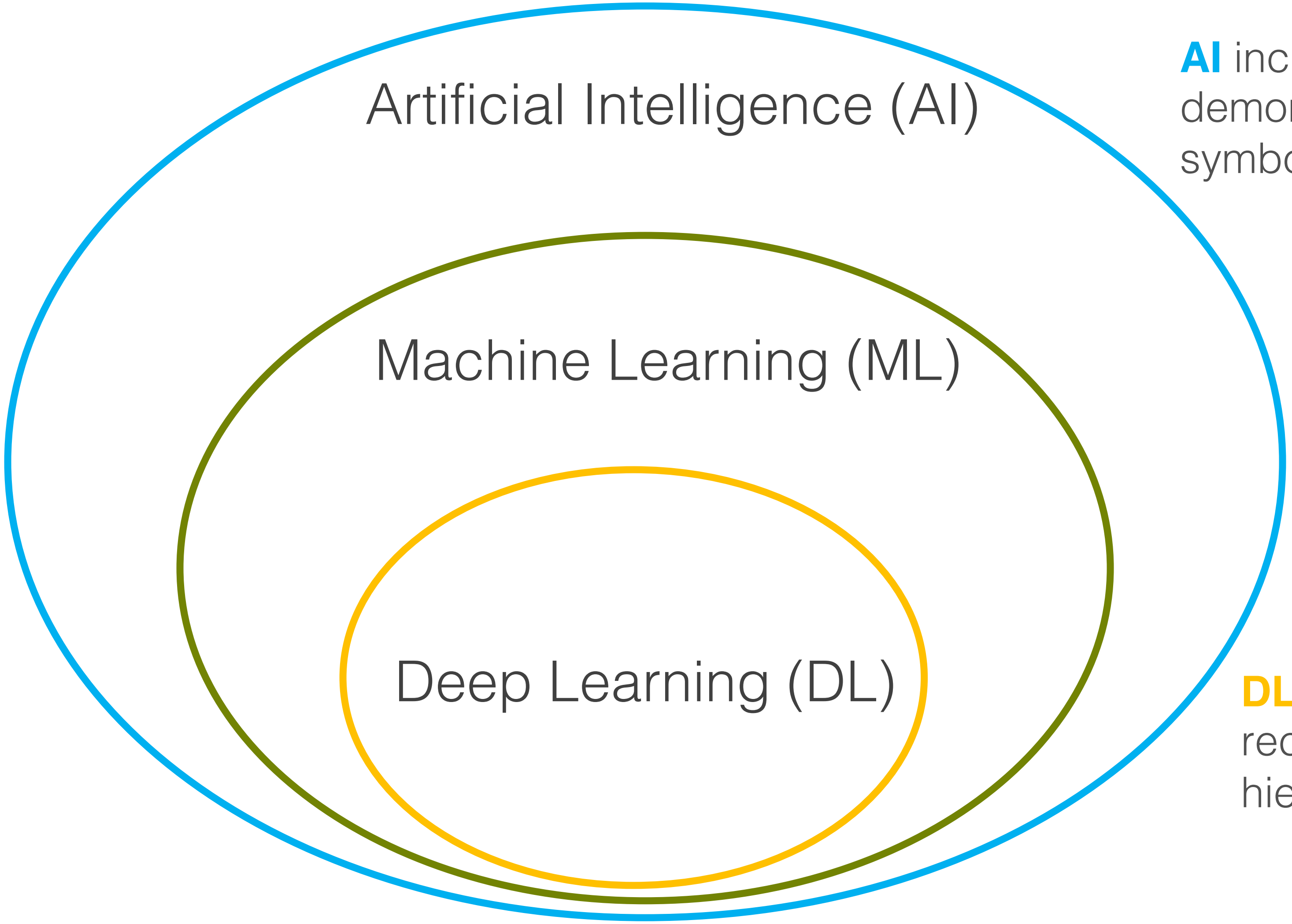
Deep Learning

Lecture 18

Hierarchy of Learning



AI includes many types of intelligence demonstrated by machines: cybernetics, symbolic, statistical learning

ML can…

Uncover structure in data (unsupervised)

Make predictions (supervised)

Learn by doing (reinforcement)

DL is a type of **ML** that makes use of recent advances in computation to learn hierarchical representation of data

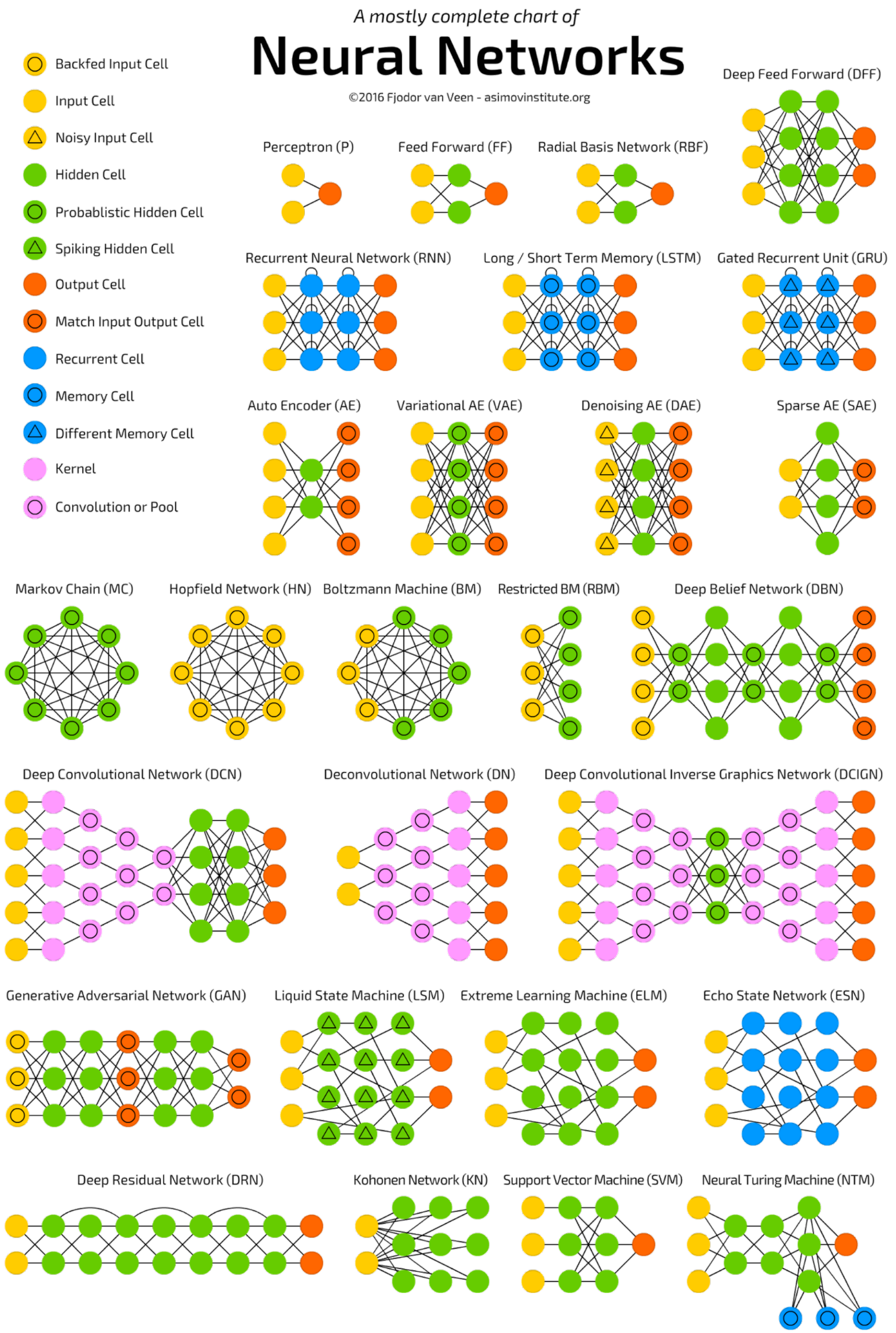
Types of Deep Learning Tools

Autoencoders

Convolutional Neural Networks

Recurrent Neural Networks (including LSTMs)

Generative Adversarial Networks (GANs)



Azimov Institute: http://www.asimovinstitute.org/neural-network-zoo/

Autoencoders

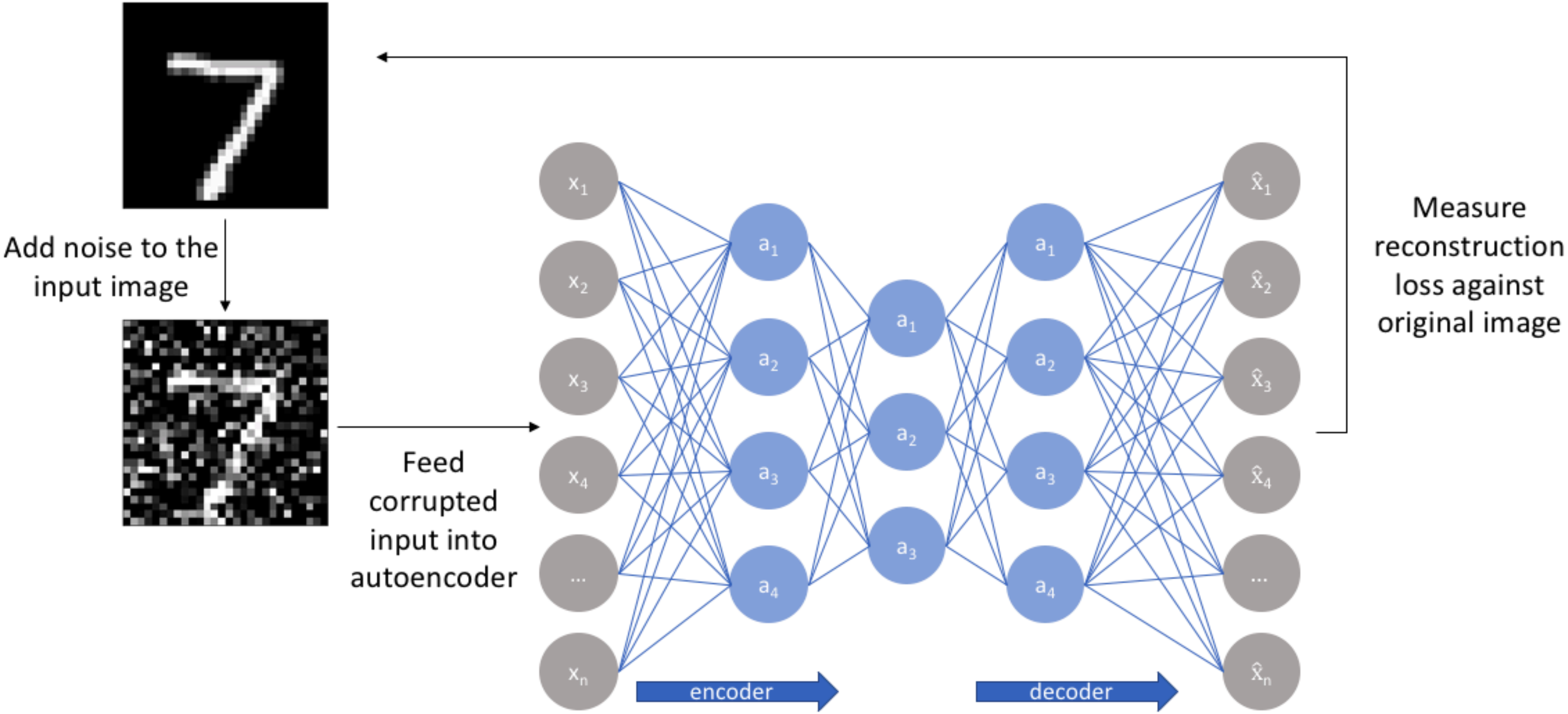
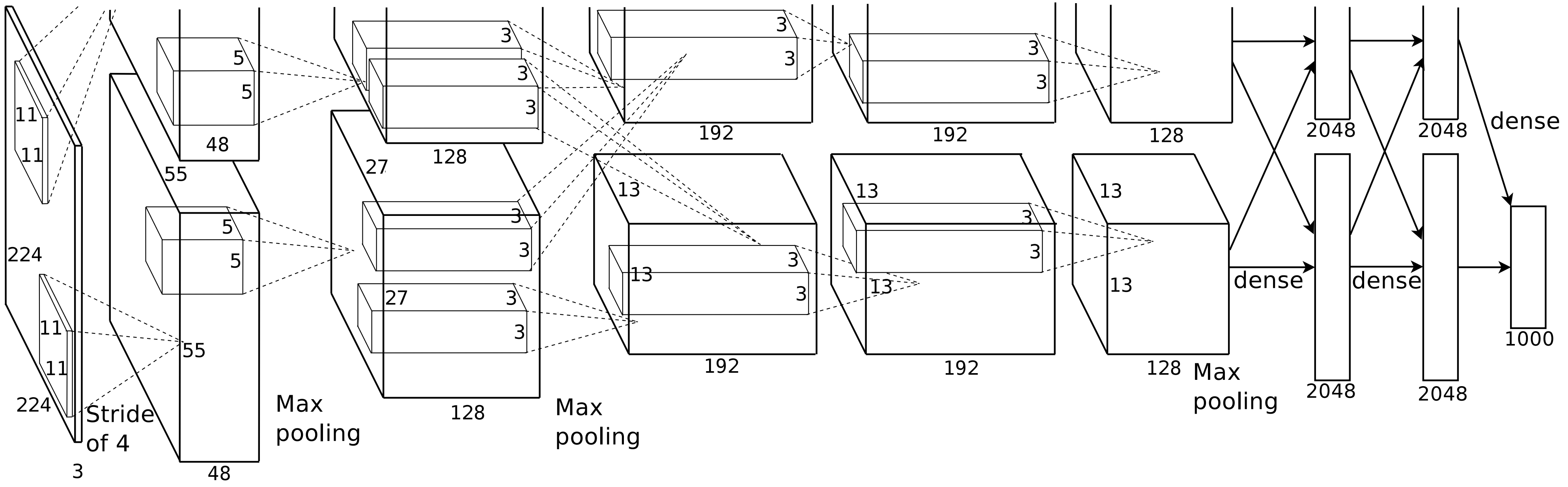


Image from: https://www.jeremyjordan.me/autoencoders/

Convolutional Neural Networks

AlexNet



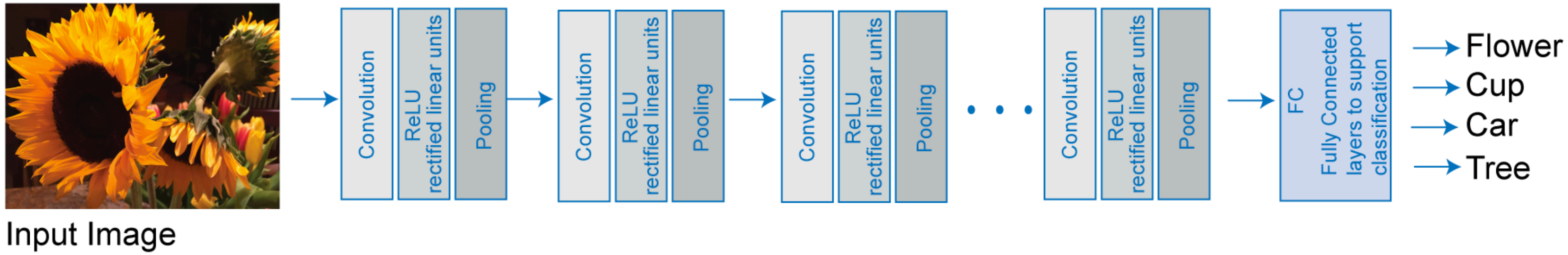
Input
11x11 conv, 96
5x5 conv, 256
max pool
3x3 conv, 384
max pool
3x3 conv, 384
3x3 conv, 256
max pool
FC 4096
FC 4096
FC 1000
softmax

Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. "Imagenet classification with deep convolutional neural networks." Advances in neural information processing systems. 2012.

Key

Input or output layer
Convolutional Layer
Fully Connected Layer
max pooling layer

Convolutional Neural Networks



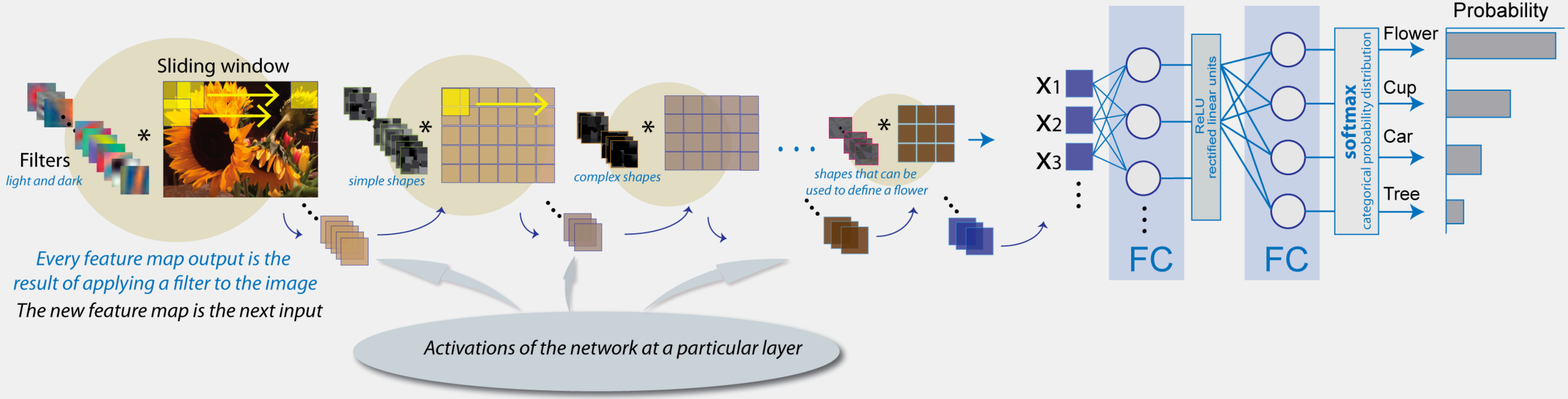


Image from the Mathworks

Data: $\boldsymbol{x}$

1	2	5	1	4	2
0	2	3	2	0	0
4	5	5	9	8	1
6	3	4	2	3	1
0	1	9	8	7	2
2	3	5	5	5	6

$*$

Weights: $\boldsymbol{w}$

1	1	1
0	0	0
-1	-1	-1

$=$

Output: $\boldsymbol{x} * \boldsymbol{w}$

2D Convolution

Data: $\boldsymbol{x}$

1	2	5	1	4	2
0	2	3	2	0	0
4	5	5	9	8	1
6	3	4	2	3	1
0	1	9	8	7	2
2	3	5	5	5	6

$*$

Weights: $\boldsymbol{w}$

1	1	1
0	0	0
-1	-1	-1

$=$

Output: $\boldsymbol{x} * \boldsymbol{w}$

Computing one output value:

$$1 \cdot 1 + 1 \cdot 2 + 1 \cdot 5 +$$
$$0 \cdot 0 + 0 \cdot 2 + 0 \cdot 3 +$$
$$(-1) \cdot 4 + (-1) \cdot 5 + (-1) \cdot 5$$

2D Convolution

Data: $\boldsymbol{x}$

1	2	5	1	4	2
0	2	3	2	0	0
4	5	5	9	8	1
6	3	4	2	3	1
0	1	9	8	7	2
2	3	5	5	5	6

$*$

Weights: $\boldsymbol{w}$

1	1	1
0	0	0
-1	-1	-1

$=$

Output: $\boldsymbol{x} * \boldsymbol{w}$

-6			

Computing one output value:

$$1 \cdot 1 + 1 \cdot 2 + 1 \cdot 5 + 0 \cdot 0 + 0 \cdot 2 + 0 \cdot 3 + (-1) \cdot 4 + (-1) \cdot 5 + (-1) \cdot 5 = \mathbf{-6}$$

2D Convolution

Data: $\boldsymbol{X}$

1	2	5	1	4	2
0	2	3	2	0	0
4	5	5	9	8	1
6	3	4	2	3	1
0	1	9	8	7	2
2	3	5	5	5	6

$*$

Weights: $\boldsymbol{w}$

1	1	1
0	0	0
-1	-1	-1

$=$

Output: $\boldsymbol{X} * \boldsymbol{w}$

-6	**-11**		

Computing one output value:

$$1 \cdot 2 + 1 \cdot 5 + 1 \cdot 1 +$$
$$0 \cdot 2 + 0 \cdot 3 + 0 \cdot 2 +$$
$$(-1) \cdot 5 + (-1) \cdot 5 + (-1) \cdot 9 = \mathbf{-11}$$

2D Convolution

Data: $\boldsymbol{X}$

1	2	5	1	4	2
0	2	3	2	0	0
4	5	5	9	8	1
6	3	4	2	3	1
0	1	9	8	7	2
2	3	5	5	5	6

$*$

Weights: $\boldsymbol{w}$

1	1	1
0	0	0
-1	-1	-1

$=$

Output: $\boldsymbol{X} * \boldsymbol{w}$

-6	**-11**	**-12**	

Computing one output value:

$$1 \cdot 5 + 1 \cdot 1 + 1 \cdot 4 + 0 \cdot 3 + 0 \cdot 2 + 0 \cdot 0 + (-1) \cdot 5 + (-1) \cdot 9 + (-1) \cdot 8 = \mathbf{-12}$$

2D Convolution

Data: $\boldsymbol{X}$

1	2	5	1	4	2
0	2	3	2	0	0
4	5	5	9	8	1
6	3	4	2	3	1
0	1	9	8	7	2
2	3	5	5	5	6

$*$

Weights: $\boldsymbol{w}$

1	1	1
0	0	0
-1	-1	-1

$=$

Output: $\boldsymbol{X} * \boldsymbol{w}$

-6	**-11**	**-12**	**-11**

Computing one output value:

$$1 \cdot 1 + 1 \cdot 4 + 1 \cdot 2 +$$
$$0 \cdot 2 + 0 \cdot 0 + 0 \cdot 0 +$$
$$(-1) \cdot 9 + (-1) \cdot 8 + (-1) \cdot 1 = \mathbf{-11}$$

2D Convolution

Data: $\boldsymbol{X}$

1	2	5	1	4	2
0	2	3	2	0	0
4	5	5	9	8	1
6	3	4	2	3	1
0	1	9	8	7	2
2	3	5	5	5	6

$*$

Weights: $\boldsymbol{w}$

1	1	1
0	0	0
-1	-1	-1

$=$

Output: $\boldsymbol{X} * \boldsymbol{w}$

-6	**-11**	**-12**	**-11**
-7			

Computing one output value:

$$1 \cdot 0 + 1 \cdot 2 + 1 \cdot 3 + 0 \cdot 4 + 0 \cdot 5 + 0 \cdot 5 + (-1) \cdot 6 + (-1) \cdot 3 + (-1) \cdot 4 = \mathbf{-7}$$

2D Convolution

Data: $\boldsymbol{X}$

1	2	5	1	4	2
0	2	3	2	0	0
4	5	5	9	8	1
6	3	4	2	3	1
0	1	9	8	7	2
2	3	5	5	5	6

6 x 6

$*$

Weights: $\boldsymbol{w}$

1	1	1
0	0	0
-1	-1	-1

3 x 3

=

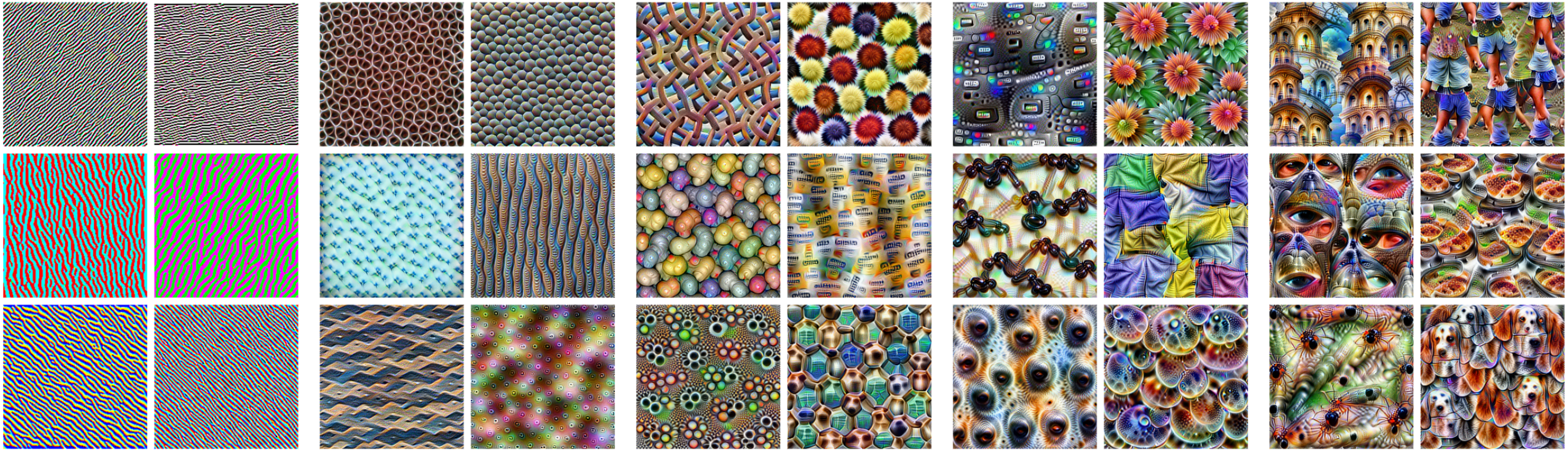
Output: $\boldsymbol{X} * \boldsymbol{w}$

-6	**-11**	**-12**	**-11**
-7	**-2**	**-2**	**-4**
4	**1**	**-2**	**1**
3	**-4**	**-6**	**-10**

4 x 4

2D Convolution

Features



Edges (layer conv2d0) **Textures** (layer mixed3a) **Patterns** (layer mixed4a) **Parts** (layers mixed4b & mixed4c) **Objects** (layers mixed4d & mixed4e)

Olah et al, 2017: https://distill.pub/2017/feature-visualization/

Features

Dataset Examples show us what neurons respond to in practice

Optimization isolates the causes of behavior from mere correlations. A neuron may not be detecting what you initially thought.

Baseball—or stripes?
mixed4a, Unit 6

Animal faces—or snouts?
mixed4a, Unit 240

Clouds—or fluffiness?
mixed4a, Unit 453

Buildings—or sky?
mixed4a, Unit 492

Olah et al, 2017: https://distill.pub/2017/feature-visualization/

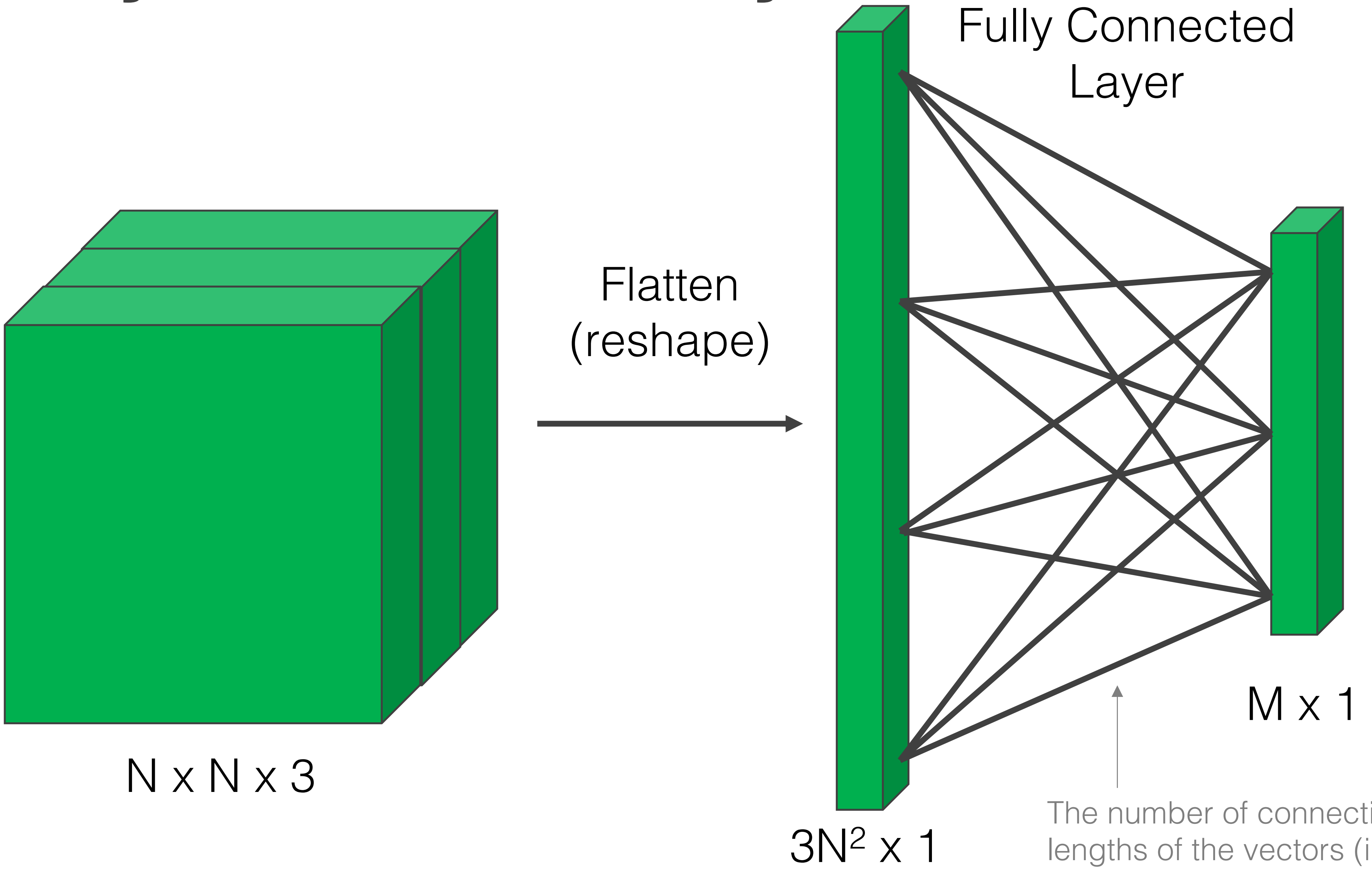
Resources on Visualization of Features

Feature visualization: https://distill.pub/2017/feature-visualization/

Building blocks of interpretability: https://distill.pub/2018/building-blocks/

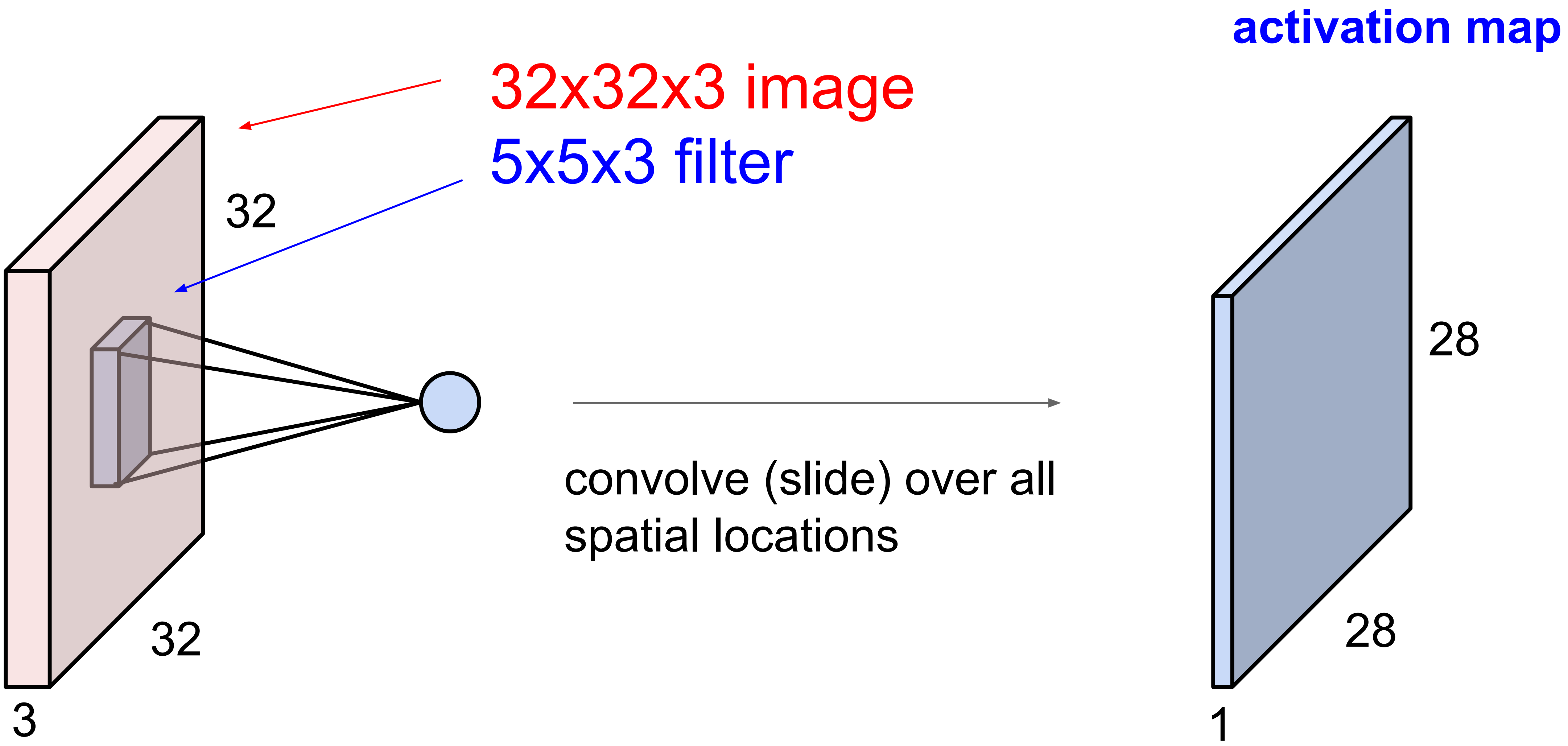
Activation Activation Atlases: https://distill.pub/2019/activation-atlas/

Fully Connected Layer



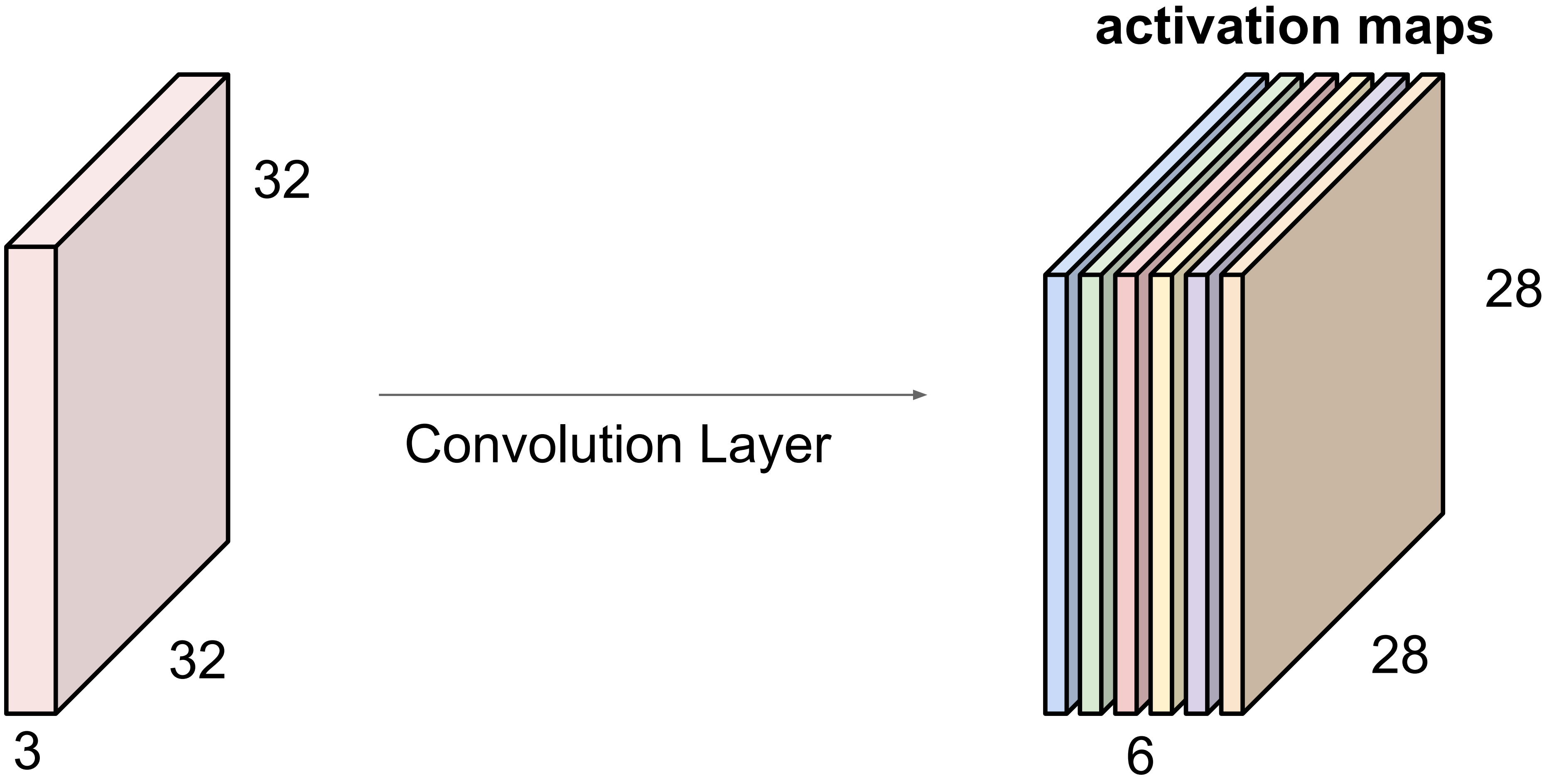
The number of connections is the product of the lengths of the vectors (in this case $3N^2M$)

Convolution Layer



From Fei-Fei Li, Justin Johnson, and Serena Young. CS231n, 2018

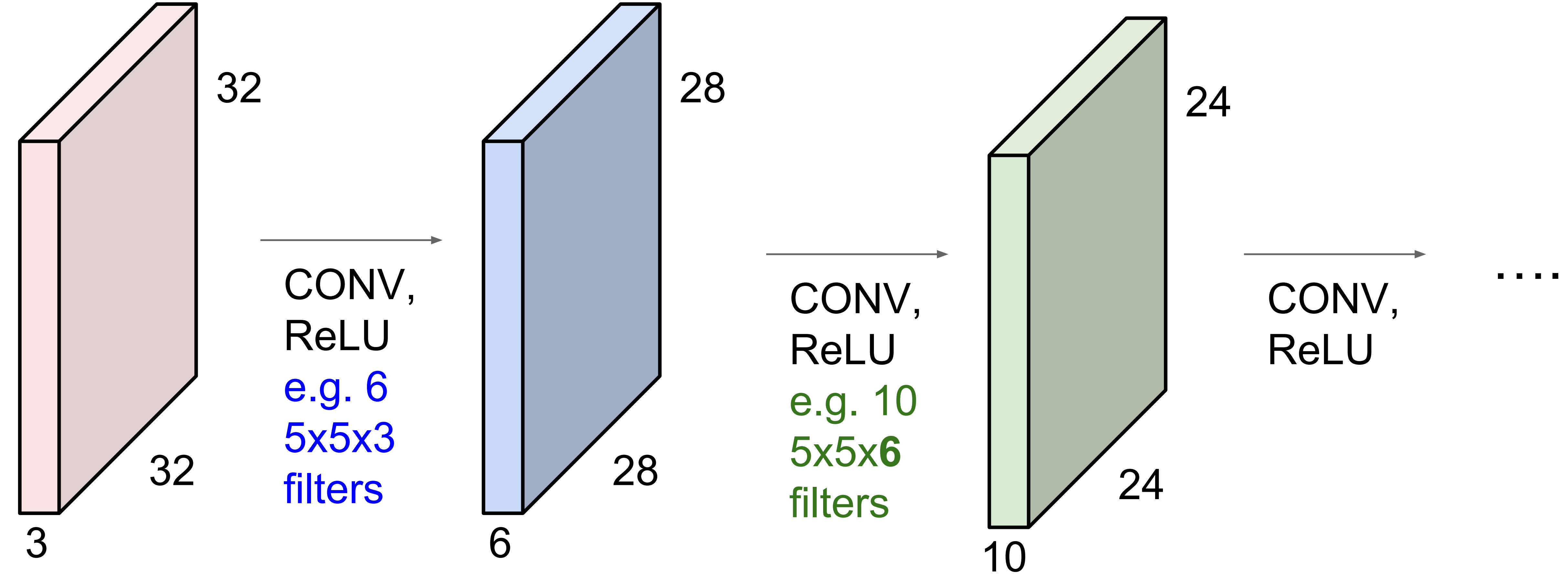
For example, if we had 6 5x5 filters, we'll get 6 separate activation maps:



We stack these up to get a "new image" of size 28x28x6!

From Fei-Fei Li, Justin Johnson, and Serena Young. CS231n, 2018

Preview: ConvNet is a sequence of Convolution Layers, interspersed with activation functions

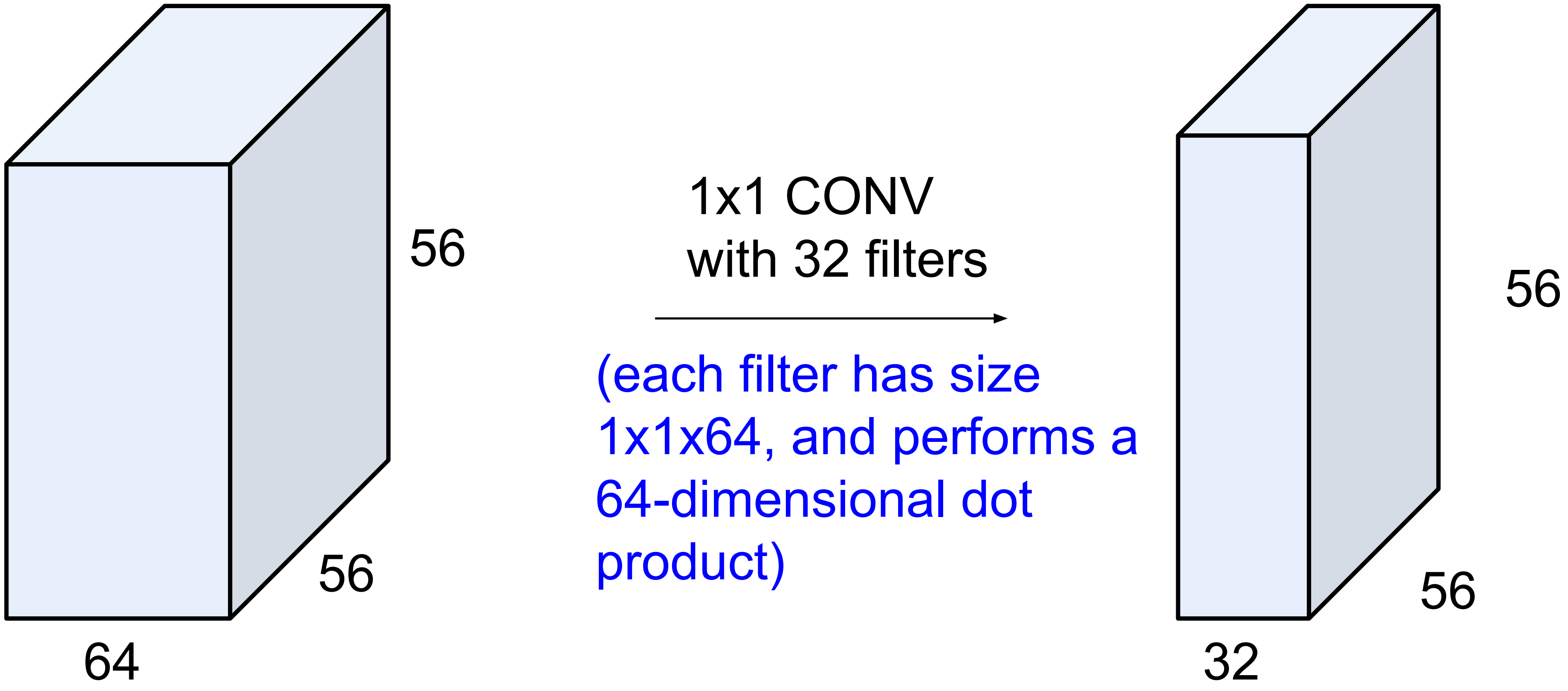


Parameters = (5*5*3)*6 = 450

(5*5*6)*10 = 1,500

From Fei-Fei Li, Justin Johnson, and Serena Young. CS231n, 2018

1 x 1 Convolution Explained



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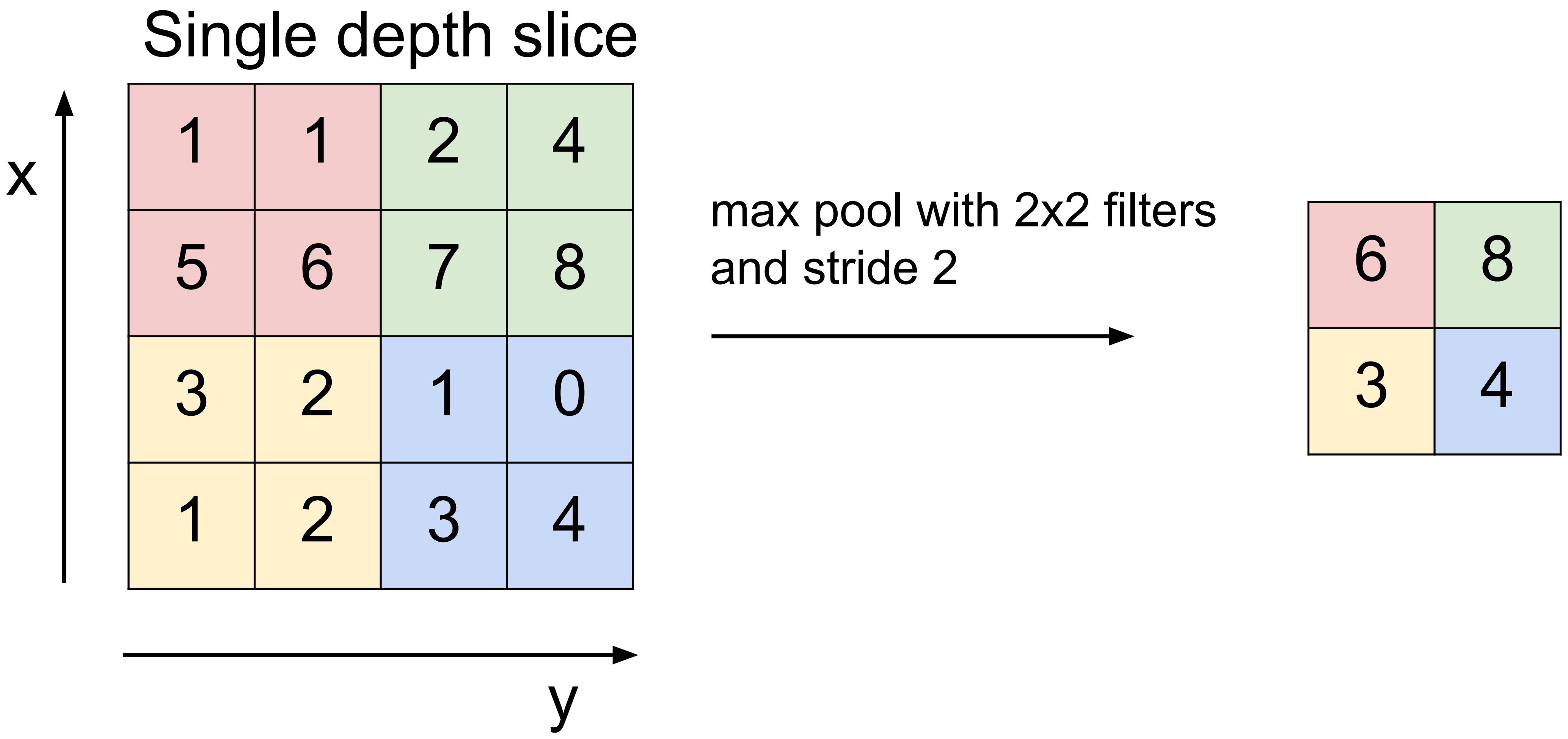
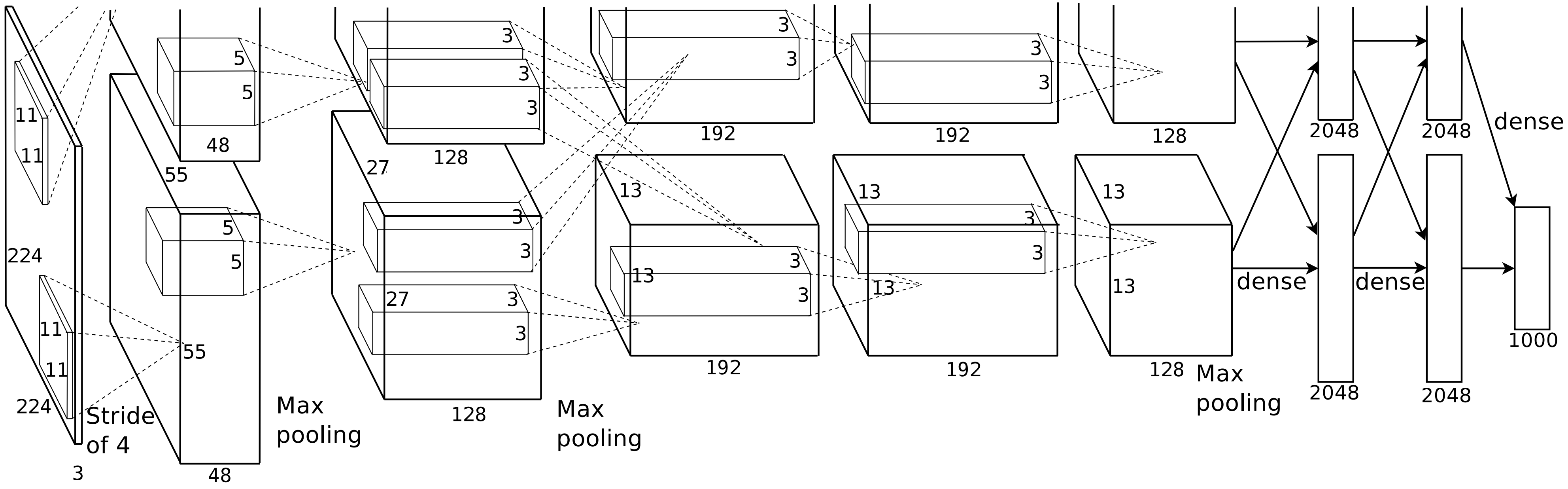
Max Pooling



From Fei-Fei Li, Justin Johnson, and Serena Young. CS231n, 2018

AlexNet



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5x5 conv, 256
max pool
3x3 conv, 384
max pool
3x3 conv, 384
3x3 conv, 256
max pool
FC 4096
FC 4096
FC 1000
softmax

Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. "Imagenet classification with deep convolutional neural networks." Advances in neural information processing systems. 2012.

Key

Input or output layer
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Fully Connected Layer
max pooling layer

CNN Architectures

Note: an activation function is applied to the output of each layer

Key

- Input or output layer
- Convolutional Layer
- Fully Connected Layer
- max pooling layer

AlexNet (2012)

- Input
- 11x11 conv, 96
- 5x5 conv, 256
- max pool
- 3x3 conv, 384
- max pool
- 3x3 conv, 384
- 3x3 conv, 256
- max pool
- FC 4096
- FC 4096
- FC 1000
- softmax

Fewer layers, larger filters

VGG16 (2014)

- Input
- 3x3 conv, 64
- 3x3 conv, 64
- max pool
- 3x3 conv, 128
- 3x3 conv, 128
- max pool
- 3x3 conv, 256
- 3x3 conv, 256
- 3x3 conv, 256
- max pool
- 3x3 conv, 512
- 3x3 conv, 512
- 3x3 conv, 512
- max pool
- 3x3 conv, 512
- 3x3 conv, 512
- 3x3 conv, 512
- max pool
- FC 4096
- FC 4096
- FC 1000
- softmax

VGG19 (2014)

- Input
- 3x3 conv, 64
- 3x3 conv, 64
- max pool
- 3x3 conv, 128
- 3x3 conv, 128
- max pool
- 3x3 conv, 256
- 3x3 conv, 256
- 3x3 conv, 256
- 3x3 conv, 256
- max pool
- 3x3 conv, 512
- 3x3 conv, 512
- 3x3 conv, 512
- 3x3 conv, 512
- max pool
- 3x3 conv, 512
- 3x3 conv, 512
- 3x3 conv, 512
- 3x3 conv, 512
- max pool
- FC 4096
- FC 4096
- FC 1000
- softmax

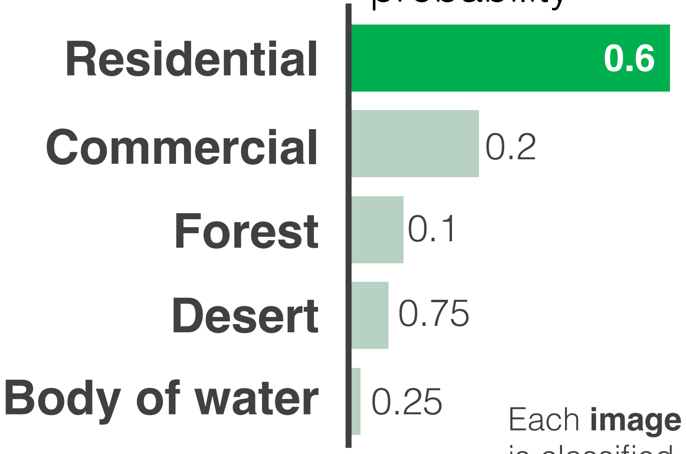
Adapted from Fei-Fei Li, Justin Johnson, and Serena Young. CS231n, 2018


Scene classification
Object detection
Image segmentation
Confidence or probability
Residential 0.6
Commercial 0.2
Forest 0.1
Desert 0.75
Body of water 0.25
Each **image (scene)** is classified
Object type & probability
Building 0.8
Building 0.7
Building 0.9
Building 0.4
Building 0.6
Car 0.85
Probability
Building 0.7
Road 0.1
Plants 0.06
Water 0.04
Each **pixel** is classified

Scene classification

AlexNet
VGG
GoogLeNet
ResNet
Inception
DenseNet
SqueezeNet
EfficientNet

Confidence or probability



Each **image (scene)** is classified

Object detection

Faster/Fast/R-CNN
Mask R-CNN
YOLO
Single Shot Detector (SSD)
RetinaNet

Object type & probability

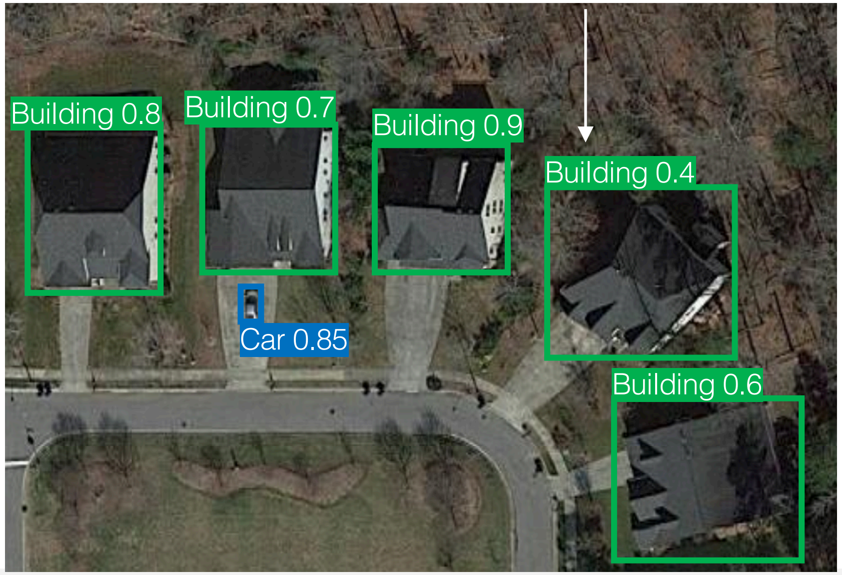


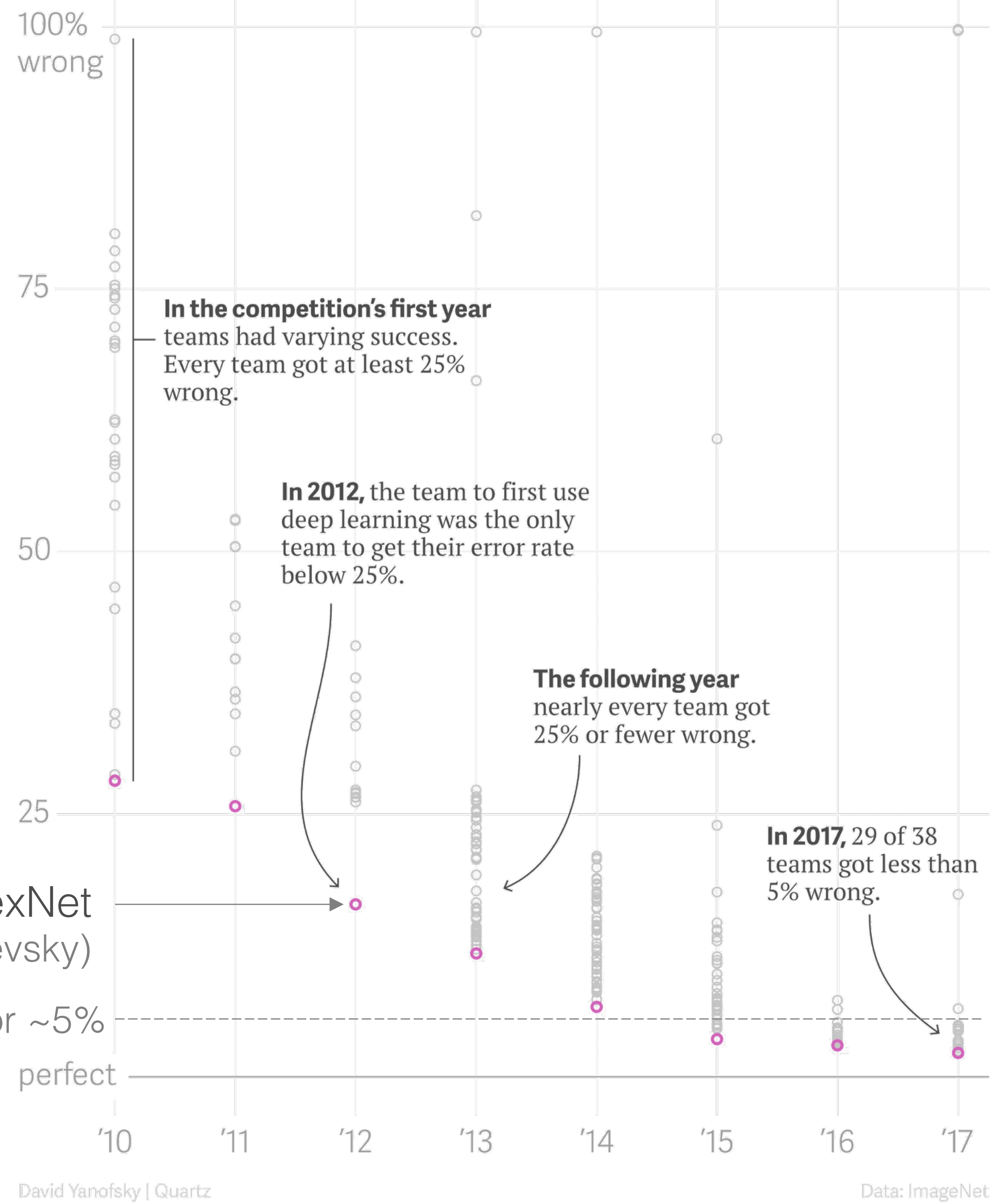
Image segmentation

U-Net (2015)
SegNet (2016)
DeepLab (2017)
FCN (2016)

ImageNet Large Scale Visual Recognition Challenge (ILSVRC)

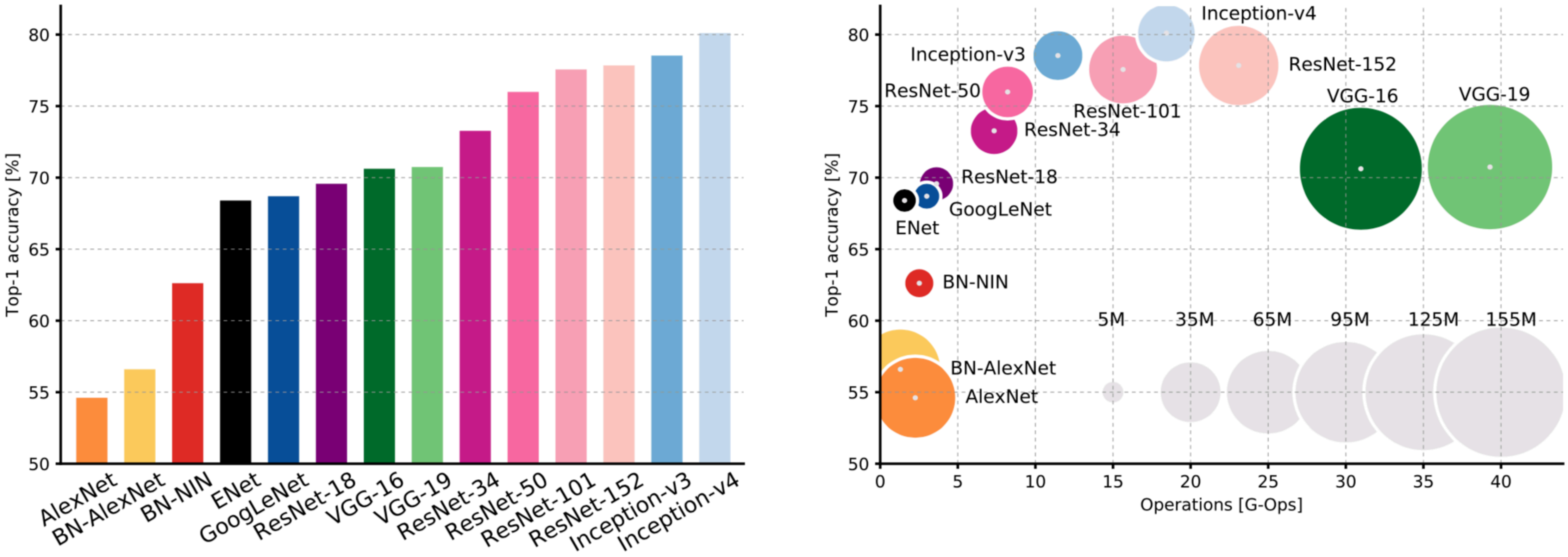
Fei-Fei Li et al. 2010 (link)

Competition at:
Conference on Computer Vision and Pattern Recognition (CVPR)



Source: Quartz, link

Deep Learning Models Compared



Models compared for ImageNet

Many of these models are available through Keras ([link]())

A. Canziani, E. Culurciello and A. Paszke, "Evaluation of neural network architectures for embedded systems," *2017 IEEE International Symposium on Circuits and Systems (ISCAS)*, Baltimore, MD, 2017, pp. 1-4.

Deep learning frameworks

Tensorflow (link)
Framework for implementing graphical models, such as neural networks

Keras (link)
Wrapper for Tensorflow to make coding easier: higher level and excellent API

PyTorch (link)
Framework for implementing graphical models, such as neural networks

KERAS DEMO

Generative Adversarial Networks

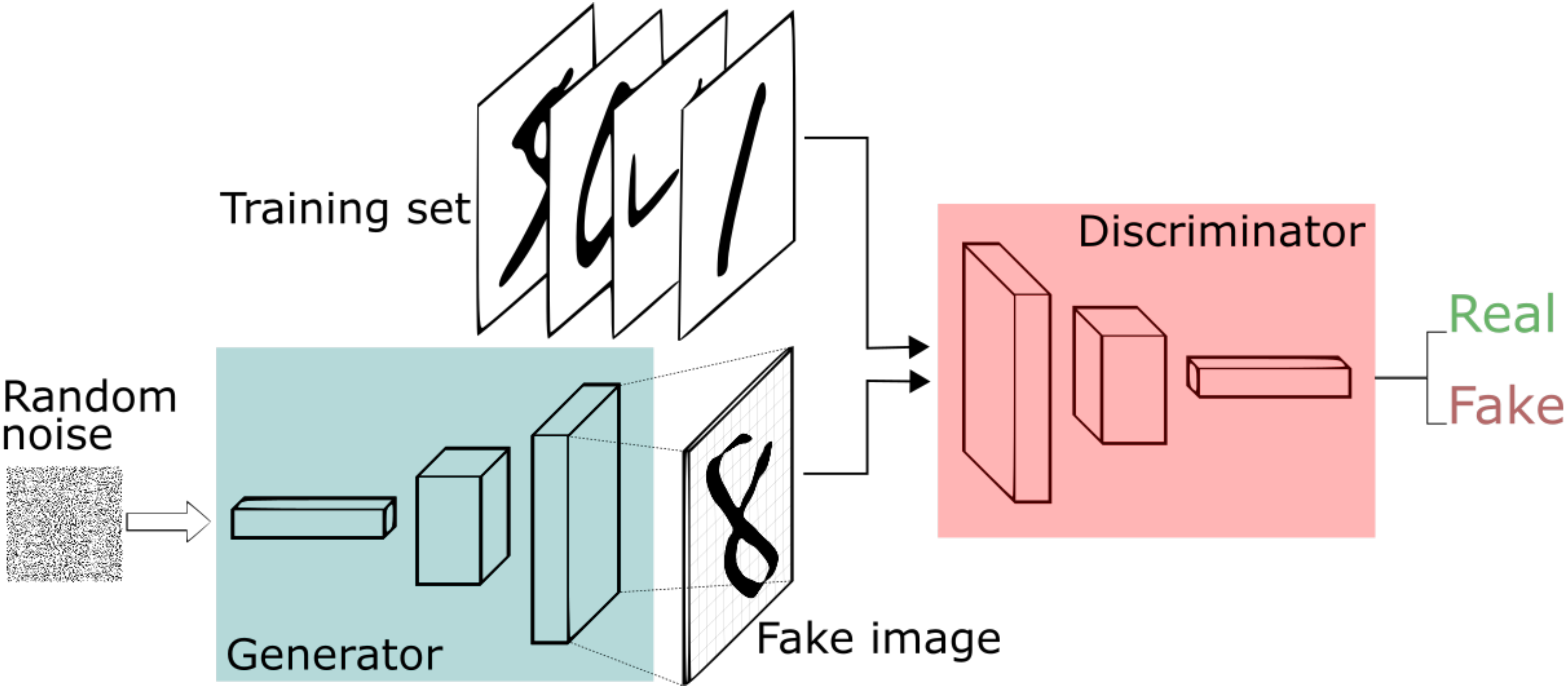


Image from: https://skymind.ai/wiki/generative-adversarial-network-gan