Università degli Studi di Pavia

Deep Learning

01-Introduction

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This presentation can be downloaded at:
http://vision.unipv.it/DL

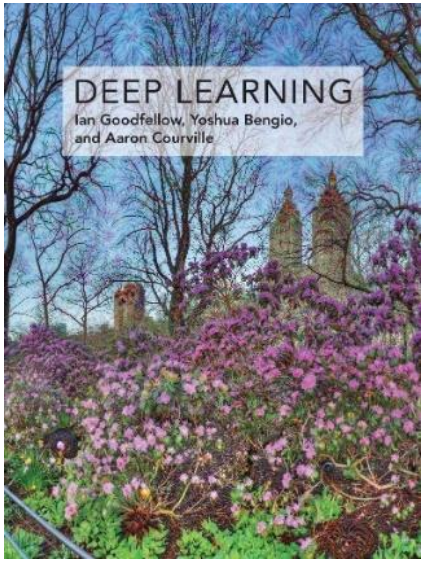
Main References for the This Course

- **Deep Learning**

  Ian Goodfellow, Yoshua Bengio and Aaron Courville

  MIT Press, 2017

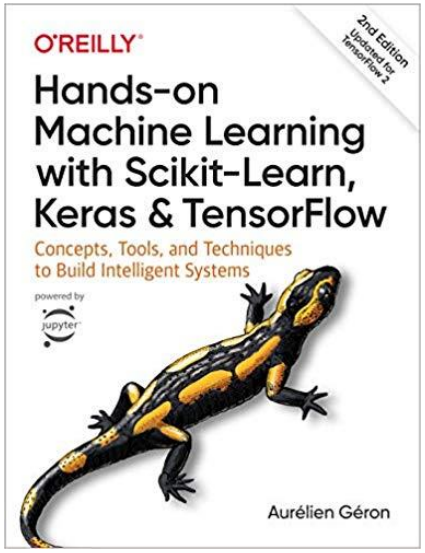
  See also
  http://www.deeplearningbook.org/



- **Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems**, 2nd Edition

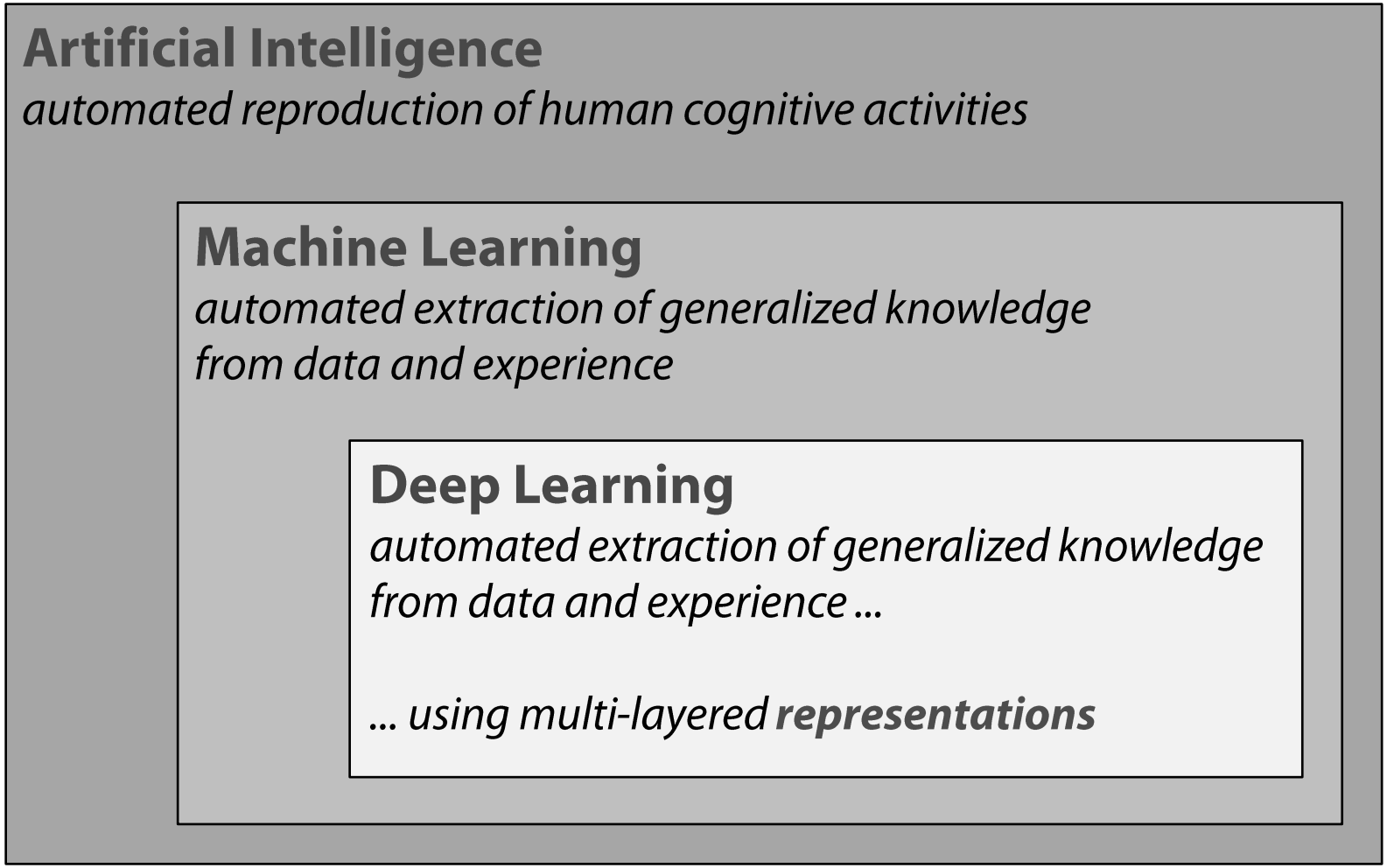
  Aurélien Géron

  O'Reilly, 2020

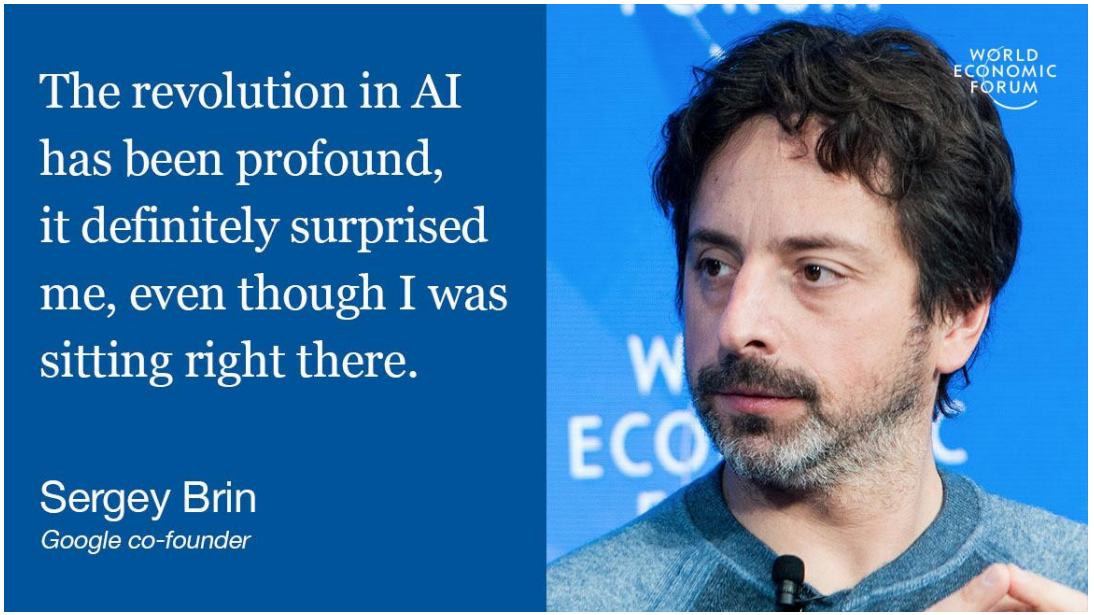


Prologue:
"Deep Learning"?

Deep Learning in the Artificial Intelligence Cosmos



AI strikes back?



- Sergey Brin [Google Co-Founder, January 2017]

  "I didn't pay attention to it [i.e. Artificial Intelligence] at all, to be perfectly honest."

  "Having been trained as a computer scientist in the 90s, everybody knew that AI didn't work. People tried it, they tried neural nets and none of it worked."

[Quote and image from https://www.weforum.org/agenda/2017/01/google-sergey-brin-i-didn-t-see-ai-coming/]

Artificial Intelligence Overhype

Forbes

10,693 views | Feb 15, 2019, 02:15pm

3 Reasons AI Is Way Overhyped

Peter Cohan Contributor ⓘ
Markets

1. Many CEOs Are Being Scared Into Caring Too Much About AI

2. There Are Very Few Examples of High Payoff AI Applications

3. Very Few Companies Can Afford or Find Good Uses For AI

[Quote from https://www.forbes.com/sites/petercohan/2019/02/15/3-reasons-ai-is-way-overhyped/#3d3fef8c5a6a/

Artificial Intelligence Risks

I'm an AI researcher, and here's what scares me about AI

Rachel Thomas Follow
Jan 30 · 11 min read

AI is being increasingly used to make important decisions. Many AI experts (including Jeff Dean, head of AI at Google, and Andrew Ng, founder of Coursera and deeplearning.ai) say that warnings about sentient robots are overblown, but other harms are not getting enough attention. I agree. I am an AI researcher, and I'm worried about some of the societal impacts that we're already seeing. In particular, these 5 things scare me about AI:

1. Algorithms are often implemented without ways to address mistakes.
2. AI makes it easier to not feel responsible.
3. AI encodes & magnifies bias.
4. Optimizing metrics above all else leads to negative outcomes.
5. There is no accountability for big tech companies.

[Quote from https://medium.com/@rachelTho/im-an-ai-researcher-and-here-is-what-scares-me-about-ai-909a406e4a71

Artificial Intelligence Hysteria?

AI isn't as scary as we imagine. AndreyZH/Shutterstock

The reality of AI is currently very different, particularly when you look at the threat of automation. Back in 2013, researchers estimated that, in the following ten to 20 years, 47% of jobs in the US could be automated. Six years later, instead of a trend towards mass joblessness, we're in fact seeing US unemployment at a historic low.

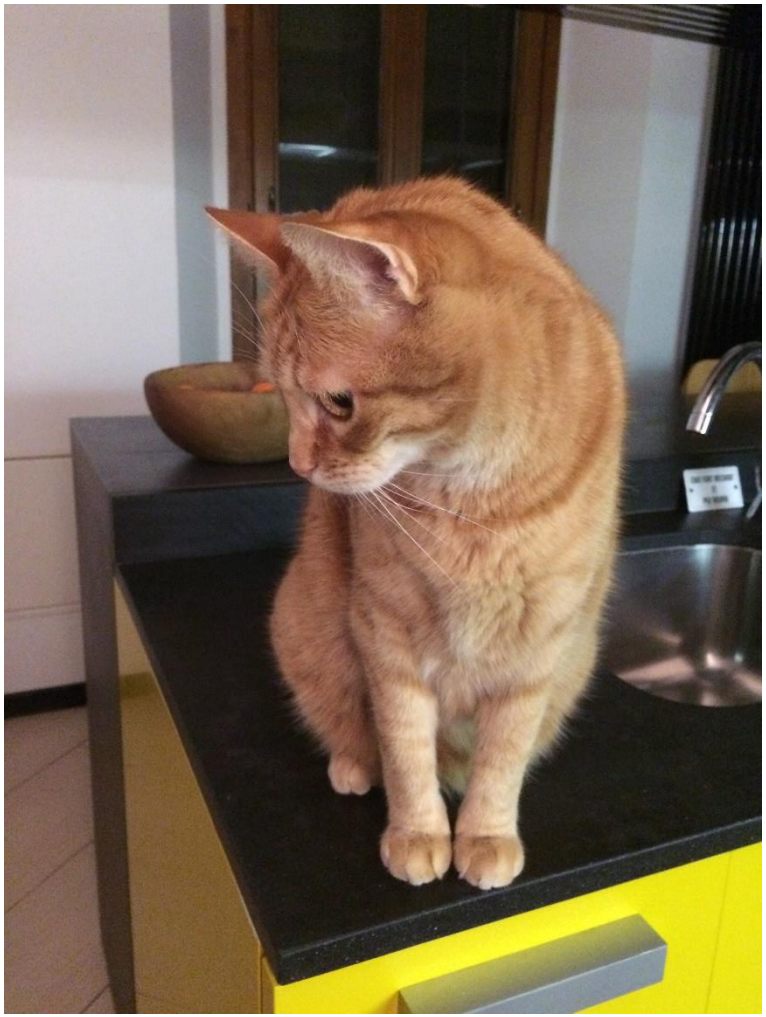
Current AI is good at finding patterns in large datasets, and not much else.

[Quote from https://theconversation.com/ais-current-hype-and-hysteria-could-set-the-technology-back-by-decades-120514]

Finding Patterns in Large Datasets

One Giant Leap for Mankind

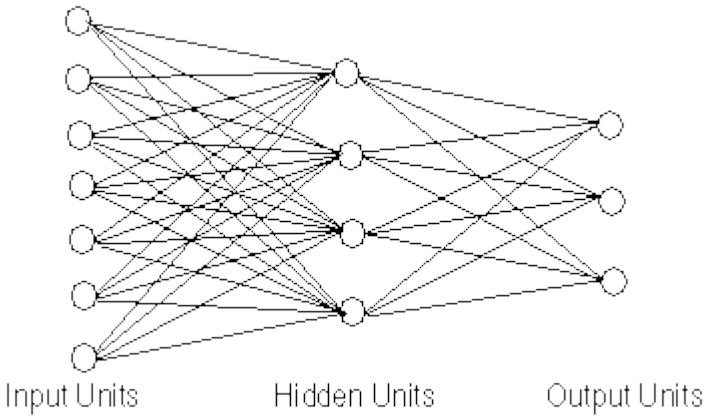
Is there a cat
in this picture?

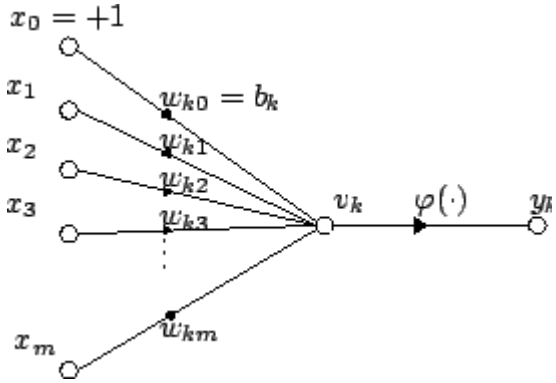


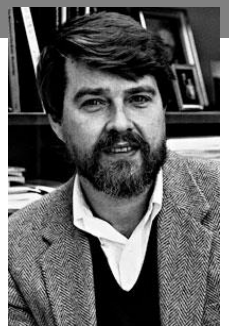
[this is *my* cat, Rabarbaro]

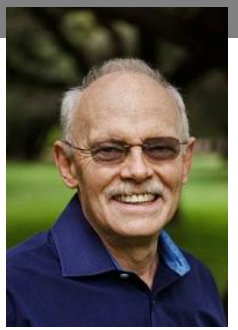
Artificial Neural Networks: The Origins

Emulation or *simulation*? Connectionism









(from Wikipedia)

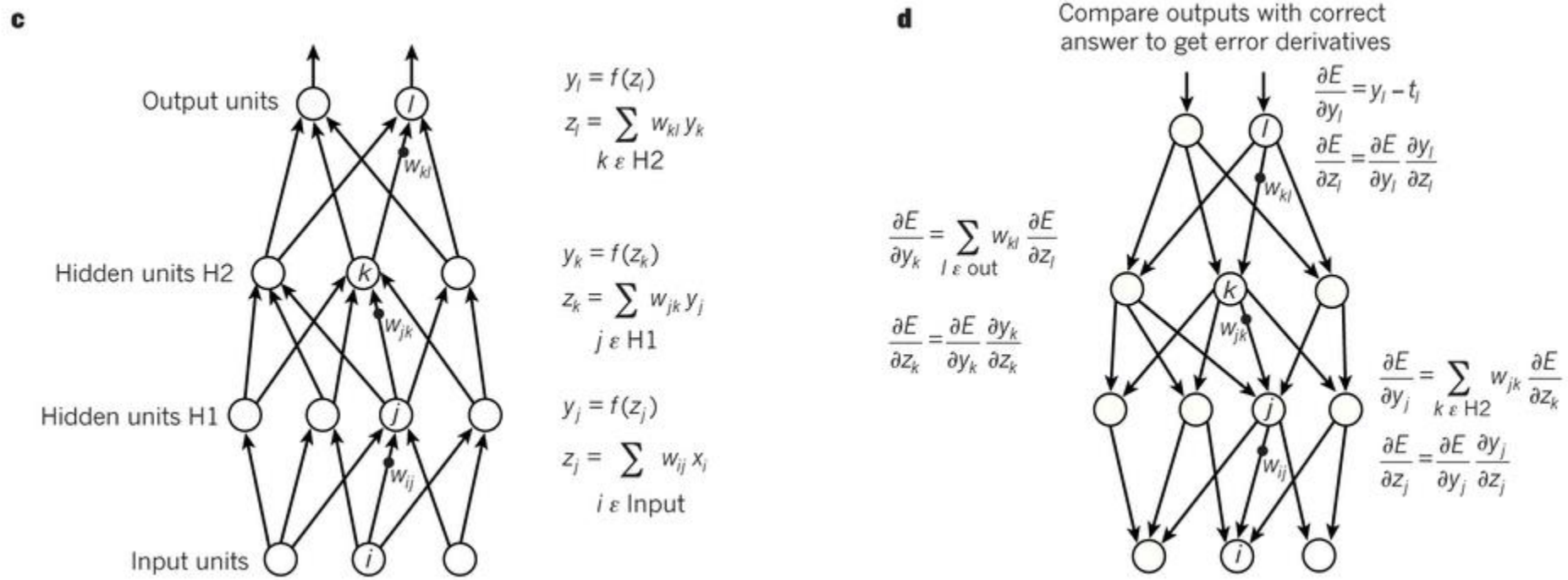
"In our view, people are smarter than today's computers because the brain employs a basic computational architecture that is more suited to deal with a central aspect of the natural information processing tasks that people are so good at."

[Rumelhart, D.E., J.L. McClelland and the PDP Research Group (1986)
Parallel Distributed Processing: Explorations in the Microstructure of Cognition]

- ***Basic assumption***

  Mental phenomena can be described by interconnected networks of simple and often uniform units

Artificial Neural Network



[figure from LeCun, Bengio, Hinton, *Deep Learning*, Nature 521, 2015]

Function approximation

Basically, this is what a 'classical' artificial neural network does

Supervised learning

The parameters (i.e. *weights*) are "learnt" from a dataset of inputs and expected outputs pairs

Incremental optimization — a.k.a. "*backward propagation*"

Weights are progressively corrected to reduce *the difference* between actual and expected outputs

- **From *shallow* to *deep* networks**

  A feed-forward neural network with one hidden layer

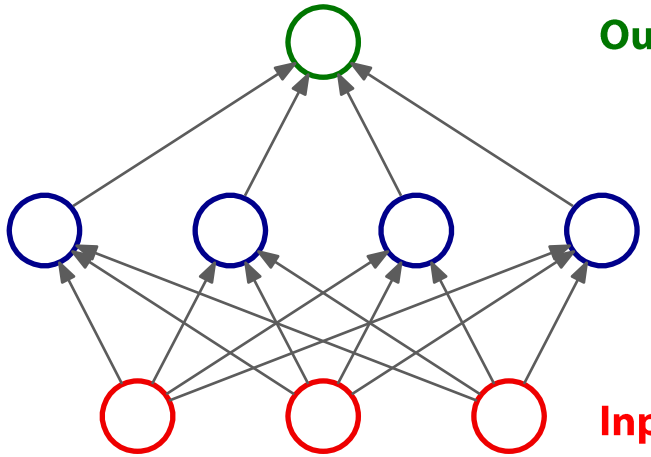
$$\tilde{y} = \boldsymbol{w} \cdot g(\boldsymbol{W}^{[1]}\boldsymbol{x} + \boldsymbol{b}^{[1]}) + b$$

Deep Learning systems (e.g. TensorFlow, PyTorch) use this representation

  It can approximate any target function

$$y = f^*(\boldsymbol{x}), \quad \boldsymbol{x} \in \mathbb{R}^d$$

  (given enough units and proper parameters)

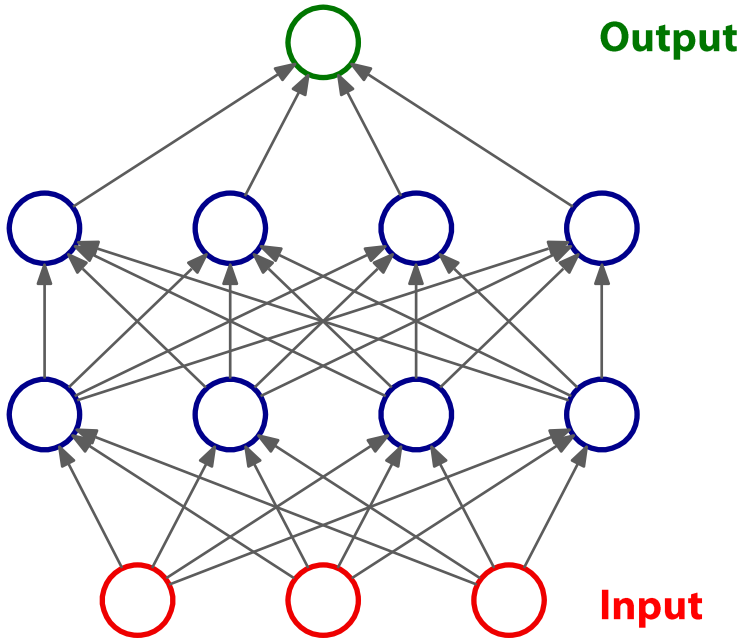


The two representations are equivalent

- **From *shallow* to *deep* networks**

  A feed-forward neural network with two hidden layers

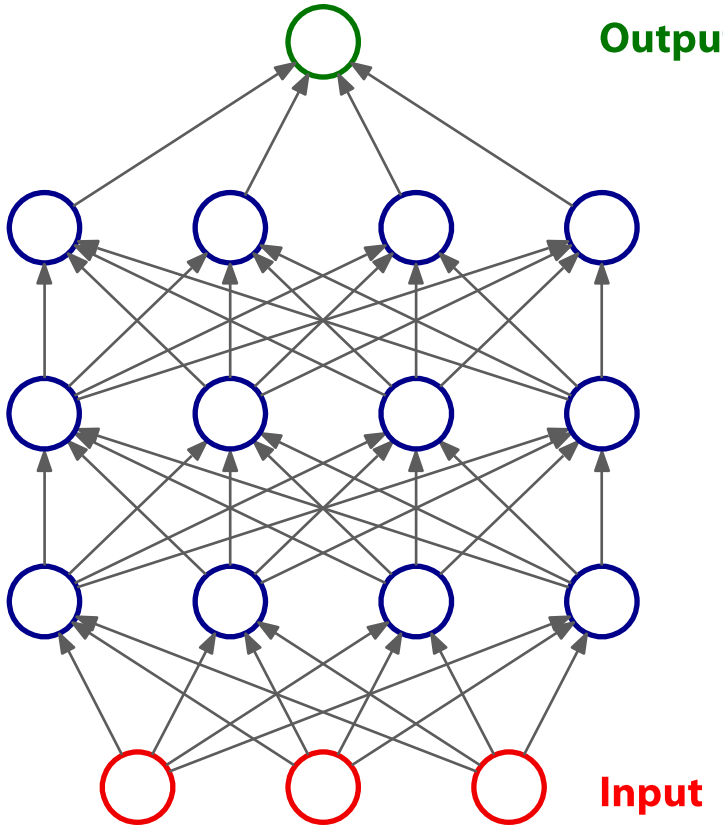
$$\tilde{y} = \boldsymbol{w} \cdot g(\boldsymbol{W}^{[2]} g(\boldsymbol{W}^{[1]} \boldsymbol{x} + \boldsymbol{b}^{[1]}) + \boldsymbol{b}^{[2]}) + b$$



- **From *shallow* to *deep* networks**

  A feed-forward neural network with three hidden layers

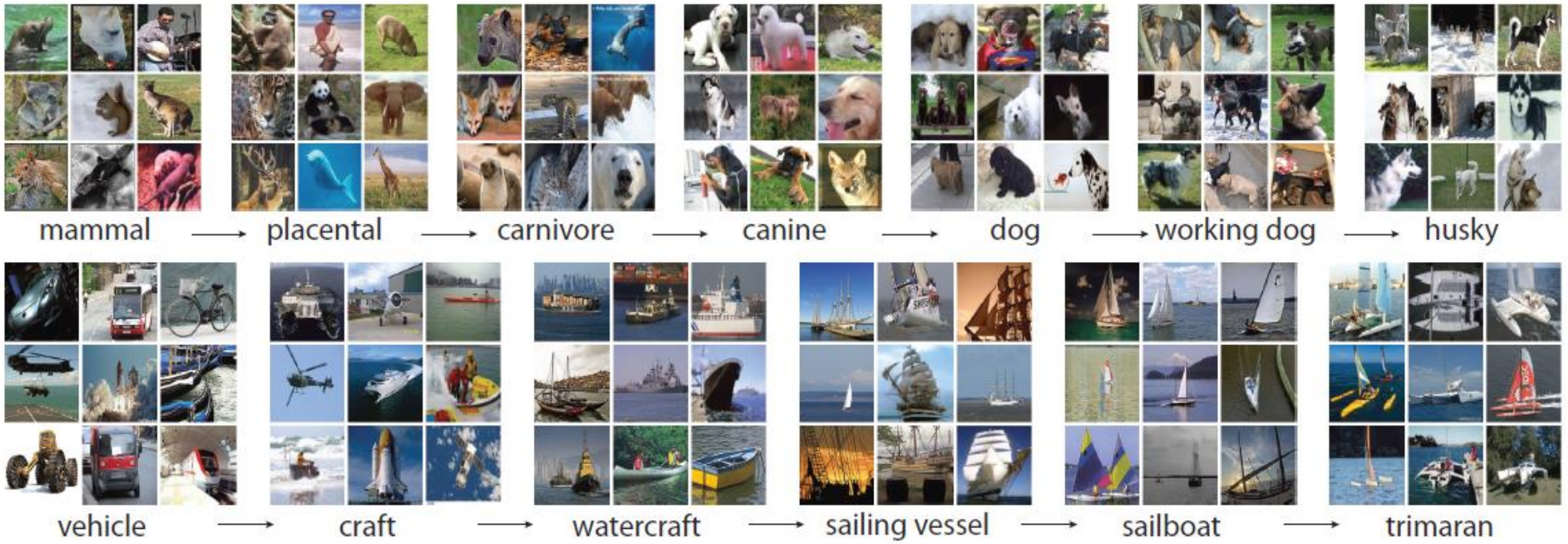
$$\tilde{y} = \boldsymbol{w} \cdot g(\boldsymbol{W}^{[3]} g(\boldsymbol{W}^{[2]} g(\boldsymbol{W}^{[1]} \boldsymbol{x} + \boldsymbol{b}^{[1]}) + \boldsymbol{b}^{[2]}) + \boldsymbol{b}^{[3]}) + b$$



Well, it's just a function anyway …

ImageNet Challenge

- The ImageNet Large Scale Visual Recognition Challenge



1,461,406 full resolution images

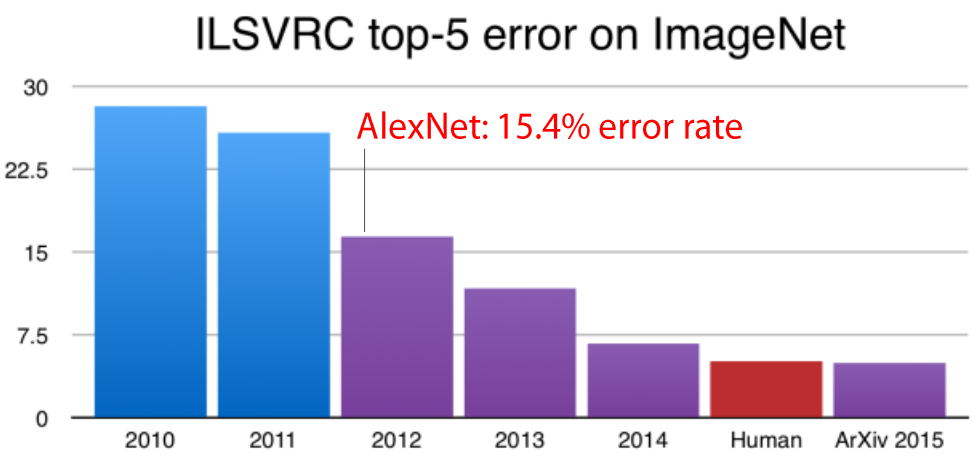
Complex and multiple textual annotation,
hierarchy of 1000 object classes along several dimensions

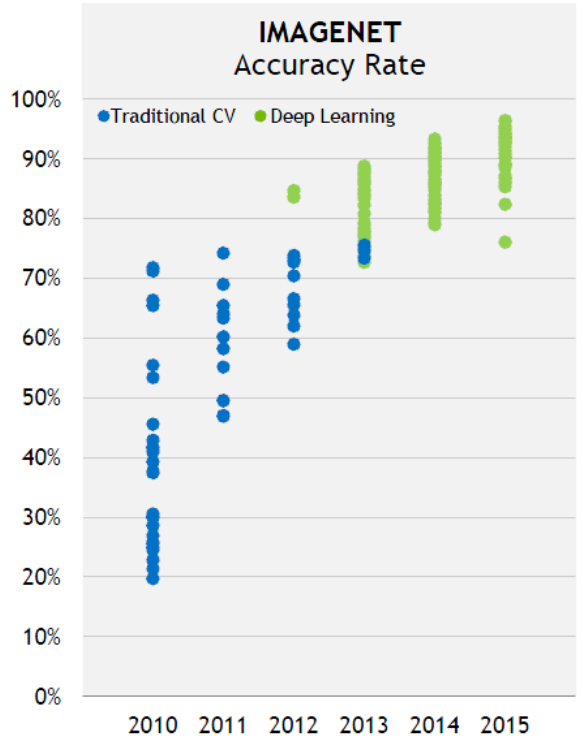
The image classification challenge was run annually from 2010 to 2017

[figures from www.nvidia.com]

ImageNet Challenge

- The ImageNet Large Scale Visual Recognition Challenge





1,461,406 full resolution images

Complex and multiple textual annotation,
hierarchy of 1000 object classes along several dimensions

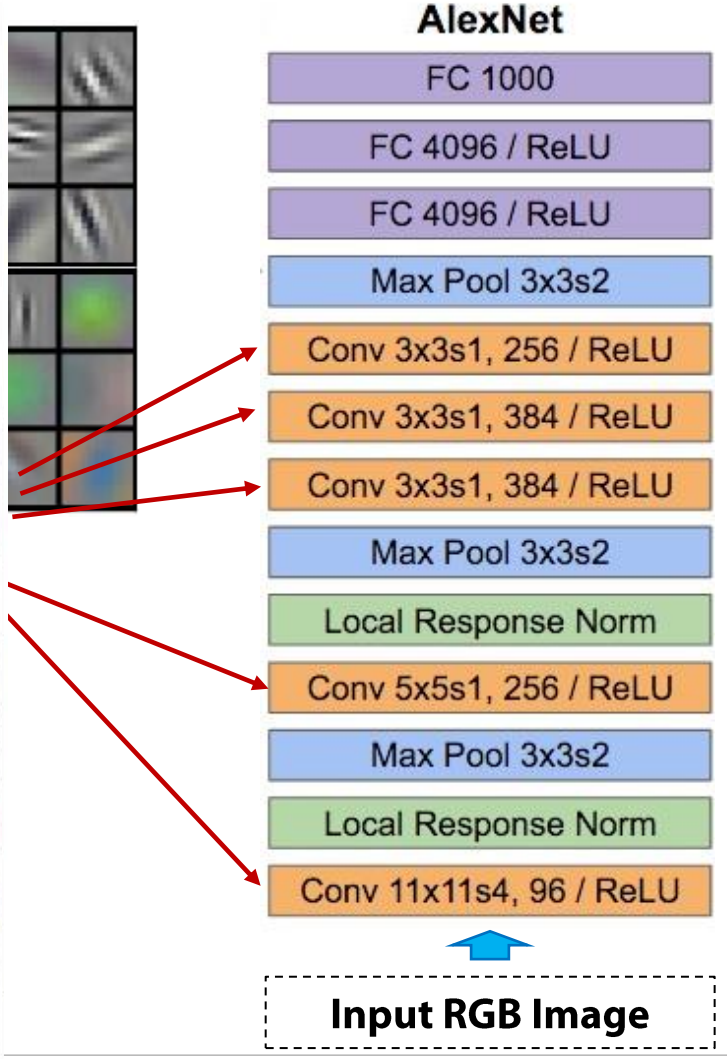
The image classification challenge was run annually from 2010 to 2017

[figures from www.nvidia.com]

Deep Convolutional Neural Networks (DCNN)

- ***AlexNet*** [Krizhevsky, Sutskever & Hinton, 2012]

Layer 3: 384 deep convo



[images from http://cs231n.github.io/convolutional-networks/]

Well, it's just a function anyway (contd.)...

Games of strategy: AlphaGo (2016)

Image from: https://nikcheerla.github.io/deeplearningschool/2018/01/01/AlphaZero-Explained/

- Mastering the game of Go with deep neural networks and tree search
  [2016, D. Silver, et al. (22 authors), http://www.nature.com/nature/journal/v529/n7587/full/nature16961.html]

There are more possible positions in Go than there are atoms in the universe

Sophisticated machine-learning techniques

Strategy selection via Monte Carlo Tree Search (MCTS)

Deep neural networks (trained on human matches) for both guidance and learning

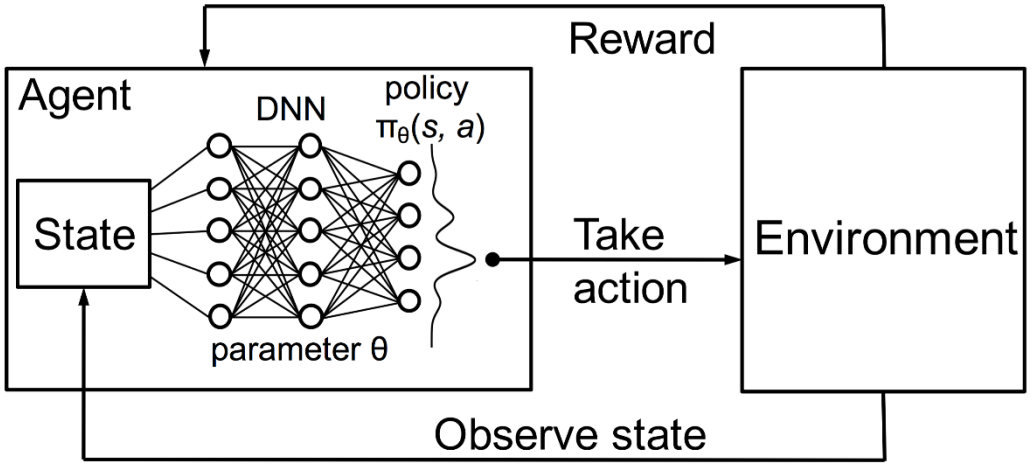
Adversarial self-training:
playing again itself and improving via reinforcement learning

Super-human player?

On March 2016, AlphaGo won 4-1 against the legendary Lee Sedol,
the top Go player in the world over the past decade

Deep Reinforcement Learning (DRL)

- ***A Deep Neural Network learns a policy***



The agent interacts with an environment (it could be a copy of itself)

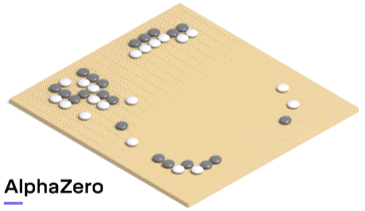
*It selects an **action** in each **state** and receives a **reward** (possibly deferred) as a function of the results obtained*

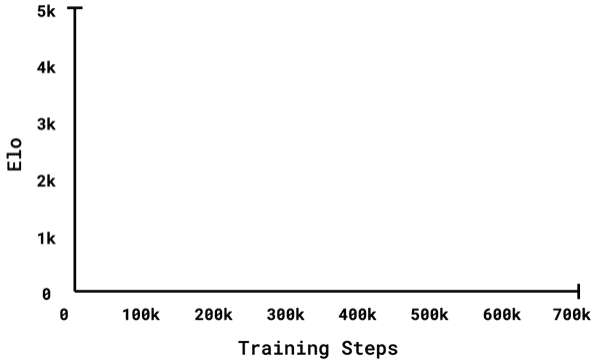
The DRL system optimizes its policy

Beyond Emulating Humans: AlphaZero (2018)

Image from: https://deepmind.com/blog/article/alphazero-shedding-new-light-grand-games-chess-shogi-and-go

AlphaGo is heavily reliant
on the experience of human players





- **AlphaZero learns by itself**
  [2018, D. Silver, et al. (13 authors), https://science.sciencemag.org/content/362/6419/1140.full]

Basic Knowledge Only

It just knows the basic rules of the games

Learning via Self-Play

It plays against a (frozen) copy of itself

MCTS and DCNN in a closed loop

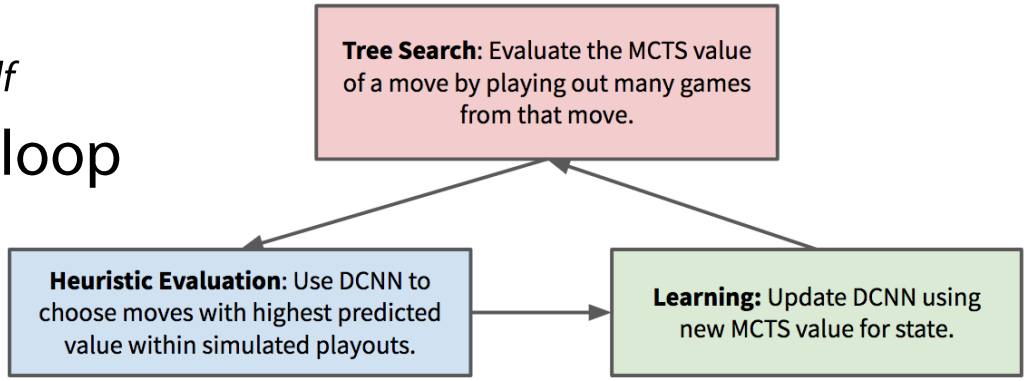


Image from: https://nikcheerla.github.io/deeplearningschool/2018/01/01/AlphaZero-Explained/

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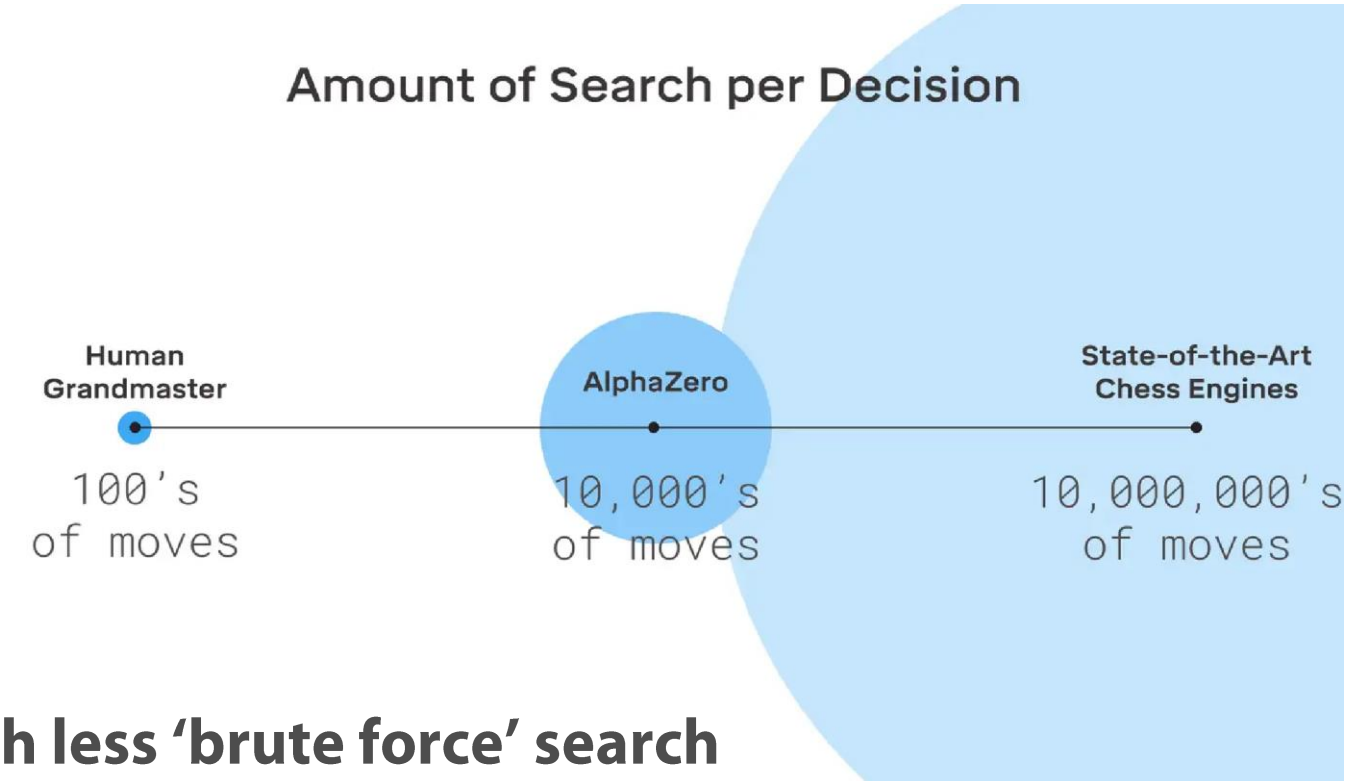


- **AlphaZero uses much less 'brute force' search**
  - When playing, the search process is driven by its neural network
    - *It acts like a memory of past experiences*
  - While training, it learns through a huge amount of self-playing
    - *But it is a faster learner than Alpha Go*

AlphaFold (2020)

Images from https://deepmind.com/blog/article/alphafold-a-solution-to-a-50-year-old-grand-challenge-in-biology

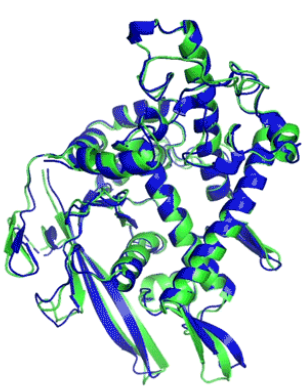
- **Predicting how proteins fold**

  Several Neural Networks

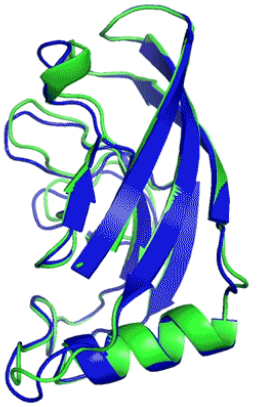
  Trained separately, working together

  A big step ahead

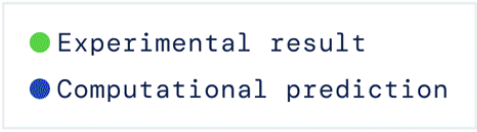
  Substantial improvement
  over the best actual systems yet

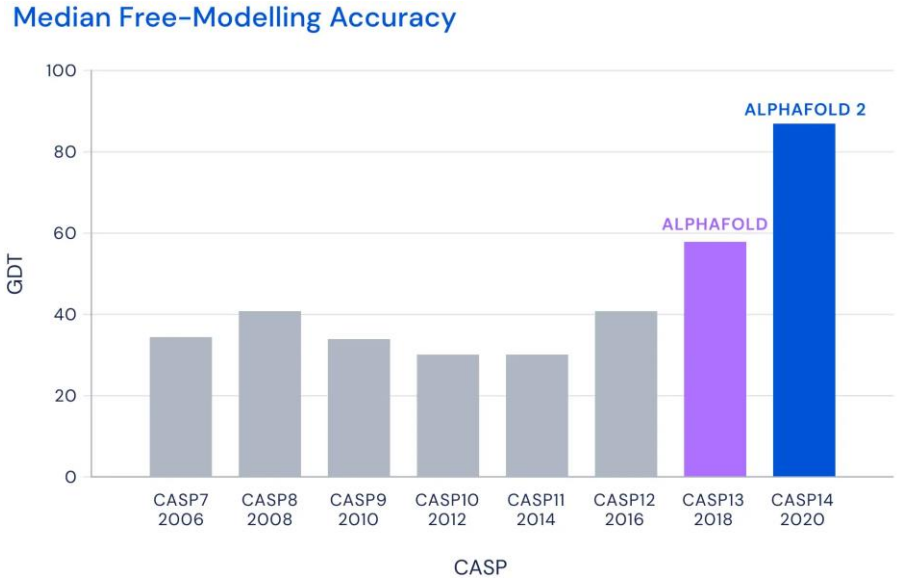


T1037 / 6vr4
90.7 GDT
(RNA polymerase domain)



T1049 / 6y4f
93.3 GDT
(adhesin tip)





It's open source

In the version used for the CASP13 challenge
https://github.com/deepmind/deepmind-research/tree/master/alphafold_casp13

GPT-3 (2020)

Image from https://www.theguardian.com/commentisfree/2020/sep/08/robot-wrote-this-article-gpt-3

GPT-3 (2020)

Image from https://www.nytimes.com/2020/07/29/opinion/gpt-3-ai-automation.html

Fortier fed GPT-3 a strange prompt: "Below is a transcript from an interview where Barack Obama explained why he was banned from Golden Corral for life." The system then filled in the rest of the interview, running with the concept that Obama had been banned from an all-you-can-eat buffet.

Obama: Yes. It's true. I am no longer allowed in Golden Corral.

Interviewer: Is this because of your extensive shrimp-n-crab legs policy?

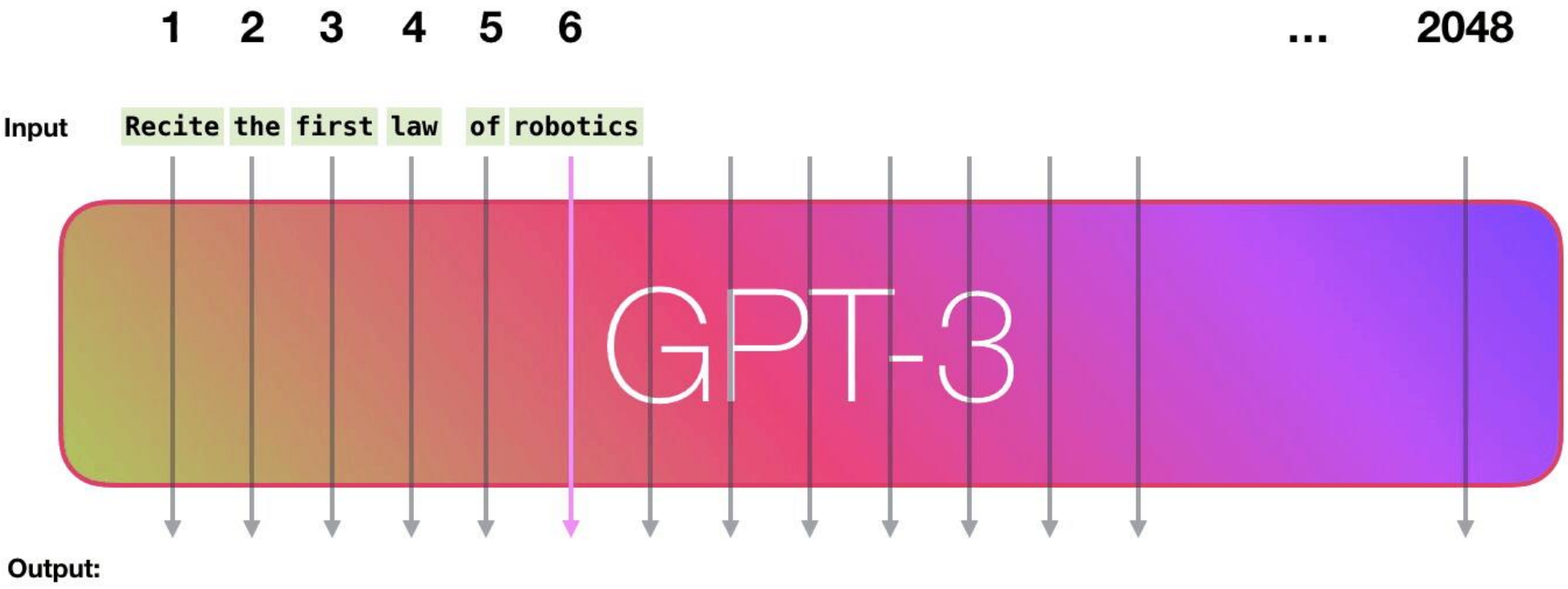
Obama: Absolutely.

Interviewer: What is your extensive shrimp-n-crab legs policy?

Obama: Oh, well, in brief, they were offering an all-you-can-eat shrimp-n-crab leg buffet, and I did not hesitate. After I ate so much shrimp and crab that my stomach hurt, I would quietly sneak in and throw more shrimp and crab onto my plate. I did this over and over again until I had cleaned out the buffet and was full of shrimp-n-crab.

GPT-3 (2020)

Image from http://jalammar.github.io/how-gpt3-works-visualizations-animations/



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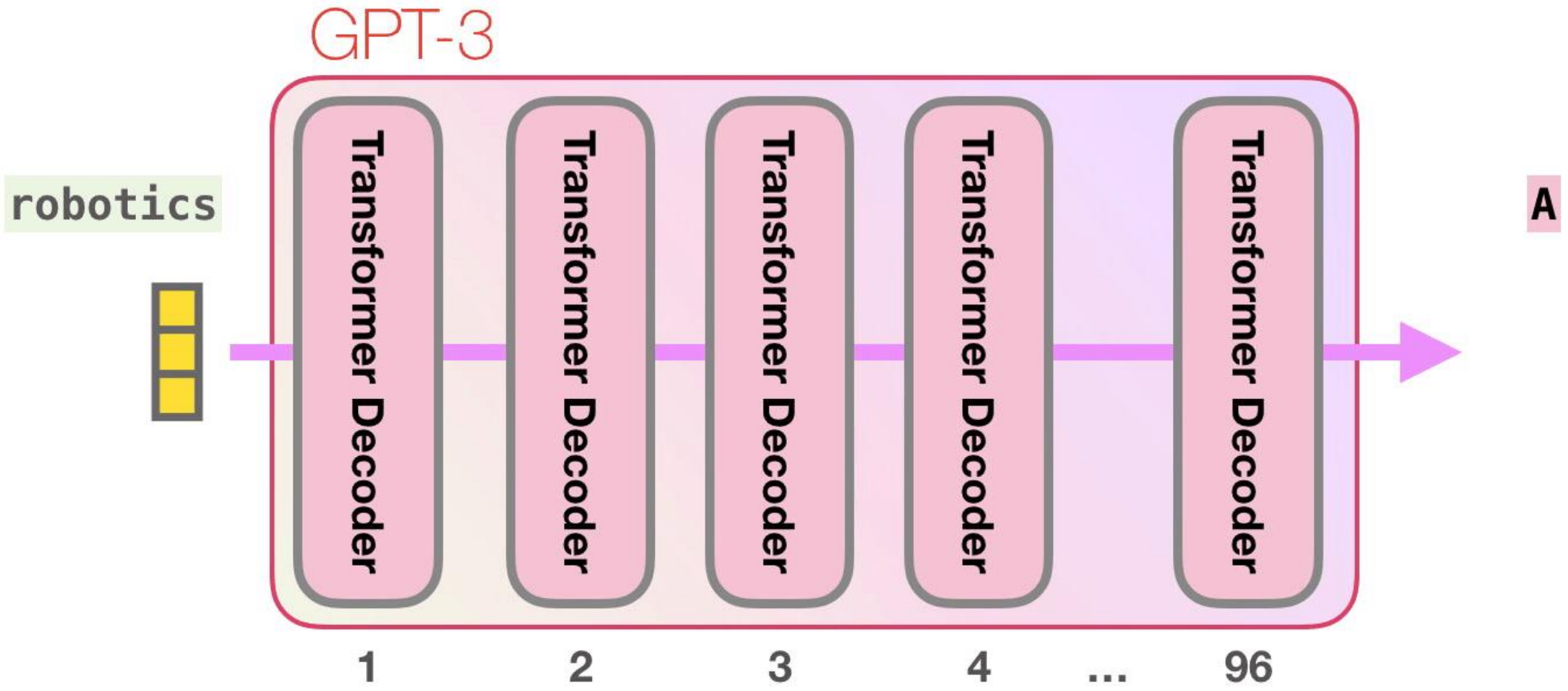


One of the biggest Neural Networks yet

GPT-3 has 175 Billion parameters
(AlexNet has 64 Million)

OK, about this course ...

This Course in a Nutshell

1) **Fundamentals**

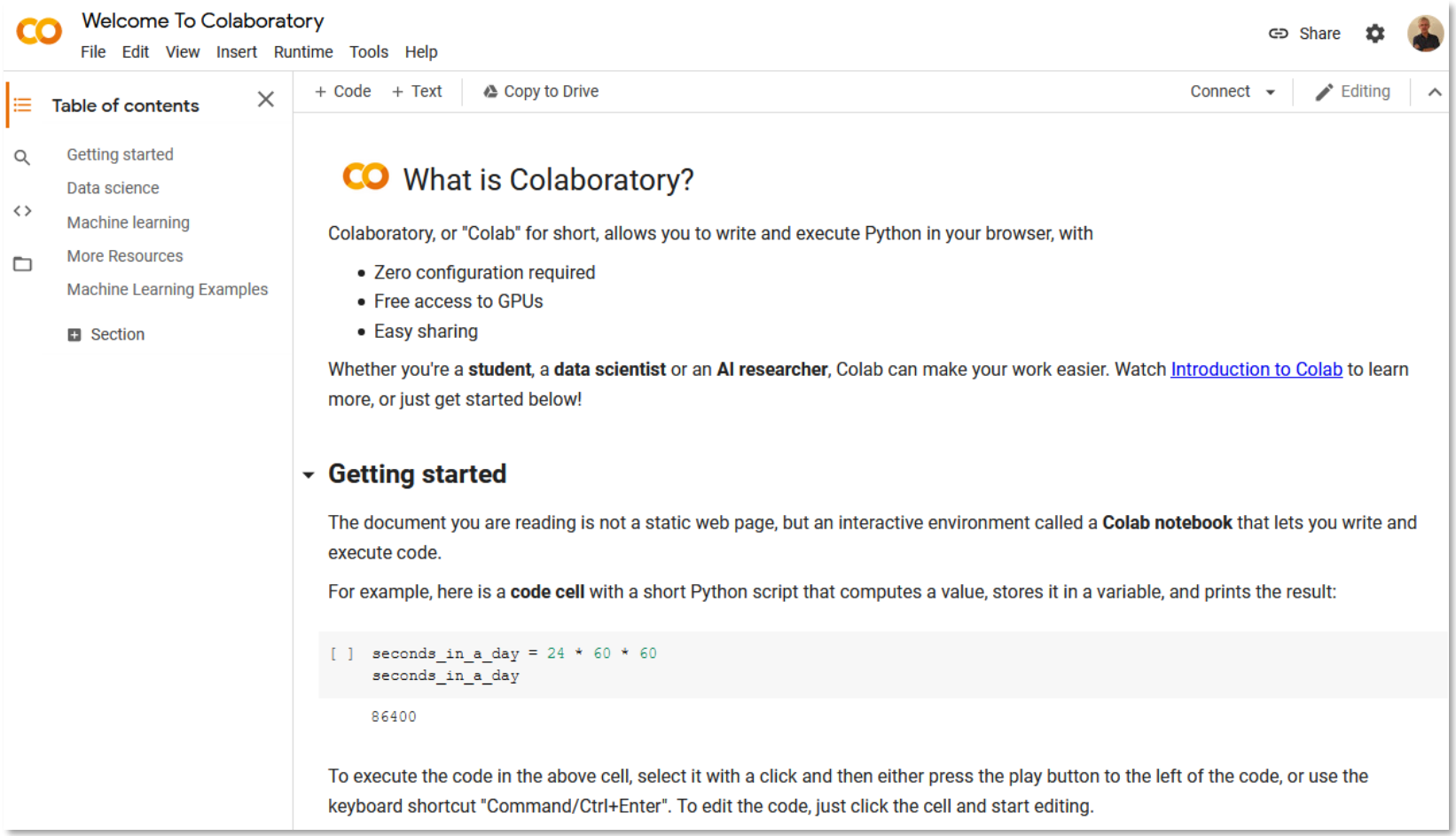
2) **Deep Supervised Learning**

3) **Deep Convolutional Neural Networks**

4) **Deep Recurrent Networks**

5) **Deep Reinforcement Learning**

Labs with Google Colab



Make sure you have a look!

Better yet: follow the tutorial at
https://colab.research.google.com/notebooks/intro.ipynb

PyCharm (optional)

However, if you really want to see how things work...

- ***Set it up on your computer***

  Python 3.7+
  Numpy 1.17+
  TensorFlow 2.+

  ... and, above all ...

  Install PyCharm (Community Edition)
  https://www.jetbrains.com/pycharm/
  It's free
  Learn using the *debugger* :
  it will change the way you learn

CAUTION: no assistance whatsoever will be provided for this ...
"Legions of students succeeded in doing this on their own: you can make it too!"

The Final Exam

1) Choose and propose a final project

The topic could be any of your choice
The techniques adopted must be (strongly) related with the course
Groupwork is allowed, with a maximum of two *(no exceptions)*

2) Develop and submit your projects

Each final project must be submitted as a Google Colab notebook plus dataset *(if required)*

Submission must be made at least two days before the exams

3) Be strong on theory as well

Not even a *phenomenal* final project, alone, will give you a final grade *(sorry)*

See also below

4) Final Exam

Oral interview, about both theory and final project

Relative weights: theory 60%, final project 40%