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Deep Learning for Medical Image Analysis

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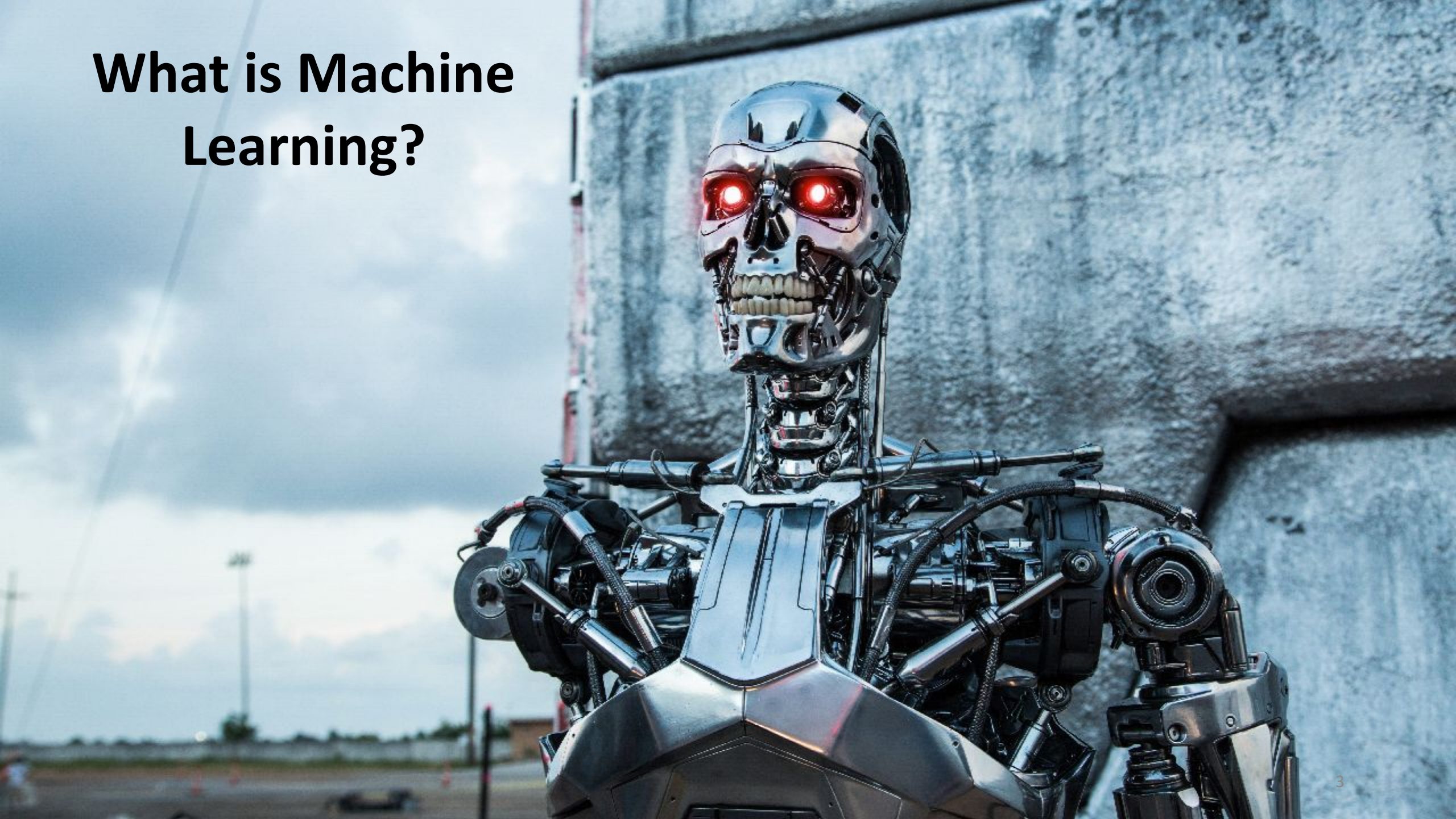
DIOS

MRC OULU medical research center

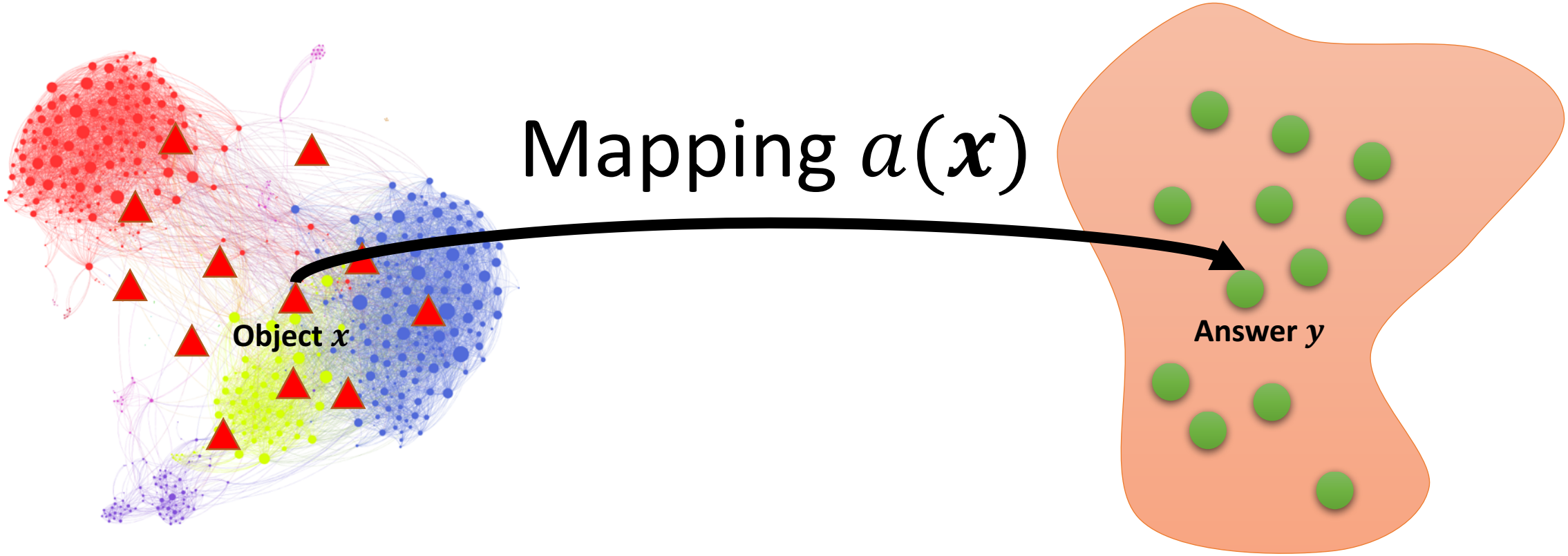
Outline

- What is Deep Learning
  - Machine Learning
  - Convolutional neural networks: computer vision breakthrough
  - Applications: Images, Video, Audio
  - Interpretability
  - Transfer learning
  - Limitations
- Medical Image analysis
  - Segmentation
  - Skin cancer detection at a dermatologist level
  - Diabetic Retinopathy
  - Own study: Knee Osteoarthritis diagnosis

What is Machine Learning?



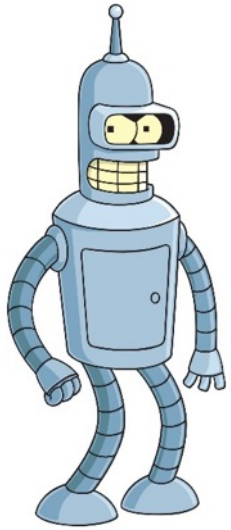
Machine Learning

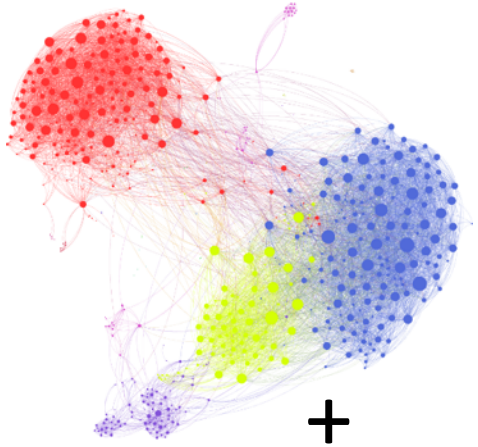


Space $\boldsymbol{X}$ (objects)

Space $\boldsymbol{Y}$ (labels)

Learning (supervised)





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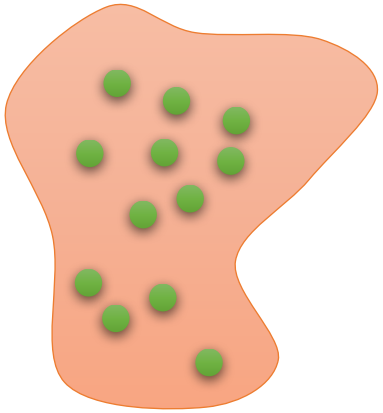
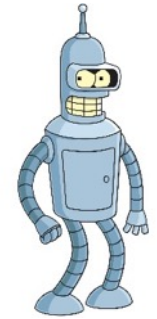


Learning

Looking for optimal parameters θ

$a_\theta(\boldsymbol{x}) \approx a(\boldsymbol{x})$

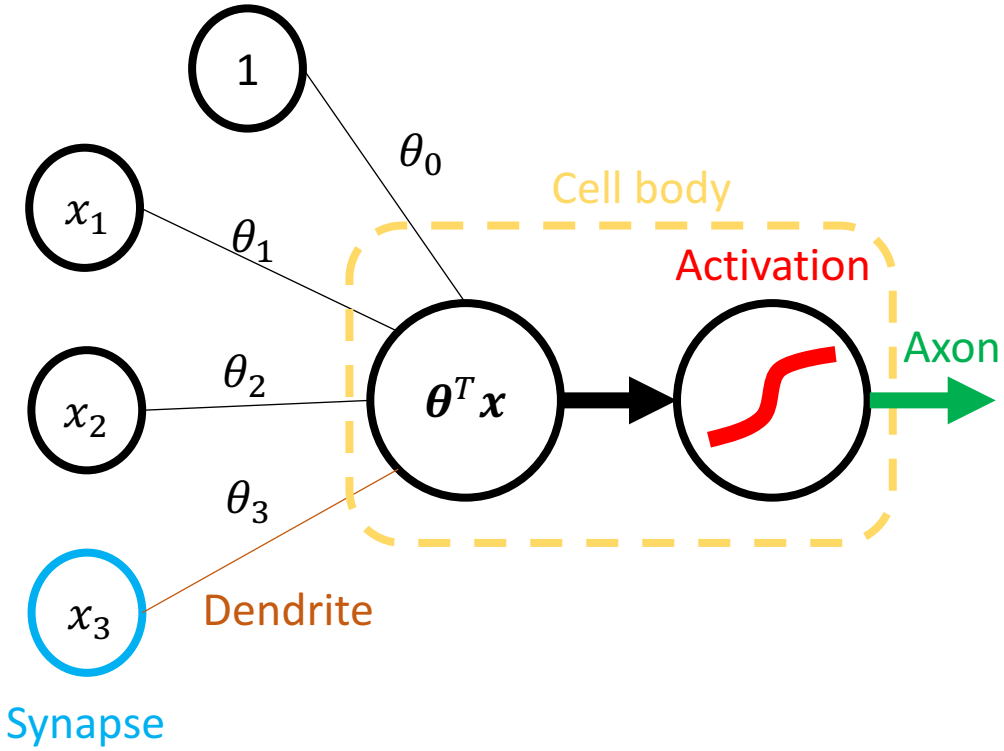
New data

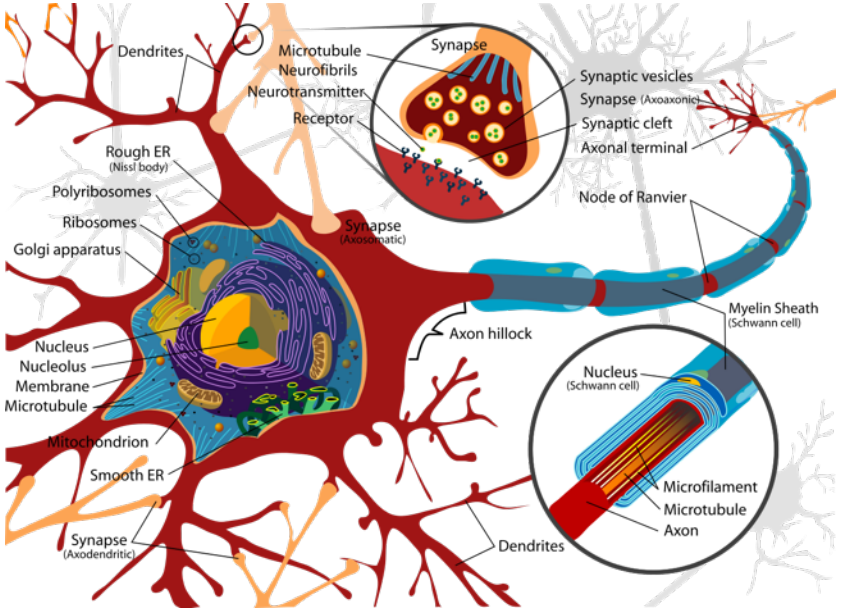


Prediction

Label

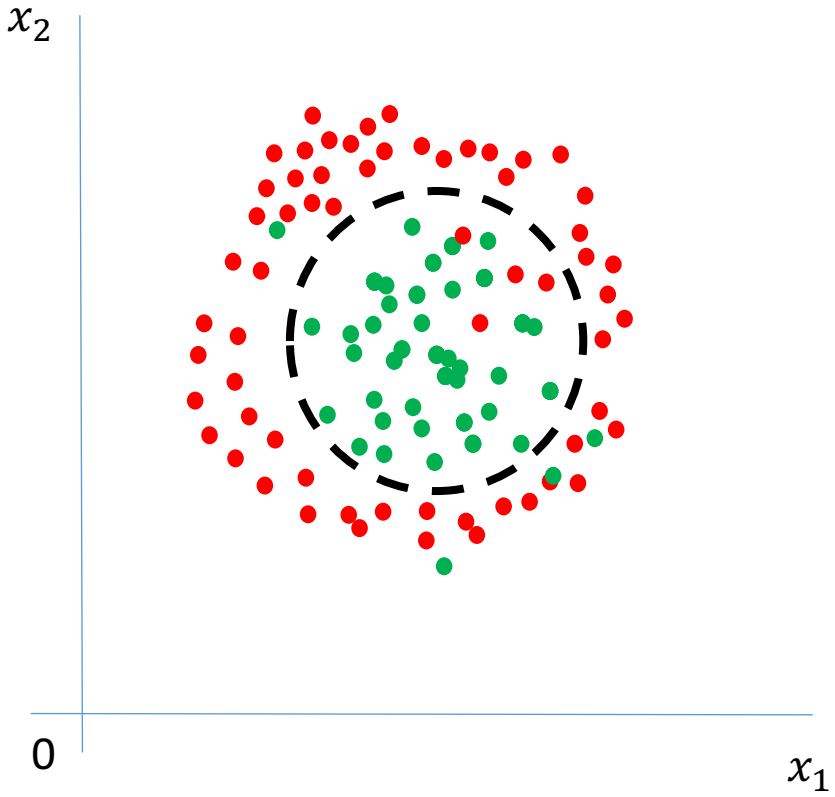
Artificial neuron

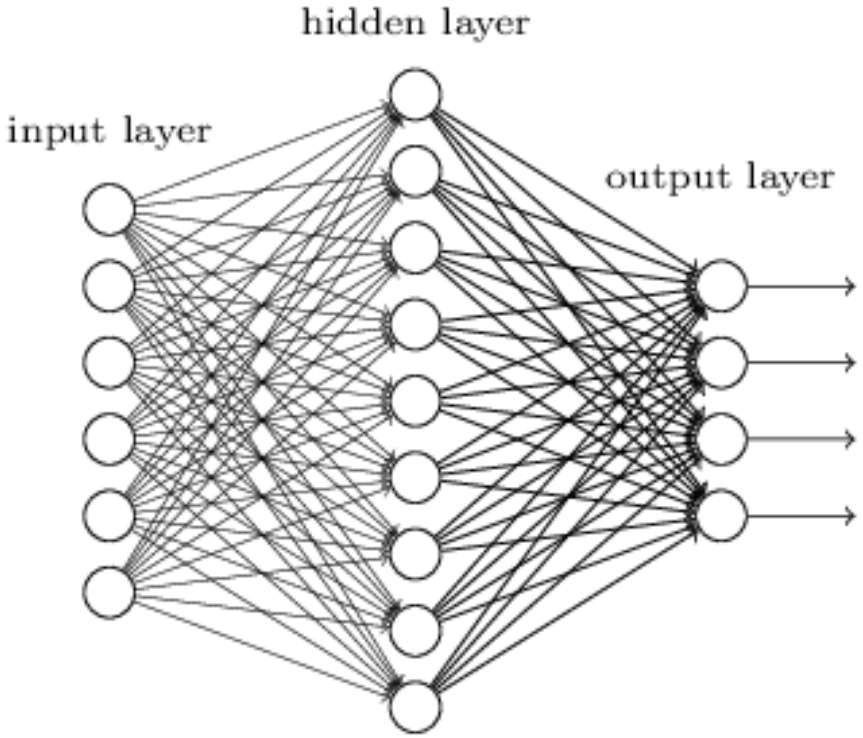




https://upload.wikimedia.org/wikipedia/commons/thumb/a/a9/Complete_neuron_cell_diagram_en.svg/1280px-Complete_neuron_cell_diagram_en.svg.png

Artificial Neural Networks: non-liner functions

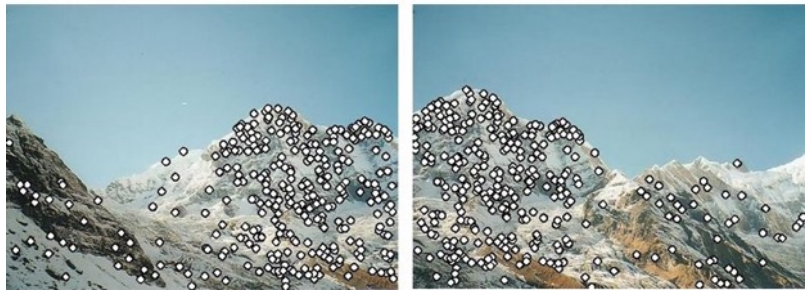


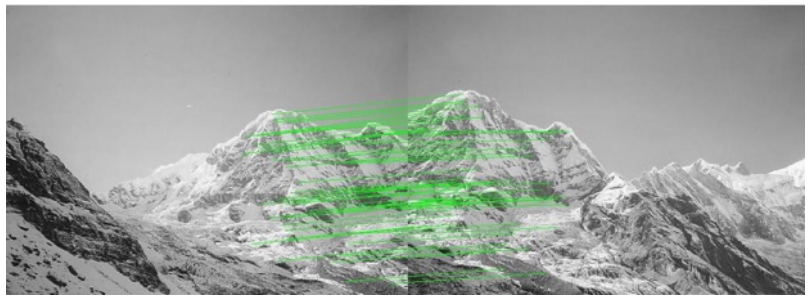


http://neuralnetworksanddeeplearning.com/images/tikz35.png

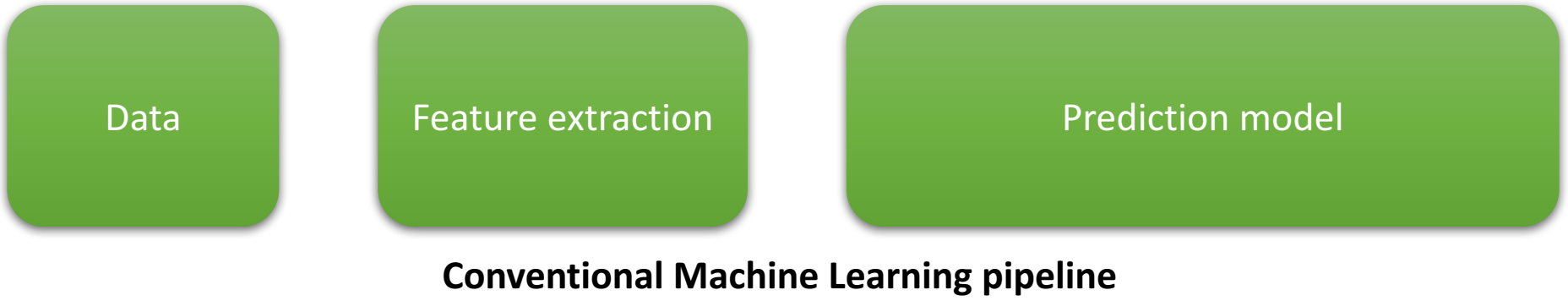
Popular image feature descriptors

- Histogram of Oriented Gradients - HoG
  - Detection of everything
    - Person, car, road sign, face, …
- Shift-Invariant Feature transform - SIFT
  - Key-point matching
  - …
- LBP
  - Face detection
  - Texture analysis

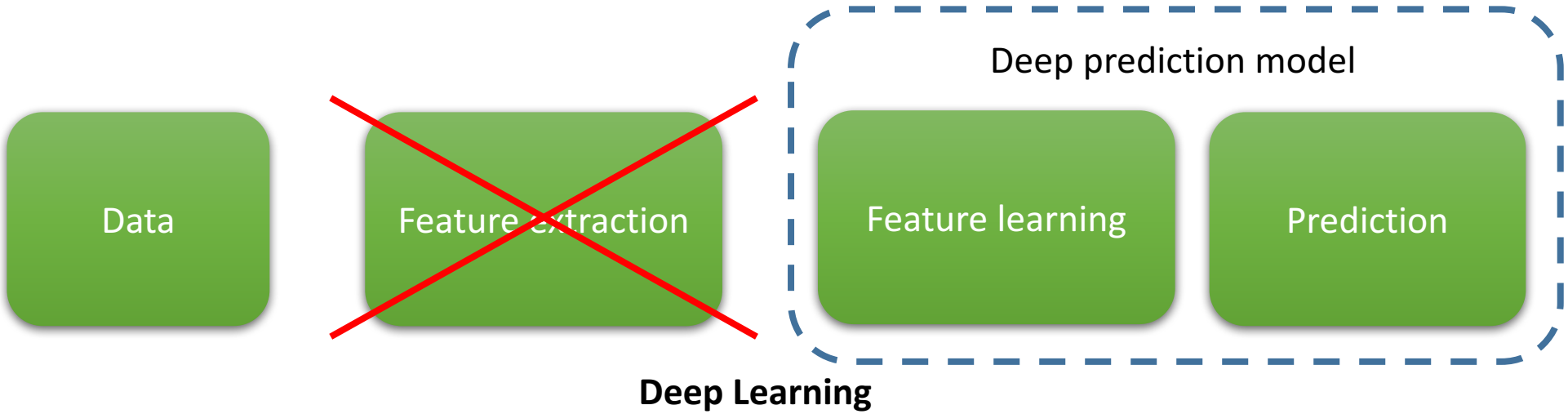




What is Deep Learning



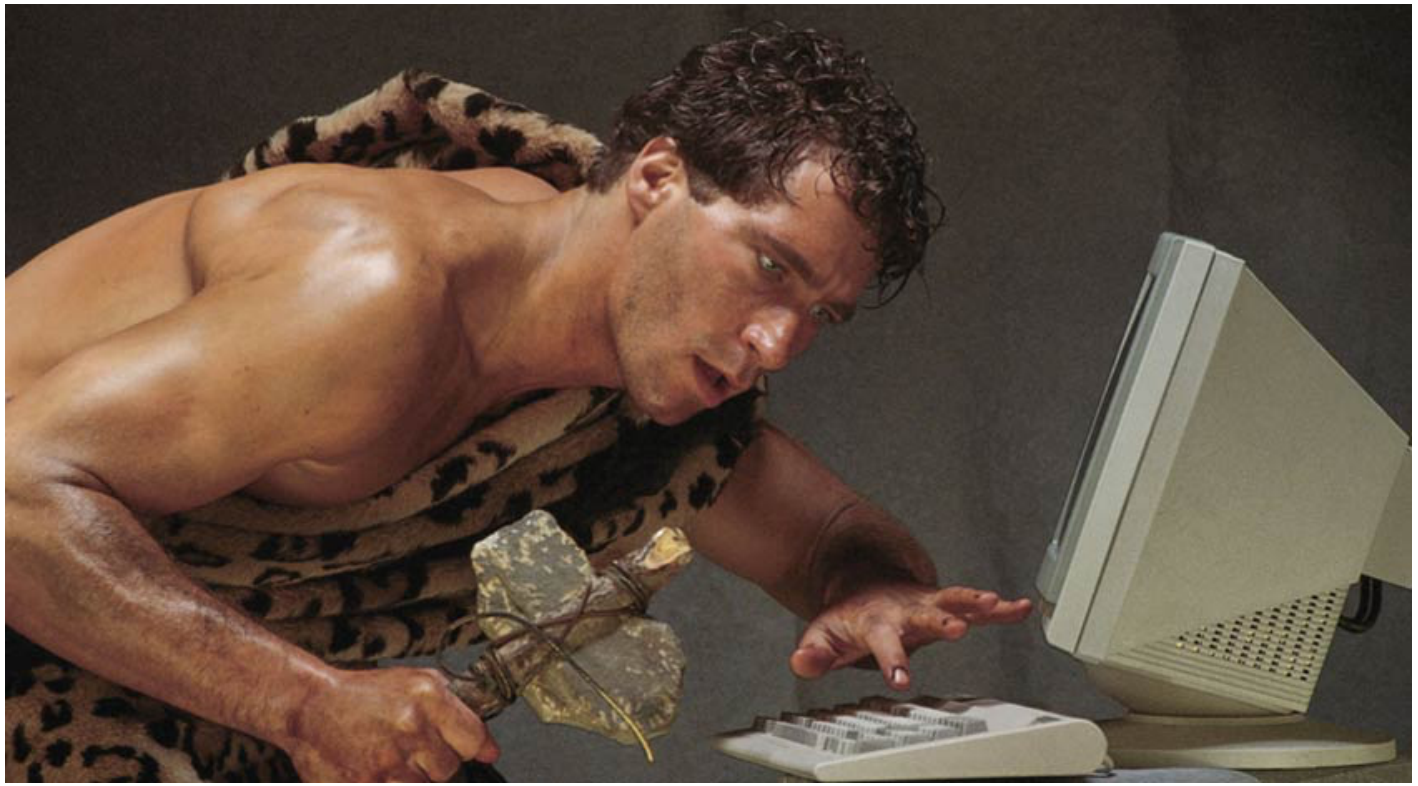
Conventional Machine Learning pipeline



Deep Learning

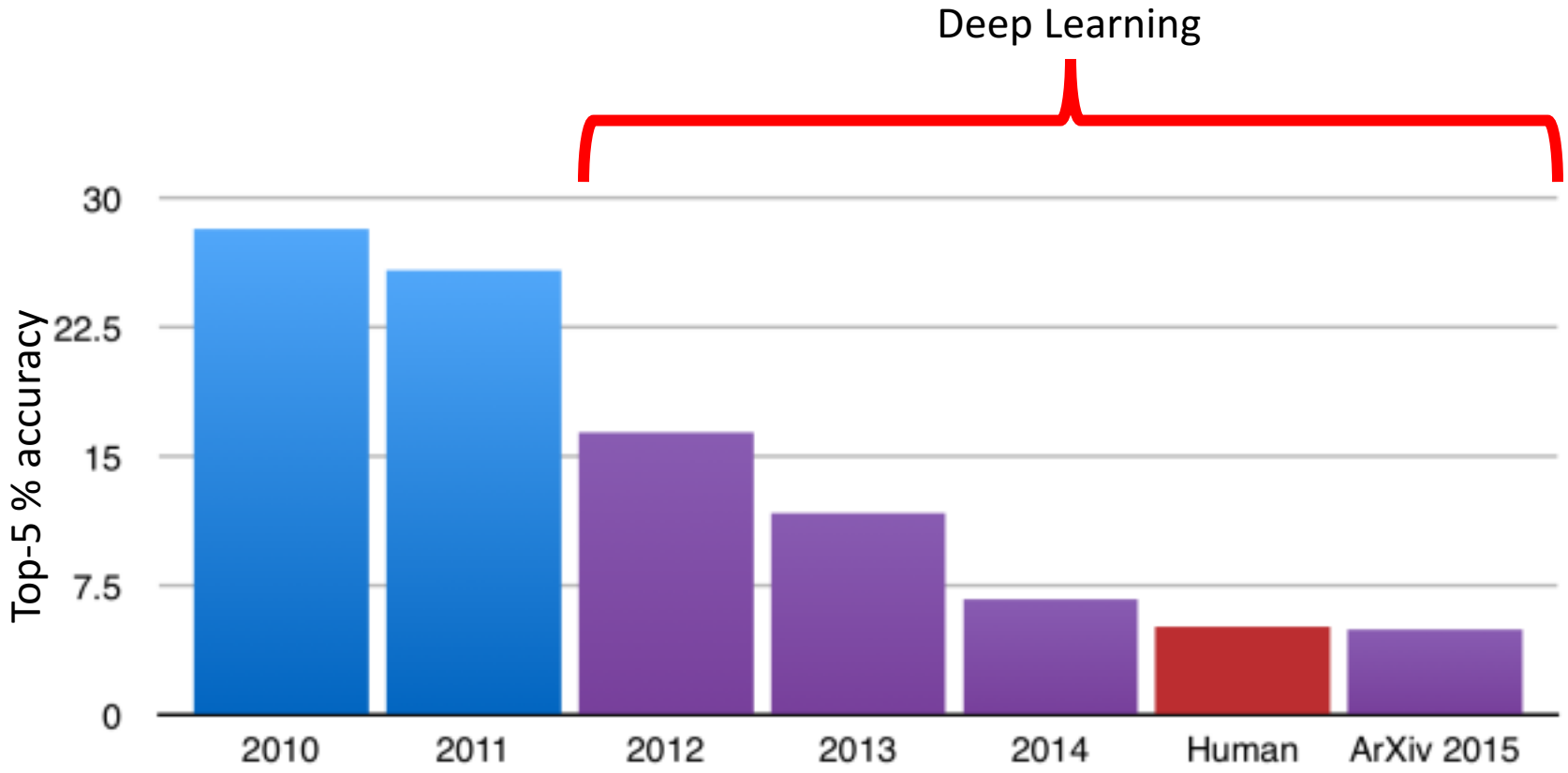
Deep Learning vs. Hand-crafted features

Hand-crafting features……



Why do we need it?

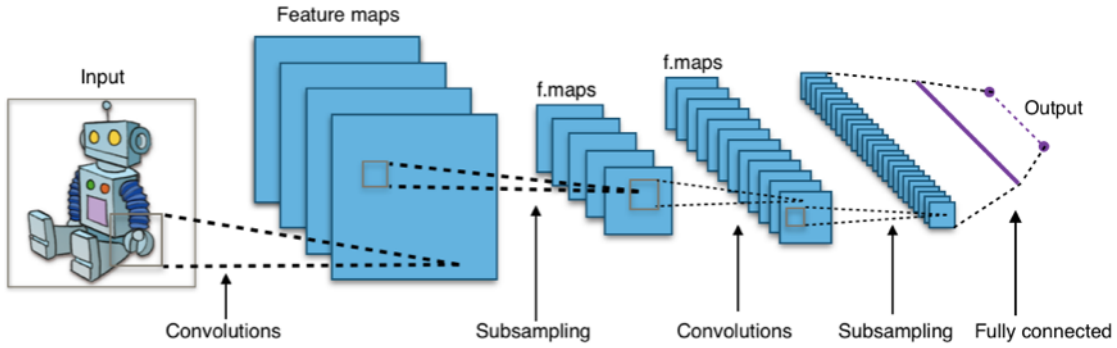
- ImageNet – general image recognition challenge
- 1000 classes
- **Millions** of training images



https://www.quora.com/What-is-the-winning-top-5-error-rate-on-ImageNet-2016

Deep Learning breaktrough: AlexNet

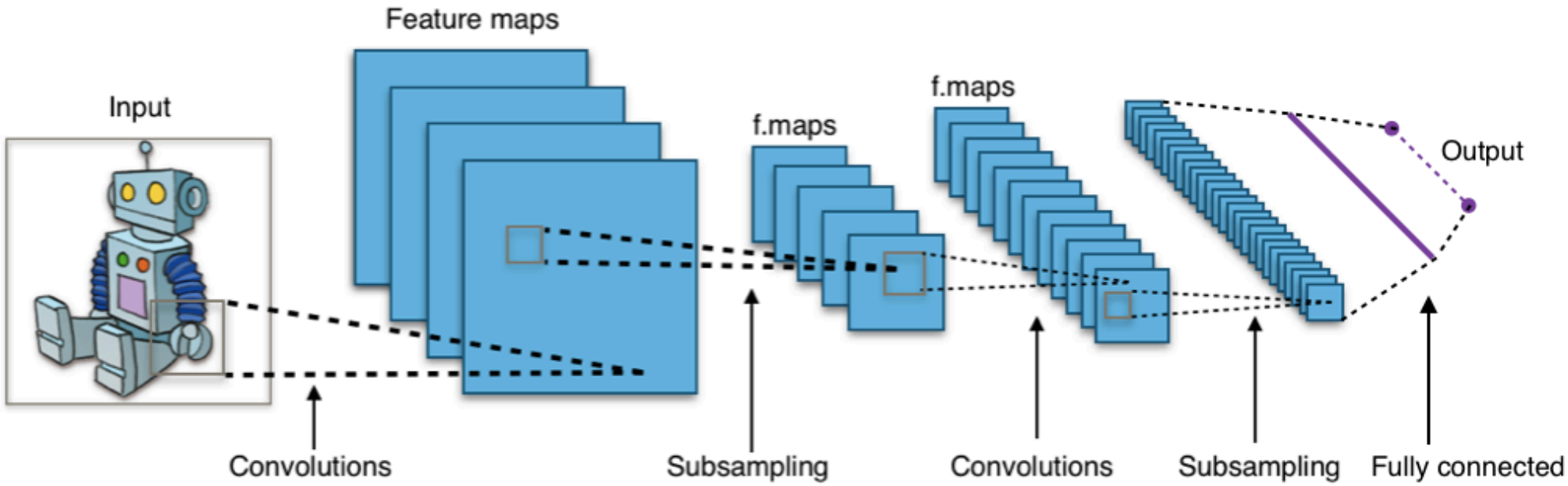
- AlexNet
  - Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. In *Advances in neural information processing systems* (pp. 1097-1105).
  - Cited **>11800** times according to Google Scholar



Drastic error rate drop (>10%) achieved by **learning features directly from data!**

http://whatsnext.nuance.com/in-the-labs/convolutional-neural-networks-applied-to-natural-language-understanding-research/

ConvNet layer hierarchy: local connections



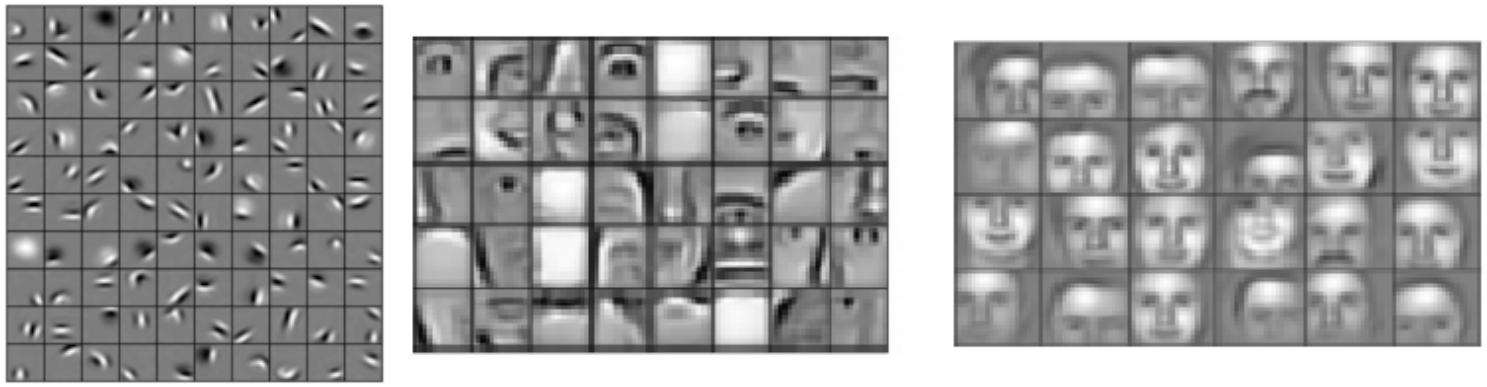
Deep Learning: concepts out of simple concepts

Deep learning allows computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction

Yann LeCun et. al, doi:10.1038/nature14539

Deep learning allows the computer to build complex concepts out of simpler concepts.

Ian Goodfellow et. al, Deep Learning Book



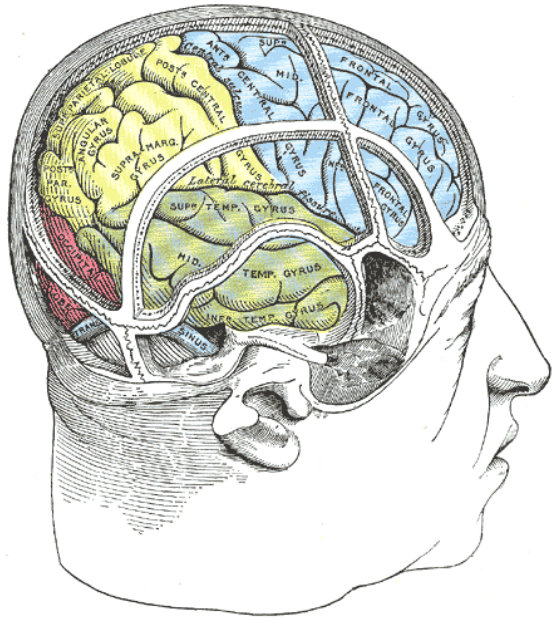
https://devblogs.nvidia.com/parallelforall/deep-learning-nutshell-core-concepts/

Convnets: model of the brain

Deep Neural Networks Rival the Representation of Primate IT Cortex for Core Visual Object Recognition

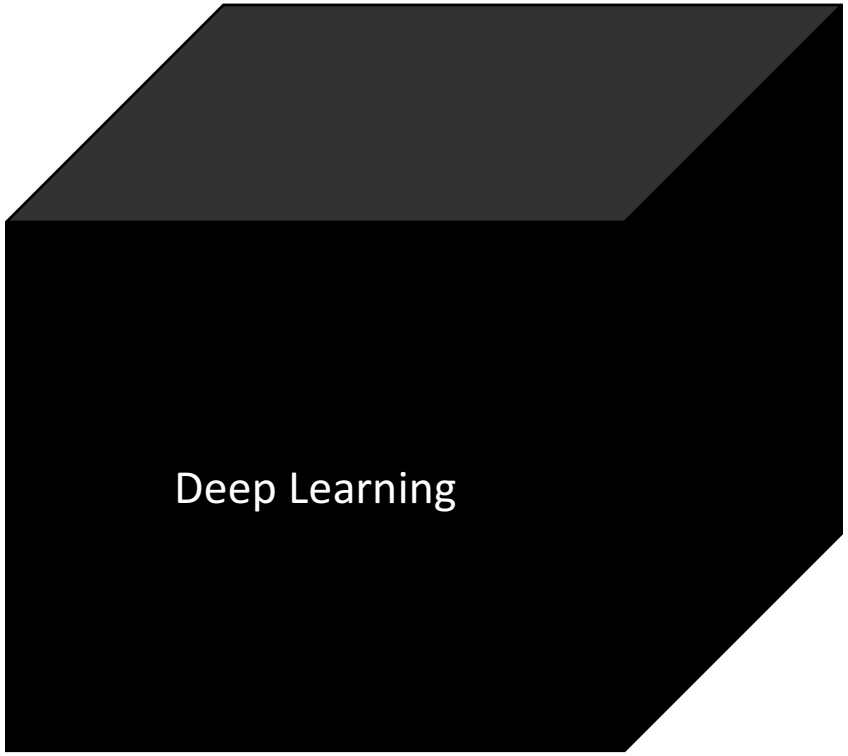
Charles F. Cadieu[1]*, Ha Hong[1,2], Daniel L. K. Yamins[1], Nicolas Pinto[1], Diego Ardila[1], Ethan A. Solomon[1], Najib J. Majaj[1], James J. DiCarlo[1]

1 Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States of America, **2** Harvard–MIT Division of Health Sciences and Technology, Institute for Medical Engineering and Science, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States of America



- Inferior Temporal (IT) cortex
  - Visual recognition tasks
- ConvNet performs equivalently well to SVM trained on top of the activations from IT cortex

Is it really a black-box?



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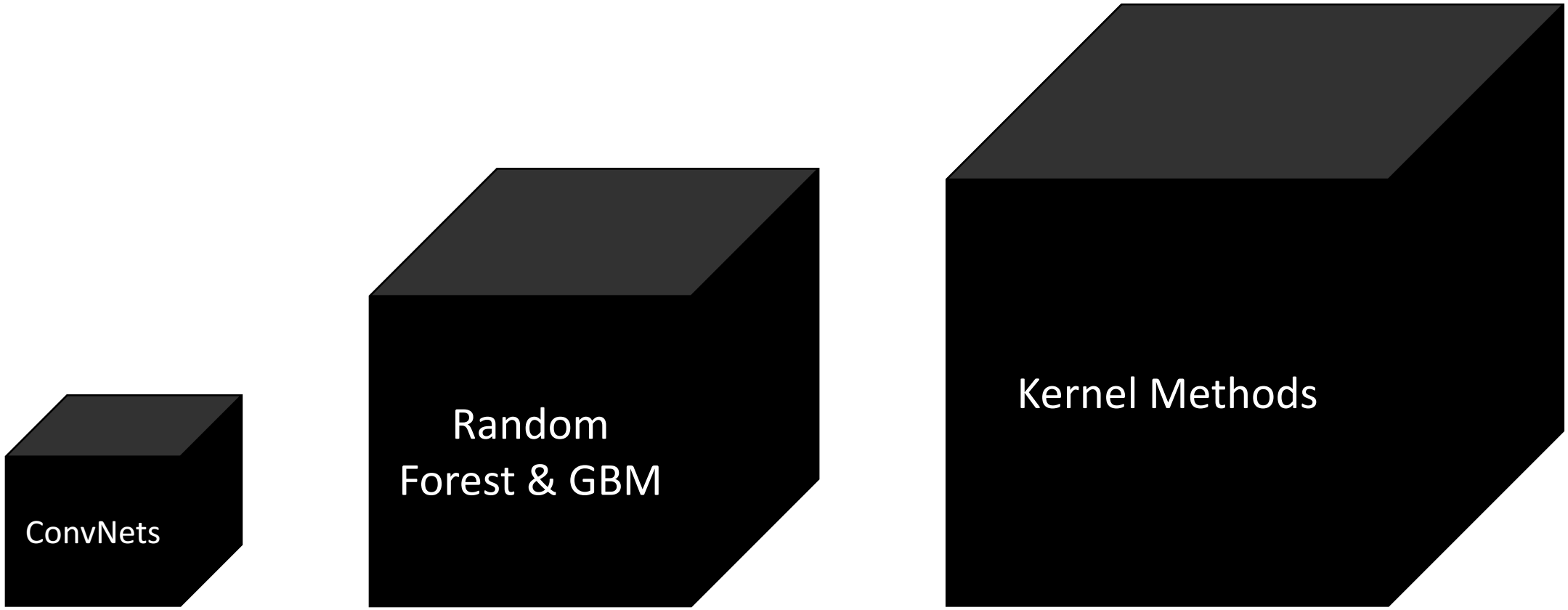
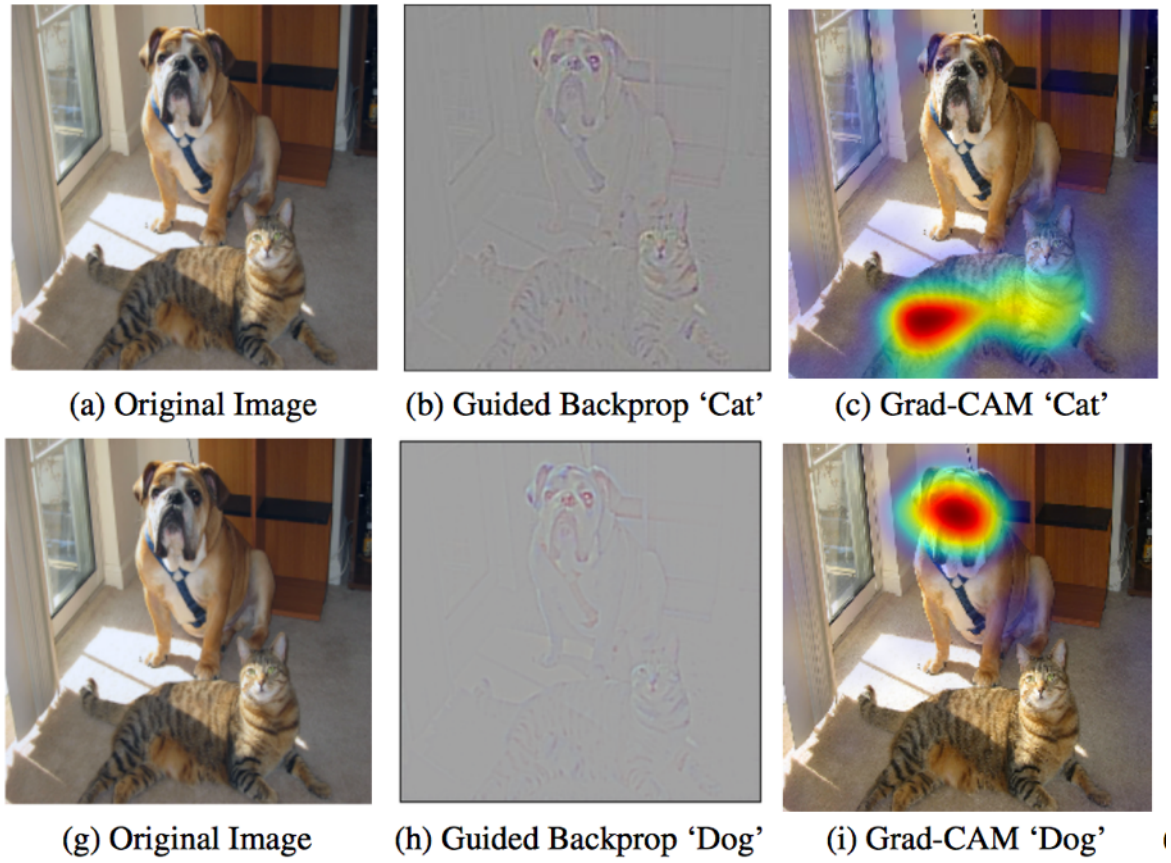


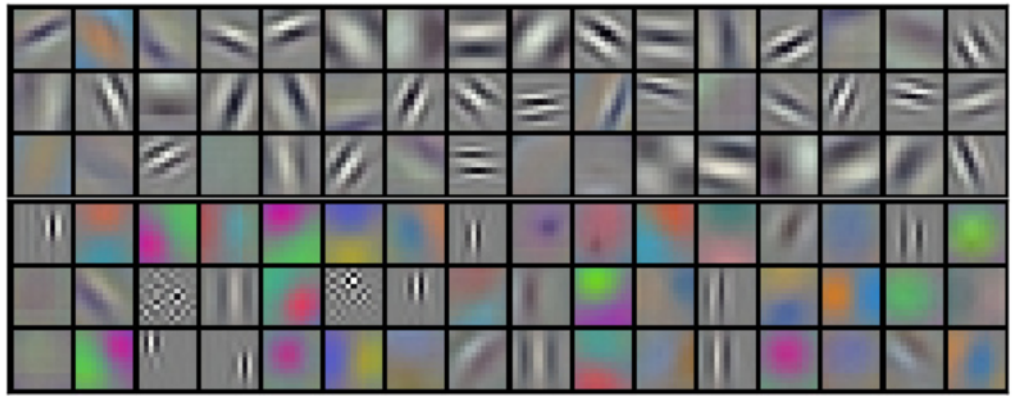
Attention maps & Guided Backpropagation

- Neural net is a differentiable function
- We can find a gradient with respect to the image for any class
- Details: GradCAM

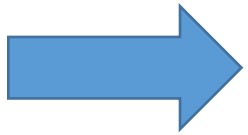


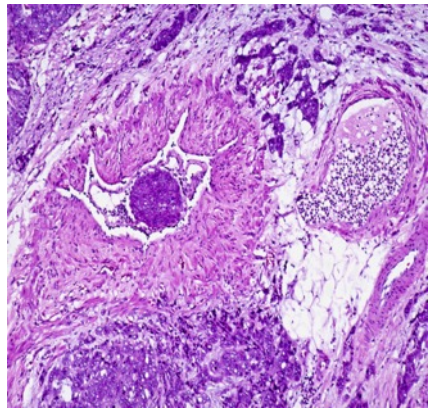
Transfer learning

- Deep models learn very generic features at the first layers
  - If they trained on a large dataset having many categories, e.g. ImageNet
- Can we used pre-trained features in the new domains?



ImageNet features



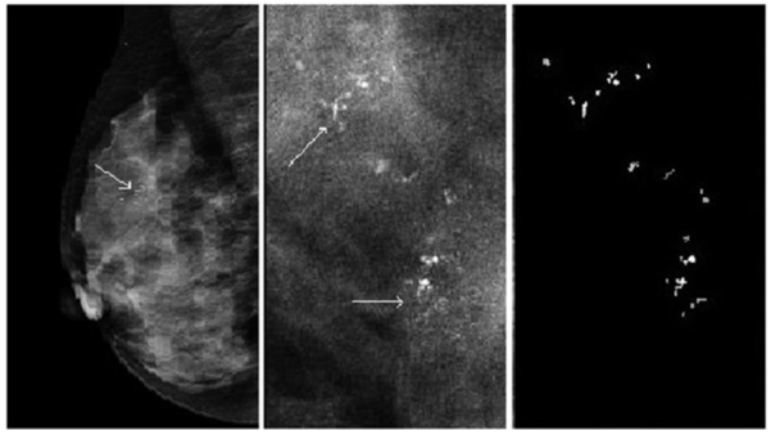


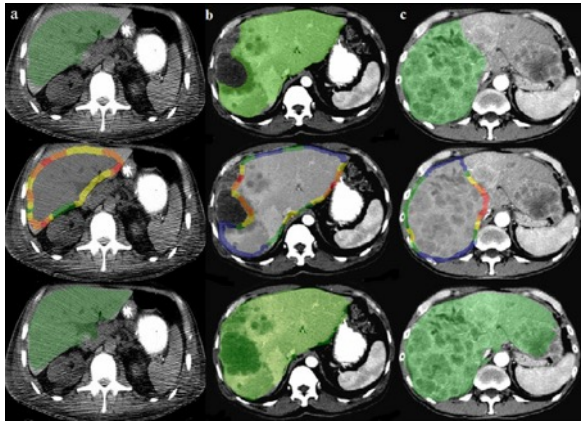
Breast cancer diagnosis

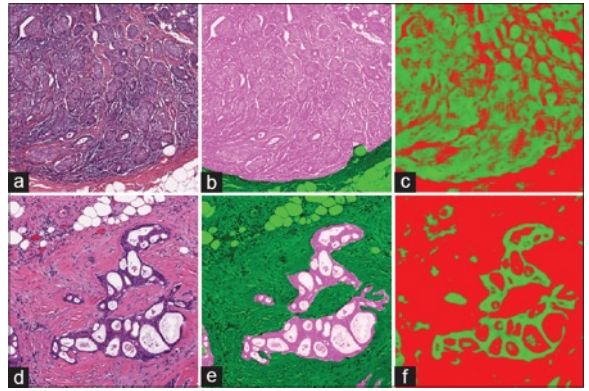
Limitations

- Data
- Models with many parameters easily overfit
- Wise architecture design is needed to perform well
- High-end equipment is needed to train the models
- Linear nature of the models allows to “fool” them
  - **See, Adversarial examples**

Medical Image segmentation

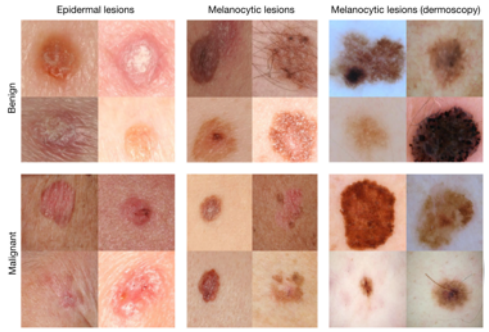


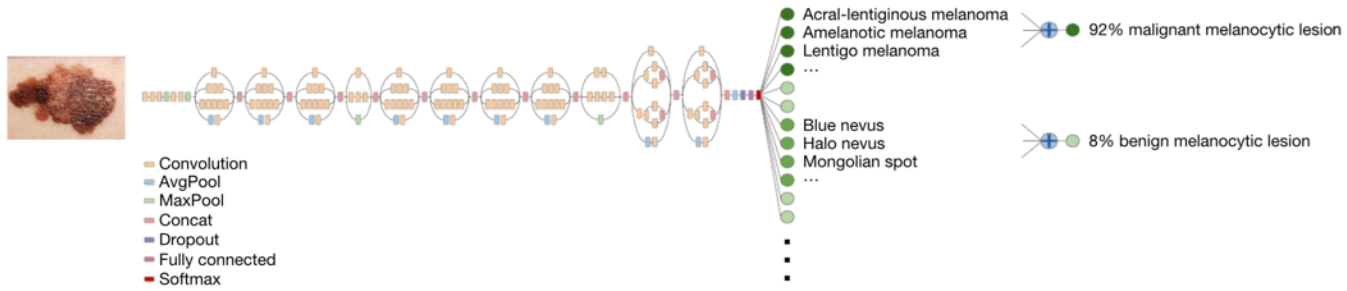




Skin Cancer: transfer learning success

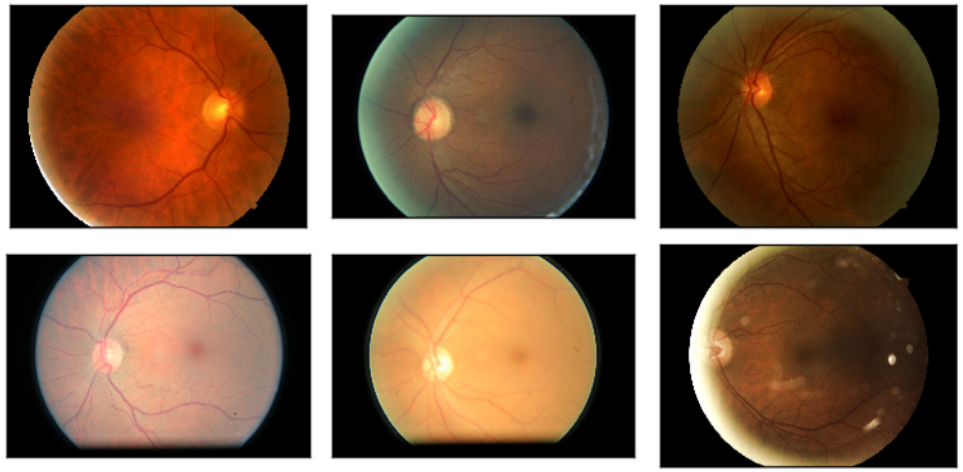
- Inception V3 network
  - ImageNet
- Dermatologist level classification
- Can be soon in your mobile phone

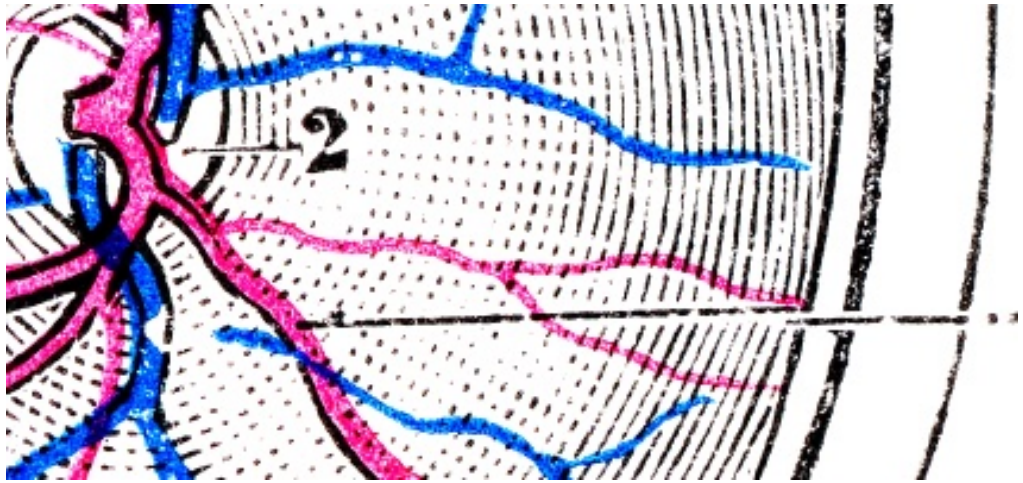




Diabetic Retinopathy

- Kaggle competition
- $100 000 prize
- **Kappa coefficient 0.85 was achieved**





Summary

- With Deep learning we can do practically anything
  - Classify
  - Regress
  - Segment
- We need a lot of data to train deep models
- We also need powerful hardware to train the networks
- Pre-trained models can be used to achieve a really good performance in classification and regression

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- http://cdn2-www.superherohype.com/assets/uploads/gallery/terminator-genisys/terminator-genisys-018.jpg
- http://2.bp.blogspot.com/-7BaGjkSq6rc/VKBPTRYzNgI/AAAAAAAANyo/4VsIBTP-NVY/s1600/hog.jpg
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- https://blogs.nvidia.com/wp-content/uploads/2016/09/19-beck-image.jpg

Images used

- https://www.nature.com/article-assets/npg/srep/2016/160607/srep27327/images/w582/srep27327-f1.jpg
- https://www.researchgate.net/profile/Marius_George_Linguraru/publication/262293298/figure/fig2/AS:296674879655946@1447744211805/Fig-2-Examples-of-liver-segmentation-overlayed-in-green-on-axial-views-of-3D-CT-data.png
- http://www.jpathinformatics.org/articles/2016/7/1/images/JPatholInform_2016_7_1_29_186902_u11.jpg
- https://deepsense.io/wp-content/uploads/2015/09/pred_2.jpg

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- http://5047-presscdn.pagely.netdna-cdn.com/wp-content/uploads/2015/08/DR4_1.png
- https://www.kaggle.com/c/diabetic-retinopathy-detection