CONVOLUTIONAL NEURAL NETWORK

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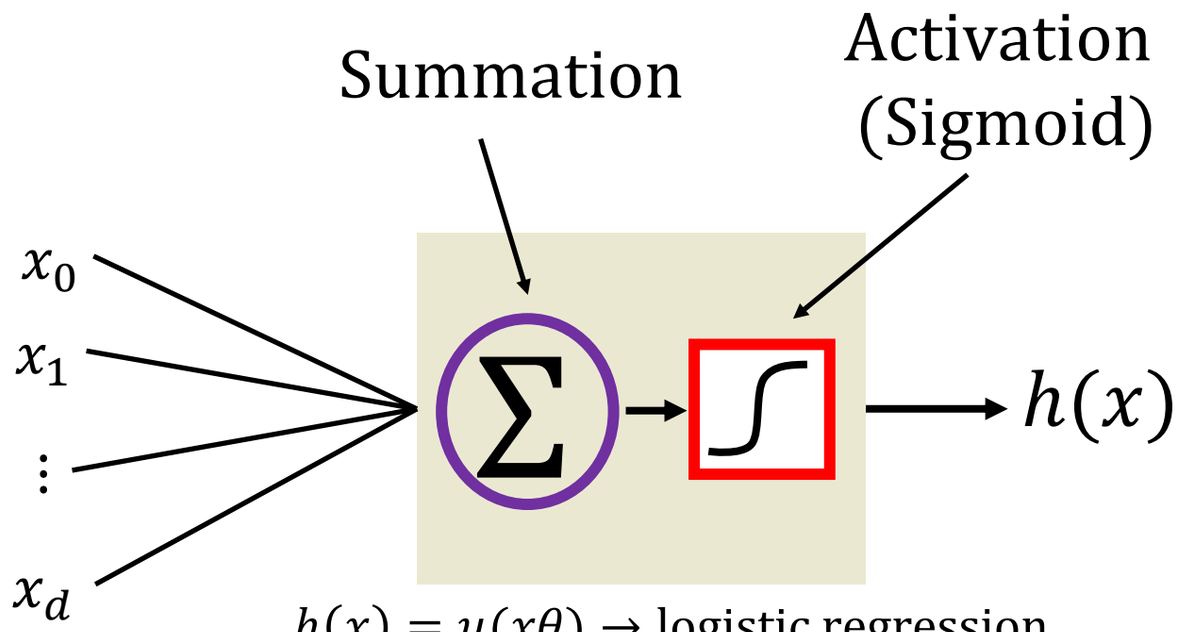
Slides are based on Ming Li and Mahdi Roozbahani

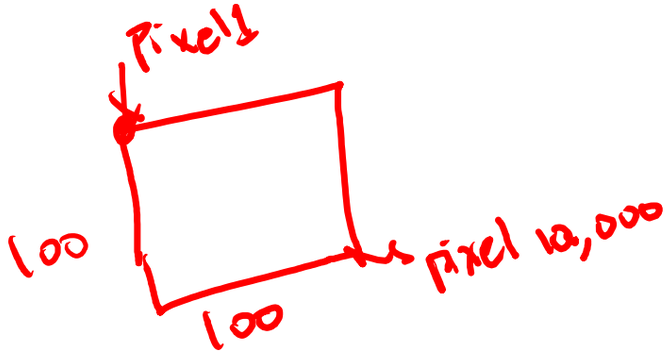


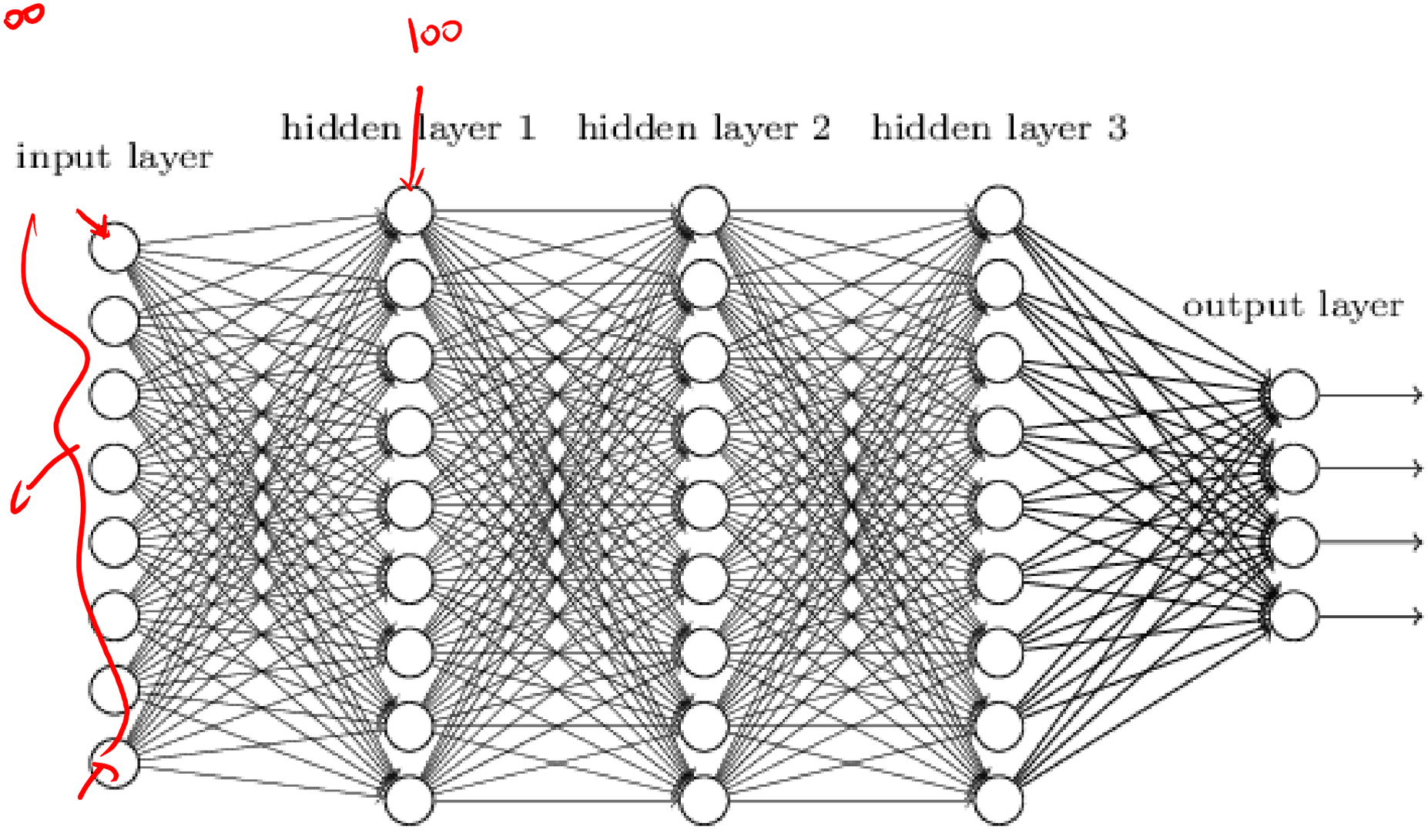
$h(x) = u(x\theta) \rightarrow$ logistic regression

$$output = activation(x\theta + b)$$

Name of the neuron	Activation function: $activation(z)$
Linear unit	$x\theta$
Threshold/sign unit	$sign(x\theta)$
Sigmoid unit	$\frac{1}{1+\exp(-x\theta)}$
Rectified linear unit (ReLU)	$\max(0, x\theta)$
Tanh unit	$\tanh(x\theta)$

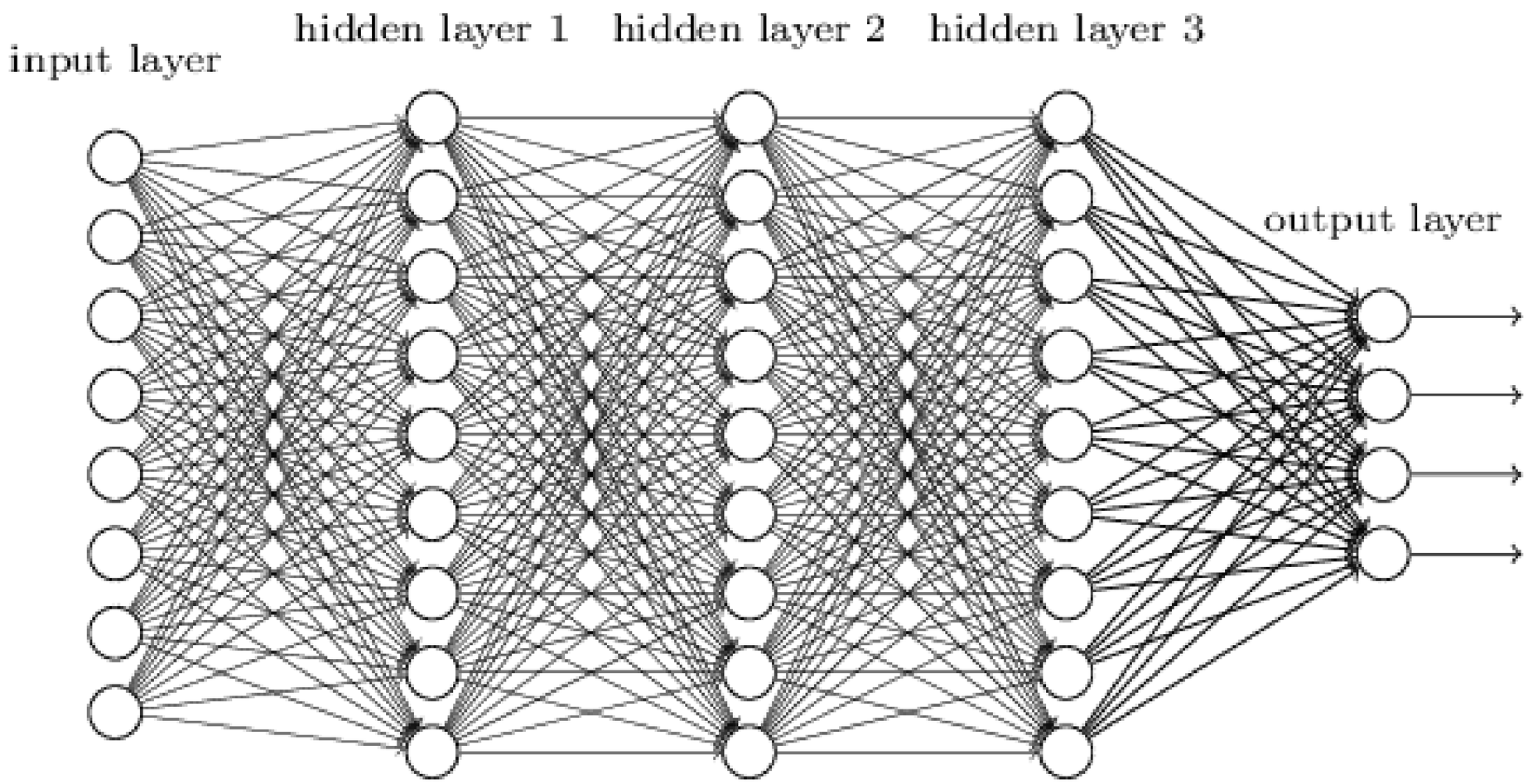
Put an image in





Smaller Network: CNN

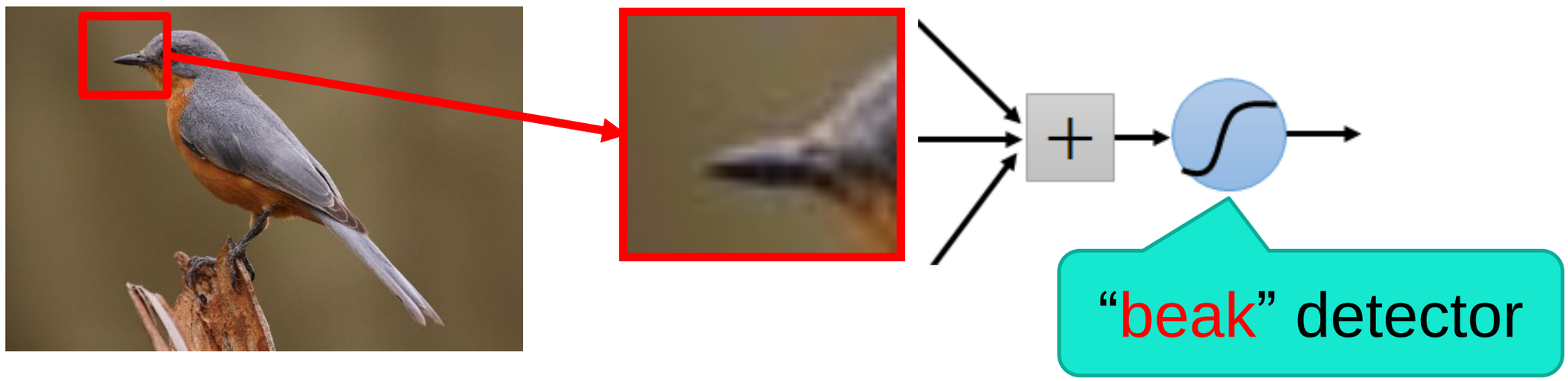
- We know it is good to learn a small model.
- From this fully connected model, do we really need all the edges?
- Can some of these be shared?



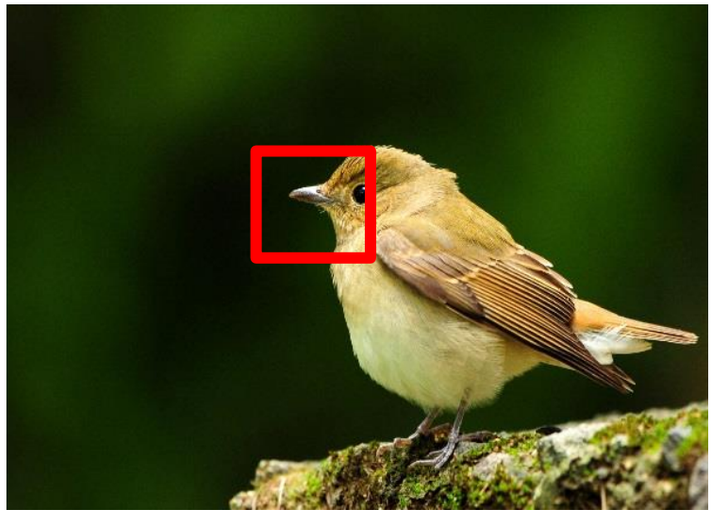
Consider learning an image:

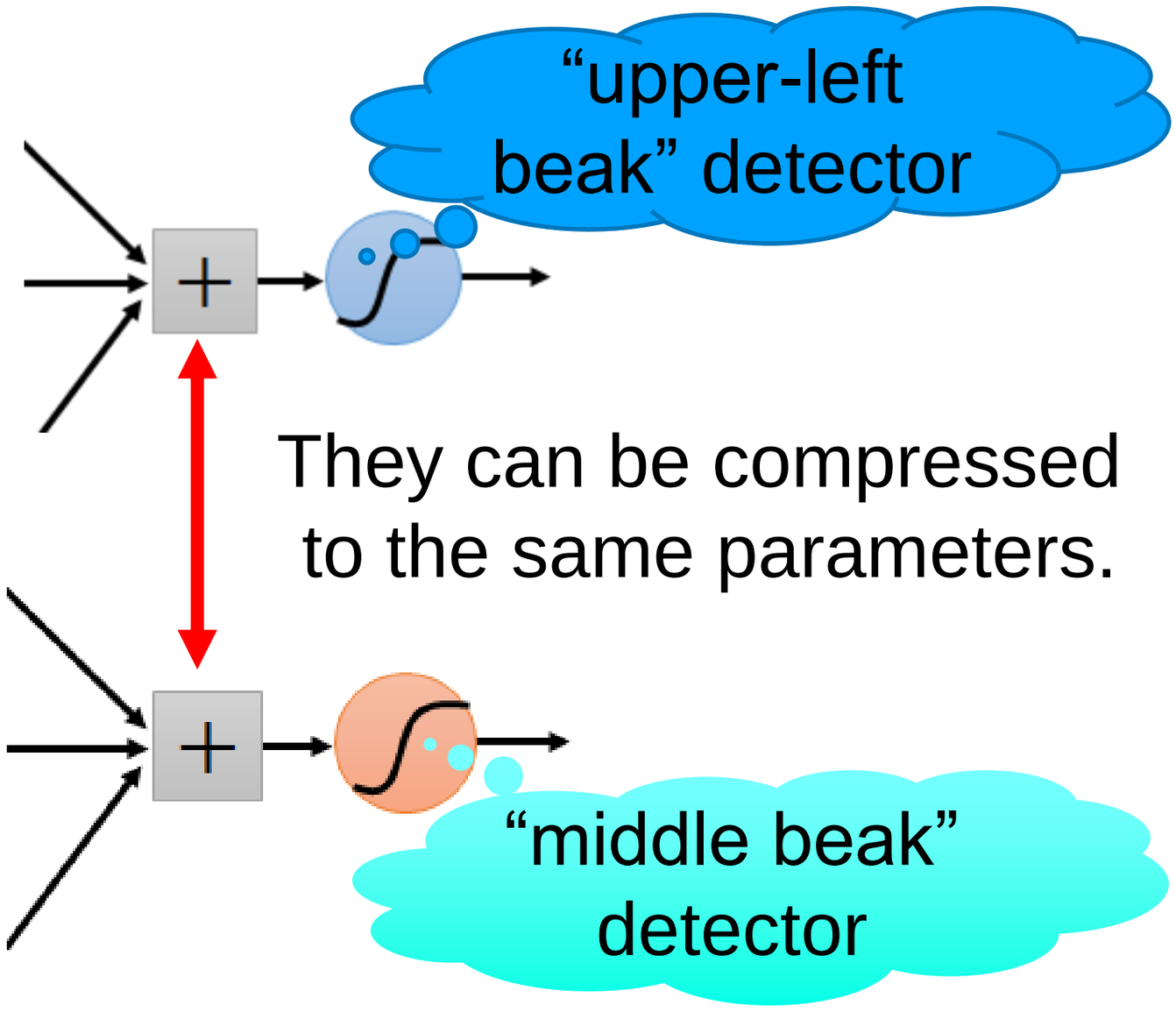
- Some patterns are much smaller than the whole image

Can represent a small region with fewer parameters



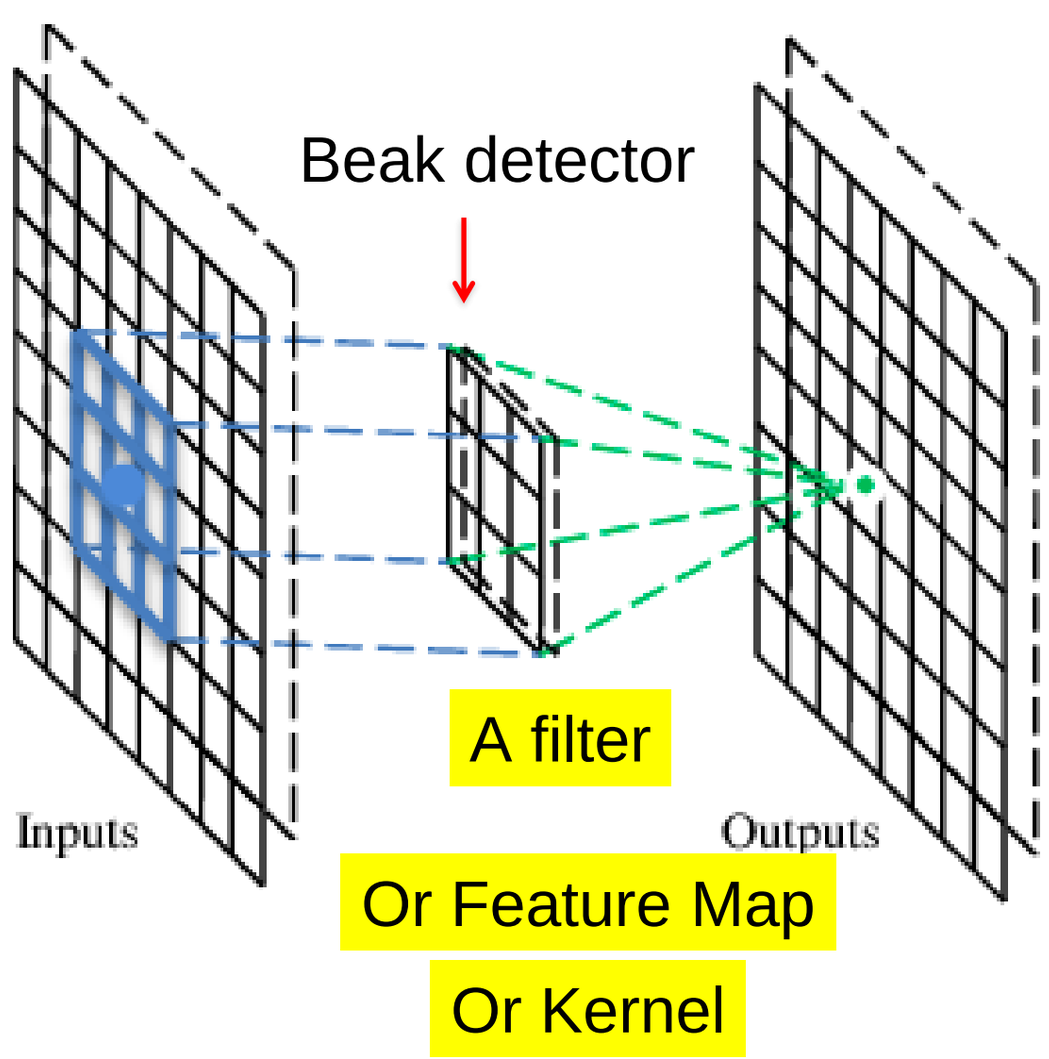
Same pattern appears in different places:
They can be compressed!
What about training a lot of such “small” detectors and each detector must “move around”.





A convolutional layer

A CNN is a neural network with some convolutional layers (and some other layers). A convolutional layer has a number of filters that does convolutional operation. Neocognitron by Kunihiko Fukushima (1980).



A filter

Or Feature Map

Or Kernel

Convolution

These are the network parameters to be learned.

weights

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

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

Filter 2

⋮ ⋮

Filter 10

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

Dot product →

3 -1

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

Convolution – diagonal edges?

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

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

Convolution - Vertical edges?

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

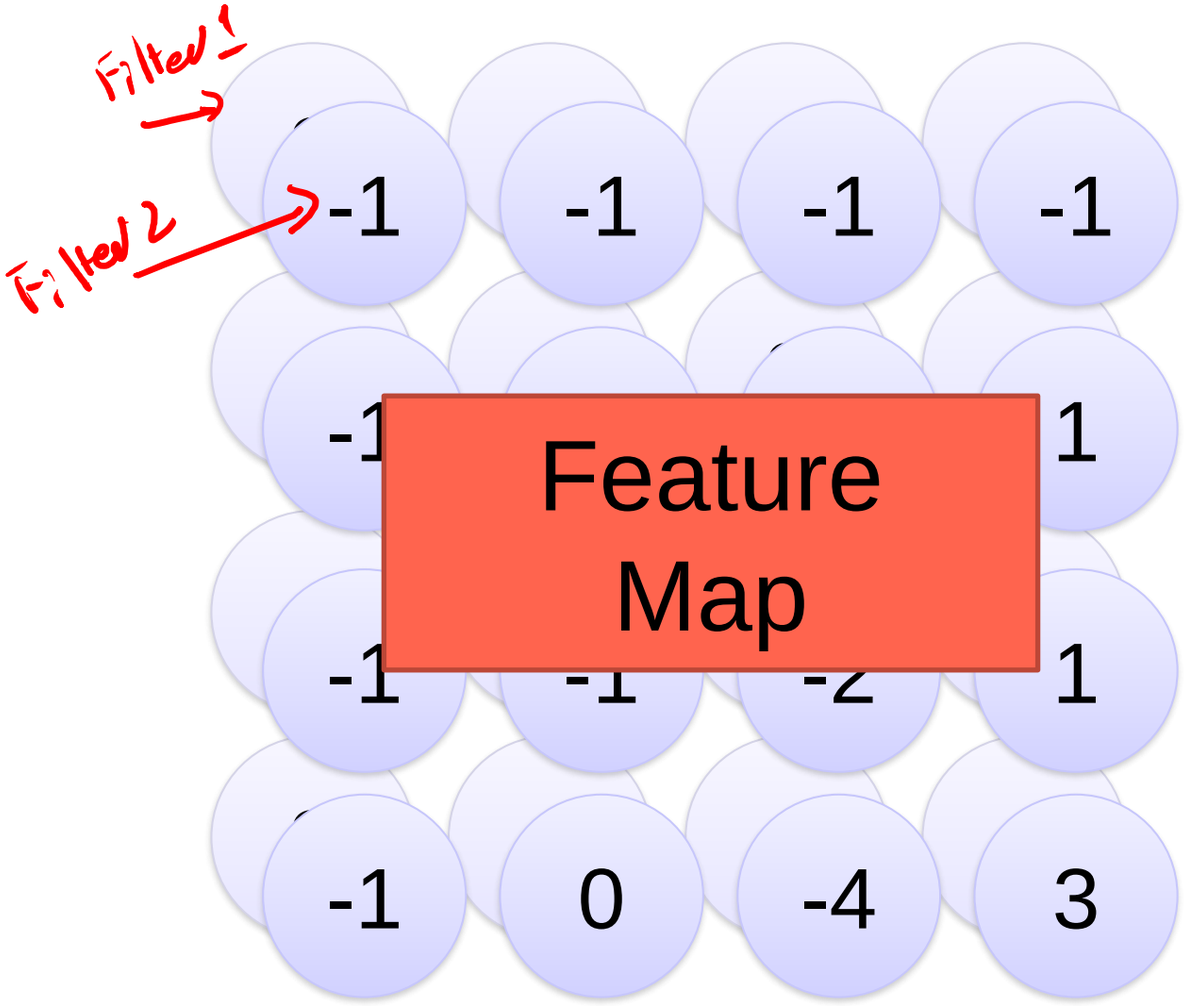
Filter 2

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

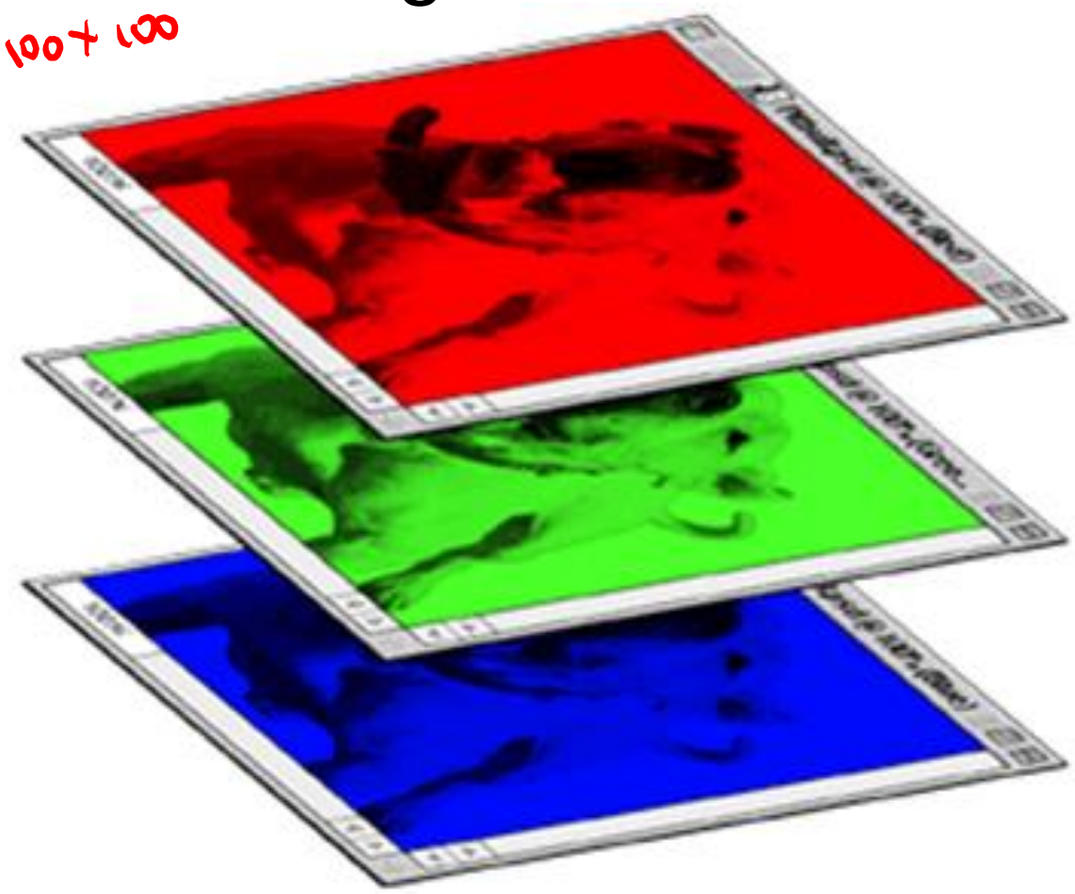
Filter 1

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

Filter 2

Color image

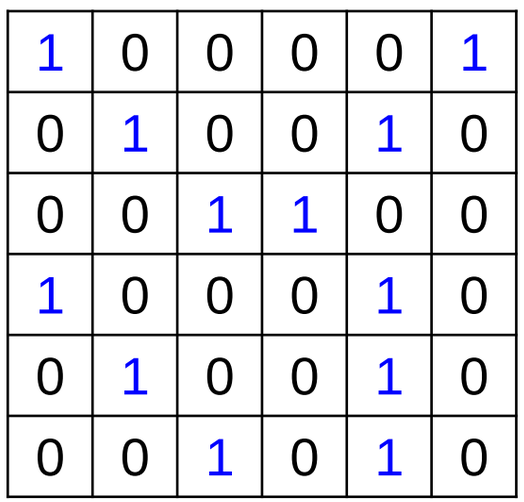
3 x 100 x 100



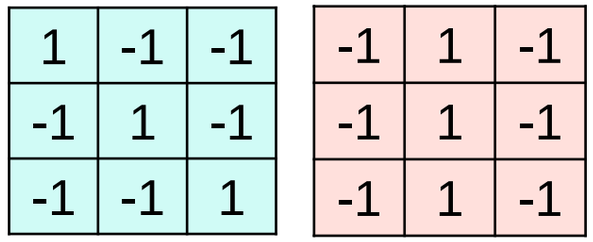
6 x 4 x 4

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

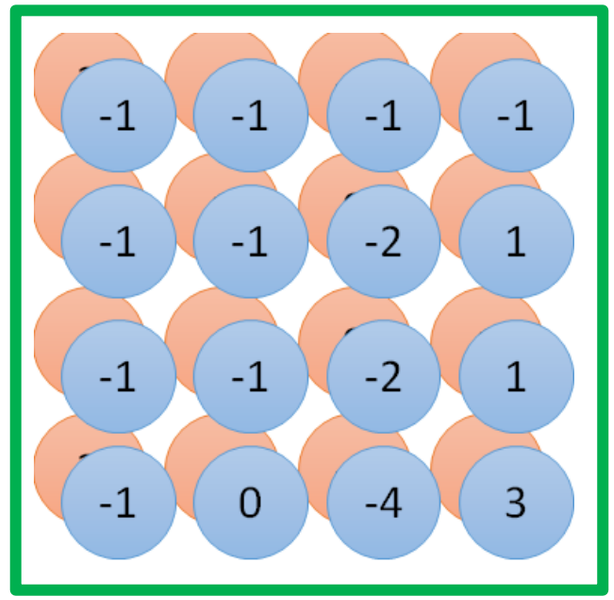
Convolution v.s. Fully Connected



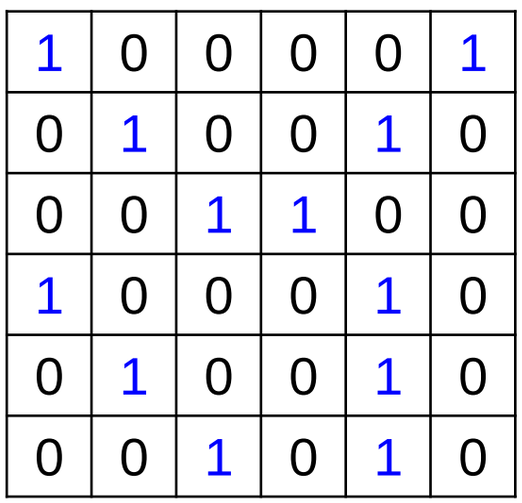
image

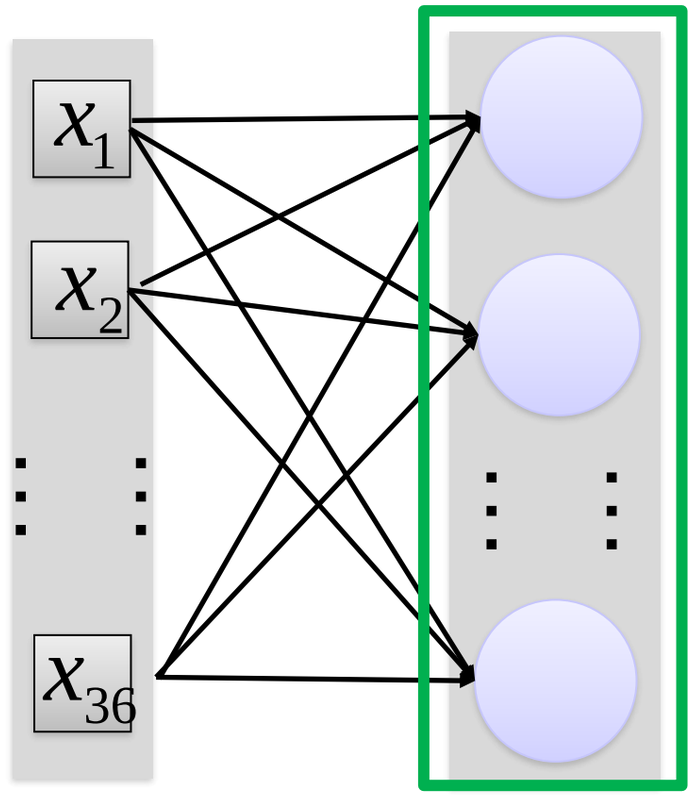


convolution



Fully-connected

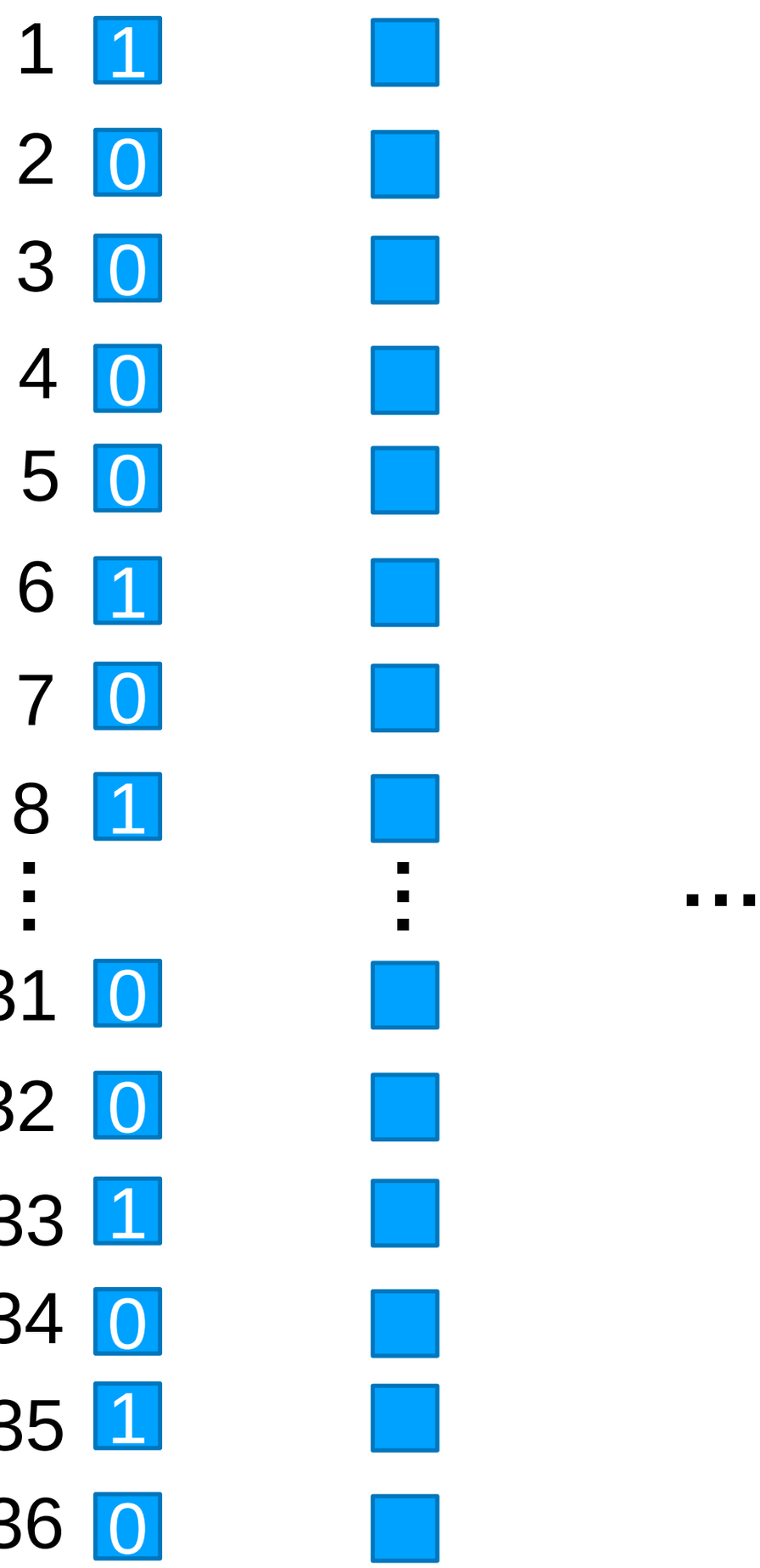


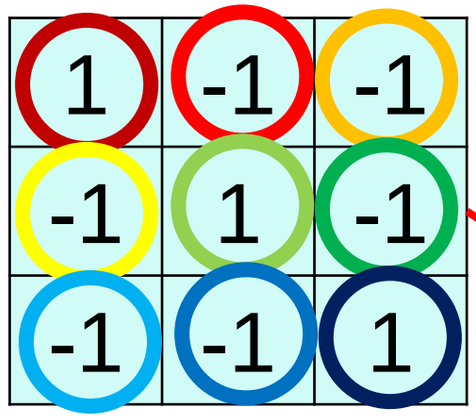


Conventional
Fully Connected
layers
(FC layers)

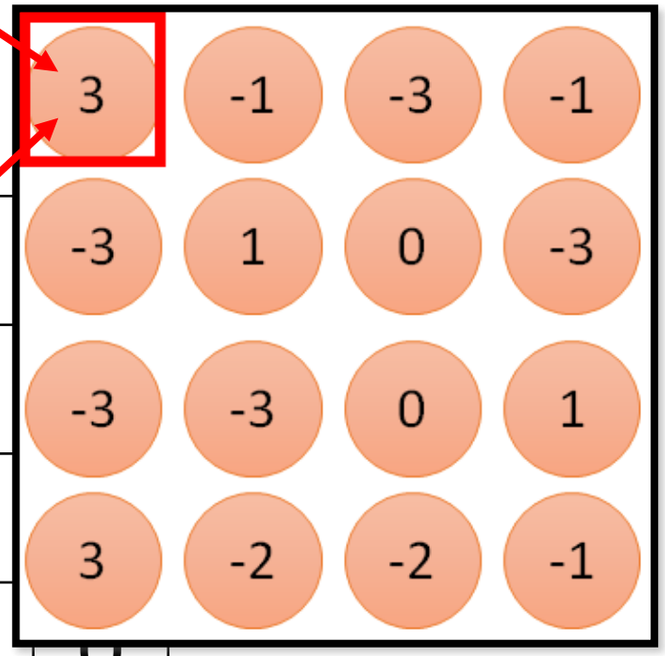
1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image





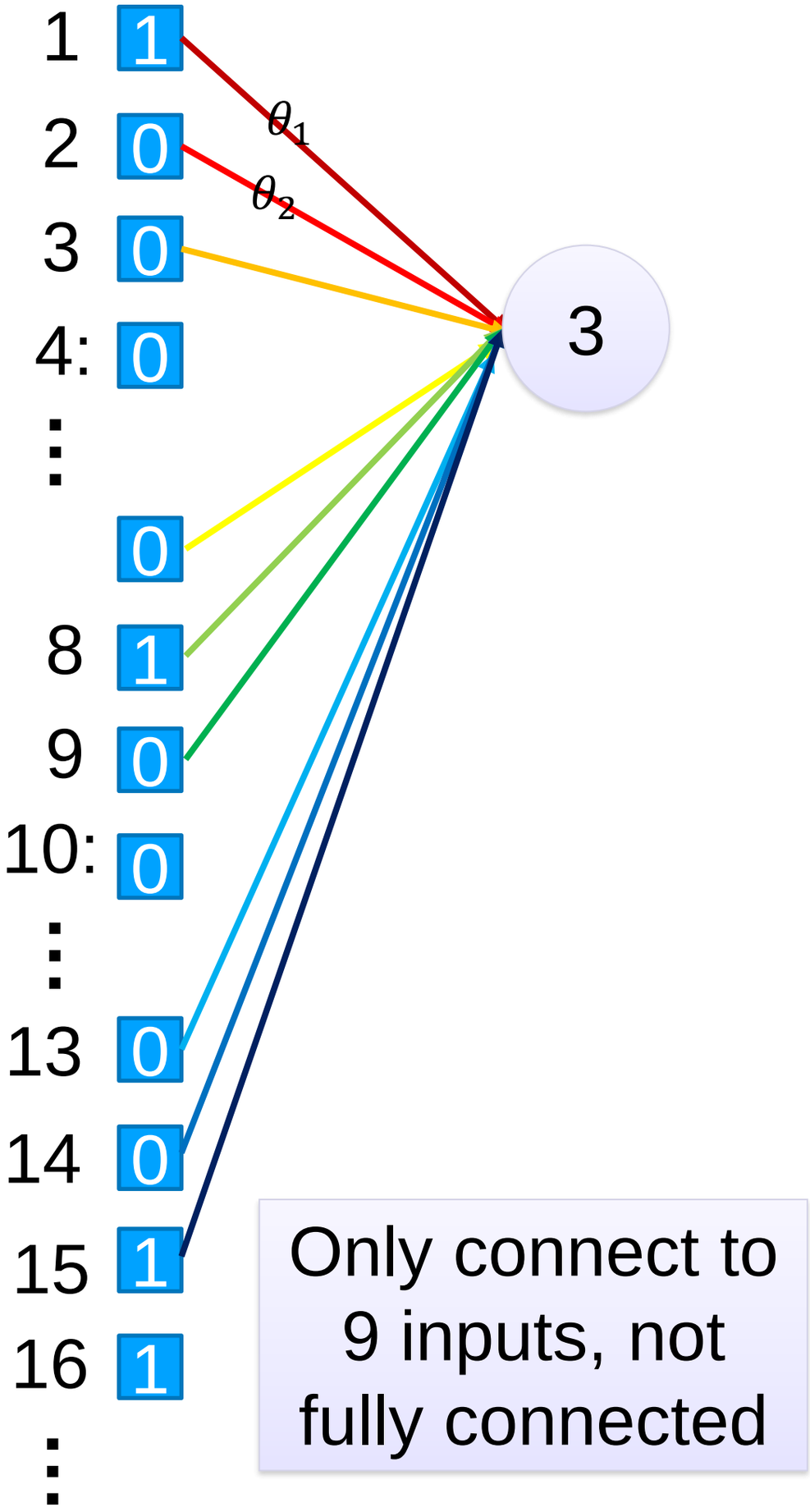
Filter 1



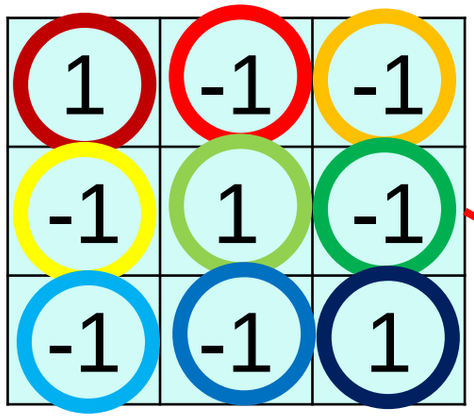
1	0	0	0	0	
0	1	0	0	1	
0	0	1	1	0	
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

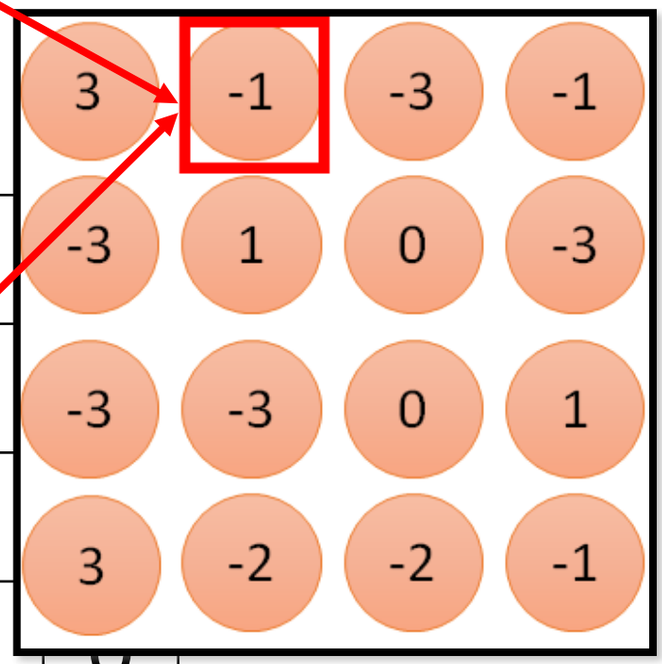
fewer parameters!



Only connect to 9 inputs, not fully connected



Filter 1

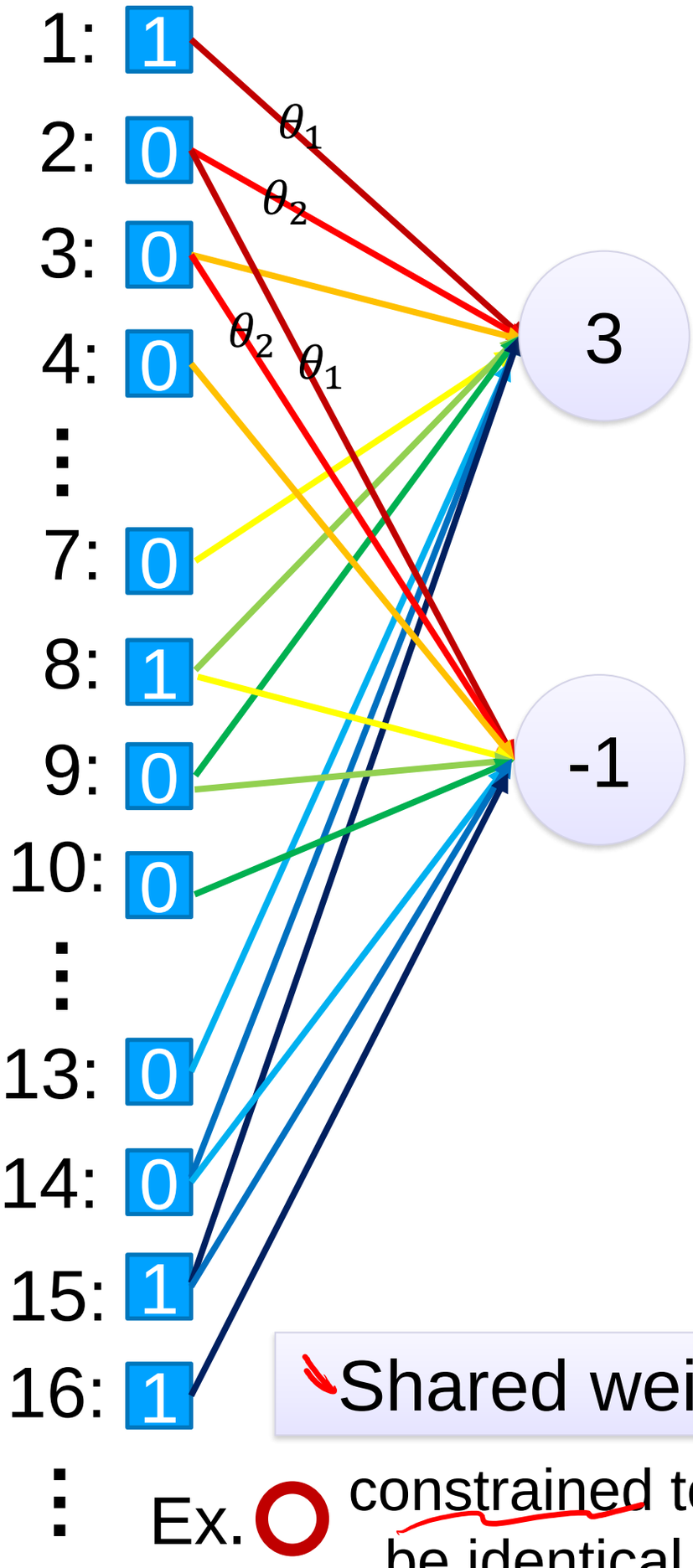


1	0	0	0	0	0
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

Fewer parameters

Even fewer parameters



Shared weights

Ex. O constrained to be identical

An example classfier using CNNs

Convolution

Max Pooling

Convolution

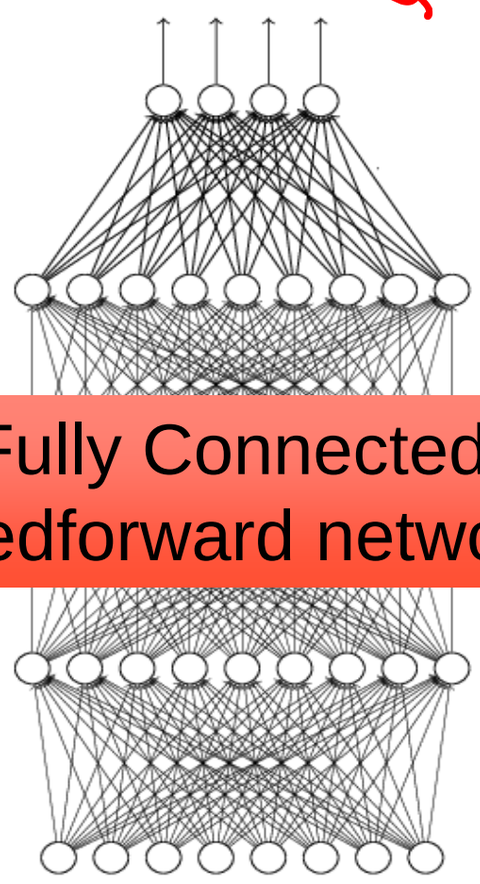
Max Pooling

Can repeat many times

Flattened

Fully Connected Feedforward network

cat dog ……



cross entropy

error

Max Pooling

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

Filter 1

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

Filter 2

4

6x

2x2 after max pooling

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

Why Pooling

- Subsampling pixels will not change the object

bird

Subsampling

bird

We can subsample the pixels to make image smaller

→ fewer parameters to characterize the image

A CNN compresses a fully connected network in two ways:

- Reducing number of connections
- Shared weights on the edges
- Moreover, Max pooling further reduces the complexity

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

Conv

Max Pooling

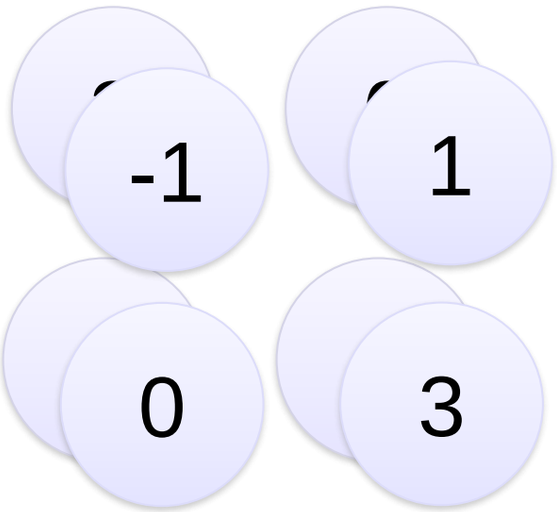
New image but smaller

-1	1
0	3

2 x 2 image

Each filter is a "channel"

Example network



A new image

Convolution

Max Pooling

Convolution

Max Pooling

Can repeat many times

Smaller than the original image

The number of channels is the number of filters

Example network

Convolution

Max Pooling

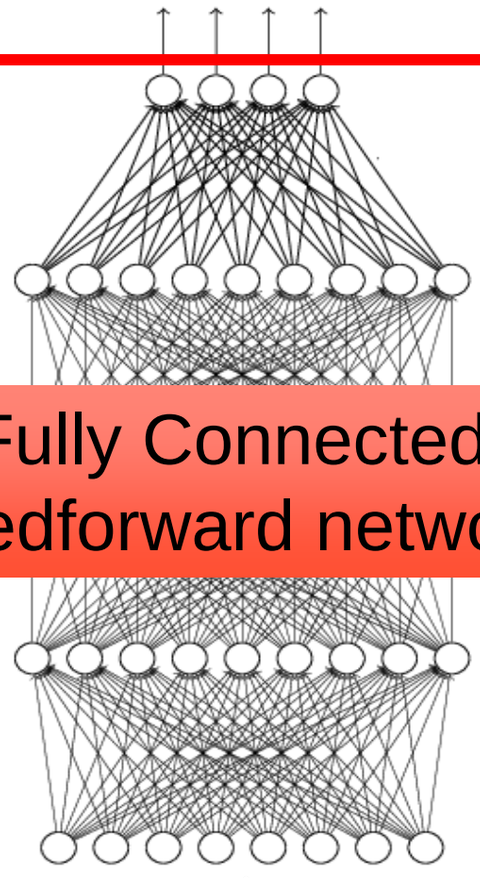
A new image

Convolution

Max Pooling

A new image

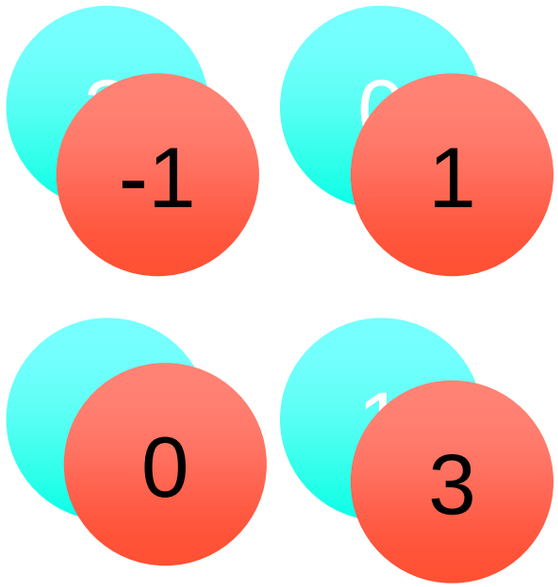
cat dog ……



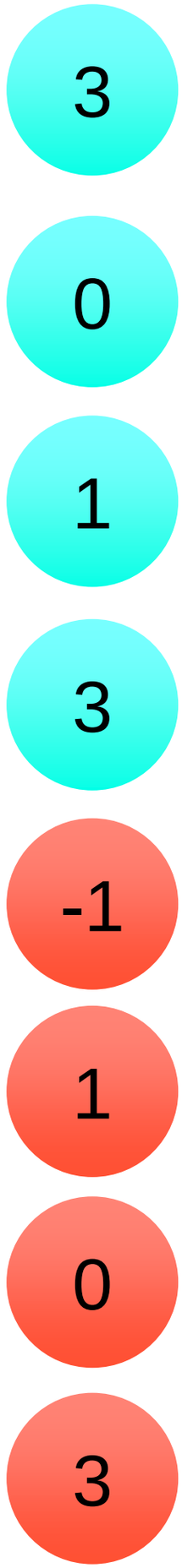
Fully Connected Feedforward network

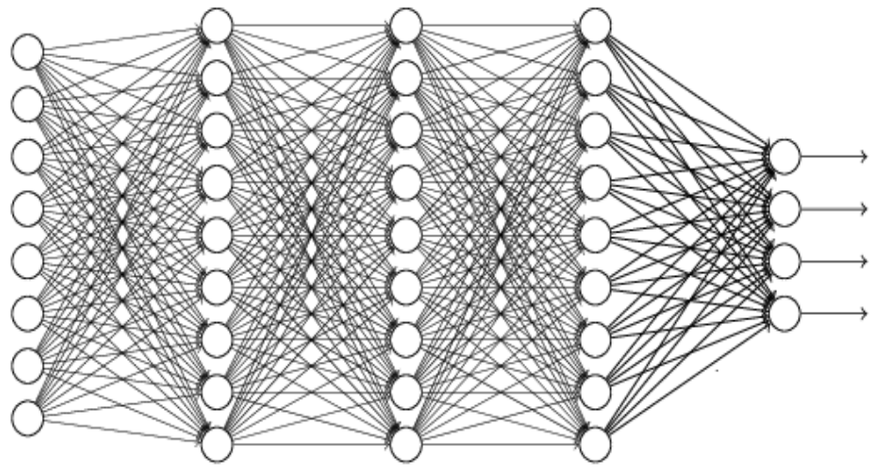
Flattened

Flattening



Flattened



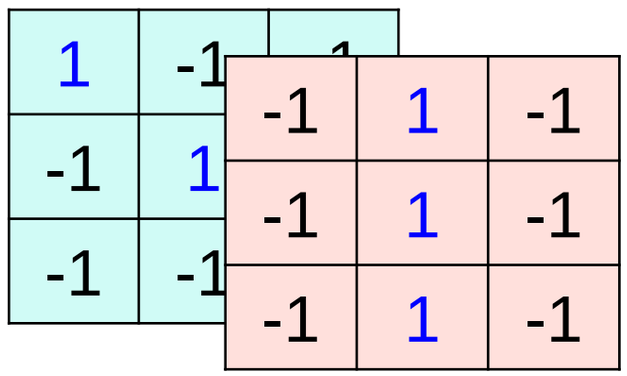


Fully Connected
Feedforward network

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)) )
```



…

…

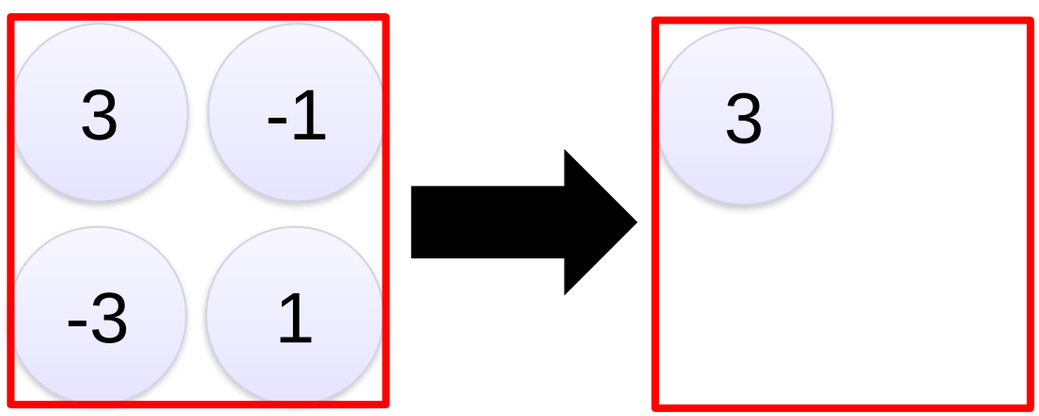
There are 25 3x3 filters.

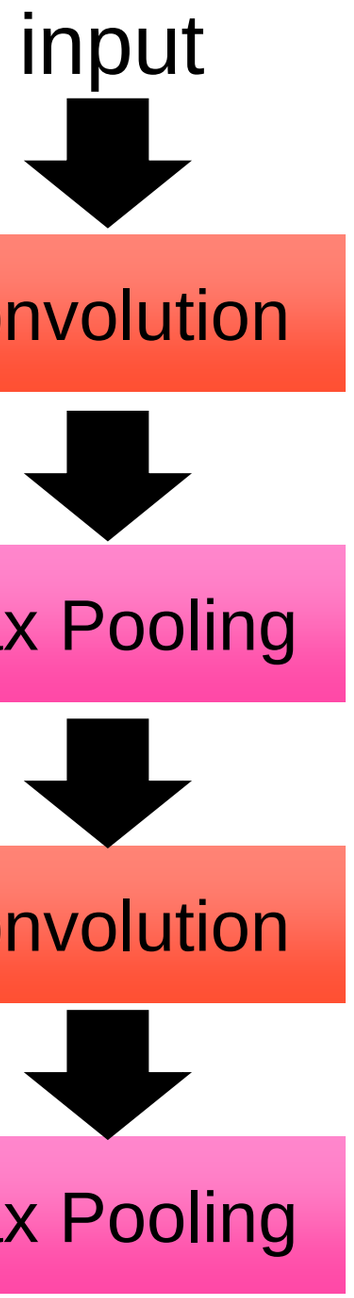
Input_shape = (28 , 28 , 1)

28 x 28 pixels

1: black/white, 3: RGB

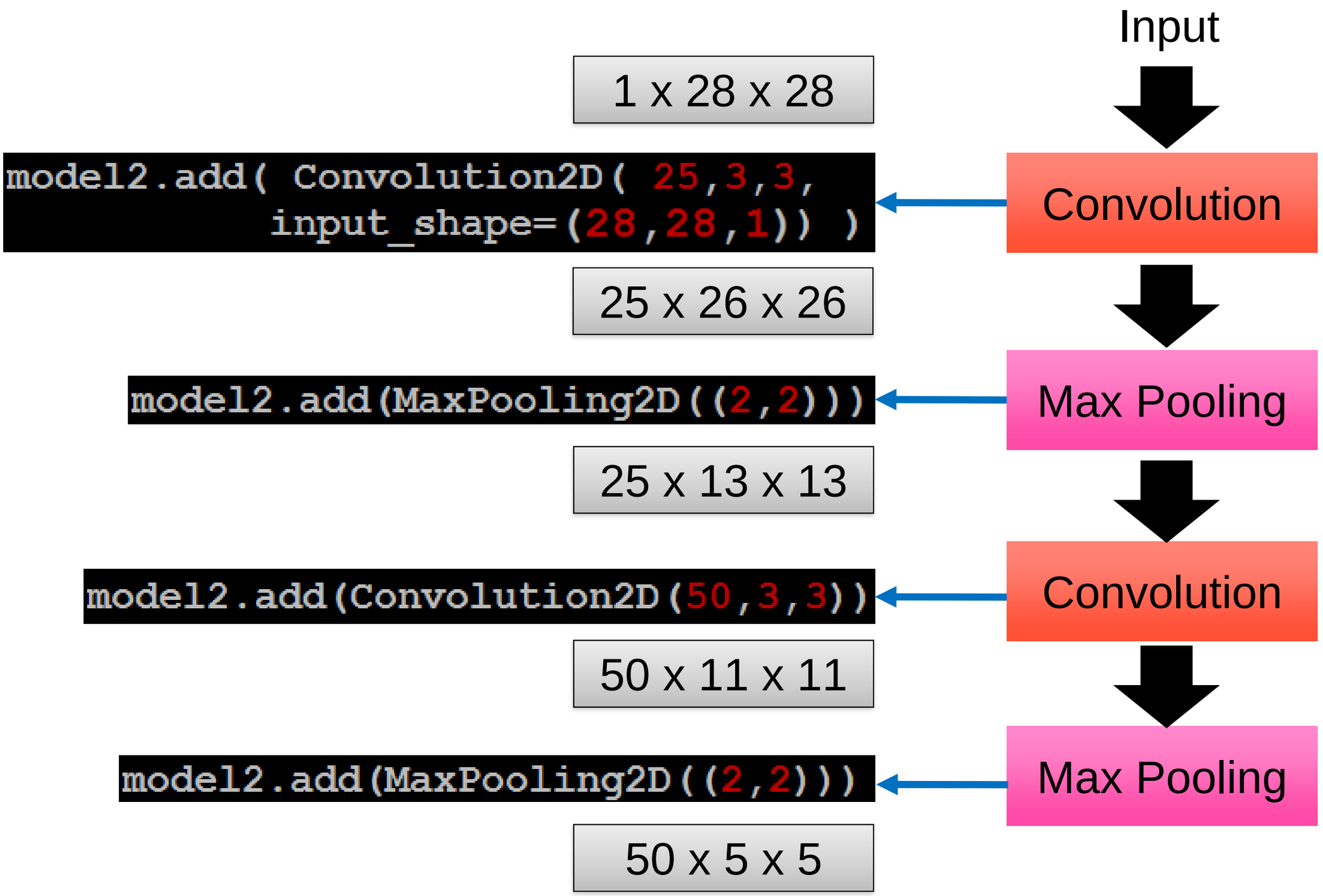
```
model2.add(MaxPooling2D((2,2)))
```





CNN in Keras

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



CNN in Keras

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

Input

1 x 28 x 28

Convolution + ReLU

25 x 26 x 26

Max Pooling

25 x 13 x 13

Convolution + ReLU

50 x 11 x 11

Max Pooling

50 x 5 x 5

Flattened

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

1250

Output

Fully connected feedforward network

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

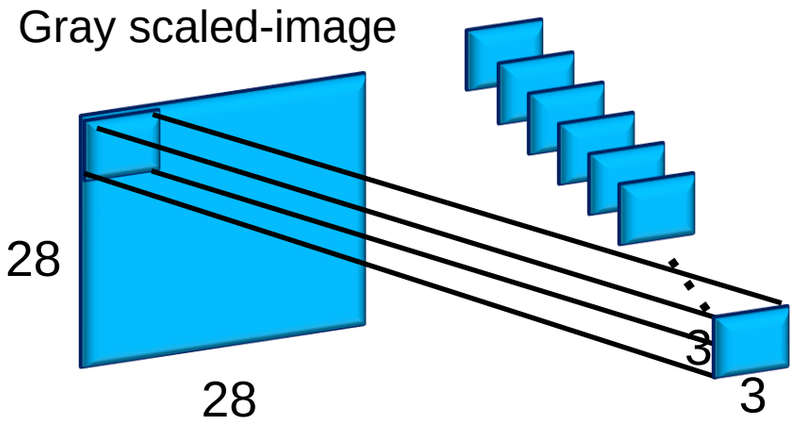
Number of Parameters

25X3X3+25 parameters

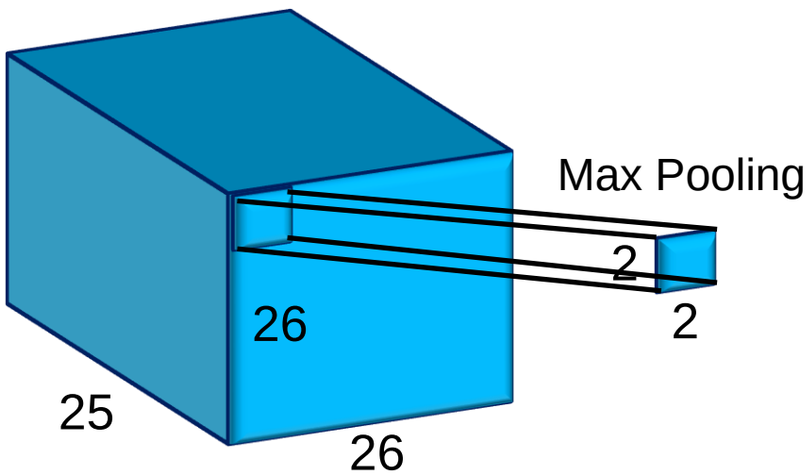
25 filters - Conv1

25: 3X3

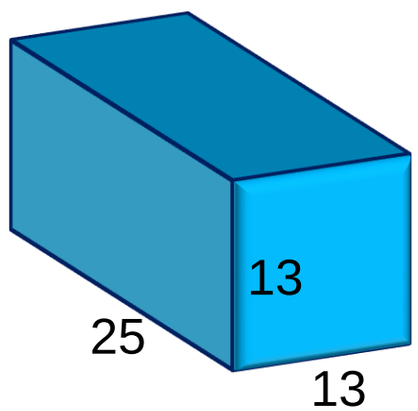
Gray scaled-image

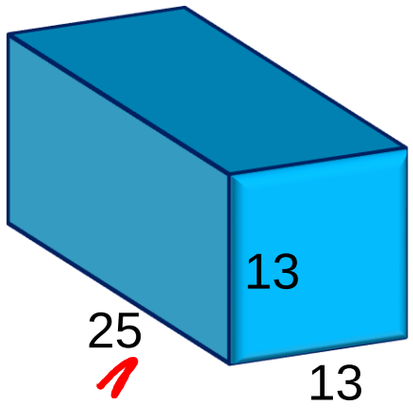


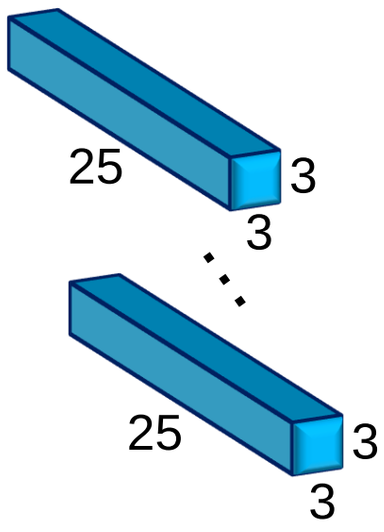
Convoluted result for 25 filters



Result after Max Pooling

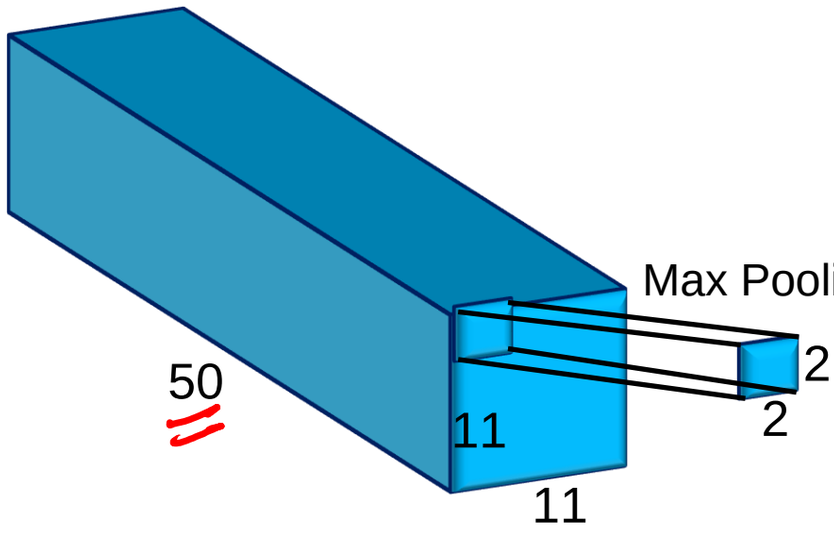






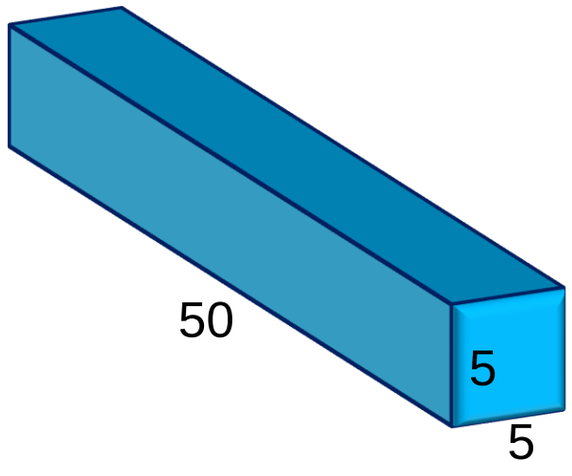
50: 3X3X25

50 filters – Conv2

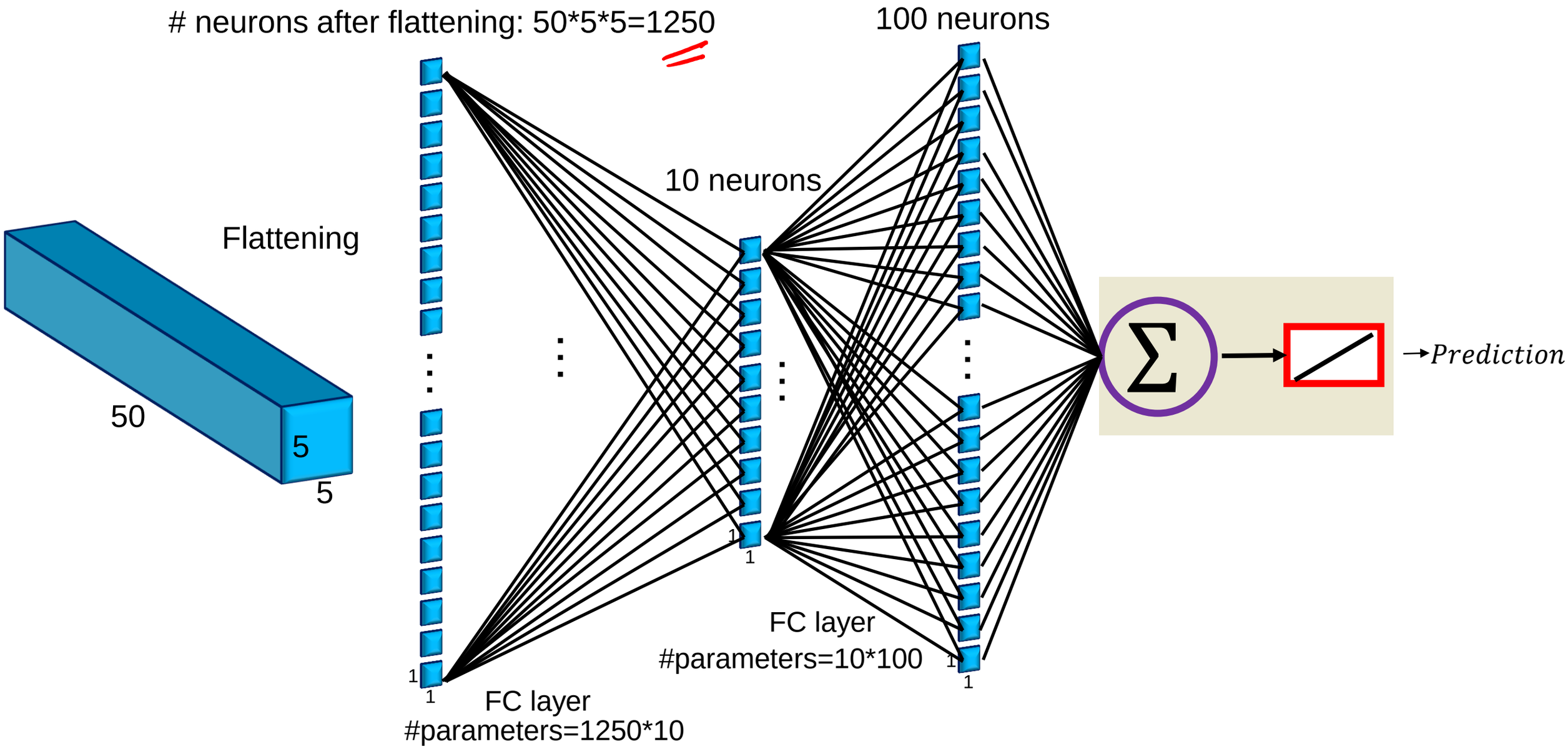


Convoluted result for 50 filters

Result after Max Pooling



50X3X3X25+50 parameters



[10 CNN Architecture]