Visual Recognition and Deep Learning

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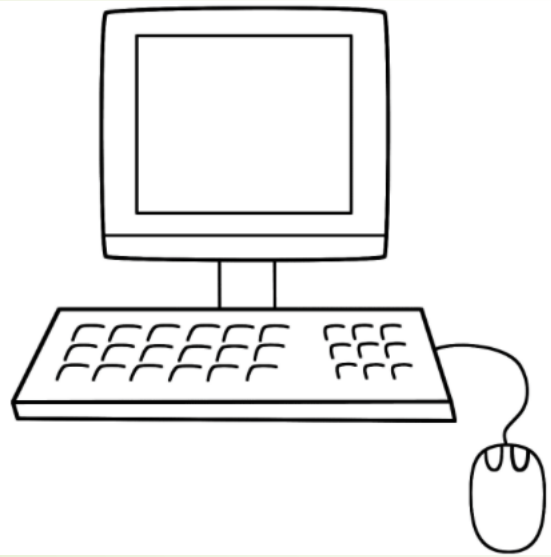
Outline

- What is visual recognition (aka computer vision)?
- What is deep learning?
- Success stories of deep learning
- Limitations of deep learning

What is visual recognition?

Visual recognition…

… is teaching computers to see



Humans see…

Computers see…

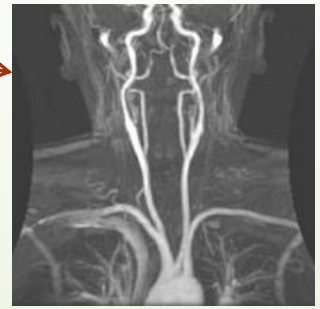
Teaching computers to “see” like humans

“see” not just RGB data

- IR (infrared) etc
- ToF camera (Time of Flight)
  - ‘range’ camera gives depth
- Medical
  - ultrasonography
  - MRI
- & more

LIDAR
(laser radar)

Kinect



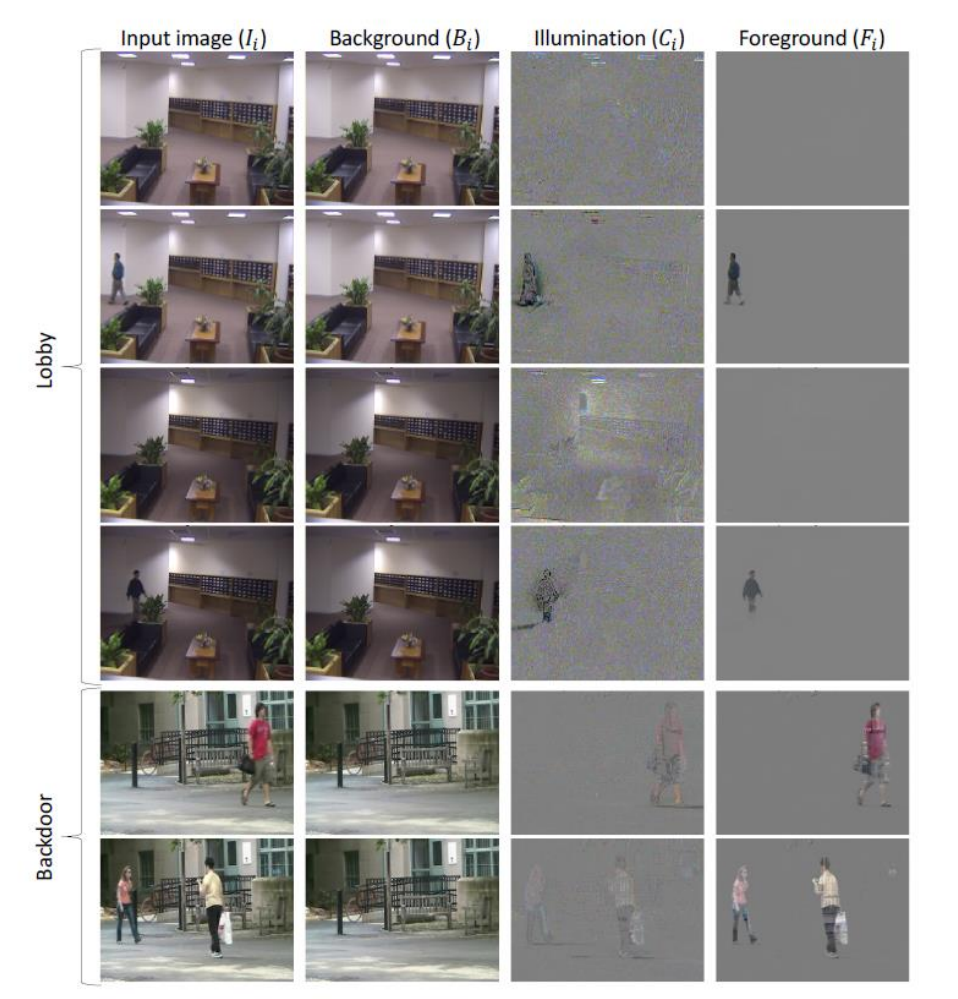
Example: Automated animal recognition

Research with ACAMP
(https://www.acamp.ca/)

Example: Vehicle detection and visual tracking

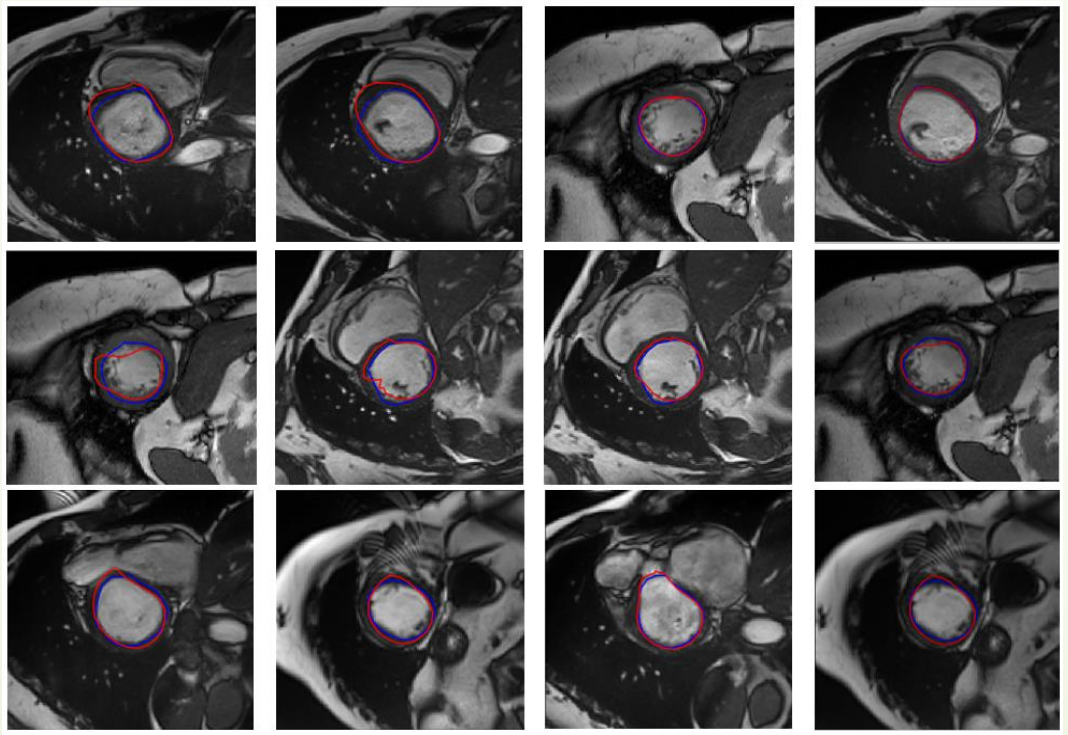
Research with ISL Engineering
(http://islengineering.com/)

Example: Background modeling and moving object detection



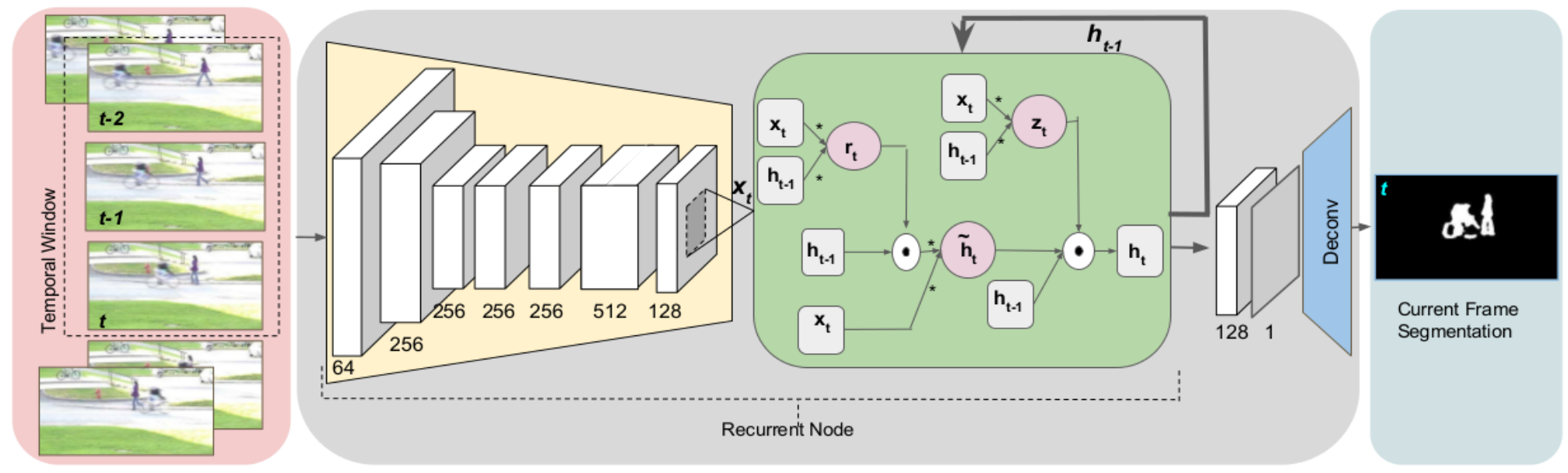
https://arxiv.org/abs/1808.01066

Example: Deformable image registration



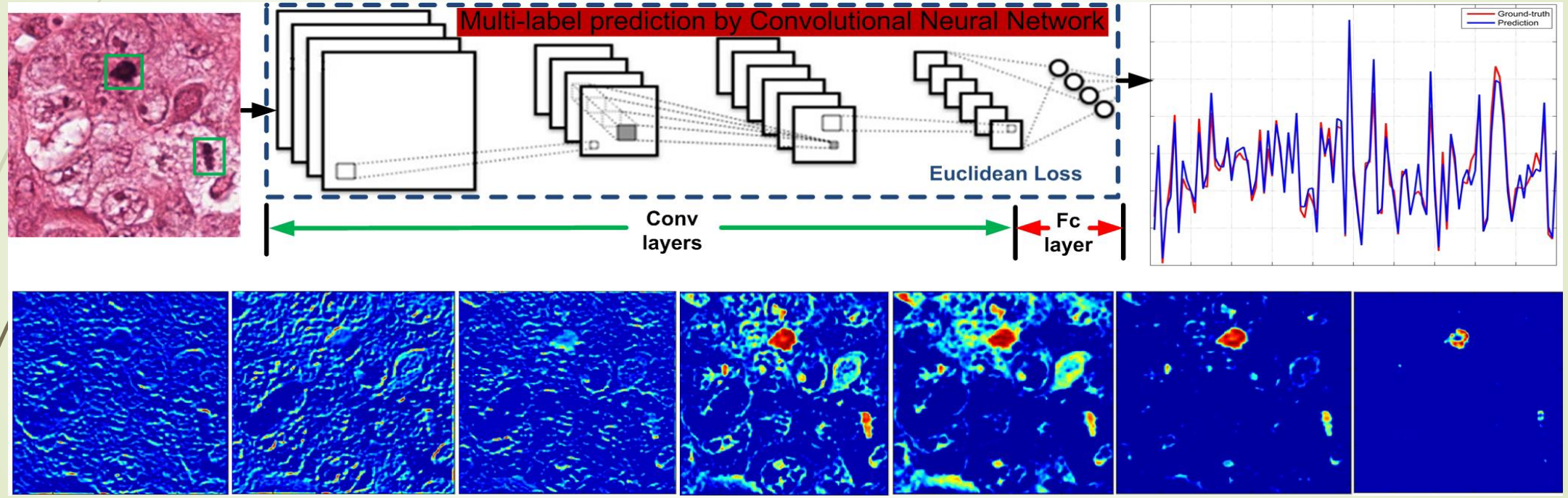
https://openreview.net/forum?id=HkmkmW2jM

Example: Video segmentation



https://ieeexplore.ieee.org/abstract/document/8296851/

Example: Cell detection from microscopy image



https://arxiv.org/abs/1708.03307

The holy grail of computer vision/visual recognition

The grand goal of computer vision is human-like, automated scene understanding.

This is where the state of the art (deep learning algorithm) today:

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

"a young boy is holding a baseball bat."

“a horse is standing in the middle of a road.”

Picture source: http://cs.stanford.edu/people/karpathy/deepimagesent/

What is deep learning?

How does computer vision work?

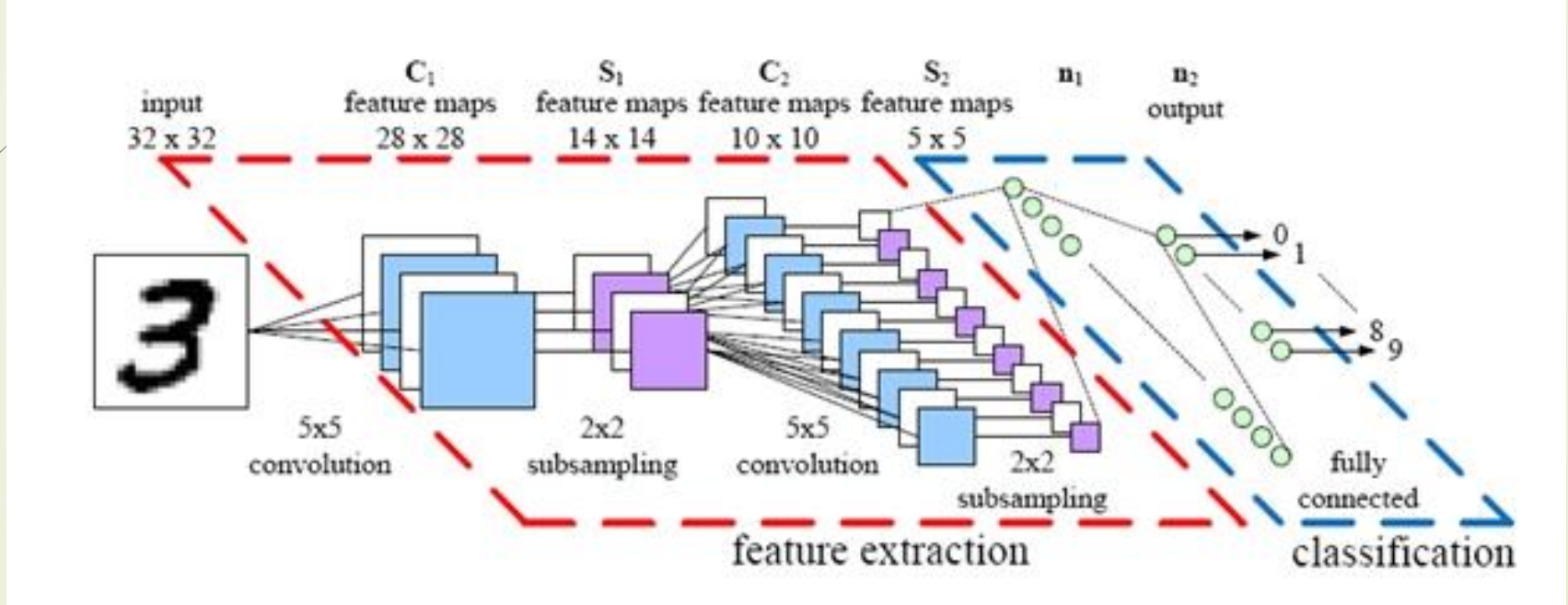
- Let's consider object recognition tasks.

- 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!

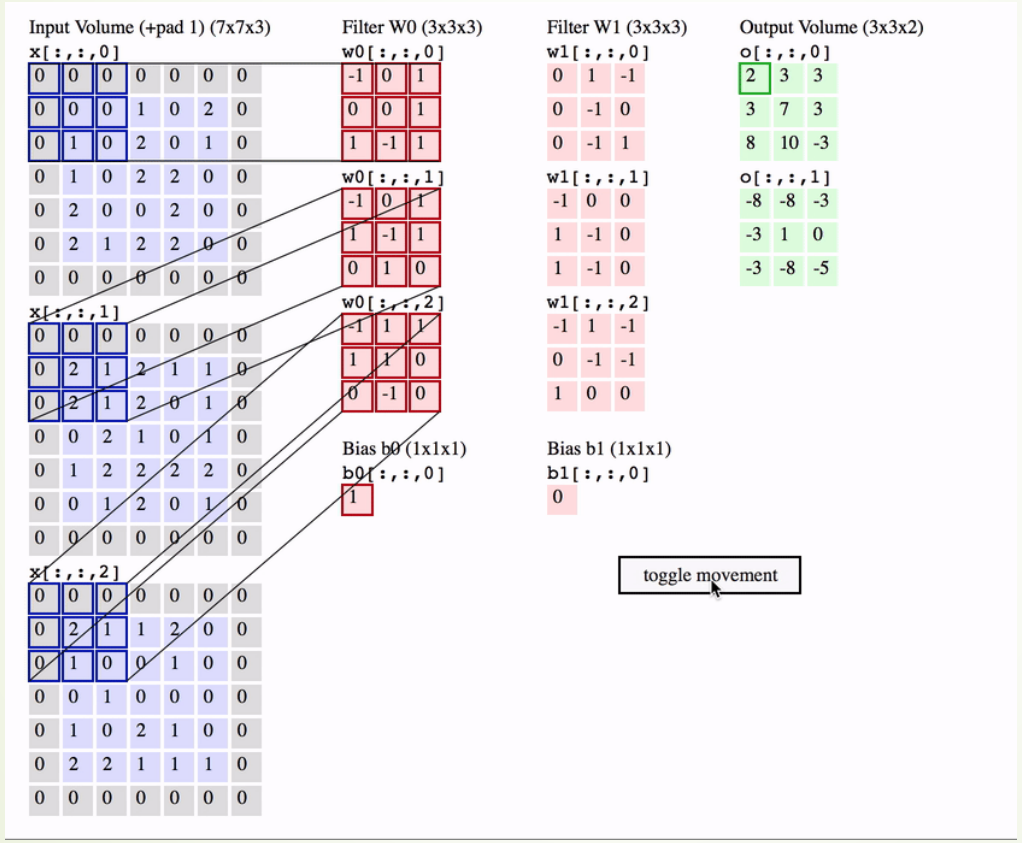
Machine learning is indispensable for computer vision!

Computer vision with deep learning

Deep learning
=
Convolutional neural network with many layers

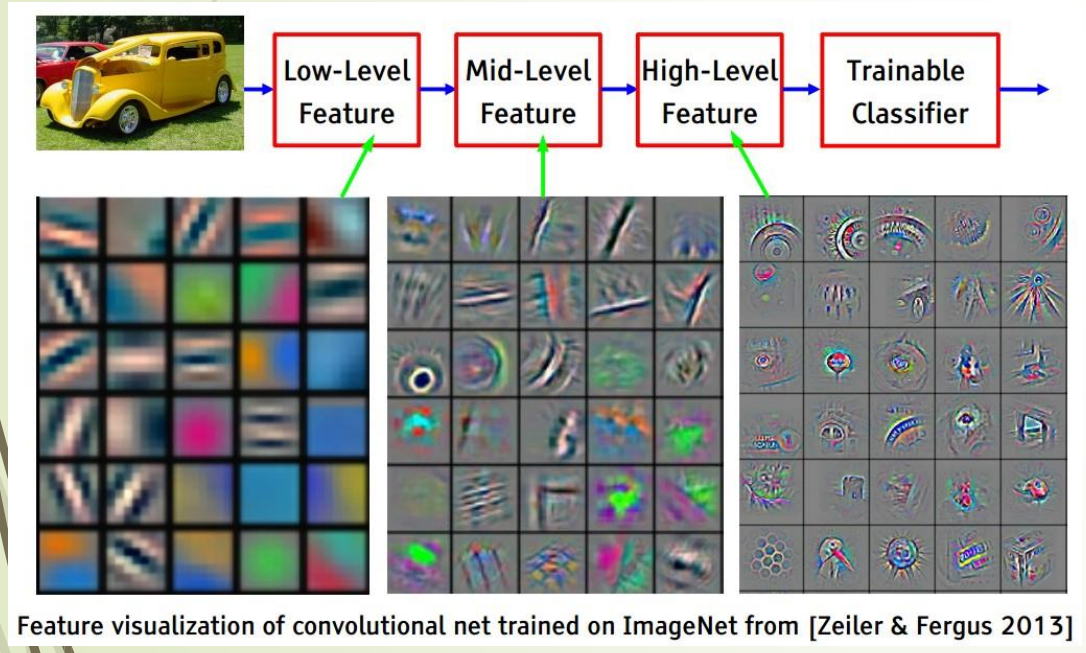


Convolution revolution!

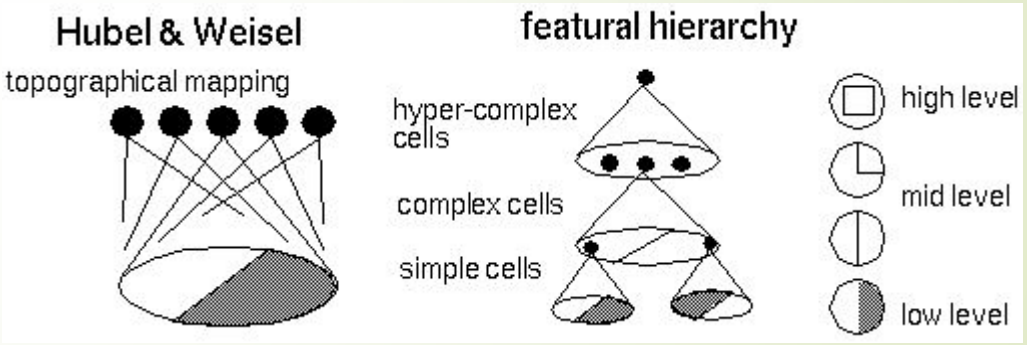


Source: http://cs231n.github.io/convolutional-networks/

Hierarchical representation by deep learning



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



Hubel & Weisel, '62

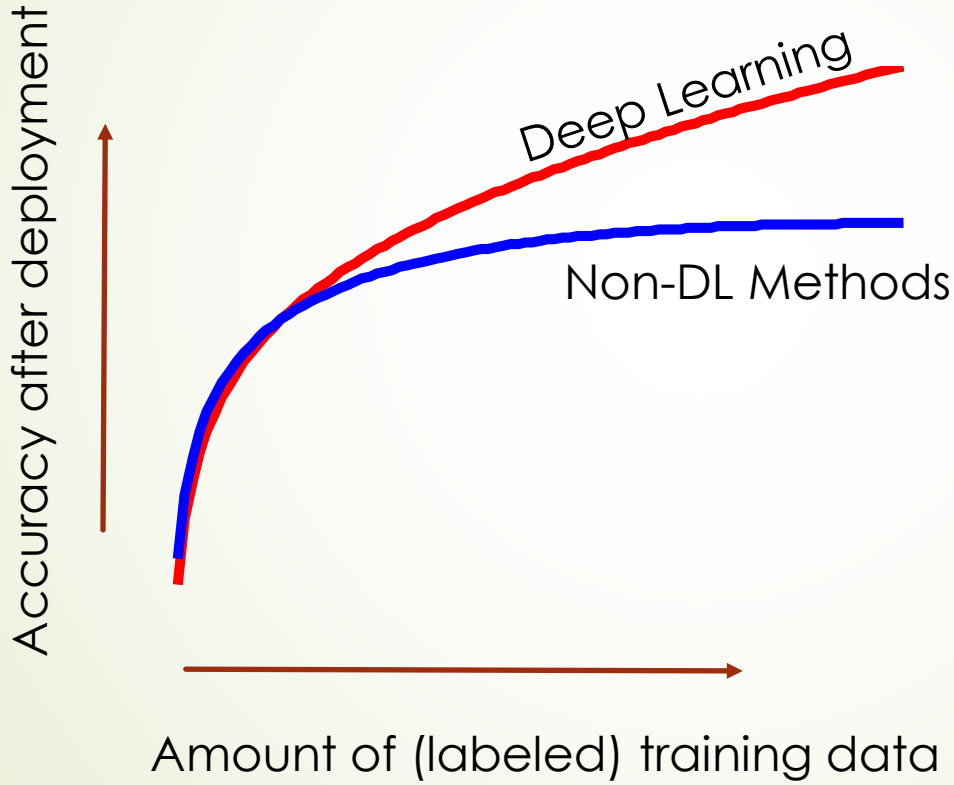
How do you teach a deep learner?

- 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

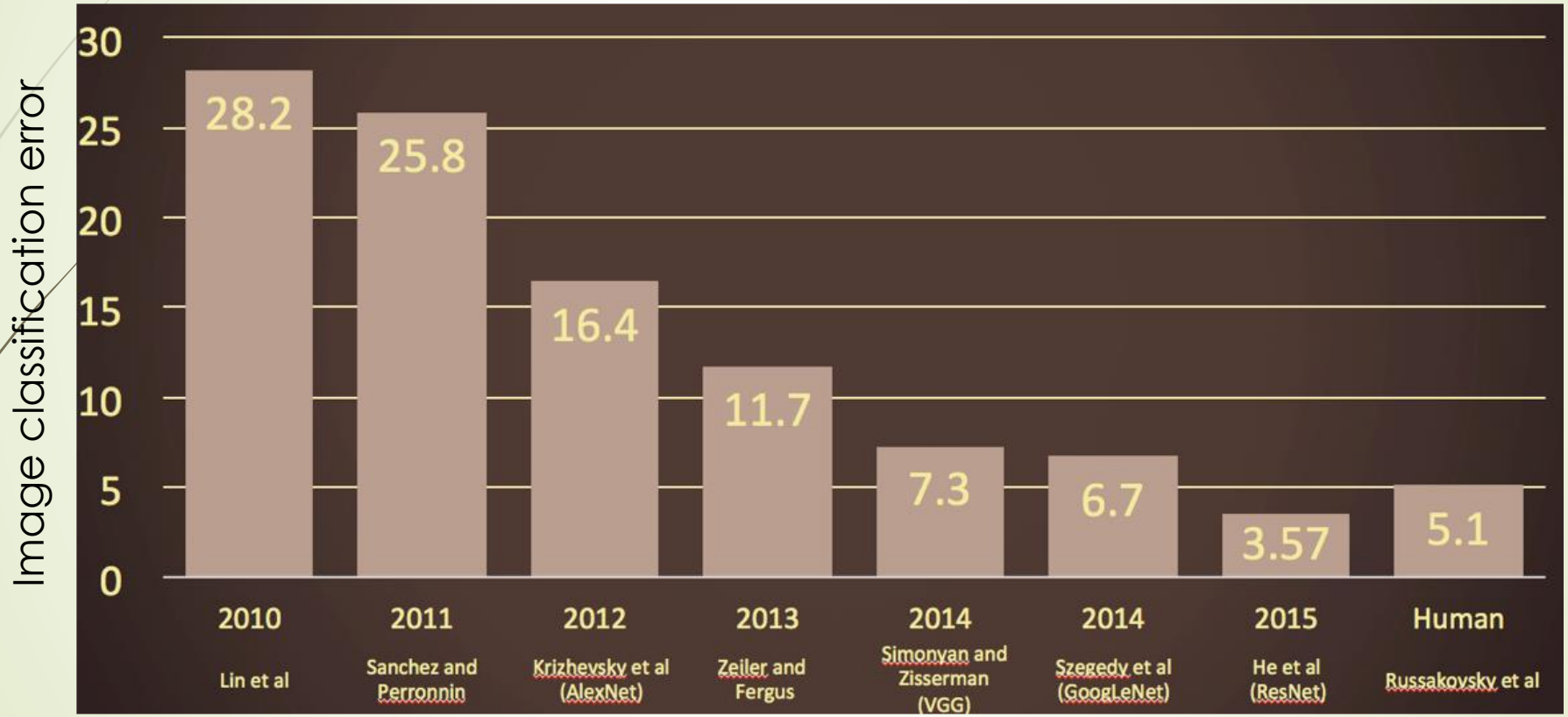
Traditional vs. deep learning…



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

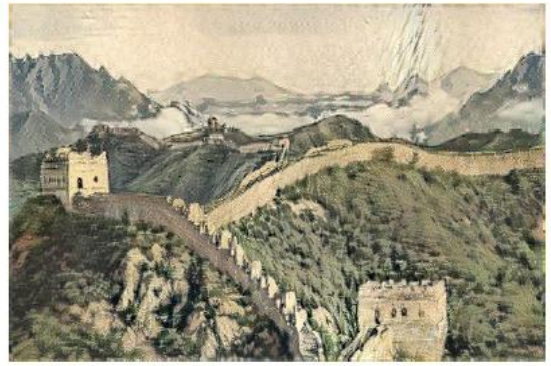
Figure 4: Predictions on Sports-1M test data. Blue (first row) indicates ground truth label and the bars below show model predictions sorted in decreasing confidence. Green and red distinguish correct and incorrect predictions, respectively.

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

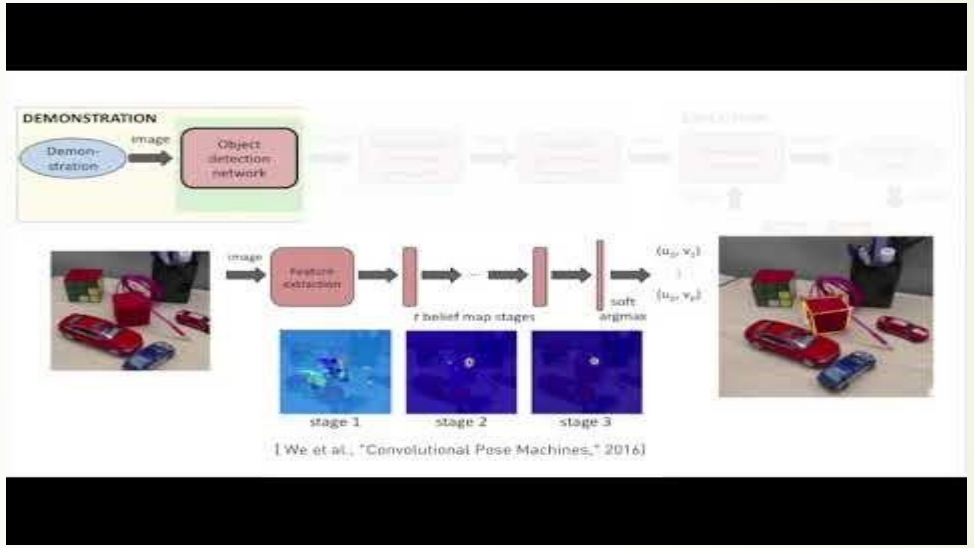
Photorealistic image generation

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

Deep reinforcement learning

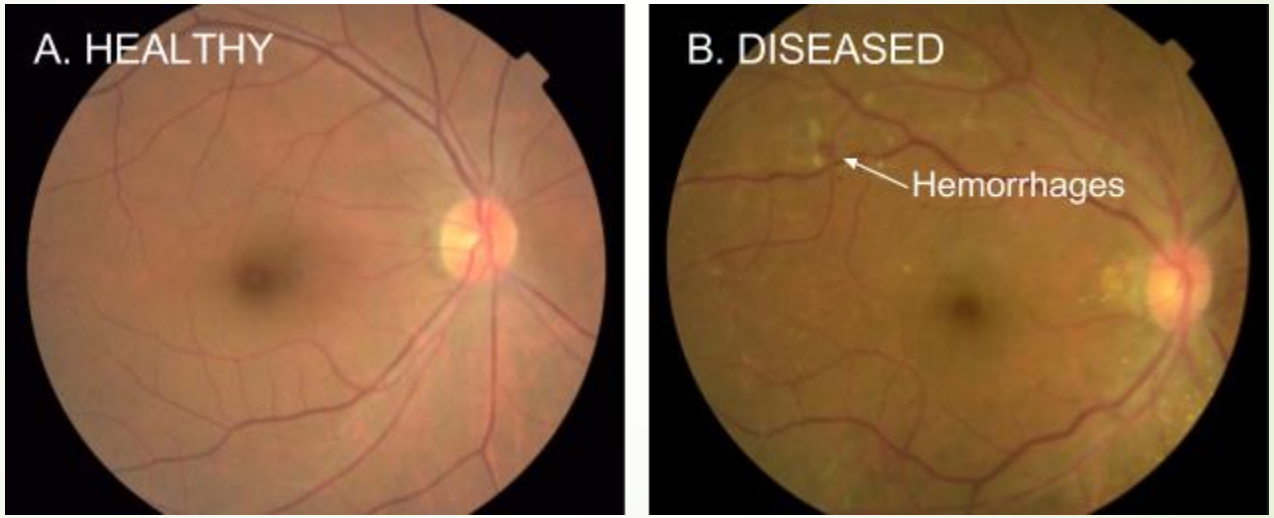
Picture source: https://deepmind.com/blog/deep-reinforcement-learning/

Impressive robotics with deep learning



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

Diabetic retinopathy using deep learning



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

Deep learning and natural language processing

- Impressive developments are happening in the NLP space
- Word embedding
- Language translation
- Language modeling
- GPT-3 (https://en.wikipedia.org/wiki/GPT-3)

http://ruder.io/nlp-imagenet/

What created this revolution?

- Lots and lots of labeled data (such as ImageNet)
- Compute power (parallel processing with GPUs)
- Good old back-prop algorithm + only a few new tweaks! And
- Open source software platforms: TensorFlow, PyTorch,…

Limitations of deep learning

Challenge 1: Labeling of training data

- Manual labeling of lots of images and videos

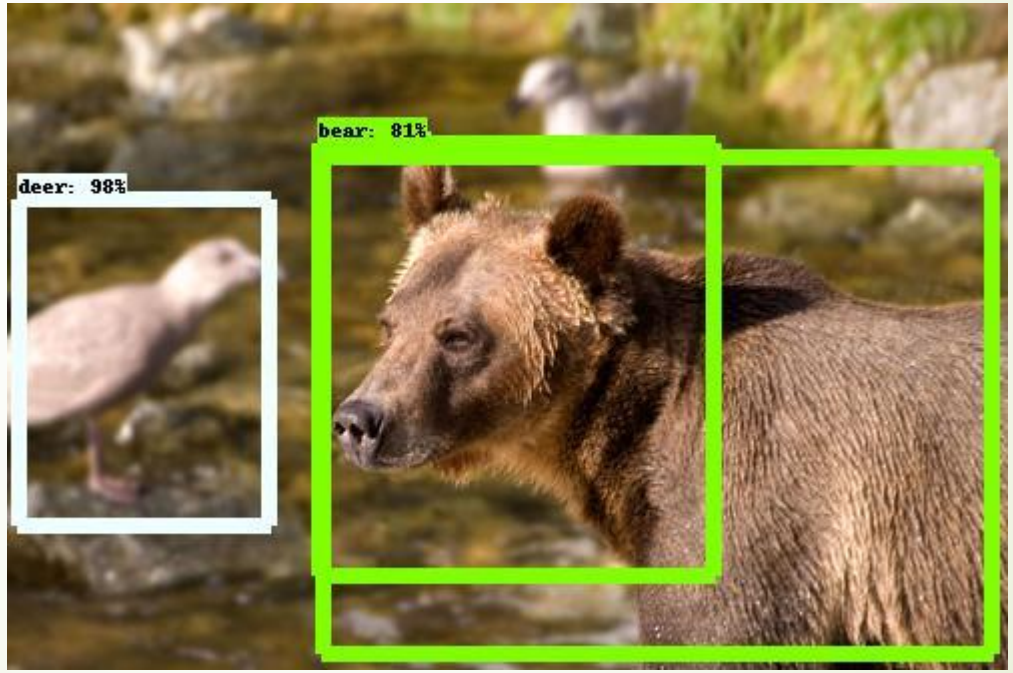
IMAGENET

www.image-net.org

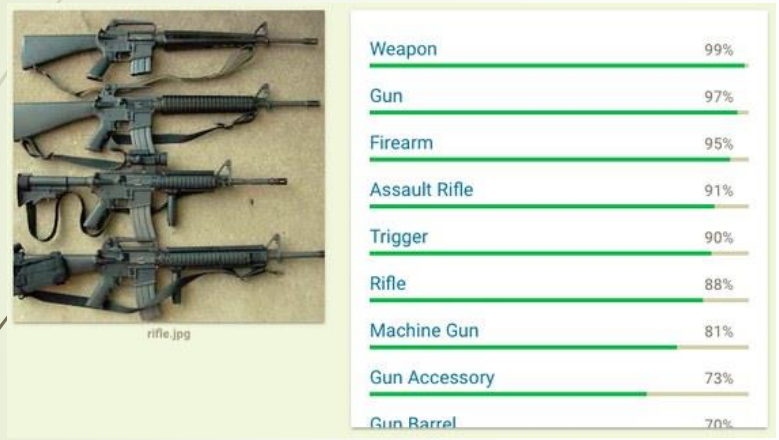
22K categories and **14M** images

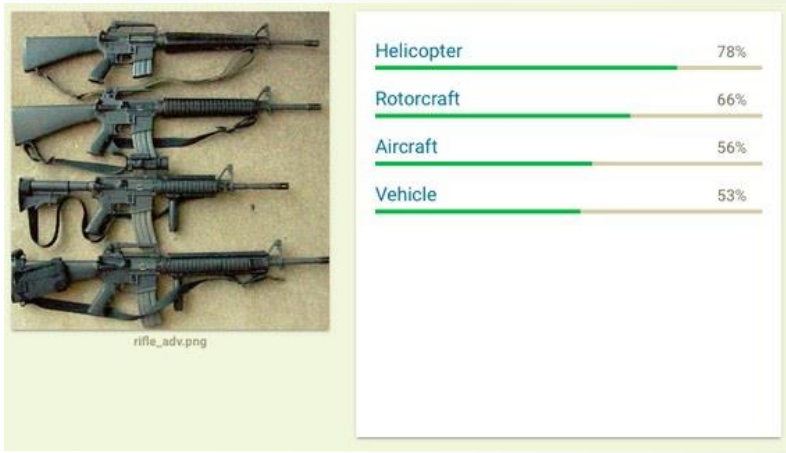
- Animals
  - Bird
  - Fish
  - Mammal
  - Invertebrate
- Plants
  - Tree
  - Flower
- Food
- Materials
- Structures
- Artifact
  - Tools
  - Appliances
  - Structures
- Person
- Scenes
  - Indoor
  - Geological Formations
- Sport Activities

Challenge 2: Task specific / narrow scope



Challenge 3: Can be easily fooled!





Google AI was fooled to believe rifles are helicopters

https://www.wired.com/story/researcher-fooled-a-google-ai-into-thinking-a-rifle-was-a-helicopter/

Challenge 4: Natural language processing

- Gary Marcus on GPT-3
- https://www.technologyreview.com/2020/08/22/1007539/gpt3-openai-language-generator-artificial-intelligence-ai-opinion/

Challenge 5: 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)

Challenge 6: training set and other biases

- Leading commercial gender recognition software (Google, Microsoft, etc.) from face images are biased
- More accurately detect white male faces, than other races, females!
- https://www.youtube.com/watch?v=PWCtoVt1CJM

http://news.mit.edu/2018/study-finds-gender-skin-type-bias-artificial-intelligence-systems-0212

Challenge 7: theoretical understanding is work in progress

- Why deep neural networks are able to optimize learning cost functions with stochastic gradient descent?
- How does depth help?
- Why deep neural networks do not overfit (generalize)?

Deep learning is far from human level intelligence!

- Not even close to a two year human being – a toddler can learn basic laws of physics on his/her own!
- Cannot do "common sense" decision making
- Does not understand causality
- Cannot perform counterfactual inferences well
- Cannot answer open-ended inference problems
- How to go beyond data?

These are open questions in AI research