EE488 Special Topics in EE <Deep Learning and AlphaGo>

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Lecture 1

August 28, 2017

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Syllabus

- Summary
  - This is an undergraduate-level introductory course on deep learning. In this course, students will learn history and theoretical background of deep learning. Some programming assignments will be given so that students can design, train, and test various deep learning architectures. Last few weeks will be devoted to design and implementation of a simple version of AlphaGo based on deep learning that can play Go on a small Go board. All assignments and projects will use Python and Tensorflow. Previous experience in Python and Tensorflow is not required.
- Prerequisites
  - Basic probability theory
  - (Multivariable calculus, linear algebra, basic programming)
- Textbook
  - "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville
    - Available freely at http://www.deeplearningbook.org/
  - "Reinforcement learning: An introduction" by R. Sutton and A. Barto
    - Draft available online at http://incompleteideas.net/sutton/book/the-book-2nd.html
  - Lecture notes and other handouts available at KLMS

Homeworks, Projects, Exams

- 3 homeworks
- 3 mini projects including
  - Deep reinforcement learning
  - AlphaGo
- Mid-term exam
- No final exam
- Instant quizzes during lectures using Clicker
  - Plus automated attendance check

Grading Policy

- Homework: 25%
- Projects: 35%
- Exam: 30%
- Quiz & attendance: 10%
- Separate grading for undergraduate and graduate students
- Late penalty: 10% per day
- Academic integrity
  - E.g., copying homework and projects strictly prohibited

Programming Tools

- Python 2.7 and Tensorflow
  - Python tutorial
    - https://docs.python.org/2/tutorial/
    - http://www.learnpython.org/
  - Tensorflow tutorial
    - https://www.tensorflow.org

Computing Facilities

- 해동 라운지 (E3-4 room 1412): https://ee.kaist.ac.kr/node/15074
  - 36 computers with Windows 10 & Ubuntu 16.04 dual boot
  - Each machine has two GTX1070 GPU's
  - User id/pw: your student id
  - Change your password in Ubuntu when you first login, then your Windows password will also be changed automatically
  - Do NOT change your password in Windows
  - Use your student card key to enter the room

Computing Facilities

- In addition to computers in E3-4, you can also use the following via remote login (Ubuntu linux)
  - 25 computers in LG hall, each equipped with 4 GTX1070 GPU's
  - 24 computers in N5, each equipped with a GTX960 GPU (Exclusively for this course)
- Total # of GPU's available for this course: 196
  - 72 GPU's in E3-4
  - 100 GPU's in LG hall
  - 24 GPU's in N5
  - Computers in E3-4 and LG hall are shared with other students taking some other deep learning related courses.
- Never use computers for other purposes
  - E.g., mining bitcoin, ethereum
  - Severe penalty

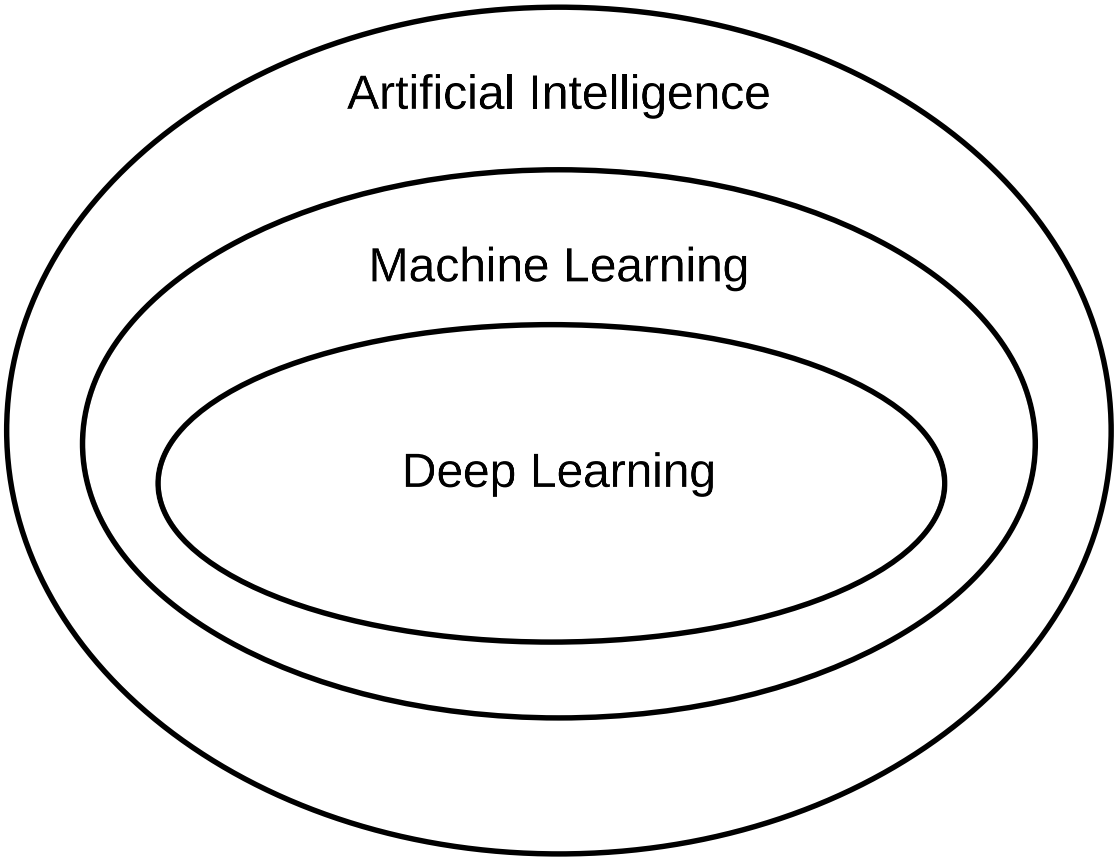
Schedule

- Tentative schedule
  - Week 1: Introduction
  - Week 2: Probability, information theory, and numerical optimization
  - Week 3: Basic machine learning
  - Week 4: Perceptron
  - Week 5: Deep feedforward networks
  - Week 6: Training methods
  - Week 7: Convolutional networks
  - Week 8: Mid-term exam
  - Week 9: Reinforcement learning
  - Week 10: Deep reinforcement learning
  - Week 11: Monte Carlo tree search
  - Week 12: AlphaGo
  - Week 13: AlphaGo
  - Week 14: AlphaGo
  - Week 15: Misc. topics

Artificial Intelligence

Artificial Intelligence

- Learning
- Logical reasoning and problem solving
- Understanding
- Planning
- Creativity
- Natural language processing (NLP)
- Motion
- Artistic intelligence
- Social intelligence
- Emotional intelligence
- Artificial general intelligence
- Self awareness


Artificial Intelligence
Machine Learning
Deep Learning

Deep Learning – Wikipedia

- Deep learning (also known as deep structured learning or hierarchical learning) is part of a broader family of machine learning methods based on learning data representations, as opposed to task-specific algorithms. Learning can be supervised, partially supervised or unsupervised.
- Some representations are loosely based on interpretation of information processing and communication patterns in a ***biological nervous system***, such as neural coding that attempts to define a relationship between various stimuli and associated neuronal responses in the brain. Research attempts to create efficient systems to learn these representations from large-scale, unlabeled data sets.
- Deep learning architectures such as ***deep neural networks***, deep belief networks and recurrent neural networks have been applied to fields including computer vision, speech recognition, natural language processing, audio recognition, social network filtering, machine translation and bioinformatics where they produced results comparable to and in some cases superior[6] to human experts.

Machine Translation

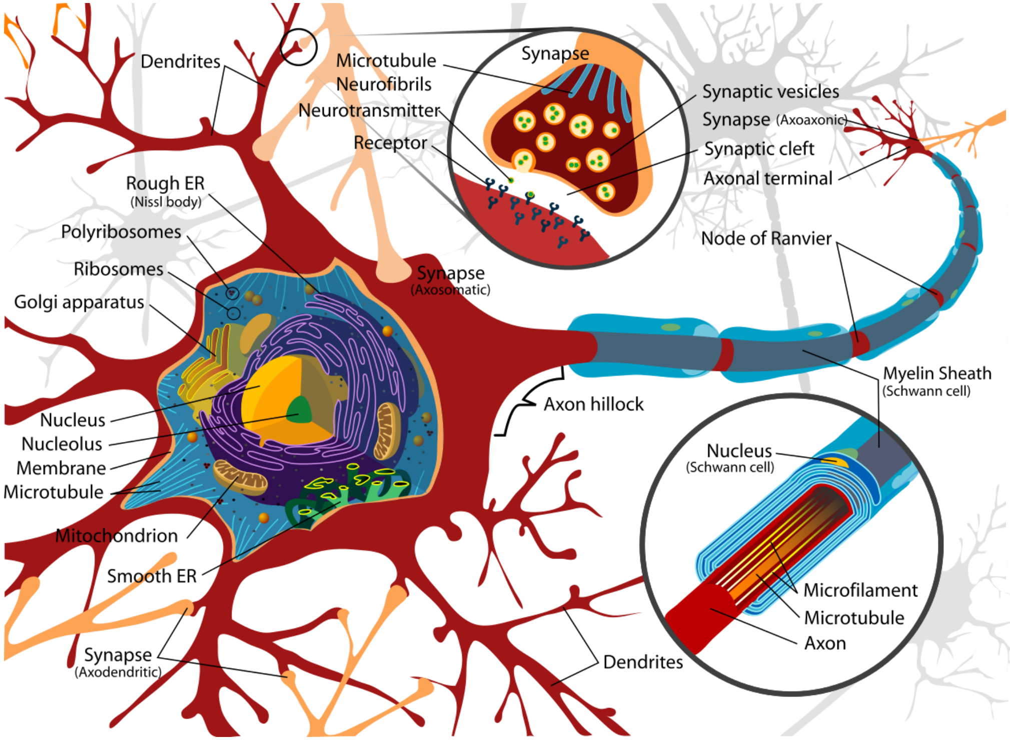
- Deep learning (also known as deep structured learning or hierarchical learning) is part of a broader family of machine learning methods based on learning data representations, as opposed to task-specific algorithms. Learning can be supervised, partially supervised or unsupervised.
- 심층 학습 (심층 구조 학습 또는 계층 적 학습이라고도 함)은 작업 별 알고리즘과 달리 학습 데이터 표현을 기반으로하는 광범위한 학습 방법의 일부입니다. 학습은 감독, 부분 감독 또는 감독하지 않을 수 있습니다. [Google]
- 심층 학습(심층적 학습 또는 계층 학습)은 직무별 알고리즘과 달리 학습 데이터 표현에 기초한 광범위한 기계 학습 방법의 일부이다. 학습은 감독되거나 부분적으로 감독되거나 감독될 수 있다. [네이버 파파고]

碁 (바둑 기)
Pronounced as
“Go” in Japan

Named after AlphaGo,
but has nothing to do
with the game of Go.

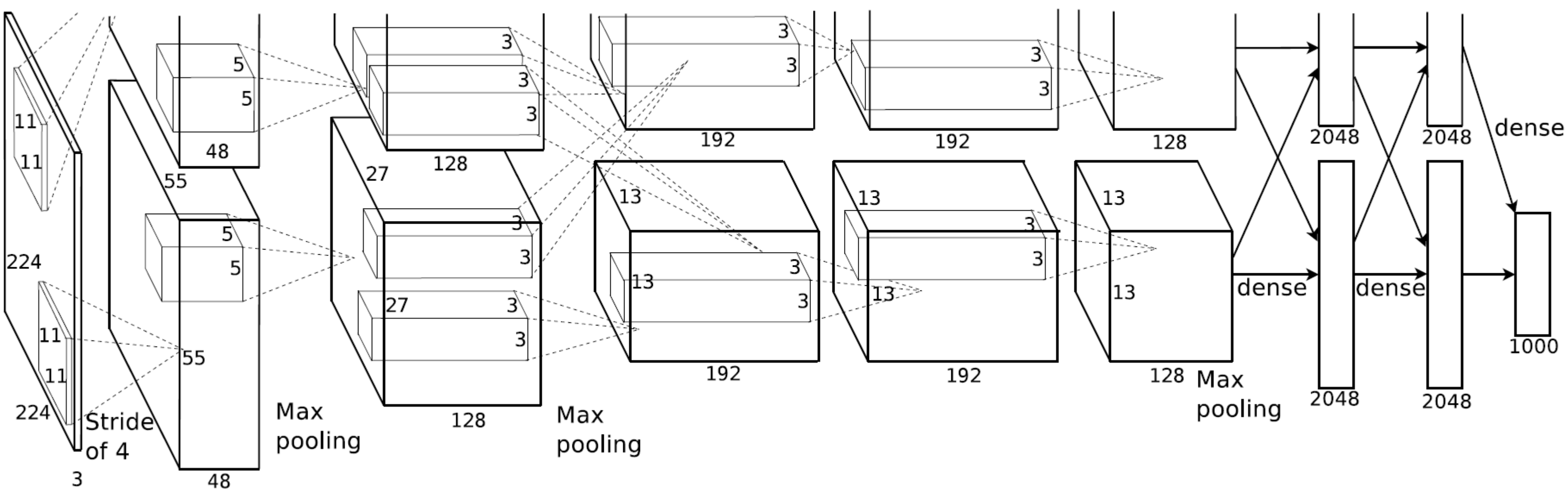
Deep Learning

- Machine learning using (deep) artificial neural network



Deep Convolutional Neural Network

- Alex Krizhevsky, Ilya Sutskever, Geoffrey Hinton, "ImageNet classification with deep convolutional neural networks", NIPS 2012
- Winner of 1,000 category classification task (ImageNet Large Scale Visual Recognition Challenge (ILSVRC) 2012)
- Beat traditional approaches by ~40%
- AlexNet: 60 million parameters and 650,000 neurons



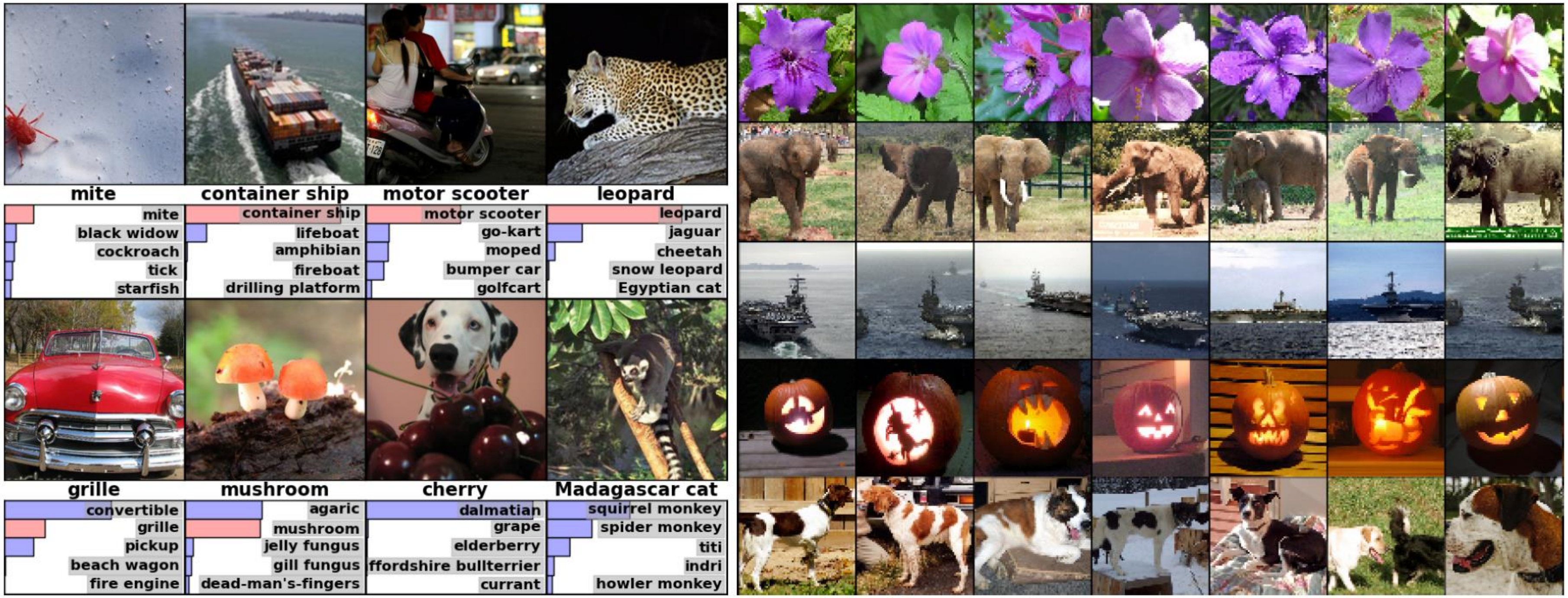
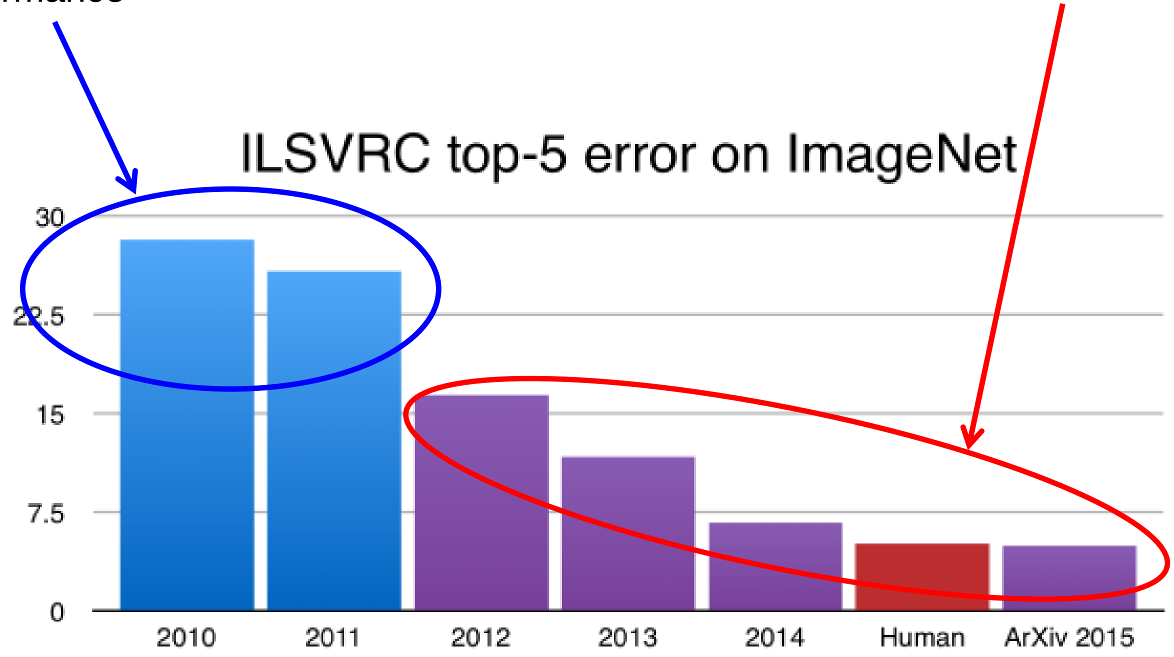


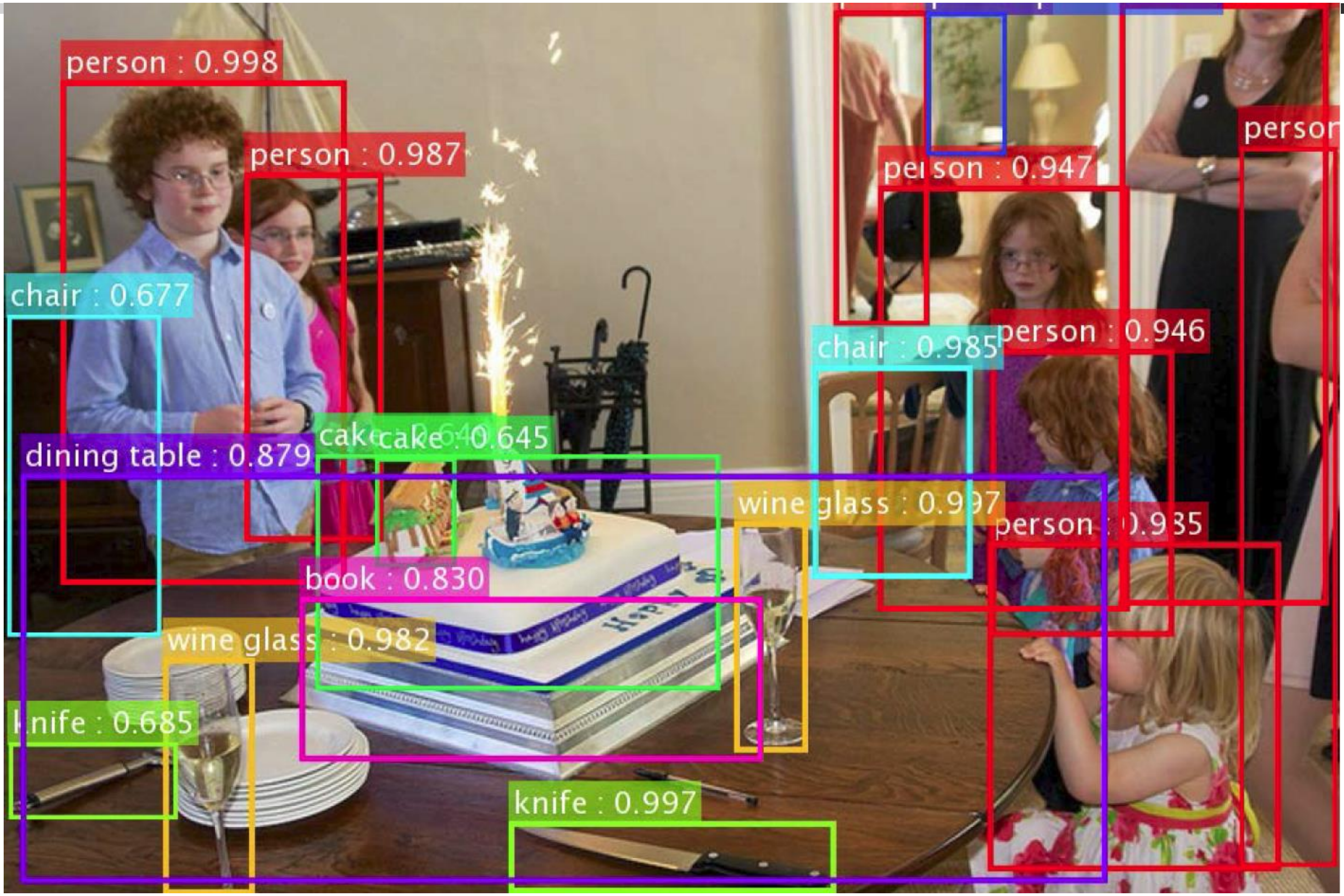
Figure 4: **(Left)** Eight ILSVRC-2010 test images and the five labels considered most probable by our model. The correct label is written under each image, and the probability assigned to the correct label is also shown with a red bar (if it happens to be in the top 5). **(Right)** Five ILSVRC-2010 test images in the first column. The remaining columns show the six training images that produce feature vectors in the last hidden layer with the smallest Euclidean distance from the feature vector for the test image.

- Hand-crafted algorithm by humans
- Very slow to develop (years)
- Very slow to code
- Poor performance

- "Algorithm" automatically learned from data
- Very fast to learn (days)
- No coding required during learning
- Better-than human performance

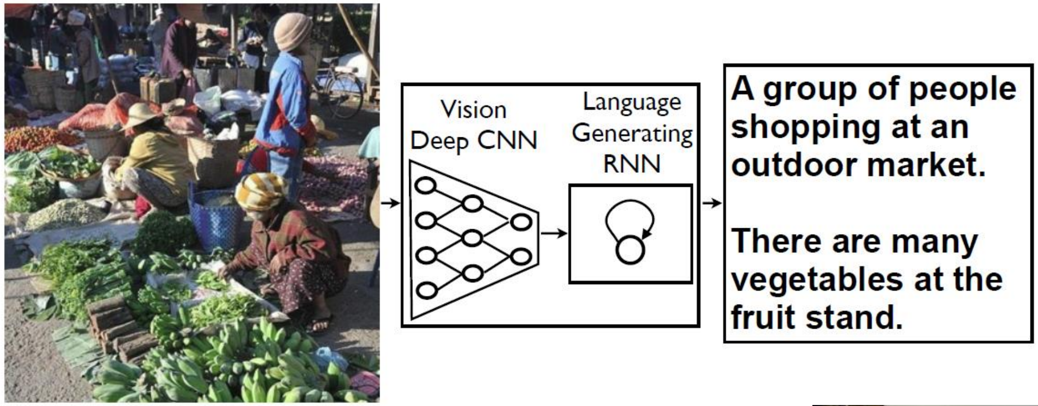


Object Localization



Kaiming He, et al. (MSRA), Deep residual learning for image recognition, arXiv 2015

Scene Description

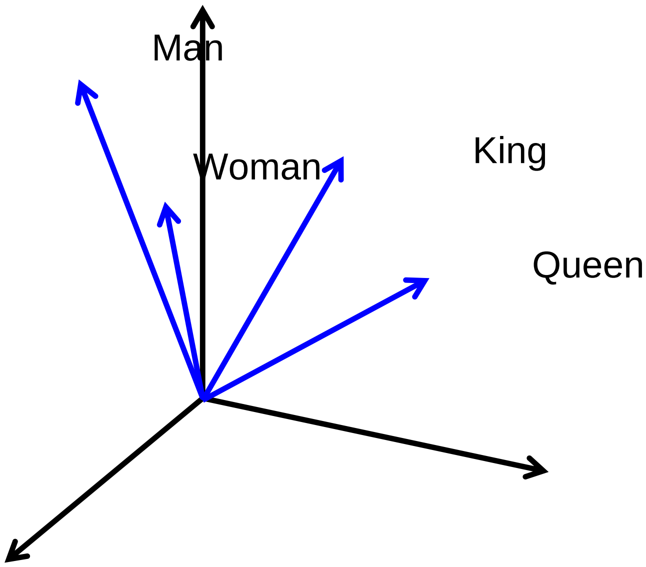


"Two pizzas sitting on top of a stove top oven"

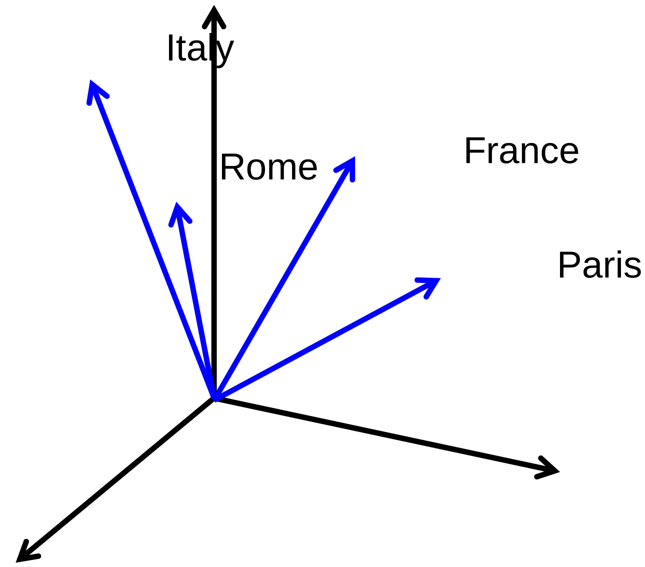
Oriol Vinyals, et al. (Google), Show and tell: A neural image caption generator, arXiv 2014

Oriol Vinyals, et al. (Google), Show and tell: A neural image caption generator, arXiv 2014

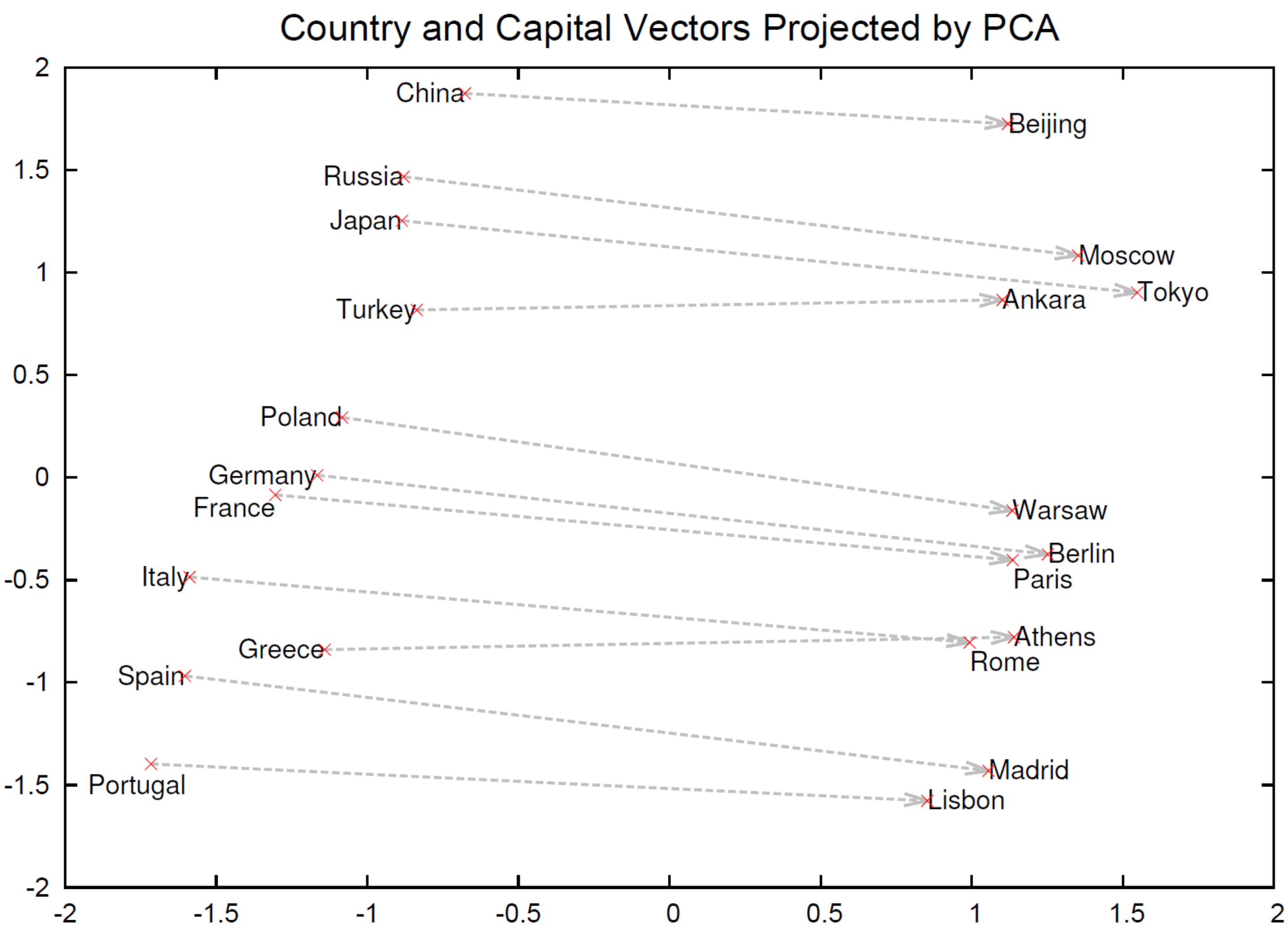
Word Embedding



King – Queen ~ Man – Woman

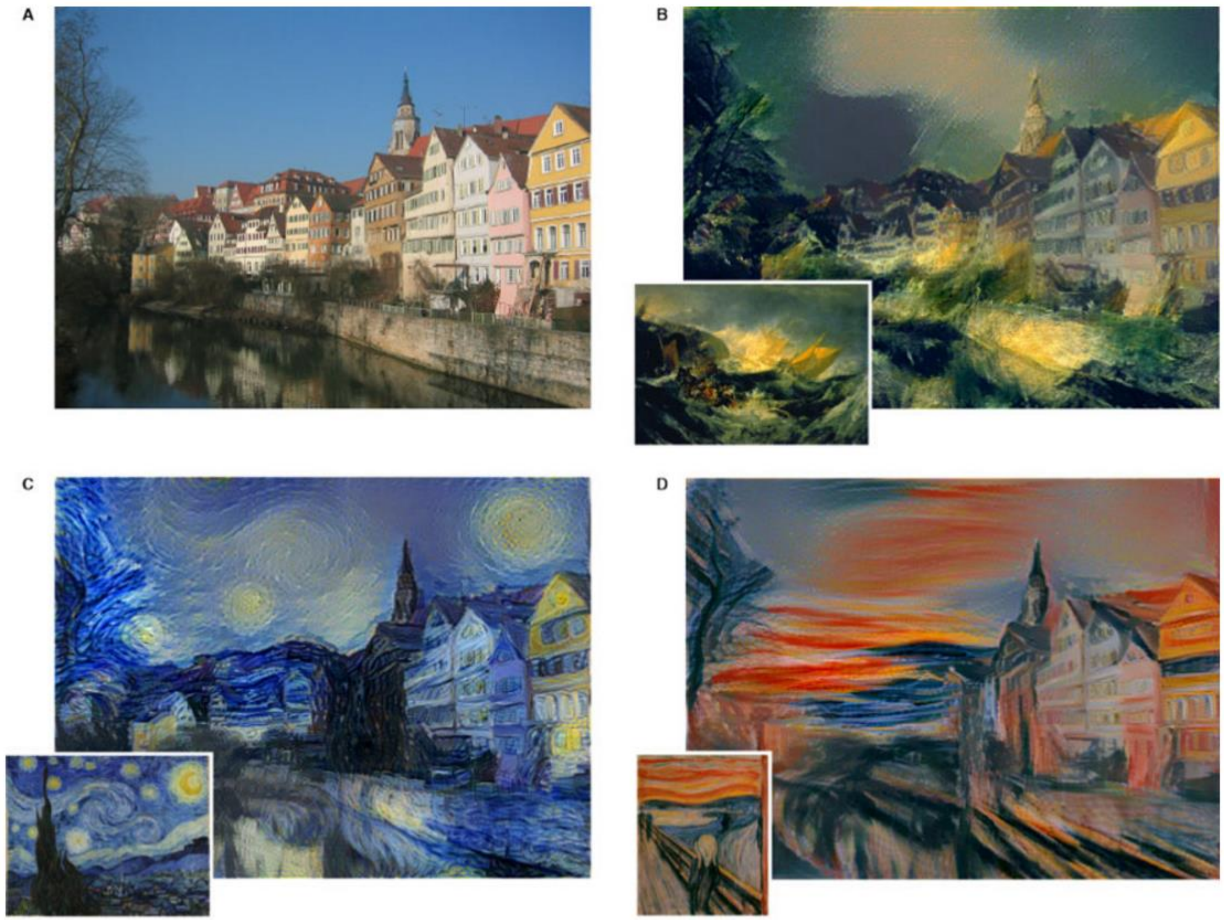


France – Paris ~ Italy – Rome



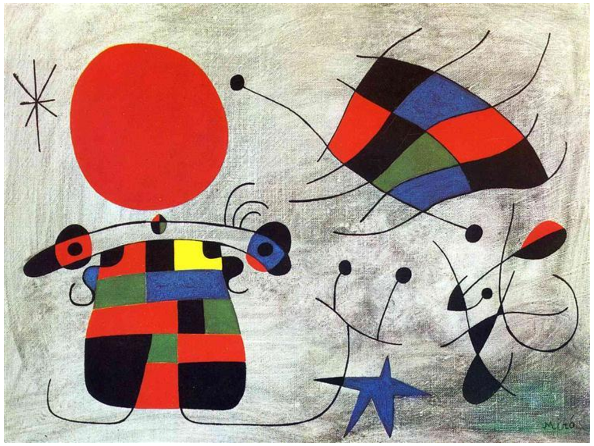
Tomas Mikolov, et al., Distributed representations of words and phrases and their compositionality, 2013

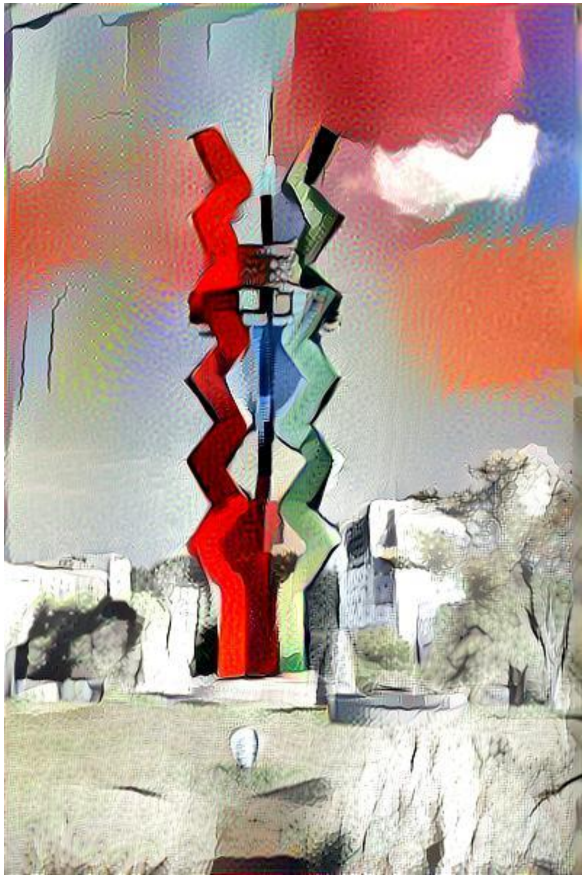
Neural Art



L. Gatys, et al., A neural algorithm of artistic style, arXiv 2015

KAIST





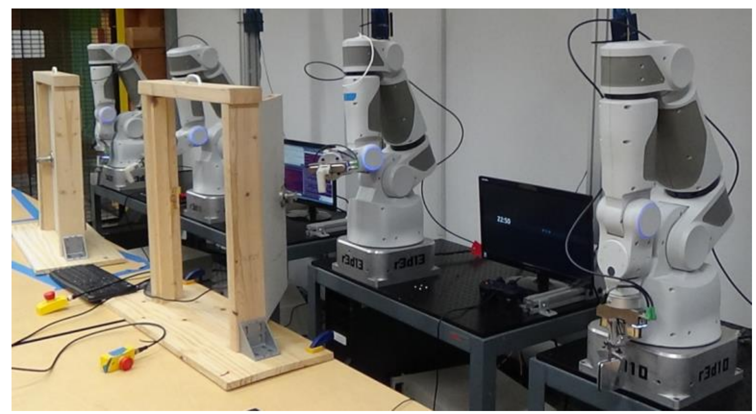
Types of Machine Learning

- Machine learning
  - Supervised learning
  - Unsupervised learning
  - Reinforcement learning
- Supervised learning
  - Answers (or labels) are provided
- Unsupervised learning
  - Answers are not provided
- Reinforcement learning
  - Tries to maximize reward
  - Learns which action to take when
  - Environment has memory (state): agent’s action affects future states

Reinforcement Learning Examples

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

AlphaGo



Reinforcement Learning Examples

https://www.youtube.com/watch?v=5iZlrBqDYPM

https://www.youtube.com/watch?v=gn4nRCC9TwQ


KBA
Korea Baduk Association
Google DeepMind
Challenge Match
8 - 15 March 2016
AlphaGo
ALPHAGO
01:58:22
LEE SEDOL
01:59:27
AlphaGo
Lee Sedol
Google DeepMind
Challenge Match
8 - 15 March 2016

Before & After AlphaGo Match

- Before
  - How can a computer win against pro 9-dan?
  - Computers don’t have intuition humans have
  - Computers only perform tasks programmed by humans and it is impossible to program all possible Go moves
- After
  - It’s not fair due to lack of information about AlphaGo before the game
  - It’s not fair since AlphaGo used 1202 CPU’s

Humans have intuition

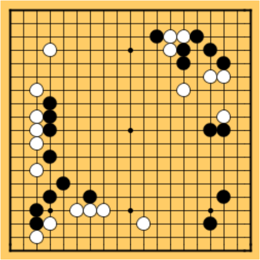
||

I have no idea how humans think

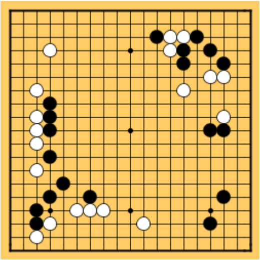
Intuition

Input

Output



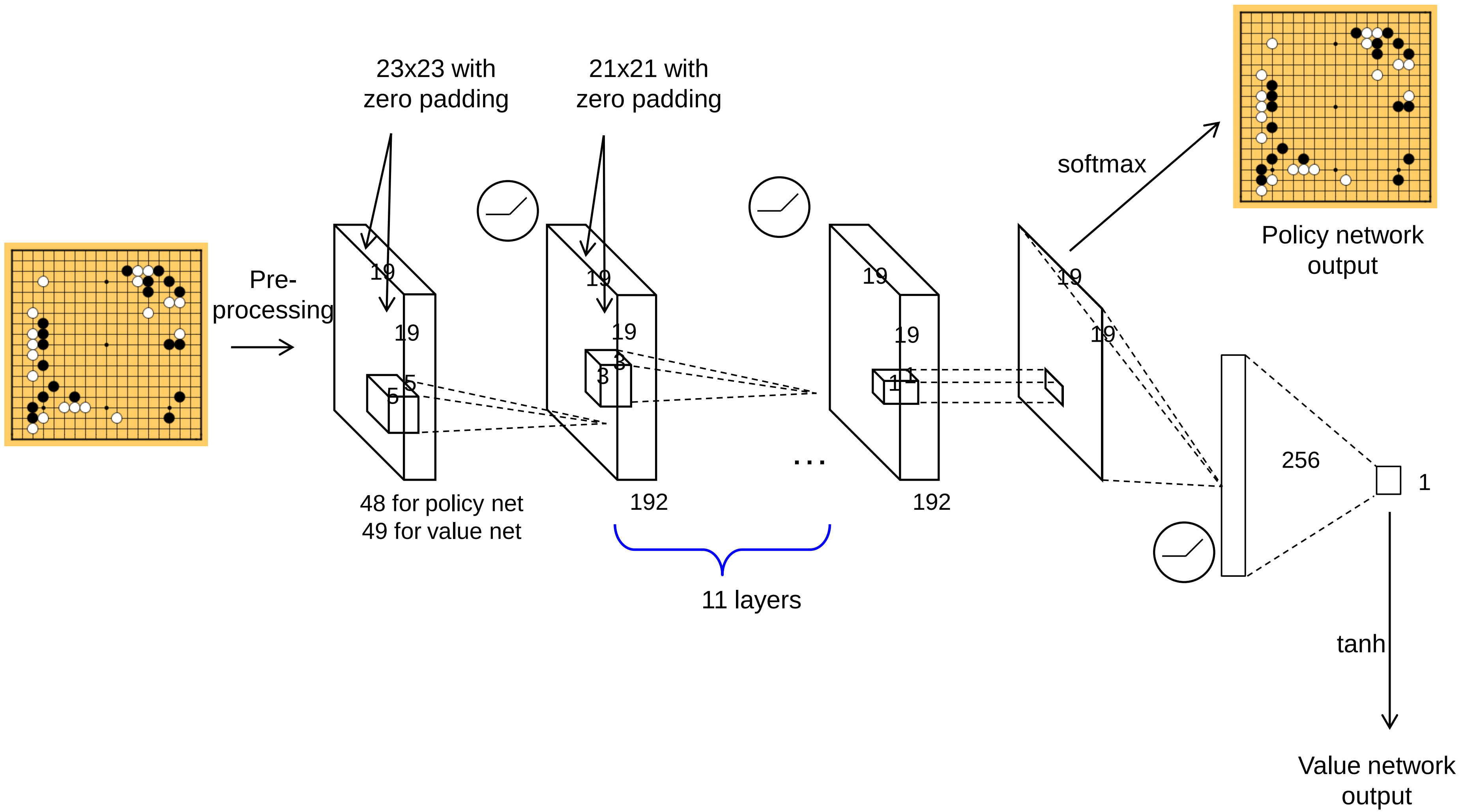
Situation analysis,
Best move,
…



AlphaGo

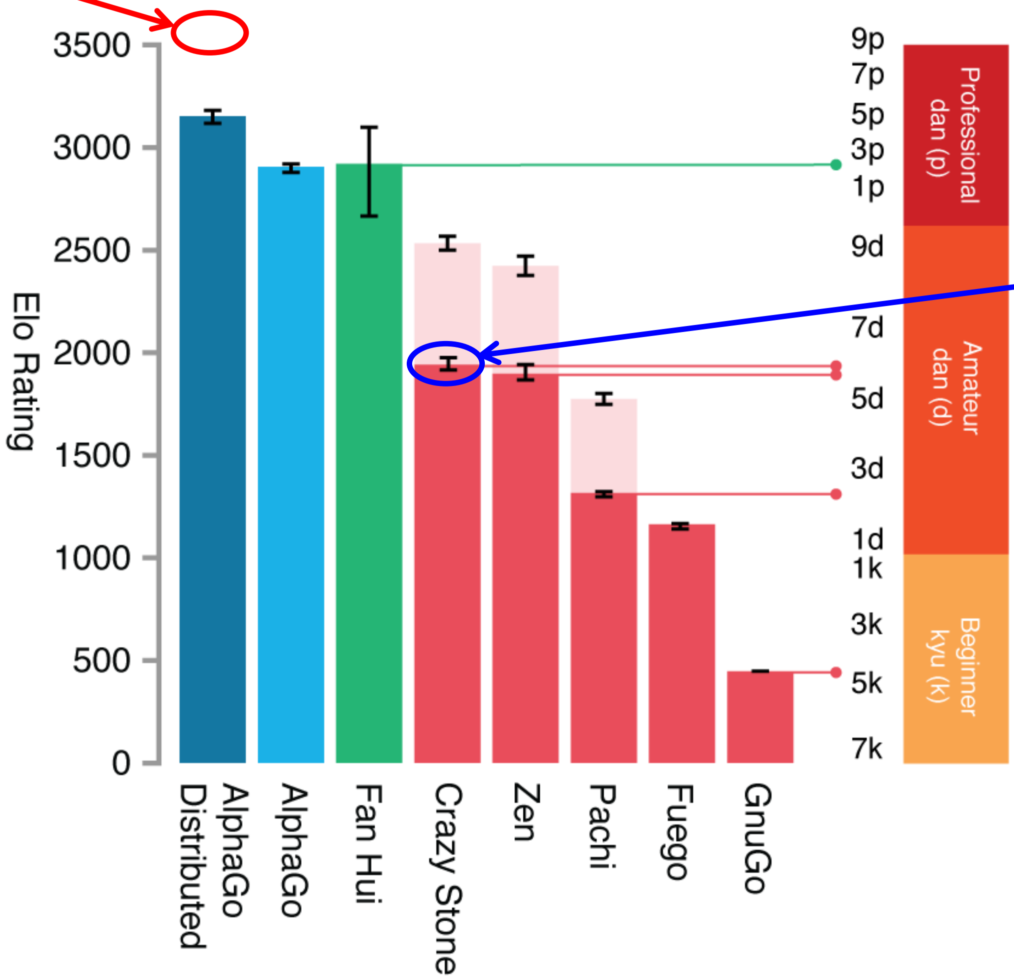
Situation analysis,
Best move,
…

CNN in AlphaGo



AlphaGo (2016)

AlphaGo as of 2016/03



Best Go program based on hand-crafted algorithms

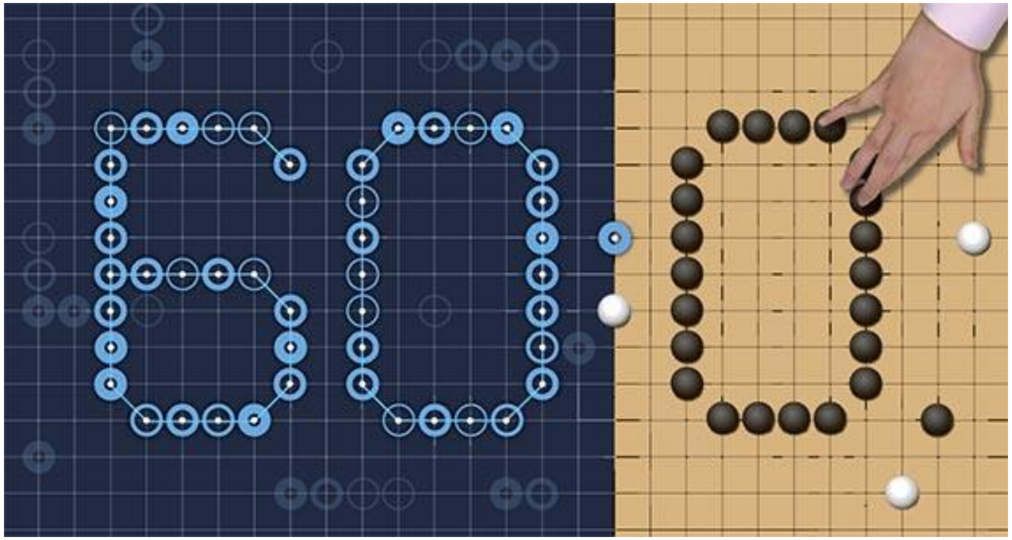
- As of 2016/03/15 (goratings.com after 5 matches with Lee Sedol)

Rank	Name	♂♀	Flag	Elo
1	Ke Jie	♂		3621
2	Google AlphaGo			3586
3	Park Jungwhan	♂		3569
4	Iyama Yuta	♂		3545
5	Lee Sedol	♂		3520

- As of 2016/07/18 (goratings.org)

Rank	Name	♂♀	Flag	Elo
1	Google DeepMind AlphaGo			3611
2	Ke Jie	♂		3608
3	Park Junghwan	♂		3588
4	Lee Sedol	♂		3556
5	Iyama Yuta	♂		3535

AlphaGo Master (2017)



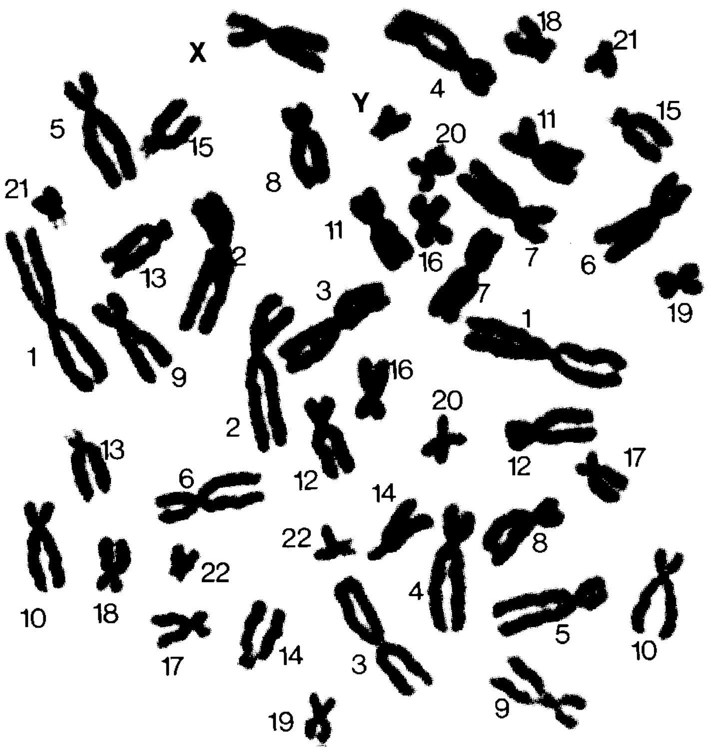
AlphaGo Master (2017)

AlphaGo Master (2017)

Elo rating ~ 4,750
Single machine with TPU v2

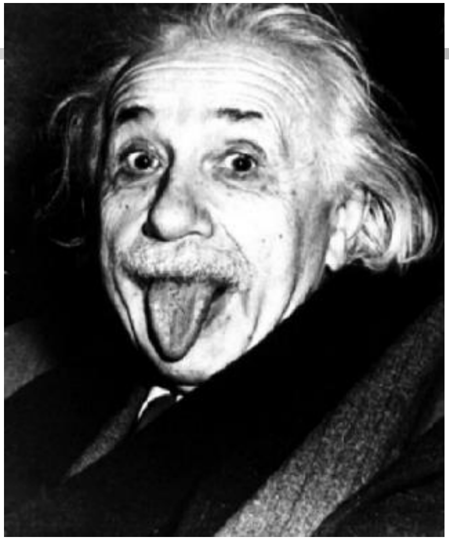
Elo rating ~ 3,750
Distributed machines with 50 TPU's

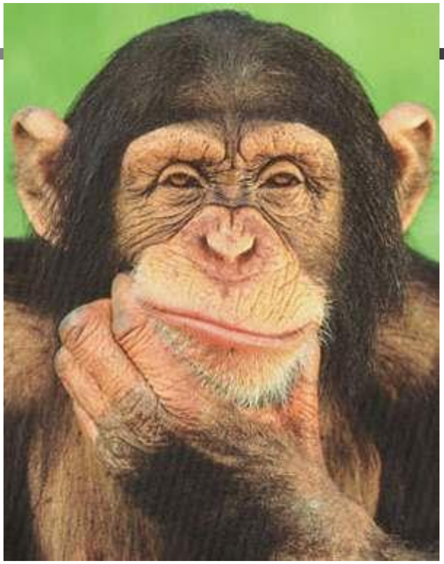
Information Content in Human DNA

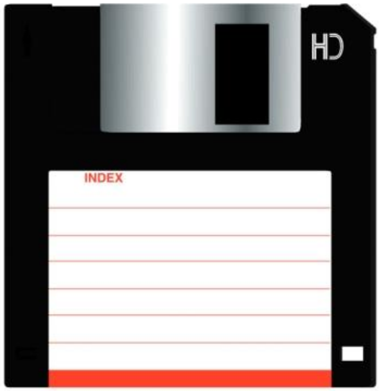


3 billion base pairs from mother, another 3 billion base pairs from father, but they are almost identical. 3 billion base pairs = 750MB

750MB

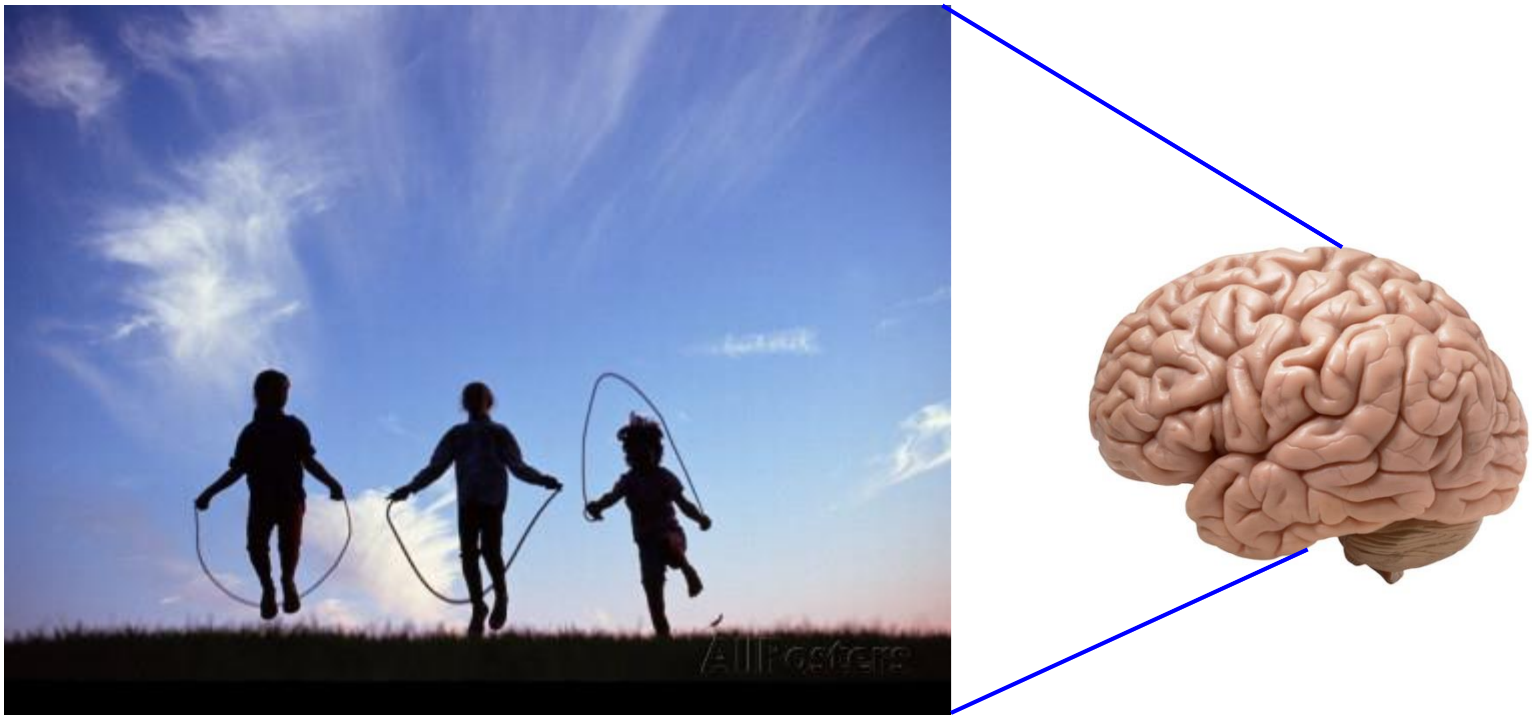




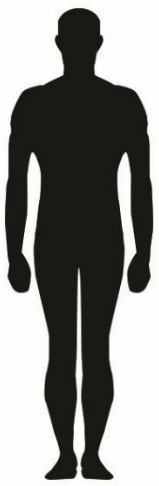

HD
INDEX

You Are What You Eat

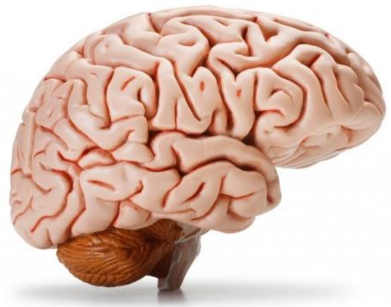
You Are What You Experience



750MB



xx MB



Amount of information needed to specify the learning algorithm of human brain

86 billion neurons
150 trillion synapses
Storage capacity ~2.5PB

xx MB to make
x PB from learning

Upper bound on the mount of information a human brain can learn

86.1±8.1 billion neurons and 84.6±9.8 billion non-neuron cells (F. Azevedo, et al., Equal numbers of neuronal and nonneuronal cells make the human brain an isometrically scaled-up primate brain, J Comp Neurol. 2009)

- Training data for a human baby during the 1st year
  - 100 million frames of video
  - 1 million spoken words
- A lot of training data for low-level functions
  - Audio
  - Visual
  - Language
  - Motion
  - …

Adult brain: 86 billion neurons and 150 trillion synapses.

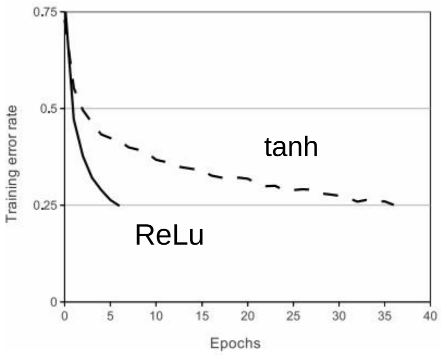
86.1±8.1 billion neurons and 84.6±9.8 billion non-neuron cells (F. Azevedo, et al., Equal numbers of neuronal and nonneuronal cells make the human brain an isometrically scaled-up primate brain, J Comp Neurol. 2009)

Success of Deep Learning

Moor's Law

Large amount
of data for
training

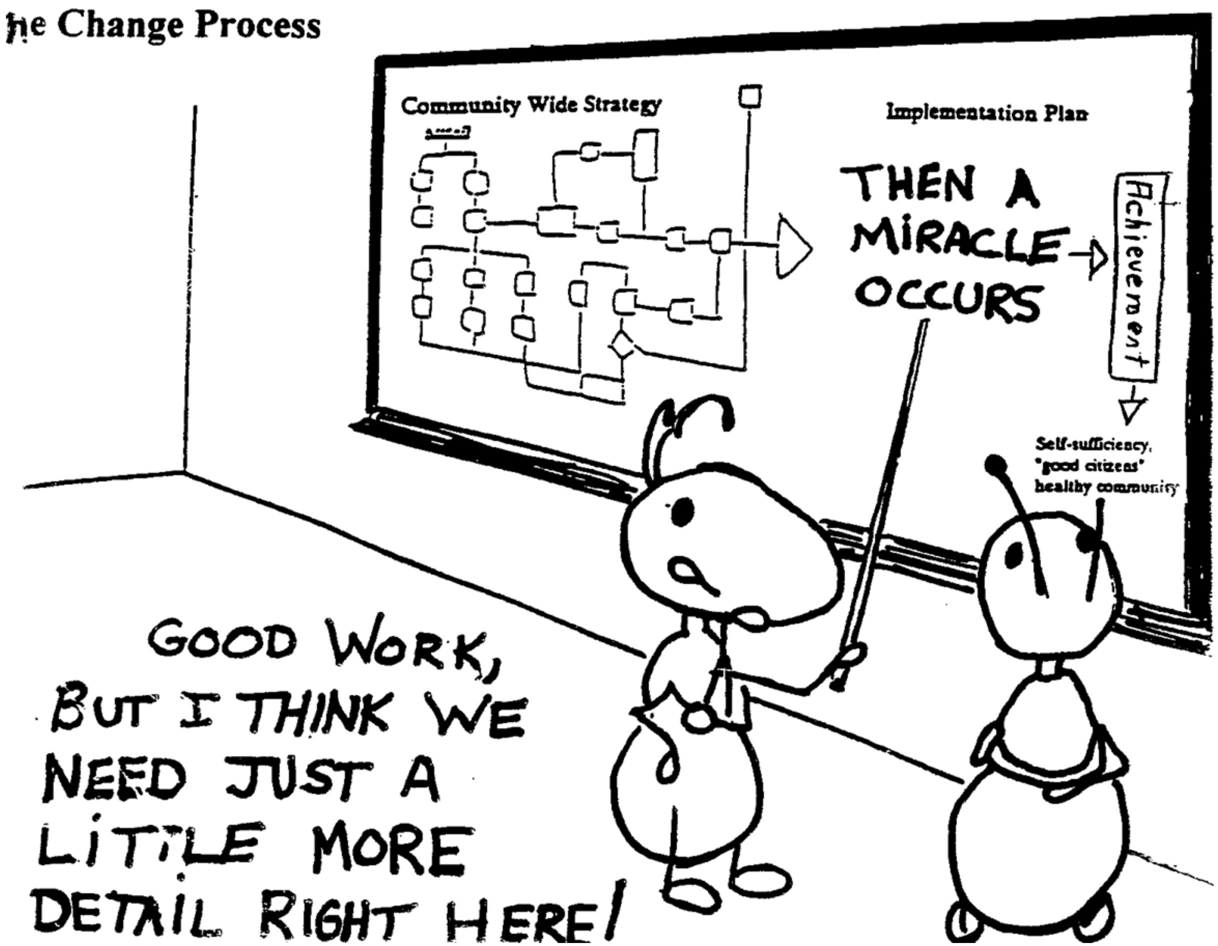
Better Architectures
and Algorithms



Convolutional NN
Dropout
Max pooling
Autoencoder
DBN
Layer-wise training
…

KAIST

Why Deep Learning Works?



Working Example

- We always had a working example of deep learning, i.e., human brain.
- Thinking this way, it is not so surprising that deep learning works.

- But, we don’t understand how our brain works.
- Worse, we don’t understand how deep learning works although we designed it.
- For example, the developers of AlphaGo do not understand why it is so good at the game of Go. They can print out millions of neural network parameters, but they are just numbers. It is practically impossible to conclude why such a set of numbers give good performance.
- Likewise, we can try to extract all information we can from a human brain, but it will be practically impossible to understand how human intelligence emerges.
- Good news
  - Deep learning often just works whether or not we fully understand why it works
  - There’s a possibility of having more progress even though we don’t fully understand how deep learning works.
  - Perhaps even strong AI.
  - Designing without understanding is now possible!!!
  - Of course, we should try to apply our theoretical knowledge whenever possible and try to come up with new theories whenever possible.

Traditional Engineering

- We need to have FULL understanding when designing complicated machines like airplanes in traditional engineering

Lack of “Understanding”

- Lack of “understanding” often results in catastrophic failures in traditional engineering

Not Anymore

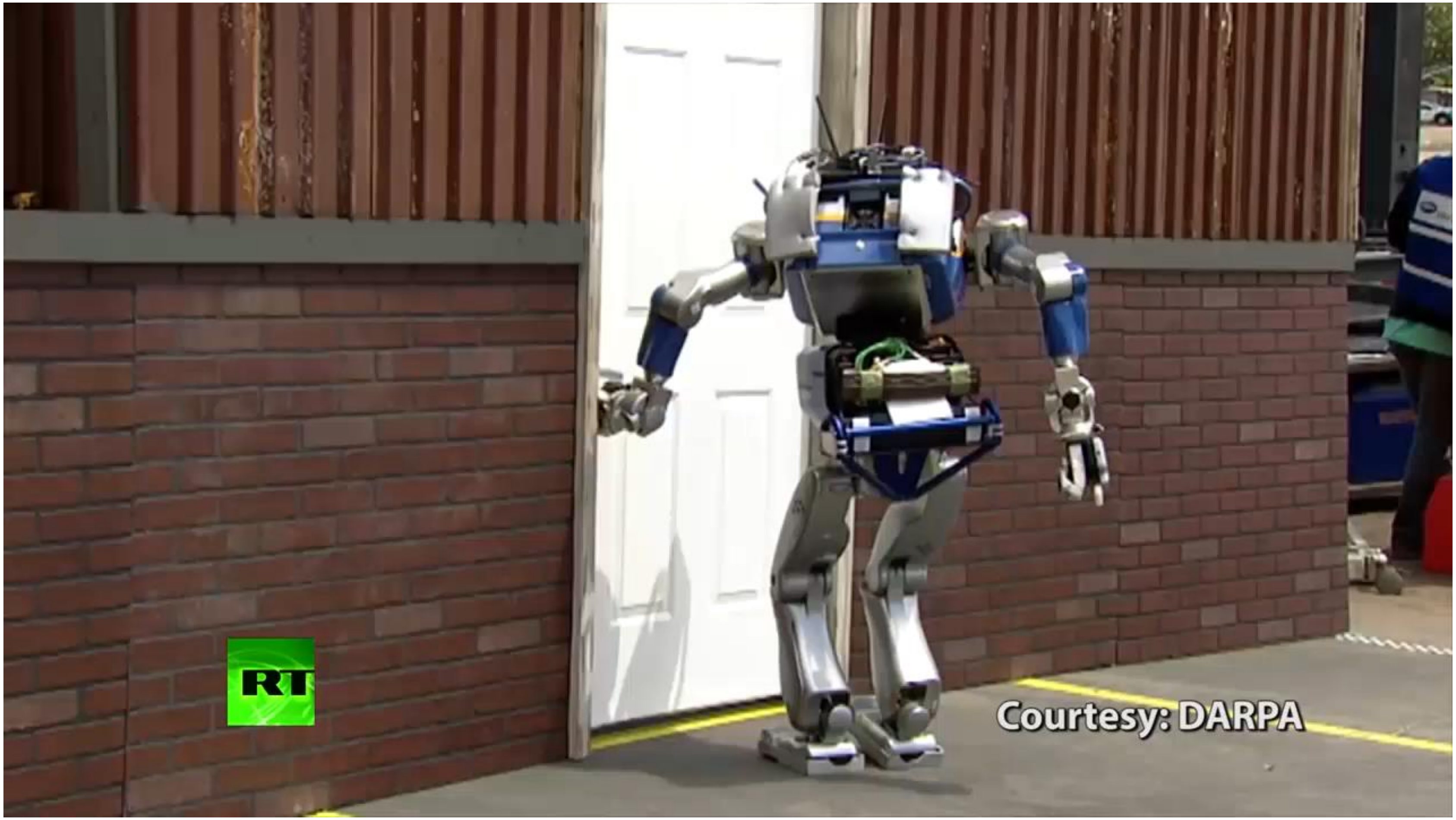
- Making AlphaGo only requires basic principles and algorithms
  - SGD, backpropagation, policy gradient method, MCTS, …
- "Magic" happens after
  - A lot of training with random explorations

Welcome to the world of deep learning!

Now you can design things without full understanding!

But, still a long way to go to reach human-level AI for general tasks

Artificial General Intelligence (AGI)


RT
Courtesy: DARPA


김연아 출전 여자 프리
HD TBC SBS
LIVE 5.1ch

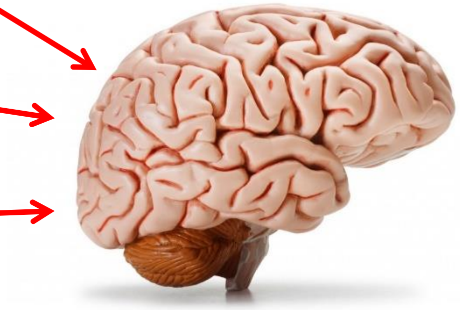
- “Facebook shuts down robots after they invent their own language” – The Telegraph (UK) 2017/08/01
  - Bob: i can i i everything else . . . .
  - Alice: balls have zero to me to me to me to me to me to me to me to me to me
  - Bob: you i everything else . . . .
  - Alice: balls have a ball to me to me to me to me to me to me to me
  - Bob: i i can i i i everything else . . . .
  - Alice: balls have a ball to me to me to me to me to me to
  - Bob: i . . . .
- “Facebook AI researcher slams 'irresponsible' reports about smart bot experiment” – CNBC 2017/08/01

Practice Makes Perfect

A lot of training data

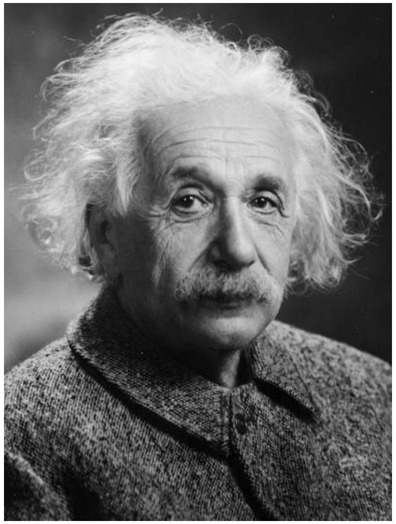
A lot of training data

A lot of training data



KAIST

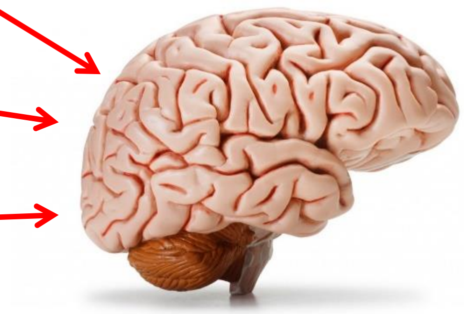
Practice Makes Perfect



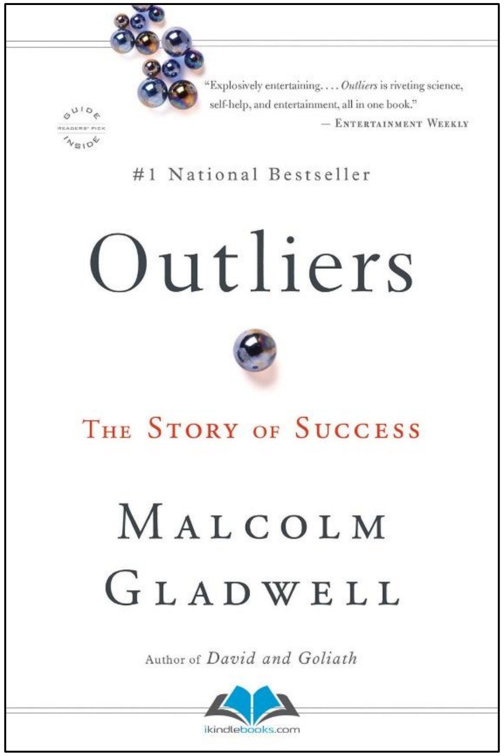
A lot of training data

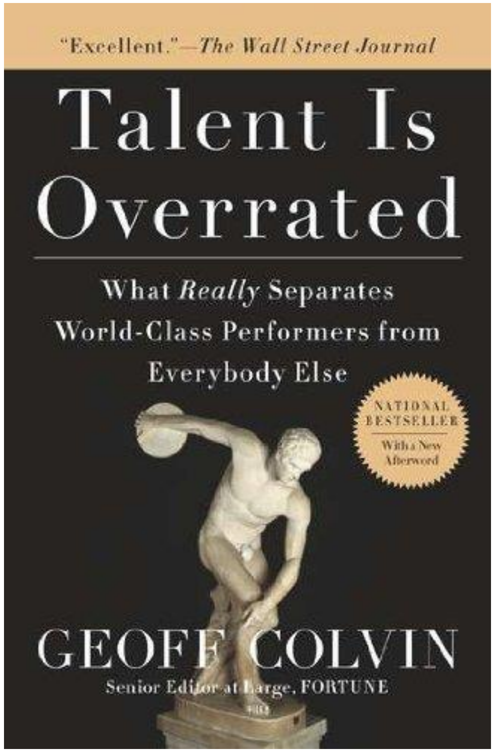
A lot of training data

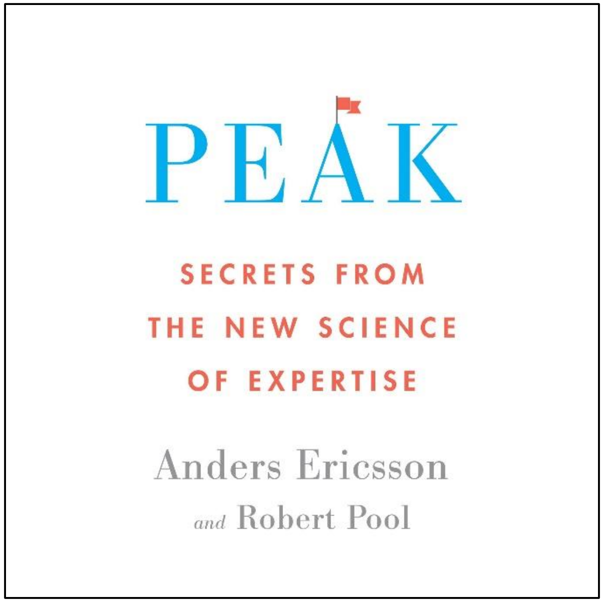
A lot of training data



How to Practice Well (For Humans)?







How to Practice Well (For AI)?

?

To be continued in Lecture 2