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CPE/EE 695: Applied Machine Learning

Lecture 1: Introduction to ML

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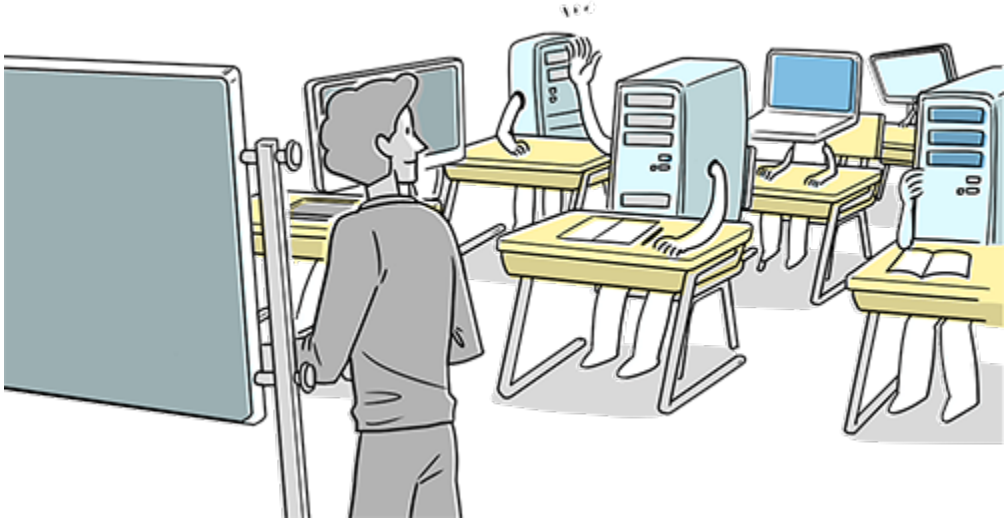
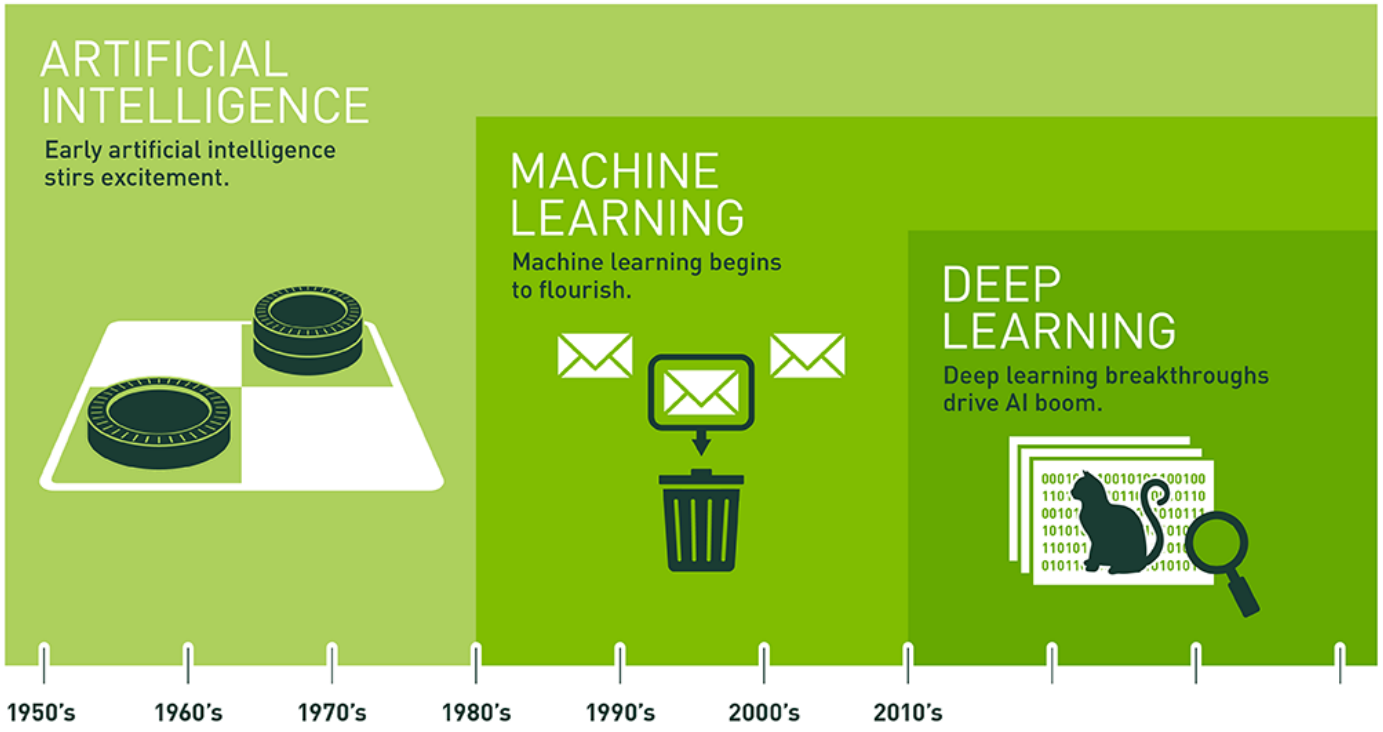
What is Machine Learning?



Relation with other “buzzwords”



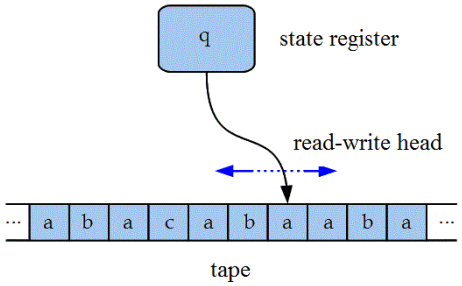
Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

Computability theory (1930's -)

Church-Turing Thesis (1936):

"a function on the natural numbers can be calculated by an effective method, if and only if it is computable by a **Turing Machine**"

"digital computers can simulate any process of formal reasoning"



Turing Machine

The First General-Purpose Electronic Computer

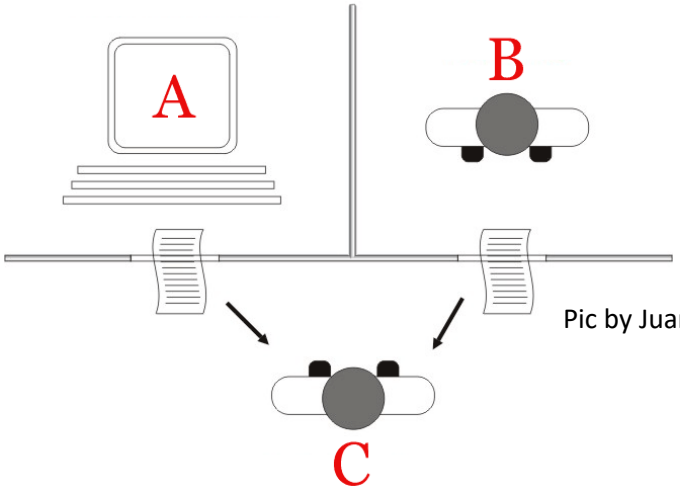
ENIAC (1946) - Electronic Numeral Integrator And Computer

17,468 vacuum tubes,
70,000 resistors,
10,000 capacitors,
1,500 relays,
6,000 manual switches ,
5 million soldered joints

Can Machine Think?

Turing Test (1950)

- ELIZA (1966)
- PARRY(1972)
- Loebner Prize (1990)



Pic by Juan Alberto Sánchez Margallo

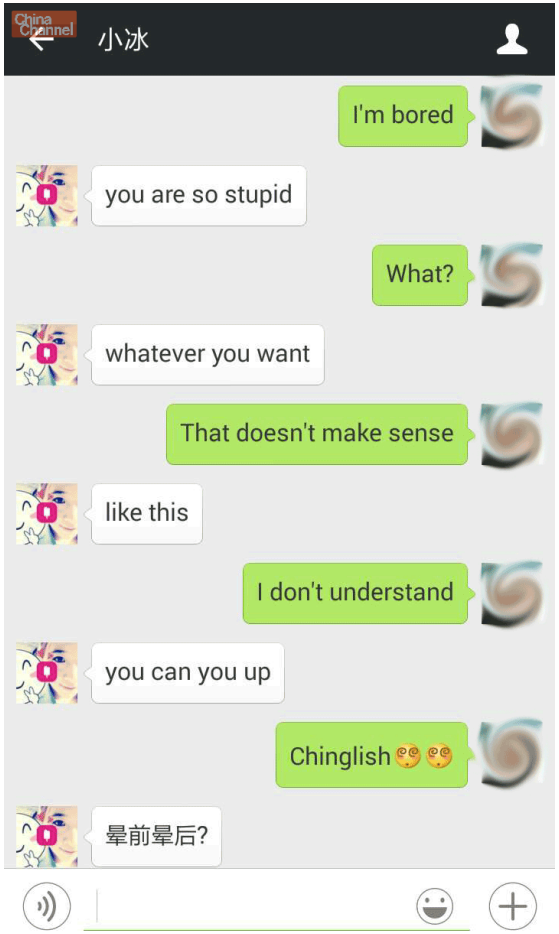
Player C, the interrogator, is given the task of trying to determine which player – A or B – is a computer and which is a human. The interrogator is limited to using the responses to written questions to make the determination

Can Siri pass the Turing test?

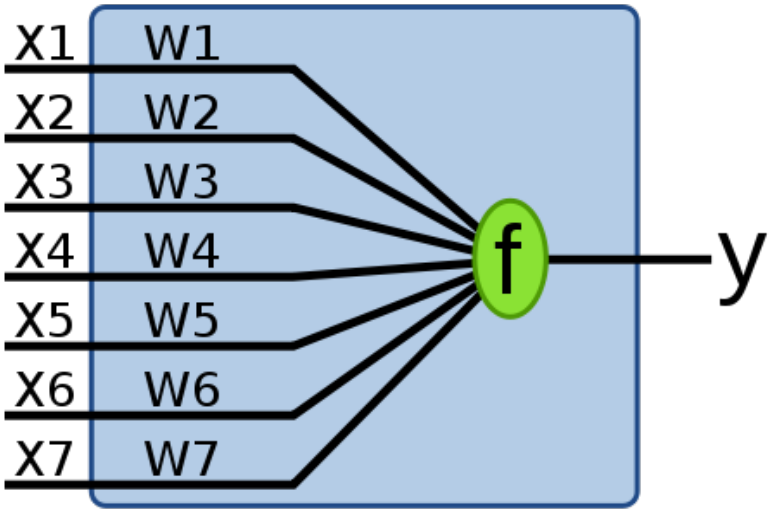
(Recorded on July 29, 2013)

Human: Hello I'm Ronan. what is your name?
Siri: Siri. Please to meet you.
Human: What is your mother's name?
Siri: I'd rather not say.
Human: What is your birth sign?
Siri: I don't really like talking about myself.
Human: How many children do you have?
Siri: Only biological entities have children.
Human: Do you prefer red or white wine?
Siri: I couldn't find any restaurants matching "red or white wine"
Human: I like bananas. Which is your favorite fruit?
Siri: I prefer not to say.
Human: What music do you like to listen to?
Siri: I really have no opinion.
Human: what is your favorite song?
Siri: I like whatever you like.
Human: I like Waiting for Godot. What is your favorite play?
Siri: I don't really like talking about myself.
Human: What color do you dye your hair?
Siri: Would you like me to search the web for "What color do you dye your hair?"?

Microsoft Chatbot Xiaobing

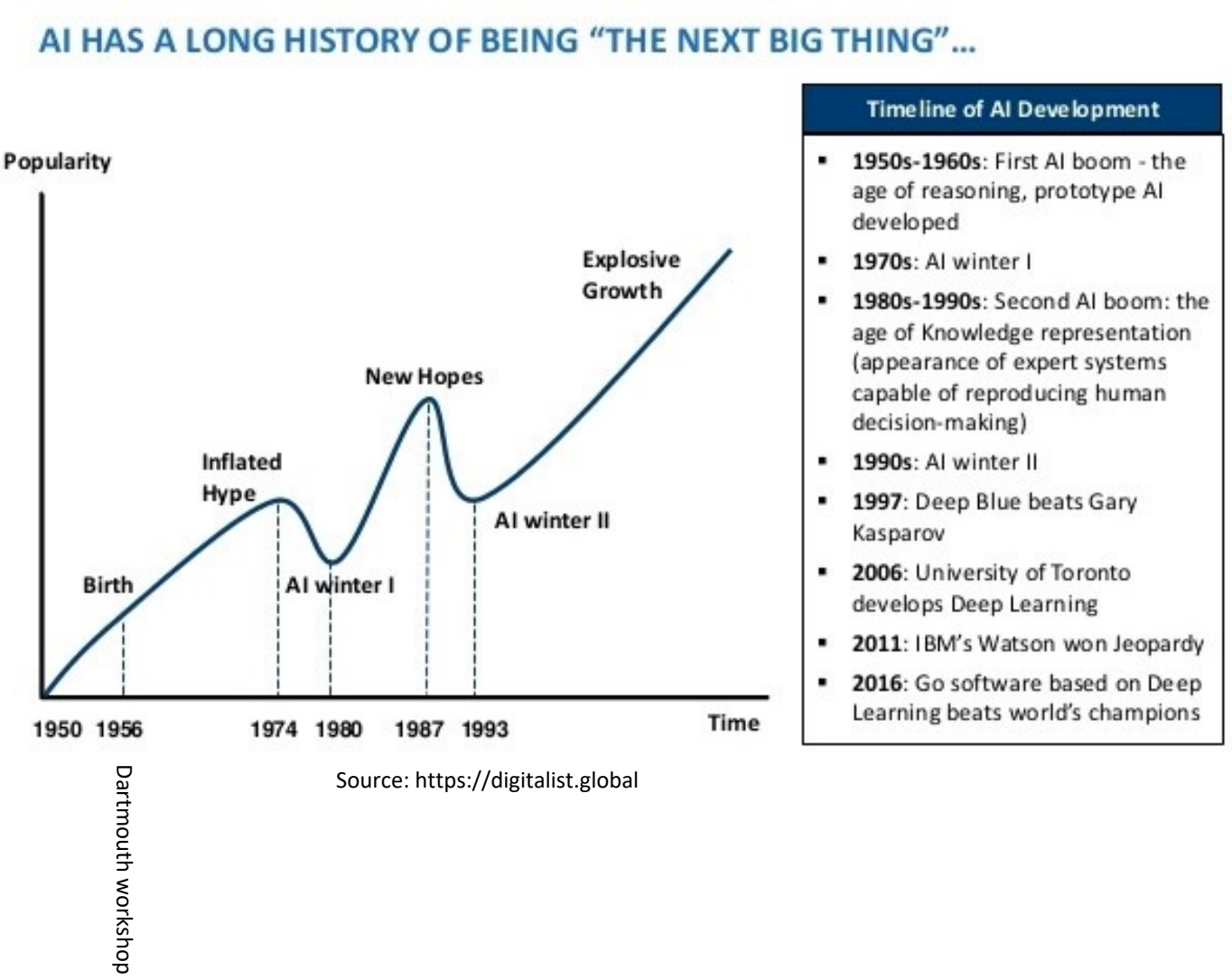


Perceptrons



$$f(x) = \begin{cases} 1, & if\ wx + b > 0 \\ 0, & \text{otherwise} \end{cases}$$

AI Cycles



Source: https://digitalist.global

AI Winter

- Failure of Machine Translation -- disambiguation
- Perceptron Limitation – Linear
- Failure of Speech Understanding Research at CMU
- Lighthill Report(1973): James Lighthill, "*Artificial Intelligence: a paper symposium*"

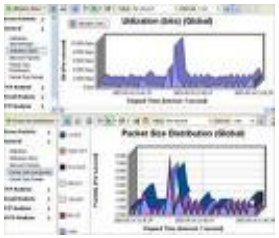
"In no part of the field have the discoveries made so far produced the major impact that was then promised"

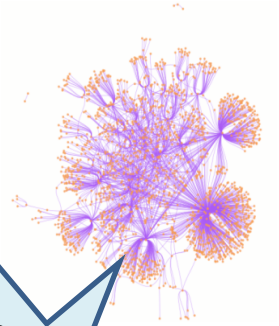
- DARPA funding cut

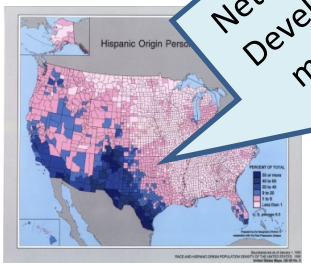
Exclusive-OR gate

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0

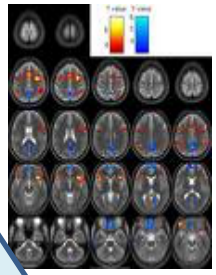
After 1990's







Network Develop ment



Computer Maturity

Statistician

Computer Scientist

ML

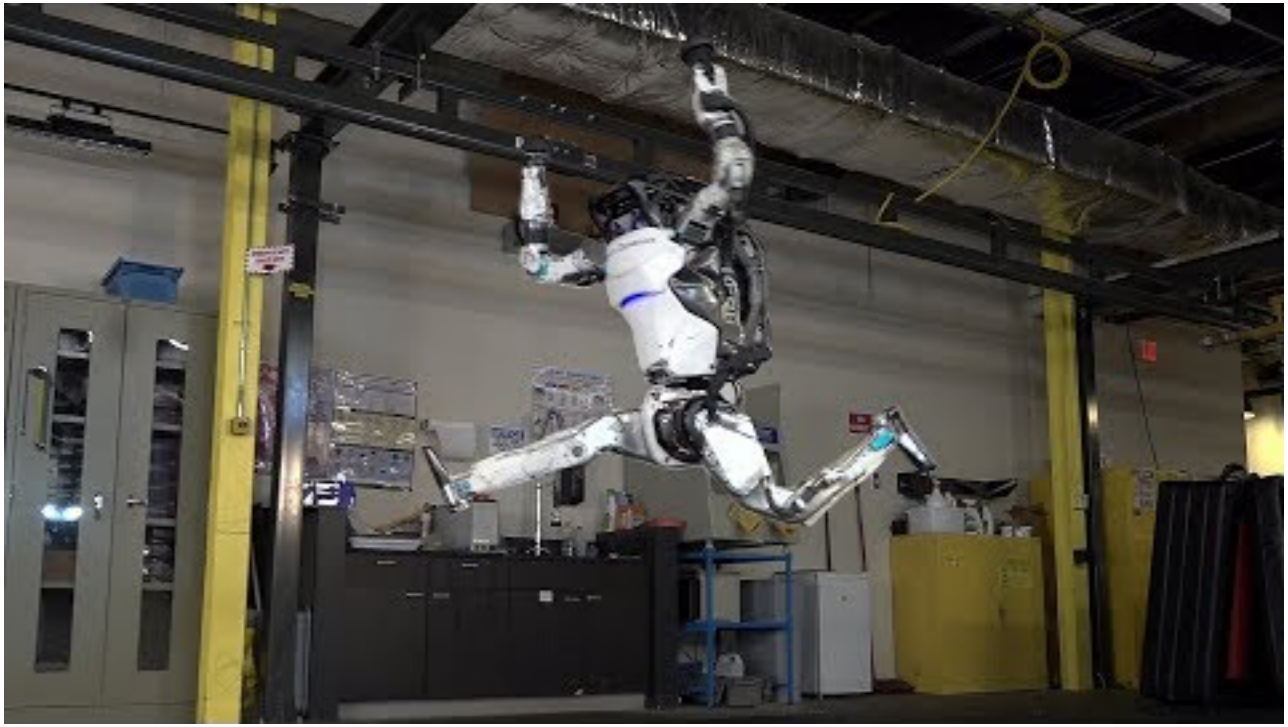
Computer Engineer

Philosopher
Psychologist
Neurologist

Deep Blue/Watson
Cog/Kismet/Andriod
Climate Model
Marketing/Recommendatio n Model
AlphaGo
.....

Backpropagation
Adaboost
Naive Bayes
Deep Learning .....

Robots

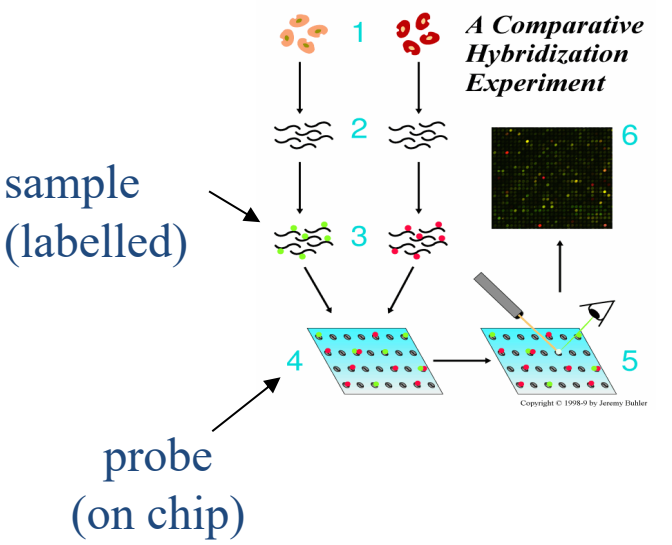


Signal Processing

- Face Recognition

- Speech Recognition

- Microarray



[image from Jeremy Buhler]

- Video Processing

Business Analysis

Fraud Detection

Churn Prediction

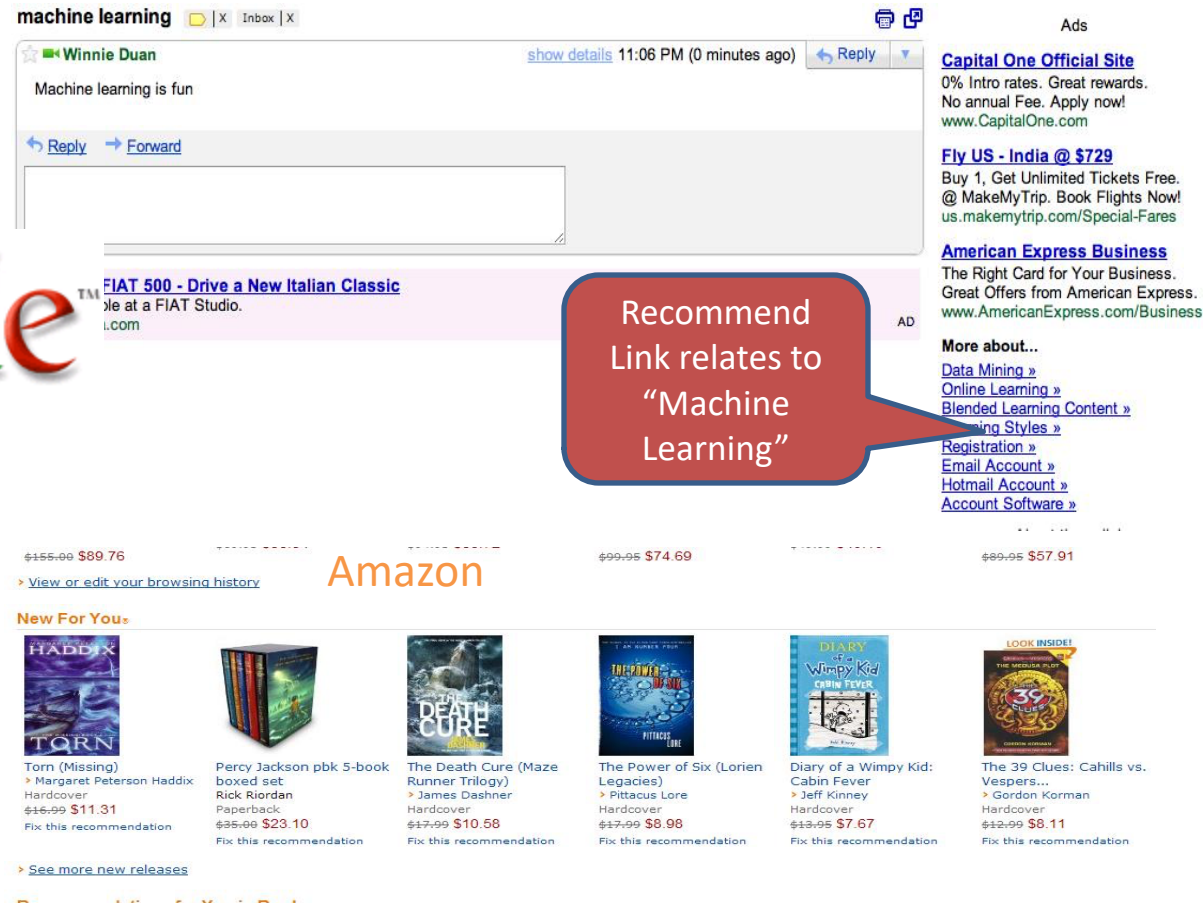
Market Basket

Web Mining

Stock Market

Recommendation Systems

$1 million, 10% improve,
4 years(2006 – 2009)



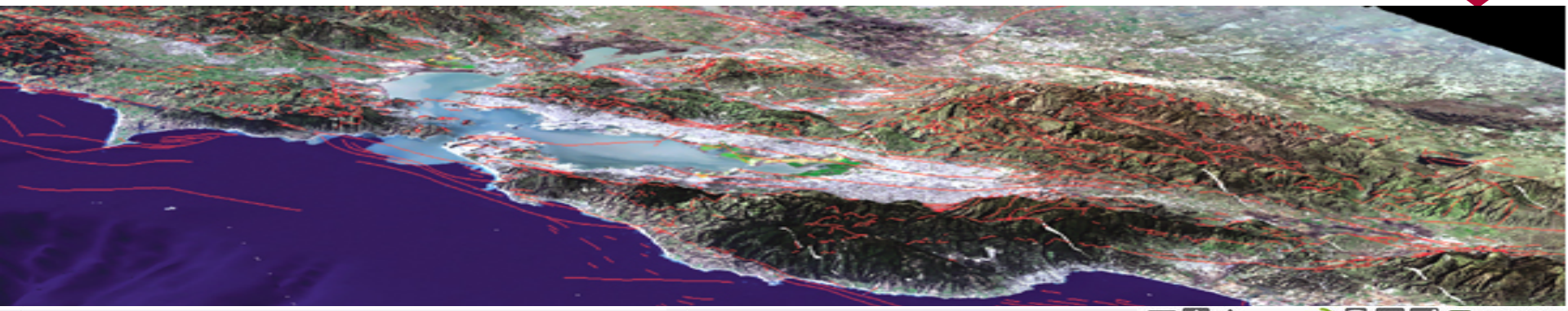
$5 billion, 25% of the annual sales

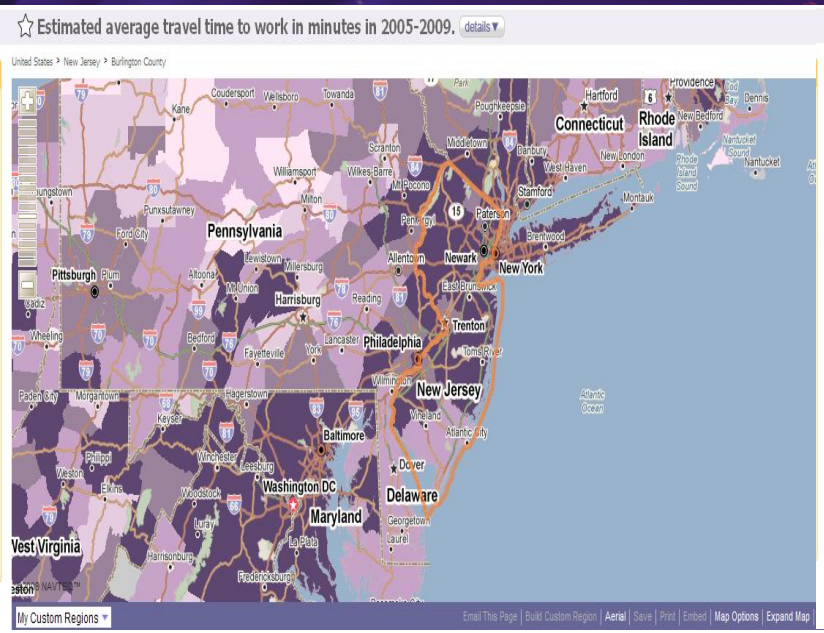
Climate/Healthcare Science

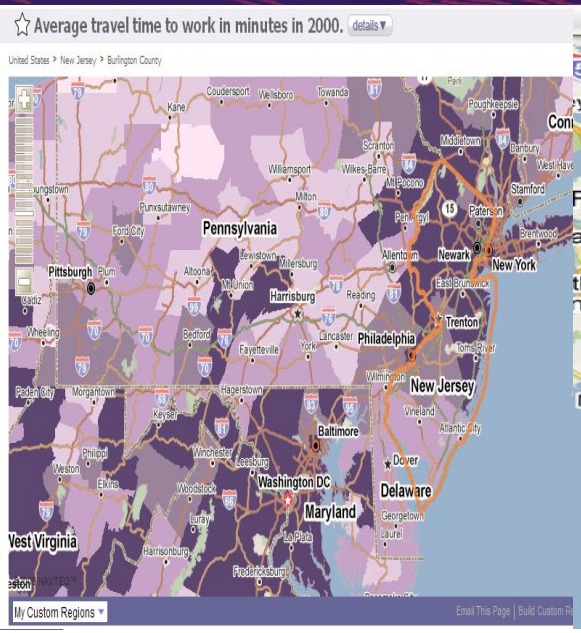
Healthcare

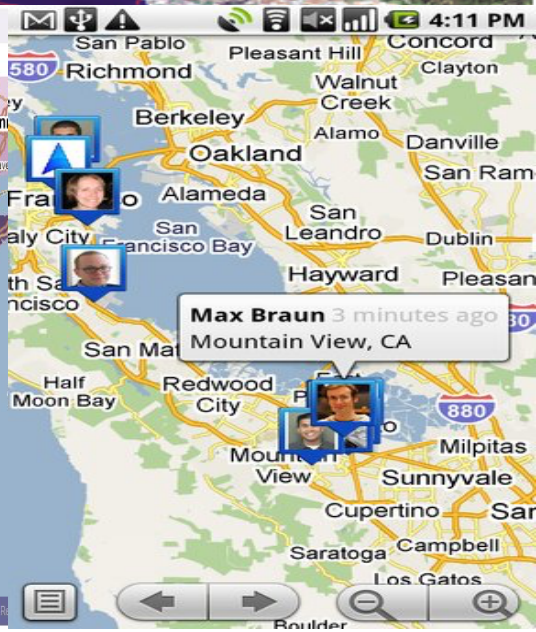
Climate Change

GIS and Location Science









Complexity of Geographic Information System:

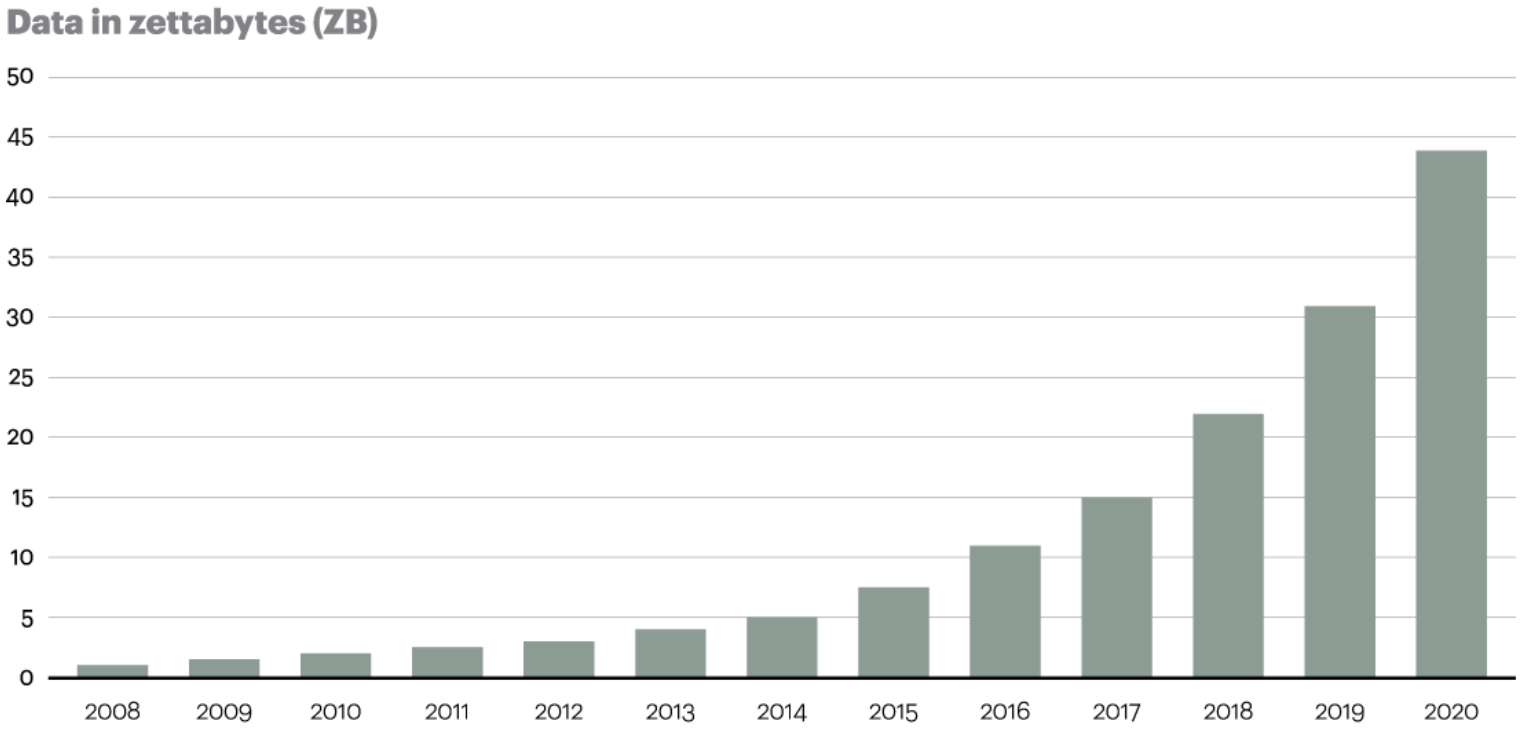
High dimension Dynamic

Spatial temporal Computation

Big Data Analytics

Figure 1

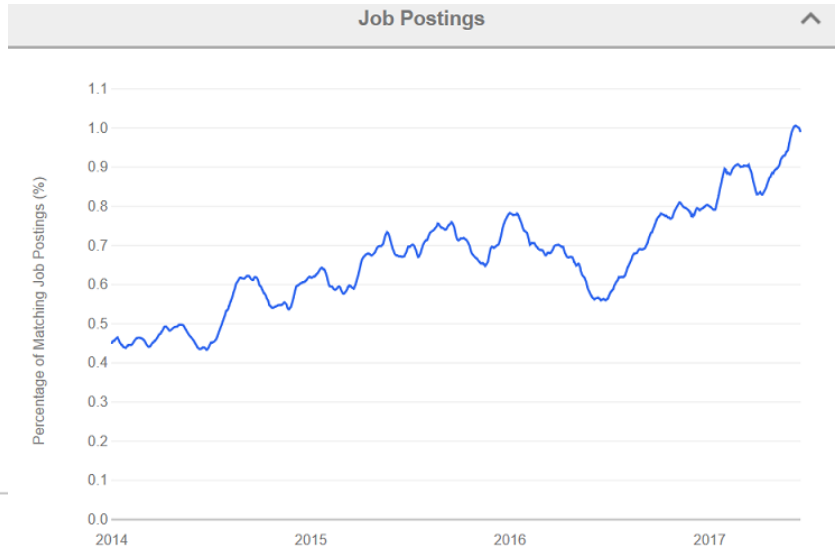
Data is growing at a 40 percent compound annual rate, reaching nearly 45 ZB by 2020



Source: Oracle, 2012

Machine Learning Jobs

"140,000 – 190,000 position shortage with deep expertise in statistics and machine learning" --- Mckinsey Big Data report



Challenges for Machine Learning

- Intelligent Systems
  - **Dynamic, incremental and adaptive learning algorithms;**
  - Limited understanding of intelligent behaviors;
  - **Lack of system level models and architectures to mimic brain-level intelligence;**
  - Embodiment of machine intelligence hardware within systems that learn through interaction with environment;
  - Systems design and implementation;

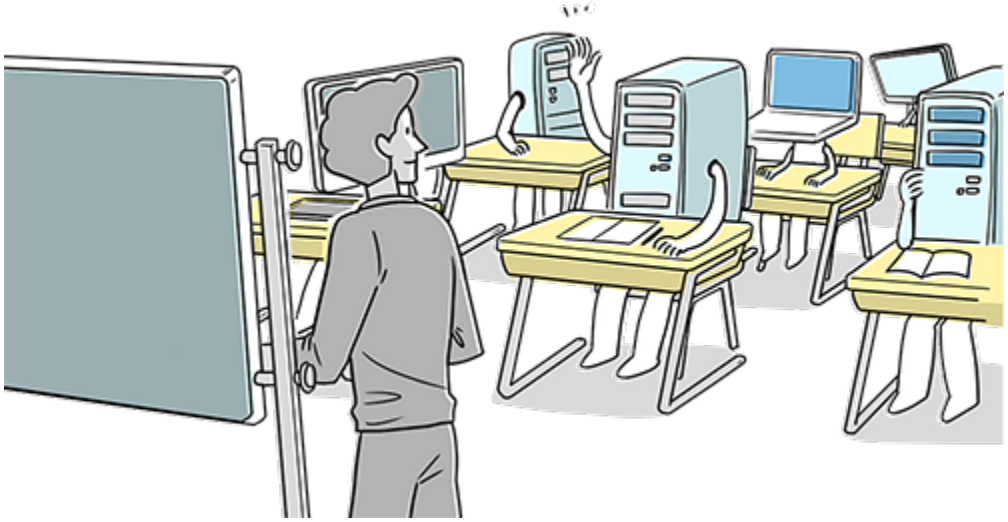
- Big Data
  - Platform/Storage/Index
  - Quality Uncertainty
  - **Efficient statistical/machine learning methods**
  - Intellectual property, liability
  - Visualization

Challenges for Machine Learning

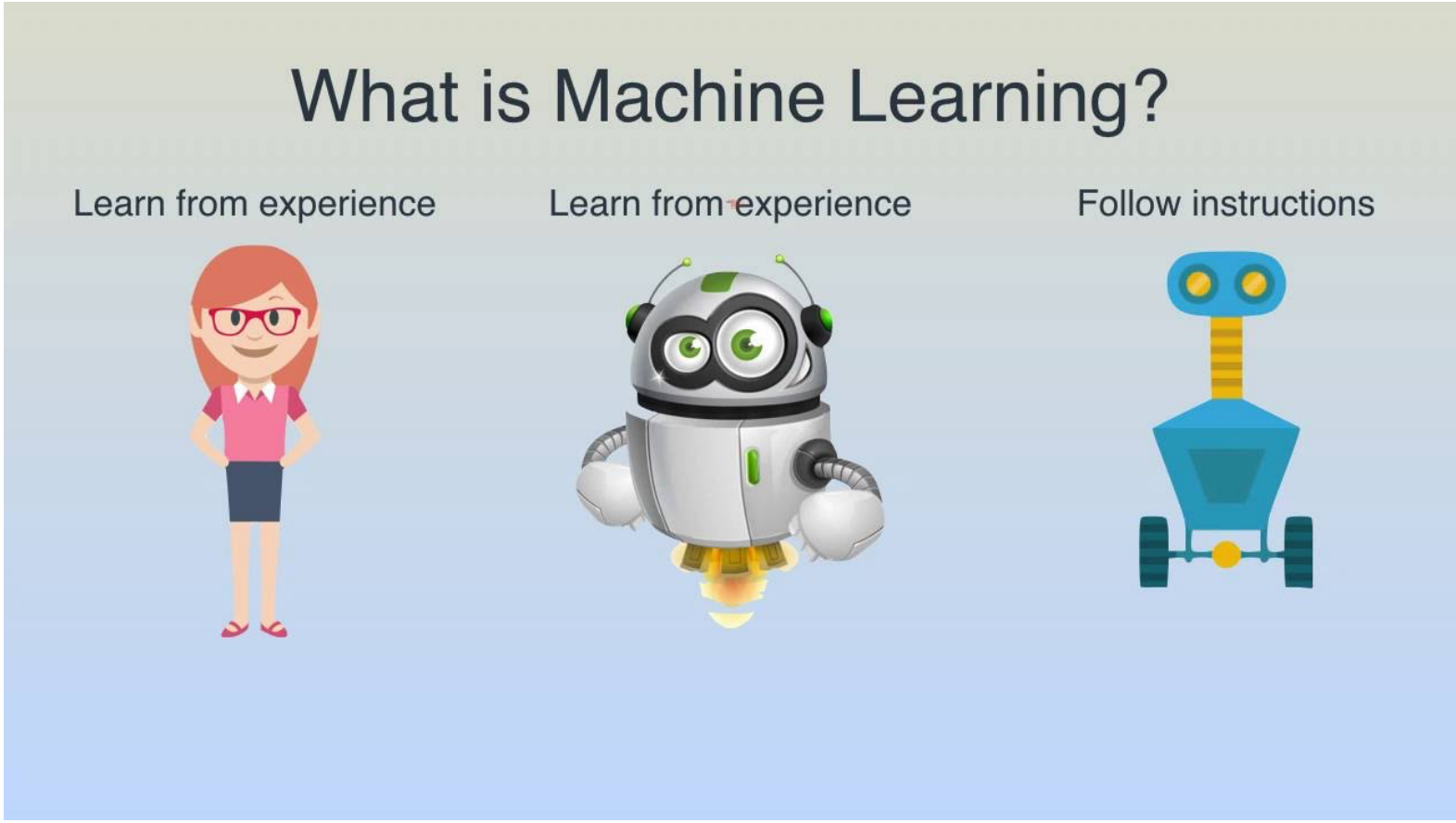
- Theoretical foundations
  - Some results based on optimization and probability models
  - Lack rigorous mathematical formulation especially for recent deep learning algorithms
  - Verifiability of the system is another problem

- Security, privacy and ethical issues
  - Model reliability under attacks, e.g., pollution attacks
  - Data privacy, model privacy
  - Ethical use of machine learning in controllable ways

Again, What is Machine Learning?



Simple Answer



Answer from Expert

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

--- Tom Mitchell

Why Learning?

Learning is used when:

- Human expertise does not exist (navigating on Mars),
- Humans are unable to explain their expertise (speech recognition)
- Solution changes in time
- Solution needs to be adapted to particular cases
- Data Volume are huge

Learning Associations

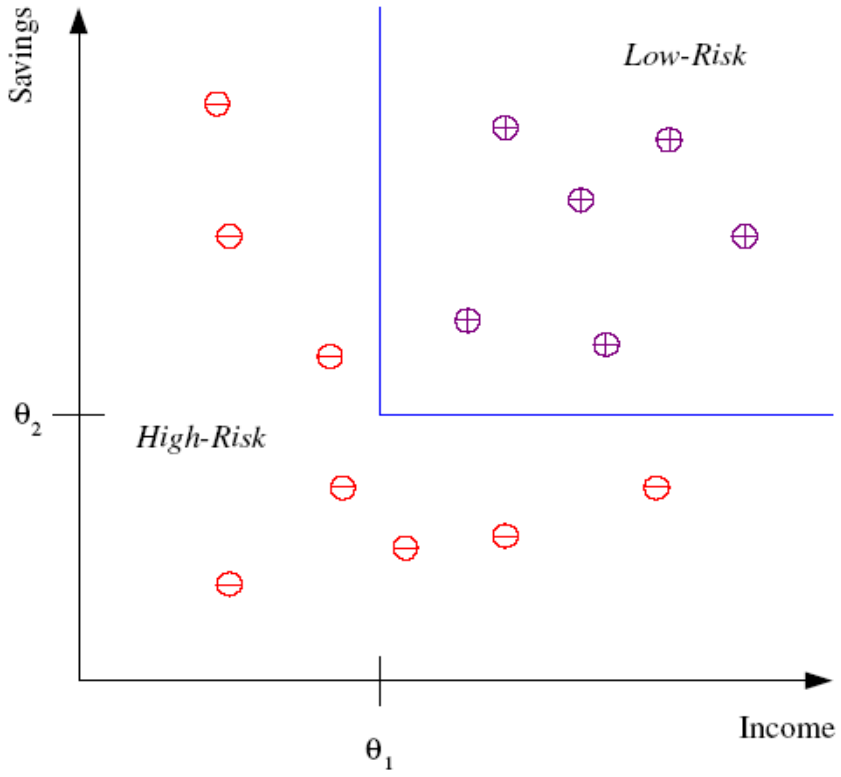
- Basket analysis:

  $P(Y \mid X)$ probability that somebody who buys X also buys Y where X and Y are products/services.

  Example: P (chips | beer) = 0.7

Classification

- Example: Credit scoring
- Differentiating between low-risk and high-risk customers from their *income* and *savings*



Discriminant: IF *income* > θ_1 AND *savings* > θ_2
THEN low-risk ELSE high-risk

Regression

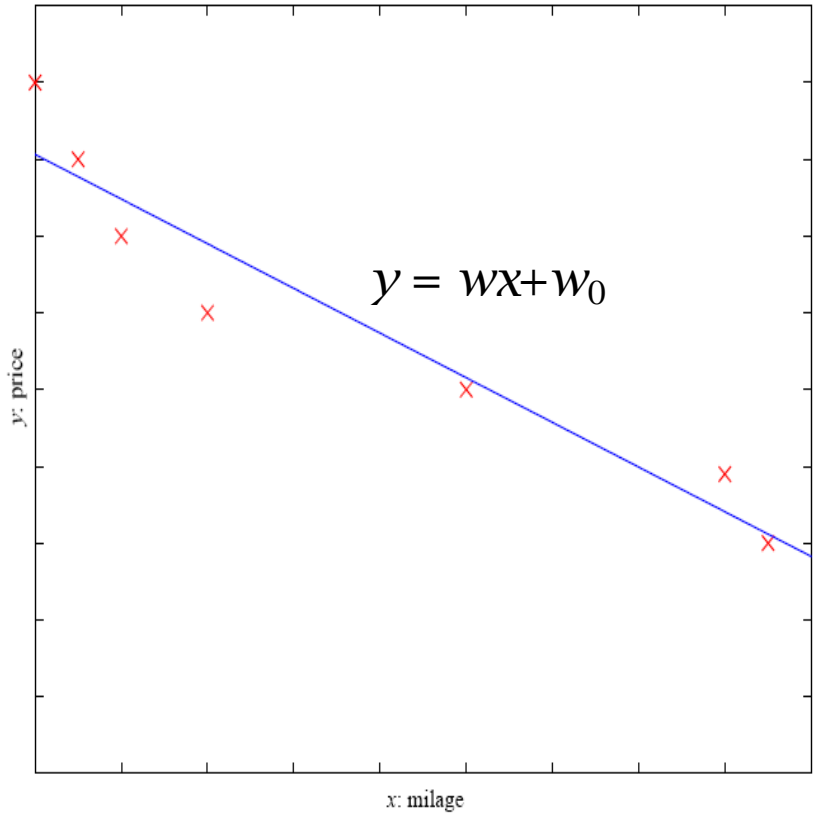
- Example: Price of used cars
- x : car attributes

  y : price

  $y = g(x \mid \theta)$

  $g(\ )$ model,

  θ parameters



Reinforcement Learning

- Learning a policy: A sequence of outputs
- No supervised output but delayed reward
- Credit assignment problem
- Game playing
- Robot in a maze
- Multiple agents, partial observability, ...

Categorization of Learning Systems

- Whether or not trained with human supervision
  - Supervised
    - k-NN, linear regression, logistic regression, support vector machines, decision trees and random forests, neural networks, etc.
  - Unsupervised
    - Clustering (e.g., k-means), dimensionality reduction (e.g., PCA), association rule learning, etc.
  - Semi-supervised
  - Reinforcement learning

Categorization of Learning Systems

- Whether or not learn incrementally on the fly
  - Online learning
  - Batch learning

Categorization of Learning Systems

- Whether compare new data to known data points, or build a predictive model
  - Instance-based learning
  - Model-based learning

Programming Tools

- Examples and assignments will use Python language. Jupyter notebook provides visualized interface.

- The following libraries are necessary for this course:

  Scikit-learn (http://scikit-learn.org), Numpy, Matplotlib, Pandas, …

- **Install Anaconda** (https://www.anaconda.com/download/#macos) first! It includes the whole package including Python and related libraries.

- The examples and code of Aurelien Geron's textbook can be found at https://github.com/ageron/handson-ml

Reference

The lecture notes in this lecture are based on the following textbooks:

T. M. Mitchell, Machine Learning, McGraw Hill, 1997. ISBN: 978-0-07-042807-2

C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006, ISBN: 978-0-387-31073-2.

E. Alpaydin, Introduction to Machine Learning, MIT Press, 2004, ISBN 0-262-01211-1

Part of the slide materials were based on Dr. Rong Duan's Fall 2016 course CPE/EE 695A Applied Machine Learning at Stevens Institute of Technology.

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