Introduction to Machine Learning

Brown University CSCI 1950-F, Spring 2012

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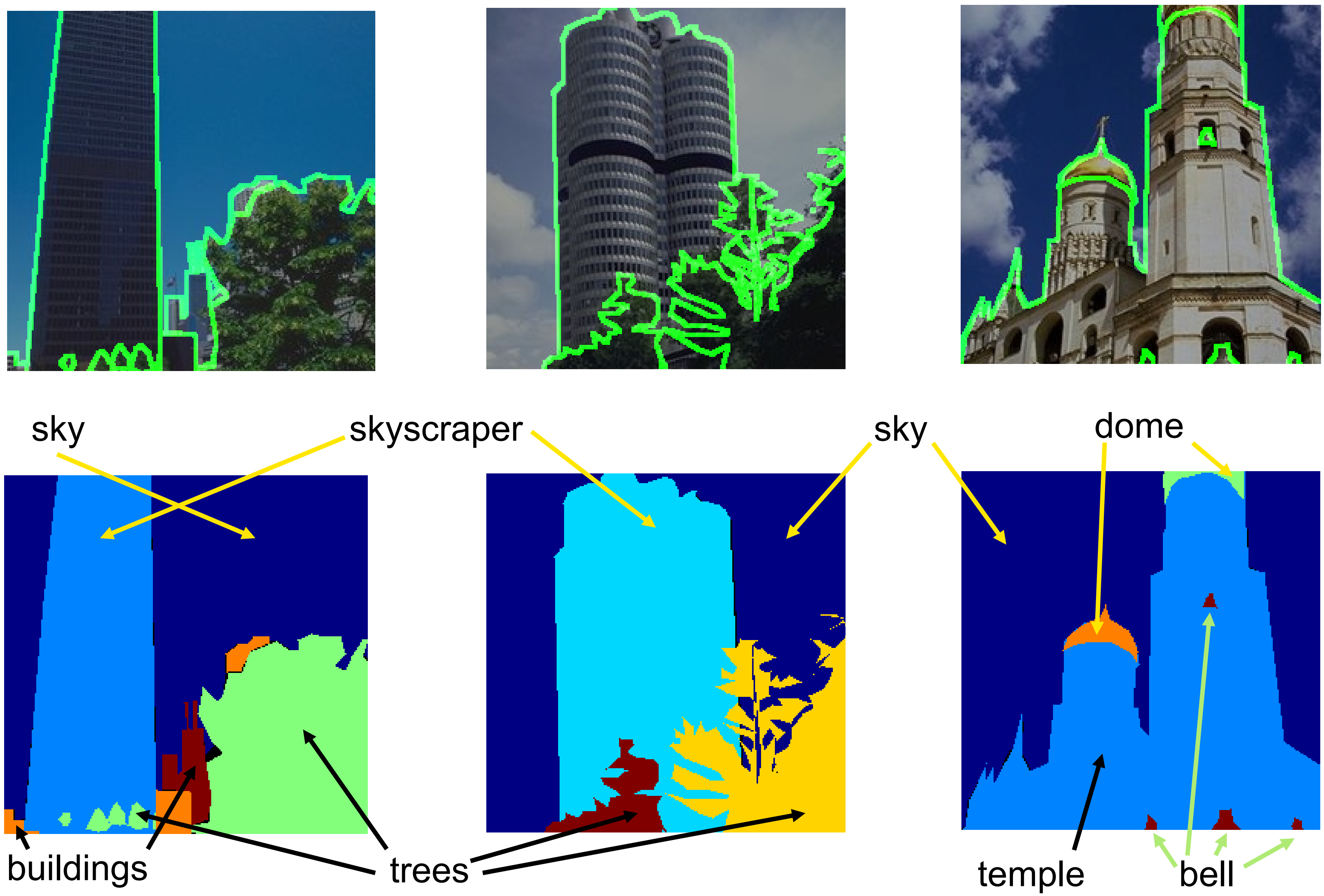
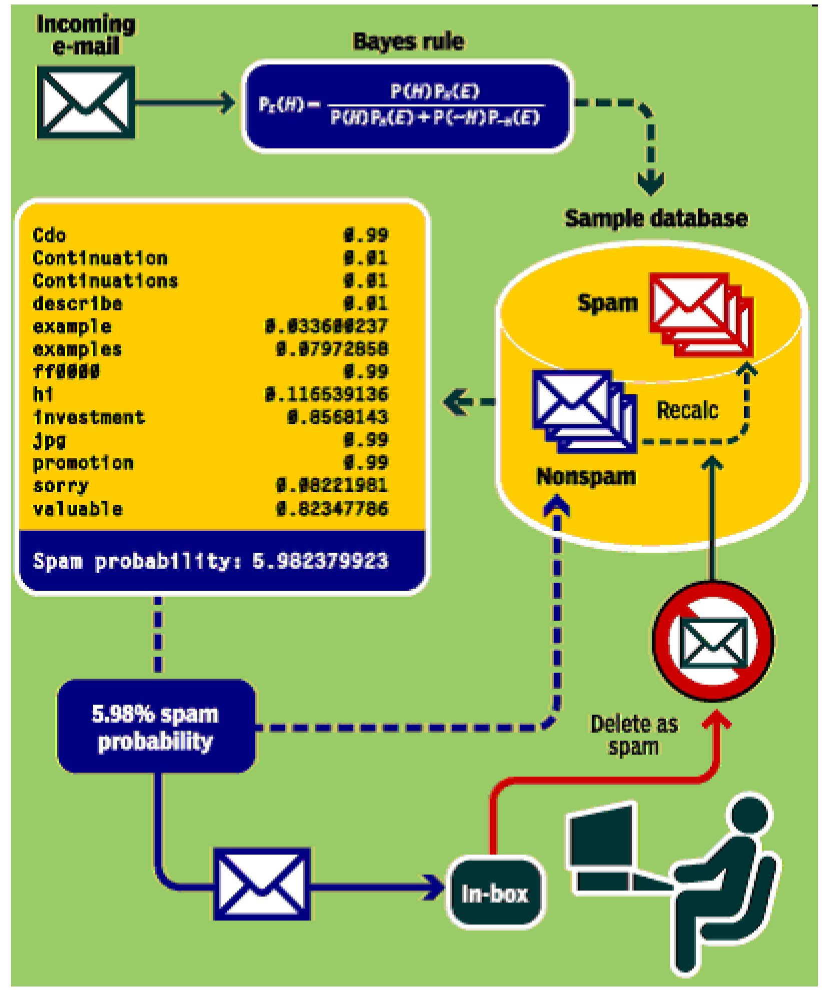
Visual Object Recognition



Spam Filtering

- Binary classification problem: is this e-mail spam or useful (ham)?
- Noisy training data: messages previously marked as spam
- Wrinkle: spammers evolve to counter filter innovations



Spam Filter Express
http://www.spam-filter-express.com/

Collaborative Filtering

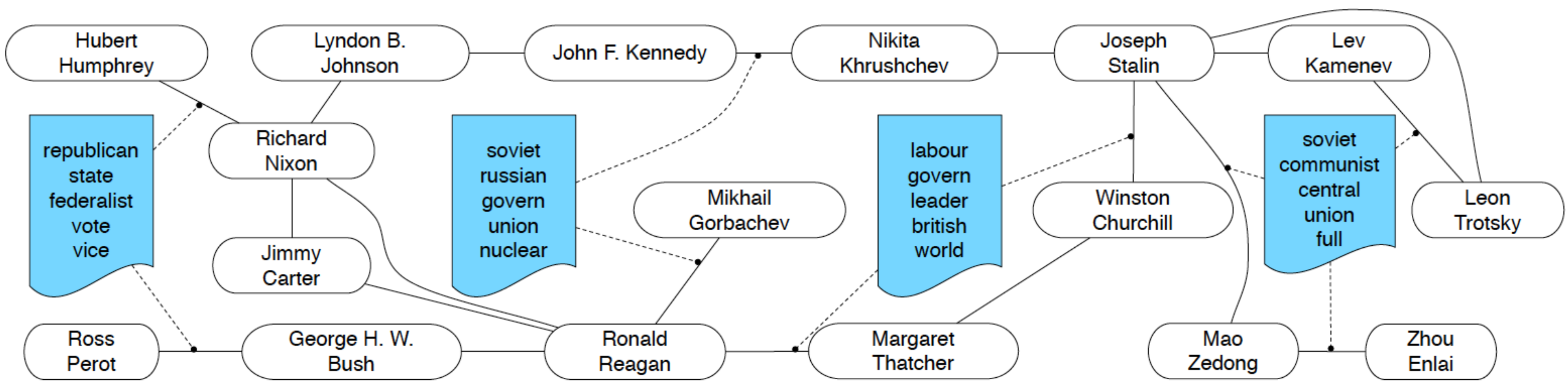
Leaderboard

Display top 20 leaders.

Rank	Team Name	Best Score	% Improvement	Last Submit Time
1	The Ensemble	0.8553	10.10	2009-07-26 18:38:22
2	BellKor's Pragmatic Chaos	0.8554	10.09	2009-07-26 18:18:28
Grand Prize - RMSE <= 0.8563				
3	Grand Prize Team	0.8571	9.91	2009-07-24 13:07:49
4	Opera Solutions and Vandelay United	0.8573	9.89	2009-07-25 20:05:52
5	Vandelay Industries !	0.8579	9.83	2009-07-26 02:49:53
6	PragmaticTheory	0.8582	9.80	2009-07-12 15:09:53
7	BellKor in BigChaos	0.8590	9.71	2009-07-26 12:57:25
8	Dace_	0.8603	9.58	2009-07-24 17:18:43
9	Opera Solutions	0.8611	9.49	2009-07-26 18:02:08
10	BellKor	0.8612	9.48	2009-07-26 17:19:11
11	BigChaos	0.8613	9.47	2009-06-23 23:06:52
12	Feeds2	0.8613	9.47	2009-07-24 20:06:46
Progress Prize 2008 - RMSE = 0.8616 - Winning Team: BellKor in BigChaos				
13	xiangliang	0.8633	9.26	2009-07-21 02:04:40
14	Gravity	0.8634	9.25	2009-07-26 15:58:34
15	Ces	0.8642	9.17	2009-07-25 17:42:38
16	Invisible Ideas	0.8644	9.14	2009-07-20 03:26:12
17	Just a guy in a garage	0.8650	9.08	2009-07-22 14:10:42
18	Craig Carmichael	0.8656	9.02	2009-07-25 16:00:54
19	J Dennis Su	0.8658	9.00	2009-03-11 09:41:54
20	acmehill	0.8659	8.99	2009-04-16 06:29:35
Progress Prize 2007 - RMSE = 0.8712 - Winning Team: KorBell				
Cinematch score on quiz subset - RMSE = 0.9514				

Social Network Analysis

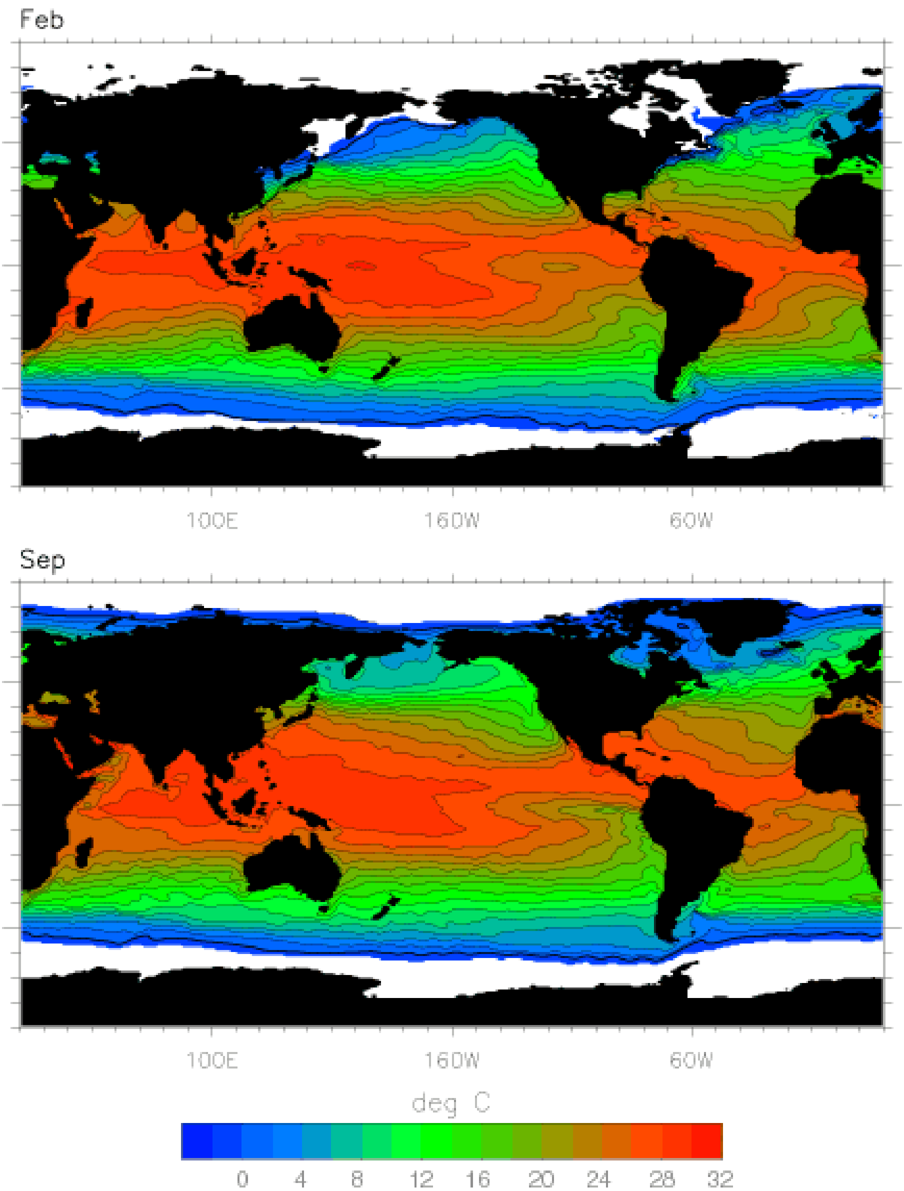
- Unsupervised discovery and visualization of relationships among people, companies, etc.
- Example: infer relationships among named entities directly from Wikipedia entries



Chang, Boyd-Graber, & Blei, KDD 2009

Climate Modeling

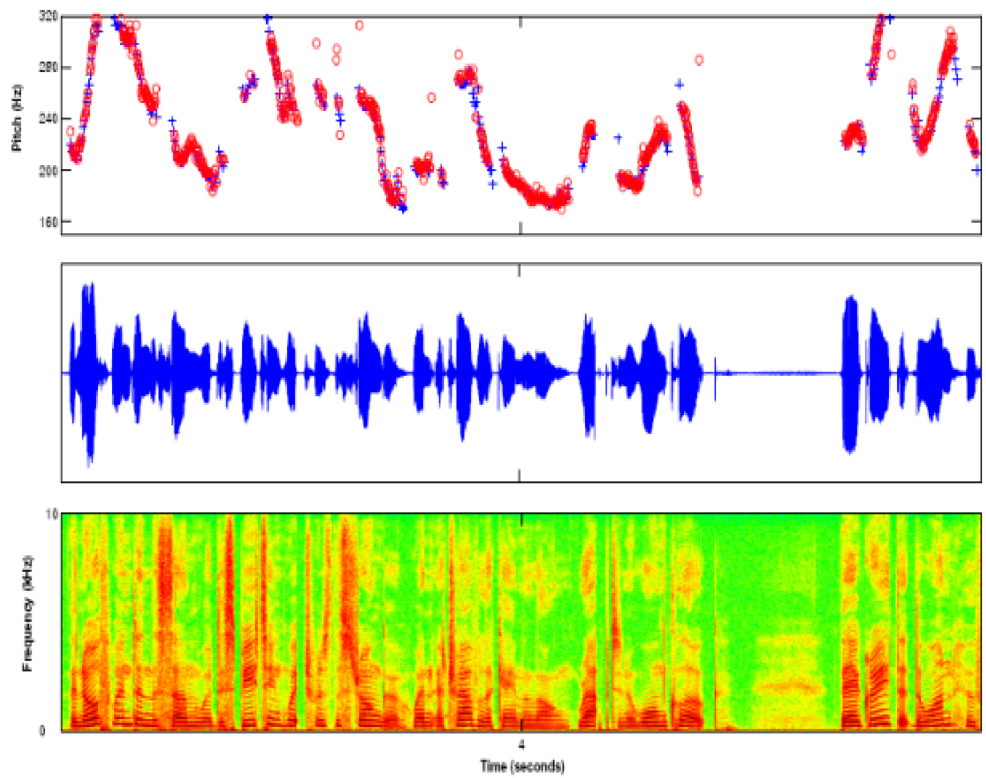
- Satellites measure sea-surface temperature at sparse locations
  - Partial coverage of ocean surface
  - Sometimes obscured by clouds, weather
- Would like to infer a dense temperature field, and track its evolution

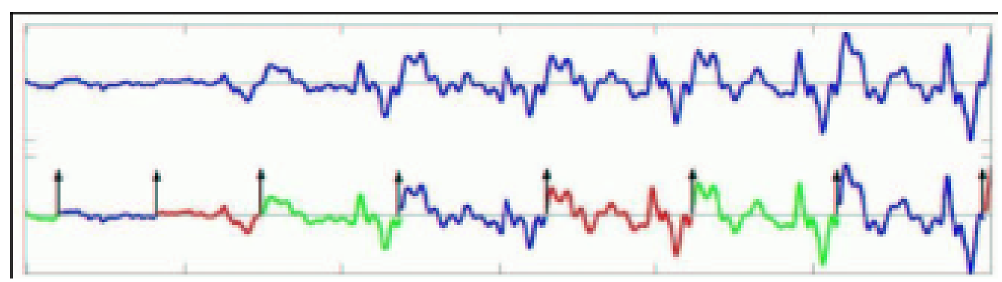


NASA Seasonal to Interannual Prediction Project
http://ct.gsfc.nasa.gov/annual.reports/ess98/nsipp.html

Speech Recognition

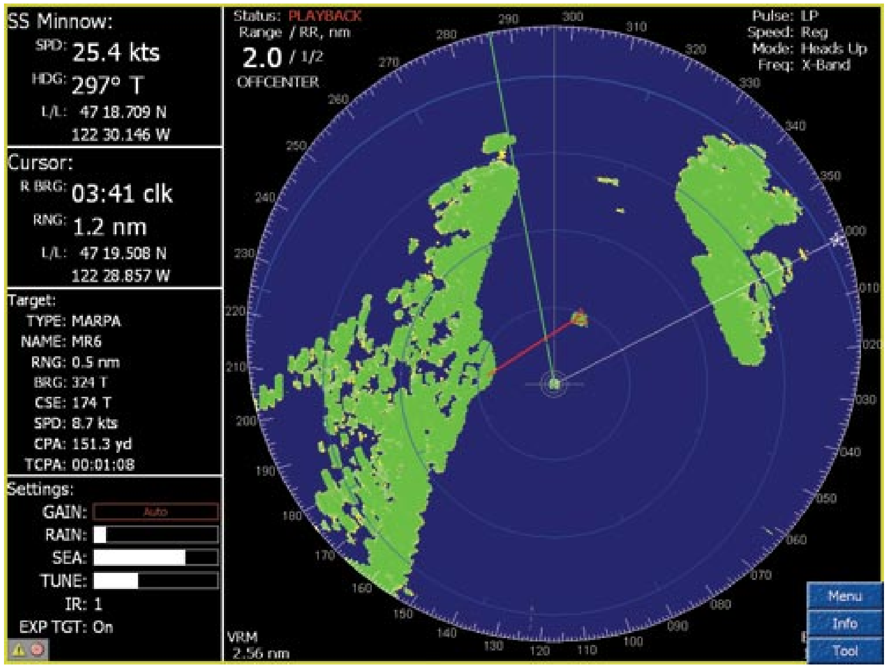
- Given an audio waveform, robustly extract & recognize any spoken words
- Statistical models can be used to
  - ➢ Provide greater robustness to noise
  - ➢ Adapt to accent of different speakers
  - ➢ Learn from training



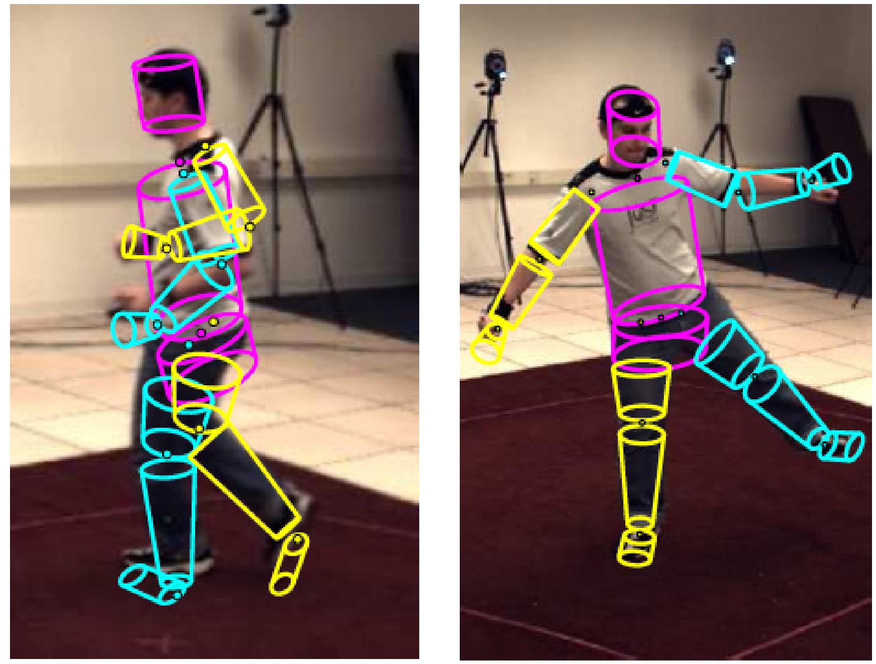


S. Roweis, 2004

Target Tracking



Radar-based tracking of multiple targets

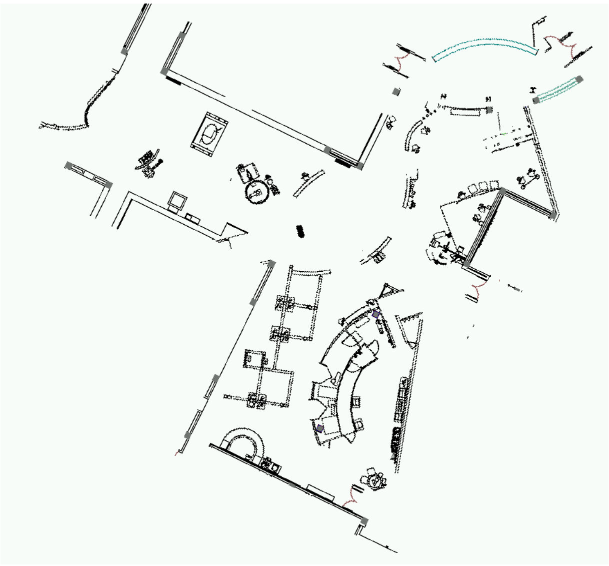


Visual tracking of articulated objects
(L. Sigal et. al., 2009)

- Estimate motion of targets in 3D world from indirect, potentially noisy measurements

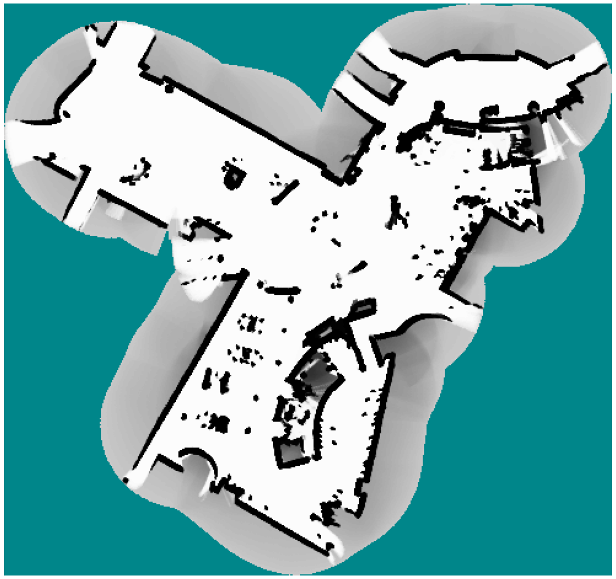
Robot Navigation: *SLAM*

Simultaneous Localization and Mapping



CAD Map

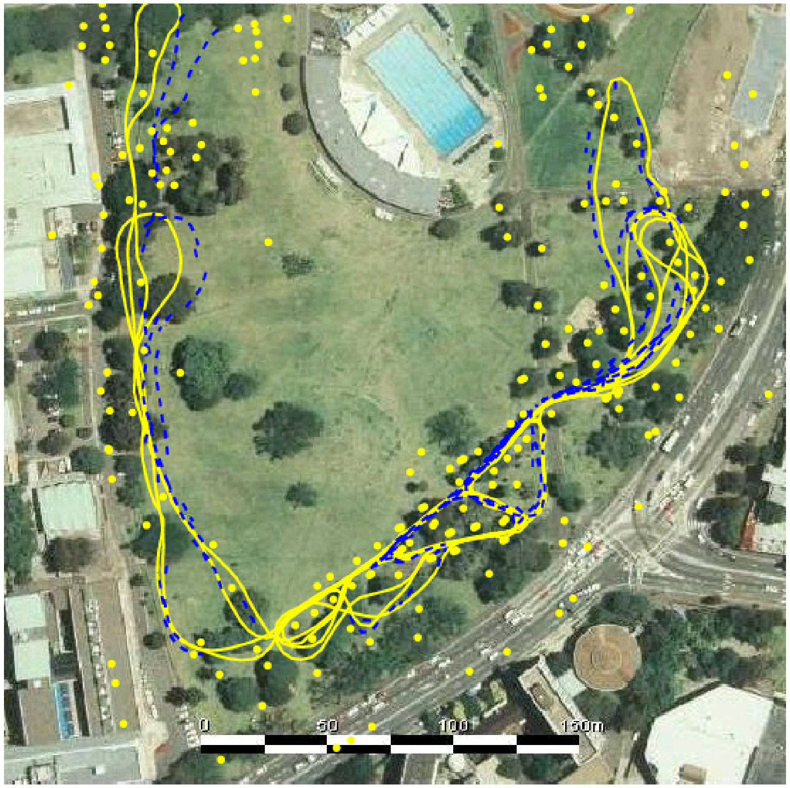
(S. Thrun, San Jose Tech Museum)



Estimated Map

Landmark SLAM

(E. Nebot, Victoria Park)



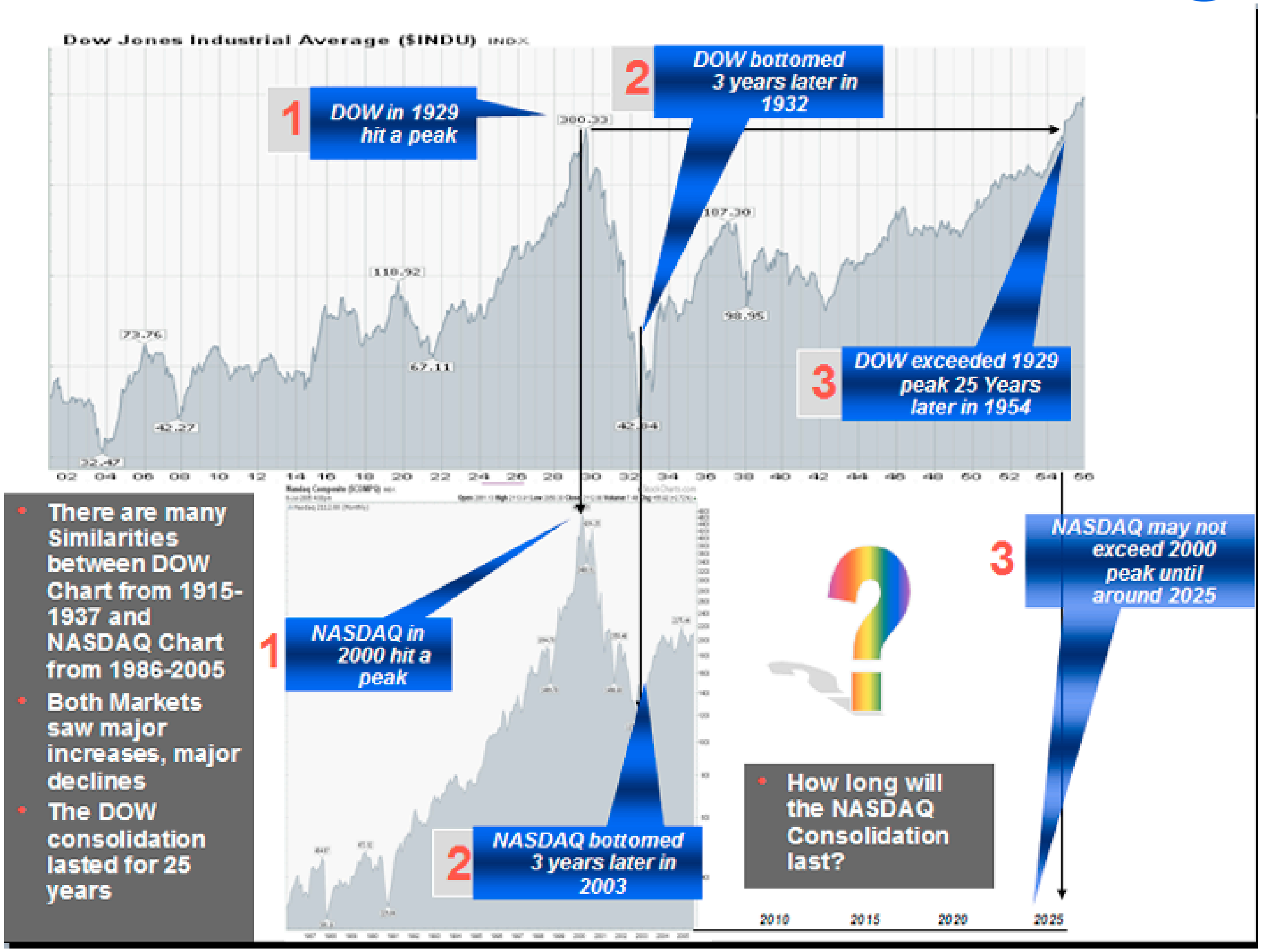
- As robot moves, estimate its pose & world geometry

Human Tumor Microarray Data

- 6830×64 matrix of real numbers.
- Rows correspond to genes, columns to tissue samples.
- Cluster rows (genes) can deduce functions of unknown genes from known genes with similar expression profiles.
- Cluster columns (samples) can identify disease profiles: tissues with similar disease should yield similar expression profiles.

Gene expression matrix

Financial Forecasting



http://www.steadfastinvestor.com/

- Predict future market behavior from historical data, news reports, expert opinions, …

What is "machine learning"?

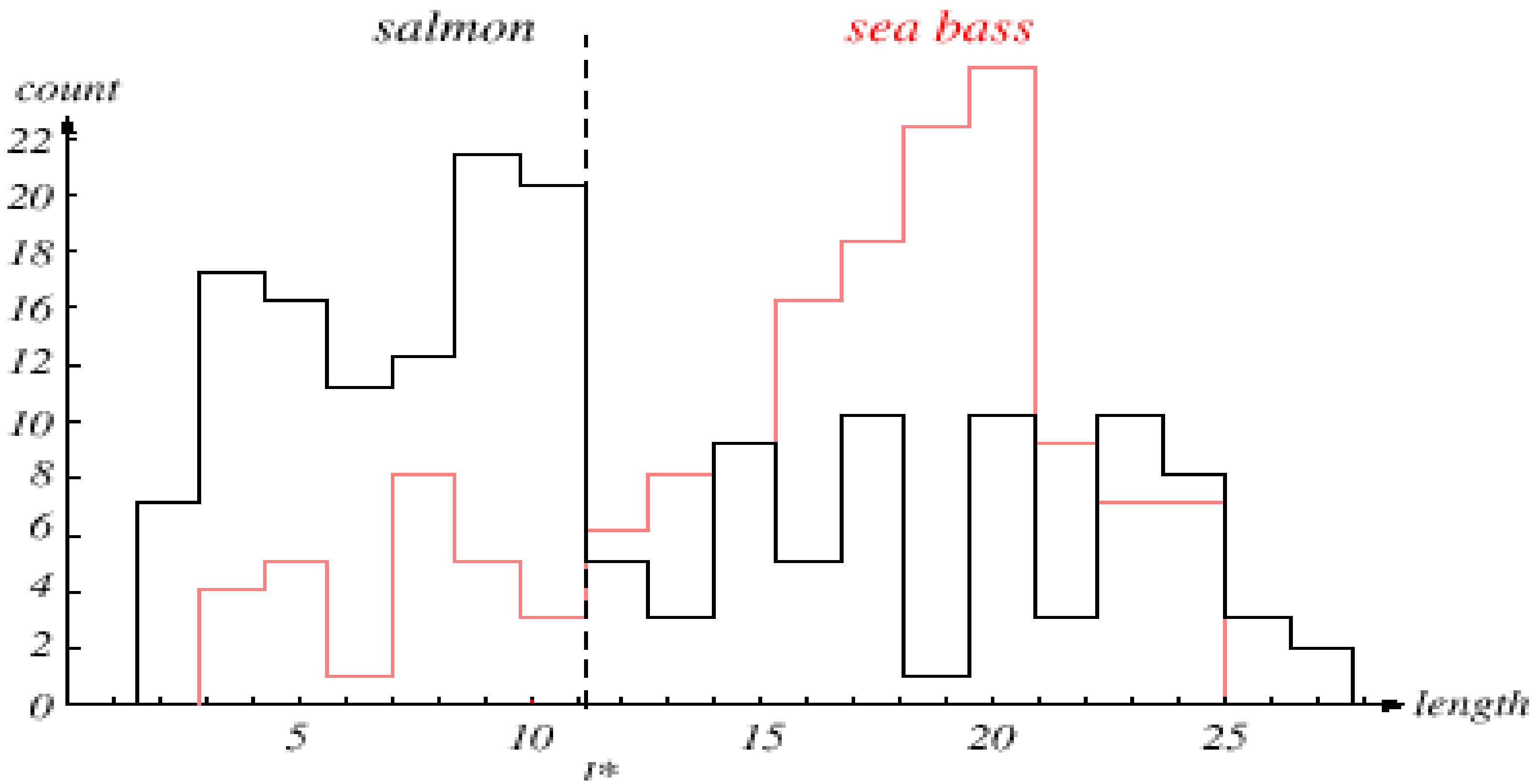
- Given a collection of examples (the "training data"), *predict something* about novel examples
  - The novel examples are usually *incomplete*
- Example (via Mark Johnson): sorting fish
  - Fish come off a conveyor belt in a fish factory
  - Your job: figure out what kind each fish is

Automatically sorting fish

Sorting fish as a machine learning problem

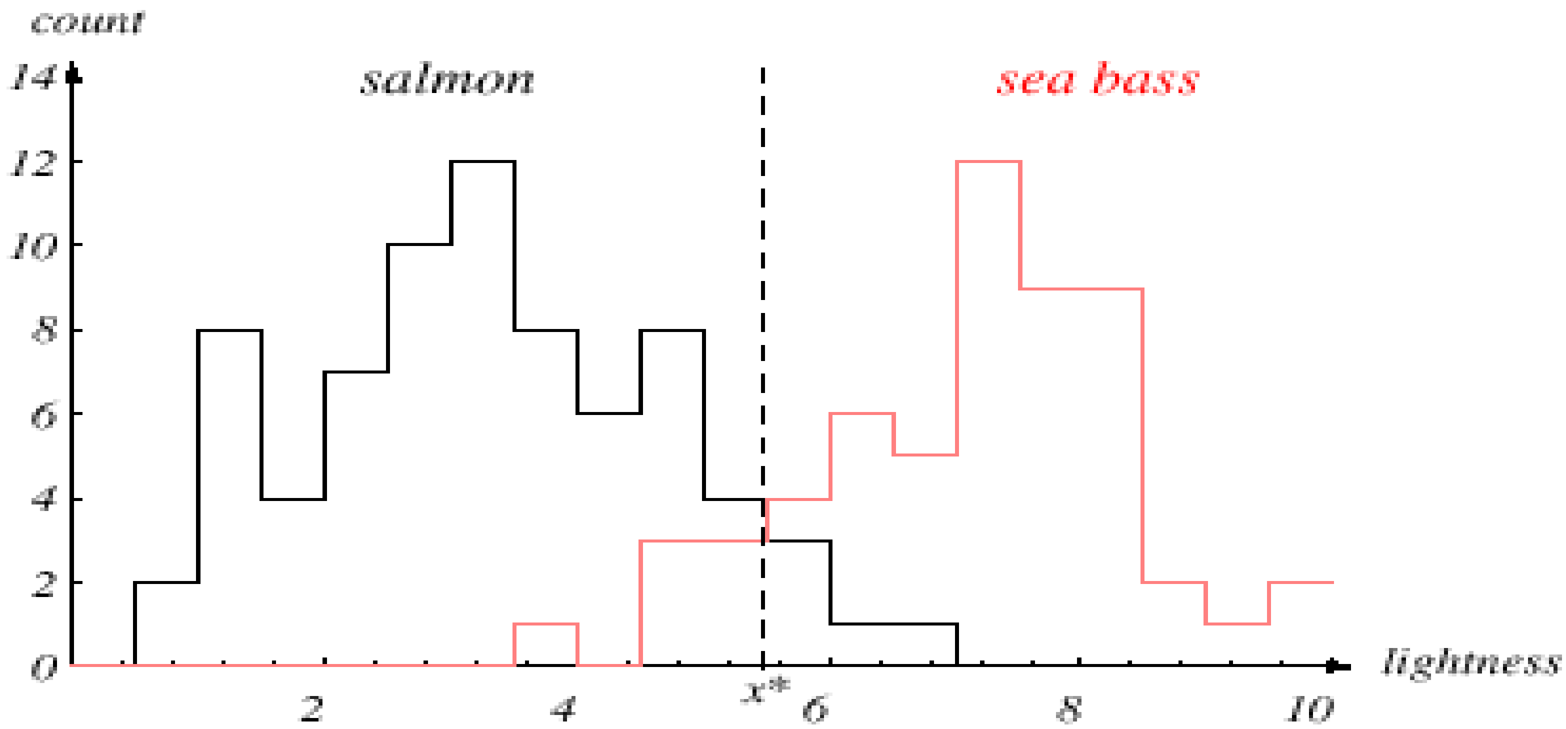
- Training data $D = ((x_1,y_1), \ldots, (x_n,y_n))$
  - A vector of measurements (*features*) x_i (e.g., weight, length, color) of each fish
  - A *label* y_i for each fish
- At run-time:
  - given a novel feature vector x
  - *predict* the corresponding label y

Length as a feature for classifying fish

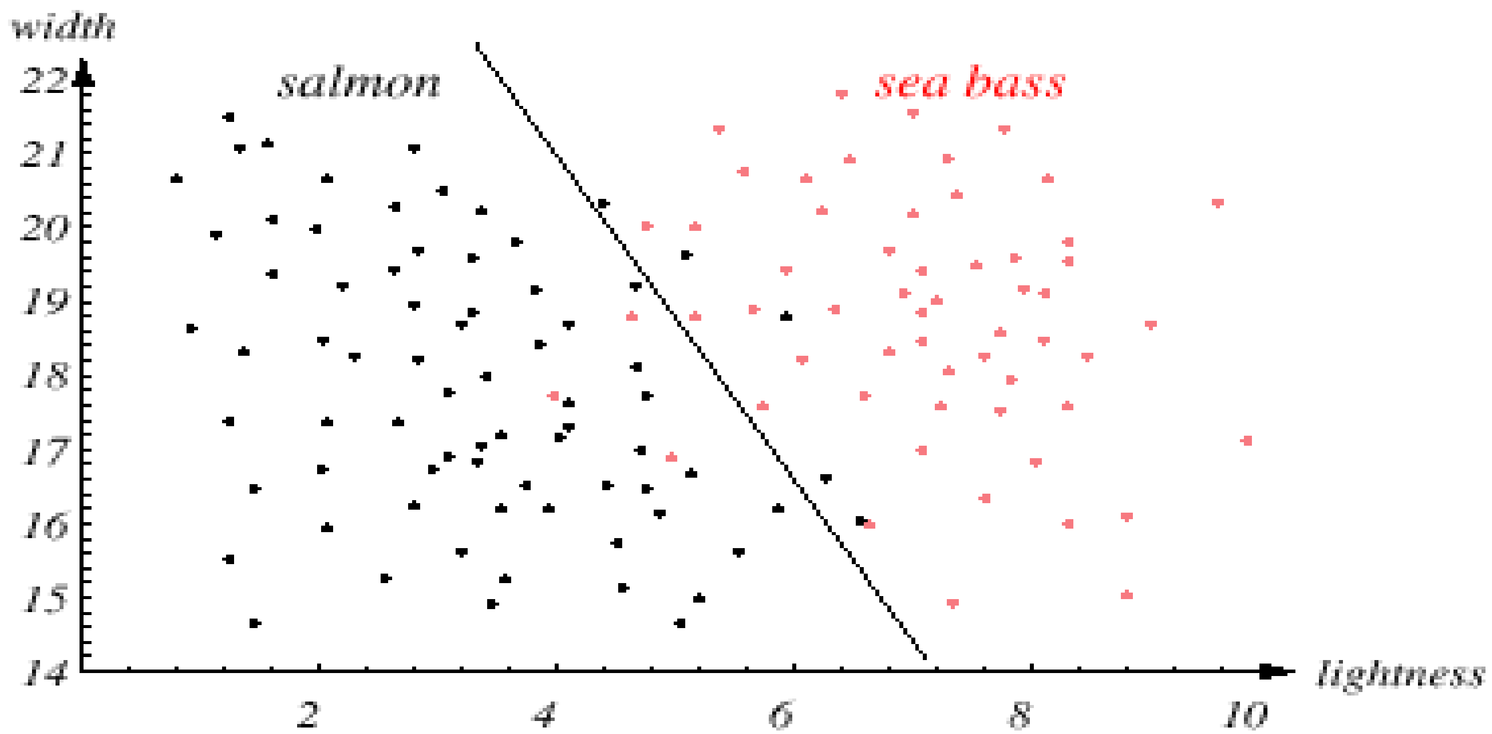


- Need to pick a *decision boundary*
  - Minimize *expected loss*

Lightness as a feature for classifying fish

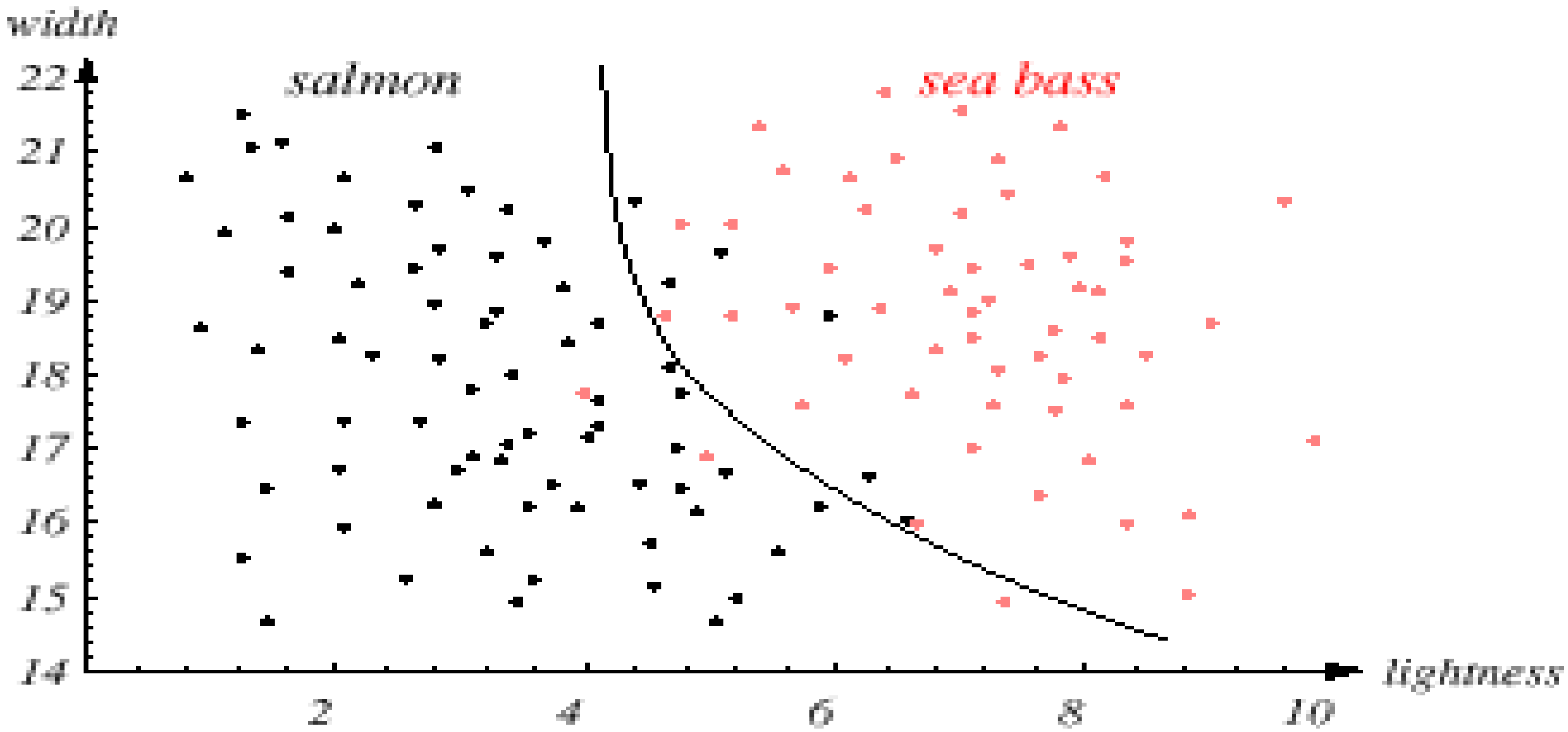


Length and lightness together as features

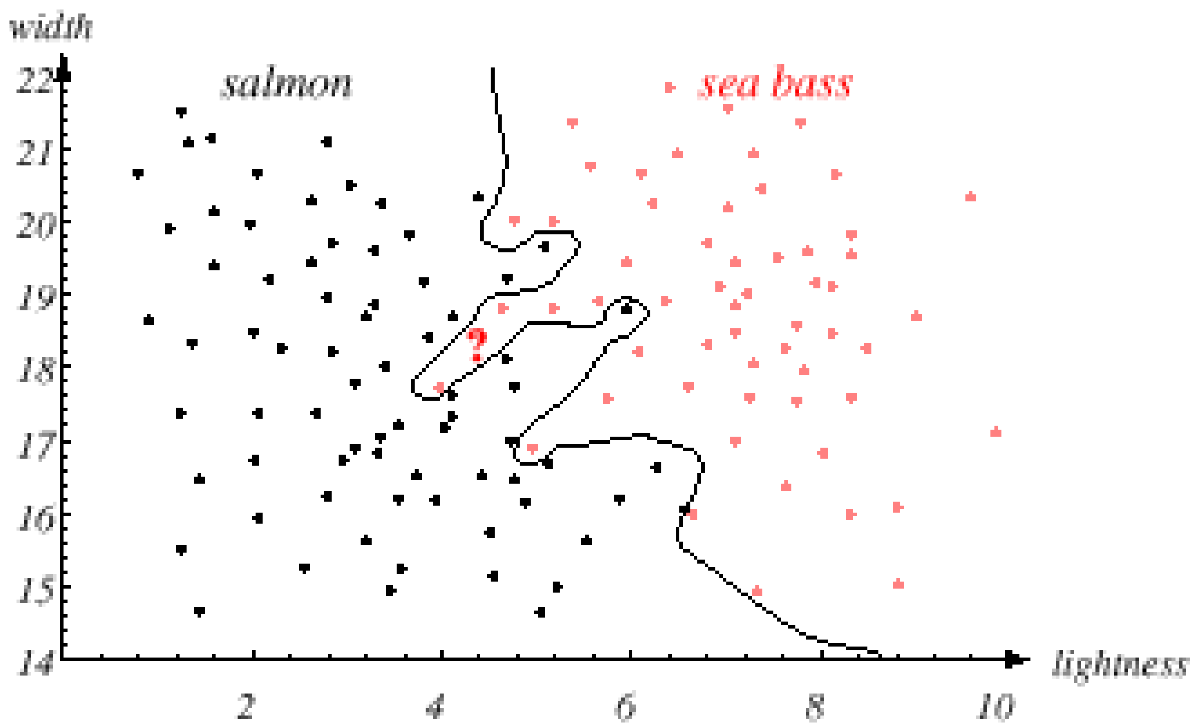


- Not unusual to have millions of features

More complex decision boundaries



Training set error ≠ test set error



- Occam's razor
- Bias-variance dilemma
  - More data!

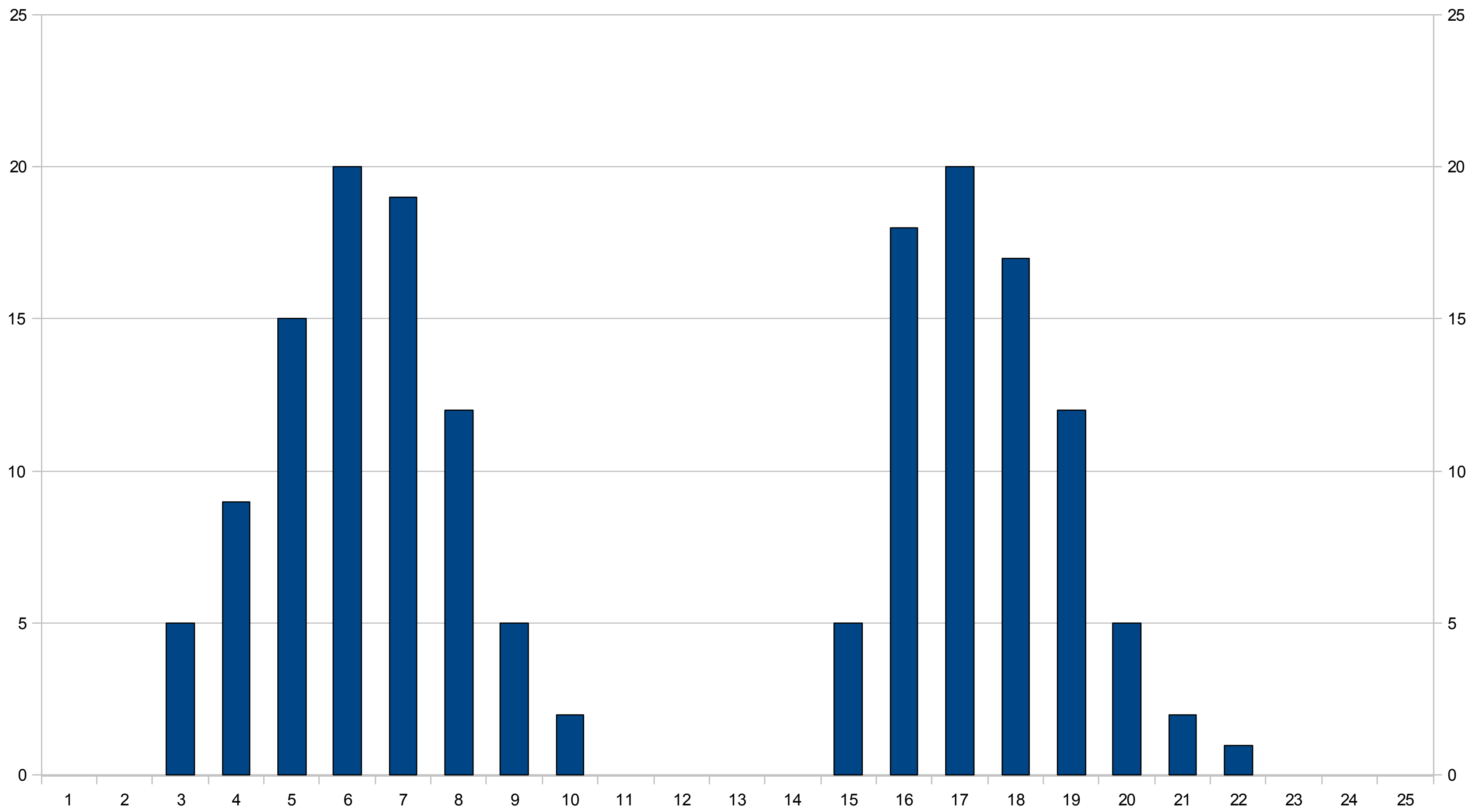
Recap: designing a fish classifier

- Choose the features
  - Can be *the most important step*!
- Collect training data
- Choose the model (e.g., shape of decision boundary)
- Estimate the model from training data
- Use the model to classify new examples
  - Basic machine learning is about the last 3 steps
  - More advanced methods can help learn which features are best, or decide which data to collect

Supervised versus unsupervised learning

- Supervised learning
  - Training data includes labels we must predict: labels are *visible variables* in training data
- Unsupervised learning
  - Training data does not include labels: labels are *hidden variables* in training data
- For classification models, unsupervised learning usually becomes a kind of *clustering*

Unsupervised learning for classifying fish



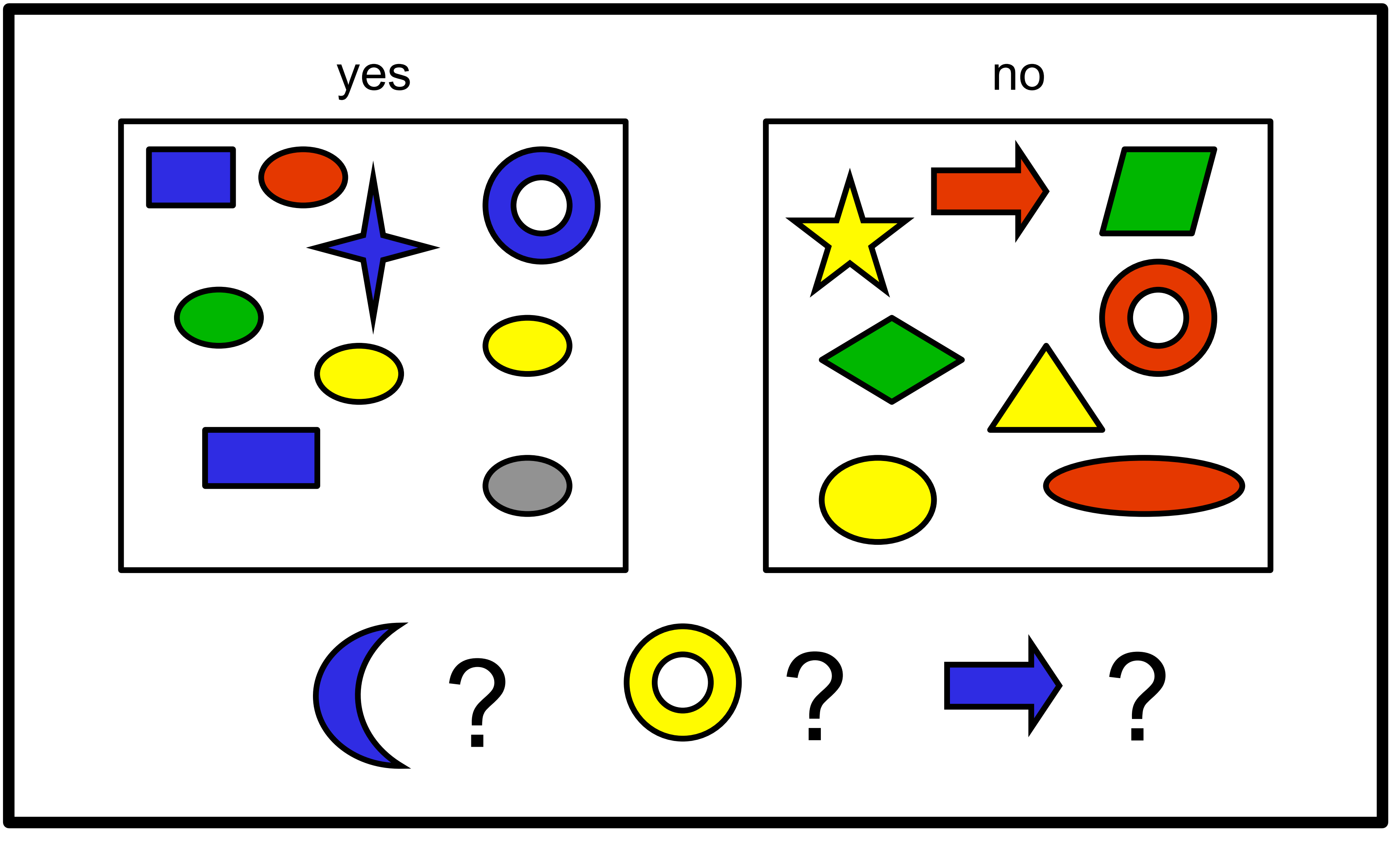
Salmon versus Sea Bass?

Adults versus juveniles?

Machine Learning Problems

	Supervised Learning	***Unsupervised Learning***
Discrete	classification or categorization	clustering
Continuous	regression	dimensionality reduction

Classification Problems



Classification Encoding

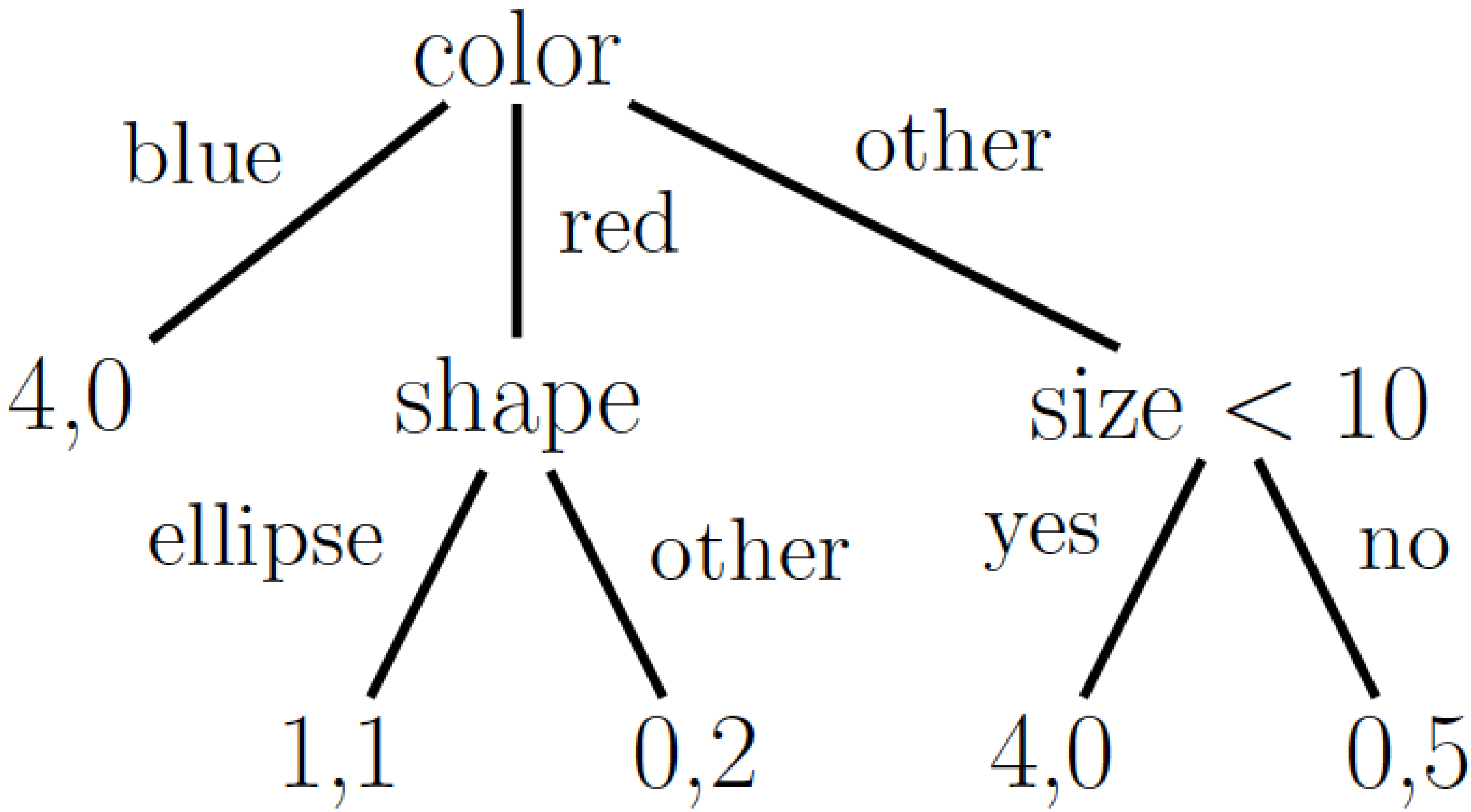
d features (attributes)

n cases

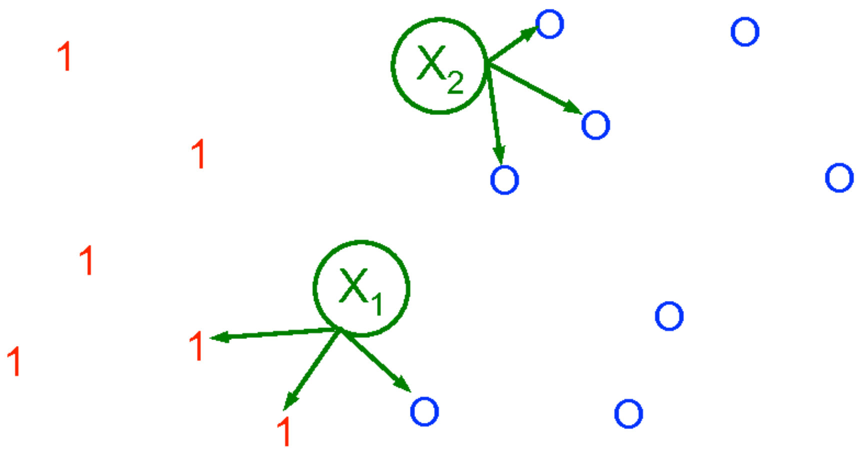
Color	Shape	Size (cm)
Blue	Square	10
Red	Ellipse	2.4
Red	Ellipse	20.7

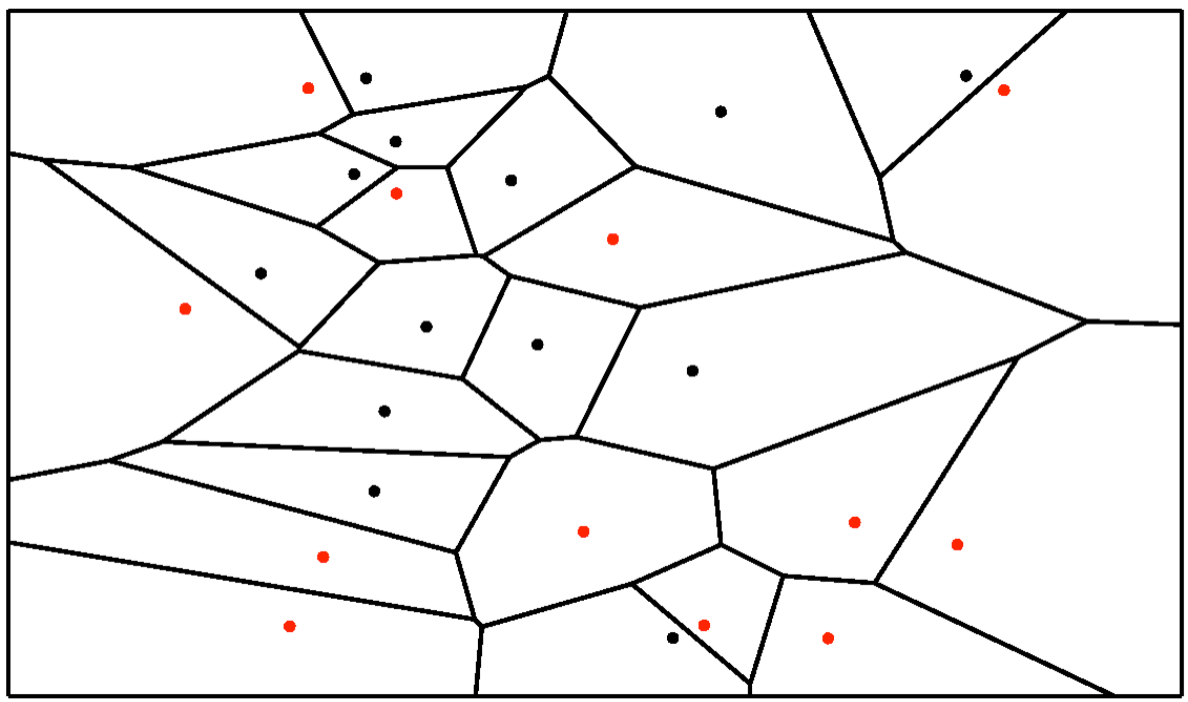
Binary Label
1
1
0

Example: Decision Tree



Example: Nearest Neighbor





Issues to Understand

- Given two candidate classifiers, which is better?
  - Accuracy at predicting training data?
  - Complexity of classification function?
  - Are all mistakes equally bad?
- Given a family of classifiers with free parameters (e.g., all possible decision trees), which member of that family is best?
  - Are there general design principles?
  - What happens as I get more data?
  - Can I test all possible classifiers?
  - What if there are lots of parameters?

Probability & Statistics

Algorithms & Linear Algebra

Course Prerequisites

- Prerequisites: *comfort* with basic
  - Programming: Matlab for assignments
  - Calculus: simple integrals, partial derivatives
  - Linear algebra: matrix factorization, eigenvalues
  - **Probability**: discrete and continuous
- Probably sufficient: You did well in (and still remember!) at least one course in each area
- We will do some review, but it will go quickly!
  - Graduate TAs will lead weekly recitations to review prereqs, work example problems, etc.

Course Evaluation

- 50% homework assignments
  - Mathematical derivations for statistical models
  - Computer implementation of learning algorithms
  - Experimentation with real datasets
- 20% midterm exam: Tuesday March 13
  - Pencil and paper, focus on mathematical analysis
- 25% final exam: May 16, 2:00pm
- 5% class participation:
  - Lectures contain material not directly from text
  - Lots of regular office hours to get help

CS Graduate Credit

- CS Master's and Ph.D. students who want 2000-level credit must complete a *project*
- Flexible: Any application of material from (or closely related to) the course to a problem or dataset you care about
- Evaluation:
  - Late March: Very brief (few paragraph) proposal
  - Early May: Short oral presentation of results
  - Mid May: Written project report (4-8 pages)
- A poor or incomplete project won't hurt your grade, but will mean you don't get grad credit

Course Readings

MACHINE LEARNING: A PROBABILISTIC PERSPECTIVE

Kevin P. Murphy
University of British Columbia, Canada
http://www.cs.ubc.ca/~murphyk
murphyk@cs.ubc.ca
murphyk@stat.ubc.ca

http://www.cs.ubc.ca/~murphyk/MLbook/index.html

Two-volume reader available at Metcalf Copy Center.

Machine Learning Buzzwords

- Bayesian and frequentist estimation: MAP and ML
- Model selection, cross-validation, overfitting
- Linear least squares regression, logistic regression
- Robust statistics, sparsity, L1 vs. L2 regularization
- Features and kernel methods: support vector machines (SVMs), Gaussian processes
- Graphical models: hidden Markov models, Markov random fields, efficient inference algorithms
- Expectation-Maximization (EM) algorithm
- Markov chain Monte Carlo (MCMC) methods
- Mixture models, PCA & factor analysis, manifolds