Machine Learning: CS 6375

Introduction

The University of Texas at Dallas

Source Materials

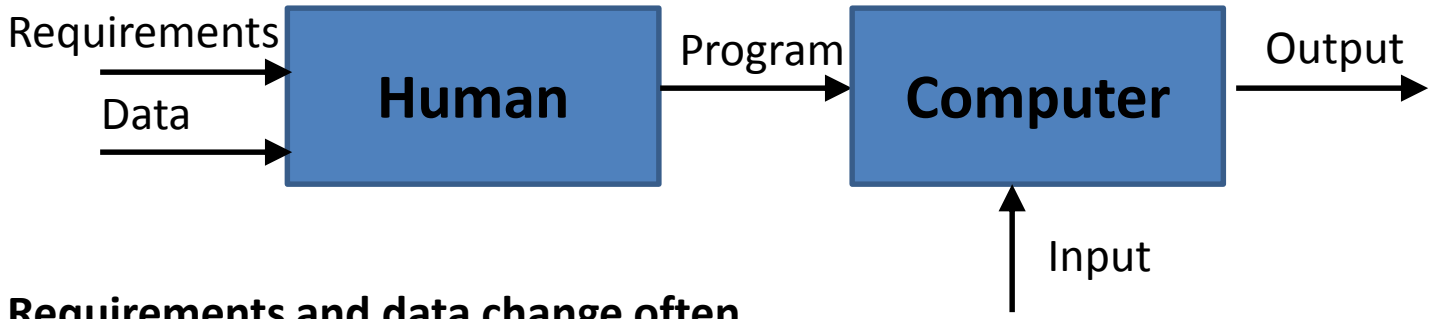
- T. Mitchell, ***Machine Learning,*** McGraw-Hill
- C. Bishop, **Pattern Recognition and Machine Learning**, Springer
- Kevin Murphy, **Machine Learning: A probabilistic perspective**
- Class Notes/Slides

Why Study Machine Learning: A Few Quotes

- “A breakthrough in machine learning would be worth ten Microsofts” (Bill Gates, Microsoft)
- “Machine learning is the next Internet” (Tony Tether, Former Director, DARPA)
- Machine learning is the hot new thing” (John Hennessy, President, Stanford)
- “Web rankings today are mostly a matter of machine learning” (Prabhakar Raghavan, Former Dir. Research, Yahoo)
- “Machine learning is going to result in a real revolution” (Greg Papadopoulos, CTO, Sun)

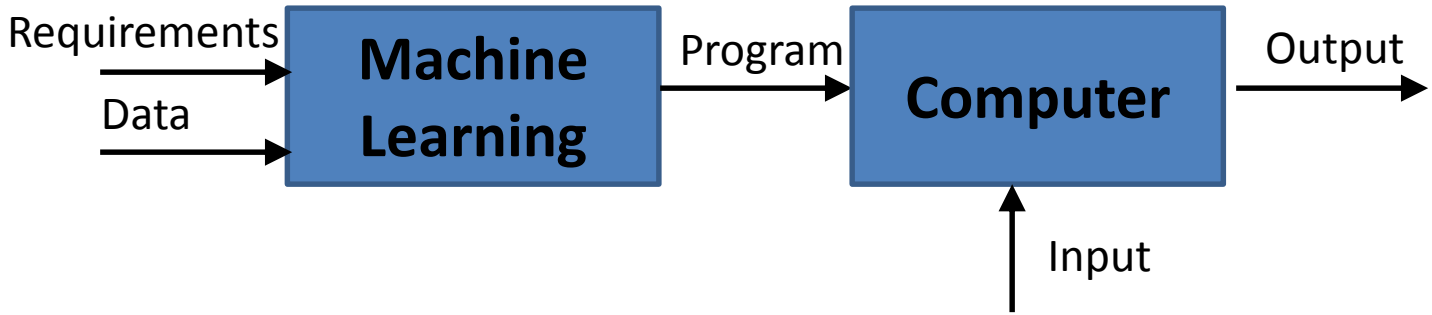
- Getting computers to program themselves
- Writing software is the bottleneck, let data do the work

Traditional Programming



Requirements and data change often

Machine Learning



Training Data

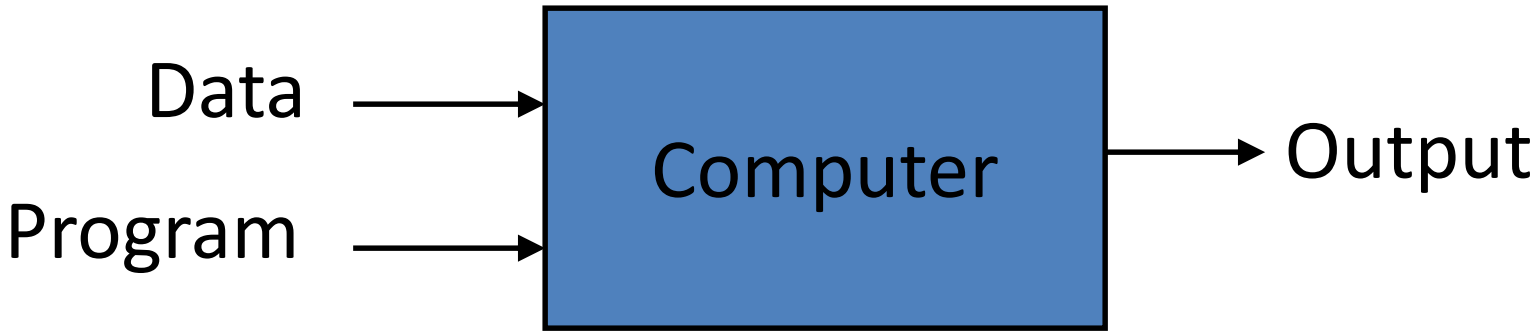
Training Example

Day	Outlook	Temperature	Humidity	Wind	PlayTennis
D1	Sunny	Hot	High	Weak	No
D2	Sunny	Hot	High	Strong	No
D3	Overcast	Hot	High	Weak	Yes
D4	Rain	Mild	High	Weak	Yes
D5	Rain	Cool	Normal	Weak	Yes
D6	Rain	Cool	Normal	Strong	No
D7	Overcast	Cool	Normal	Strong	Yes
D8	Sunny	Mild	High	Weak	No
D9	Sunny	Cool	Normal	Weak	Yes
D10	Rain	Mild	Normal	Weak	Yes
D11	Sunny	Mild	Normal	Strong	Yes
D12	Overcast	Mild	High	Strong	Yes
D13	Overcast	Hot	Normal	Weak	Yes
D14	Rain	Mild	High	Strong	No

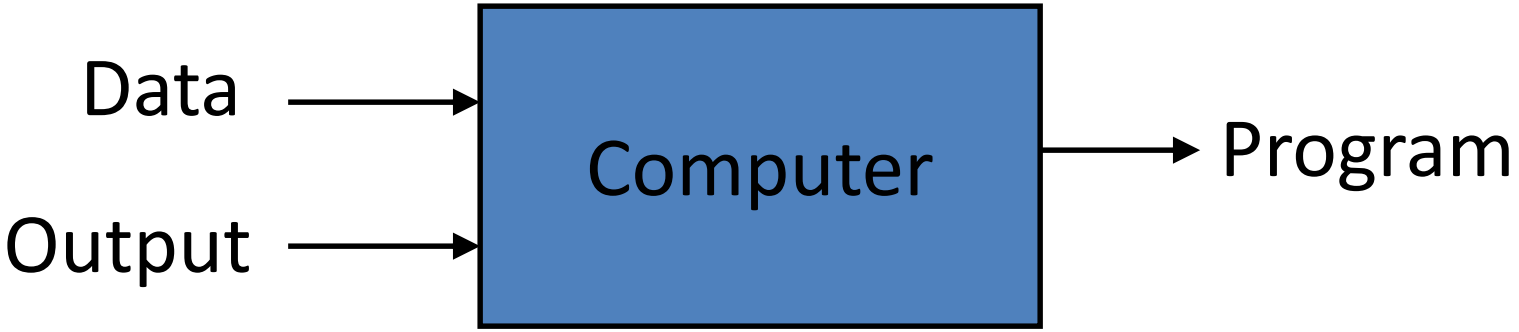
Two Classes: {Yes,No}

- Getting computers to program themselves
- Writing software is the bottleneck, let data do the work

Traditional Programming



Machine Learning



Magic?

No, more like gardening

- **Seeds** = Algorithms
- **Nutrients** = Data
- **Gardener** = You
- **Plants** = Programs

Definition: Machine Learning!

- T. Mitchell: Well posed machine learning
  - Improving performance via experience
  - Formally, A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, it its performance at tasks in T as measured by P, improves with experience.
- H. Simon
  - 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.

The ability to perform a task in a situation which has never been encountered before (Learning = Generalization)

Definition: Machine Learning!

- Pioneer machine learning researcher Arthur Samuel defined machine learning as: "***the field of study that gives computers the ability to learn without being explicitly programmed".***

Example 1: A Chess learning problem

- Task T: playing chess
- Performance measure P: percent of games won against opponents
- Training Experience E: playing practice games against itself

Example 2: Autonomous Vehicle Problem

- Task T: driving on a public highway/roads using vision sensors
- Performance Measure P: percentage of time the vehicle is involved in an accident
- Training Experience E: a sequence of images and steering commands recorded while observing a human driver

When to use Machine Learning?

- Human expertise is absent
  - Example: navigating on mars
- Humans are unable to explain their expertise
  - Example: vision, speech, language
- Requirements and data change over time
  - Example: Tracking, Biometrics, Personalized fingerprint recognition
- The problem or the data size is just too large
  - Example: Web Search

Types of Learning

- **Supervised (inductive) learning**
  - Training data includes desired outputs
- **Unsupervised learning**
  - Training data does not include desired outputs
  - Find hidden/interesting structure in data
- **Semi-supervised learning**
  - Training data includes a few desired outputs
- **Reinforcement learning**
  - the learner interacts with the world via “actions” and tries to find an optimal policy of behavior with respect to “rewards” it receives from the environment

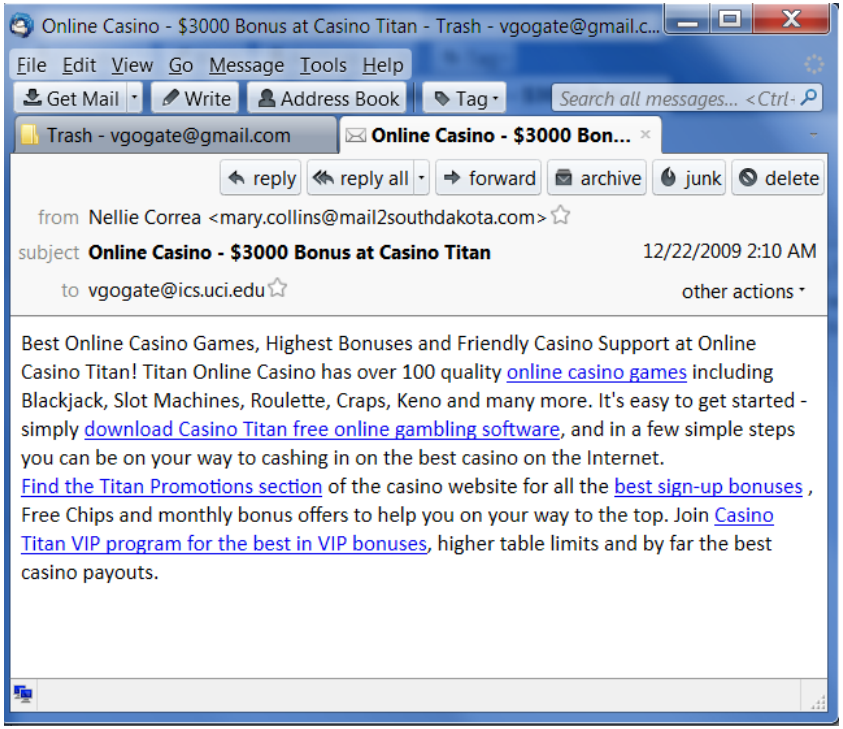
Examples/Types of Machine Learning Tasks

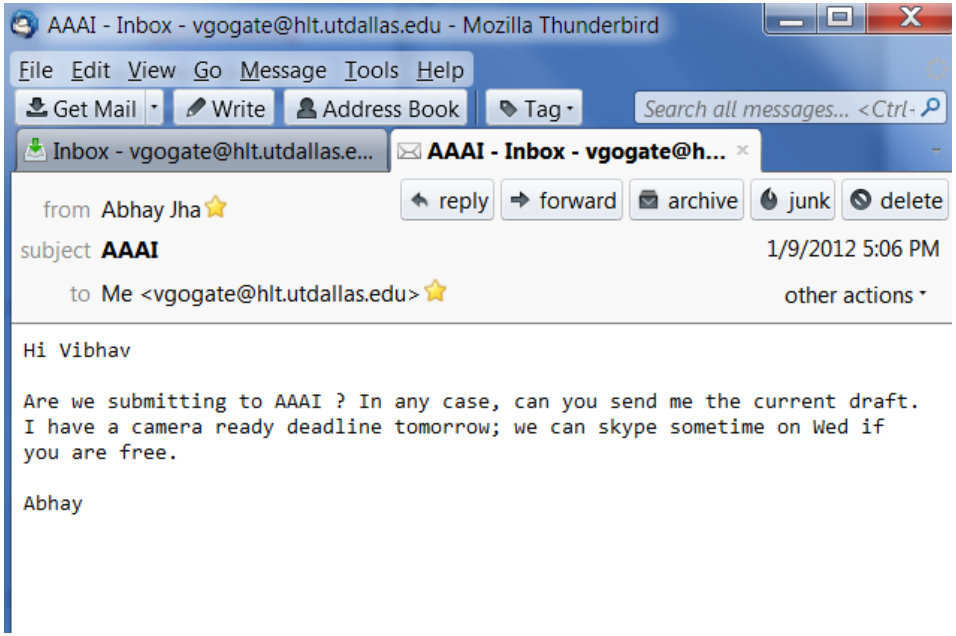
- Forecasting or Prediction
  - Stock price of Google tomorrow?
- Classification and Regression
  - Is Ana credit-worthy?
  - What is Ana's credit score?
- Ranking
  - How to rank images that contain "An awesome machine learning model"?
- Outlier/Anomaly/Fraud detection
  - Is it Ana" using the credit card in Mexico or is it someone else?
- Finding patterns
  - Almost 60% of shoppers buy Diapers and Milk together!

Machine Learning: Applications

Examples of what you will study in class in action!

Classification Example: Spam Filtering





Classify as “Spam” or “Not Spam”

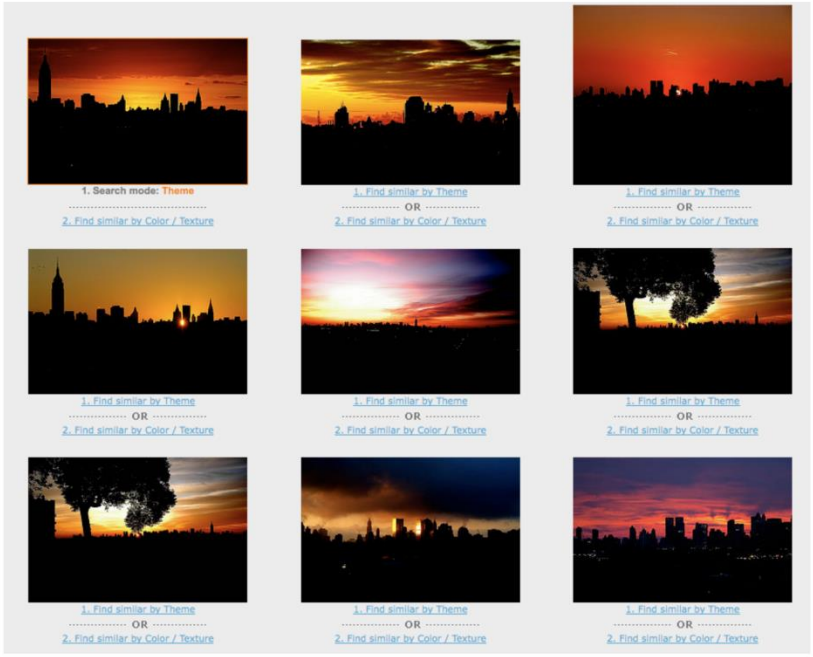
Classification Example: Weather Prediction

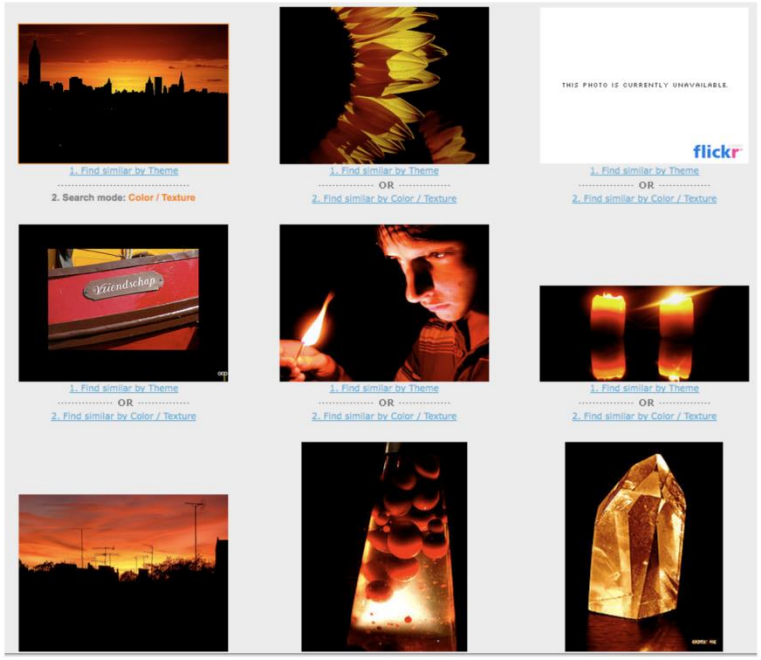
Regression example: Predicting Gold/Stock prices

Good ML can make you rich (but there is still some risk involved).

Given historical data on Gold prices, predict tomorrow's price!

Similarity Determination

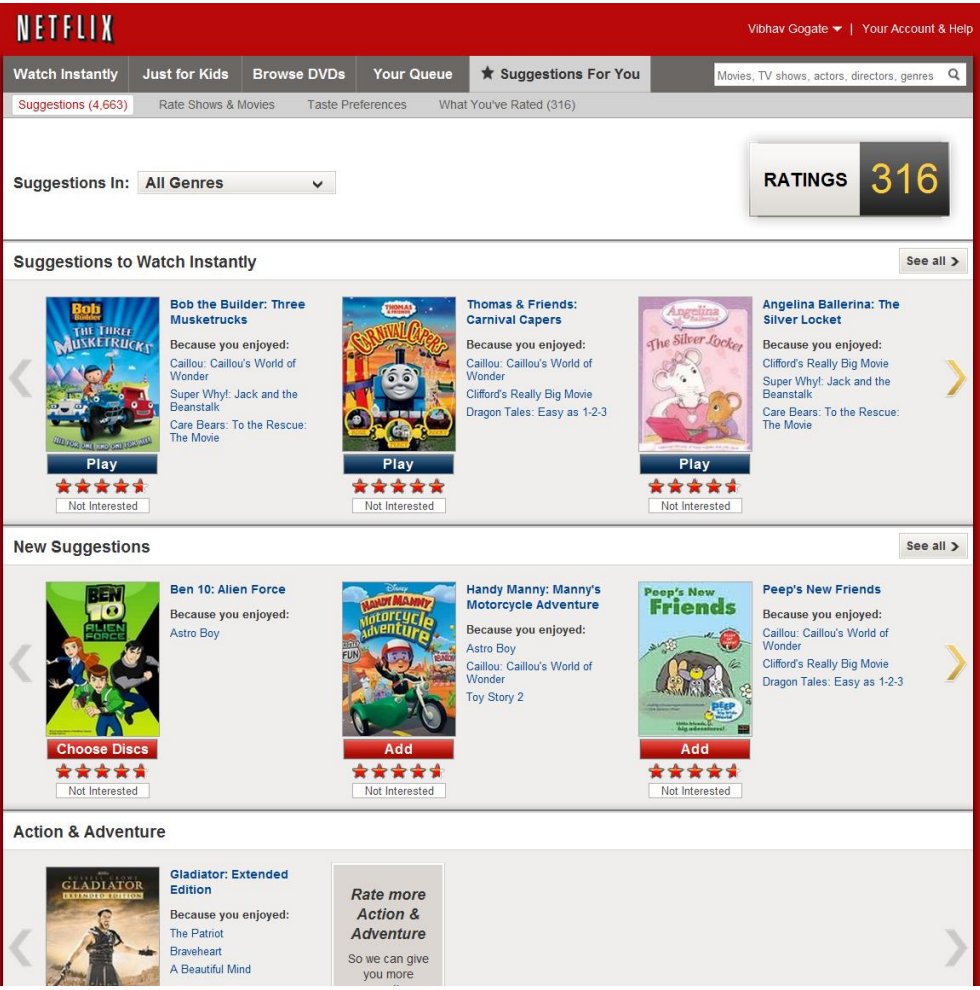




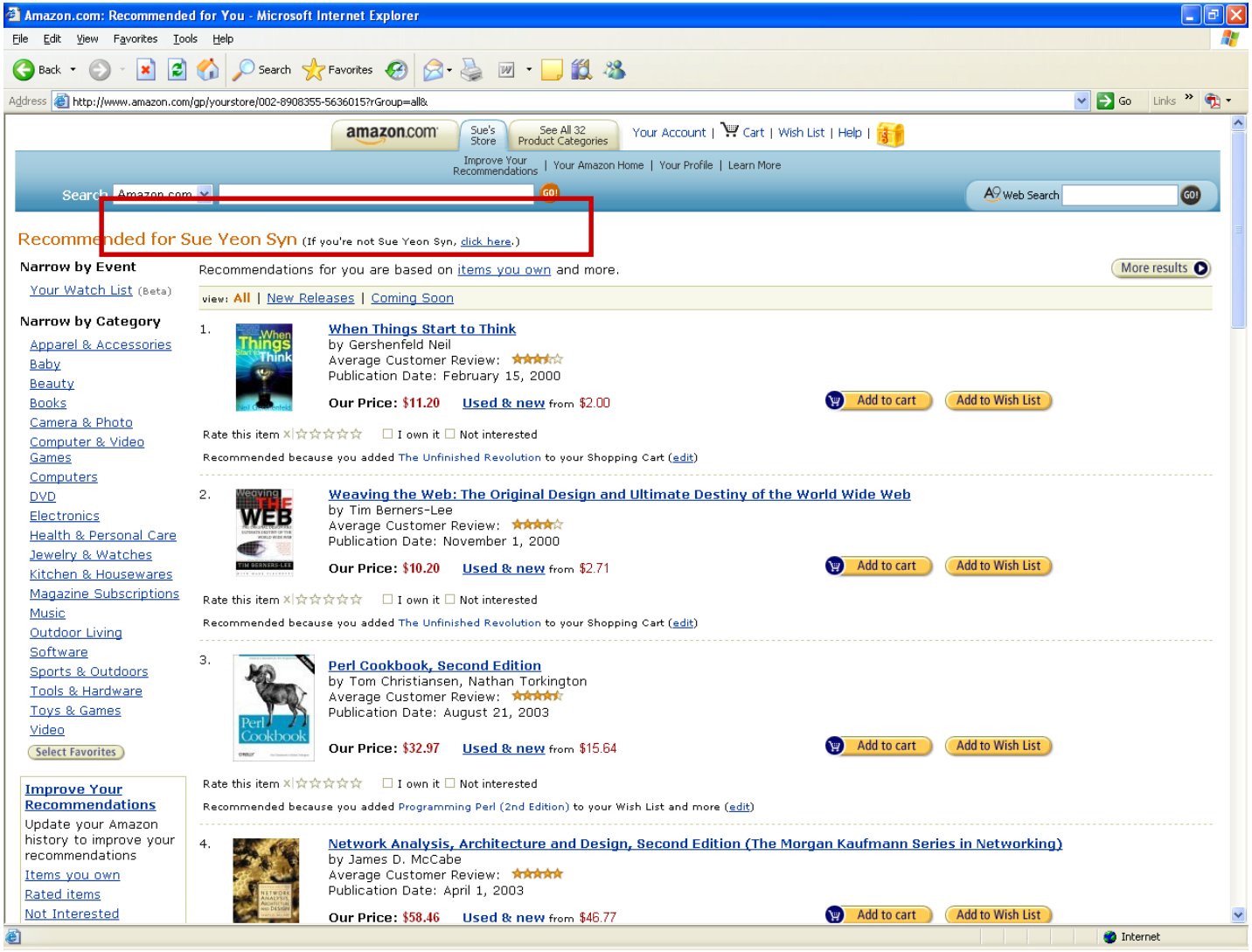
Collaborative Filtering

- *The problem of collaborative filtering is to predict how well a user will like an item that he has not rated given a set of historical preference judgments for a community of users.*

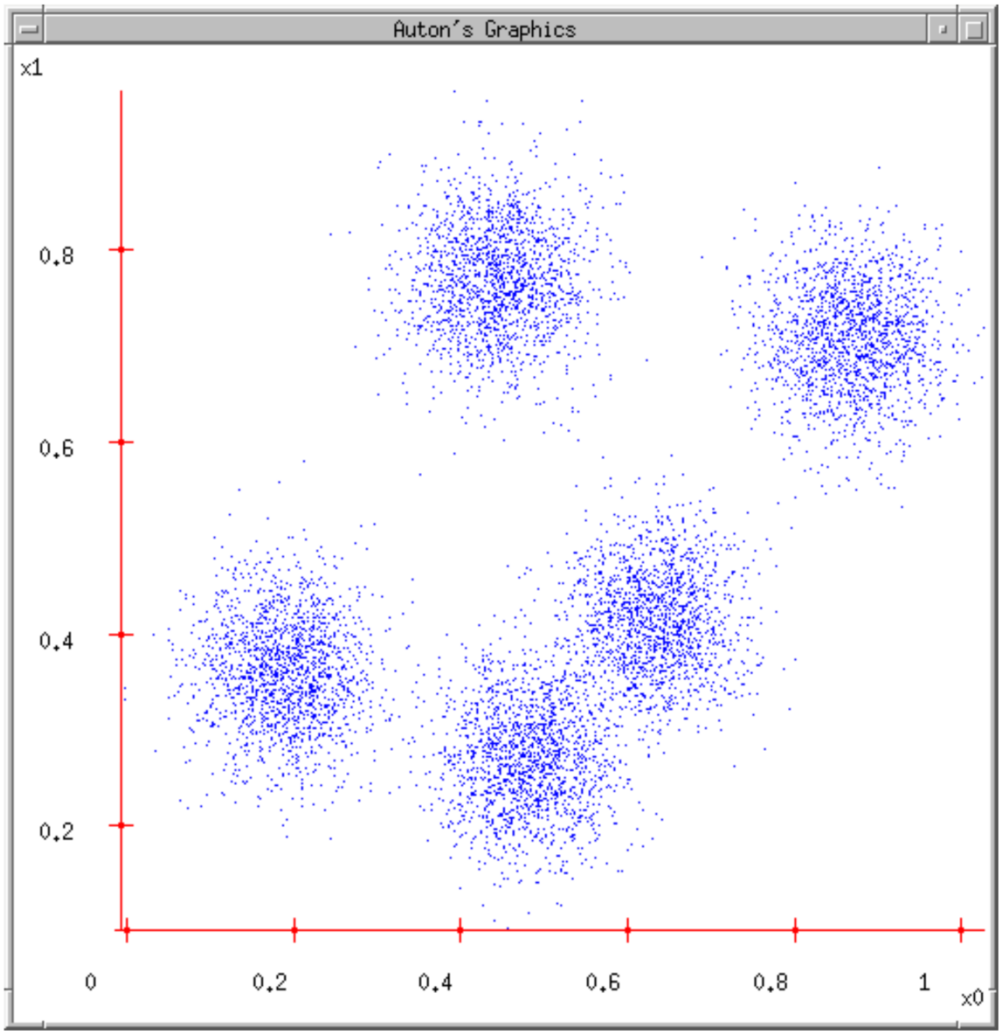
Collaborative Filtering



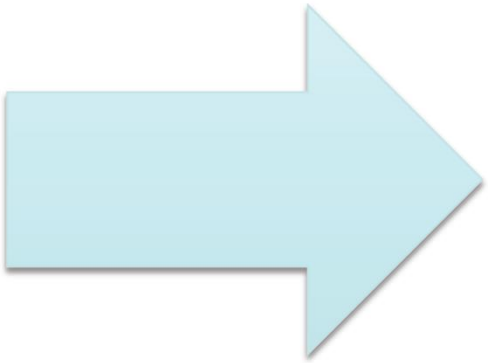
Collaborative Filtering



Clustering: Discover Structure in data



Clustering images



[Goldberger et al.]

Representation

- Decision trees
- Sets of rules / Logic programs
- Instances
- Graphical models (Bayes/Markov nets)
- Neural networks
- Support vector machines
- Model ensembles
- Etc.

Evaluation

- Accuracy
- Precision and recall
- Squared error
- Likelihood
- Posterior probability
- Cost / Utility
- Margin
- Entropy
- K-L divergence
- Etc.

Optimization

- Combinatorial optimization
  - E.g.: Greedy search
- Convex optimization
  - E.g.: Gradient descent
- Constrained optimization
  - E.g.: Linear programming

Machine learning has grown in leaps and bounds

- The main approach for
  - Speech Recognition
  - Robotics
  - Natural Language Processing
  - Computational Biology
  - Sensor networks
  - Computer Vision
  - Web
  - And so on

Alice/Bob says: I know machine learning very well!

Potential Employer: You are hired!!!

What We'll Cover

- **Supervised learning:** Decision tree induction, Rule induction, Instance-based learning, Bayesian learning, Neural networks, Support vector machines, Linear Regression, Model ensembles, Graphical models, Learning theory, etc.
- **Unsupervised learning:** Clustering, Dimensionality reduction
- **Reinforcement learning:** Markov Decision Processes, Q-learning, etc.
- **General machine learning concepts and techniques**: Feature selection, cross-validation, maximum likelihood estimation, gradient descent, expectation-maximization
- **Your responsibility:**
  - **Brush up on some important background**
  - **Linear algebra, Statistics 101, Vectors, Probability theory**