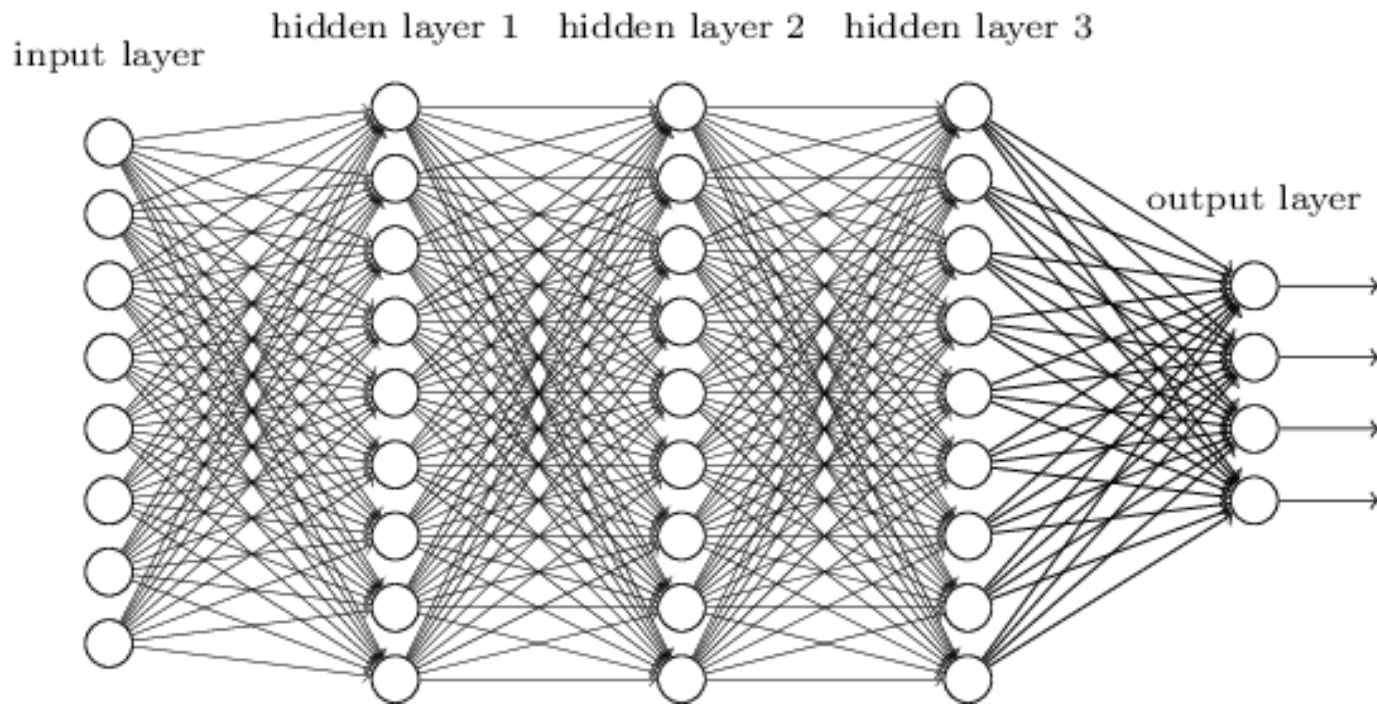
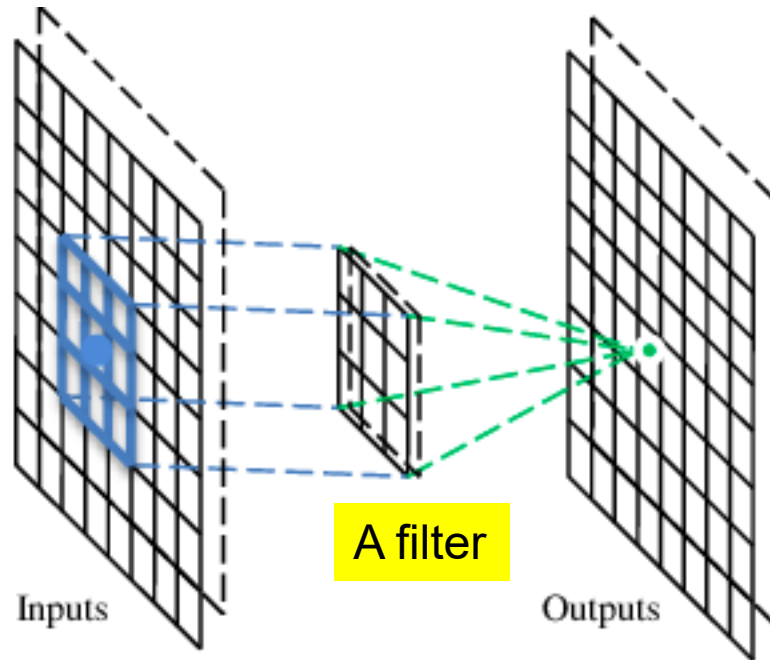


Fully-connected Neural Network



Why do we need Convolutional Neural Network (CNN)?

A convolutional 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

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

stride=1

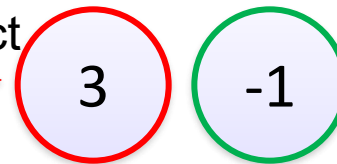
1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

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

Filter 1

Dot
product



Convolution

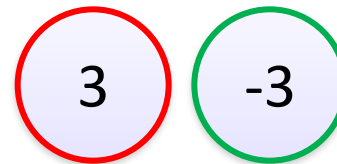
If stride=2

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



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

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

Convolution

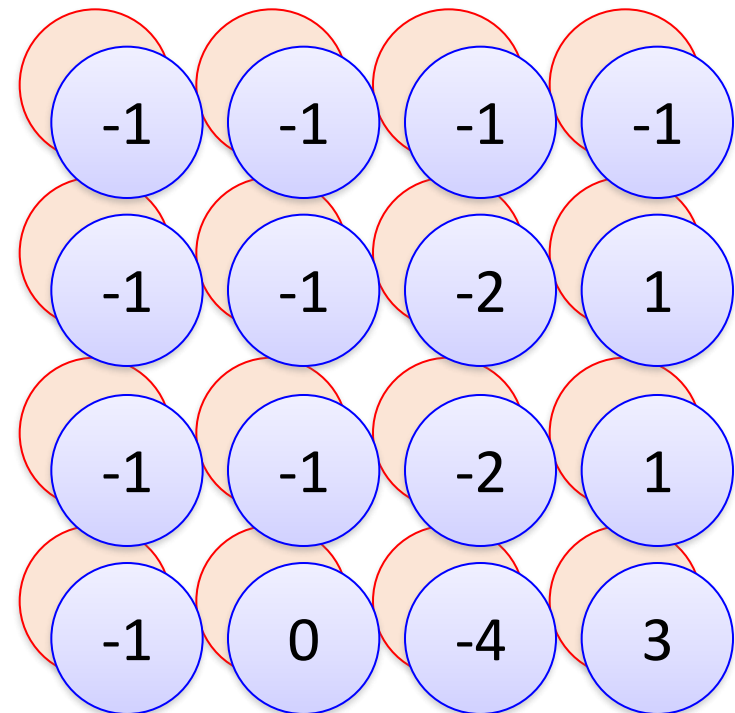
-1	1	-1
-1	1	-1
-1	1	-1

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

Color image: RGB 3 channels

Filter 1

Filter 2

The diagram shows a 3x3x3 volume of light blue cubes. The front face is a 3x3 grid of cubes. The top row of the front face contains cubes with values -1, 1, and -1. The middle row contains cubes with values -1, 1, and -1. The bottom row contains cubes with values -1, 1, and -1. The top and bottom faces of the volume are also visible, showing a 3x3 grid of cubes.



RGB channel

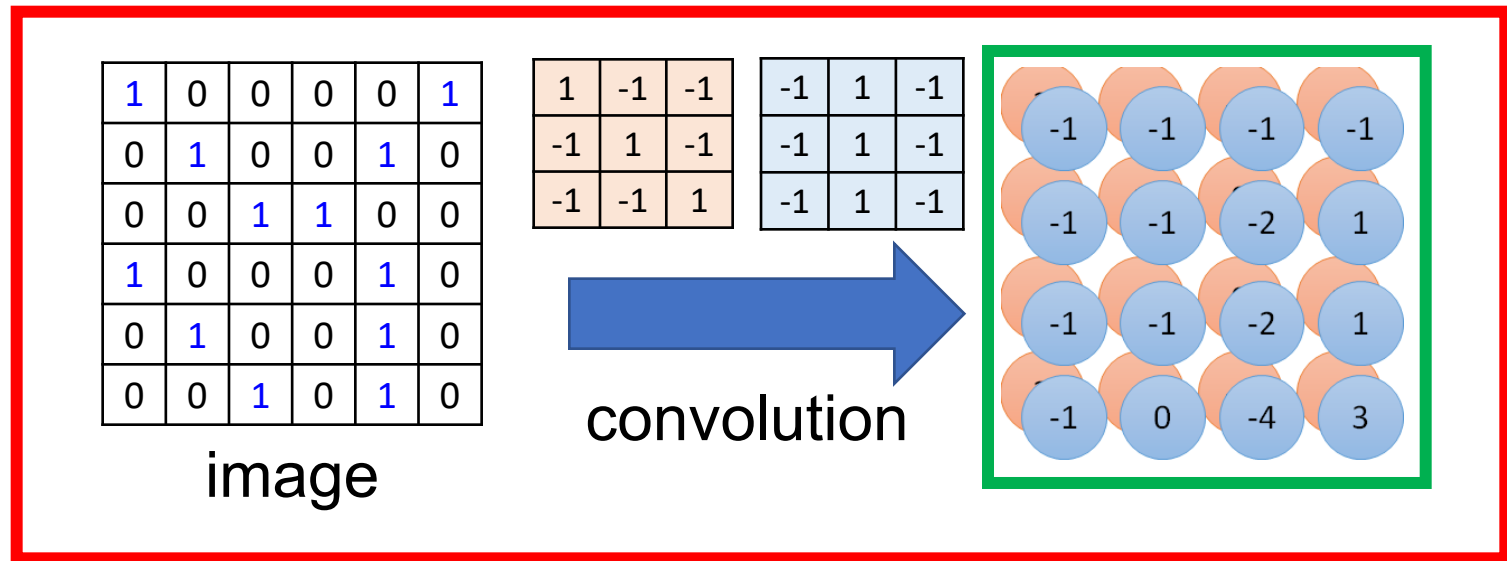


The diagram shows a 6x6 grid of cells. Each cell contains either a blue '1' or a black '0'. The grid is as follows:

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

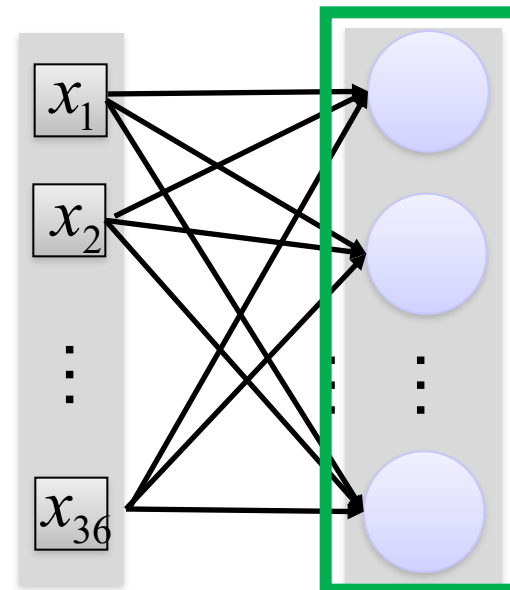
On the left side of the grid, there is a vertical stack of 6 cards. Each card has a small circle on its left edge. The top card has a blue '1' on its left edge, and the other five cards have black '0's on their left edges.

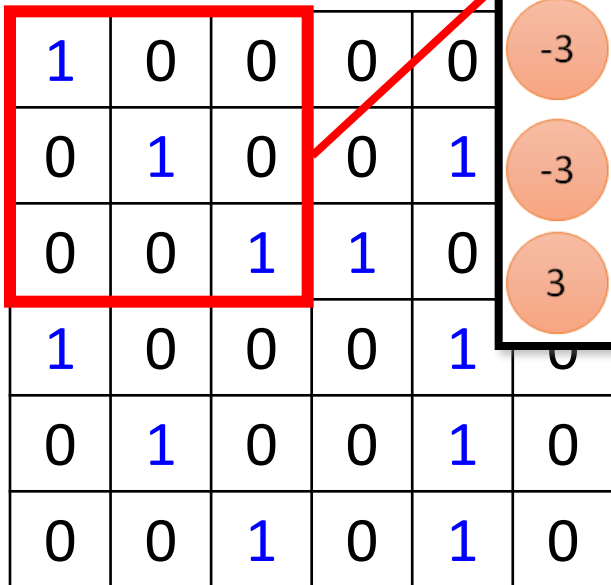
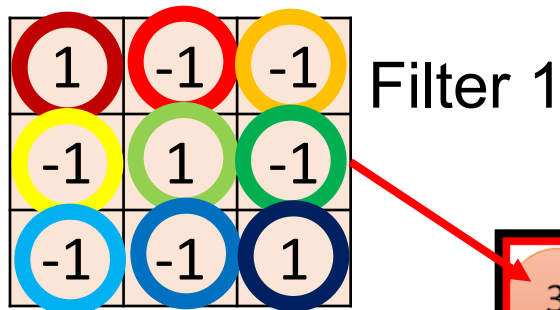
Convolution vs. Fully Connected



Fully-
connected

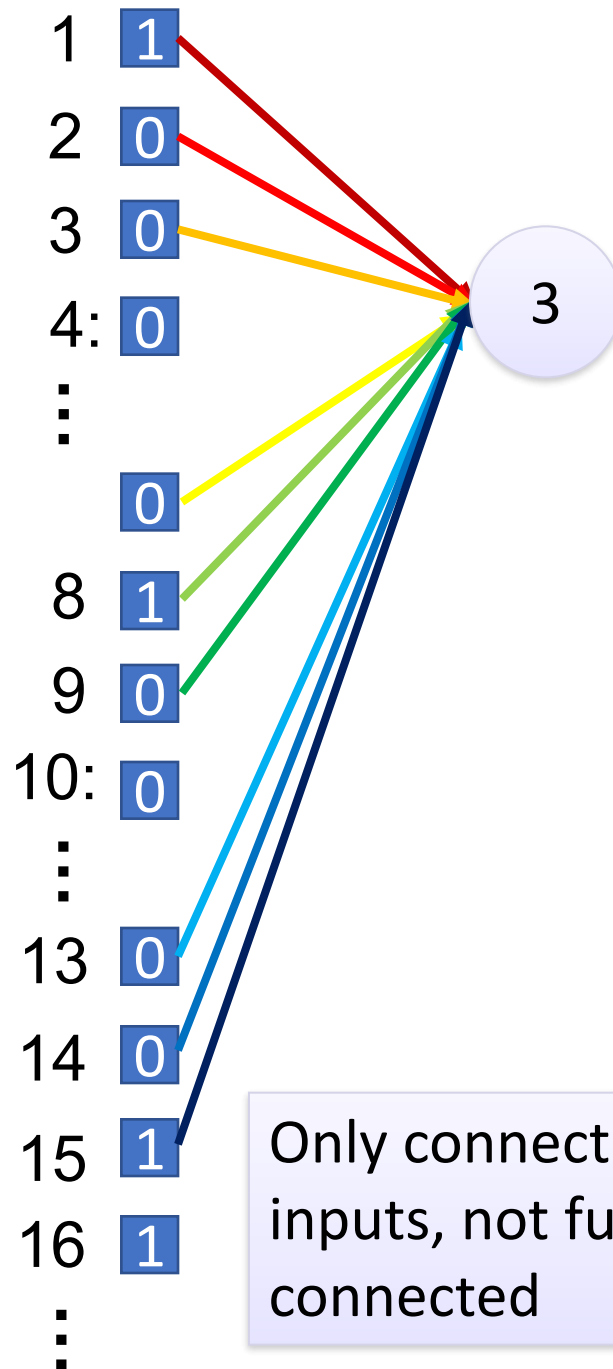
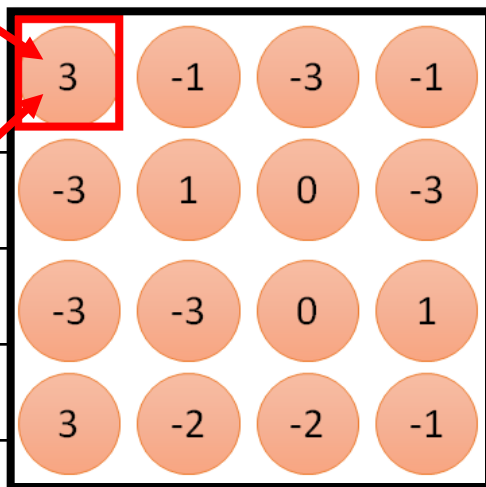
1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0



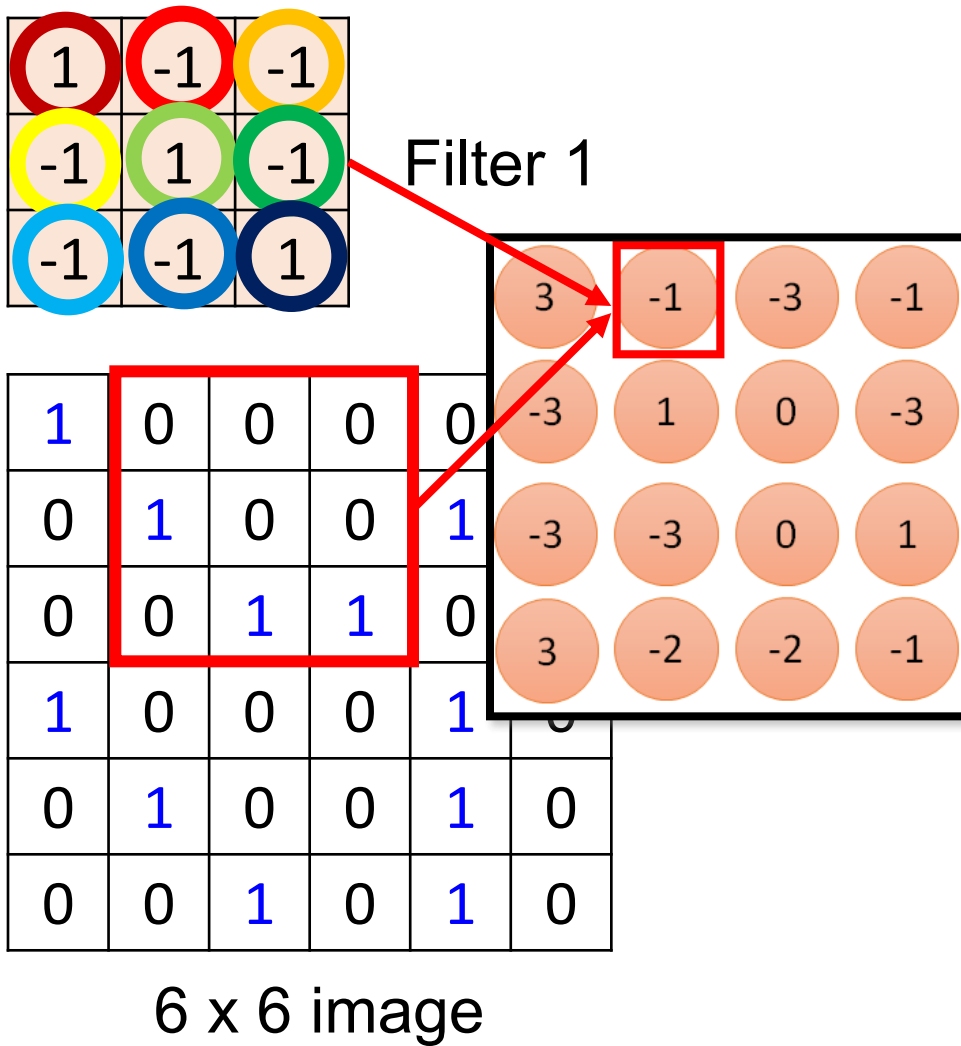


6 x 6 image

fewer parameters!

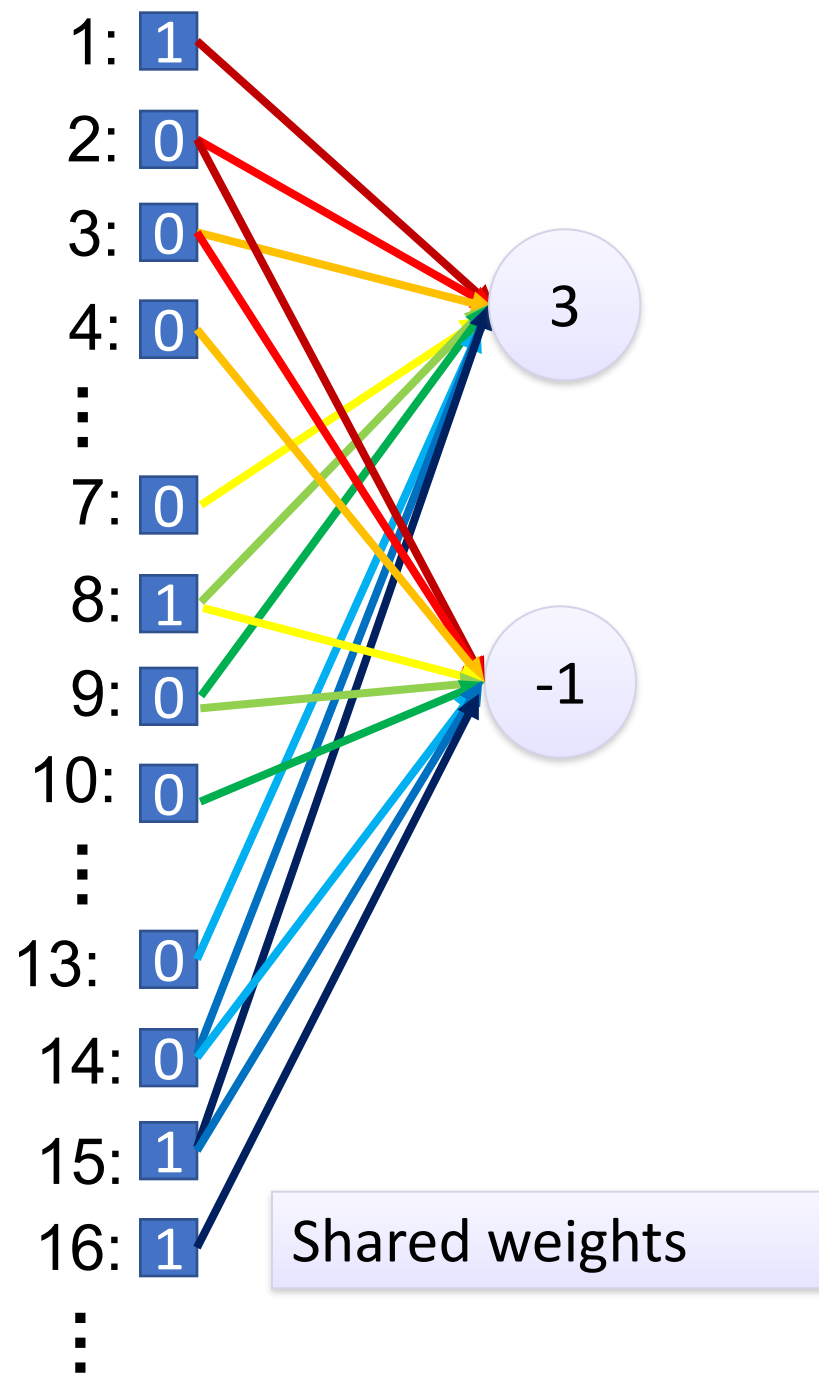


Only connect to 9 inputs, not fully connected



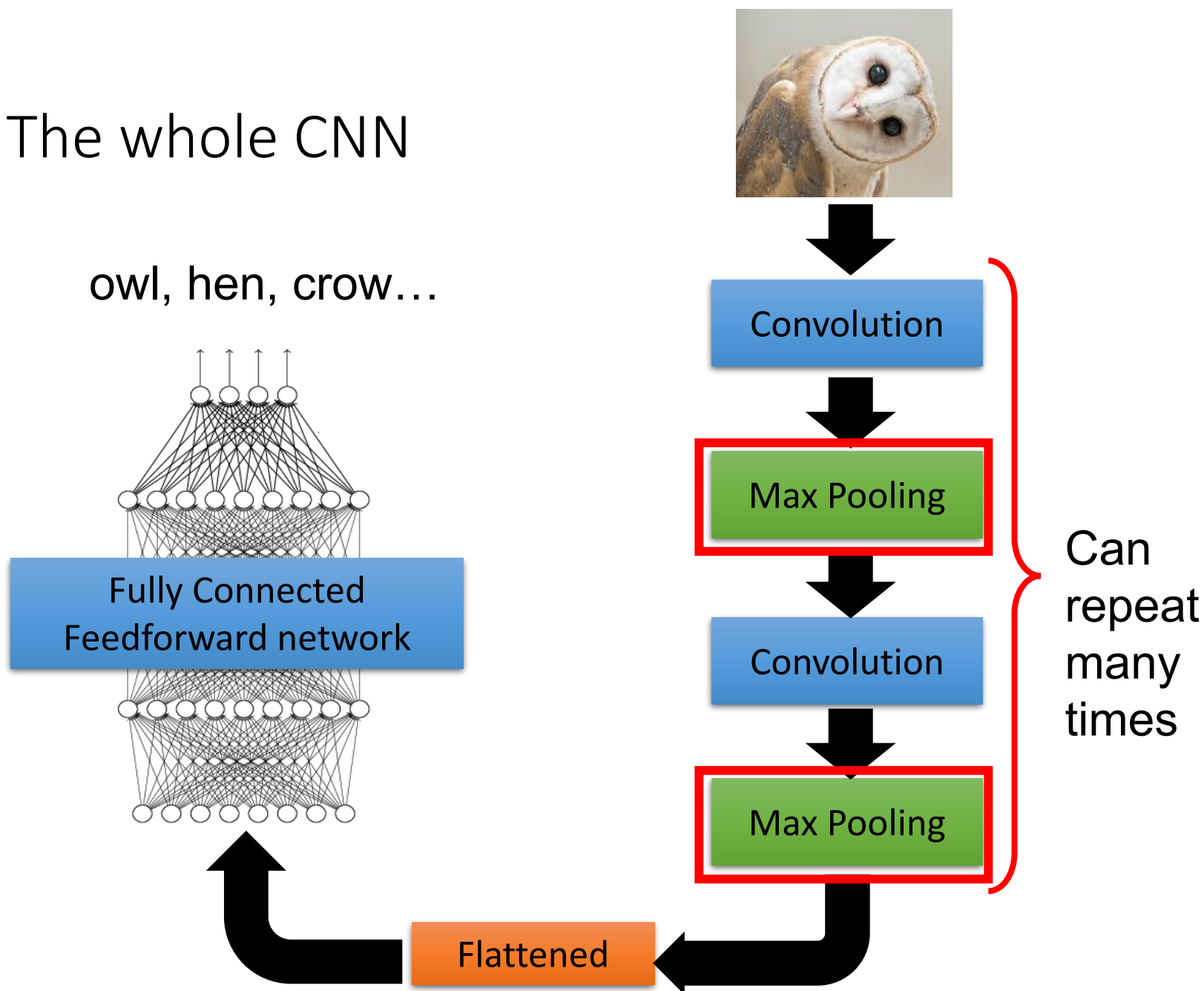
Fewer parameters

Even fewer parameters



The whole CNN

owl, hen, crow...



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

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

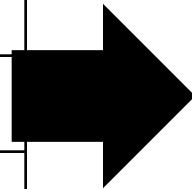
A CNN compresses a fully connected network in two ways:

- Reducing number of connections
- Shared weights on the edges
- 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

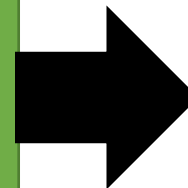
6 x 6 image



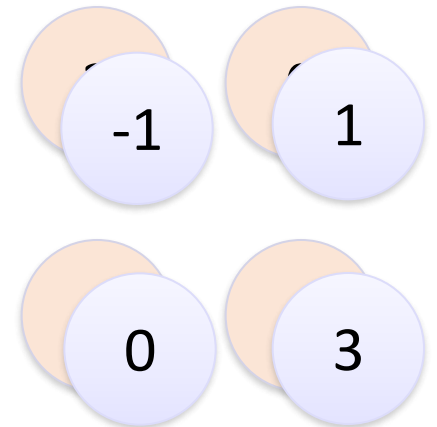
Conv



Max
Pooling



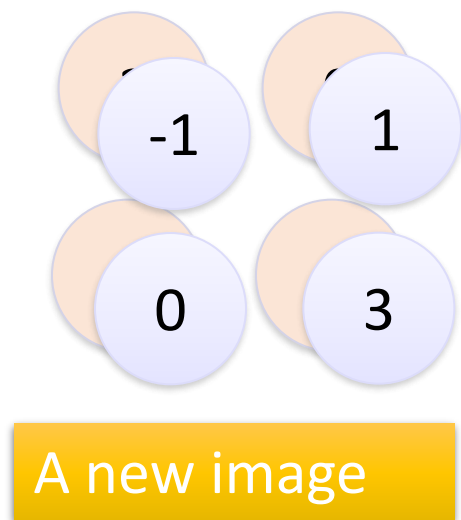
New image
but smaller



2 x 2 image

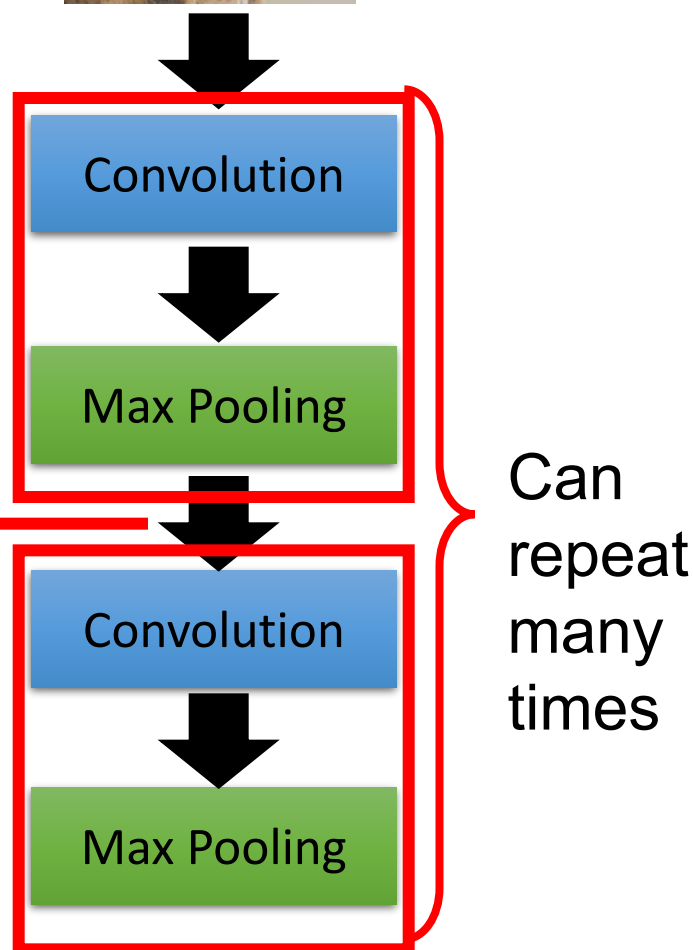
Each filter
is a channel

The whole CNN



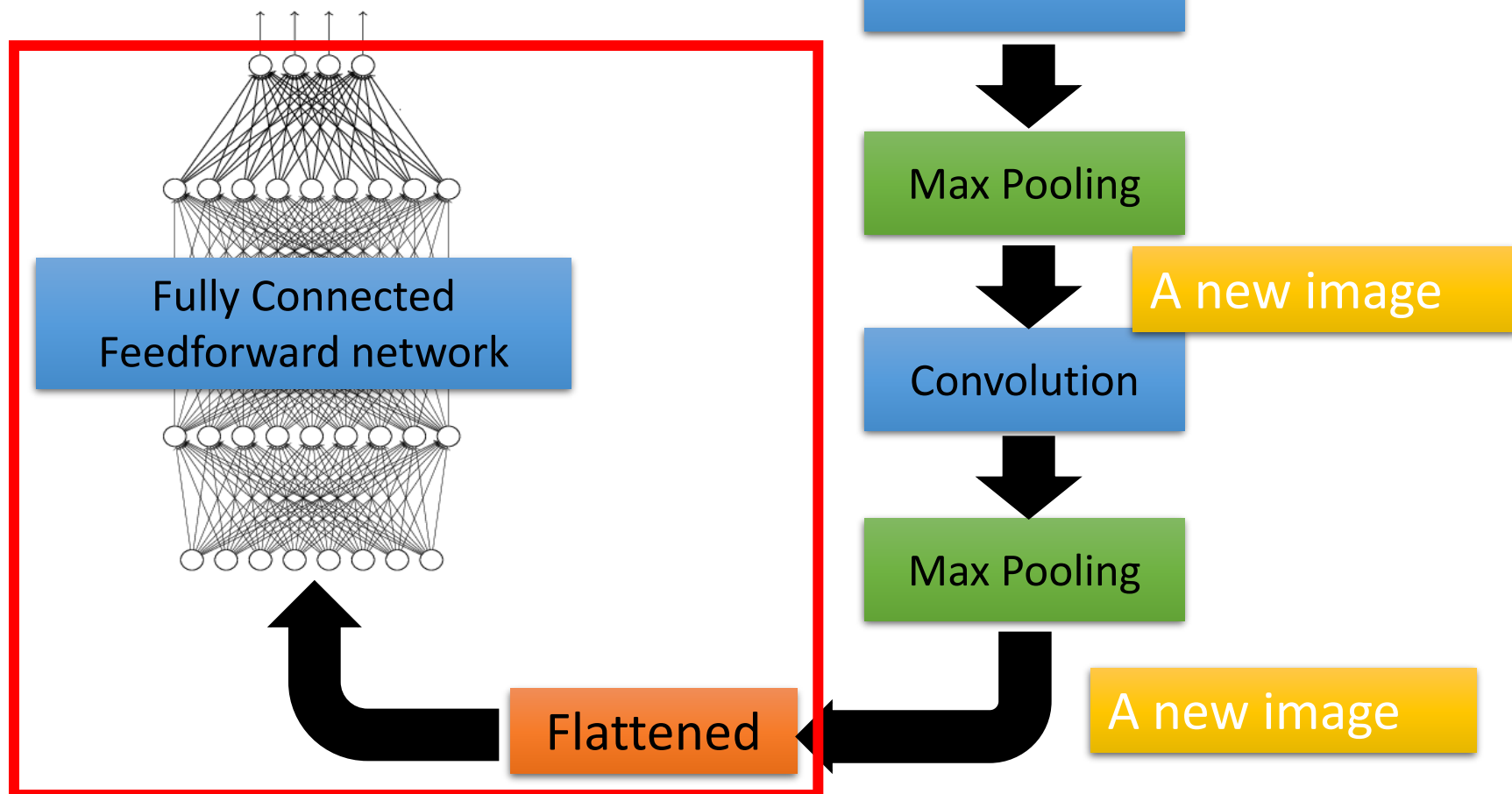
Smaller than the original image

The number of channels is the number of filters



The whole CNN

owl, hen, crow...



Flattening

