Medical Image Analysis with Deep Learning

CMPUT 617

Nilanjan Ray
Associate Professor
Computing Science
University of Alberta
Canada

Agenda

- Deep learning (DL)
- Some applications of DL in medical image analysis (MIA)
- DL for MIA tasks: segmentation, detection, etc.
- Challenges and future directions

What is deep learning?

How does computer vision work?

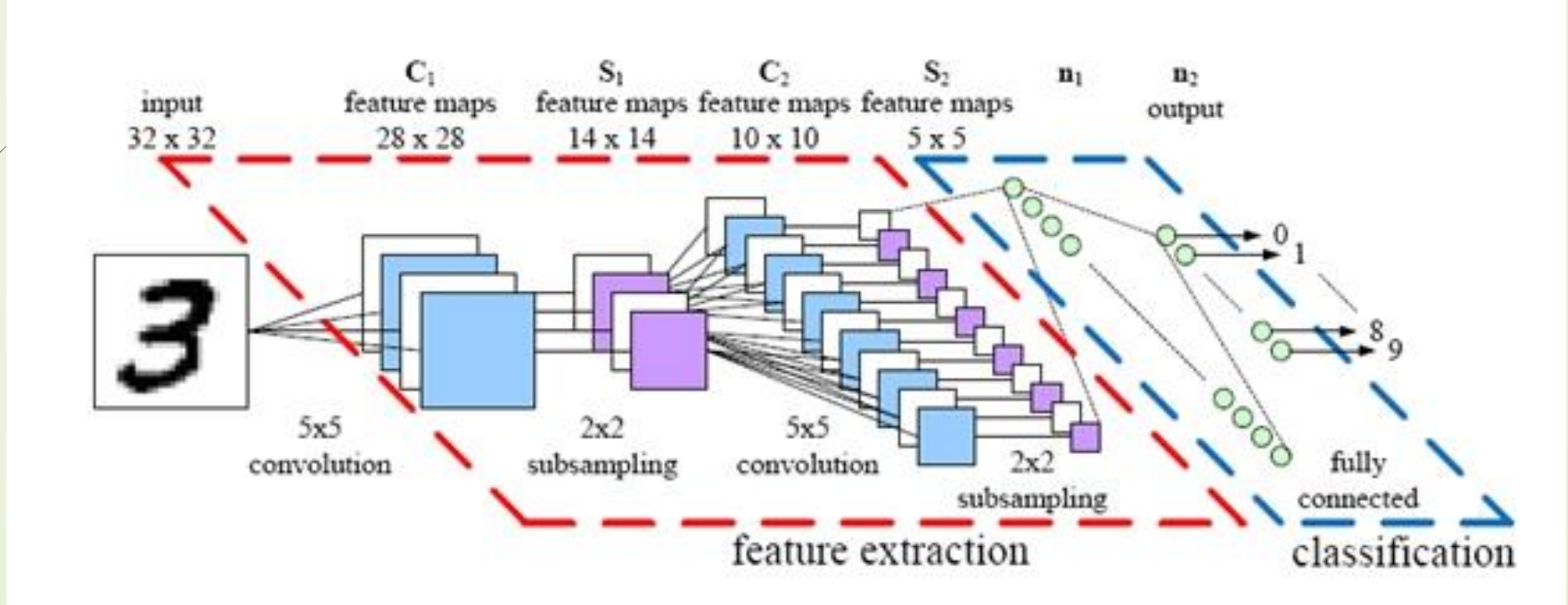
- Let's consider object recognition tasks.

- How do we describe a cat or a dog or a …?
- It is impossible to write "explicit rules" to recognize visual objects/scenes.
- Much easier to learn from examples!

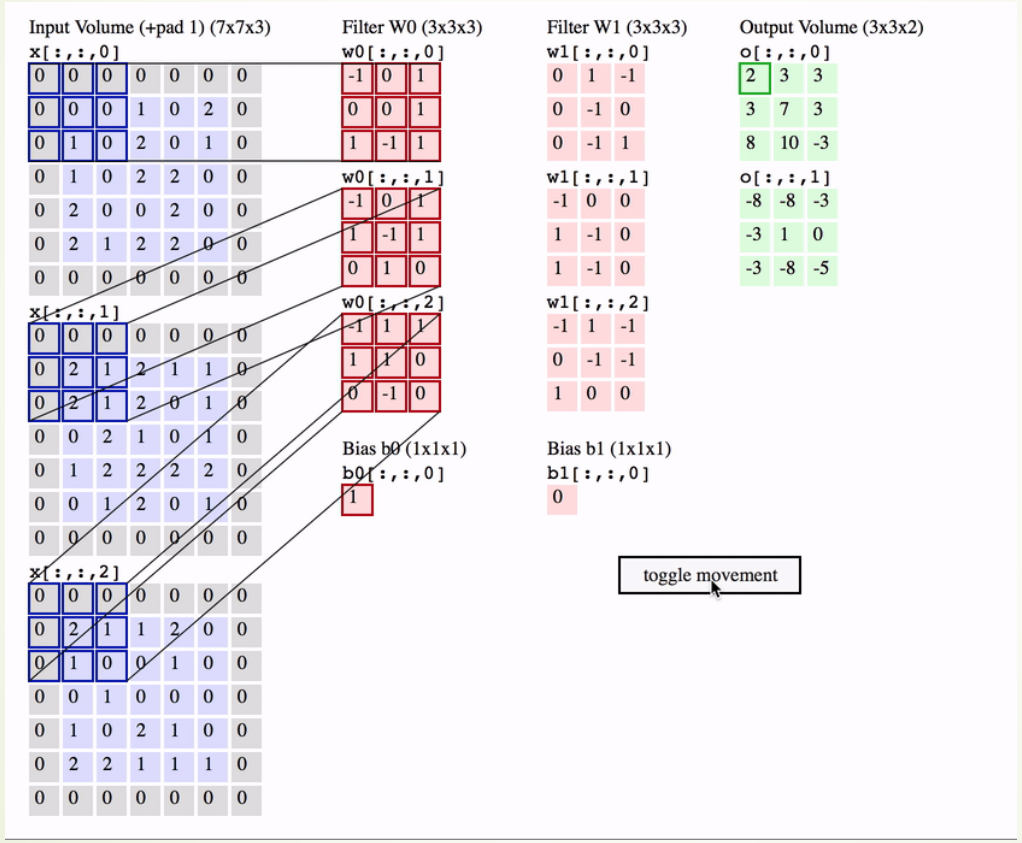
Machine learning is indispensable for computer vision!

Computer vision with deep learning

Deep learning
=
Convolutional neural network with many layers

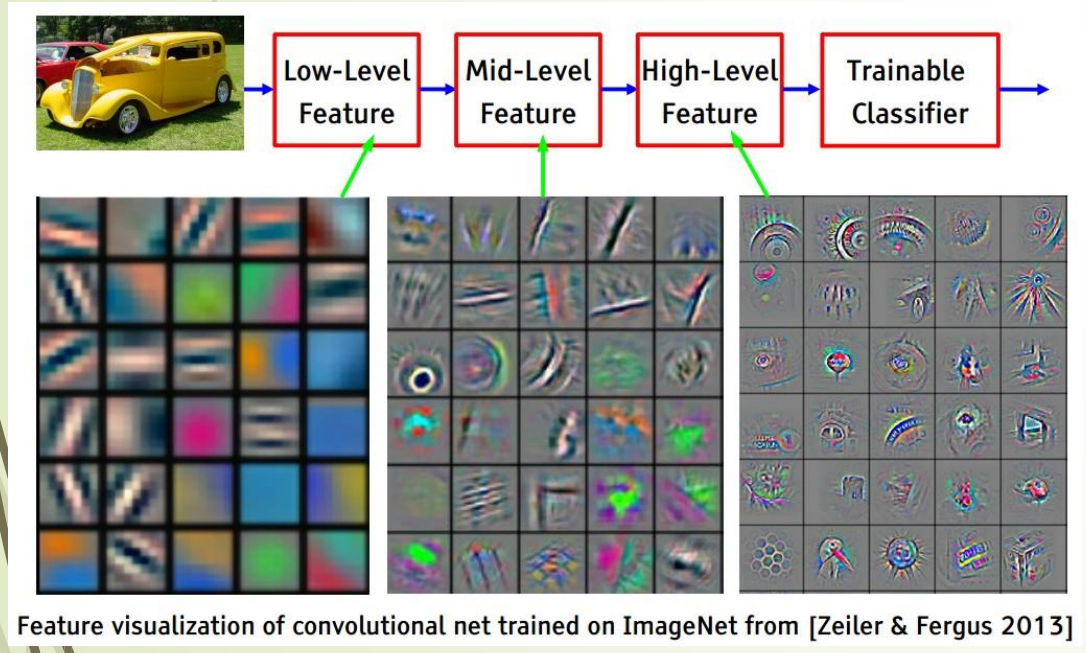


Convolution revolution!

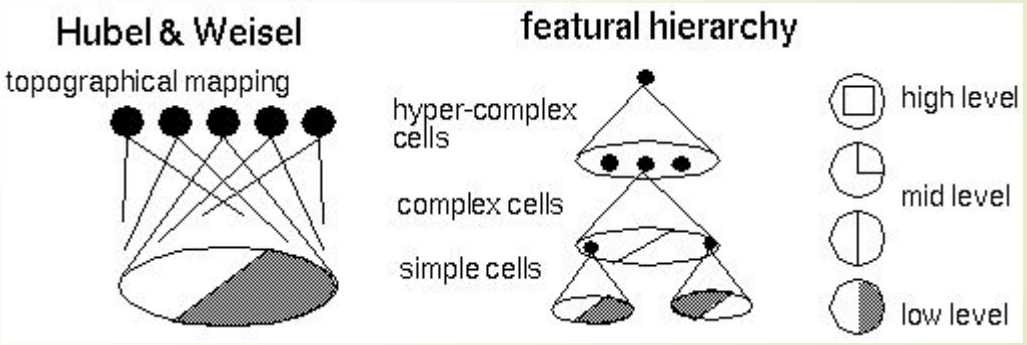


Source: http://cs231n.github.io/convolutional-networks/

Hierarchical representation by deep learning



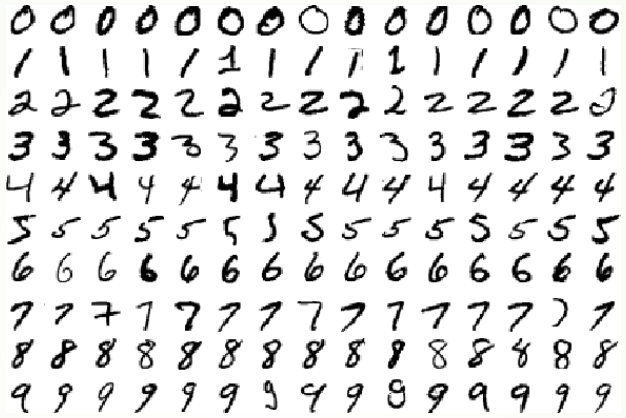
Feature visualization of convolutional net trained on ImageNet from [Zeiler & Fergus 2013]



Hubel & Weisel, '62

How do you teach a deep learner?

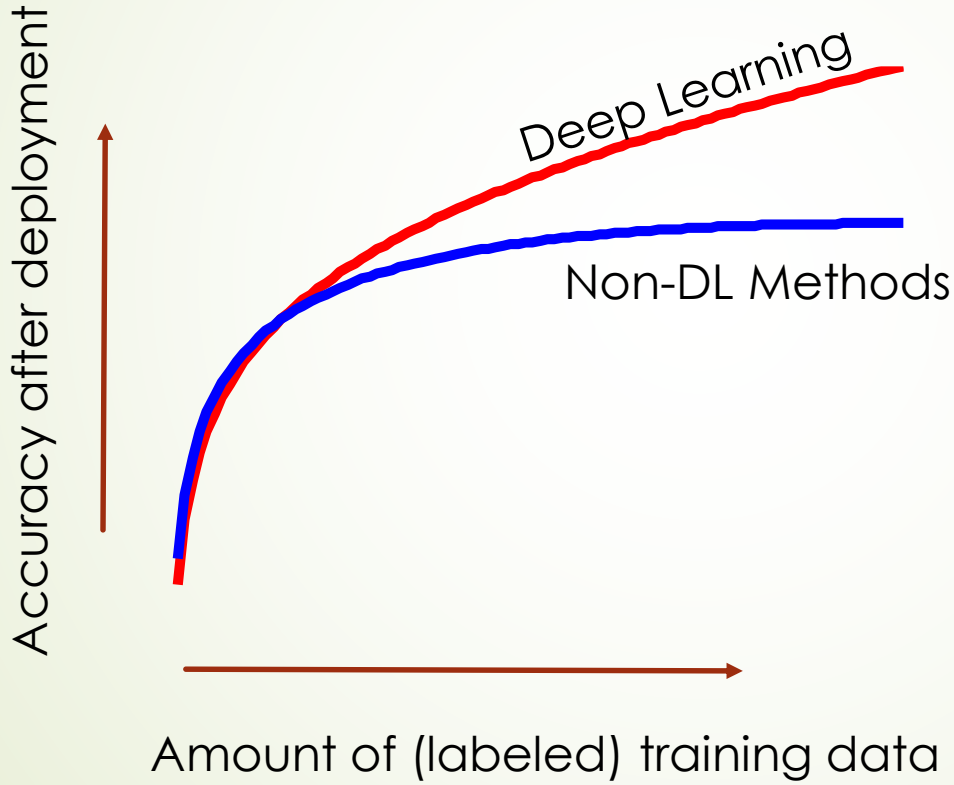
- Step 1: Create training image set (example set):



Repeat steps 2, 3 and 4

- Step 2: Show these examples to the deep learner
- Step 3: Measure mistakes made by the deep learner
- Step 4: Tune (millions of) parameters of the deep learner to minimize its mistakes

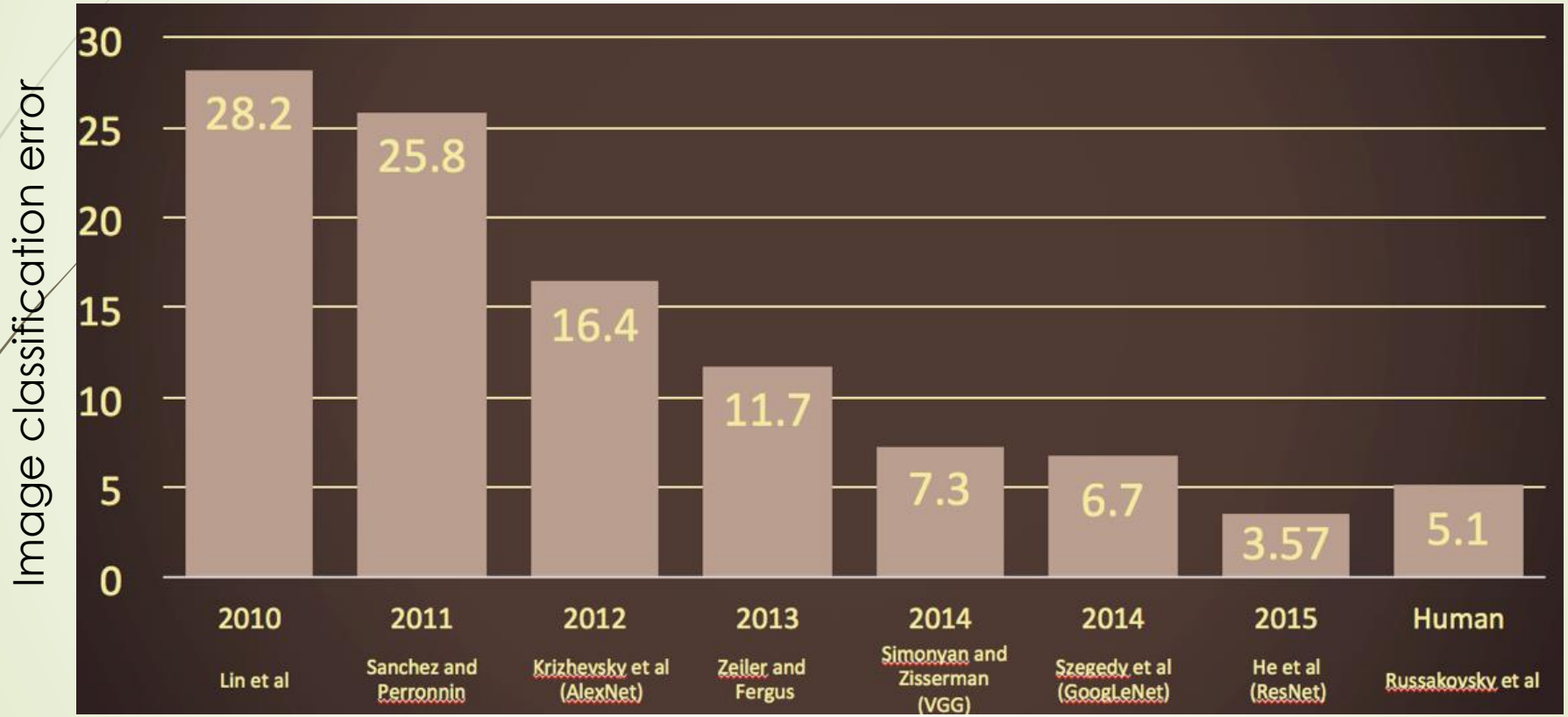
Traditional vs. deep learning…



Success stories of deep learning

Image classification results

ImageNet- Large scale visual recognition challenge: 1000 categories, 1,000,000 images



Computer vision has surpassed human level performance on this benchmark!

Picture courtesy: http://cs231n.stanford.edu/index.html

Large scale video classification

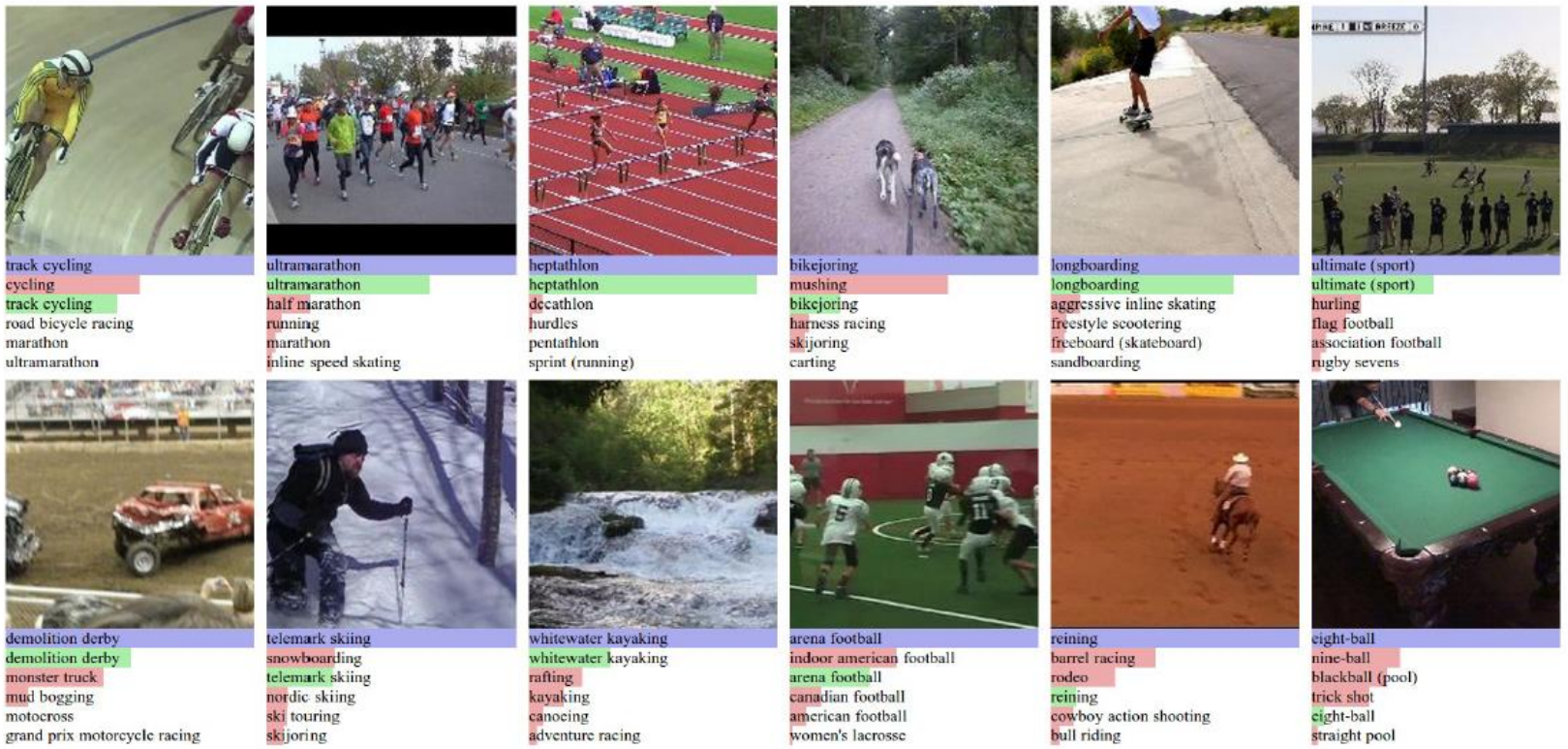


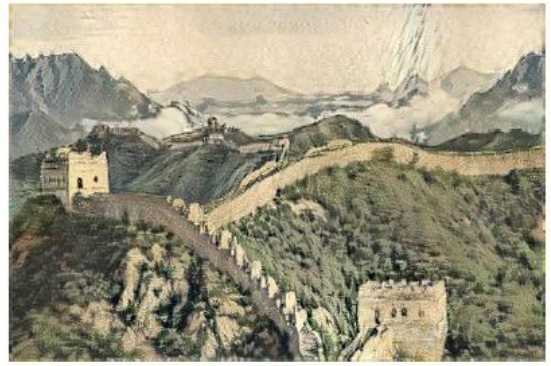
Figure 4: Predictions on Sports-1M test data. Blue (first row) indicates ground truth label and the bars below show model predictions sorted in decreasing confidence. Green and red distinguish correct and incorrect predictions, respectively.

http://cs.stanford.edu/people/karpathy/deepvideo/

Style Transfer

(a) Content

(b) Style



(c) Content + Style

Figure 1. Example of using the Neural Style Transfer algorithm of Gatys *et al.* to transfer the style of Chinese painting (b) onto The Great Wall photograph (a). The painting that served as style is named "Dwelling in the Fuchun Mountains" by Gongwang Huang.

https://arxiv.org/abs/1705.04058

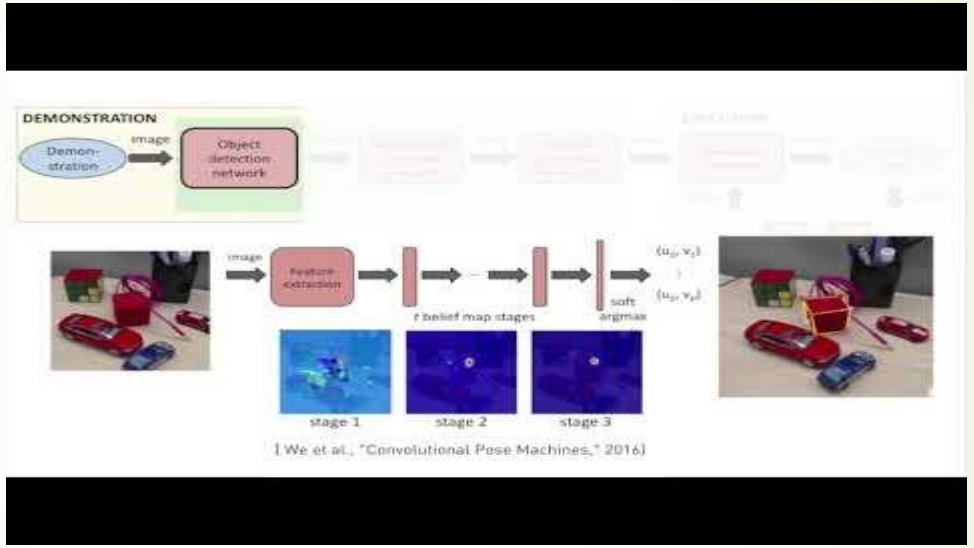
Photorealistic image generation

From NVIDIA research: https://arxiv.org/pdf/1710.10196v1.pdf

Deep reinforcement learning

Picture source: https://deepmind.com/blog/deep-reinforcement-learning/

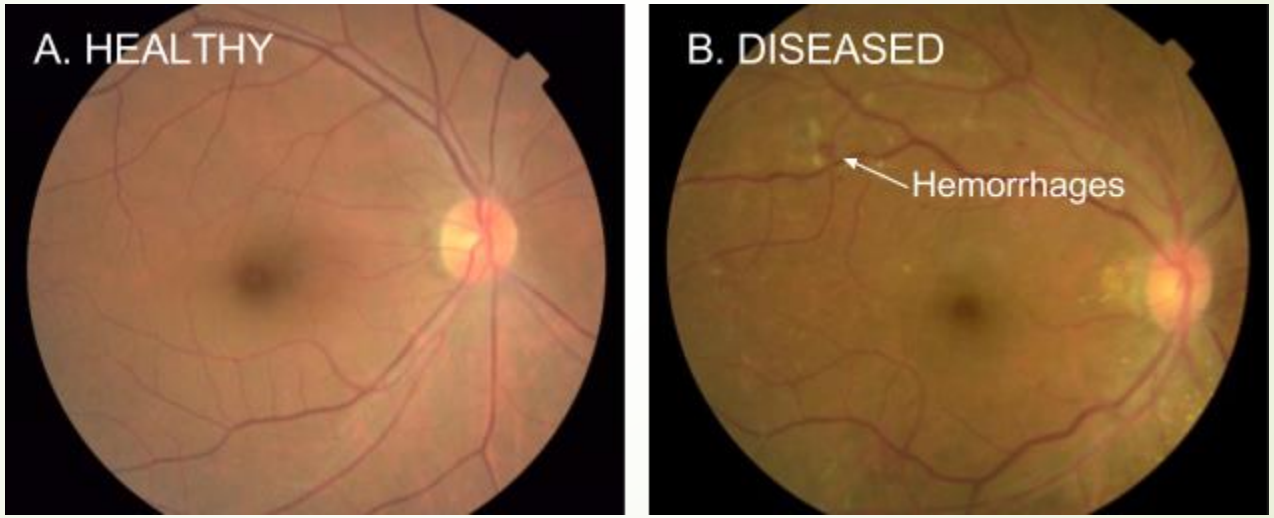
Impressive robotics with deep learning



https://www.youtube.com/watch?v=B7ZT5oSnRys

Applications of deep learning in medical image analysis

Diabetic retinopathy using deep learning



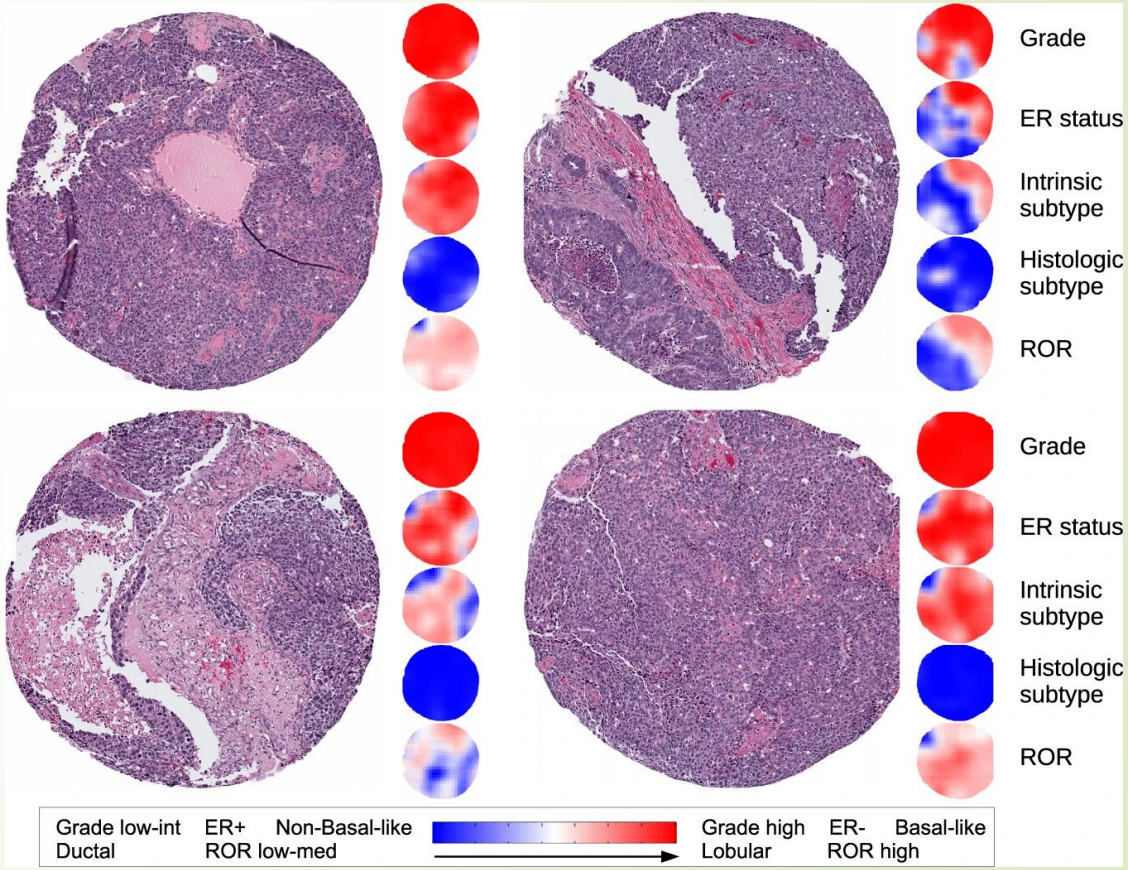
https://ai.googleblog.com/2016/11/deep-learning-for-detection-of-diabetic.html

Skin cancer detection

- Expert level classification accuracy
- Uses deep CNN (inception net)
- Recent studies show DL outperformed most dermatologists (see: https://www.ejcancer.com/article/S0959-8049(19)30221-7/fulltext)

Predicting breast cancer grade

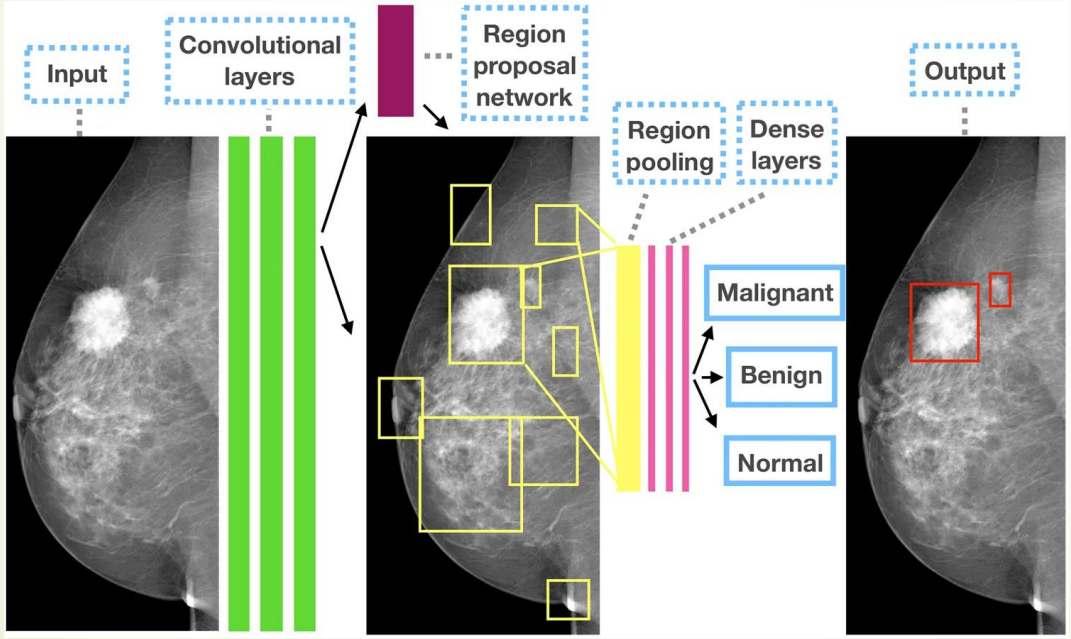
- RNA-based genomic tests are expensive
- H&E image analysis with DL can target right group of patients for genetic tests



https://www.nature.com/articles/s41523-018-0079-1

Mammogram analysis with DL

- Detecting and classifying lesions in mammogram

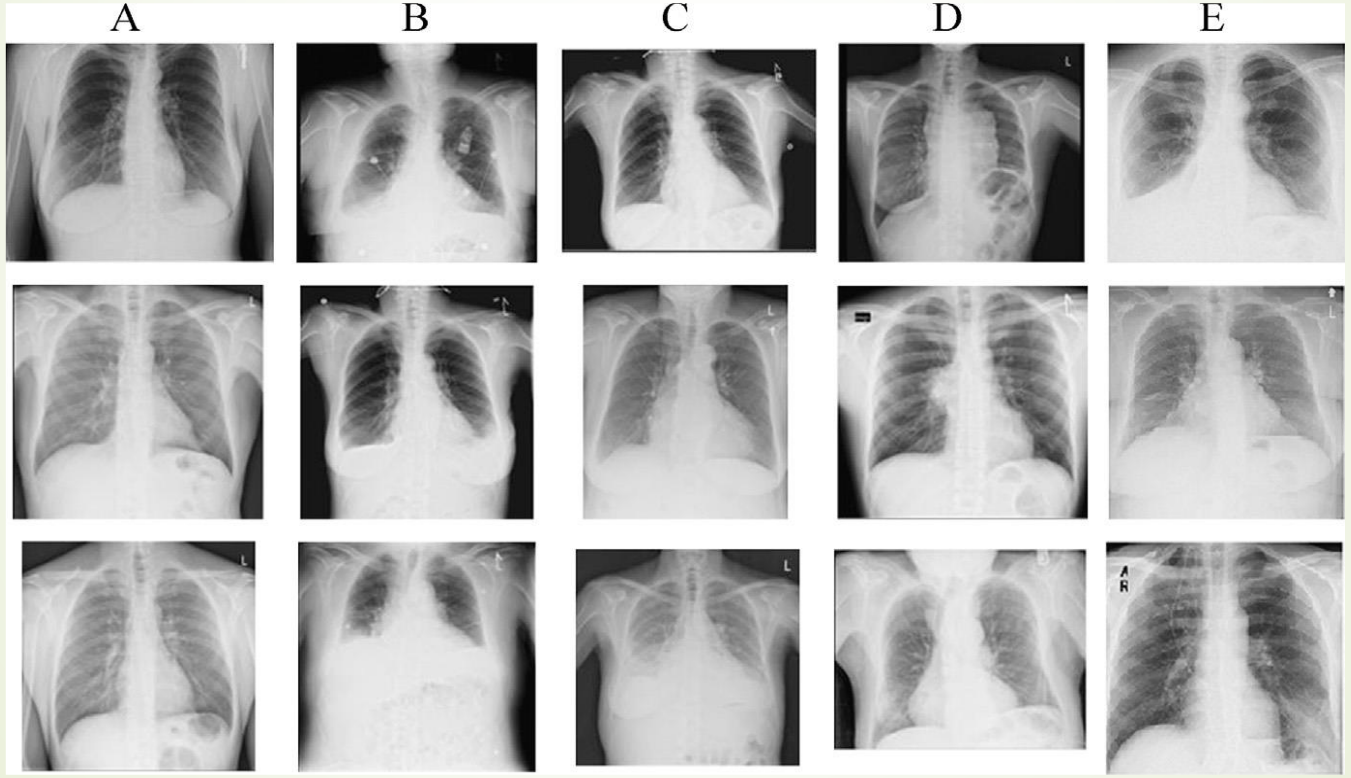


https://www.nature.com/articles/s41598-018-22437-z

MIA tasks with DL

Classification/categorization

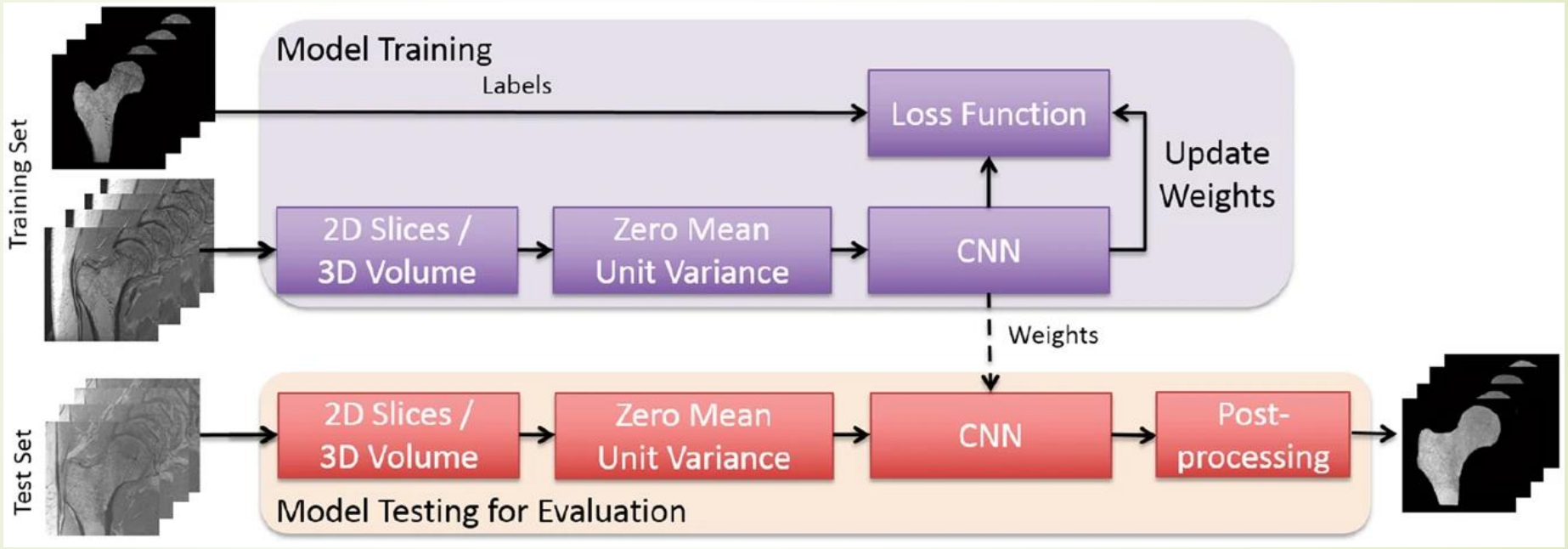
Example: Chest radiograph categorization
(source: Deep learning for medical image analysis by Zhou, Greenspan, Shen)



Chest X-rays categories examples: (A) healthy, (B) left or right pleural effusion, (C) enlarged heart (cardiomegaly), (D) enlarged mediastinum, (E) left or right consolidation.
Source: Diagnostic Imaging Department, Sheba Medical Center, Tel Hashomer, Israel

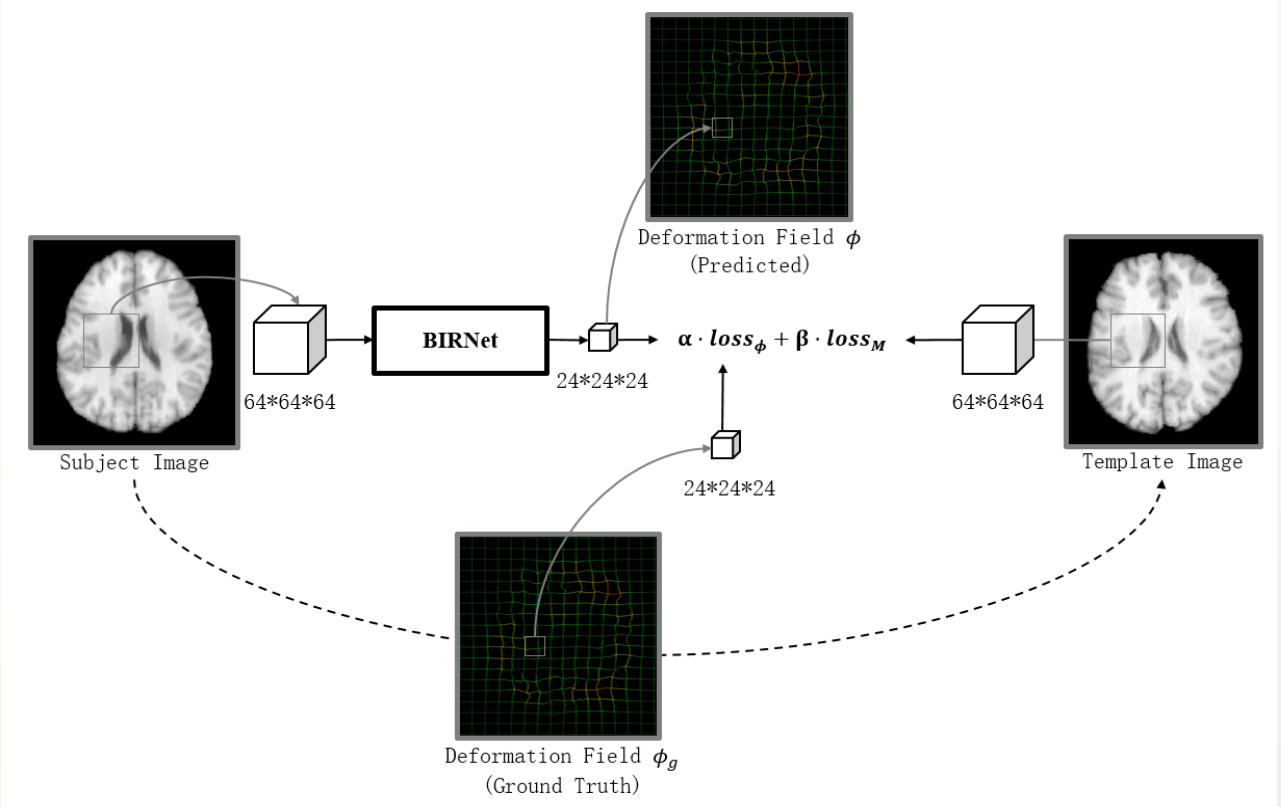
Segmentation

Example: Femur segmentation using CNN
(https://www.nature.com/articles/s41598-018-34817-6)



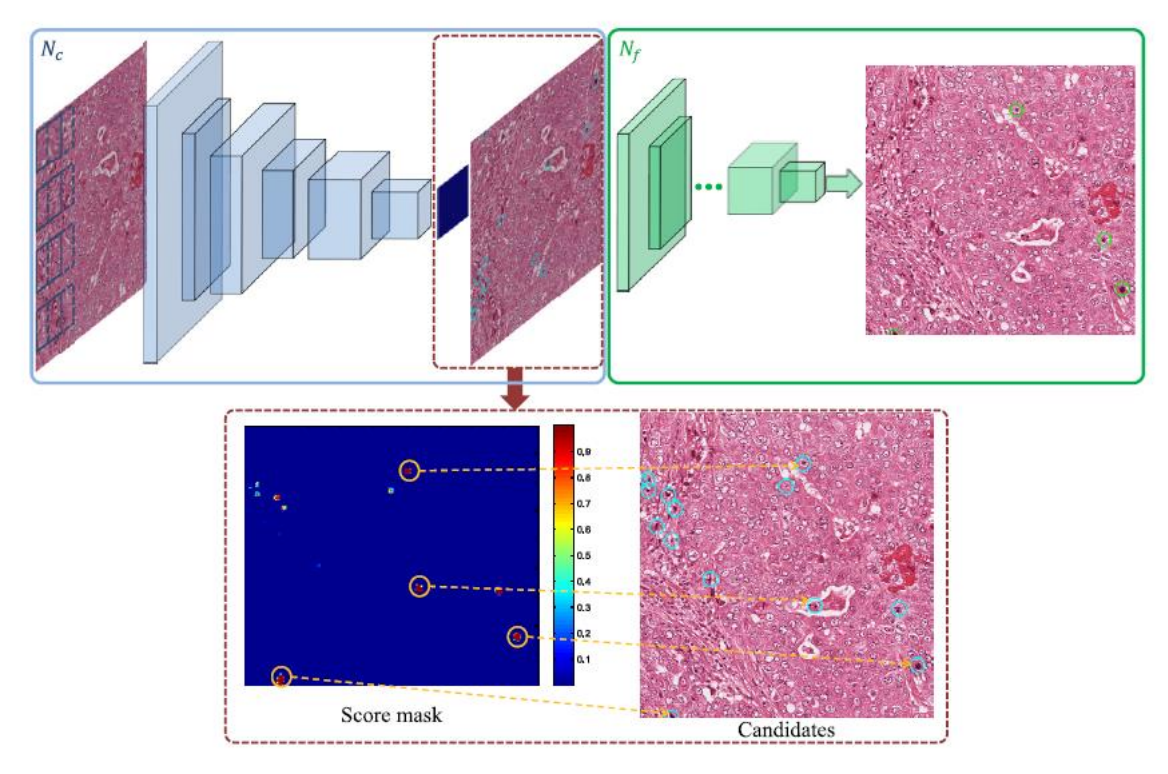
Registration

Example: brain image registration
(https://arxiv.org/ftp/arxiv/papers/1802/1802.04692.pdf)

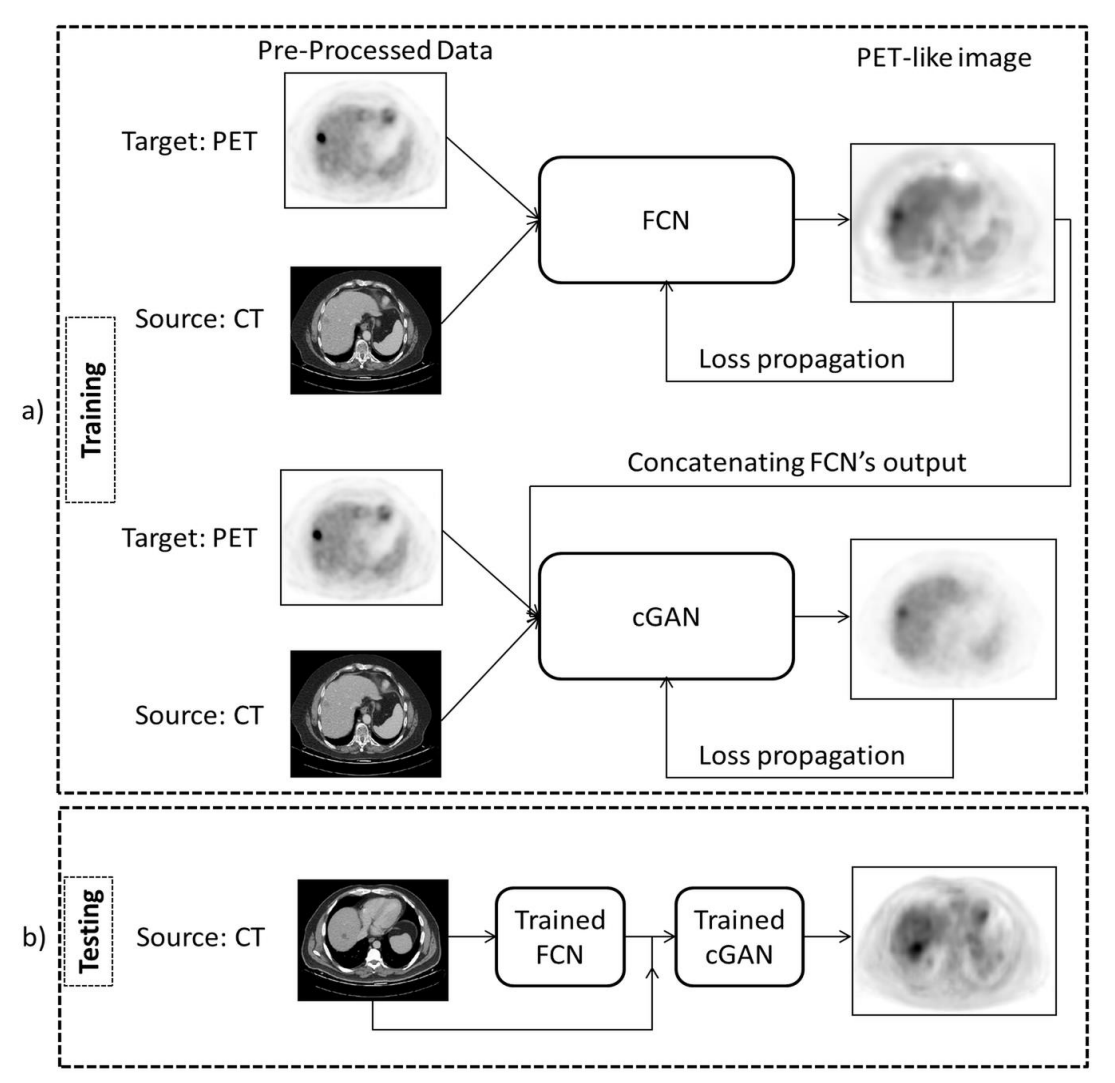


Detection

Example: Mitosis detection
(source: Deep learning for medical image analysis by Zhou, Greenspan, Shen)



Synthesis



Example: CT to PET synthesis (https://arxiv.org/pdf/1802.07846.pdf)

Challenges and future directions

“Big picture” challenges

- Read https://www.nature.com/articles/s41746-019-0155-4
  - Various issues in data including training set bias
  - Political and policy-based challenges in healthcare
- DL is data and computation hungry
  - Power is shifting towards large corporations

DL often requires lots of labeled data

- Read: New York Times article: https://www.nytimes.com/2019/08/16/technology/ai-humans.html?utm_s
- Labeling data in MIA applications is expensive
- Transfer learning from natural images does not always work well

Lack of interpretability

- Interpretability = explaining decision making to humans
- Deep learning systems have poor interpretability
- European Union drafted the General Data Protection Regulation, which will require some interpretability of AI algorithms (https://www.eugdpr.org/, https://arxiv.org/abs/1606.08813)

DL is quite sensitive for intensity changes

- Staining variations in histopathology images cause significant roadblock for deep learning methods (https://www.frontiersin.org/articles/10.3389/fbioe.2019.00198/full)
- Also, read https://arxiv.org/pdf/1902.06543.pdf

Future directions

- Weak supervision and reinforcement learning
- Domain adaptation for intensity variations, so forth
- Object shape modeling
- Unsupervised learning (e.g., for anomaly detection)
- Towards interpretable DL for MIA
- …