Deep Learning on Azure

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Microsoft

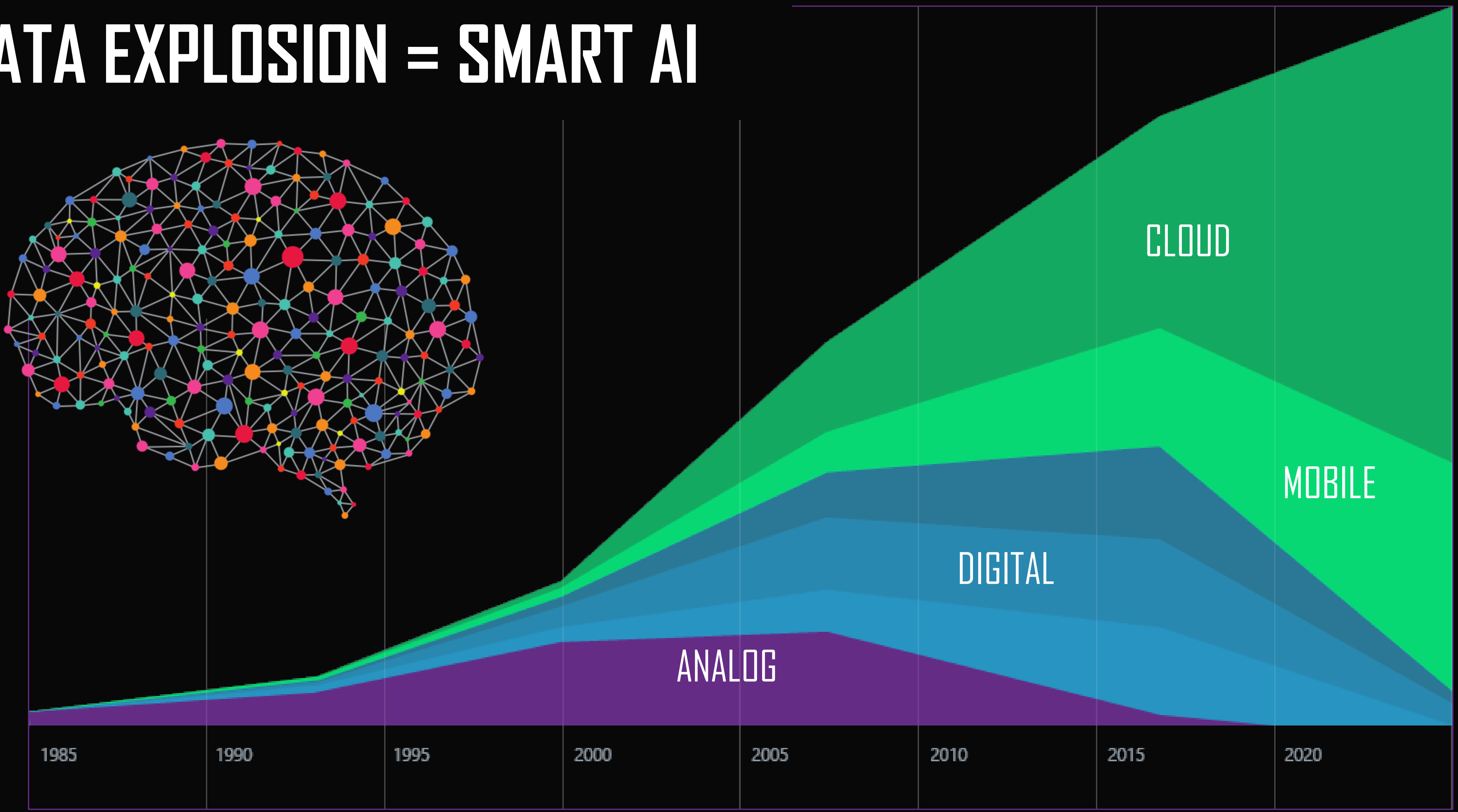
“Our goal is to **democratise AI** to empower every person and every organisation to achieve more.”

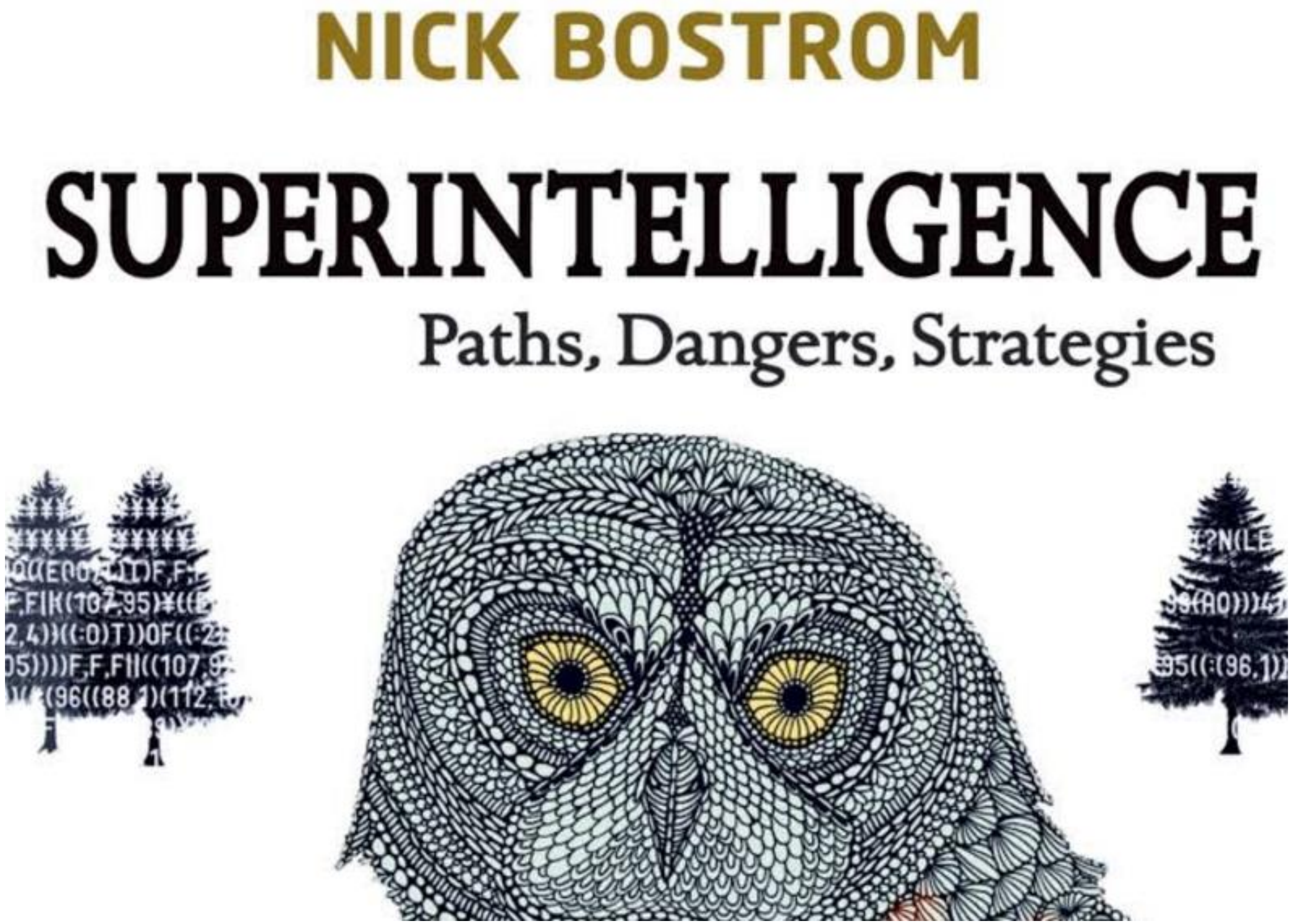
Satya Nadella

WHAT IS MACHINE LEARNING?

Machine learning is about learning from previous experience so you can make accurate predictions about the future.

DATA EXPLOSION = SMART AI





DON'T WORRY ABOUT GENERAL INTELLIGENCE

1. Privacy
2. Opaque AI
3. Data is not neutral
4. Manipulating markets and consumers/voters
5. Lack of human connection
6. Automation of labour / Socioeconomic ramifications
7. Engineers are not philosophers (moral reasoning)

DO WORRY ABOUT ETHICS

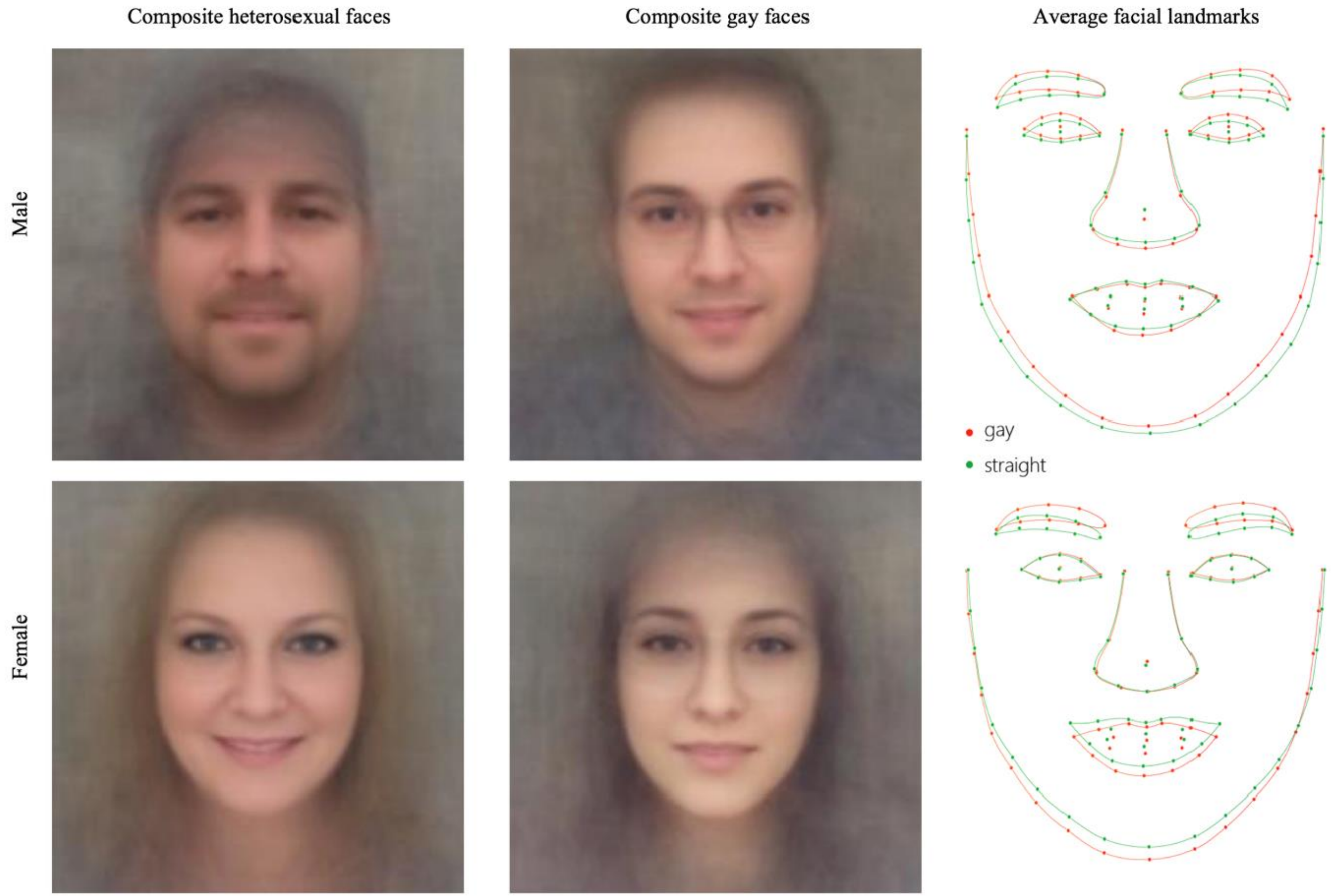
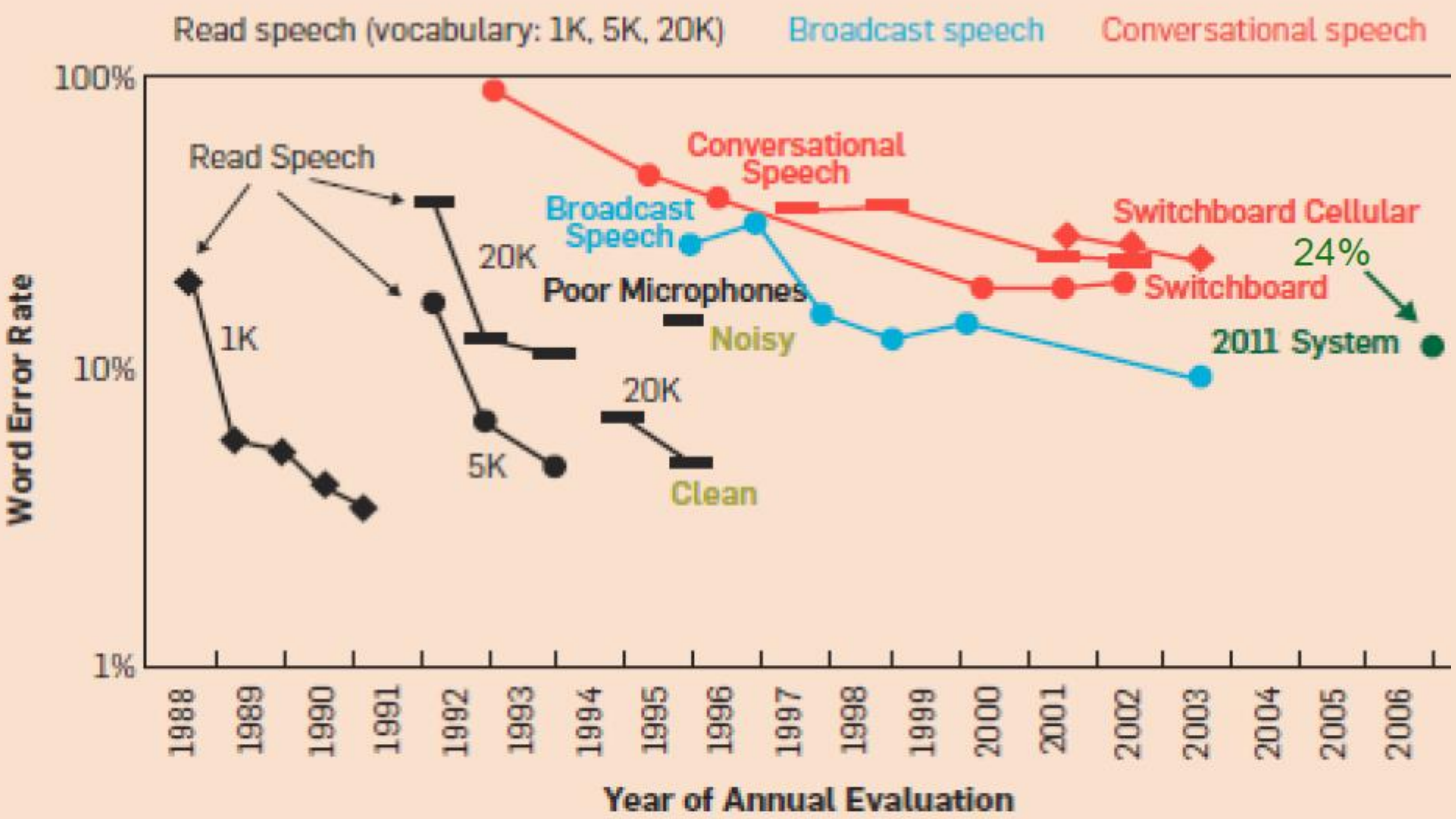
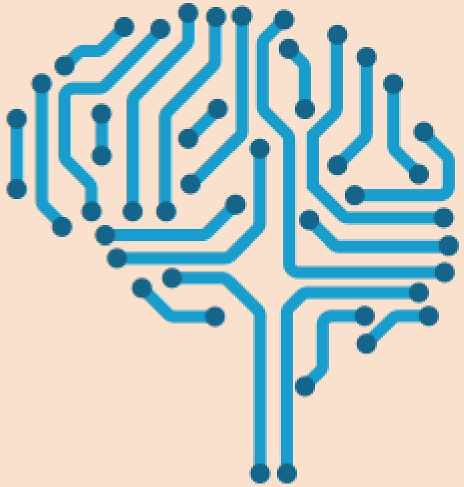


Figure 4. Composite faces and the average facial landmarks built by averaging faces classified as most and least likely to be gay.

PHYSIOGNOMY IS BACK?



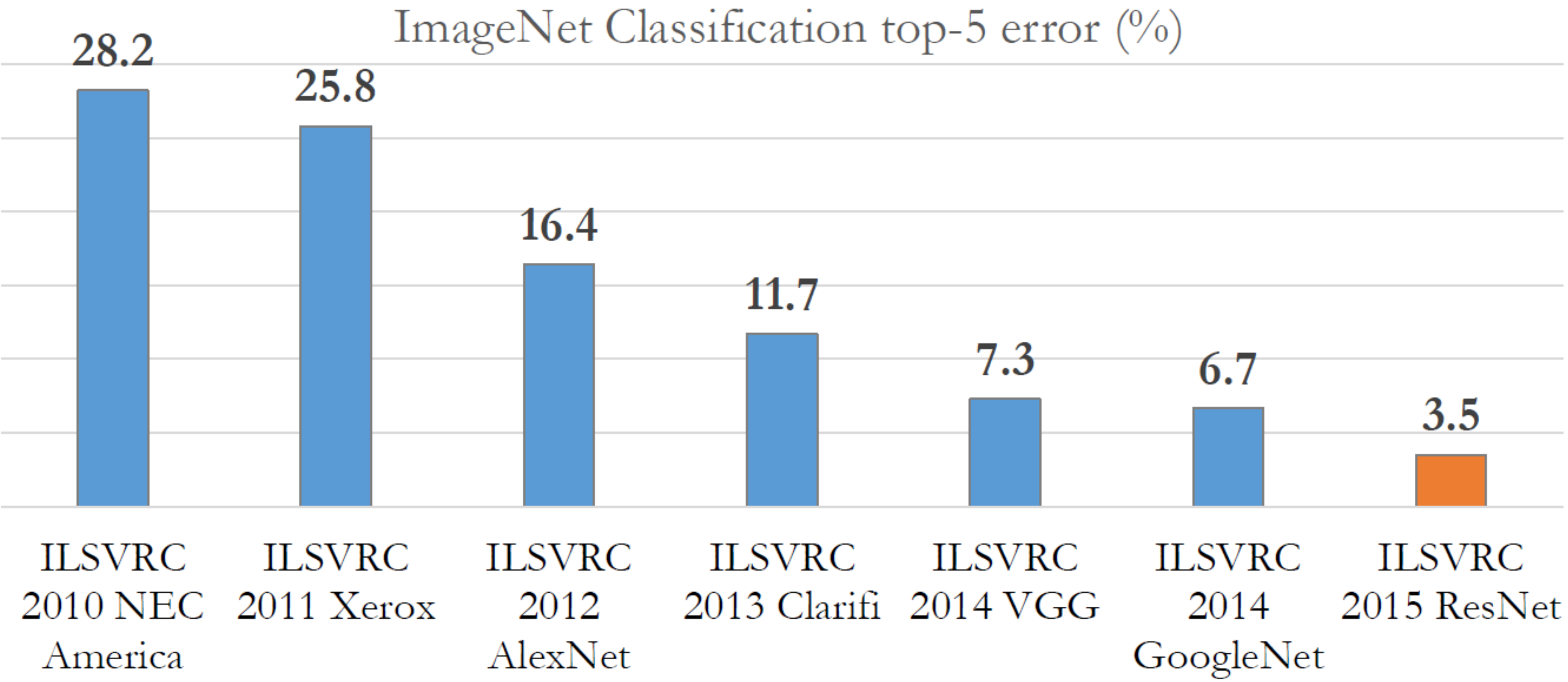


2017: ~5%!

Human error: ~5%

IMPROVEMENTS IN SPEECH RECOGNITION

IMPROVEMENTS IN COMPUTER VISION



2017: ~2.2%

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Machine Learning/AI Stack at Microsoft

R Server

python™

Cognitive Services

Azure
Machine Learning

Data Science
Languages

Cognitive Toolkit (CNTK)

Project “Vienna” (2018)

SaaS (REST)

PaaS (Drag/Drop)

Code
(R vs Python)

- We are #1 contributors to open source
- Platinum member of the Linux foundation
- We support all main deep learning frameworks
- CNTK is 100% open source
- You don't have to use CNTK if you don't want to
- Project "Vienna" will support all frameworks and execution environments on-prem and cloud (cloud/containers/Spark)

THE NEW MICROSOFT

Batch vs. on-line

Regression

Predicting sequences/images

Supervised

Classification

Anomaly Detection

Unsupervised

Clustering

Agent Based Learning

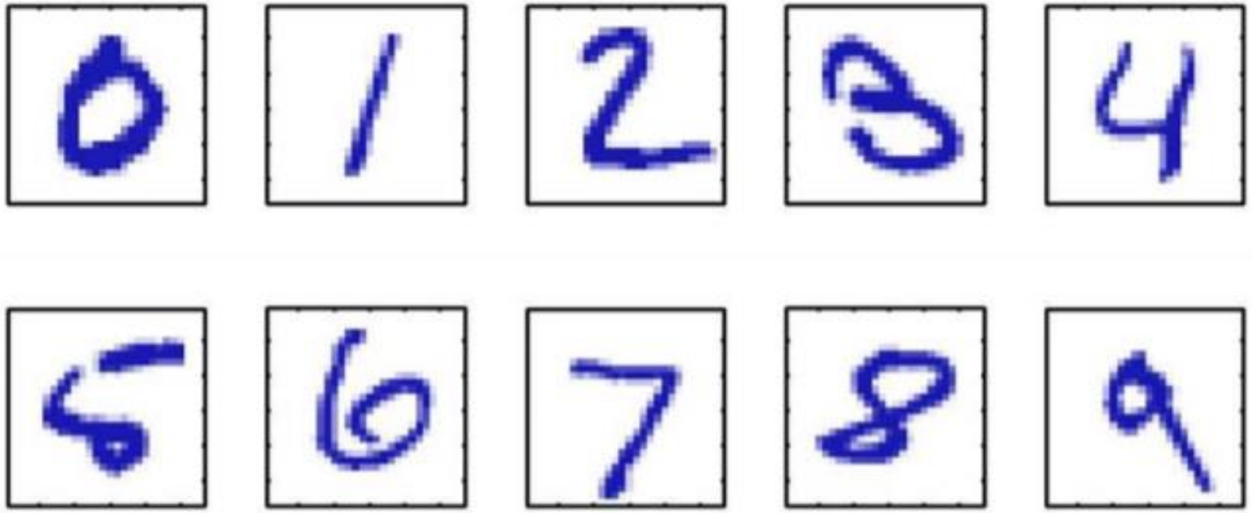
Reinforcement Learning

TYPES OF MACHINE LEARNING

- Approximate a function which maps from signals (image) to labels (has-cat)
- This "decision function" can predict missing labels on new, previously unseen signals.
- Historically; different algorithms for different tasks
  - now; deep learning does everything

WHAT DO MACHINE LEARNING ALGORITHMS DO?

MNIST Digit Classification



Images are 28 x 28 pixels

Represent input image as a vector $\mathbf{x} \in \mathbb{R}^{784}$

Learn a classifier $f(\mathbf{x})$ such that,

$$f : \mathbf{x} \rightarrow \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$$

Signals

Labels

DEEP LEARNING/NEURAL NETWORK DISCUSSION

- Deep Learning = Neural Networks
- Actually, an old technology!
- Universal function approximators; extremely flexible prediction scenarios
- Less emphasis on feature extraction
- Got seriously popular after 2012 due to data+compute explosion
- Particularly good for vision, speech, RL and NLP

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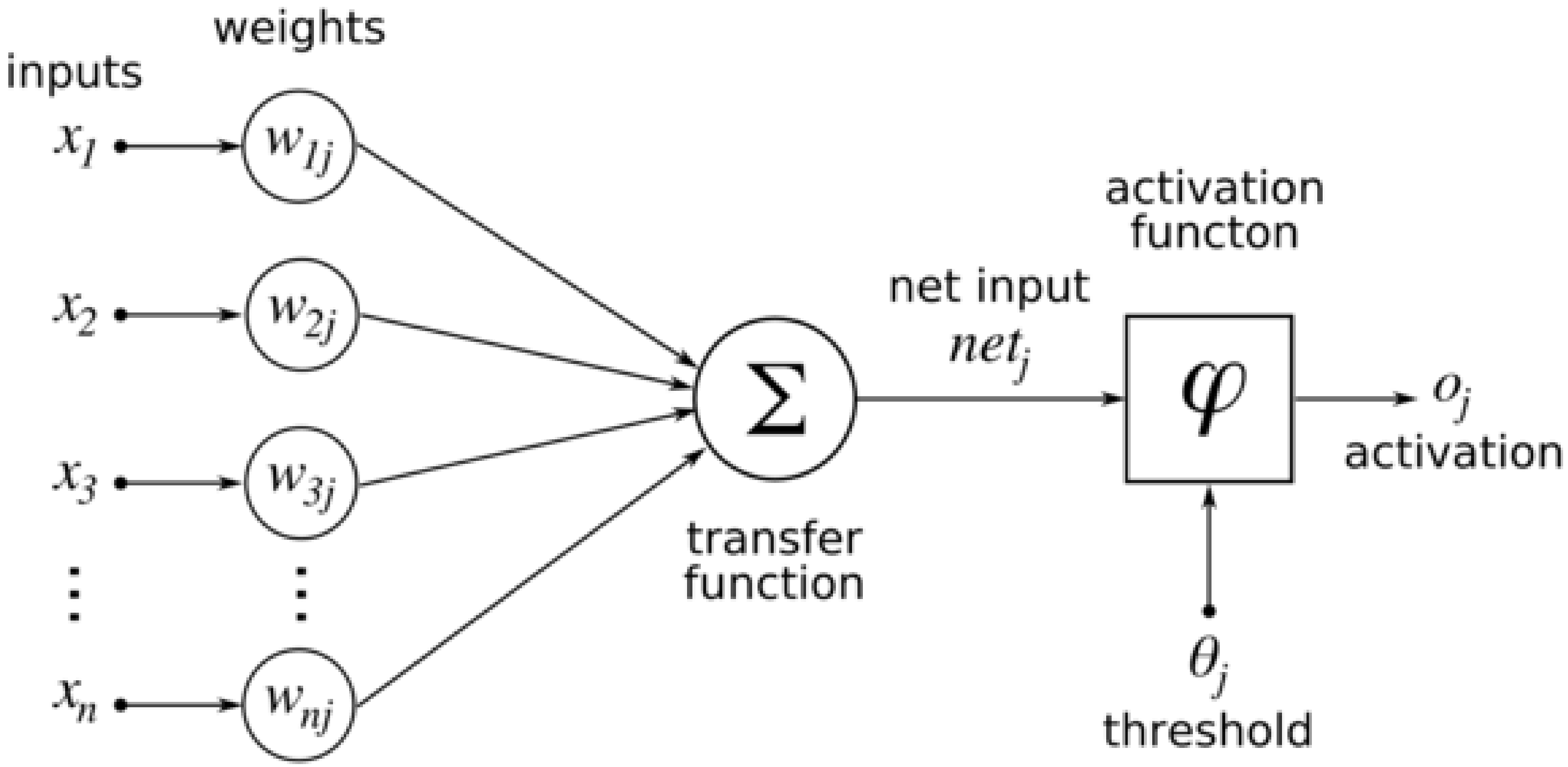
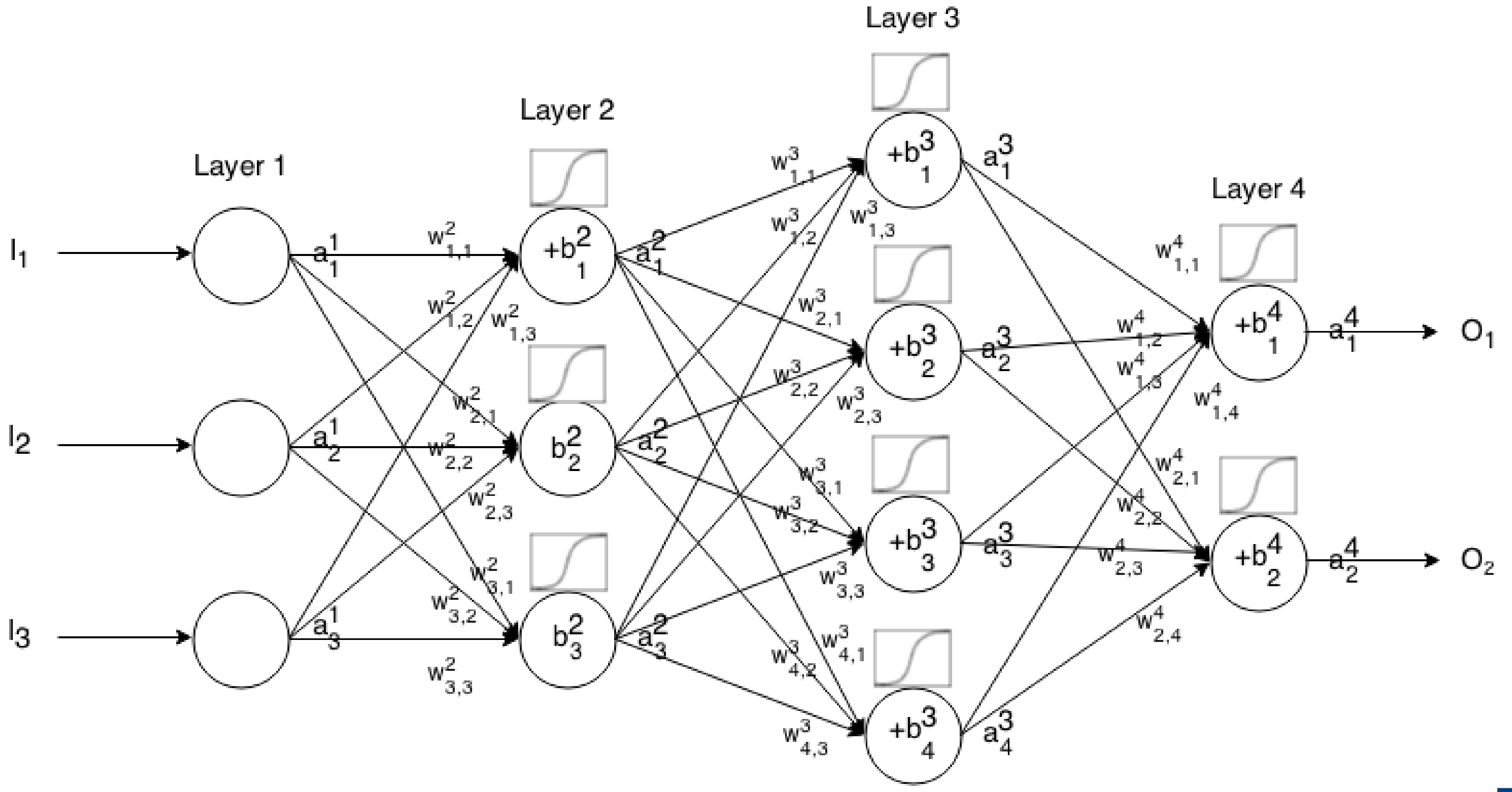
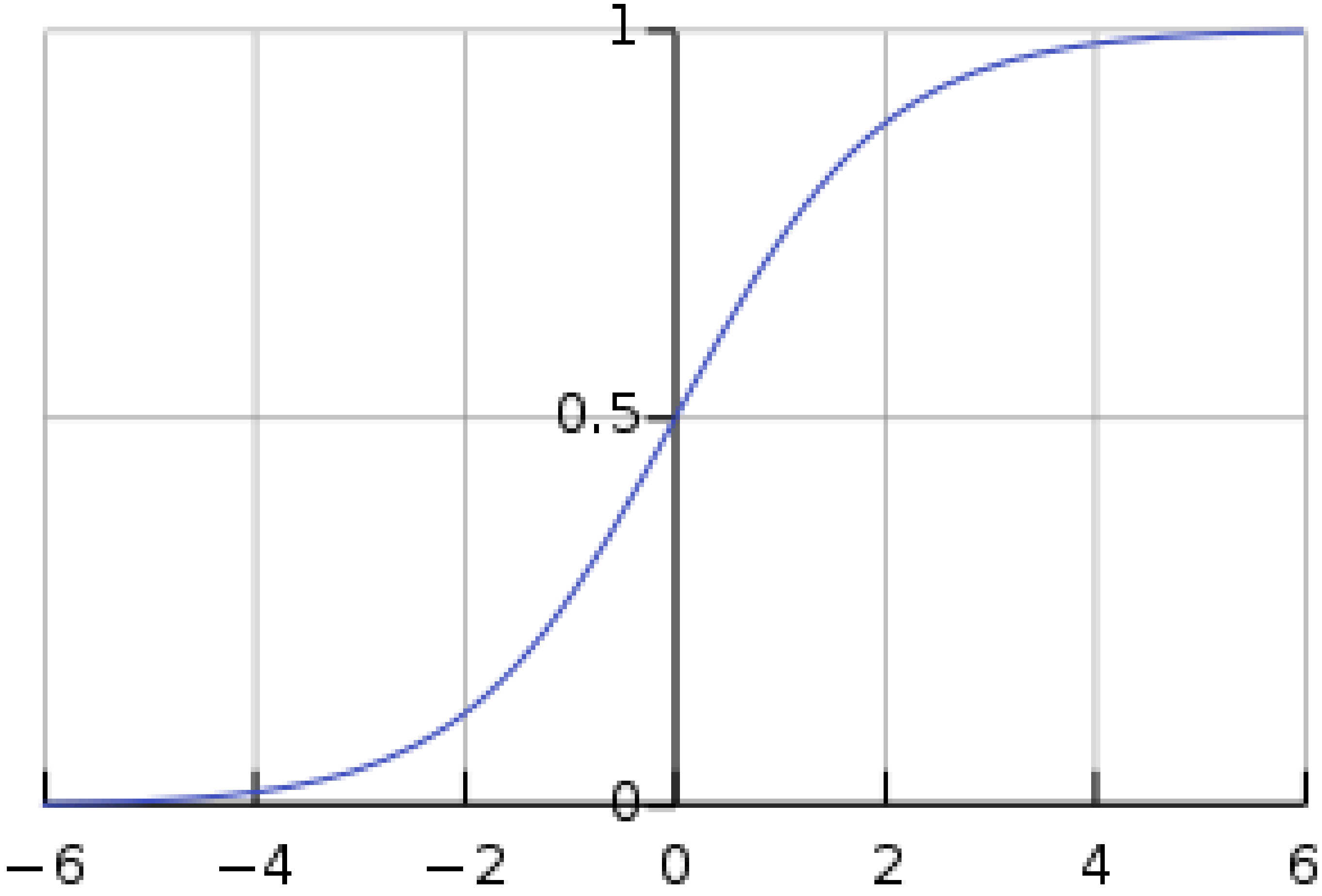
WHAT ARE NEURAL NETWORKS?



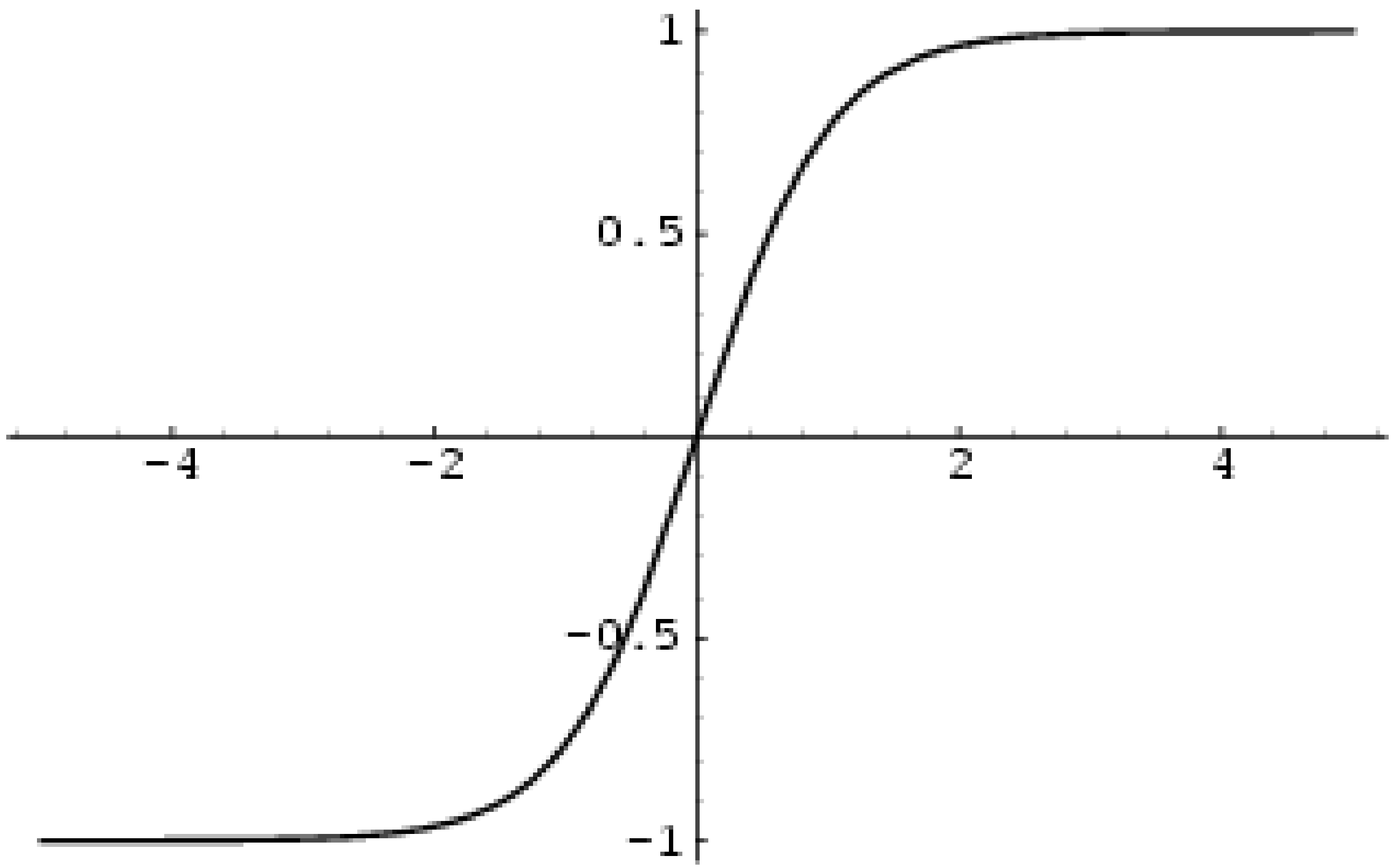
WHAT ABOUT “DEEP” NEURAL NETWORKS?





$$\frac{e^x}{e^x + 1}$$

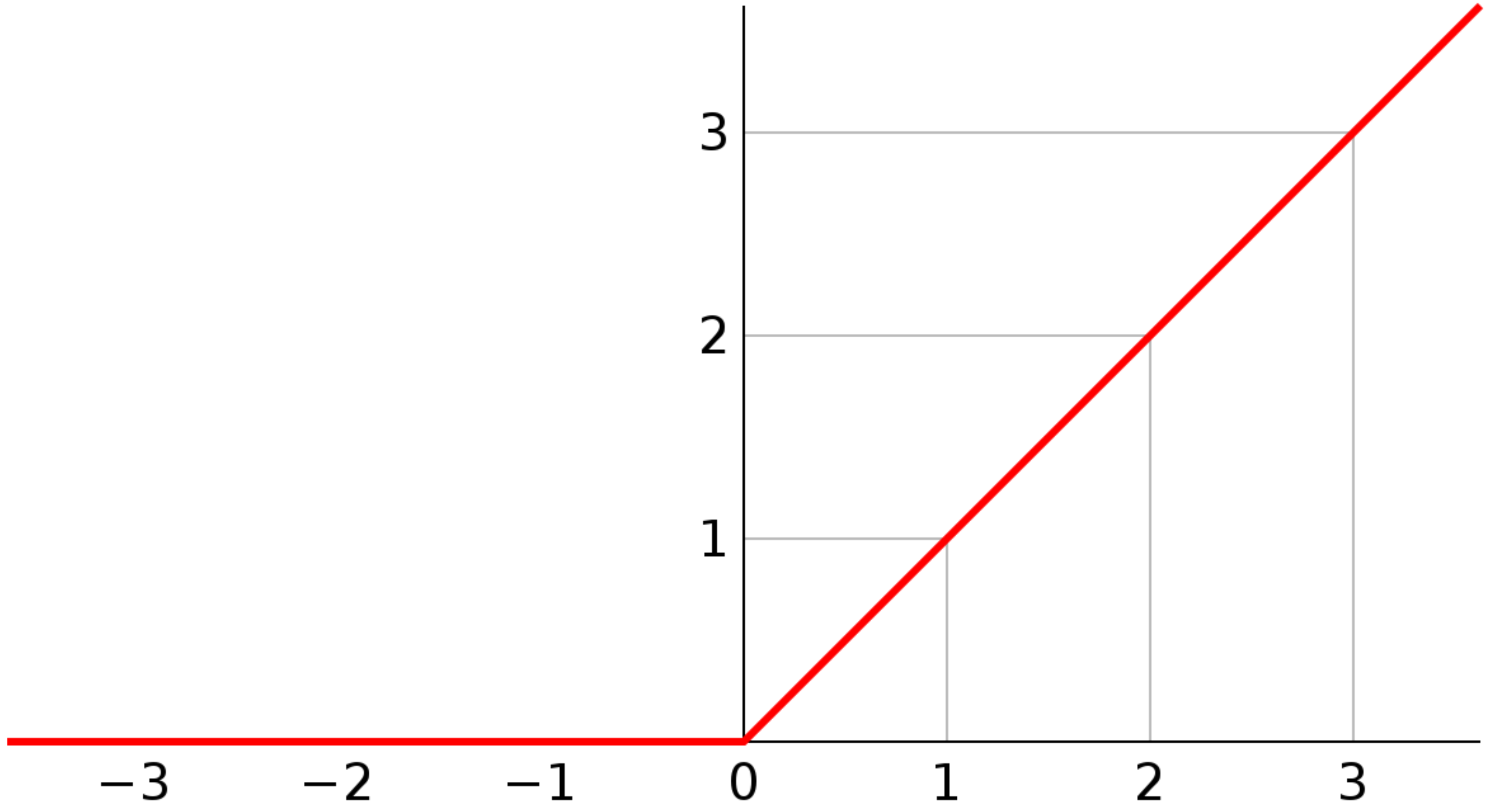
SIGMOID SQUASHING FUNCTION



$$\frac{1-e^{-2x}}{1+e^{-2x}}$$

TANH SQUASHING FUNCTION

$$f(x) = x^+ = \max(0, x)$$



RELU SQUASHING FUNCTION

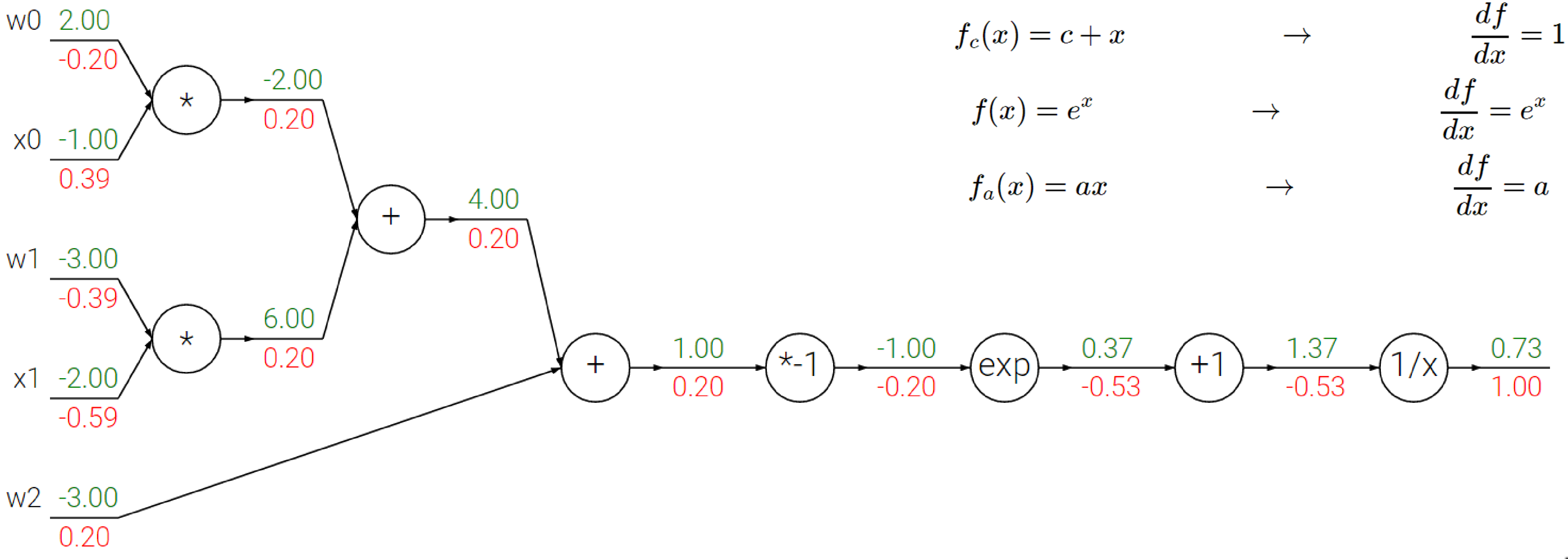
BACKPROPAGATION

$$f(x) = \frac{1}{x} \quad \rightarrow \quad \frac{df}{dx} = -1/x^2$$

$$f_c(x) = c + x \quad \rightarrow \quad \frac{df}{dx} = 1$$

$$f(x) = e^x \quad \rightarrow \quad \frac{df}{dx} = e^x$$

$$f_a(x) = ax \quad \rightarrow \quad \frac{df}{dx} = a$$



$$\frac{\partial E}{\partial w_{jk}}$$

Example circuit for a 2D neuron with a sigmoid activation function. The inputs are [x0,x1] and the (learnable) weights of the neuron are [w0,w1,w2]. As we will see later, the neuron computes a dot product with the input and then its activation is softly squashed by the sigmoid function to be in range from 0 to 1.

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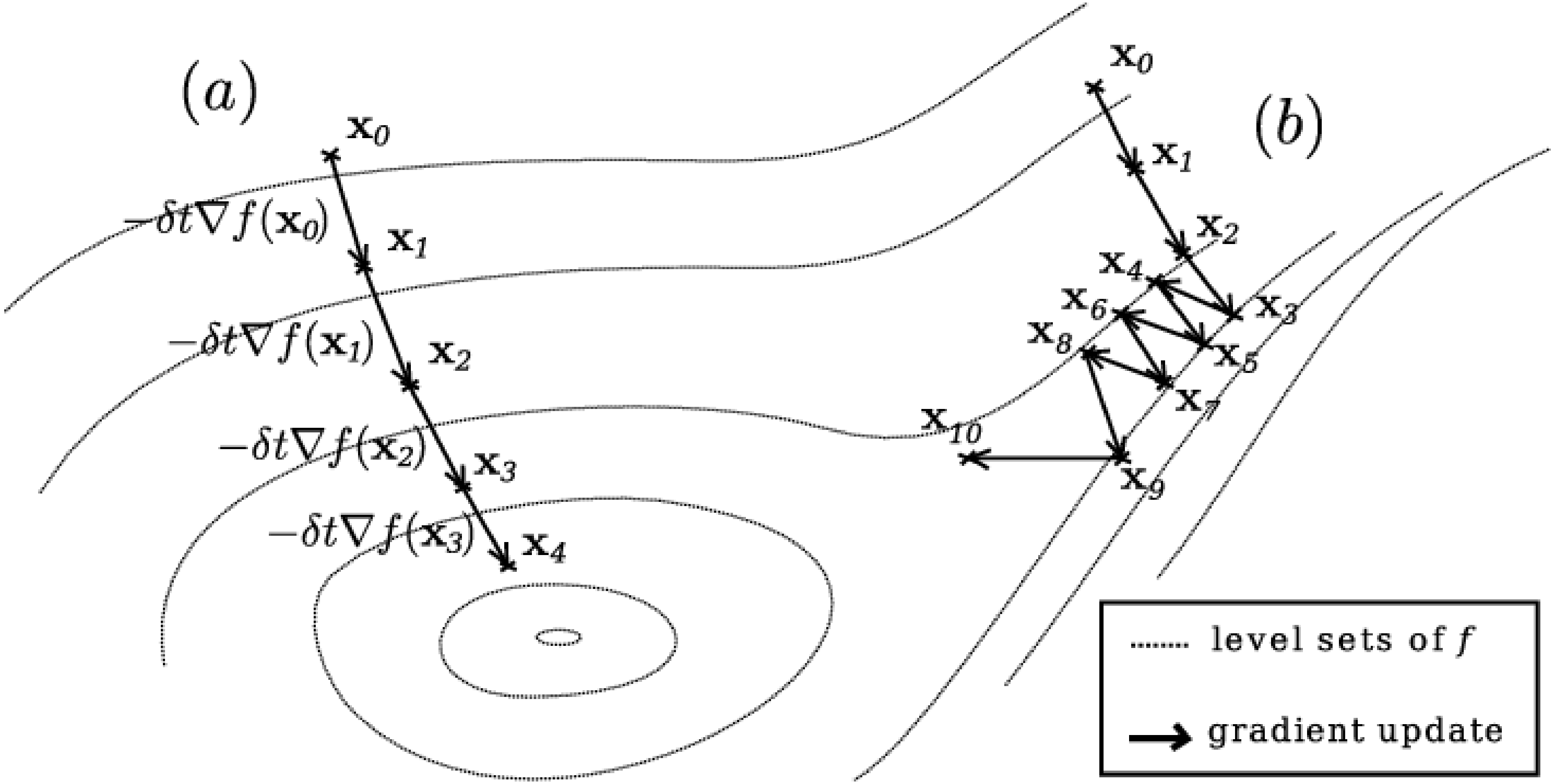
$$\Delta w_{jk} = \underset{\uparrow\ \text{learning rate}}{\eta} * \left[\overbrace{x_j * \underbrace{\underbrace{(o_k - t_k)}_{\text{error } e_k} * \underbrace{o_k * (1 - o_k)}_{\text{derivative of output activation } \varphi_k{}'}}_{\text{signal } \delta_k}}^{\frac{\partial E}{\partial w_{jk}}} \right]$$

WEIGHT UPDATE

```
loop maxEpochs times
  for-each training item
    get target values
    compute output values
    compute the gradient of each weight
    use gradient to compute delta for each weight
    update each weight using its delta
  end-for
end-loop
```

BACKPROP ALGORITHM

OPTIMIZATION/GRADIENT DESCENT



WEIGHT UPDATES IN EPOCHS / TRAINING DATA SPLIT INTO MINIBATCHES

DEMO

http://playground.tensorflow.org

NEURAL NETWORK PLAYGROUND

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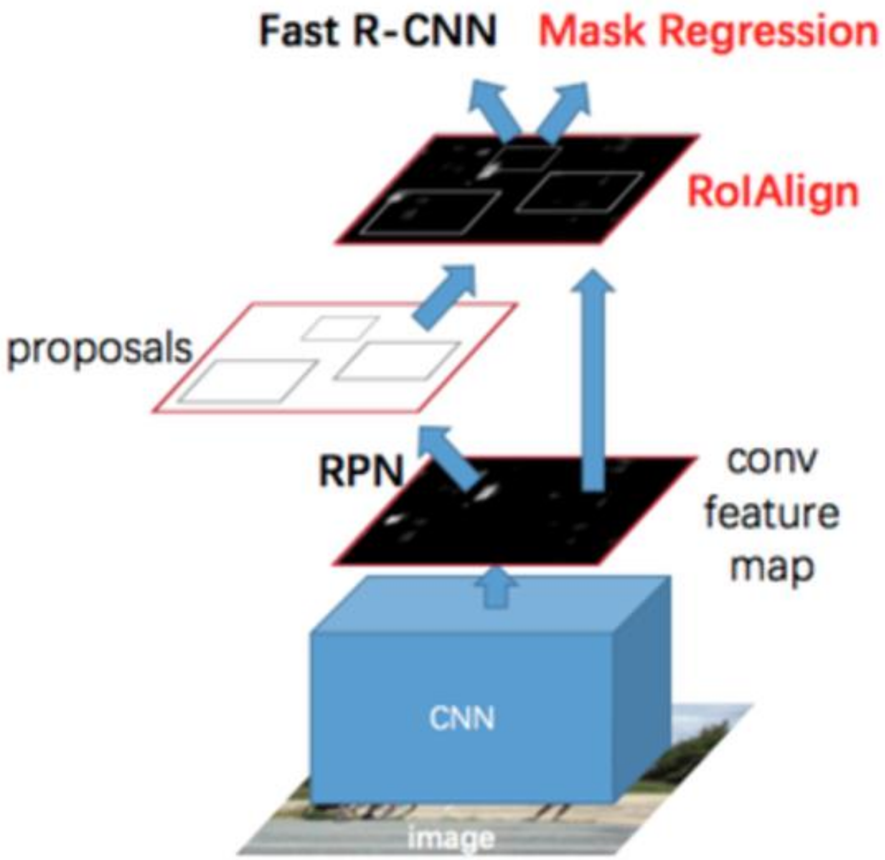
WHY IS DEEP LEARNING SPECIAL, IS IT A FAD?

- The way we think about neural networks now is totally different to 30 years ago
- Previous frequentist algorithms were just learning weighted combinations of hand-crafted features
- NNs learn a hierarchy of representations which work really well in many domains
- Before we used to talk about classification and regression, now we talk about *predictive architectures*

MASK R-CNN ARCHITECTURE (2017)



PARADGM-SHIFT

- Three narratives currently exist to describe deep learning
  - Neuroscience
  - Probabilistic
  - Manifold
- The *differentiable programming* narrative is emerging

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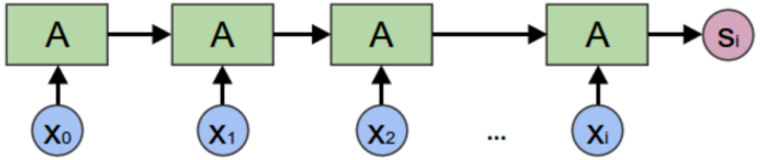
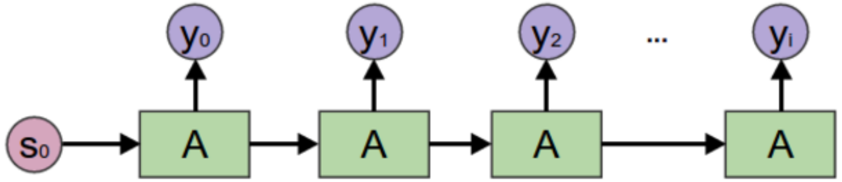
http://colah.github.io/posts/2015-09-NN-Types-FP/

FUNCTIONAL PROGRAMMING IN DL



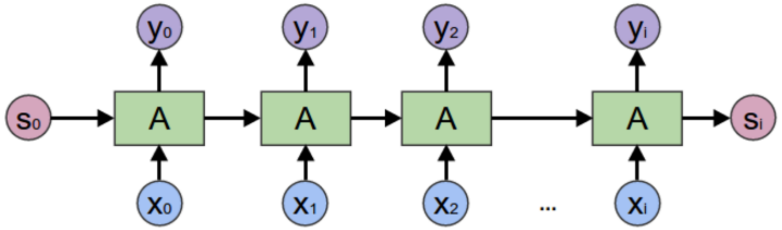
fold = Encoding RNN

Haskell: `foldl a s`



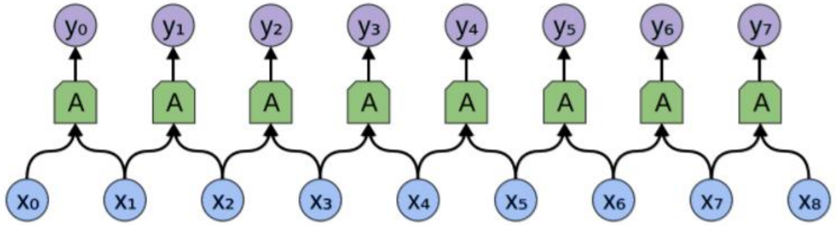
unfold = Generating RNN

Haskell: `unfoldr a s`



Accumulating Map = RNN

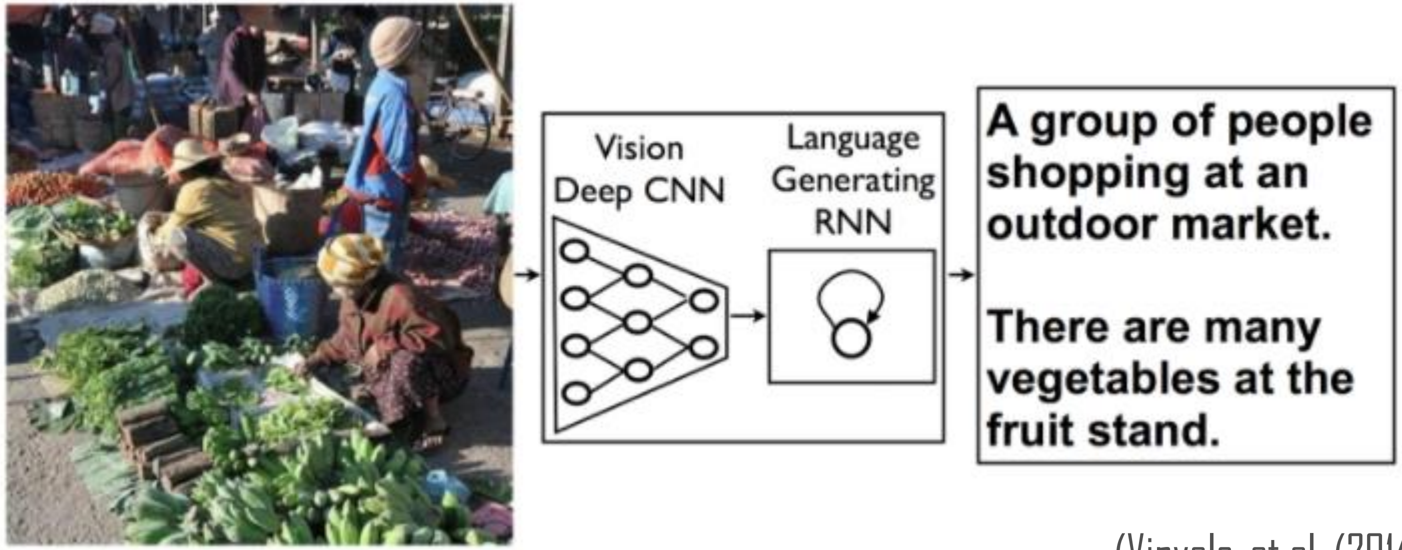
Haskell: `mapAccumR a s`



Windowed Map = Convolutional Layer

Haskell: `zipWith a xs (tail xs)`

BUILDING PREDICTIVE ARCHITECTURES WITH COMPONENTS



(Vinyals, et al. (2014))

WHAT IS CNTK?

- DECLARITIVELY DESCRIBE AND TRAIN DEEP NEURAL NETWORKS
- DOES ALL THE HARD WORK FOR YOU
- 80% INTERNAL MS DL WORKLOADS USE CNTK
- 1ST CLASS ON LINUX, WINDOWS, DOCKER
- C#, PYTHON, COMMANDLINE
- KERAS BINDINGS

http://dlbench.comp.hkbu.edu.hk/

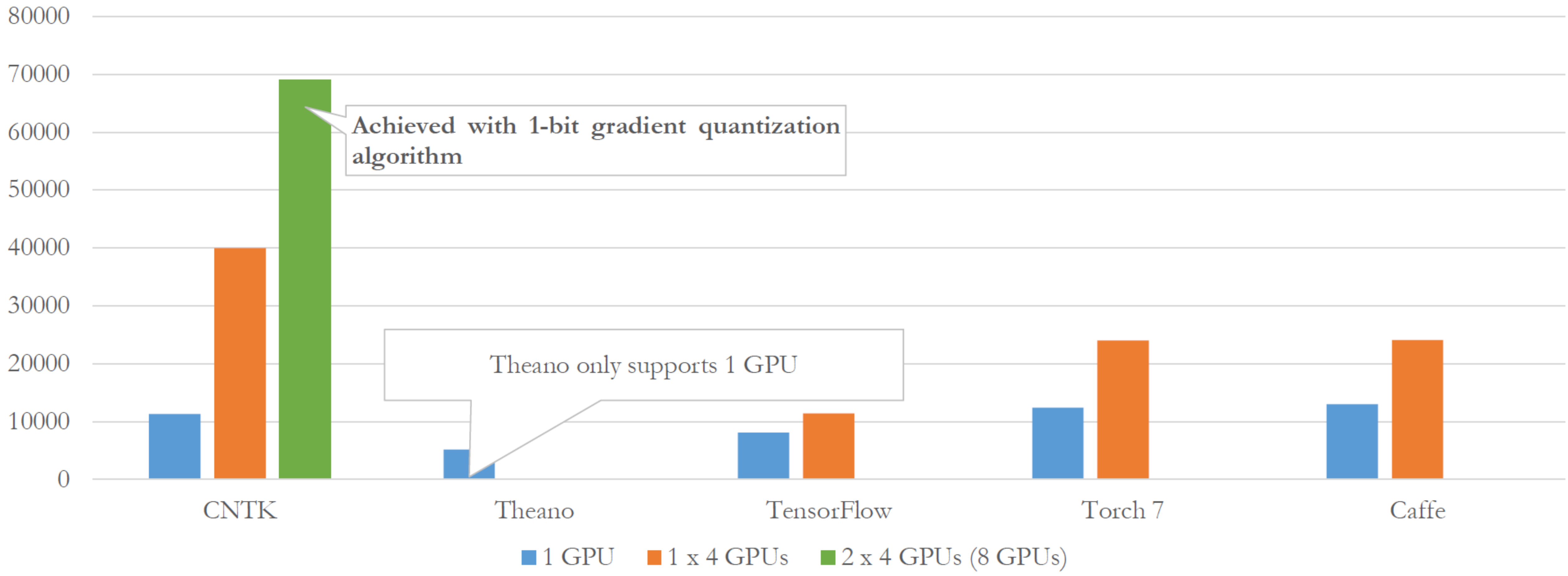
Benchmarking by HKBU, Version 8

Single Tesla K80 GPU, CUDA: 8.0 CUDNN: v5.1

Caffe: 1.0rc5(39f28e4)
CNTK: 2.0 Beta10(1ae666d)
MXNet: 0.93(32dc3a2)
TensorFlow: 1.0(4ac9c09)
Torch: 7(748f5e3)

	Caffe	CNTK	MxNet	TensorFlow	Torch
FCN5 (1024)	55.329ms	**51.038ms**	60.448ms	62.044ms	52.154ms
AlexNet (256)	36.815ms	**27.215ms**	28.994ms	103.960ms	37.462ms
ResNet (32)	143.987ms	**81.470ms**	84.545ms	181.404ms	90.935ms
LSTM (256) (v7 benchmark)	-	**43.581ms** (44.917ms)	288.142ms (284.898ms)	- (223.547ms)	1130.606ms (906.958ms)

THE FASTEST TOOLKIT



MOST SCALABLE TOOLKIT (2016)

INSTALLING CNTK

- GOOGLE “CNTK INSTALL” (WITH BING)
- USE THE “SCRIPT DRIVEN INSTALLATION”

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WHEN TO USE DEEP LEARNING FRAMEWORKS

- Sequence modelling (speech, language, time-series)
- Complex vision tasks (localisation, detection)
- Novel prediction architectures
- Generative models
- Reinforcement learning
- … and many more!

DEEP LEARNING ON AZURE CLOUD

- Data Science Virtual Machine (Ubuntu and Windows)
- Batch AI Training Service
- AzureML supports some deep learning workloads
- R Server supports some deep learning

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DEMO

CNTK IRIS DEMO

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WHAT ABOUT VISION AND NATURAL LANGUAGE PROCESSING?

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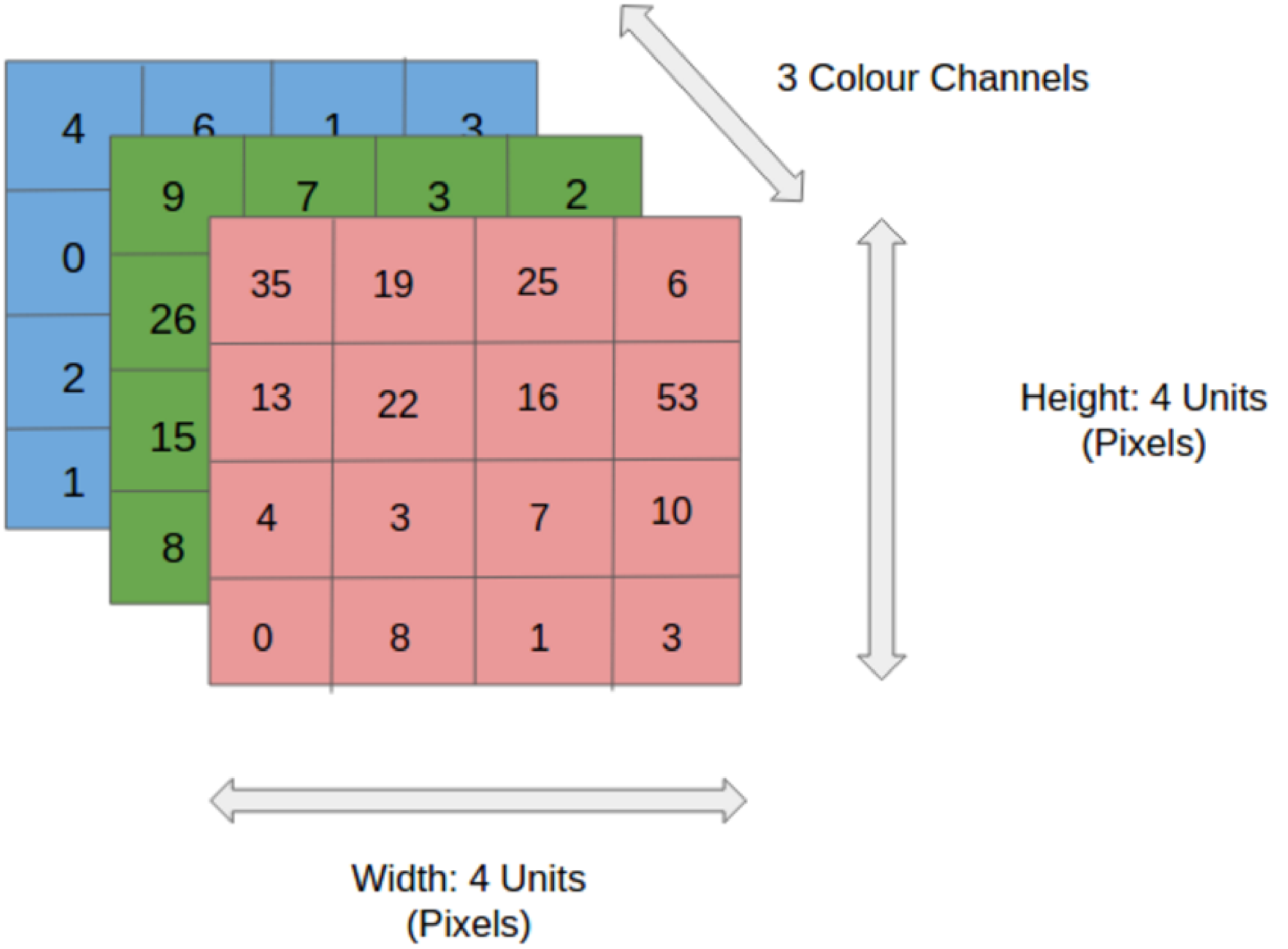
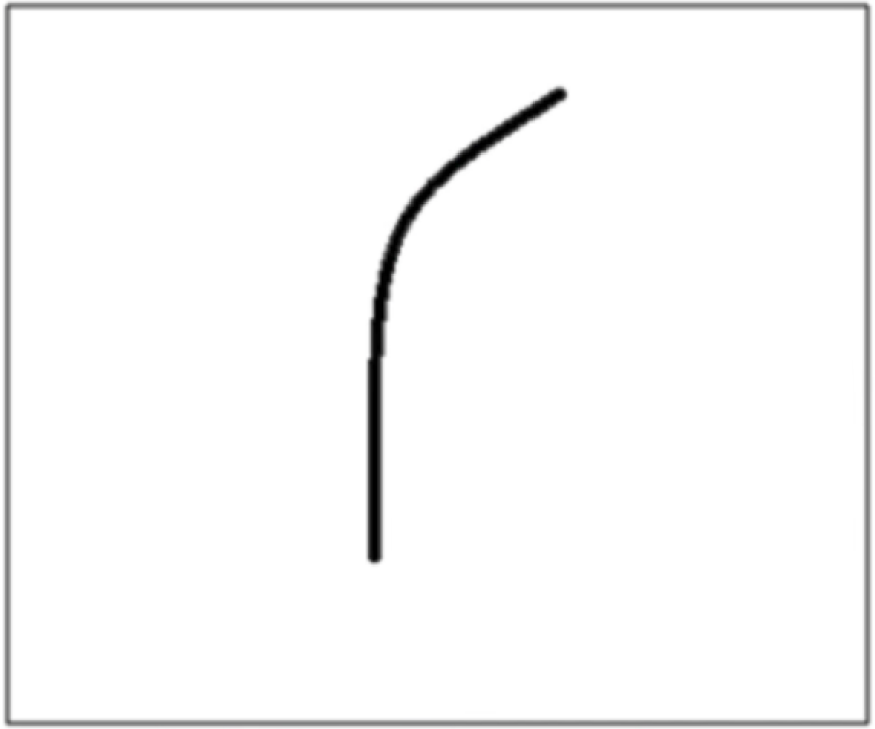
PREPARE DATASET OF IMAGES



0	0	0	0	0	30	0
0	0	0	0	30	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	0	0	0	0

Pixel representation of filter



Visualization of a curve detector filter

CONVOLUTION FILTER

Visualization of the filter on the image

$$(50*30)+(50*30)+(50*30)+(20*30)+(50*30) = 6600$$

Visualization of the receptive field

0	0	0	0	0	0	30
0	0	0	0	50	50	50
0	0	0	20	50	0	0
0	0	0	50	50	0	0
0	0	0	50	50	0	0
0	0	0	50	50	0	0
0	0	0	50	50	0	0

Pixel representation of the receptive field

*

0	0	0	0	0	30	0
0	0	0	0	30	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	0	0	0	0

Pixel representation of filter

CONVOLUTION FILTER MATCH

Visualization of the filter on the image

MULTIPLY AND SUMMATION = 0

0	0	0	0	0	0	0
0	40	0	0	0	0	0
40	0	40	0	0	0	0
40	20	0	0	0	0	0
0	50	0	0	0	0	0
0	0	50	0	0	0	0
25	25	0	50	0	0	0

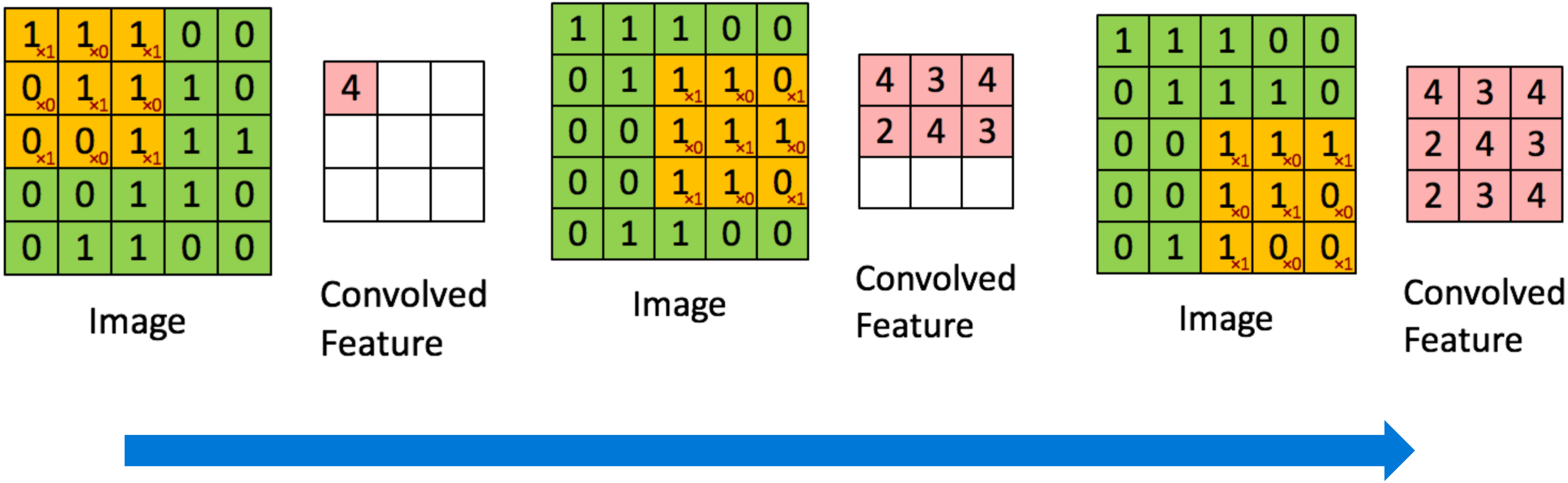
Pixel representation of receptive field

*

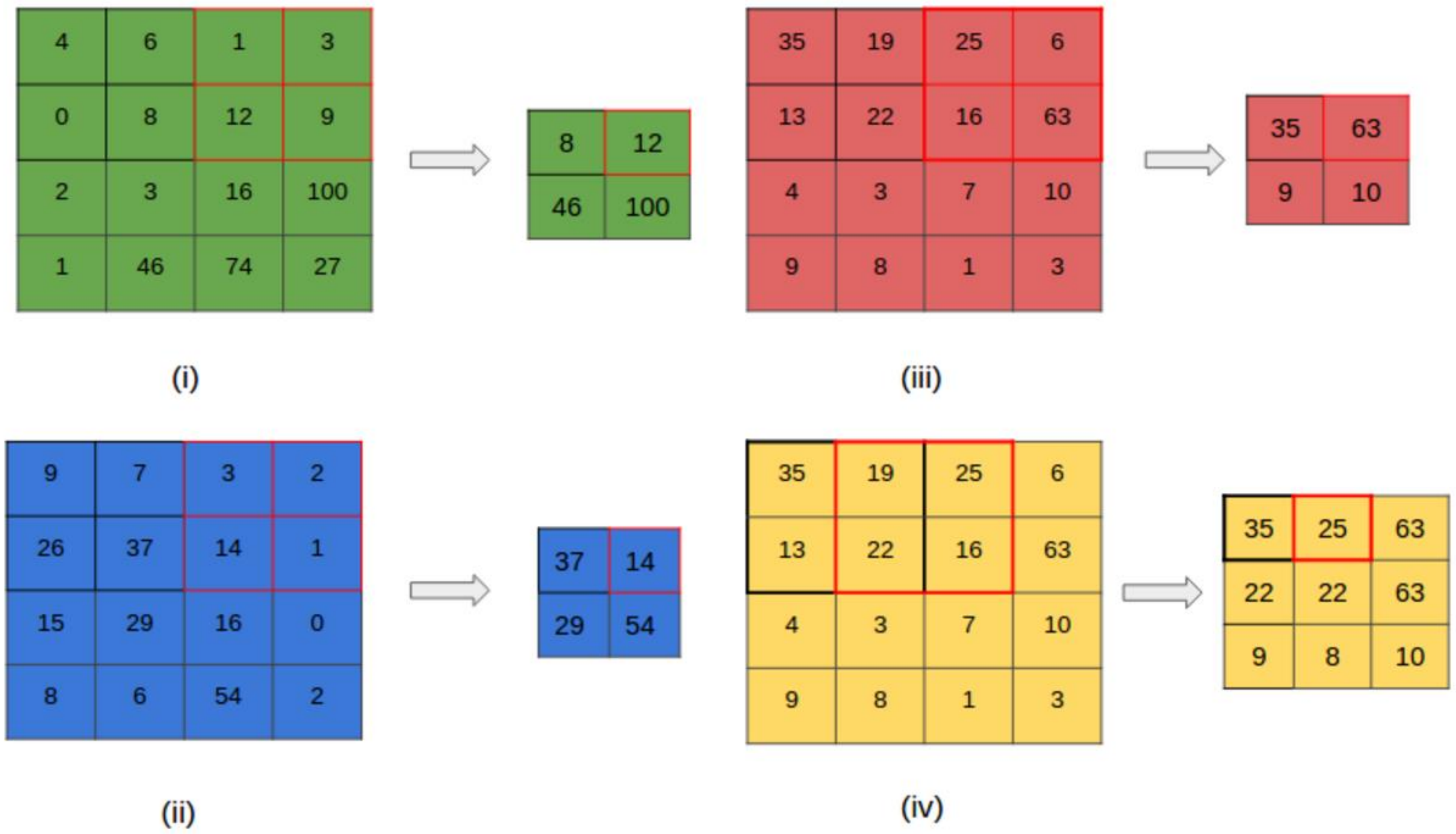
0	0	0	0	0	30	0
0	0	0	0	30	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	0	0	0	0

Pixel representation of filter

CONVOLUTION FILTER NO MATCH

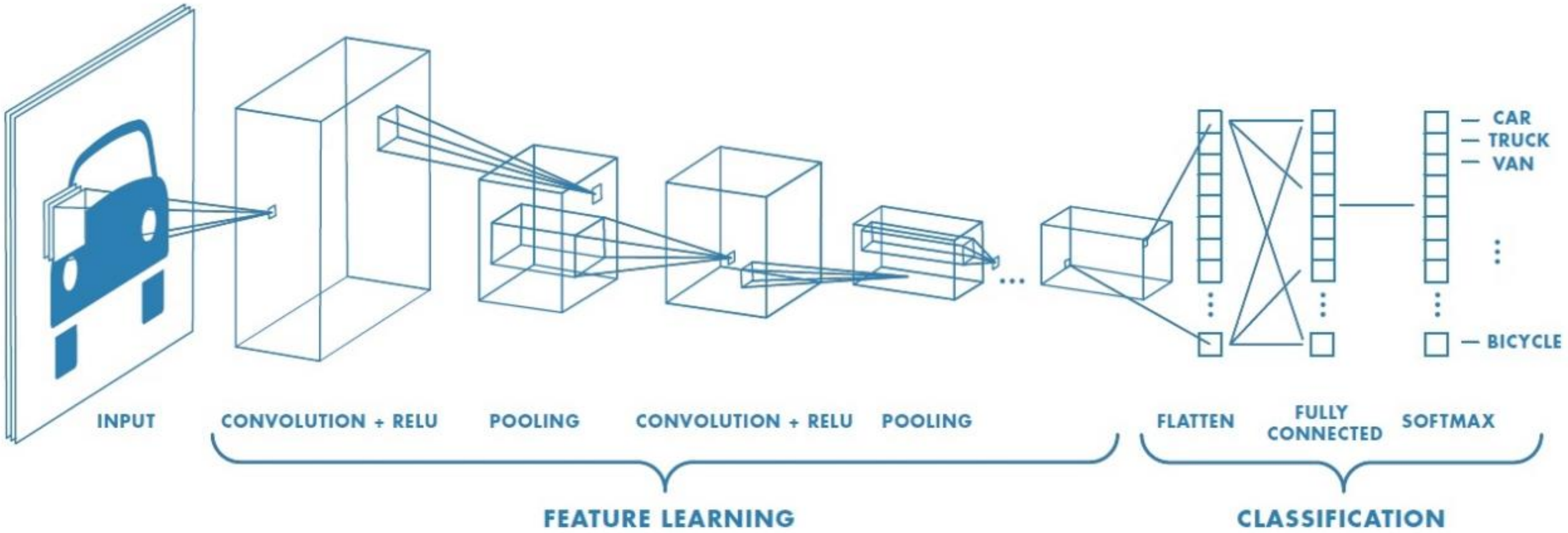


CONVOLUTION

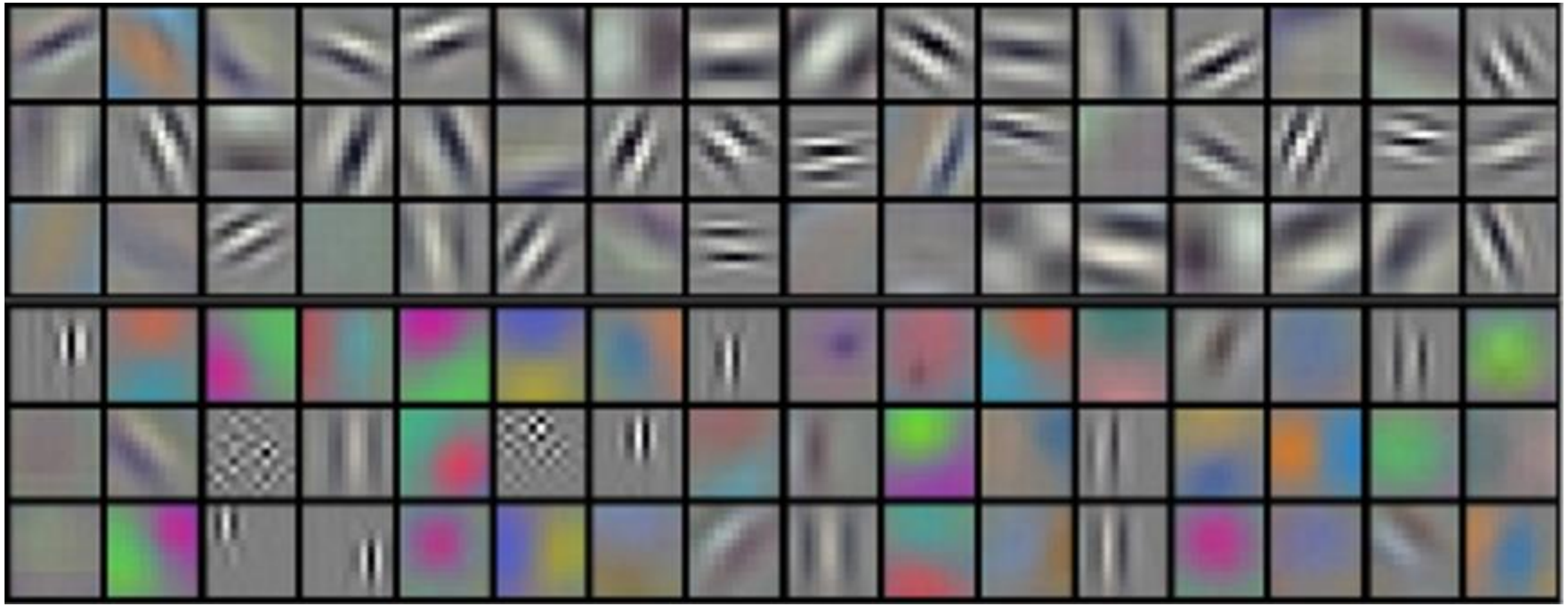

4 6 1 3
0 8 12 9
2 3 16 100
1 46 74 27
8 12
46 100
(i)
35 19 25 6
13 22 16 63
4 3 7 10
9 8 1 3
35 63
9 10
(iii)
9 7 3 2
26 37 14 1
15 29 16 0
8 6 54 2
37 14
29 54
(ii)
35 19 25 6
13 22 16 63
4 3 7 10
9 8 1 3
35 25 63
22 22 63
9 8 10
(iv)

POOLING

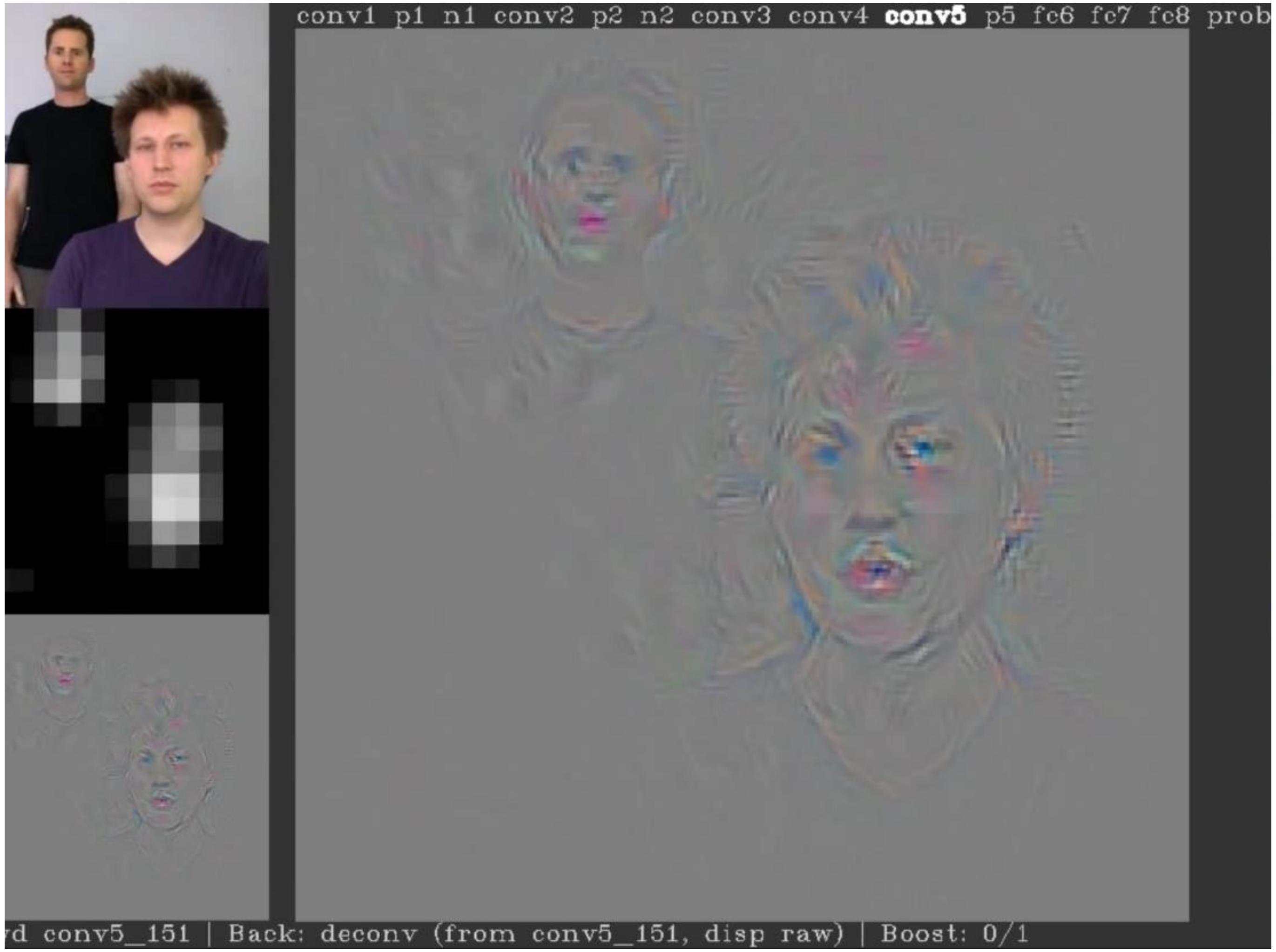
Image Classification Example



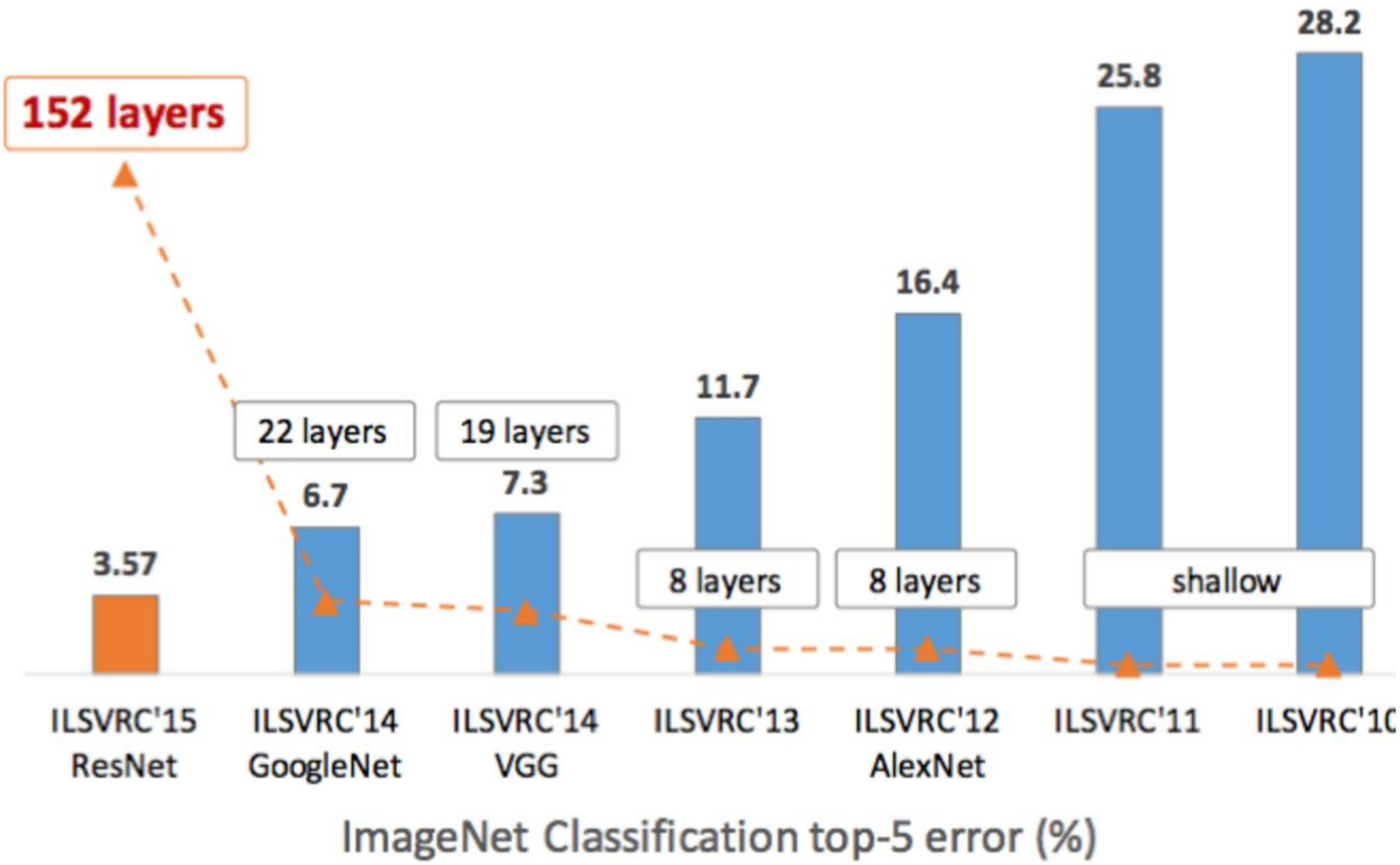
VISUALISING THE FILTERS

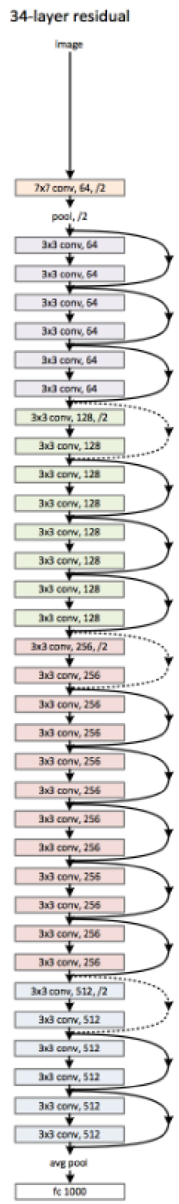


DEEP VISUALISATION TOOLBOX



RESOLUTION OF DEPTH





DEMO

CNTK MNIST DEMO

Microsoft

THANK YOU

tim.scarfe@microsoft.com