Overview: Machine Learning

Slides adapted from lectures by
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Machine Learning:

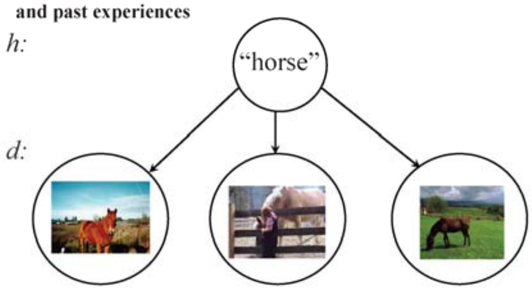
What is Machine Learning?

- "Learning denotes changes in the system that are adaptive in the sense that they enable the system to do the task or tasks drawn from the same population more efficiently and more effectively the next time."
  --Herbert Simon
- Closely related to
  - Statistics (fitting models to data and testing them)
  - Data mining / exploratory data analysis (discovering models)
  - Adaptive control theory
  - And of course AI

Machine Learning:

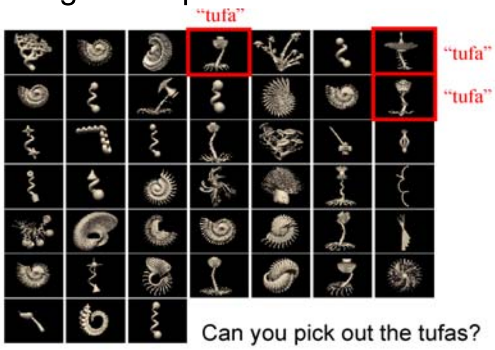
Abstractions from Observation

Learning is the process of automatically constructing abstractions of the real world from a set of observations and past experiences



Machine Learning:

Learning Concepts and Words

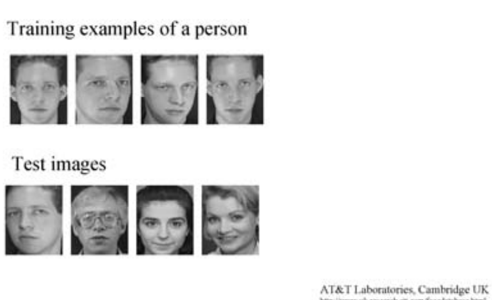


Machine Learning:

Recognizing Noisy Input

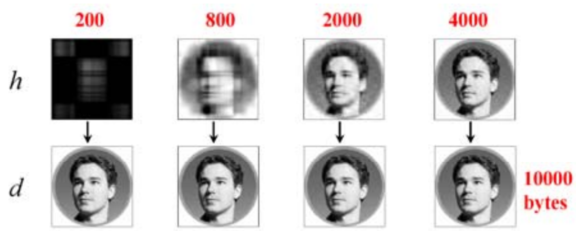
Machine Learning:

Classic Recognition Problem



Machine Learning:
Information Theory Perspective

- Data compression and transmission over a noisy channel



- Which compression captures the essence of the image?
- Which one is best to recognize the same subject in a different photo?

Machine Learning:
Why Learn?

- Special Approach to Programming
  - To optimize a performance using example data or past experience.
- Not always needed
  - There is no need to “learn” to calculate payroll
- But used when
  - Human expertise does not exist (navigating on Mars),
  - Humans are unable to explain their expertise (speech recognition)
  - Solution changes in time (routing on a computer network)
  - Solution needs to be adapted to particular cases (user biometrics)

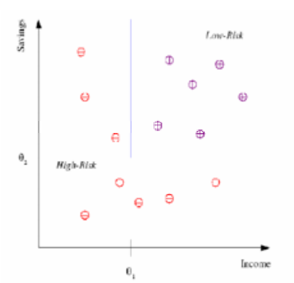
Types of Machine Learning

- Supervised Learning
  - Classification(pattern recognition)
  - Regression
- Unsupervised Learning
- Reinforcement Learning

Supervised Learning

Supervised Learning:
Classification

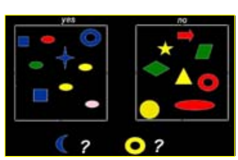
- Example: Credit scoring
  Differentiating between low-risk and high-risk customers from their *income* and *savings*



- Input data is two dimensional, output is binary

Discriminant:
IF *income*> θ1AND *savings*> θ2THEN low-risk
ELSE high-risk

Supervised Learning:
Classification



p features (attributes)

Training Set: (n cases)

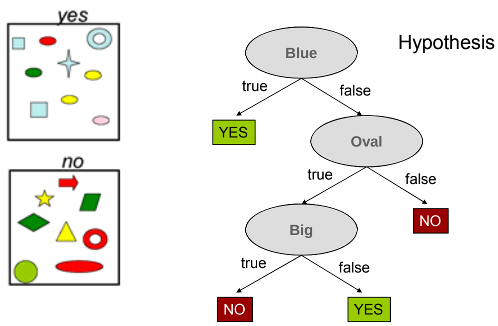
Color	Shape	Size	Label
Blue	Square	Small	Yes
Red	Ellipse	Small	Yes
Red	Ellipse	Large	No

Test Set:

Blue	Crescent	Small	?
Yellow	Ring	Small	?

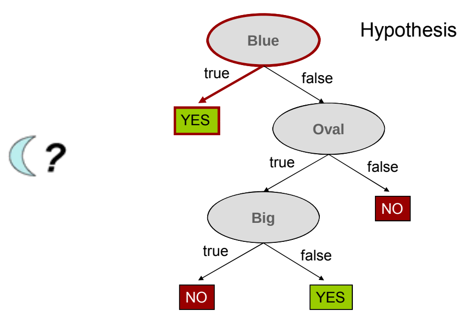
Supervised Learning:

Classification - Decision Tree



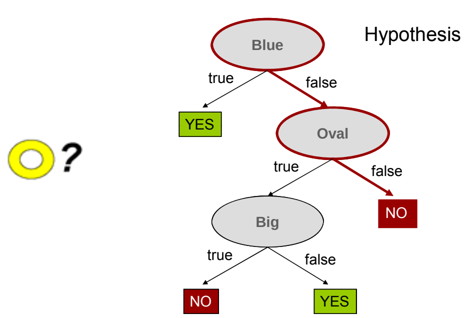
Supervised Learning:

Classification - Decision Tree

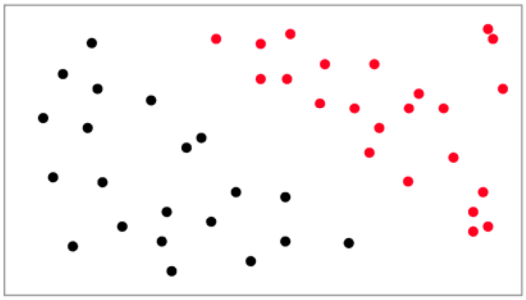


Supervised Learning:

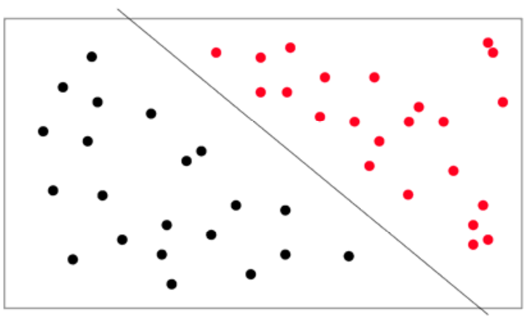
Classification - Decision Tree



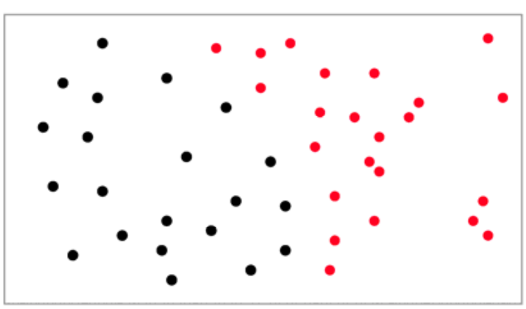
Supervised Learning:
What is the right Hypothesis?



Supervised Learning:
Hypothesis – Linear Separation

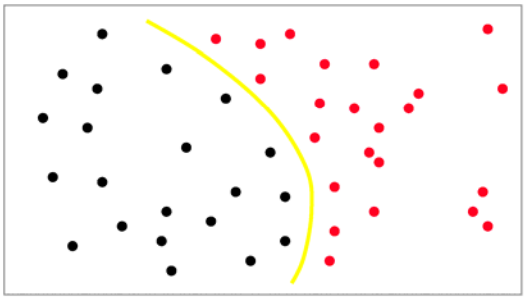


Supervised Learning:
Hypothesis – Linear Separation?



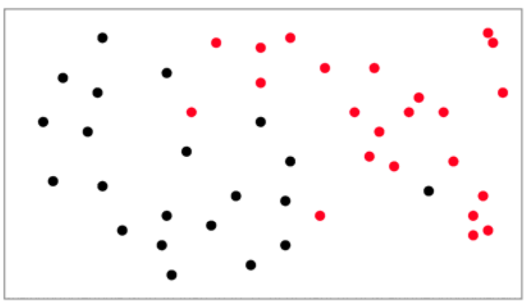
Supervised Learning:

Hypothesis – Quadratic Separation



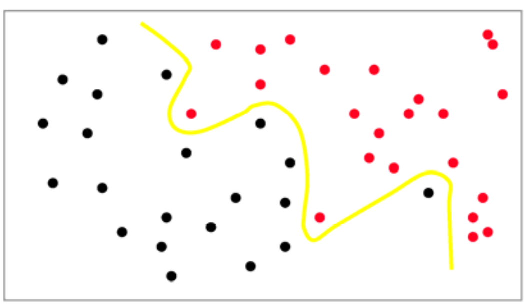
Supervised Learning:

Hypothesis – Noisy/Mislabeled Data



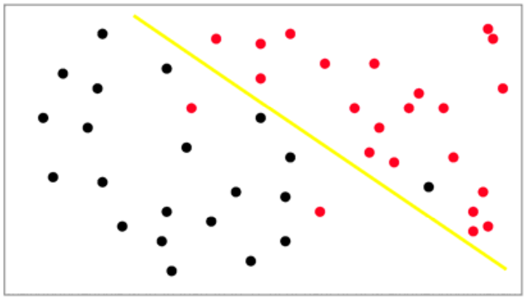
Supervised Learning:

Hypothesis – Overfitting



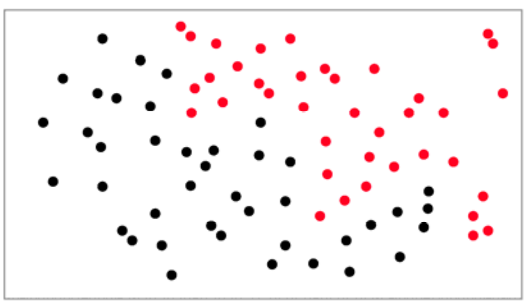
Supervised Learning:

Hypothesis – Underfitting?



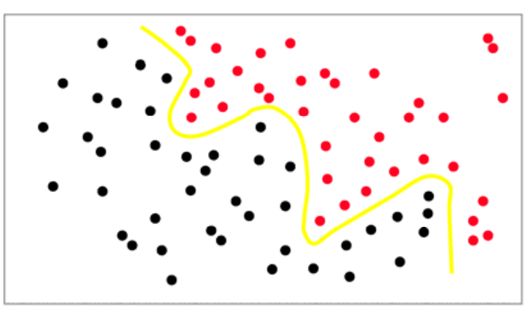
Supervised Learning:

Hypothesis – More data



Supervised Learning:

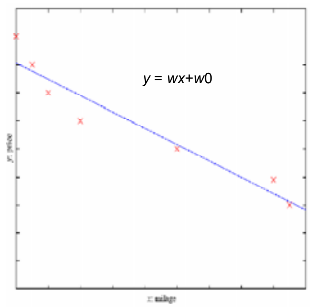
Hypothesis – More complex



Supervised Learning:

Linear Regression

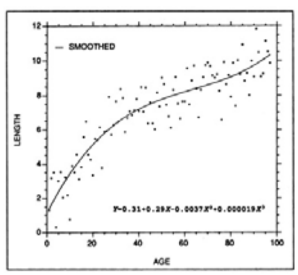
- Example:
  Price of a used car
  x : car attribute
  y : price
- $y = g(x \mid \theta)$
  model:
  $g(\ )$
  parameters:
  $\theta = (w, w_0)$



Supervised Learning:

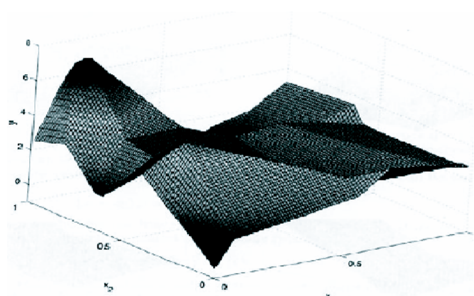
Polynomial Regression

- Example:
  Growth of a species
  x : age
  y : length
- $y = g(x \mid \theta)$
  model:
  $g(\ )$
  parameters:
  $\theta = (w_3, w_2, w_1, w_0)$



Supervised Learning:

Piecewise Linear 2D Regression



Supervised Learning:
Some Regression Applications

- Cost estimation
  - Energy consumption
- Control
  - Angle of steering wheel for robot car
  - Kinematics of a robot arm
- Predicted response
  - Surface materials

Supervised Learning:
Range of Methods

- Methods differ in terms of
  - The form of hypothesis space
  - The way to find best hypothesis given data
- There are many successful approaches
  - Decision trees
  - Support vector machines
  - Neural networks
  - Case-based reasoning
  - ...

Supervised Learning:
General Uses

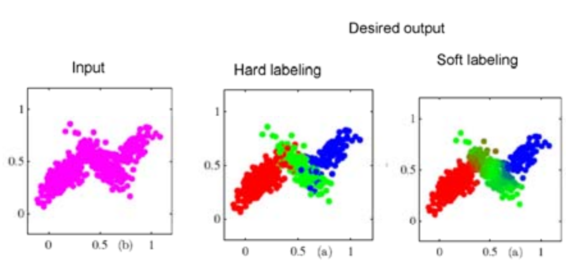
- Prediction of future cases
  Use the rule to predict the output for future inputs
- Knowledge extraction
  The rule is easy to understand
- Compression
  The rule is simpler than the data it explains
- Outlier detection
  Exceptions that are not covered by the rule (e.g. fraud)

Unsupervised Learning

Unsupervised Learning:
Overview

- General characteristics
  - Learning “what normally happens”
  - No output available
  - Can be formalized in terms of probability density estimation
- Examples
  - Clustering
  - Dimensionality reduction
  - Abnormality detection
  - Latent variable estimation

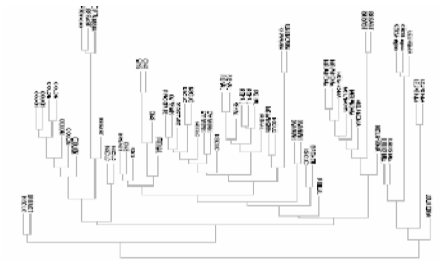
Unsupervised Learning:
K-means clustering



K=3 is the number of clusters, here chosen by hand

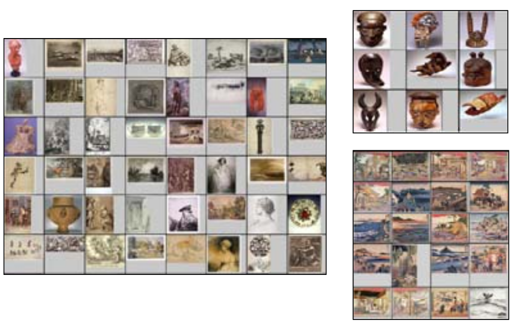
Unsupervised Learning:

Dendrogram Creation



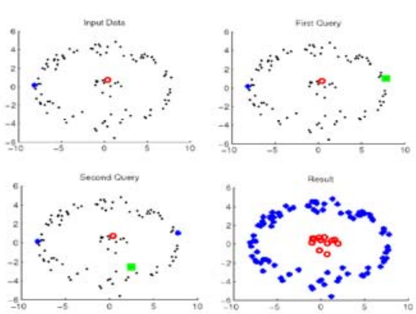
Unsupervised Learning:

Image Clustering



Unsupervised Learning:

Active Learning – Asking Questions



Reinforcement Learning

Reinforcement Learning:

Overview

- Characteristics
  - Learning a Policy: A sequence of outputs
  - No supervised output, but a delayed reward
  - Credit assignment problem:
    - Which action led me to winning the game?
- Examples
  - Elevator scheduling
  - Backammon and Chess
  - Robot control