INTRODUCTION TO DEEP LEARNING

COMP4660/8420

Adapted from a lecture by Christopher Chow and Josephine Plested

Presented by Nathan Elazar

WHAT CAN'T NEURAL NETWORKS DO?

COMPLICATED DATA

Images

Text

Audio

- Inputs have very high dimension.
- Individual features are not informative.
- Traditional machine learning models will struggle to learn.

OVERVIEW

What is deep learning?

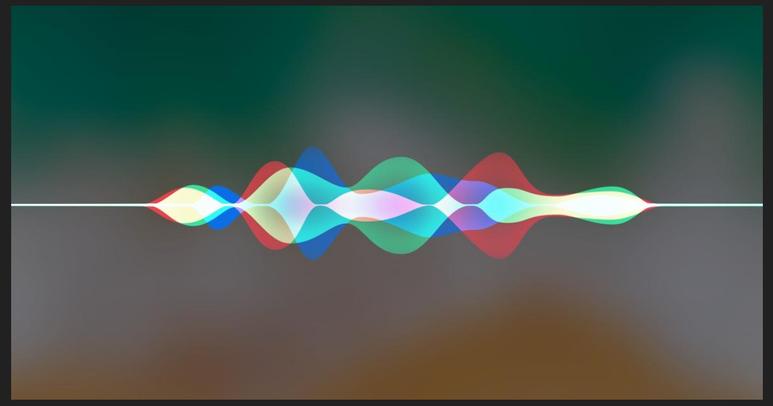
Why is it successful?

Where is it applied?

Who uses it and how?

WHAT IS DEEP LEARNING?

EXAMPLE: IMPROVEMENTS TO SIRI'S VOICE

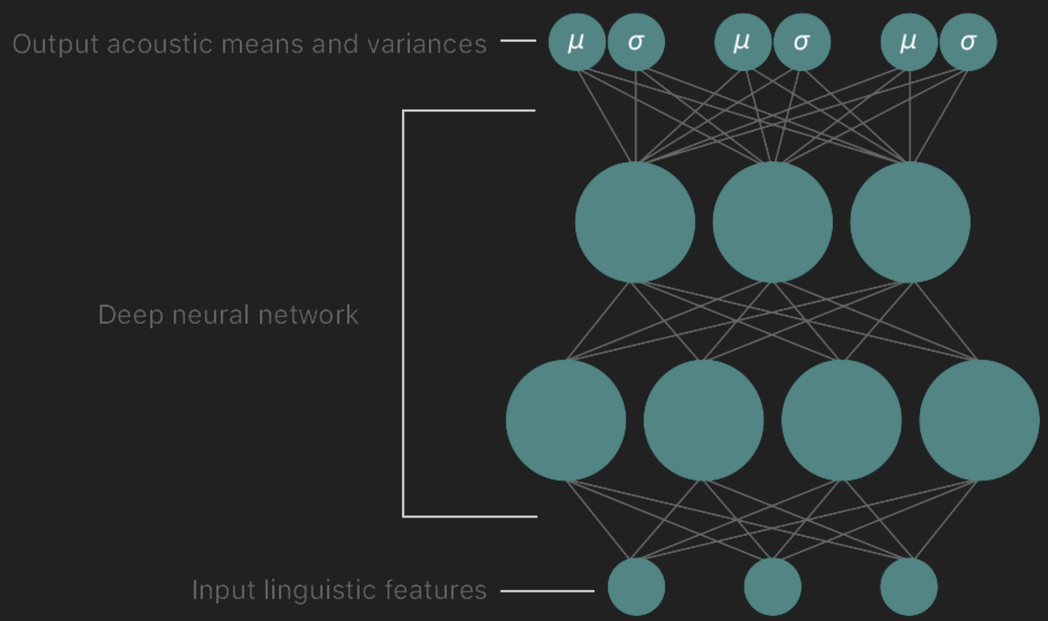


Starting in iOS 10 and continuing with new features in iOS 11, we base Siri voices on deep learning. The resulting voices are more natural, smoother, and allow Siri's personality to shine through

It has been deployed into hundreds of millions of desktop and mobile devices (e.g. iPhone, iPad, Mac, etc.) via iOS and macOS in multiple languages.

iOS 9 iOS 10 iOS 11

EXAMPLE: IMPROVEMENTS TO SIRI'S VOICE

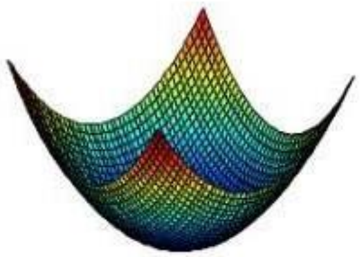


Read more in the paper

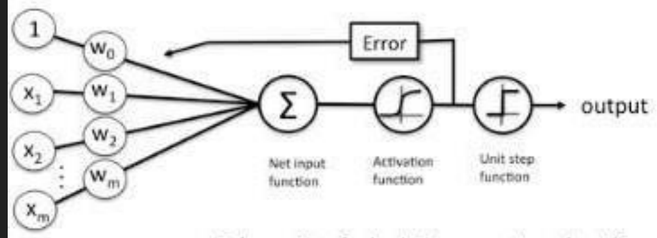
FROM ANNS TO DNNS

The concepts learnt from ANNs are the basis for deep learning

You

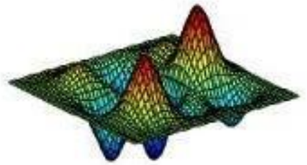


- Unique optimum: global/local.



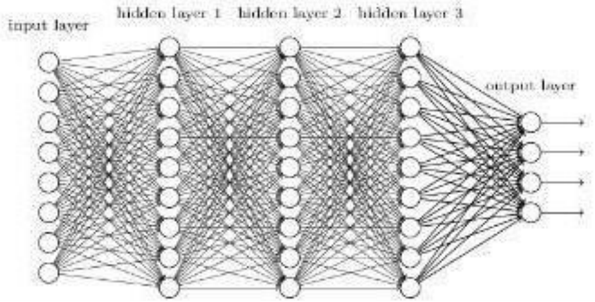
Schematic of a logistic regression classifier.

The guy she tells you not to worry about



- Multiple local optima
- In high dimensions possibly

Deep neural network



DEEP LEARNING

Neural network research suffers from a large amount of hype

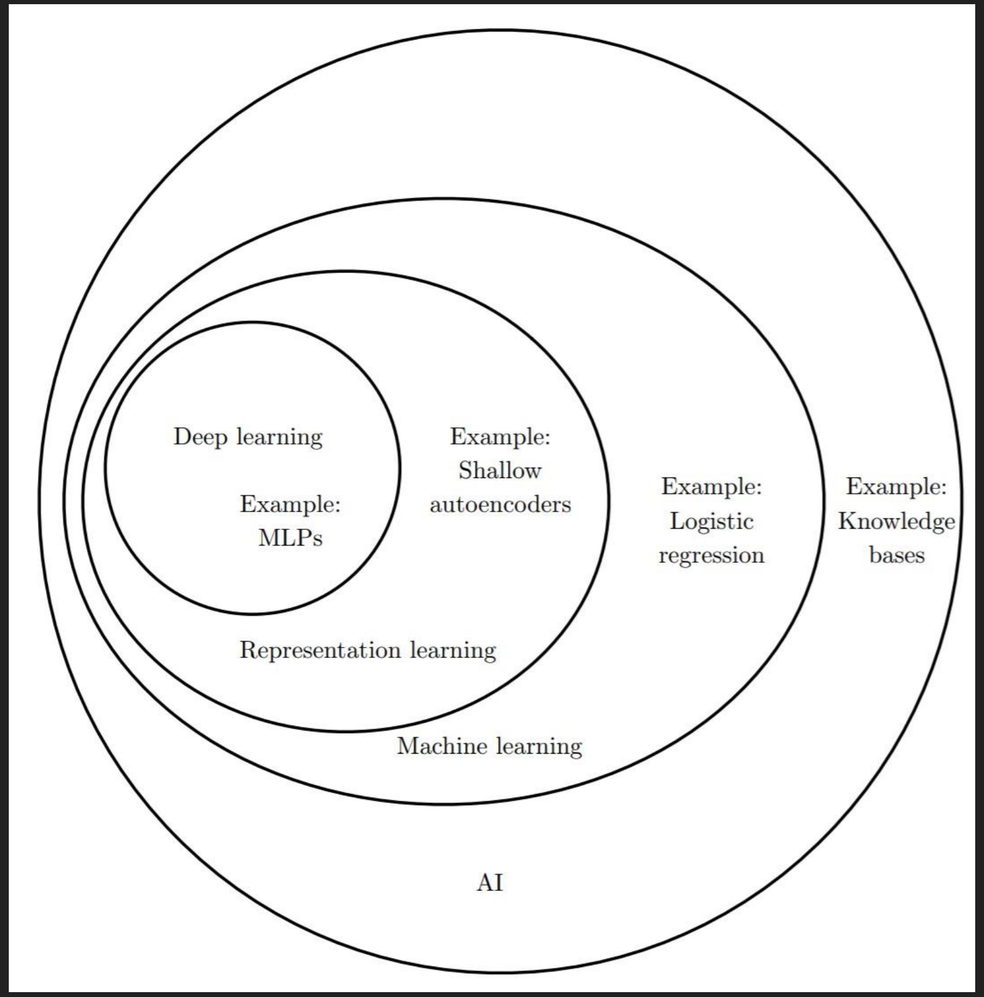
OK, Deep Learning has outlived its usefulness as a buzz-phrase...Deep Learning was a rebranding of the modern incarnations of neural nets with more than two layers

- A common view is that deep learning is a class of machine learning techniques that are able to understand the world through a hierarchy of concepts. Data representation is learnt through multiple levels of abstraction

- Schmidhuber (2015): proposed a credit assignment path (CAP) that distinguishes deep learning models as those that have at least three layers of representational processing. A CAP of 10 or more can be considered very deep

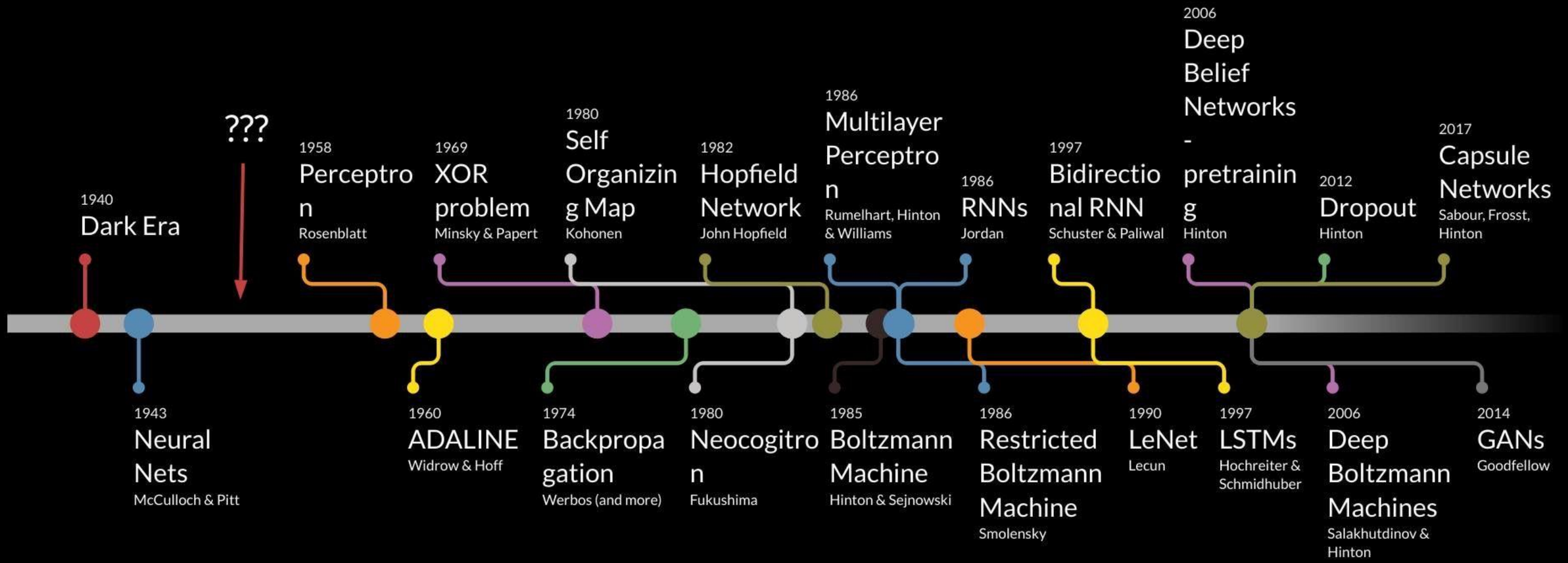
- The phrase can sometimes be misleading, as deep neural networks may not necessarily be an adequate distinction anymore

AN APPROACH TO AI



BIOLOGICAL INSPIRATION

Deep Learning Timeline



Made by Favio Vázquez

DEEP LEARNING MODELS

There are many different types of deep learning models including:

- Deep Neural Networks (DNN)
- Deep Belief Networks (DBNs)
- Convolutional Neural Networks (CNNs)
- Recurrent Neural Networks (RNNs)
- Long Short-Term Memory Networks (LSTMs)
- Generative Adversarial Networks (GANS)
- Autoencoders

HOW IT WORKS

A BLACK BOX


THIS IS YOUR MACHINE LEARNING SYSTEM?
YUP! YOU POUR THE DATA INTO THIS BIG PILE OF LINEAR ALGEBRA, THEN COLLECT THE ANSWERS ON THE OTHER SIDE.
WHAT IF THE ANSWERS ARE WRONG?
JUST STIR THE PILE UNTIL THEY START LOOKING RIGHT.
DATA
ANSWERS

FEATURE ENGINEERING AND SELECTION

Extracting and choosing suitable features to represent the data.
Consider features to determine the difference between the digits 7 and 2.

Flat top
Slightly curved line from top to bottom
No bottom

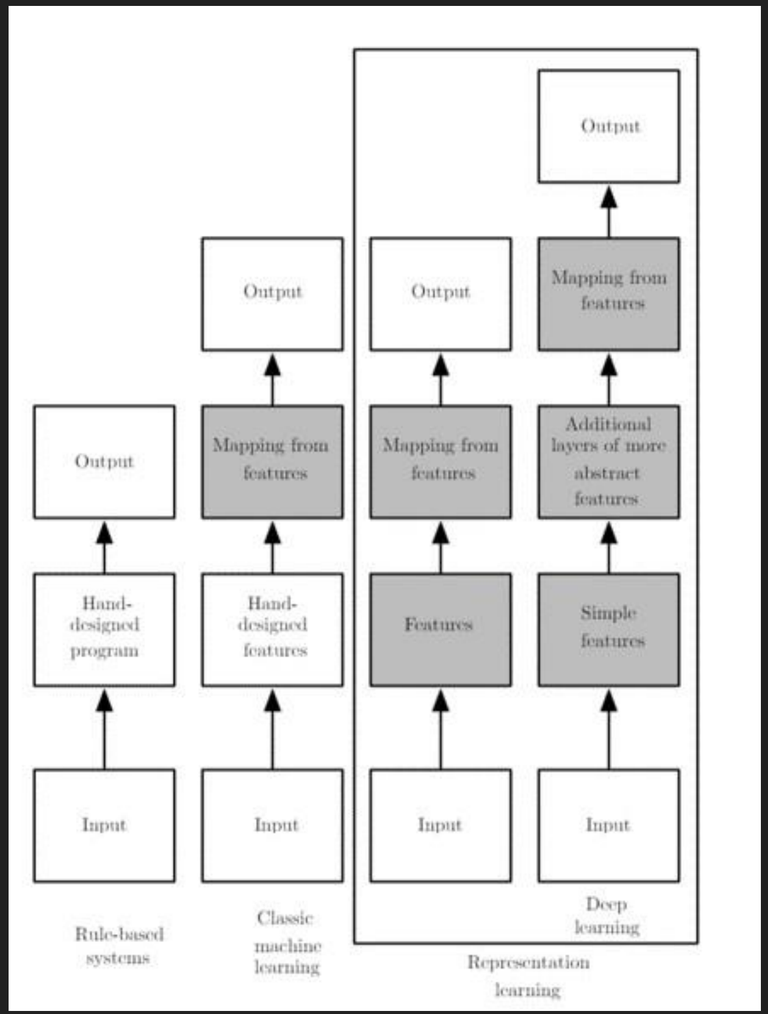
Curved top
Slightly curved line from top to bottom
Flat bottom

A CHALLENGE

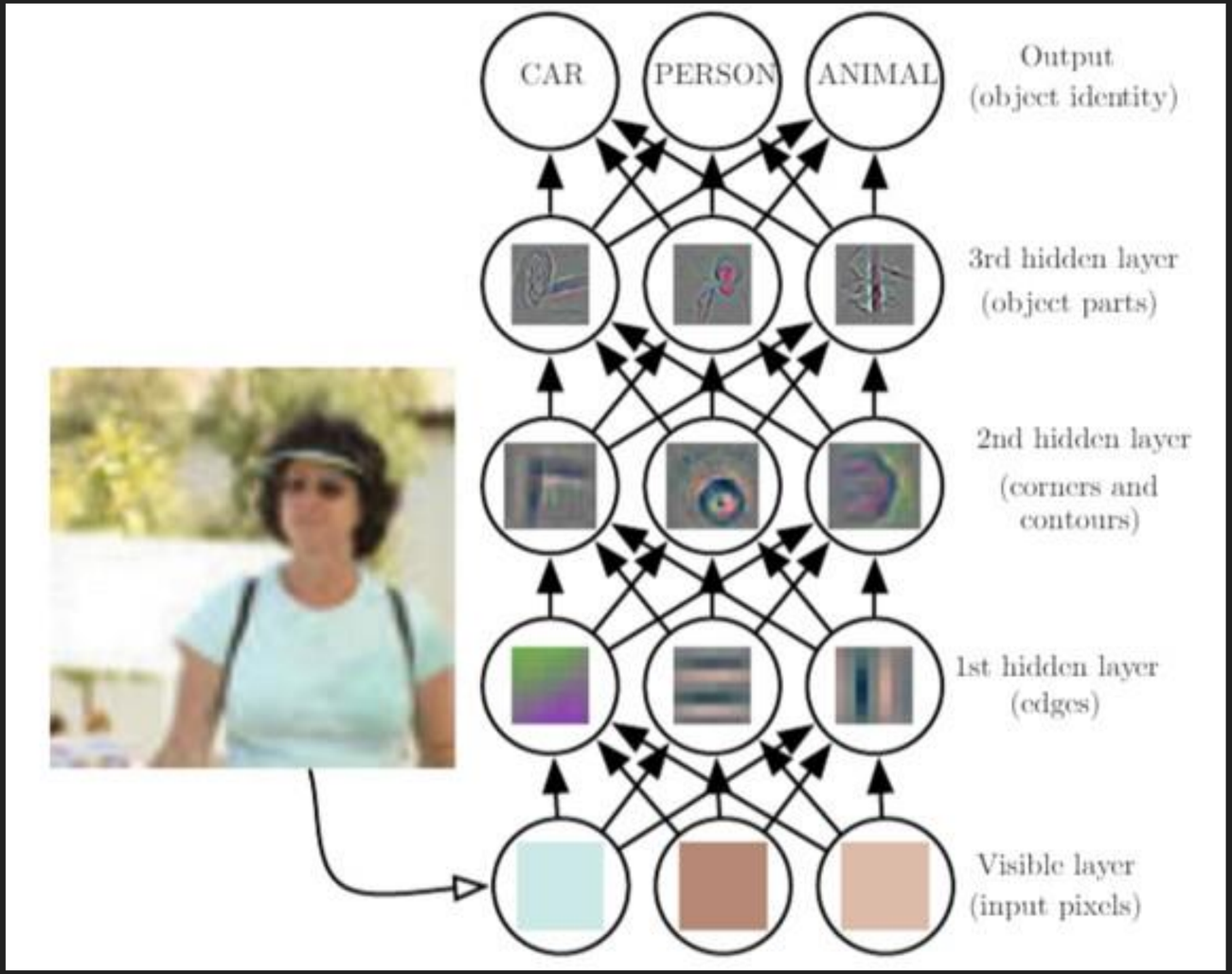
Feature engineering and selection has been a challenge for machine learning for a long time

What features should we use for classifying cats vs. dogs?

REPRESENTATION LEARNING

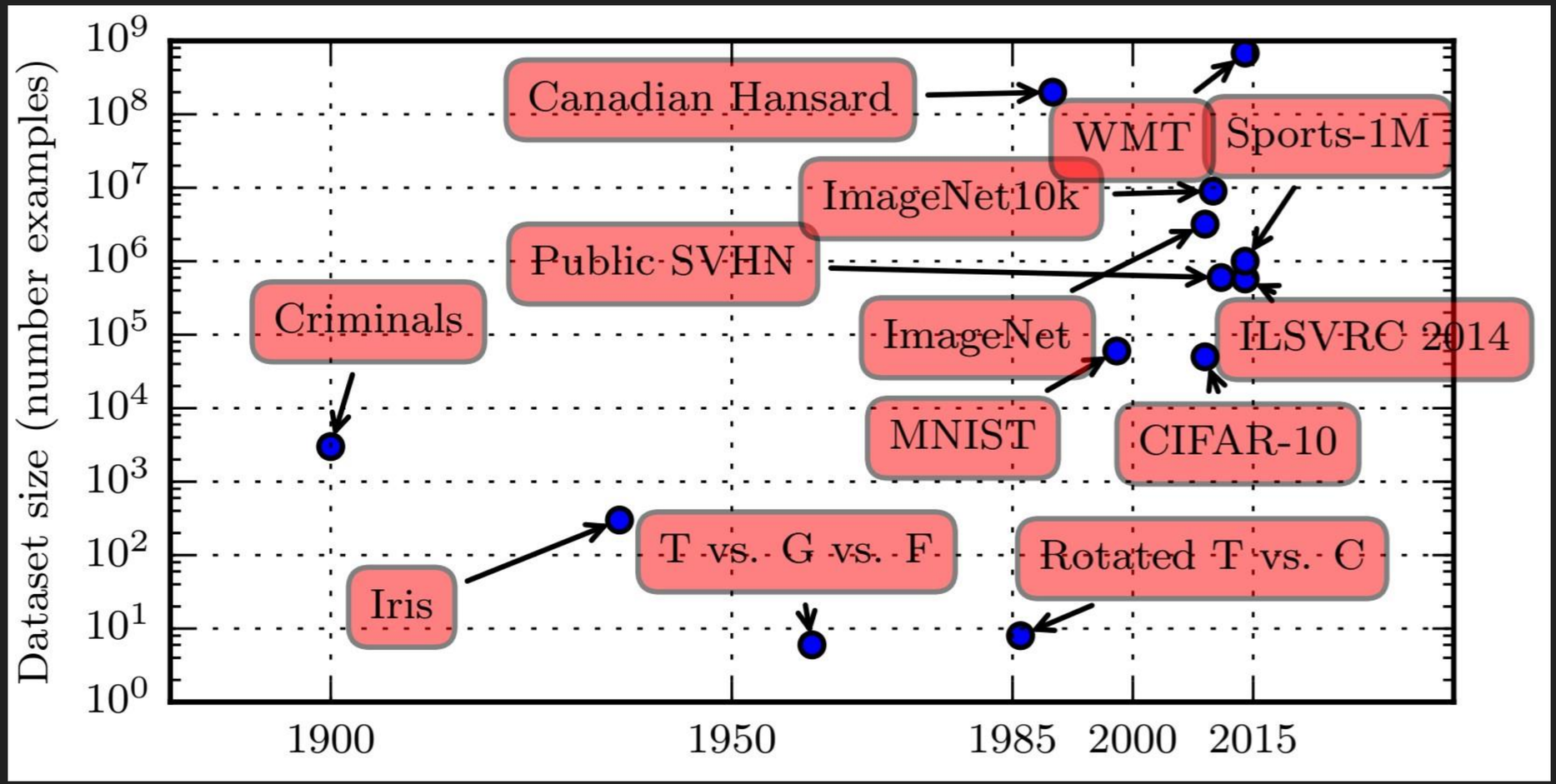


HIERARCHICAL REPRESENTATION LEARNING



WHY NOW?

BIG DATA


Dataset size (number examples)
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
1900
1950
1985
2000
2015
Canadian Hansard
WMT
Sports-1M
ImageNet10k
Public SVHN
Criminals
ImageNet
ILSVRC 2014
MNIST
CIFAR-10
T vs. G vs. F
Rotated T vs. C
Iris

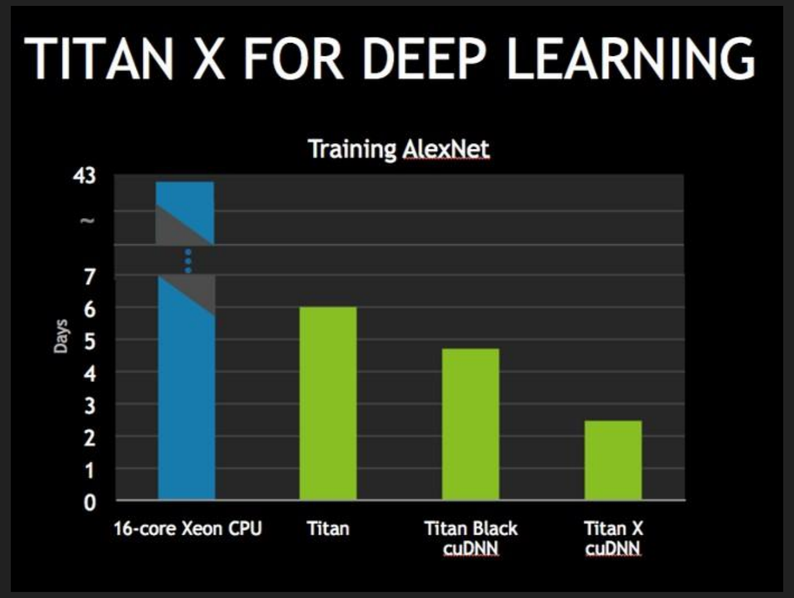
SPECIALISED PROCESSORS

NVIDIA Graphics Processing Unit (GPU)

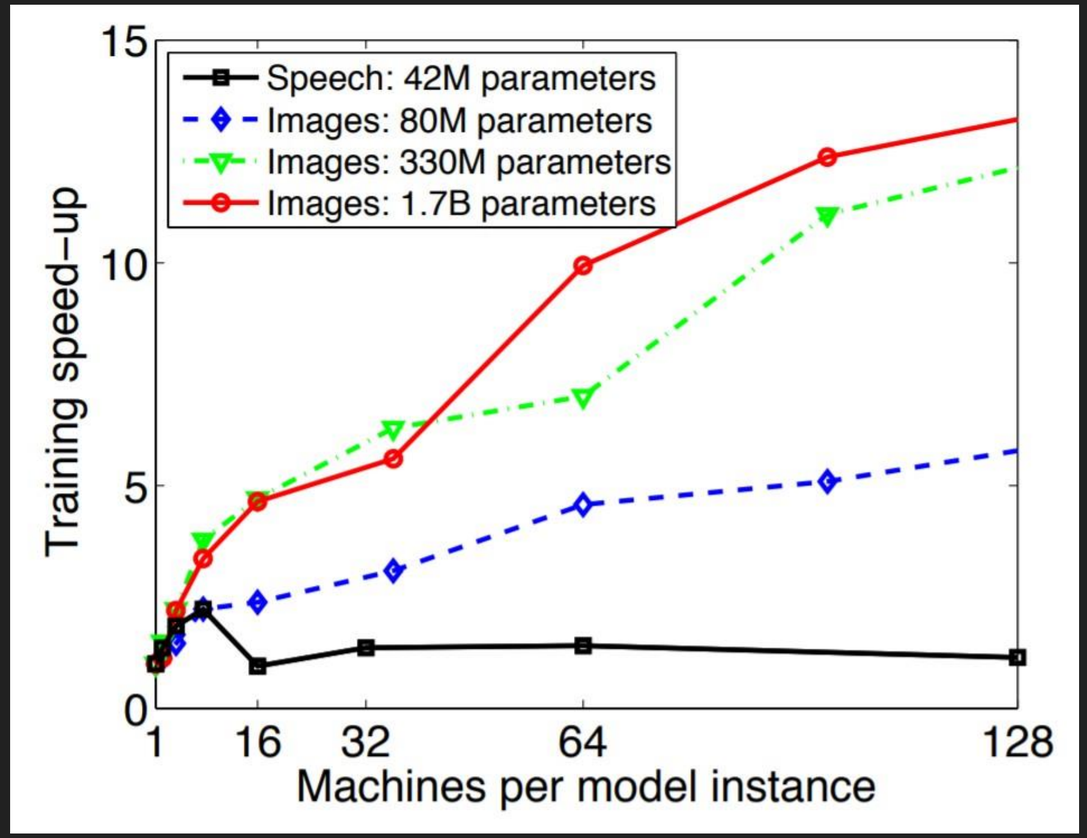
Google Tensor Processing Unit (TPU)

GPU SPEED IMPROVEMENTS

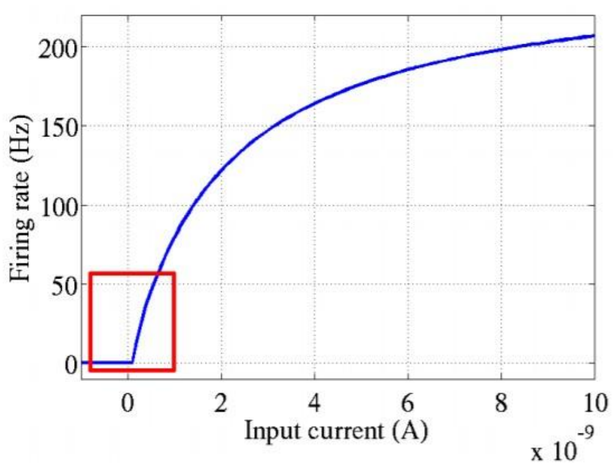
Package	Architecture	576x1024	1024x4096	2304x16000	4096x11008
Goto BLAS	Single CPU	563s	3638s	172803s	223741s
Goto BLAS	Dual-core CPU	497s	2987s	93586s	125381s
GPU		38.6s	184s	1376s	1726s
GPU Speedup		**12.9x**	**16.2x**	**68.0x**	**72.6x**



DISTRIBUTION SPEED IMPROVEMENTS



MORE PLAUSIBLE ACTIVATIONS



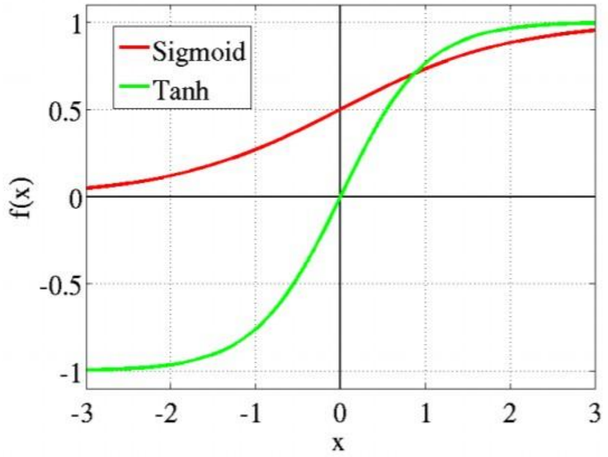
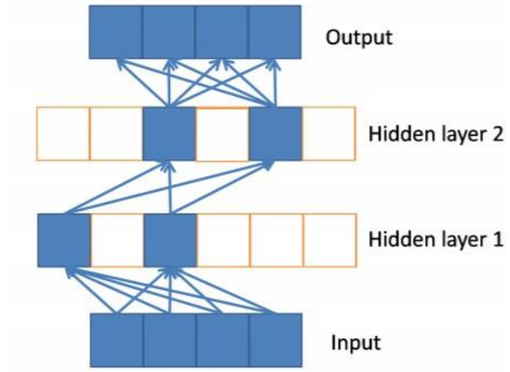


Figure 1: *Left:* **Common neural activation function motivated by biological data.** *Right:* **Commonly used activation functions** in neural networks literature: logistic sigmoid and hyperbolic tangent (*tanh*).

ReLU



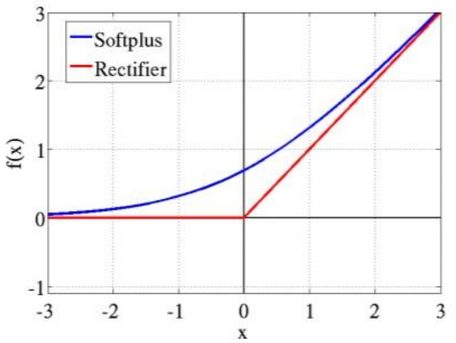
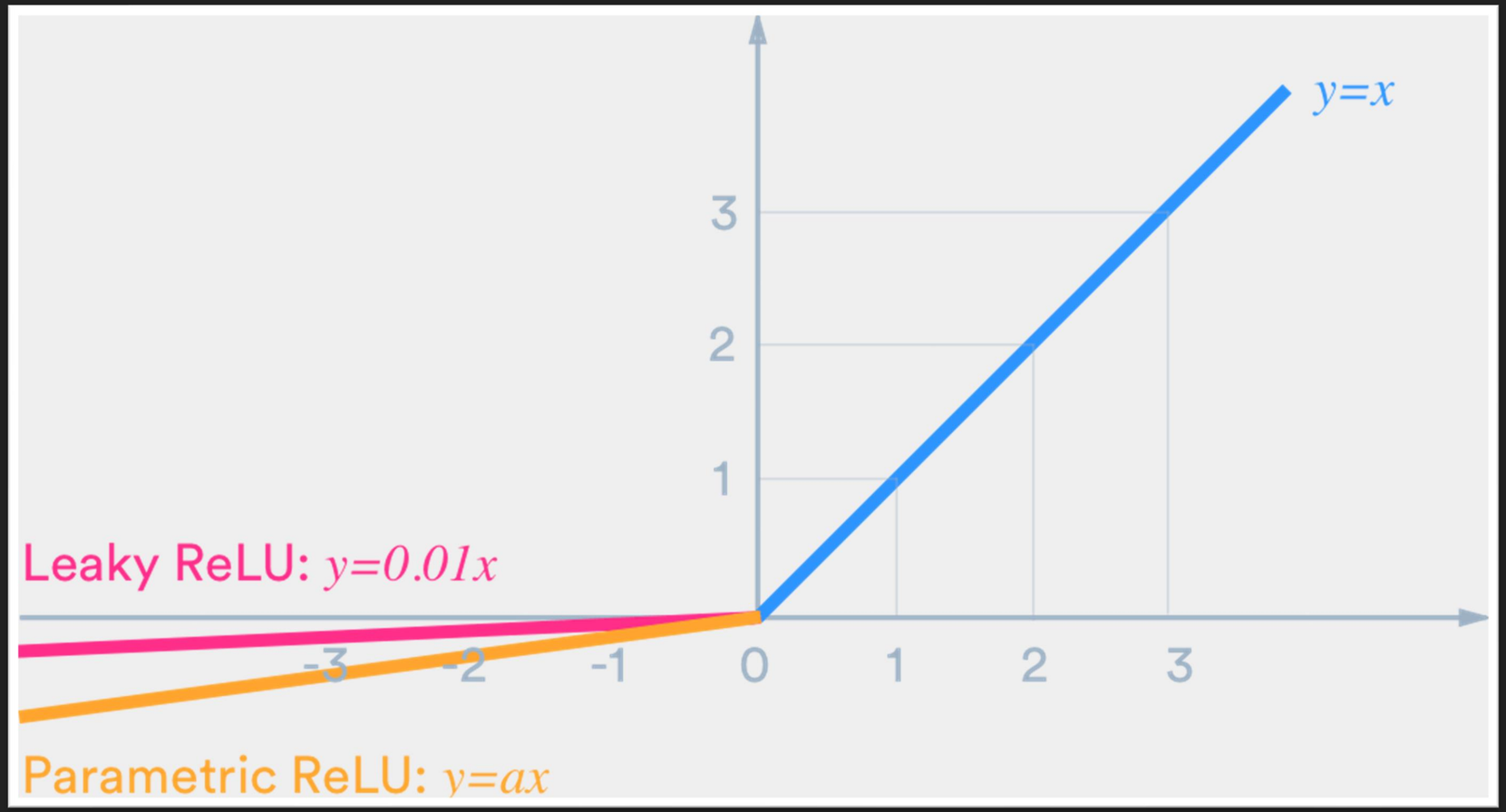


Figure 2: *Left:* **Sparse propagation of activations and gradients in a network of rectifier units.** The input selects a subset of active neurons and computation is linear in this subset. *Right:* **Rectifier and softplus activation functions.** The second one is a smooth version of the first.

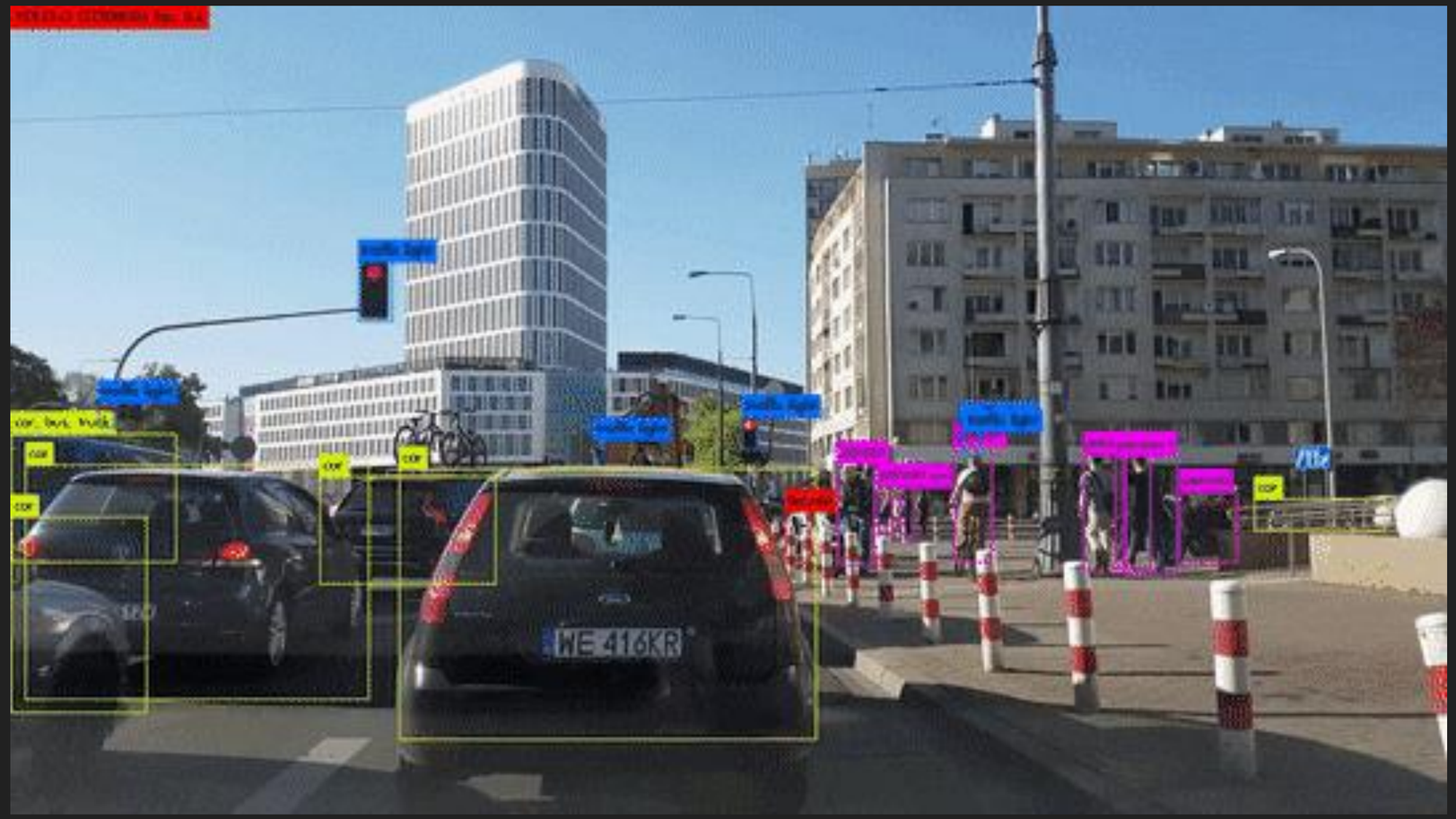
Leaky ReLU



APPLICATION AREAS

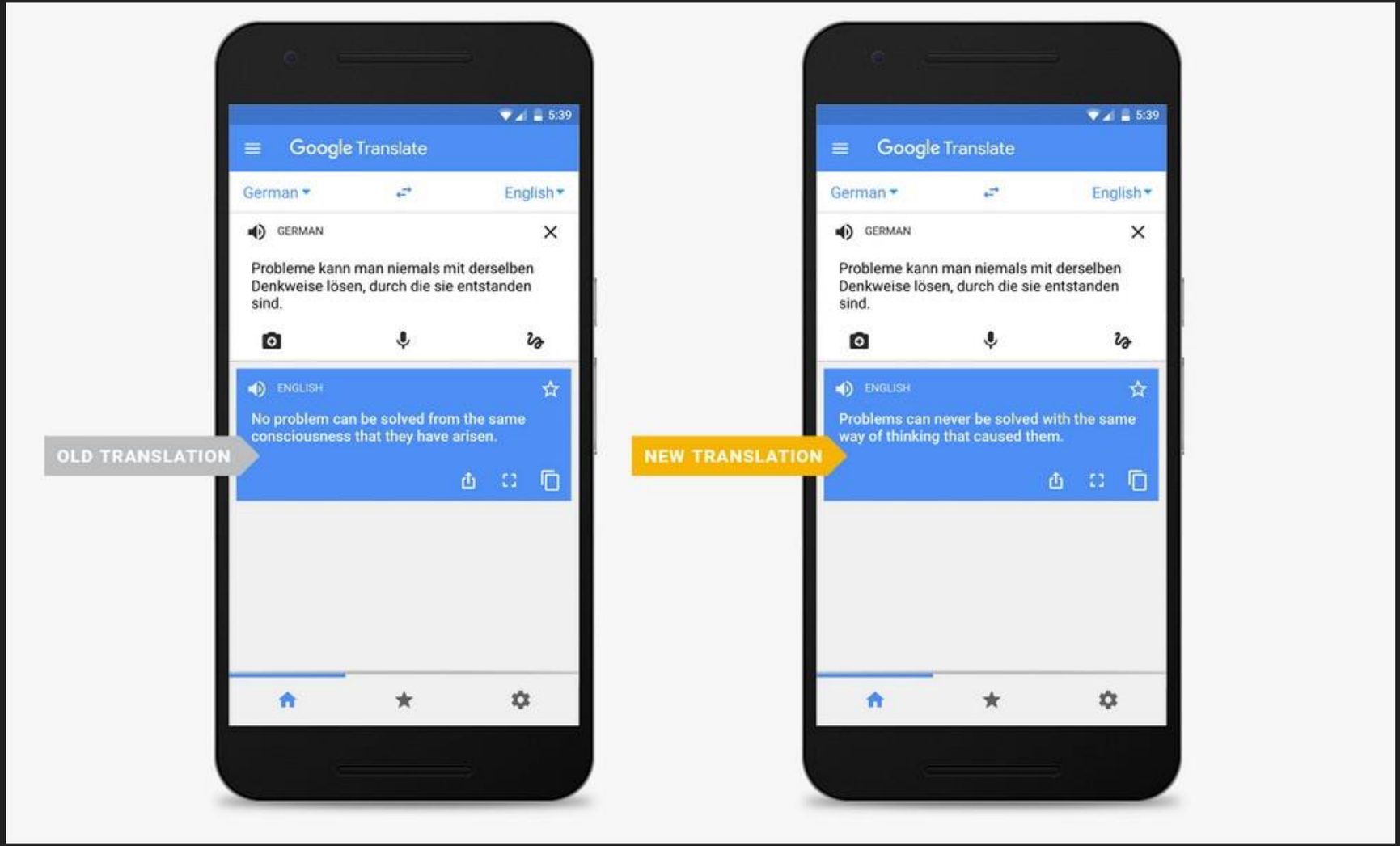
OBJECT RECOGNITION

OBJECT DETECTION



OBJECT SEGMENTATION

LANGUAGE TRANSLATION



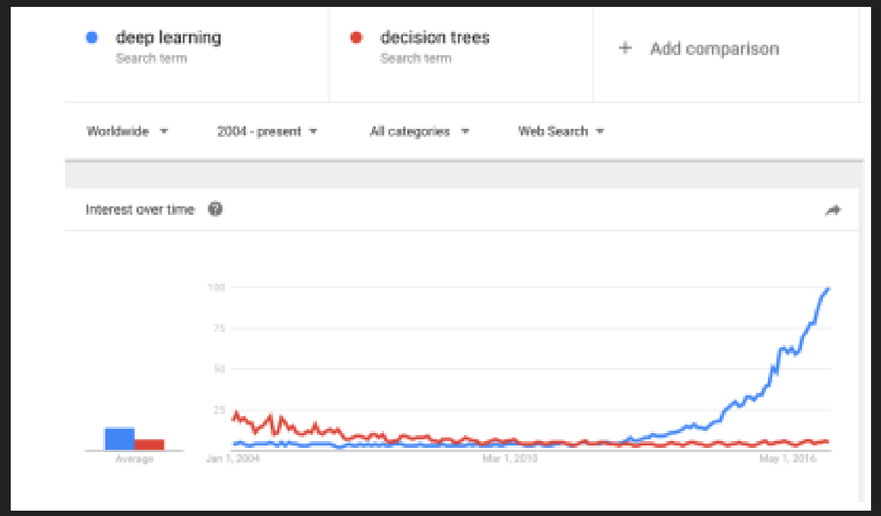
OTHER APPLICATIONS

- Speech recognition
  - Deep Speech and Deep Speech 2
- Recommendation systems
  - Amazon and Netflix
- Games
  - AlphaGo
- Bio-informatics
  - Prediction of cardiovascular risk factors from retinal photographs

… plus more

DEEP LEARNING IN PRACTICE

AN ACTIVE AREA OF RESEARCH



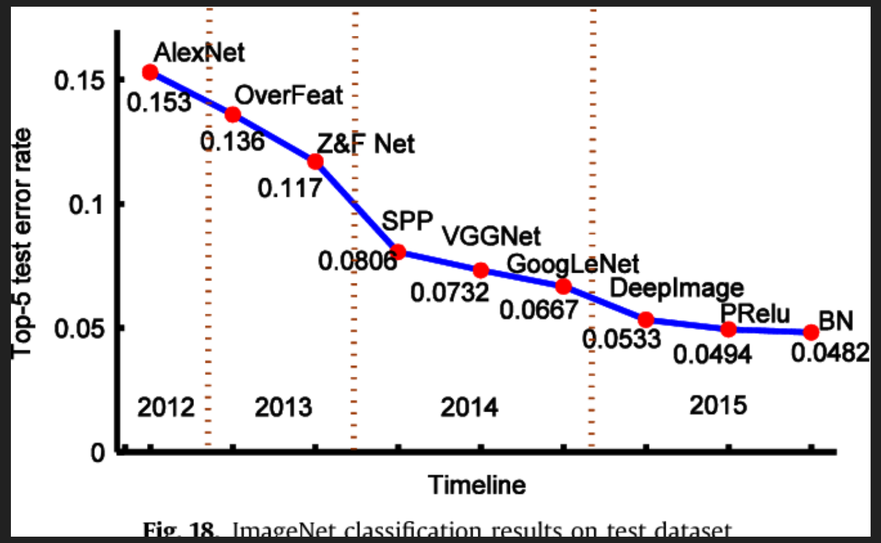
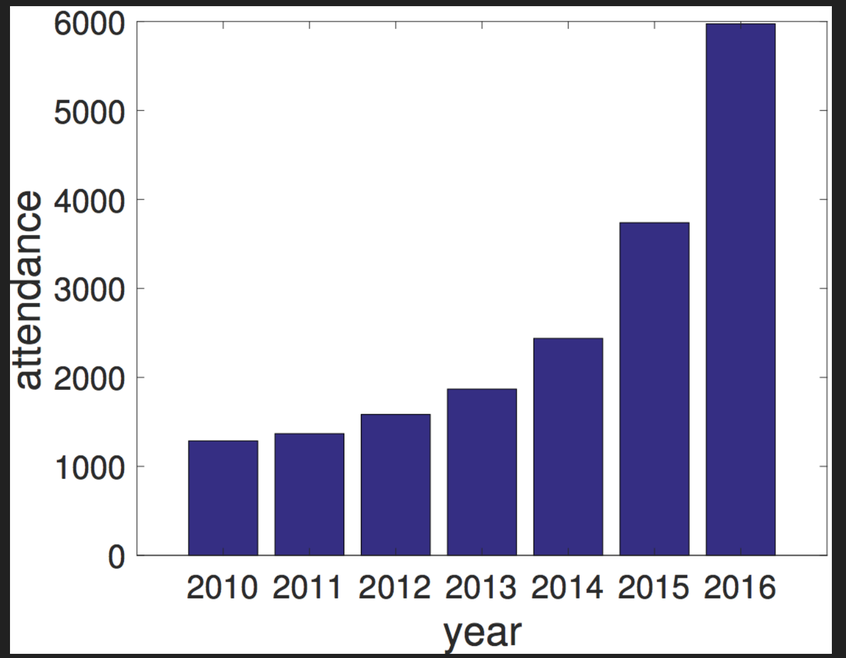


Fig. 18. ImageNet classification results on test dataset

Neural Information Processing Systems Conference



FRAMEWORKS AND LIBRARIES

...plus many more!

Software comparison

RESEARCH TRENDS

- Rush to apply deep learning algorithms to a variety of application domains
- Shift toward unsupervised/self-supervised and reinforcement learning
- Critical evaluation of deep learning approaches including fairness and interpretability
- Understanding representation learning

PRACTICALITY

- A set of approaches among many; not necessarily a saving grace
- Typically large data sets
- Large parameter space can lead to overfitting
- Often too complex

SUMMARY

- Hierarchical representation learning
- Inspired by the brain's highly-connected network structure
- Boosted by big data and GPUs
- Groundbreaking successes in many areas
- High popularity and hype

UP NEXT

Convolutional Neural Networks