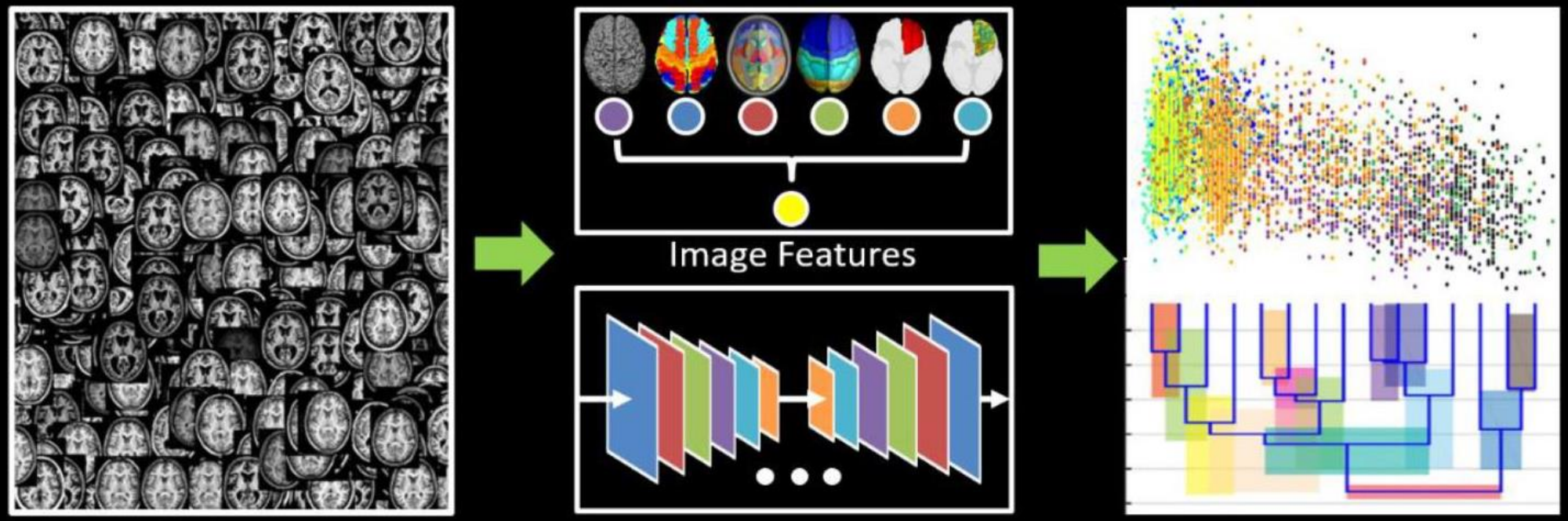


Overview of Deep Learning in Medical Image Computing

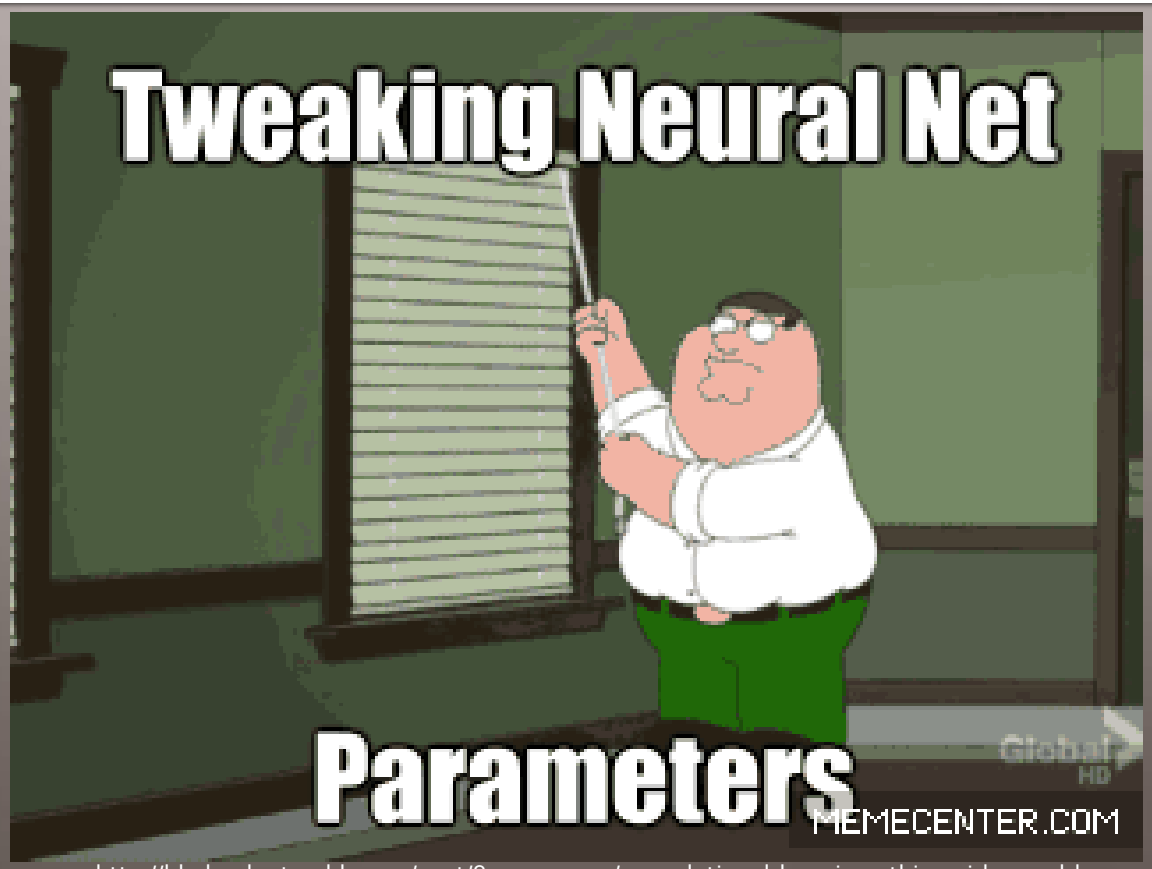
[Spring 2020 CS-8395-02 Deep Learning in Medical Image Computing]

Instructor: Yuankai Huo, Ph.D.
Department of Electrical Engineering and Computer Science
Vanderbilt University

Topics

- Introduction
- About the Class
- Syllabus
- Deep Learning in Medical Image Computing
- Assignment 0

Why this class



http://bbabenko.tumblr.com/post/83319141207/convolutional-learnings-things-i-learned-by

I see "Deep Learning" in the class name!

Goals for This Course

https://fyspringfield.com/post/94170889415

- Cover Basic Concepts in Deep Learning
- Applications in Medical Image Computing
- Write Deep Learning Code on Basic Tasks
- Deep Learning Project for Medical Imaging
- Find a Good Job & Do Better Research

  - For basic math:
  - CS 6362: Machine Learning
  - CS 5260: Artificial Intelligence
  - CS 3891: Deep Learning

Organization of Course

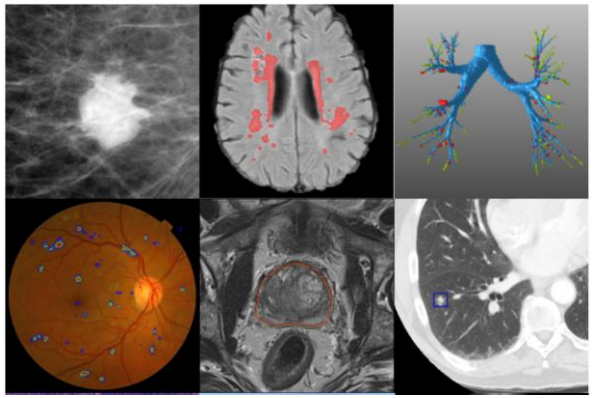
Overview

Overview of Deep Learning in Medical Image Computing
Neural Networks and CNN

Key Techs

Classification (Medical Image Diagnosis)
Detection (Landmark Localization and Detection)
Segmentation (Medical Image Segmentation)
GAN (Medical Image Synthesis)

Topics in Medical Image Computing



Overview of "Deep Learning"

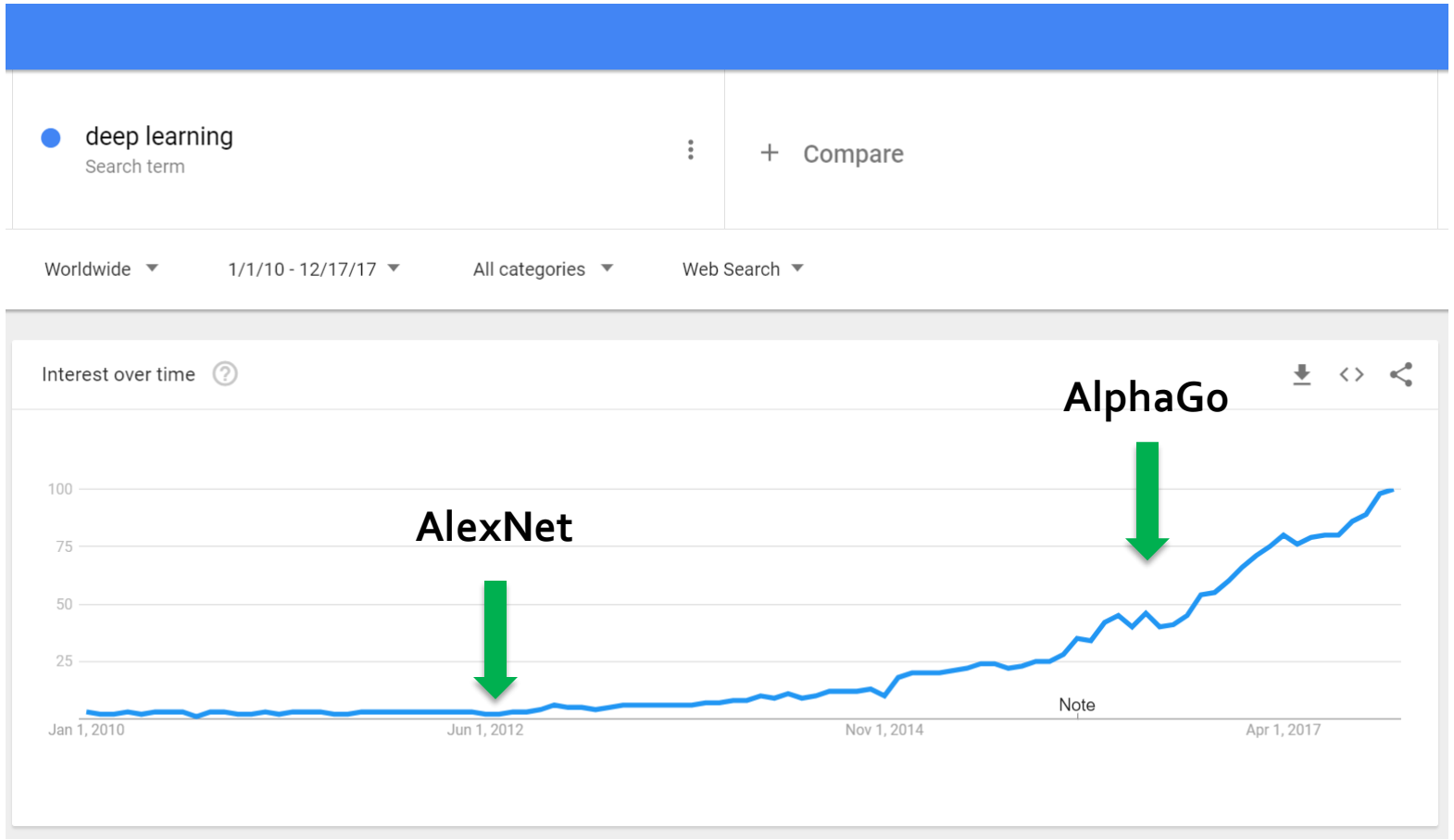
[PDF] A Fast Learning Algorithm for Deep Belief Nets - University of Toront…
www.cs.toronto.edu/~fritz/absps/ncfast.pdf ▾
by GE Hinton - Cited by 8687 - Related articles
fast, greedy algorithm that can **learn deep**, directed belief networks one layer at a time, provided the ... Neural Computation 18, 1527–1554 (**2006**). C **2006** ... contrastive version of the wake-sleep algorithm (**Hinton**, Dayan, Frey,. & Neal, 1995) ...

People also search for

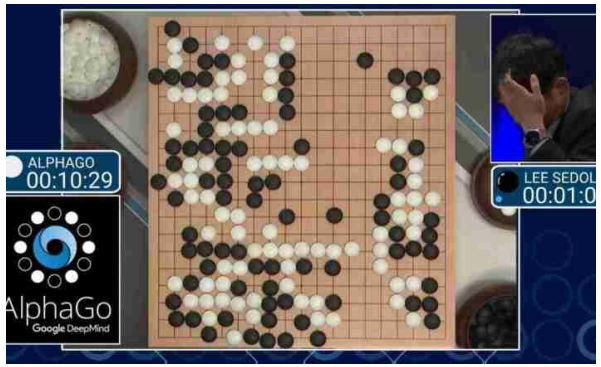
bengio et al., 2007	yee-whye teh
deep belief nets	deep learning research papers pdf
neural network reading	deep learning survey

"I want to call SVM shallow learning"
-- Geoffrey Everest Hinton

Deep Learning Became Hot

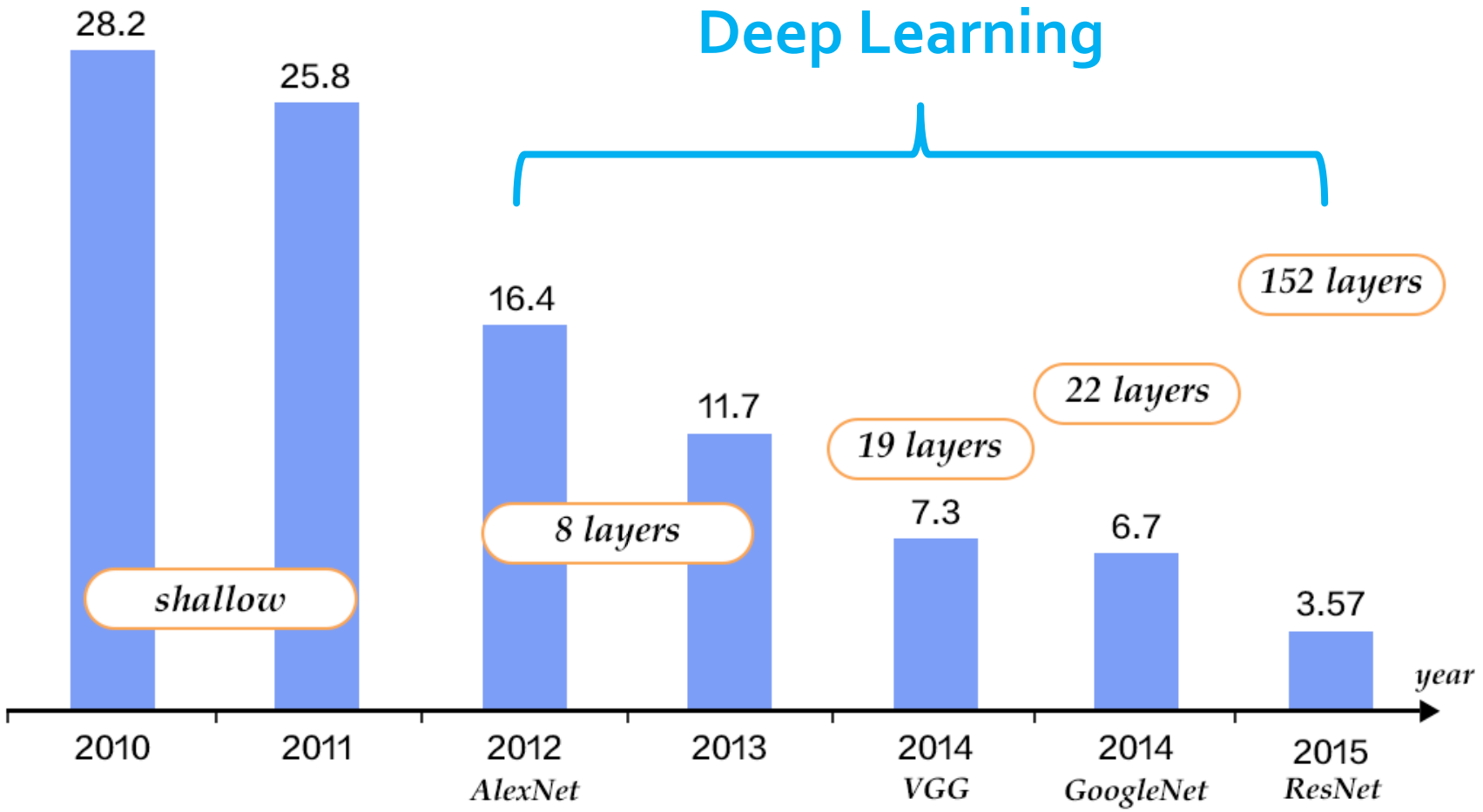


2016
MARCH
DeepMind's AlphaGo, using deep learning, defeats world champion **Lee Sedol** in the Chinese game of go, four games to one.



http://fortune.com/ai-artificial-intelligence-deep-machine-learning/

Performance on ImageNet



Top 5 error rate:
Computer > 25%
Human ~= 5%

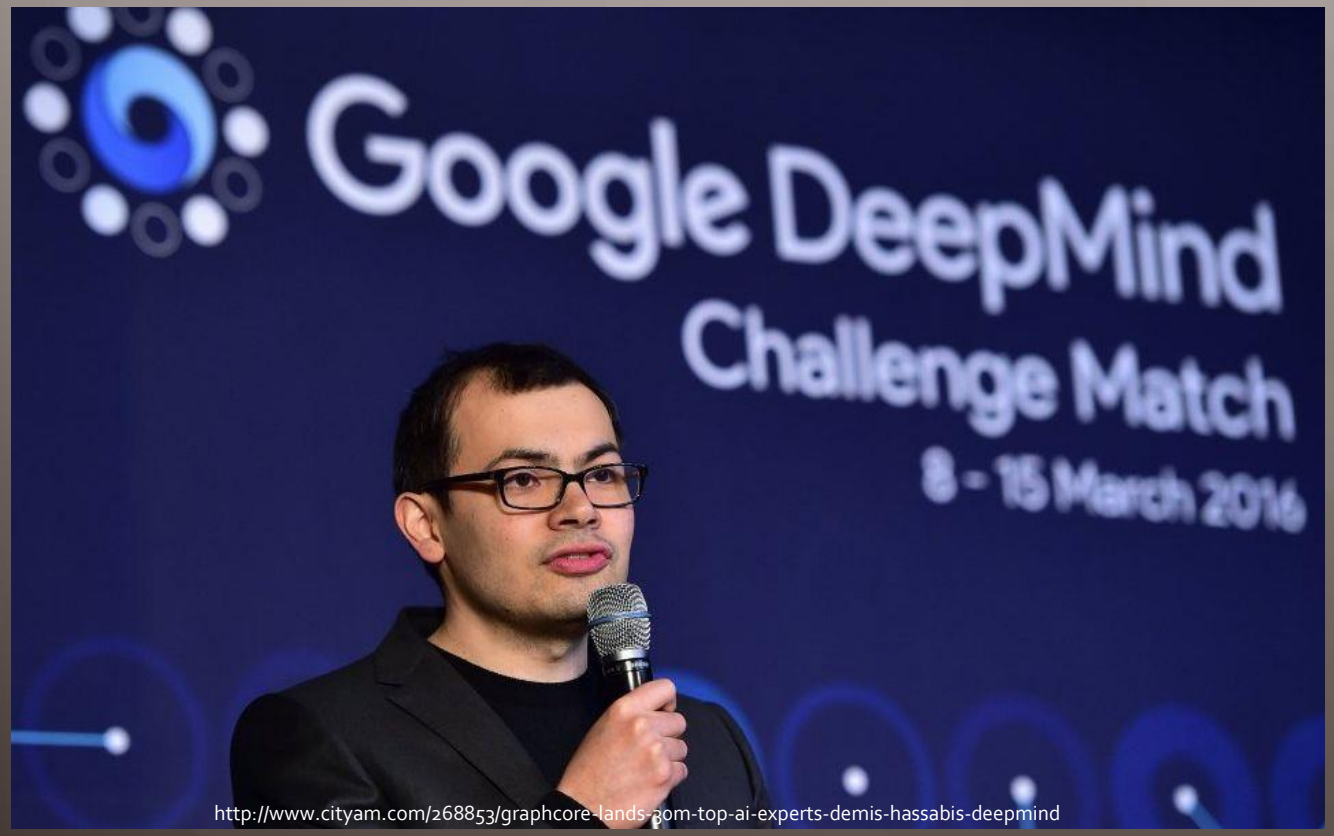
AlexNet
Computer ~=16 %

http://paddlepaddle.org/docs/develop/book/03.image_classification/index.html

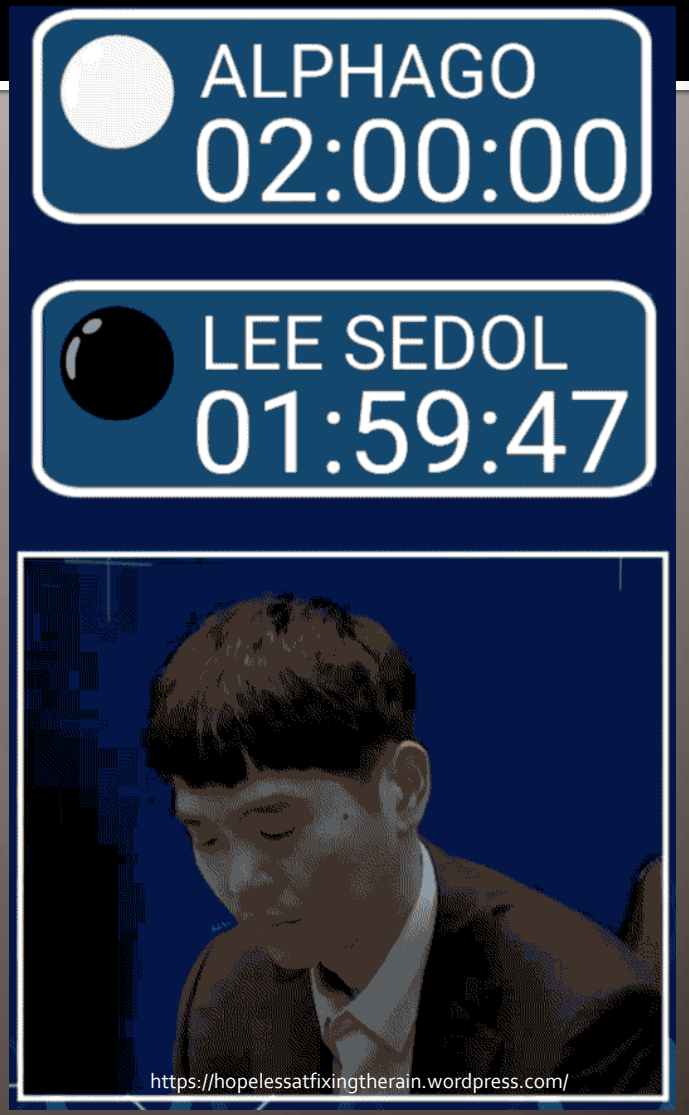
Great Marking!

AlphaGo

October 2015

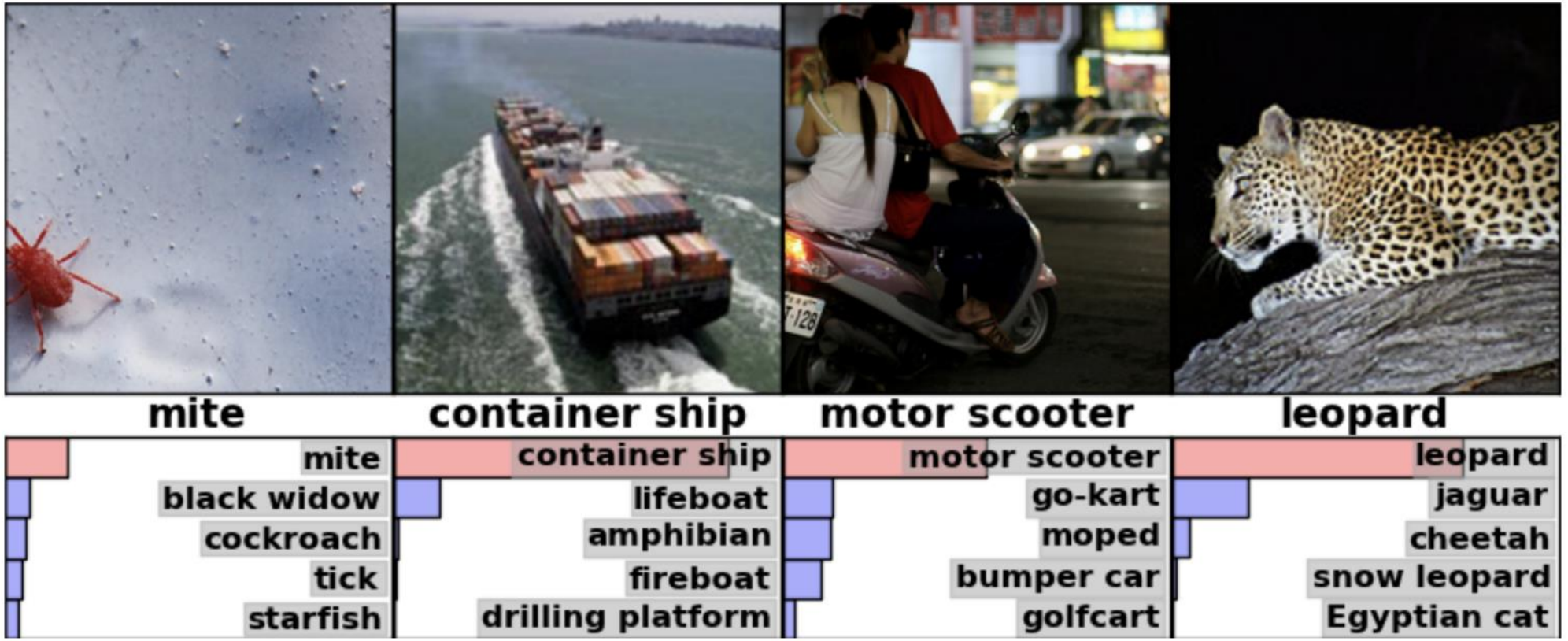


http://www.cityam.com/268853/graphcore-lands-3om-top-ai-experts-demis-hassabis-deepmind



https://hopelessatfixingtherain.wordpress.com/

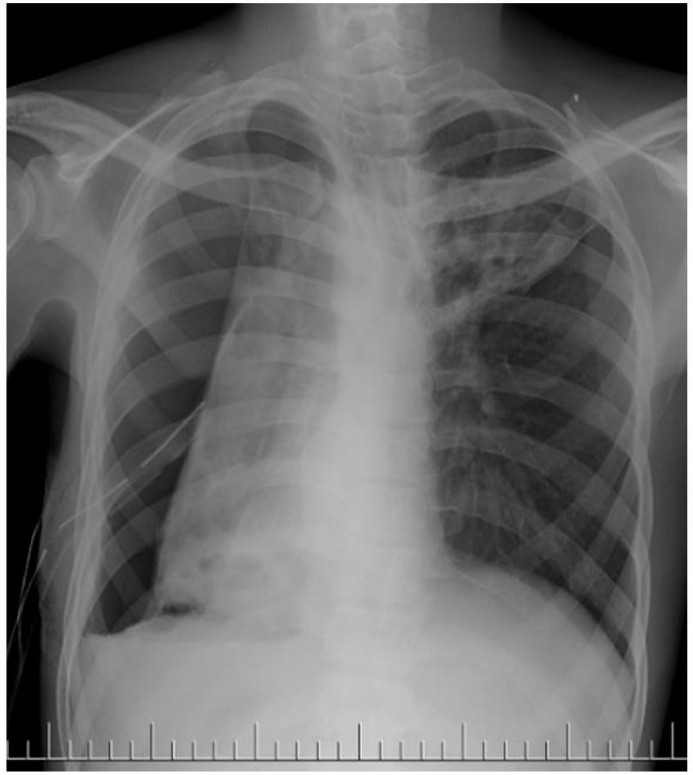
Success on Vision

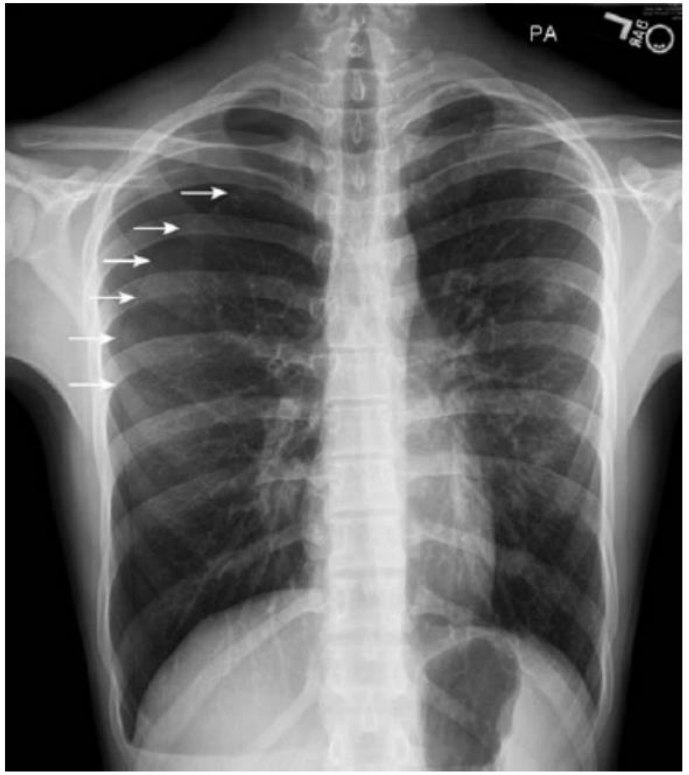


http://introtodeeplearning.com/materials/2018_6S191_Lecture1.pdf

Success on Medical Imaging

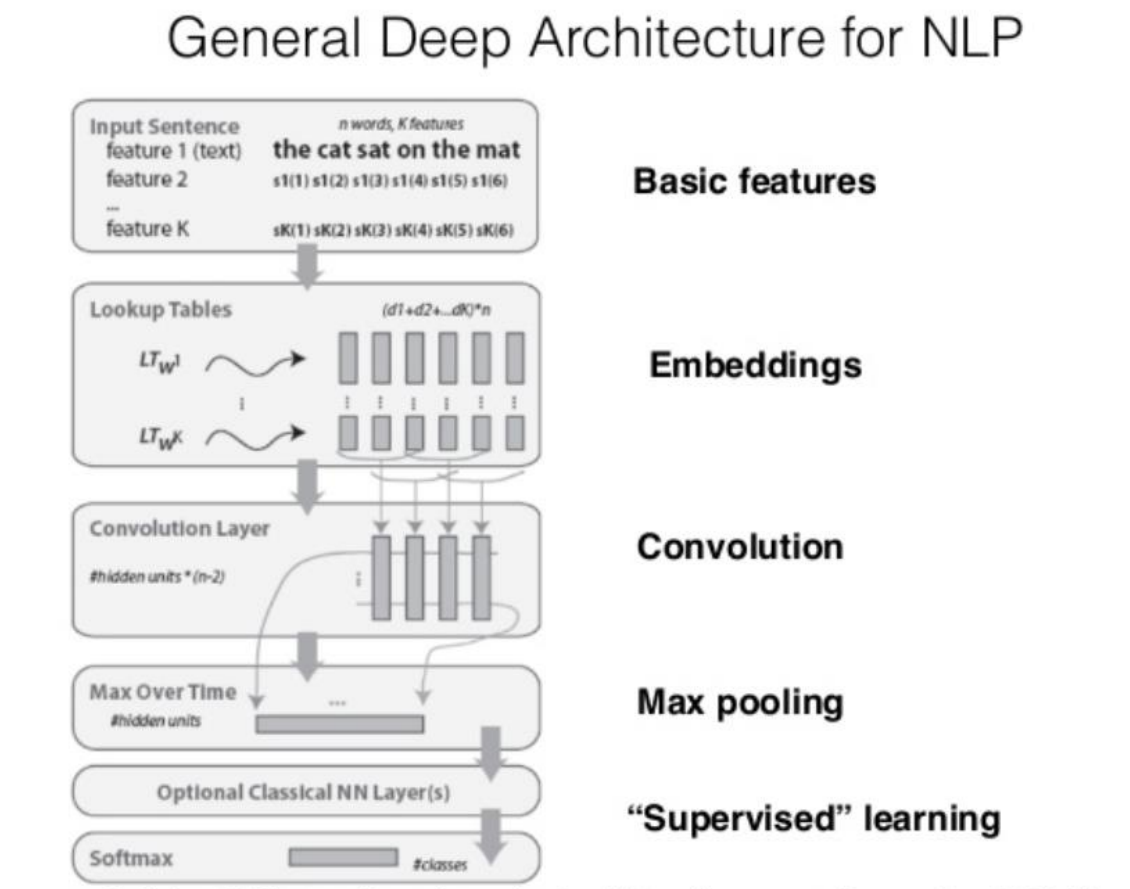
Detect pneumothorax in real X-Ray scans



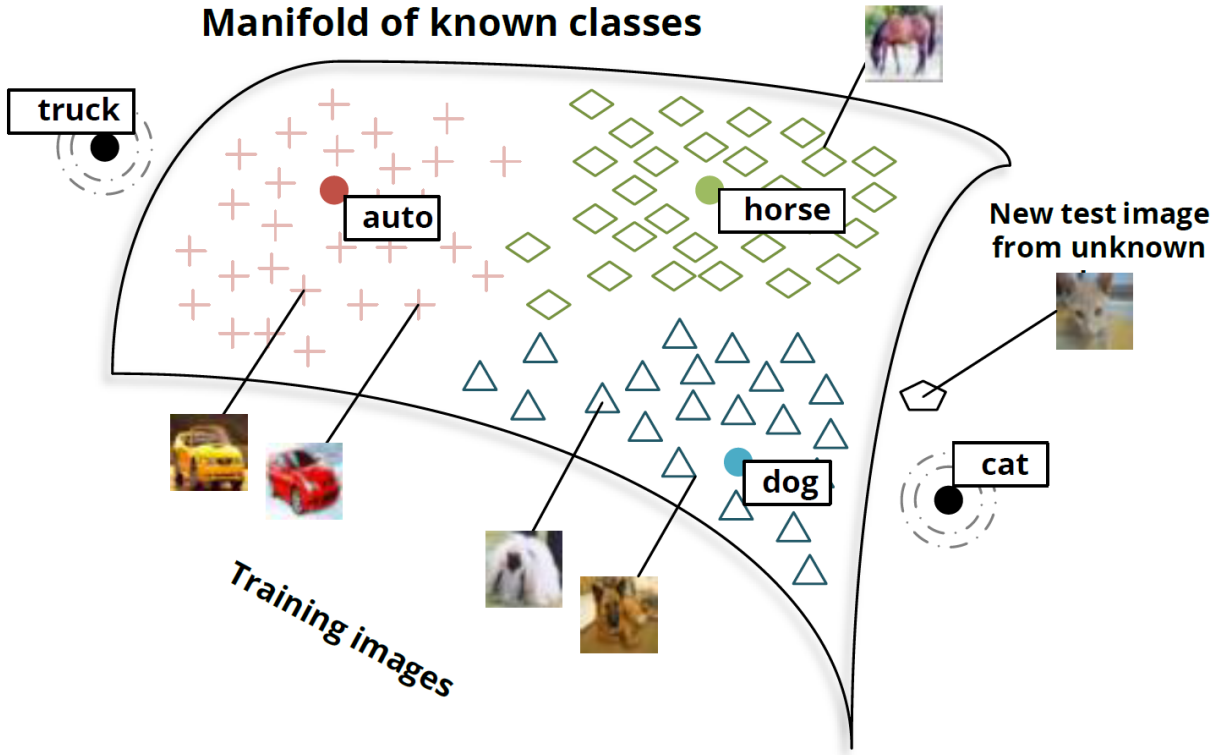


http://introtodeeplearning.com/materials/2018_6S191_Lecture1.pdf

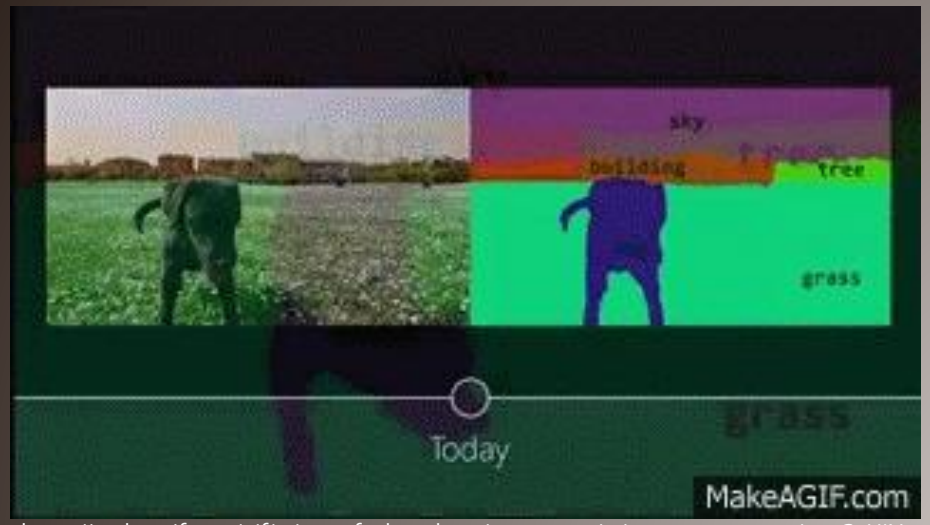
Success on NLP



source: Collobert & Weston, Deep Learning for Natural Language Processing. 2009 Nips

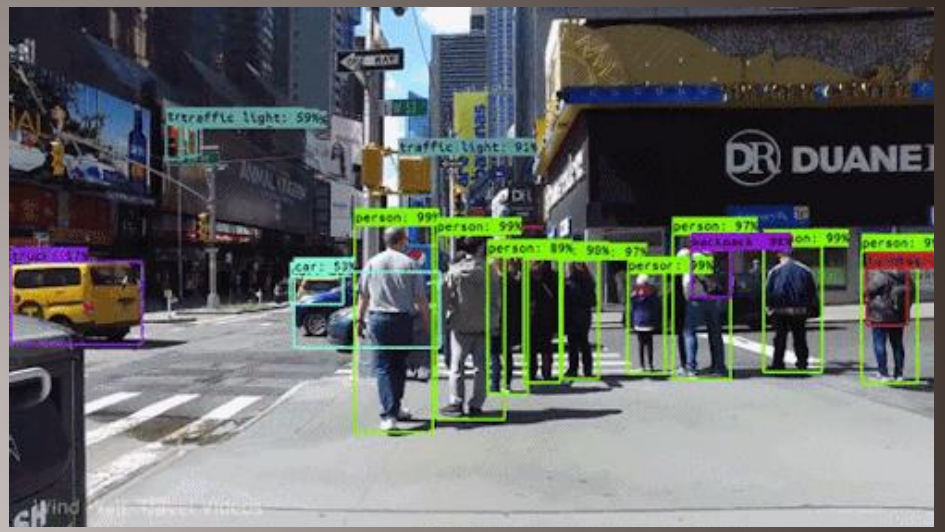


http://colah.github.io/posts/2014-07-NLP-RNNs-Representations/



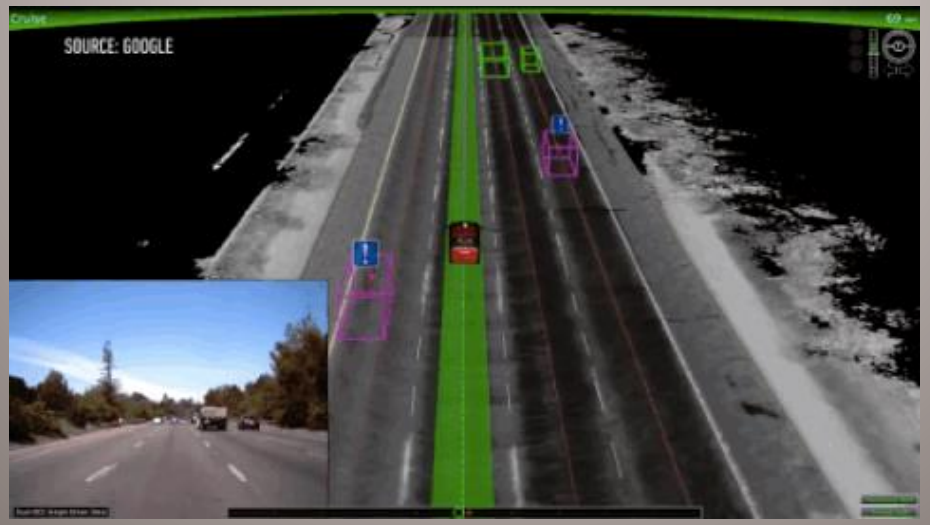
https://makeagif.com/gif/microsoft-deep-learning-semantic-image-segmentation-G_HiNa

https://gifer.com/en/SRL8



https://mc.ai/deep-learning-for-object-detection-from-the-start-to-the-state-of-the-art-2-2/

http://www.thesarahshow.com/



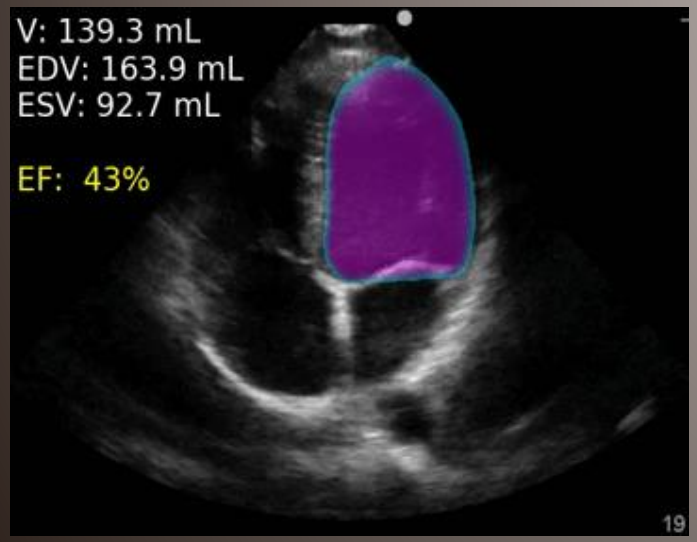
https://www.theverge.com/2016/2/29/11133682/deep-learning-ai-explained-machine-learning

http://gizmodo.com/researchers-just-created-the-most-amazing-lip-reading-s-1788748163

https://www.technologyreview.com/s/542921/robot-toddler-learns-to-stand-by-imagining-how-to-do-it/https://www.technologyreview.com/s/542921/robot-toddler-learns-to-stand-by-imagining-how-to-do-it/

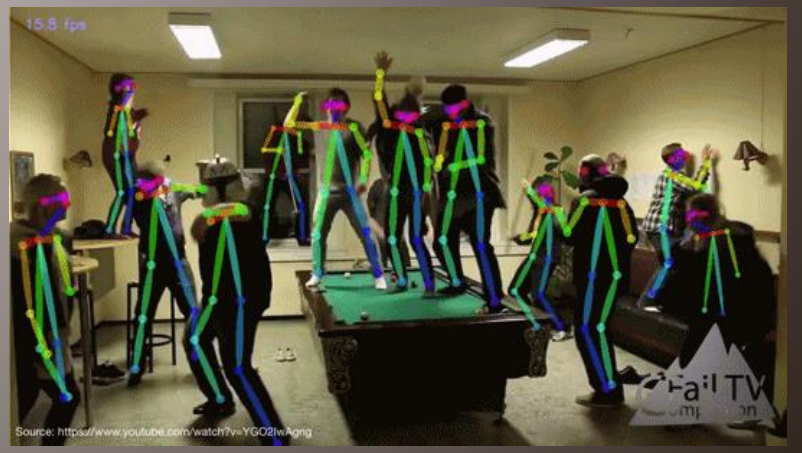
https://people.eecs.berkeley.edu/~pathak/

https://www.instadeep.com/



http://naturalvision.de/

https://kotaku.com/blizzard-wants-to-know-if-googles-deepmind-ai-can-conqu-1788615284



http://d.hatena.ne.jp/hanecci/20170513/p8

Over Marketing

http://do-androidsdreamof-electricsheep.tumblr.com/post/47576669265/ai-artificial-intelligence-2001

In Public & Media

https://www.reddit.com/r/reactiongifs/comments/7077cb/mrw_i_read_the_news_that_the_us_will_end_the/

AI Scientists

Still Limited

Emergent Tech ▸ Artificial Intelligence

OpenAI bots smashed in their first clash against human Dota 2 pros

AI can react faster than humans, but don't play well enough to beat the masters yet

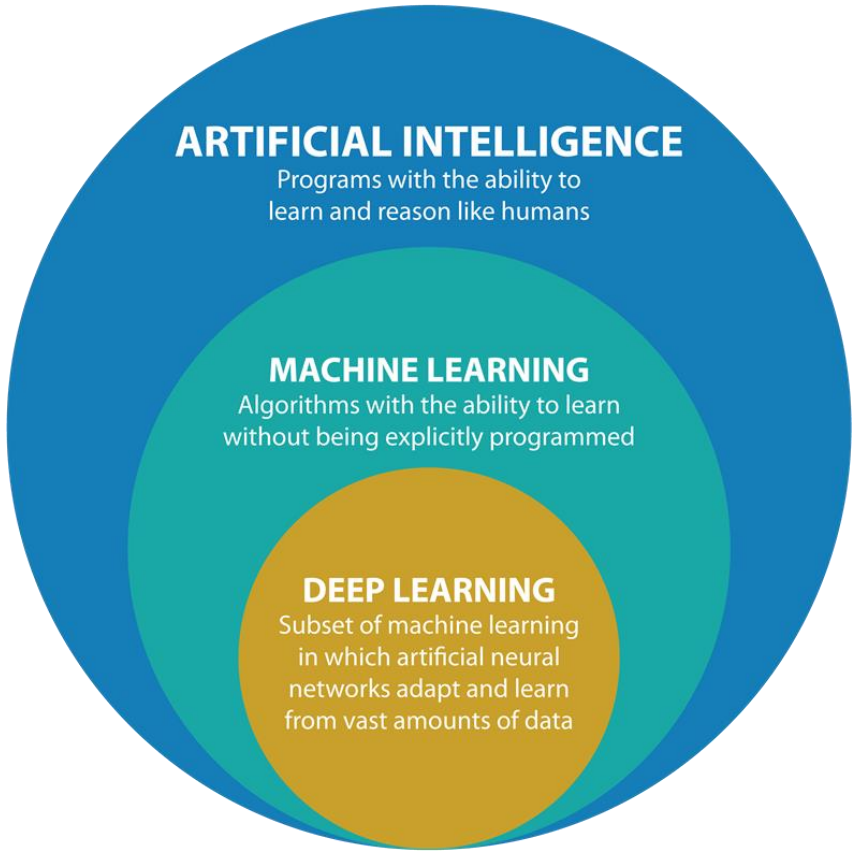
By Katyanna Quach 23 Aug 2018 at 02:19 1 SHARE ▼

http://wq0326.tumblr.com/post/93428031577/push-until-the-end-ti4-newbee-vs-eg

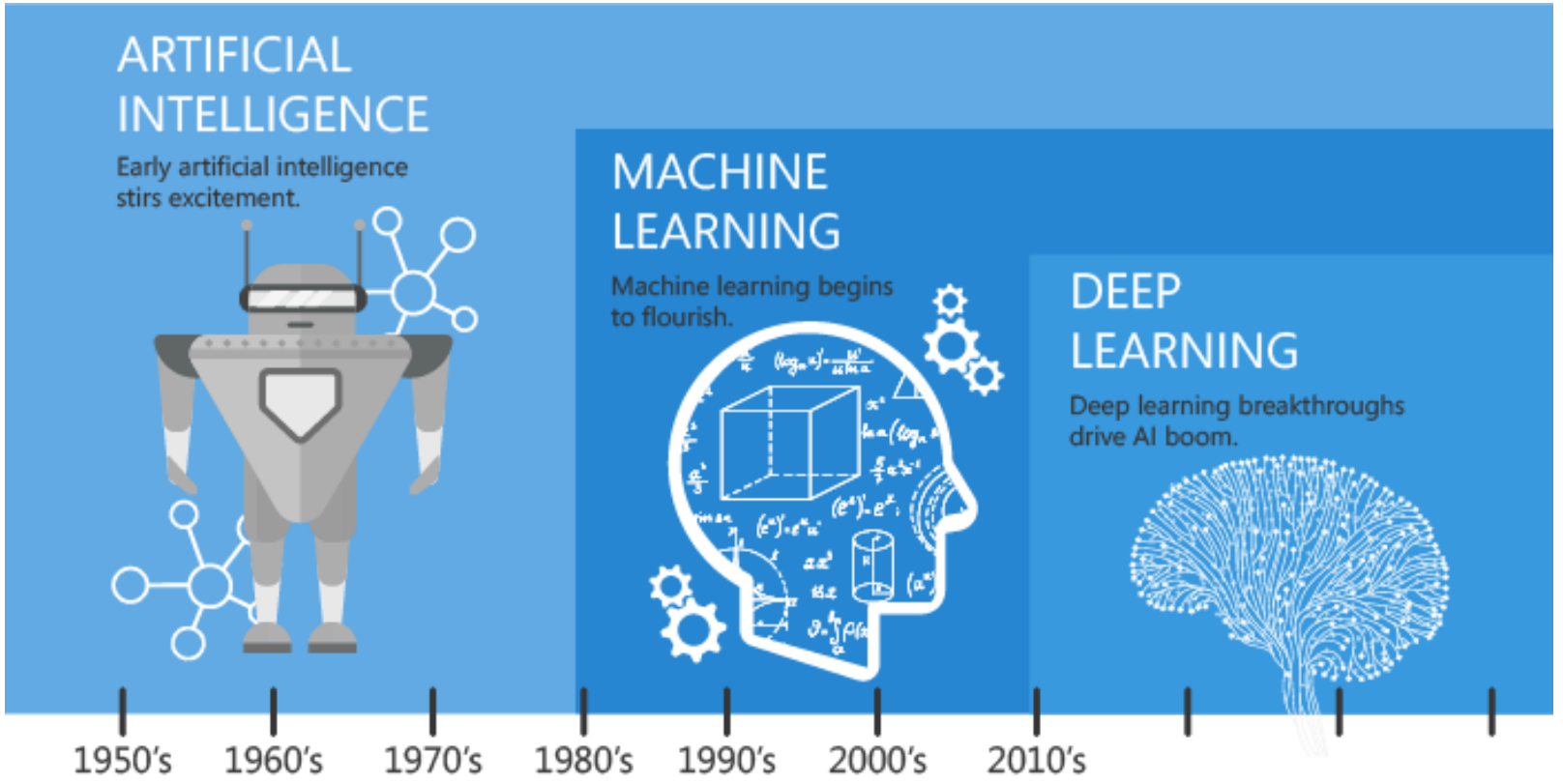
Two Attitudes

https://visual.ly/community/infographic/humor/optimist-or-pessimist

Deep Learning, Machine Learning, AI



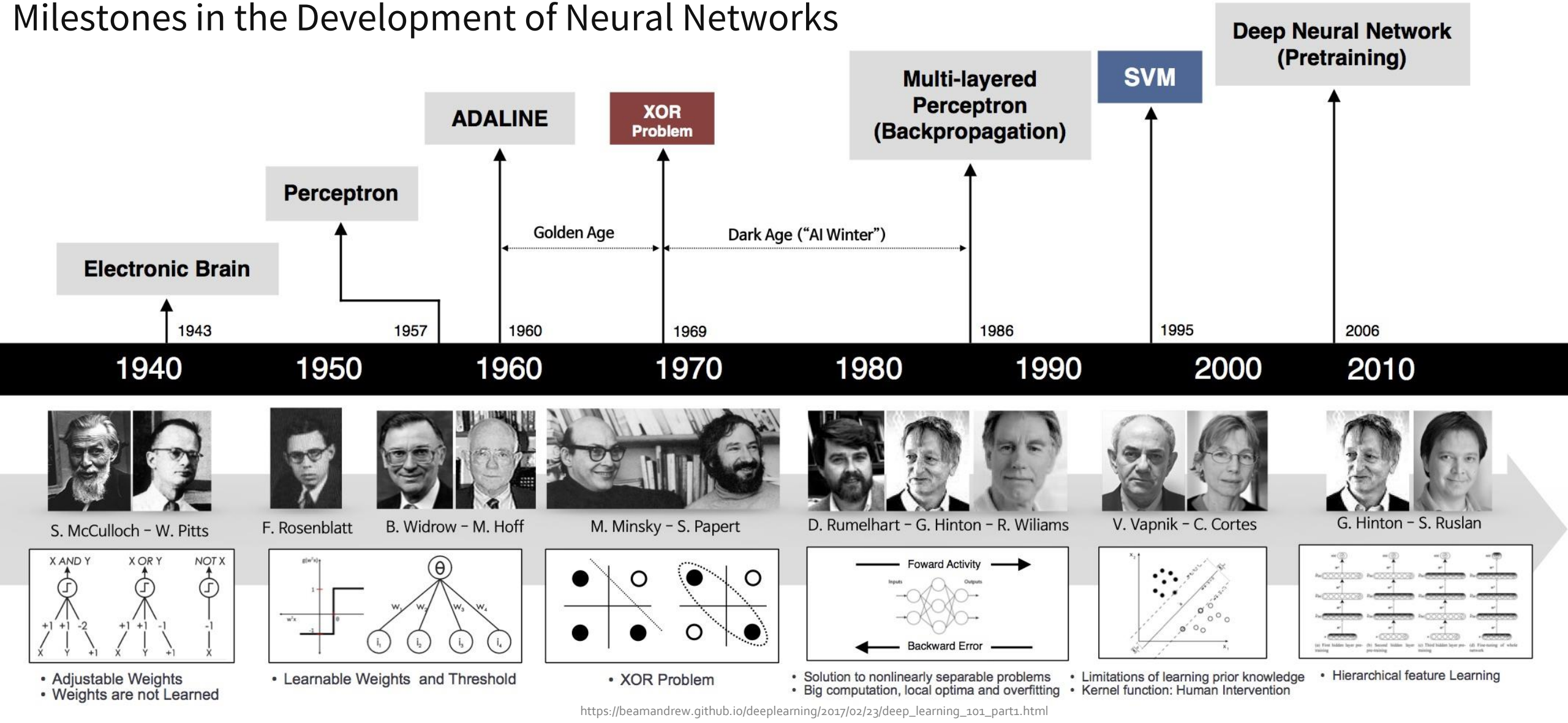
https://www.argility.com/argility-ecosystem-solutions/industry-4-0/machine-learning-deep-learning/



Since an early flush of optimism in the 1950's, smaller subsets of artificial intelligence - first machine learning, then deep learning, a subset of machine learning - have created ever larger disruptions.

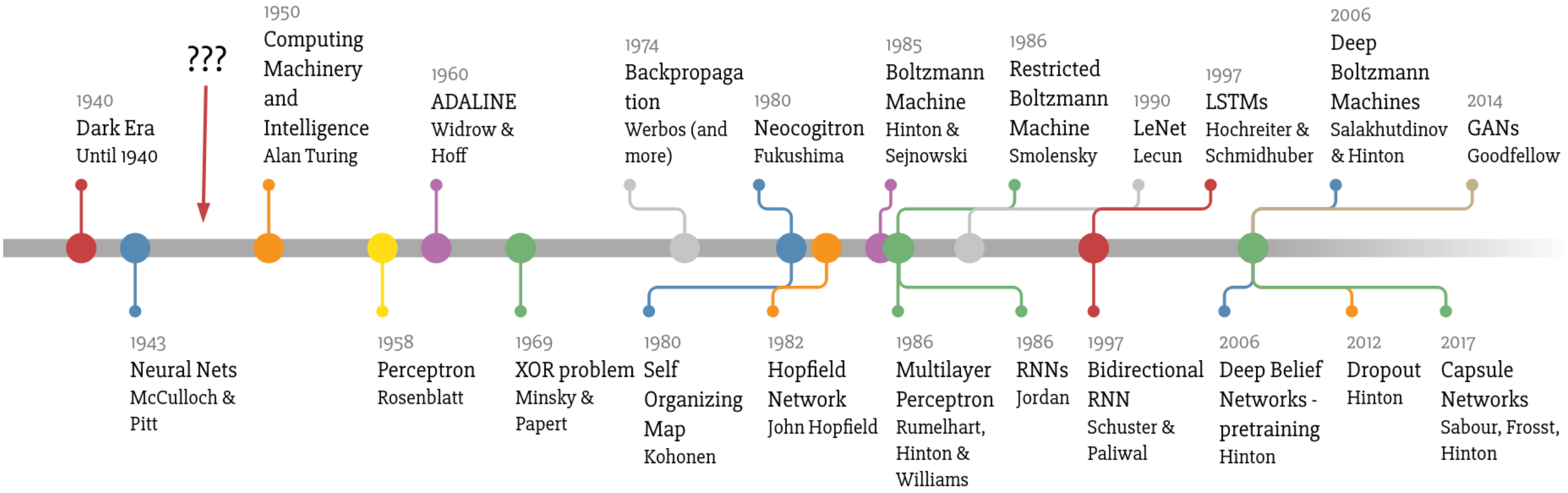
http://blog.aimagnifi.com/index.php/2017/10/13/what-is-the-difference-between-machine-learning-and-deep-learning/

Milestones in the Development of Neural Networks



https://beamandrew.github.io/deeplearning/2017/02/23/deep_learning_101_part1.html

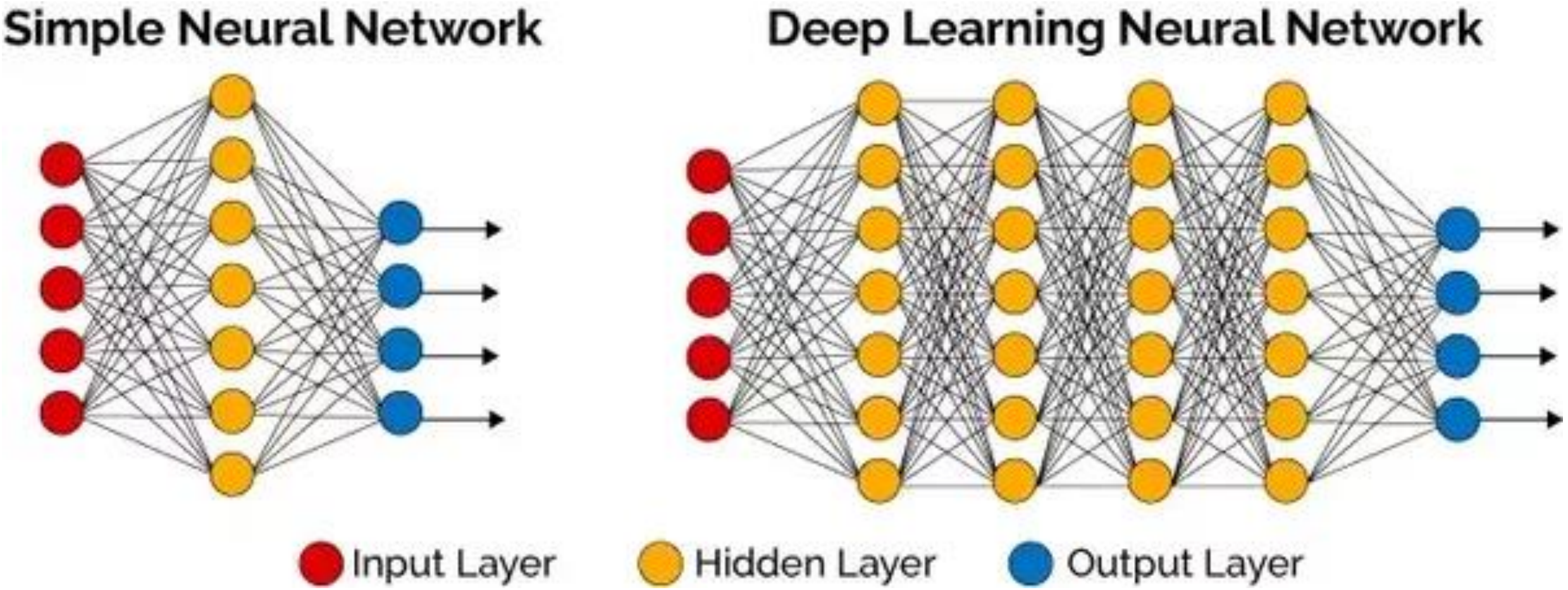
Deep Learning Timeline



https://towardsdatascience.com/a-weird-introduction-to-deep-learning-782880369 3bo?gi=6a575eef7393

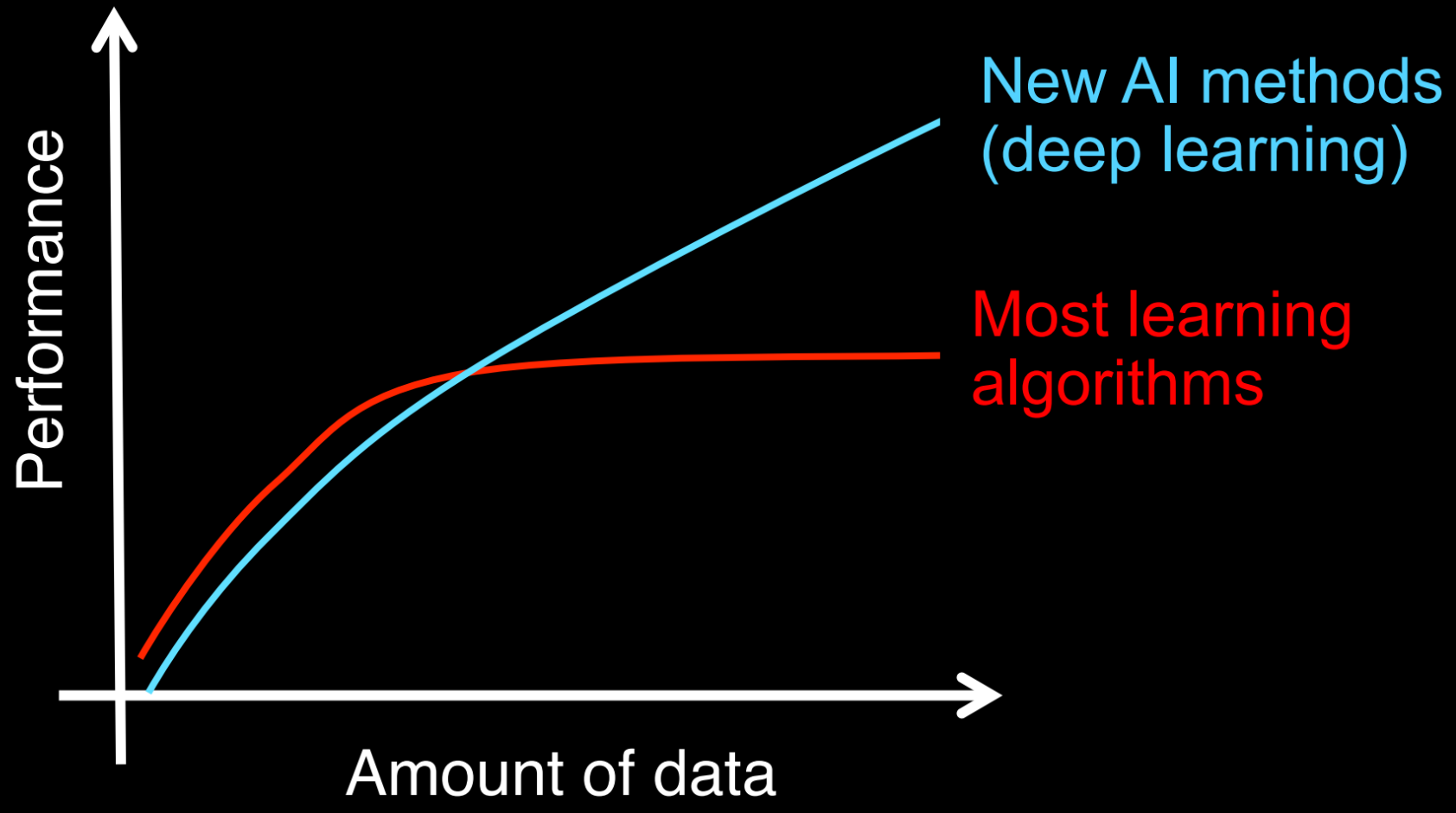
Made by Favio Vázquez

Deep Learn = Deep Neural Network



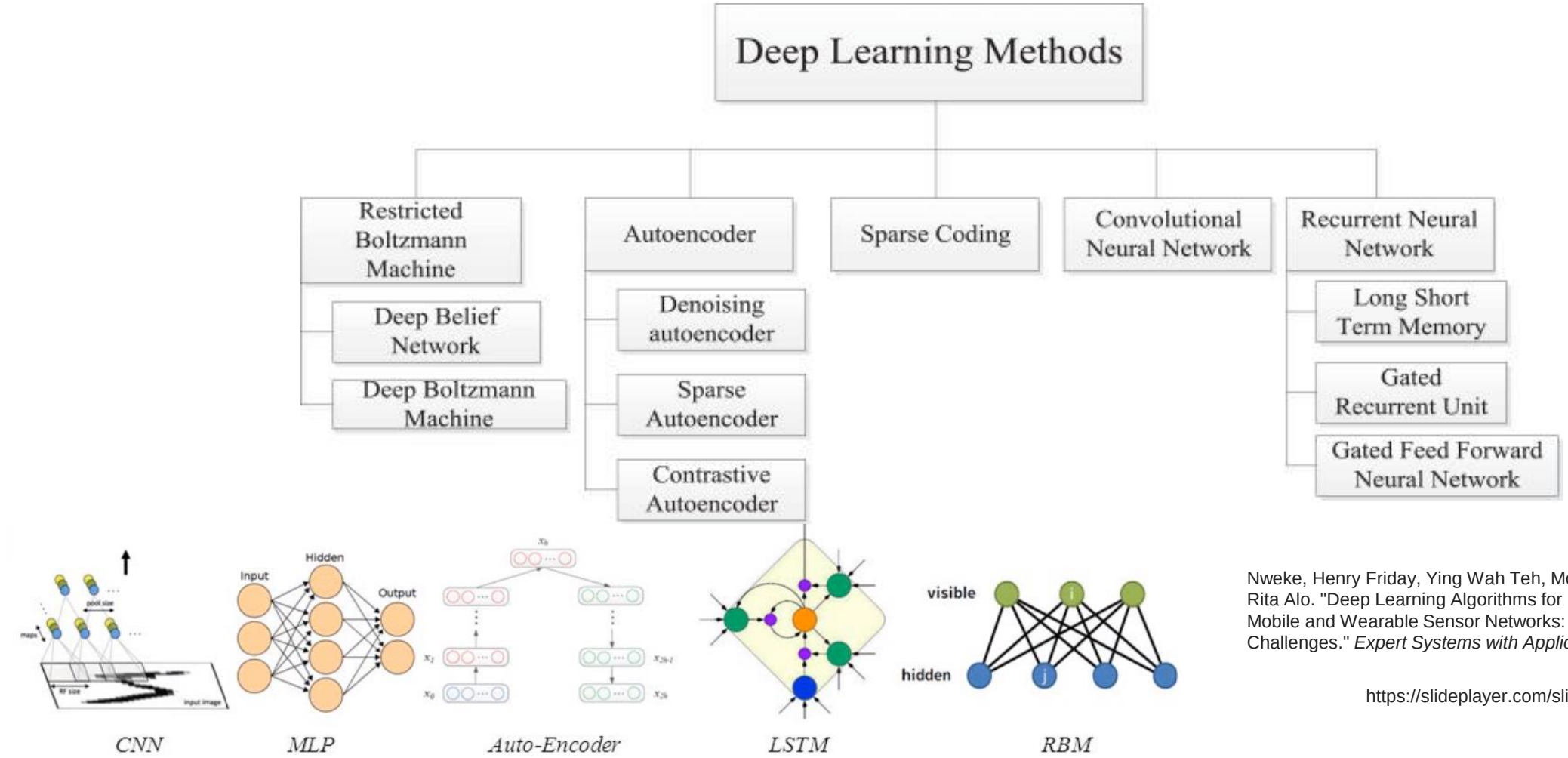
https://www.quora.com/What-is-the-difference-between-Neural-Networks-and-Deep-Learning

Advantages



cs229.stanford.edu/materials/CS229-DeepLearning.pdf

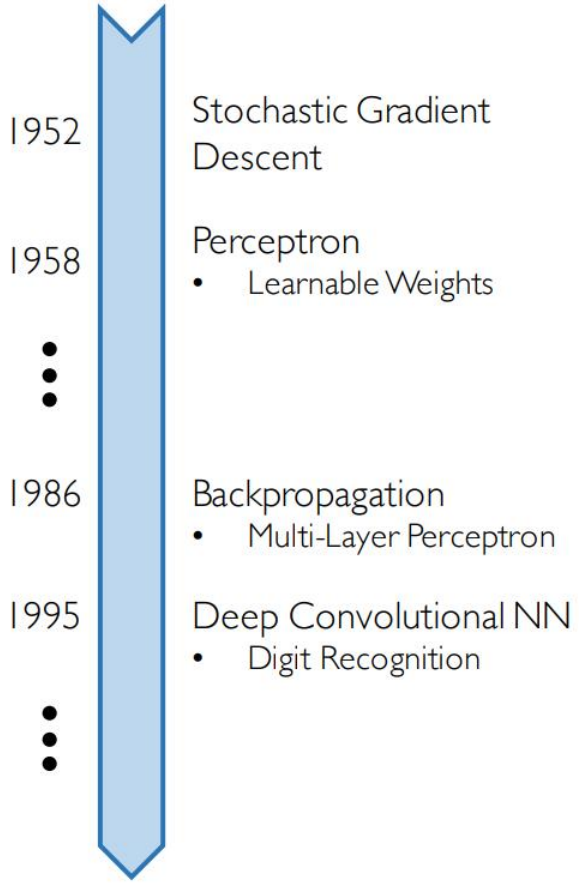
Overview of Method



Nweke, Henry Friday, Ying Wah Teh, Mohammed Ali Al-Garadi, and Uzoma Rita Alo. "Deep Learning Algorithms for Human Activity Recognition using Mobile and Wearable Sensor Networks: State of the Art and Research Challenges." *Expert Systems with Applications* (2018).

https://slideplayer.com/slide/7483751/

New but also Old



Nothing new !

- **Alexnet 2012**
  - **based on CNN (LeCunn, 1989)**
- **Alpha Go**
  - **based on Reinforcement learning and MCTS (Sutton, 1998)**

https://elearningindustry.com/artificial-intelligence-will-shape-elearning

njkim@Jamonglab.com, 2016

Ian Goodfellow, Deep Learning (MIT press, 2016).

Why Now?

1. Big Data

- Larger Datasets
- Easier Collection & Storage

IMAGENET

WIKIPEDIA
The Free Encyclopedia

2. Hardware

- Graphics Processing Units (GPUs)
- Massively Parallelizable

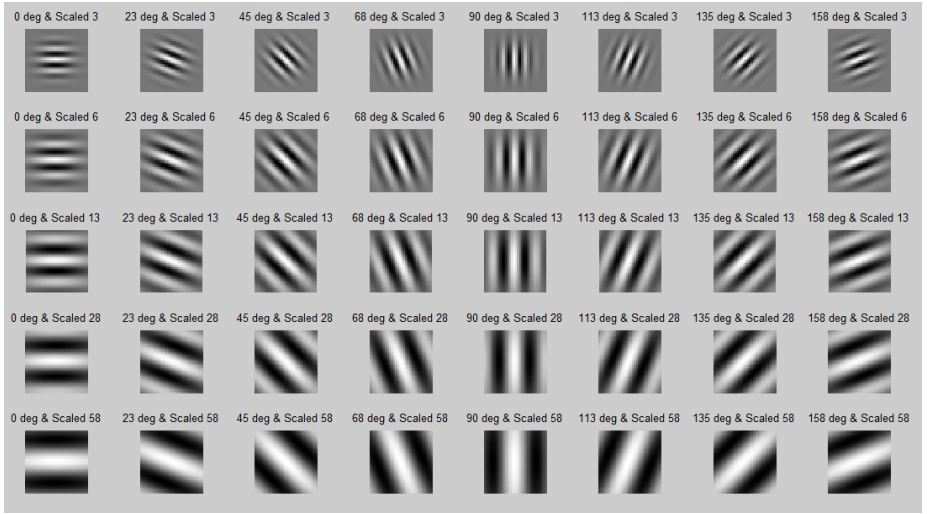
3. Software

- Improved Techniques
- New Models
- Toolboxes

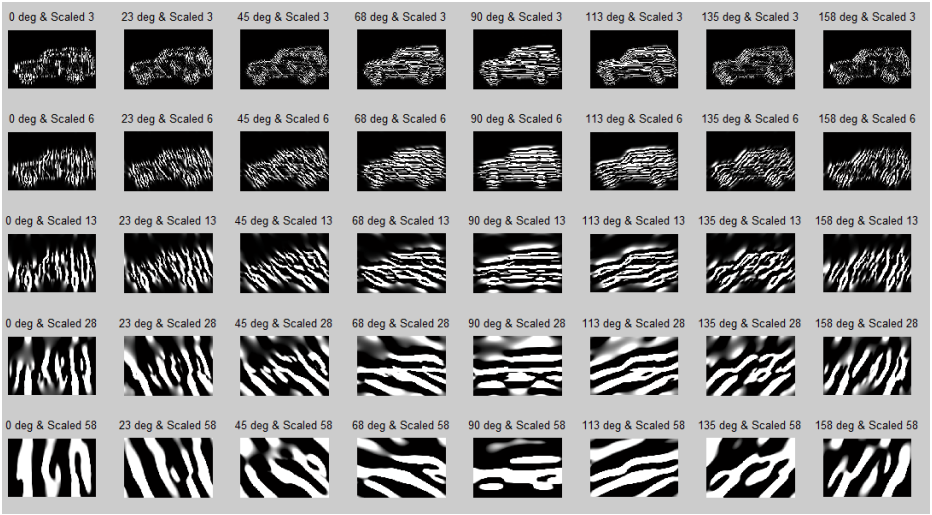
TensorFlow

http://introtodeeplearning.com/materials/2018_6S191_Lecture1.pdf

Handcrafted Feature



Gabor Filter



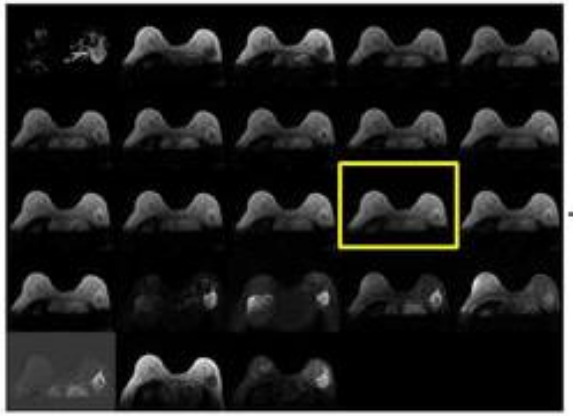
Features

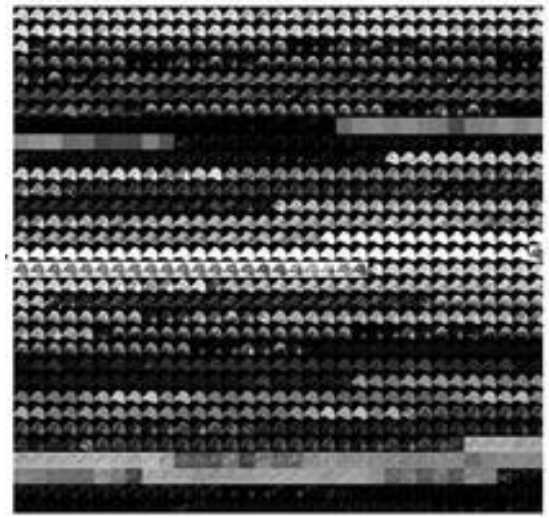
Not as good as human's performance

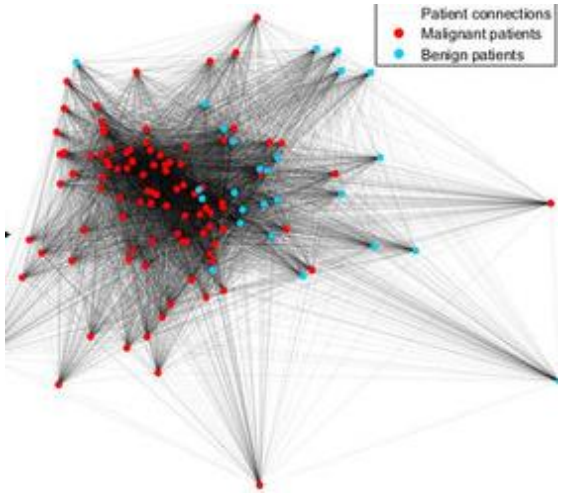
https://stackoverflow.com/questions/20608458/gabor-feature-extraction

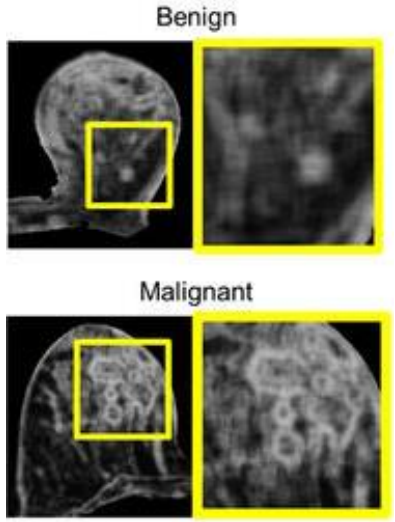
Traditional Framework of Understanding Medical Image

Parekh et al., NPJ breast Cancer, 2017









Imaging Data

- MRI T1w
- MRI T2w
- CT

...

Feature Extraction

- Gabor
- [illegible]gram
- Fourier

Handcrafted Features

...

Classification

- SVM
- [illegible]twork
- Random Forest

Shallow Models

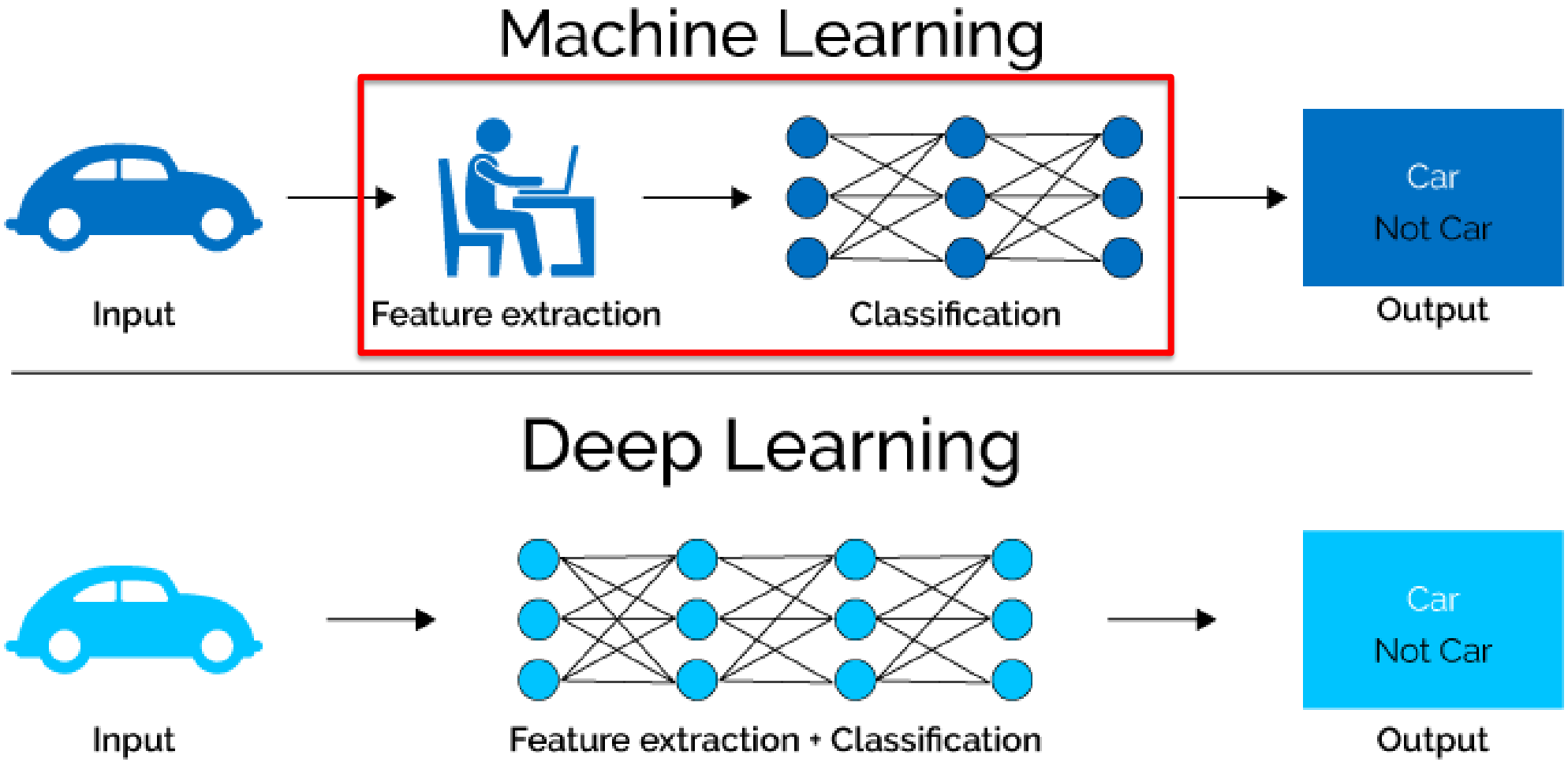
...

Results

- Classification
- Detection
- Segmentation

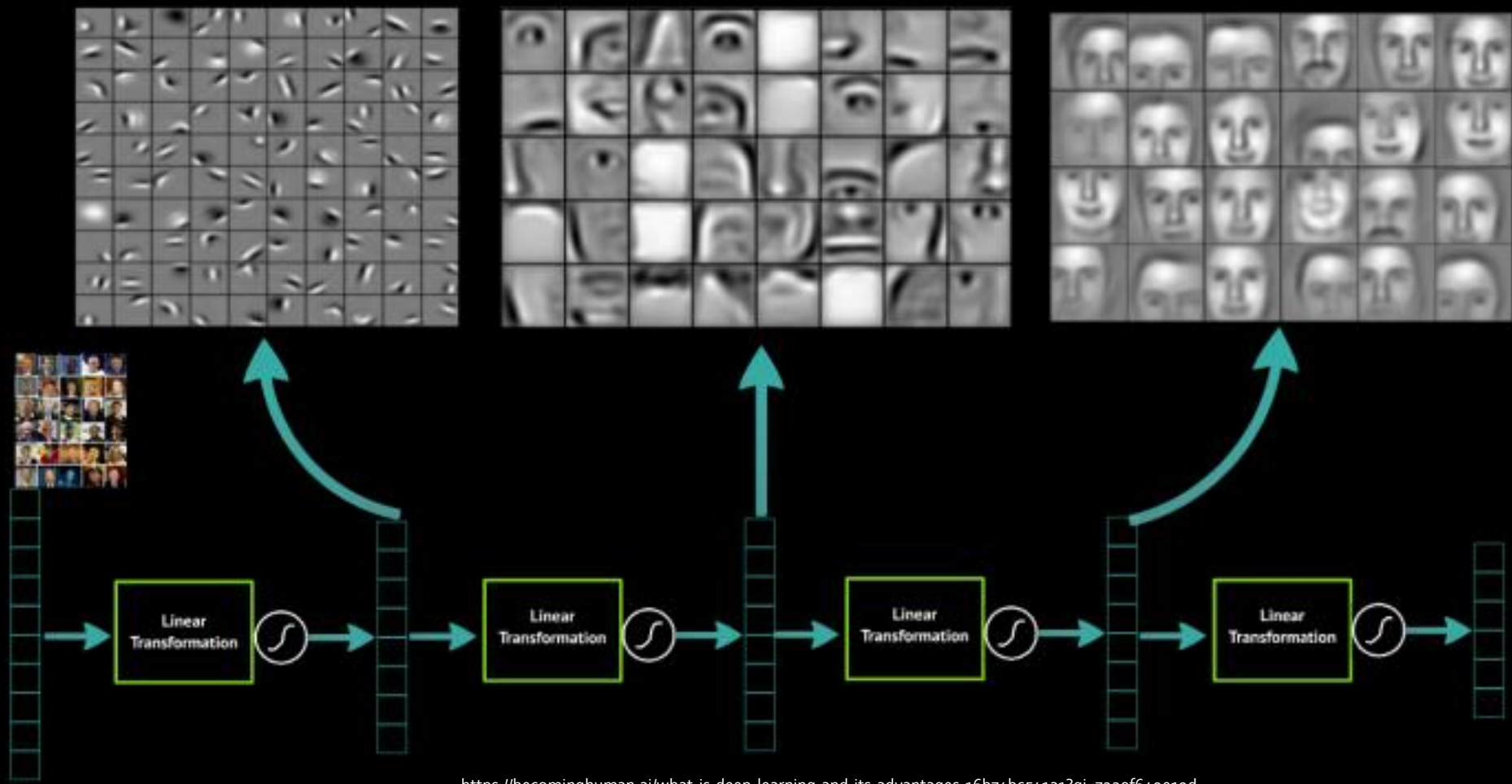
...

Deep Learning vs. Machine Learning



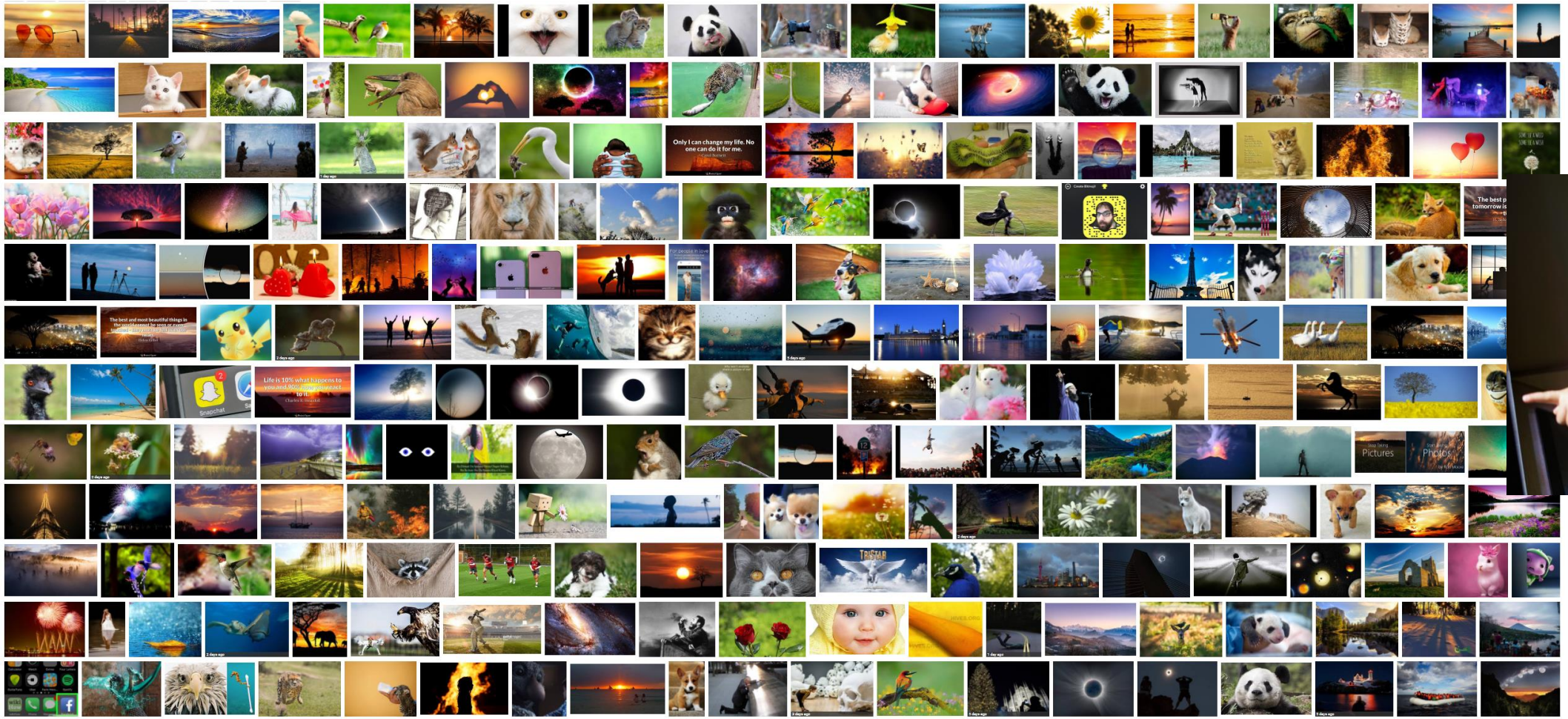
https://www.quora.com/How-do-I-start-learning-machine-learning-and-deep-learning-using-C++

Deep Features Learned by Computer



https://becominghuman.ai/what-is-deep-learning-and-its-advantages-16b74bc541a1?gi=7220f649e19d

Miss Another Reasons



[Rossion, 2014]

200 ms to process image in the brain

>100 million trainings for 3 years old kids

ImageNet

2007
Fei-Fei Li founds ImageNet and begins assembling a database of 14 million labeled images that can be used for machine-learning research. →

IMAGENET

- 1,000 object classes (categories).
- Images:
  - 1.2 M train
  - 100k test.

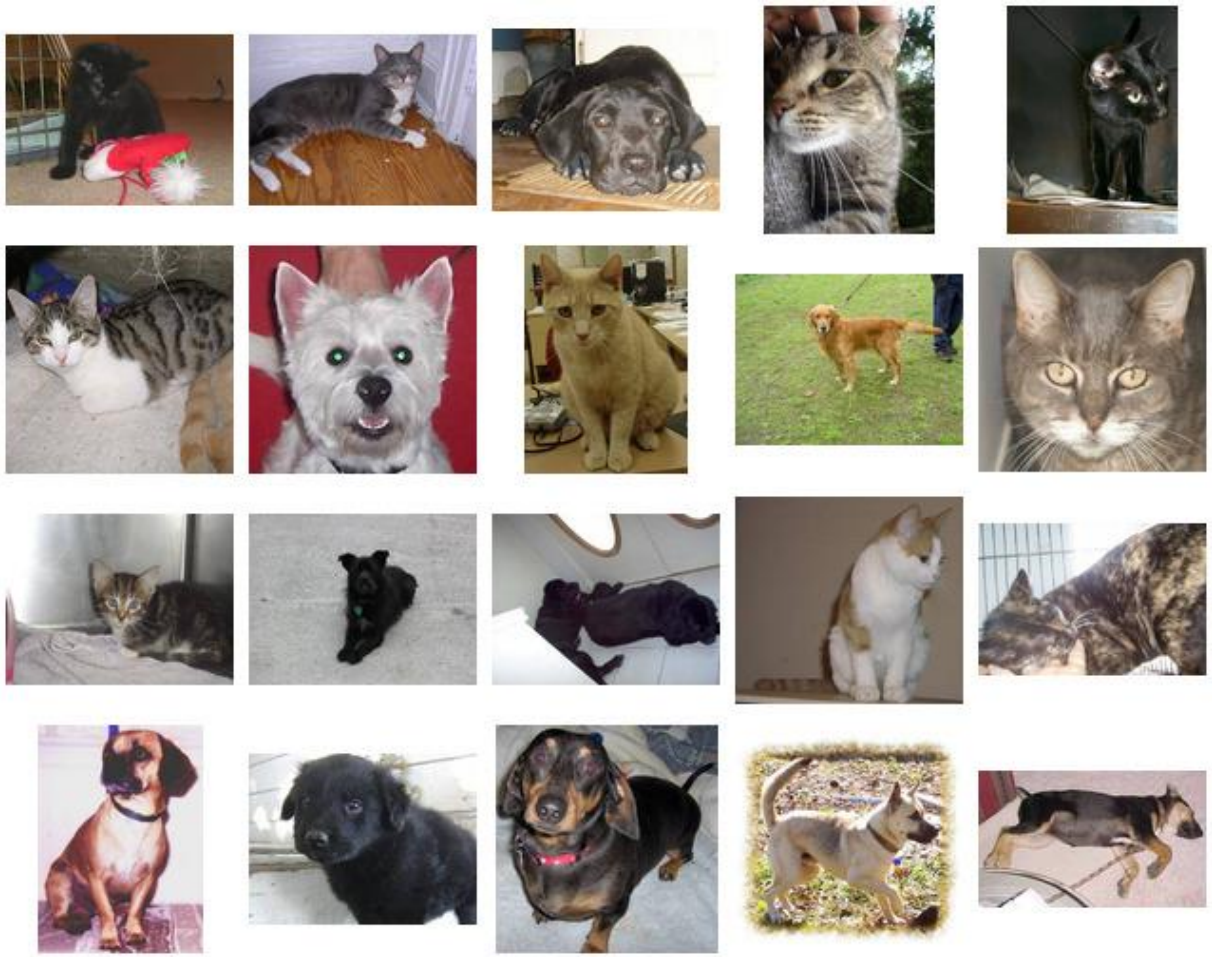
ImageNet Dataset

IMAGENET

Russakovsky, O., Deng, J., Su, H., Krause, J., Satheesh, S., Ma, S., ... & Fei-Fei, L. (2015). Imagenet large scale visual recognition challenge. *arXiv preprint arXiv:1409.0575*. [web]

4

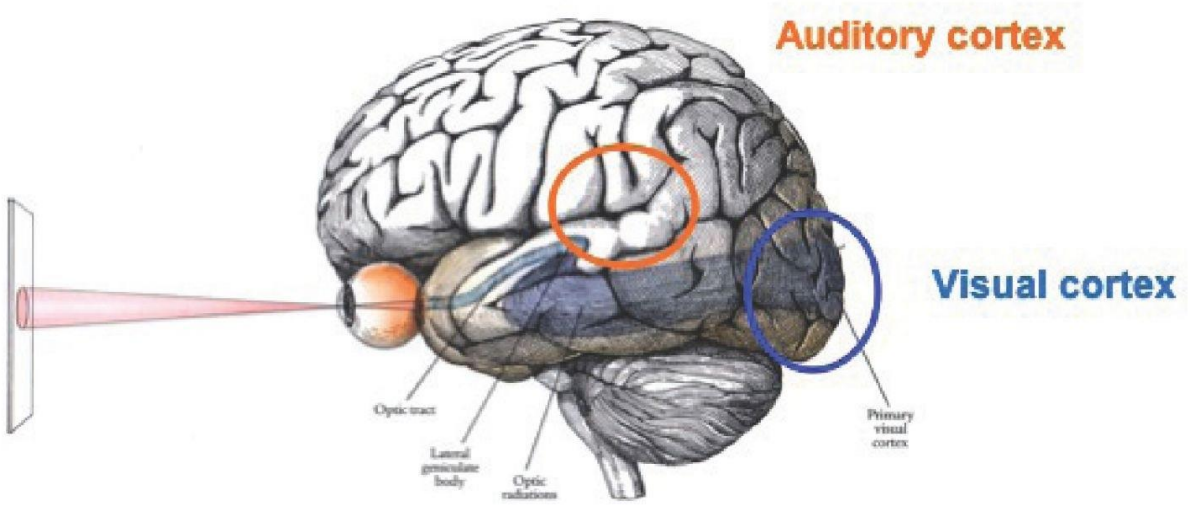
Amazing Human Vision



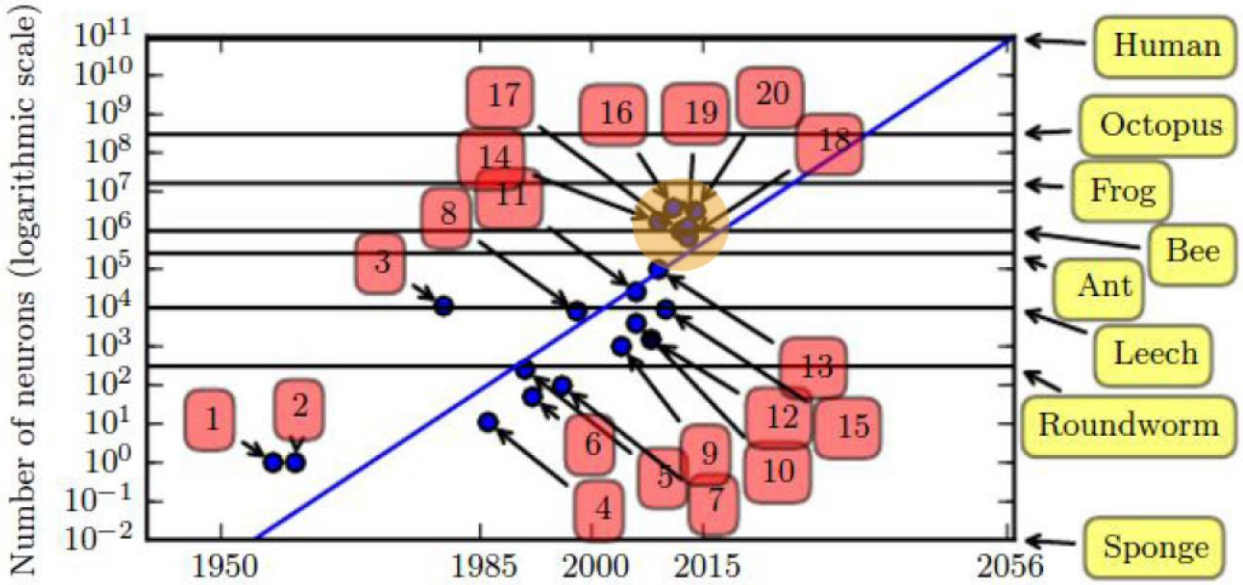
https://www.pyimagesearch.com/2016/08/08/k-nn-classifier-for-image-classification/

https://www.bcm.edu/healthcare/care-centers/diagnostics
https://www.chestercountyhospital.org/services-and-treatments/radiology

Why Human is Better?



http://what-when-how.com/wp-content/uploads/2012/05/tmpD1.jpg

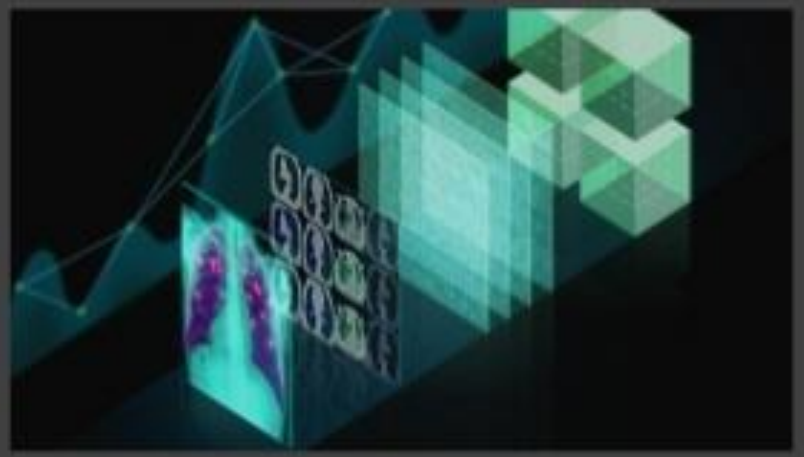


Ian Goodfellow, Deep Learning (MIT press, 2016).

Super Hot in Healthcare

2

AI IS STORMING THROUGH THE $6.5 TRILLION HEALTHCARE INDUSTRY



MICCAI 2017 brought together some of the world's best biomedical scientist, engineers and clinicians, and AI became a central theme for the medical imaging conference.

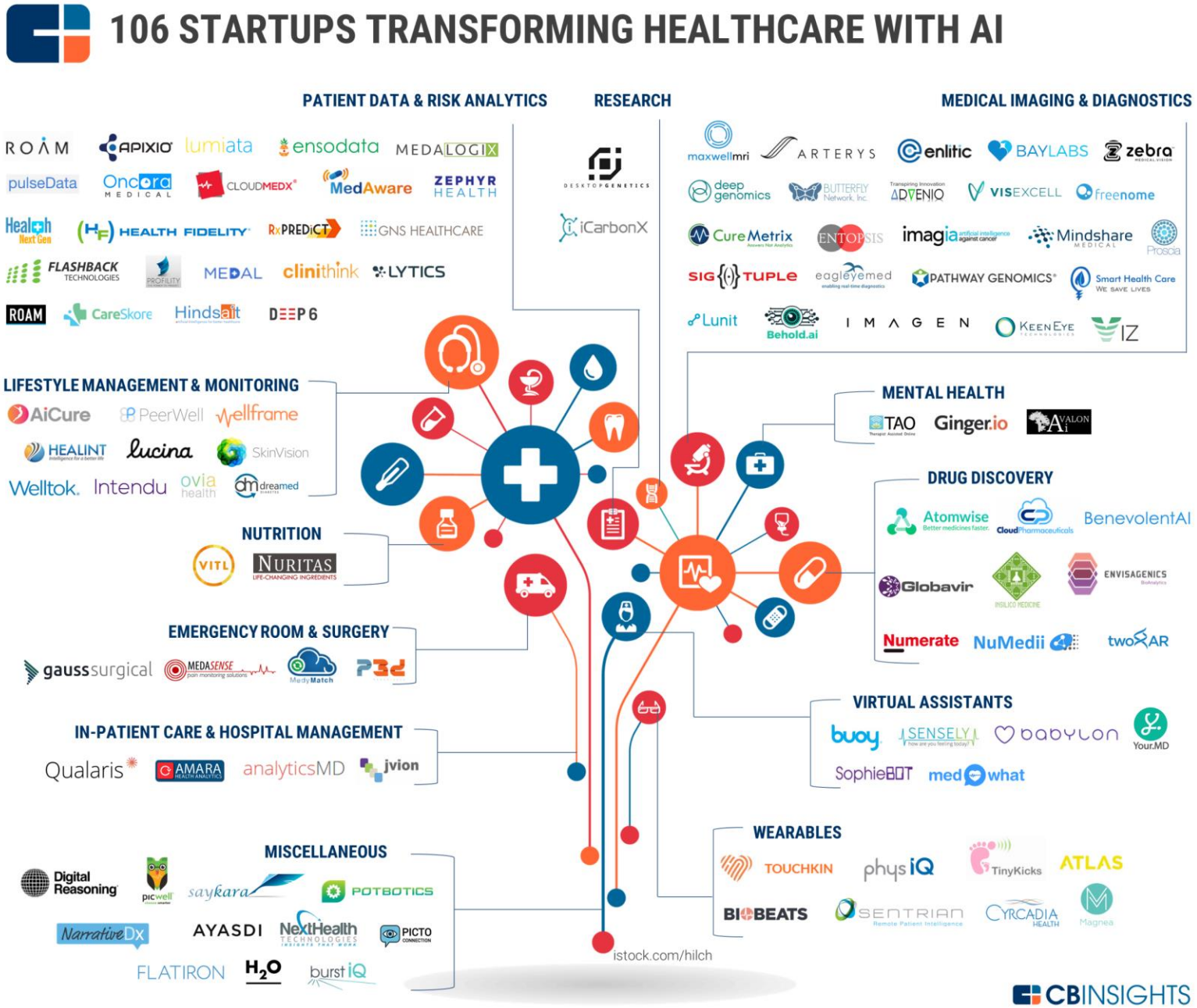
"One sure sign of this: the number of AI-focused papers submitted by the health research community is surging. Of the 800 manuscripts submitted at MICCAI, 60 percent are focused on machine learning. And of those papers, 80 percent use deep learning"

READ ARTICLE

https://www.slideshare.net/NVIDIA/top-5-deep-learning-and-ai-stories-september-22-2017

Industry

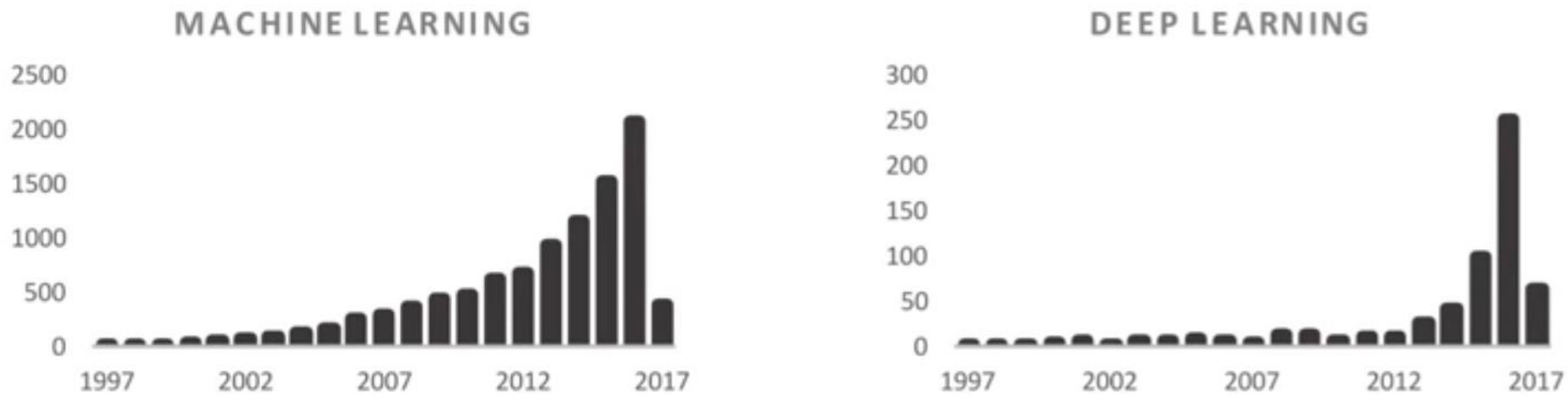
https://triteq.com/news/10-largest-medical-device-companies-world/



https://www.cbinsights.com/research/artificial-intelligence-startups-healthcare/

Academia

the rise of deep learning

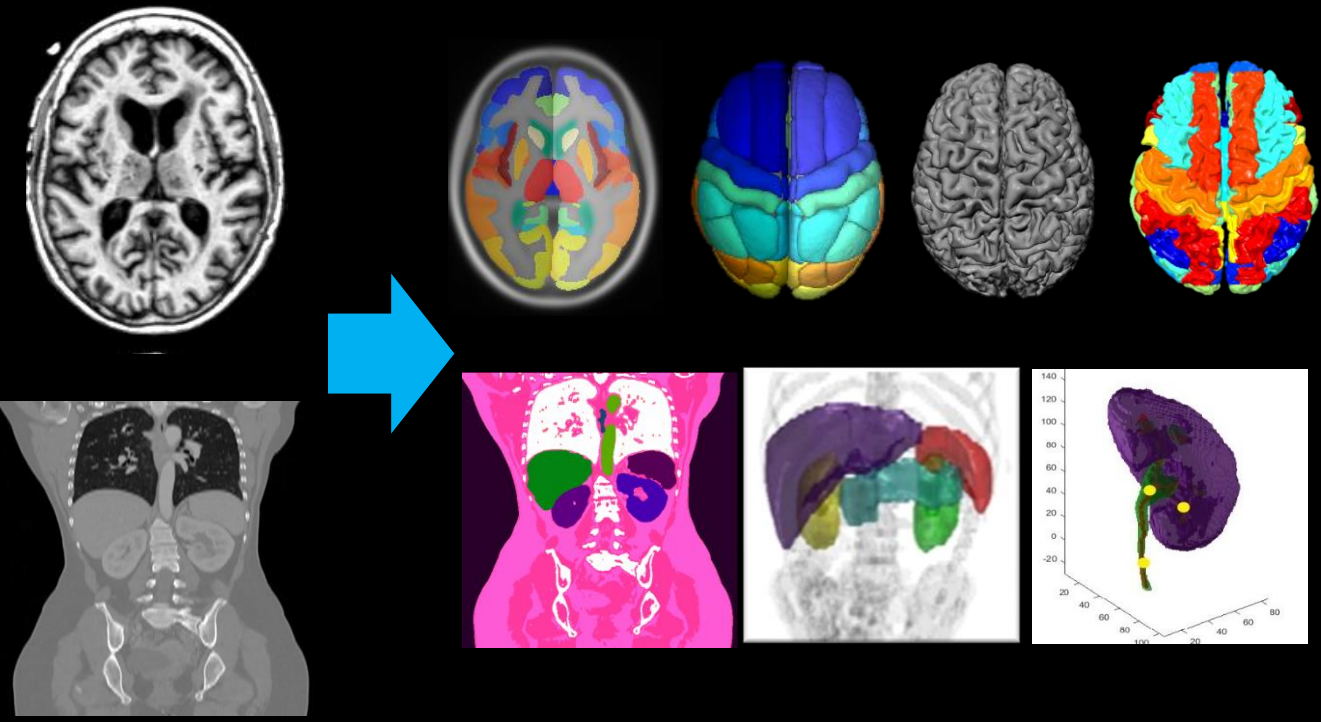


Number of publications on PubMed containing these terms in title or abstract, queried 15/02/2017

Ben Gocker "Deep Learning in Medical Imaging" https://www.youtube.com/watch?v=2_Jv11VpOF4

Medical Image Analysis

X ? Y

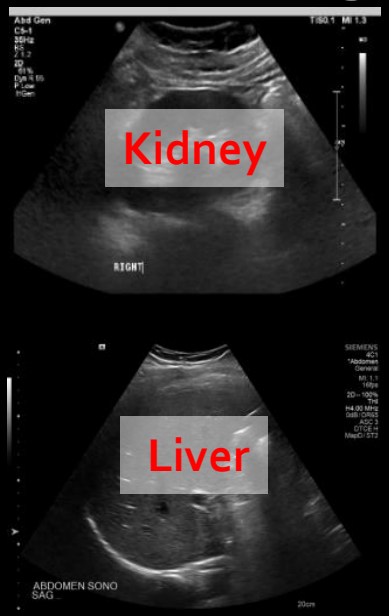


Tasks In Medical Imaging

X → Y

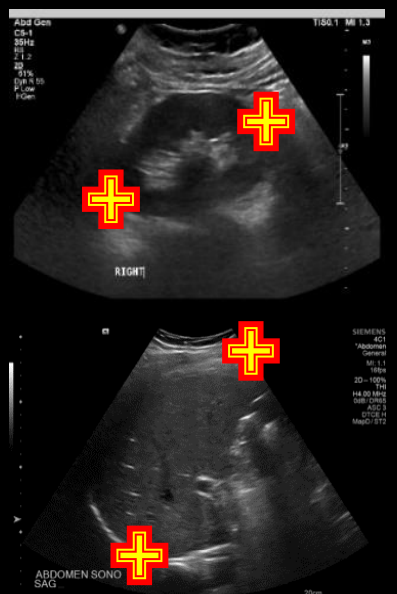
Understand A Image

Classification/Regression



Understand A Region

Detection



Understand Every Pixel

Segmentation

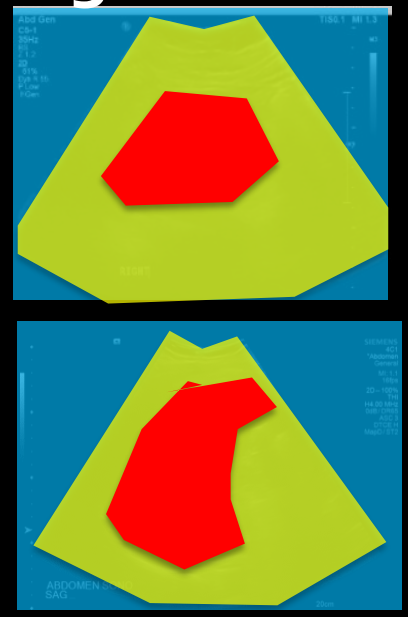
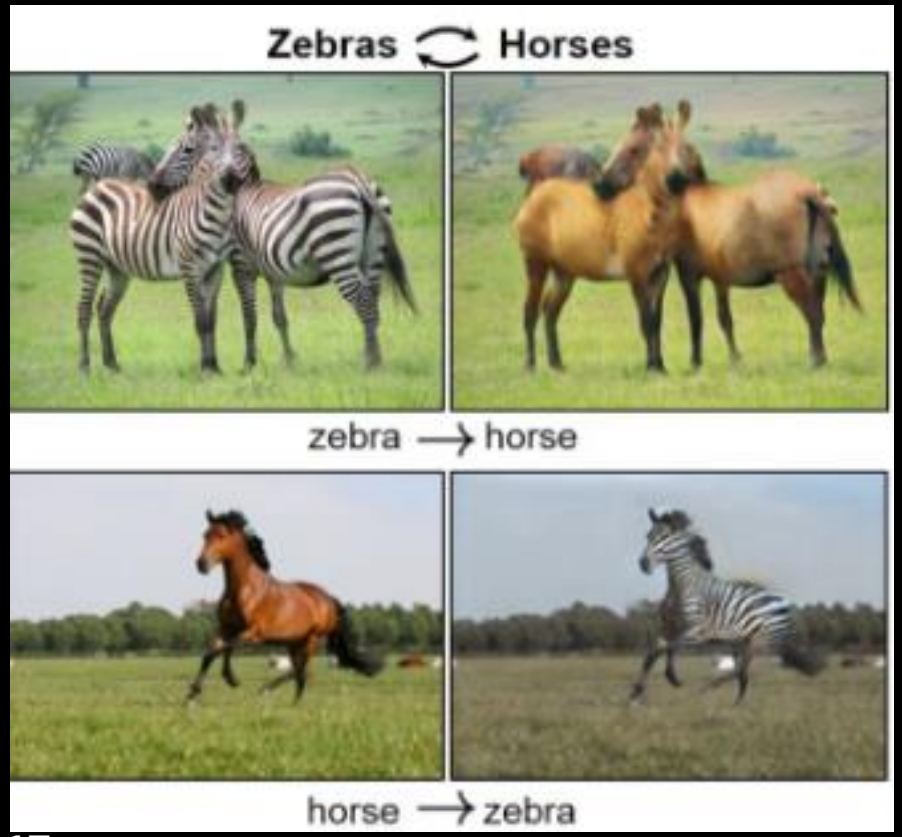
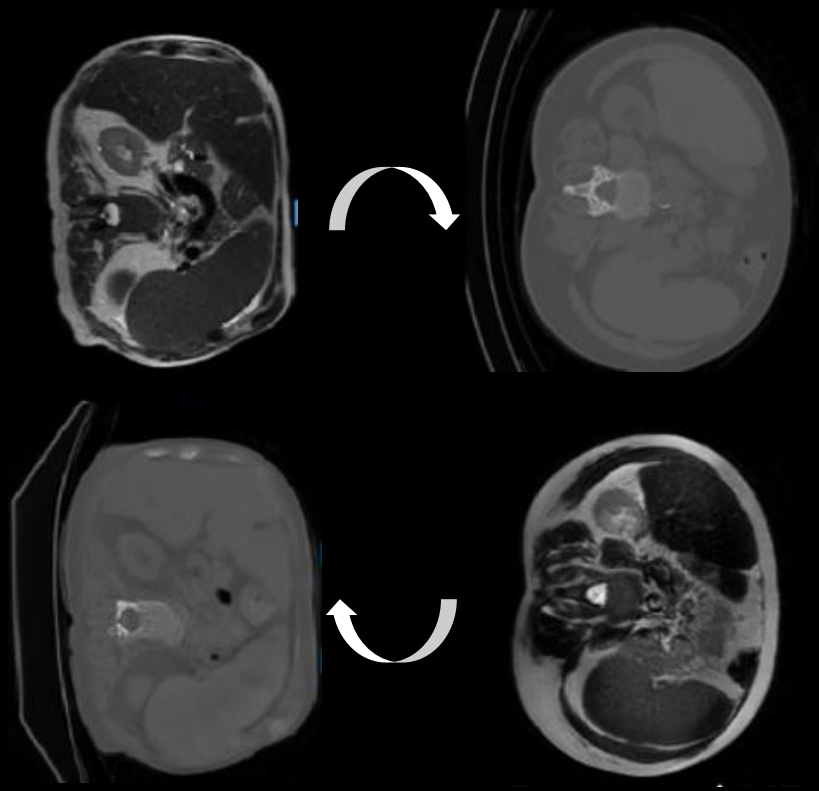


Image Synthesis
Generative Adversarial Network (GAN)

X: CT/MRI → Y: Synthesis/ Seg.

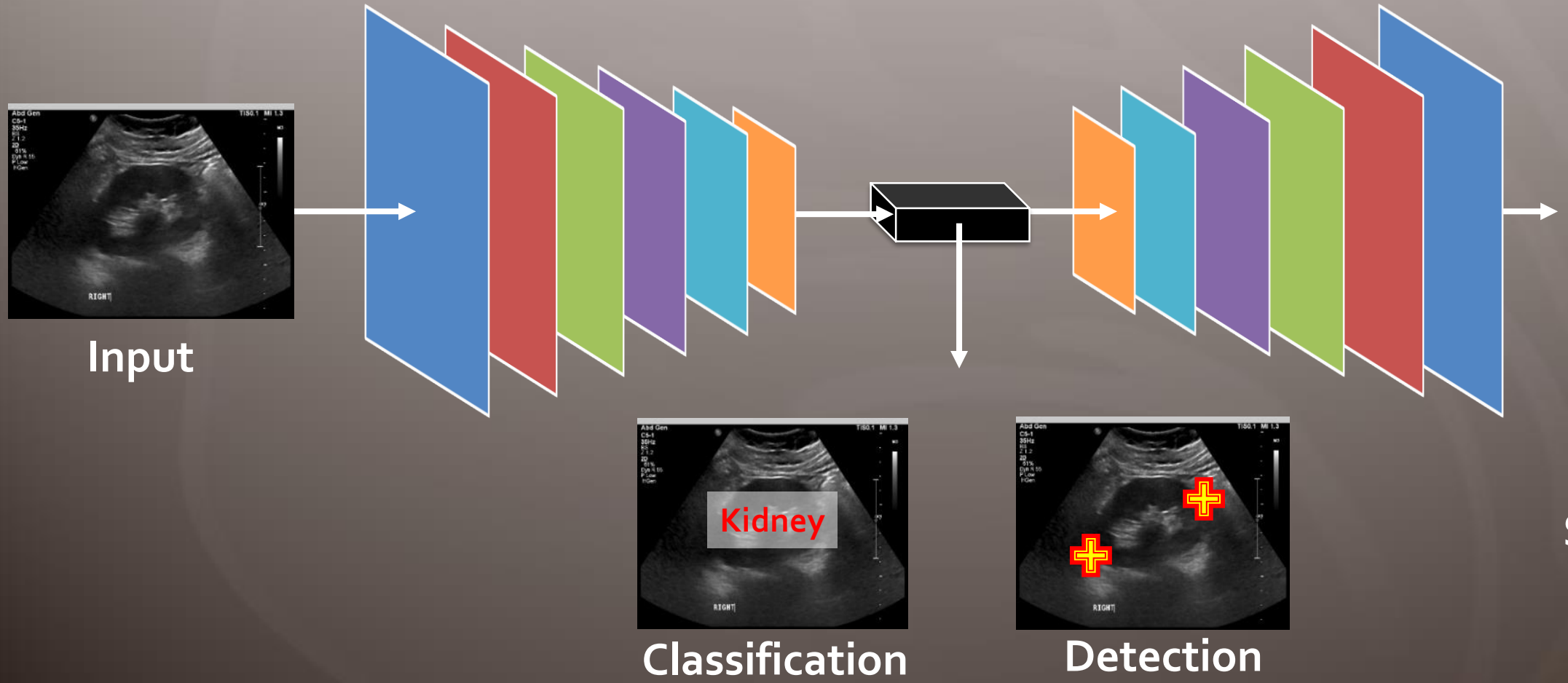




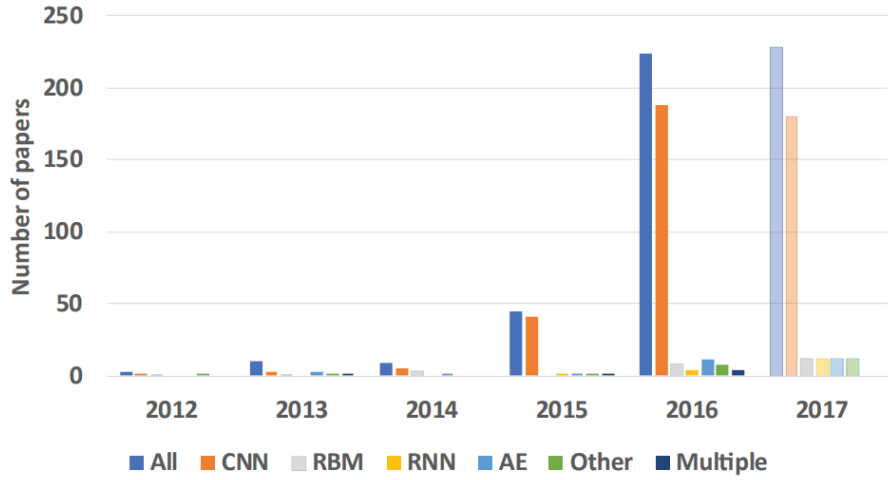
Zhu et al, 2017

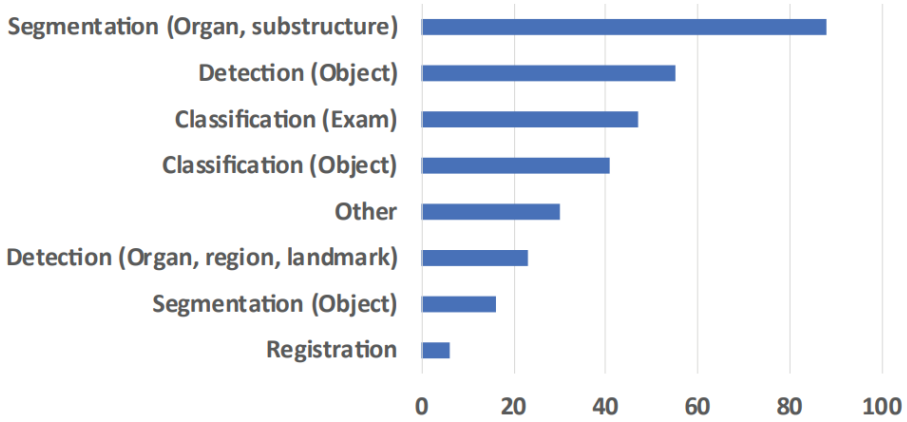
Summary

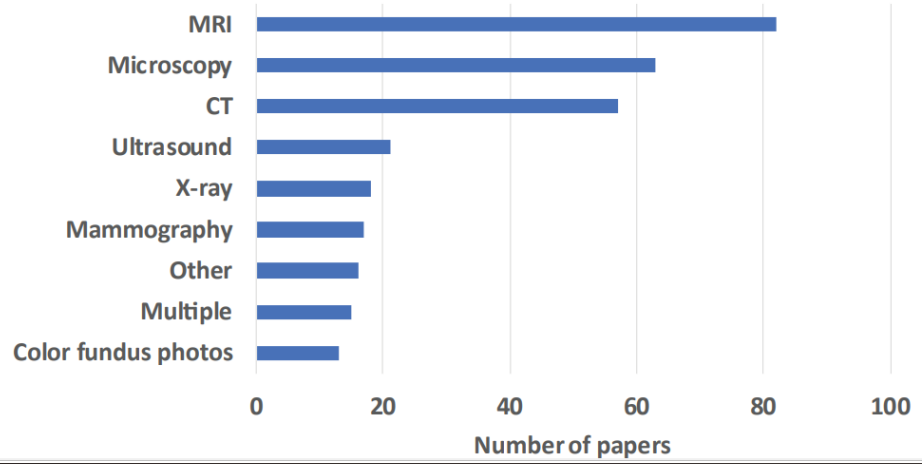
Jan 14	Classification (Medical Image Diagnosis)
Jan 16	Detection (Landmark and Computer Aided Detection)
Jan 21	Segmentation (Medical Image Segmentation)
Jan 23	GAN (Medical Image Synthesis)

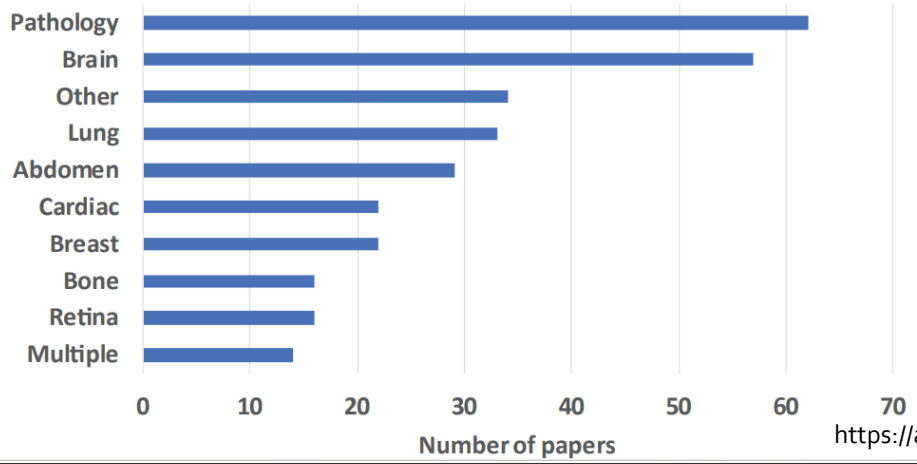


Applications



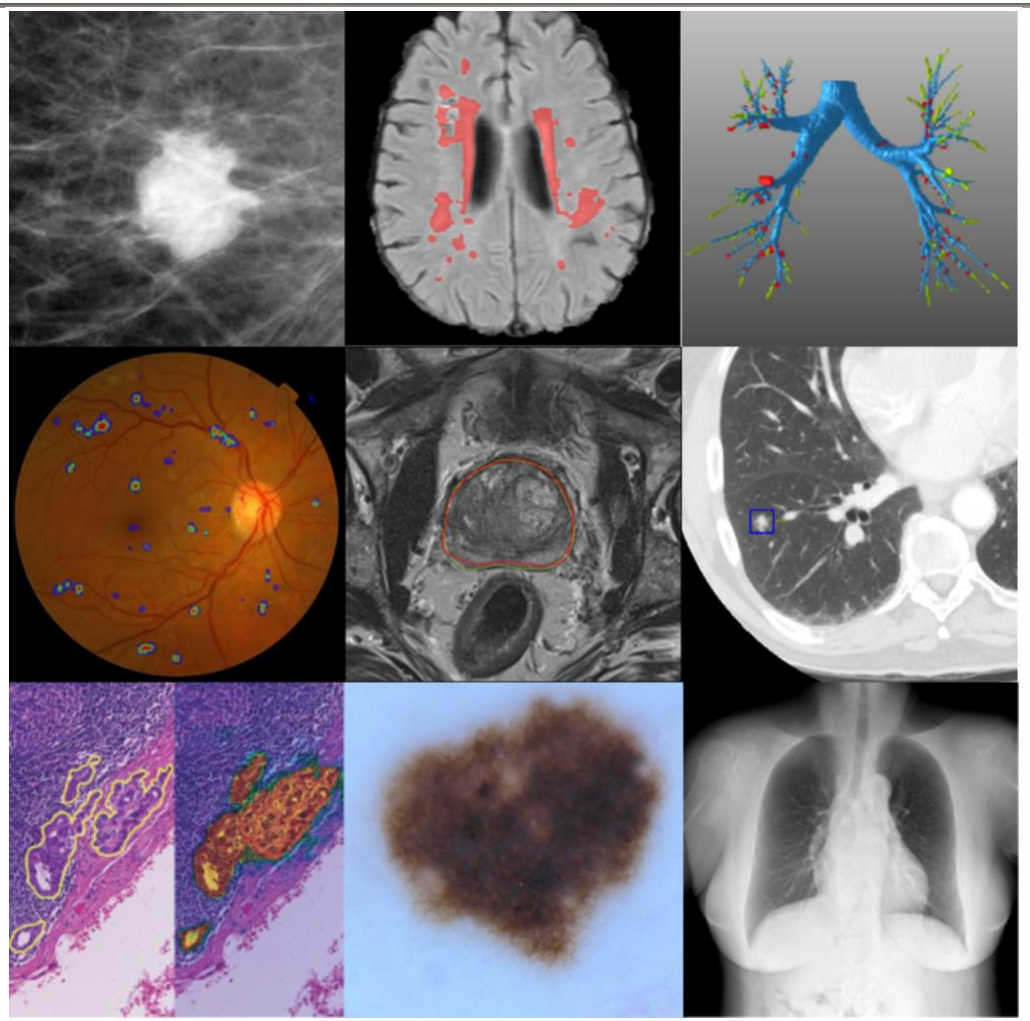






https://arxiv.org/abs/1702.05747

Applications



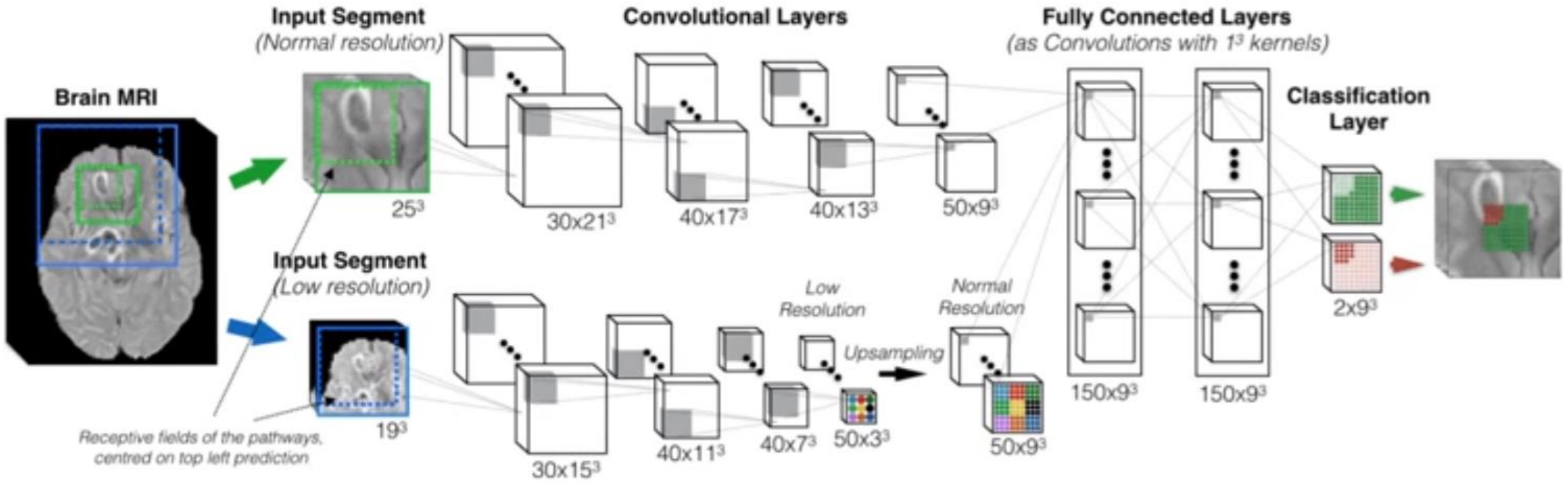
Some medical imaging applications in which deep learning has achieved state-of-the-art results. From top-left to bottom-right:

- mammographic mass classification (Kooi et al., 2016)
- segmentation of lesions in the brain (Ghafoorian et al. (2016b)
- leak detection in airway tree segmentation (Charbonnier et al., 2017)
- diabetic retinopathy classification (Kaggle challenge 2015
- image from van Grinsven et al. (2016)
- prostate segmentation (top rank in PROMISE12 challenge)
- nodule classification (top ranking in LUNA16 challenge)
- breast cancer metastases detection in lymph nodes (CAMELYON16)
- human expert performance in skin lesion classification (Esteva et al., 2017)
- state-of-the-art bone suppression in x-rays, image from Yang et al. (2016c).

https://arxiv.org/abs/1702.05747

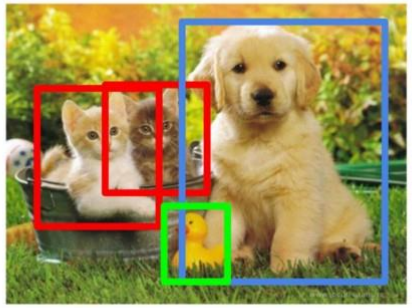
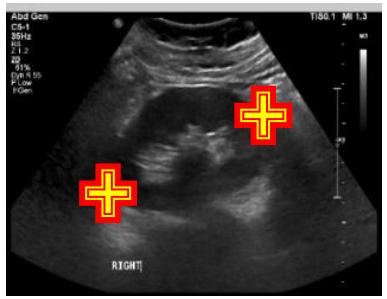
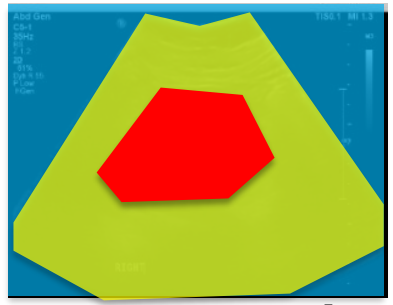
Success 1: Brain Cancer

brain lesions



Ben Gocker "Deep Learning in Medical Imaging" https://www.youtube.com/watch?v=2_Jv11VpOF4

Compare with Computer Vision

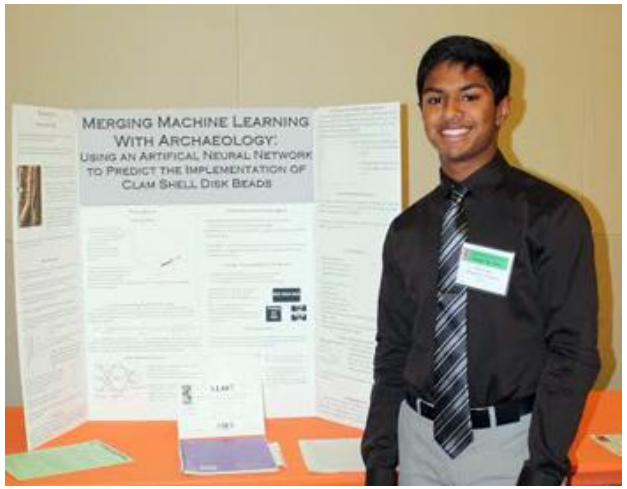
	Classification	Classification + Localization	Object Detection	Instance Segmentation	Synthesis
Computer Vision	 CAT	 CAT	 CAT, DOG, DUCK	 CAT, DOG, DUCK	
Medical Image Computing	 Input	 Classification	 Detection	 Segmentation	 Synthesis

https://medium.com/comet-app/review-of-deep-learning-algorithms-for-object-detection-c1f3d437b852

Simply Call APIs to Perform Deep Learning

Packages

- Caffe and Caffe2
  - NVIDIA Digits
- Theano
  - Lasagne
  - Keras
  - Blocks
- Torch
- TensorFlow
- MxNet
- MatConvNet
- Nervana Neon
- Leaf



https://www.slideshare.net/xavigiro/software-frameworks-for-deep-learning-d1l7-2017-upc-deep-learning-for-computer-vision

https://www.sciencebuddies.org/blog/family-history-fuels-student-engineers-passion-for-medical-engineering

Bar is Lower and Lower

GOOGLE CLOUD PLATFORM

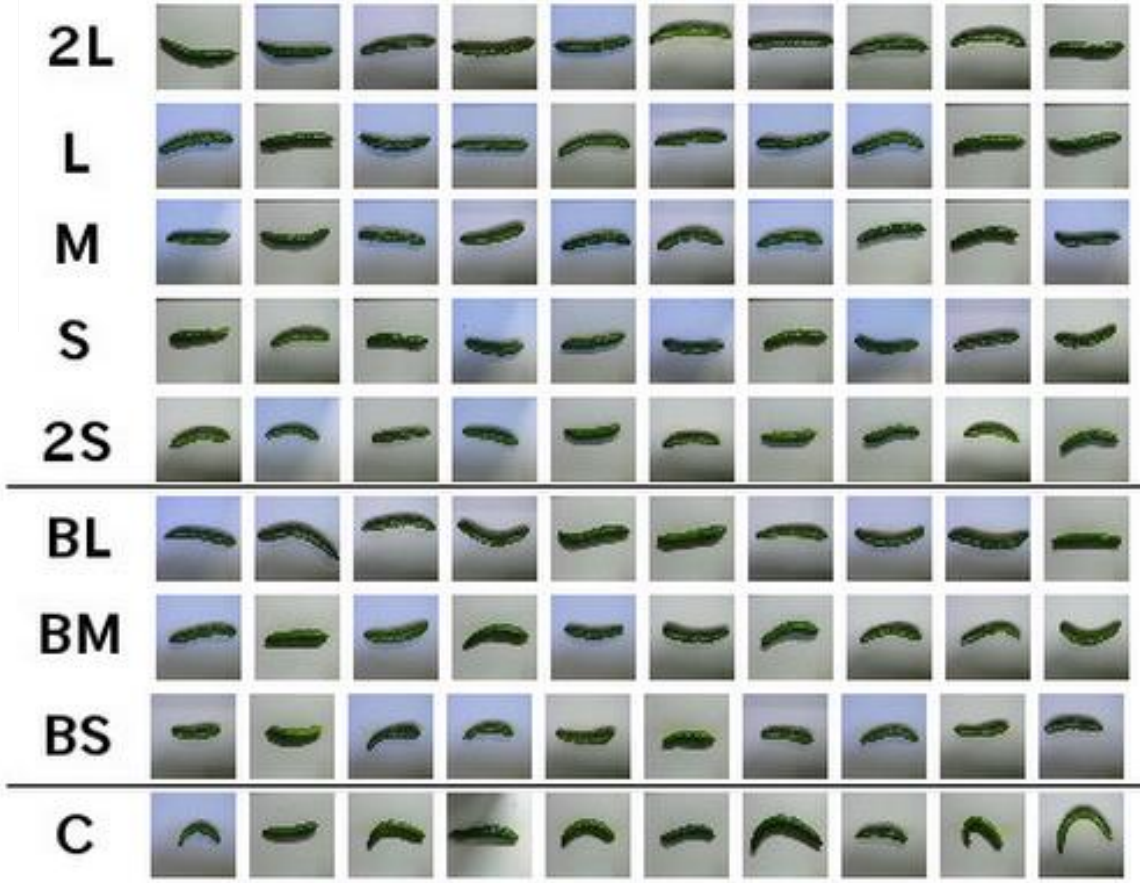
How a Japanese cucumber farmer is using deep learning and TensorFlow

Kaz Sato
Developer Advocate, Google Cloud Platform

August 31, 2016

It's not hyperbole to say that use cases for machine learning and deep learning are only limited by our imaginations. About one year ago, a former embedded systems designer from the Japanese automobile industry named Makoto Koike started helping out at his parents' cucumber farm, and was amazed by the amount of work it takes to sort cucumbers by size, shape, color and other attributes.

https://cloud.google.com/blog/products/gcp/how-a-japanese-cucumber-farmer-is-using-deep-learning-and-tensorflow



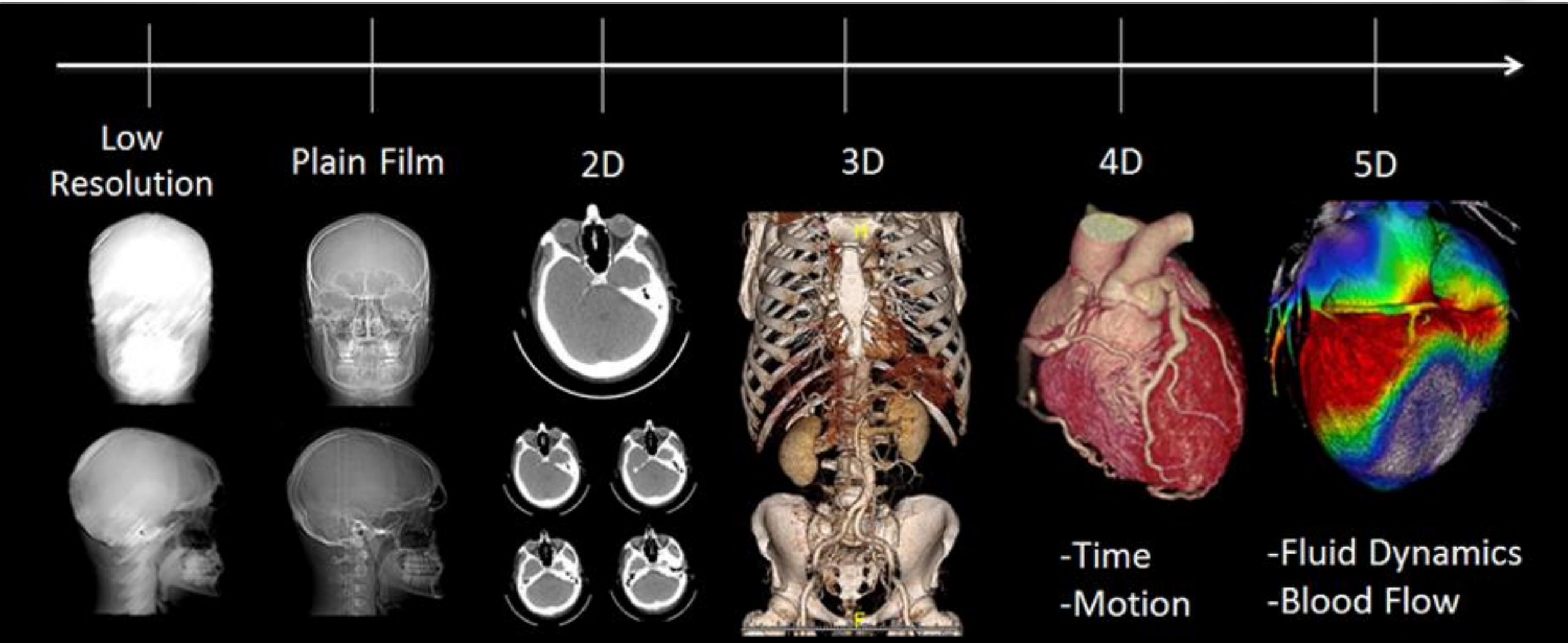
https://comedycentral.com/

https://www.nmr.mgh.harvard.edu/lab/laboratory-computational-imaging-biomarkers/miccai-2014-machine-learning-challenge

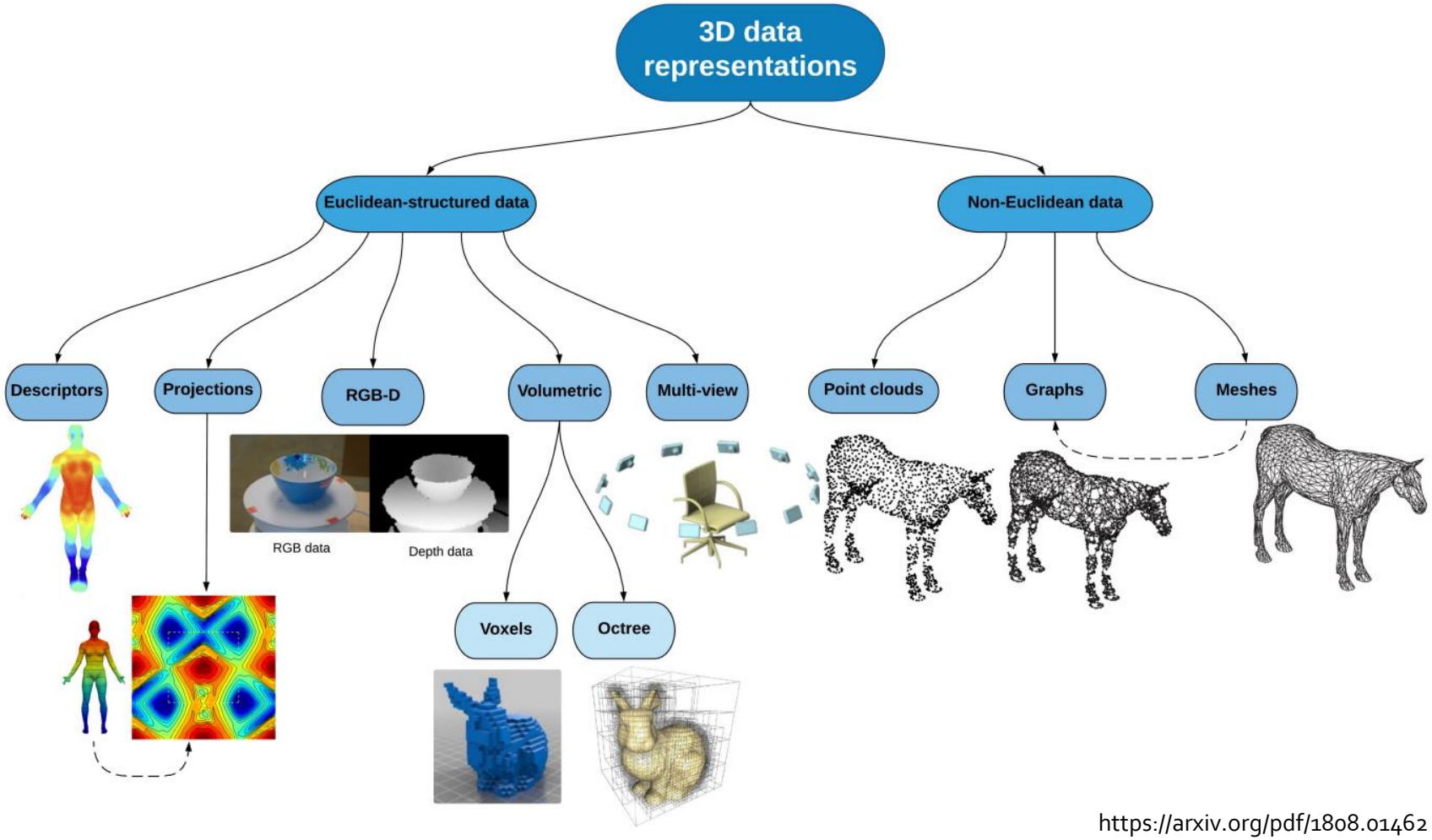
Solve the challenges in medical imaging!

1. How to use longitudinal images
2. How to use multi-modal images
3. Multi-task learning
4. Medical images are mostly 3D, even 4D, 5D
5. Learn from big unlabeled images
6. Utilize previous efforts (registration, multi-atlas …)
7. Incorporate strong prior (shape, contour …)
8. Annotations are rare and expensive
9. Co-learn from clinical data and other biomarkers
10. How to add new annotations (online learning)

Medical images are mostly 3D, even 4D, 5D



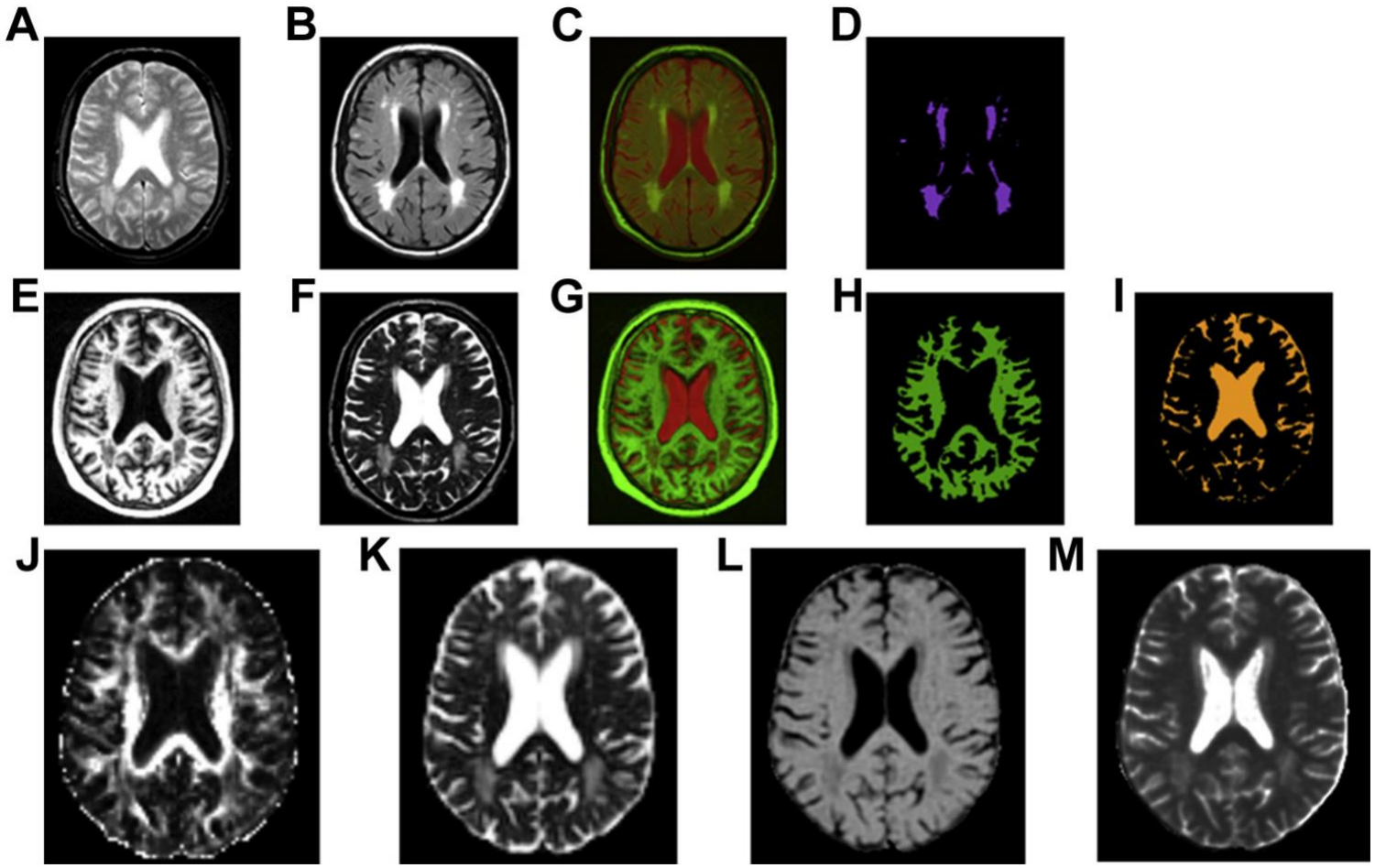
3D Data



https://arxiv.org/pdf/1808.01462

Feb 06	Beyond 2D: 3D and 4D (RNN) Networks

How to use multi-modal images

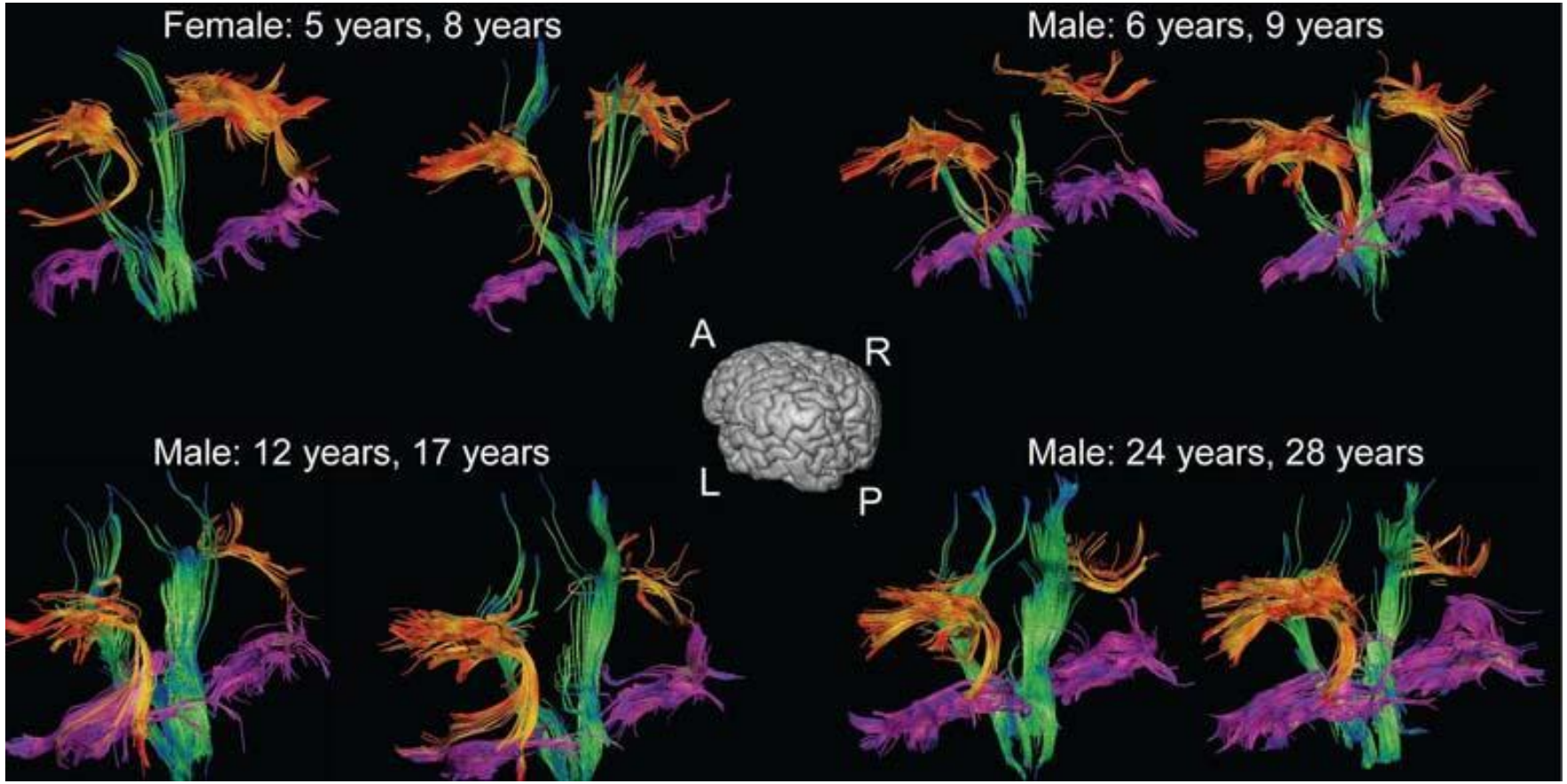


S.M. Maniega et al. / Neurobiology of Aging 36 (2015) 909e918

T2*W (A) and FLAIR (B) structural scans are combined in red-green color space (C) to facilitate the extraction of WMH voxels (D). T1W (E) and T2W (F) structural scans are combined in red-green color space (G) to facilitate the extraction of NAWM (H) and CSF (I) voxels; the latter is subtracted from the WMH and NAWM masks to avoid CSF partial volume averaging within the measurement masks. The last row shows reconstructed parametric images of MRI biomarkers: FA (J), MD (K), MTR (L) and T1 relaxation time (M)

Jan 30	Multi-model Learning

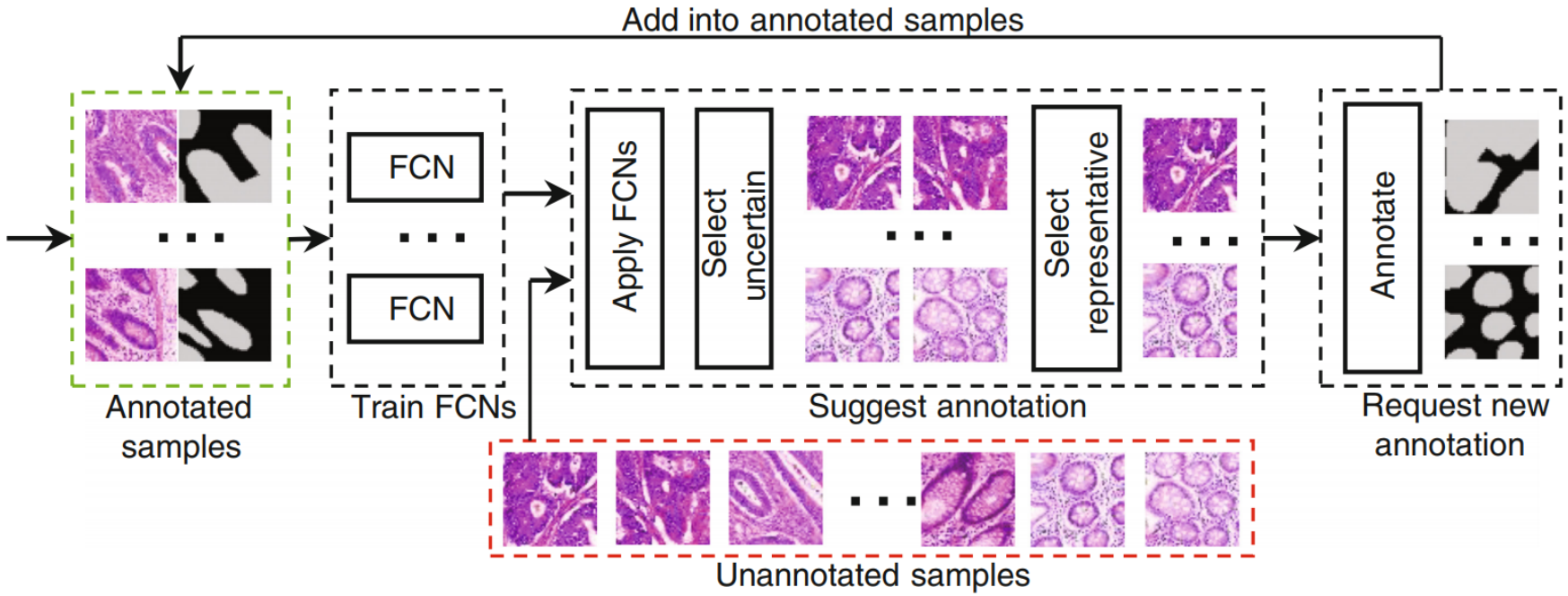
How to use longitudinal images



Mar 12	Spatial Temporal Learning

https://brainchemist.wordpress.com/2011/09/23/development-of-human-brain-wiring-continues-into-adulthood-a-longitudinal-dti-study/

Annotations are rare and expensive

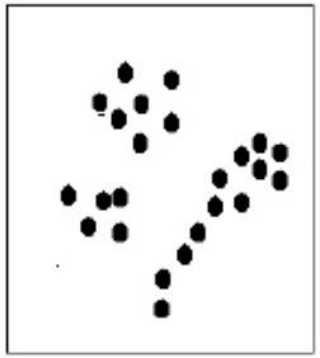


Mar 17	Image Retrieval and Active Learning

L. Yang et al. MICCAI 2017

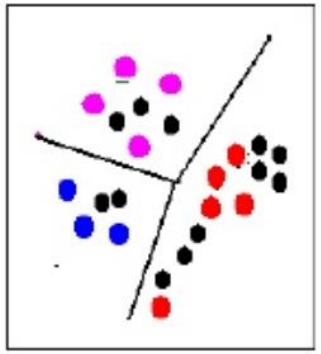
Learn from big unlabeled images

Unsupervised Learning



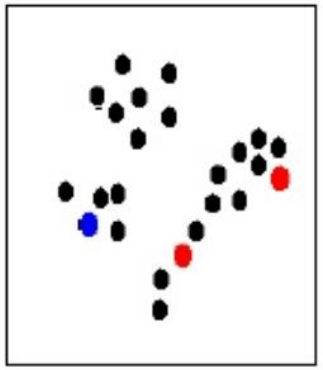
We know nothing about data sructure

Supervised Learning



We know well data sructure

Semi-Supervised Learning

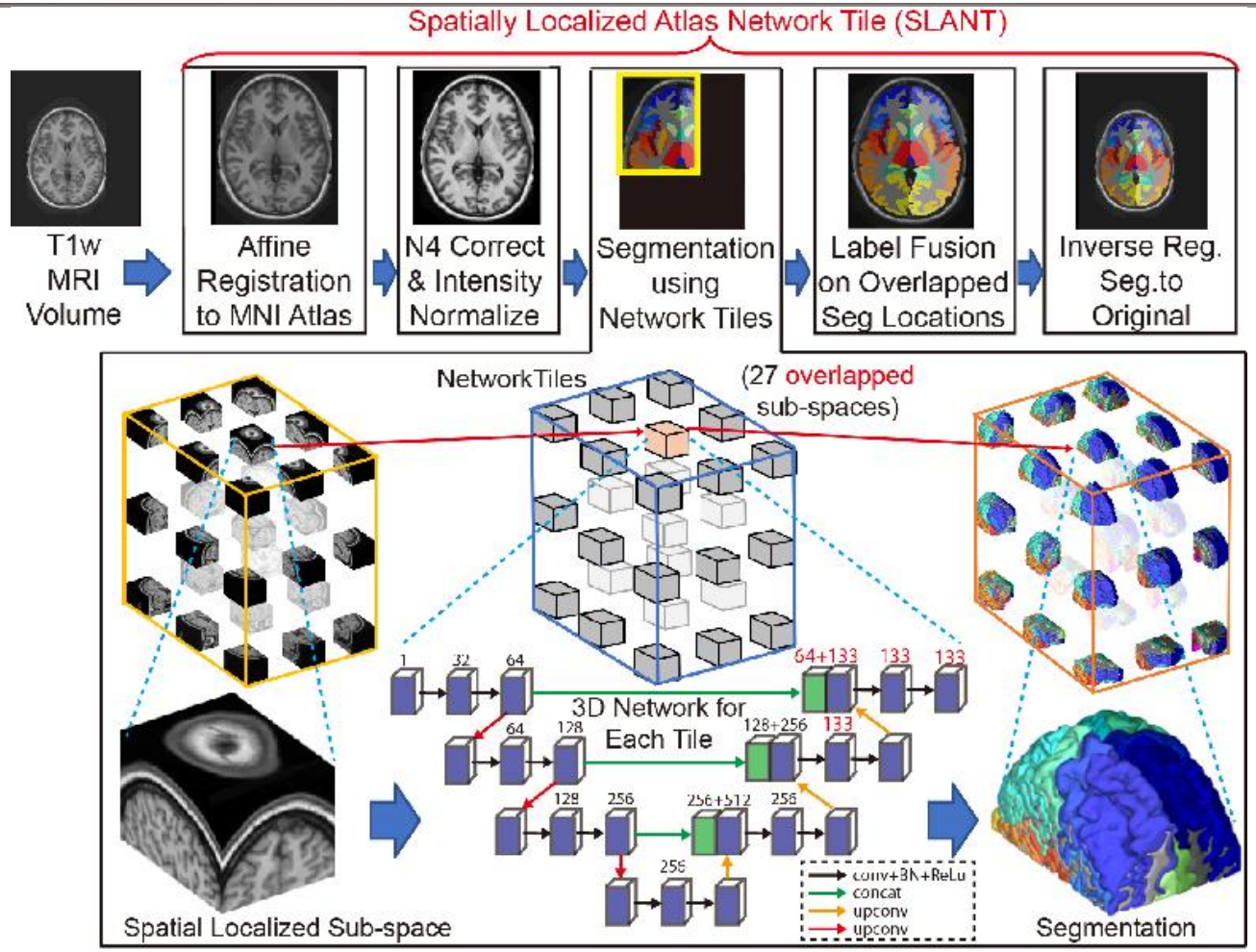


We know something about data sructure

Feb 11	Semi-supervised Learning
Feb 13	Unsupervised Learning

https://www.slideshare.net/Tatiana.lando/clustering-presentation

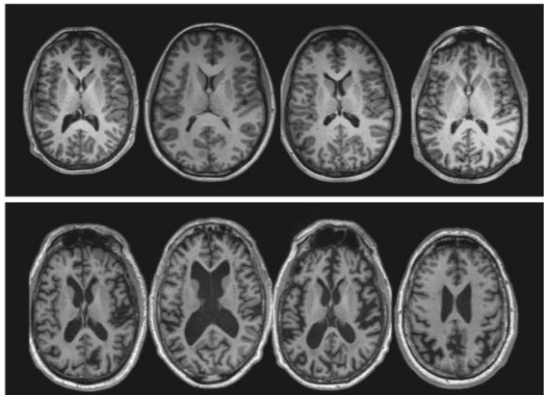
Utilize previous efforts (registration, multi-atlas …)



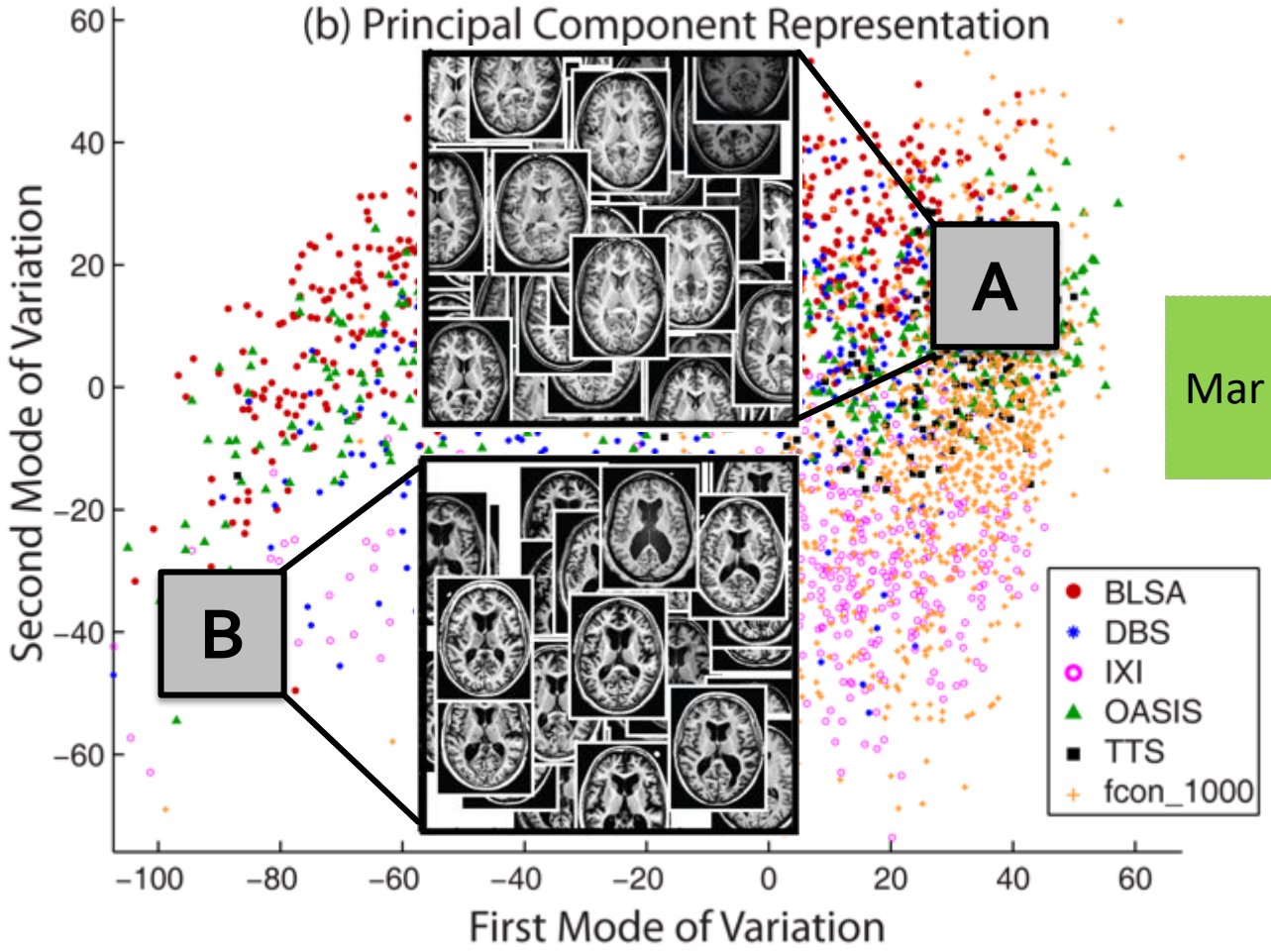
Feb 20	Data Augmentation and Preprocessing

Incorporate strong prior and attention

http://www.diegoantognini.com/projects/image_classification/

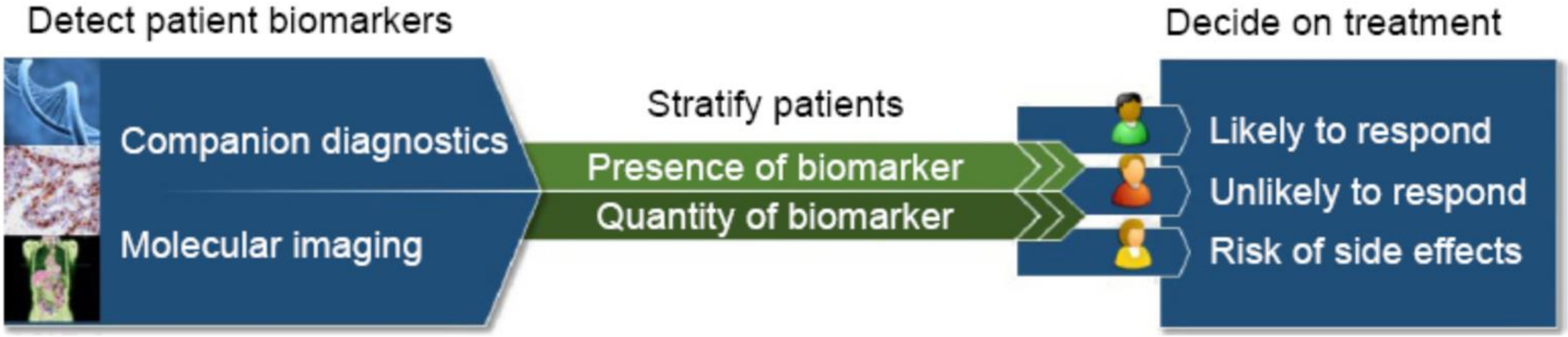


http://www.mahoningvalleylanes.com/2425/car-picture-for-kids.html



Mar 10	Attention Mechanism and Postprocessing

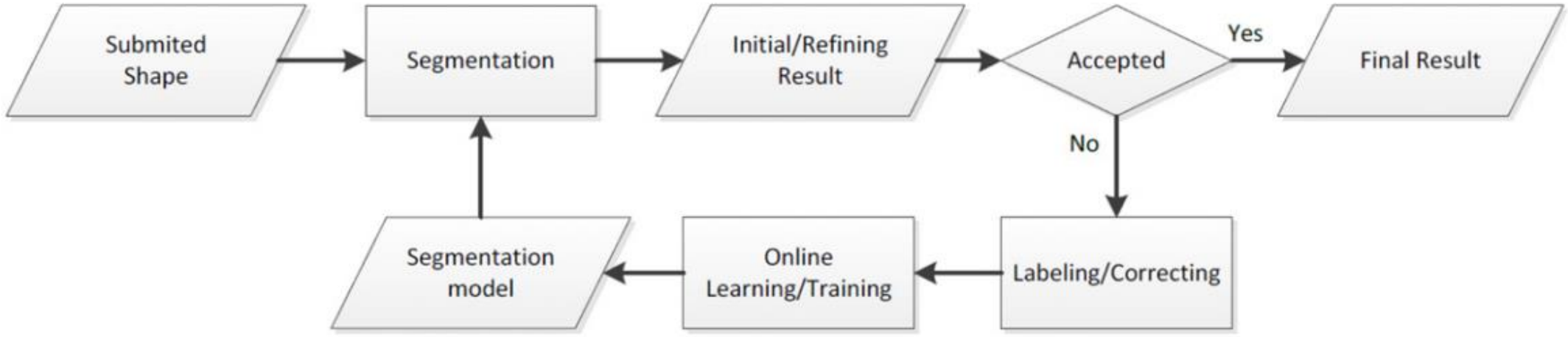
Co-learn from clinical data and other biomarkers



Mar 31	Image Text Co-learning

Van Heertum, Ronald L., Robert Scarimbolo, Robert Ford, Eli Berdougo, and Michael O'Neal. "Companion diagnostics and molecular imaging-enhanced approaches for oncology clinical trials." *Drug design, development and therapy* 9 (2015): 5215.

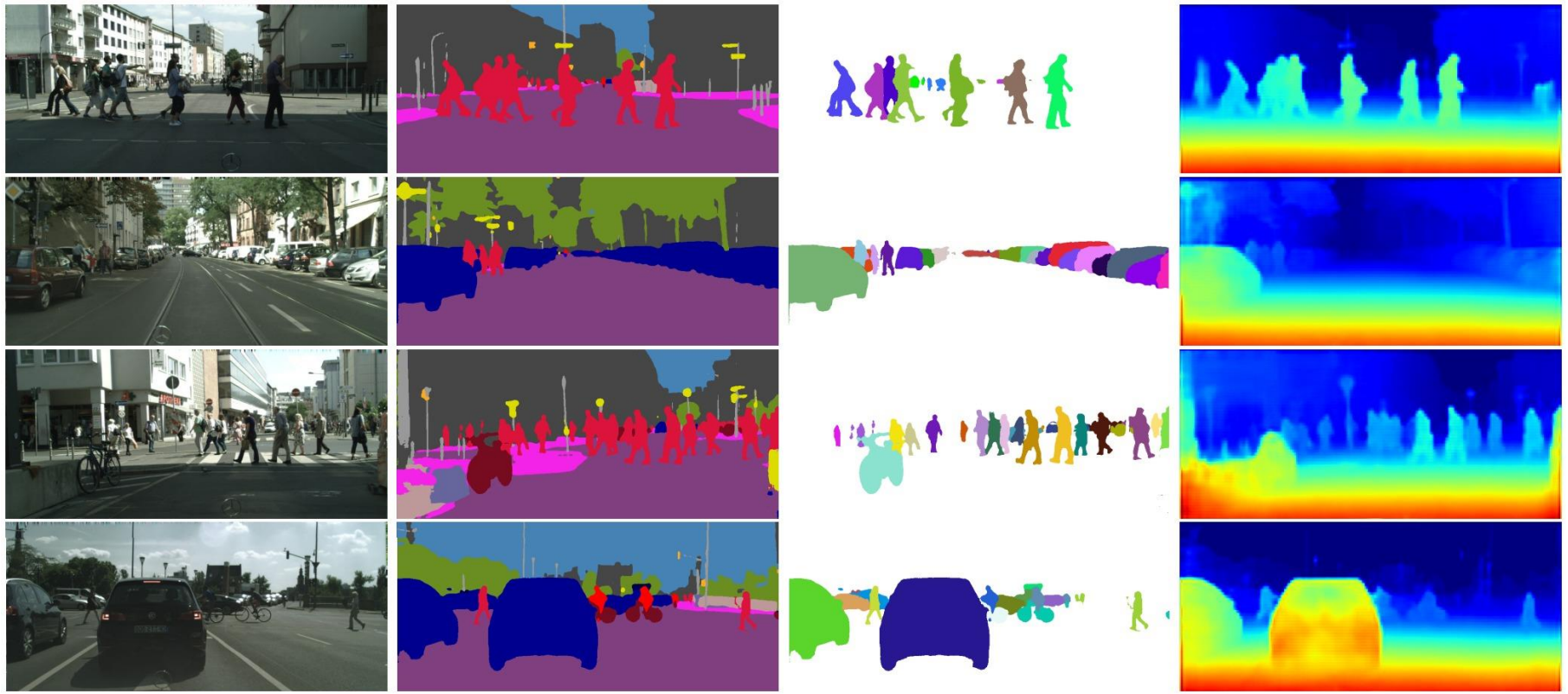
How to add new annotations (online learning)



Nov 15	Online Learning

Zhang, Feiqian, Zhengxing Sun, Mofei Song, and Xufeng Lang. "Progressive 3D shape segmentation using online learning." *Computer-Aided Design* 58 (2015): 2-12.

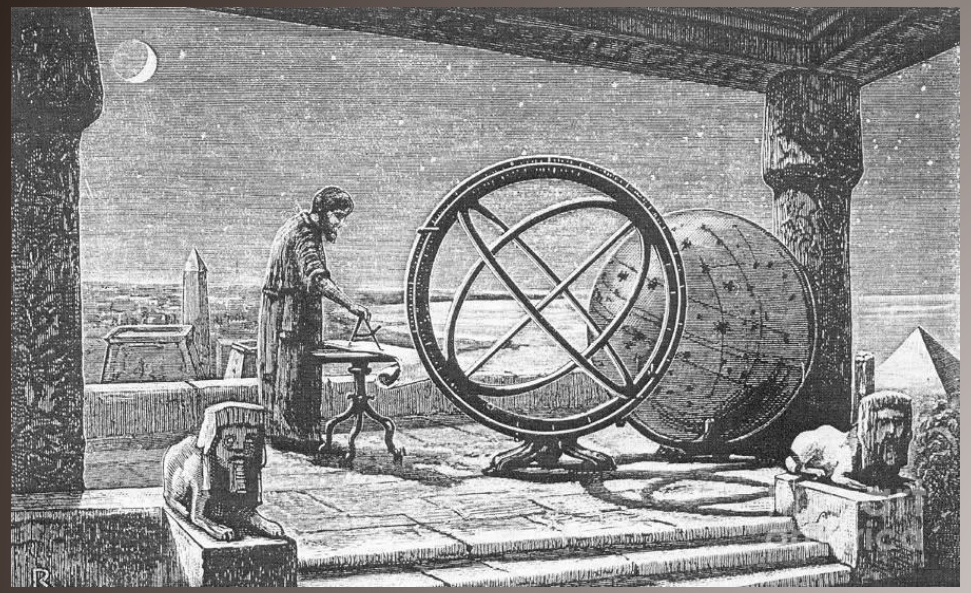
Multi-task Learning



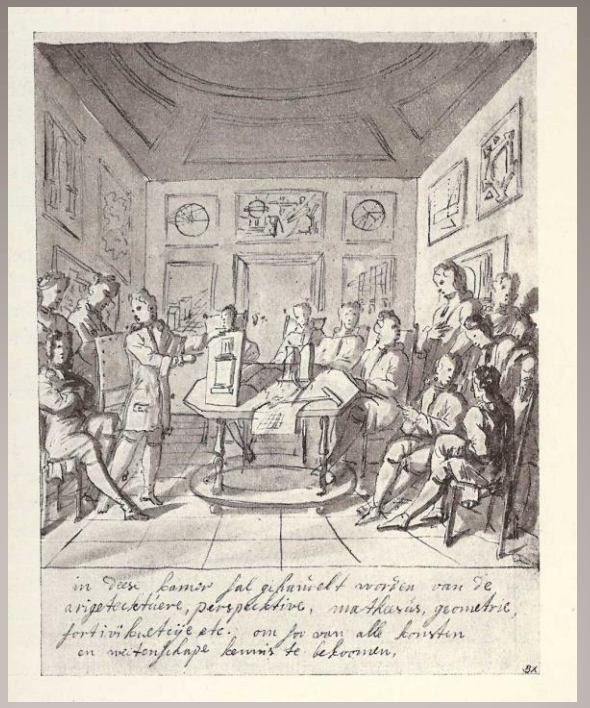
(a) Input image (b) Segmentation output (c) Instance output (d) Depth output

https://alexgkendall.com/computer_vision/bayesian_deep_learning_for_safe_ai/

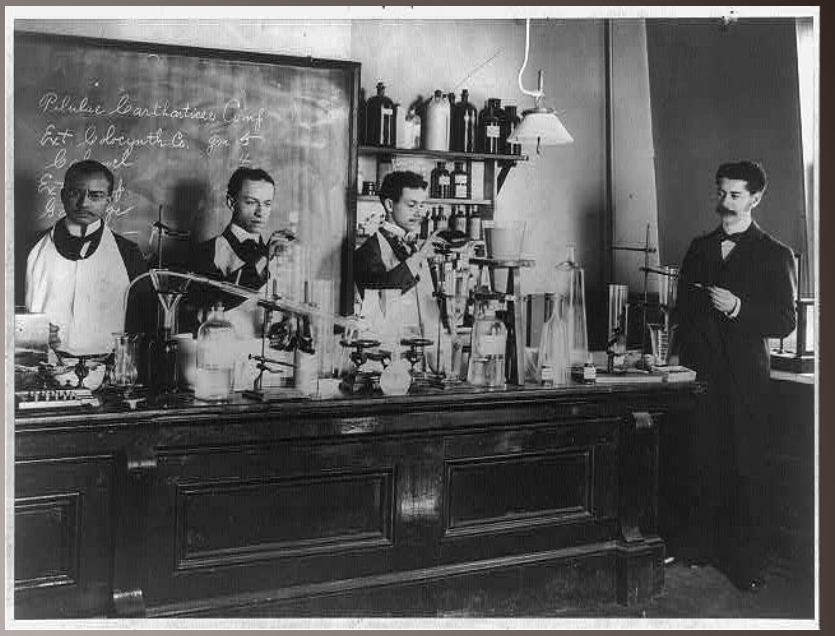
Feb 04	Multi-task Learning



http://www.sohu.com/a/142293687_672687



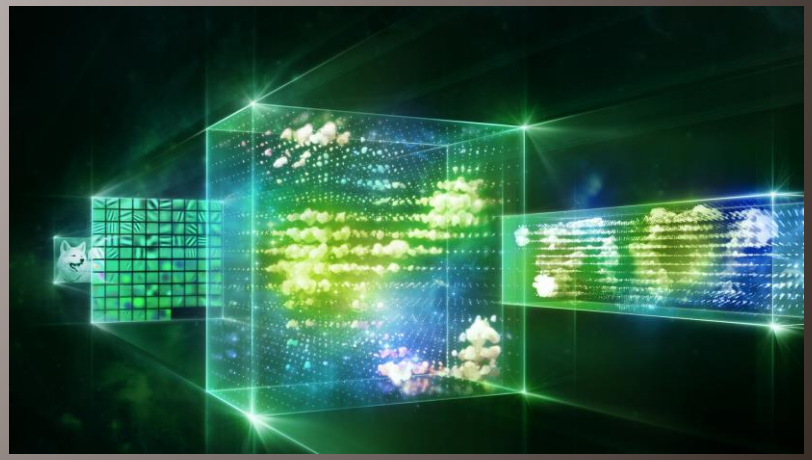
http://criticalarchitecture.org/en/research-projects/



http://libguides.law.umn.edu/druglaw

https://www.flickr.com/photos/llnl/3094229534

https://www.scmp.com/lifestyle/travel-leisure/article/1983144/why-growing-army-digital-nomads-are-choosing-asia-their



https://www.pcrevue.sk/a/Umela-inteligencia-Googlu-vytvara-vlastnych-potomkov--ktori-prekonaju-systemy-vytvorene-ludmi

Contact

Instructor: Yuankai Huo **Email:** yuankai.huo@vanderbilt.edu

Teaching Assistant: Roza Bayrak **Email:** roza.g.bayrak@vanderbilt.edu

Class Meets: Tuesday & Thursday, 4:00 pm – 5:15 pm, FGH 110

TA Office Hours: Tuesday & Thursday, 1:00 pm – 4:00 pm, TA Office (FGH 385)

Instructor Office Hours: Tuesday & Thursday, 3:00 pm – 4:00 pm, FGH 376

Course Website: https://my.vanderbilt.edu/cs8395

Submission & Discussion: https://www.vanderbilt.edu/brightspace