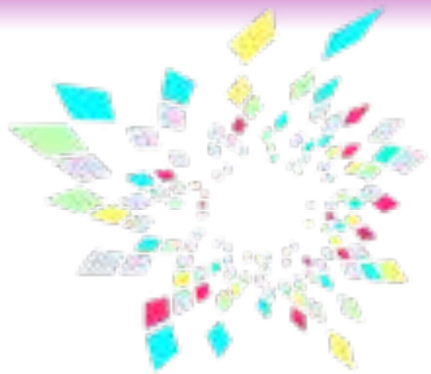


IVADO
INSTITUTE FOR DATA VALORISATION

DEEP LEARNING

Yoshua Bengio

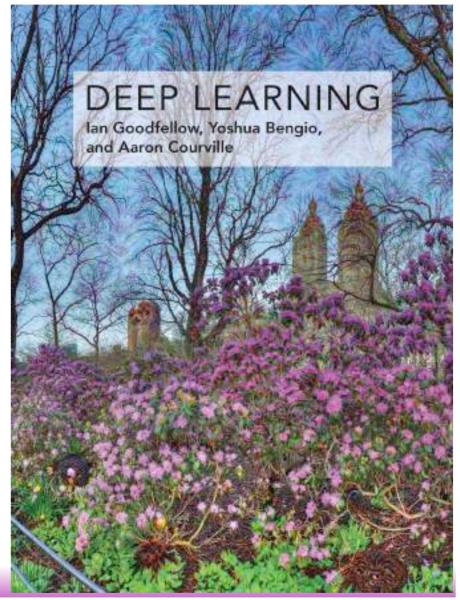
13 December 2016

ICDM'2016, Barcelona

CIFAR
CANADIAN INSTITUTE FOR ADVANCED RESEARCH

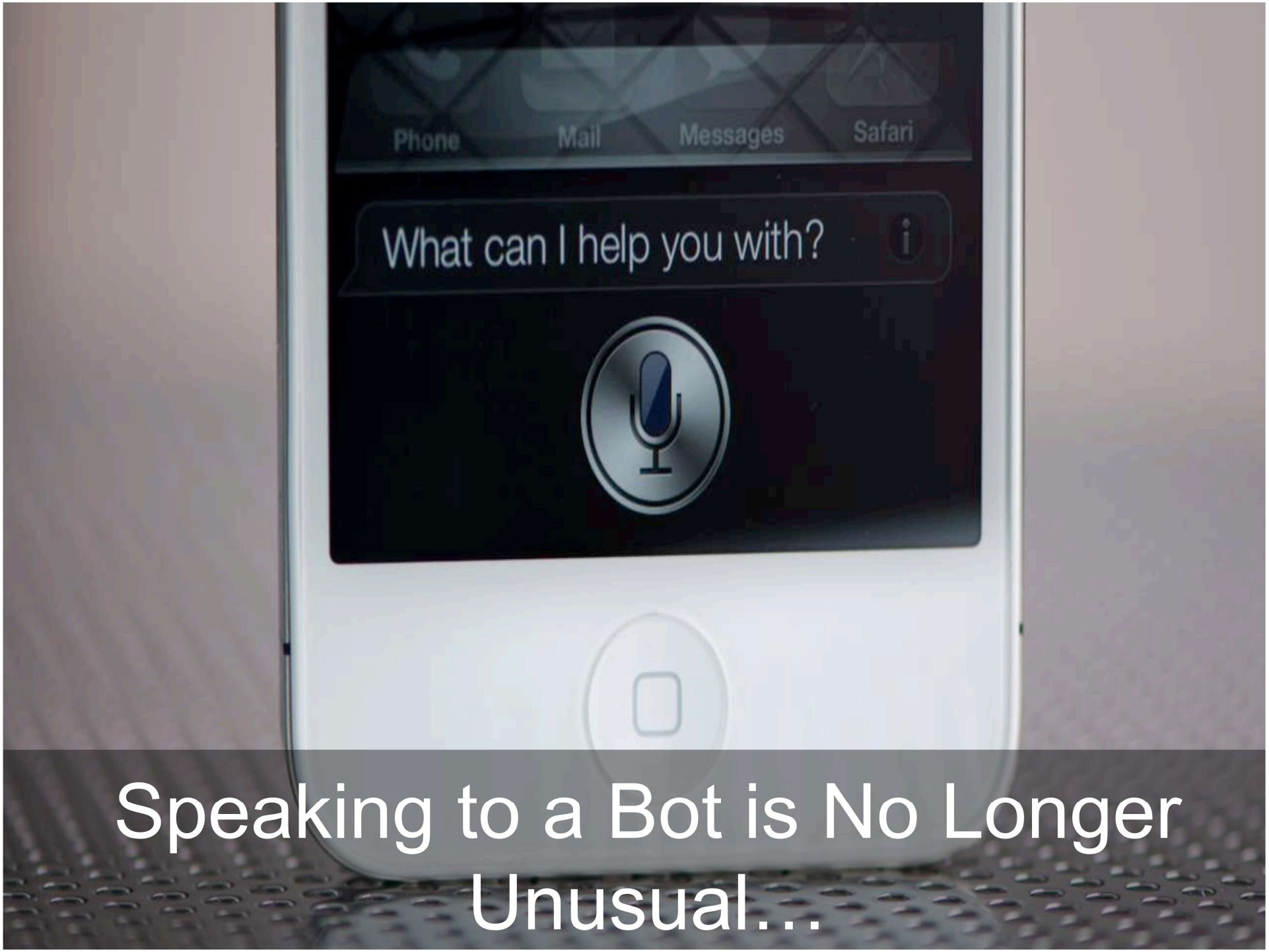
Université de Montréal

PLUG: **Deep Learning**, MIT Press book on sale, chapters online for feedback

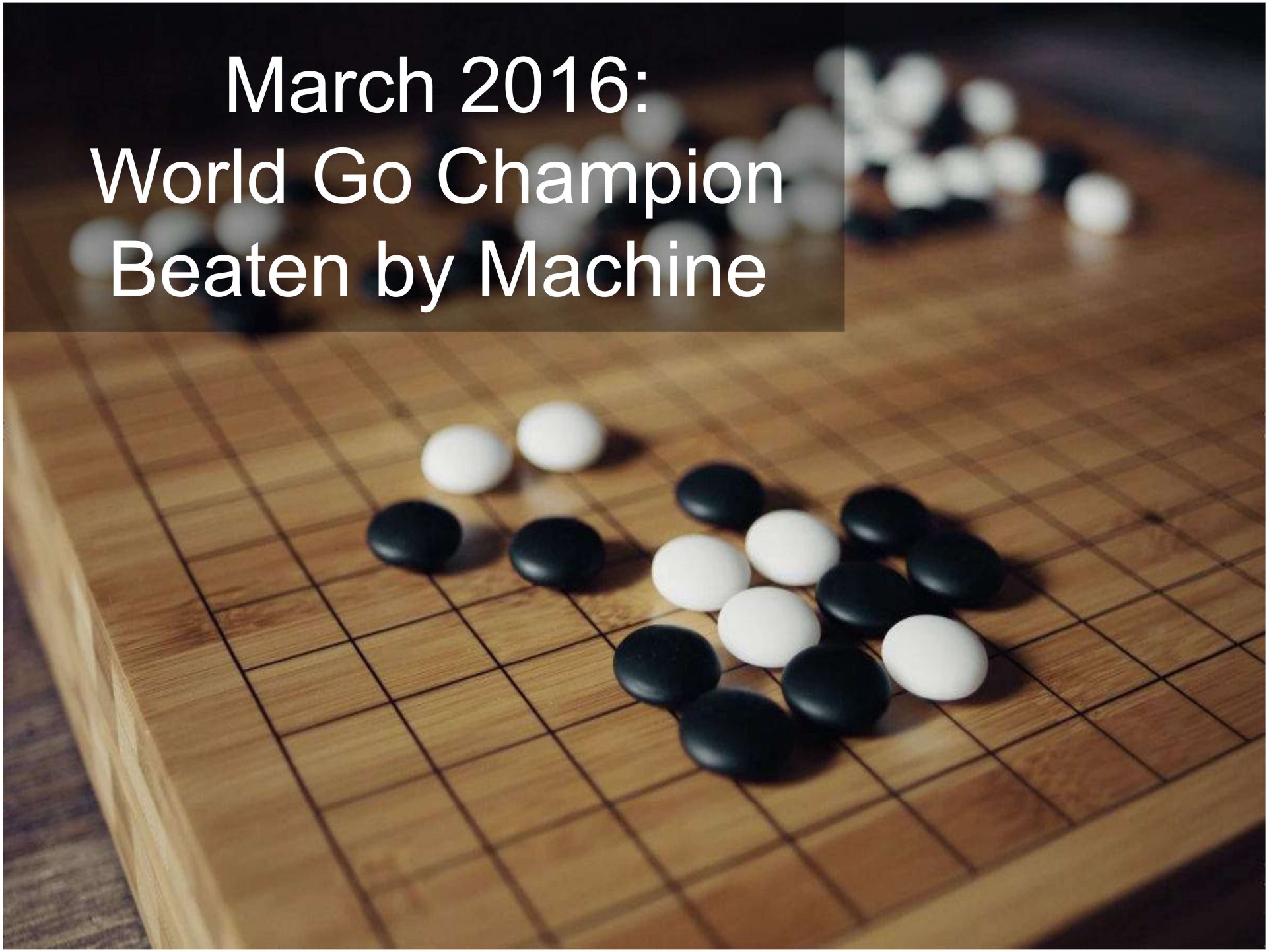


Cars are now driving themselves…

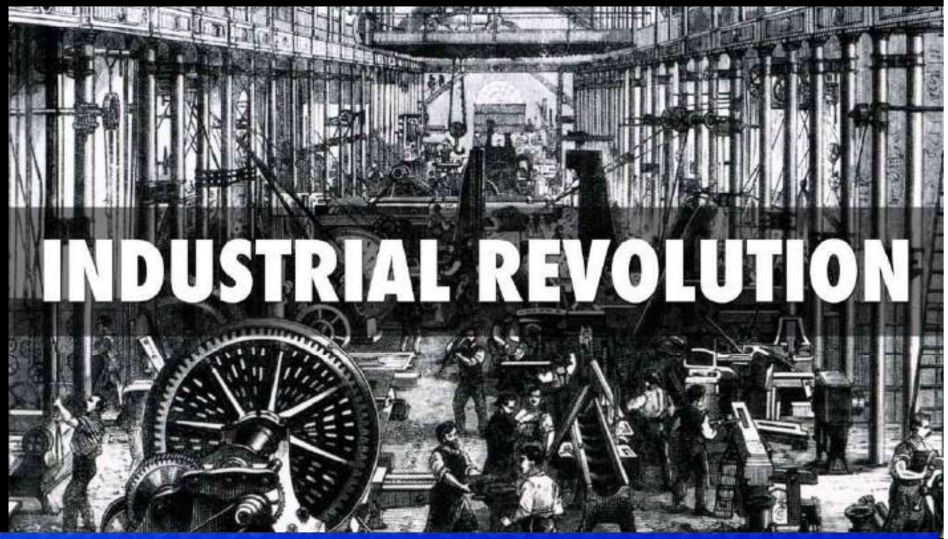
(far from perfectly, though)



Speaking to a Bot is No Longer Unusual…


March 2016:
World Go Champion
Beaten by Machine

AI: The Upcoming Industrial Revolution

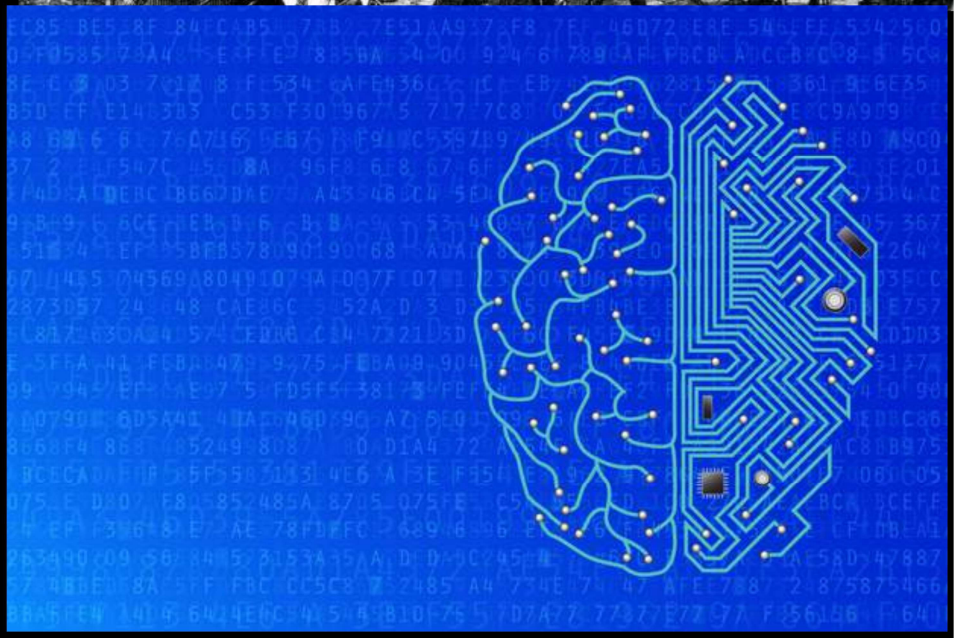


First industrial revolution:

- Machines extending humans' **mechanical power**

Upcoming industrial revolution:

- Machines extending humans' **cognitive power**
  - From the digital economy to the AI economy
  - Predicted growth at least 25%/yr
  - All sectors of the economy



A new revolution seems to be in the work after the industrial revolution.

Devices are becoming intelligent.

And Deep Learning is at the epicenter of this revolution.

Breakthrough in deep learning

A Canadian-led trio at CIFAR initiated the deep learning AI revolution

- Fundamental breakthrough in 2006:

first successful recipe for training a deep supervised neural network

- Second major advance in 2011, with rectifiers
- Breakthroughs in applications since then

AI Needs Knowledge

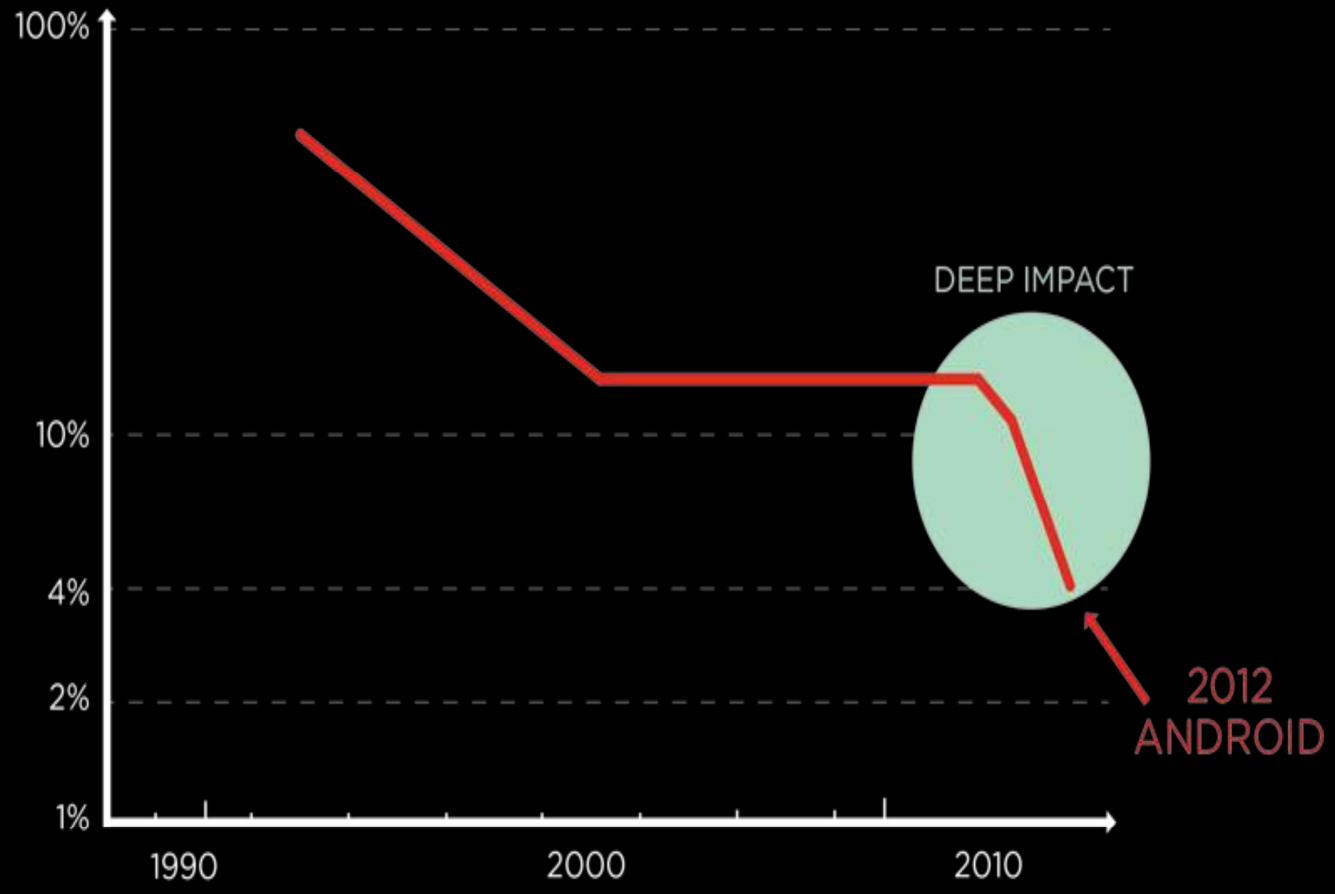
- Failure of classical AI: a lot of knowledge is not formalized, expressed with words
- Solution: computer gets knowledge from data, learns from examples

MACHINE LEARNING

Machine Learning, AI & No Free Lunch

- Five key ingredients for ML towards AI
  1. Lots & lots of data
  2. Very flexible models
  3. Enough computing power
  4. Computationally efficient inference
  5. **Powerful priors that can defeat the curse of dimensionality**

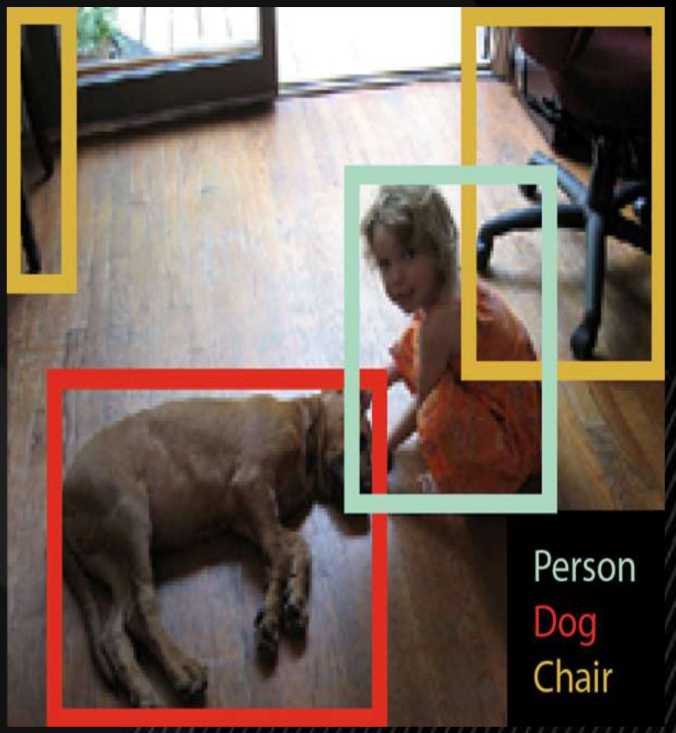
2010-2012: breakthrough in speech recognition



Source: Microsoft

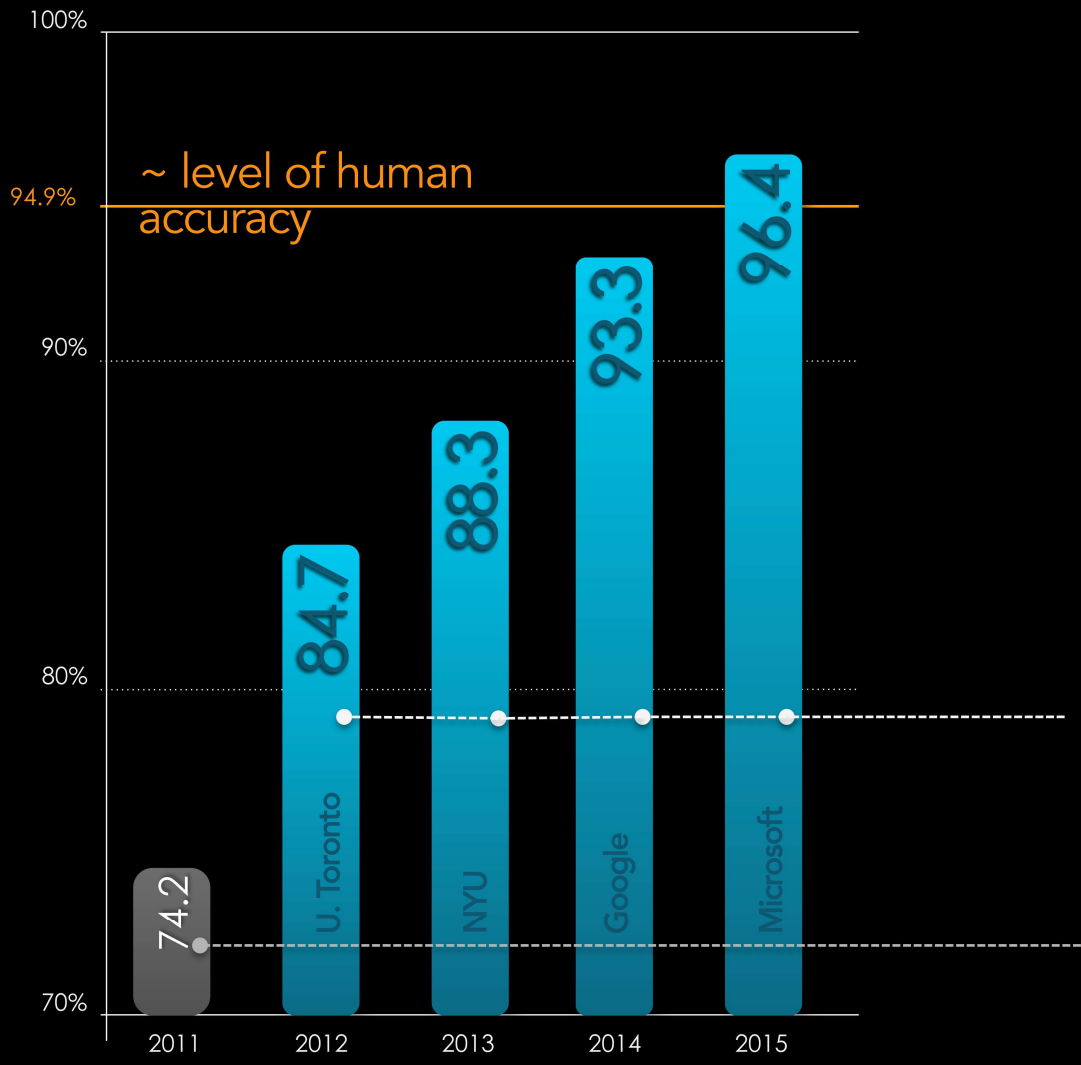
2012-2015: breakthrough in computer vision

- Graphics Processing Units (GPUs) + 10x more data
- 1,000 object categories,
- Facebook: millions of faces
- ***2015: human-level performance***



ImageNet Accuracy Still Improving

Top-5 Classification task



Use of
Deep Learning
over
Conventional
Computer Vision

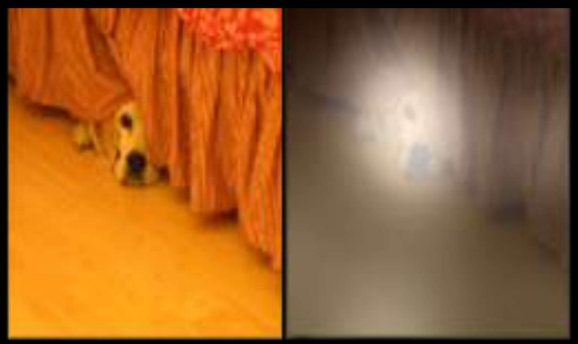
IT companies are racing into deep learning

From computer vision to self-driving cars: 2016

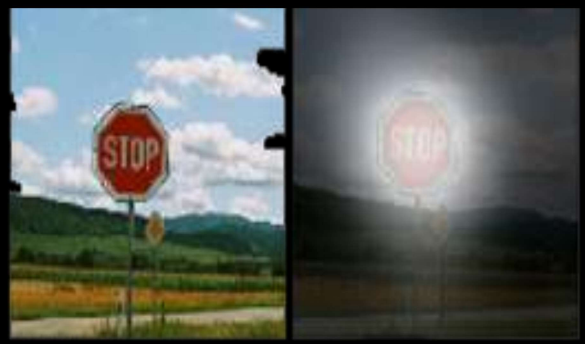
Holmdel, New Jersey
February 2016

Ongoing progress: combining vision and natural language understanding

A woman is throwing a frisbee in a park.



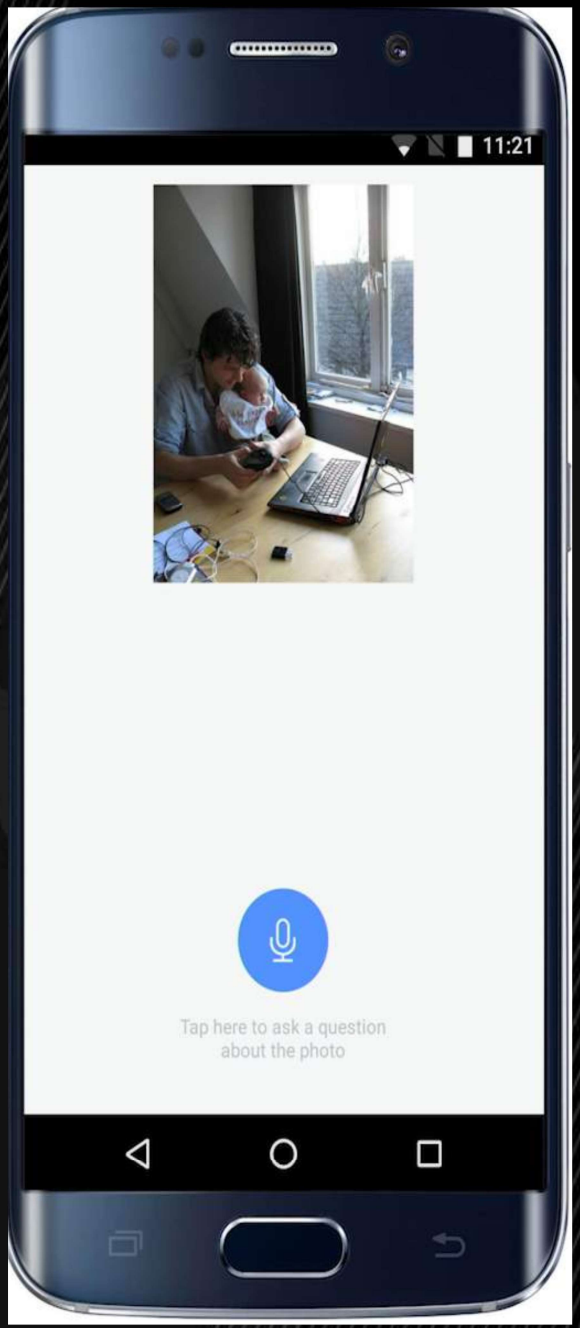
A dog is standing on a hardwood floor



A stop sign is on a road with a mountain in the background

With a lot more data…

visual question answering



Deep Learning: Beyond Pattern Recognition, towards AI

- Many researchers believed that neural nets could at best be good at pattern recognition
- And they are really good at it!

- But many more ingredients needed towards AI. Recent progress:

  - REASONING: with extensions of recurrent neural networks
    - Memory networks & Neural Turing Machine

  - PLANNING & REINFORCEMENT LEARNING: DeepMind (Atari and Go game playing) & Berkeley (Robotic control)

The next frontier:
to reason and answer questions

Sam walks into the kitchen.
Sam picks up an apple.
Sam walks into the bedroom.
Sam drops the apple.

Q: Where is the apple?
A: Bedroom

Brian is a lion.
Julius is a lion.
Julius is white
Bernhard is green

Q: What colour is Brian?
A: White

The Biggest Challenge: Unsupervised Learning & Learning Commonsense Autonomously

- Recent progress mostly in supervised DL
- Real technical challenges for unsupervised DL
- Potential benefits:
  - Exploit tons of unlabeled data
  - Answer new questions about the variables observed
  - Regularizer – transfer learning – domain adaptation
  - Easier optimization (local training signal)
  - Structured outputs
  - Necessary for RL without given model or domain simulator

Applications on the horizon

Computer Interaction

Healthcare

Robotics

How to Attract the Best Researchers in Industry

- Extreme current demand for deep learning expertise, crazy salaries and acquisitions
- Not enough trained PhDs, too much industry demand
- Long-term **open research**
  - Necessary to attract and retain the strongest researchers
  - Success stories: DeepMind, FAIR, OpenAI
  - Need a pipeline & portfolio of different horizons
- Focused research: strategic, targeted choices
- Untying research org. from product-driven R&D

Open Science & Open Source

- Best deep learning researchers (even in industry) demand open science →
  - Open and early publications (arXiv)
  - Accessible open source code (github)
- Both are
  - Reputation building (attracts more scientists)
  - Reproducible science
  - Generate follow-ups, citations & impact
  - Responsible: contribute to the community