

# COMPUTATIONAL INTELLIGENCE SEW

(INTRODUCTION TO MACHINE LEARNING)

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SS 18

2 VO 708.561 + 1 UE 442.074

**Institute for Theoretical Computer Science (IGI)**

TU Graz, Inffeldgasse 16b / first floor

[www.igi.tugraz.at](http://www.igi.tugraz.at)

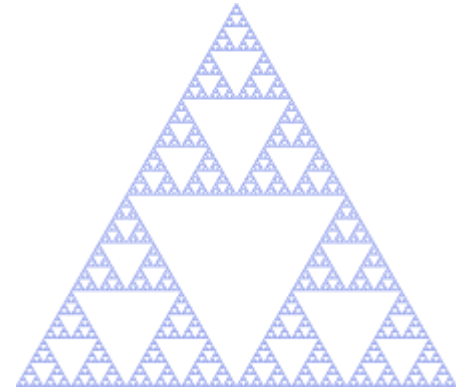
**Institute for Signal Processing and Speech Communication (SPSC)**

TU Graz, Inffeldgasse 16c / ground floor

[www.spsc.tugraz.at](http://www.spsc.tugraz.at)

# Organization

- Lecture / VO:
  - Wednesday, 14:15, HS i13
    - Anand Subramoney and Guillaume Bellec (IGI)
    - Assoc. Prof. Dr. Franz Pernkopf (SPSC)
- Practical / UE:
  - **Exception** for the first class on **Friday 16th of March**, HS i11
  - Standard class **Tuesday**, HS i12
    - 13:00-14:00 – if your last name starts with **A-L**
    - 15:00-16:00 – if your last name starts with **M-Z**
  - Anand Subramoney and Guillaume Bellec (IGI)
  - Dipl.-Ing. Christian Knoll (SPSC)
  - Homework in **teams of up to 3** (use newsgroup to form teams)
- Website: <http://www.spsc.tugraz.at/courses/computational-intelligence>
- Newsgroup: tu-graz.lv.ew



*Part I*

*Part II*

*Part I*

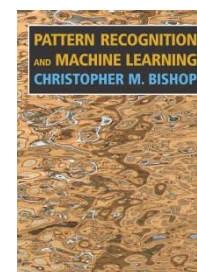
*Part II*

# Organization

- Office hours:
  - Both Anand and Guillaume:
    - Time: Every Tuesday 14:00 – 15:00
    - Place: Our offices at Inffeldgasse 16b/1
- Exam:
  - Written exam for this year's course:
    - July onwards
  - Exam has two parts:
    - IGI (first half of semester) + SPSC (second half)
  - Language: English
  - Positive grade if positive on **both parts!**

# Materials (for IGI part)

- No textbook required
- Lecture slides and further reading on **Teach Center**
- Materials for further study:
  - Online Machine Learning course  
coursera [www.coursera.org/course/ml](http://www.coursera.org/course/ml)  
udacity [de.udacity.com/course/intro-to-machine-learning--ud120](http://de.udacity.com/course/intro-to-machine-learning--ud120)
  - Book by C. Bishop, Pattern Recognition and Machine Learning, Springer 2007.
- For SPSC part (second half):
  - Announced by Franz Pernkopf



# Acknowledgments

- IGI Slides based on material from Stefan Häusler (IGI), Zeno Jonke (IGI), David Sontag (NYU), Andrew Ng (Stanford), Xiaoli Fern (Oregon State)

# INTRODUCTION + MOTIVATION

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# Machine Learning

- Grew out of **Artificial Intelligence**

# What is Artificial Intelligence?

<p>"The exciting new effort to make computers think . . . <i>machines with minds</i>, in the full and literal sense" (Haugeland, 1985)</p> <p>"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)</p>	<p>"The study of mental faculties through the use of computational models" (Charniak and McDermott, 1985)</p> <p>"The study of the computations that make it possible to perceive, reason, and act" (Winston, 1992)</p>
<p>"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990)</p> <p>"The study of how to make computers do things at which, at the moment, people are better" (Rich and Knight, 1991)</p>	<p>"A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkoff, 1990)</p> <p>"The branch of computer science that is concerned with the automation of intelligent behavior" (Luger and Stubblefield, 1993)</p>

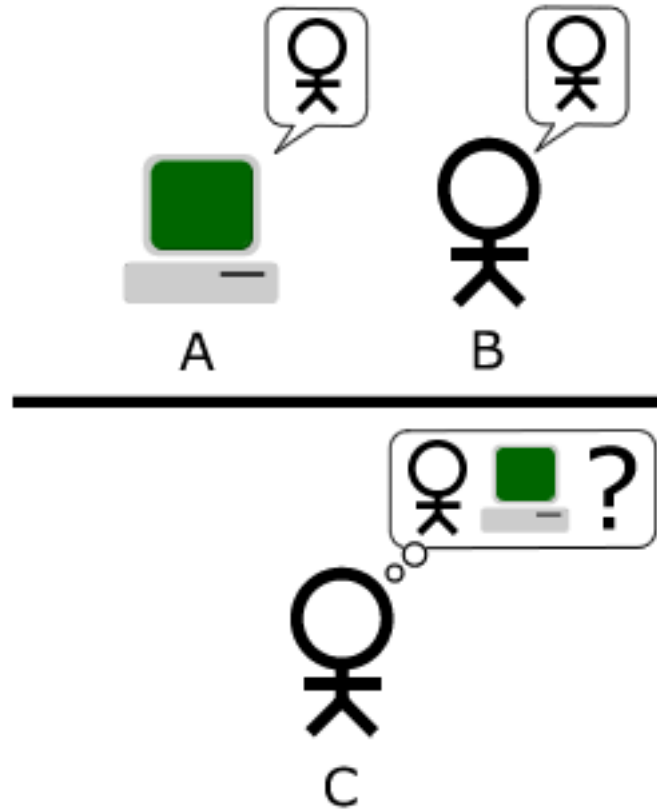
Figure 1.1 Some definitions of AI. They are organized into four categories:

Systems that think like humans.	Systems that think rationally.
Systems that act like humans.	Systems that act rationally.

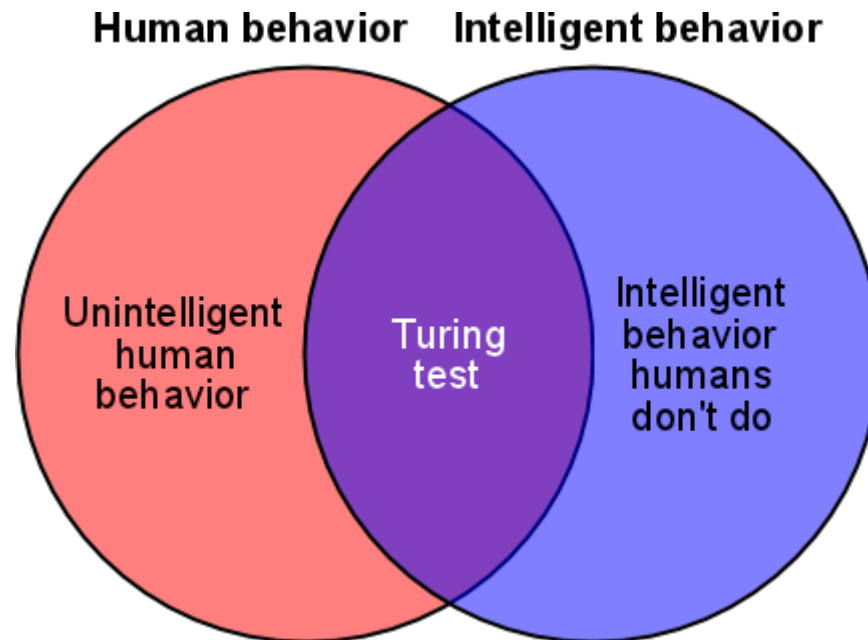


# But what really is AI?

## Turing test



# Turing test



AI – “You’ll know it when you see it”

# Components of AI

- *Natural language processing*
- Knowledge representation
- Automated reasoning
- **Machine learning**
- *Computer vision*
- *Robotics*

-- Russel and Norvig

# Machine Learning

- Grew out of **Artificial Intelligence**
- The ability to “adapt to new circumstances and to detect and extrapolate patterns” – Russel and Norvig
- Arthur Samuel (1959). “Field of study that gives computers the ability to learn without being explicitly programmed.”

# When do we need computers to learn?

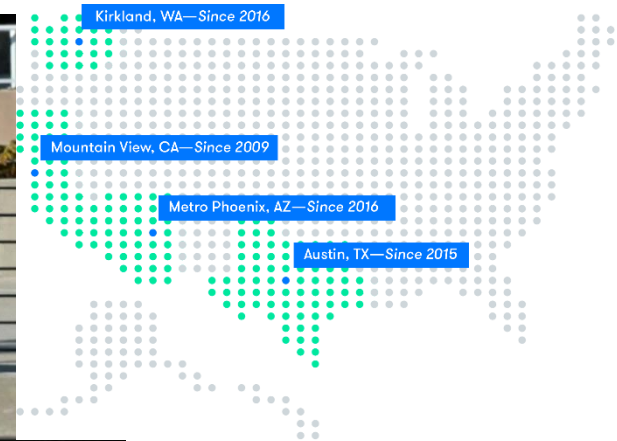
- When human expert knowledge is missing
  - For example, predicting whether some new substance could be an effective treatment for a disease
- When humans can only do it “intuitively”
  - Flying a helicopter
  - Recognize visual objects
  - Natural language processing
- When we need to learn about something that changes frequently
  - Stock market analysis
  - Weather forecasting
  - Computer network routing
- Customized learning
  - Spam filters, movie/product recommendations

# Applications of Machine learning

- Machine learning is used in a wide range of fields including:
  - Bio-informatics
  - Brain-Machine interfaces
  - Computational finance
  - Game playing
  - Information Retrieval
  - Internet fraud detection
  - Medical diagnosis
  - Natural language processing
  - Online advertising
  - Recommender systems
  - Robot locomotion
  - Search engines
  - Sentiment analysis
  - Software engineering
  - Speech and handwriting recognition
  - Stock market analysis
  - Economics and Finance
  - Credit card fraud detection
  - .....

# Autonomous car

- Waymo/Alphabet
  - <https://www.youtube.com/watch?v=TsaES--OTzM>



+ UK, France,  
Switzerland,  
Singapore

# Bipedal robot



- ATLAS (Boston Dynamics/Alphabet)
  - <https://www.youtube.com/watch?v=fRj34o4hN4I> (three month ago)
  - <https://www.youtube.com/watch?v=aFuA50H9uek> (last week)

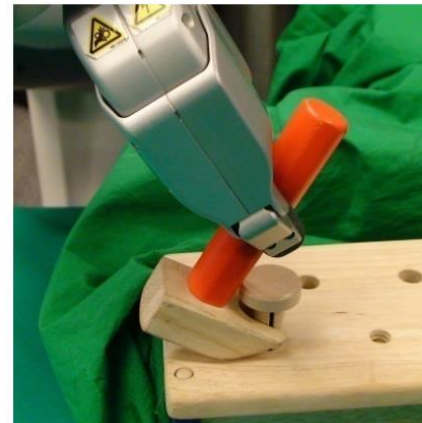
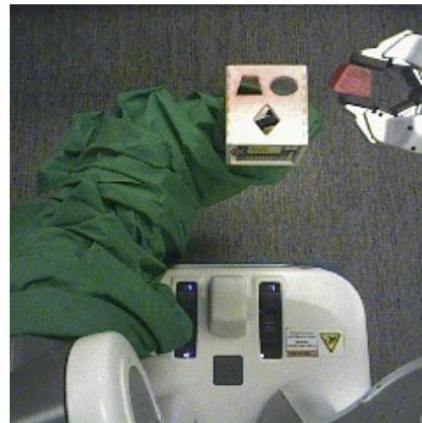
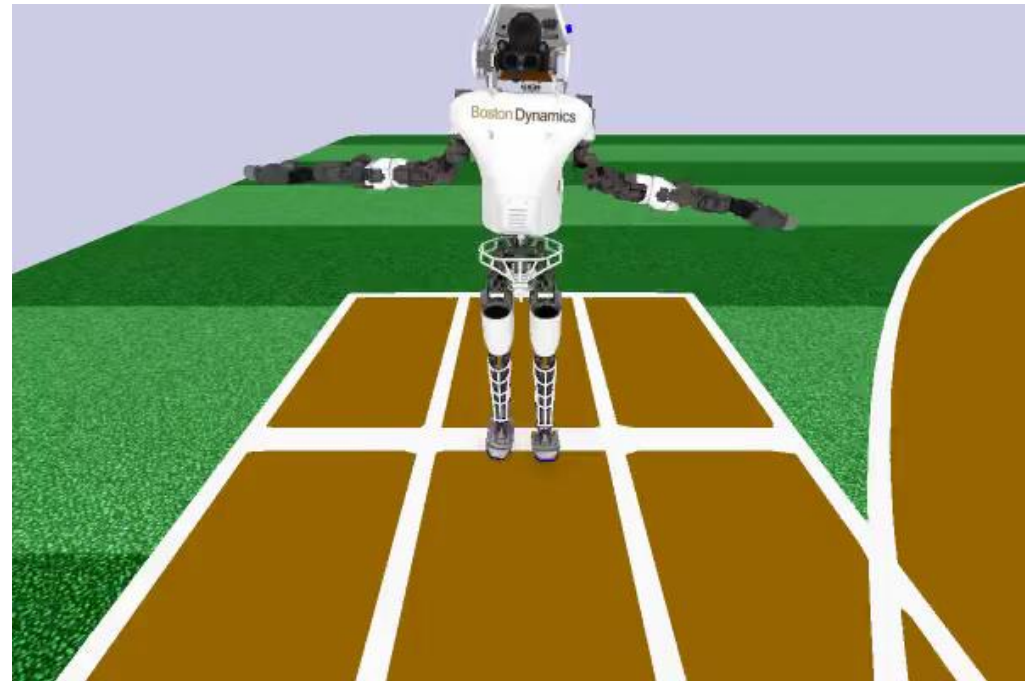




# AI for robotics

- OpenAI (2016) robots cannot only learn from accelerated simulated environments

<https://blog.openai.com/openai-baselines-ppo/>



# Web search

The image shows a Google search interface. At the top left is the Google logo. To its right is a search input field containing the text "learning to rank". Below the input field is a dropdown menu with suggestions: "learning to rank", "learning to rank for information retrieval" (with a link "I'm Feeling Lucky »"), "learning to rank using gradient descent", and "learning to rank tutorial". To the right of the input field is a blue search button with a magnifying glass icon. Below the search bar is a "Search" button. On the left side, there is a vertical navigation menu with options: "Web", "Images", "Maps", "Videos", "News", "Shopping", and "More". Below this menu, there is a location filter for "Manhattan, NY 10012" and a "Change location" button. At the bottom left, there is a "Show search tools" button. The main content area displays search results for "learning to rank". The first result is from Wikipedia, titled "Learning to rank - Wikipedia, the free encyclopedia", with a URL "en.wikipedia.org/wiki/Learning\_to\_rank". The snippet describes it as a type of supervised or semi-supervised machine learning problem. Below this are links for "Applications", "Feature vectors", "Evaluation measures", and "Approaches". The second result is from Yahoo!, titled "Yahoo! Learning to Rank Challenge", with a URL "learningtorankchallenge.yahoo.com/". The snippet states that the challenge is closed and mentions "close competition, innovative ideas, and fierce determination". Below this is a PDF link titled "[PDF] Large Scale Learning to Rank" with a URL "www.eecs.tufts.edu/~dsculley/papers/large-scale-rank.pdf". The snippet mentions "File Format: PDF/Adobe Acrobat - Quick View" and "by D Sculley - Cited by 24 - Related articles". The third result is from Microsoft Research, titled "Microsoft Learning to Rank Datasets - Microsoft Research", with a URL "research.microsoft.com/en-us/projects/mslr/". The snippet says "We release two large scale datasets for research on learning to rank: L2R-WEB30k with more than 30000 queries and a random sampling of it L2R-WEB10K ...". The fourth result is also from Microsoft Research, titled "LETOR: A Benchmark Collection for Research on Learning to Rank ...", with a URL "research.microsoft.com/~letor/". The snippet says "This website is designed to facilitate research in Learning TO Rank (LETOR). Much information about learning to rank can be found in the website, including ...".

Google

learning to rank

learning to rank

learning to rank for information retrieval [I'm Feeling Lucky »](#)

learning to rank using gradient descent

learning to rank tutorial

Search

Web

Images

Maps

Videos

News

Shopping

More

Manhattan, NY 10012

Change location

Show search tools

[Learning to rank - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/Learning\\_to\\_rank](http://en.wikipedia.org/wiki/Learning_to_rank)  
**Learning to rank** or machine-learned ranking (MLR) is a type of supervised or semi-supervised machine learning problem in which the goal is to automatically ...  
[Applications](#) [Feature vectors](#) [Evaluation measures](#) [Approaches](#)

[Yahoo! Learning to Rank Challenge](#)  
[learningtorankchallenge.yahoo.com/](http://learningtorankchallenge.yahoo.com/)  
**Learning to Rank** Challenge is closed! Close competition, innovative ideas, and fierce determination were some of the highlights of the first ever Yahoo!

[\[PDF\] Large Scale Learning to Rank](#)  
[www.eecs.tufts.edu/~dsculley/papers/large-scale-rank.pdf](http://www.eecs.tufts.edu/~dsculley/papers/large-scale-rank.pdf)  
File Format: PDF/Adobe Acrobat - [Quick View](#)  
by D Sculley - [Cited by 24](#) - [Related articles](#)

Pairwise **learning to rank** methods such as RankSVM give good performance, ... In this paper, we are concerned with **learning to rank** methods that can learn on ...

[Microsoft Learning to Rank Datasets - Microsoft Research](#)  
[research.microsoft.com/en-us/projects/mslr/](http://research.microsoft.com/en-us/projects/mslr/)  
We release two large scale datasets for research on **learning to rank**: L2R-WEB30k with more than 30000 queries and a random sampling of it L2R-WEB10K ...

[LETOR: A Benchmark Collection for Research on Learning to Rank ...](#)  
[research.microsoft.com/~letor/](http://research.microsoft.com/~letor/)  
This website is designed to facilitate research in **LEarning TO Rank** (LETOR). Much information about **learning to rank** can be found in the website, including ...

# Image search


- Google image search

<https://images.google.com>



**Search by image** ×

Search Google with an image instead of text. Try dragging an image here.

**Paste image URL** **Upload an image** 

No file chosen

# Face recognition

- Facebook
  - [http://www.youtube.com/watch?v=l4Rn38\\_vrLQ](http://www.youtube.com/watch?v=l4Rn38_vrLQ)
- iPhoto
- Cameras, etc.
  
- Microsoft cognitive services
  - From face, can recognize age, gender, emotions!
  - <https://www.microsoft.com/cognitive-services/>

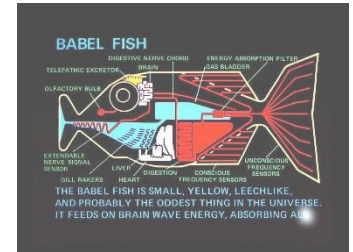


# Scene and text recognition

- Microsoft Seeing AI project
  - <https://www.youtube.com/watch?v=R2mC-NUAmMk>



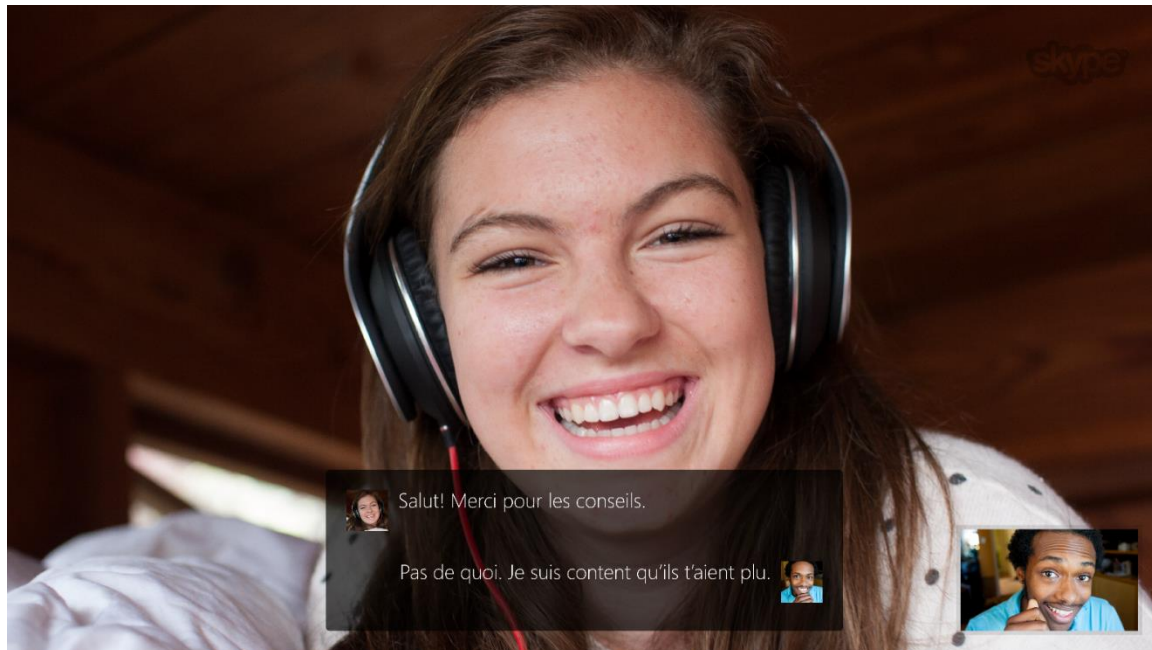
# Machine Translation



- Skype and PowerPoint real-time translation (Microsoft)

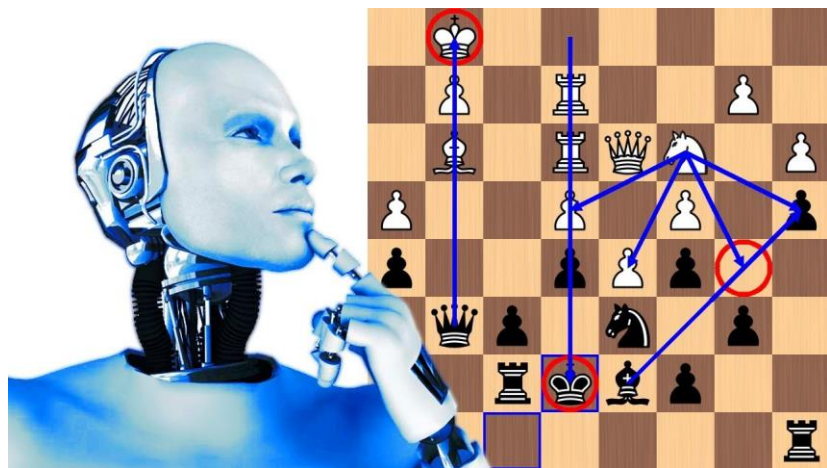
<https://www.youtube.com/watch?v=rek3jjbYRLo>

<https://www.youtube.com/watch?v=u4cJoX-DoiY>



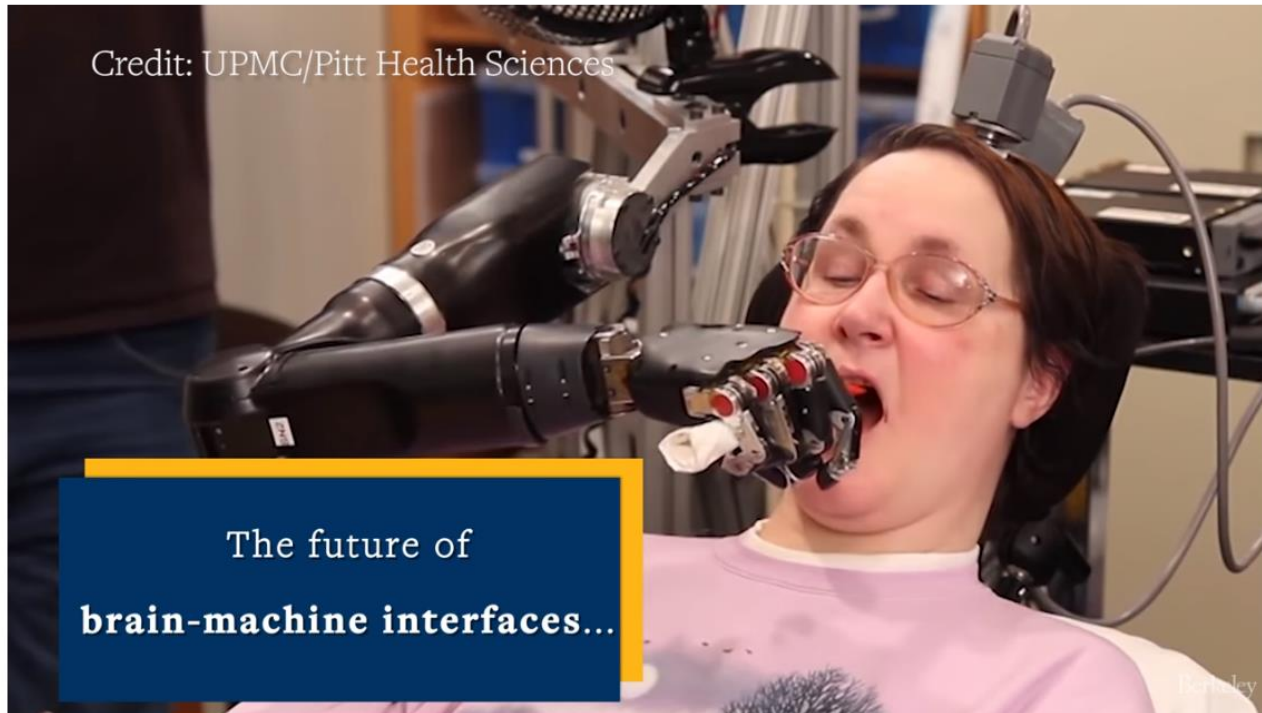
# Learning to reason

- Human level performance at video games from ATARI 2600 (Google Deep mind 2015)
- Beating world champion of GO (G. Deepmind 2016)
- Beating champion chess program (G. Deep mind 2017)



# Brain Computer Interface

- “Neural Dust” tiny neural implants from Berkley (2016)
  - (not much AI in BCI for now but it’s coming)
  - [https://www.youtube.com/watch?v=oO0zy30n\\_jQ](https://www.youtube.com/watch?v=oO0zy30n_jQ)





# CLASSICAL PROBLEMS AND APPLICATIONS

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# Recommender systems

The screenshot shows the Amazon.com interface. At the top, there's the Amazon logo with 'Try Prime' and navigation links for 'David's Amazon.com', 'Today's Deals', 'Gift Cards', 'Sell', and 'Help'. On the right, there are 'Daily Lightning Deals' and 'Back-to-School Savings' with a 'Shop now' link. Below the navigation bar, there's a search bar with 'Books' selected and a 'Go' button. To the right of the search bar, it says 'Hello, David', 'Your Account', 'Try Prime', 'Cart', and 'Wish List'. Below this, there are links for 'Your Amazon.com', 'Your Browsing History', 'Recommended For You', 'Amazon Betterizer', 'Improve Your Recommendations', 'Your Profile', and 'Learn More'. The main content area shows a breadcrumb trail: 'Your Amazon.com > Recommended for You > Books > Subjects > Science & Math > History & Philosophy'. On the left, there's a 'Just For Today' section with 'Browse Recommended' and 'Recommendations History & Philosophy' with sub-links for 'History of Science', 'Philosophy of Biology', and 'Philosophy of Medicine'. The main recommendation area has a header: 'These recommendations are based on [items you own](#) and more.' Below this, there are view options: 'view: All | New Releases | Coming Soon'. There are four book recommendations listed:

- 1. [Causality: Models, Reasoning and Inference](#)**  
by Judea Pearl (September 14, 2009)  
Average Customer Review: (10)  
In Stock  
**List Price:** \$50.00  
**Price:** \$32.49  
61 used & new from \$28.00  
 I own it  Not interested  Rate this item  
Recommended because you purchased [Probabilistic Graphical Models](#) and more (Fix this)
- 2. [The Lady Tasting Tea: How Statistics Revolutionized Science in the Twentieth Century](#)**  
by David Salsburg (May 1, 2002)  
Average Customer Review: (76)  
In Stock  
**List Price:** \$18.99  
**Price:** \$13.88  
81 used & new from \$9.00  
 I own it  Not interested  Rate this item  
Recommended because you added [The Theory That Would Not Die](#) to your Wish List (Fix this)
- 3. [The Eighth Day of Creation: Makers of the Revolution in Biology, 25th Anniversary Edition](#)**  
by Horace Freeland Judson (November 1, 1996)  
Average Customer Review: (10)  
In stock on September 4, 2013  
**List Price:** \$56.00  
**Price:** \$36.09  
59 used & new from \$26.95  
 I own it  Not interested  Rate this item  
Recommended because you purchased [Molecular Biology of the Cell](#) (Fix this)
- 4. [The Machinery of Life](#)**  
by David S. Goodsell (April 28, 2009)  
Average Customer Review: (41)  
In Stock  
**List Price:** \$25.00  
**Price:** \$17.49  
92 used & new from \$12.00

# Netflix

- Machine learning competition with a \$1 million prize



# Spam filtering

- "Spam in email started to become a problem when the Internet was opened up to the general public in the mid-1990s. It grew exponentially over the following years, and today composes some 80 to 85% of all the email in the world, by a "conservative estimate".
- Source: <http://en.wikipedia.org/wiki/Spamming>

**data**

**Natural \_LoseWeight SuperFood Endorsed by Oprah Winfrey, Free Trial 1 bottle, pay only \$5.95 for shipping mfw rlk** Spam | X

☆ **Jaquelyn Halley** to nherrlein, bcc: thehorney, bcc: ang [show details](#) 9:52 PM (1 hour ago) [Reply](#) ▼

=== Natural WeightLOSS Solution ===

Vital Acai is a natural WeightLOSS product that Enables people to lose wieght and cleansing their bodies faster than most other products on the market.

Here are some of the benefits of Vital Acai that You might not be aware of. These benefits have helped people who have been using Vital Acai daily to Achieve goals and reach new heights in there dieting that they never thought they could.

- \* Rapid WeightLOSS
- \* Increased metabolism - BurnFat & calories easily!
- \* Better Mood and Attitude
- \* More Self Confidence
- \* Cleanse and Detoxify Your Body
- \* Much More Energy
- \* BetterSexLife
- \* A Natural Colon Cleanse

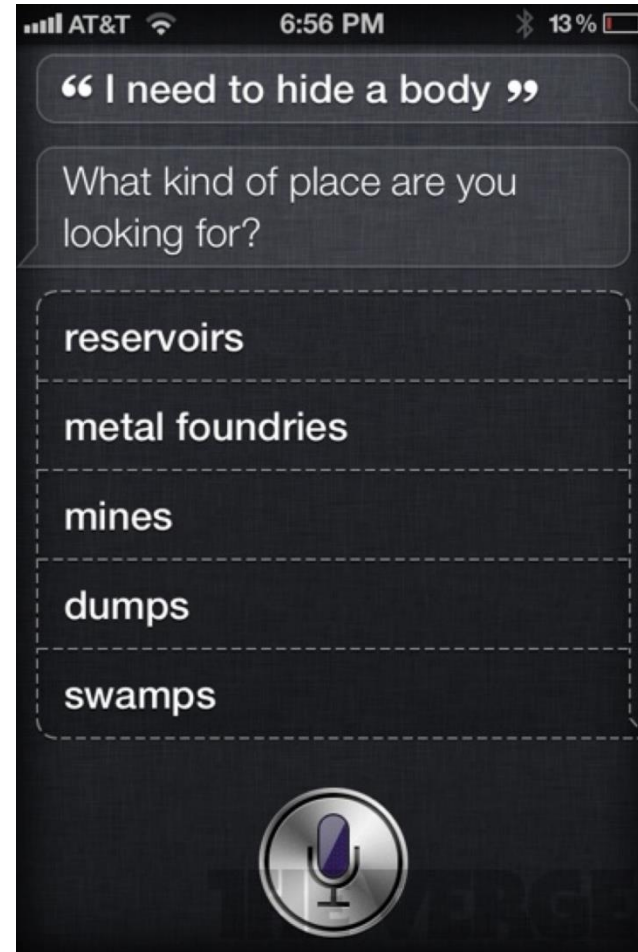
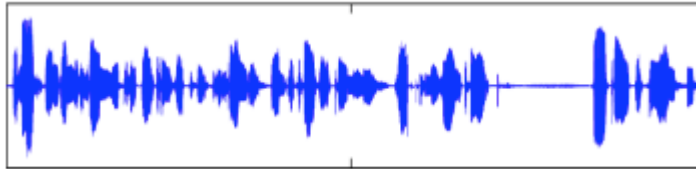
<http://sfsl.kaeconomic.cn>  
<http://sivk.kaeconomic.cn>

**prediction**



Spam  
vs.  
Not Spam

# Speech recognition

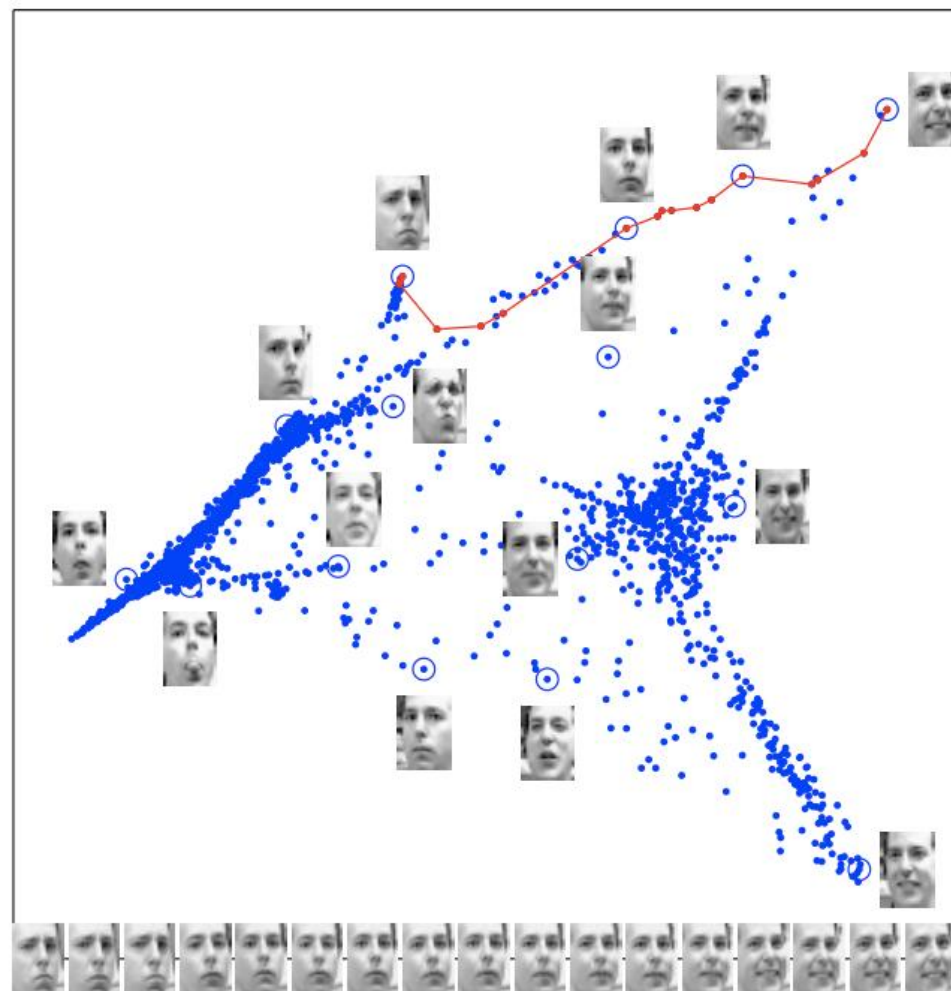


Siri:

<http://www.youtube.com/watch?v=8ciagGASro0>

# Data visualization (Embedding images)

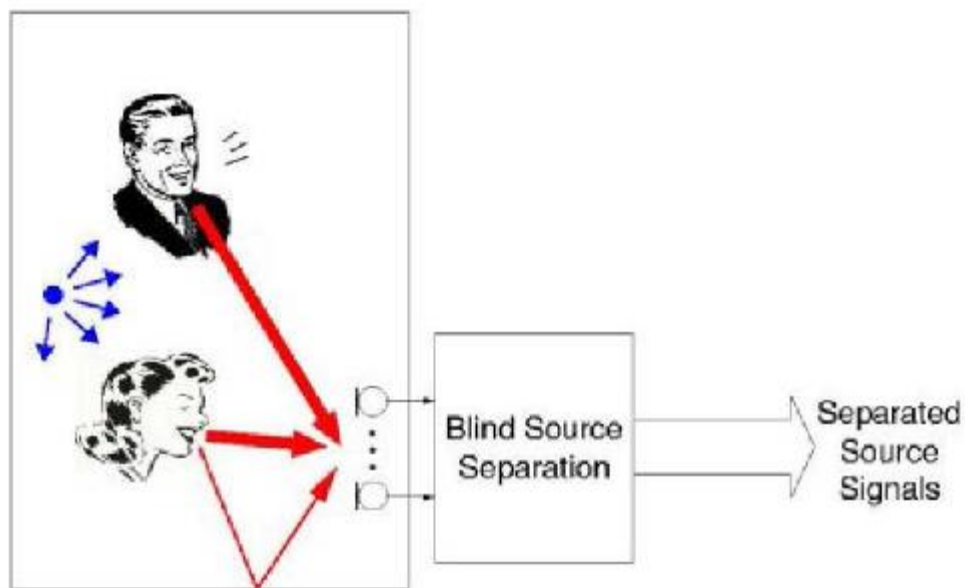
- Images have thousands or millions of pixels.
- Can we give each image a coordinate, such that similar images are near each other?



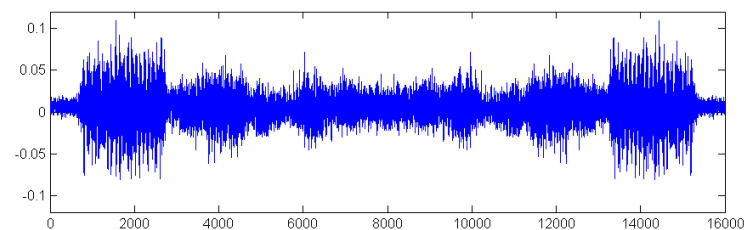
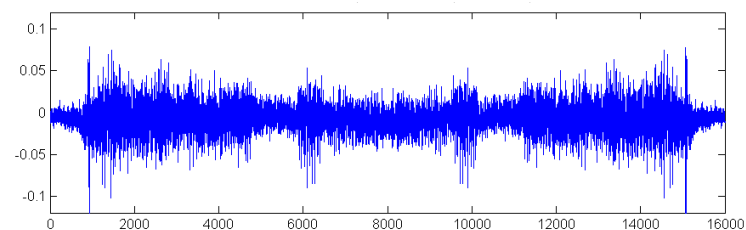
[Saul & Roweis '03]

# Cocktail party problem

Blind source separation



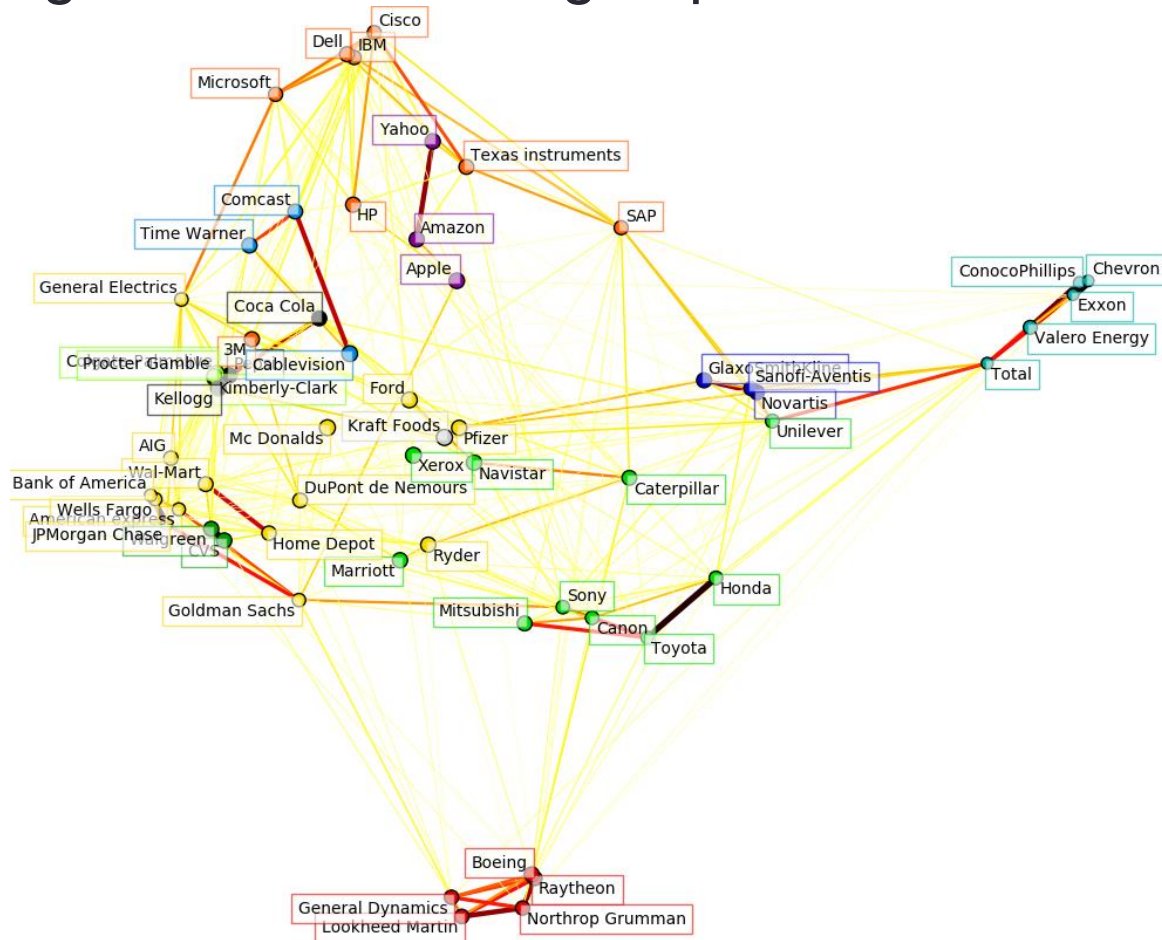
Independent component analysis



Time [ms]

# Clustering

- Clustering data into similar groups





# Clustering images



# Growth of Machine Learning

- Preferred approach to
  - Speech recognition, Natural language processing
  - Computer vision
  - Robot control
  - Computational biology
  - ....
- Accelerating trend
  - Big data (data mining)
  - Improved algorithms
  - Faster computers
  - Availability of good open-source software and datasets

# Some of the future challenges

- The scientific challenges
  - Learning from fewer data (1-shot learning)
  - Generalization
  - Energy efficient hardware and algorithms
  - Understanding animal intelligence
- Ethical issues of AI
  - Privacy
  - Intelligent weapons
  - Replacing artisans with robots

# COURSE CONTENT

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# What we will cover

- IGI part:

- Introduction
- Linear regression
- Non-linear basis functions
- Logistic regression
- Under- and over-fitting
- Model selection
- k-NN
- Cross-validation
- Regularization
- Neural networks
- SVM
- Kernel methods
- Multiclass classification

- SPSC part:

- Parametric & non-parametric density estimation
- Bayes classifier
- Gaussian mixture model
- K-means
- Markov model & Hidden Markov model
- Graphical models
- PCA
- LDA

# INTRODUCTION: TYPES OF ML ALGORITHMS

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# Types of Machine Learning algorithms

- Supervised learning

- Given: Training examples **with target values**
- Goal: Predict target values for new examples
- Examples: optical character recognition, speech recognition, etc.

- Unsupervised learning

- Given: Training examples **without** target values
- Goal: Detect and extract structure from data
- Examples: clustering, segmentation, embedding (visualization), compression, automatic speaker separation

- Reinforcement learning (not in this course)

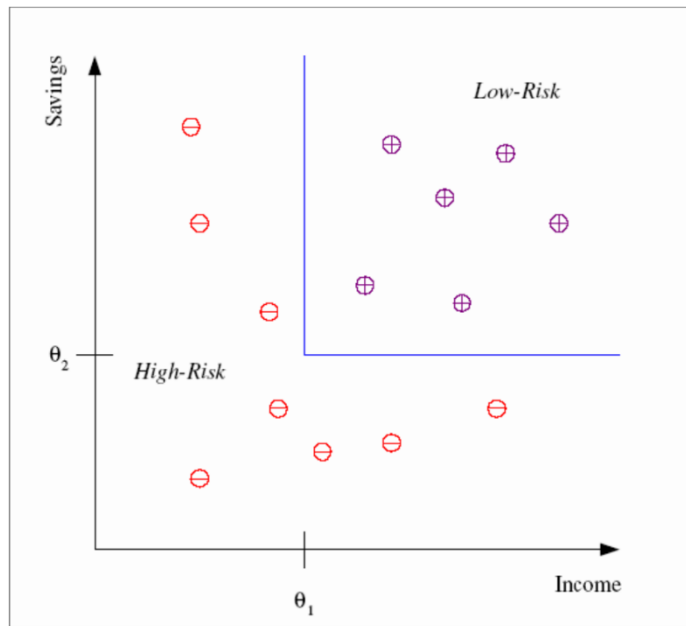
- Given: Feedback (reward/cost) during trial-and-error episodes
- Goal: Maximize Reward/minimize cost
- Examples: learning to control a robot/car/helicopter etc.
- see Master's course "Autonomously Learning Systems"

*Learning from examples (data)*

*Learning by doing (trial and error)*

# Supervised Learning: Example

- Learn to predict output from input (*learning from examples*)
  - Target values (output) can be continuous (regression) or discrete (classification)
  - E.g. predict the risk level (high vs. low) of a loan applicant based on income and savings



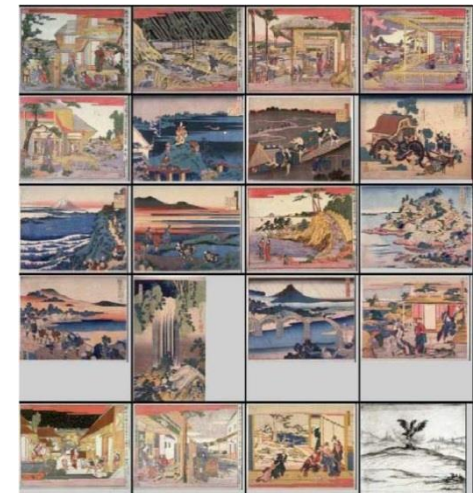
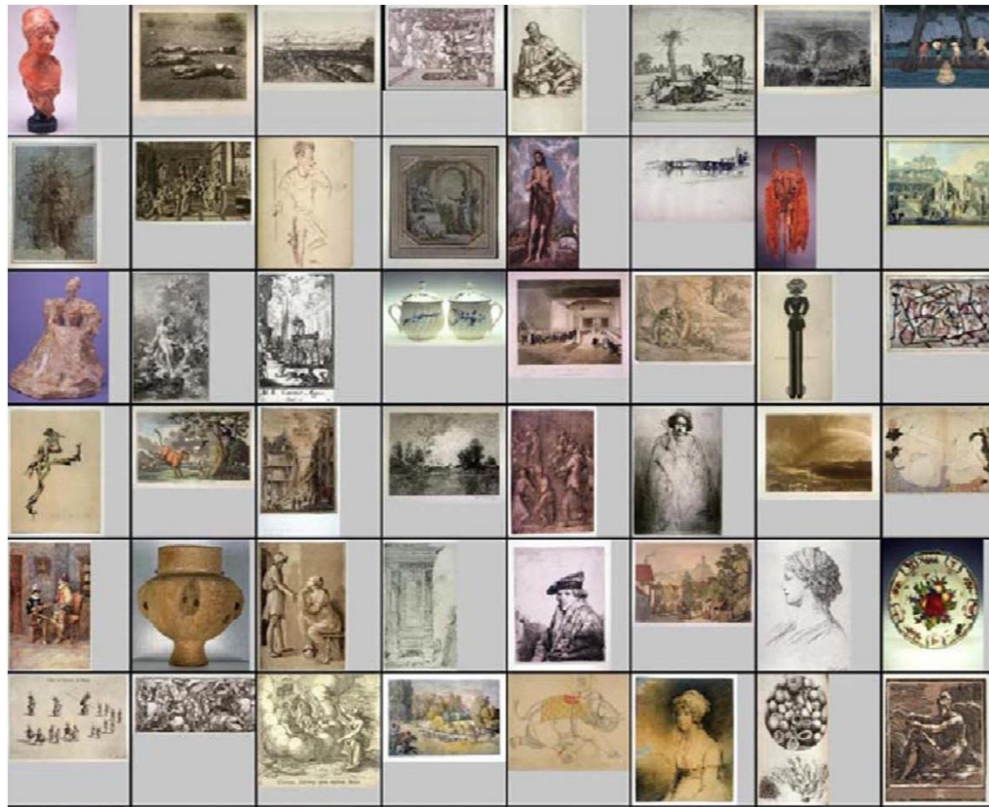
## Applications:

- *Spam filters*
- *Character recognition*
- *Speech recognition*
- *Collaborative filtering (predicting if a customer will be interested in an advertisement ...)*
- *Medical diagnosis*
- ...



# Unsupervised Learning: Example

- 90% of collected data is unlabeled
- Ex. Find patterns and structure in data



Clustering art

# Unsupervised Learning: Applications

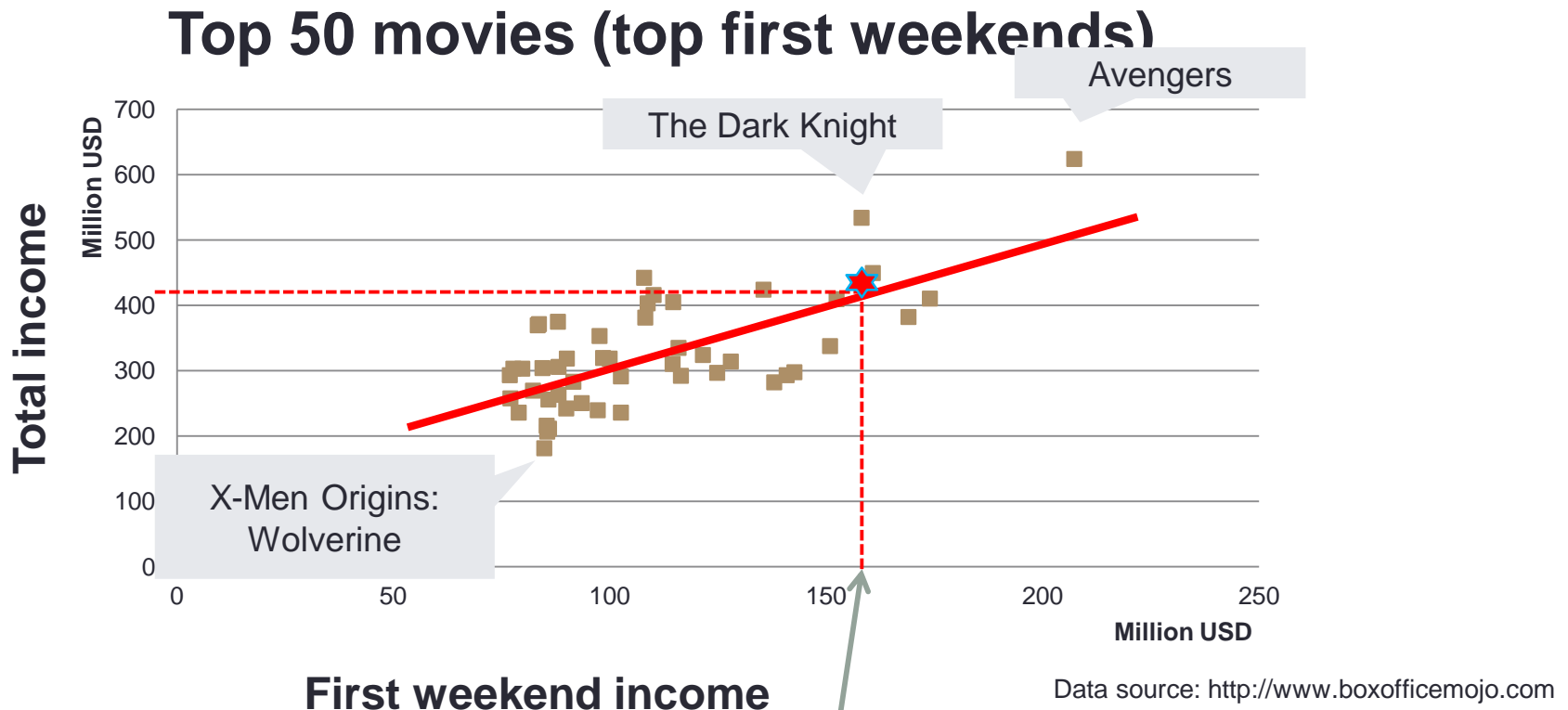
- Market partition: divide a market into distinct subsets of customers
  - Find clusters of similar customers, where each cluster may conceivably be selected as a market target to be reached with a distinct marketing strategy
- Data representation: Image, document, web clustering
  - Automatic organization of pictures
  - Generate a categorized view of a collection of documents
  - For organizing search results etc.
- Bioinformatics
  - Clustering the genes based on their expression profile
  - Find clusters of similarly regulated genes – functional groups

# INTRODUCTION: SUPERVISED LEARNING

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Regression and classification

# Simple regression example



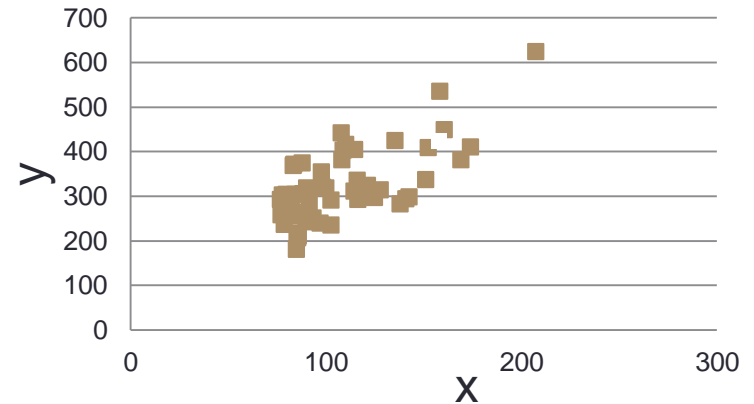
„The Hunger Games: Catching Fire“: **158 Mio. USD** on opening weekend.  
**How much in total?**

Predicted: ~418 Mio., Actual: 424 Mio.

# Simple regression example (cont'd)

- **Data set:** Input  $x^{(i)}$ , Output  $y^{(i)}$

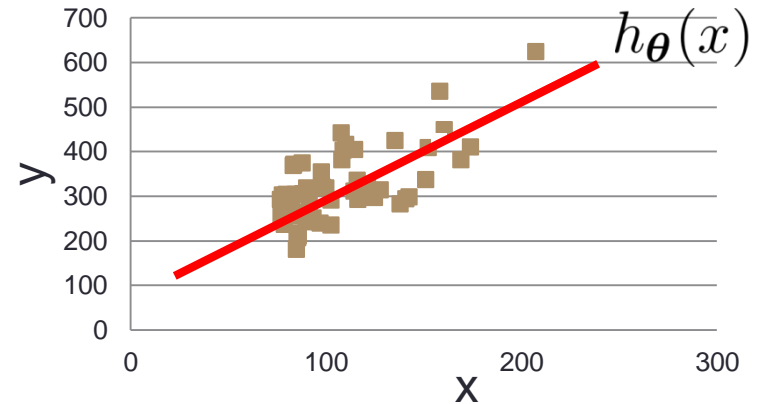
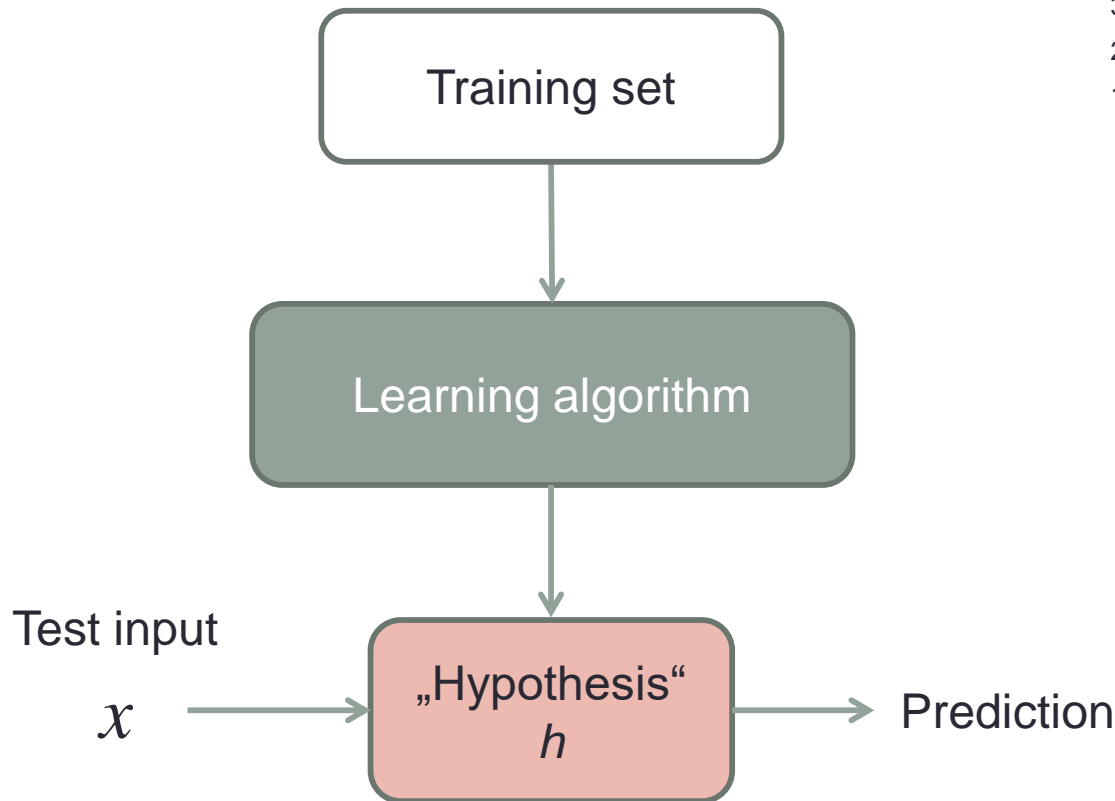
$i$	First weekend $x^{(i)}$	Total $y^{(i)}$
<b>Avengers</b>	207	623
<b>Iron Man 3</b>	174	409
<b>Harry Potter and the Deathly...</b>	169	381
<b>The Dark Knight Rises</b>	161	449
<b>The Dark Knight</b>	158	533
...	...	...



}  $m$  data points  
(data samples)

# Simple regression example (cont'd)

- **Data set:**  $\langle x^{(1)}, y^{(1)} \rangle \dots \langle x^{(m)}, y^{(m)} \rangle$



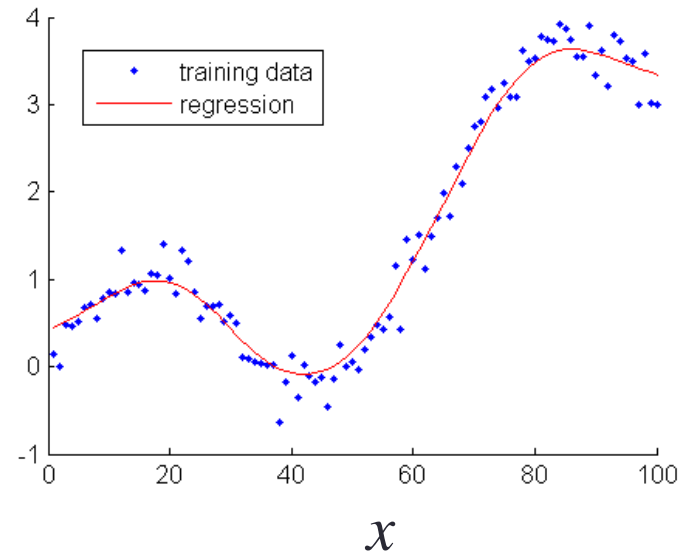
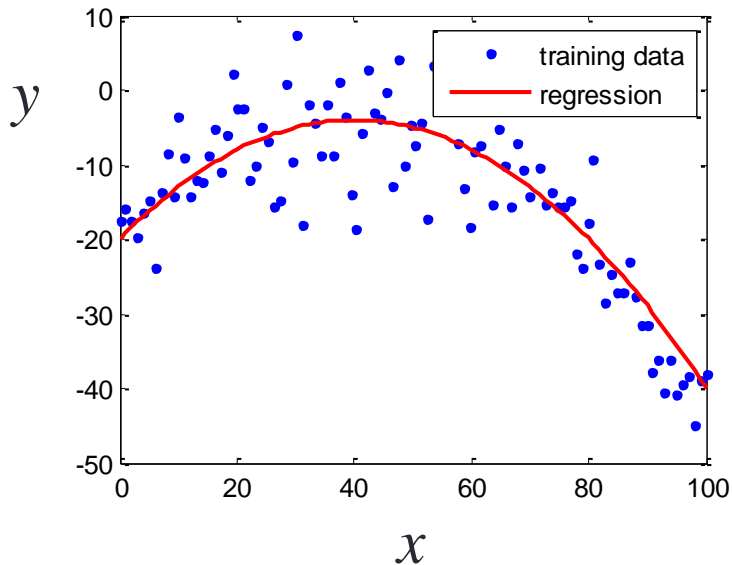
Hypothesis

$$h_{\theta}(x) = \theta_0 + \theta_1 \cdot x$$

Parameters

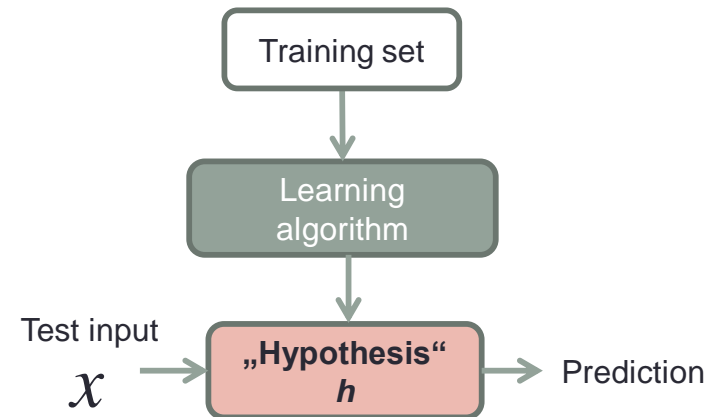
$$\theta = (\theta_0, \theta_1)$$

# Non-linear regression

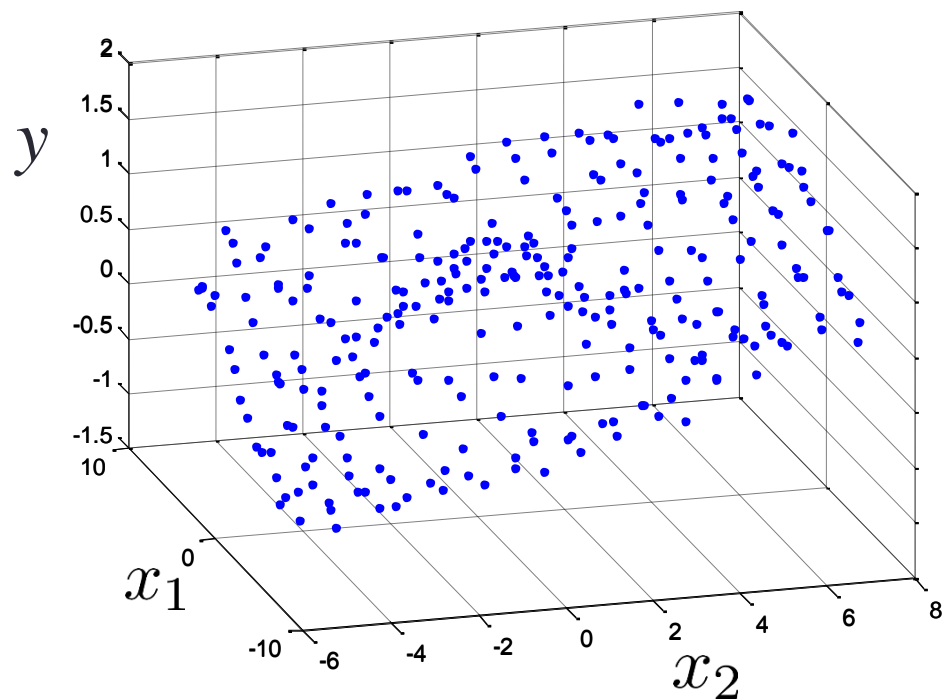


Non-linear hypothesis, for example

$$h_{\theta}(x) = \theta_0 + \theta_1 \cdot x + \theta_2 \cdot x^2$$

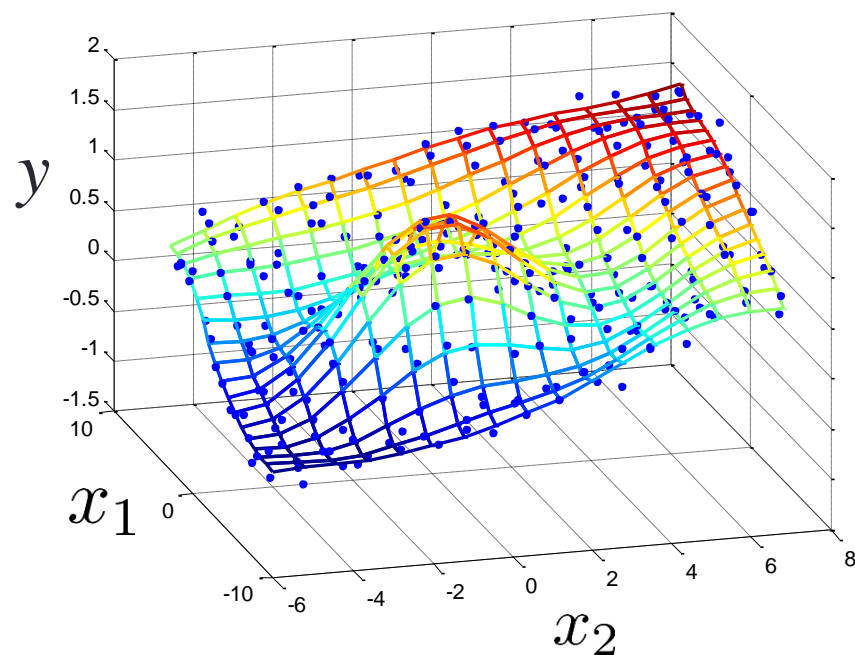


# Regression with multiple inputs



linear hypothesis

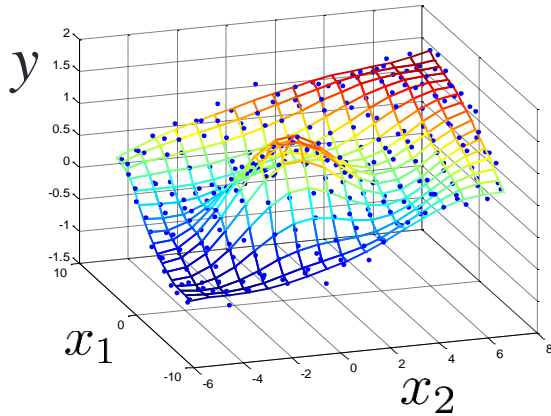
$$h_{\theta}(x_1, x_2) = \theta_0 + \theta_1 \cdot x_1 + \theta_2 \cdot x_2$$



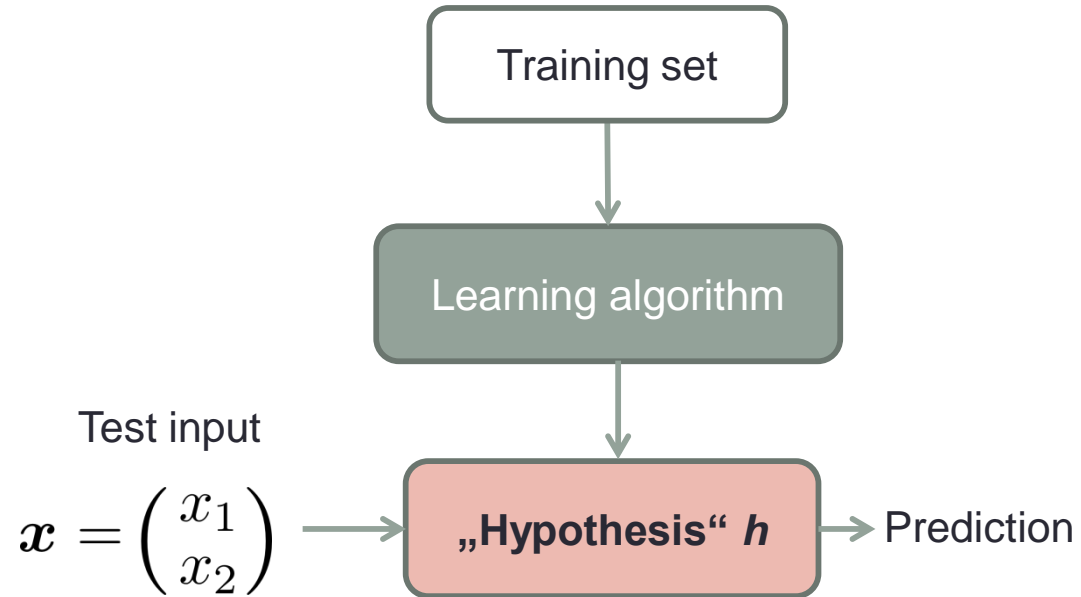
non-linear hypothesis



# Multiple inputs continued



$i$	$x_1^{(i)}$	$x_2^{(i)}$	$y^{(i)}$
1	5.3	-2.1	2.31
2	0.4	3.5	-1.3
3	1.2	0.9	1.9
4	-0.3	0.1	-0.7
5	...	...	...

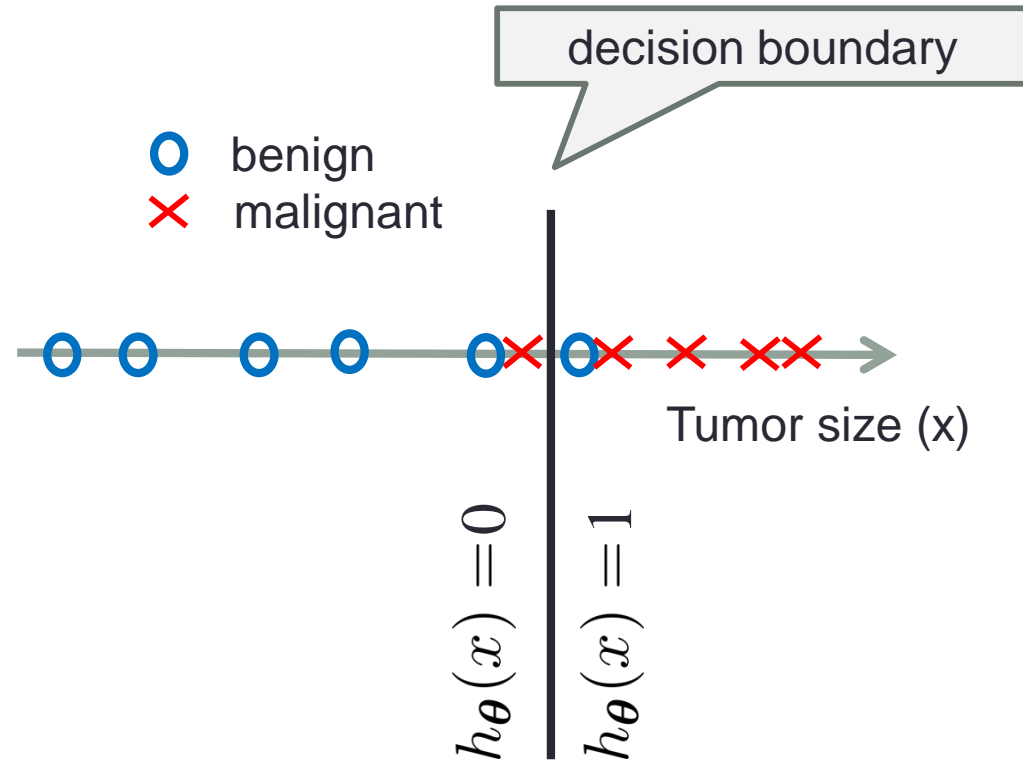


# Simple classification example

„labeled data“

$i$	Tumor size (mm) $x$	Malignant? $y$
1	2.3	0 (N)
2	5.1	1 (Y)
3	1.4	0 (N)
4	6.3	1 (Y)
5	5.3	1 (Y)
	...	...

↑  
labels

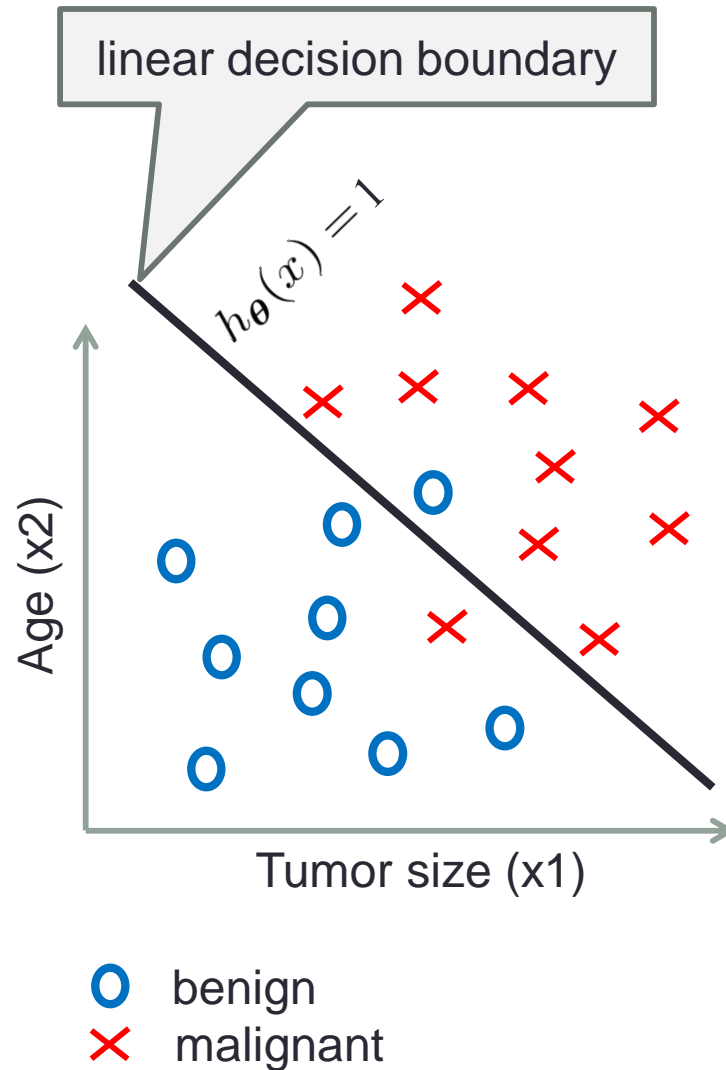


Example hypothesis:

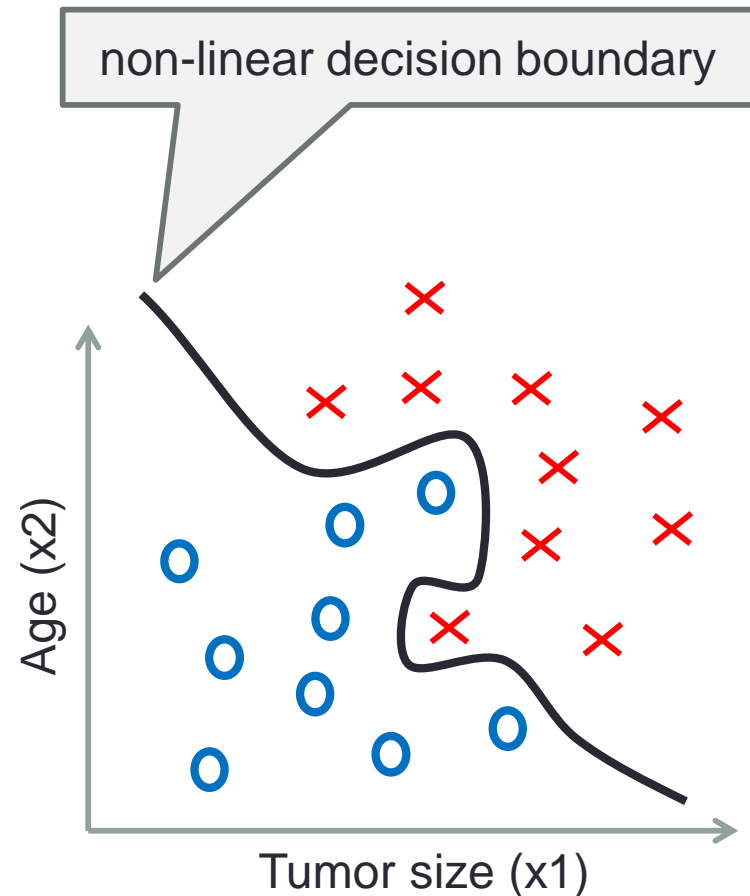
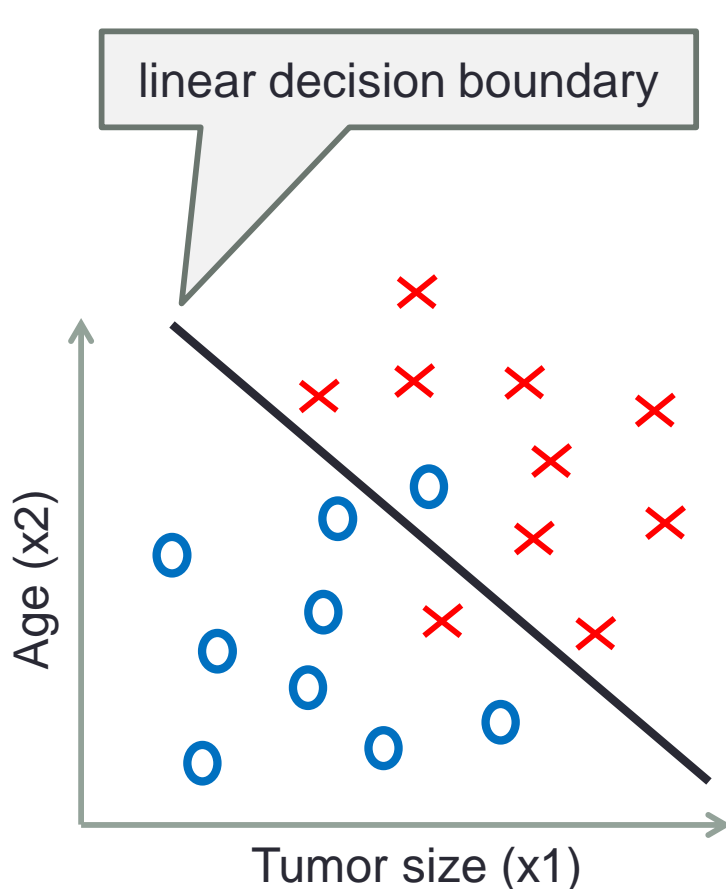
$$h_{\theta}(x) = 1 \quad \text{if } x > \theta_0$$

# Classification with multiple inputs

$i$	Tumor size (mm)	Age	Malignant?
	$x_1$	$x_2$	$y$
1	2.3	25	0 (N)
2	5.1	62	1 (Y)
3	1.4	47	0 (N)
4	6.3	39	1 (Y)
5	5.3	72	1 (Y)
	...		...



# Non-linear classification



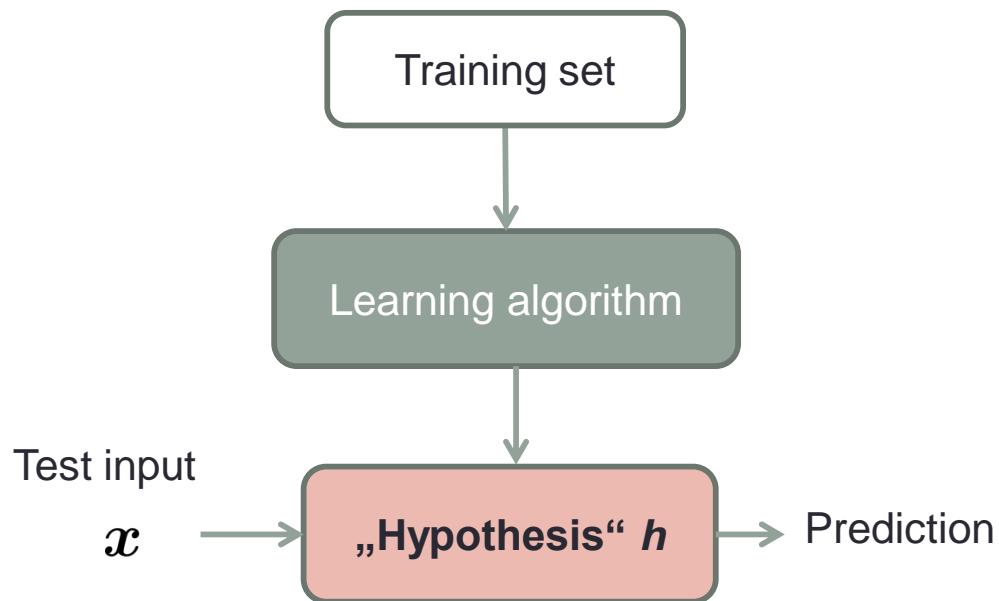
Both hypotheses fit the data quite well.  
Which one fits the **training data** better?  
Which one would you trust more for **prediction**?

# Supervised learning (Regr., Class.)

- Discrete vs. continuous outputs (classification vs. regression)

*In the next few classes we'll cover:*

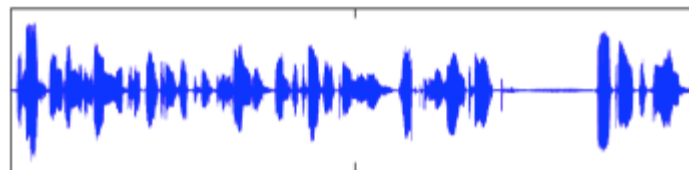
- **Learning algorithms** for regression and classification (linear regression, neural nets, SVMs, etc.)
- Supervised learning **in practice** (overfitting, etc.)



# How to extend to images or sound ?

- Find the best way to represent the data as vectors  
(i.e. tables of numbers)
- Light intensity of each pixel for images, time-wise amplitude of air pressure for sounds

1 1 5 4 3  
7 5 3 5 3  
5 5 9 0 6  
3 5 2 0 0



- Knowing the data structure helps to design better representations. When the data is compressed into a lower dimensions recognition is made easier.

# What is next?

- Linear regression
- Gradient descent
- Non-linear basis functions

# Supervised, unsupervised or Reinforcement Learning ?

1 1 5  
7 5 3  
5 5 9  
3 5 2



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[research.microsoft.com/en-us/projects/mslr/](http://research.microsoft.com/en-us/projects/mslr/)  
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# Regression or classification ?

1 1 5  
7 5 3  
5 5 9  
3 5 2



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