Data Mining: Introduction

Lecture Notes for Chapter 1

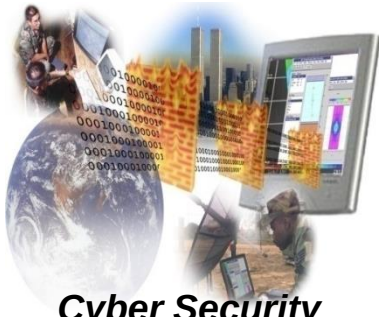
Principles of Data Mining

by

Xiaowei Jia

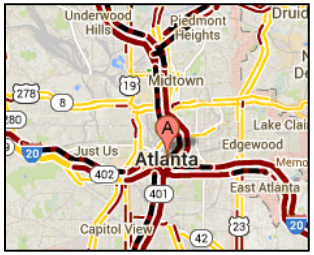
Large-scale Data is Everywhere!

- There has been enormous data growth in both commercial and scientific databases due to advances in data generation and collection technologies
- New mantra
  - Gather whatever data you can whenever and wherever possible.
- Expectations
  - Gathered data will have value either for the purpose collected or for a purpose not envisioned.

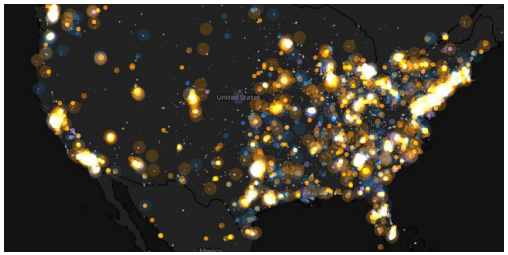


Cyber Security

E-Commerce

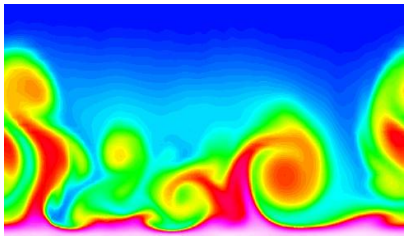


Traffic Patterns



Social Networking: Twitter

Sensor Networks



Computational Simulations

Why Data Mining? Commercial Viewpoint

Lots of data is being collected and warehoused

- Web data
  - Google has Peta Bytes of web data
  - Facebook has billions of active users
- purchases at department/ grocery stores, e-commerce
  - Amazon handles millions of visits/day
- Bank/Credit Card transactions

Computers have become cheaper and more powerful

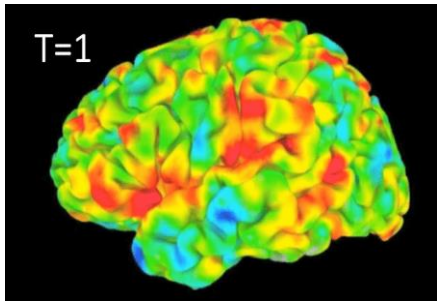
Competitive Pressure is Strong

- Provide better, customized services for an edge (e.g. in Customer Relationship Management)

Why Data Mining? Scientific Viewpoint

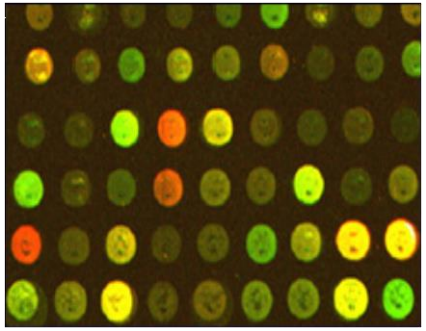
Data collected and stored at enormous speeds

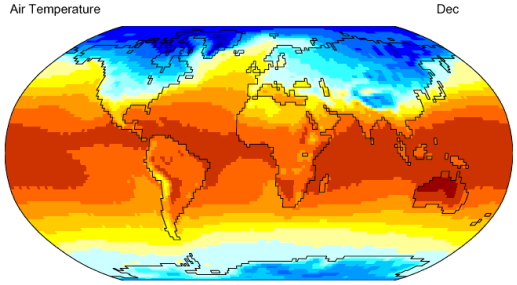
- remote sensors on a satellite
  - NASA EOSDIS archives over petabytes of earth science data / year
- telescopes scanning the skies
  - Sky survey data
- High-throughput biological data
- scientific simulations
  - terabytes of data generated in a few hours



fMRI Data from Brain


Sky Survey Data


Gene Expression Data



Surface Temperature of Earth

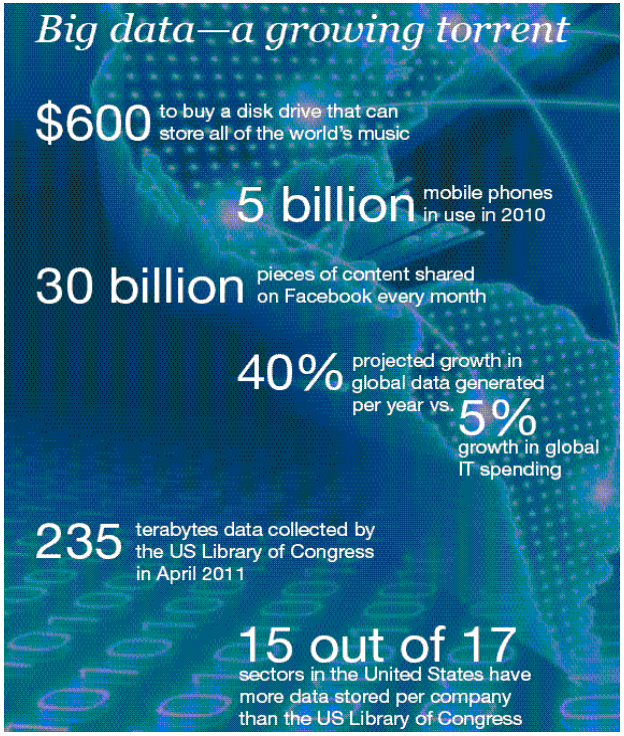
Data mining helps scientists

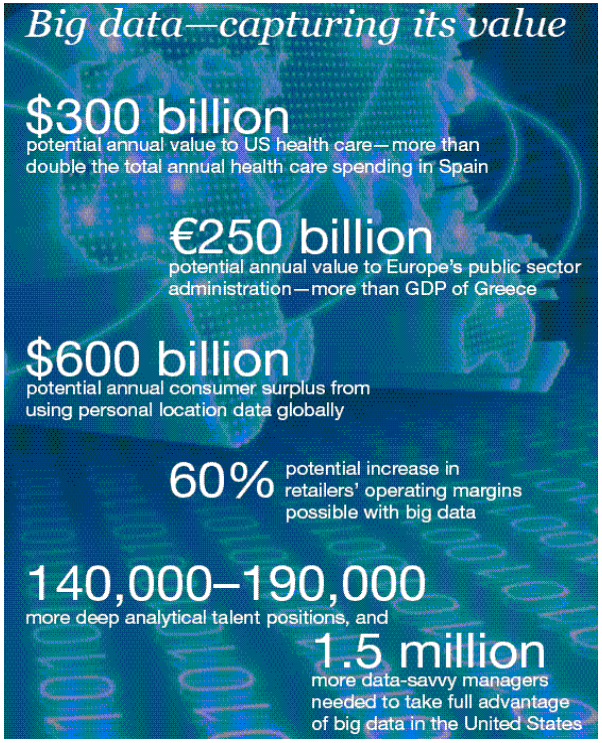
- in automated analysis of massive datasets
- In hypothesis formation

Great opportunities to improve productivity in all walks of life

McKinsey Global Institute

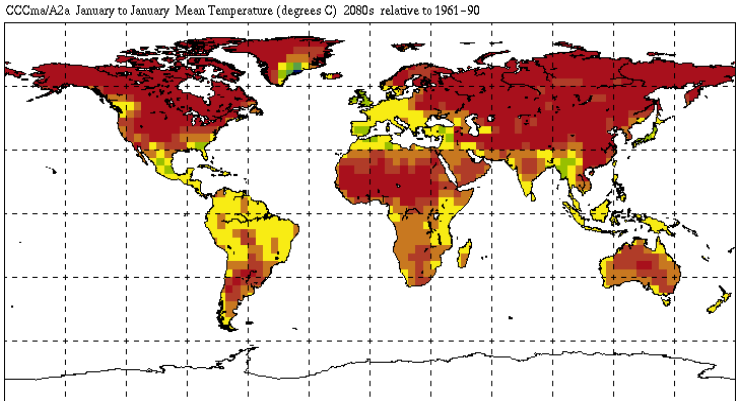
Big data: The next frontier for innovation, competition, and productivity





Great Opportunities to Solve Society's Major Problems

Improving health care and reducing costs



Predicting the impact of climate change

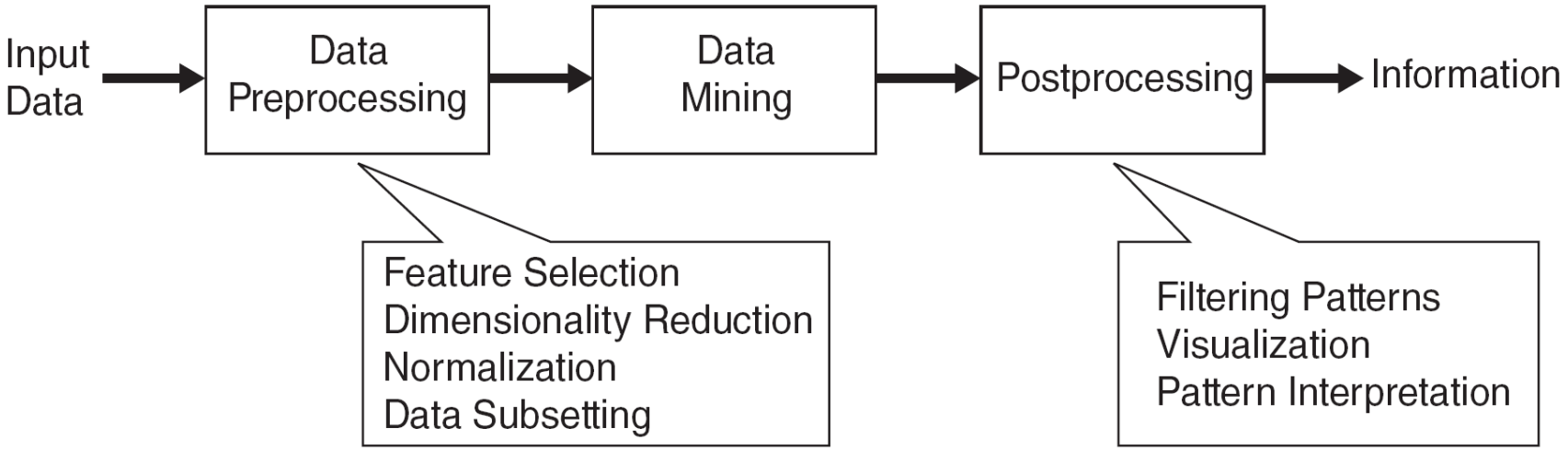
Finding alternative/ green energy sources

Reducing hunger and poverty by increasing agriculture production

What is Data Mining?

Many Definitions

- Non-trivial extraction of implicit, previously unknown and potentially useful information from data
- Exploration & analysis, by automatic or semi-automatic means, of large quantities of data in order to discover meaningful patterns

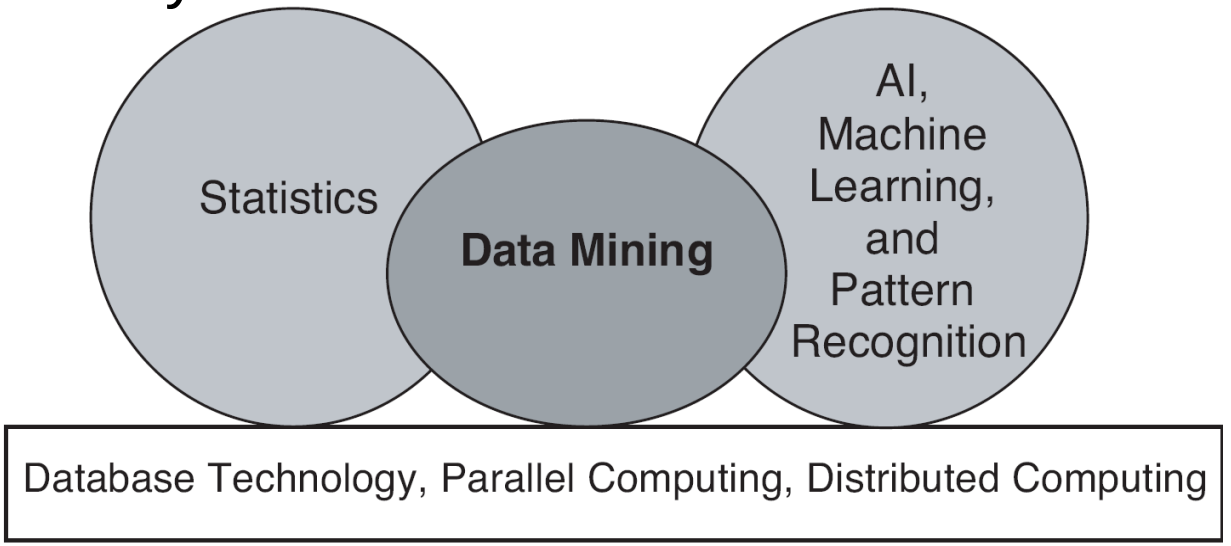


Origins of Data Mining

Draws ideas from machine learning/AI, pattern recognition, statistics, and database systems

Traditional techniques may be unsuitable due to data that is

- Large-scale
- High dimensional
- Heterogeneous
- Complex
- Distributed



A key component of the emerging field of data science and data-driven discovery

Data Mining Tasks

Prediction Methods

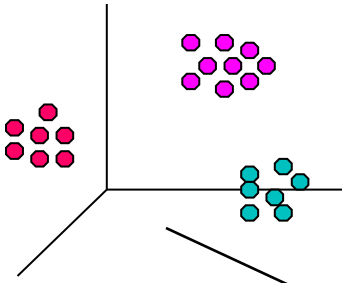
- Use some variables to predict unknown or future values of other variables.

Description Methods

- Find human-interpretable patterns that describe the data.

From [Fayyad, et.al.] Advances in Knowledge Discovery and Data Mining, 1996

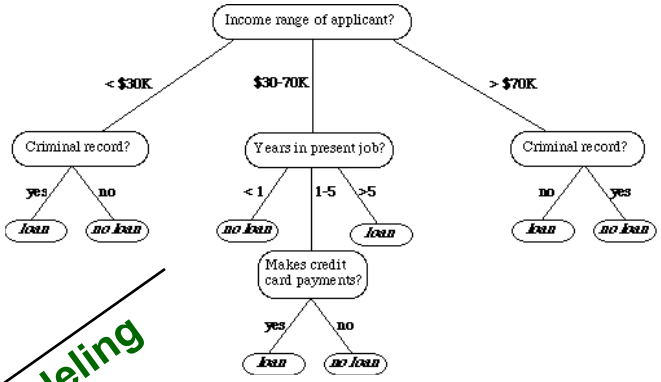
Data Mining Tasks ...



Clustering

Data

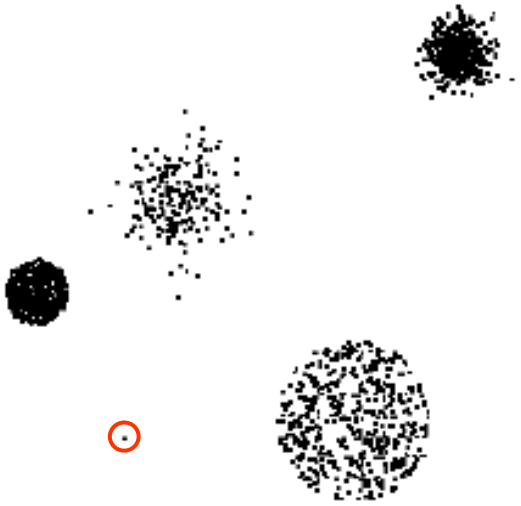
Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes
11	No	Married	60K	No
12	Yes	Divorced	220K	No
13	No	Single	85K	Yes
14	No	Married	75K	No
15	No	Single	90K	Yes



Predictive Modeling

Association Rules

Anomaly Detection



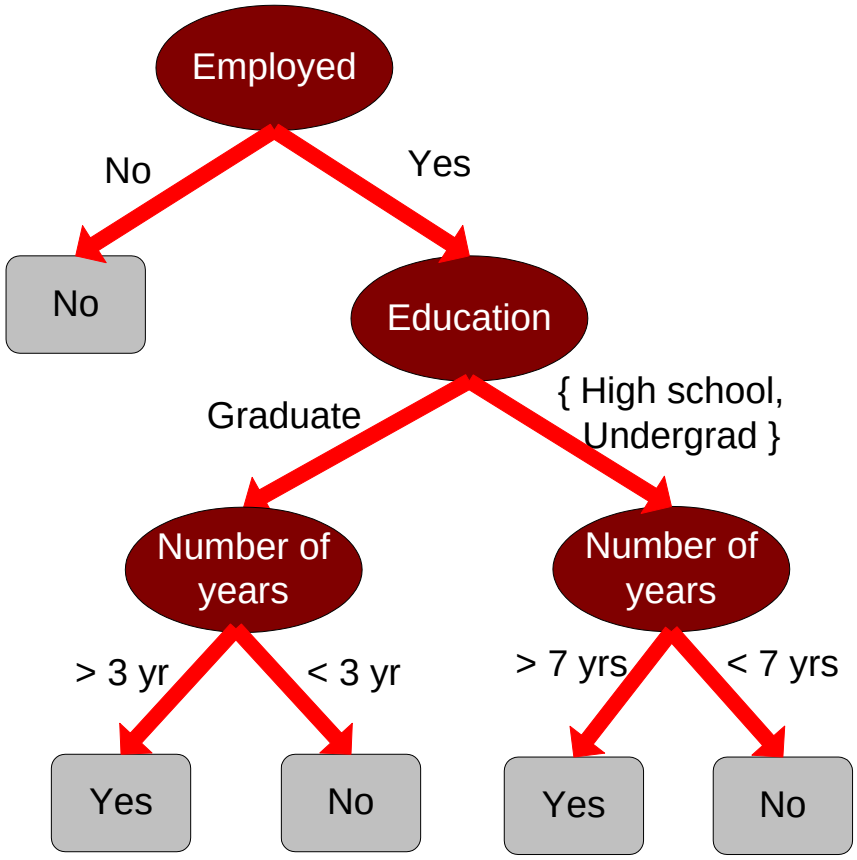
Predictive Modeling: Classification

Find a model for class attribute as a function of the values of other attributes

Class

Tid	Employed	Level of Education	# years at present address	Credit Worthy
1	Yes	Graduate	5	Yes
2	Yes	High School	2	No
3	No	Undergrad	1	No
4	Yes	High School	10	Yes
…	…	…	…	…

Model for predicting credit worthiness

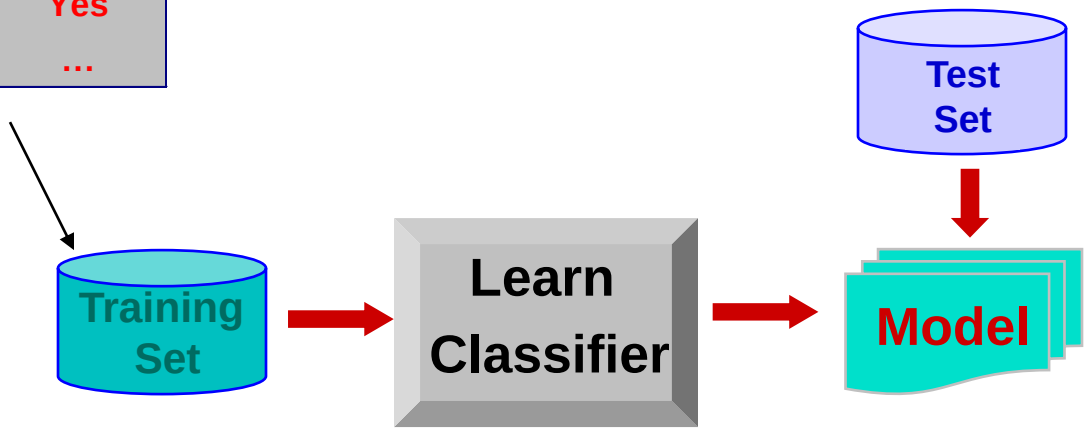


Classification Example

categorical categorical quantitative class

Tid	Employed	Level of Education	# years at present address	Credit Worthy
1	Yes	Graduate	5	Yes
2	Yes	High School	2	No
3	No	Undergrad	1	No
4	Yes	High School	10	Yes
…	…	…	…	…

Tid	Employed	Level of Education	# years at present address	Credit Worthy
1	Yes	Undergrad	7	?
2	No	Graduate	3	?
3	Yes	High School	2	?
…	…	…	…	…



Examples of Classification Task

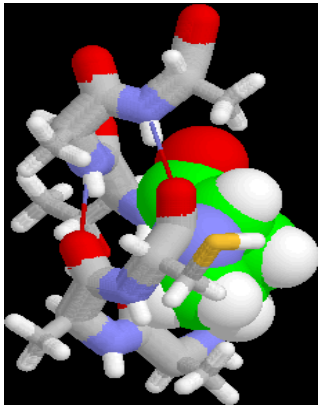
Classifying credit card transactions as legitimate or fraudulent

Classifying land covers (water bodies, urban areas, forests, etc.) using satellite data

Categorizing news stories as finance, weather, entertainment, sports, etc

Identifying intruders in the cyberspace

Predicting tumor cells as benign or malignant



Classifying secondary structures of protein as alpha-helix, beta-sheet, or random coil

Classification: Application 1

Fraud Detection

- **Goal:** Predict fraudulent cases in credit card transactions.
- **Approach:**
  - Use credit card transactions and the information on its account-holder as attributes.
    - When does a customer buy, what does he buy, how often he pays on time, etc
  - Label past transactions as fraud or fair transactions. This forms the class attribute.
  - Learn a model for the class of the transactions.
  - Use this model to detect fraud by observing credit card transactions on an account.

Classification: Application 2

Churn prediction for telephone customers

- **Goal:** To predict whether a customer is likely to be lost to a competitor.
- **Approach:**
  - Use detailed record of transactions with each of the past and present customers, to find attributes.
    - How often the customer calls, where he calls, what time-of-the day he calls most, his financial status, marital status, etc.
  - Label the customers as loyal or disloyal.
  - Find a model for loyalty.

From [Berry & Linoff] Data Mining Techniques, 1997

Classification: Application 3

Sky Survey Cataloging

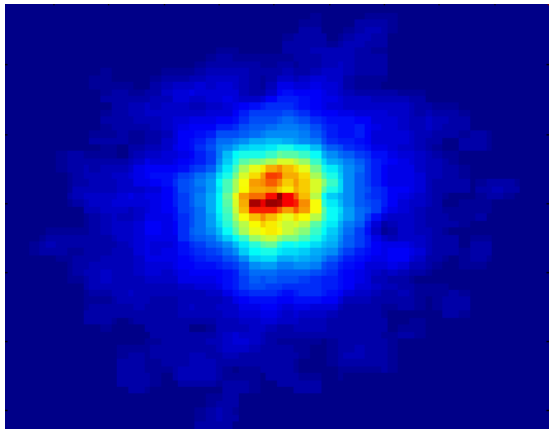
- **Goal:** To predict class (star or galaxy) of sky objects, especially visually faint ones, based on the telescopic survey images (from Palomar Observatory).
  - 3000 images with 23,040 x 23,040 pixels per image.
- **Approach:**
  - Segment the image.
  - Measure image attributes (features) - 40 of them per object.
  - Model the class based on these features.
  - Success Story: Could find 16 new high red-shift quasars, some of the farthest objects that are difficult to find!

From [Fayyad, et.al.] Advances in Knowledge Discovery and Data Mining, 1996

Classifying Galaxies

Courtesy: http://aps.umn.edu

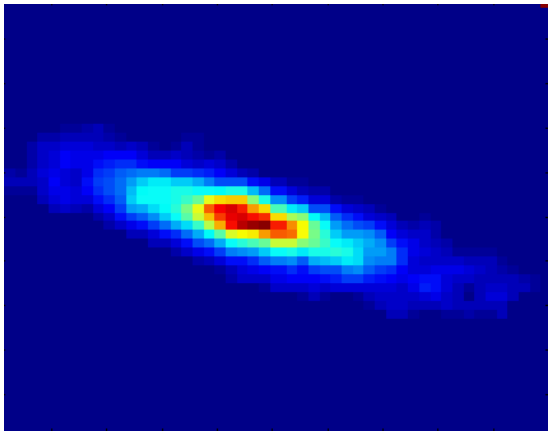
Early



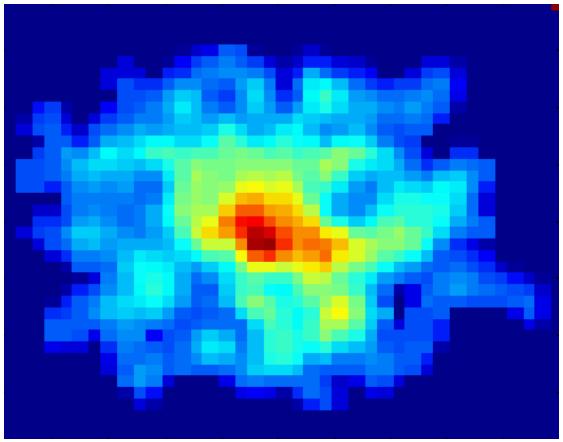
Class:
- **Stages of Formation**

Attributes:
- **Image features,**
- **Characteristics of light waves received, etc.**

Intermediate



Late



Data Size:
- **72 million stars, 20 million galaxies**
- **Object Catalog: 9 GB**
- **Image Database: 150 GB**

Regression

Predict a value of a given continuous valued variable based on the values of other variables, assuming a linear or nonlinear model of dependency.

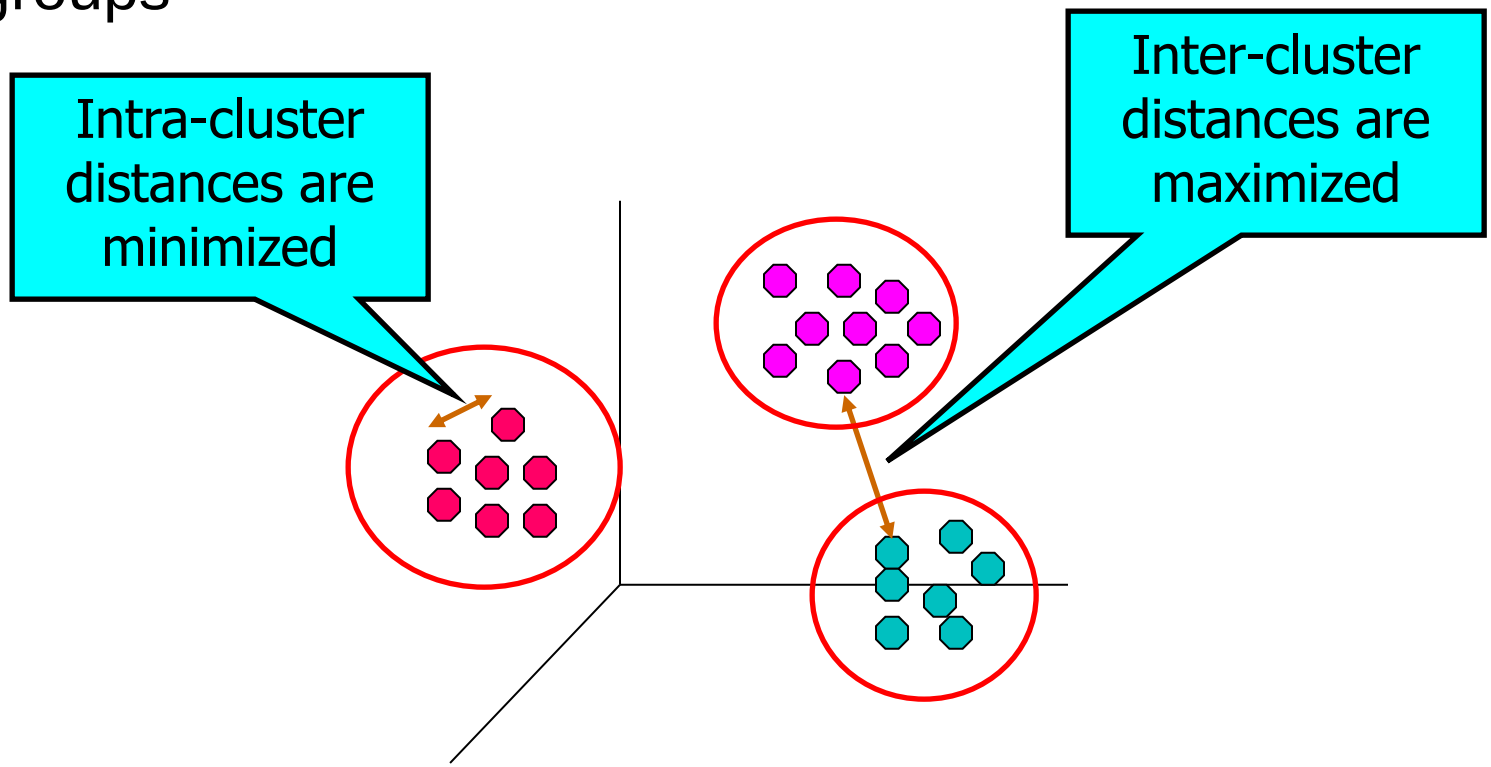
Extensively studied in statistics, neural network fields.

Examples:

- Predicting sales amounts of new product based on advetising expenditure.
- Predicting wind velocities as a function of temperature, humidity, air pressure, etc.
- Time series prediction of stock market indices.

Clustering

Finding groups of objects such that the objects in a group will be similar (or related) to one another and different from (or unrelated to) the objects in other groups



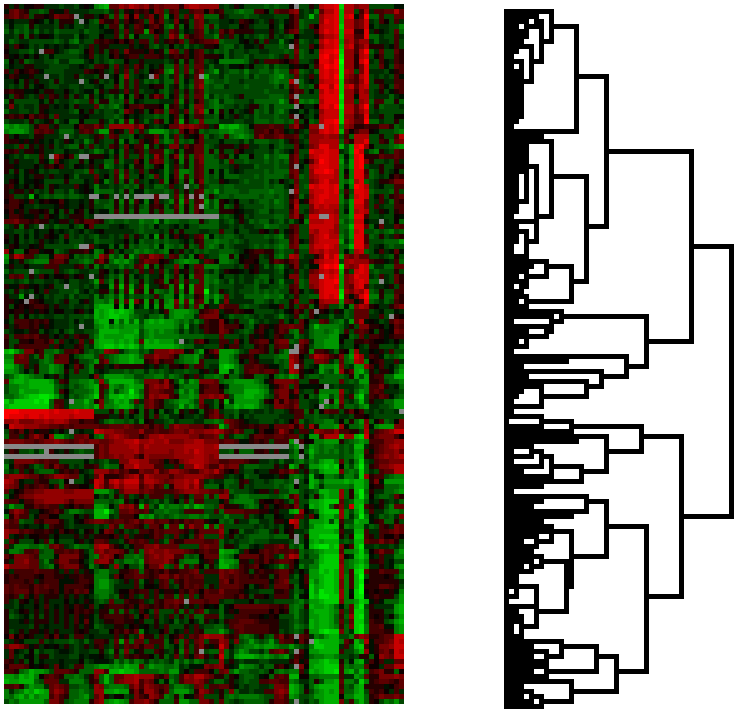
Applications of Cluster Analysis

Understanding

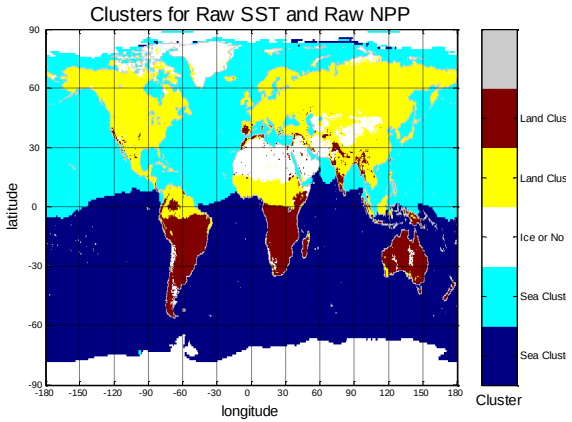
- Custom profiling for targeted marketing
- Group related documents for browsing
- Group genes and proteins that have similar functionality
- Group stocks with similar price fluctuations

Summarization

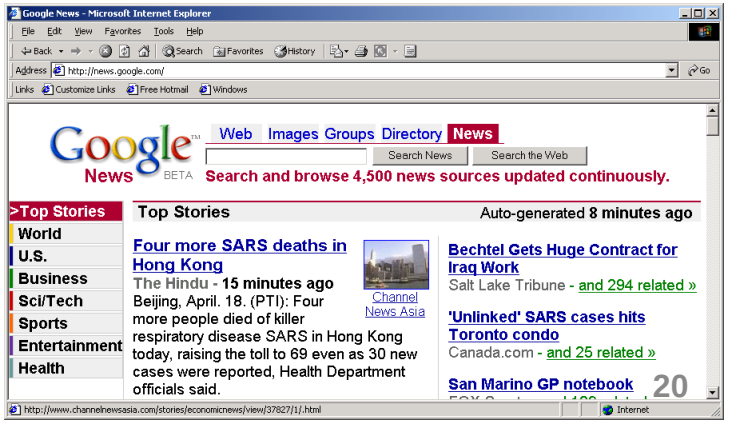
- Reduce the size of large data sets



Courtesy: Michael Eisen



Use of K-means to partition Sea Surface Temperature (SST) and Net Primary Production (NPP) into clusters that reflect the Northern and Southern Hemispheres.



Clustering: Application 1

Market Segmentation:

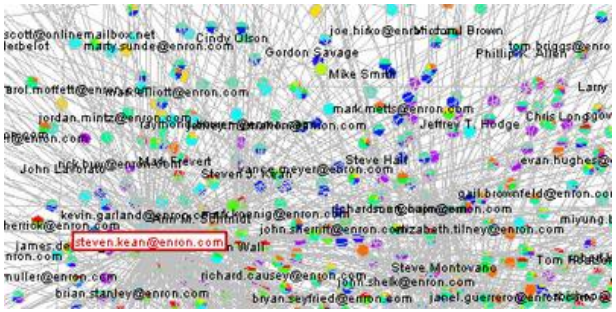
- **Goal:** subdivide a market into distinct subsets of customers where any subset may conceivably be selected as a market target to be reached with a distinct marketing mix.
- **Approach:**
  - Collect different attributes of customers based on their geographical and lifestyle related information.
  - Find clusters of similar customers.
  - Measure the clustering quality by observing buying patterns of customers in same cluster vs. those from different clusters.

Clustering: Application 2

Document Clustering:

- **Goal:** To find groups of documents that are similar to each other based on the important terms appearing in them.
- **Approach:** To identify frequently occurring terms in each document. Form a similarity measure based on the frequencies of different terms. Use it to cluster.

Enron email dataset



Association Rule Discovery: Definition

Given a set of records each of which contain some number of items from a given collection

- Produce dependency rules which will predict occurrence of an item based on occurrences of other items.

TID	*Items*
1	Bread, Coke, Milk
2	Beer, Bread
3	Beer, Coke, Diaper, Milk
4	Beer, Bread, Diaper, Milk
5	Coke, Diaper, Milk

Rules Discovered:

{Milk} --> {Coke}

{Diaper, Milk} --> {Beer}

Association Analysis: Applications

Market-basket analysis

- Rules are used for sales promotion, shelf management, and inventory management

Telecommunication alarm diagnosis

- Rules are used to find combination of alarms that occur together frequently in the same time period

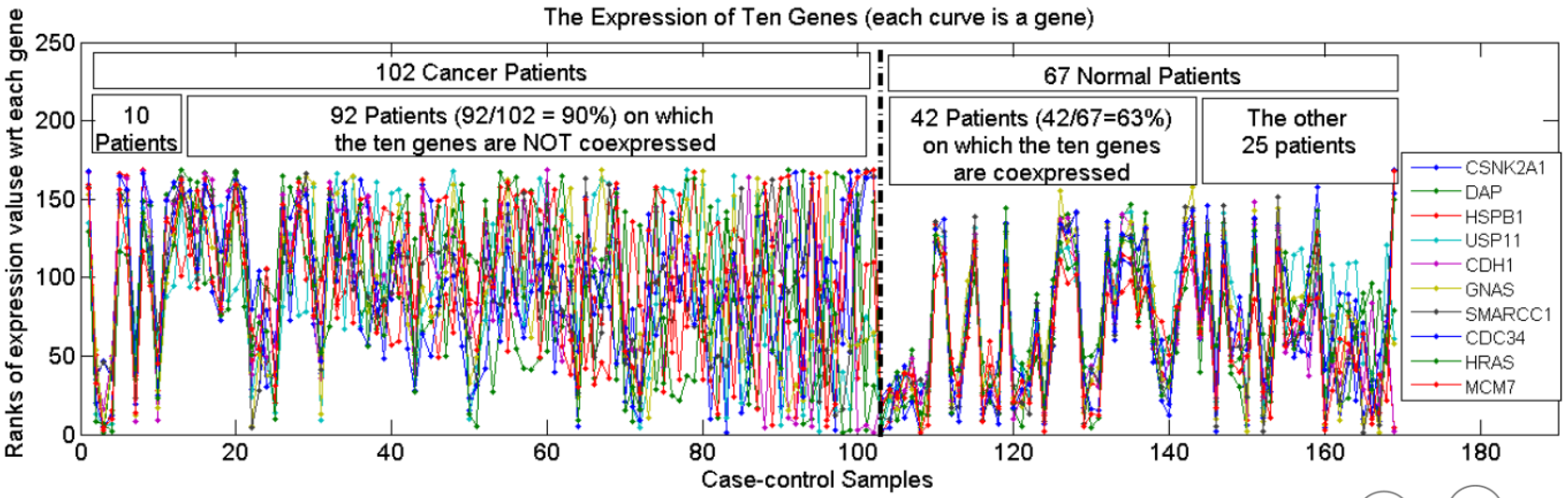
Medical Informatics

- Rules are used to find combination of patient symptoms and test results associated with certain diseases

Association Analysis: Applications

An Example Subspace Differential Coexpression Pattern from lung cancer dataset

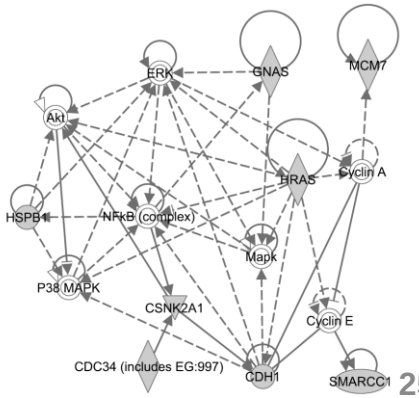
Three lung cancer datasets [Bhattacharjee et a
2001], [Stearman et al. 2005], [Su et al. 2007]



Enriched with the TNF/NFB signaling pathway

which is well-known to be related to lung cancer

P-value: $1.4*10^{-5}$ (6/10 overlap with the pathway)



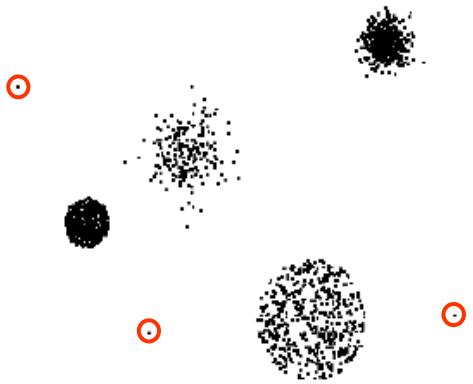
[Fang et al PSB 2010]

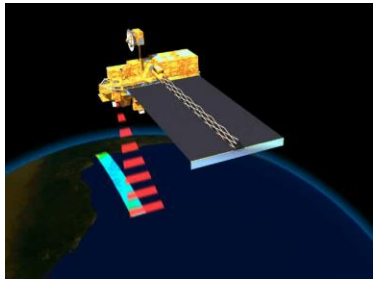
Deviation/Anomaly/Change Detection

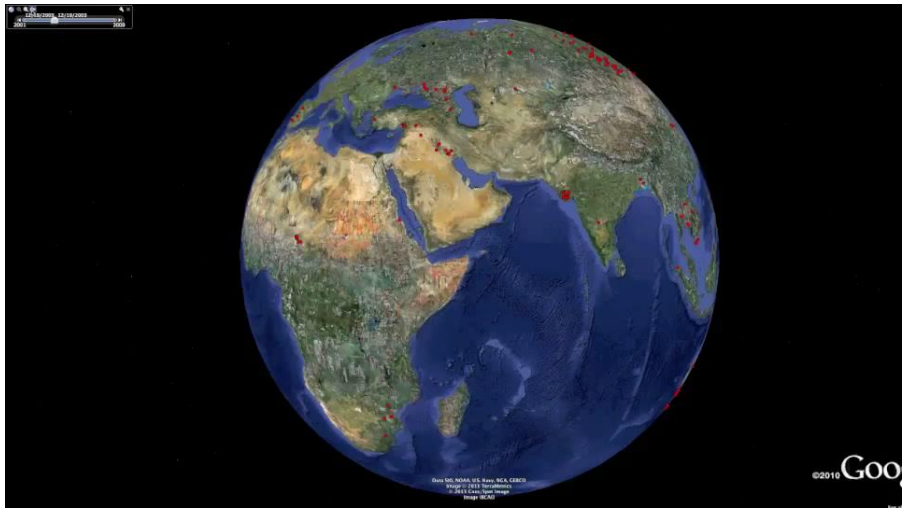
Detect significant deviations from normal behavior

Applications:

- Credit Card Fraud Detection
- Network Intrusion Detection
- Identify anomalous behavior from sensor networks for monitoring and surveillance.
- Detecting changes in the global forest cover.







Motivating Challenges

Scalability

High Dimensionality

Heterogeneous and Complex Data

Data Ownership and Distribution

Non-traditional Analysis