# Deep Learning

Lecture 0: Introduction

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# Why learning?

What do you see?

Sheepdog or mop?

Credits: Karen Zack, 2016.

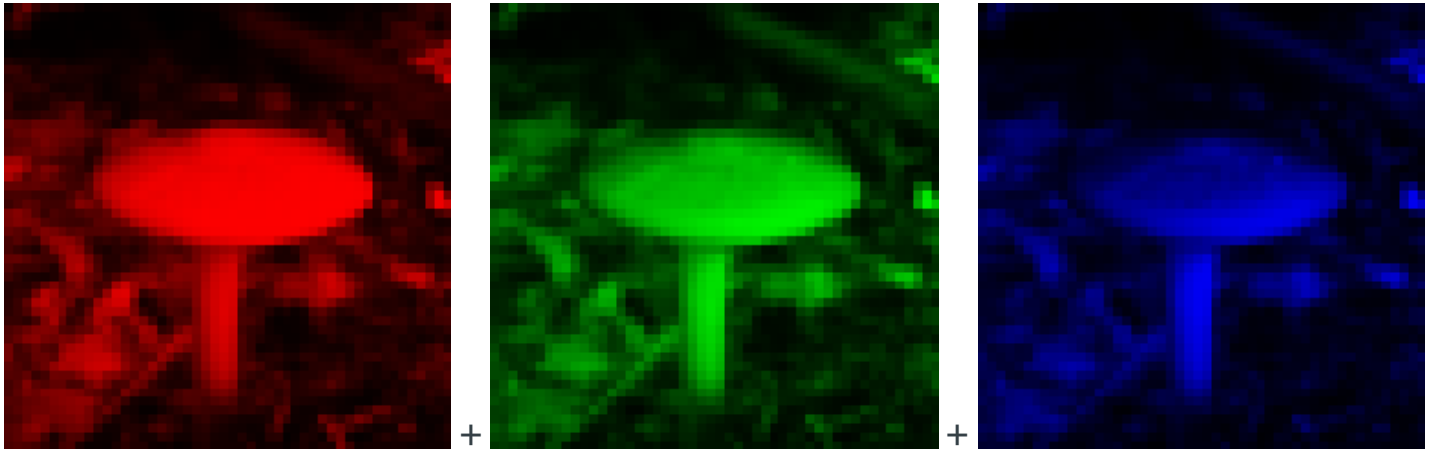
Chihuahua or muffin?

Credits: Karen Zack. 2016.

The (human) brain is so good at interpreting visual information that the gap between raw data and its semantic interpretation is difficult to assess intuitively:

This is a mushroom.

This is a mushroom.



This is a mushroom.

```
array([[[0.03921569, 0.03529412, 0.02352941, 1.        ],
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        [0.4117647 , 0.34117648, 0.37254903, 1.        ],
        ...,
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        [0.18039216, 0.18039216, 0.14117648, 1.        ]],

       [[0.1254902 , 0.11372549, 0.09411765, 1.        ],
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        [0.21176471, 0.2       , 0.20392157, 1.        ],
        ...,
        [0.1764706 , 0.24705882, 0.12156863, 1.        ],
        [0.10980392, 0.15686275, 0.07843138, 1.        ],
        [0.16470589, 0.20784314, 0.11764706, 1.        ]],

       [[0.14117648, 0.12941177, 0.10980392, 1.        ],
        [0.21176471, 0.1882353 , 0.16862746, 1.        ],
        [0.14117648, 0.13725491, 0.12941177, 1.        ],
        ...,
        [0.10980392, 0.15686275, 0.08627451, 1.        ],
        [0.0627451 , 0.08235294, 0.05098039, 1.        ],
        [0.14117648, 0.2       , 0.09803922, 1.        ]],

       ...,
```
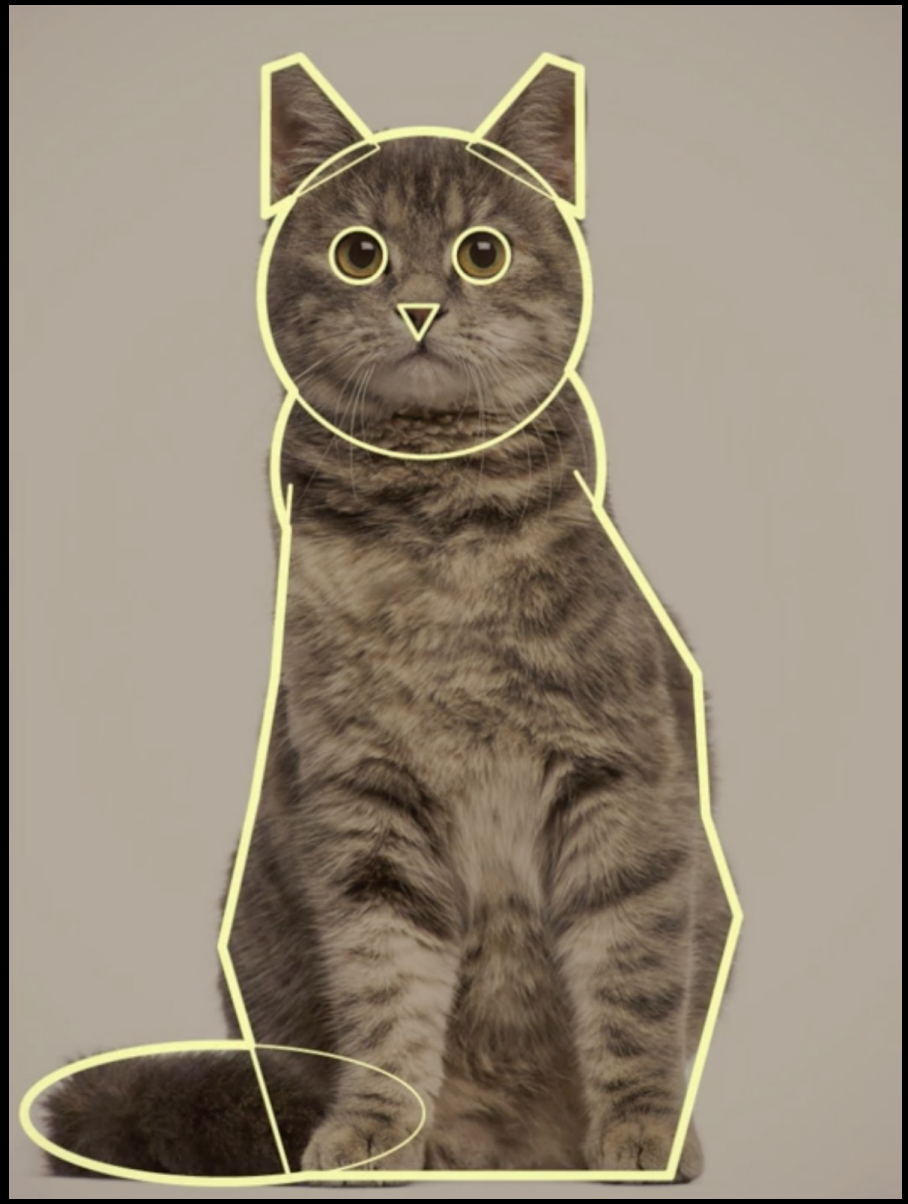
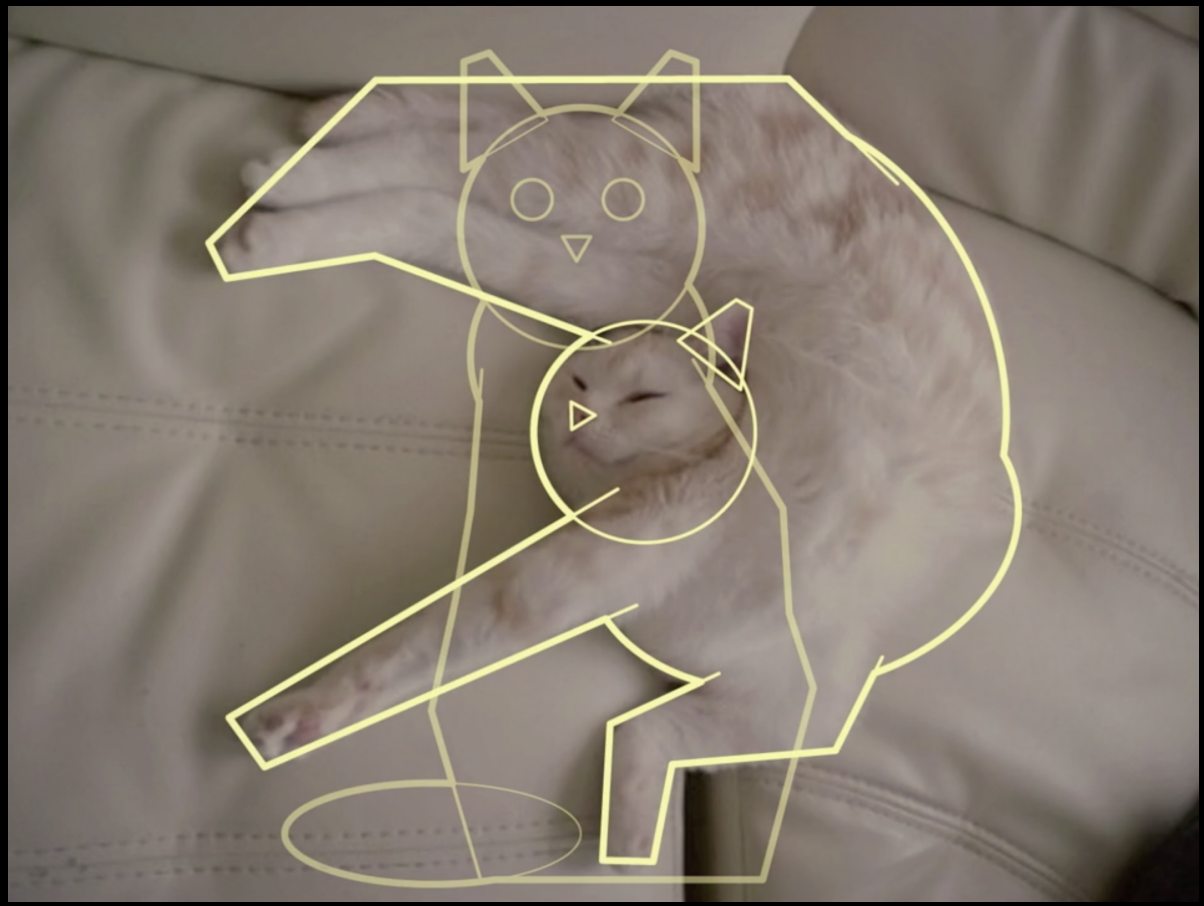

This is a mushroom.

Writing a computer program that sees?





Extracting semantic information requires models of high complexity, which cannot be designed by hand.

However, one can write a program that learns the task of extracting semantic information.


Techniques used in practice consist of:

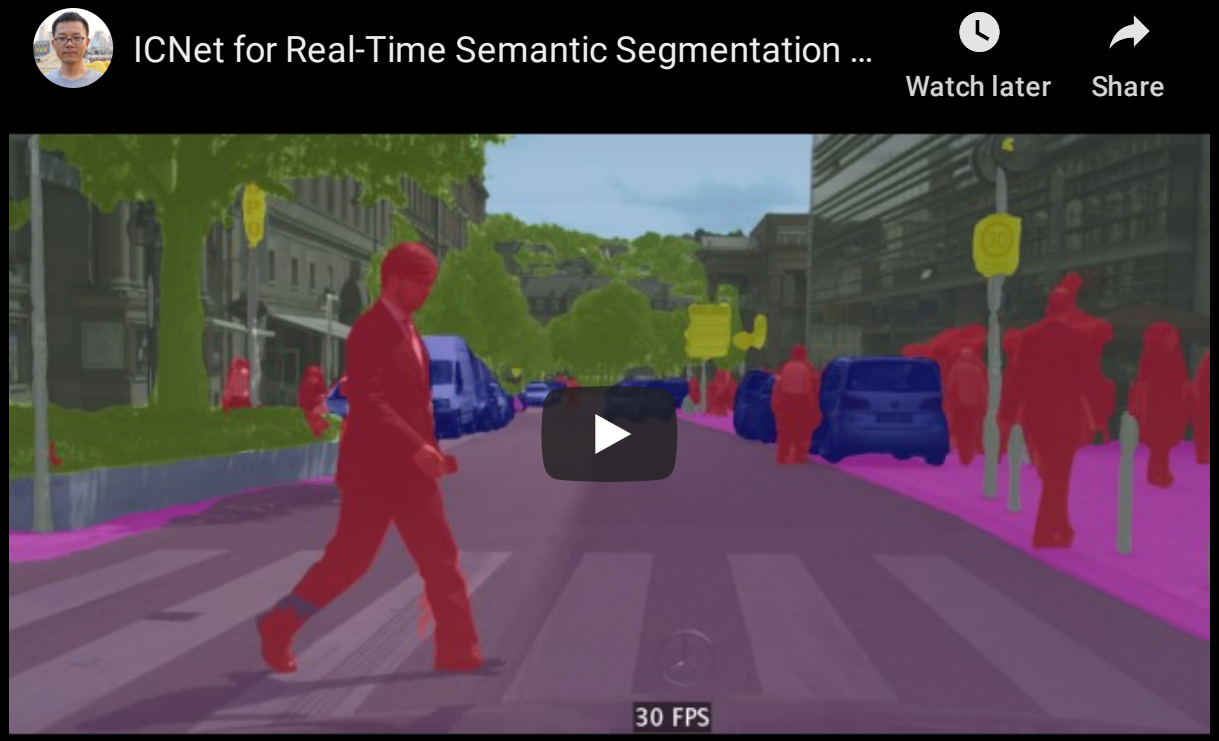
- defining a parametric model with high capacity,
- optimizing its parameters, by "making it work" on the training data.

This is similar to biological systems for which the model (e.g., brain structure) is DNA-encoded, and parameters (e.g., synaptic weights) are tuned through experiences.

Deep learning encompasses software technologies to scale-up to billions of model parameters and as many training examples.

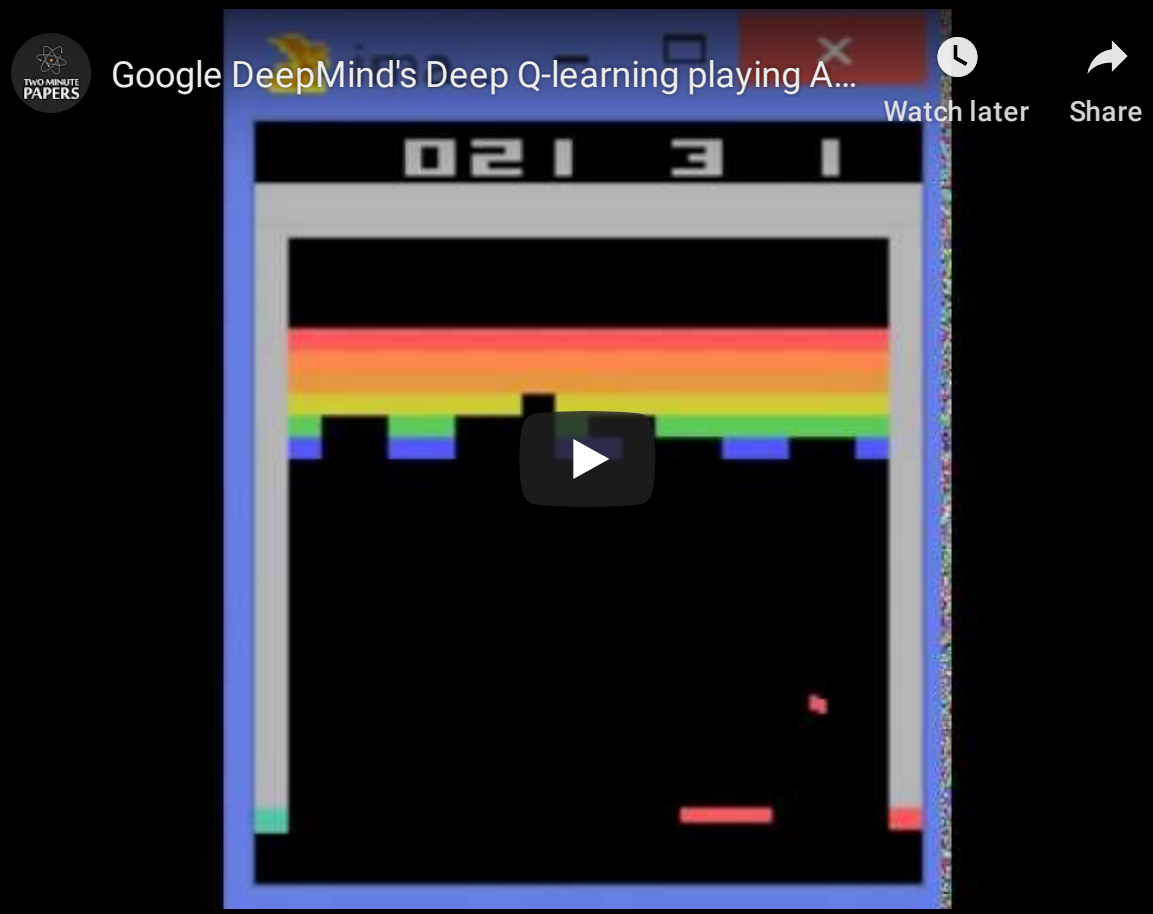
# Applications and successes


Real-time object detection (Redmon and Farhadi, 2018)

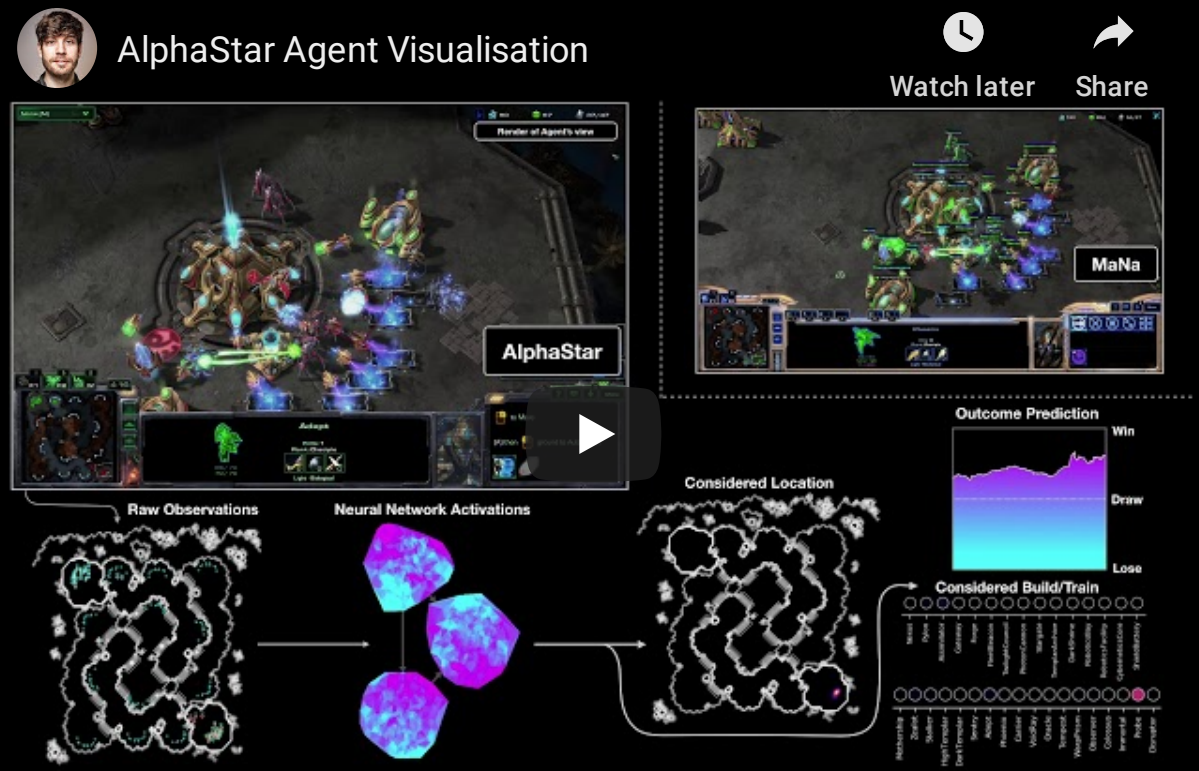



Segmentation (Hengshuang et al, 2017)

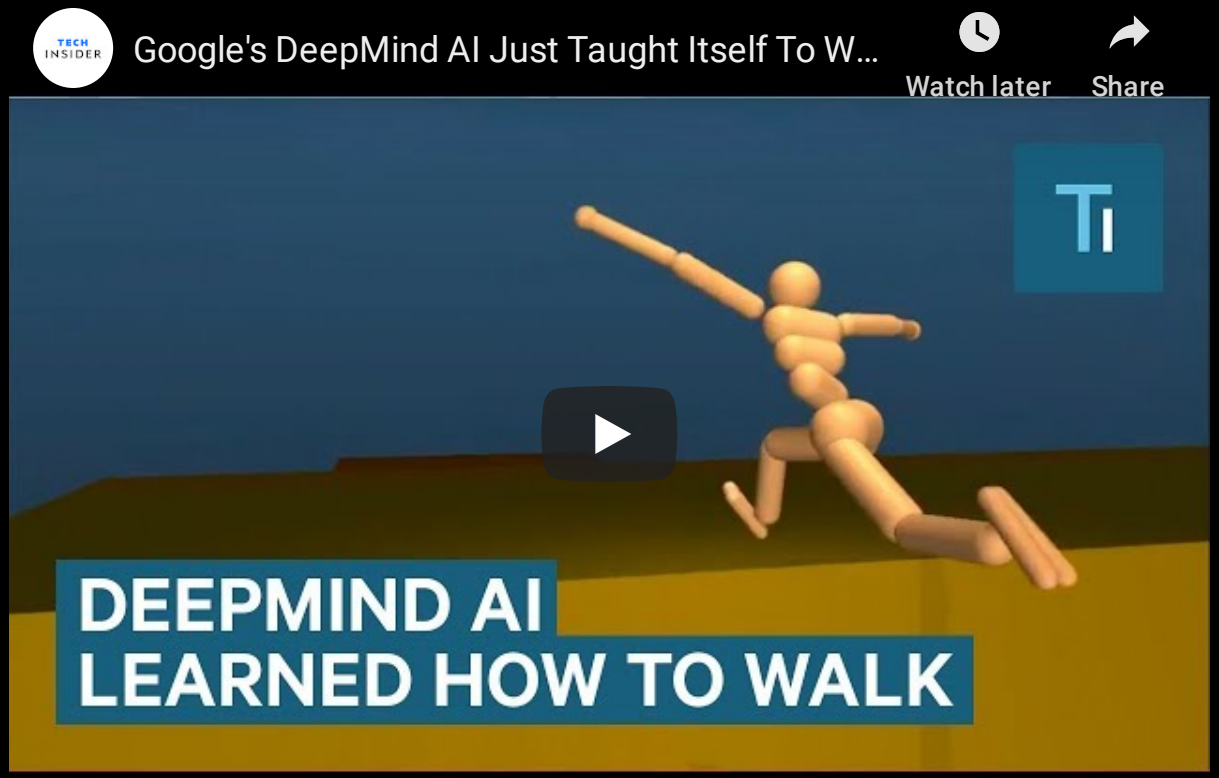

Pose estimation (Cao et al, 2017)




Reinforcement learning (Mnih et al, 2014)




Strategy games (Deepmind, 2016-2018)




Learning to walk (2017)

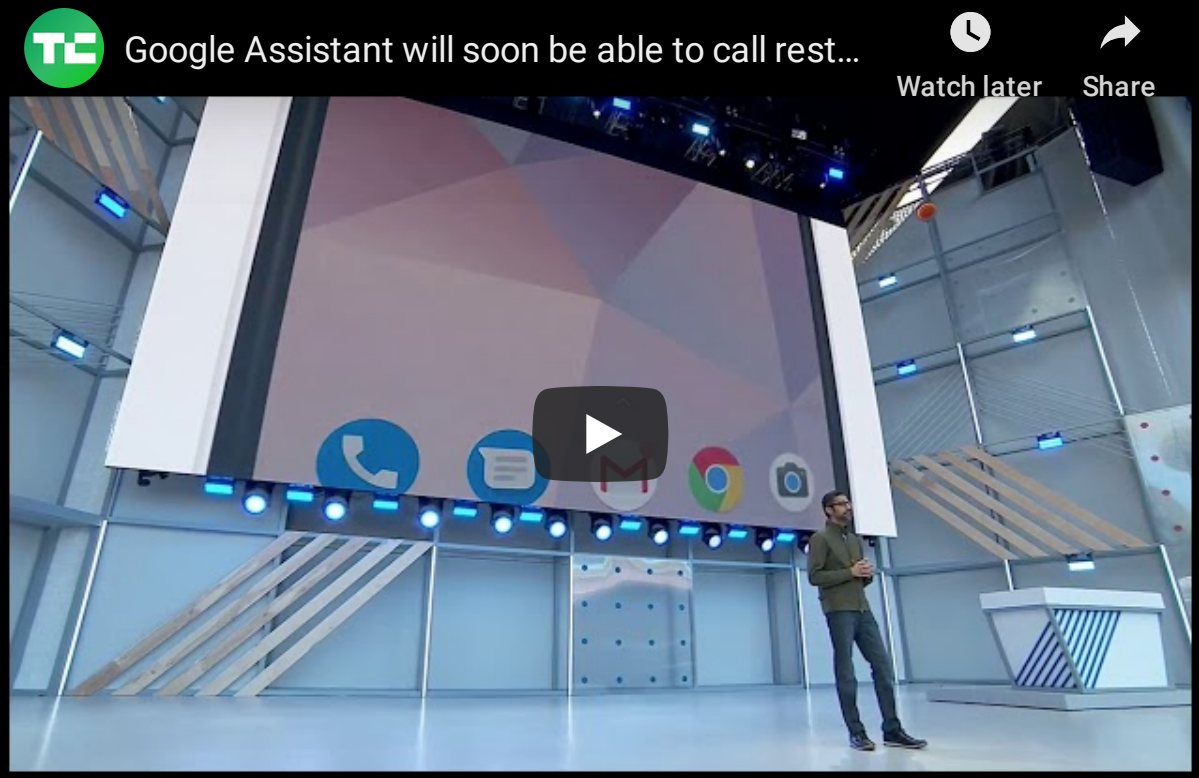

Autonomous cars (NVIDIA, 2016)


Autopilot (Tesla, 2019)

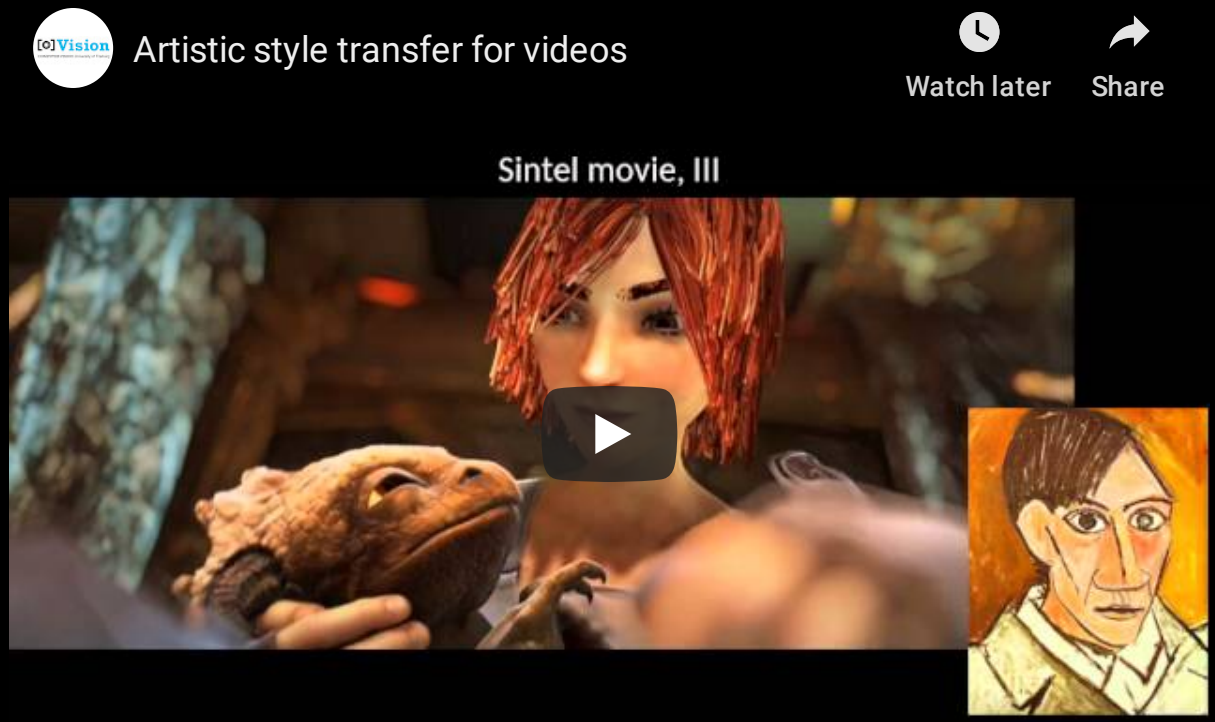

... while preventing accidents.


Speech recognition, translation and synthesis (Microsoft, 2012)


Auto-captioning (2015)




Speech synthesis and question answering (Google, 2018)




Artistic style transfer (Ruder et al, 2016)

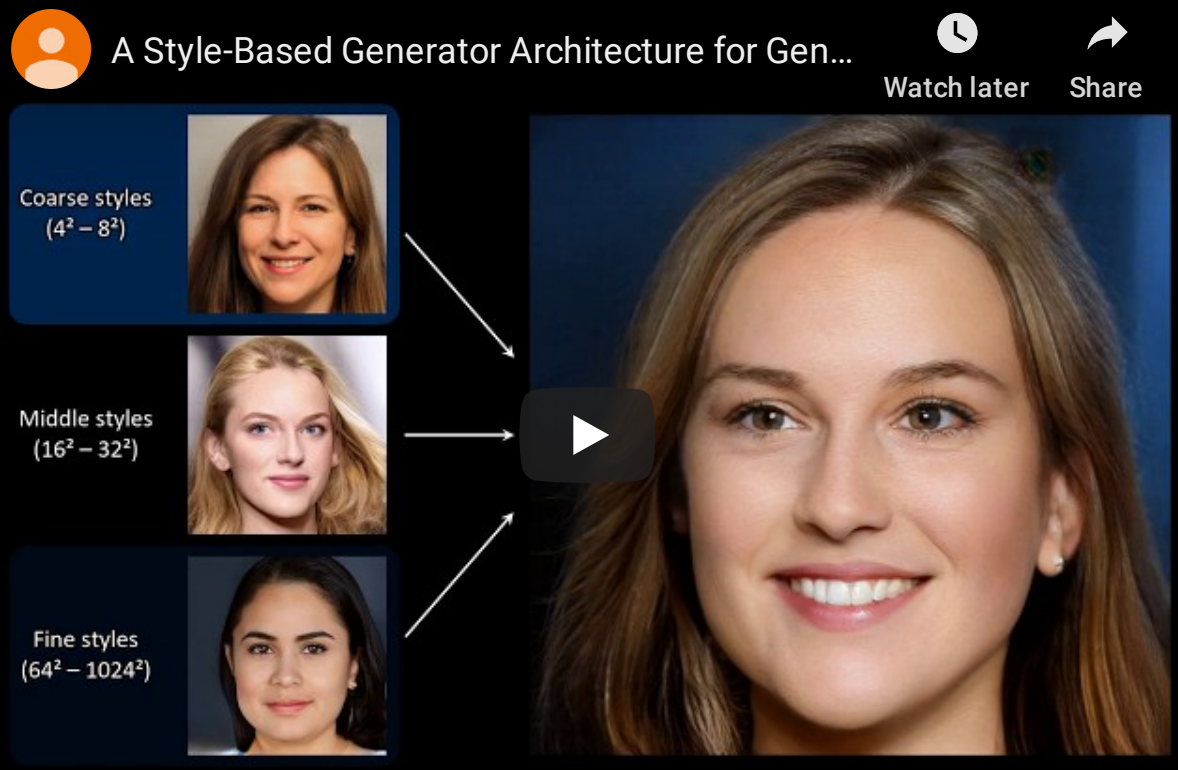
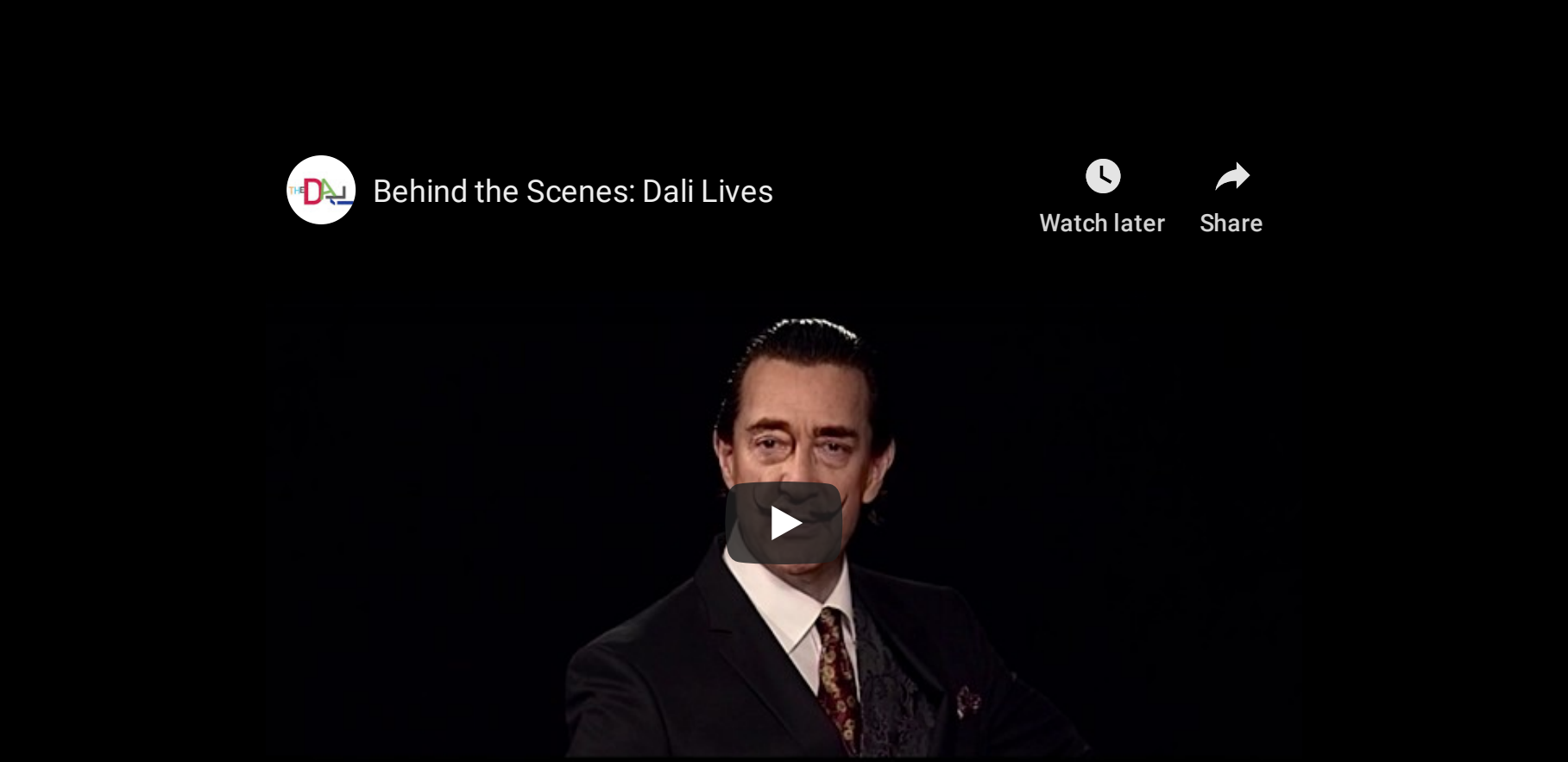



Image generation (Karras et al, 2018)


Music composition (NVIDIA, 2017)

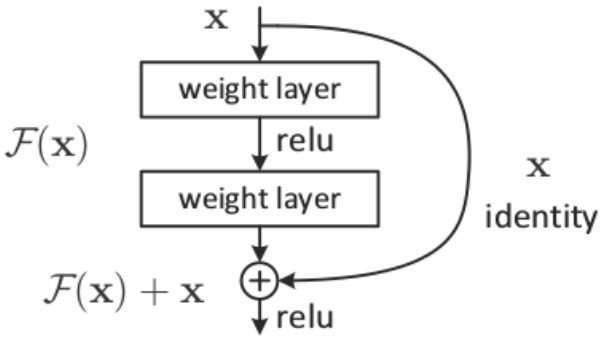



Dali Lives (2019)

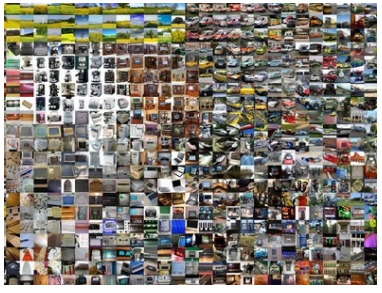
*"ACM named **Yoshua Bengio**, **Geoffrey Hinton**, and **Yann LeCun** recipients of the **2018 ACM A.M. Turing Award** for conceptual and engineering breakthroughs that have made deep neural networks a critical component of computing."*

# Why does it work now?

## Algorithms (old and new)




## More data



## Software

Caffe2 · Microsoft CNTK · TensorFlow · theano · Chainer · PYTORCH · dmlc mxnet · K

## Faster compute engines

## Building on the shoulders of giants

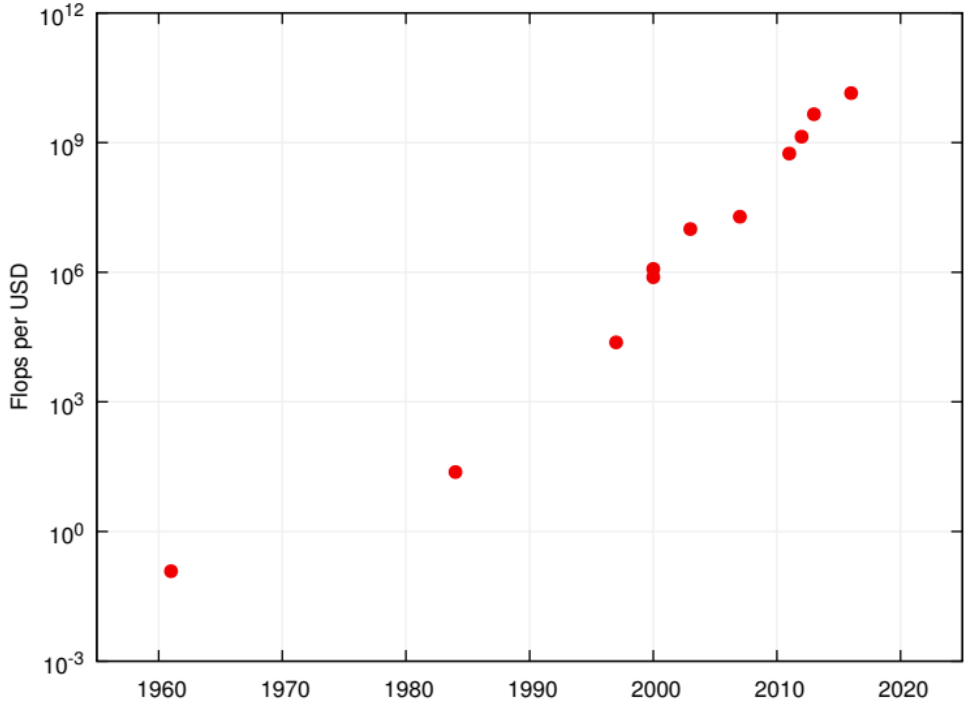
Five decades of research in machine learning provided

- a taxonomy of ML concepts (classification, generative models, clustering, kernels, linear embeddings, etc.),
- a sound statistical formalization (Bayesian estimation, PAC),
- a clear picture of fundamental issues (bias/variance dilemma, VC dimension, generalization bounds, etc.),
- a good understanding of optimization issues,
- efficient large-scale algorithms.

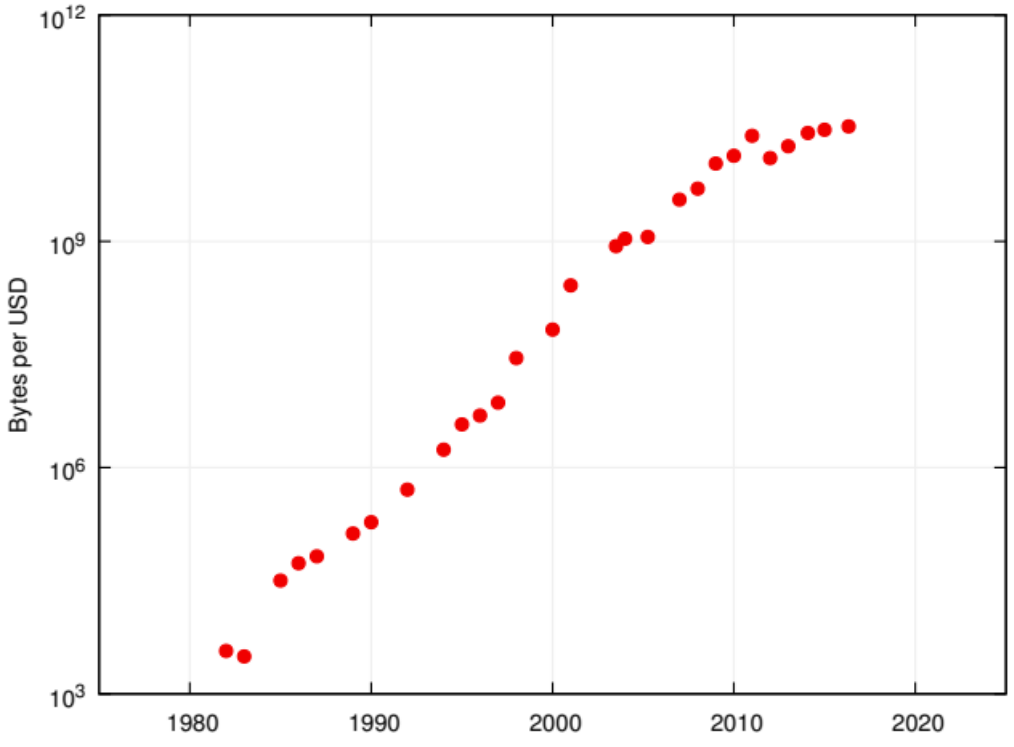
## Deep learning

From a practical perspective, deep learning

- lessens the need for a deep mathematical grasp,
- makes the design of large learning architectures a system/software development task,
- allows to leverage modern hardware (clusters of GPUs),
- does not plateau when using more data,
- makes large trained networks a commodity.




| | TFlops ($10^{12}$) | Price | GFlops per $ |
|---|---|---|---|
| Intel i7-6700K | 0.2 | $344 | 0.6 |
| AMD Radeon R-7 240 | 0.5 | $55 | 9.1 |
| NVIDIA GTX 750 Ti | 1.3 | $105 | 12.3 |
| AMD RX 480 | 5.2 | $239 | 21.6 |
| NVIDIA GTX 1080 | 8.9 | $699 | 12.7 |




The typical cost of a 4Tb hard disk is less than 100 USD (February 2020).

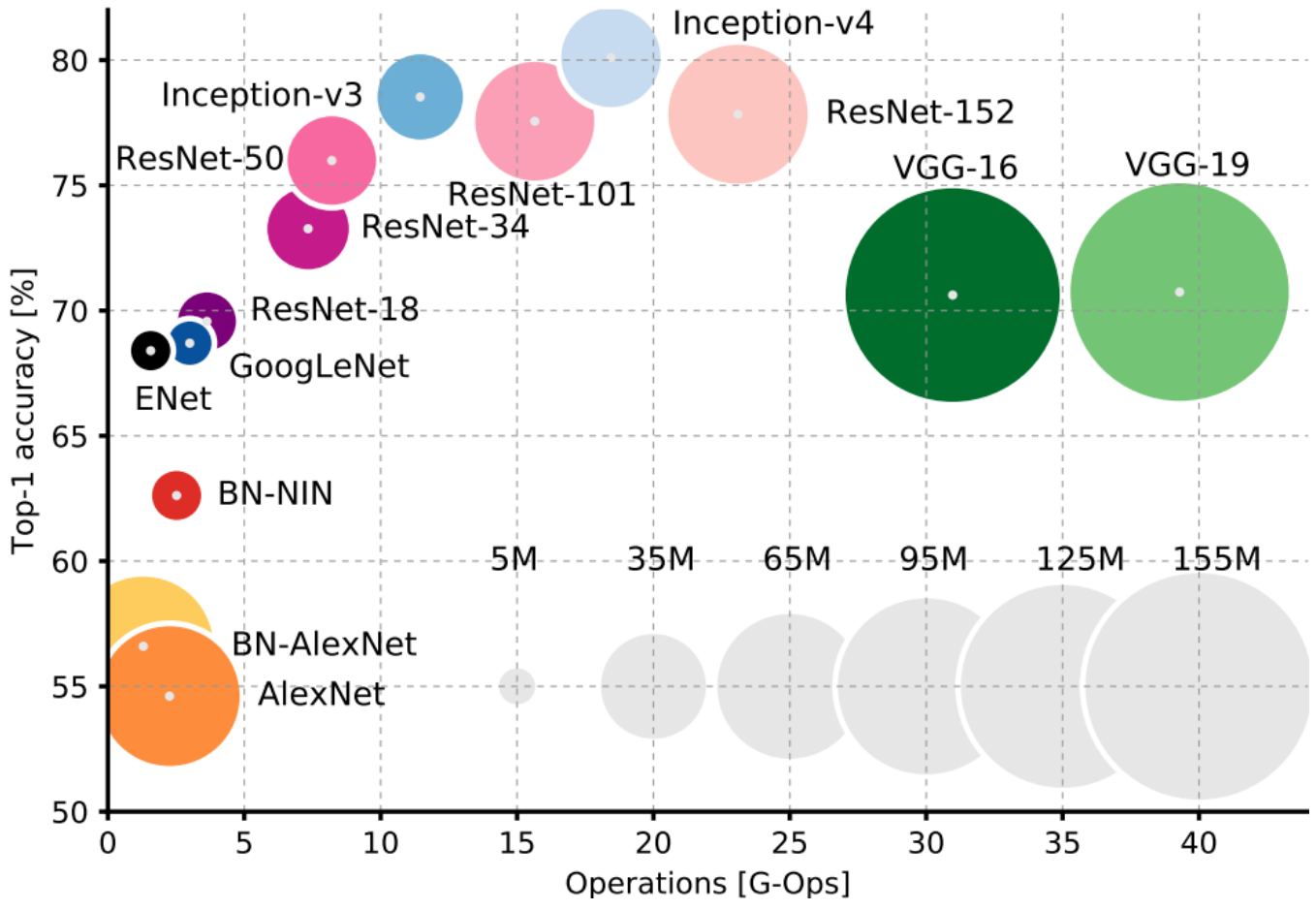
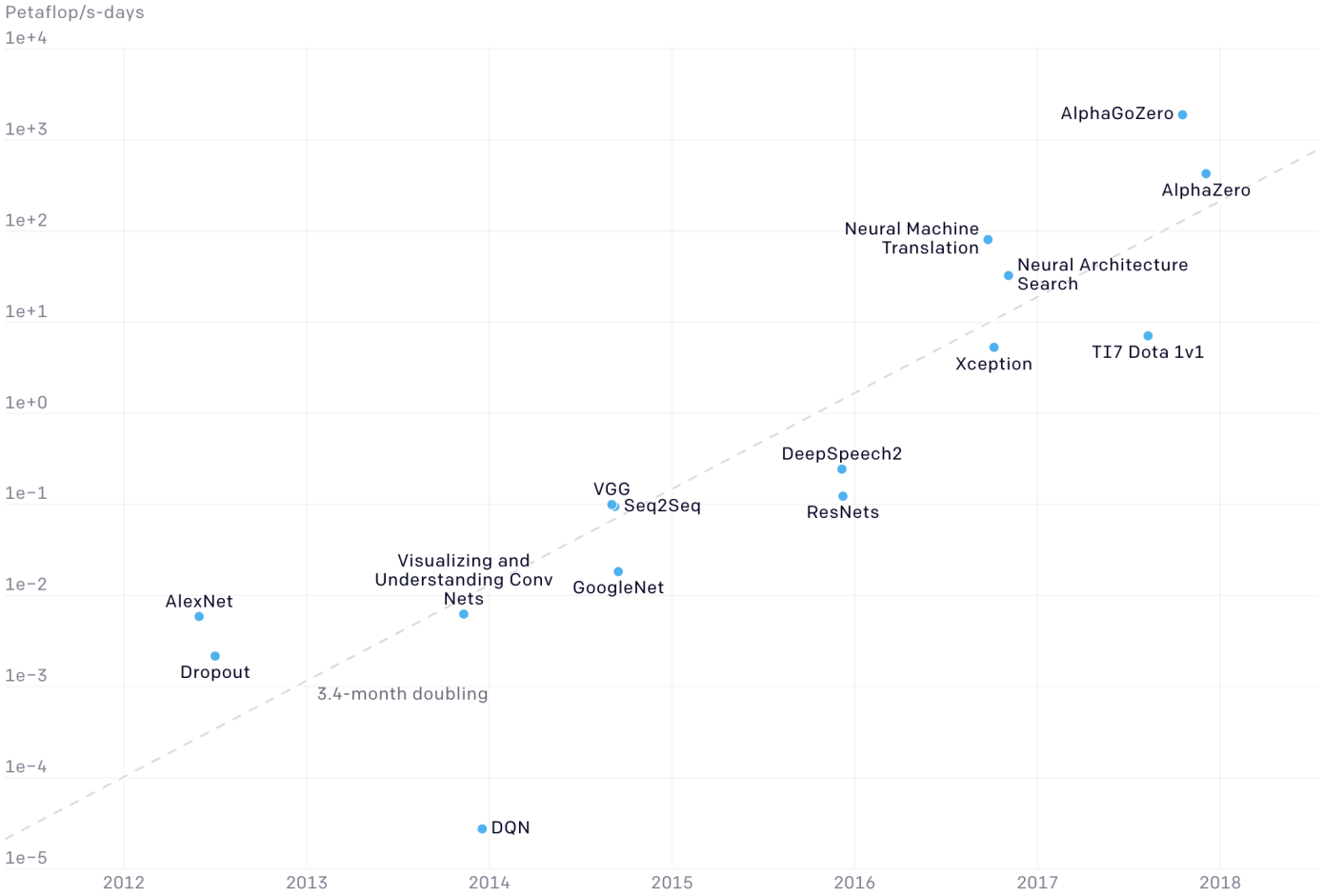



Image credits: Canziani et al, 2016, arXiv:1605.07678.

## AlexNet to AlphaGo Zero: A 300,000x Increase in Compute (Log Scale)




Credtis: AI and Compute, Open AI, 2018.

$1$ petaflop/s-day
$= 10^{15}$ neural net operations per second for one day
$= 10^{20}$ opetations
$\approx 100$ GPUs for one day
$\approx 500\text{kWh}$

The end.

# References


- LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. nature, 521(7553), 436-444.