From Human Vision to Computer Vision: Rolling in the deep with an image

ICGEB

सत्यमेव जयते
DEPARTMENT OF BIOTECHNOLOGY
GOVERNMENT OF INDIA

Submitted By :

Nimisha Tiwari

Project Associate

Translational Bioinformatics Group

ICGEB, New Delhi

Email: nimisha@icgeb.res.in

Content

- What is an Image, how does a computer perceives it?
- Intro Google Colab.
- Image Preprocessing.
- The algorithmic story of Convolution Neural Network.
- CNN architecture Models : Transfer Learning For Image Classification

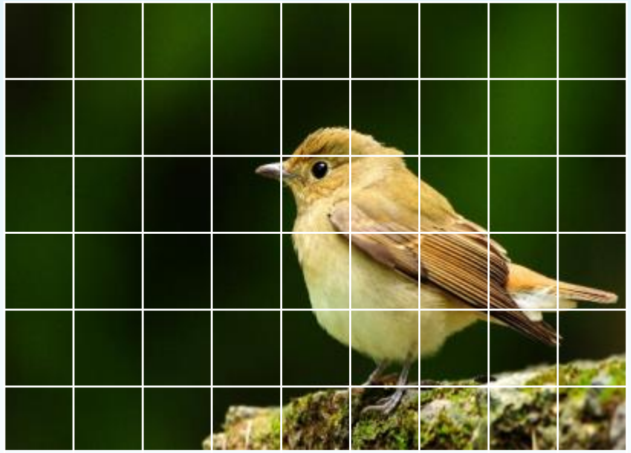
What is an Image ?

{What is difference in the vision of a human and a computer}

What a human sees

What a computer sees

Color/RGB Image



6x9 pixels

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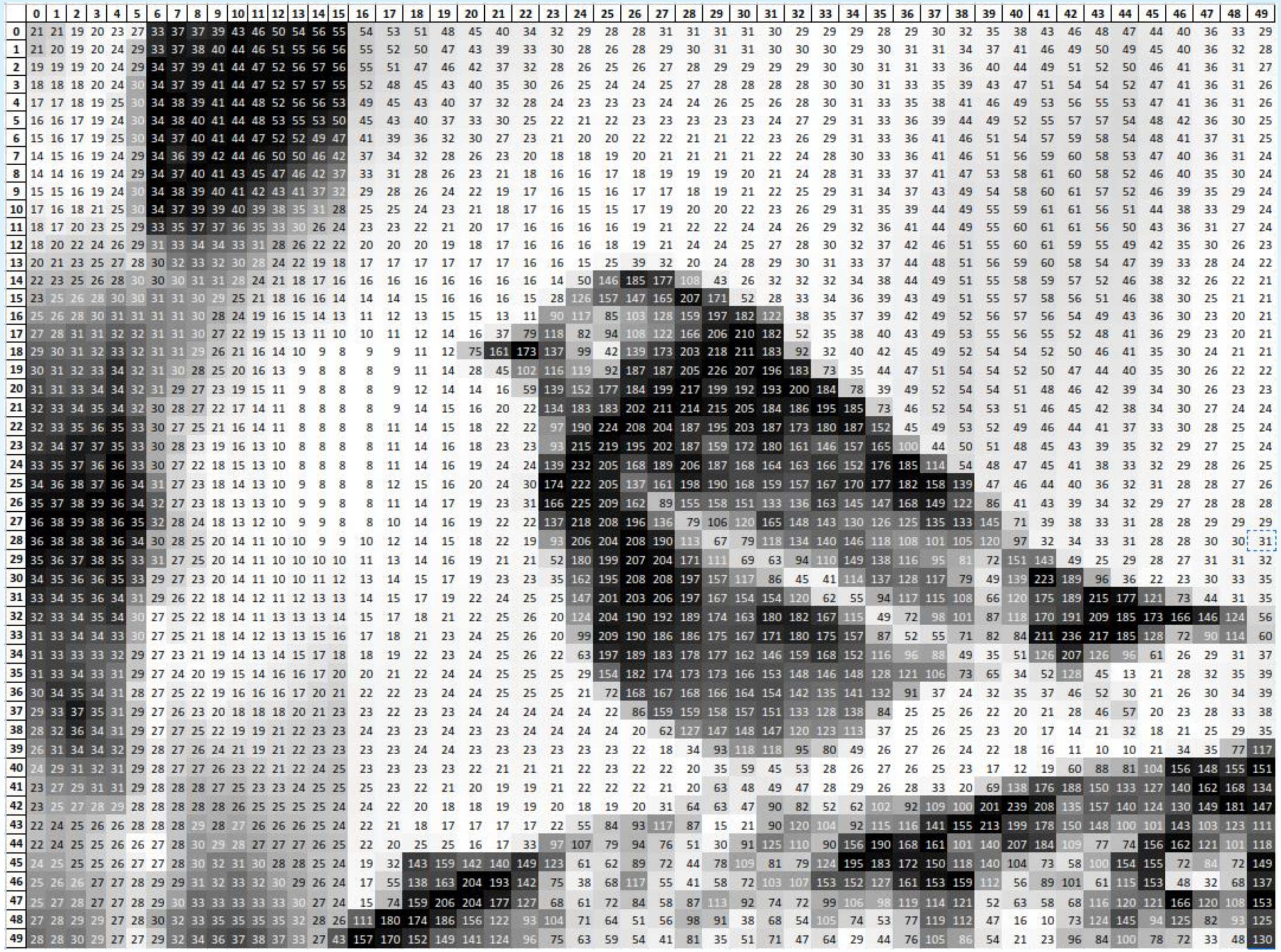
32	30	27	31	99	75	64	48	33
31	32	29	30	45	68	54	50	36
30	31	30	52	48	54	55	56	58

- 256 pixels
- 0 – 255
- Black - 0
- White - 255



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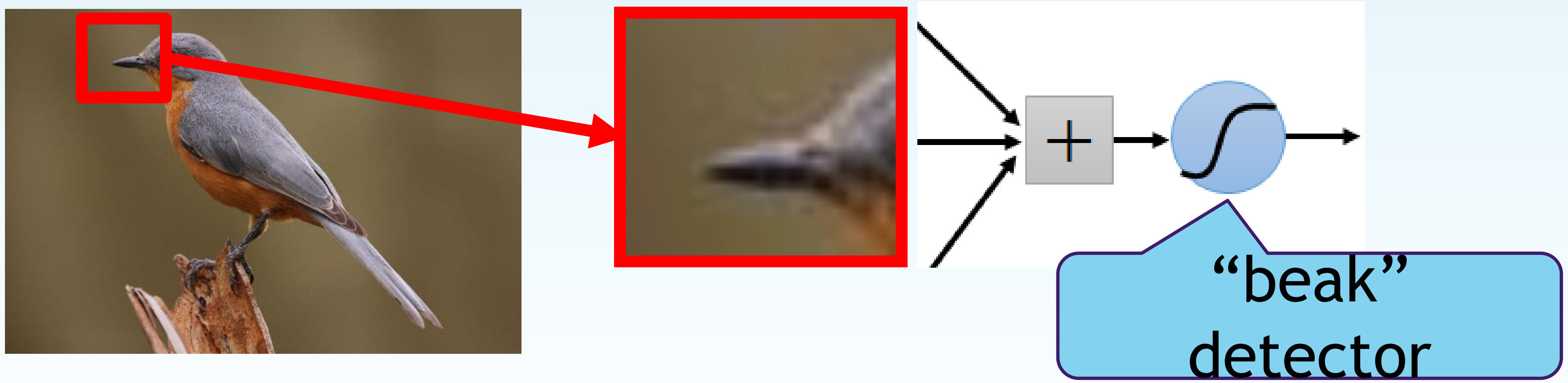
Consider learning an image:

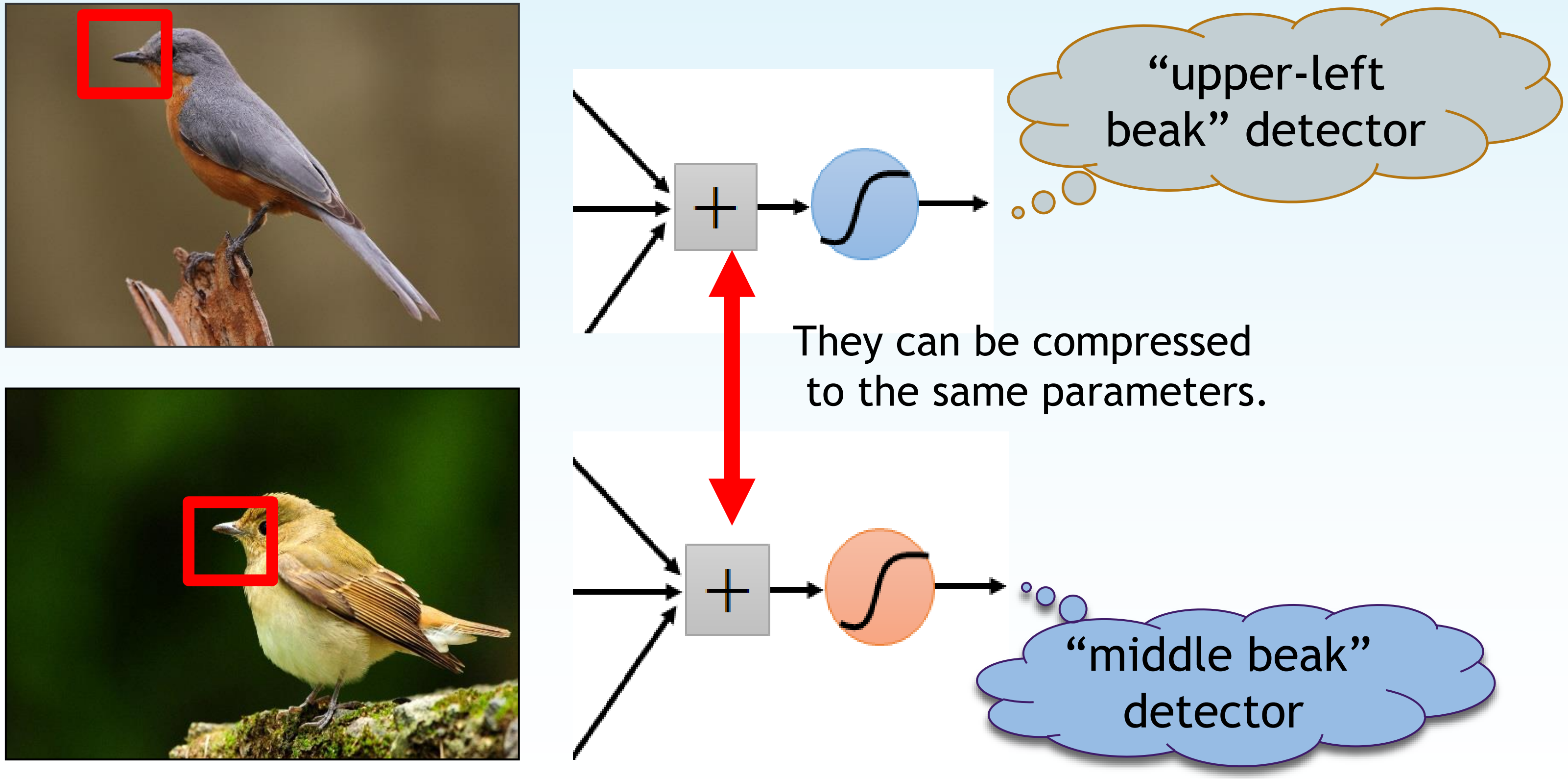
- Some patterns are much smaller than the whole image

Can represent a small region with fewer parameters



“beak” detector

Same pattern appears in different places:
They can be compressed!
What about training a lot of such “small” detectors
and each detector must “move around”.



“upper-left beak” detector

They can be compressed to the same parameters.

“middle beak” detector

Convolution Neural Network

- Deep learning explores the possibility of learning features directly from input data, avoiding hand-crafted features.

- A deep net is trained by feeding it input and letting it compute layer-by-layer to generate the final output for comparison with the correct answer.

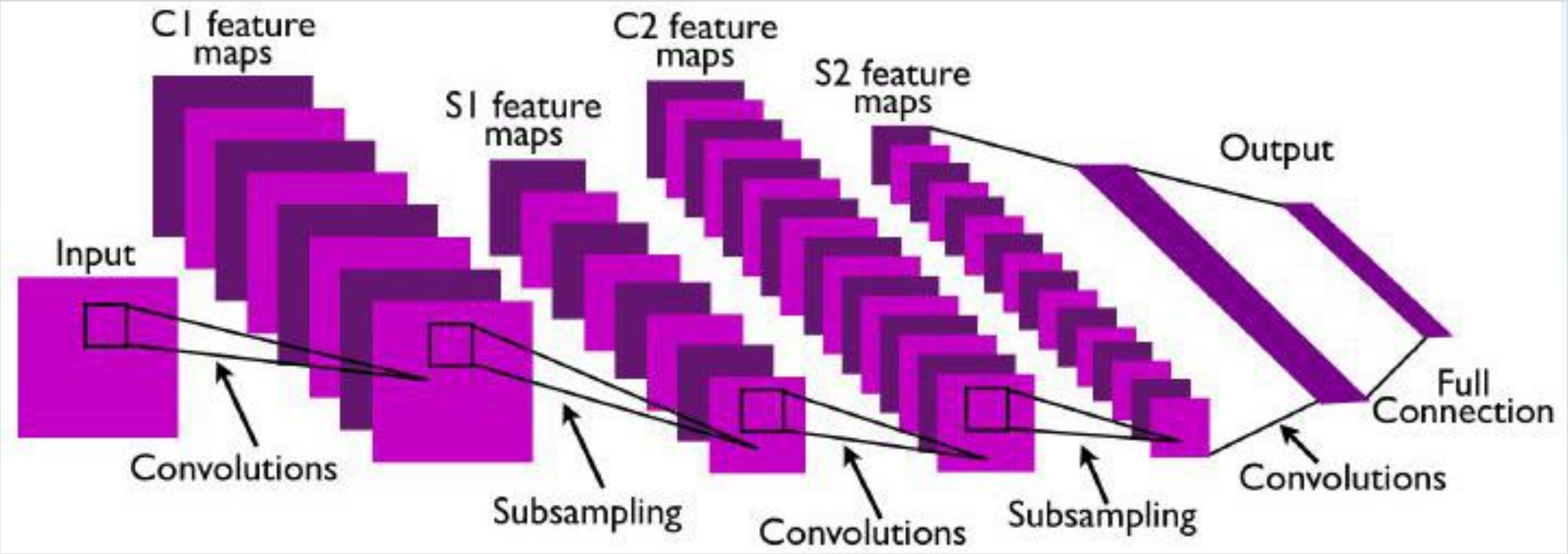
- After computing the error at the output, this error flows backward through the net by backpropagation.

- At each step backward the model parameters are tuned in a direction that tries to reduce the error.

- helps in model improvement, training is an iterative process that involves multiple passes of the input data until the model converges.

Convolution Neural Network: CNN

- There are three layers used to build CNN architectures:-
  - Convolutional layer,
  - Pooling layer, and
  - Fully connected layer.



Convolution

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

These are the network parameters to be learned

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

Filter 1

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

Filter 2

⋮ ⋮

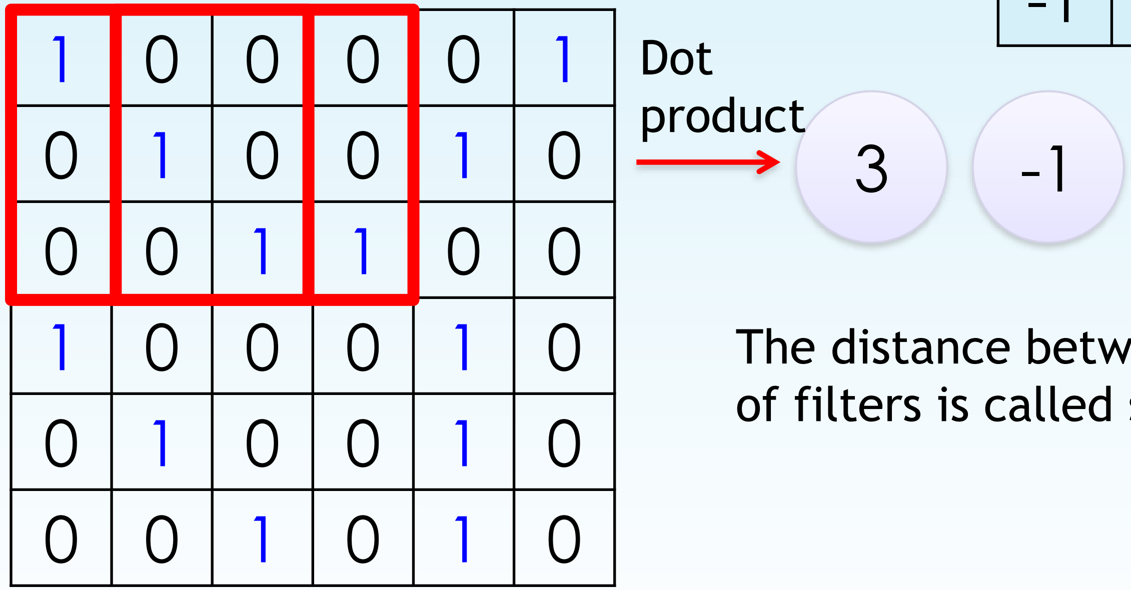
Each filter detects a small pattern (3 x 3).

Convolution

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

Filter 1

stride=1



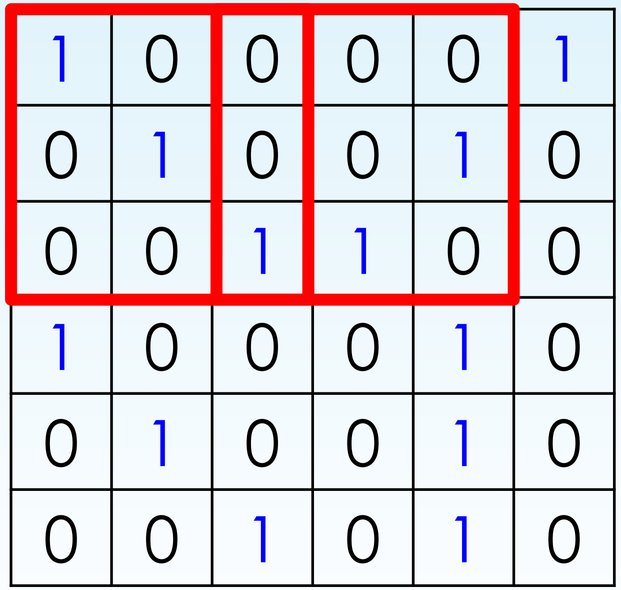
1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

The distance between the applications of filters is called stride.

Convolution

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

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

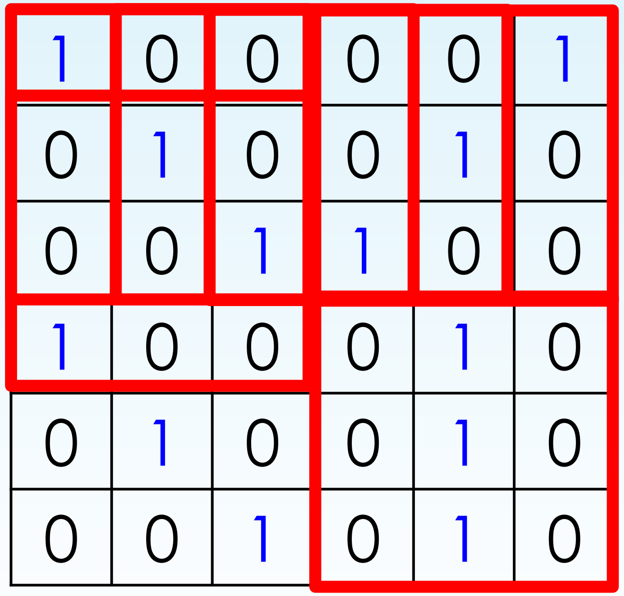
Filter 1

3 -3

Stride hyper parameter is smaller than the filter size the convolution is applied in overlapping windows

Convolution

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

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

Filter 1

3	-1	-3	-1
-3	1	0	-3
-3	-3	0	1
3	-2	-2	-1

Convolution

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

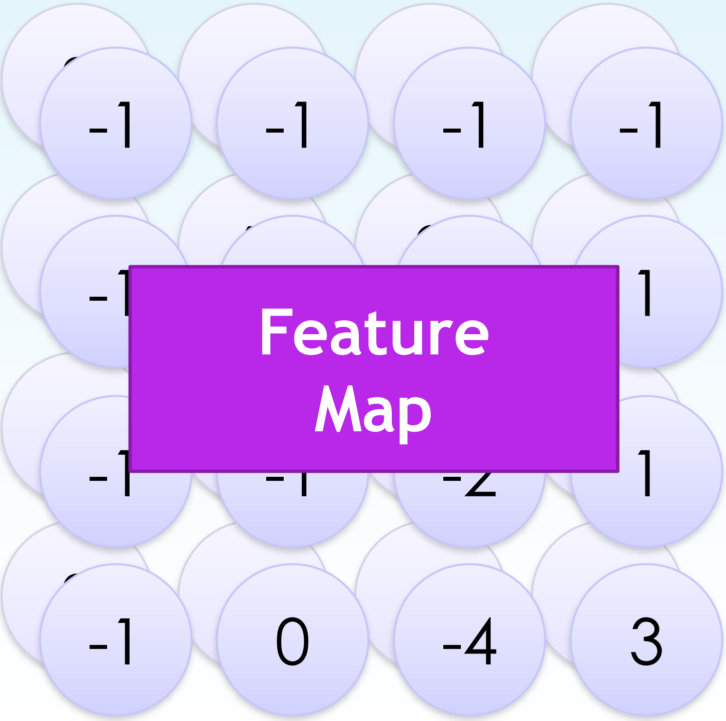
Filter 2

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

Repeat this for each filter



Two 4 x 4 images
Forming 2 x 4 x 4 matrix

Color image: RGB 3 channels

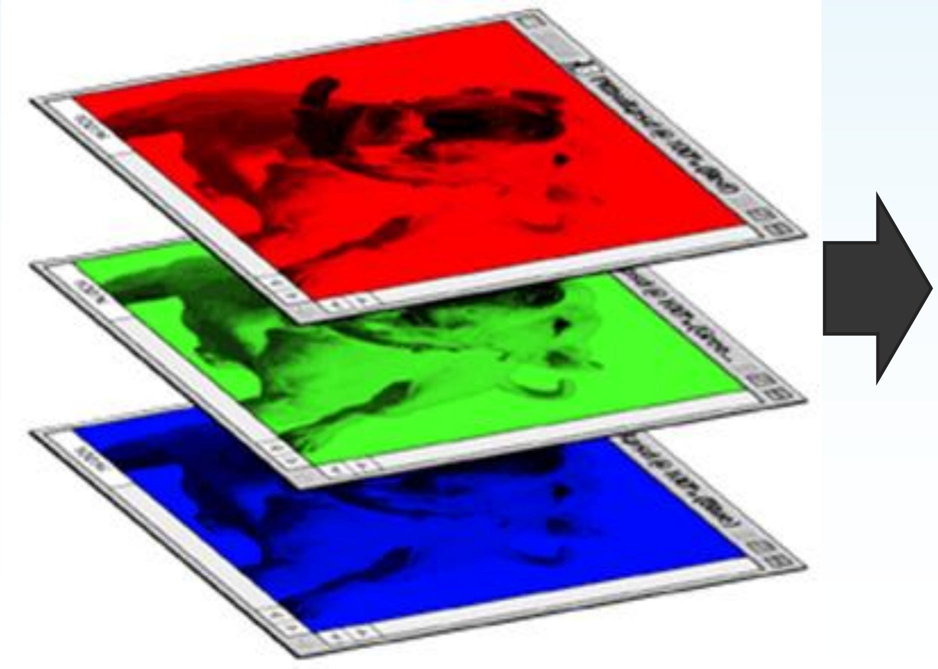
1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

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

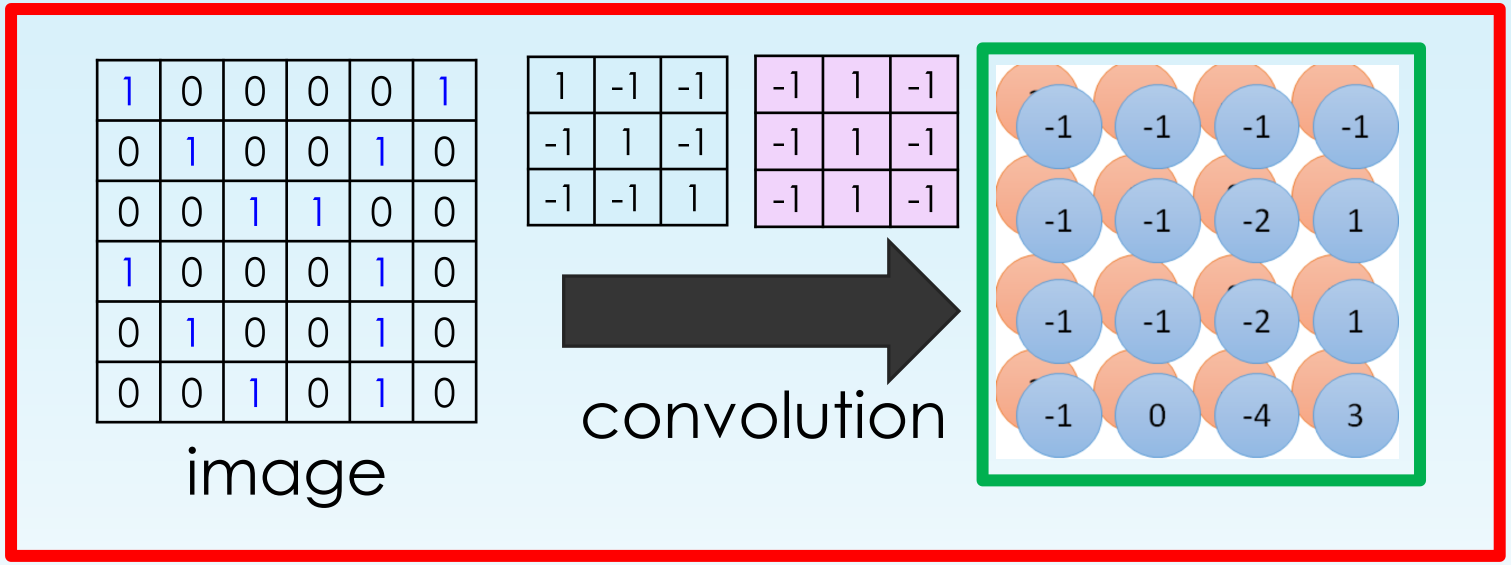
Filter 2

Color 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



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

image

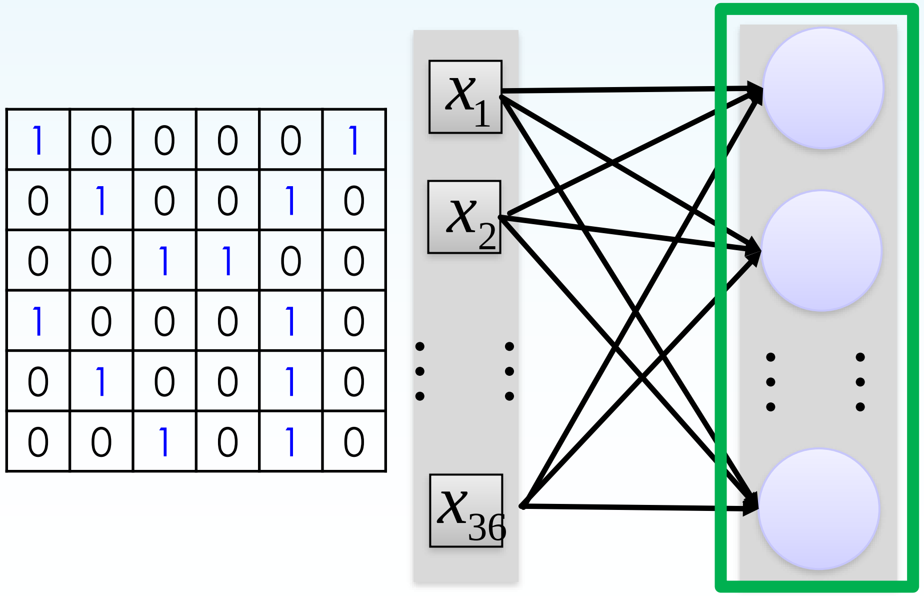
1	-1	-1
-1	1	-1
-1	-1	1

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

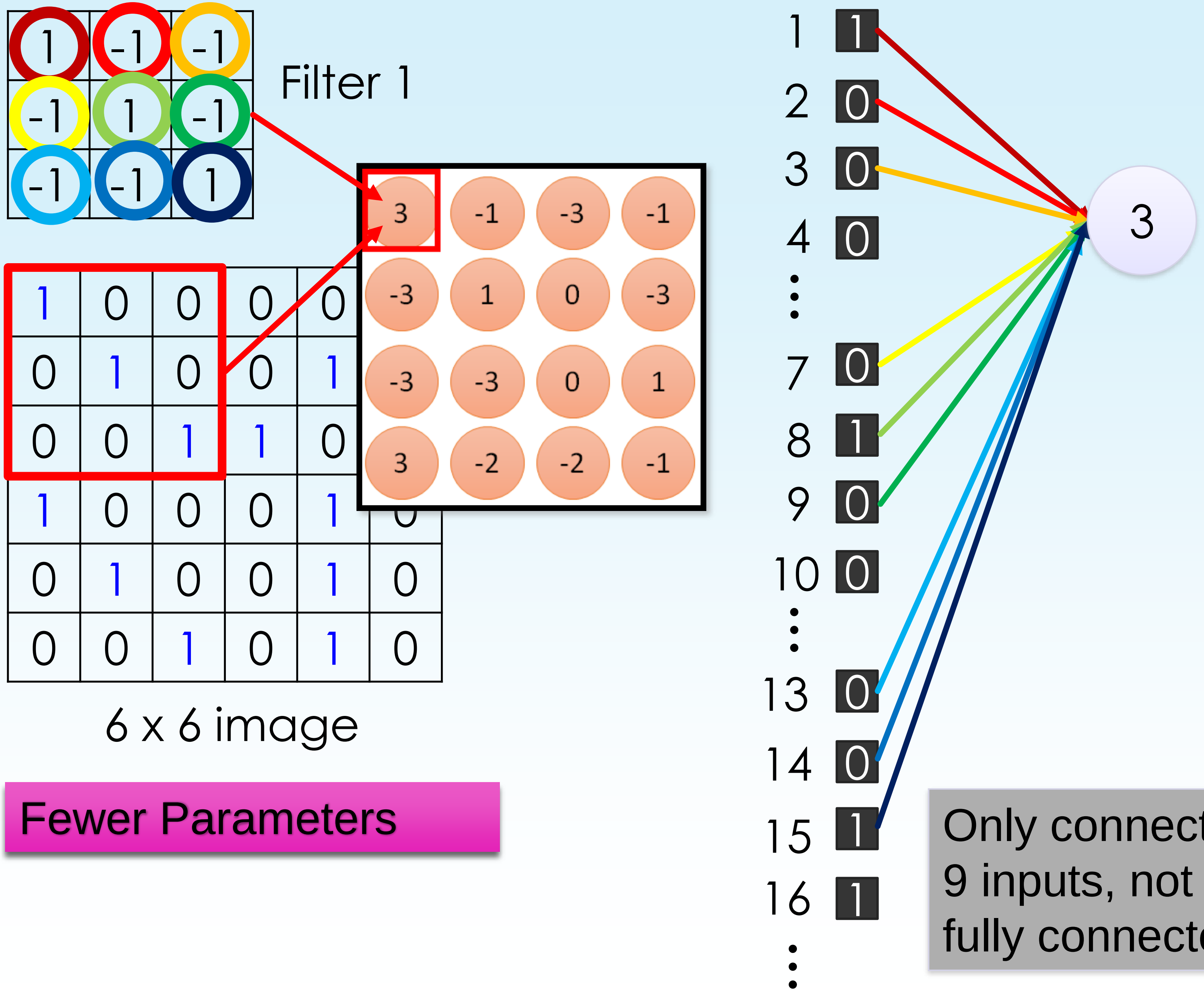
convolution

-1	-1	-1	-1
-1	-1	-2	1
-1	-1	-2	1
-1	0	-4	3

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



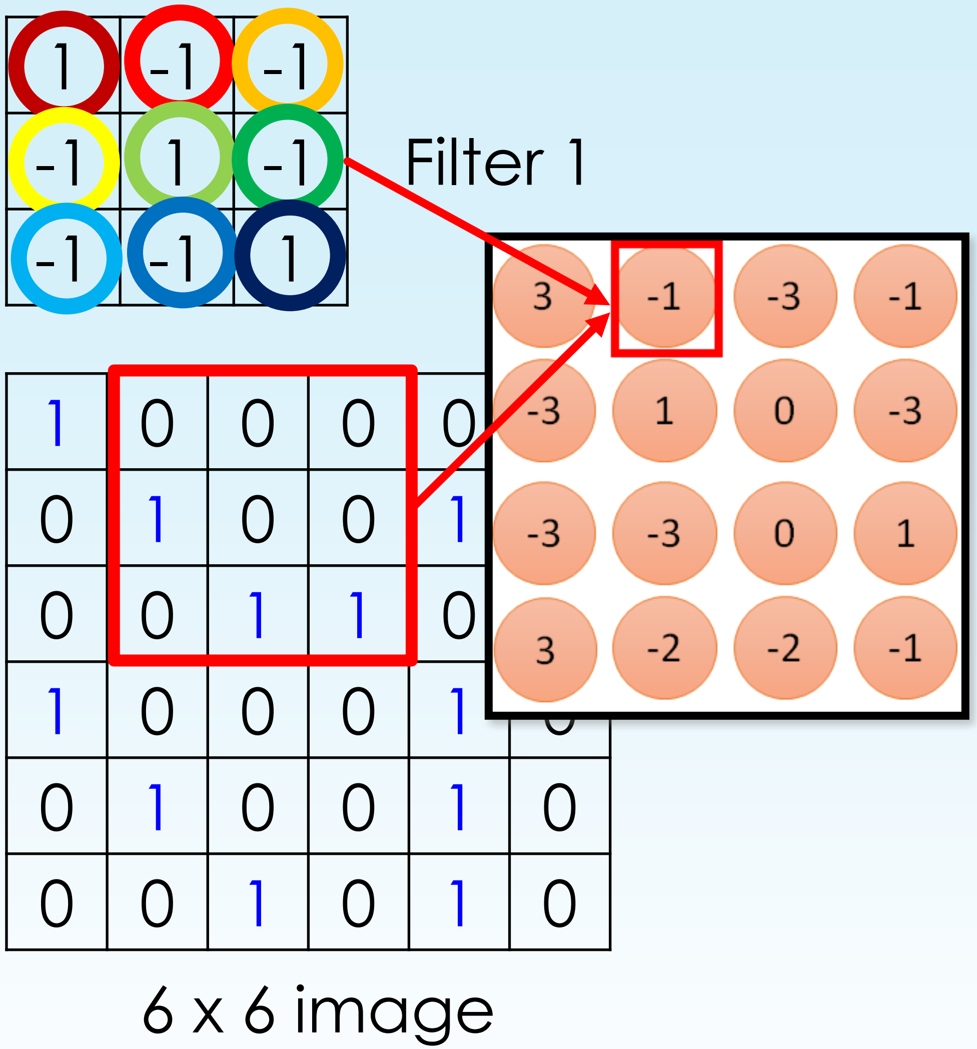
1	-1	-1
-1	1	-1
-1	-1	1

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

3	-1	-3	-1
-3	1	0	-3
-3	-3	0	1
3	-2	-2	-1

Fewer Parameters

Only connect to 9 inputs, not fully connected



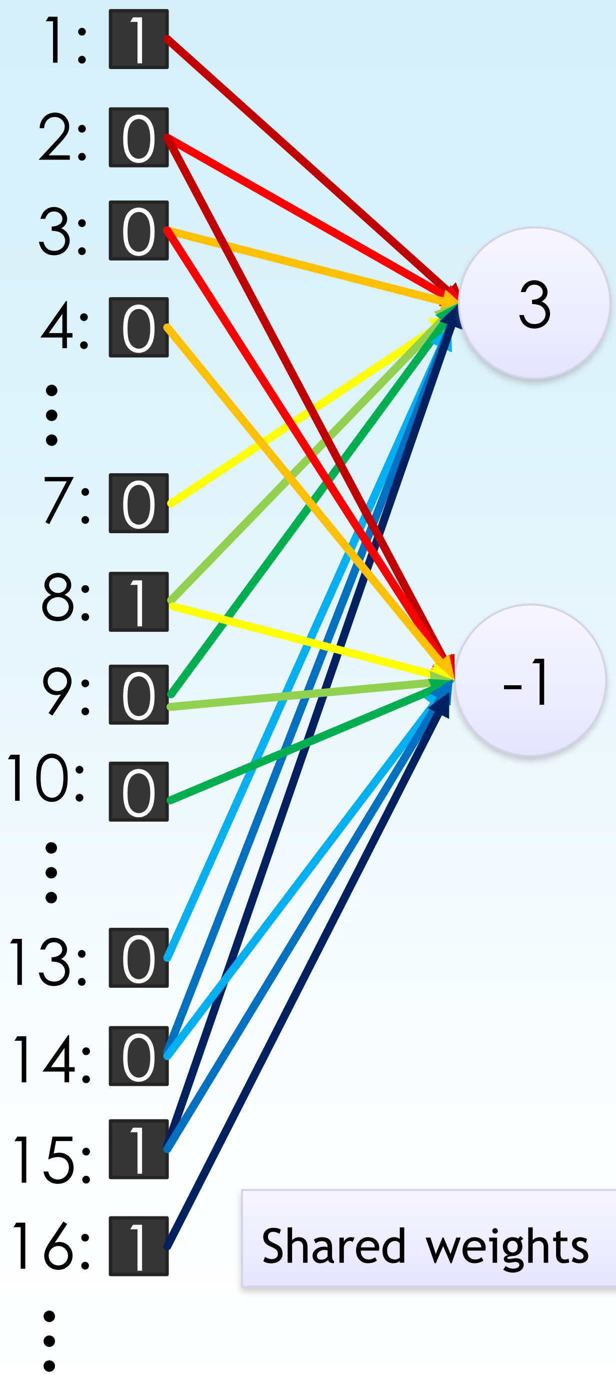
Filter 1

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

3	-1	-3	-1
-3	1	0	-3
-3	-3	0	1
3	-2	-2	-1

6 x 6 image



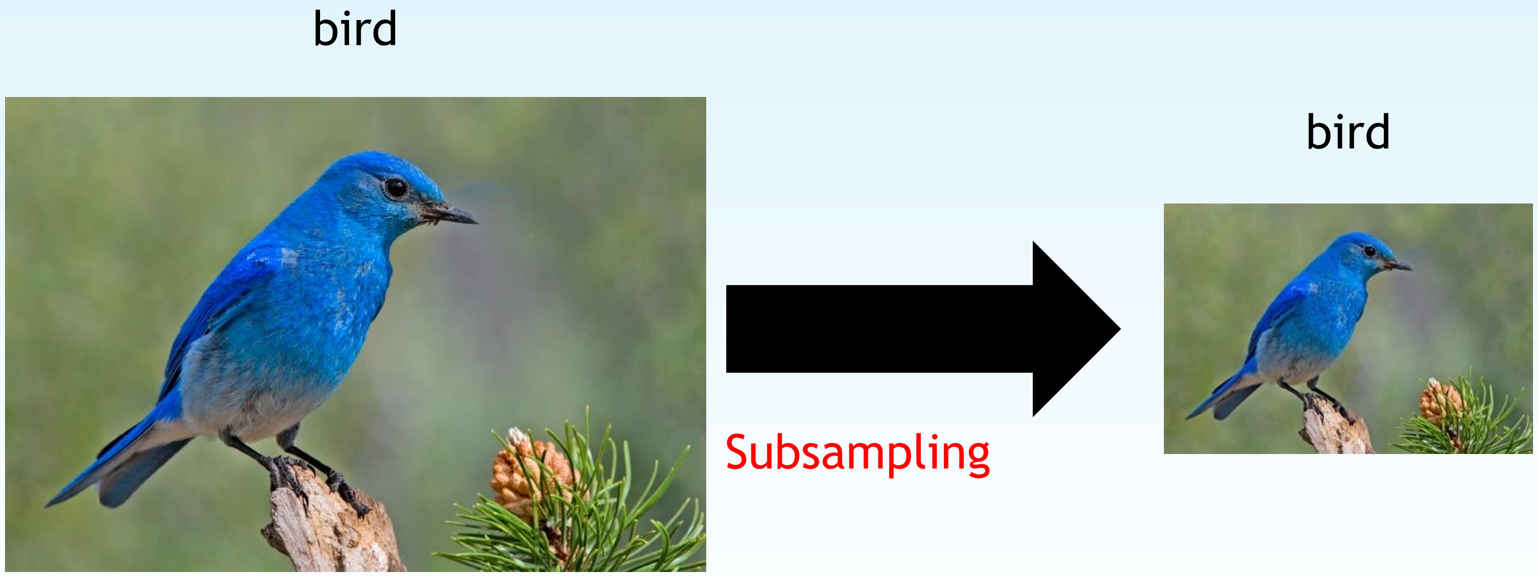
Fewer parameters

Even fewer parameters

Shared weights

Why Pooling

- Subsampling pixels will not change the object



We can subsample the pixels to make image smaller

→ fewer parameters to characterize the image

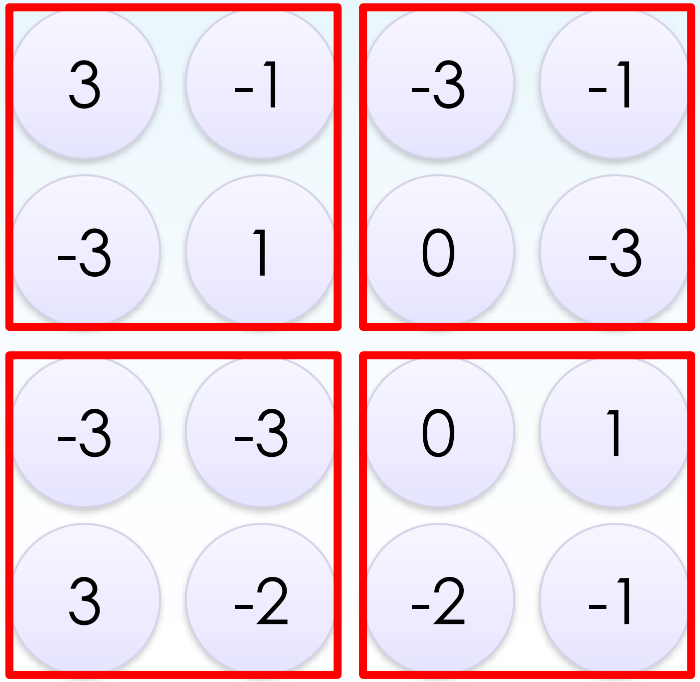
Max Pooling

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

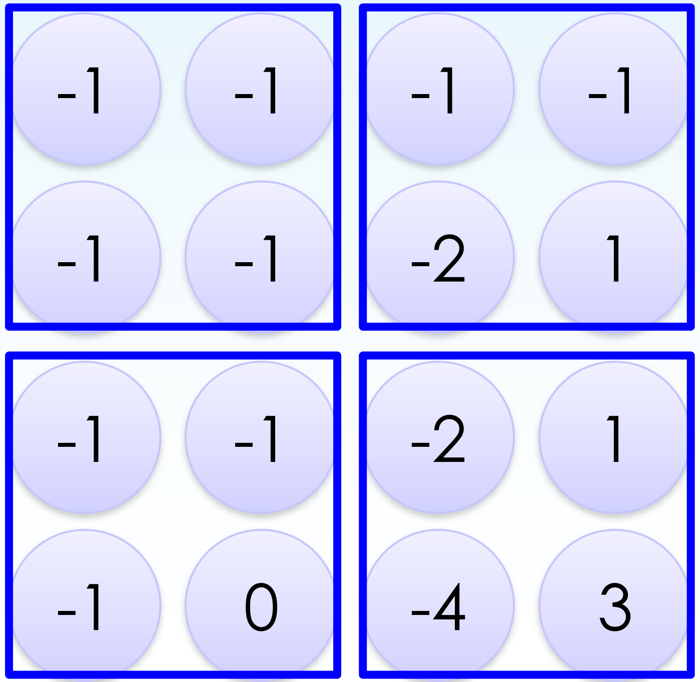
Filter 1

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

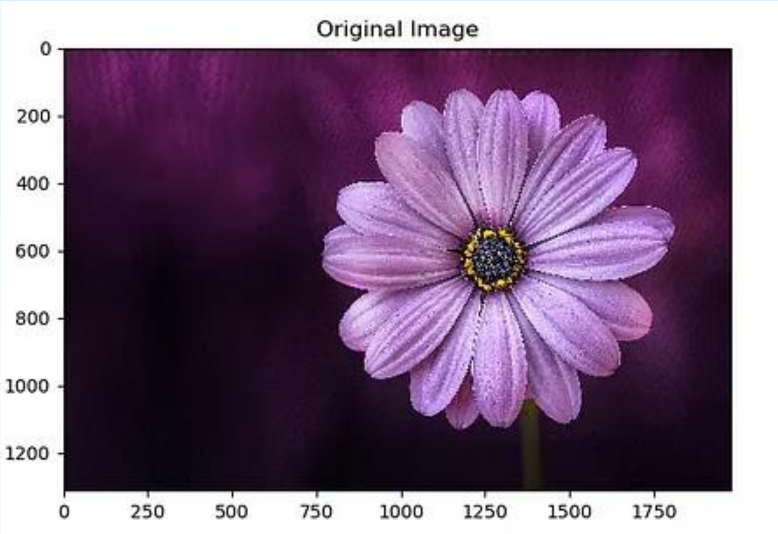
Filter 2

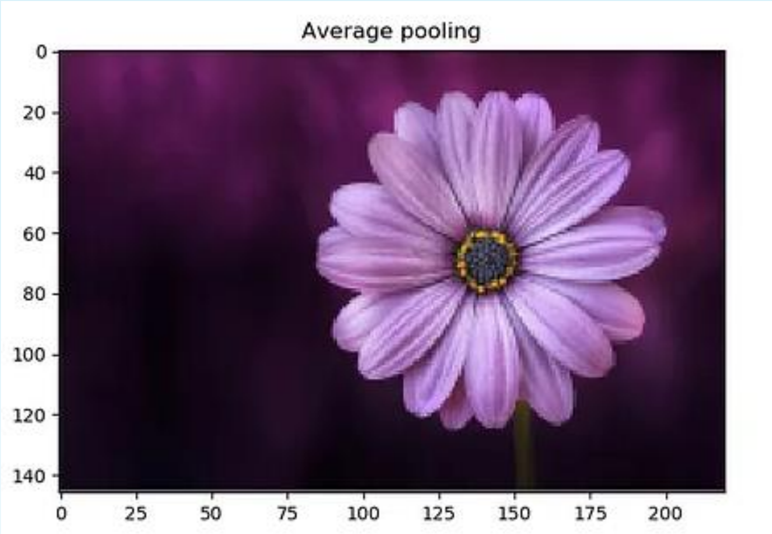


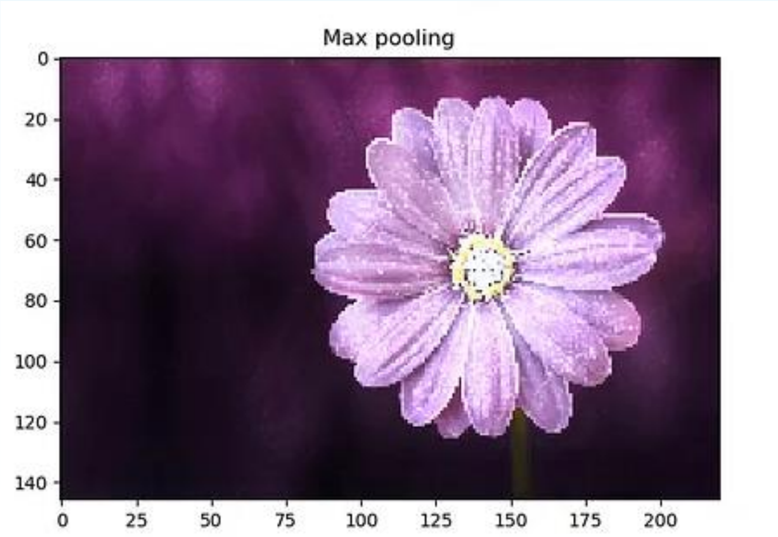
3	-1	-3	-1
-3	1	0	-3
-3	-3	0	1
3	-2	-2	-1

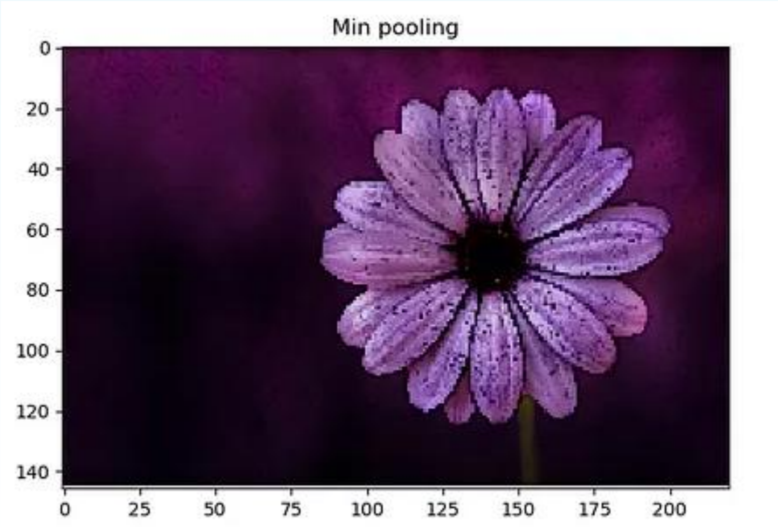


-1	-1	-1	-1
-1	-1	-2	1
-1	-1	-2	1
-1	0	-4	3

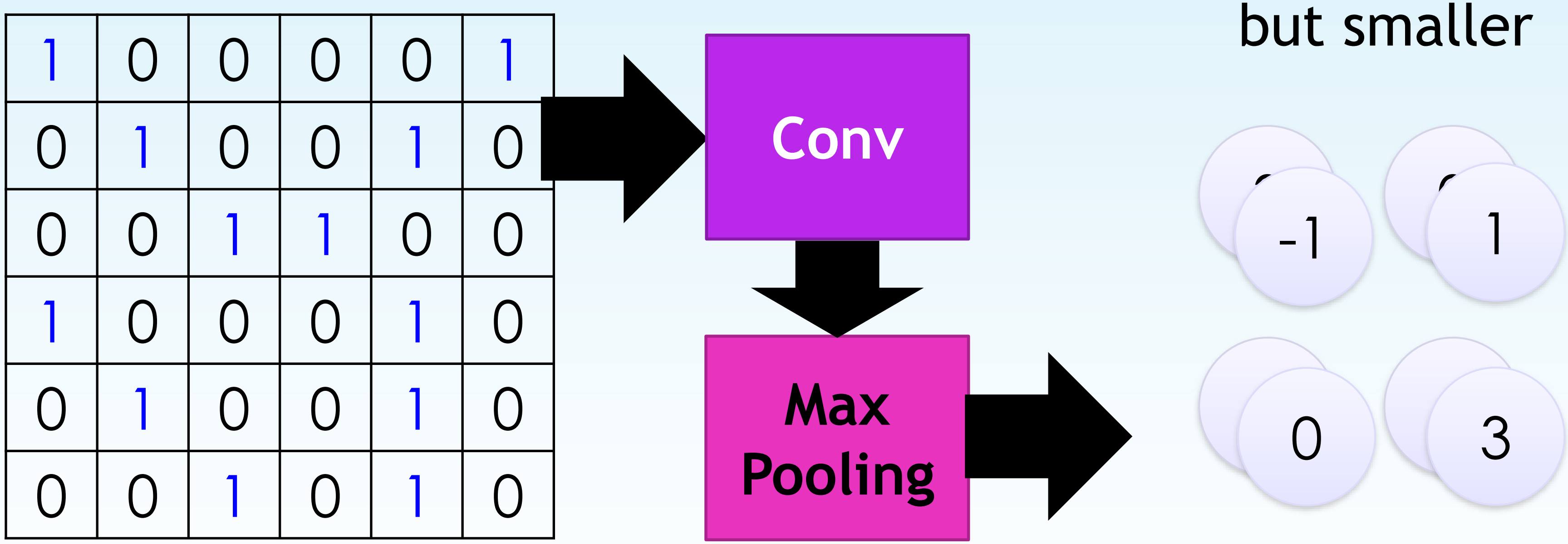

Original Image
0
200
400
600
800
1000
1200
0
250
500
750
1000
1250
1500
1750


Average pooling
0
20
40
60
80
100
120
140
0
25
50
75
100
125
150
175
200


Max pooling
0
20
40
60
80
100
120
140
0
25
50
75
100
125
150
175
200


Min pooling
0
20
40
60
80
100
120
140
0
25
50
75
100
125
150
175
200

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

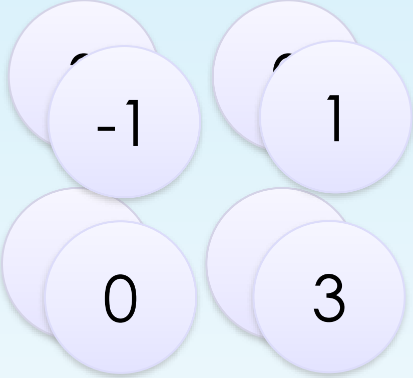
6 x 6 image

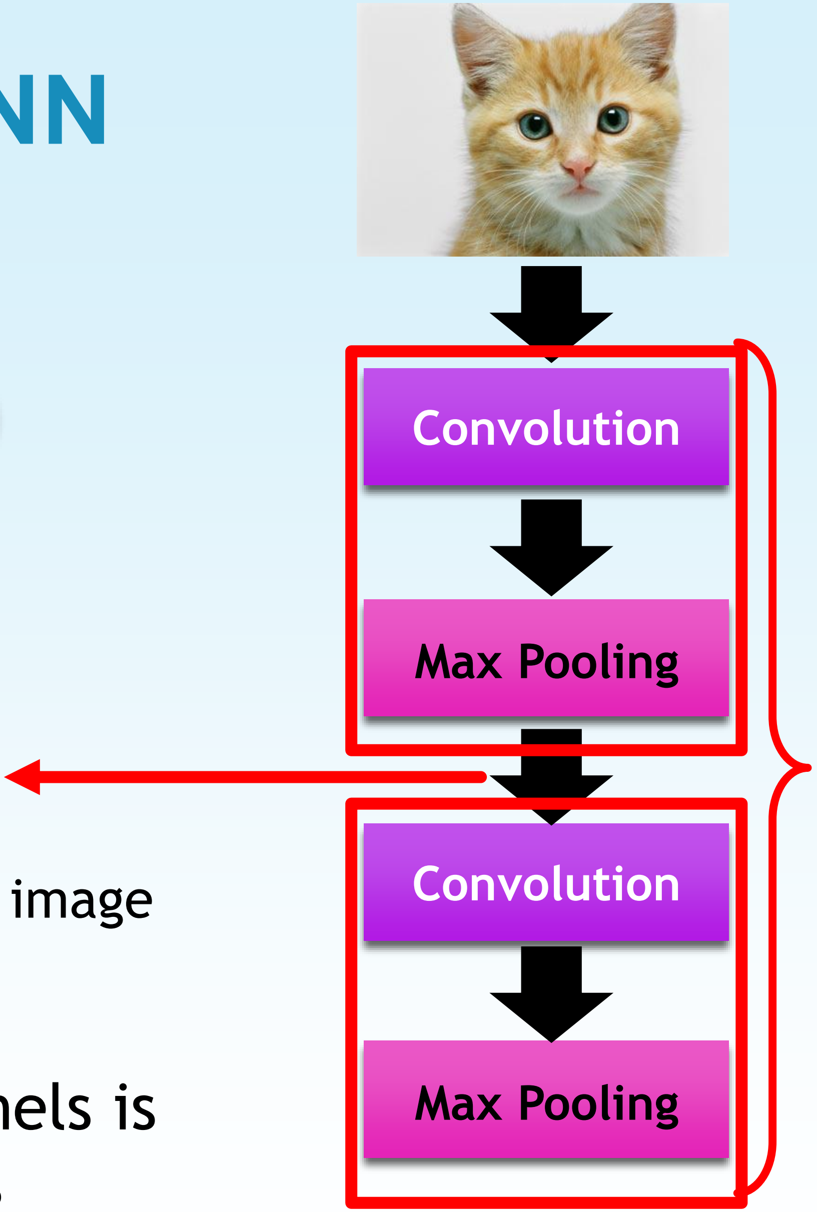
New image
but smaller

2 x 2 image

Each filter
is a channel

The whole CNN





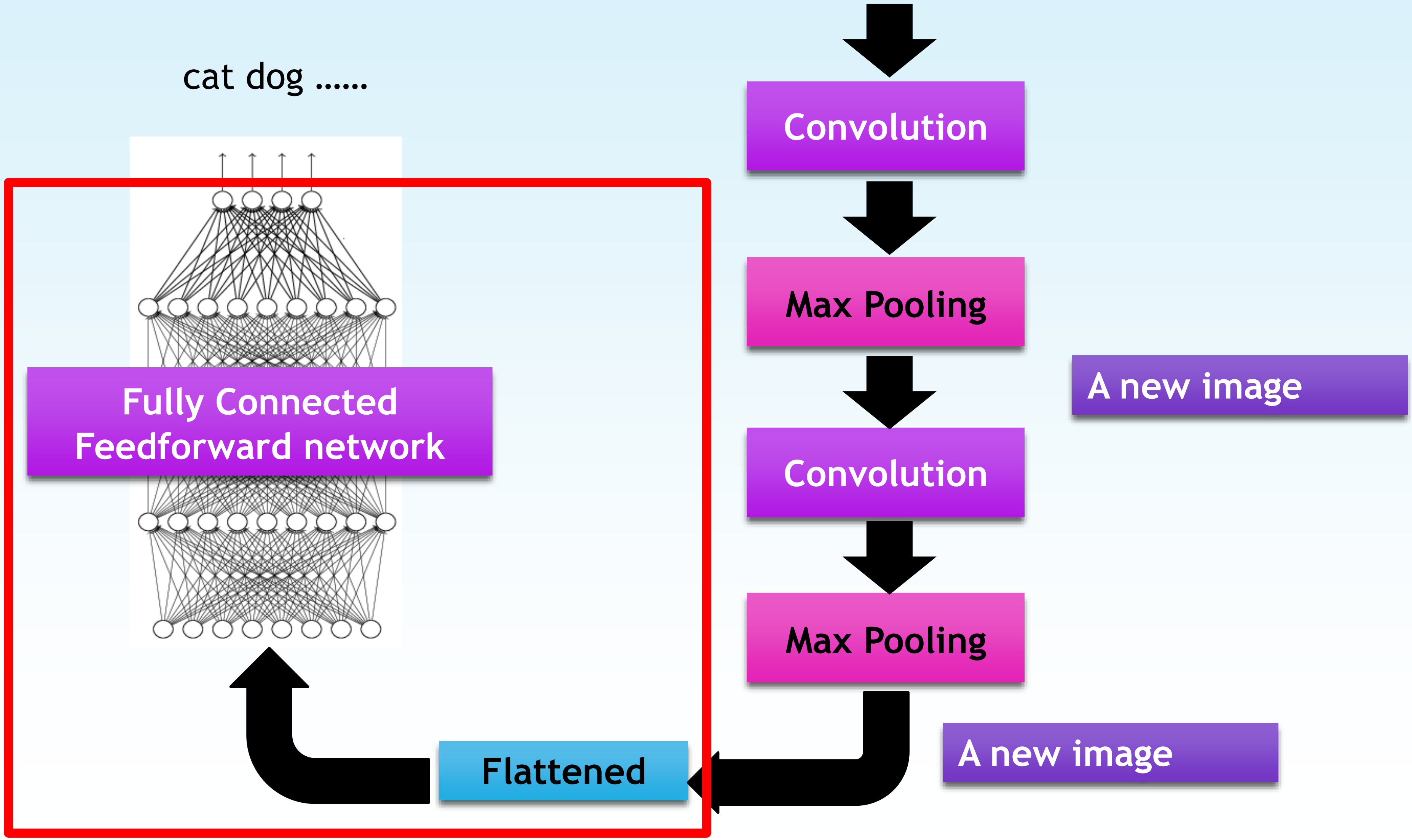
A new image

Smaller than the original image

The number of channels is the number of filters

Can repeat many times

The whole CNN



cat dog ……

Convolution

Max Pooling

A new image

Convolution

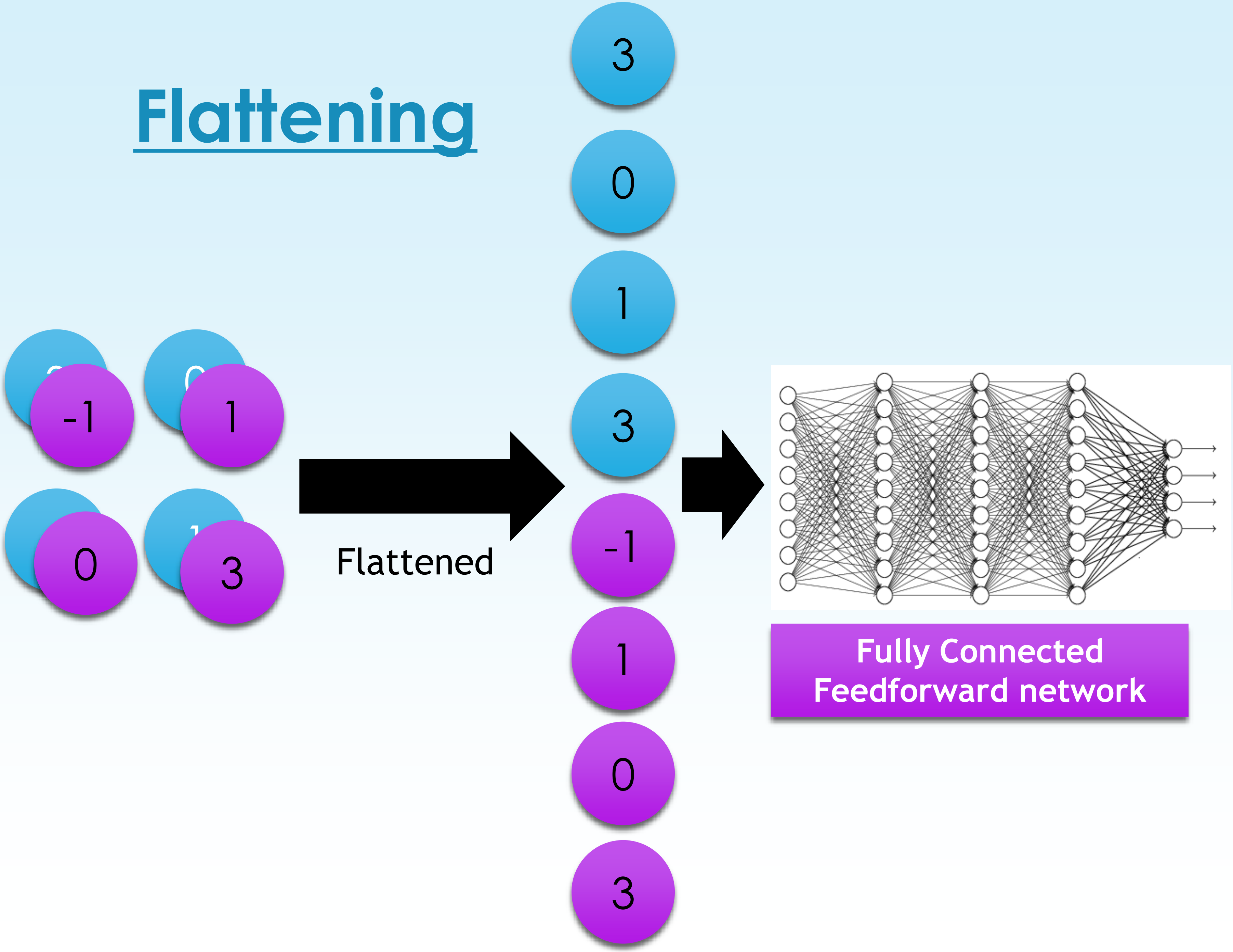
Max Pooling

A new image

Flattened

Fully Connected Feedforward network

Flattening

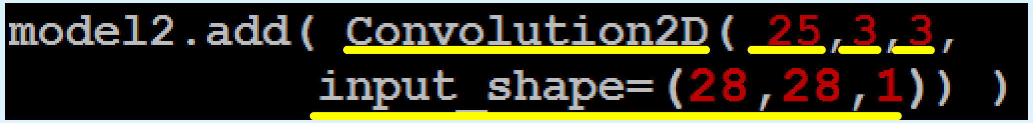


Flattened

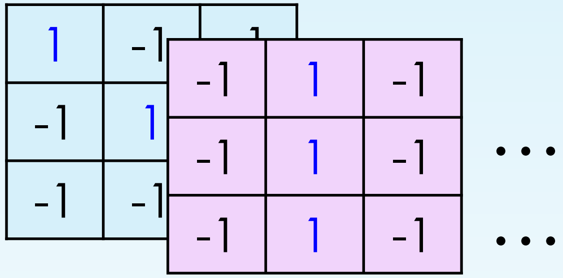
Fully Connected Feedforward network

CNN in Keras

Only modified the ***network structure*** and ***input format (vector -> 3-D tensor)***



```
model2.add( Convolution2D( 25,3,3,
             input_shape=(28,28,1)) )
```

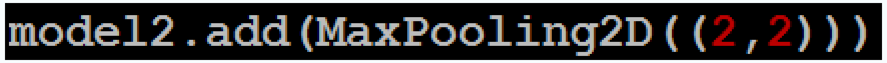


There are 25 3x3 filters.

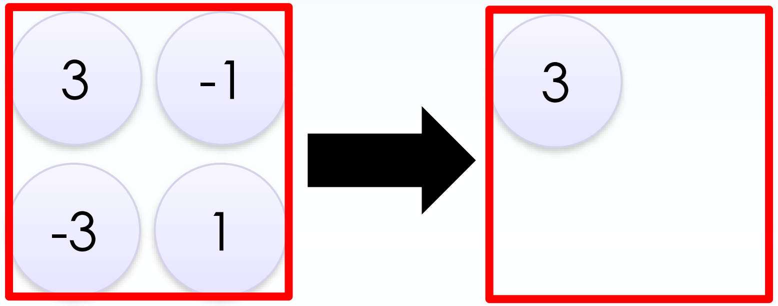
Input_shape = (28 , 28 , 1)

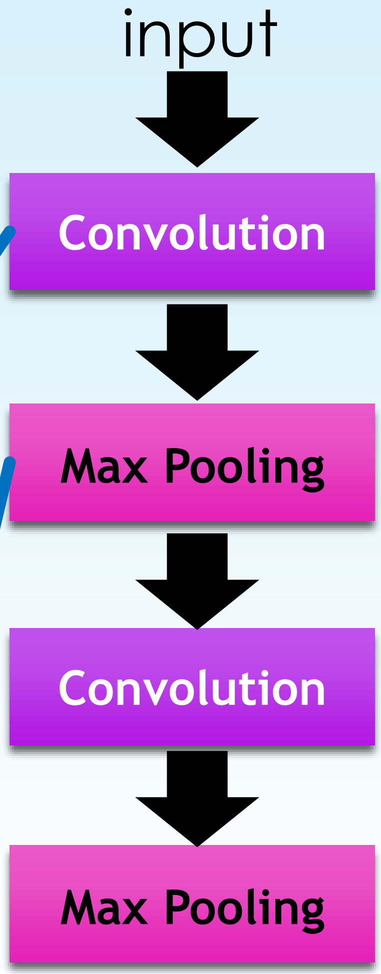
28 x 28 pixels

1: black/white, 3: RGB



```
model2.add(MaxPooling2D((2,2)))
```



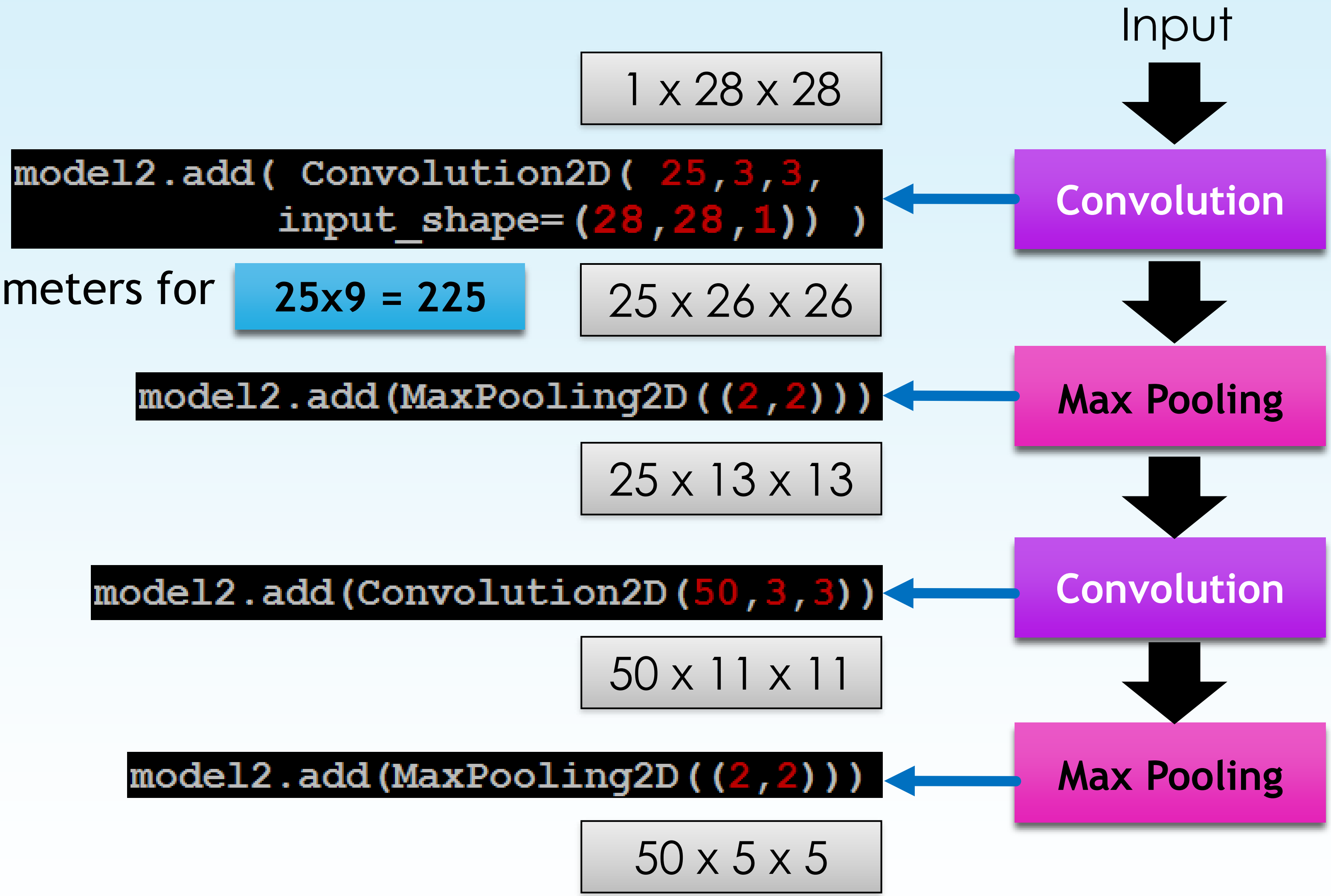


CNN in Keras

Only modified the ***network structure*** and ***input format (vector -> 3-D array)***

How many parameters for each filter?

25x9 = 225



```
model2.add( Convolution2D( 25,3,3,
            input_shape=(28,28,1)) )
```

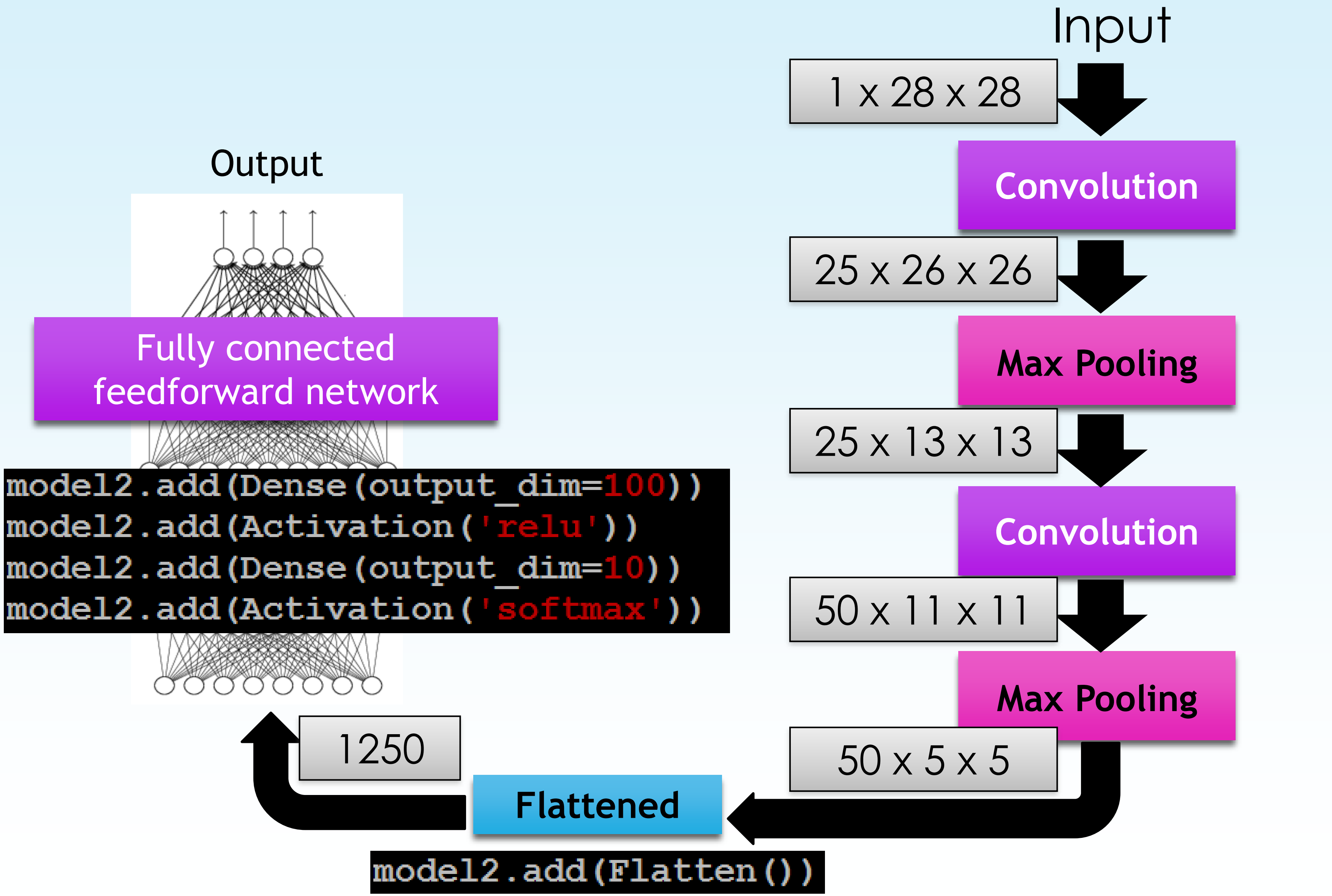
```
model2.add(MaxPooling2D((2,2)))
```

```
model2.add(Convolution2D(50,3,3))
```

```
model2.add(MaxPooling2D((2,2)))
```

CNN in Keras

Only modified the ***network structure*** and ***input format (vector -> 3-D array)***

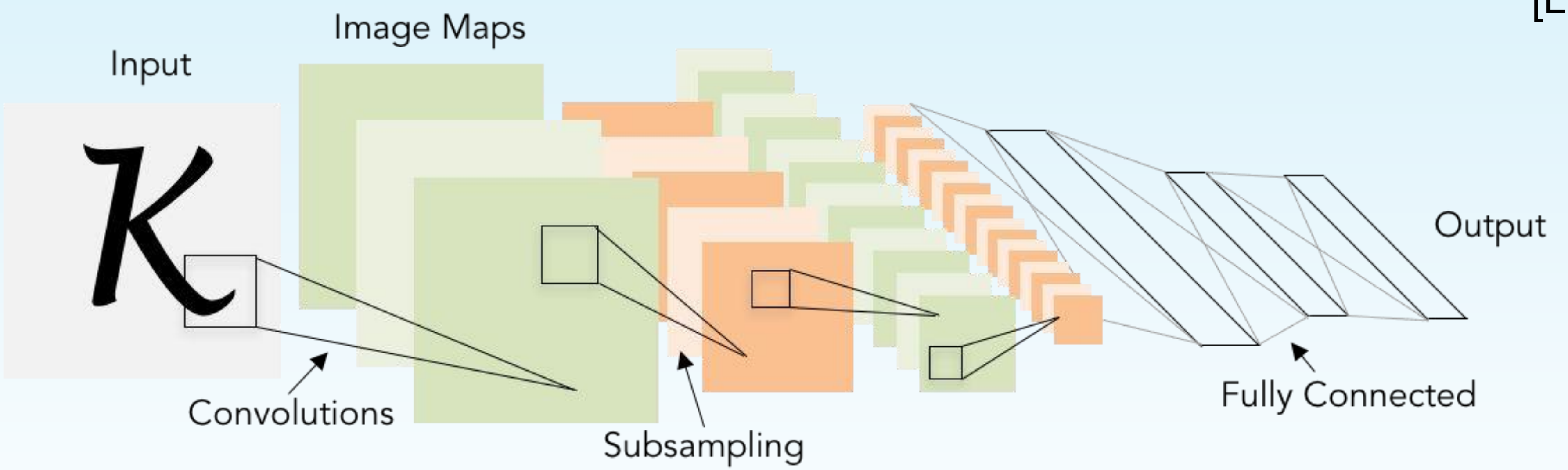


```
model2.add(Dense(output_dim=100))
model2.add(Activation('relu'))
model2.add(Dense(output_dim=10))
model2.add(Activation('softmax'))
```

```
model2.add(Flatten())
```

CNN Architectures

LeNet-5
[LeCun et al., 1998]

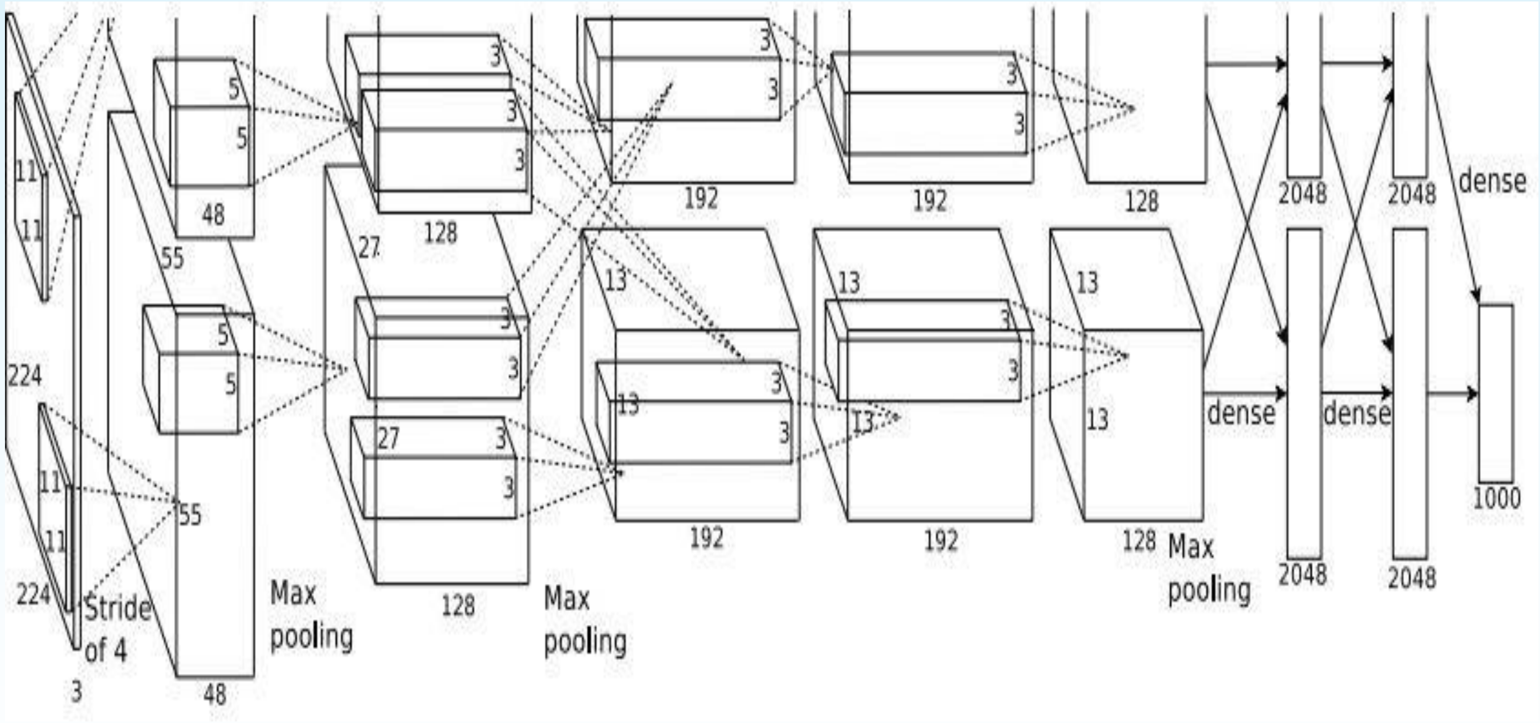


- Conv filters were 5x5, applied at stride 1
- Subsampling (Pooling) layers were 2x2 applied at stride 2
- i.e. architecture is [CONV-POOL-CONV-POOL-FC-FC]

AlexNet

[Krizhevsky et al. 2012]

Architecture:
CONV1
MAX POOL1
NORM1
CONV2
MAX POOL2
NORM2
CONV3
CONV4
CONV5
Max POOL3
FC6
FC7
FC8



What is ImageNet DataSet

- It is a large dataset of annotated photographs.
- This dataset consists of about 14 million images, more than 21000 groups or classes and more than 1 million images that have bounding box annotation.

ImageNet large scale visual recognition Challenge (ILSVRC)

- ImageNet large scale visual recognition Challenge for short ILSVRC. The goal of this challenge is to train a model that can correctly classify an image into a class out of 1000 separate object categories.

ImageNet Large Scale Visual Recognition Challenge (ILSVRC) winners

- AlexNet
- GoogLeNet (e.g. InceptionN),
- VGGNet (e.g. VGG16 or VGG19),
- Residual Network (e.g. ResNetN)

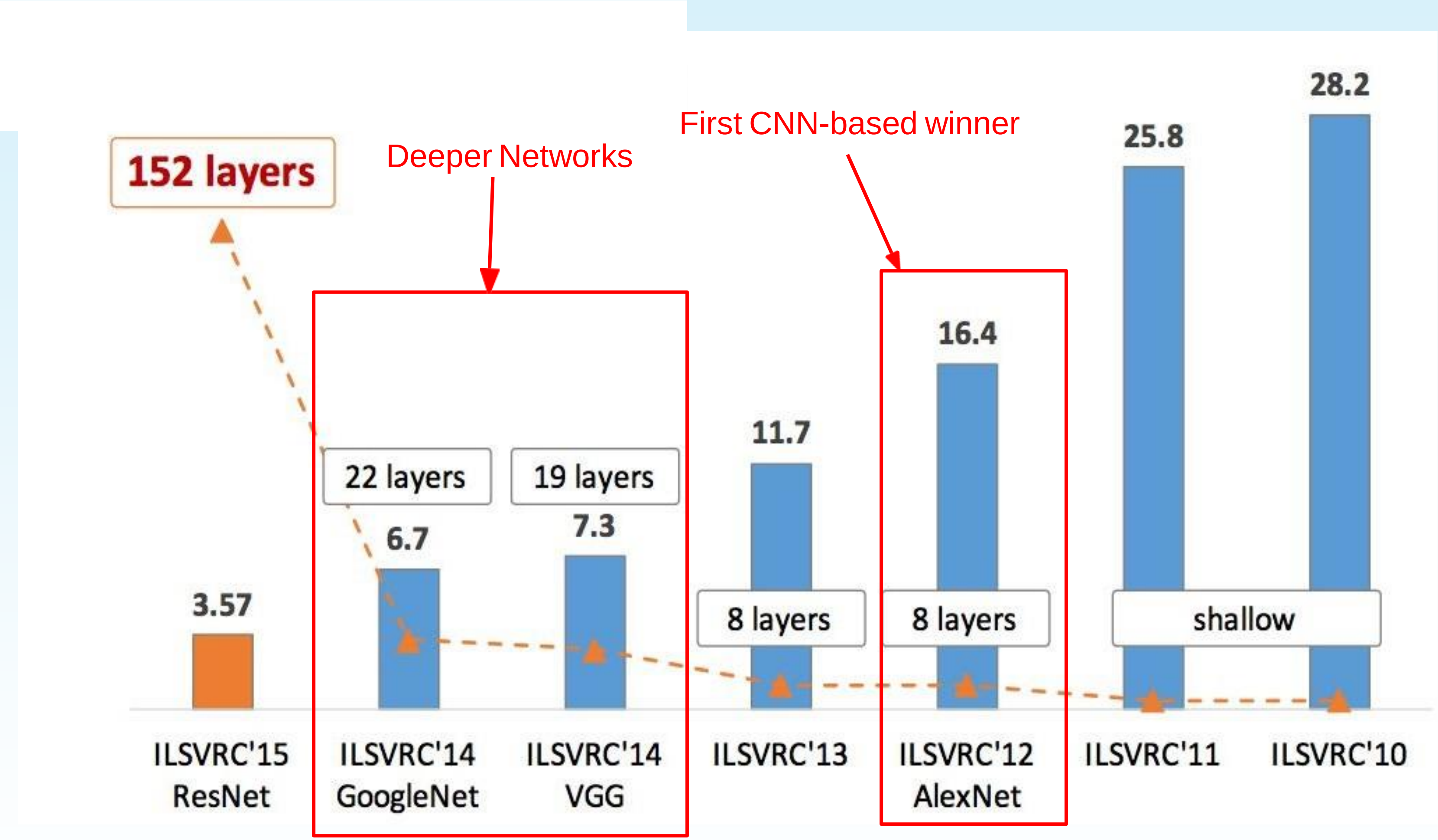
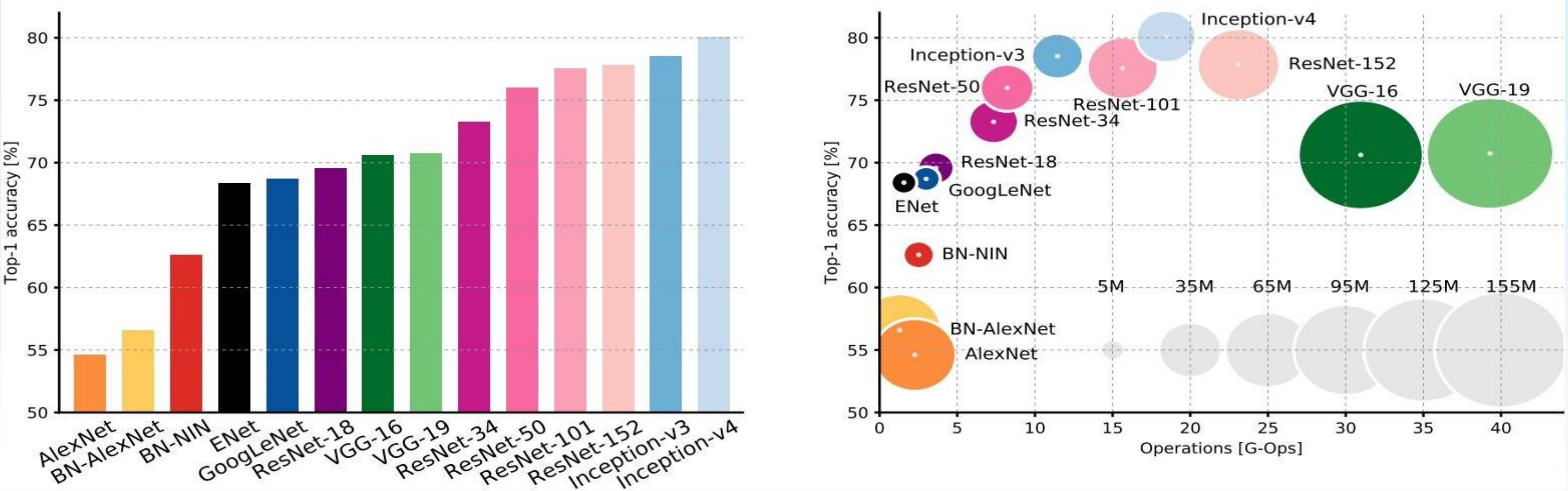


Fig: ILSVRC winners (with training error % vs Years)

Figure copyright Kaiming He, 2016. Reproduced with permission.



An Analysis of Deep Neural Network Models for Practical Applications, 2017.

Figures copyright Alfredo Canziani, Adam Paszke, Eugenio Culurciello, 2017. Reproduced with permission.

VGG: Highest memory, most operations.

GoogLeNet: Most efficient.

AlexNet: Smaller compute, still memory heavy, lower accuracy.

ResNet: Moderate efficiency depending on model, highest accuracy

Transfer Learning Model

- Transfer learning is a technique whereby a neural network model is first trained on a problem similar to the problem that is being solved.

- One or more layers from the trained model are then used in a new model hence, transfer learning is a method of reusing a pre-trained model knowledge for another task.

- There are perhaps a dozen or more top-performing models for image recognition that can be used. AlexNet, ResNet, VGG, and Inception etc. are some of the CNN based transfer learning model.

Thank You