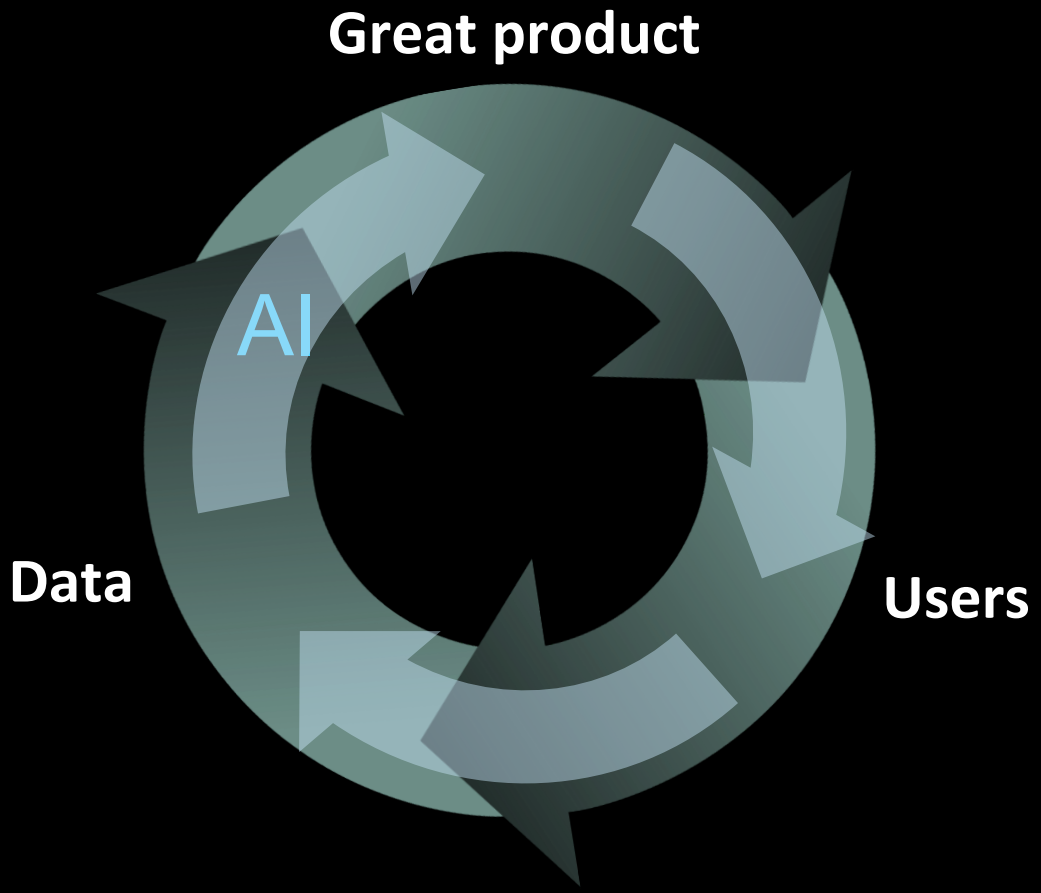
Deep Learning

Andrew Ng

Thanks to Adam Coates, Kai Yu, Tong Zhang, Sameep Tandon, Swati Dube, Brody Huval, Tao Wang, ….

Virtuous circle of AI



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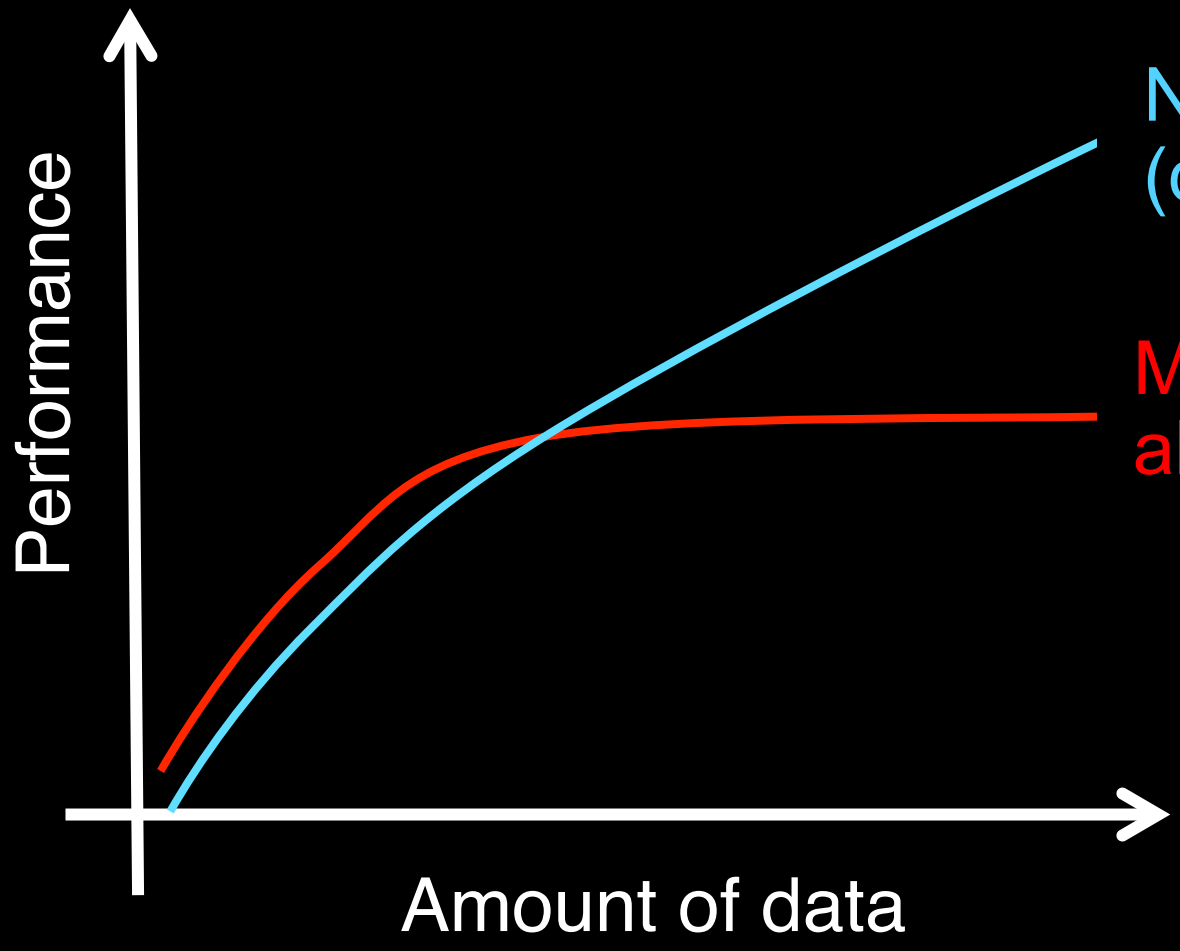
Data and machine learning



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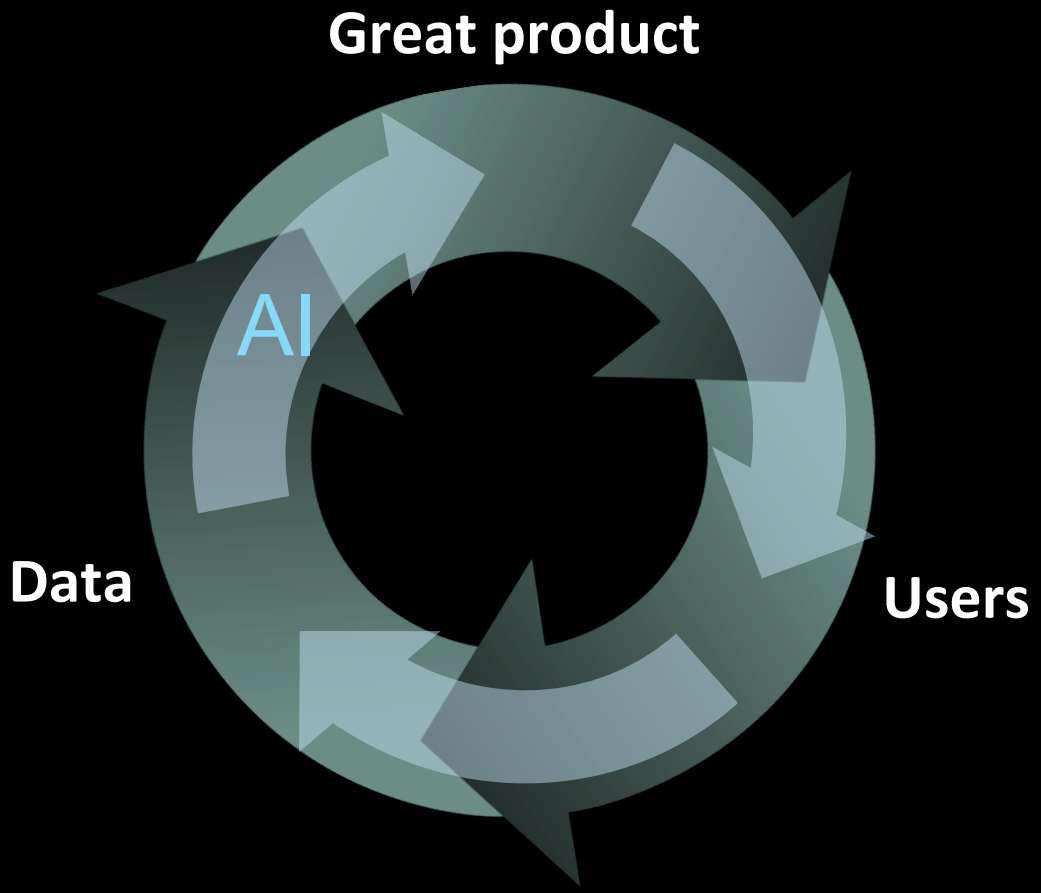
Virtuous circle of AI



Andrew Ng

Deep Learning

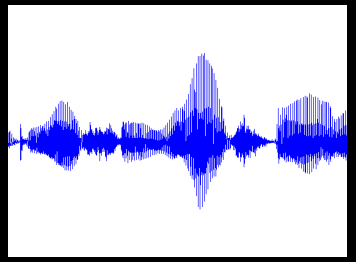
Adam Coates, Yoshua Bengio, Tom Dean, Jeff Dean, Nando de Freitas, Jeff Hawkins, Geoff Hinton, Quoc Le, Yann LeCun, Honglak Lee, Tommy Poggio, Ruslan Salakhutdinov, Yoram Singer, Josh Tenenbaum, Kai Yu, Tong Zhang, ….

Things we want to do with data

Images

Label image

Audio



Speech recognition

Text

Web search

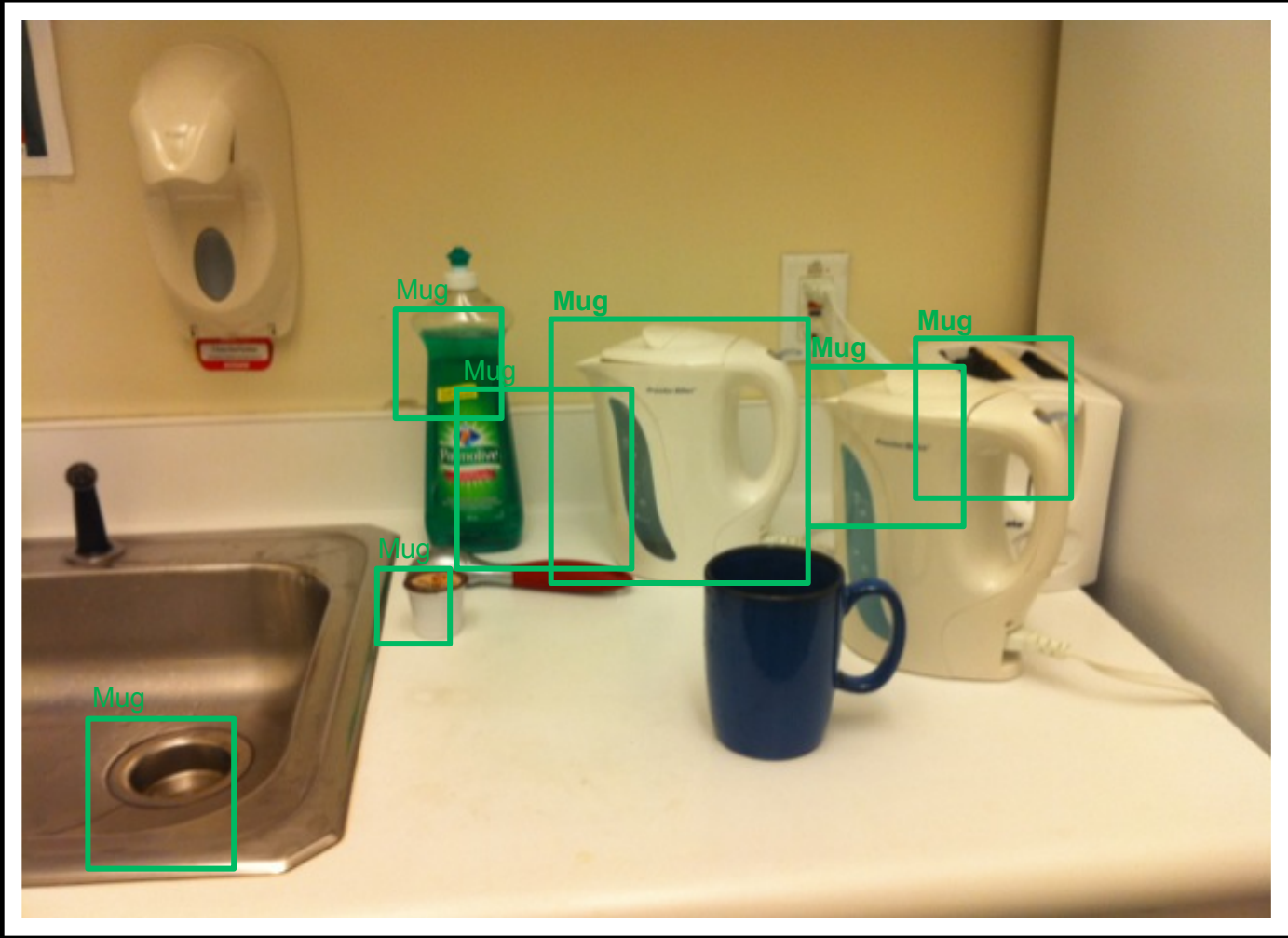
STanford AI Robot (STAIR)

Andrew Ng

Computer vision: Identify coffee mug

Andrew Ng

Computer vision: Identify coffee mug



Why is computer vision hard?

The camera sees :

194	210	201	212	199	213	215	195	178	158	182	209
180	189	190	221	209	205	191	167	147	115	129	163
114	126	140	188	176	165	152	140	170	106	78	88
87	103	115	154	143	142	149	153	173	101	57	57
102	112	106	131	122	138	152	147	128	84	58	66
94	95	79	104	105	124	129	113	107	87	69	67
68	71	69	98	89	92	98	95	89	88	76	67
41	56	68	99	63	45	60	82	58	76	75	65
20	43	69	75	56	41	51	73	55	70	63	44
50	50	57	69	75	75	73	74	53	68	59	37
72	59	53	66	84	92	84	74	57	72	63	42
67	61	58	65	75	78	76	73	59	75	69	50

Computer vision

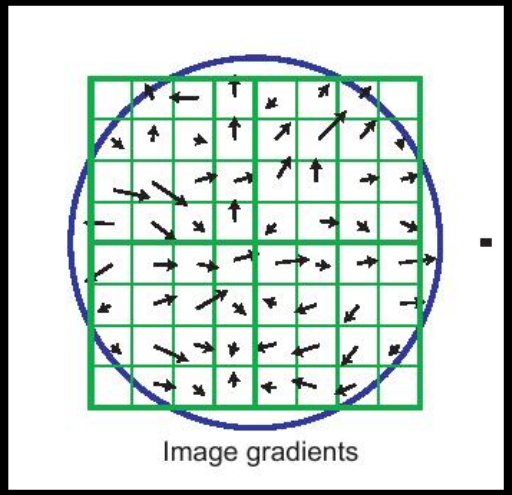
Learning algorithm

Computer vision

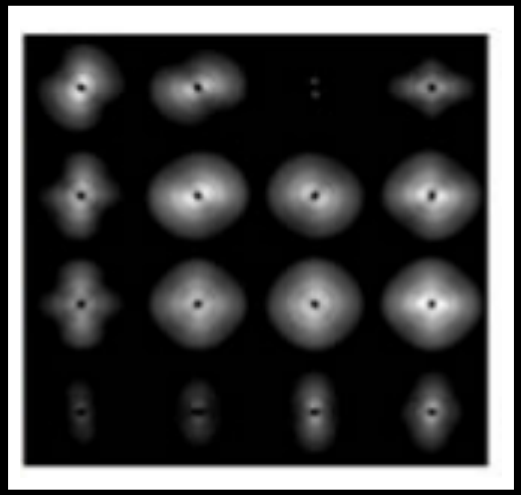
Feature representation

Learning algorithm

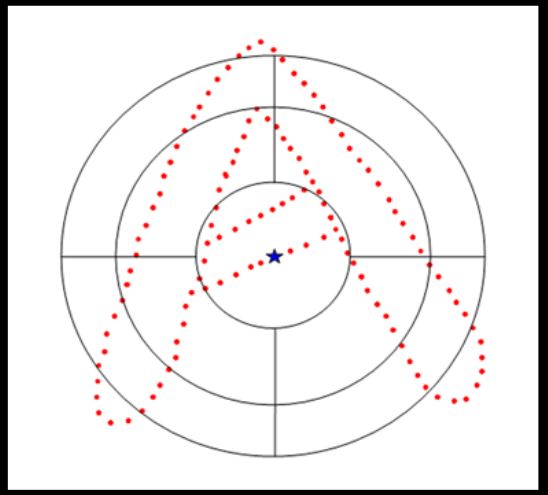
Features for vision



SIFT



GIST

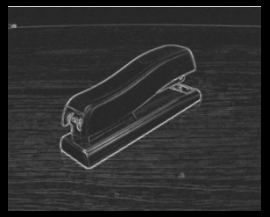


Shape context

Features for machine learning

Images

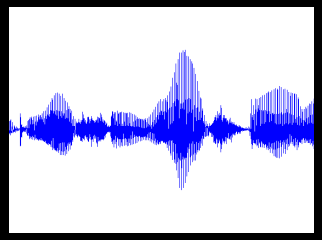
Image



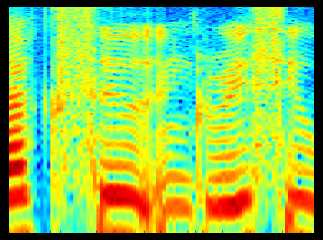
Vision features

Detection

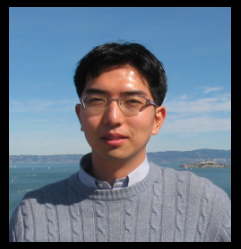
Audio



Audio



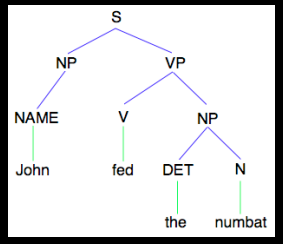
Audio features



Speaker ID

Text

Text



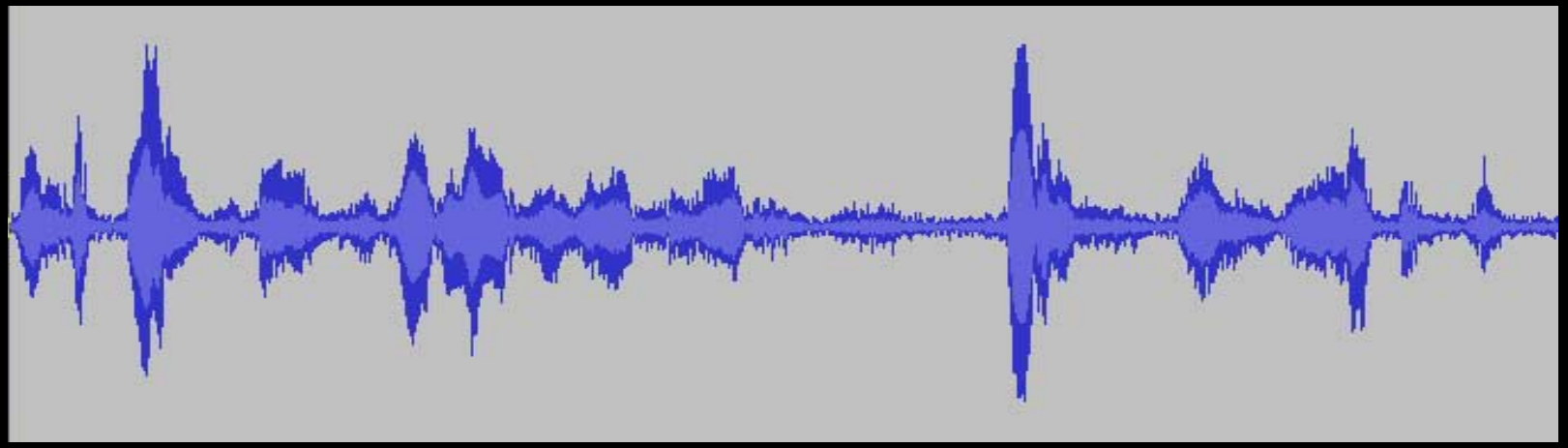
Text features

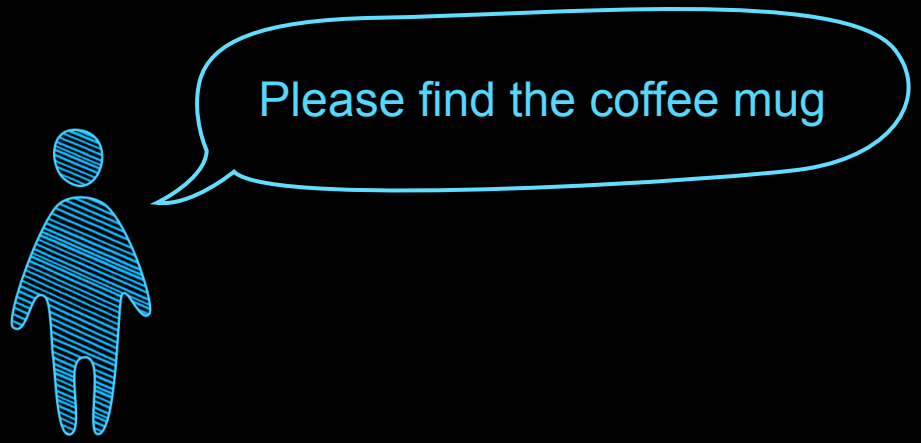
Web search

…

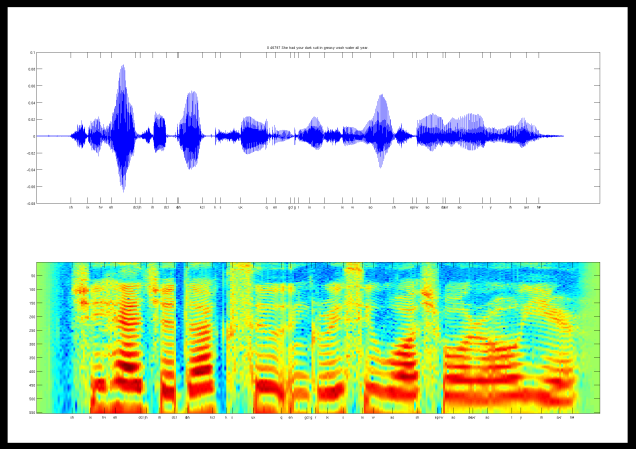
Why is speech recognition hard?

Microphone recording:

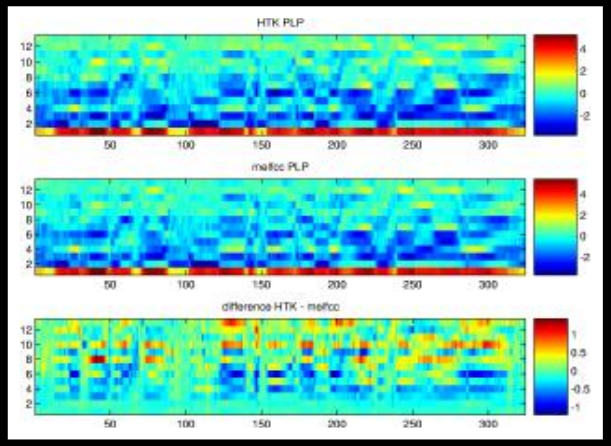




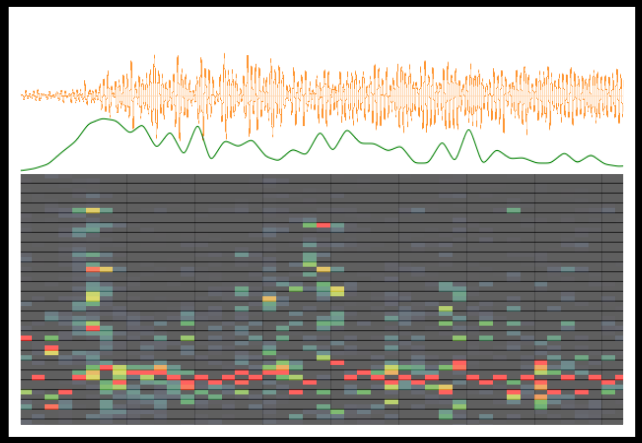
Features for audio



Spectrogram

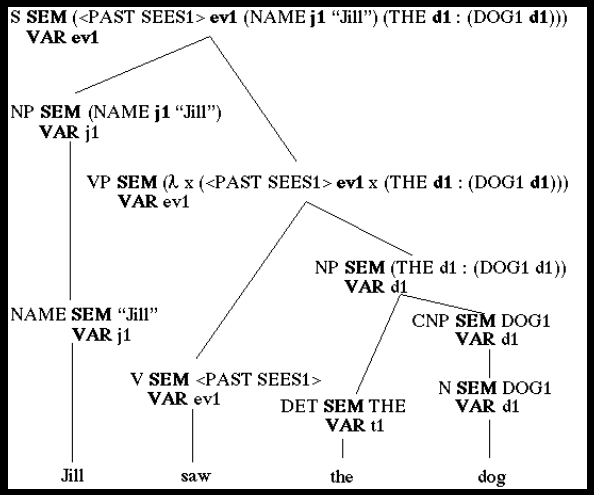


MFCC

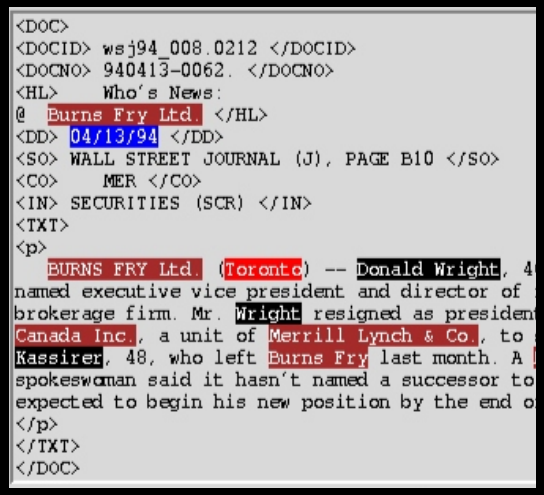


Flux

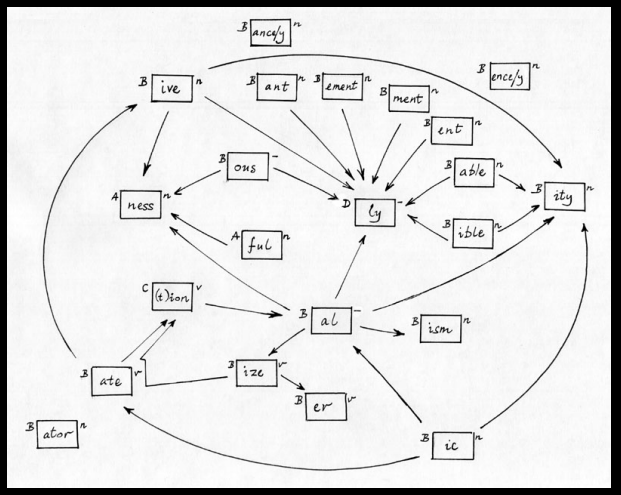
Features for text



Parser



Named entity



Stemming

The idea:

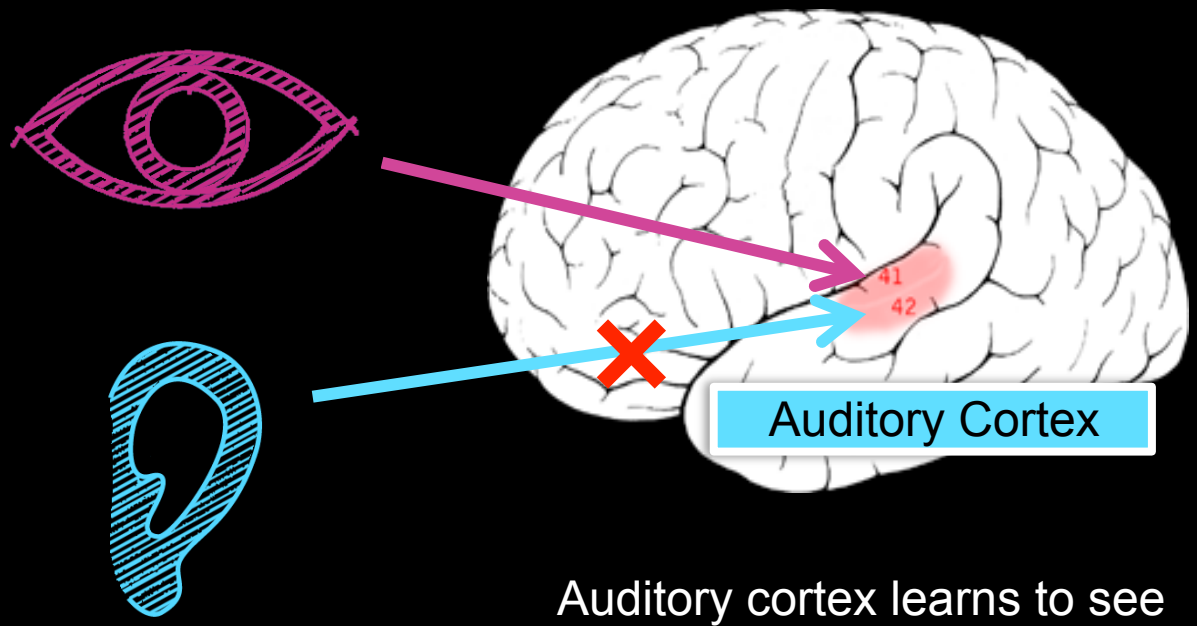
Most perception (input processing) in the brain may be due to one learning algorithm.

The idea:

Build learning algorithms
that mimic the brain.

Most of human intelligence may
be due to one learning algorithm.

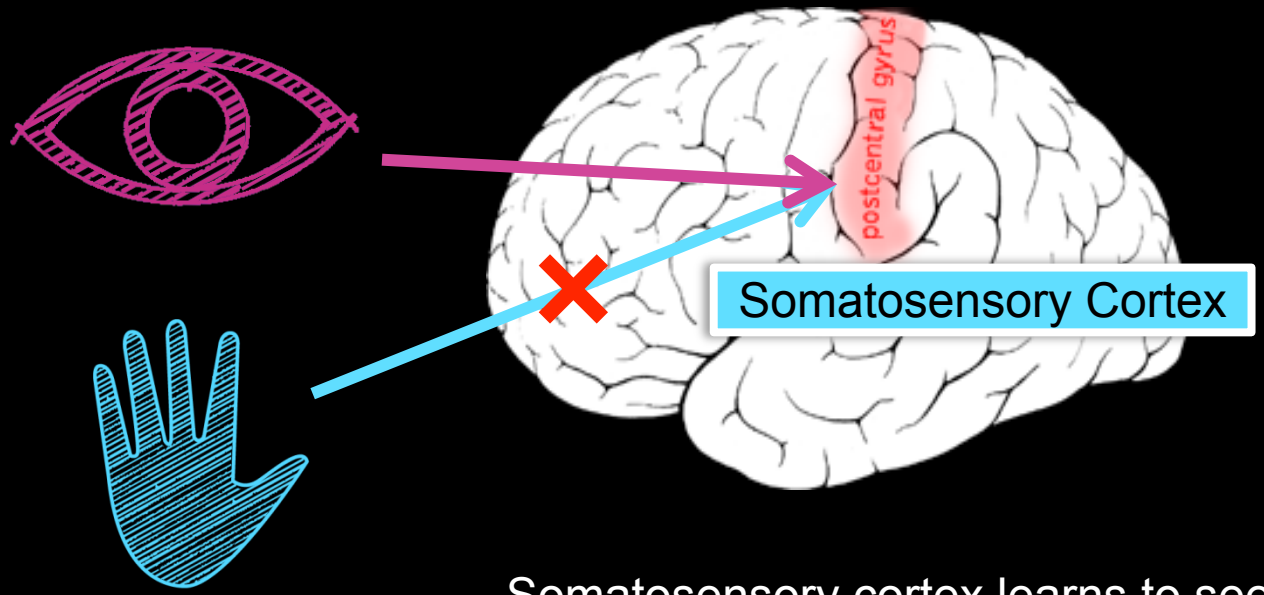
The “one learning algorithm” hypothesis



Auditory cortex learns to see

[Roe et al., 1992]

The “one learning algorithm” hypothesis

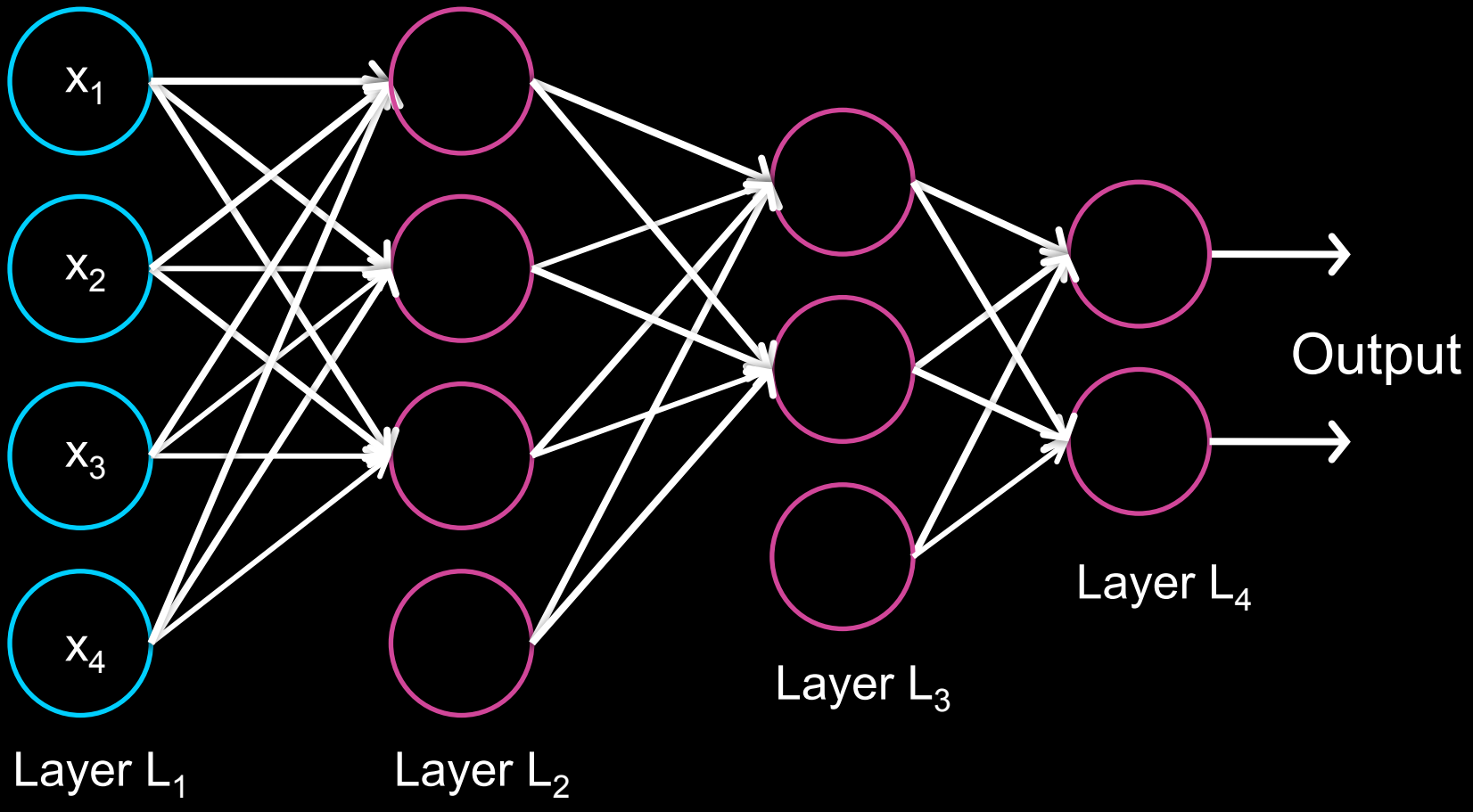


Somatosensory cortex learns to see

[Metin & Frost, 1989]

Neurons in the brain

Neural Network (Deep Learning)



Andrew Ng

Deep Learning trends

Now

0-2 years
Tagged data

3-5 years
Tagged & untagged data

Learning from tagged data (supervised)

Coffee mug

Coffee mug

Coffee mug

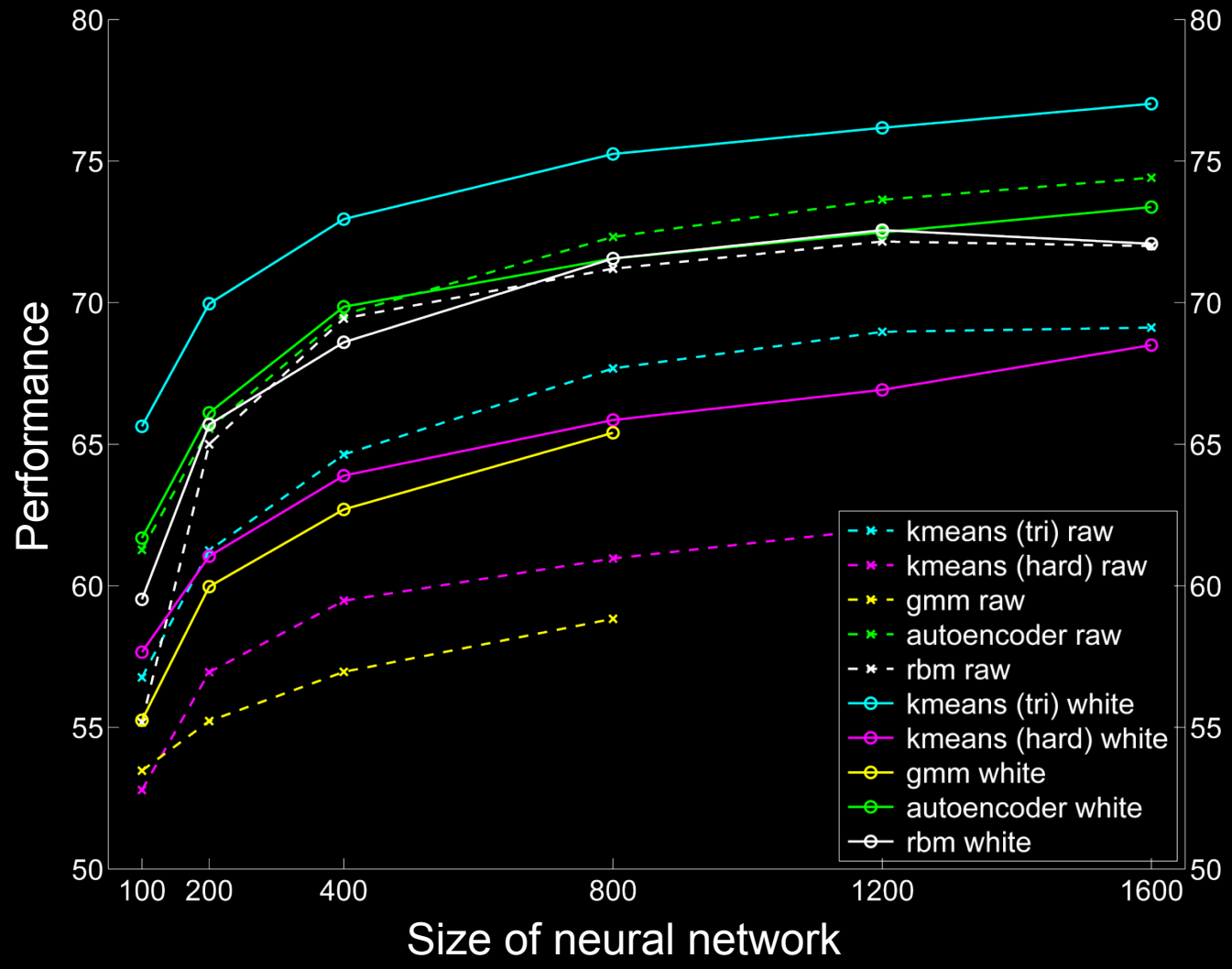
Coffee mug

Coffee mug

Coffee mug

Testing: What is this?

Bigger is better



[Adam Coates]

Google Brain

Andrew Ng

AI as a computer systems problem

10 million connections

1 billion connections

Speech recognition, and more….

[with Vincent Vanhoucke]

Deep Learning applications

Speech recognition

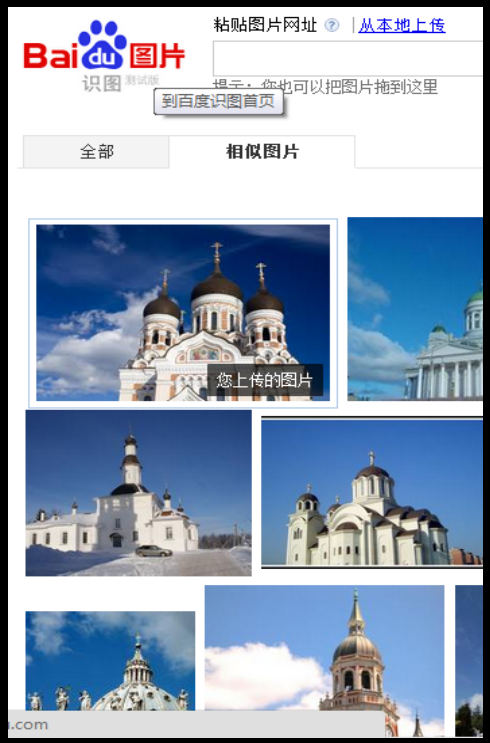


Image Search

Ads; Web search

Tagged vs. untagged data

Coffee mug

Coffee mug

Coffee mug

Coffee mug

Coffee mug

Coffee mug

Untagged data (unsupervised learning)

Unknown

Unknown

Unknown

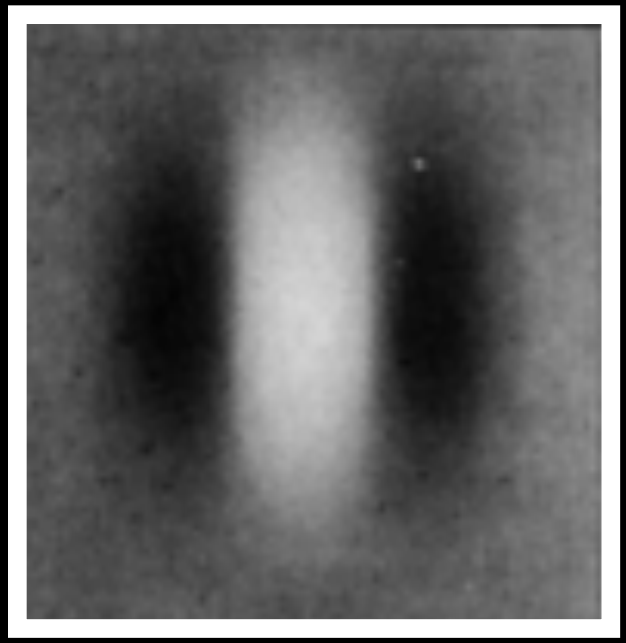
Unknown

Unknown

Unknown

How does the brain process images?

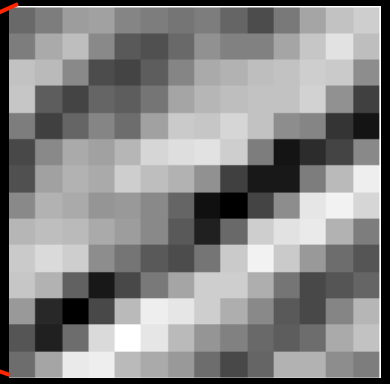
Visual cortex looks for lines/edges.



Neuron #1 of visual cortex (model)

Neuron #2 of visual cortex (model)

Start with Image patches



152	147	128	84
129	113	107	87
98	95	89	88
60	82	58	76
51	73	55	70

$R^{14 \times 14}$

Sparse Coding

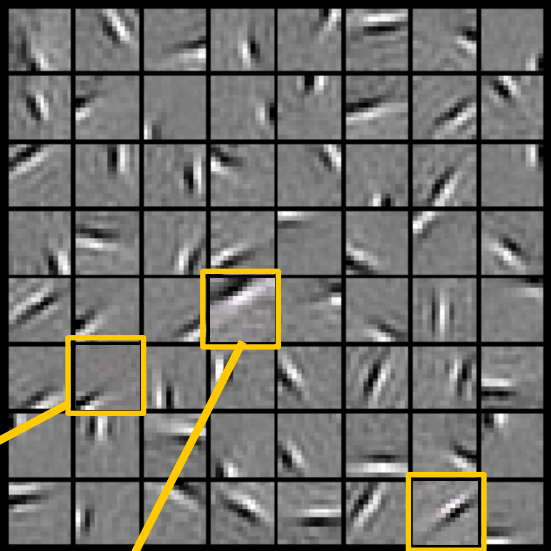
Input: Images patches $x^{(1)}$, $x^{(2)}$, … (each in $R^{14 \times 14}$)

Learn: Set of matrices $\phi_1, \phi_2, \ldots, \phi_{64}$ (also $R^{14 \times 14}$), so that each input x can be approximately written as a weighted sum of the ϕ_j's:

$$x \approx \sum_{j=1}^{64} a_j \phi_j$$

s.t. a_j's are mostly zero ("sparse")

Sparse Coding

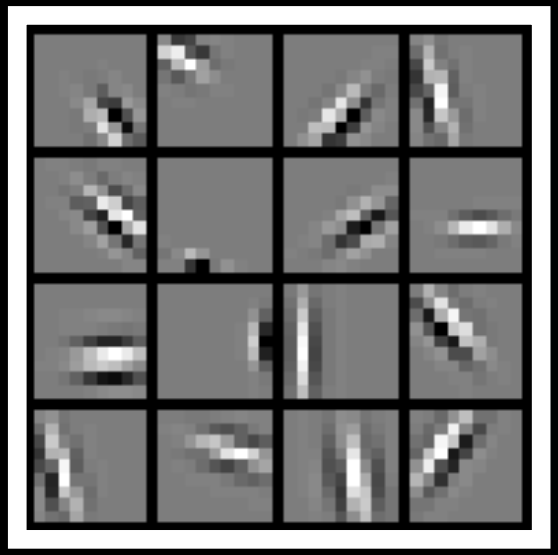


Test example

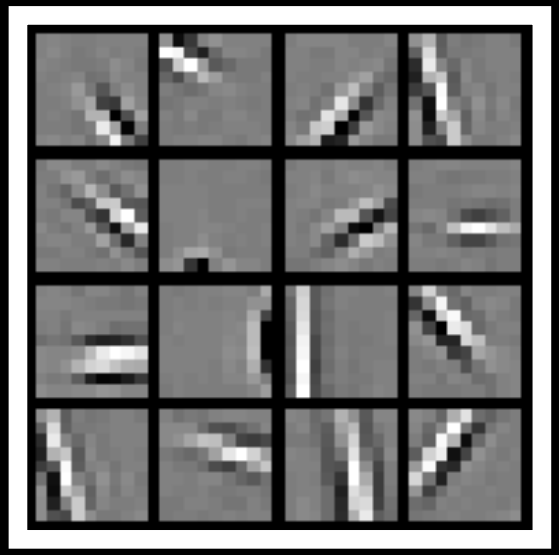
$$x \approx 0.8 * \phi_{36} + 0.3 * \phi_{42} + 0.5 * \phi_{63}$$

Comparing to Biology

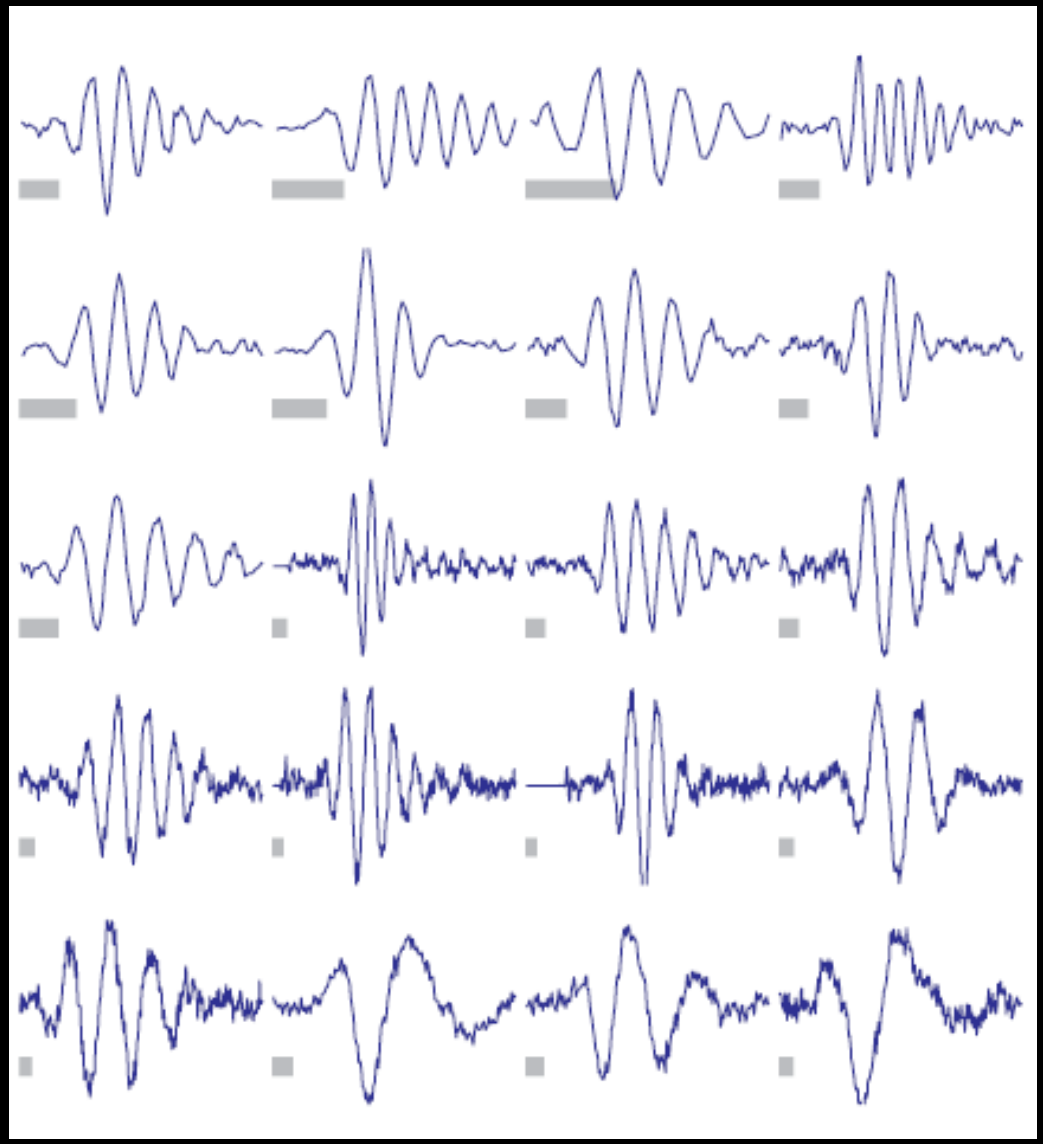
Brain (visual cortex)



Learning algorithm

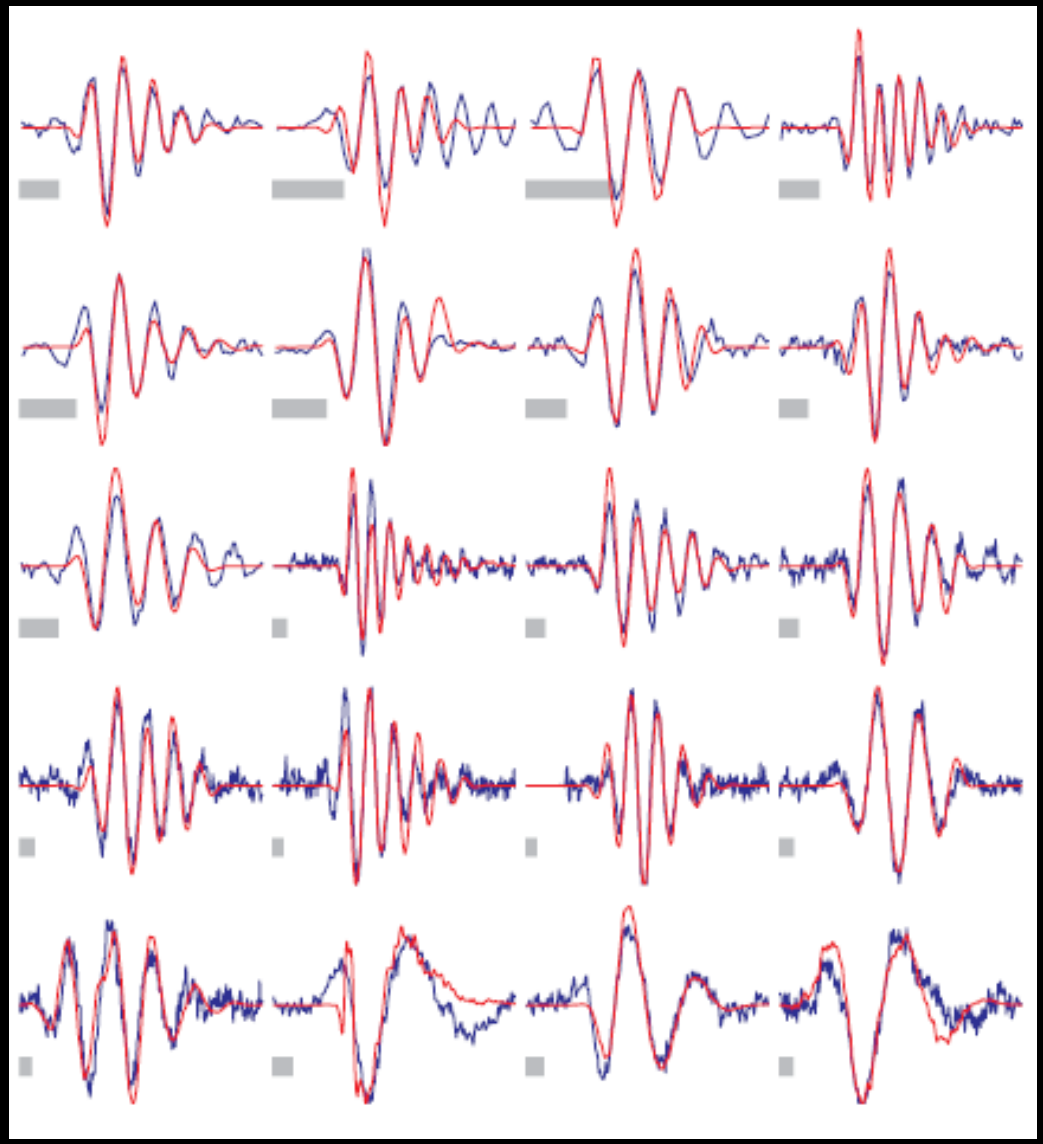


Comparing to Biology



[Evan Smith]

Comparing to Biology



[Evan Smith]

Learning from YouTube videos

Unknown

Unknown

Unknown

Unknown

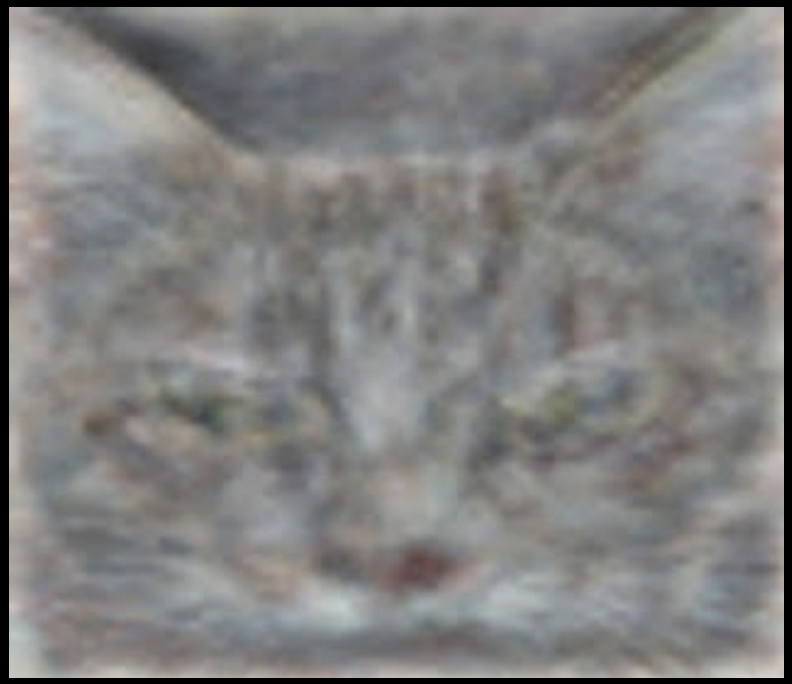
Unknown

Unknown

Face neuron

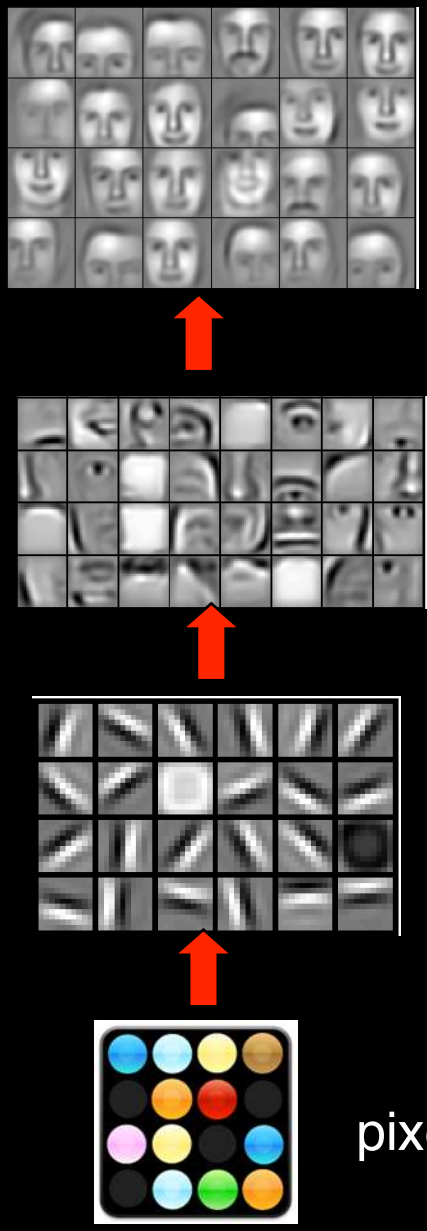
[Le et al., 2012]

Cat neuron



[Le et al., 2012]

Deep Learning



16,000 CPUs is expensive

Andrew Ng

GPUs (Graphics Processor Unit)

[Adam Coates, Bryan Catanzaro, et al.]

Building huge neural networks

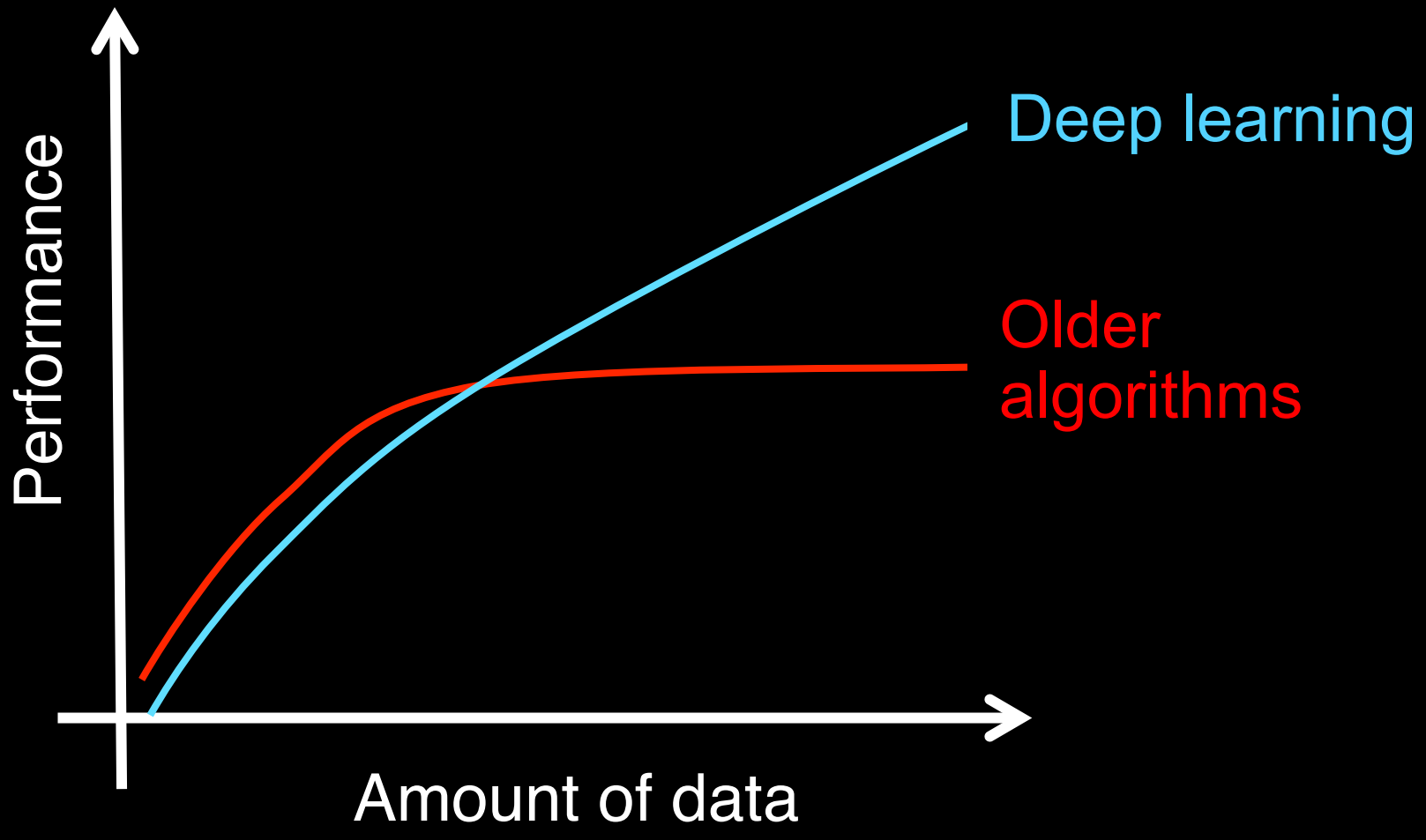
10 million connections

1 billion connections

10 billion connections

[Adam Coates, Bryan Catanzaro]

Learning from tagged data



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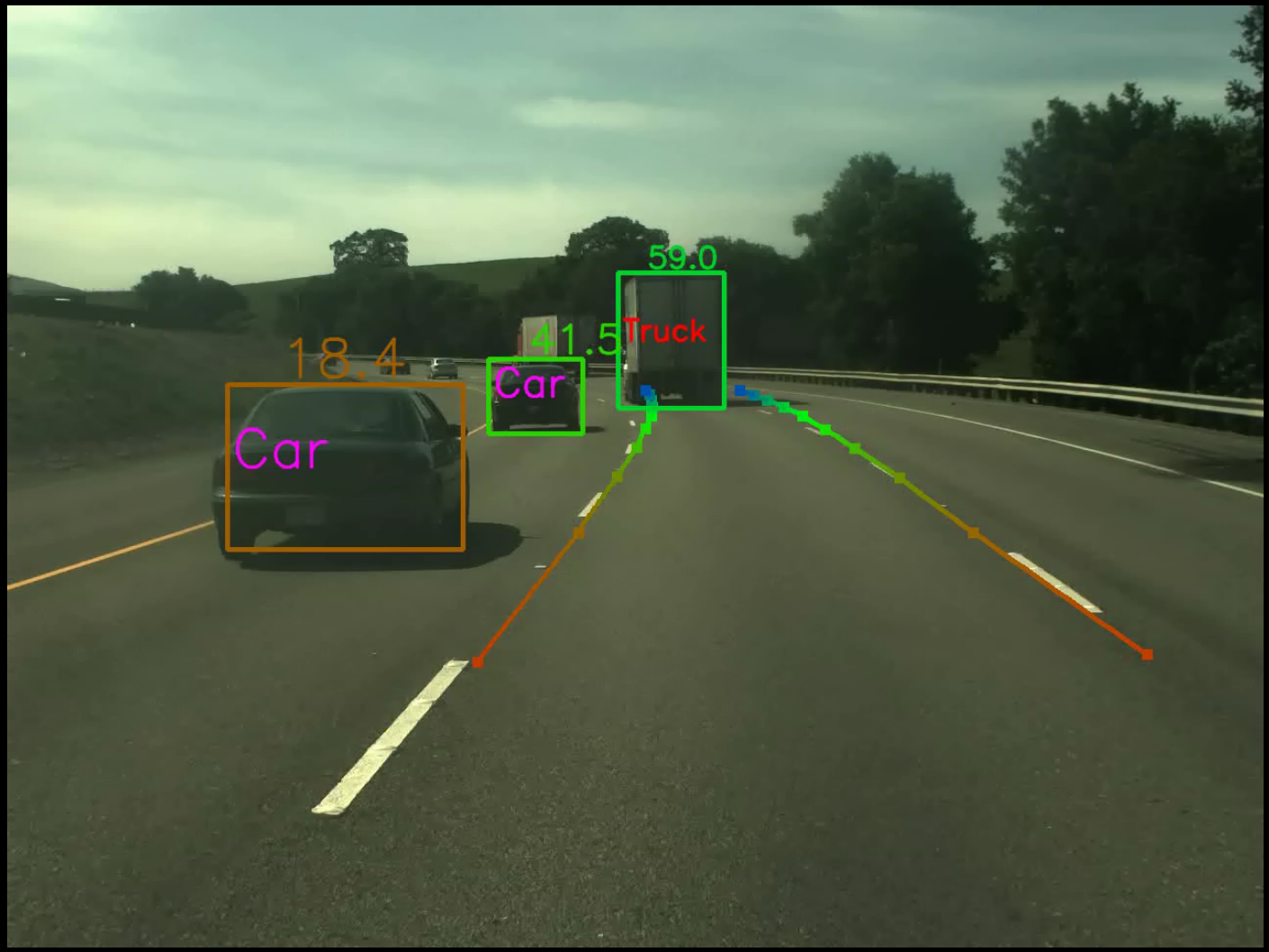
Highway perception



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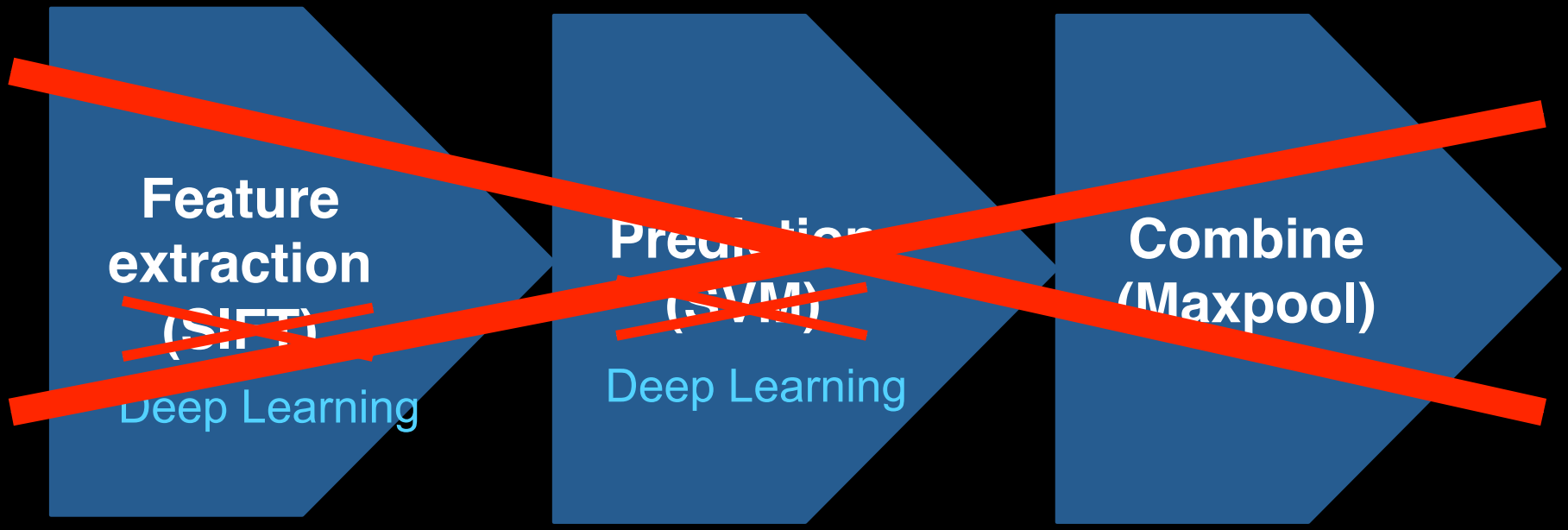
Deep Learning trends

0-2 years
Tagged data

3-5 years
Tagged & untagged data

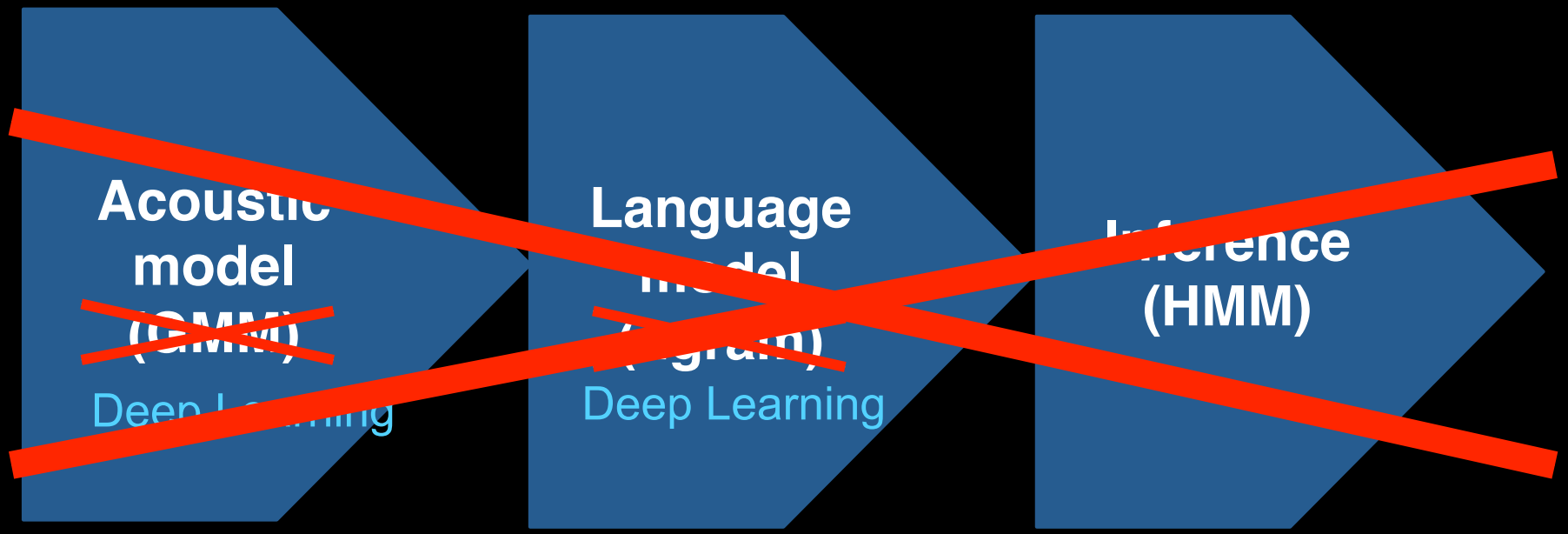
Untagged data and AI (unsupervised learning)

Computer vision (~6 years)



Deep Learning

Speech recognition (next 2-3 years?)



Deep Learning

AI will transform the internet

Speech

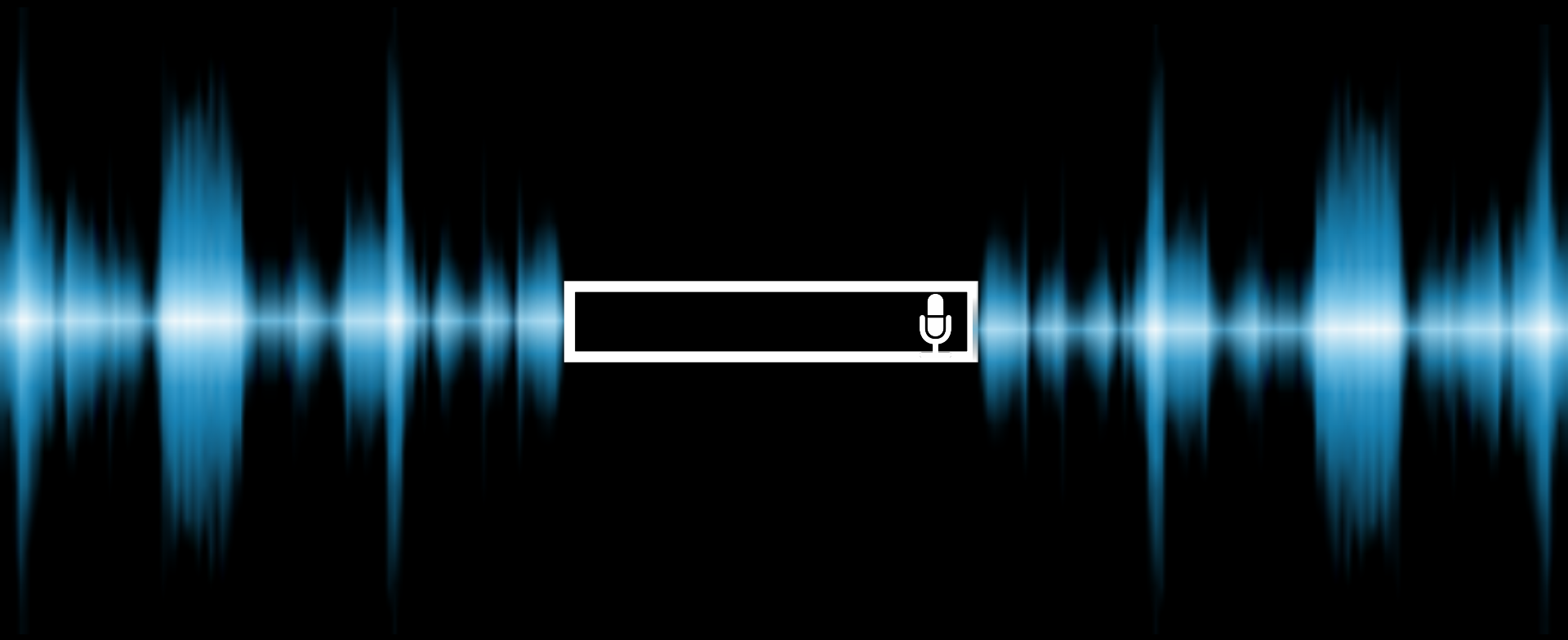
Images

Text

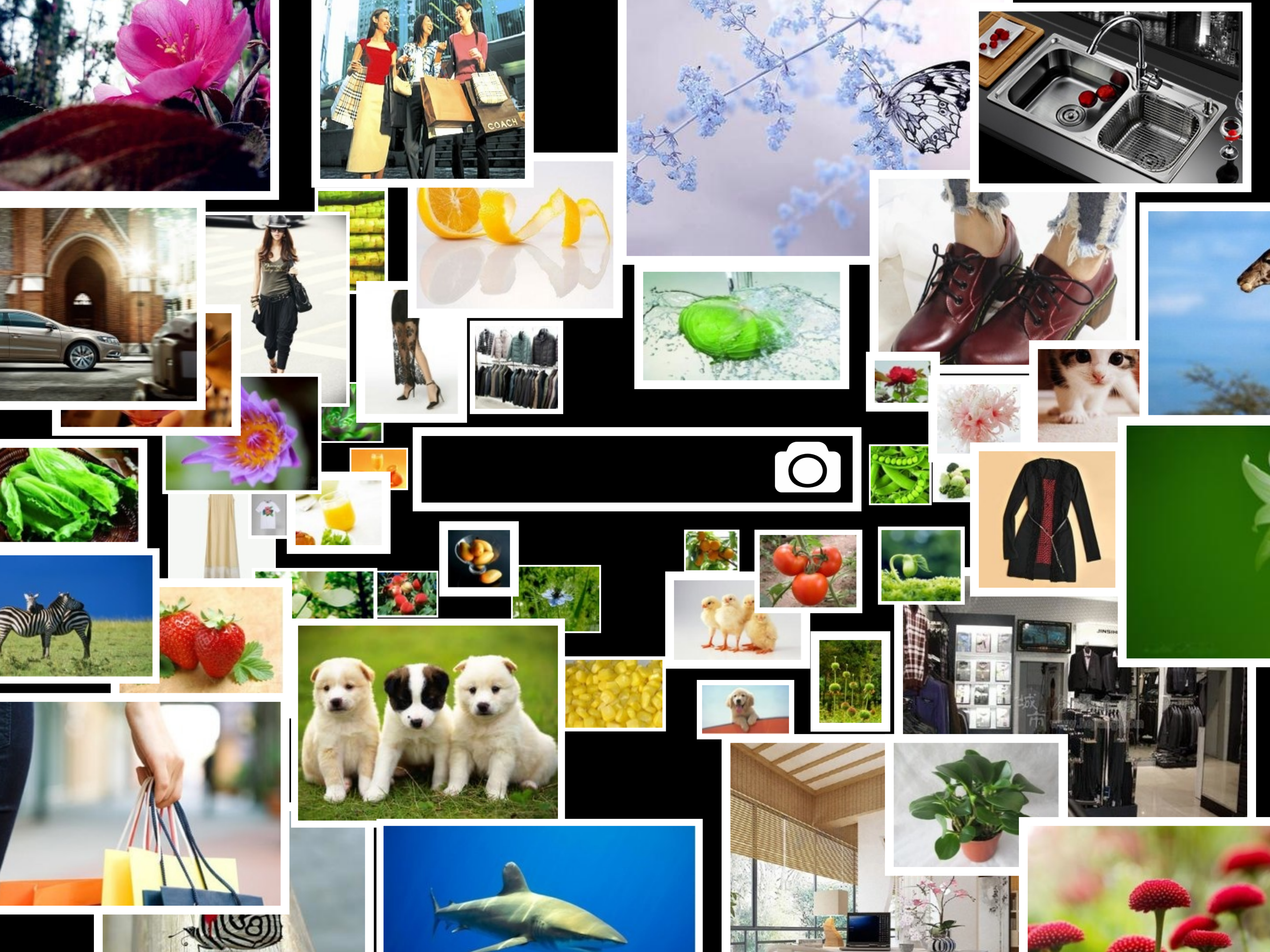
Speech

Images

Speech recognition



Baidu Cool Box


COACH

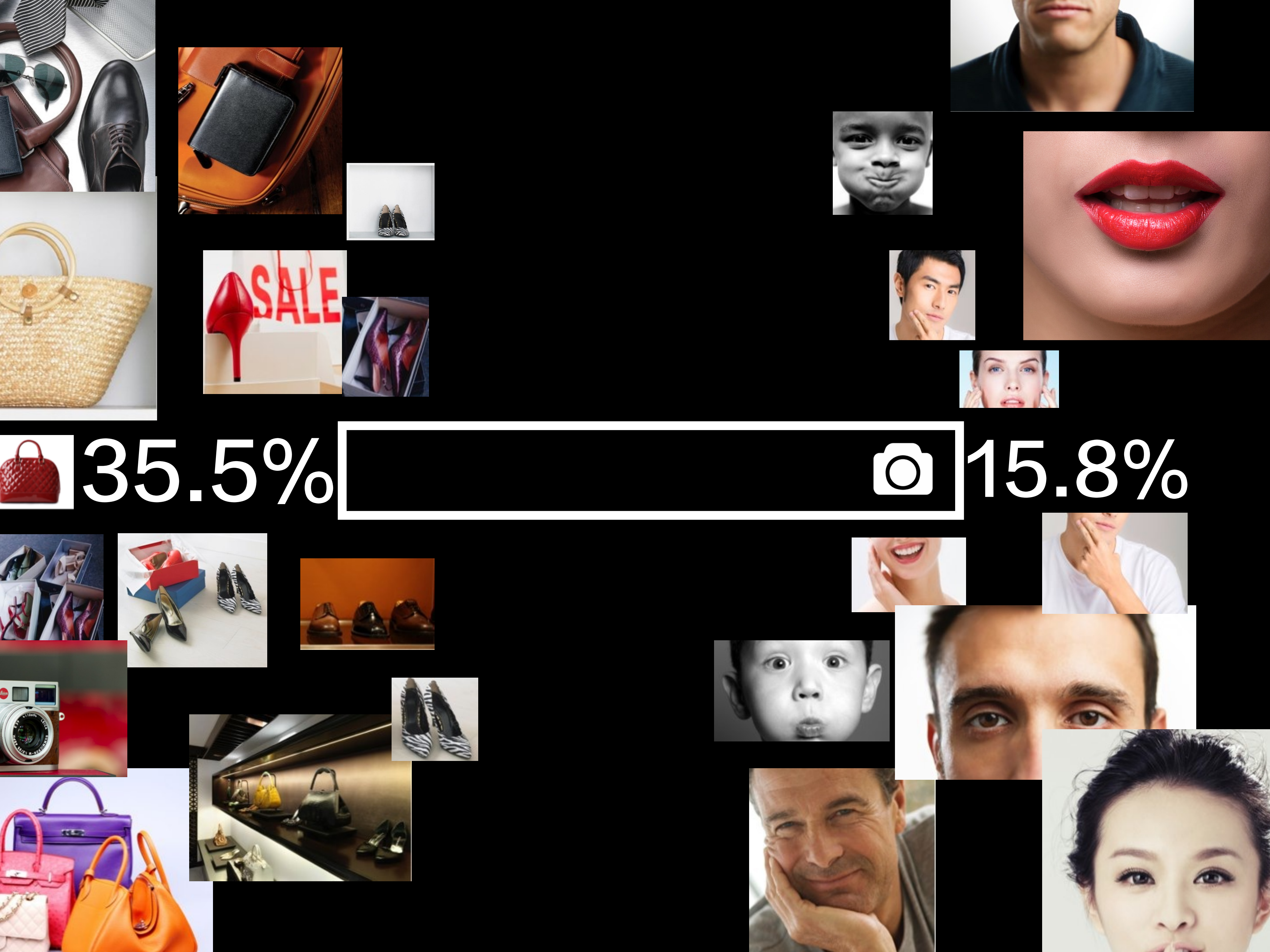
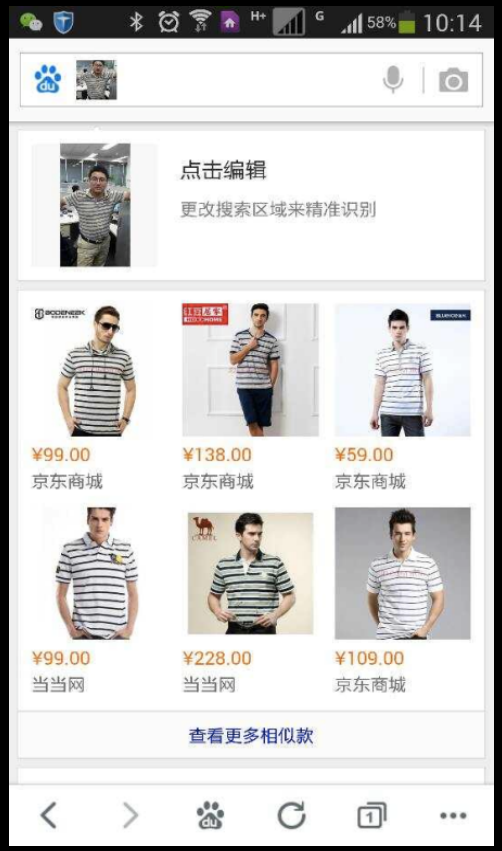
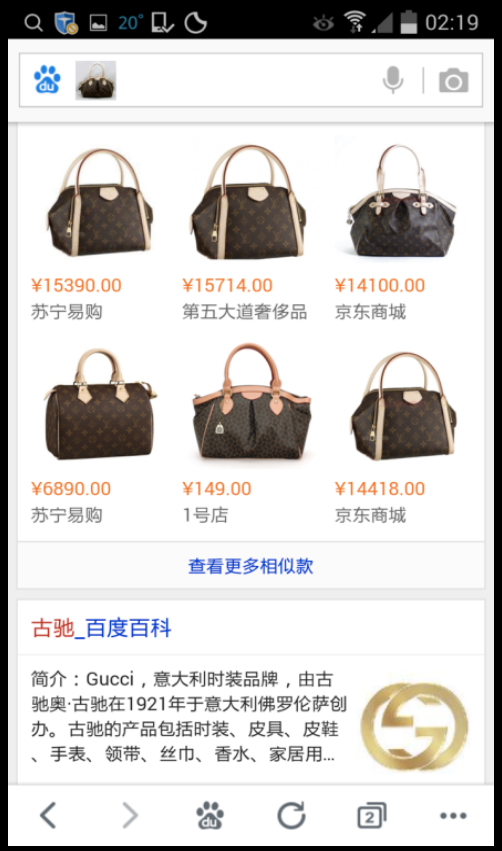

35.5%
15.8%
SALE

Image queries



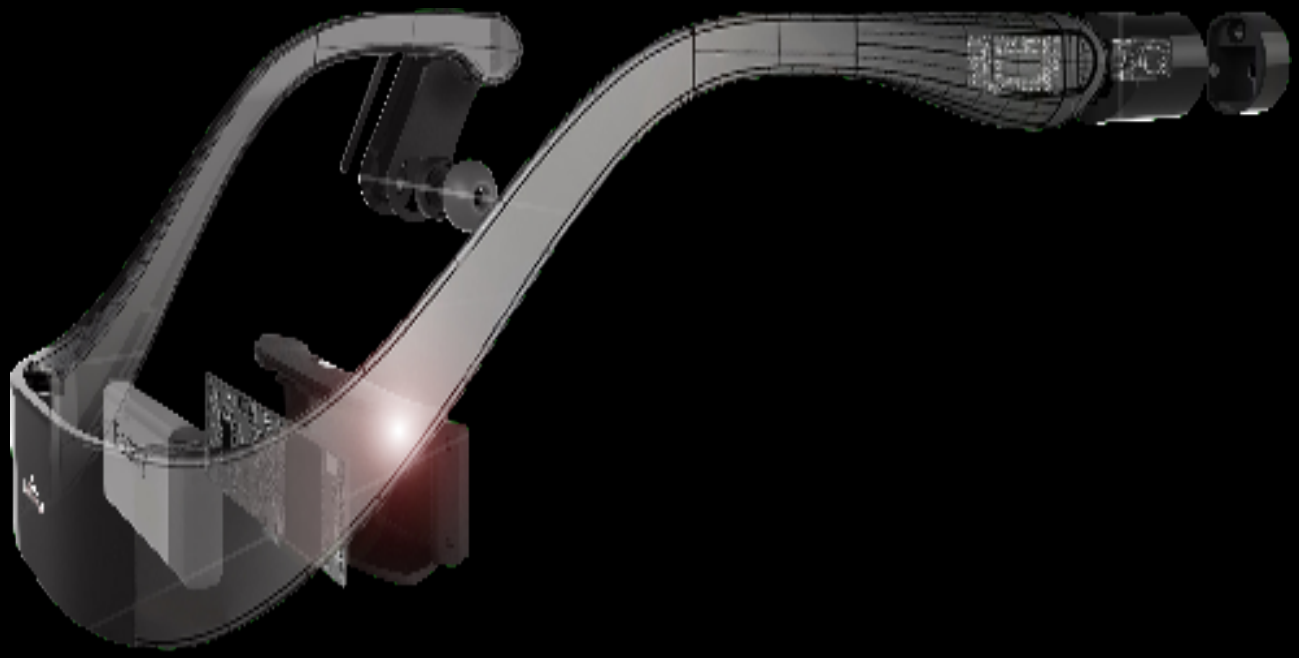
Clothing



Bags

Fruits & Vegetables

Baidu Eye



Andrew Ng

“Smart glasses” designs



Extending human perception

Extending human perception

Comparison to “smart glasses” designs

Speech

Images

Text

From Control to Perception

Stanford’s PR-1 robot

[Ken Salisbury]

AI will transform the internet

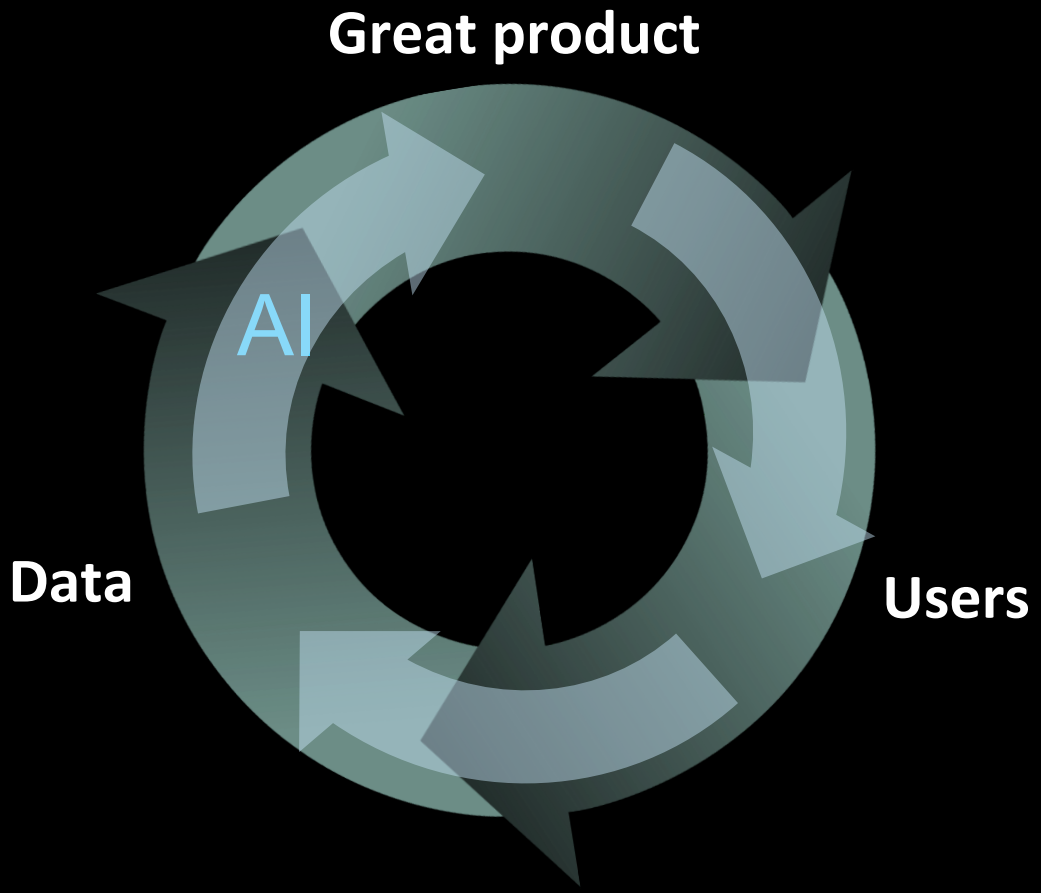
Technology areas with potential for paradigm shift:

- Computer vision
- Speech recognition & speech synthesis
- Language understanding: Machine translation; Web search; Dialog systems; ….
- Advertising
- Personalization/recommendation systems
- Robotics

All this is hard: scalability, algorithms.

Andrew Ng

Virtuous circle of AI



Andrew Ng

The AI mission

Thank you.

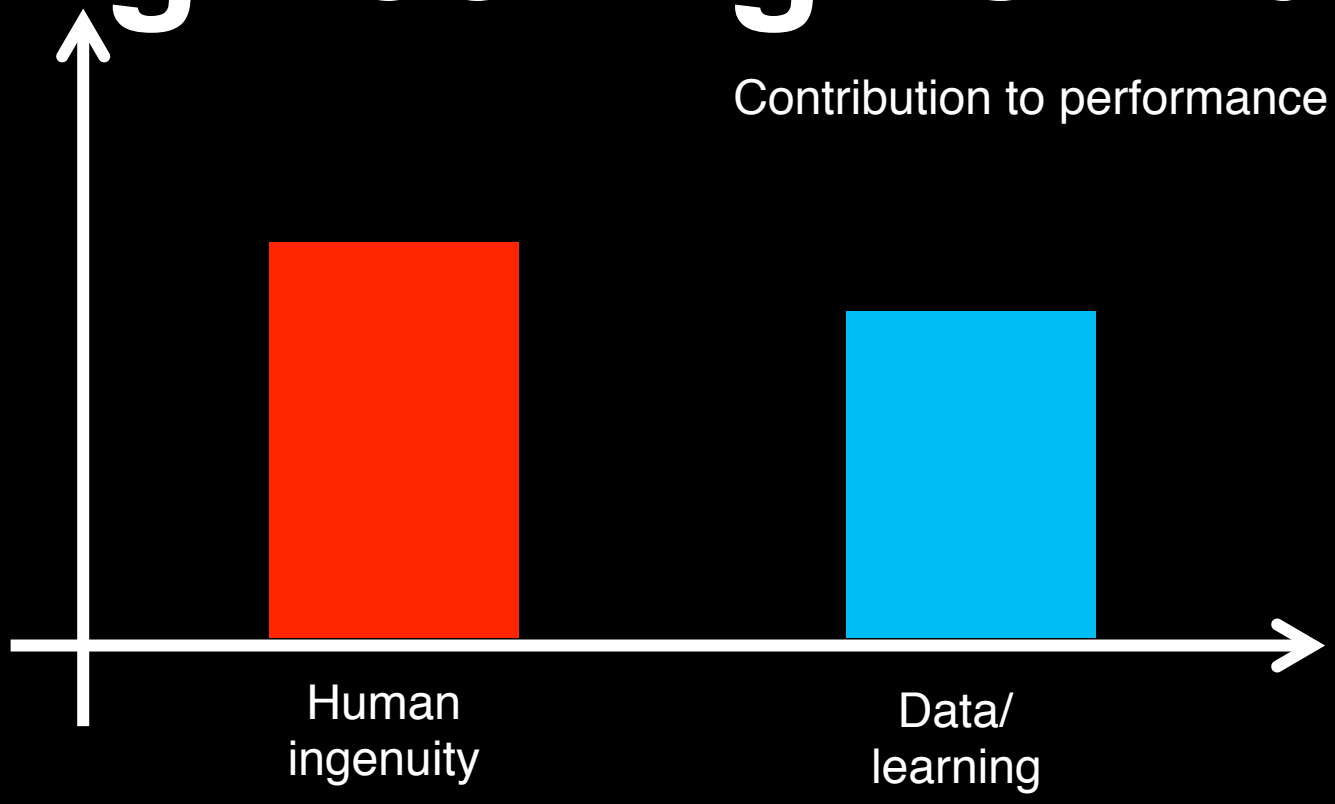
Thanks to Adam Coates, Yu Kai, Zhang Tong, Sameep Tandon, Swati Dube, Brody Huval, Tao Wang, ….

Tutorial: deeplearning.stanford.edu

END END

END END

Discussion: Engineering vs. Data



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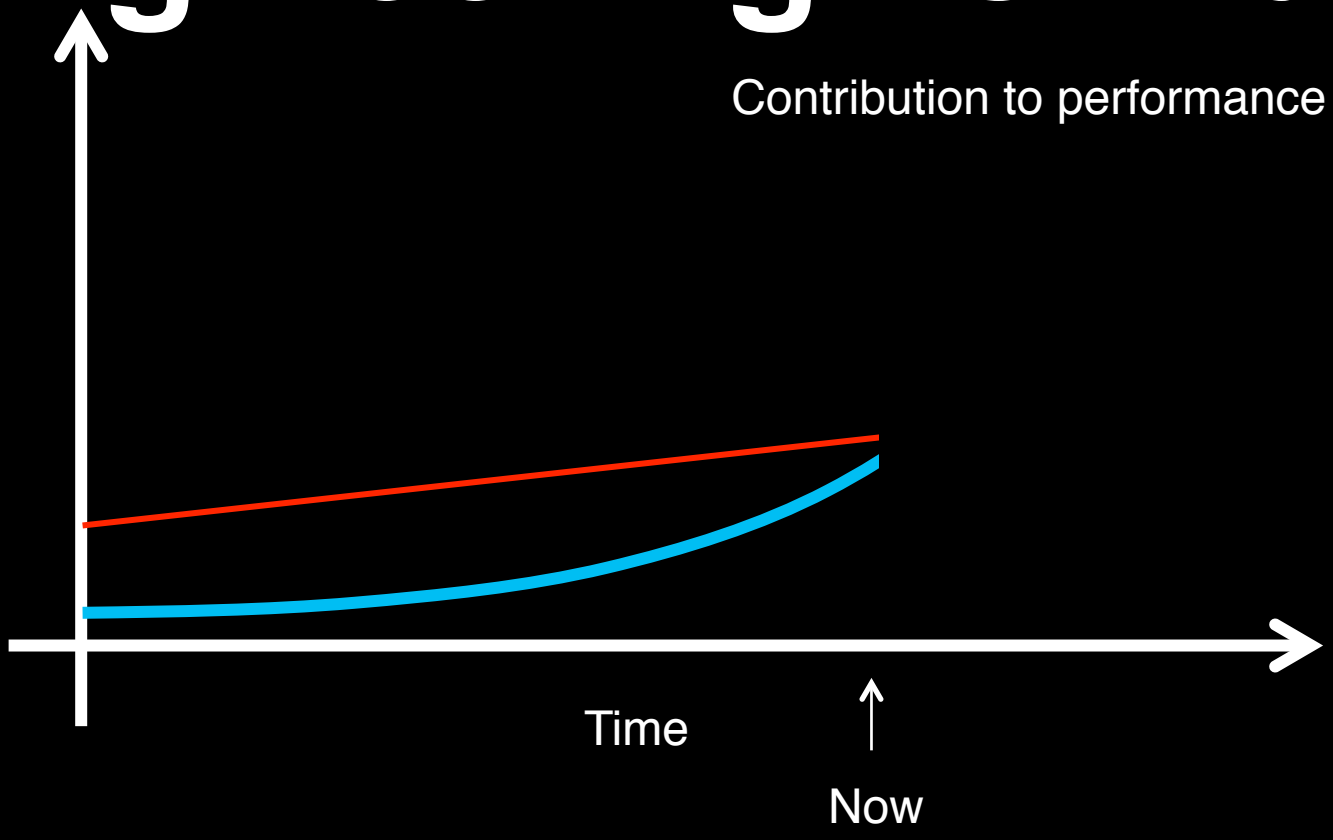
Discussion: Engineering vs. Data



Andrew Ng


Correctly found mug
Mistake


Correctly found mug
Mistake


Correctly found mug
Mistake


Correctly found mug
Mistake