Deep Learning
CS60010

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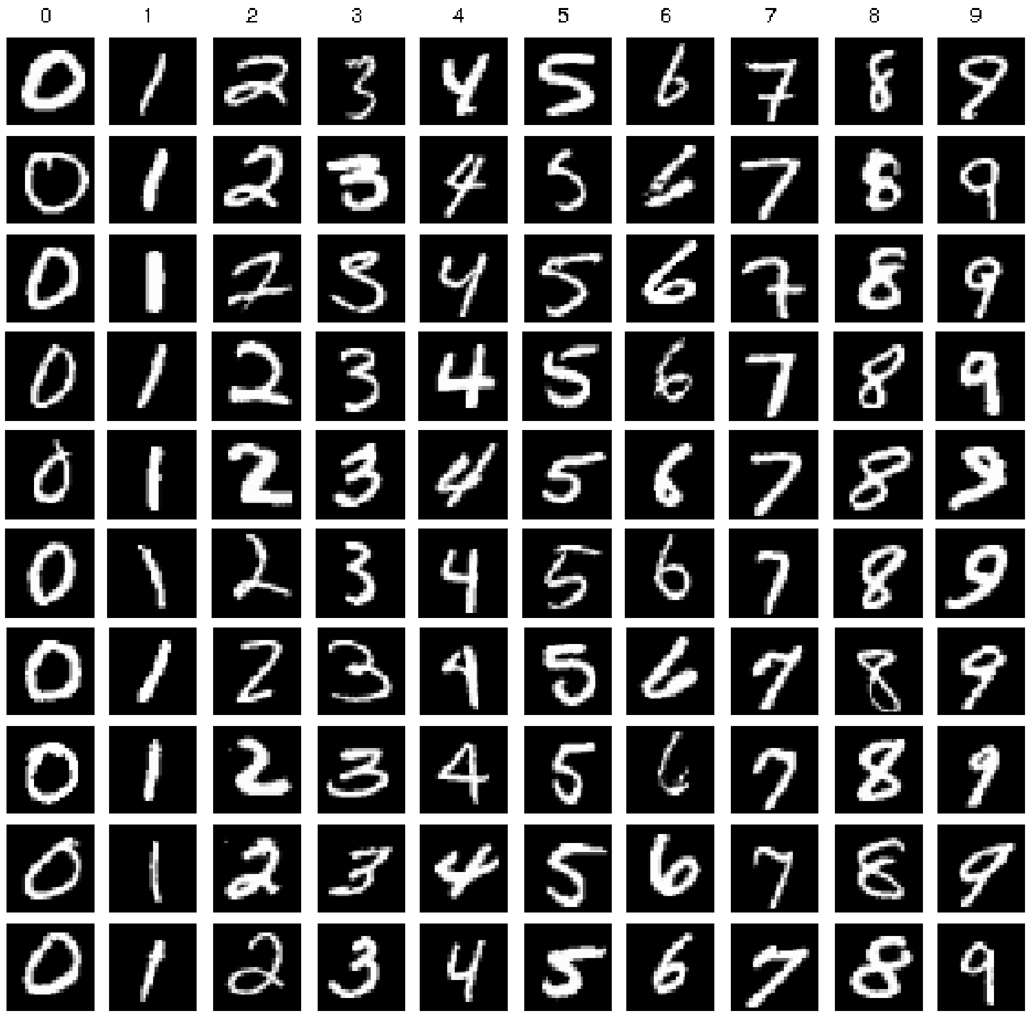
Agenda

The Building Blocks of Convolutional Neural Networks/CNNs/ConvNets

Importance of MNIST

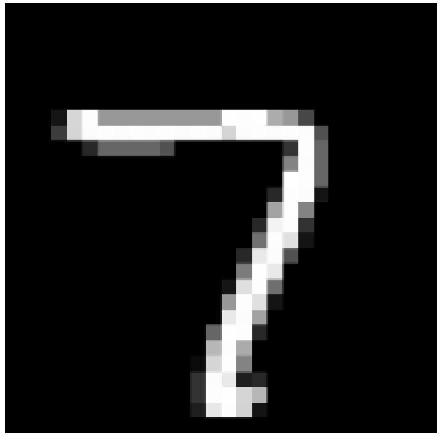
MNIST



- database of handwritten digits
- 10 classes
  - Training set 60,000 images
  - Test set of 10,000 images
- Greyscale images of size 28x28
- Often treated as `Hello World' for any ML/DL practitioner

Image taken from Researchgate

Example from MNIST



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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	21	214	253	152	152	152	152	152	152	152	152	254	253	254	172	152	71	0	0	0	0	0	0	0	0
0	0	0	61	213	252	253	252	253	252	253	252	253	252	213	252	253	252	253	252	82	0	0	0	0	0	0	0
0	0	0	0	0	41	102	102	102	102	82	0	0	0	0	0	0	0	52	253	102	0	0	0	0	0	0	0
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	113	253	224	20	0	0	0	0	0	0	0	0
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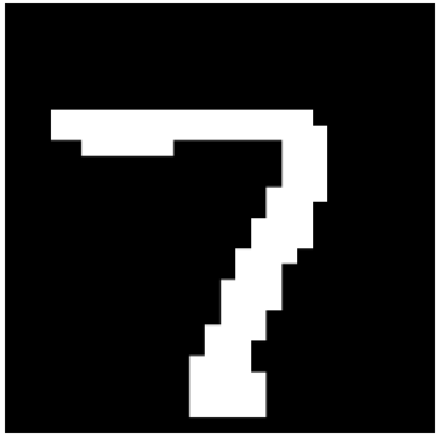
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

7 Like Window?



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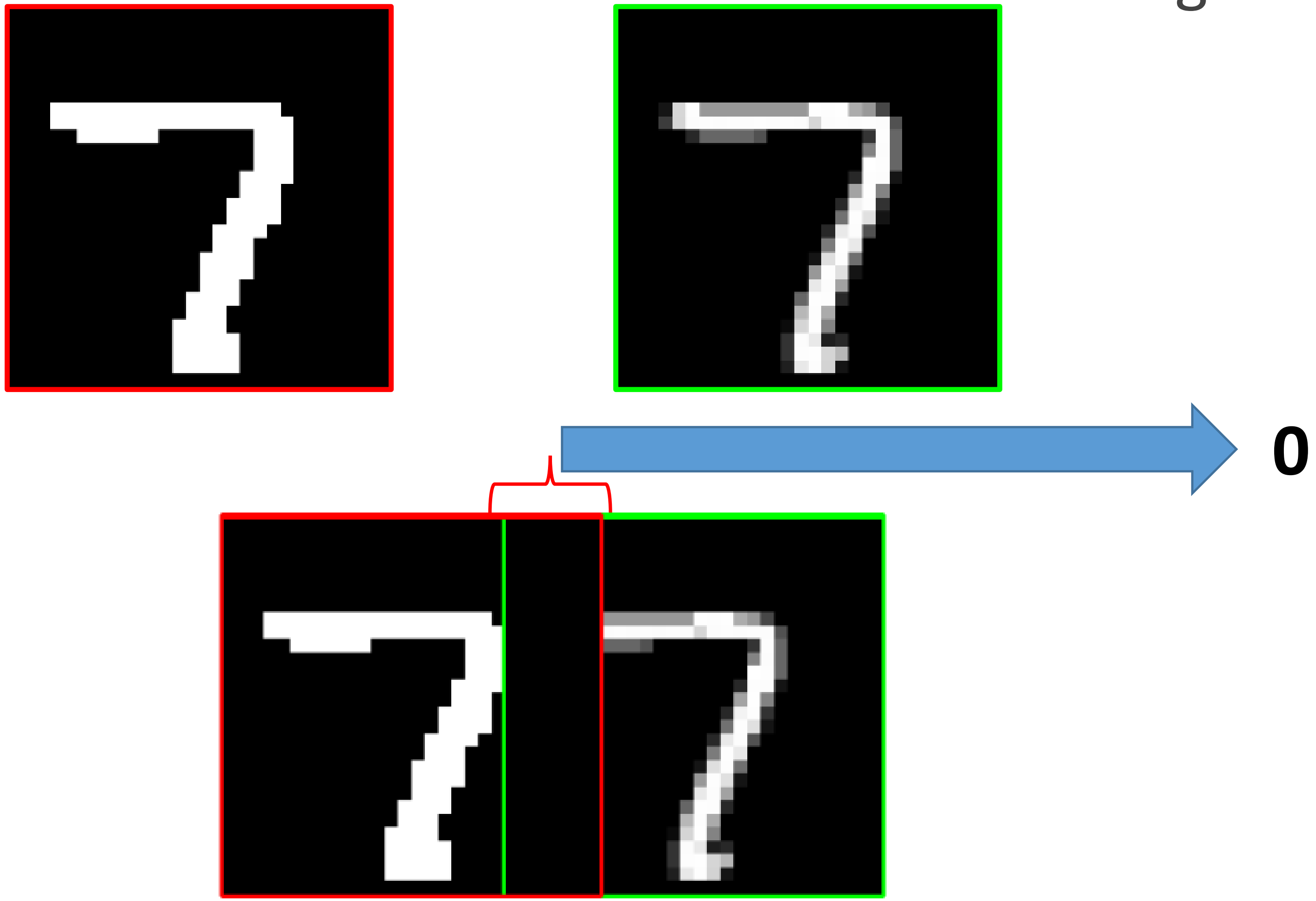
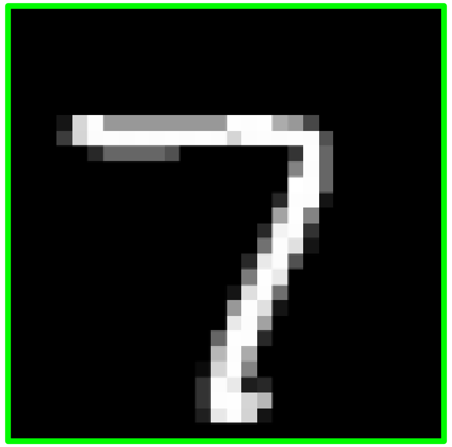
Filtering

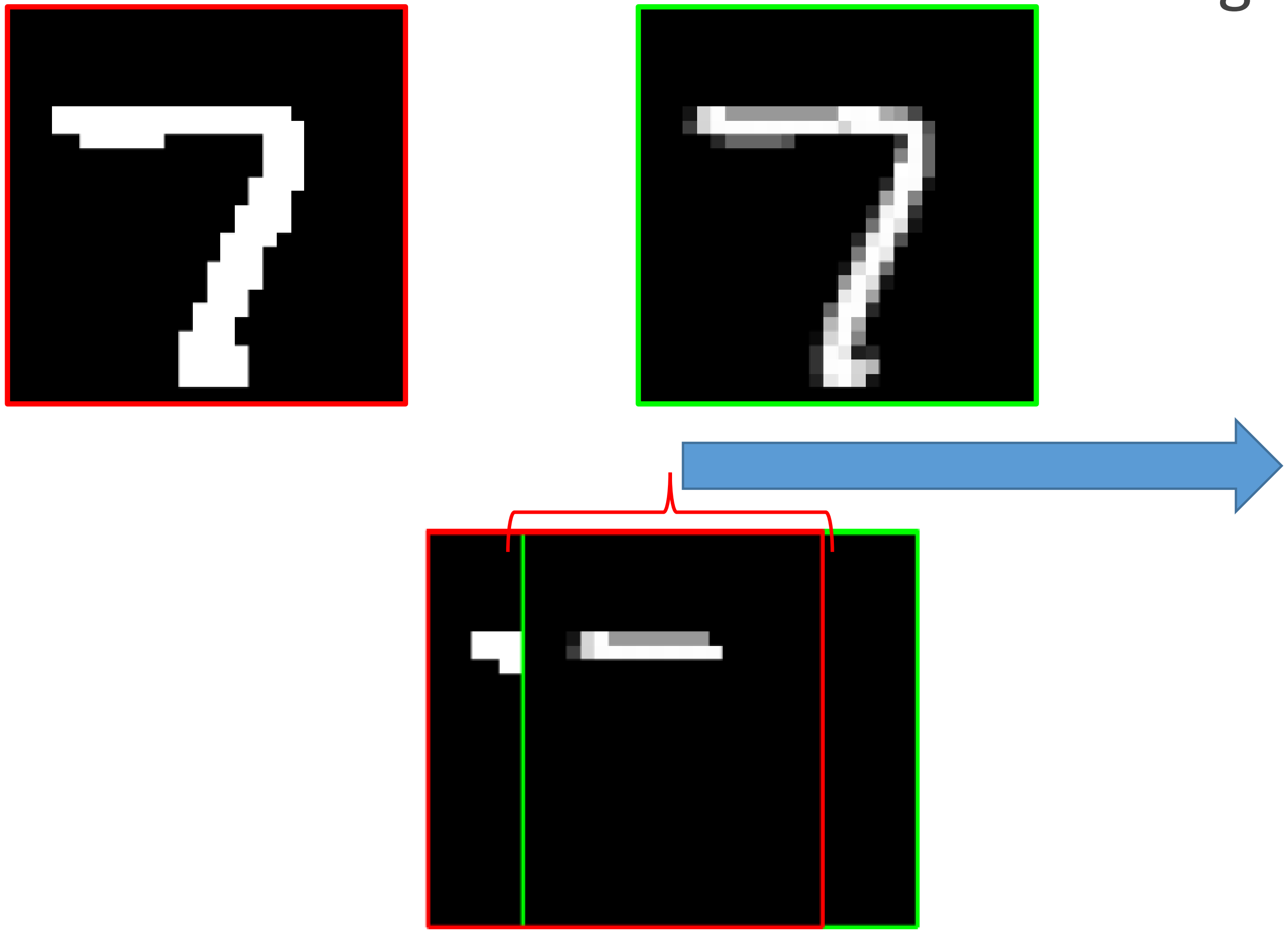


Filtering



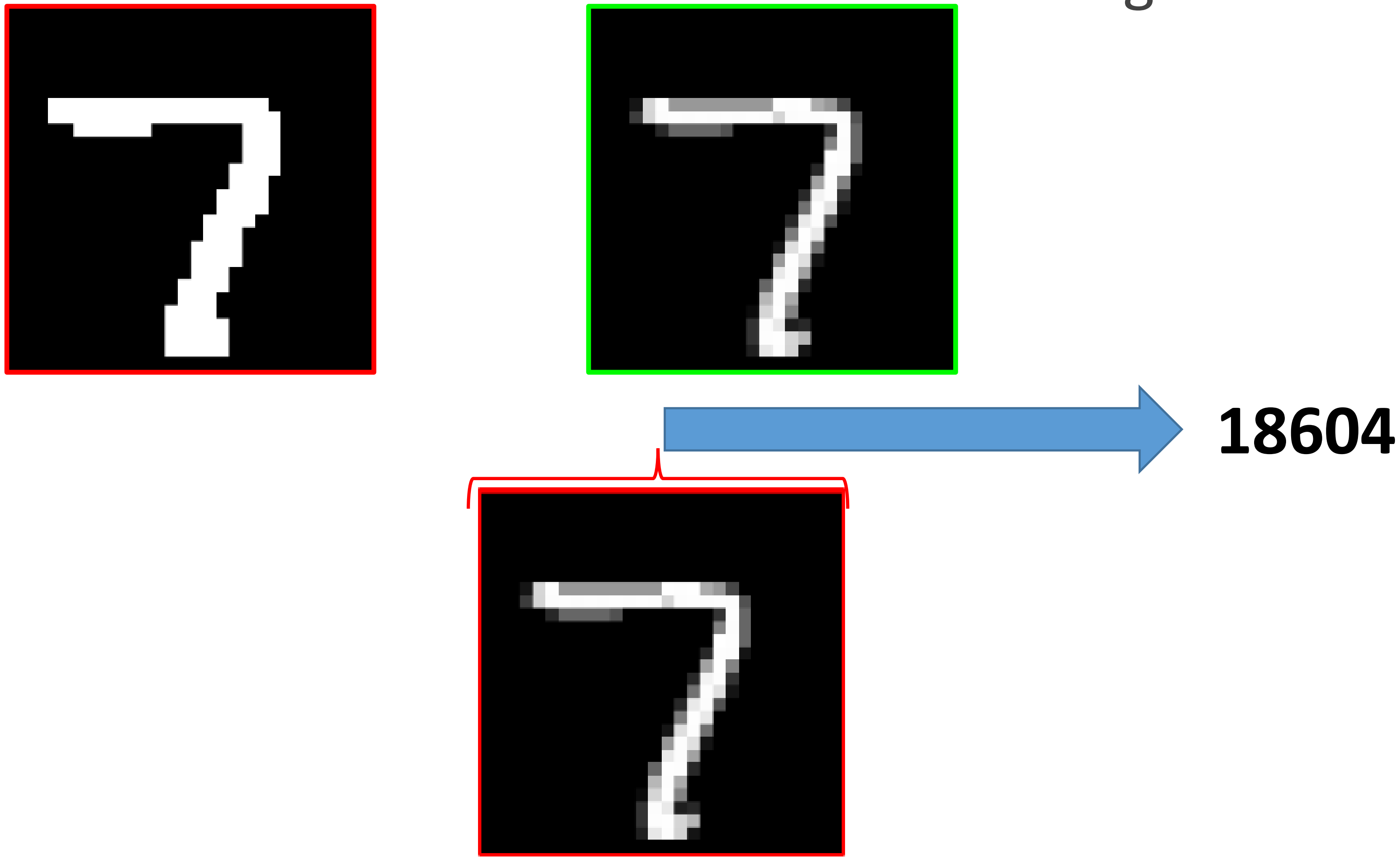
1410

Filtering

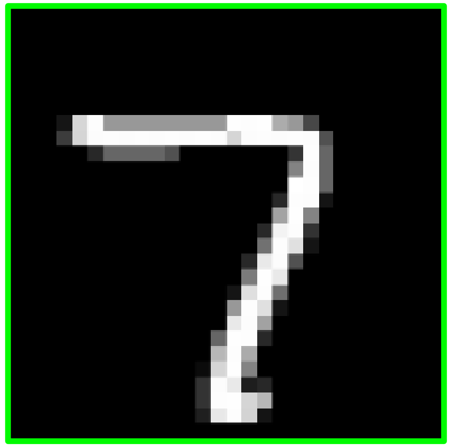


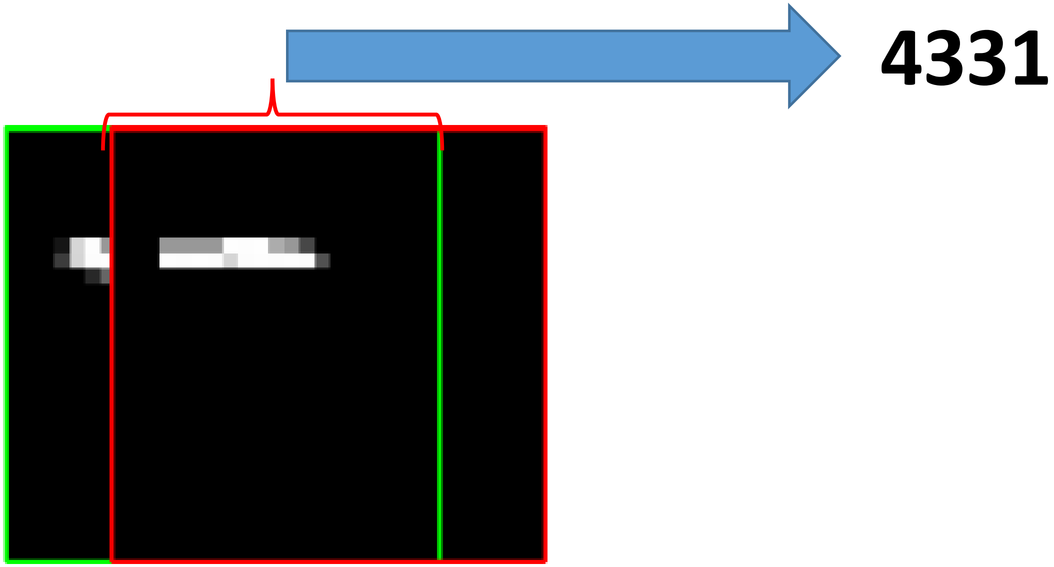
4098

Filtering

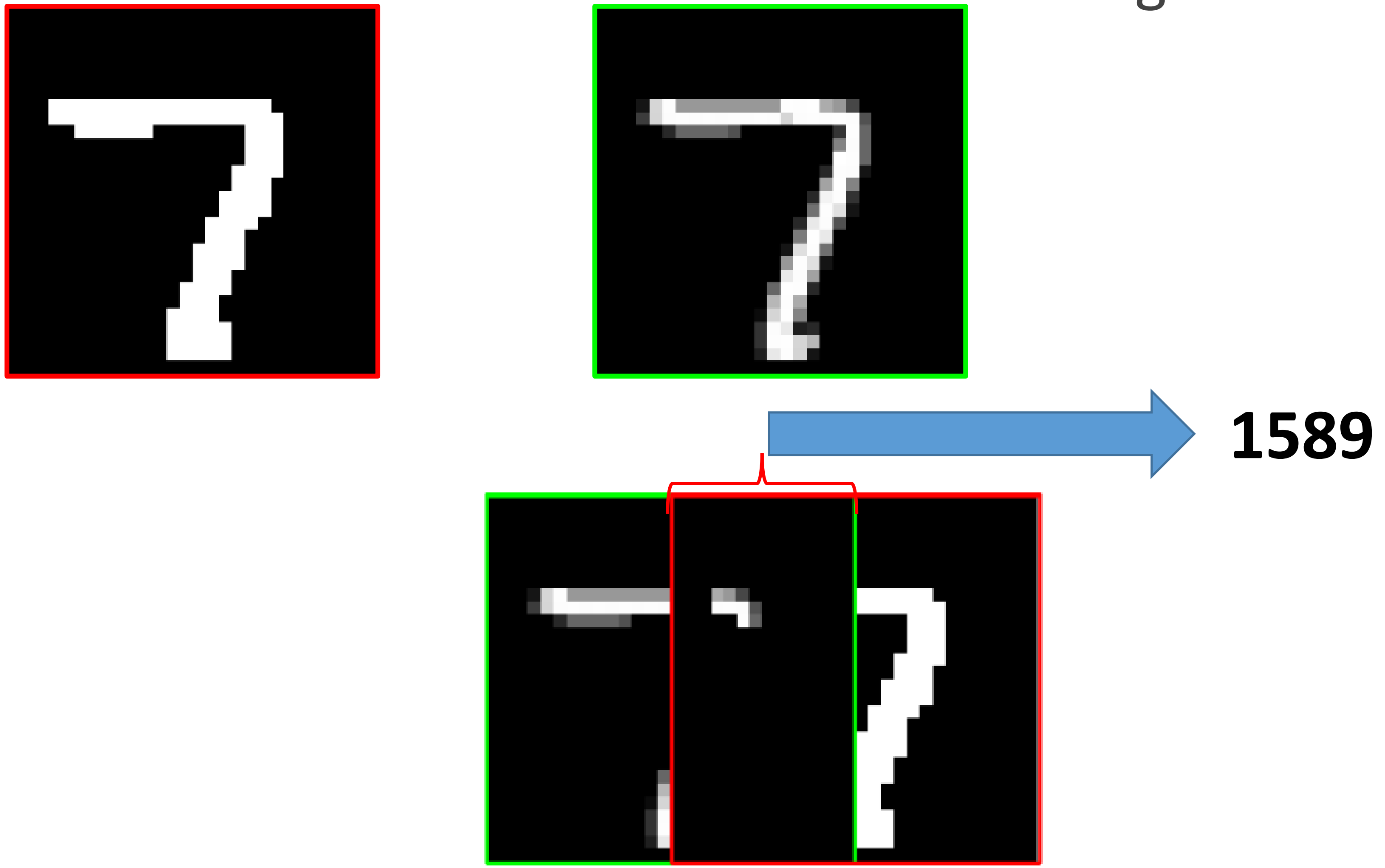


Filtering

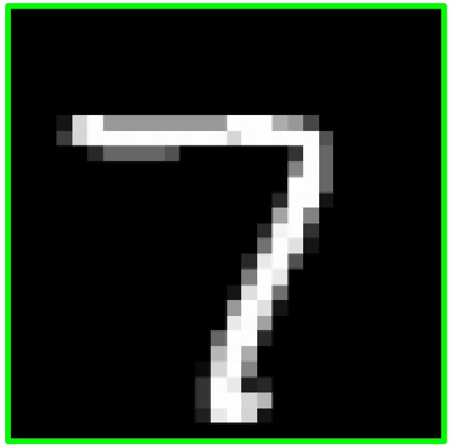


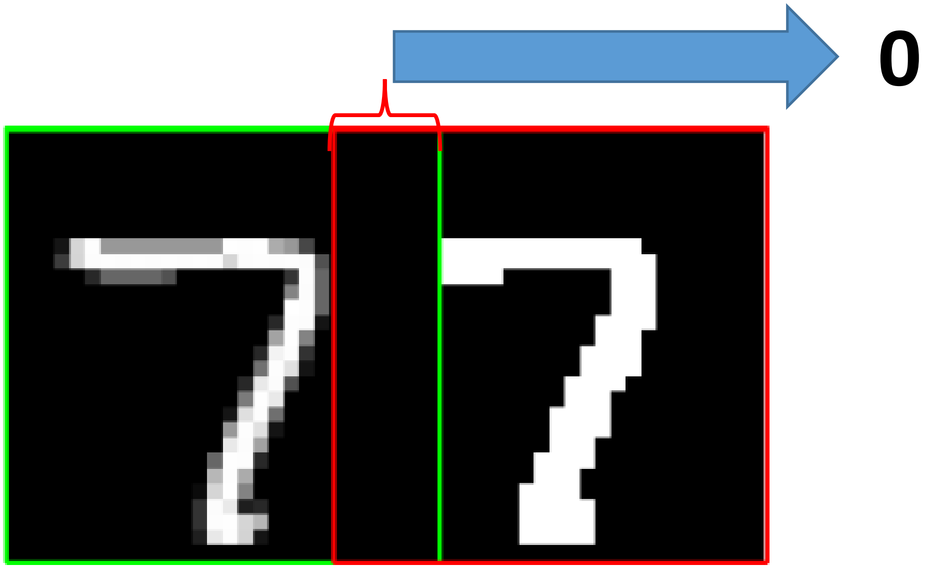


Filtering



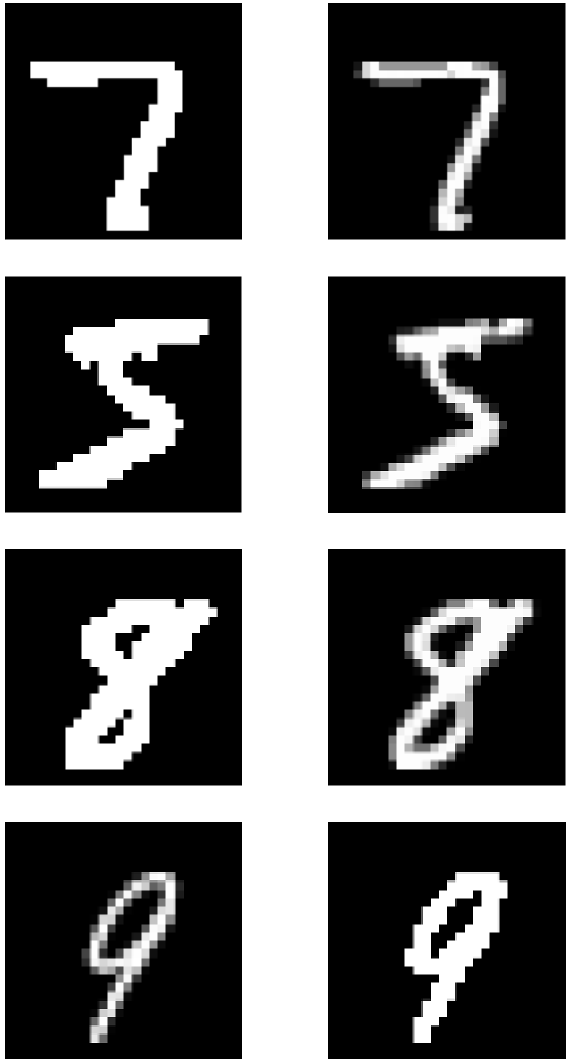
Filtering





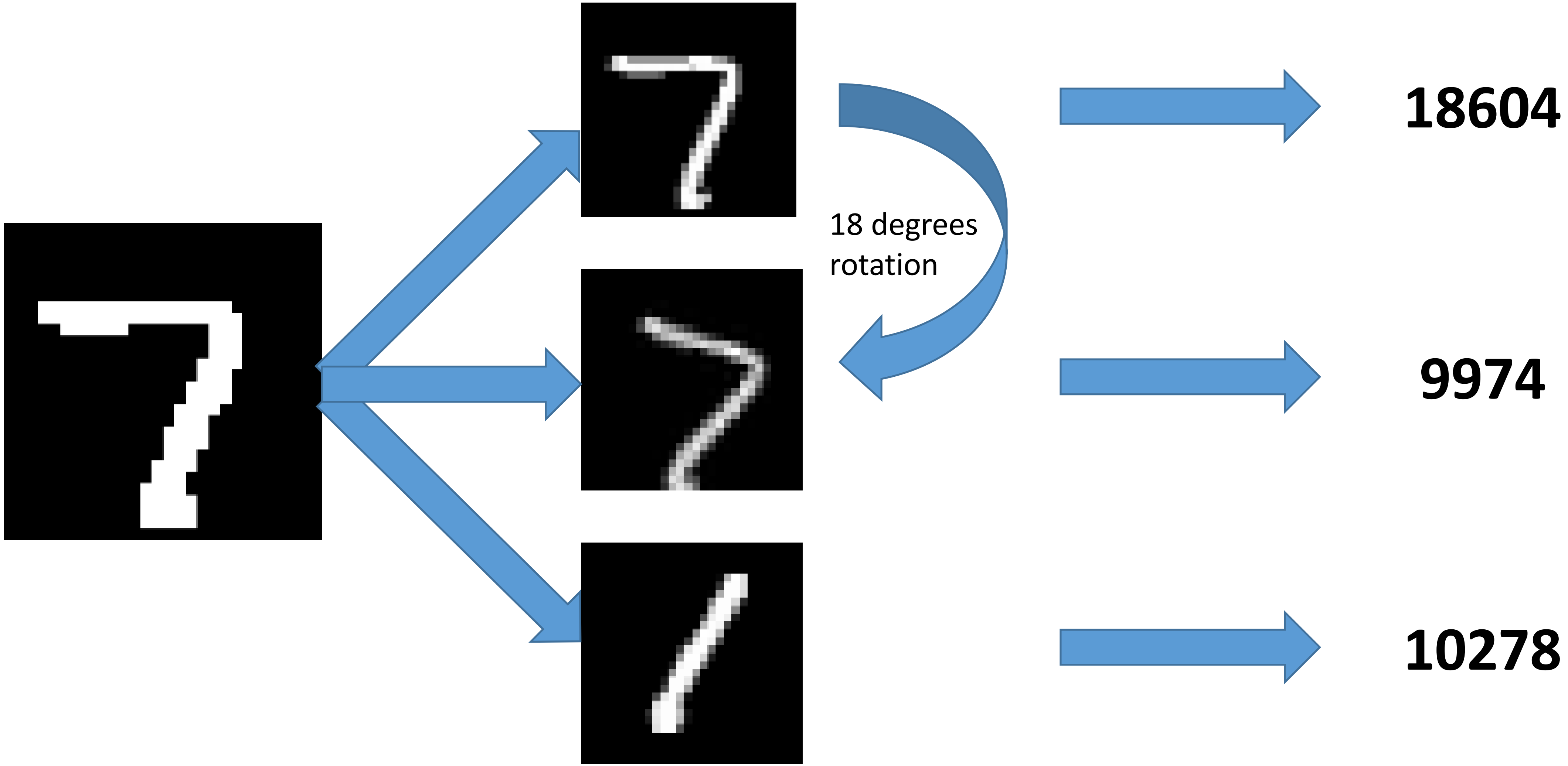
Classification by Matching Filters

Filters | Test Images

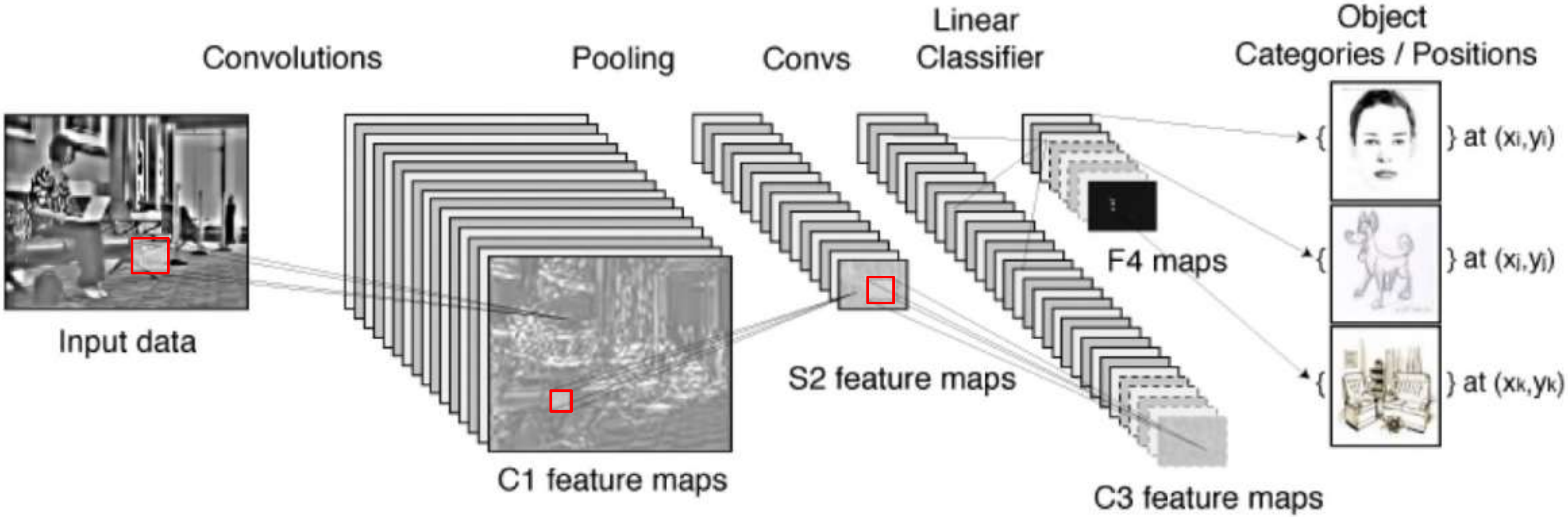


But what if the test image is a little
Rotated (or)
Skewed (or)
Zoomed out and so on

Effect of Slight Rotation

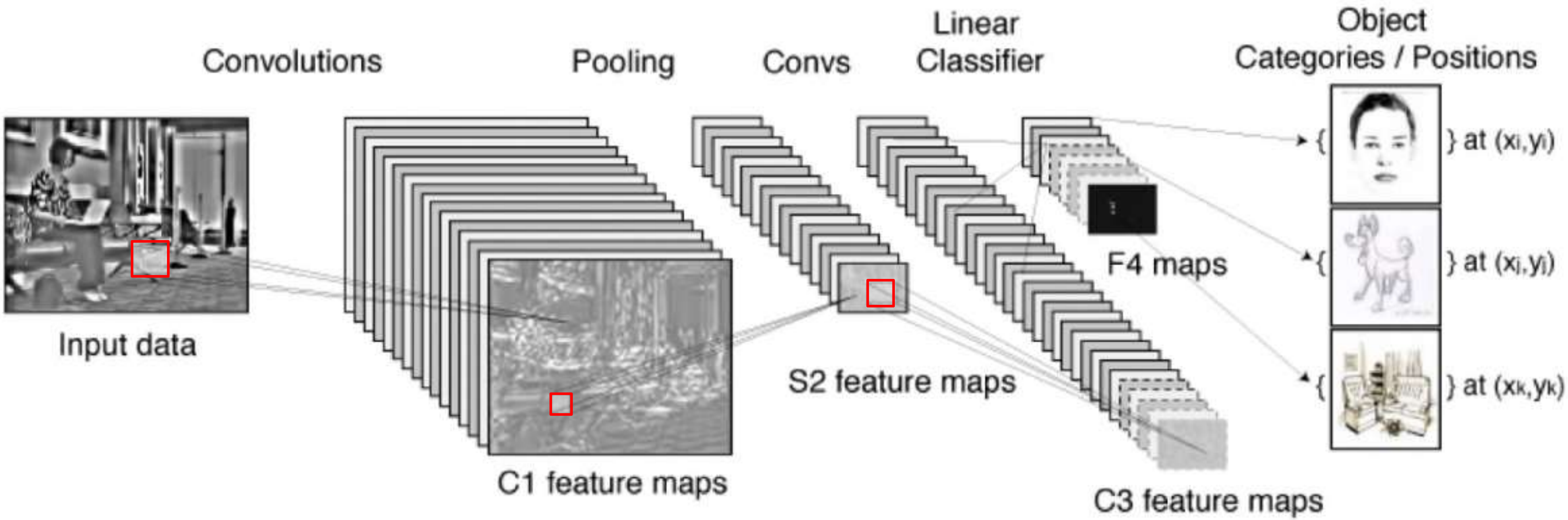


Convnets (Fukushima, LeCun, Hinton)



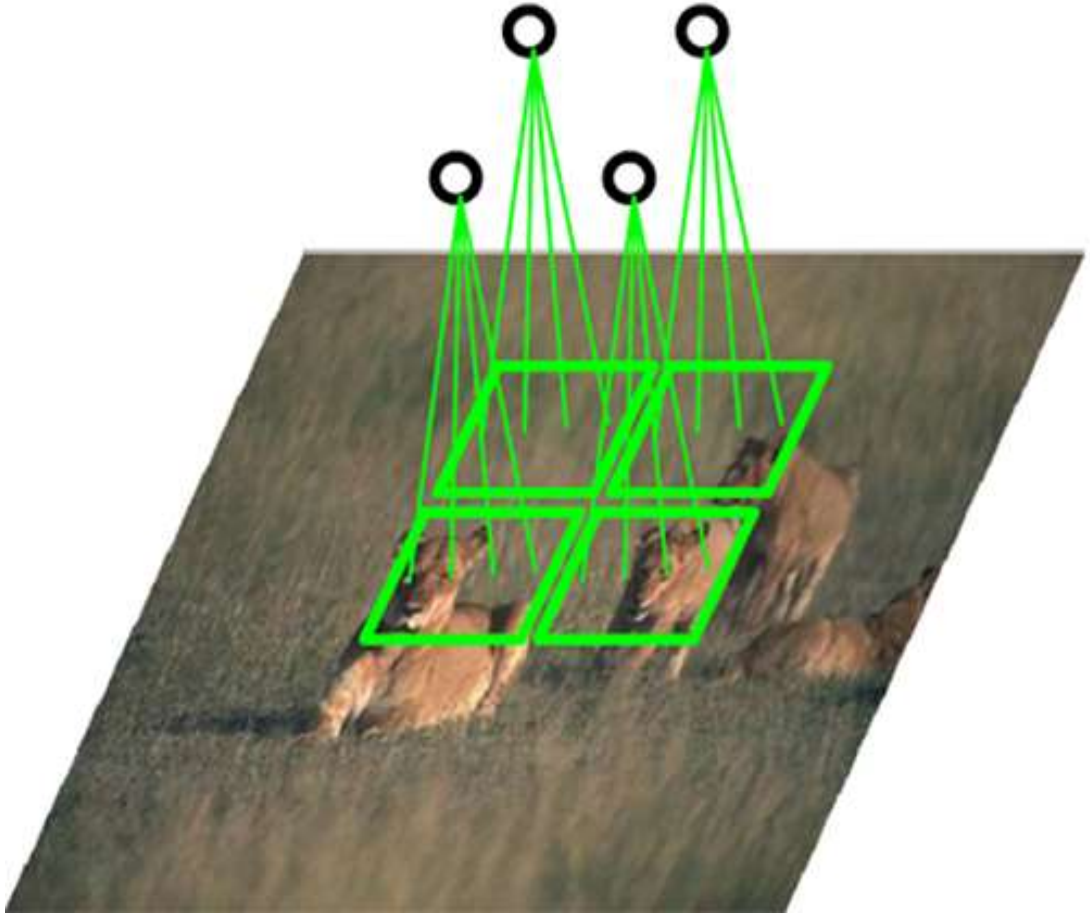
Slide courtesy: Nando de Freitas, University of Oxford

Convnets (Fukushima, LeCun, Hinton)



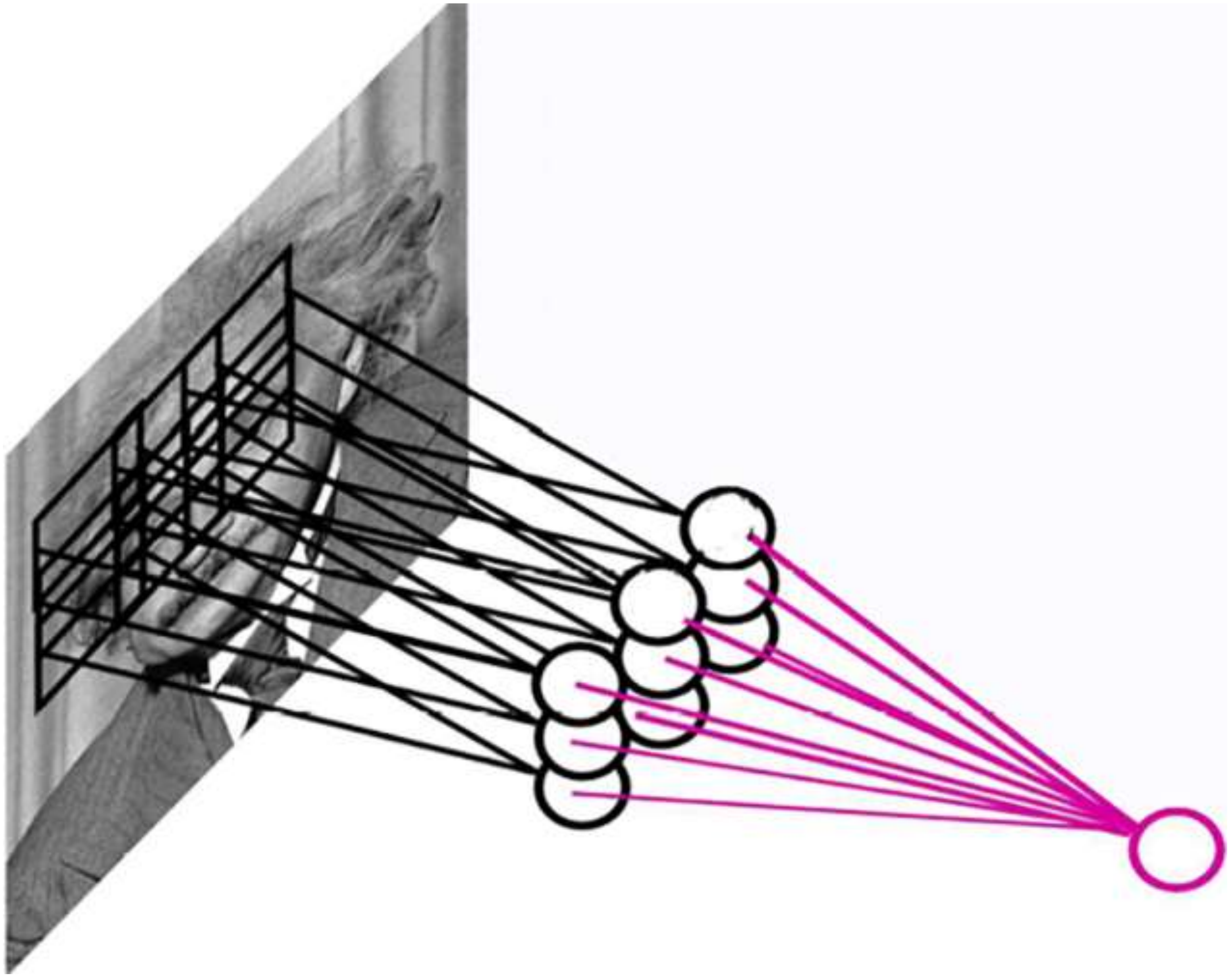
Slide courtesy: Nando de Freitas, University of Oxford

Convnets (Fukushima, LeCun, Hinton)



Slide courtesy: Nando de Freitas, University of Oxford

Pooling



By "pooling" (e.g., max or average) filter responses, we gain robustness to the exact spatial location of features.

Image courtesy: Nando de Freitas, University of Oxford

Convolution

Filter

0	1	2
2	2	0
0	1	2

Image

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

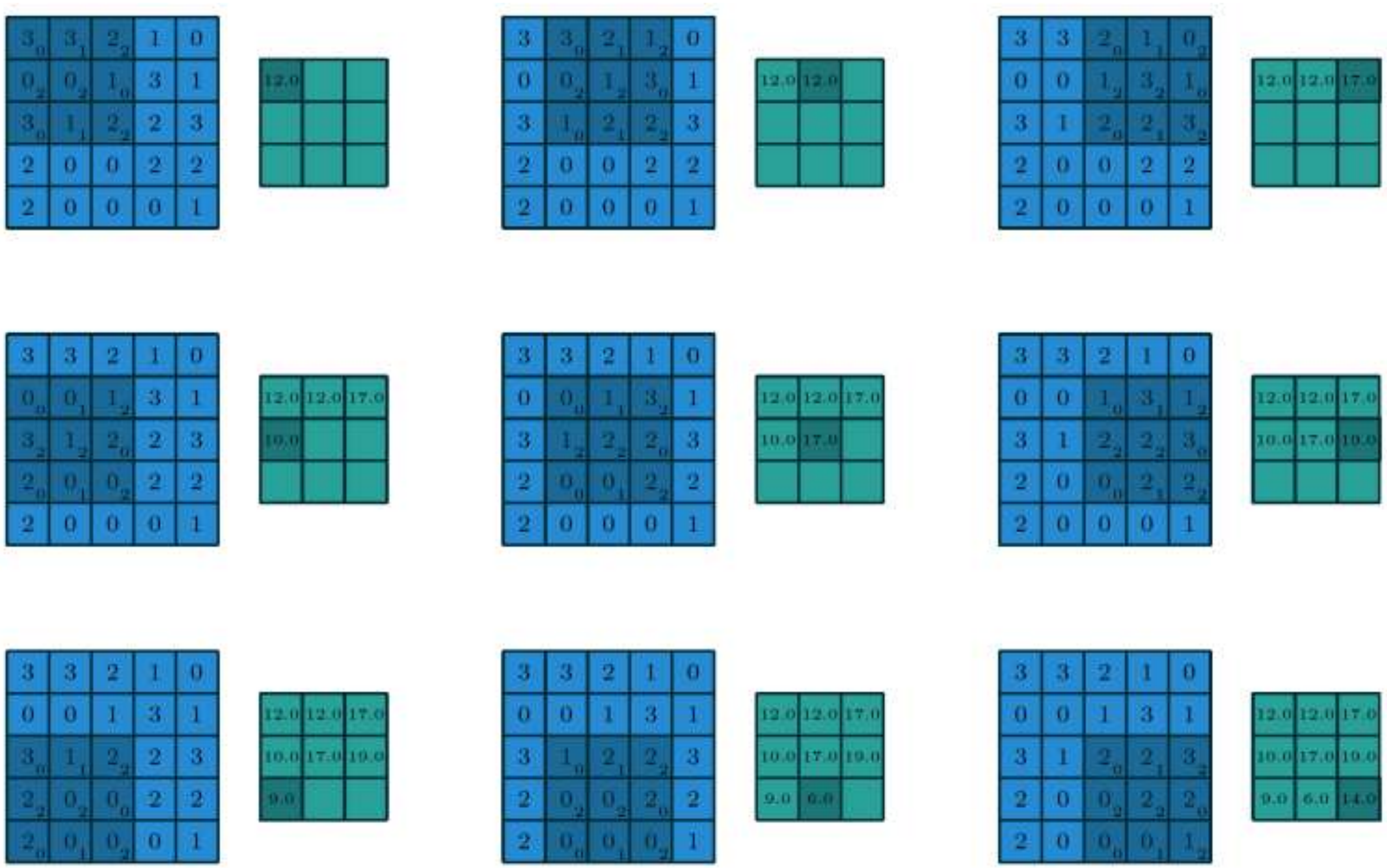


Image courtesy:Vincent Dumoulin

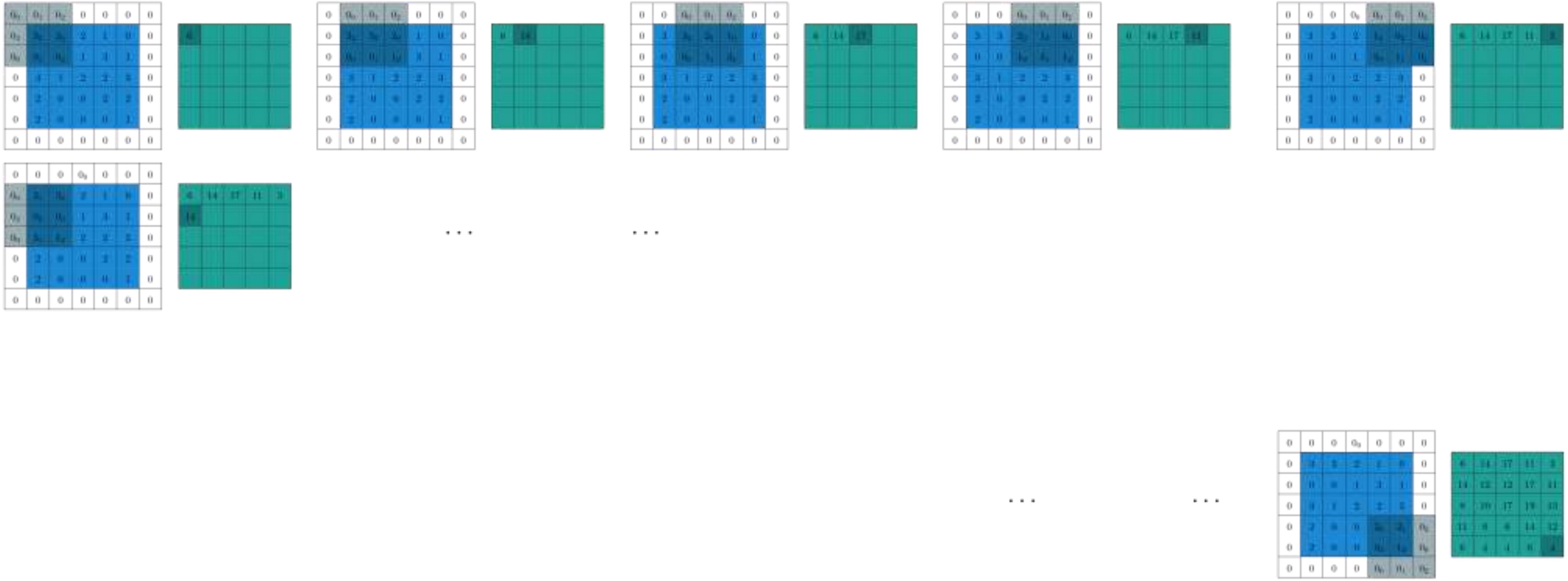
Convolution with Zero Padding

Filter

0	1	2
2	2	0
0	1	2

Image

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



Convolution with Strides

Convolving a 3x3 kernel over a 5x5 input using 2x2 strides

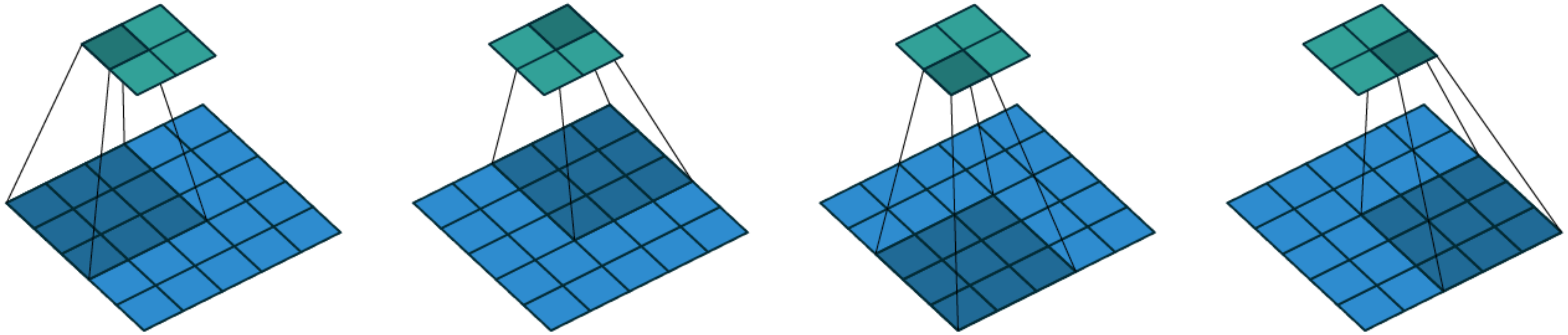


Image courtesy:Vincent Dumoulin

Convolution with Strides and Zero Padding

Convolving a 3x3 kernel over a 5 x5 input using 1 x1 strides and half padding

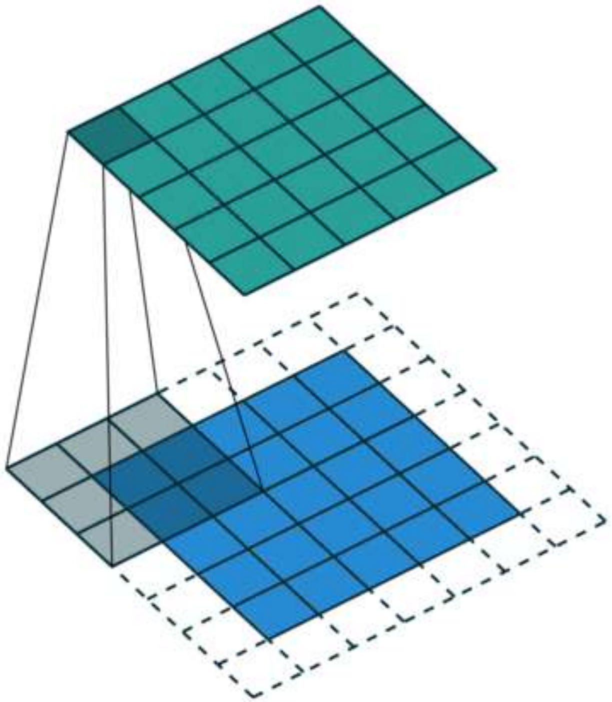


Image courtesy:Vincent Dumoulin

Inputs Generally have Multiple Channels

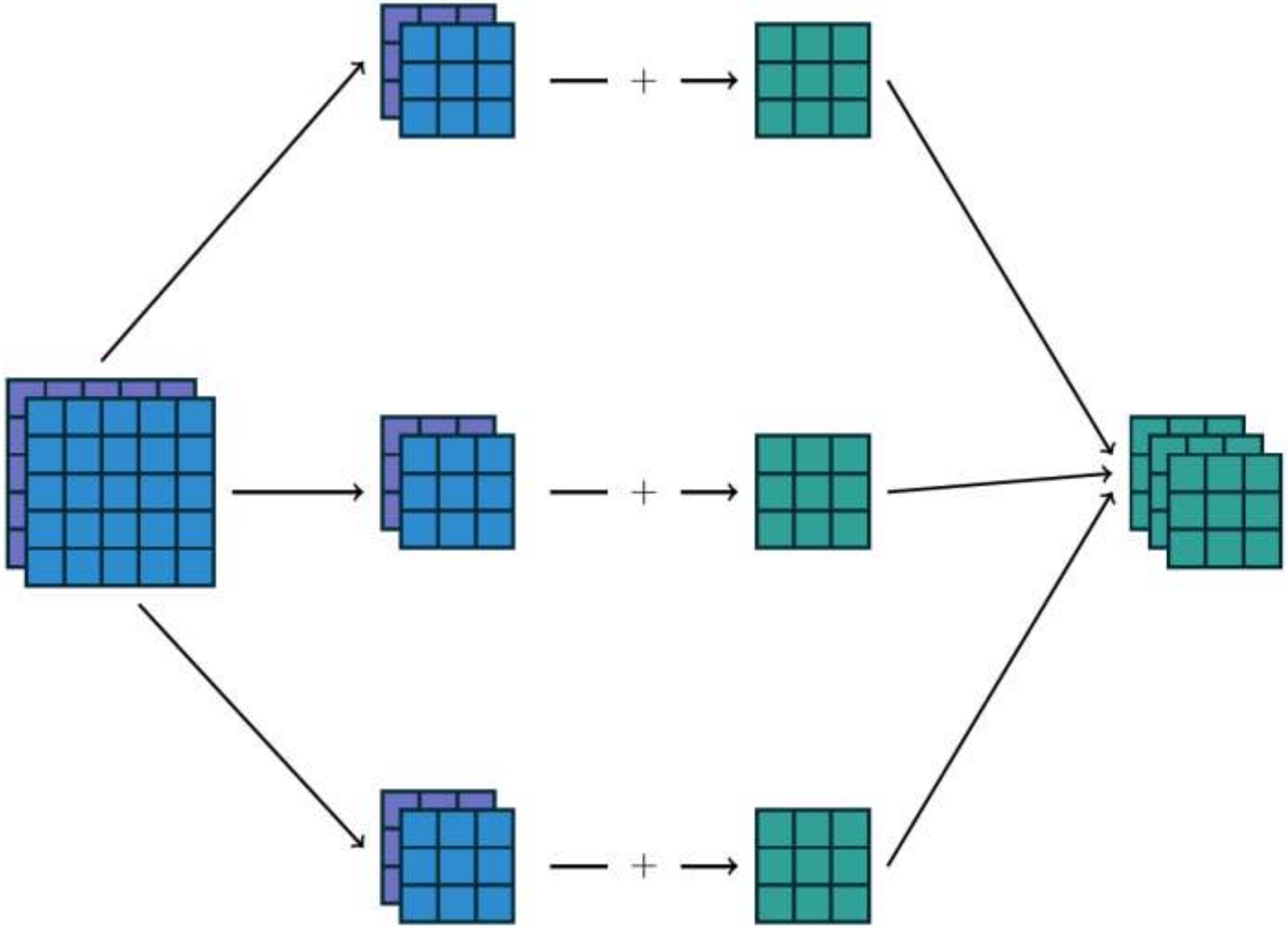


Image courtesy:Vincent Dumoulin

Convolution Arithmetic

(For simplicity we are assuming square image and filter/kernel)

Image width = image height = w

Filter width = Filter height = k

Stride = s

Output size = $\left\lfloor \frac{w-k}{s} \right\rfloor + 1$

Padding = p → This means image dimension becomes $w + 2p$

So, output size = $\left\lfloor \frac{w+2p-k}{s} \right\rfloor + 1$

Note the box function

$$w = 6, p = 1, k = 3, s = 2$$

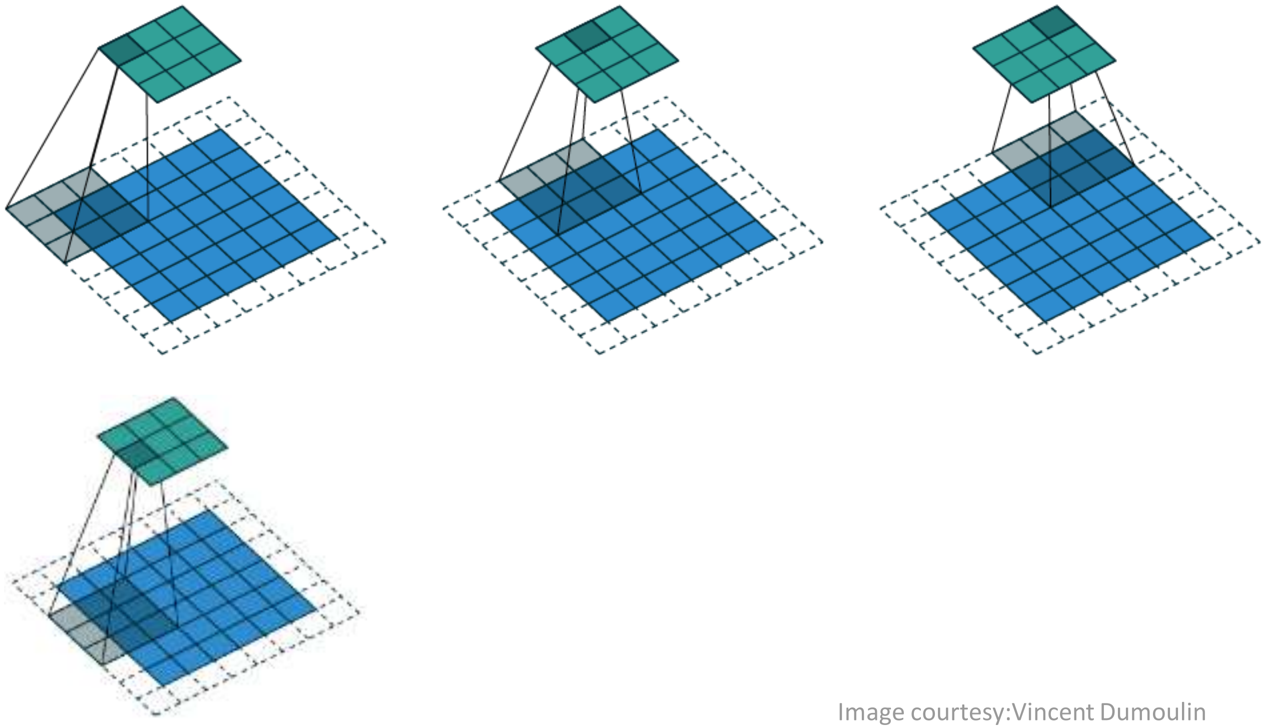
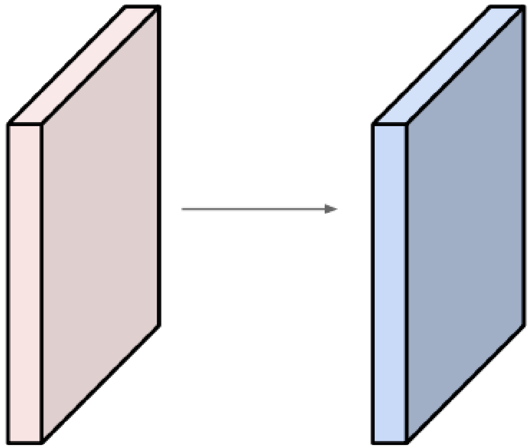


Image courtesy:Vincent Dumoulin

Convolution Arithmetic

Input volume: 32x32x3 [w, h, c].
64 filters of size 3x3 [k, k] with
stride 2 [s], pad 1 [p]



What is the output feature map size?

$$\left\lfloor \frac{32 + 2 * 1 - 3}{2} \right\rfloor + 1 = 16$$

So, $16 \times 16 \times 64$ [w, h, c]

And What is the number of parameters in this convolution layer?

$64 \times 3 \times 3 \times 3$ [c_out, w, h, c_in] = 1728

Image courtesy: Andrej Karpathy

Pooling

3x3 max-pooling on 5x5 input with 1x1 stride

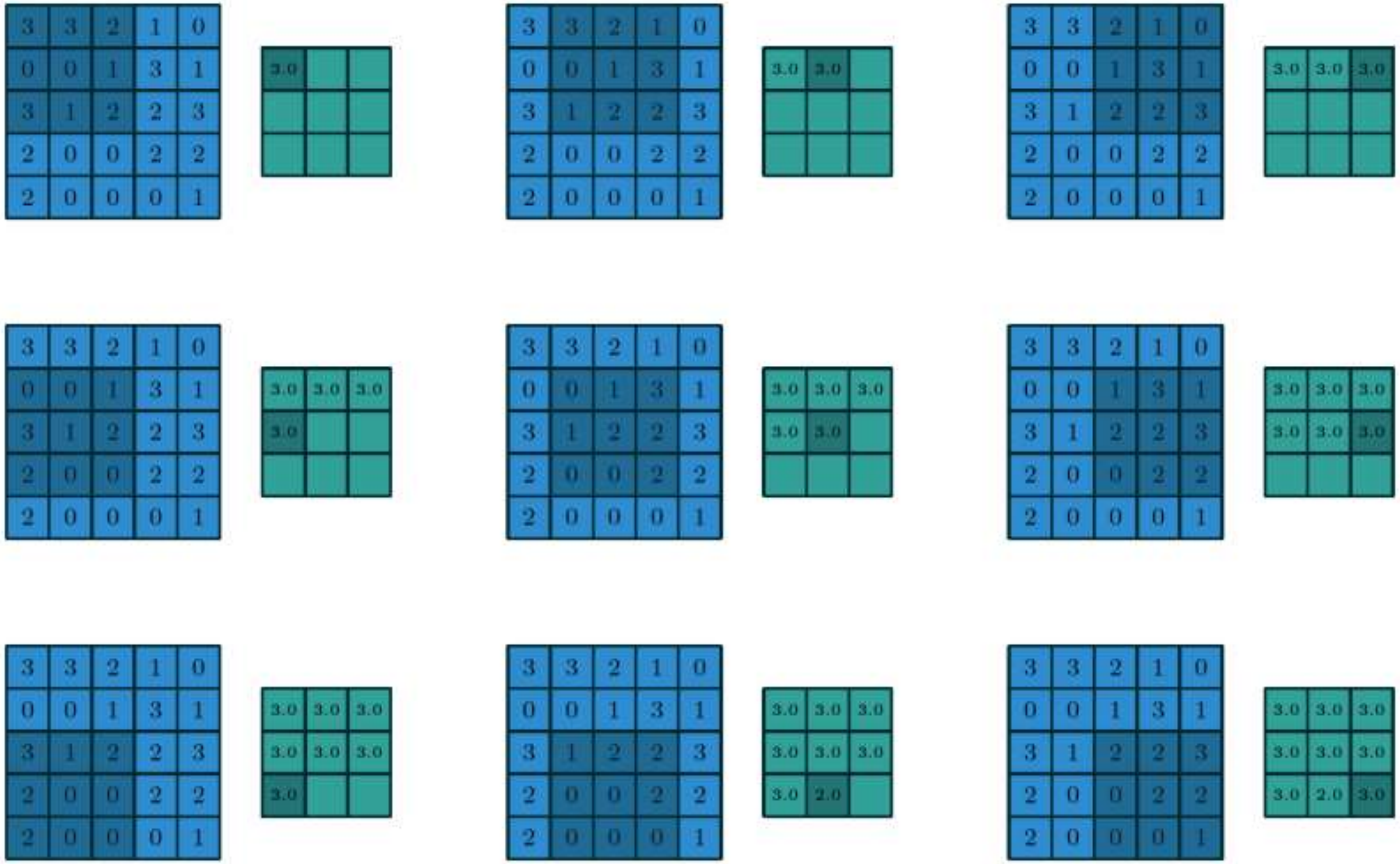


Image courtesy:Vincent Dumoulin

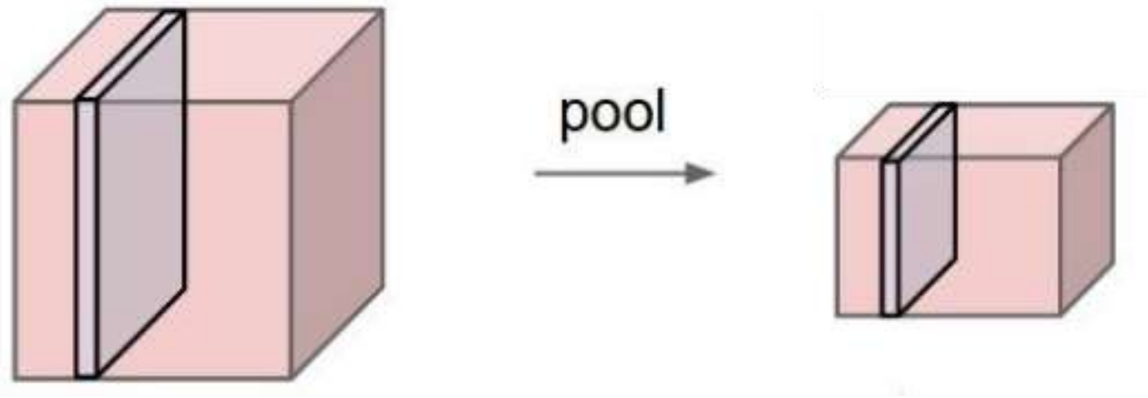
Pooling Arithmetic

(For simplicity we are assuming square input and max pooling kernel)
Input width = Input height = w
Filter width = Filter height = k
Stride = s
Output size = $\left\lfloor \frac{w-k}{s} \right\rfloor + 1$

Input volume: 32x32x3 [w, h, c].
Max-pooling kernel of size 2x2 [k, k] with stride 2 [s]
What is the output feature map size?

$$\left\lfloor \frac{32-2}{2} \right\rfloor + 1 = 16$$

So, $16 \times 16 \times 3$ [w, h, c]



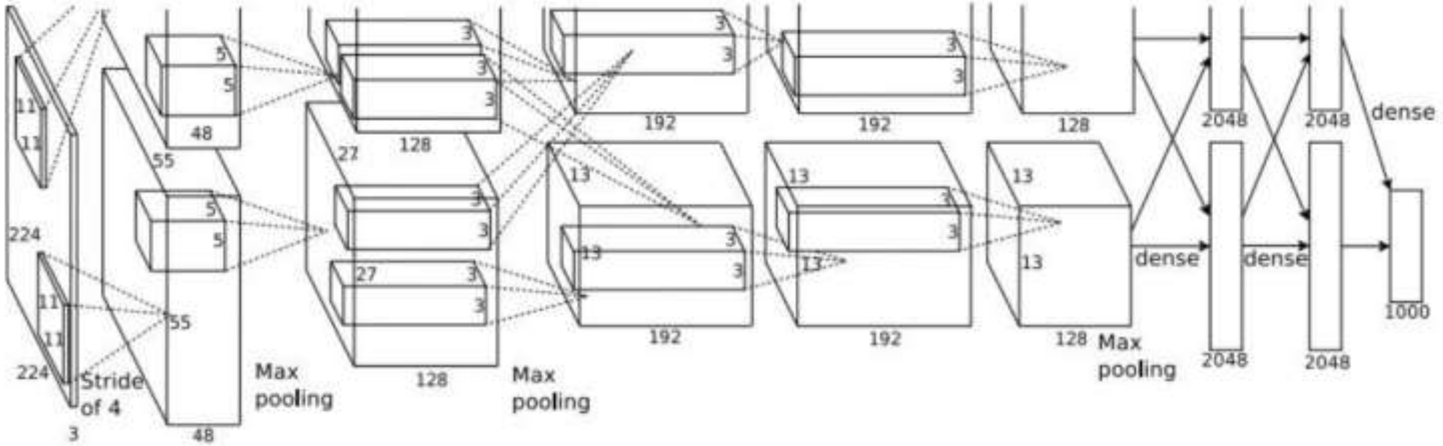
And What is the number of parameters in this pooling layer?

0

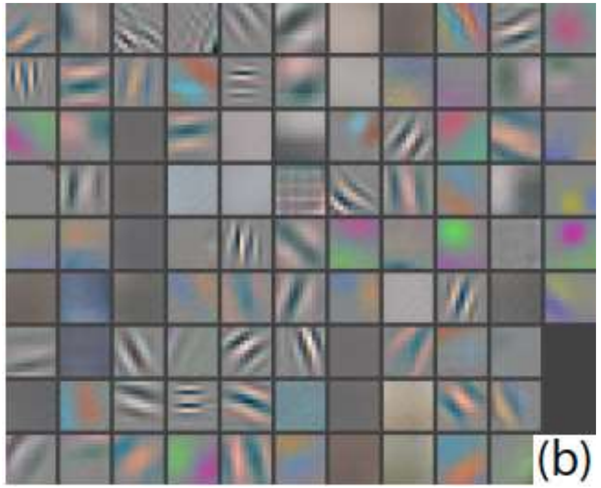
Image courtesy: Andrej Karpathy

Visualizations

AlexNet (2012)



First layer (CONV1): 96 11x11 filters



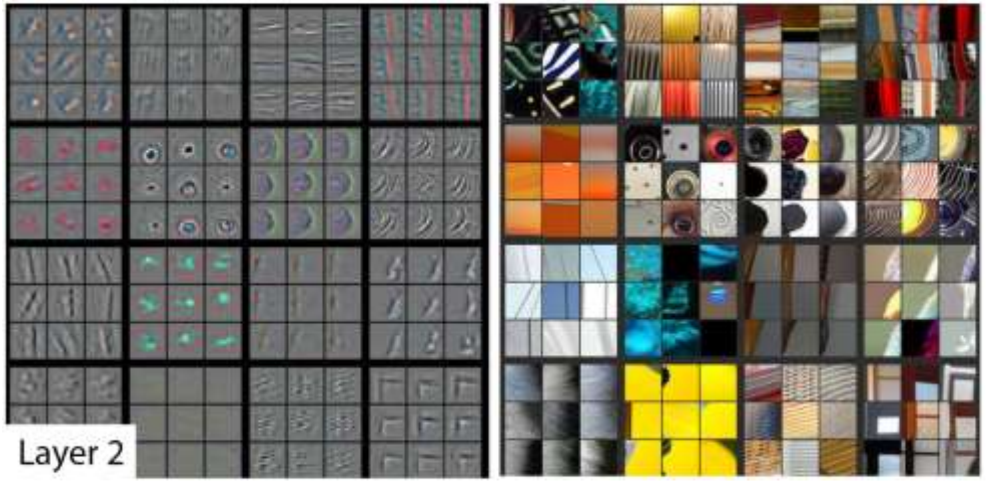
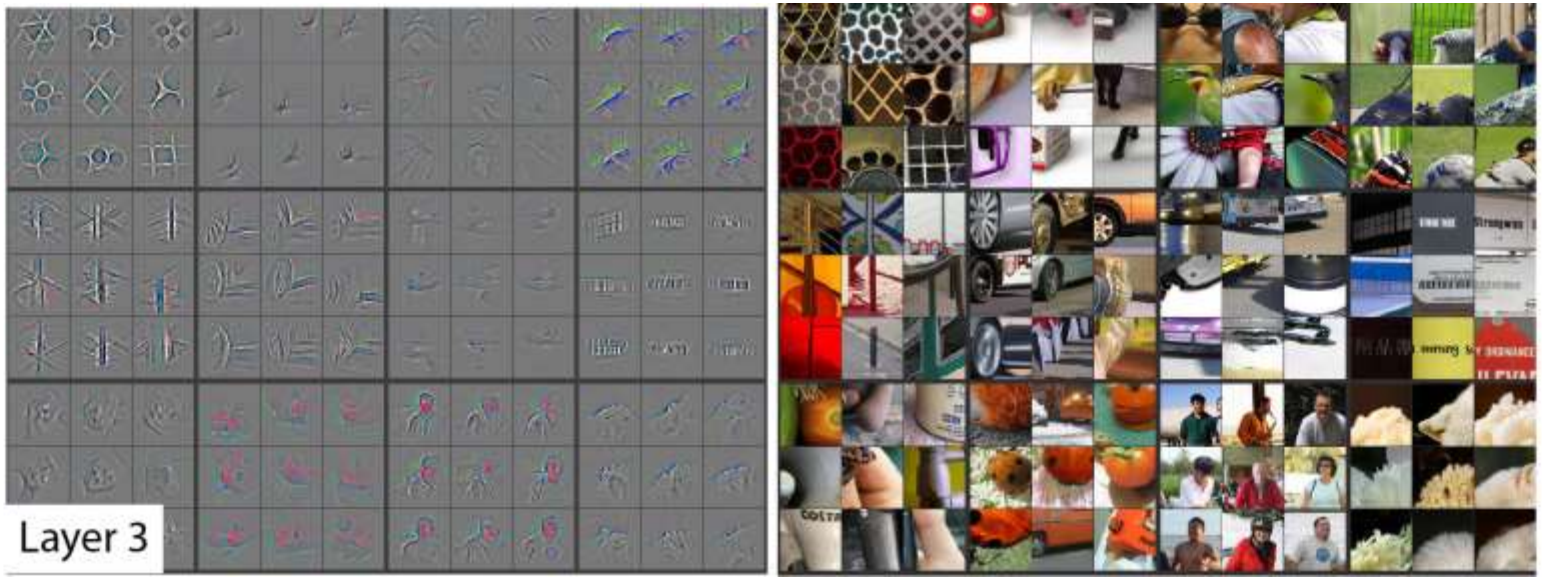


Image courtesy: Zeiler, Fergus, 2013

Visualizations



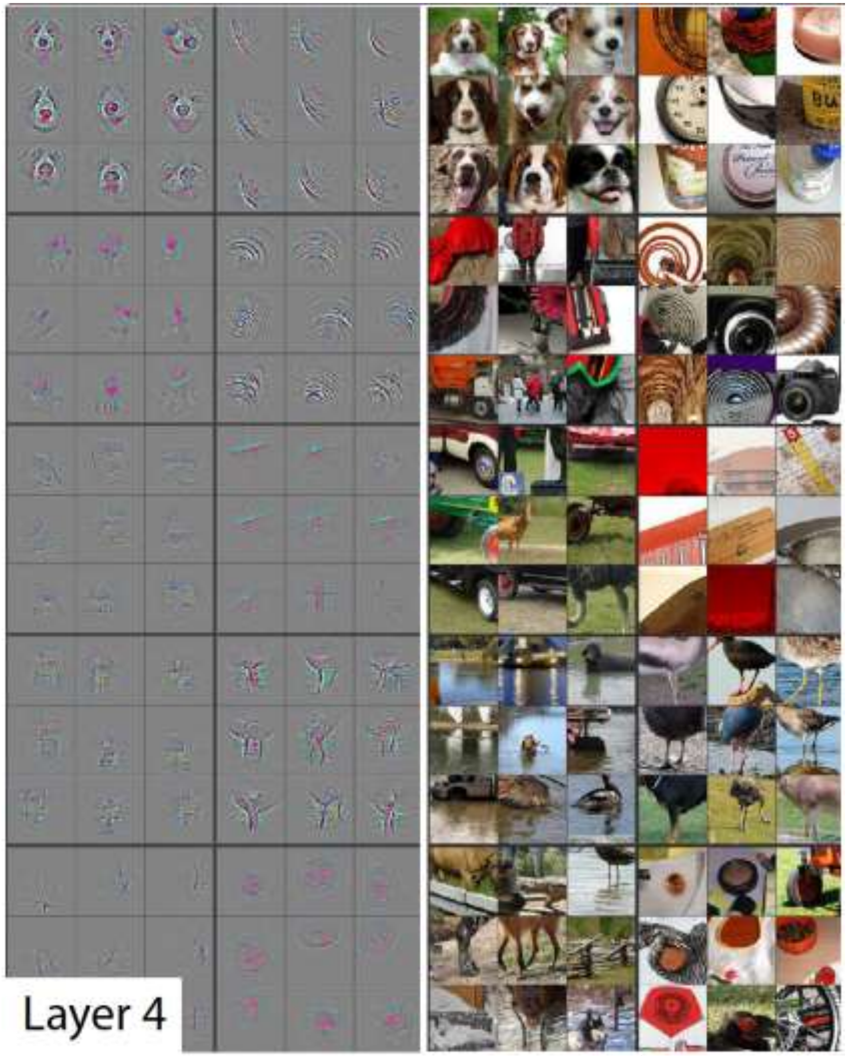


Image courtesy: Zeiler, Fergus, 2013

Distill ABOUT PRIZE SUBMIT

https://distill.pub/2018/building-blocks/

The Building Blocks of Interpretability

Interpretability techniques are normally studied in isolation.
We explore the powerful interfaces that arise when you combine them — and the rich structure of this combinatorial space.

CHOOSE AN INPUT IMAGE

For instance, by combining feature visualization (*what is a neuron looking for?*) with attribution (*how does it affect the output?*), we can explore how the network decides between labels like **Labrador retriever** and **tiger cat**.

Several floppy ear detectors seem to be important when distinguishing dogs, whereas pointy ears are used to classify "tiger cat".

CHANNELS THAT MOST SUPPORT ... LABRADOR RETRIEVER TIGER CAT