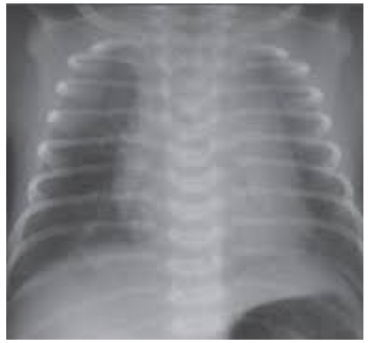
# AI for Oil & Gas

Andrea Panizza

https://github.com/AndreaPi/docker-training-2019-public

# AI is around us


Self-driving cars



Health

Wearables

Voice assistant

Surveillance


Smart home


Translation

# Video synthesis

https://www.youtube.com/watch?v=p1b5aiTrGzY

# Which of these persons is fake?

1

2

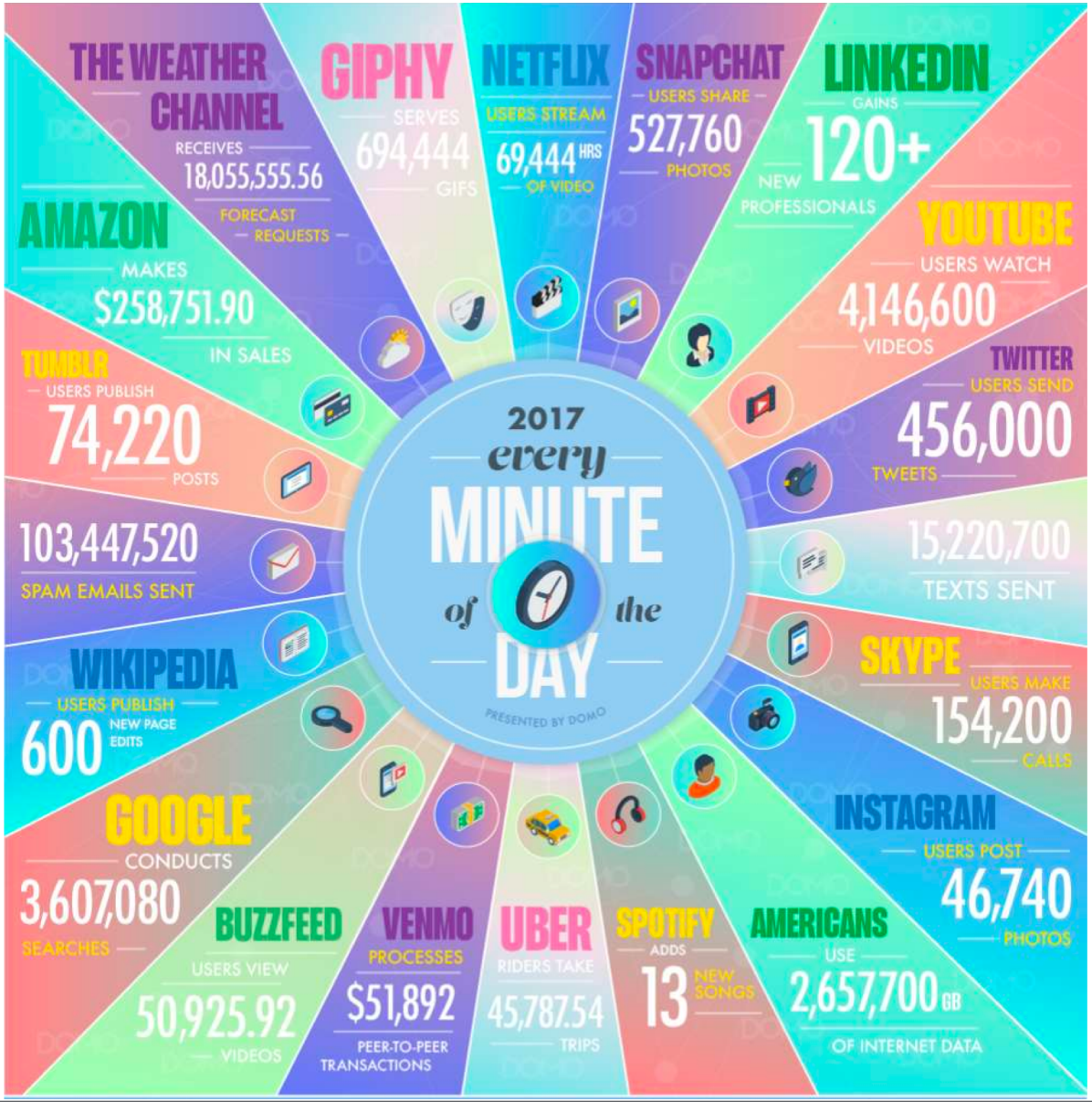
3

4

# Video synthesis

https://youtu.be/c-NJtV9Jvp0

# BIG data


2017
every
MINUTE
of the
DAY
PRESENTED BY DOMO
THE WEATHER CHANNEL
RECEIVES
18,055,555.56
FORECAST REQUESTS
GIPHY
SERVES
694,444
GIFS
NETFLIX
USERS STREAM
69,444 HRS
OF VIDEO
SNAPCHAT
USERS SHARE
527,760
PHOTOS
LINKEDIN
GAINS
120+
NEW PROFESSIONALS
AMAZON
MAKES
$258,751.90
IN SALES
YOUTUBE
USERS WATCH
4,146,600
VIDEOS
TUMBLR
USERS PUBLISH
74,220
POSTS
TWITTER
USERS SEND
456,000
TWEETS
103,447,520
SPAM EMAILS SENT
15,220,700
TEXTS SENT
WIKIPEDIA
USERS PUBLISH
600
NEW PAGE EDITS
SKYPE
USERS MAKE
154,200
CALLS
GOOGLE
CONDUCTS
3,607,080
SEARCHES
INSTAGRAM
USERS POST
46,740
PHOTOS
BUZZFEED
USERS VIEW
50,925.92
VIDEOS
VENMO
PROCESSES
$51,892
PEER-TO-PEER TRANSACTIONS
UBER
RIDERS TAKE
45,787.54
TRIPS
SPOTIFY
ADDS
13
NEW SONGS
AMERICANS
USE
2,657,700 GB
OF INTERNET DATA

# BIG data in Oil & Gas

**Drilling Data**
**0.3 GB/well/day**

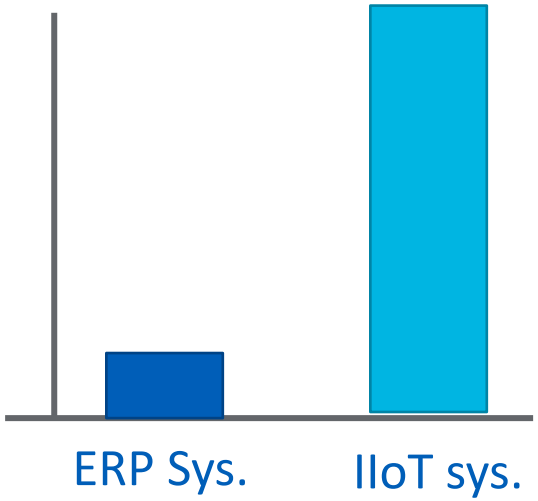
**Ultrasound: Tubes**
**1.2 TB/ 8 hrs**

**Wireline Data**
**5 GB/well/day**

**Pipeline Inspection**
**1.5 TB / 600 km**

**Seismic Data**
**100 GB/survey**

**Process Data**
**6 GB/plant/day**

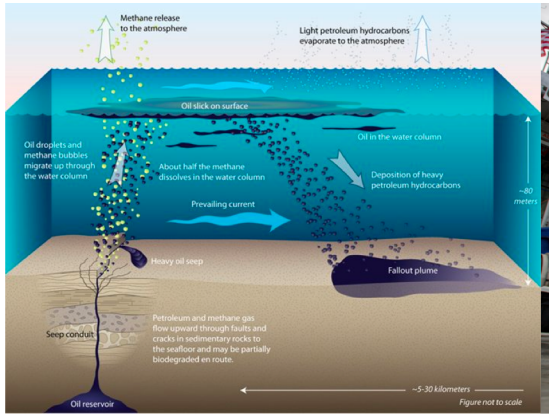



- ~10-100x more volume
- ~100-1000x more velocity

# AI in Oil & Gas

## ExxonMobil

- working with MIT to design AI robots for ocean exploration
- The robots fly over the ocean to detect natural seeps which occur when oil escapes from rock found in the ocean floor



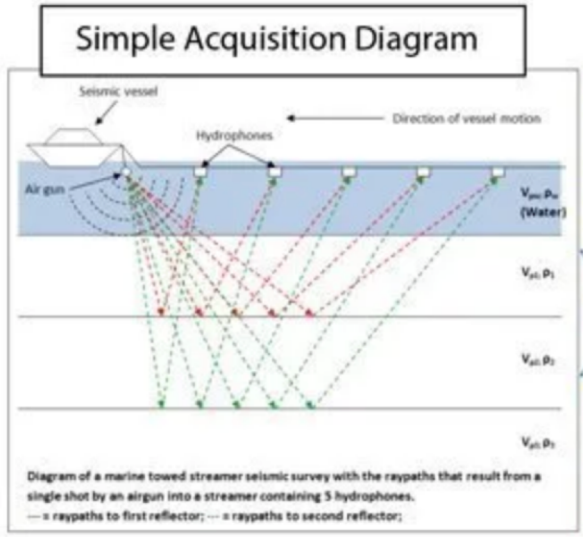

## Sinopec

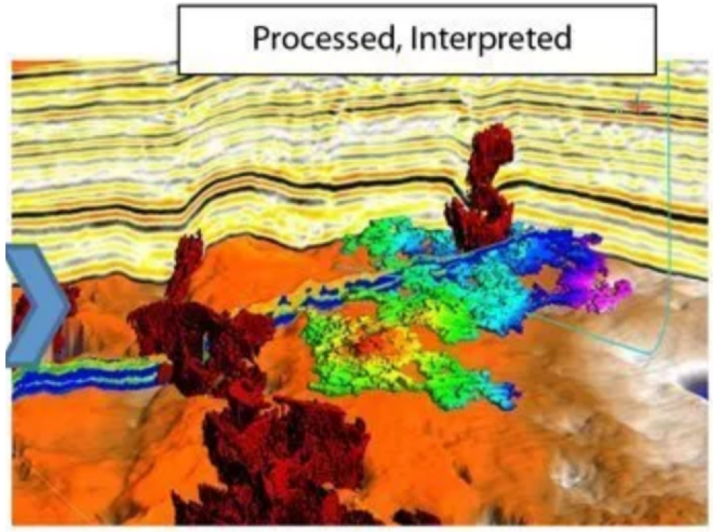
- long-term plan to build 10 AI-driven plants, 20% reduction in operation costs
- Collaboration with Huawei (an AI giant) in April 2017 to design a “smart manufacturing platform” for centralized data management and integration of data to manage factory operations
- AI will interpret data and look for opportunities to improve factory operations

# AI in Oil & Gas

## Total & Google Cloud Platform

- Traditionally subsurface seismic images at Total were analyzed manually by geologists
- Total & GCP are collaborating to develop AI systems that can help geologists interpret such images images using **computer vision, NLP & conversational AI**
- Goal: build a tool which analyzes image files, correlates findings with info from technical docs & summarizes info into a queryable AI assistant that can answer questions on the subsurface data in natural language.
- Total is also using machine learning for more “classical” applications such as predictive maintenance of turbines, pumps, and compressors



# AI in Oil & Gas

## Siemens

- Uses AI to control GT combustion (GT-ACO, Gas Turbine Autonomous Control Optimizer)
- NOx emission reduced by 20% with respect to settings from an expert control engineer
- Used in pilot operations in the United States and South Korea

# AI in Oil & Gas

## Many others

- Repsol uses ML to simplify and increase the accuracy of geophysical analyses
- Saudi Aramco uses clustering to reduce the control effort for its wells by using a common model for wells in the same cluster
- Shell uses ML to:
- manage unmanned service stations and check that no one smokes near a pump
- control drones which survey inhospitable locations
- perform predictive maintenance
- predict energy market trends
- It even has an AI residency program, like Google, Facebook, etc.!

**Shell RechargePlus: Managed Smart Charging for Electric Vehicles**


**A bionic inspector rolls in**

Sensabot is a robot that can help maintain oil and gas field equipment in hostile environments.

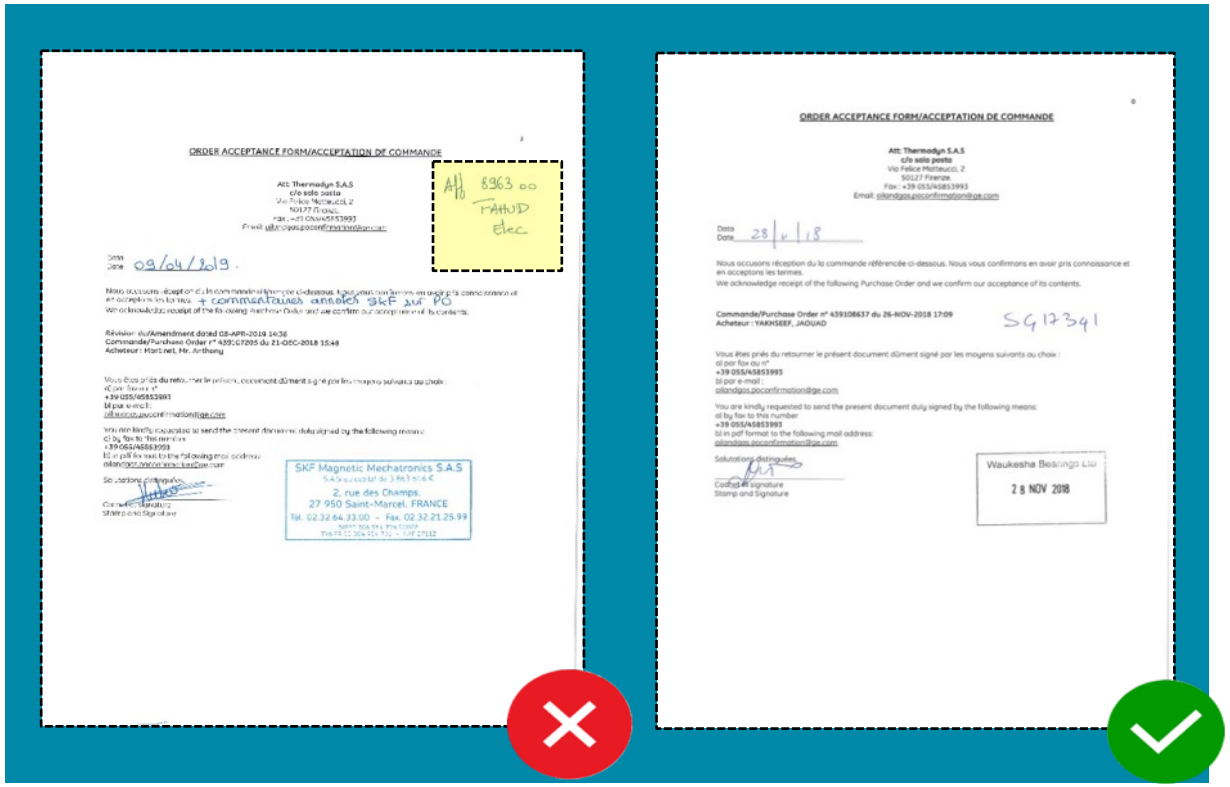
**Eye in the sky**

See how we are using high-tech drones to go places humans would rather avoid.

# AI in Oil & Gas

## And of course, Baker & Hughes!

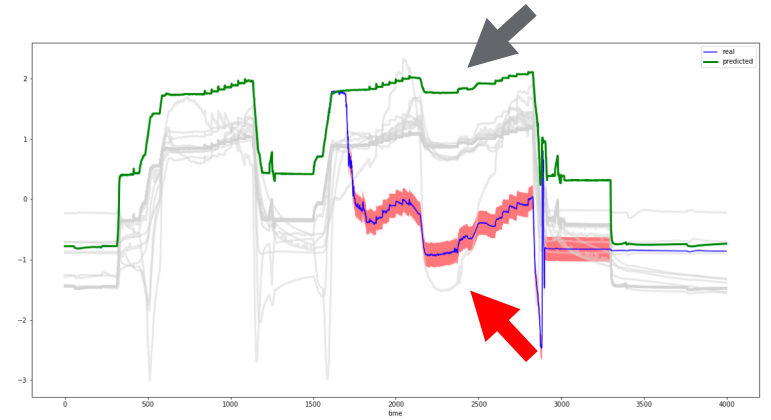
- **Document validator**
- Significantly reduce the need to outsource classification to an external supplier
- Eliminate the need for outsourcing, if CV is coupled to NLP (increase in effort/risk)
- Accelerate classification process significantly

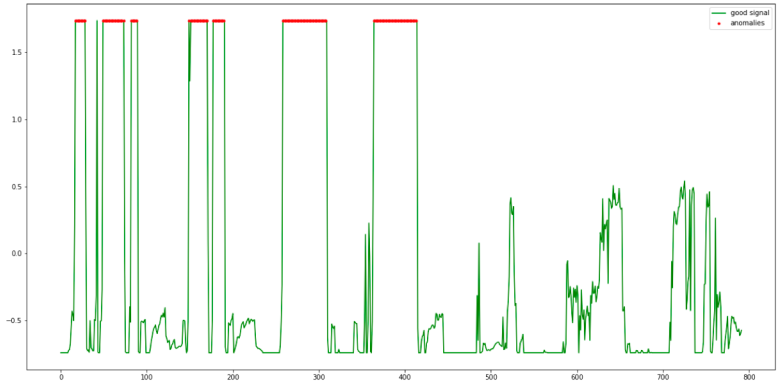


# AI in Oil & Gas

## Baker & Hughes

- **Sensor Anomaly Detection**
- Identifies complex anomalies (scaled, saturation, drifting, multivariate anomaly)
- Uses an LSTM to predict the future behavior, and compares it with the actual measured signal
- Extremely accurate
- Many other applications I can't currently show



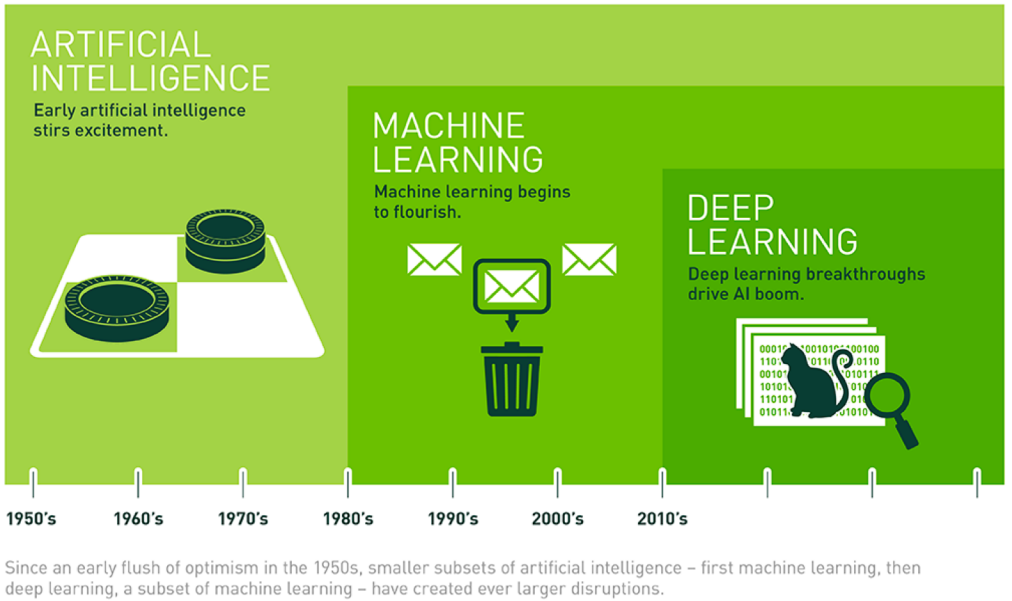



# But what is AI?

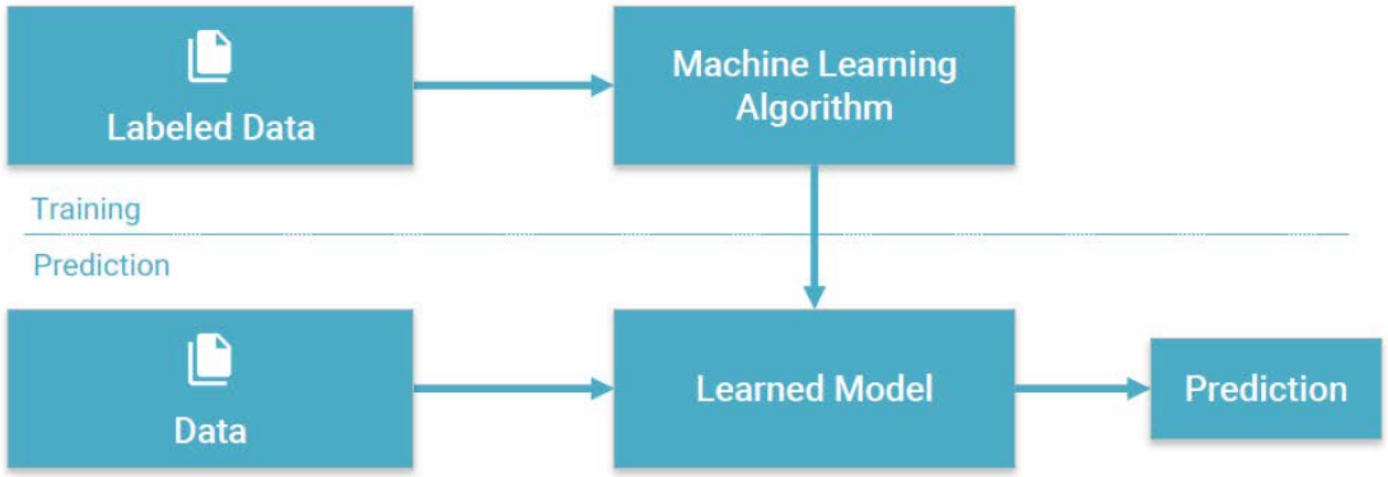
- At least 8 different definitions, according to the reference textbook
- We define AI as the study of computer agents that interact with their environment, adapt to change, pursue goals and take actions to achieve the best expected outcome
- AI is not new: its conventional birth date is the Darmouth conference (1956)
- Big enthusiam in 1950-1970, but excessive optimism and failure to meet expectations led to AI winter in 1974
- In the ‘80, success of expert systems (logic inference, symbolic AI) followed by another AI winter («expert systems work well in tightly defined subject areas [..] but are unable to learn concepts that children learn by the time they are 3 years old», Marvin Minsky)

# Machine Learning

- We skip through the rest of AI history
- The type of AI which is most successful today is **Machine Learning**, and in particular its subfield, **Deep Learning**




Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.



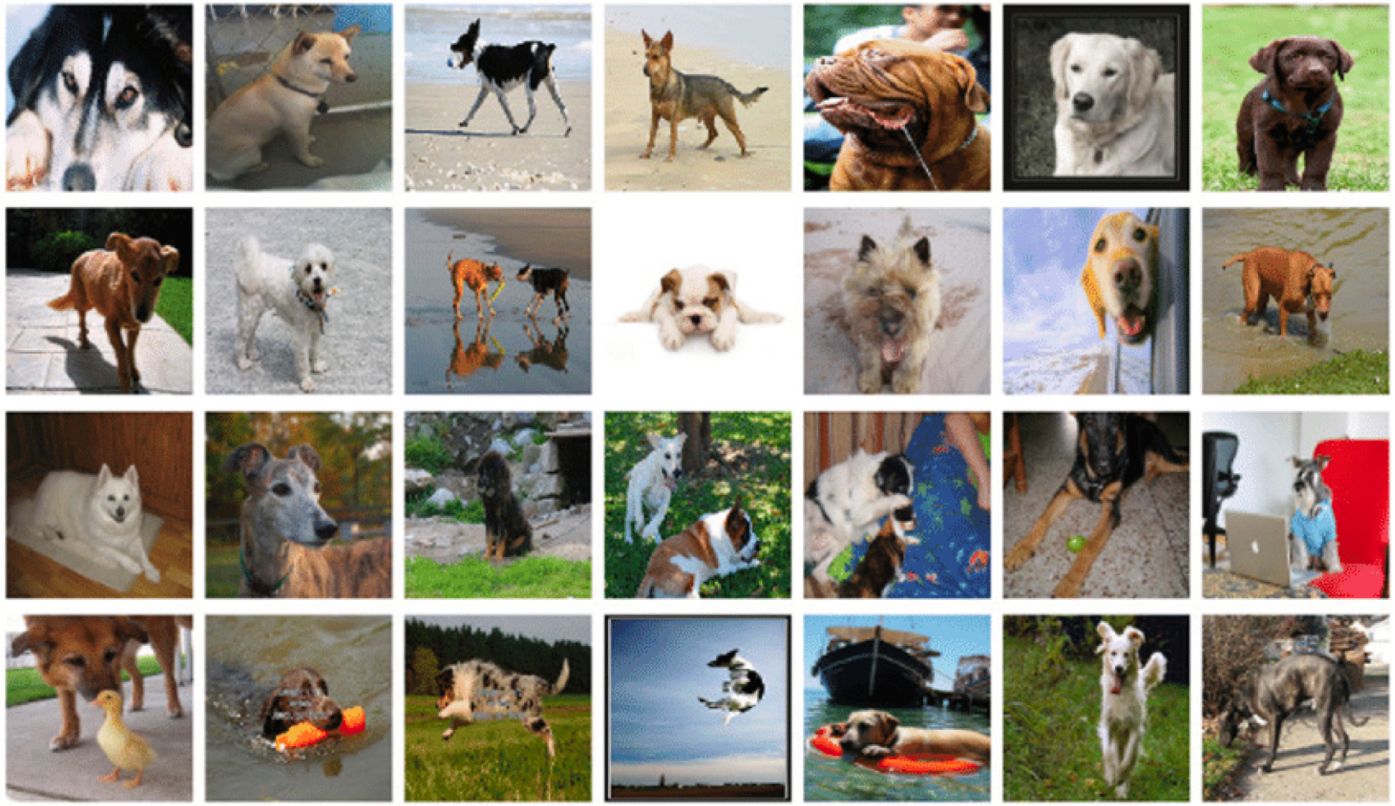

Provides various techniques that can learn from and make predictions on data

# What is Machine Learning?

- An algorithm is a sequence of steps, each of which is simple and well defined, which ends after a finite number of steps.
- In many real-world problems, it is much easier to identify **desirable behavior** of an algorithm than to explicitly define steps. Example: identify the presence and the breed of a dog in a picture (see next slide)
- A computer program is a **map** between input and output space
- A computer program is a **point** in the space of such maps
- **Search** the space of programs until desired behavior is obtained
- Surprisingly, it works!
- **Learning a function from examples** instead of explicit modelling

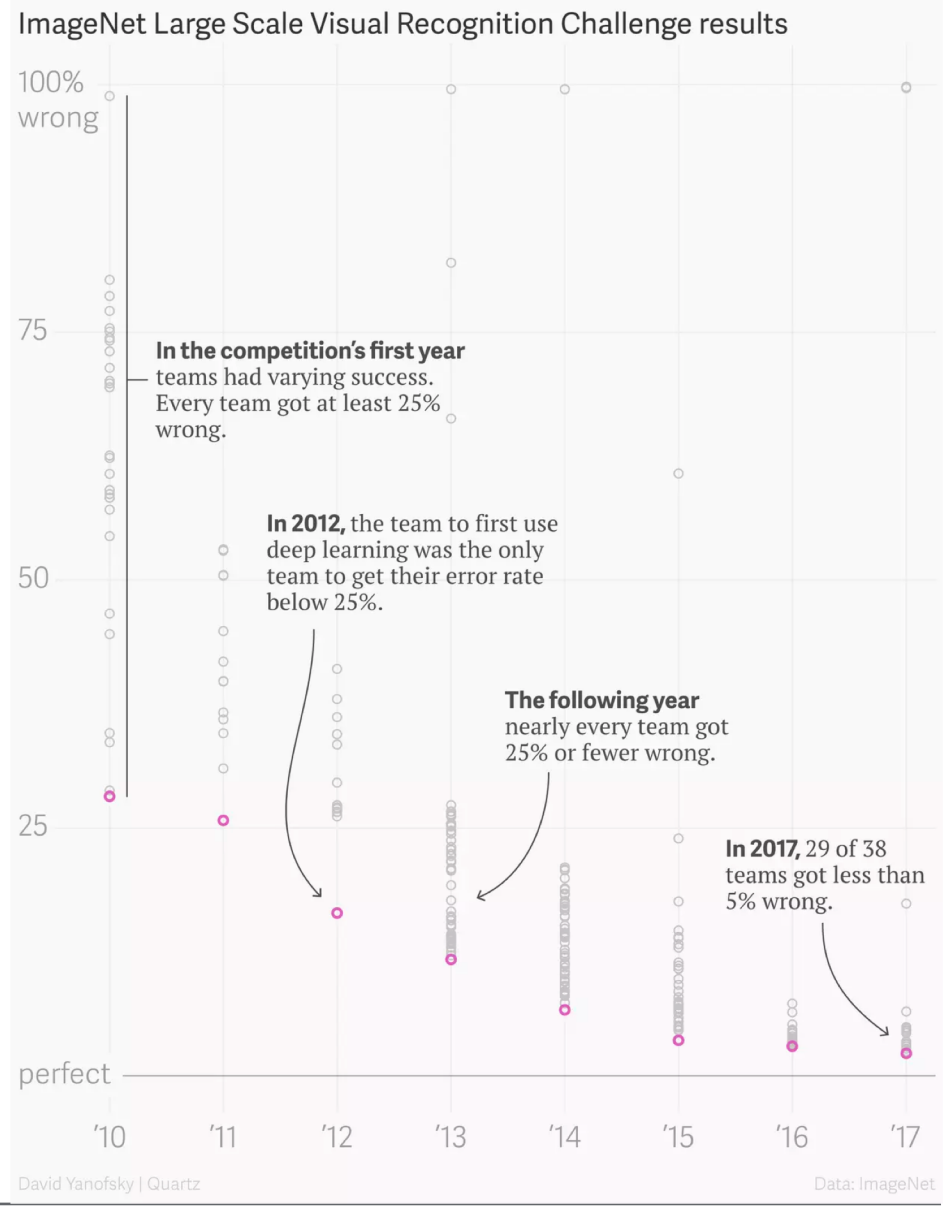
# ImageNet

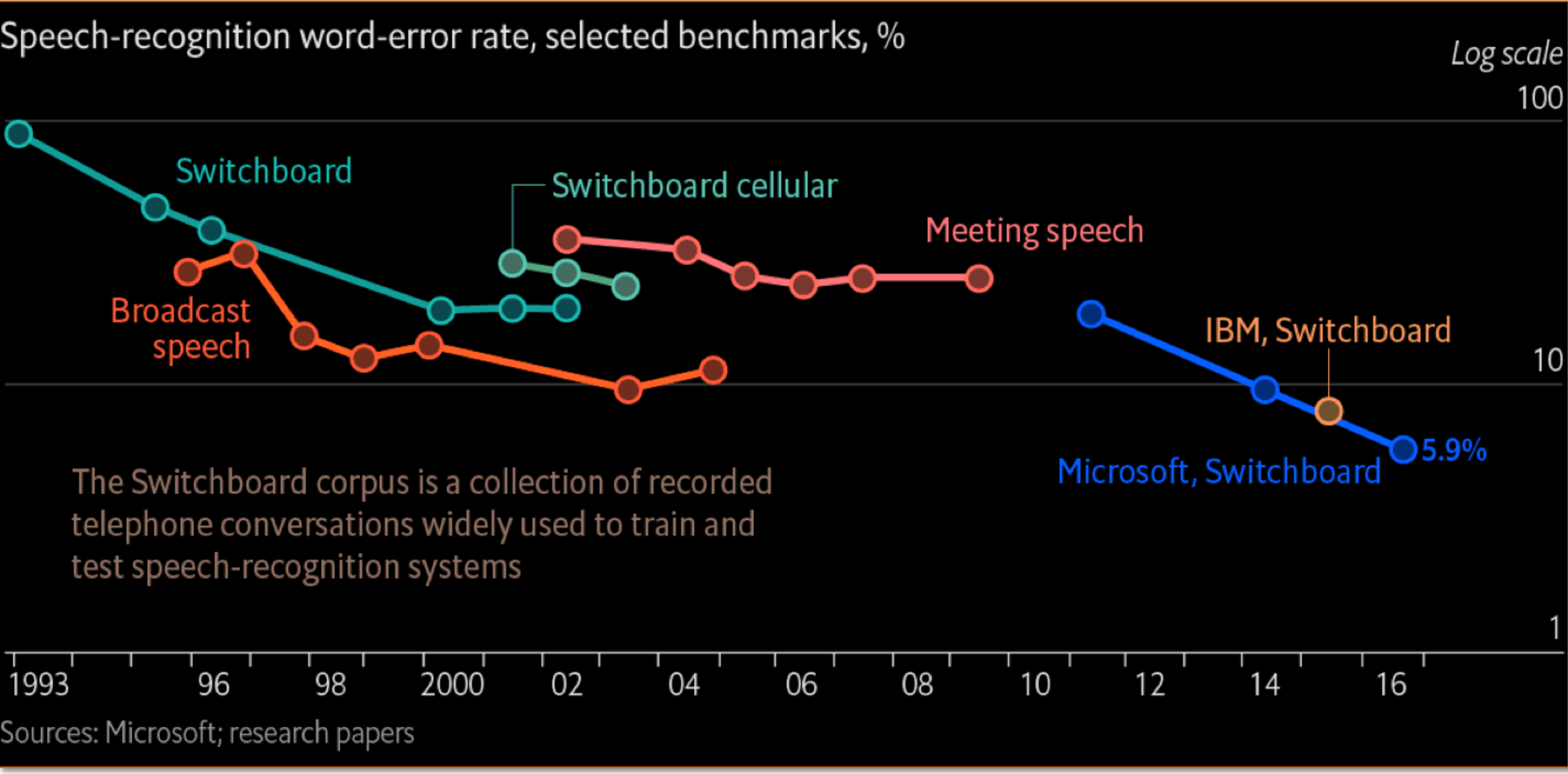
- The event which led to contemporary success, global interest and hype about AI was the 2012 edition of the ILSVRC competition, also known as ImageNet competition
- Classify correctly 1.2 millions of images, 1000 classes



# The “ImageNet moment”

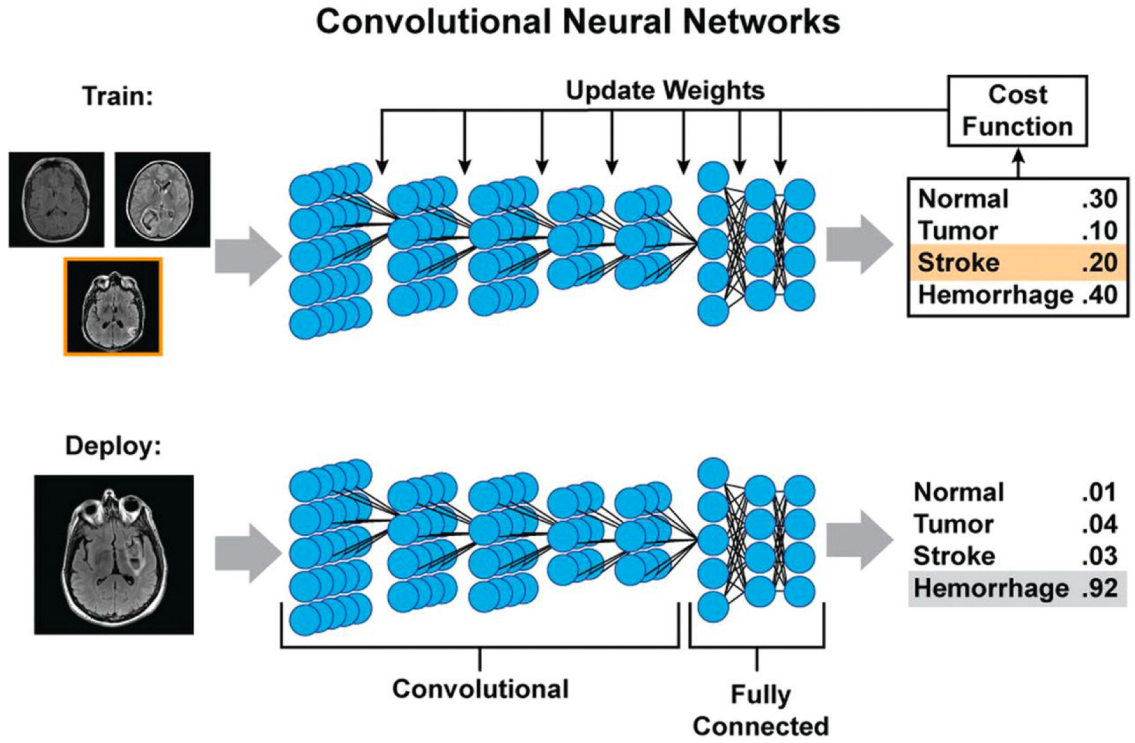
- In 2010 (ILSVRC first year), every competing team got at least 25% images wrong
- In 2012, using **Deep Learning**, team of AI legend Geoffrey Hinton reduced the error rate by nearly 50%
- This was a quantum leap, with respect to usual advance rate in AI
- Deep Learning has been used by ILSVRC winning teams since 2012, and it’s now being used in all the fields seen in slide 3




Speech-recognition word-error rate, selected benchmarks, %
Log scale
100
10
1
Switchboard
Switchboard cellular
Meeting speech
Broadcast speech
IBM, Switchboard
5.9%
Microsoft, Switchboard
The Switchboard corpus is a collection of recorded telephone conversations widely used to train and test speech-recognition systems
1993
96
98
2000
02
04
06
08
10
12
14
16
Sources: Microsoft; research papers

# What is Deep Learning?

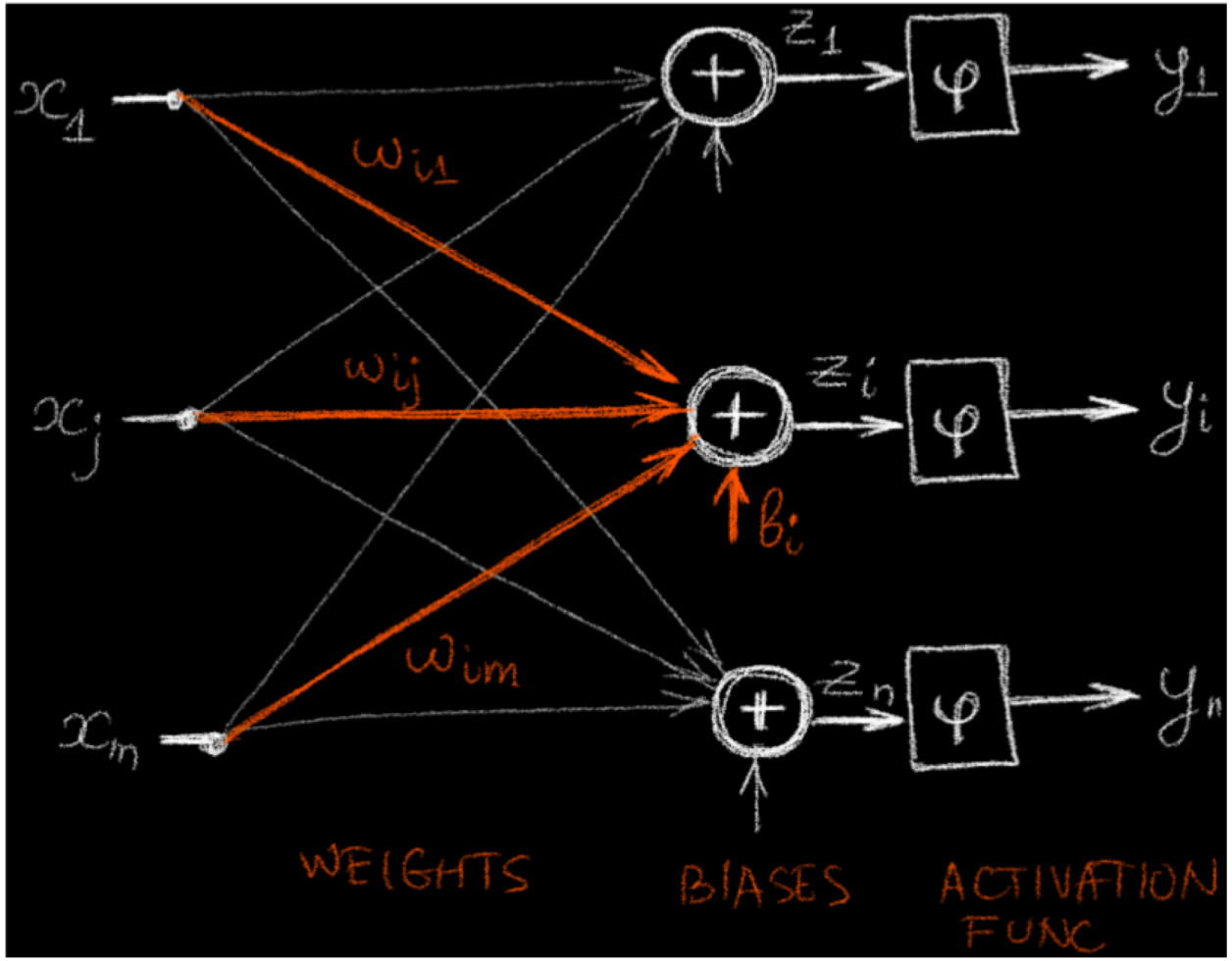
- Using **huge** ($O(10^6) \div O(10^9)$ of parameters) multilayer neural networks (NN) as the trainable model in Machine Learning
- Backpropagation-trained NN have been around since at least 1986, however the «old» NN were **much** smaller (~ 25 parameters)
- Only later, hardware (GPU), large amount of data **and** algoritmic innovations (SGD, dropout, BatchNorm, residual connections, Fixup initialization, etc.) made possible to train **Deep** (multiple layers) neural networks




The huge amount of money spent by FAANG on Deep Learning is making the field progress as never before (BigGAN, VQ-VAE-2, BERT, GPT-2, XLNet, RoBERTa, etc.)

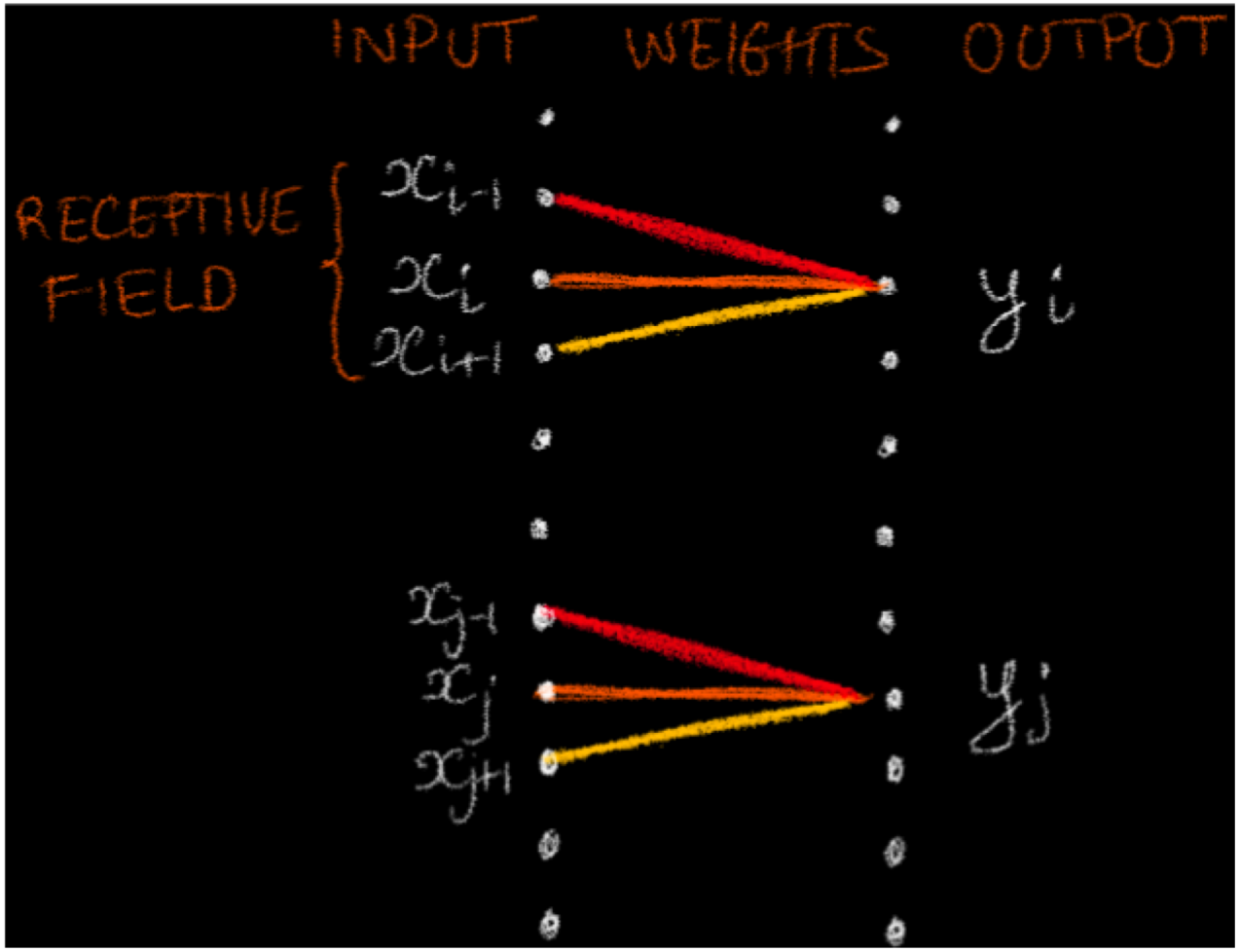
# Image classification

- An image of width $W$, height $H$ and with $C$ channels can be represented as a $W \times H \times C$ tensor
- Images are **BIG**: a low-res $256 \times 256$ RGB image is a tensor of $3 \times 256 \times 256 \approx 2 \cdot 10^5$ components
- A classical MLP (fully connected, feed-forward neural network) with 512 neurons in the first hidden layer, would use $(3 \times 256 \times 256 + 1) \times 512 \approx 10^8$ weights only in the first hidden layer, and we want to go deep!!



# Weight sharing

- Deep Learning is **HUNGRY**: $\mathrm{N} = 1.2 \cdot 10^6$ for ILSVRC!*
- It turns out we can reduce the # of weights as well as the size of the dataset with the same idea, **translation equivariance**
- $\tau_p \mathcal{H} = \mathcal{H} \tau_p \ \ \forall\, p \in \mathbb{Z}^d$
- **Translation-equivariant** representations simplify the construction of **translation-invariant** classifiers
- Also, representations should be sensitive to **local** features: the pixels identifying an eye in a face are adjacent
- Q: how do we get **locality** and **translation-equivariance**?
- A: weight sharing, a.k.a **filters**

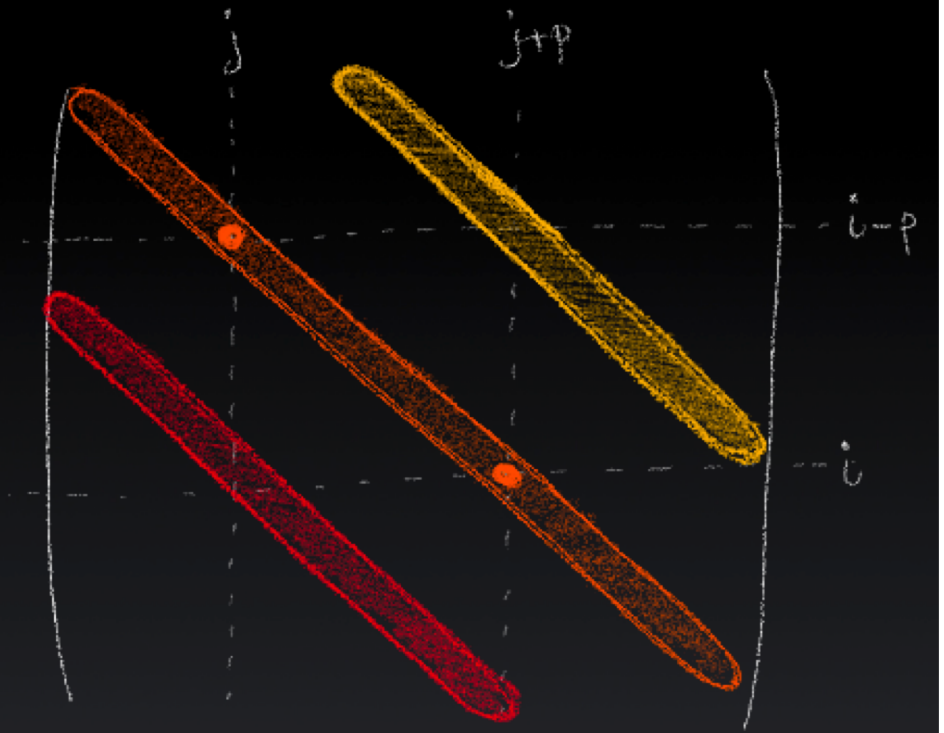


# Convolutional layer

## Toeplitz operators

$$y_{\mathrm{i}}^{k} = \sum_{l=1}^{m} \sum_{\mathrm{j} \in \mathbb{Z}^d} w_{\mathrm{i}-\mathrm{j}}^{kl} x_{\mathrm{j}}^{l} + b^{k}$$

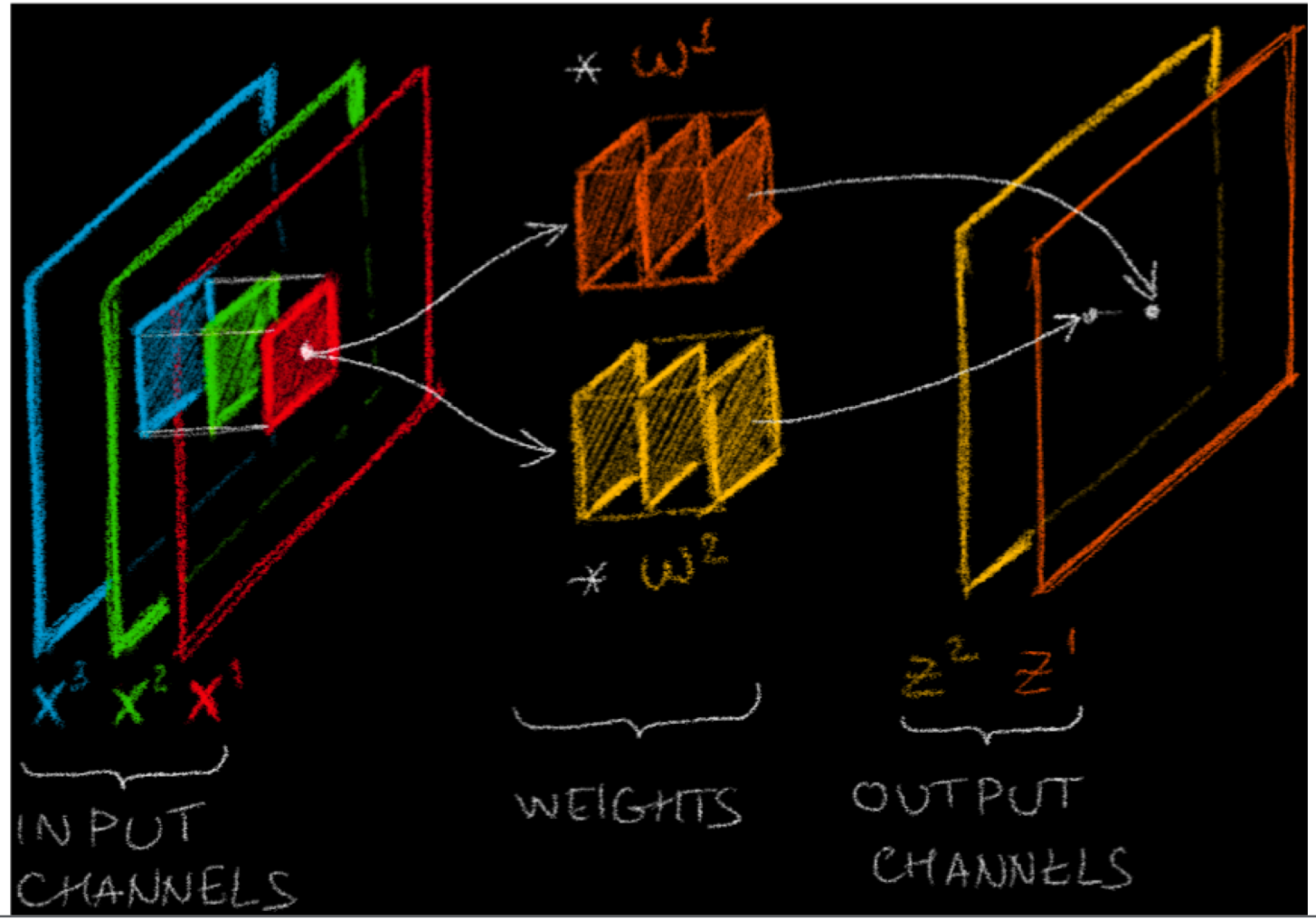
$$= \sum_{l=1}^{m} \sum_{\mathrm{j} \in \mathbb{Z}^d} w_{\mathrm{j}}^{kl} x_{\mathrm{i}-\mathrm{j}}^{l} + b^{k}$$



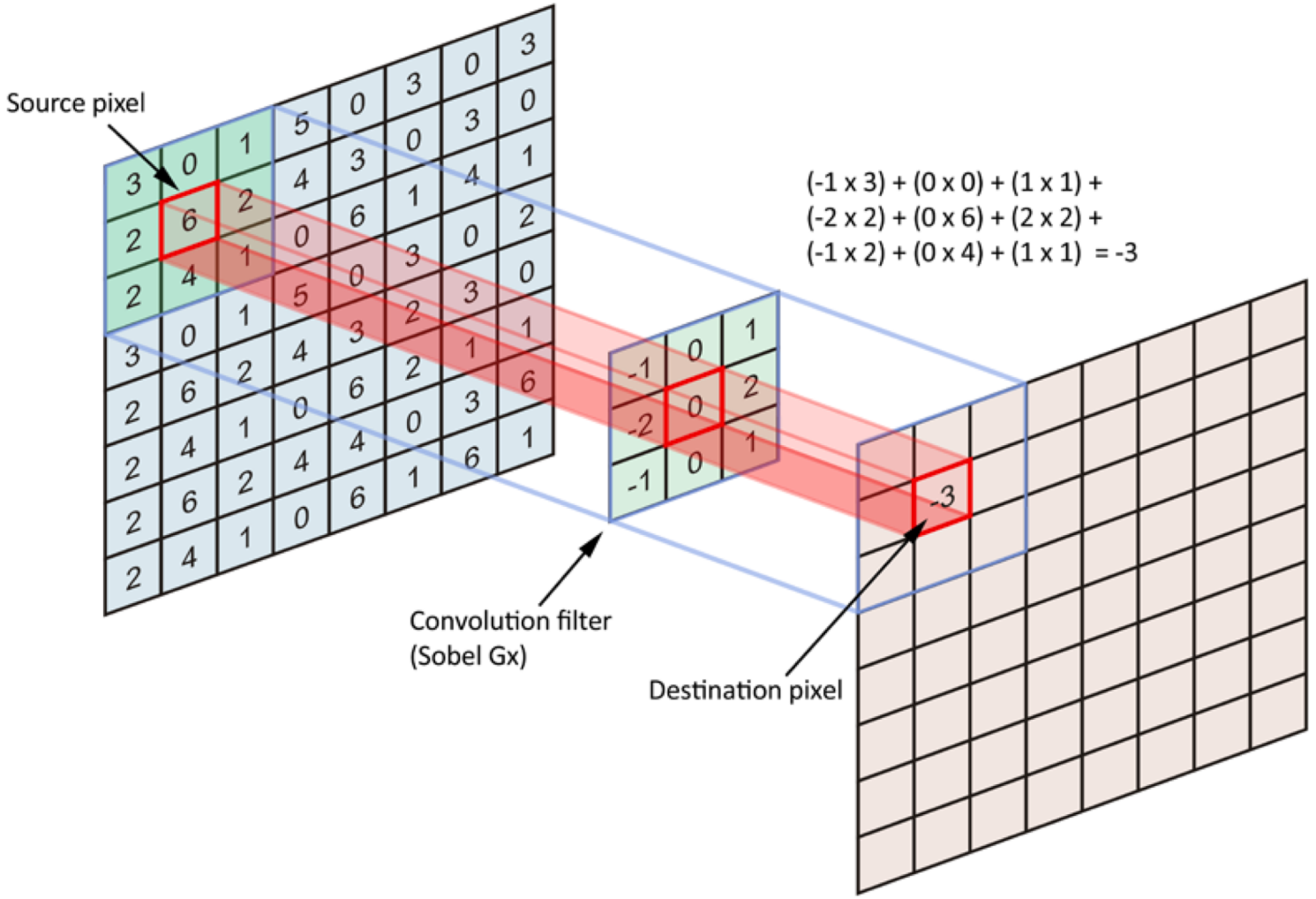

**Convolution**

$$\mathbf{y}^{k} = \sum_{l=1}^{m} \mathbf{w}^{kl} * \mathbf{x}^{l} + b^{k}$$

# Convolutional layer



# Convolutional layer

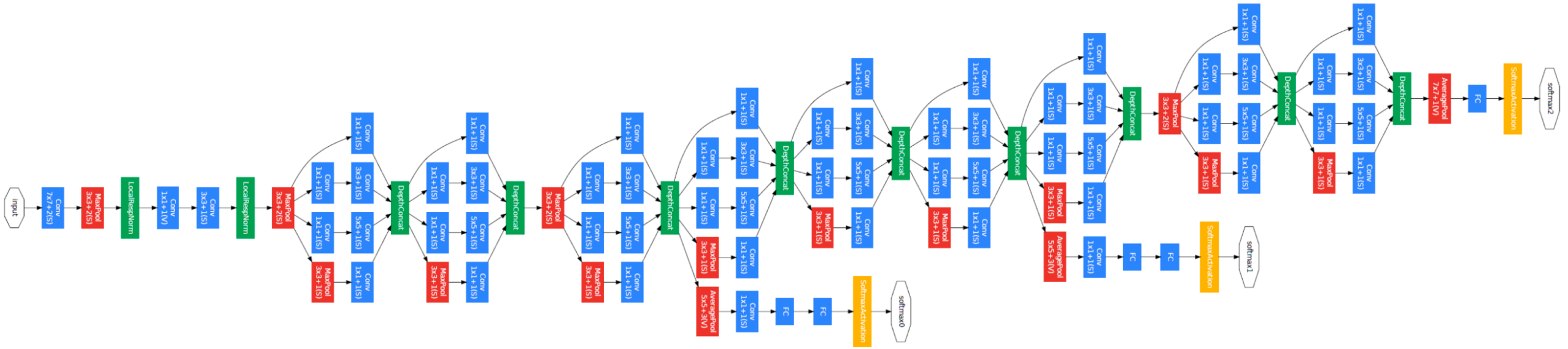


# Convolutional Neural Networks

- Stacking multiple convolutional layers one after the other gives us a **Convolutional Neural Network** (CNN)
- In practice, we need many other layers to build a good image classifier:
  - batch normalization/spectral normalization
  - max pooling, global pooling
  - strided convolutions
  - atrous convolutions
  - skip/residual connections, which enhance the CNN **topological expressivity**
  - dropout (rapidly becoming obsolete)
  - new initializations, training schedules, label modifications, data augmentation tricks, etc.
- Listing them all would take way too much time
- Let's just mention two of the most famous/robust CNN architectures in use today

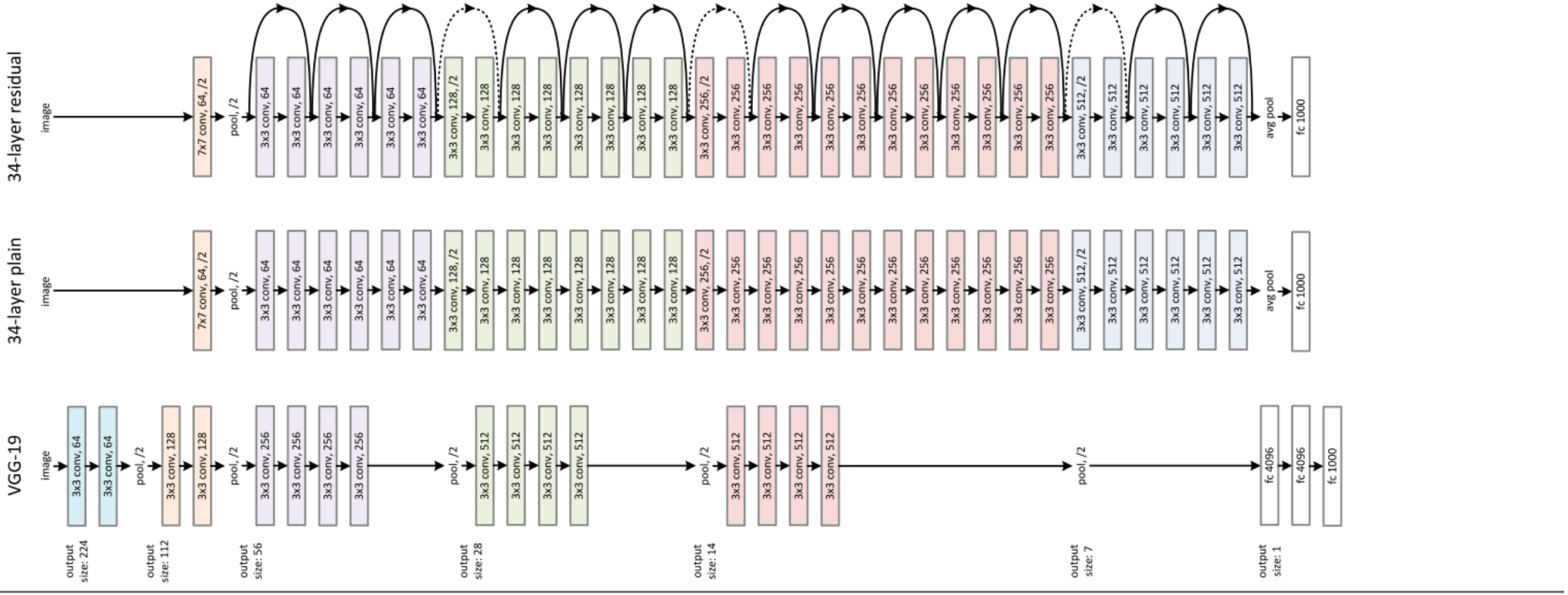
# Inception

- From Google AI
- various version, figure shows v1 (2014) but v3 is the most commonly used today



# ResNet

- a family of architectures from Microsoft Research, which introduced the residual connection
- ResNet-50 (50 layers) is the most commonly used today, but ResNet-34 (picture) and ResNet-101 are also widely adopted



# Why should we care?

- Machine Learning and in particular Deep Learning are fueling a revolution in many businesses, including Oil & Gas
- Customers know about AI, and are asking O&G companies to provide AI-powered services
- OEMs are already using it to strengthen their offering (Siemens GT low NOx emissions)
- DL will be key to building a technology competitive advantage for TPS products and services

# Conclusions

- AI is changing the world we live in, including the way we do business
- In order to build a technology competitive advantage for their products and services, O&G companies need to build strong AI skills now
- By developing focused AI demonstrators, promoting a culture of AI and fostering external collaborations and partnership, our team is making sure that we stay on top of this rapidly evolving technology


That's all Folks!