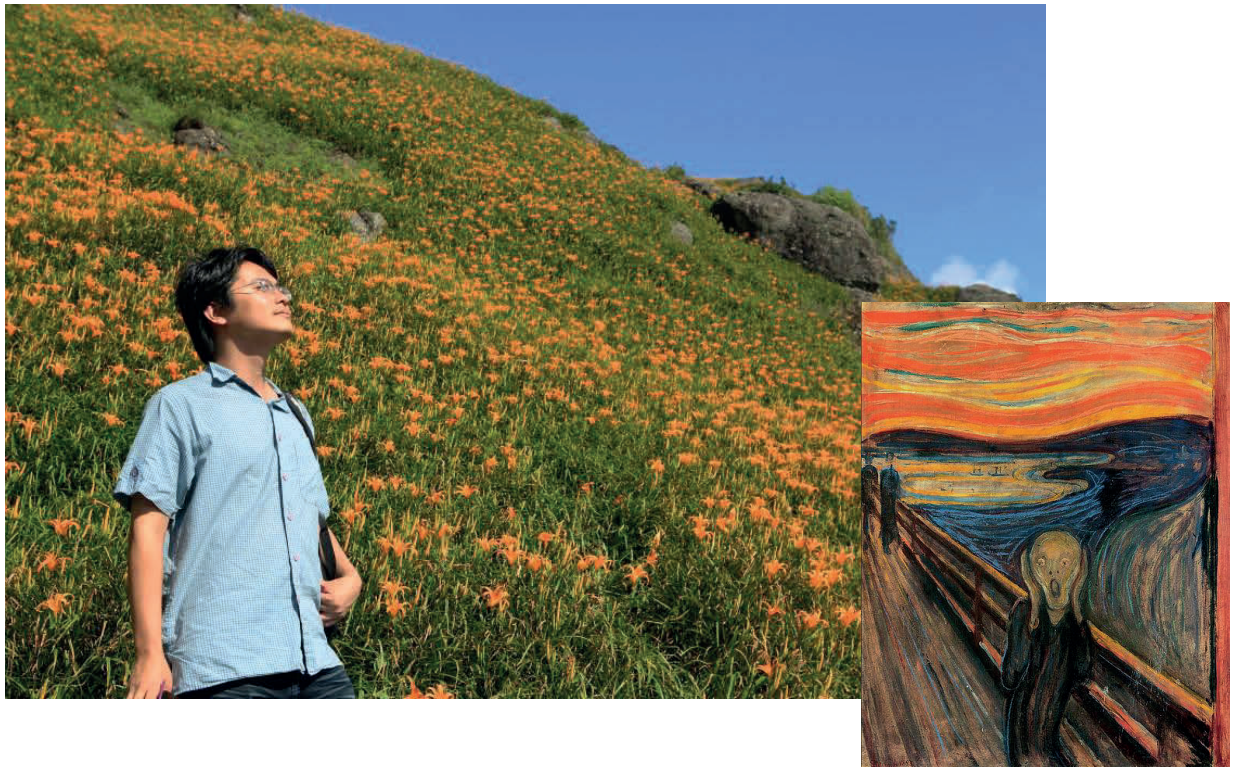
Deep Dream

- Given a photo, machine adds what it sees ……

http://deepdreamgenerator.com/

Deep Style

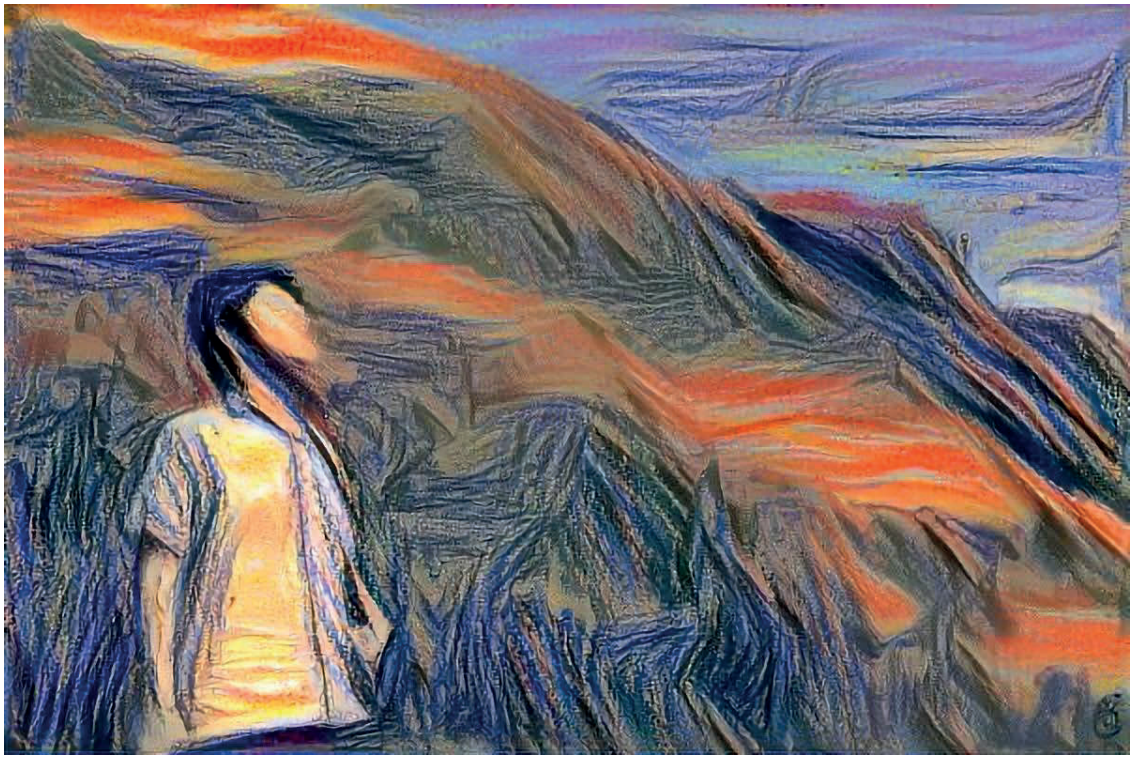
- Given a photo, make its style like famous paintings



https://dreamscopeapp.com/

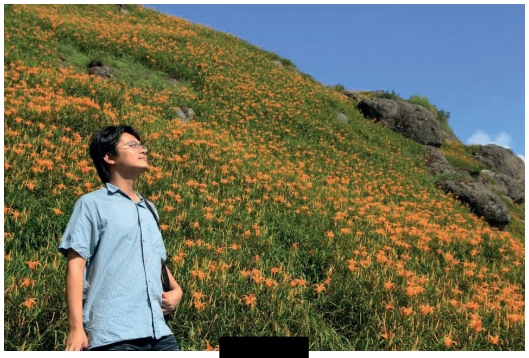
Deep Style

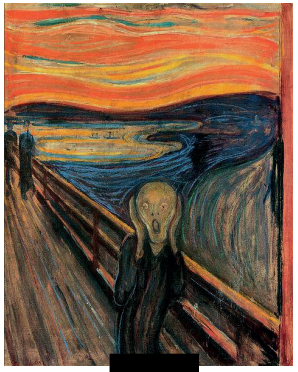
- Given a photo, make its style like famous paintings



https://dreamscopeapp.com/

Deep Style





CNN

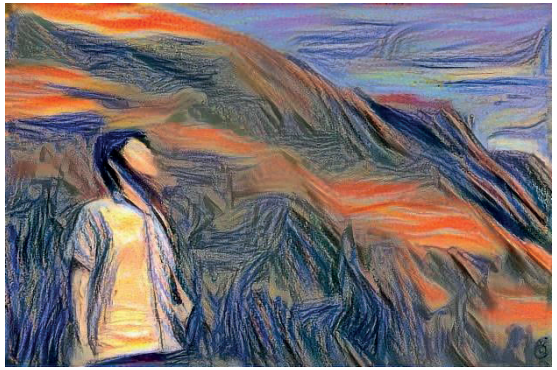
CNN

content

style

A Neural Algorithm of Artistic Style

https://arxiv.org/abs/1508.06576



CNN

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谢谢大家本学期的坚持和支持！

12月24日下午1:30 **Final Review**