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Deep Learning Application: Medical Image Segmentation using Convolutional Neural Networks

LIAA-UFSCar

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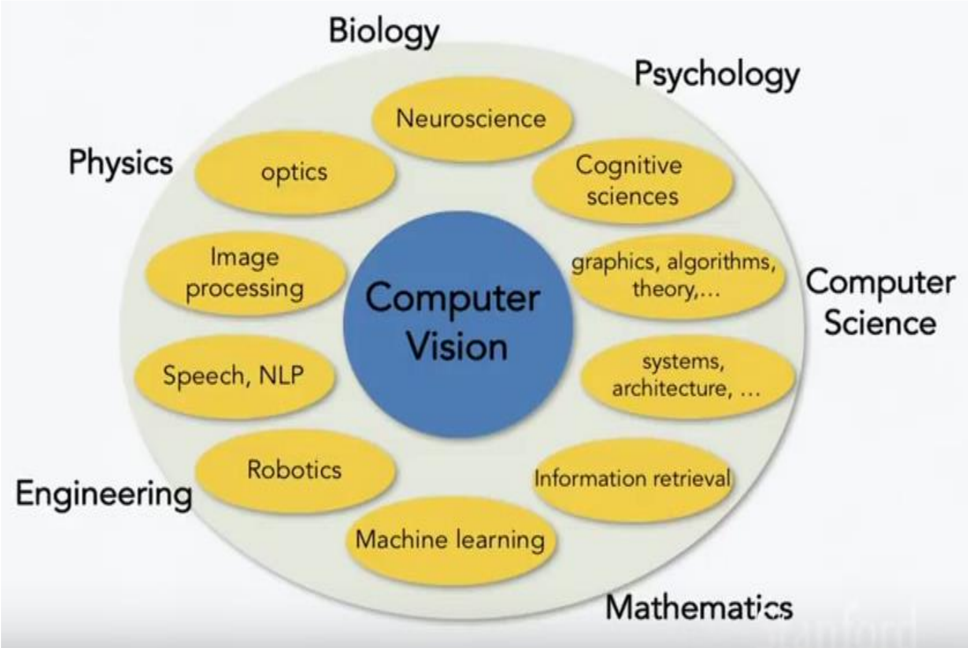
Federal University of São Carlos – Brazil

Computer Vision – Definition

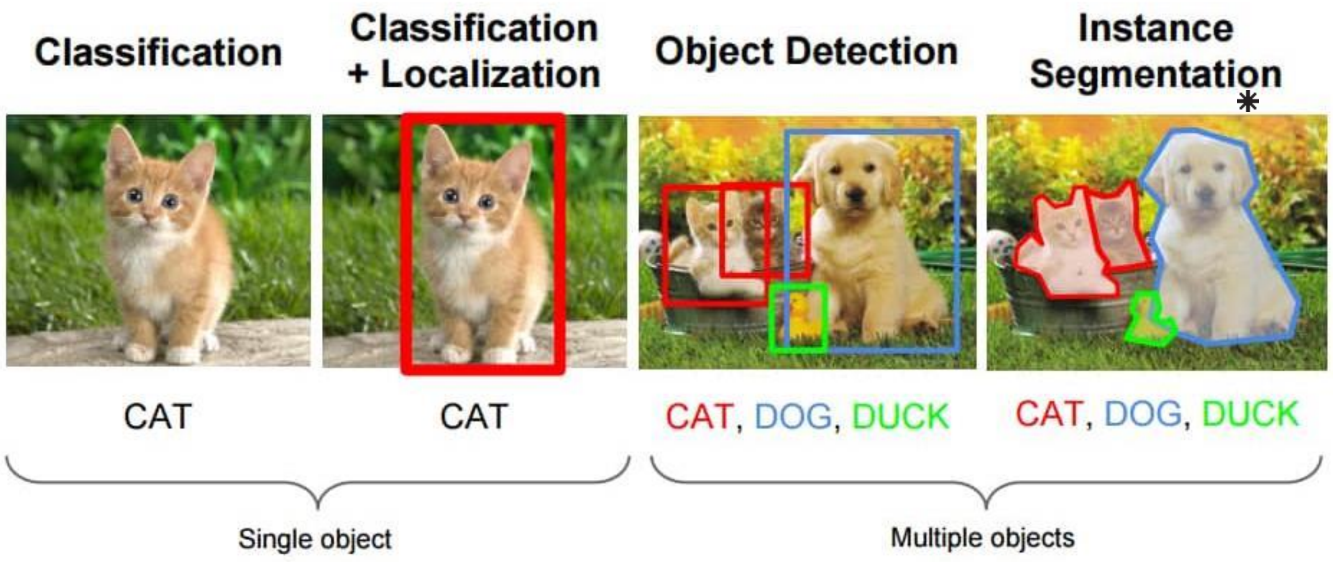
Is an interdisciplinary field that has as the goal extract knowledge from visual data.

[redacted]

Relation with other fields



Computer vision tasks

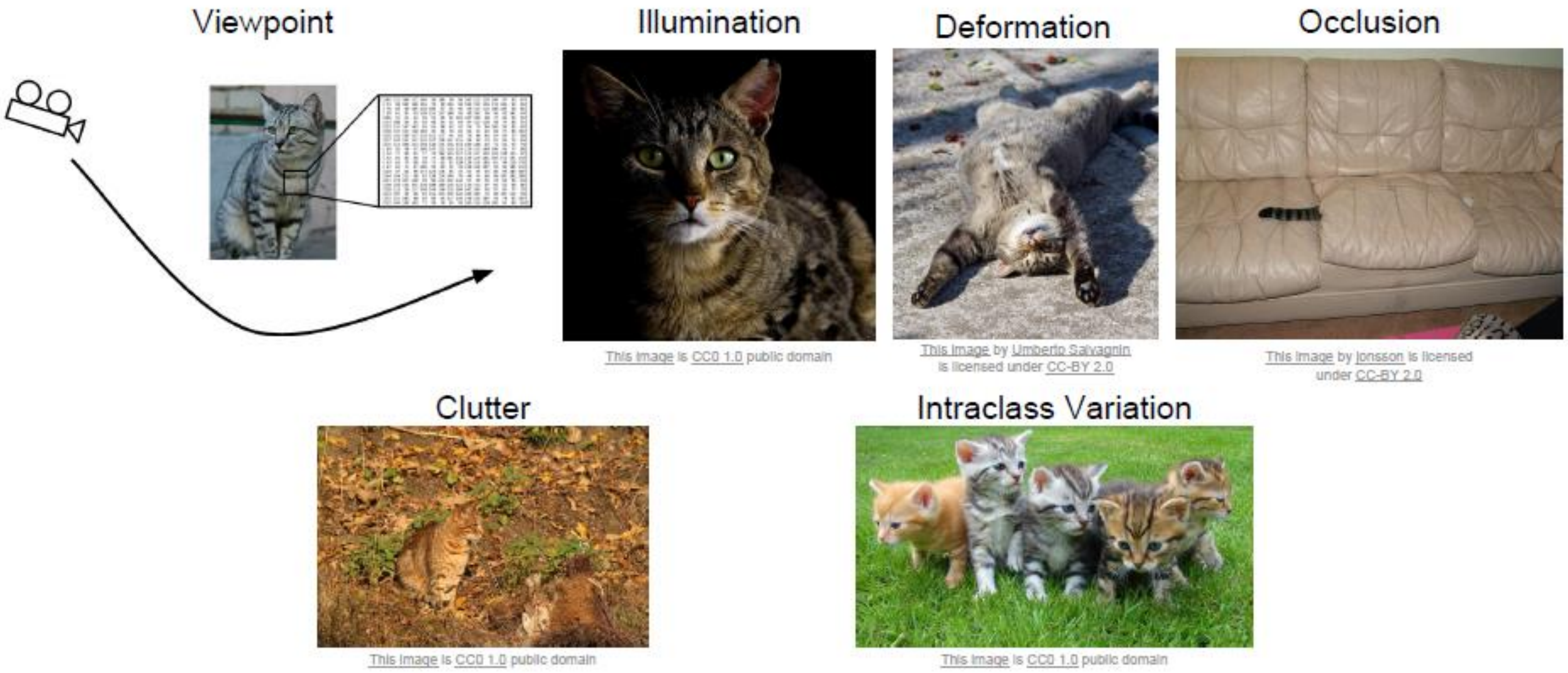


Fei-Fei Li & Justin Johnson & Serena Yeung, CS231n Course, Stanford, Spring 2017

* ***Inner the present scope***

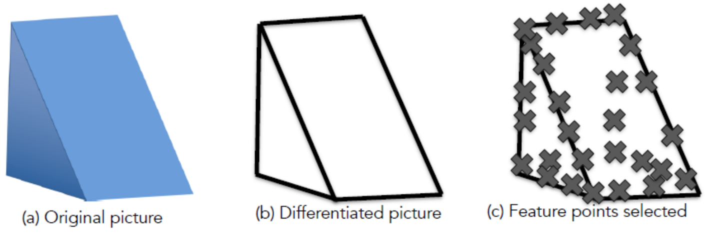
Computer Vision – Challenge

Obtaining knowledge of visual data is a challenge. [redacted]

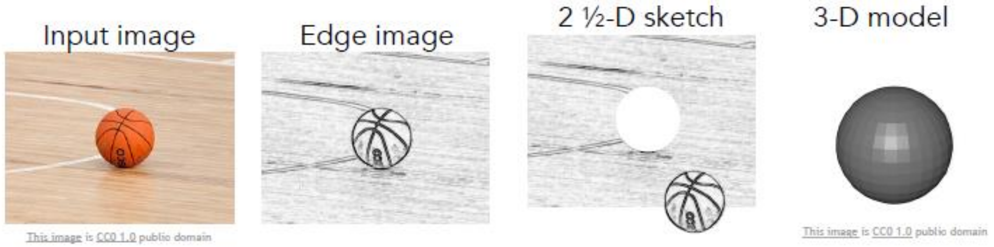


Computer Vision – Evolution

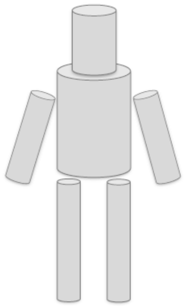
Block World (Larry Roberts, 1963)



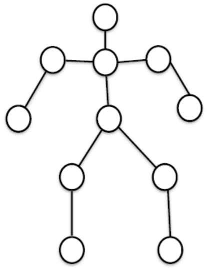
Stage of Visual Representation (David Marr, 1970s)



Generalized Cylinder
(Brook & Binford, 1979)



Pictoral Structure
(Fischler & Elschlager, 1973)

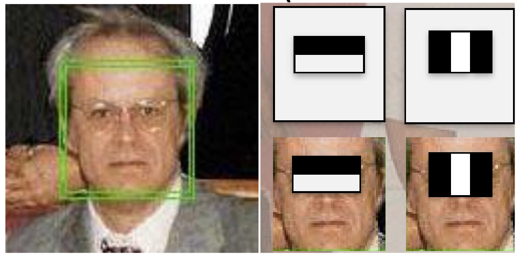


Simplification (David Lowe, 1987)

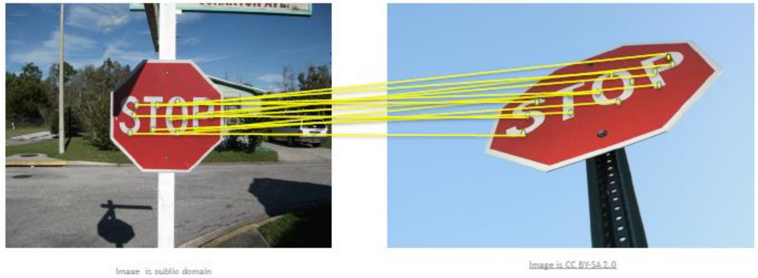
[redacted]

Normalized Cut (Shi & Malik, 1997)

Face detection (Viola & Jones, 2001)



“SIFT” (David Lowe, 1999)



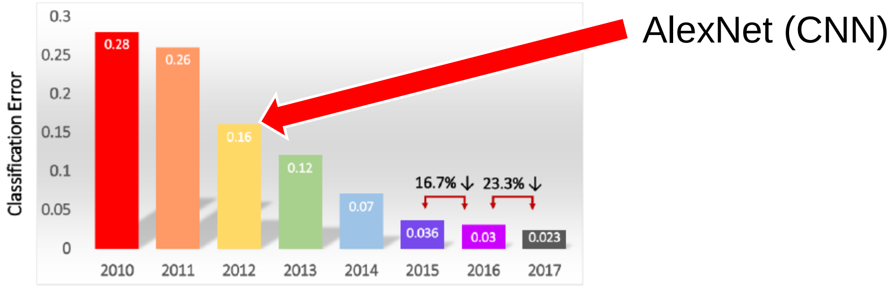
PASCAL Visual Object Challenge
(Everingham et al. 2006 – 2012)

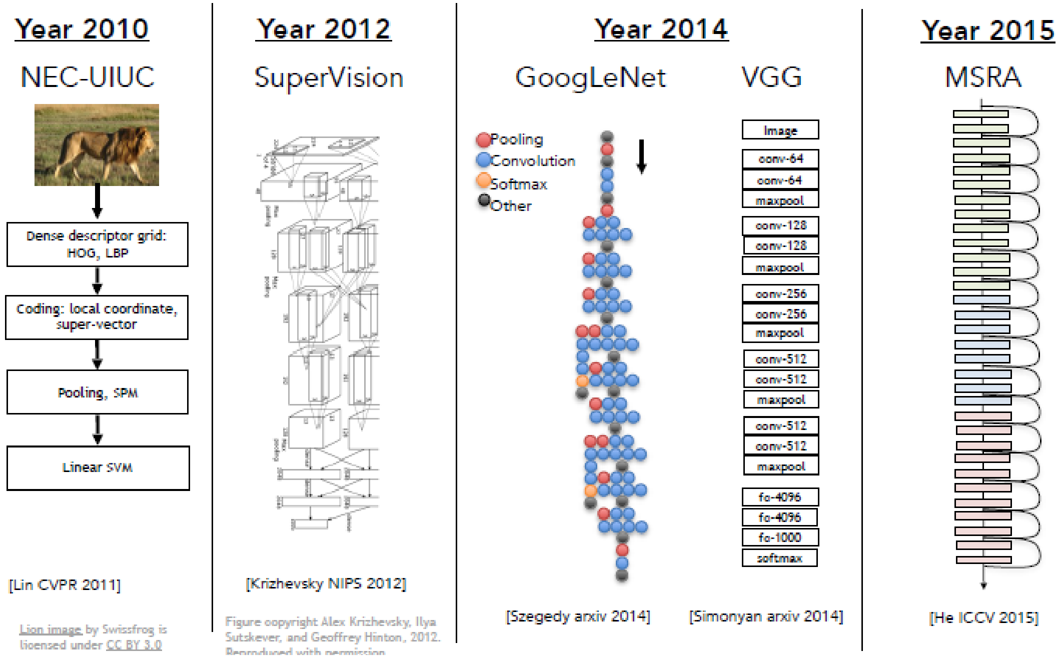
20 Classes or categories

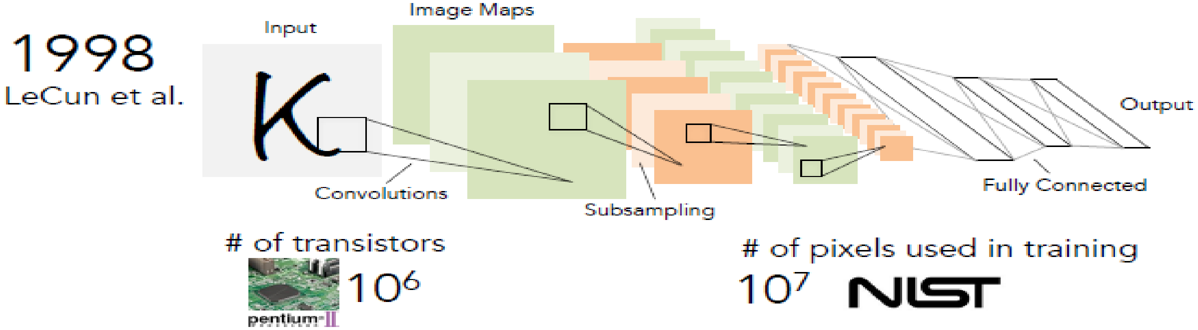
Computer Vision – Why Deep Learning?

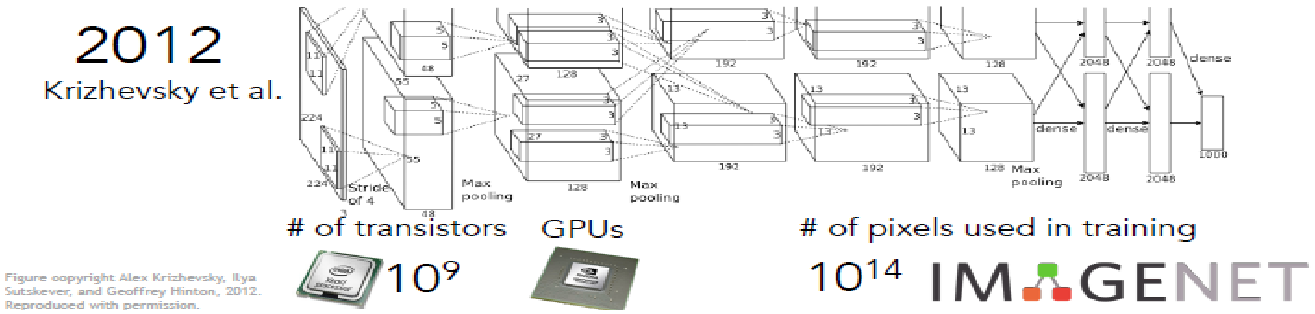
Deng, Dong, Socher, Li, Li, & Fei-Fei, 2009

Average Error (2010 – 2017) [redacted]





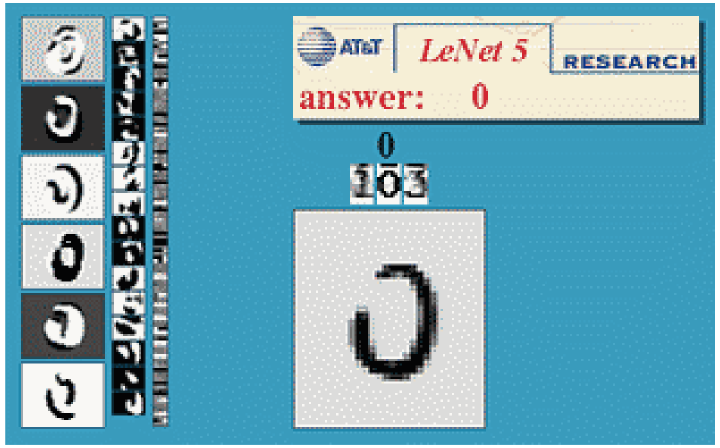


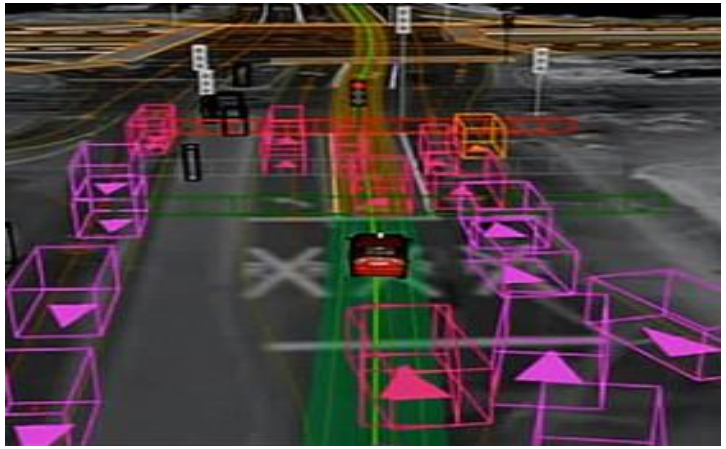


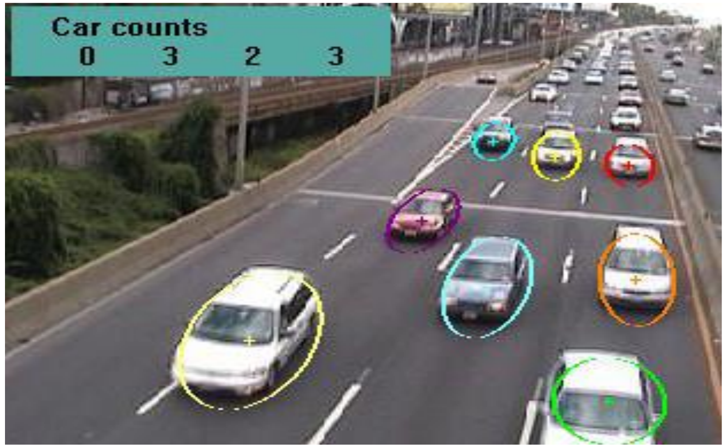
Fei-Fei Li & Justin Johnson & Serena Yeung, CS231n Course, Stanford, Spring 2017

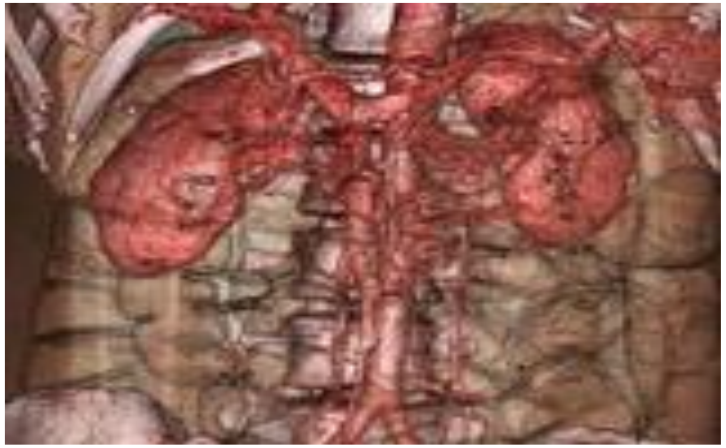
Computer Vision – Industrial Applications

Is being used today in a wide variety of real-world applications, which include: [redacted]







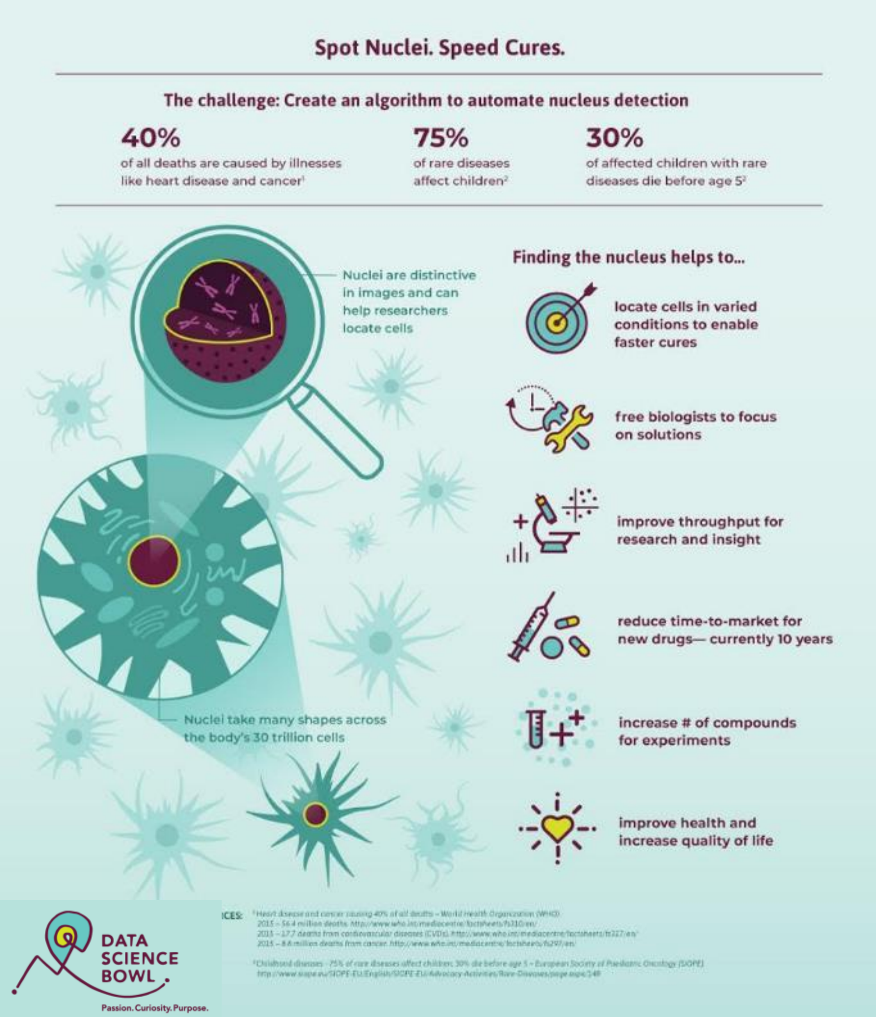

*

Richard Szeliski, Computer vision application and algorithms, September 2014 (adapted 2017)

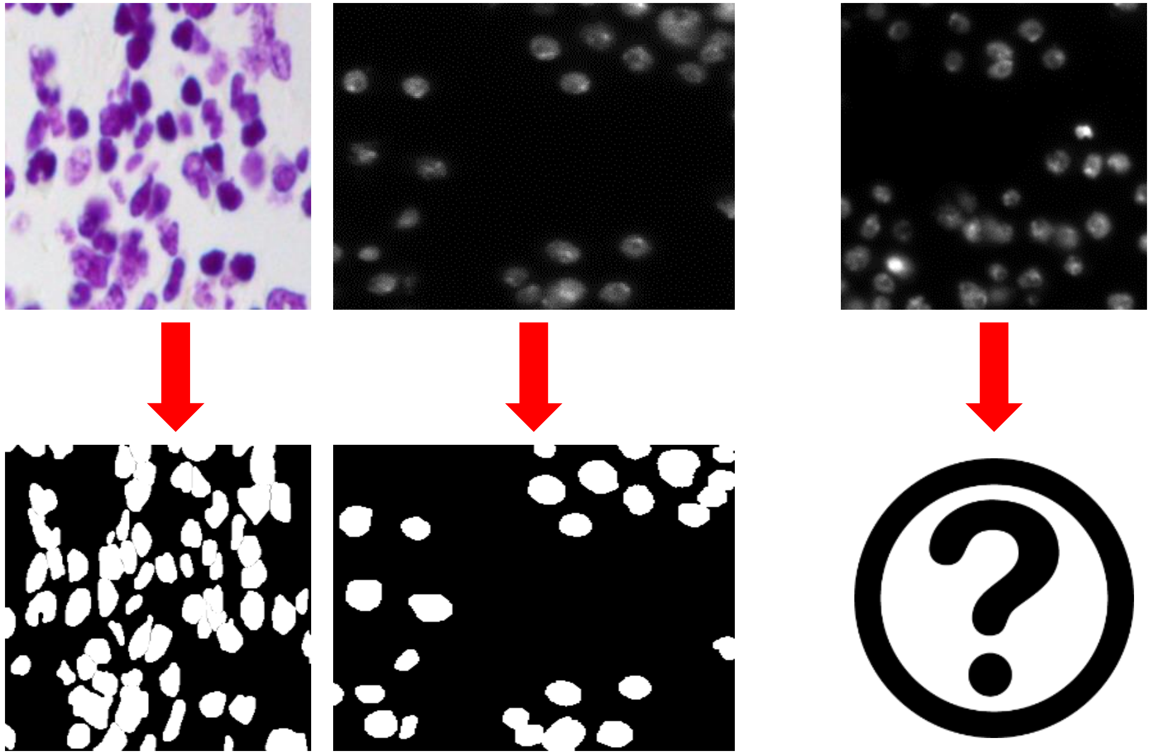
* ***Inner the present scope***

Biomedical Image Segmentation – Overview

The 2018 Data Science Bowl challenge: Create a solution to automate nucleus detection. [redacted]



Training Data (670 labeled images) | Test Data

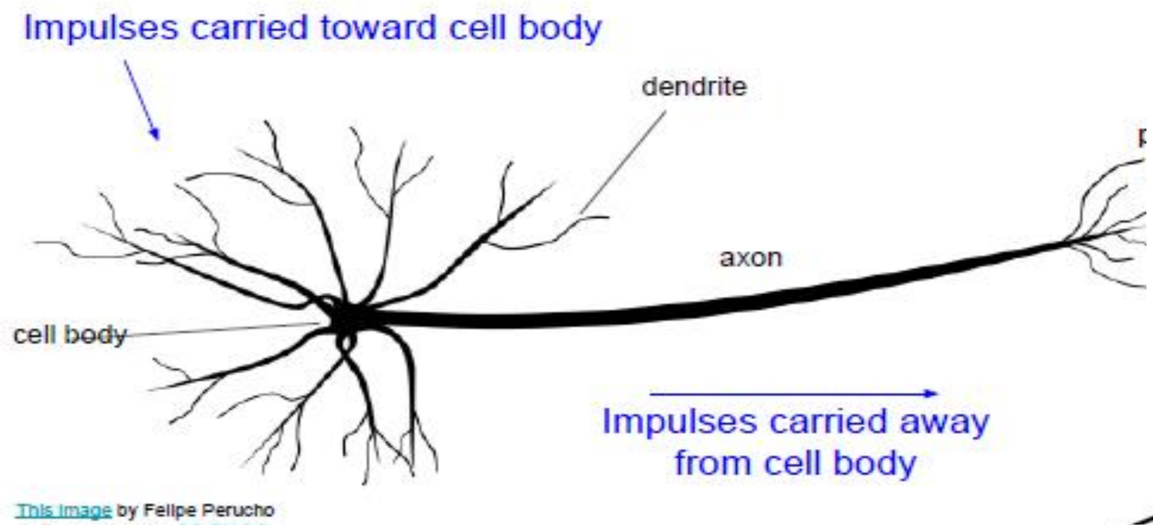


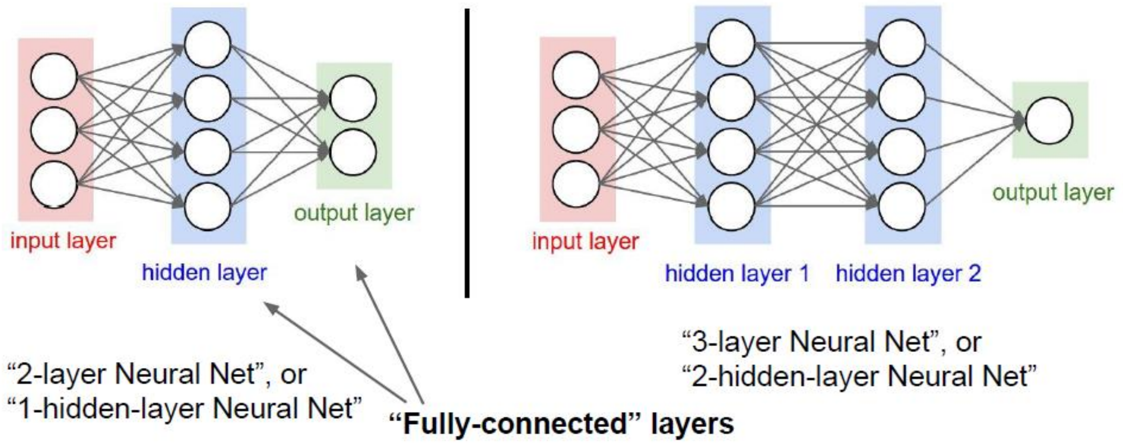
2018 Data Science Bowl (link)

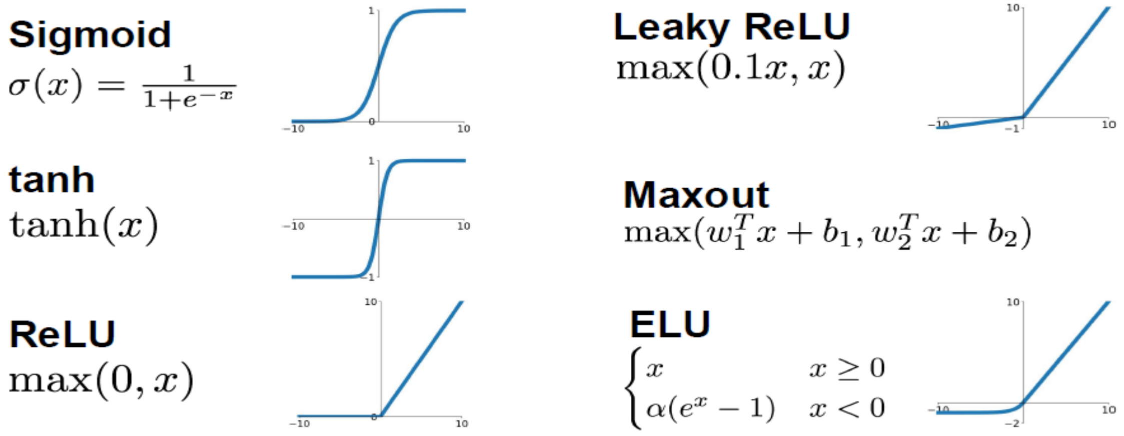
Deep Learning – Neural Network Model

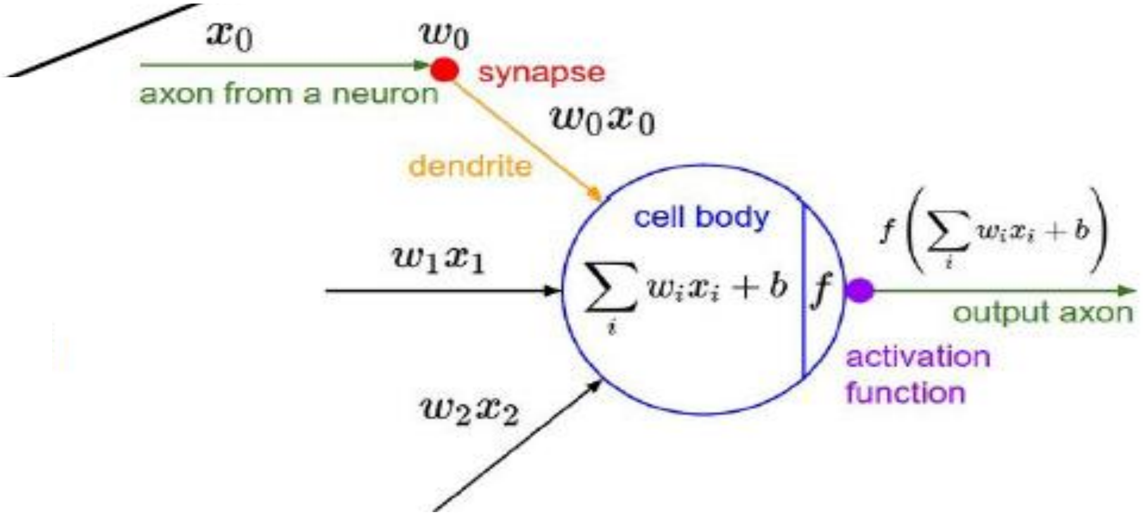
Biological Inspiration (… but just is a model)

More of 1 hidden layer => “Deep” Learning [redacted]





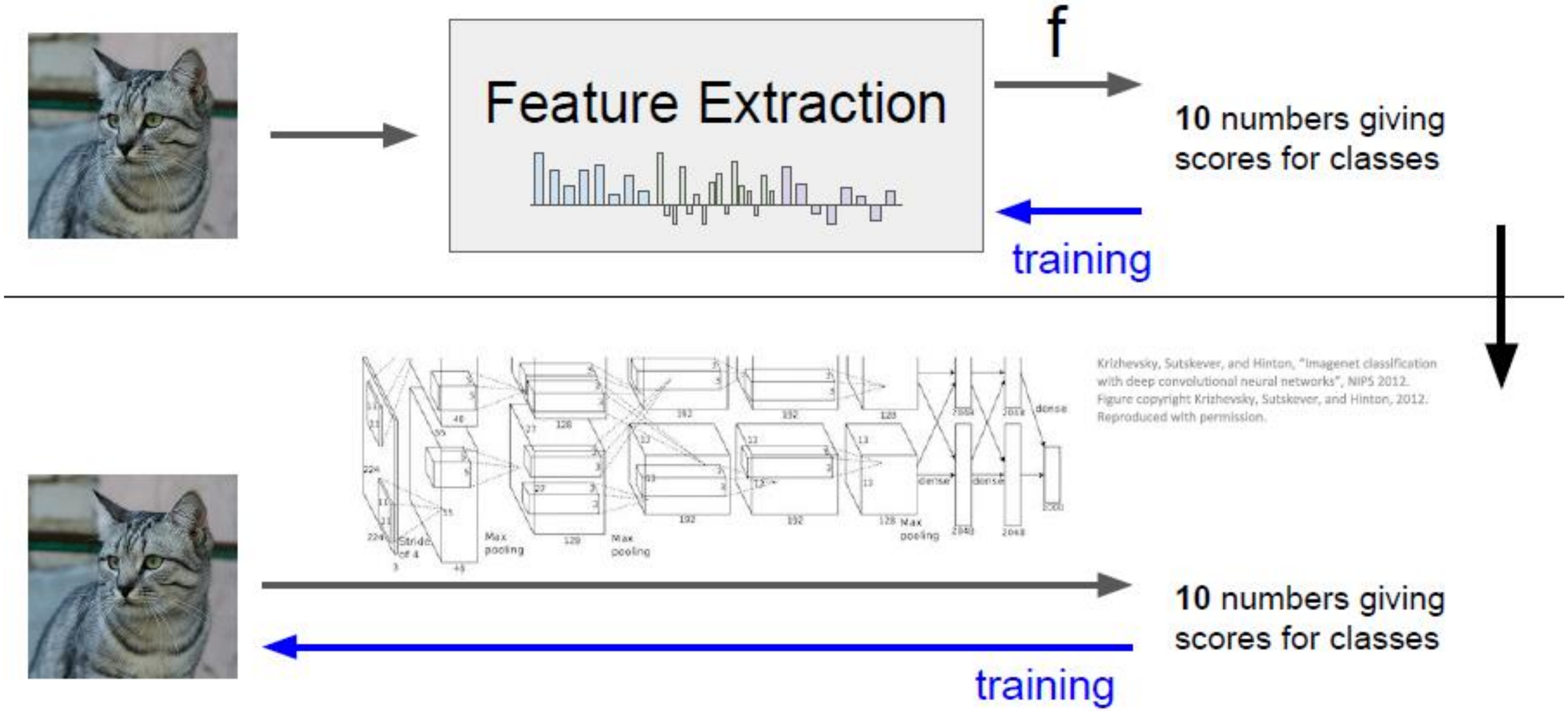




Fei-Fei Li & Justin Johnson & Serena Yeung, CS231n Course, Stanford, Spring 2017

Deep Learning – Approach Comparison

Feature Extraction vs Deep Learning [redacted]



Fei-Fei Li & Justin Johnson & Serena Yeung, CS231n Course, Stanford, Spring 2017

Deep Learning – Convolution Operator

Convolution 1D

$$f = \boxed{10} \boxed{50} \boxed{60} \boxed{10} \boxed{20} \boxed{40} \boxed{30}$$

$$g = \boxed{1/3} \boxed{1/3} \boxed{1/3}$$

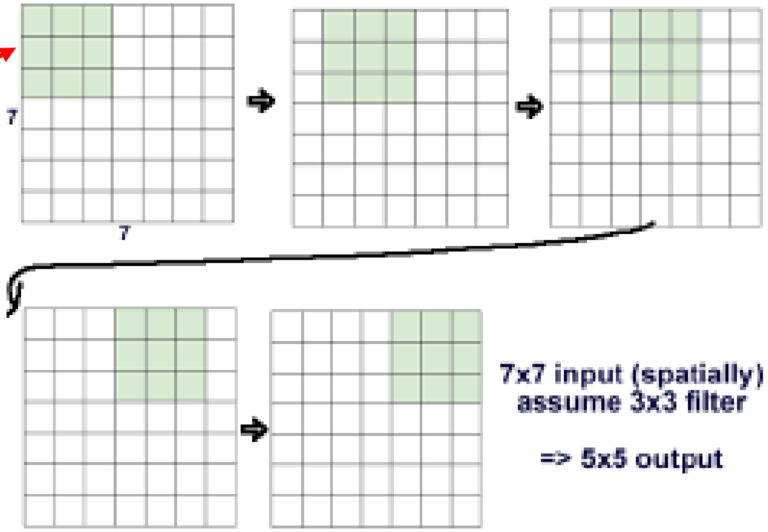
Kernel (K)

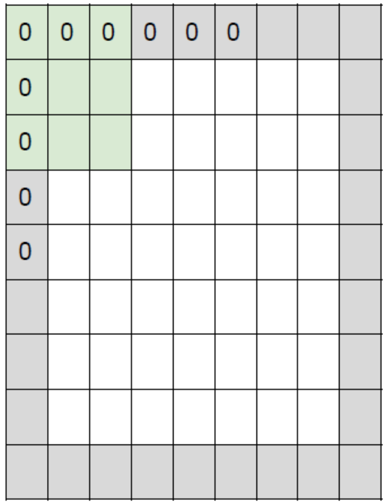
10	50	60	10	20	30	40
0	1/3	1/3	1/3	0	0	0

$$\frac{1}{3}50 + \frac{1}{3}60 + \frac{1}{3}10 = \frac{50}{3} + \frac{60}{3} + \frac{10}{3} = \frac{120}{3} = 40$$

$$h = \boxed{20} \boxed{40} \boxed{40} \boxed{30} \boxed{20} \boxed{30} \boxed{23.333}$$

Convolution 2D [redacted]





In practice: Common to zero pad the border

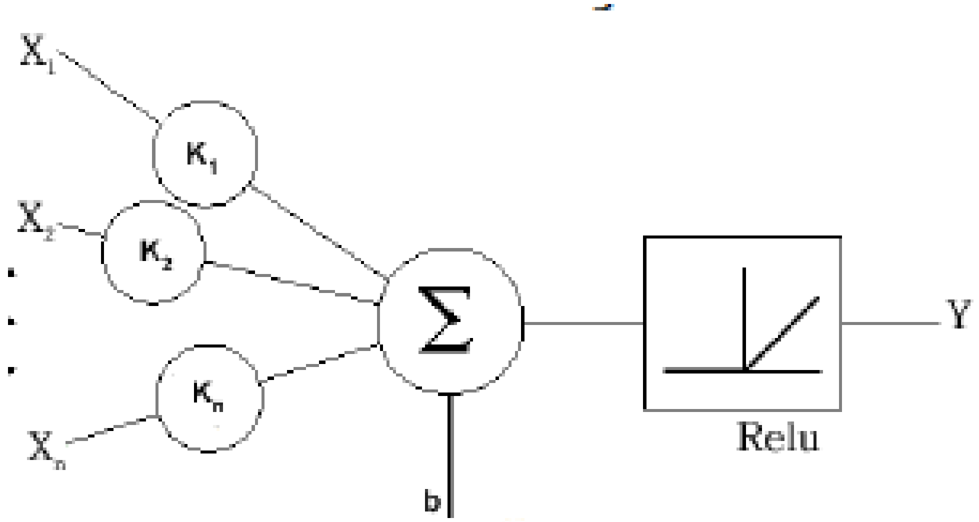
Cornell University, CS1114: Introduction to Computing using Matlab and Robotics, Spring 2013.

Fei-Fei Li & Justin Johnson & Serena Yeung, CS231n Course, Stanford, Spring 2017

Deep Learning – Convolution Neuron

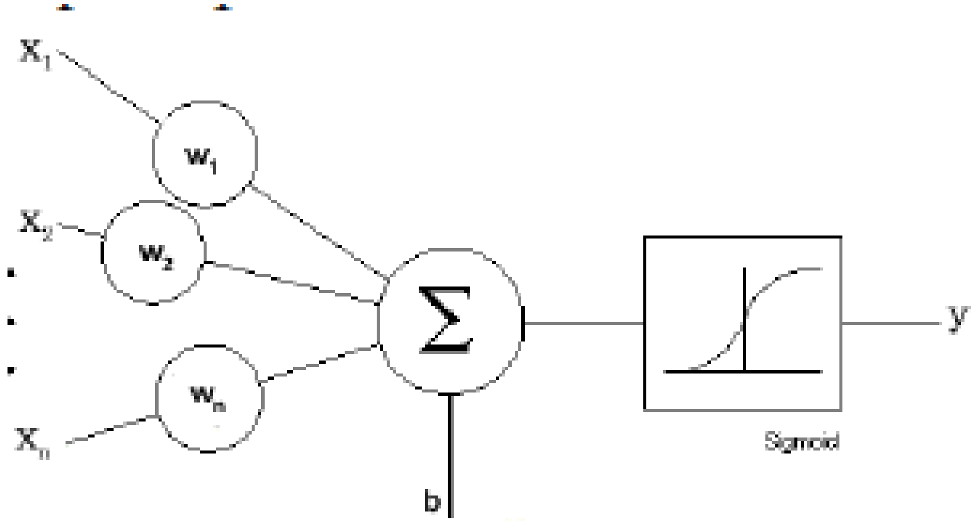
Kernel (K) vs Weights (W)

Convolution neuron



$$Y = g(b + \sum K_i * X_i)$$

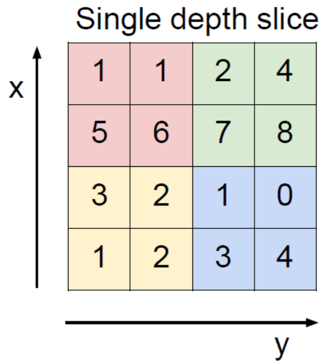
Perceptron

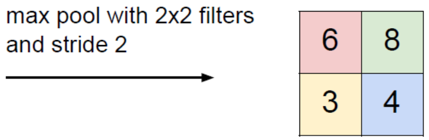


$$y = g(b + \sum w_i x_i)$$

Deep Learning – Other Functions

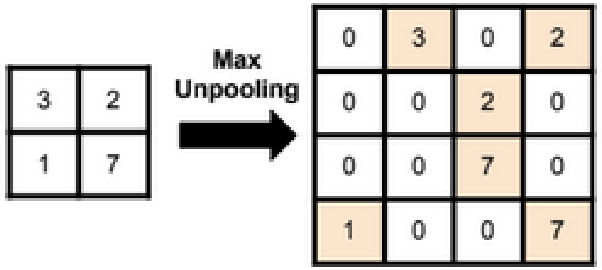
Max Pooling



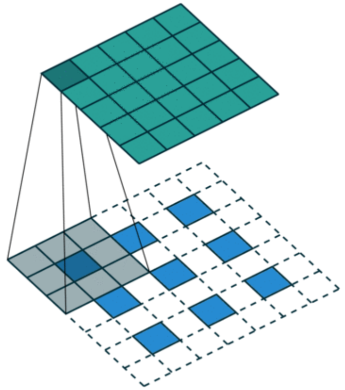


Fei-Fei Li & Justin Johnson & Serena Yeung,
CS231n Course, Stanford, Spring 2017

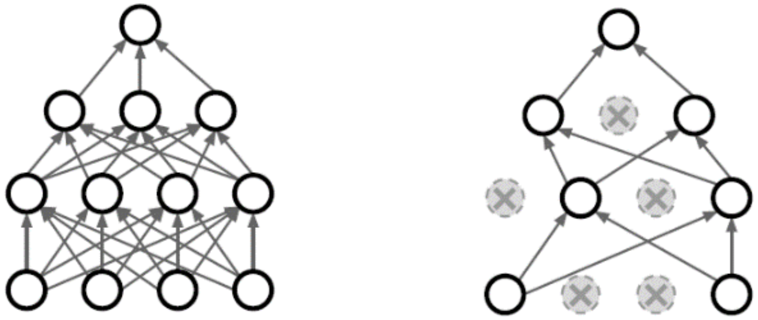
Un Max Pooling



Convolution Transpose [redacted]



Dropout

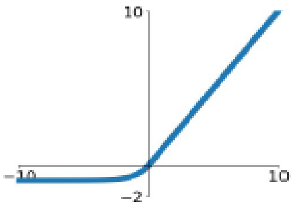


Srivastava et al, "Dropout: A simple way to prevent neural networks from overfitting", JMLR 2014

Transfer Functions

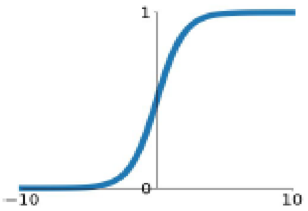
ELU

$$\begin{cases} x & x \geq 0 \\ \alpha(e^x - 1) & x < 0 \end{cases}$$



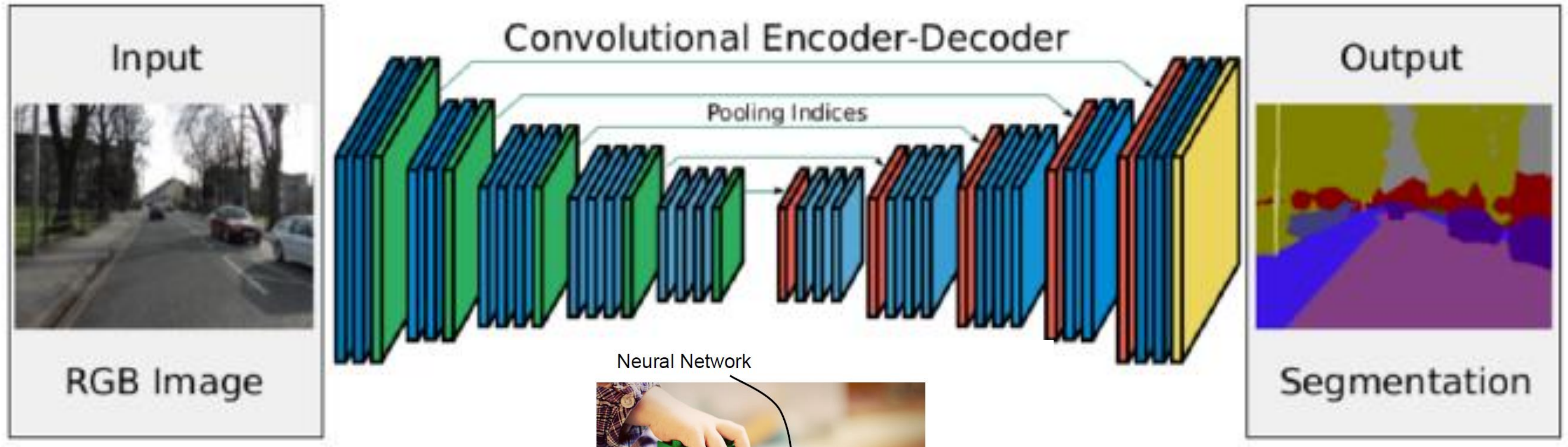
Sigmoid

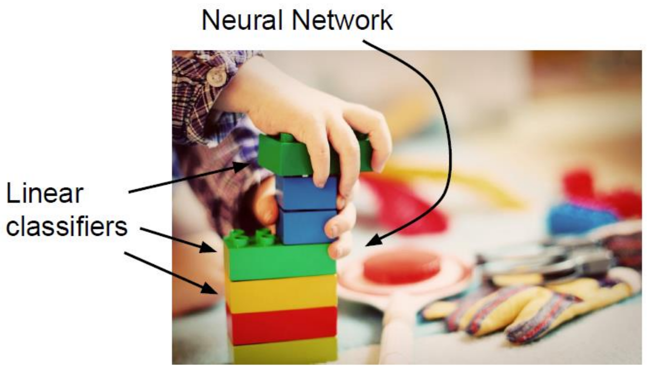
$$\sigma(x) = \frac{1}{1+e^{-x}}$$



Deep Learning – Image Segmentation

Each linear function represents a building block [redacted]





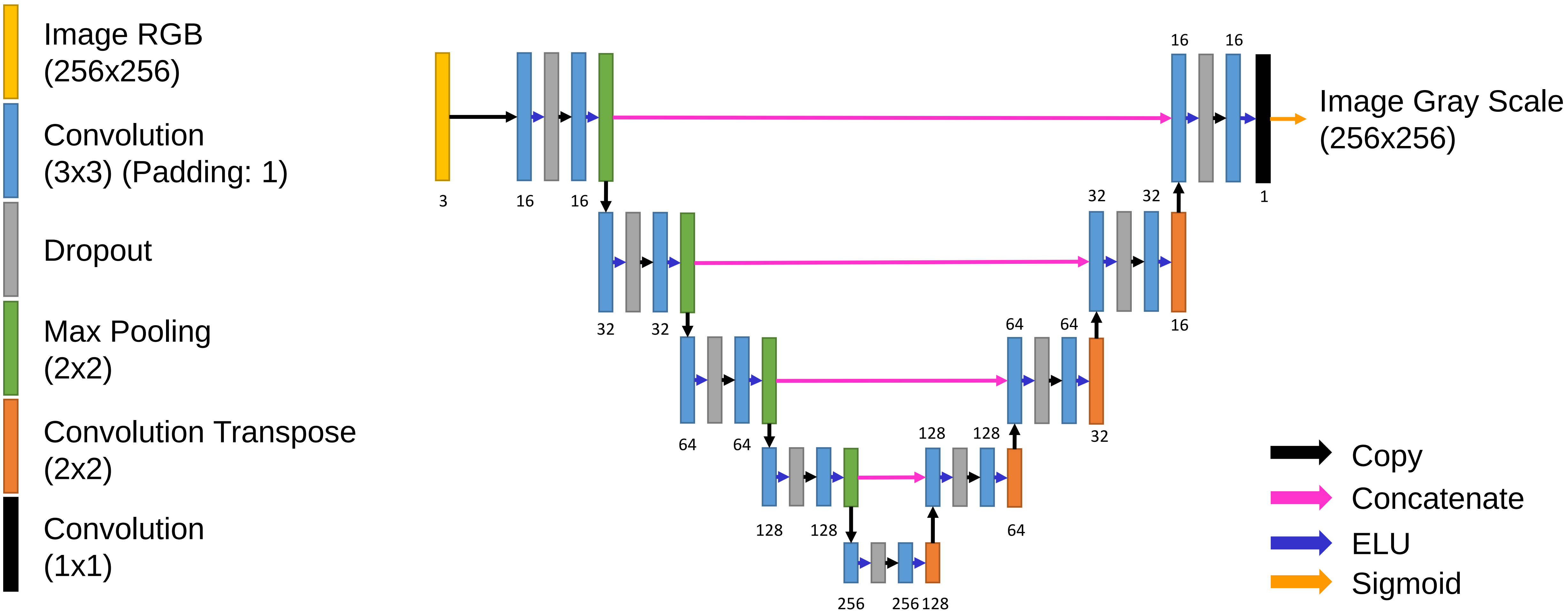
Xu, C., & Li, M. (2017). An Improved Neural Segmentation Method Based on U-NET

Fei-Fei Li & Justin Johnson & Serena Yeung, Stanford, Spring 2017

Ronneberger, O., Fischer, P., & Brox, T. (2015, October). U-net: Convolutional networks for biomedical image segmentation. In *International Conference on Medical image computing and computer-assisted intervention* (pp. 234-241). Springer, Cham.

Deep Learning – Put All Together (example)

For biomedical image segmentation challenge will be use U-net architecture. [redacted]

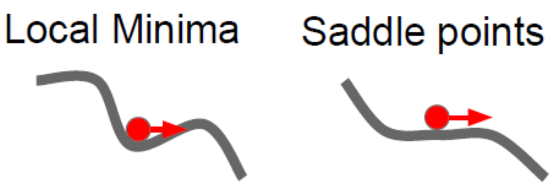


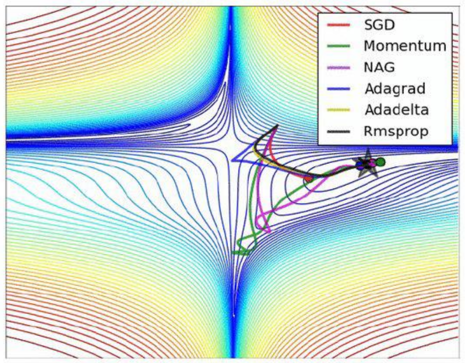
Ronneberger, O., Fischer, P., & Brox, T. (2015, October). U-net: Convolutional networks for biomedical image segmentation. In *International Conference on Medical image computing and computer-assisted intervention* (pp. 234-241). Springer, Cham.

Deep Learning – Weight/Bias calculation

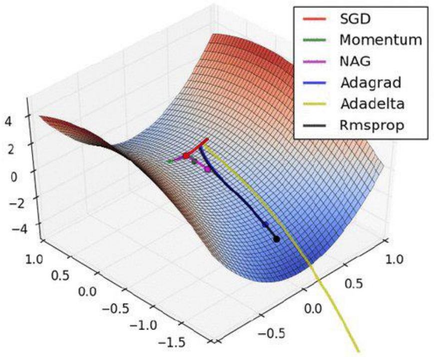
For this model (U-net example) we need to calculate <u>1,941,105 parameters</u>! [redacted]

How to obtain best solution?





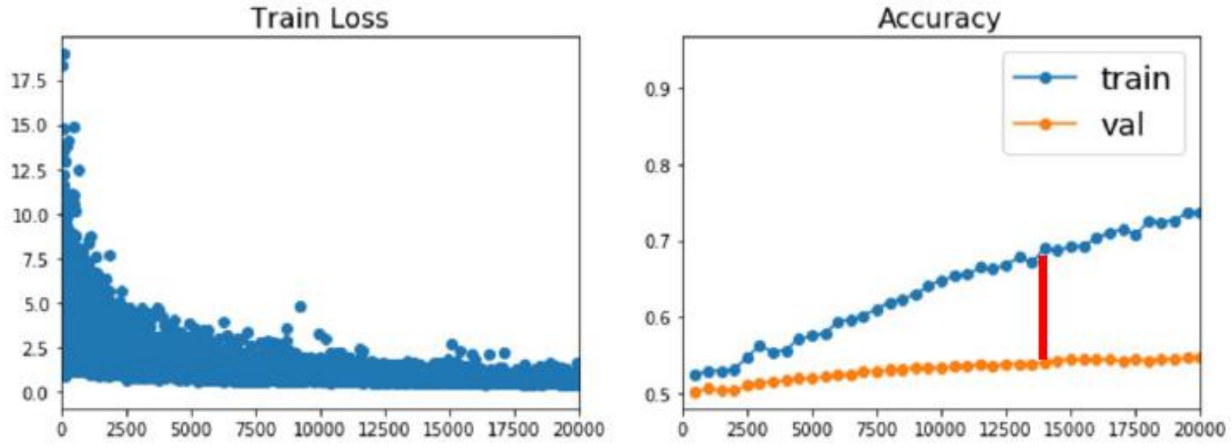
(a) SGD optimization on loss surface contours



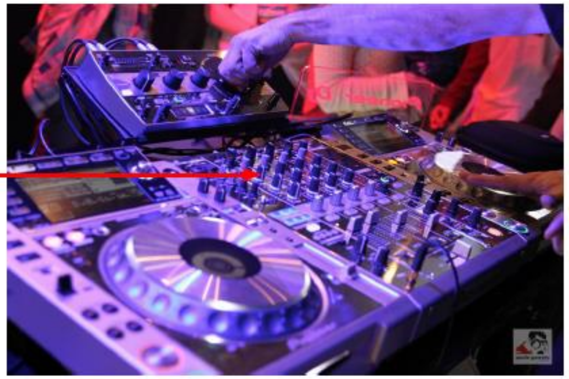
(b) SGD optimization on saddle point

Alec Radford (https://imgur.com/a/Hqolp)

How to improve single-model performance?



neural networks practitioner
music = loss function



Fei-Fei Li & Justin Johnson & Serena Yeung, CS231n Course, Stanford, Spring 2017
Ludwin Lope, Computer Vision, Master Dissertation, USP Brazil, 2018

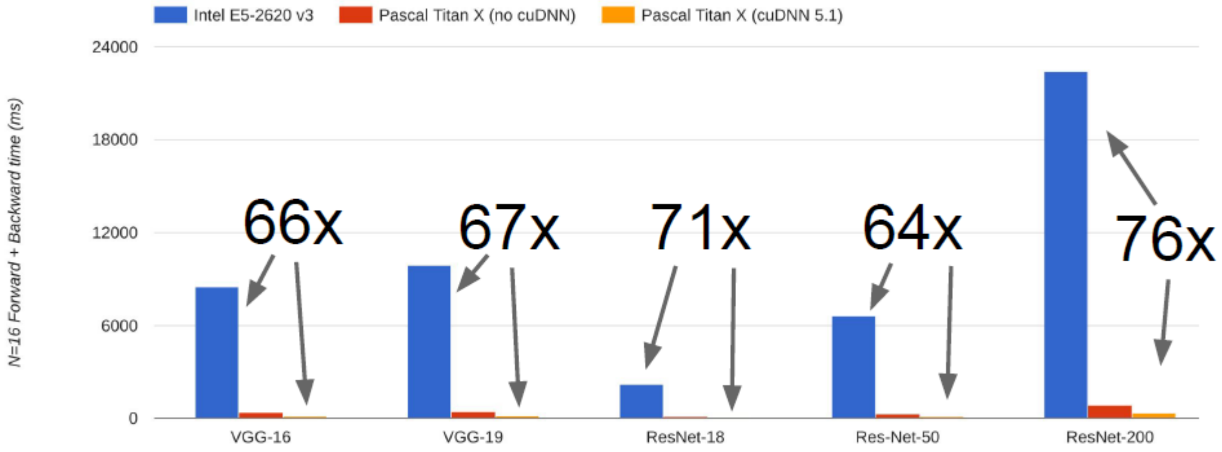
Deep Learning – Why GPU?

The massive amount of calculations require the use of hardware that helps accelerate processes.

CPU vs GPU

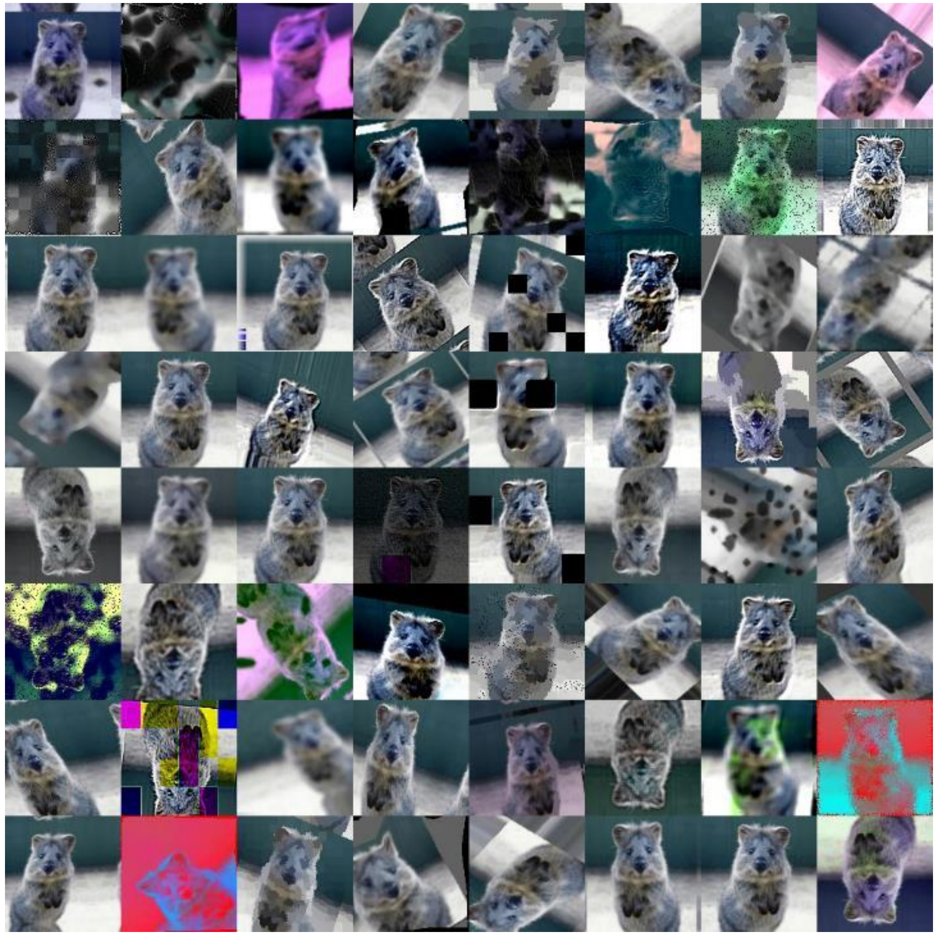
	# Cores	Clock Speed	Memory	Price
CPU (Intel Core i7-7700k)	4 (8 threads with hyperthreading)	4.4 GHz	Shared with system	$339
CPU (Intel Core i7-6950X)	10 (20 threads with hyperthreading)	3.5 GHz	Shared with system	$1723
GPU (NVIDIA Titan Xp)	3840	1.6 GHz	12 GB GDDR5X	$1200
GPU (NVIDIA GTX 1070)	1920	1.68 GHz	8 GB GDDR5	$399

CPU vs GPU in practice



Deep Learning – Data Augmentation

Is possible apply data augmentation techniques for increment training data.

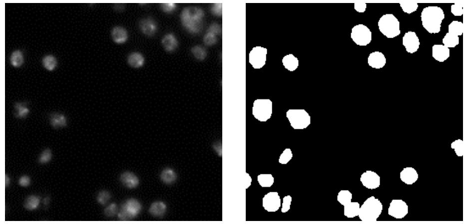


https://github.com/aleju/imgaug

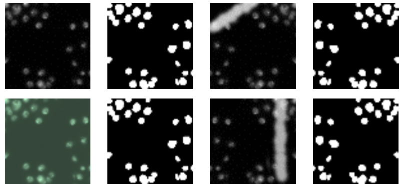
Biomedical Image Segmentation – Application

The 2018 Data Science Bowl challenge: Create a solution to automate nucleus detection. [redacted]

Training Data (670 labeled images)

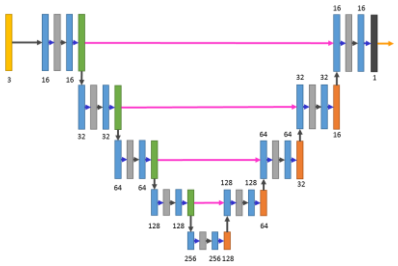


Training Data Augmented (12,730 labeled images)



... x19

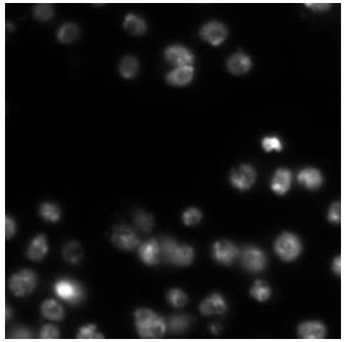
Train U-net CNN Architecture



Labeled by <u>Deep Learning</u>

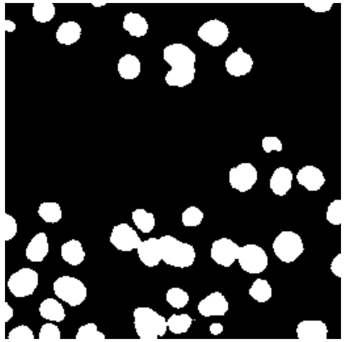
Labeled by <u>humans</u> (biomedical professionals)

Test Data



U-net CNN Trained

Result



Deep Learning – Implementation

Frameworks:

2016

Caffe
(UC Berkeley)

Torch
(NYU / Facebook)

Theano
(U Montreal) → TensorFlow
(Google)

Today

A bit about these

Caffe
(UC Berkeley) → Caffe2
(Facebook)

Torch
(NYU / Facebook) → PyTorch
(Facebook)

Theano
(U Montreal) → TensorFlow
(Google)

Mostly these

Paddle
(Baidu)

CNTK
(Microsoft)

MXNet
(Amazon)
Developed by U Washington, CMU, MIT, Hong Kong U, etc but main framework of choice at AWS

And others...

Wrappers: [redacted]

- **Keras**
- TFLearn
- TensorLayer
- tf.layers
- TF-Slim
- tf.contrib.learn
- Pretty Tensor
- **Sonnet**

“**TensorFlow** is a safe bet for most projects. Not perfect but has huge community, wide usage.
Maybe pair with high-level wrapper (Keras, Sonnet, etc)
I think **PyTorch** is best for research. However still new, there can be rough patches.
Use **TensorFlow** for one graph over many machines
Consider **Caffe**, **Caffe2,** or **TensorFlow** for production deployment
Consider **TensorFlow** or **Caffe2** for mobile”

Fei-Fei Li & Justin Johnson & Serena Yeung, CS231n Course, Stanford, Spring 2017

Deep Learning – Applications

From Medicine to Cybersecurity (your imagination is the limit!).

Mingxuan Sun, Introduction to Deep Learning and Its Applications, Louisiana State University, USA, 2016

Deep Learning – Applications

Recommender Systems Everywhere

ACM, 2nd Workshop on Deep Learning for Recommender Systems, ACM Digital Library, 2017

Deep Learning – Applications

Image Descriptors

[redacted]

"man in black shirt is playing guitar."

"construction worker in orange safety vest is working on road."

"two young girls are playing with lego toy."

"girl in pink dress is jumping in air."

"black and white dog jumps over bar."

"young girl in pink shirt is swinging on swing."

… and so on

Karpathy, A., & Fei-Fei, L. (2015). Deep visual-semantic alignments for generating image descriptions. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 3128-3137).

Deep Learning – Cloud Platforms

The battle for machine learning

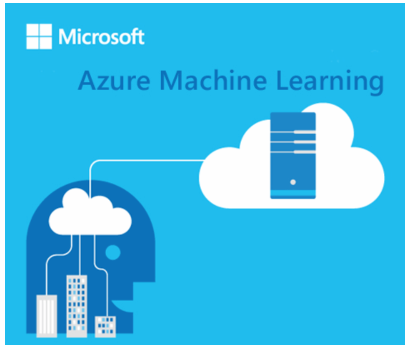
[redacted]

Google Cloud Platform

amazon web services

Amazon Machine Learning

aws.amazon.com/machine-learning



Forbes, McKinsey's State Of Machine Learning And AI, 2017

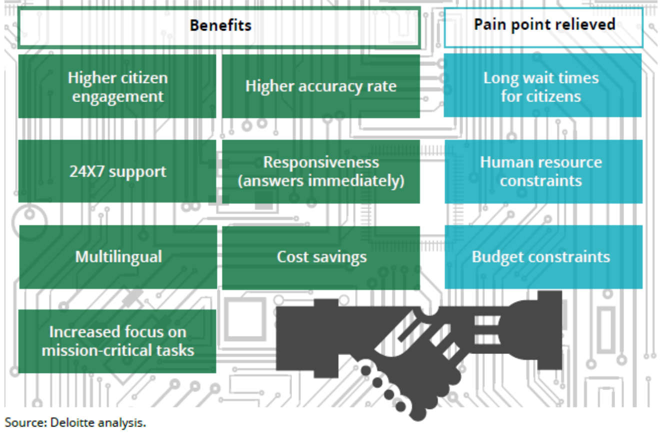
Government Use Cases and Opportunities

AI opens great opportunities for governments [redacted]

Case Study: Philippines - Department of Science and Technology - Intelligent Operations Center

Case Study: Dutch Government - Using Text Mining and Machine Learning for Detection of Child Abuse

Case Study: Singapore Government – Conversational Systems



Source: Deloitte analysis.

Indra, Best Government Emerging Technologies, 2017
Deloite, AI-augmented government, 2017

References

- ACM, 2nd Workshop on Deep Learning for Recommender Systems, ACM Digital Library, 2017.
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Thank you!

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