POLITECNICO
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Artificial Neural Networks and Deep Learning

- Machine Learning vs Deep Learning-

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Artificial Intelligence and Robotics Laboratory
Politecnico di Milano

AIRLAB
ARTIFICIAL INTELLIGENCE AND ROBOTICS LAB

«Me, Myself, and I»

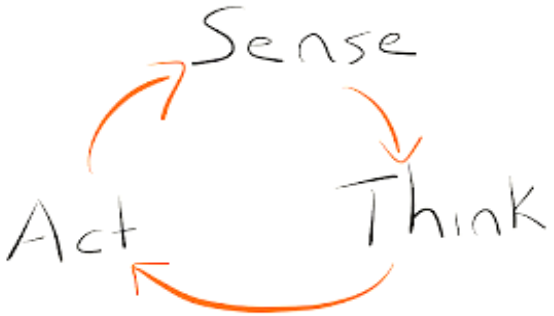
Matteo Matteucci, PhD
Associate Professor
Dept. of Electronics, Information & Bioengineering
Politecnico di Milano
matteo.matteucci@polimi.it

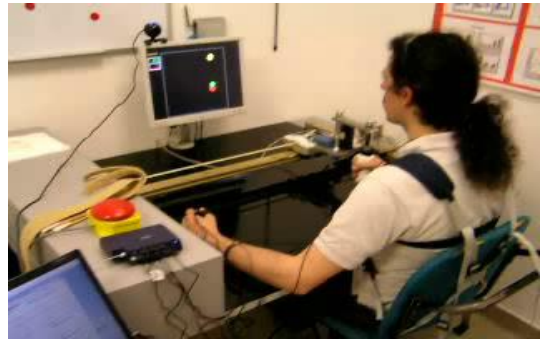
My research interests

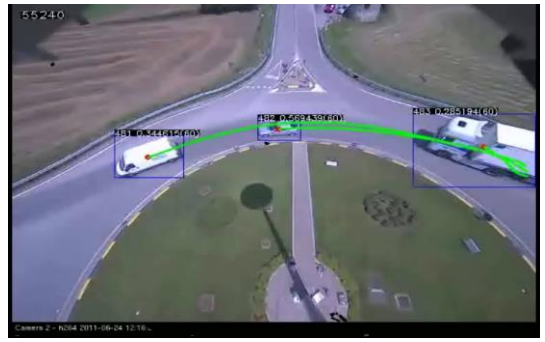
- Robotics & Autonomous Systems
- Machine Learning
- Pattern Recognition
- Computer Vision & Perception

Courses I teach

- Robotics (BS+MS)
- Machine Learning (MS)
- Deep Learning (MS+PhD)
- Cognitive Robotics (MS)

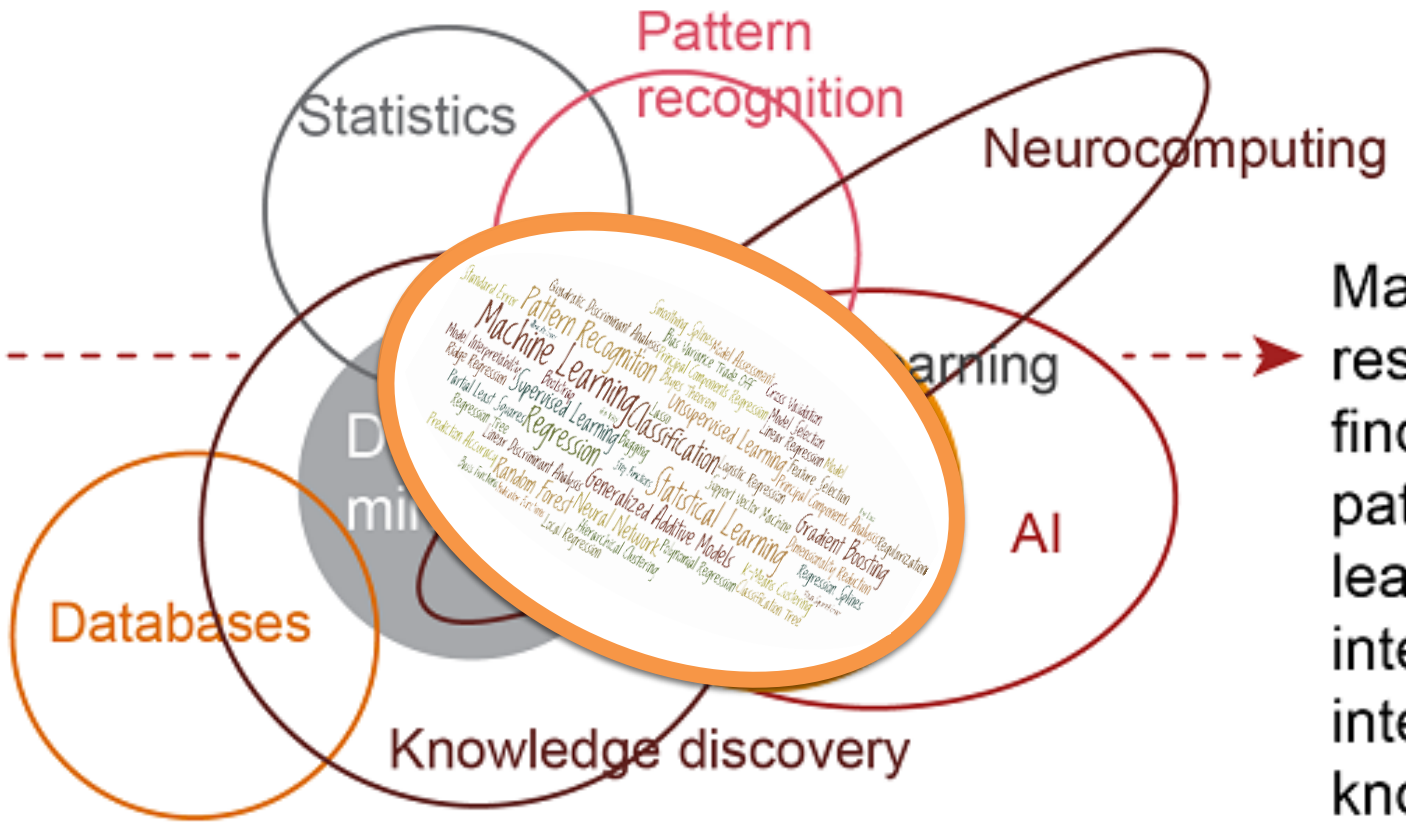






Enable physical and software autonomous systems to perceive, plan, and act without human intervention in the real world

Machine Learning



Machine learning is a category of research and algorithms focused on finding patterns in data and using those patterns to make predictions. Machine learning falls within the artificial intelligence (AI) umbrella, which in turn intersects with the broader field of knowledge discovery and data mining.

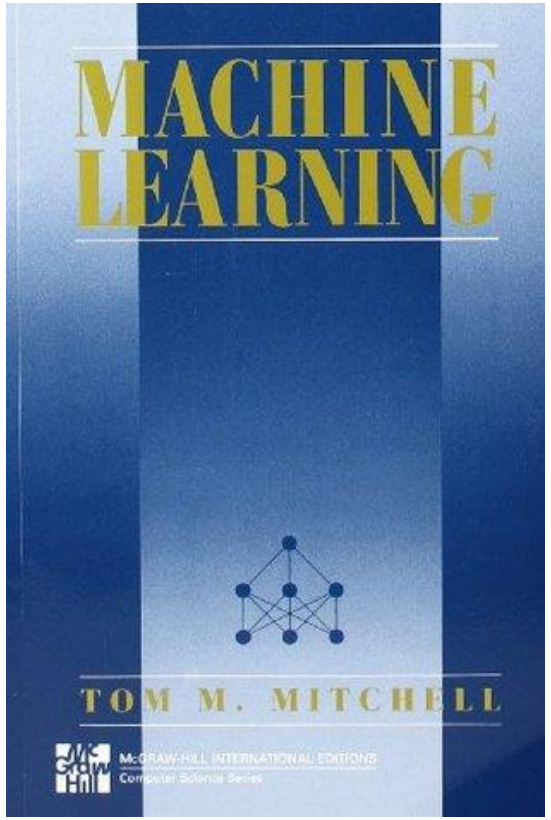
Source: SAS, 2014 and PwC, 2016 *and myself, 2017*

Machine Learning

Machine Learning (Tom Mitchell – 1997)

T = Regression/Classification/…
E = Data
P = Errors/Loss

"A computer program is said to learn from experience E with respect to some class of task T and a performance measure P, if its performance at tasks in T, as measured by P, improves because of experience E."



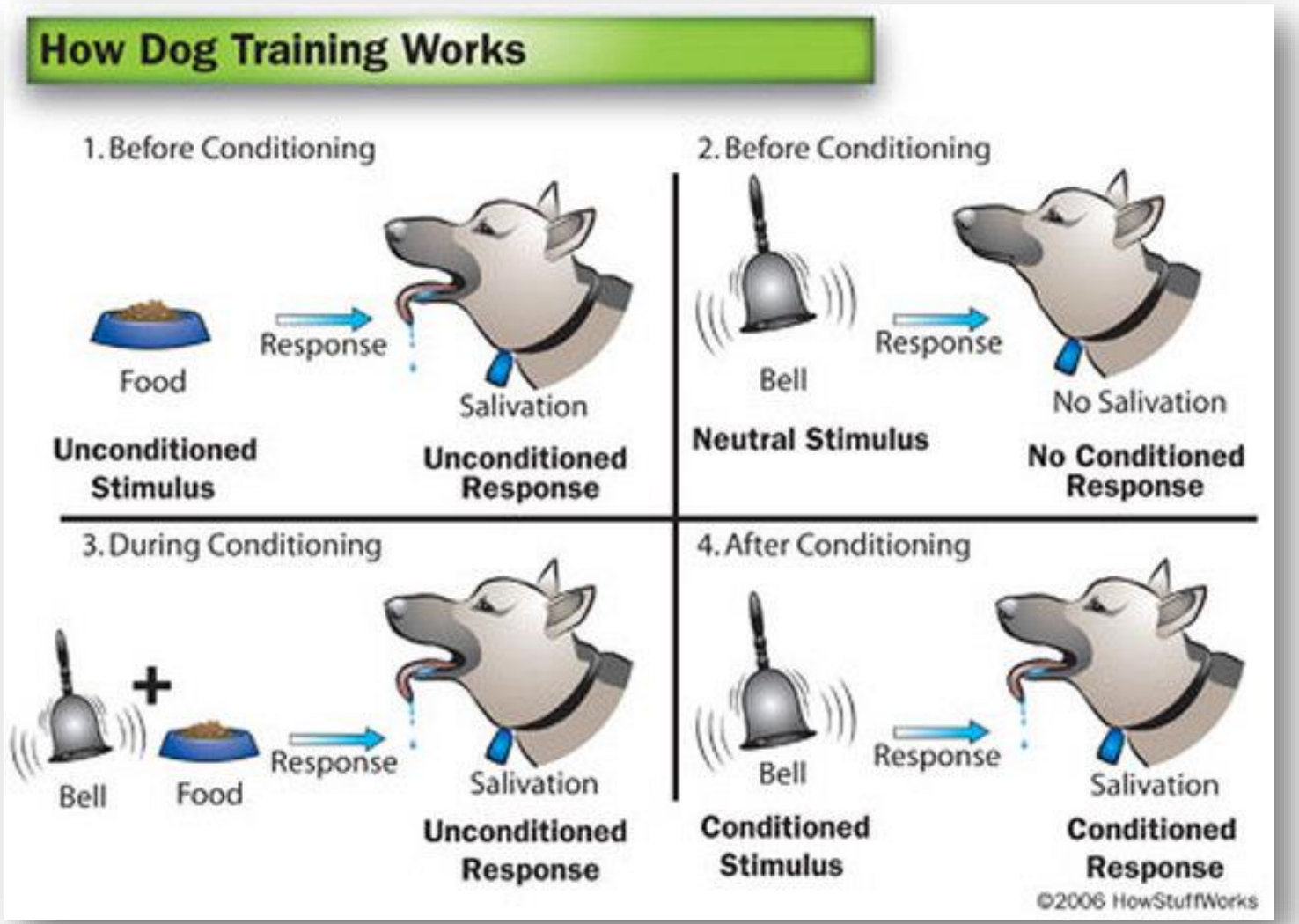
Machine Learning Paradigms

Immagine you have a certain experience E, i.e., data, and let's name it

$$D = x_1, x_2, x_3, \dots, x_N$$

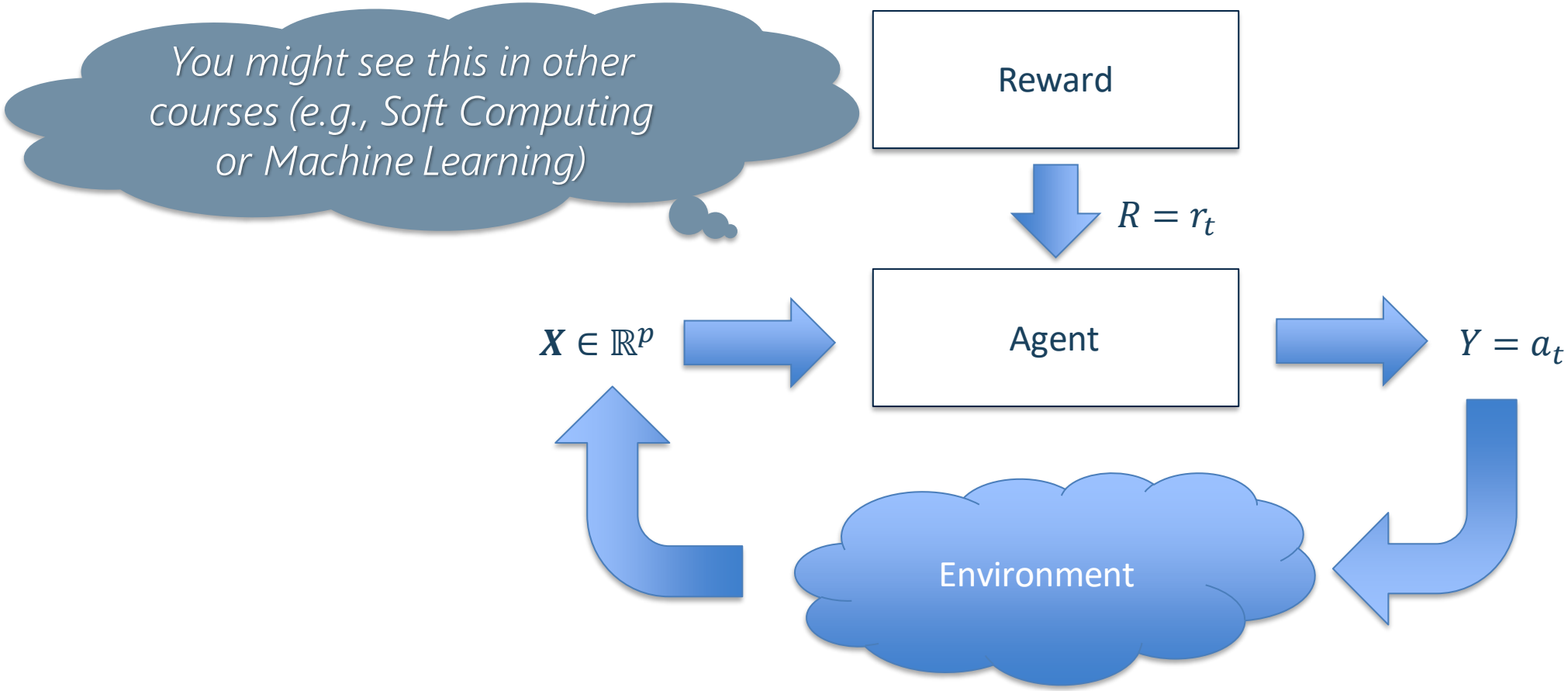
- ***Supervised learning***: given the desired outputs $t_1, t_2, t_3, \dots, t_N$ learn to produce the correct output given a new set of input
- ***Unsupervised learning***: exploit regularities in D to build a representation to be used for reasoning or prediction
- ***Reinforcement learning***: producing actions $a_1, a_2, a_3, \dots, a_N$ which affect the environment, and receiving rewards $r_1, r_2, r_3, \dots, r_N$ learn to act in order to maximize rewards in the long term

Reinforcement Learning is Wellknown



Reinforcement Learning

Let's our machine be an agent interacting with an unknown environment



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Supervised learning: Classification

Cars

Motorcy

Learning is about modeling …

Hand-crafted Features

Learned Classifier

Motorcycle

Supervised learning: Regression


12000 $


15000 $

6000 $


2000 $


8000 $


22000 $


4000 $


28000 $


6000 $


35000 $

Hand-crafted Features

Learned Regressor

3800 $

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Unsupervised learning: Clustering



















Unsupervised learning: Clustering




















Unsupervised learning: Clustering




















Unsupervised learning: Clustering




















Unsupervised learning: Clustering




















Unsupervised learning: Clustering



















Unsupervised learning: Clustering

You see this in other courses (e.g., Datamining)




















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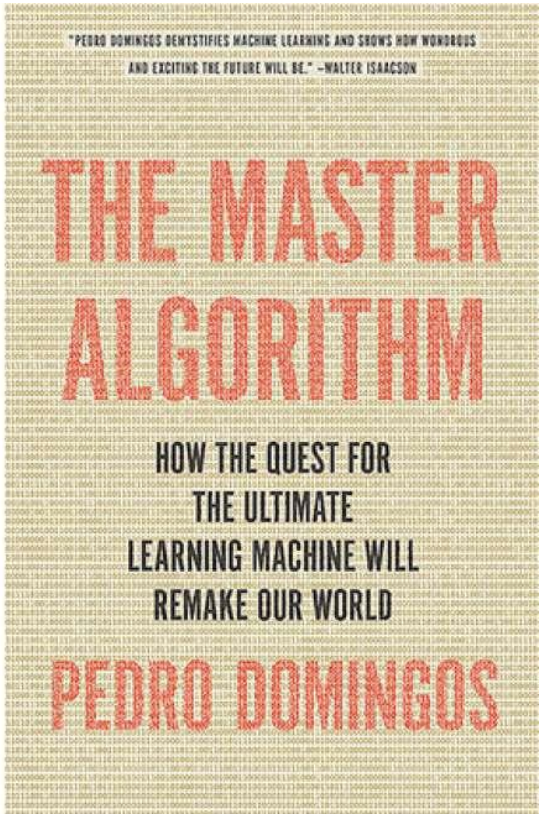
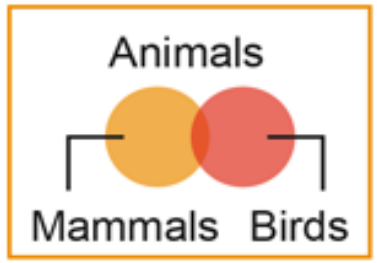
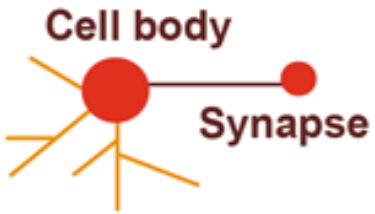
This course focuses most on Supervised Learning (with some unsupervised spots)

The Master Algorithm (Pedro Domingos, 2015)

"The master algorithm is the ultimate learning algorithm. It's an algorithm that can learn anything from data and it's the holy grail of machine learning …"



The Master Algorithm (Pedro Domingos, 2015)

Symbolists	Bayesians	Connectionists	Evolutionaries	Analogizers
				
Use symbols, rules, and logic to represent knowledge and draw logical inference	Assess the likelihood of occurrence for probabilistic inference	Recognize and generalize patterns dynamically with matrices of probabilistic, weighted neurons	Generate variations and then assess the fitness of each for a given purpose	Optimize a function in light of constraints ("going as high as you can while staying on the road")
Favored algorithm Rules and decision trees	**Favored algorithm** Naive Bayes or Markov	**Favored algorithm** Neural networks	**Favored algorithm** Genetic programs	**Favored algorithm** Support vectors

Source: Pedro Domingos, *The Master Algorithm*, 2015

Deep Learning: The Master Algorithm?

MIT Technology Review

10 BREAKTHROUGH TECHNOLOGIES 2013

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Deep Learning
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Additive Manufacturing
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Baxter: The Blue-Collar Robot
Rodney Brooks's newest creation is easy to interact with, but the complex innovations behind the robot show just how hard it is to get along with people.

Memory Implants
A maverick neuroscientist believes he has deciphered the code by which the brain forms long-term memories. Next: testing a prosthetic implant for people suffering from long-term memory loss.

Smart Watches
The designers of the Pebble watch realized that a mobile phone is more useful if you don't have to take it out of your pocket.

Ultra-Efficient Solar Power
Doubling the efficiency of a solar cell would completely change the economics of renewable energy. Nanotechnology just might make it possible.

Big Data from Cheap Phones
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Supergrids
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What is Deep Learning after all?

… let's say it with flowers!

Iris Setosa

Iris Virginica

Iris Versicolor

What is Deep Learning after all?

… let's say it with flowers!

The Iris Dataset

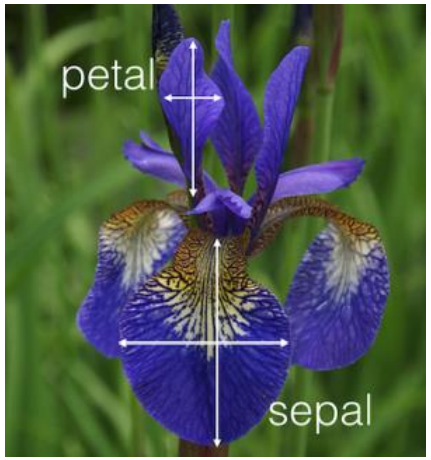
Collected by Ronald Fisher in 1936

Iris Setosa

Iris Virginica

Iris Versicolor

What is Deep Learning after all?

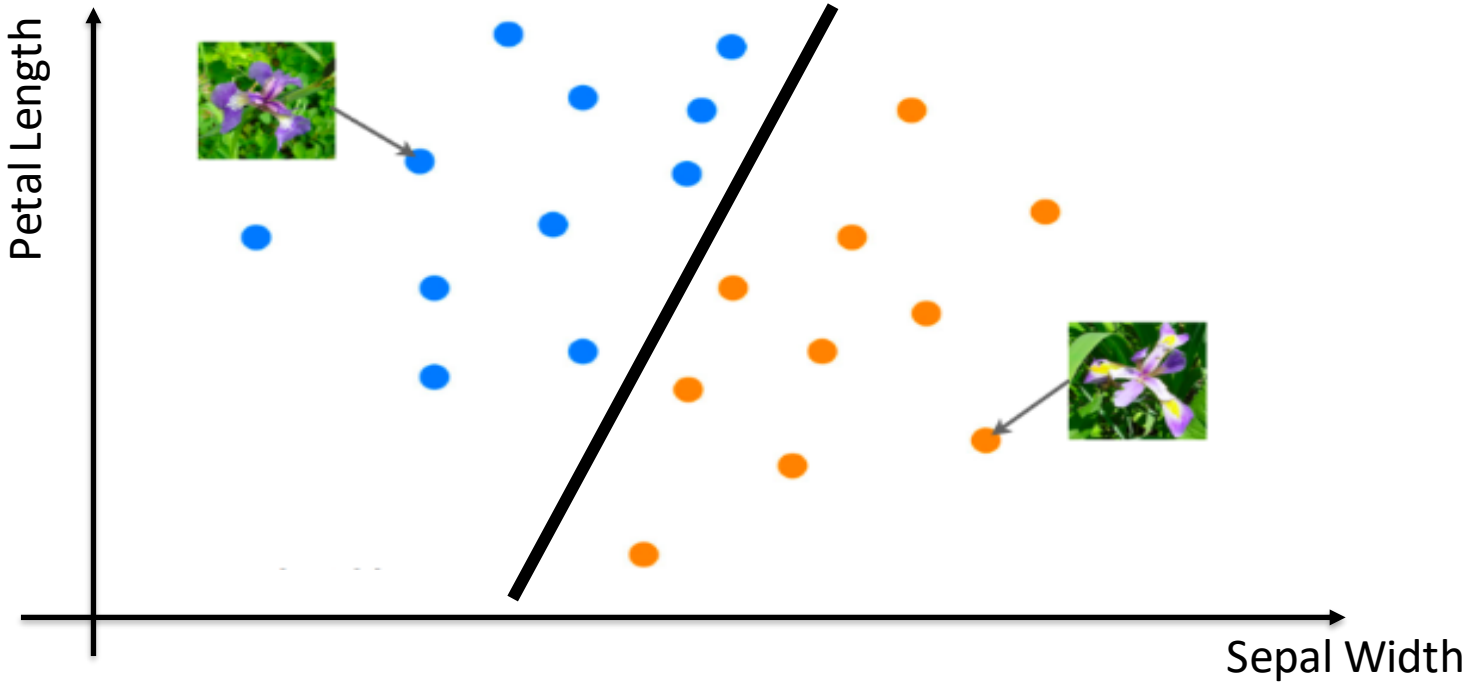


Hand-crafted Features

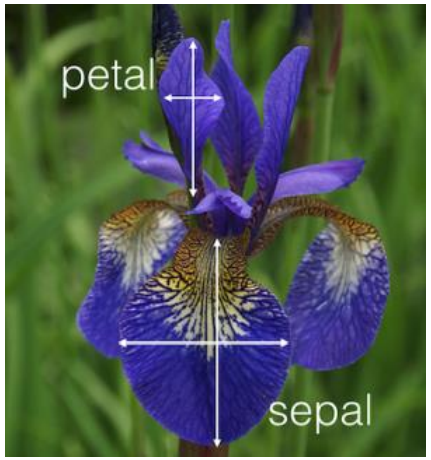
Learned Classifier

Machine learns how to take the Iris apart

setosa



What is Deep Learning after all?



Hand-crafted Features

Learned Classifier

setosa

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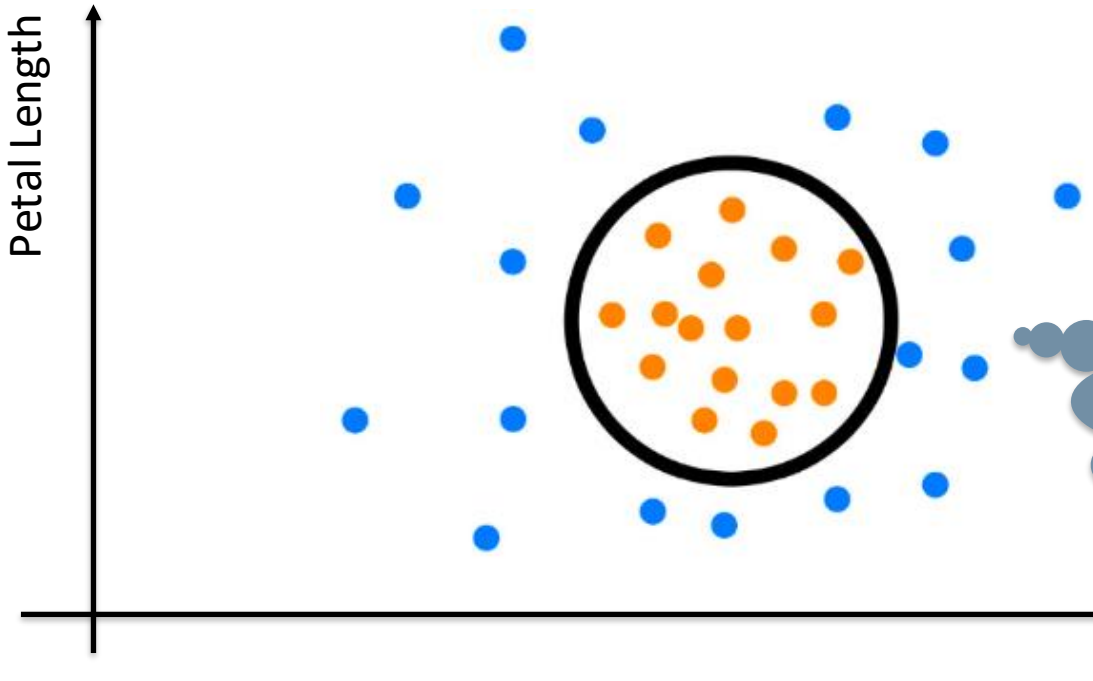
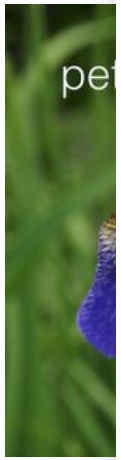
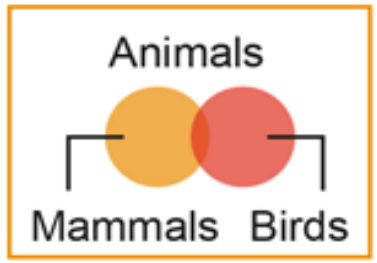
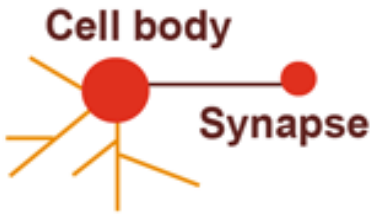


Sometimes the decision might be more complex

What is Deep Learning after all?



Symbolists	Bayesians	Connectionists	Evolutionaries	Analogizers
				
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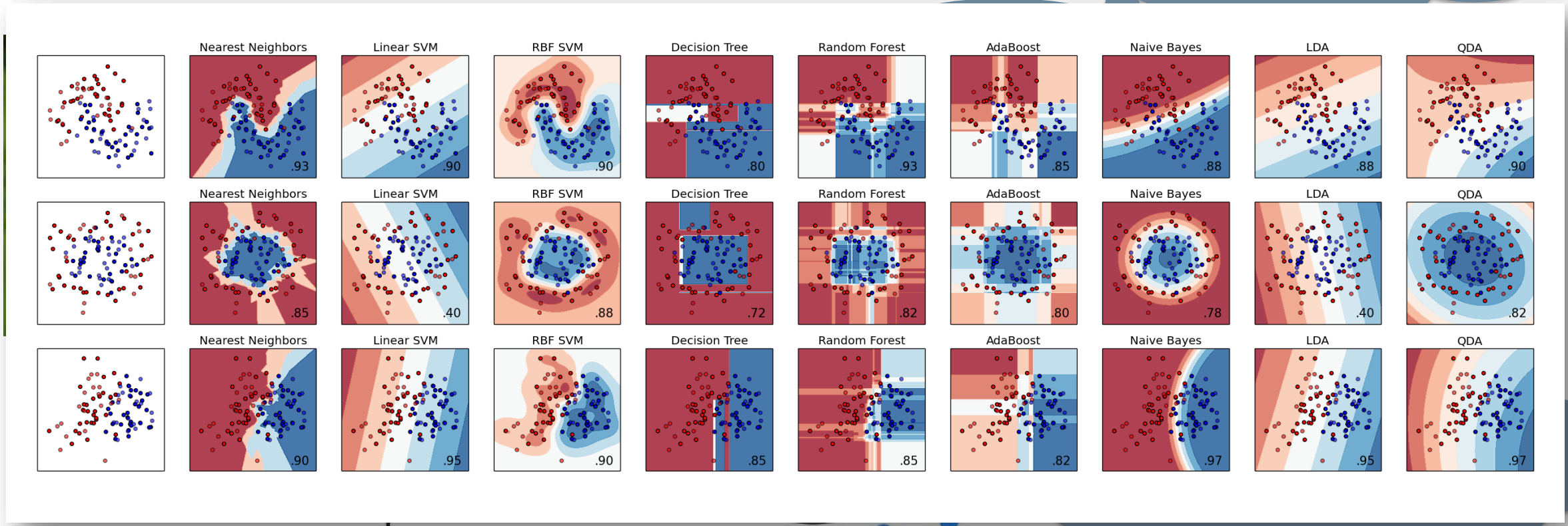
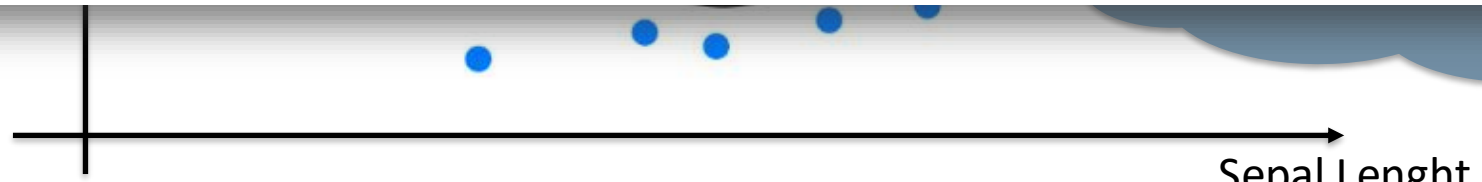
Source: Pedro Domingos, *The Master Algorithm*, 2015

Sepal Lenght

What is Deep Learning after all?

Machine learns how to take the Iris apart





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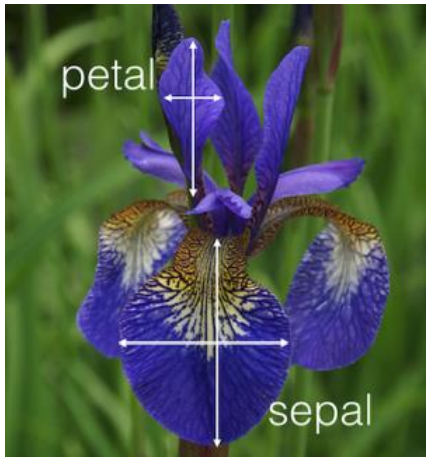

Hand-crafted Features

Learned Classifier

setosa

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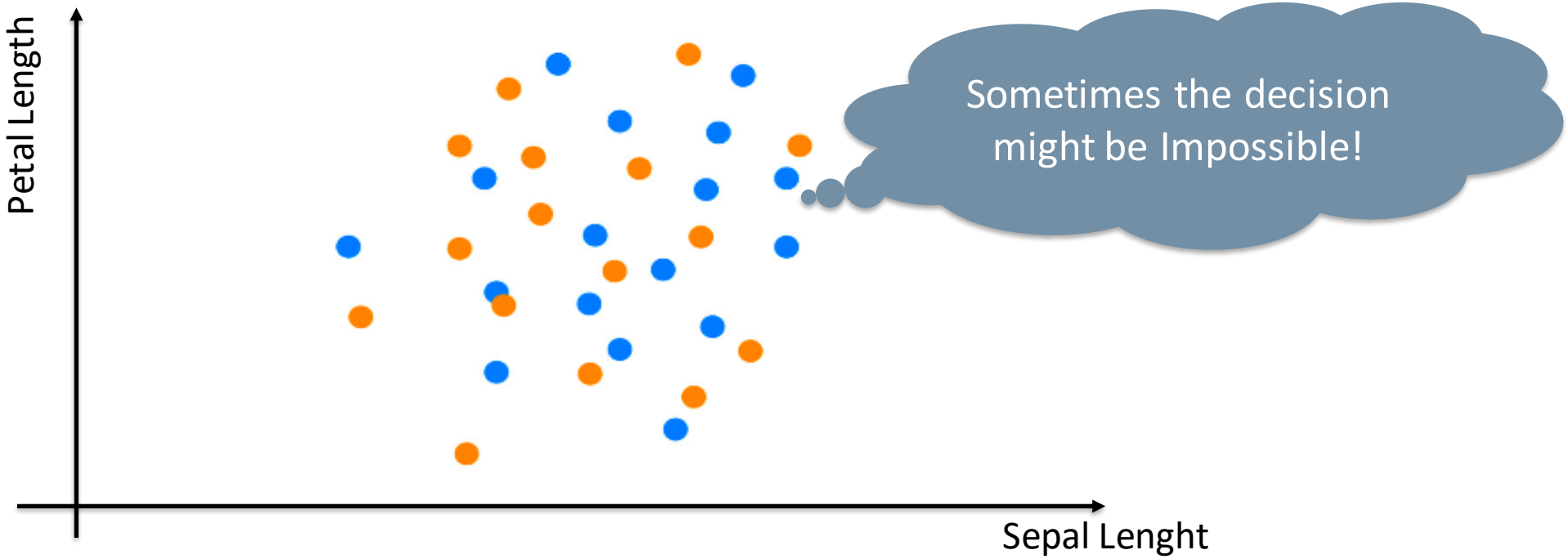
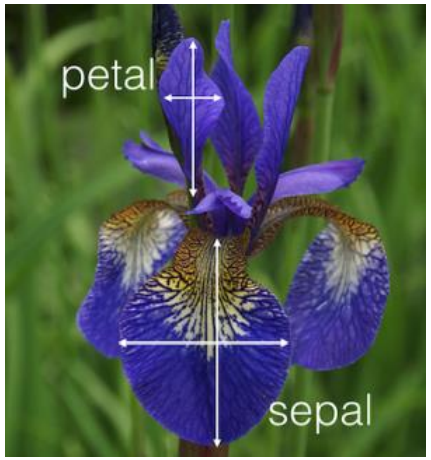


Sometimes the decision might be Impossible!

What is Deep Learning after all?

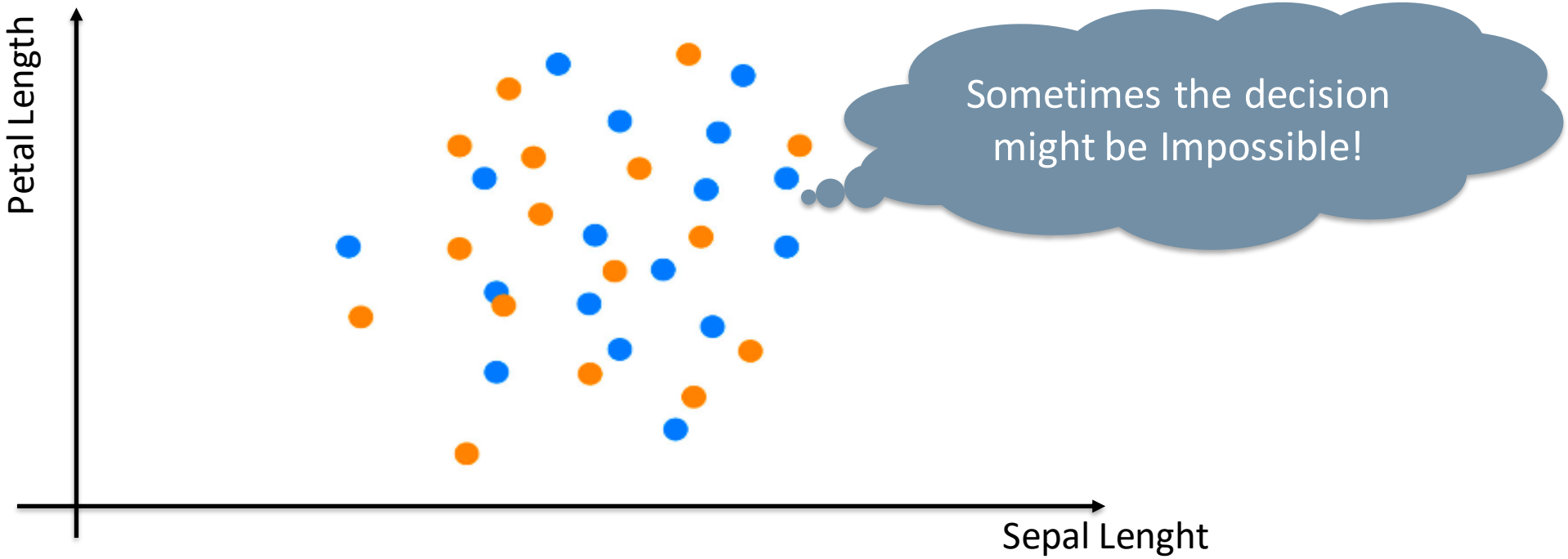


This happens if you do not know which features to extract!!!

Hand-crafted Features

Learned Classifier

setosa



Sometimes the decision might be Impossible!

Semi-supervised learning

Unlabeled images (all cars/motorcycles)

Hand-crafted Features

Unsupervised Learnng

$\phi_1, \phi_2, \ldots, \phi_k$

Car

Motorcycle

Few labeled images

$\phi_1, \phi_2, \ldots, \phi_k$

Learned Classifier

CAR / BYKE

Semi-supervised learning

Unlabeled images (all cars/motorcycles)

Hand-crafted Features

Unsupervised Learnng

$\phi_1, \phi_2, \ldots, \phi_k$

Hand-crafted Features

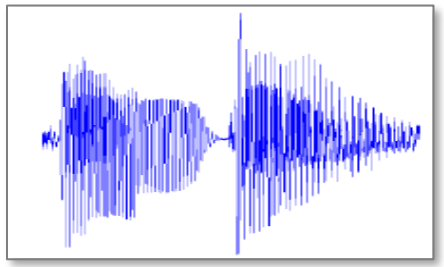
Learned Feature Projection

Learned Classifier

CAR

Modern Pattern Recogniton

Speech recognition (early 90's – 2011)



Low level features

MFCC

Fixed Features

Mid level features

Mixture of Gaussian

Unsupervised Learning

Learned Classifier

Supervised Learning

Horn

Object recognition (2006 – 2012)

Low level features

SIFT/HoG

Fixed Features

Mid level features

K-means Sparse Coding

Unsupervised Learning

Pooling

Learned Classifier

Supervised Learning

Car

Transfer Learning

Unlabeled images (all cars/motorcycles)

Hand-crafted Features

Unsupervised Learnng

$\phi_1, \phi_2, \ldots, \phi_k$

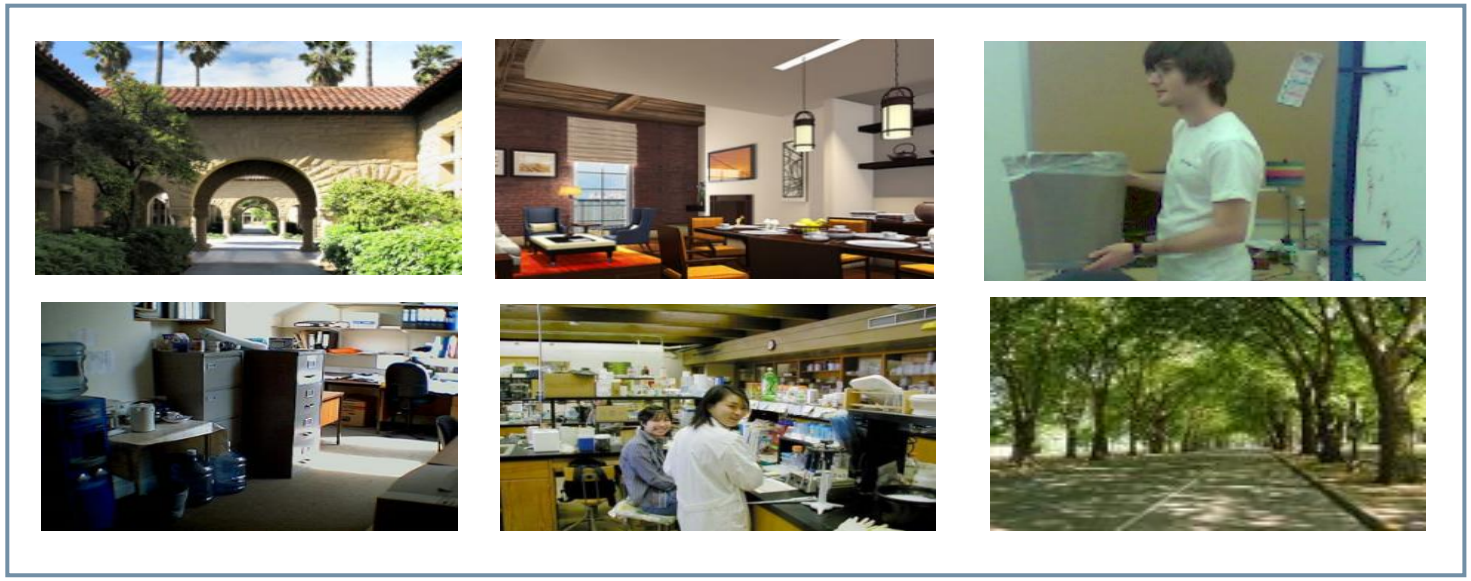
Hand-crafted Features

Learned Feature Projection

Learned Classifier

CAR

Transfer Learning

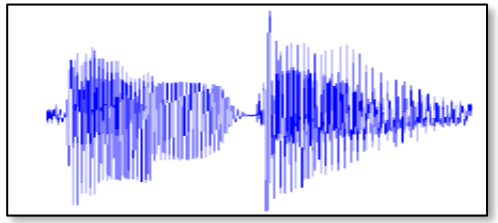


Unlabeled images (random images from the web)

$\phi_1, \phi_2, \ldots, \phi_k$

What is Deep Learning after all?

Speech Recognition (early '90s – 2



MFCC

Fixed Features

Is this the best thing to do?

Mixture of Gaussian

Unsupervised Learning

Learned Classifier

Supervised Learning

Horn

Object Recognition (2006 – 201

SIFT/HoG

Fixed Features

And what about these features?

K-means Sparse Coding

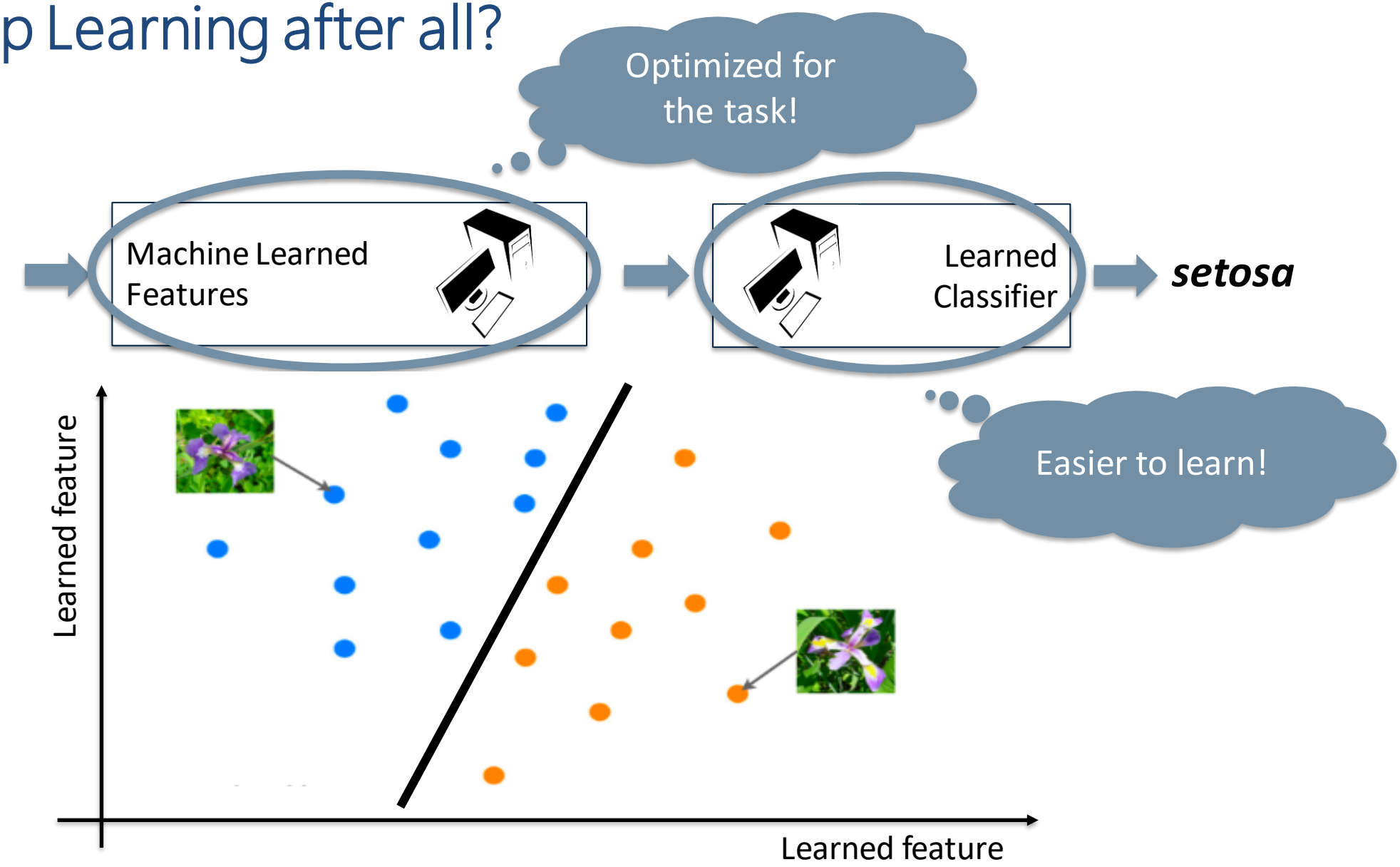
Unsupervised Learning

Learned Classifier

Supervised Learning

Car

What is Deep Learning after all?



What is Deep Learning after all?

Learn from data!

Hierarchical representation optimized for the task!

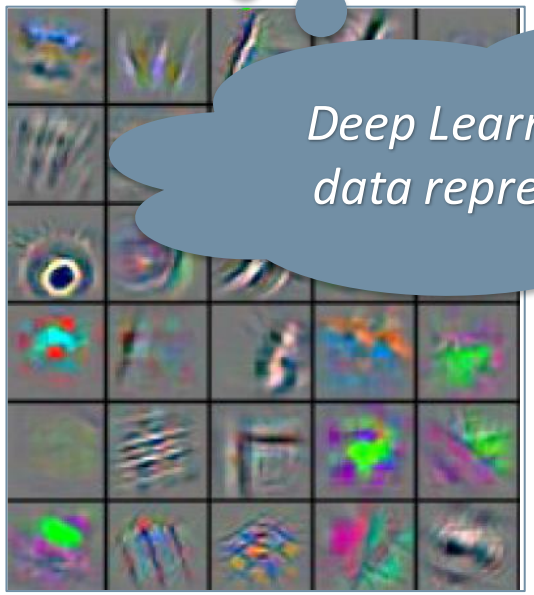
Learned features

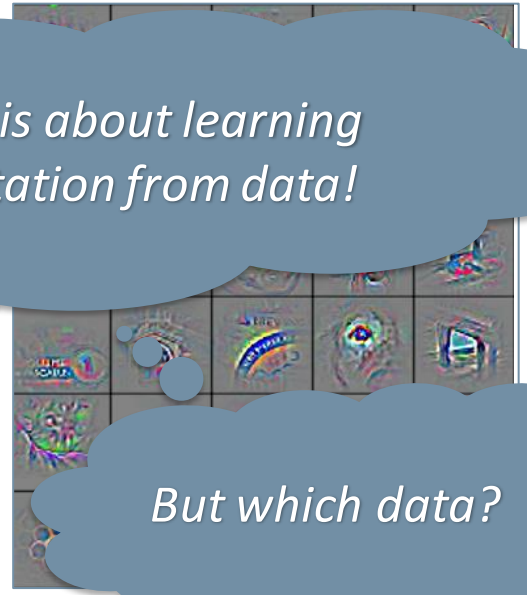
Learned features

Learned features

Learned Classifier

setosa



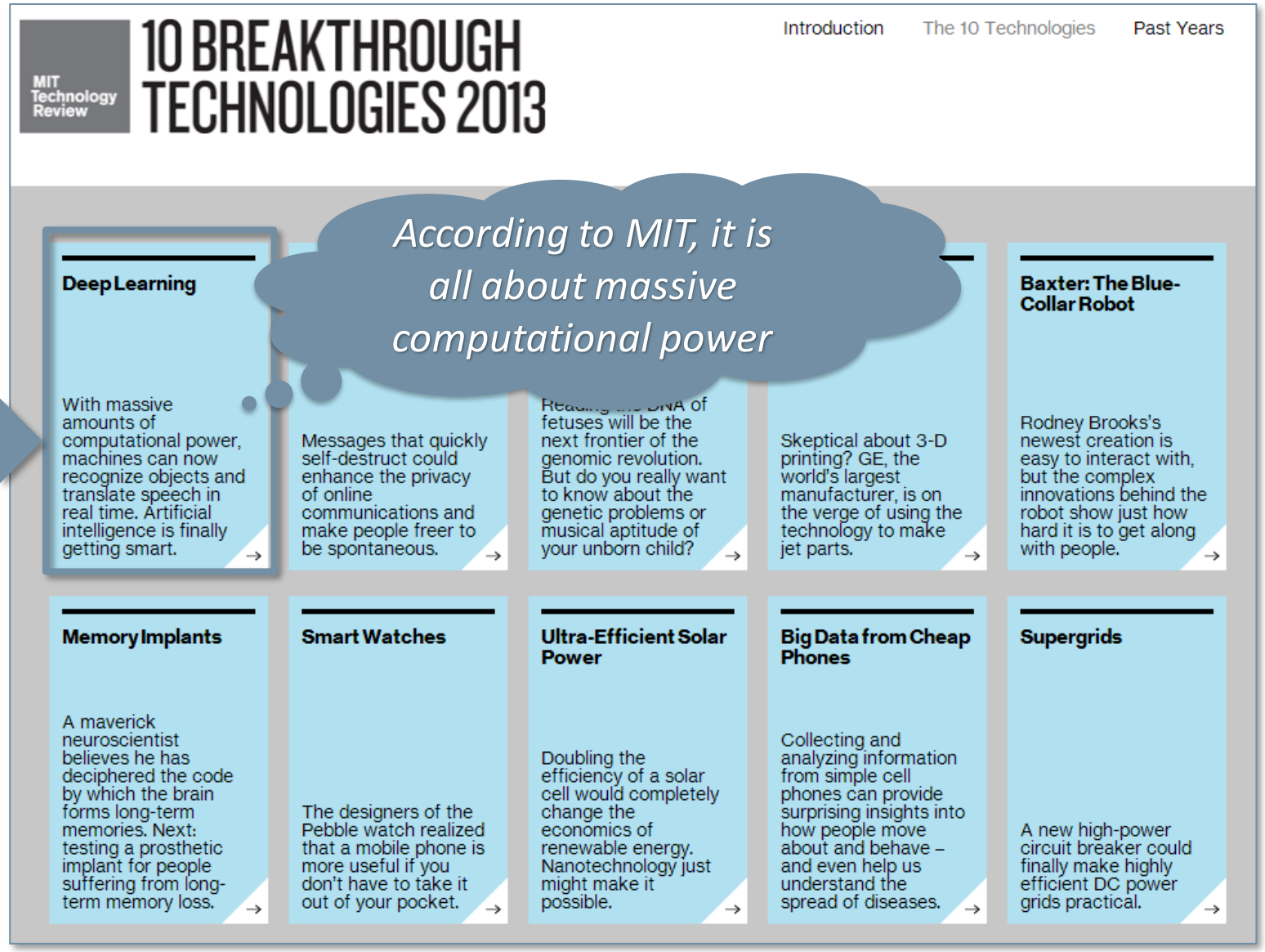


Deep Learning is about learning data representation from data!

But which data?


IN 60 SECONDS...
1 NEW DEFINITION IS ADDED ON urban
1,600+ READS ON Scribd.
13,000+ HOURS MUSIC STREAMING ON PANDORA
12,000+ NEW ADS POSTED ON craigslist
370,000+ MINUTES VOICE CALLS ON skype
98,000+ TWEETS
20,000+ NEW POSTS ON tumblr.
THE LARGEST SOCIAL READING PUBLISHING COMPANY!!
New Craigslist Ads
320+ NEW twitter ACCOUNTS
13,000+ iPhone APPLICATIONS DOWNLOADED
100+ NEW Linked in ACCOUNTS
1 associatedcontent NEW ARTICLE IS PUBLISHED
THE WORLD'S LARGEST COMMUNITY CREATED CONTENT!!
QUESTIONS ASKED ON THE INTERNET...
100+ Answers.com
40+ YAHOO! ANSWERS
600+ NEW VIDEOS
6,600+ NEW PICTURES ARE UPLOADED ON flickr
50+ WordPress DOWNLOADS
25+ HOURS TOTAL DURATION
70+ DOMAINS REGISTERED
695,000+ facebook STATUS UPDATES
125+ PLUGIN DOWNLOADS
60+ NEW BLOGS
1,500+ BLOG POSTS
168 MILLION EMAILS ARE SENT
694,445 SEARCH QUERIES
1,700+ Firefox DOWNLOADS
79,364 WALL POSTS
510,040 COMMENTS
Google
Google Search

What's behind Deep Learning?



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10 BREAKTHROUGH TECHNOLOGIES 2013

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Supergrids

A new high-power circuit breaker could finally make highly efficient DC power grids practical.

According to MIT, it is all about massive computational power

The Economist got it right! It is all about (Big) Data

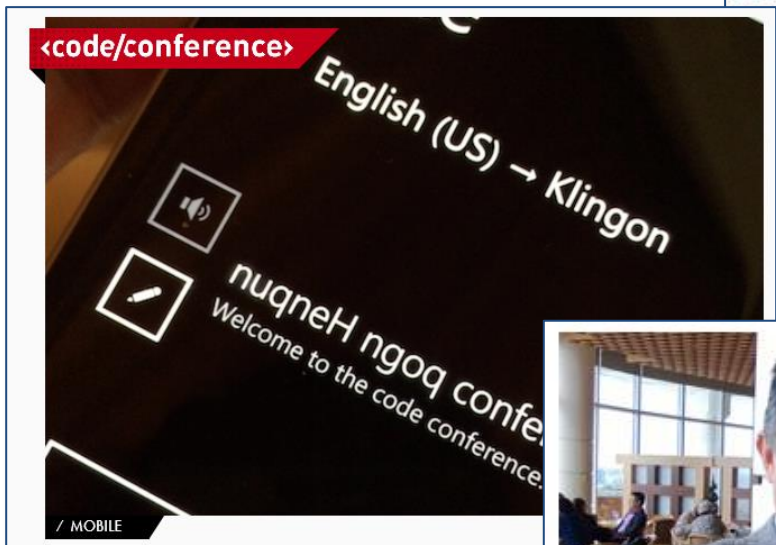
Enabling Cross-Lingual Conversations in Real Time

Microsoft Research
May 27, 2014 5:58 PM PT

The success of the team's progress to date was on display May 27, in a talk by Microsoft CEO Satya Nadella in Rancho Palos Verdes, Calif., during the Code Conference. During Nadella's conversation
n Kara Swisher and Walt Mossberg of
Re/code tech website relating to a new
of personal computing, he asked
deep Pall to join him on stage. Pall, the
rosoft corporate vice president of
pe, demonstrated for the first time
licly the Skype Translator app, with Pall
versing in English with German-

View milestones on the path to Skype Translator

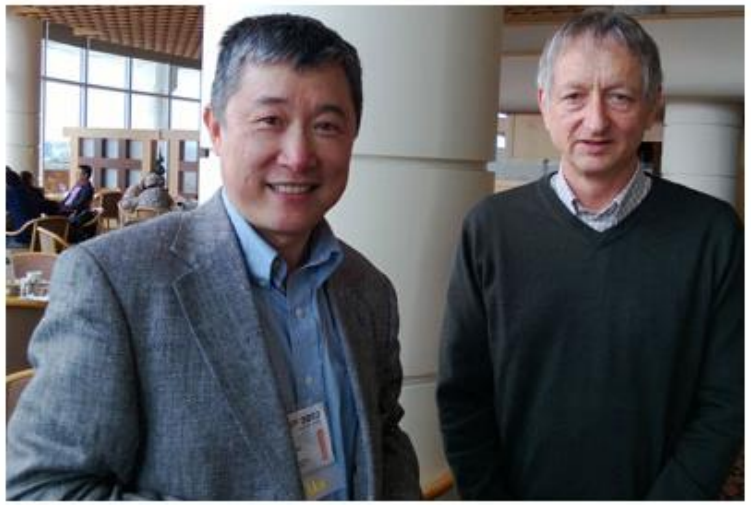
#speech2speech



Microsoft's Skype "Star Trek" Language Translator Takes on Tower of Babel

May 27, 2014, 5:48 PM PDT

Remember the universal translator on Star Trek? The gadget th
to aliens?



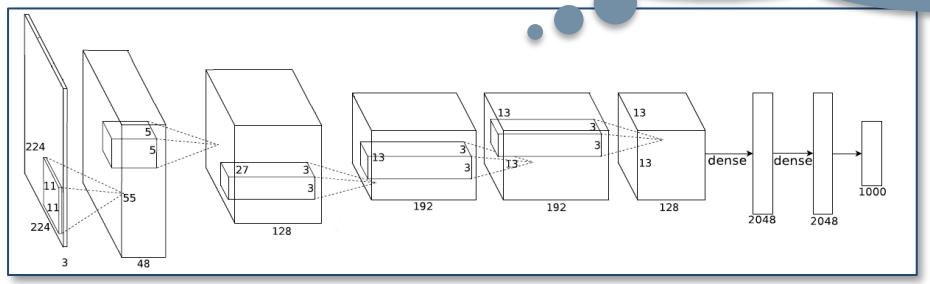
Li Deng (*left*) and Geoff Hinton.

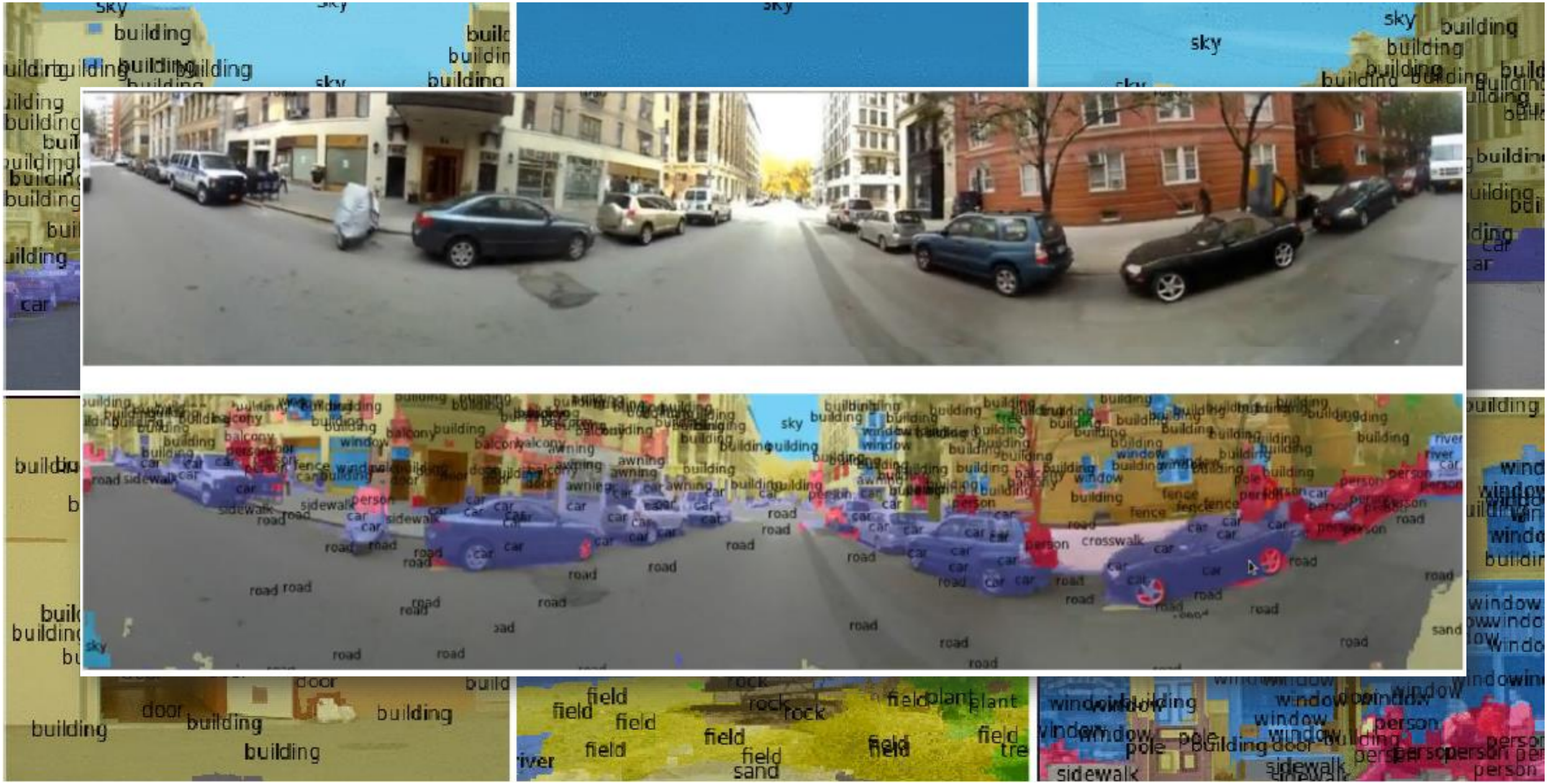
A core development that enables Skype translation came from Redmond researcher Li Deng. He invited Geoff Hinton, a professor at the University of Toronto, to visit Redmond in 2009 to work on new neural-network learning methods, based on a couple of seminal papers from Hinton and his collaborators in 2006 that had brought new

The path to the Skype Translator gained momentum with an encounter in the autumn of 2010. Seide and colleague Kit Thambiratnam had developed a system they called The Translating! Telephone for live speech-to-text and speech-to-speech translation of phone calls.

IMAGENET

What's that??






person1.00
person1.00
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car.93
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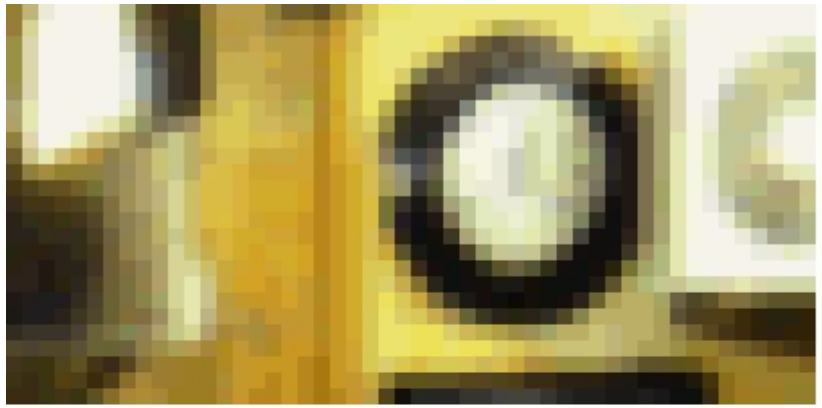
person1.00
handbag.93
skateboard.98
skateboard.99
person1.00
person1.00
person1.00
person.95
sports ball.98
sports ball1.00

https://github.com/luanfujun/deep-photo-styletransfer

https://github.com/jcjohnson/neural-style

https://github.com/jcjohnson/fast-neural-style

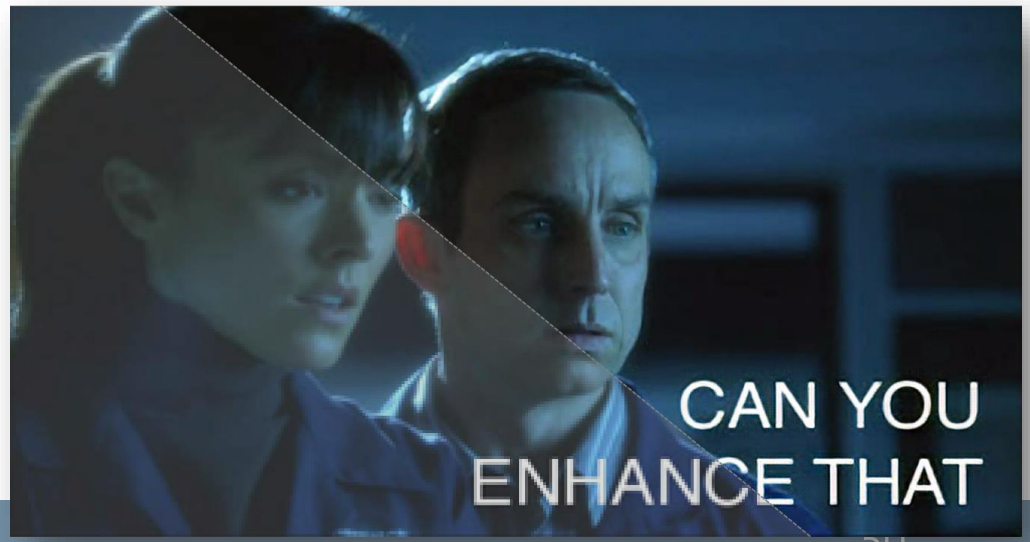
https://ml4a.github.io/ml4a/style_transfer/











https://github.com/alexjc/neural-enhance

Text description	This flower has petals that are white and has pink shading	This flower has a lot of small purple petals in a dome-like configuration	This flower has long thin yellow petals and a lot of yellow anthers in the center	This flower is pink, white, and yellow in color, and has petals that are striped	This flower is white and yellow in color, with petals that are wavy and smooth	This flower has upturned petals which are thin and orange with rounded edges	This flower has petals that are dark pink with white edges and pink stamen
256x256 StackGAN							
Text description	This bird is red and brown in color, with a stubby beak	The bird is short and stubby with yellow on its body	A bird with a medium orange bill white body gray wings and webbed feet	This small black bird has a short, slightly curved bill and long legs	A small bird with varying shades of brown with white under the eyes	A small yellow bird with a black crown and a short black pointed beak	This small bird has a white breast, light grey head, and black wings and tail
256x256 StackGAN							

'Go is implicit. It's all pattern matching. But that's what deep learning does very well.'

—DEMIS HASSABIS, DEEPMIND

The win is more than a novelty. Online services like Google, Facebook, and Microsoft, already use deep learning to identify images, recognize spoken words, and understand natural

with a technology called reinfor
methods, point the way to a futu
can learn to perform physical ta
environment. "It's a natural fit f

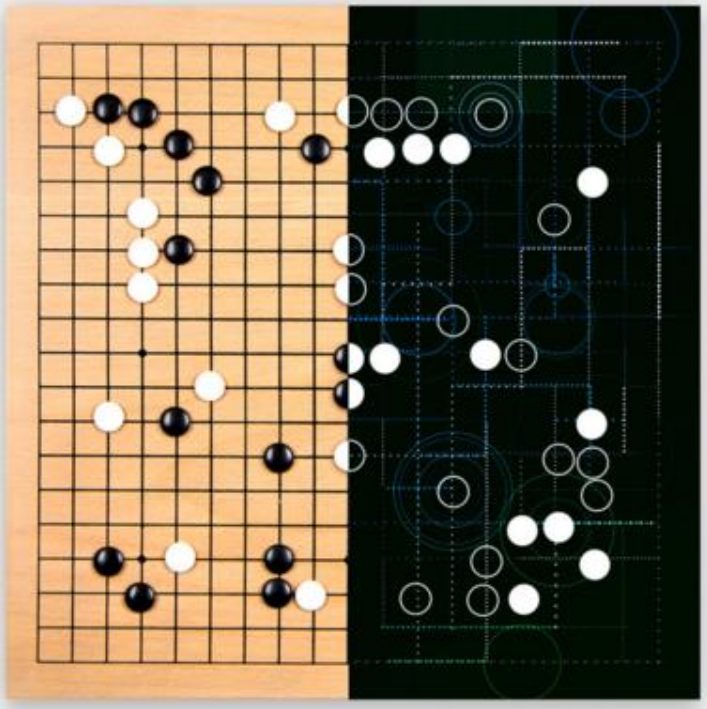
It's incredibly difficult to build a machine that duplicates the kind of intuition that makes the top human players so good at

In the mid-'90s, a computer program called Chinook beat the world's top player at the game of checkers. A few years later, IBM's Deep Blue supercomputer shocked the chess world when it wiped the proverbial floor with world champion Gary Kasparov. And more

BM machine, Watson, topped the best
dy!, the venerable TV trivia game.
o mastered Othello, Scrabble,
poker. But in the wake of Crazy Stone's
Coulom predicted that another ten years
a machine could beat a grandmaster
rt.

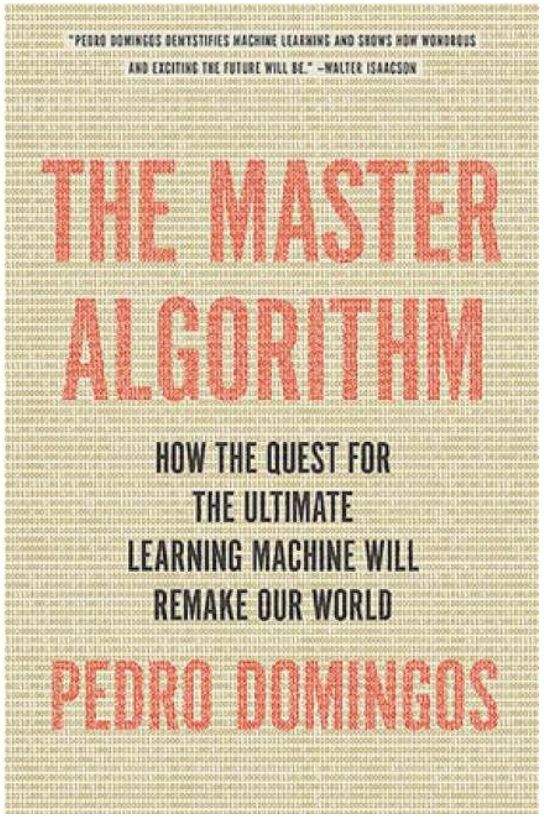
IN A HUGE BREAKTHROUGH, GOOGLE'S AI BEATS A TOP PLAYER AT THE GAME OF GO

WIRED



The Master Algorithm (Pedro Domingos, 2015)

"The master algorithm is the ultimate learning algorithm. It's an algorithm that can learn anything from data and it's the holy grail of machine learning …"

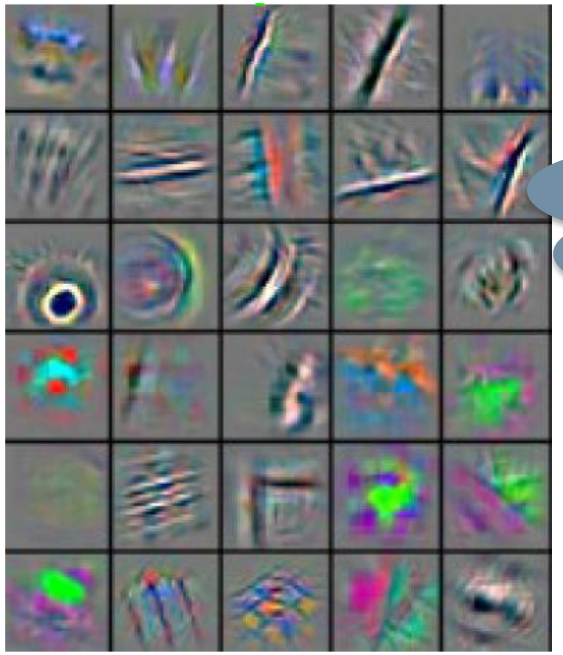


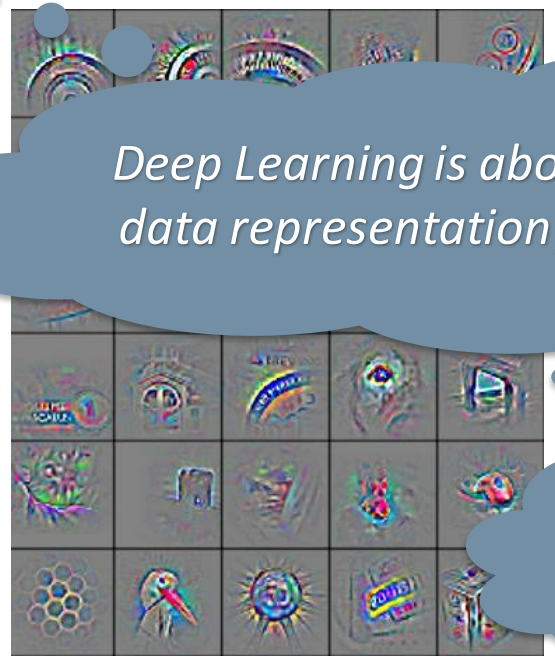
It's all about features …

Learned Features → Learned Features → Learned Features → Learned Classifier → **CAR**

Deep Learning (2012 – …)

Learn from data!





Deep Learning is about learning data representation from data!

But which data?