

# Introduction to Machine Learning

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# Why “Learn” ?

- Machine learning is programming computers to optimize a performance criterion using example data or past experience.
- There is no need to “learn” to calculate payroll
- 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 (routing on a computer network)
  - Solution needs to be adapted to particular cases (user biometrics)

# What We Talk About When We Talk About “Learning”

- Learning general models from a data of particular examples
- Data is cheap and abundant (data warehouses, data marts); knowledge is expensive and scarce.
- Example in retail: Customer transactions to consumer behavior:  
*People who bought “X” also bought “Y”*  
*(www.amazon.com)*
- Build a model that is *a good and useful approximation* to the data.

# Data Mining

- **Retail:** Market basket analysis, Customer relationship management (CRM)
- **Finance:** Credit scoring, fraud detection
- **Manufacturing:** Control, robotics, troubleshooting
- **Medicine:** Medical diagnosis
- **Telecommunications:** Spam filters, intrusion detection
- **Web mining:** Search engines
- ...

# What is Machine Learning?

- Optimize a performance criterion using example data or past experience
- Role of Statistics: Inference from a sample
- Role of Computer science: Efficient algorithms to
  - Solve the optimization problem
  - Representing and evaluating the model for inference

# Applications

- Association
- Supervised Learning
  - Classification
  - Regression
- Unsupervised Learning
- Reinforcement Learning

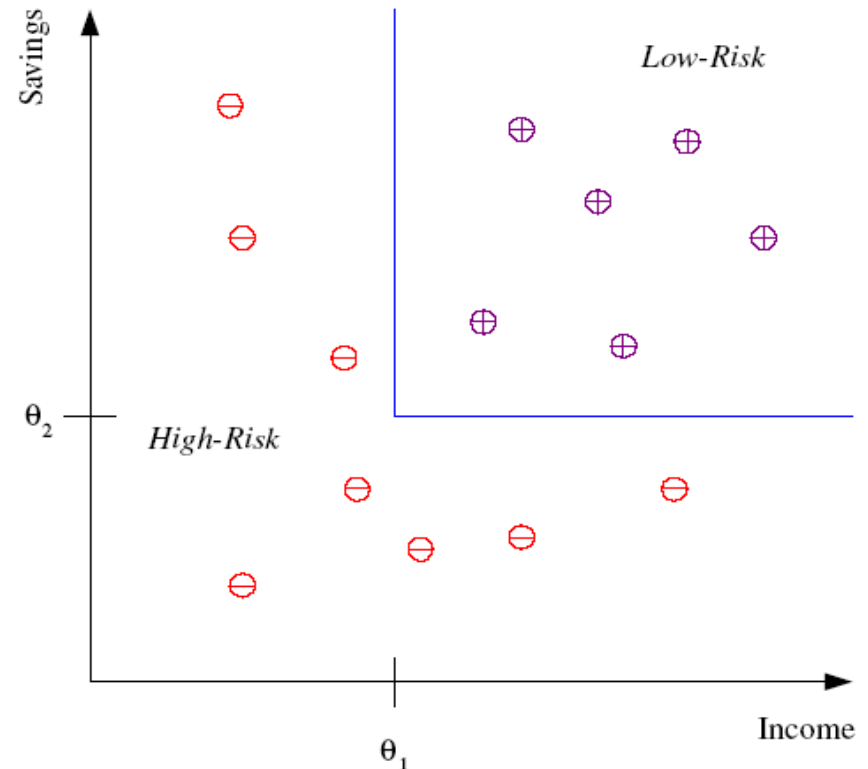
# Learning Associations

- Basket analysis:  
 $P(Y | X)$  probability that somebody who buys  $X$  also buys  $Y$  where  $X$  and  $Y$  are products/services.

Example:  $P(\text{chips} | \text{beer}) = 0.7$

# Classification

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



Discriminant: IF  $\text{income} > \theta_1$  AND  $\text{savings} > \theta_2$   
THEN **low-risk** ELSE **high-risk**



# Classification: Applications

- Aka Pattern recognition
- **Face recognition:** Pose, lighting, occlusion (glasses, beard), make-up, hair style
- **Character recognition:** Different handwriting styles.
- **Speech recognition:** Temporal dependency
- **Medical diagnosis:** From symptoms to illnesses
- ...

# Face Recognition

Training examples of a person



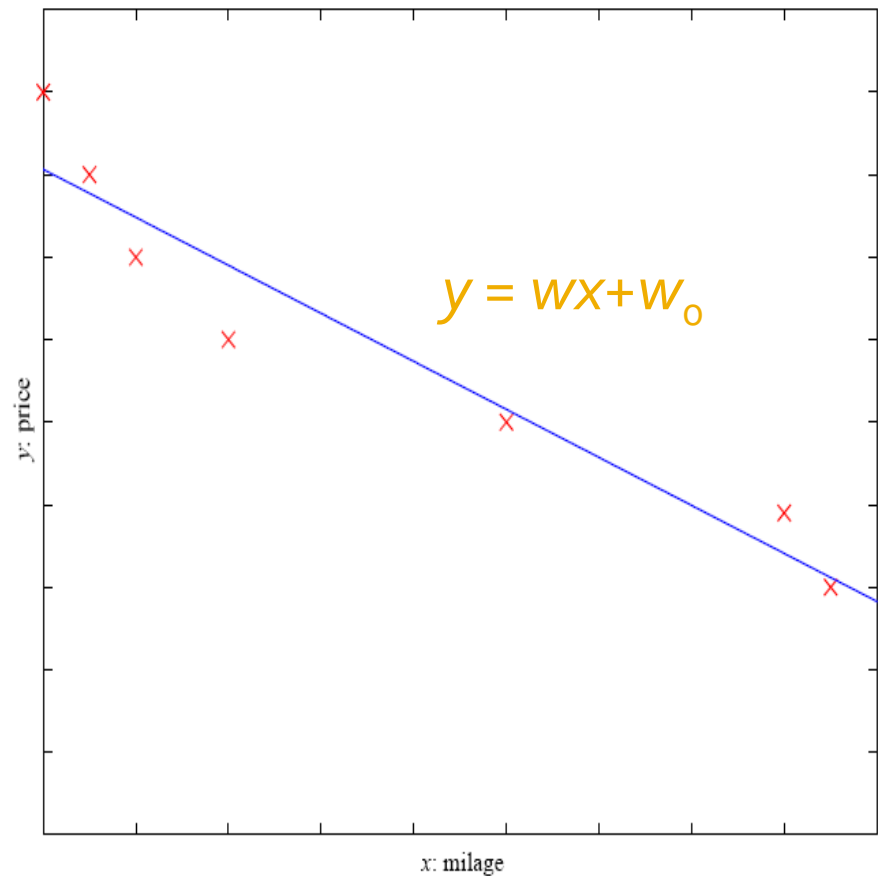
Test images



ORL dataset,  
AT&T Laboratories, Cambridge UK

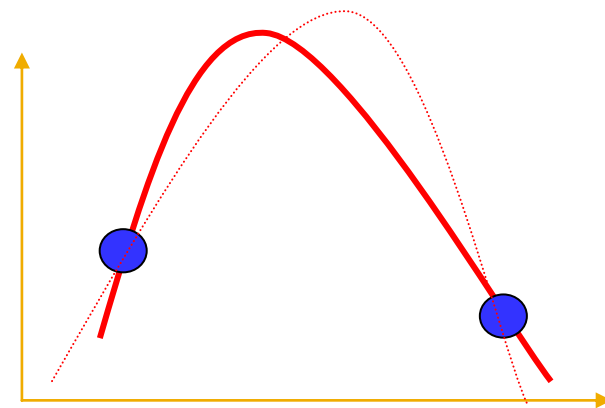
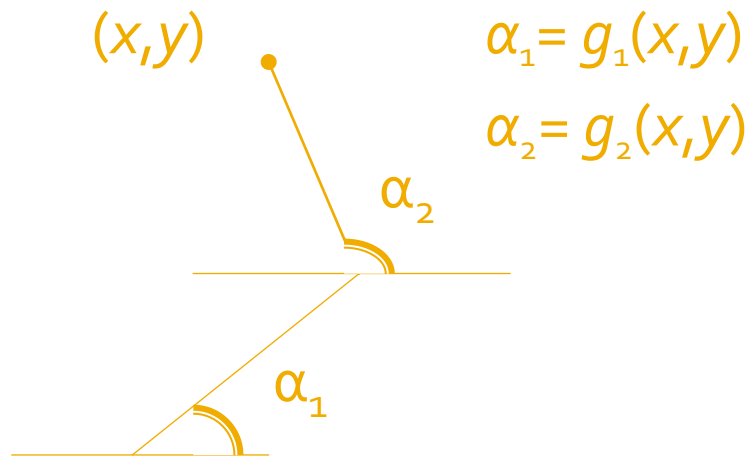
# Regression

- Example: Price of a used car
- $x$  : car attributes  
 $y$  : price  
 $y = g(x | \theta)$   
 $g()$  model,  
 $\theta$  parameters



# Regression Applications

- Navigating a car: Angle of the steering
- Kinematics of a robot arm



- Response surface design

# Supervised Learning: 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

- Learning “what normally happens”
- No output
- Clustering: Grouping similar instances
- Example applications
  - Customer segmentation in CRM
  - Image compression: Color quantization
  - Bioinformatics: Learning motifs

# 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, ...

# Resources: Datasets

- UCI Repository:  
<http://www.ics.uci.edu/~mlearn/MLRepository.html>
- UCI KDD Archive:  
<http://kdd.ics.uci.edu/summary.data.application.html>
- Statlib: <http://lib.stat.cmu.edu/>
- Delve: <http://www.cs.utoronto.ca/~delve/>



# Resources: Journals

- Journal of Machine Learning Research  
[www.jmlr.org](http://www.jmlr.org)
- Machine Learning
- Neural Computation
- Neural Networks
- IEEE Transactions on Neural Networks
- IEEE Transactions on Pattern Analysis and Machine Intelligence
- Annals of Statistics
- Journal of the American Statistical Association
- ...

# Resources: Conferences

- International Conference on Machine Learning (ICML)
- European Conference on Machine Learning (ECML)
- Neural Information Processing Systems (NIPS)
- Uncertainty in Artificial Intelligence (UAI)
- Computational Learning Theory (COLT)
- International Conference on Artificial Neural Networks (ICANN)
- International Conference on AI & Statistics (AISTATS)
- International Conference on Pattern Recognition (ICPR)
- ...