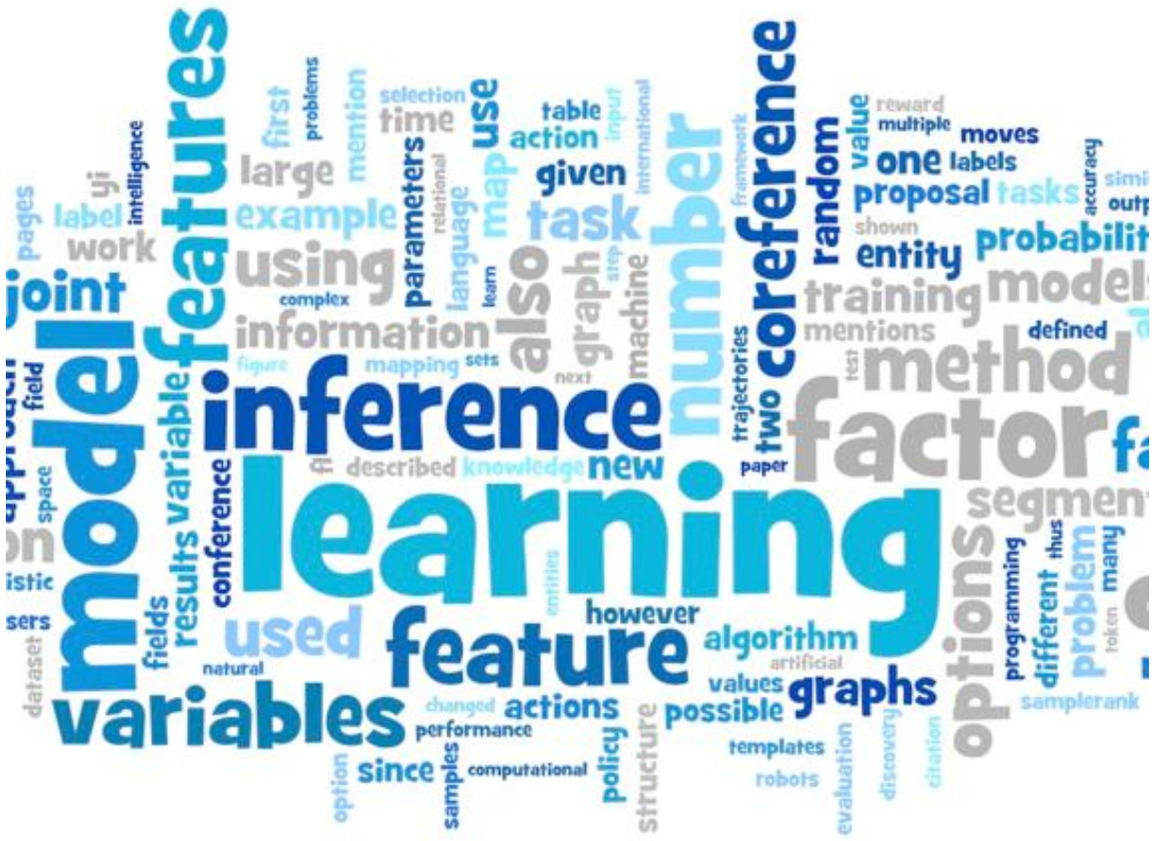
Multimodal Processing, Recognition and Interaction



Summary

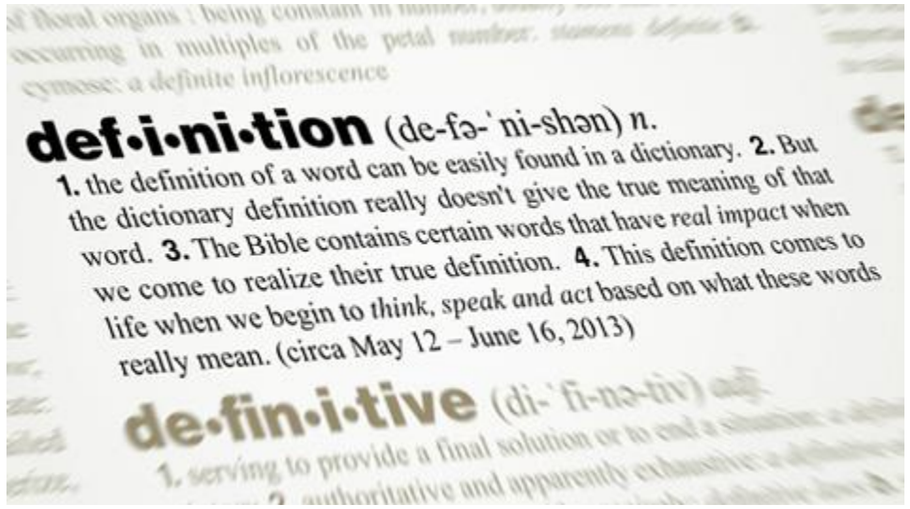
- Multimodal processing, recognition and interaction
- What is machine learning
- Supervised learning
- Unsupervised learning
- Machine learning information flow

Multimodality

- Goals:
  - Integrate computational skills of computers in the real world
  - Extend perceptual and cognitive human capabilities

Multimodality: definition

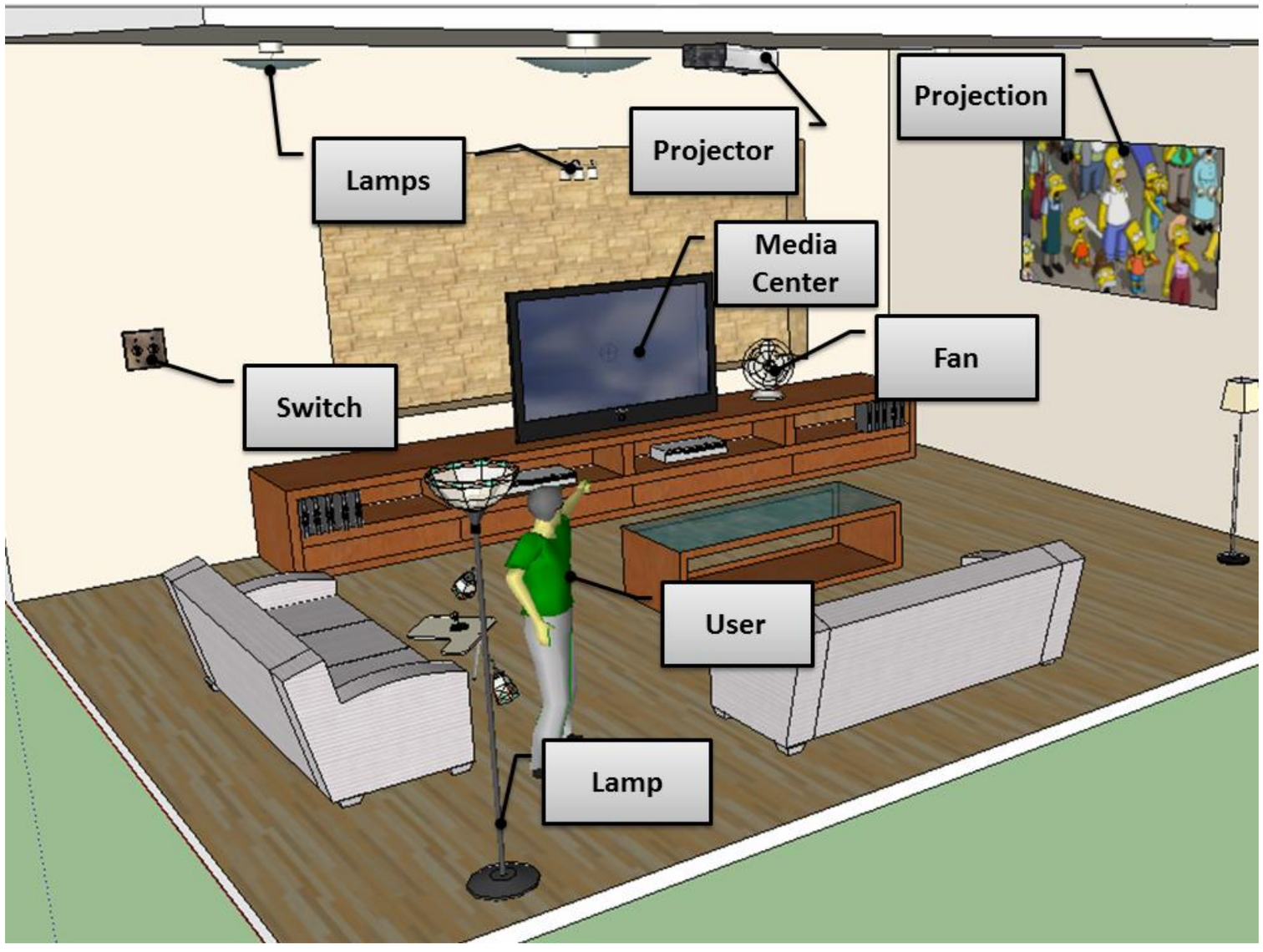
- **Modality** – A channel or path of communication between the human and the computer.

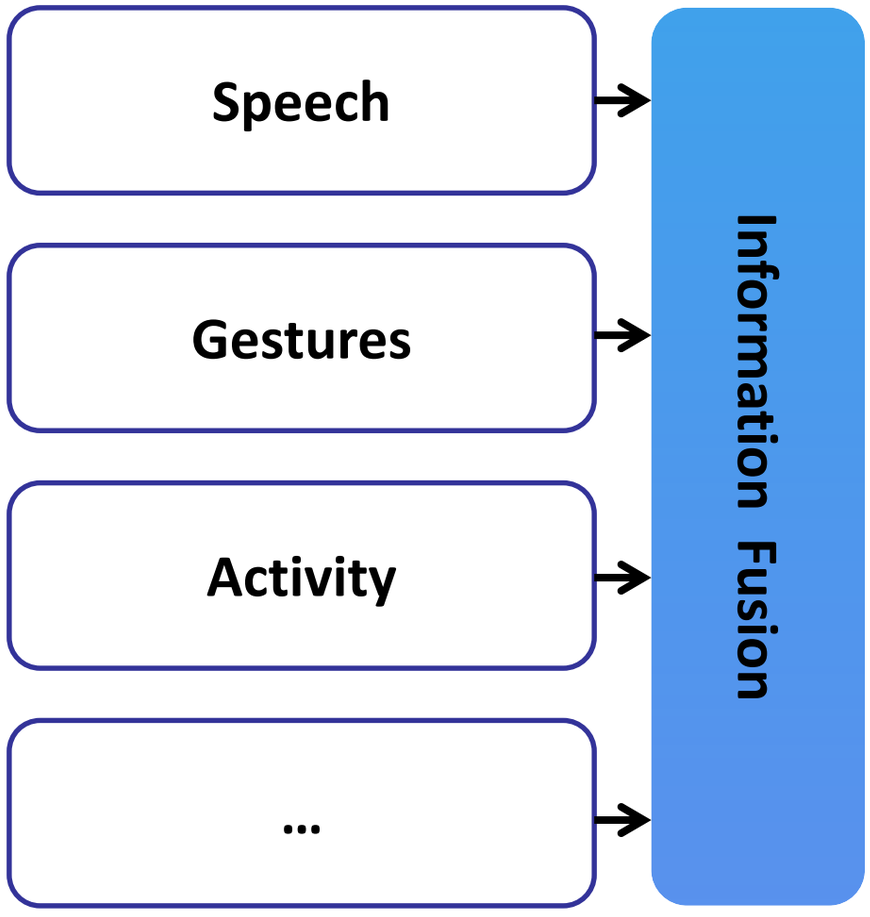


- **Multimodality**[1] – The two features that define a multimodal system are:
  - Fusion of different types of data;
  - Real-time processing: Temporal constraints imposed on information processing;

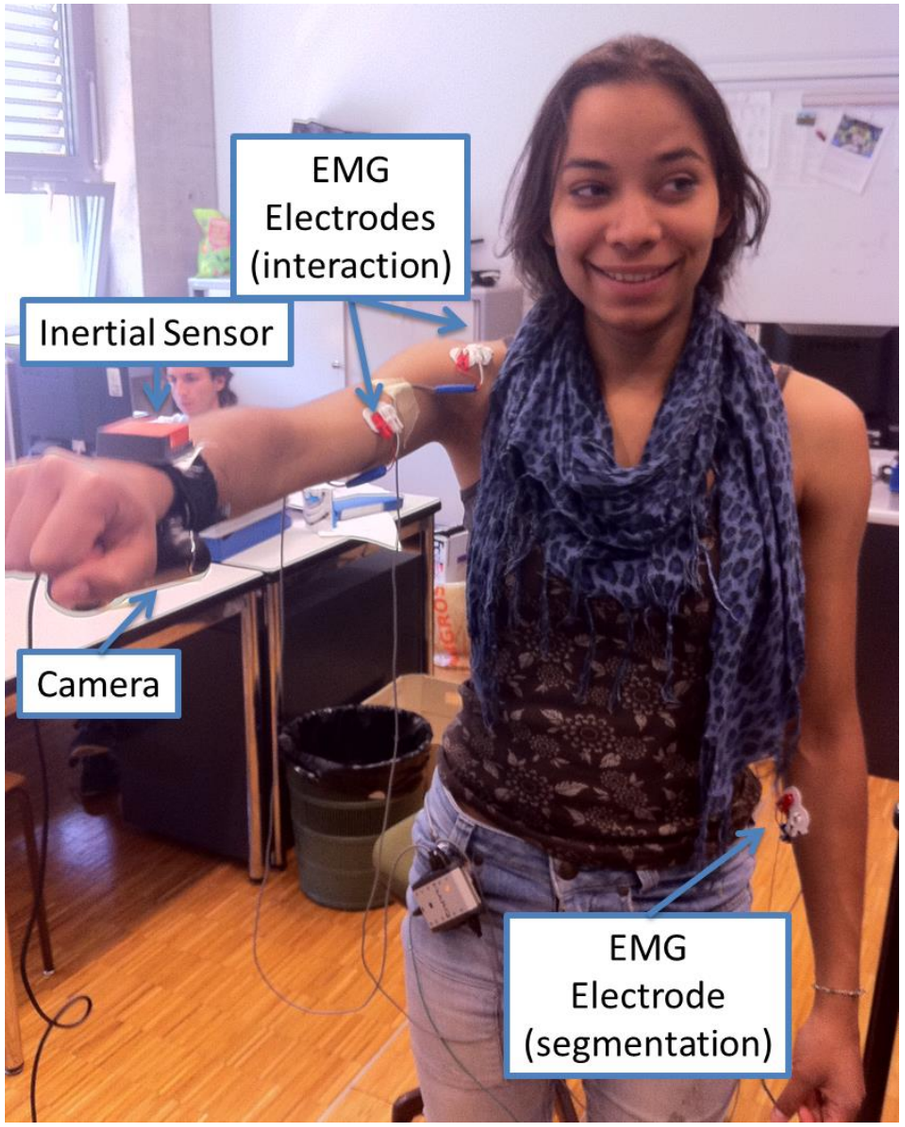
1 - Definition of (Nigay & Coutaz, 1993)

Example 1: Multimodality as multiple interaction channels



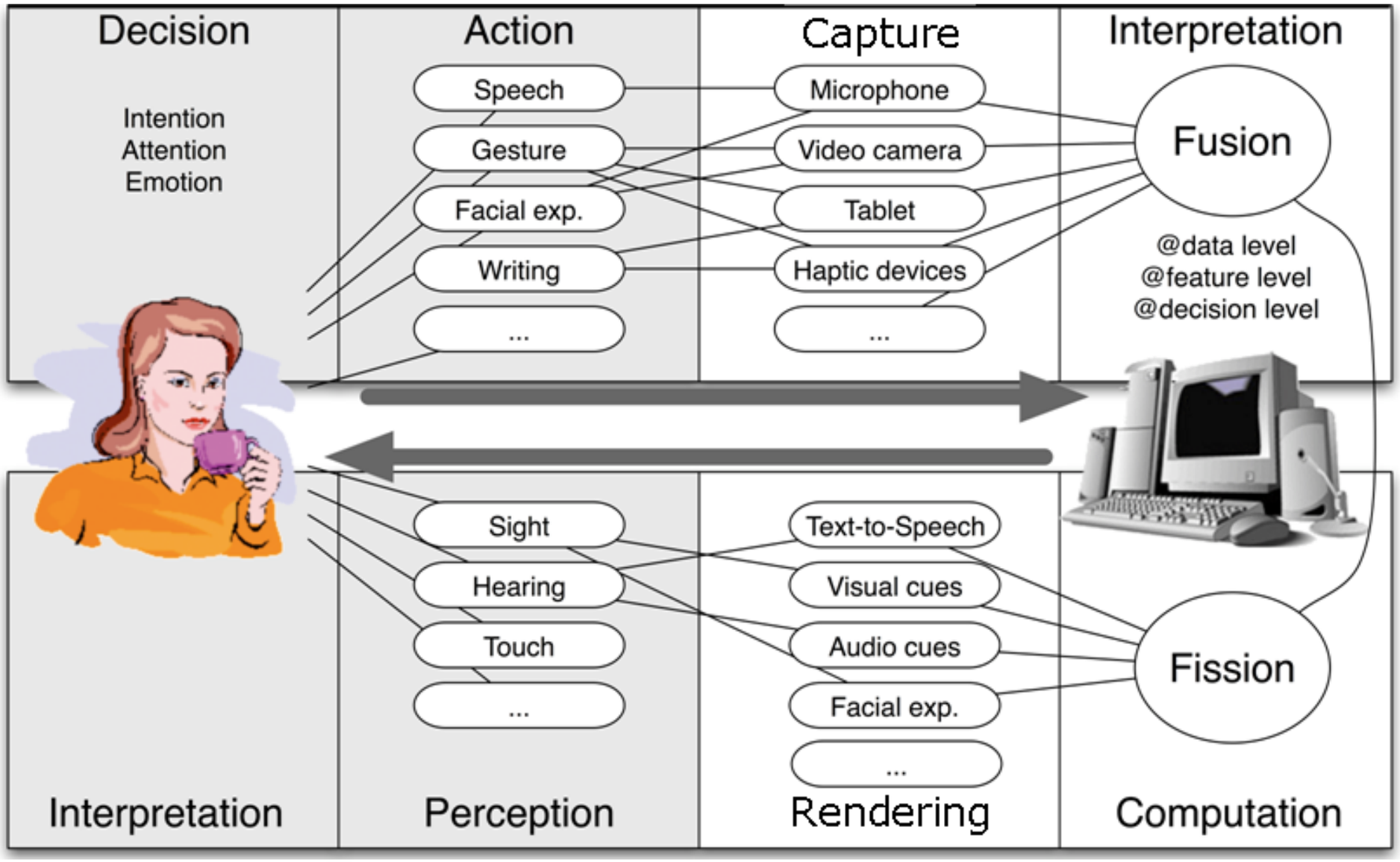


Example 2: Multimodality as fusion of different data types



- Multiple signals:
  - Cameras
  - Accelerometers
  - Physiological data
  - …

Multimodal H/M interaction

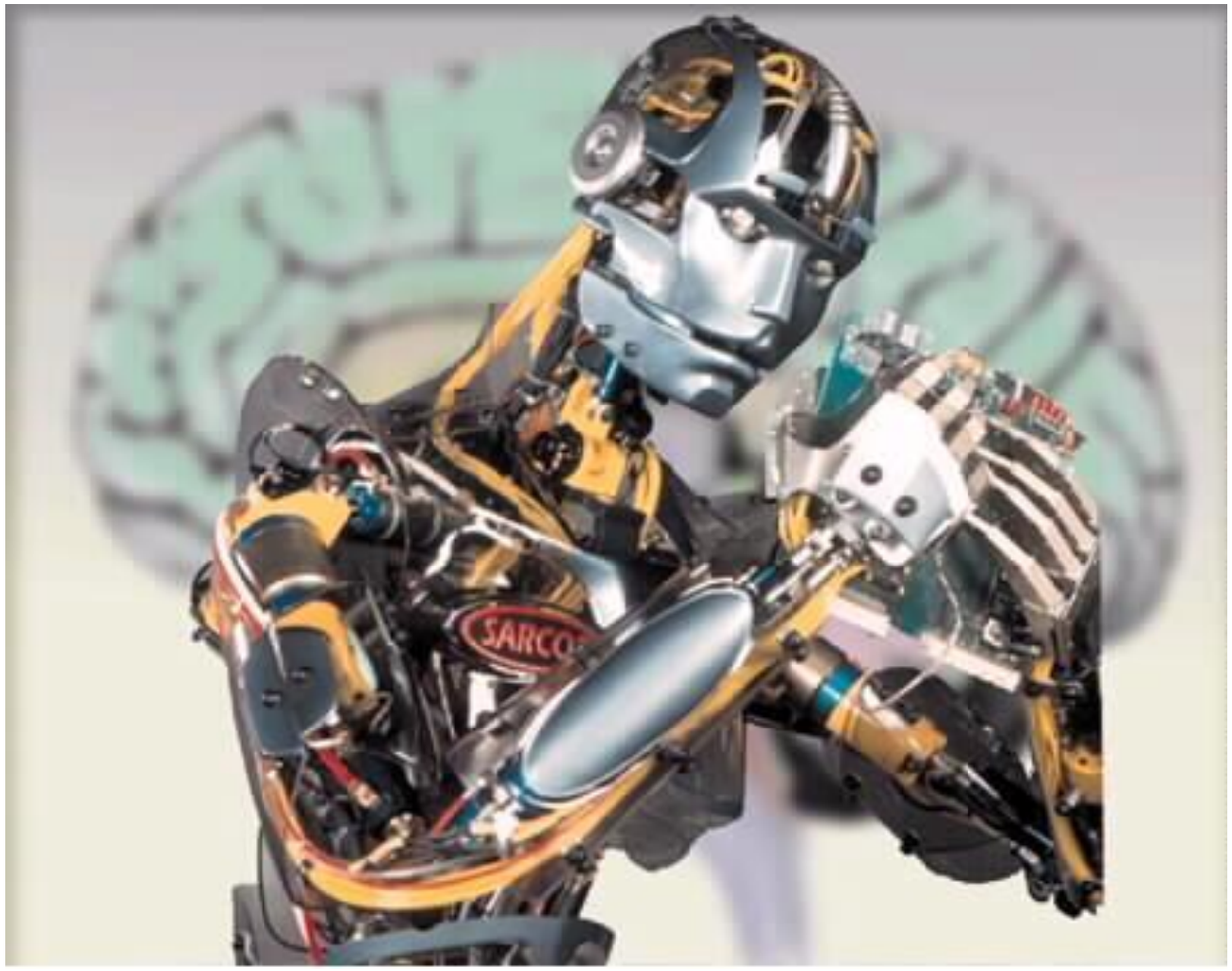


Advantages of Multimodality (potential benefits)

- A list by Maybury and Wahlster [1998, p. 15]:
  - Efficiency
  - Redundancy
  - Perceptability
  - Naturalness
  - Accuracy
  - Synergy

  - Mutual disambiguation of recognition errors [Oviatt, 1999a]

What is machine learning?

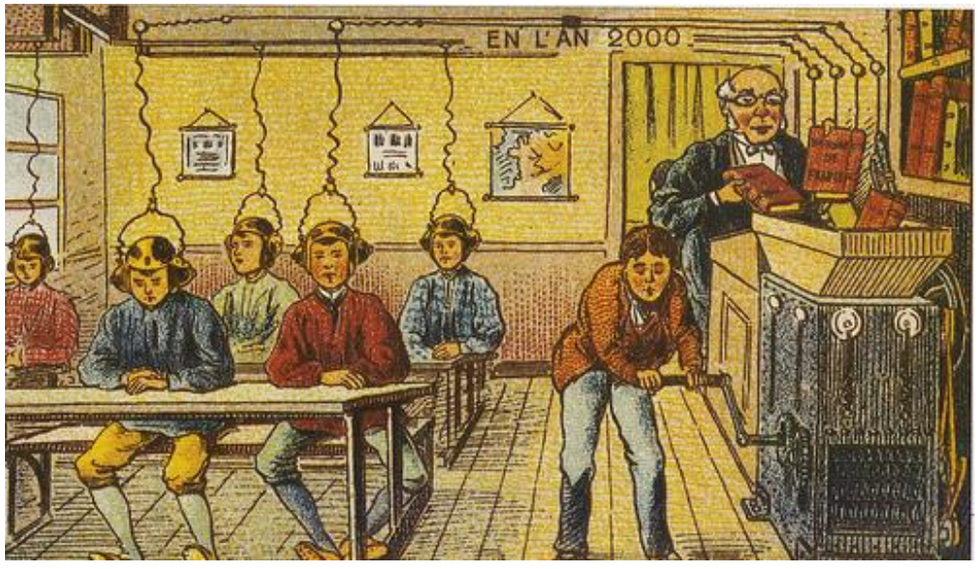


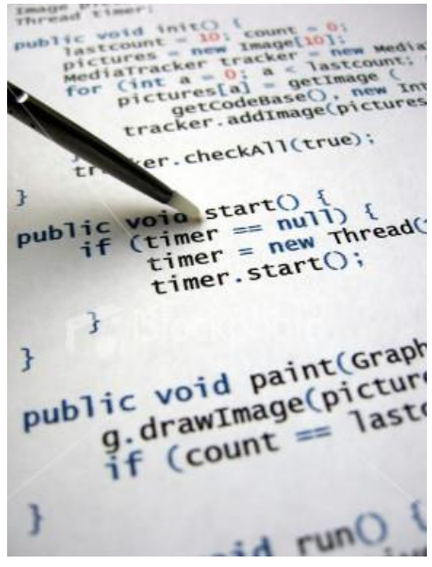
Why Machine Learning

- **3D objects recognition**
  - Different points of view
  - Different illuminations
  - Occlusion
  - Cluttered scene
- **Probability that a credit card transaction is fraudulent**
  - Not rules that are both simple and reliable
  - Need to combine a very large number of weak rules
  - Fraud is a moving target… program needs to keep changing

What is Machine Learning

- The real question is what is ***learning***?
  - *Using past experiences to improve future performance*
- For a machine, experiences come in the form of data
- What does it mean to improve performance?
  - Learning is guided by an objective, associated with a particular notion of loss to be minimized (or, equivalently, gain to be maximized)

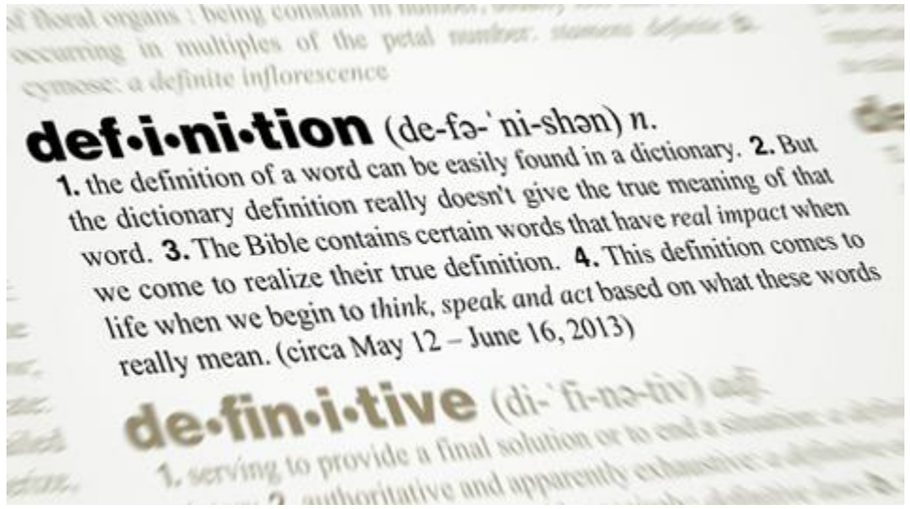


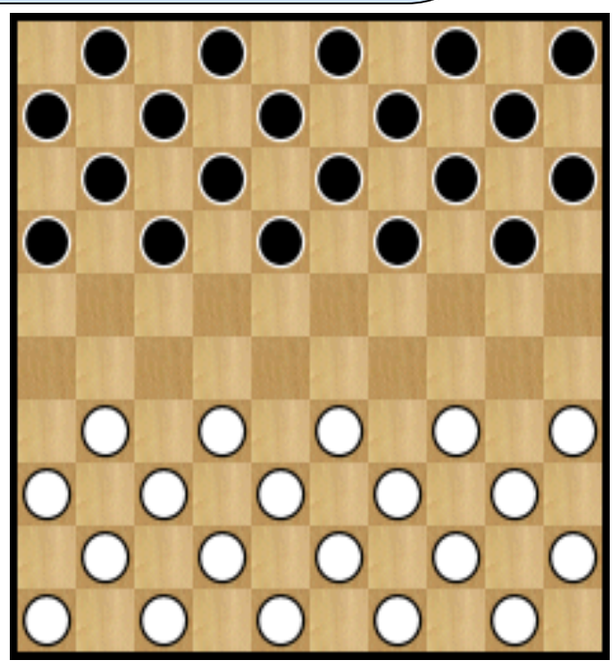


VS

Machine Learning: definition

- *Arthur Samuel (1959).*
  - Machine Learning: Field of study that gives computers the ability to learn without being explicitly programmed.





Machine Learning: definition (2)

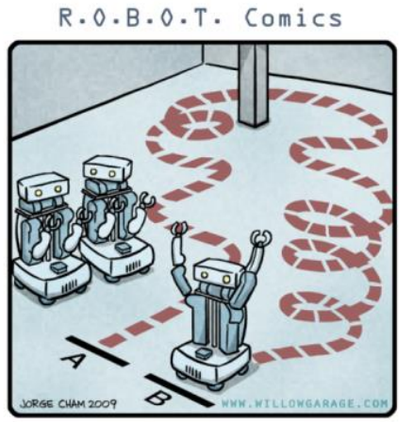
- *Tom Mitchell (1998).*
  - Well-posed Learning Problem: A computer program is said to ***learn*** from experience **E** with respect to some task **T** and some performance measure **P**, if its performance on **T**, as measured by **P**, improves with experience **E**.

Example of tasks (best) resolved by learning

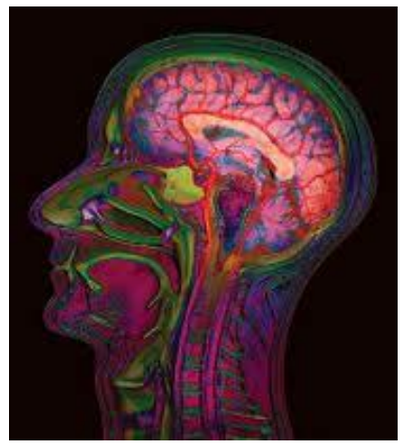
- Recognizing patterns:
  - Objects in real scenes
  - Facial identities or facial expressions
  - Spoken words
- Recognizing anomalies:
  - Unusual sequences of credit card transactions
  - Unusual patterns of sensor readings
- Prediction:
  - Future stock prices or currency exchange rates
  - Which movie will a person like

Applications domains

Recognition



Planning



Diagnosis

Robot Control

Prediction

Typologies

- Machine learning algorithms:
  - **Supervised** learning
  - **Unsupervised** learning
  - Reinforcement learning
- Others:
  - **Semi-supervised** learning
  - Recommender systems.
- We will talk about:
  - Practical advice for applying learning algorithms.

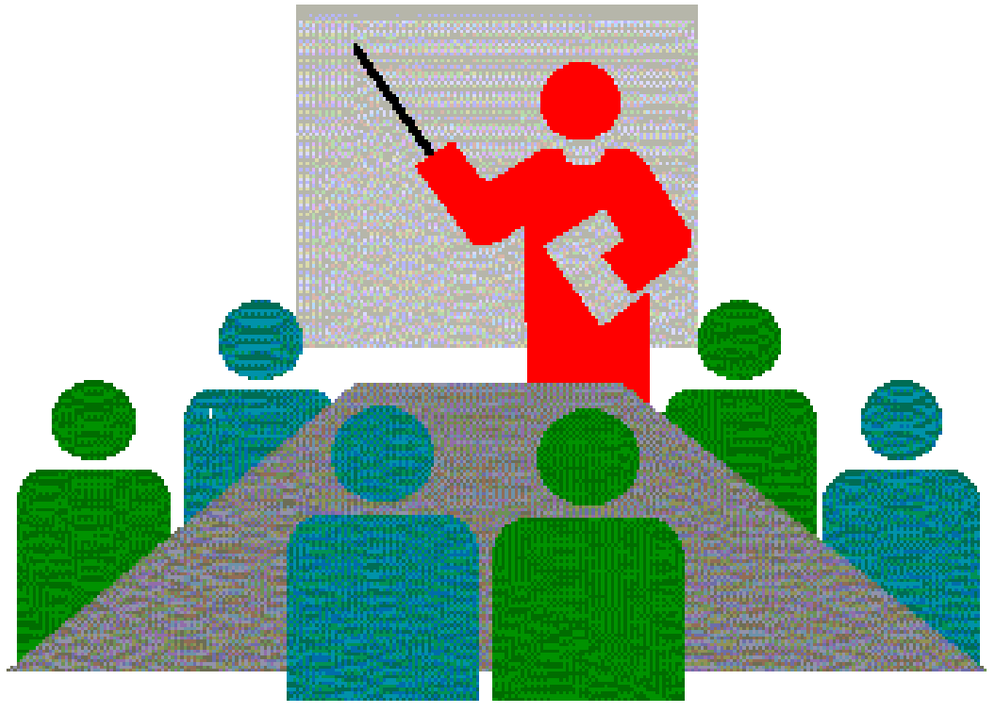
This course

- … will deal with 5 main topics
  - Classification
  - Prediction
  - Anomaly detection
  - Clustering
  - Generative (artistic) approaches

- Real world problems and use cases
- Real world data

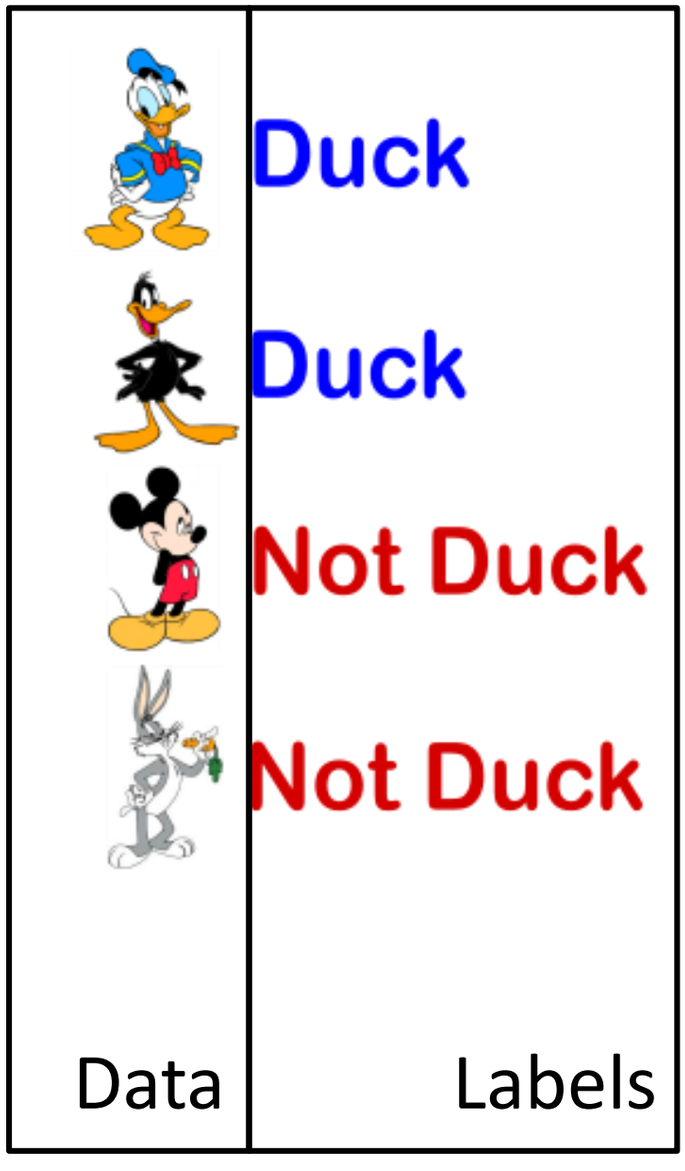
- But before starting basic knowledge is required…

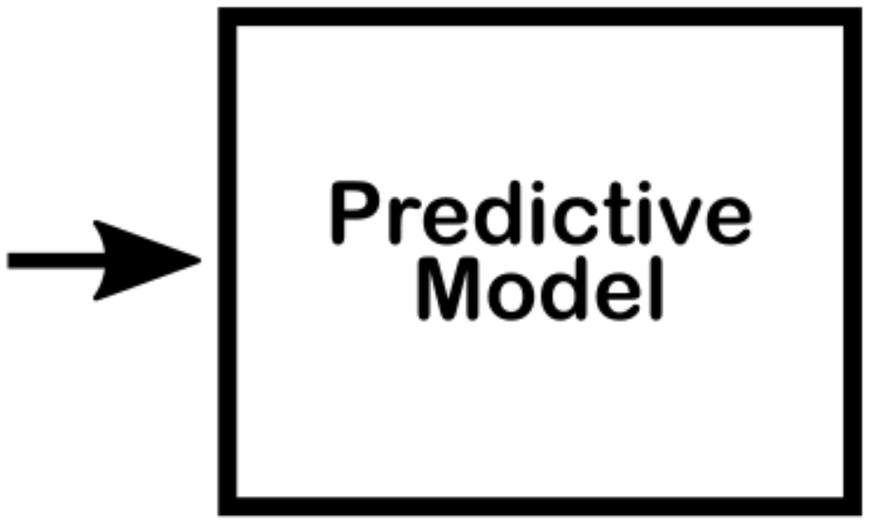
Supervised Learning



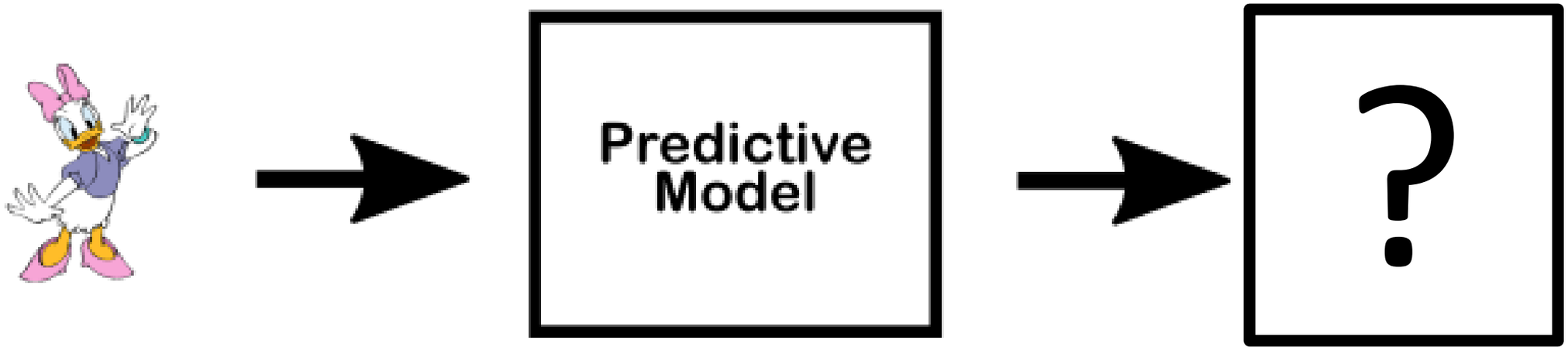
Supervised Learning

Supervised Learning

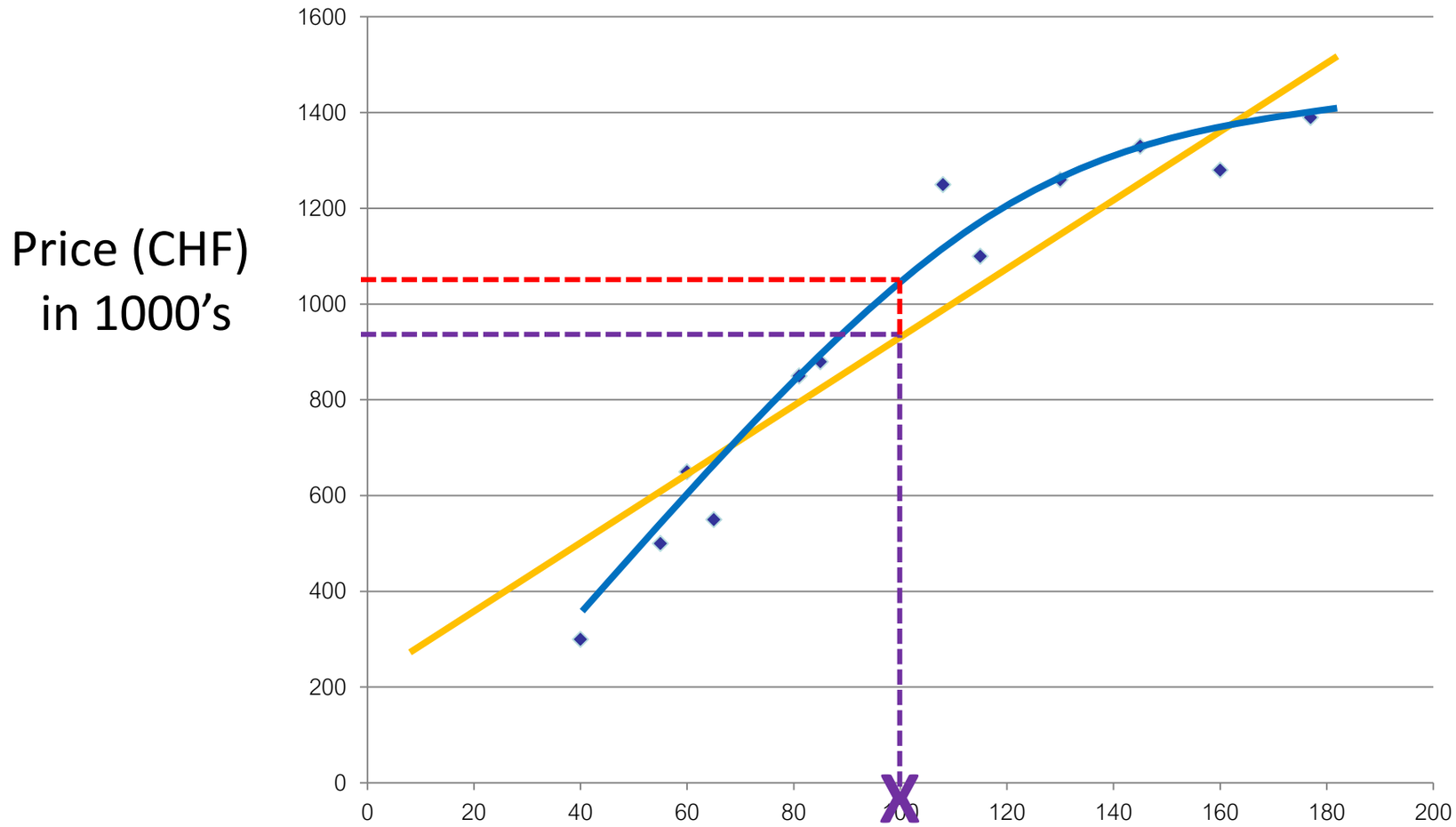




Supervised Learning



Housing price in Lausanne - prediction

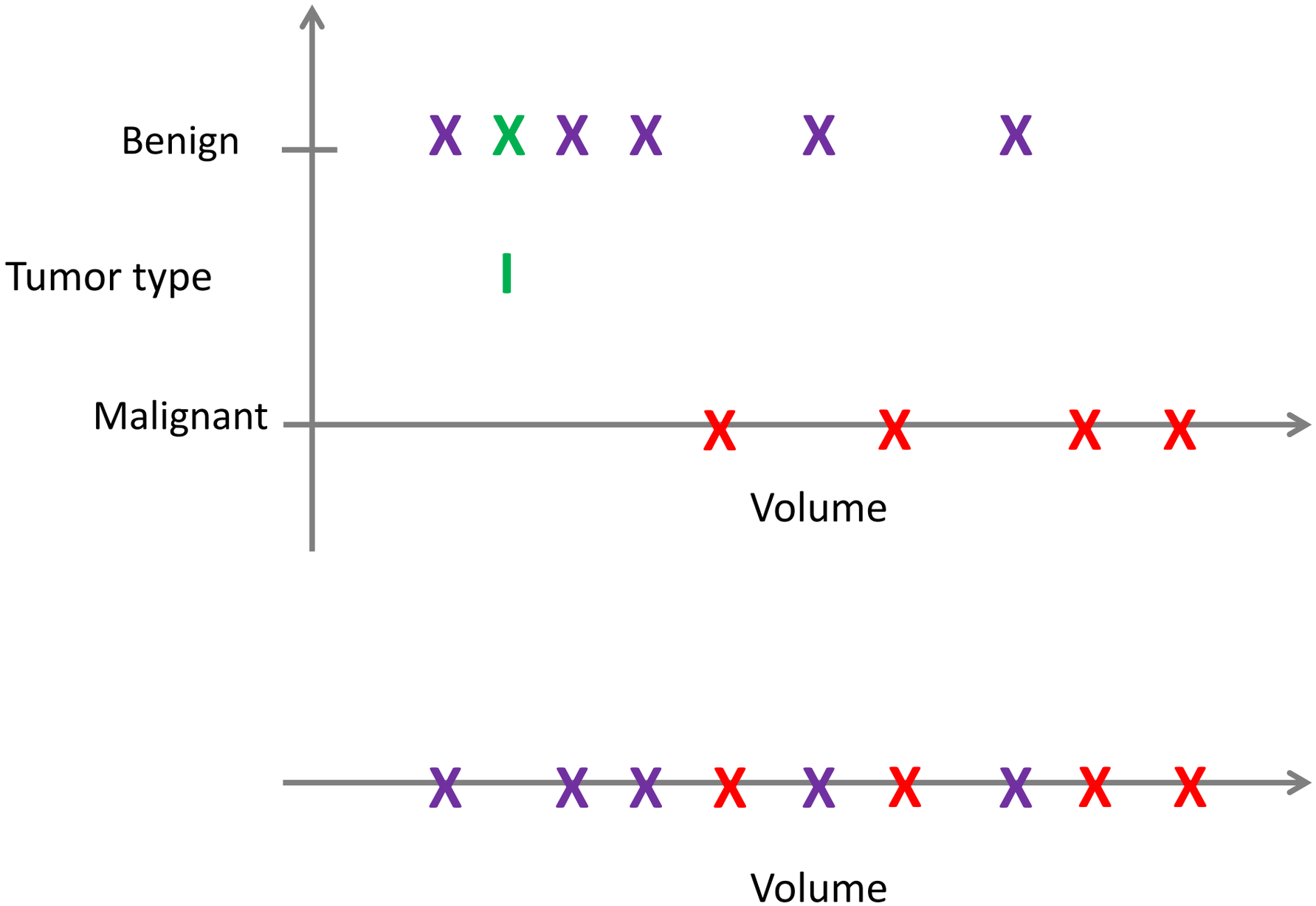


Supervised Learning:

"right answers" given for the training

Regression: Predict continuous valued output (price)

Tumor - Benign, Malignant ?

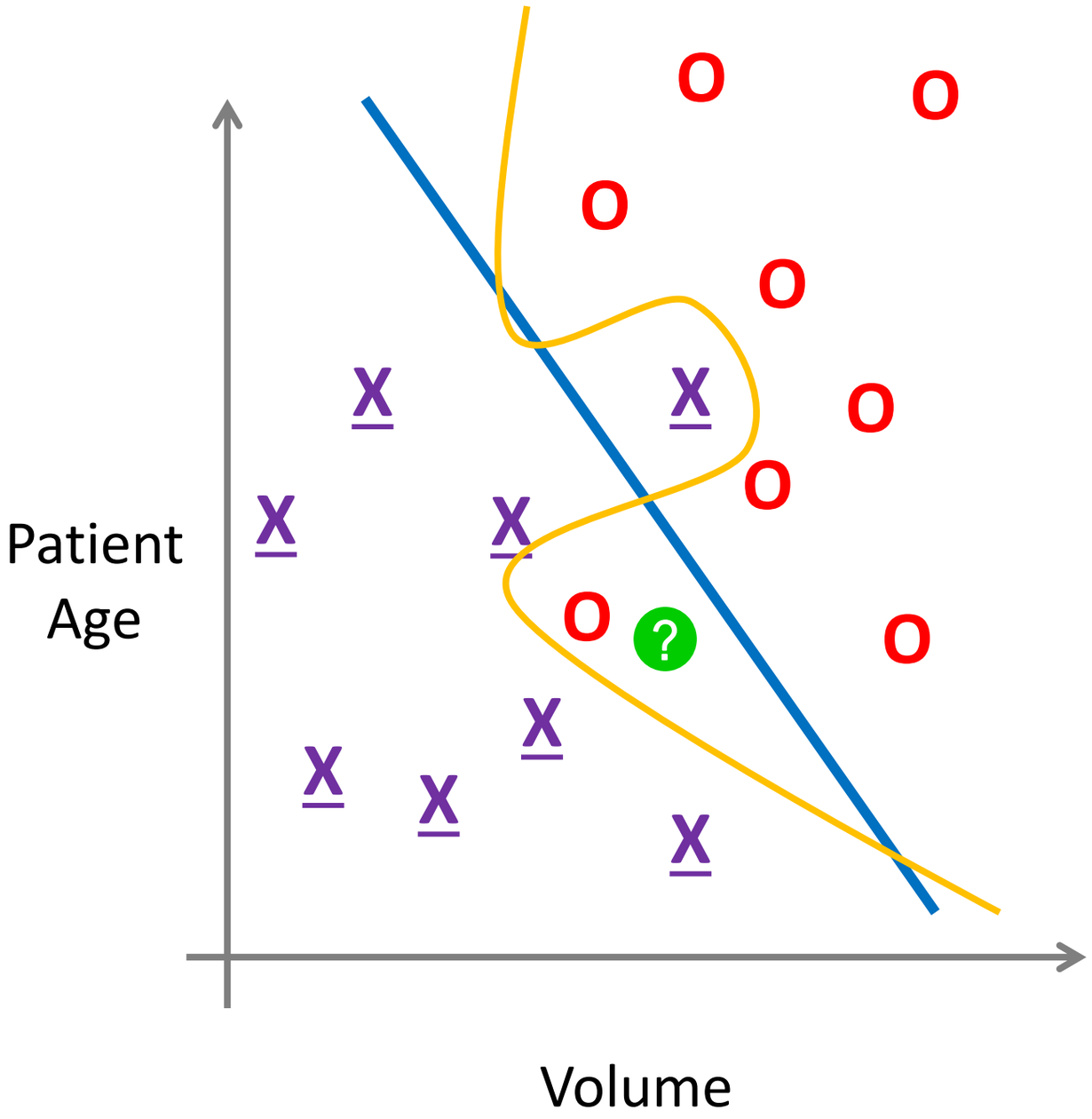


Classification

Discrete valued output

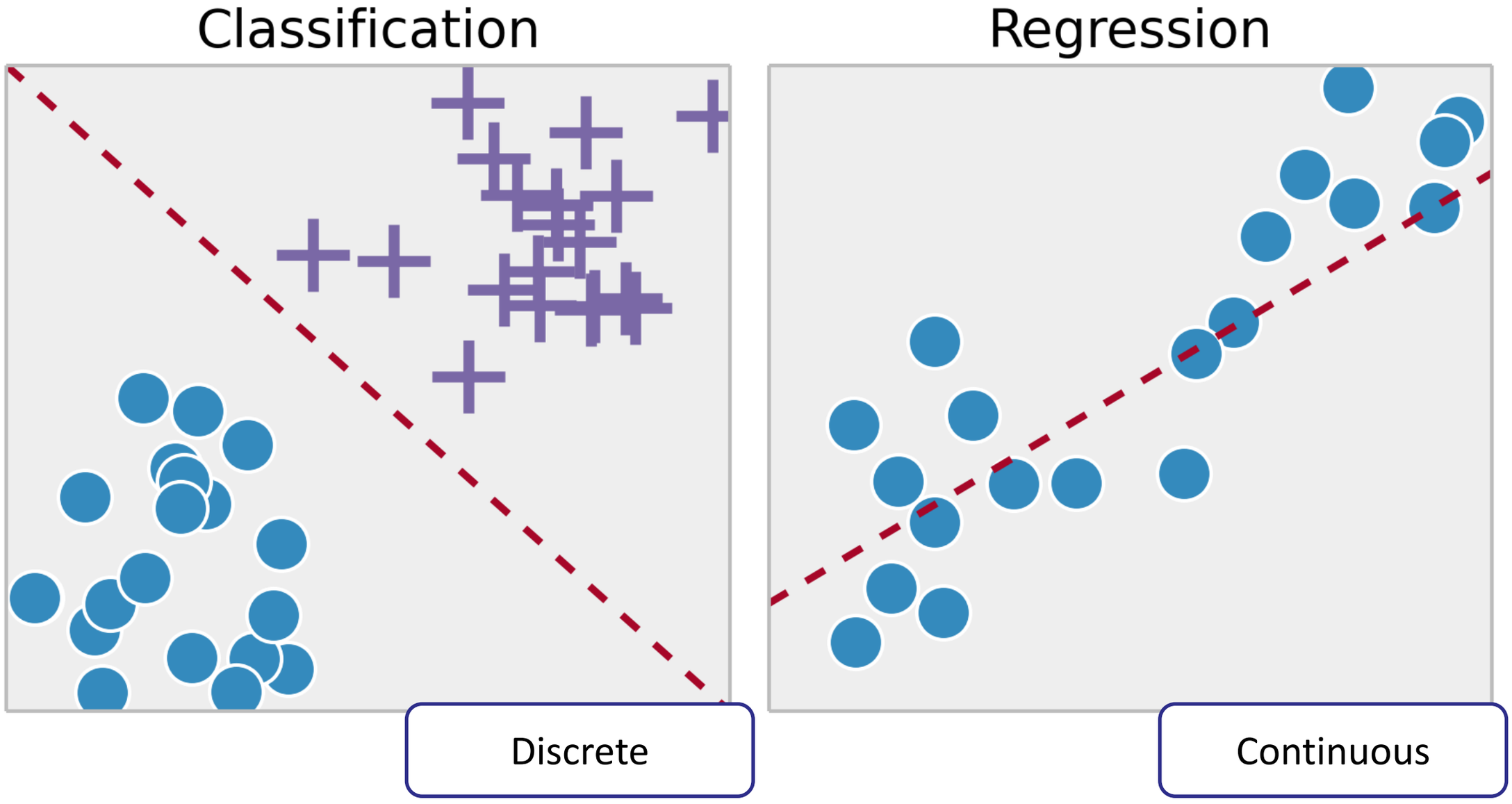
(in this case: B or M)

Tumor (Benign, Malignant)



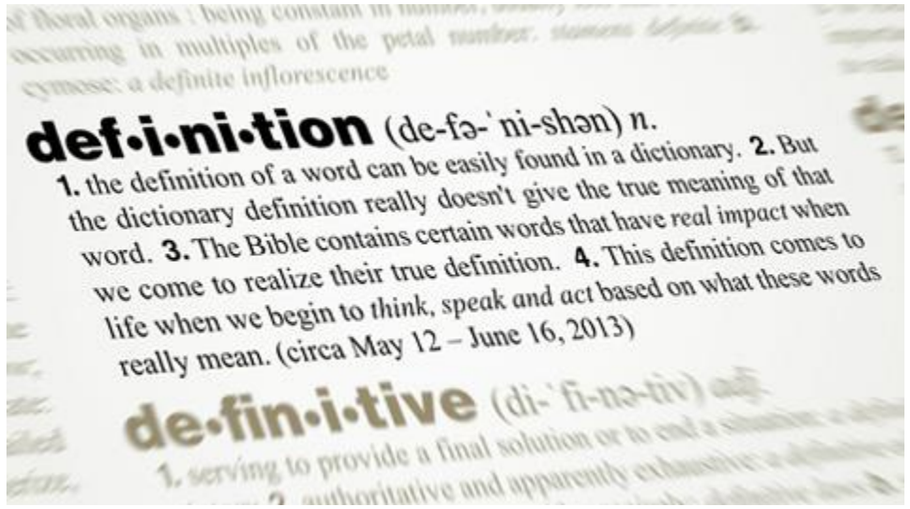
- Examples of **features**
  - Smoking habits
  - Family history
  - …

To summarize



Supervised learning: definition

Part of the data (observations, measurements, etc.) are labeled with pre-defined classes/values.



It is like that a “teacher” gives the classes (supervision).

Question: Regression Vs Classification

You're running a company developing learning algorithms. You should address of three problems for your customers:

Problem 1: Company_1 has a database with information about the sells of the last 3 years. You want to predict how many products Company_1 will sell over the next 3 months.

Problem 2: Company_1 comes back to you with the same database with information about the sells of the last 3 years. You want to predict if Company_1 will sell FEW, AVERAGE or MANY products over the next 3 months.

Problem 3: Company_2 needs a software to analyze employees e-mail accounts, and for each account filter out spam messages.

Classes and features

- Classes:
  - Def: *in a classification problem a* **class** *is the label that we want to recognize*

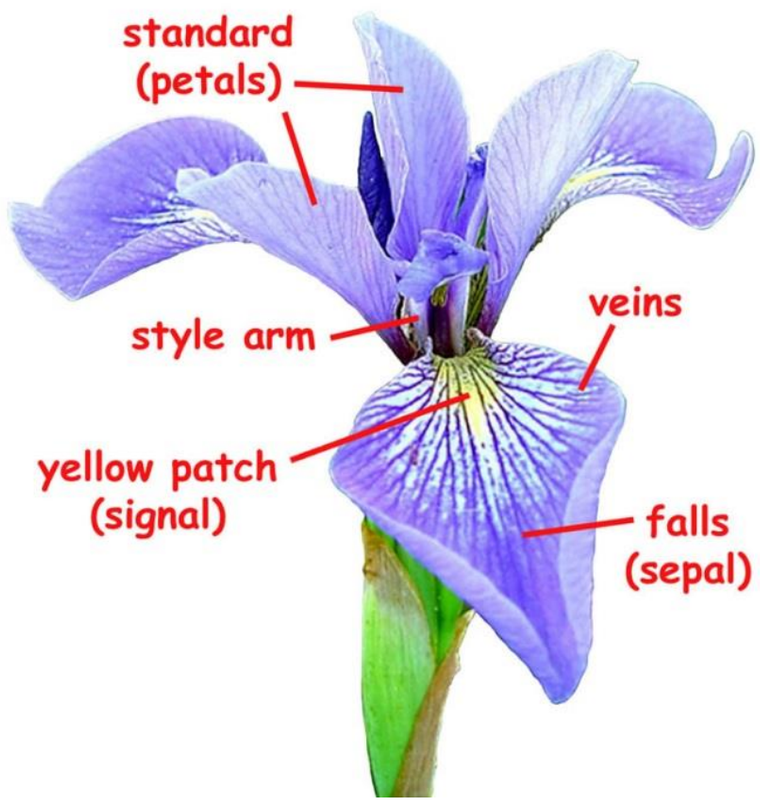
Classes and features

- Classes:
  - Def: *in a classification problem a* **class** *is the label that we want to recognize*



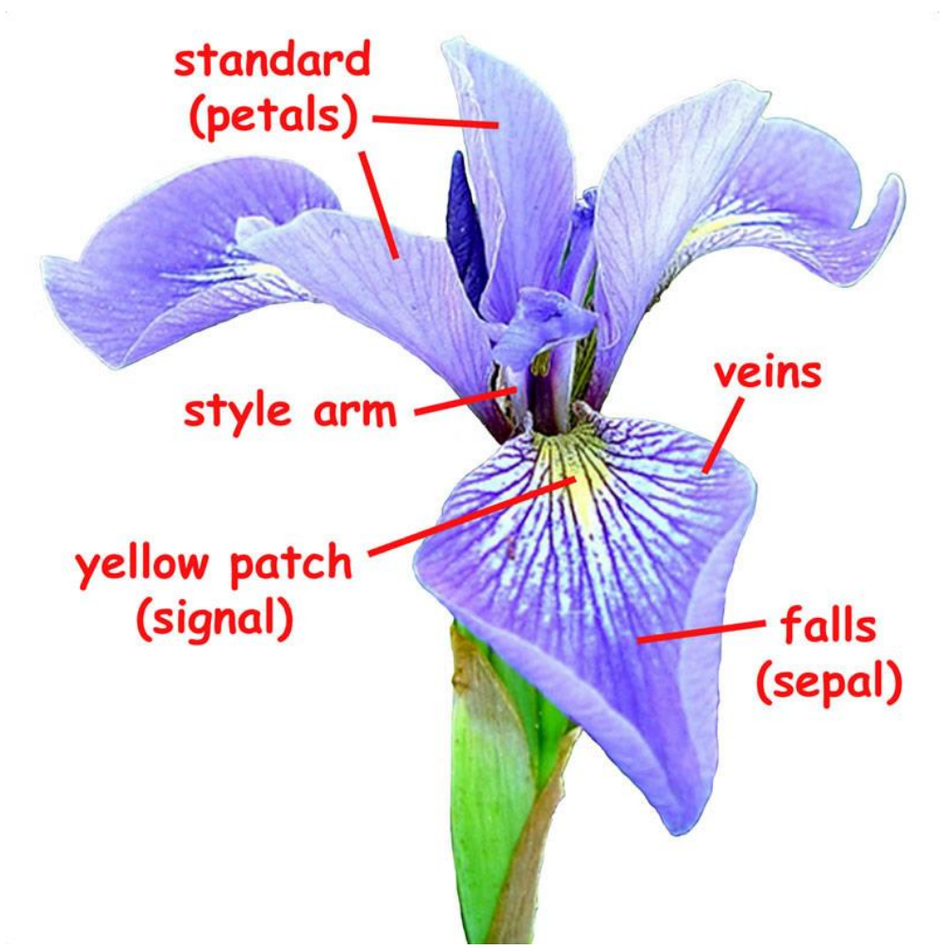
Classes and features

- Features:
  - Def: *A* feature *is the specification of an attribute and its value.*
    - For example, *color* is an attribute. ``Color is blue'' is a feature of an example.



Classes and features

➢ Number of features?

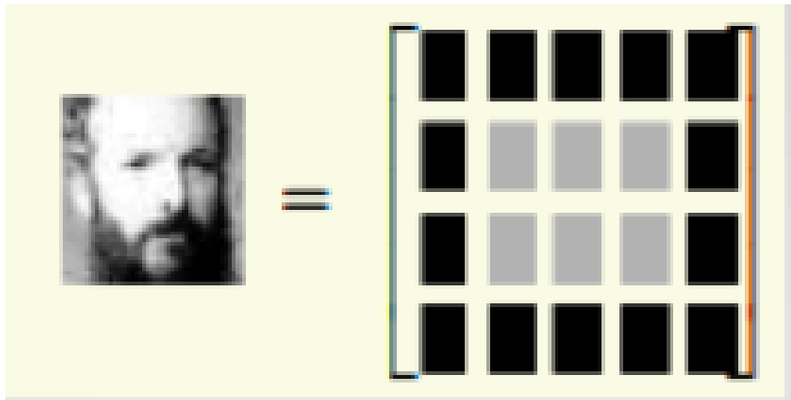


- Color
- Size
- Number of pistils
- Veins colors
- Stem color
- Stem width
- …

In a computer vision application:
Simply all the pixels in the image!

Or not?

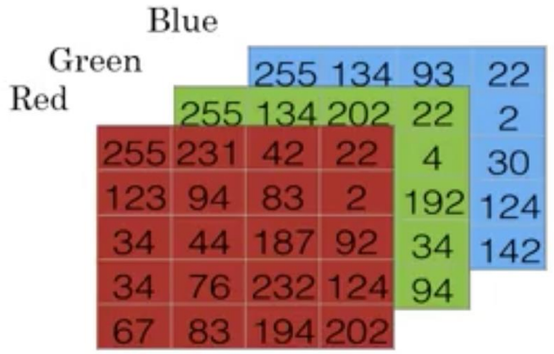
Classes and features



Example: Face detection

Classes: faces/no face

Features: image pixels



Ex. 20 by 20 pixels = 400 features!

Are these 400 features really interesting??

=> Only the most relevant features should be used!! *

** Or you should have A LOT of data!*

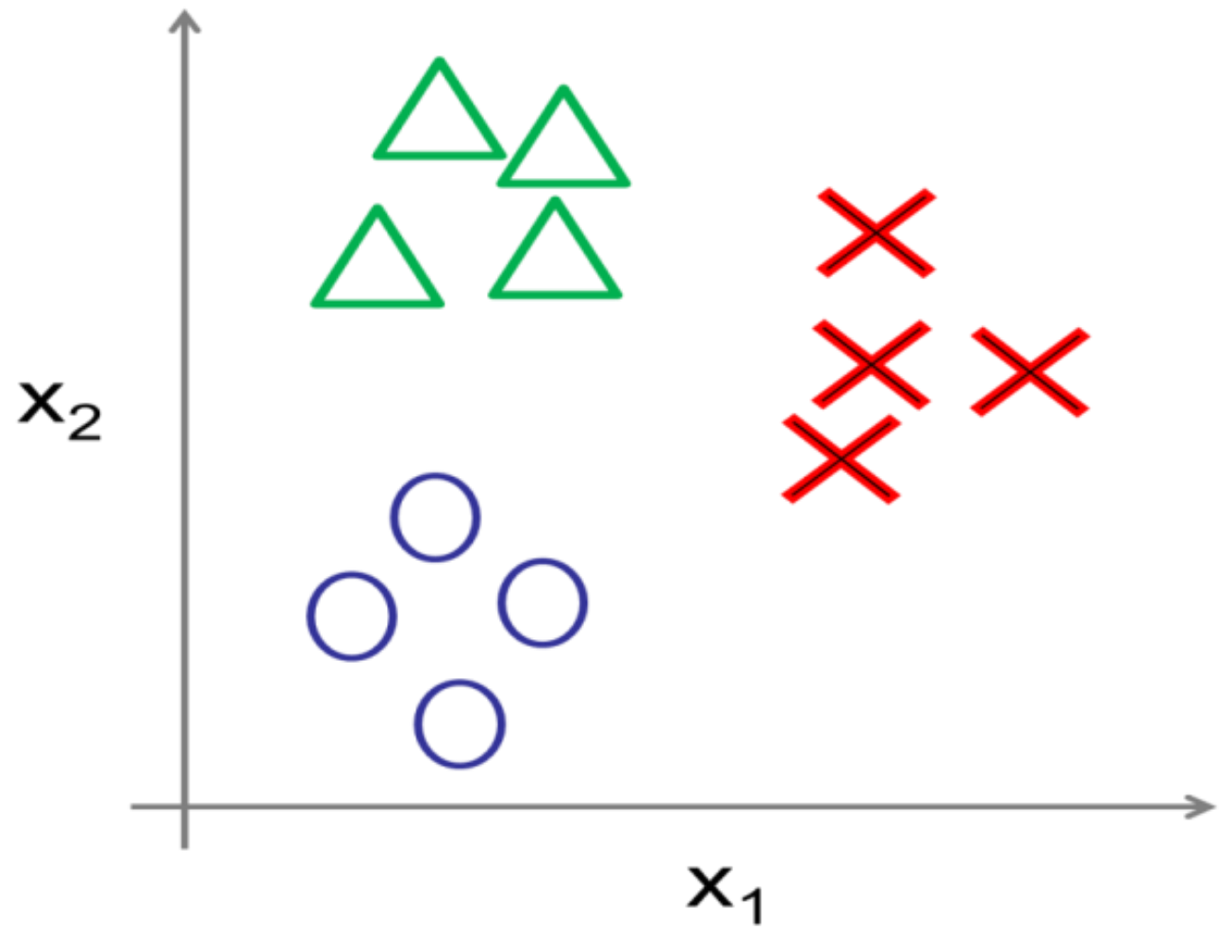
Feature Extraction

- **Essential** step in pattern recognition and machine learning problems.

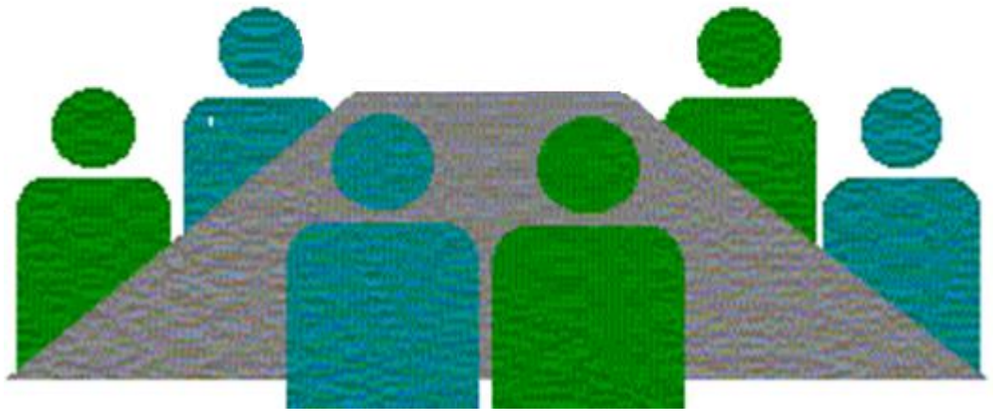
- It is often decomposed into **feature construction** and **feature selection**
  - Feature Construction:
    - Goal: balance expressiveness of features with the size of the corresponding feature space
  - Feature Selection:
    - Goal: Select relevant and informative features

Question: Terminology - Features Vs. Classes

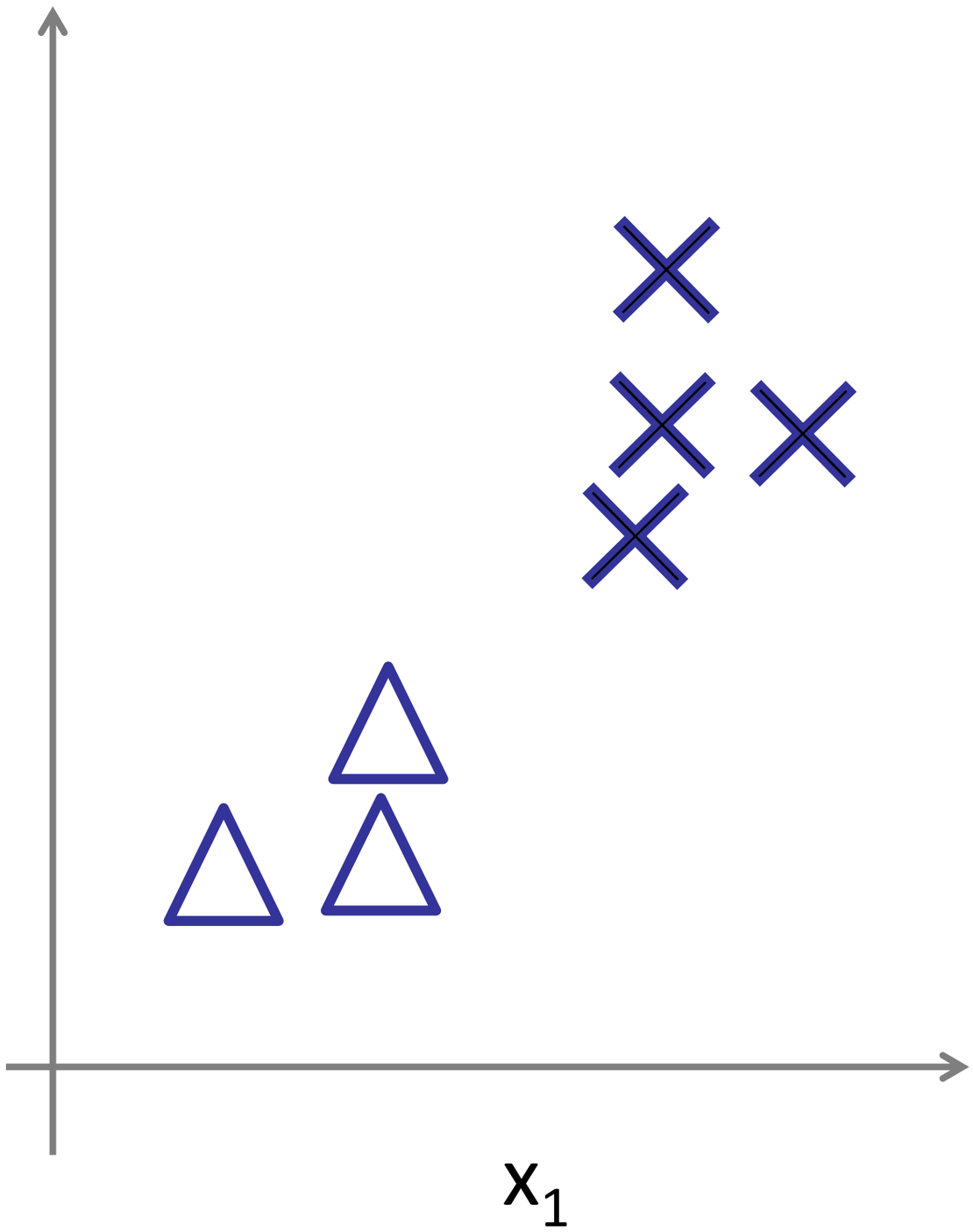
In the following representation, how many classes, how many features?



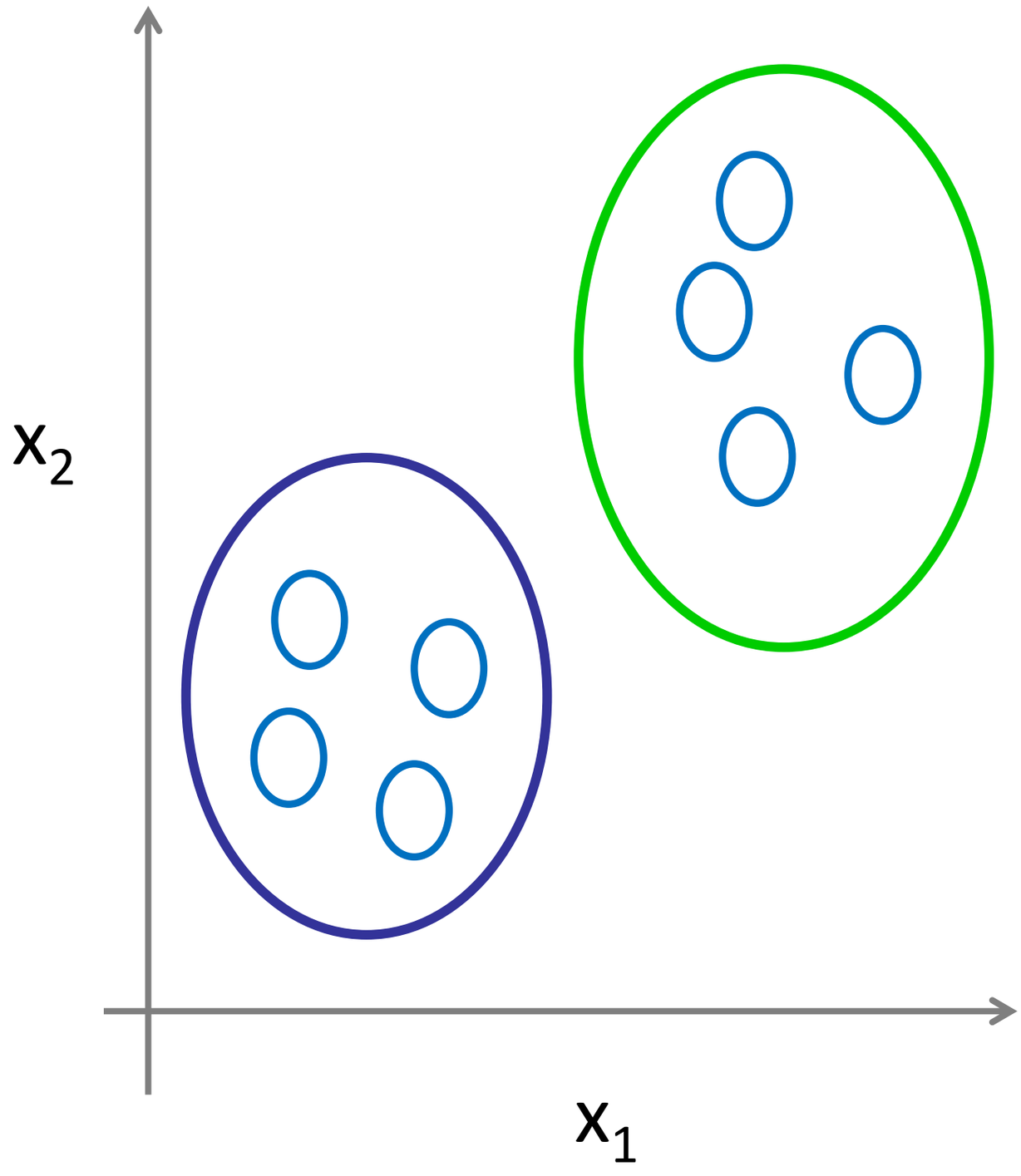
Unsupervised Learning



Supervised Learning



Unsupervised Learning



Unsupervised learning

- Goal: the basic task of unsupervised learning is to **find hidden structure in unlabeled data**

- Why?
  - Labeling is an expensive (sometime impossible) task!

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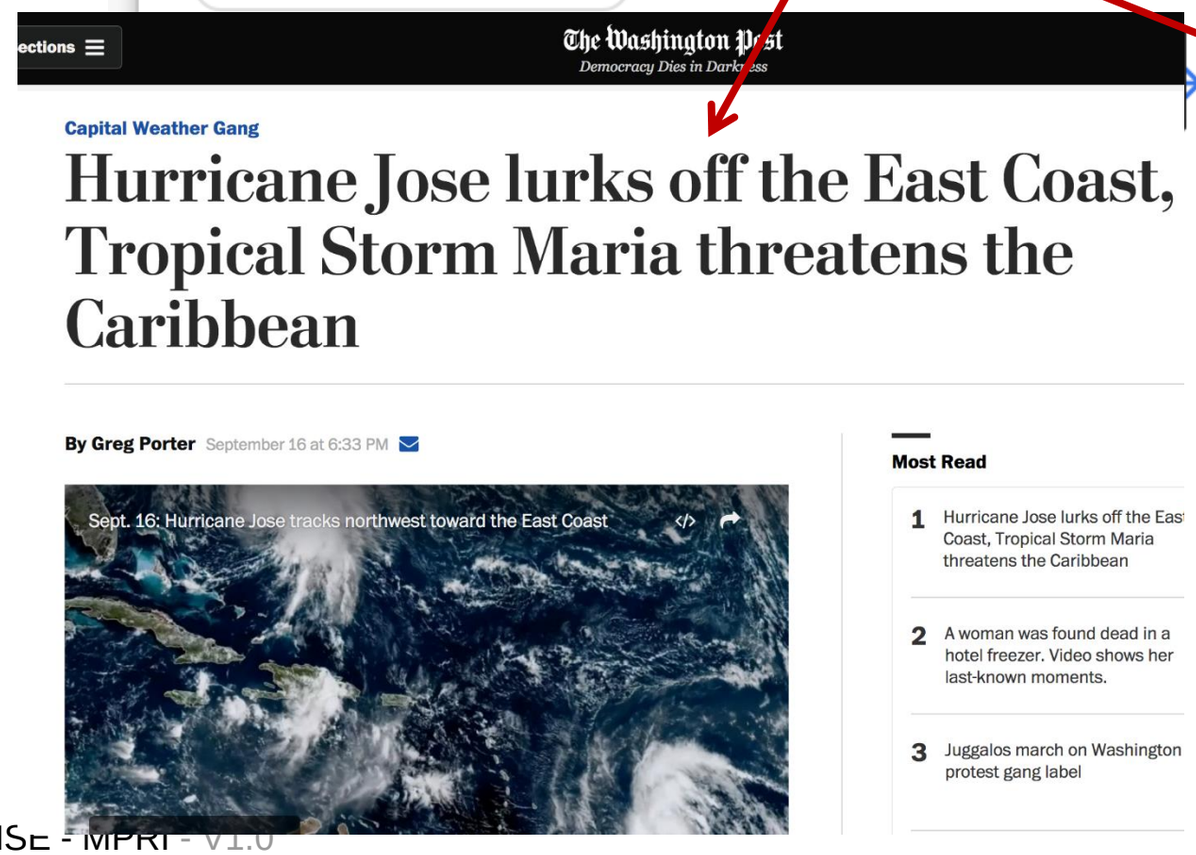
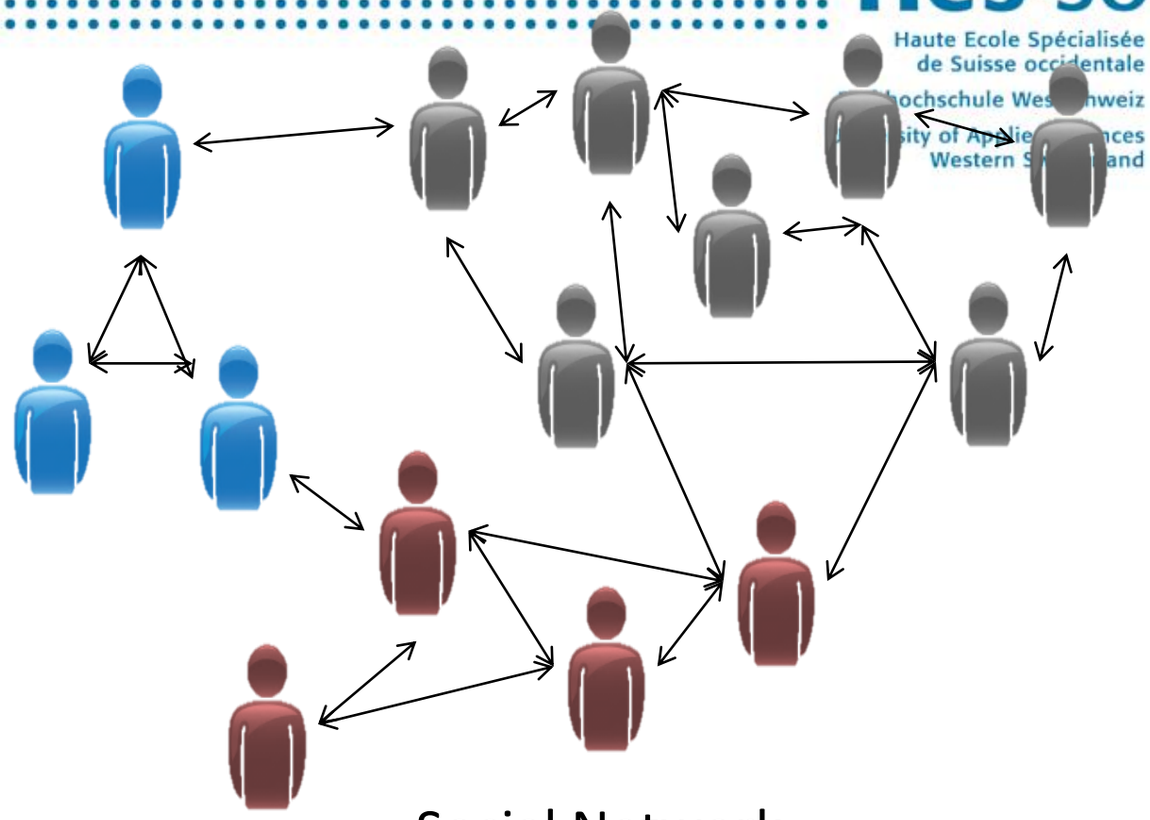
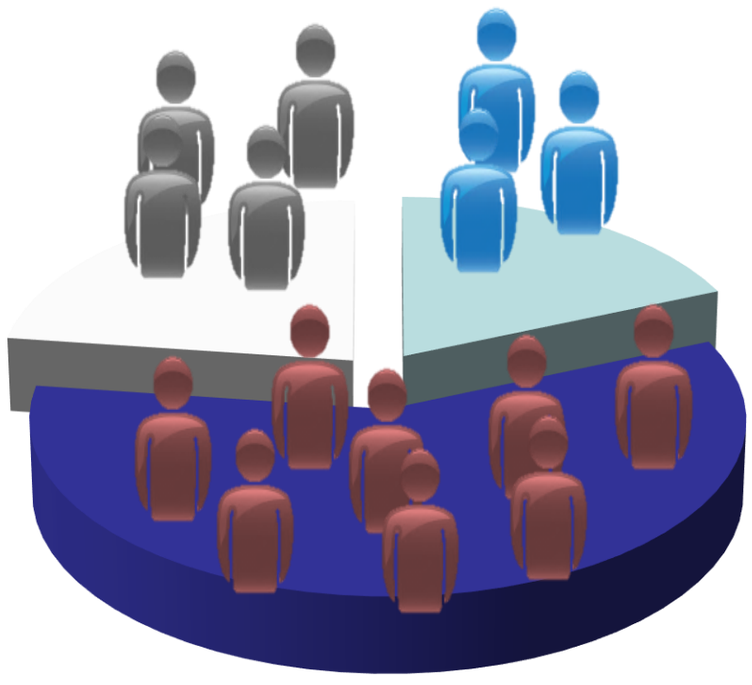


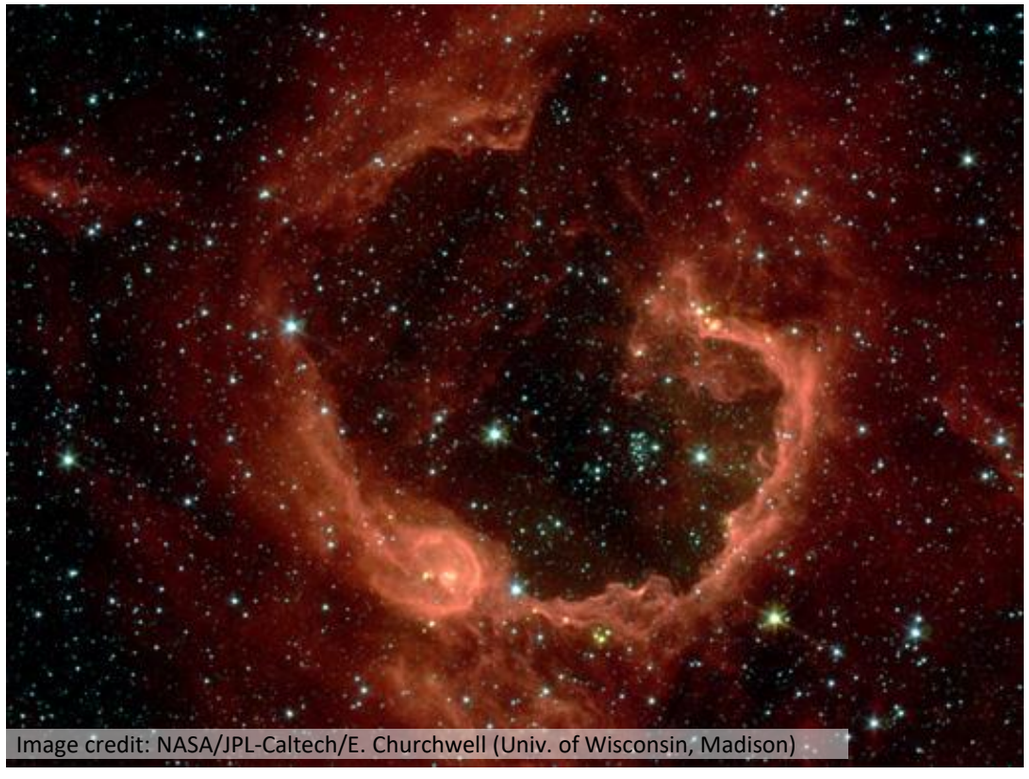
Organize computing clusters



Social Network



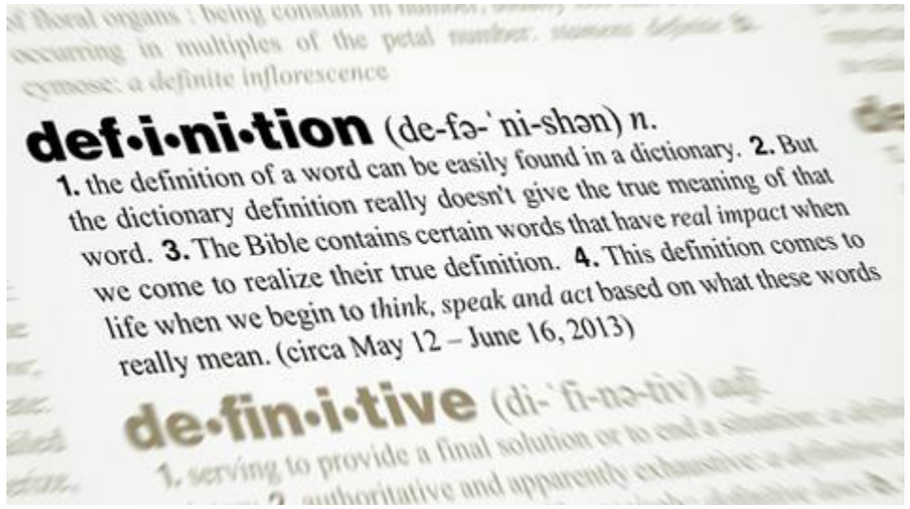
Market segmentation



Astronomical data analysis

Unsupervised learning: definition

- The term “unsupervised learning” or “learning without a teacher” is generically associated with the idea of using a collection of observation $X_1,\dots X_n$ sampled from a distribution p(X) to describe properties of p(X).



- Definition of: **Vittorio Castelli http://www.ee.columbia.edu/~vittorio/**

Of the following examples, which would you address using an unsupervised learning algorithm?

- **Given email labeled as spam/not spam, learn a spam filter.**

- **Given a dataset of not labeled images cluster similar pictures.**

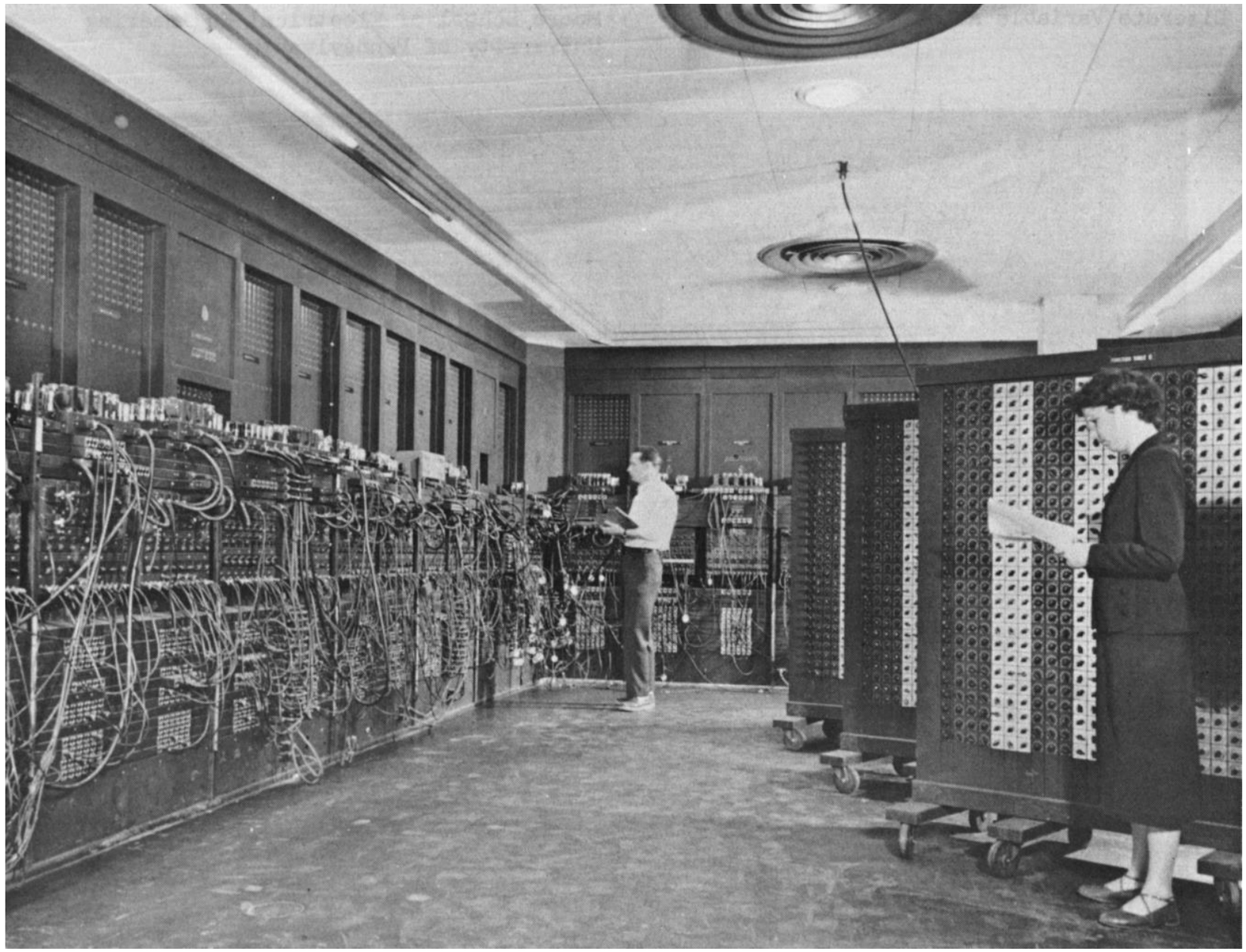
- **Given a database of customer data, automatically discover market segments and group customers into different market segments.**

- **Given a dataset of patients diagnosed as either having diabetes or not, learn to classify new patients as having diabetes or not.**

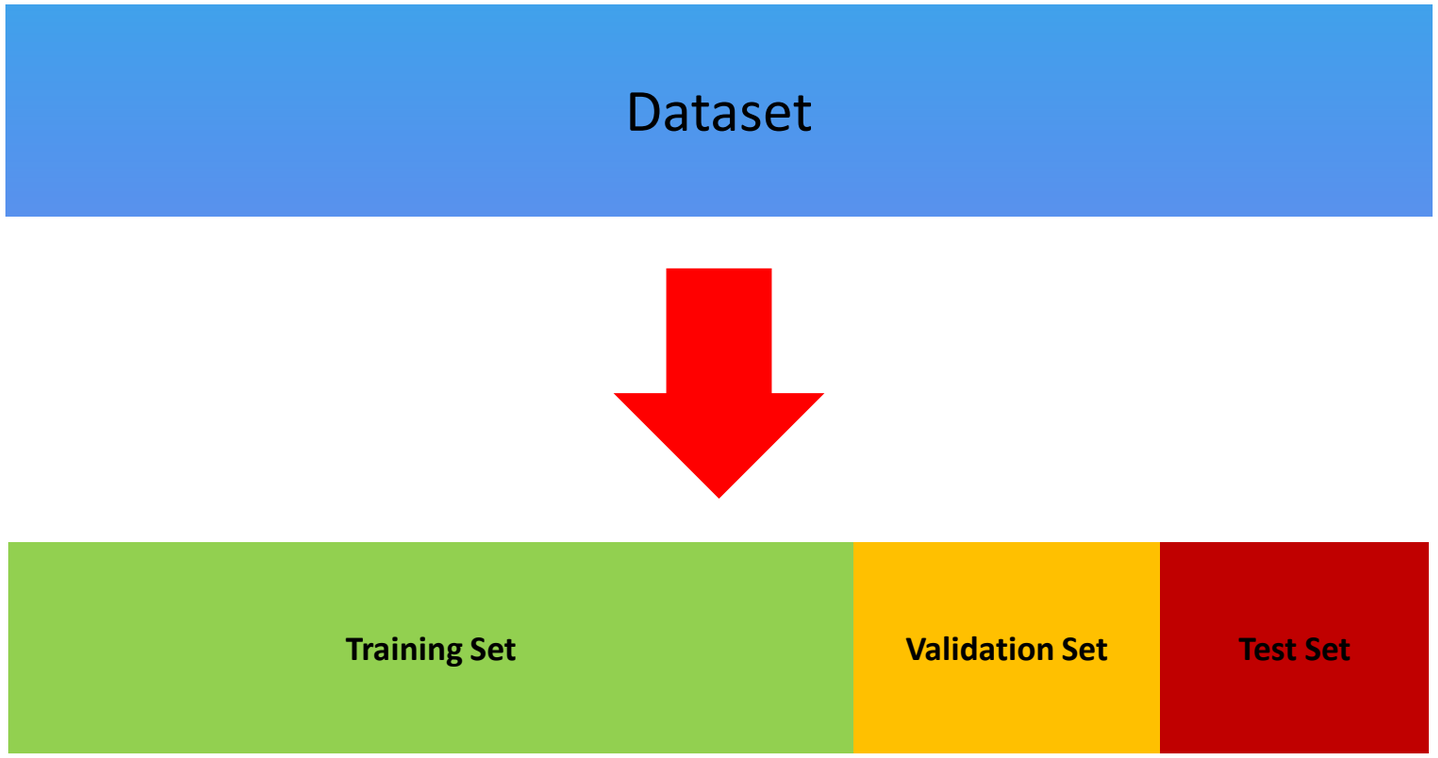
Summary:

- Supervised learning
  - Learn to produce an output when given an input vector
  - Two flavors:
    - Regression: the target output is a real number or a whole vector of real numbers
    - Classification: the target output is a class label
- Unsupervised learning
  - Discover a good internal representation of the input

Information processing



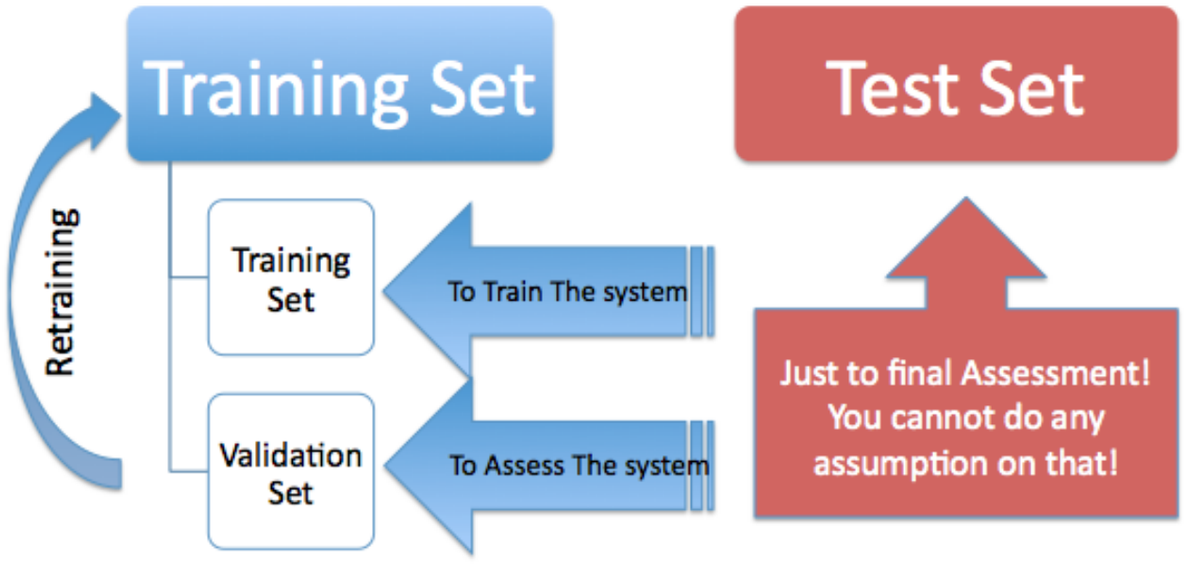
Learning Process– General Schema



Learning Process– General Schema

Steps:

1. Training Set:
   - Feature extraction
   - Data Modelization
2. Validation Set
   - Optimization of the model
3. Iterate 1 and 2
4. Test Set:
   - Final assessment!
   - No assumption using these data

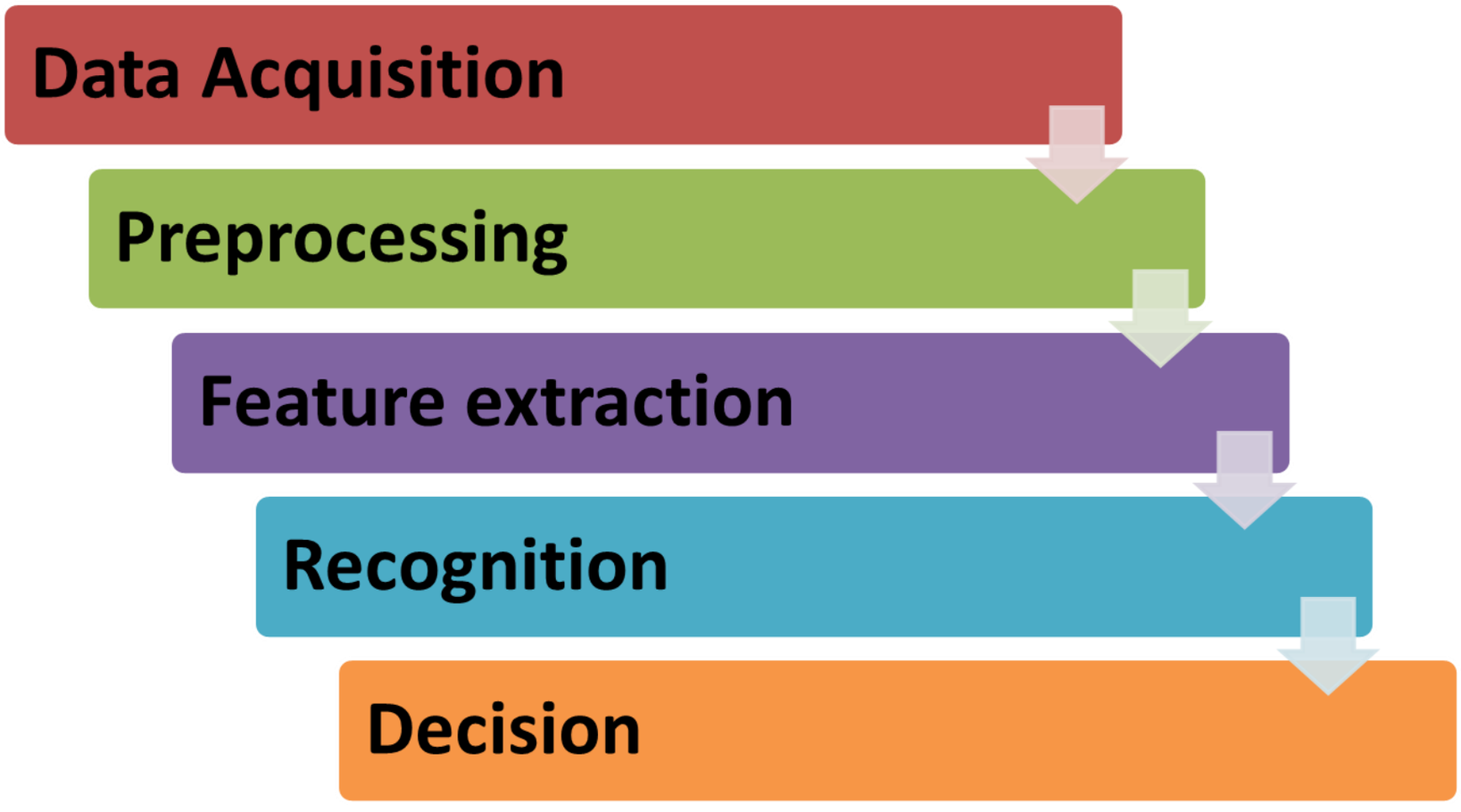


http://textanddatamining.blogspot.ch/2011/09/how-classifier-accuracy-is-conditioned.html

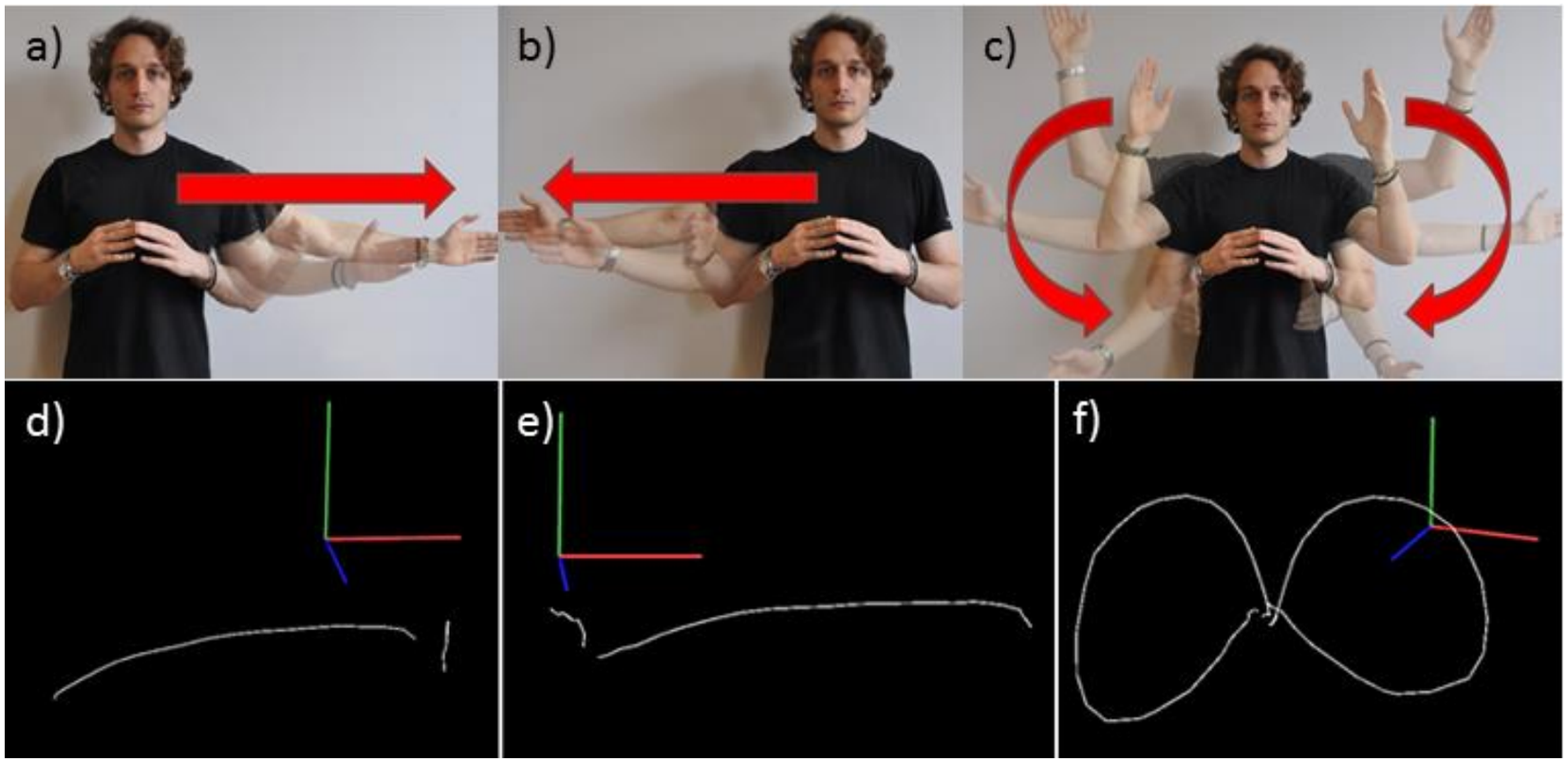
Learning Process– General Schema

- Dataset
  - **Training set:**
    - A set of examples used for learning, where the target value is known.
  - **Validation set:**
    - A set of examples used to tune the architecture of a classifier and estimate the error.
  - **Test set:**
    - Used only to assess the performances of a classifier.
    - It is never used during the training process so that the error on the test set provides an unbiased estimate of the generalization error.

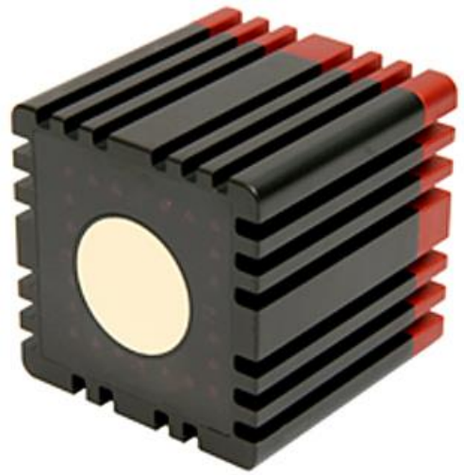
Information processing – general schema

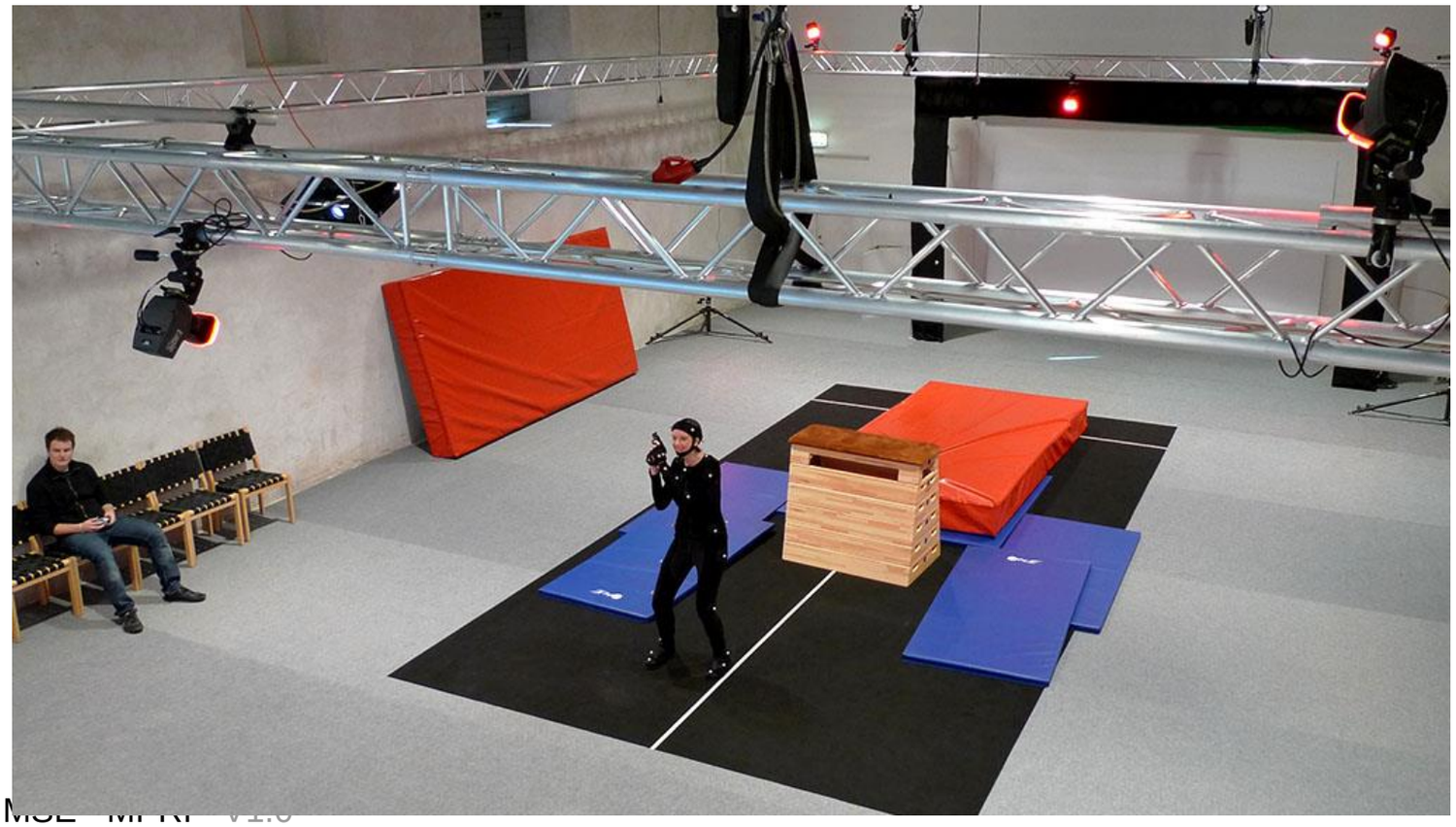


Example



Data Acquisition





- Driver
- Networking
- Synchronization
- …

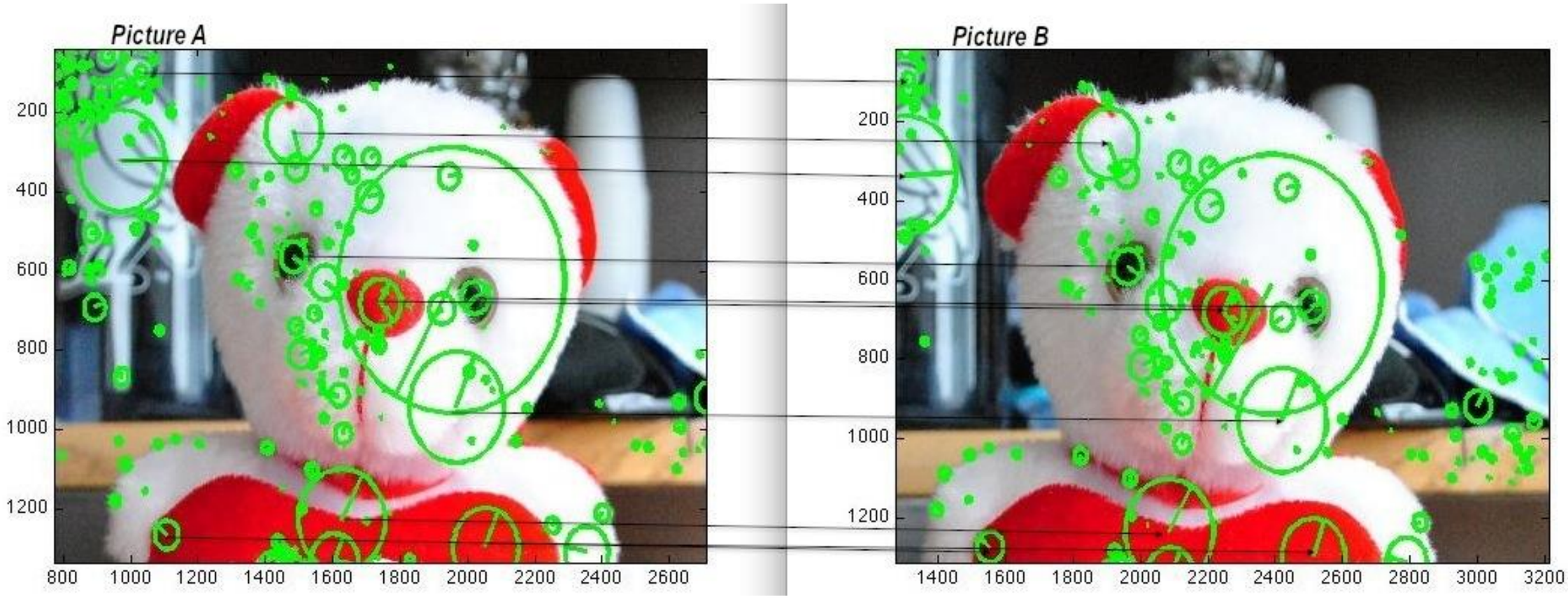
Preprocessing

- Data normalization:
  - Frame resizing
- Data segmentation:
  - Color segmentation
    - ✓ Hand detection
    - ✓ Color marker detection
- Motion segmentation:
  - Background subtraction
    - Works good on known background (static background)
    - Cannot detect stationary hands or determine which moving object is the hand

Feature Extraction

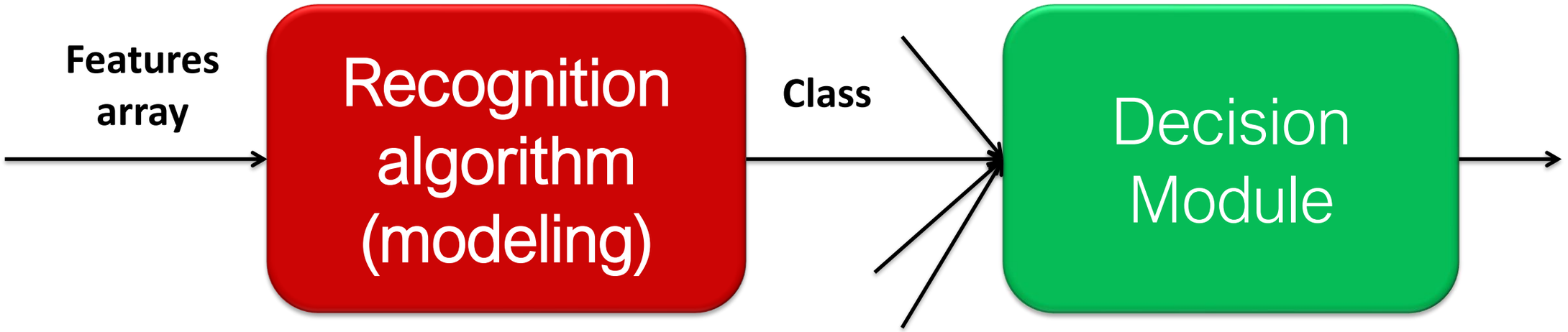
- Essential step in pattern recognition and machine learning problems.
- It is often decomposed into **feature construction** and **feature selection**
  - Feature Construction:
    - Goal: balance expressiveness of features with the size of the corresponding feature space
  - Feature Selection:
    - Goal: Select relevant and informative features

Feature Extraction



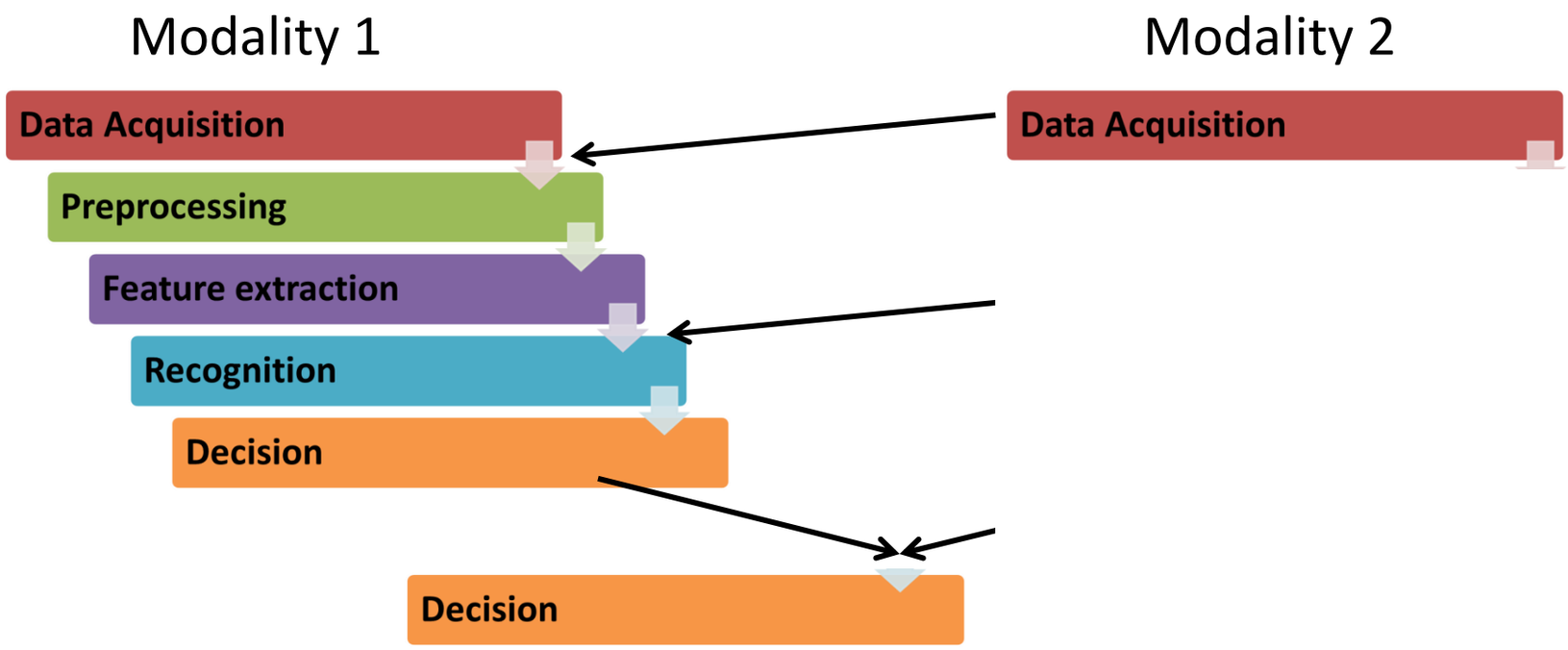
- SIFT descriptor: 128 elements

Recognition & Decision



- Decision Trees, Hidden Markov Model (HMM), Support vector machine, (Deep) Neural Networks
- Linear/Polynomial regression, Logistic regression, Conditional Random Fields (CRF), K-nearest neighbor (KNN), Dynamic time warping (DTW), boosting algorithms (AdaBoost, CatBoost, etc.), etc.
- Hybrid algorithms

Multimodal system – Information fusion



Information processing – general schema

Data Acquisition
- Sensors drivers
- Synchronization

Preprocessing
- Filtering, cropping, dropping, denoising, …
- Segmentation

Feature extraction
- Feature construction (selection)
- Feature reduction

Recognition
- Supervised approaches
- Unsupervised approaches

Decision
- Fusion

Conclusion

- Multimodality (definition)
- Machine Learning
  - Supervised Vs Unsupervised Learning
  - Classification Vs Regression
- Learning Process
  - Training set Vs Validation Set Vs Test Set
- Information processing
    - Data acquisition, pre-processing, feature extraction, recognition, decision