Chapter 1. Introduction

Meng Jiang

CS412 Summer 2017:

Introduction to Data Mining

Data and Information Systems (DAIS)

- Database Systems (Aditya Parameswaran)
- Data Mining (**Jiawei Han**, **Hari Sundaram**)
- Text Information Systems (**Kevin Chang**, ChengXiang Zhai)

DAIS Course Structures

- Data mining
  - Introduction to data warehousing and mining (CS412)
  - Data mining: Principles and algorithms (CS512)
- Database Systems
  - Introduction to database systems (CS411)
  - Advanced database systems (CS511)
- Text information systems
  - Text information system (CS410)
  - Advanced text information systems (CS510)

Official Description

- Concepts, techniques, and systems of data warehousing and data mining. Design and implementation of data warehouse and on-line analytical processing (OLAP) systems; data mining concepts, methods, systems, implementations, and applications.
- Course Information: 3 undergraduate hours. 3 or 4 graduate hours.
- Prerequisite: CS 225 (Data Structures).

About Me

- Dr. Meng Jiang (www.meng-jiang.com)

Carnegie Mellon University

Visiting Ph.D.

Bachelor and Ph.D.

清華大學

Tsinghua University

Postdoc

Assistant Professor

Visiting Postdoc

Course Page and Class Schedule

- Schedule: http://www.meng-jiang.com/teaching.html
  - https://wiki.illinois.edu/wiki/pages/viewpage.action?spaceKey=cs412&title=2.+Course+Syllabus+and+Schedule
  - Page: Wiki page is coming. Slides are being updated.
- Schedule: 11:00 am – 12:15 pm M/T/R @ 0216 SC
- Office hours: 12:15 pm – 1:00 pm M/R @ 2130 SC
- Lecture media: recorded; class attendance is critical.
- ONL (online session): http://engineering.illinois.edu/online/current-students/engineering-online-student-portal.html

Teaching Assistants

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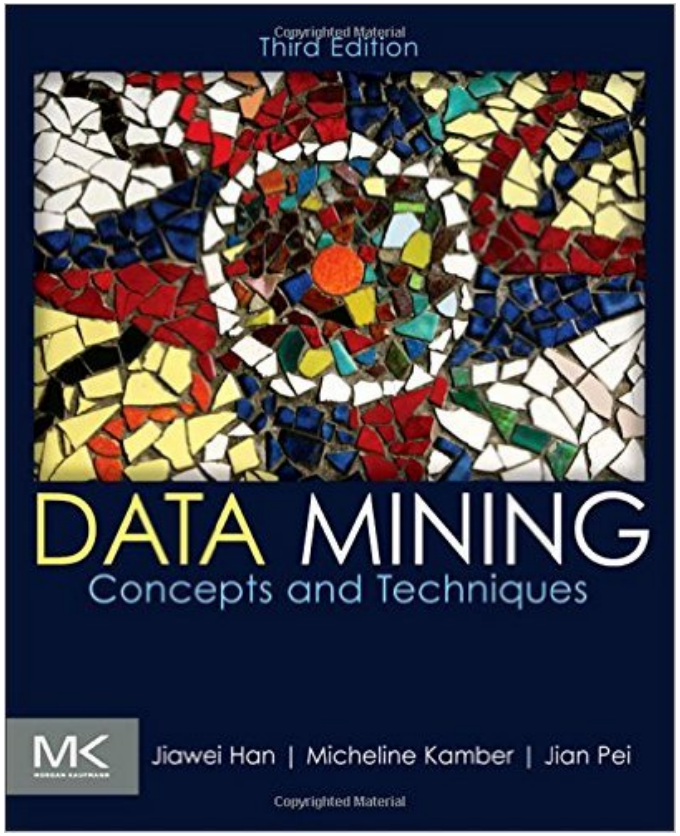
- TA office hours: 3 - 4 pm Monday @2113 SC
- Piazza: https://piazza.com/class/j2pkefesw6u67z

Textbook

- Jiawei Han, Micheline Kamber and Jian Pei, Data Mining: Concepts and Techniques (3rd ed), Morgan Kaufmann, 2011



Course Work and Grading

- Assignments and Exams
  - Written assign.: 15% (three expected)
  - Programming assign.: 20% (two expected)
  - Midterm exam: 30%
  - Final exam: 35%
- For students taking 4th credit
  - Concrete instructions on the project next week
- Piazza: https://piazza.com/class/j2pkefesw6u67z
- Check your homework/exam scores: Compass

Why Data Mining?

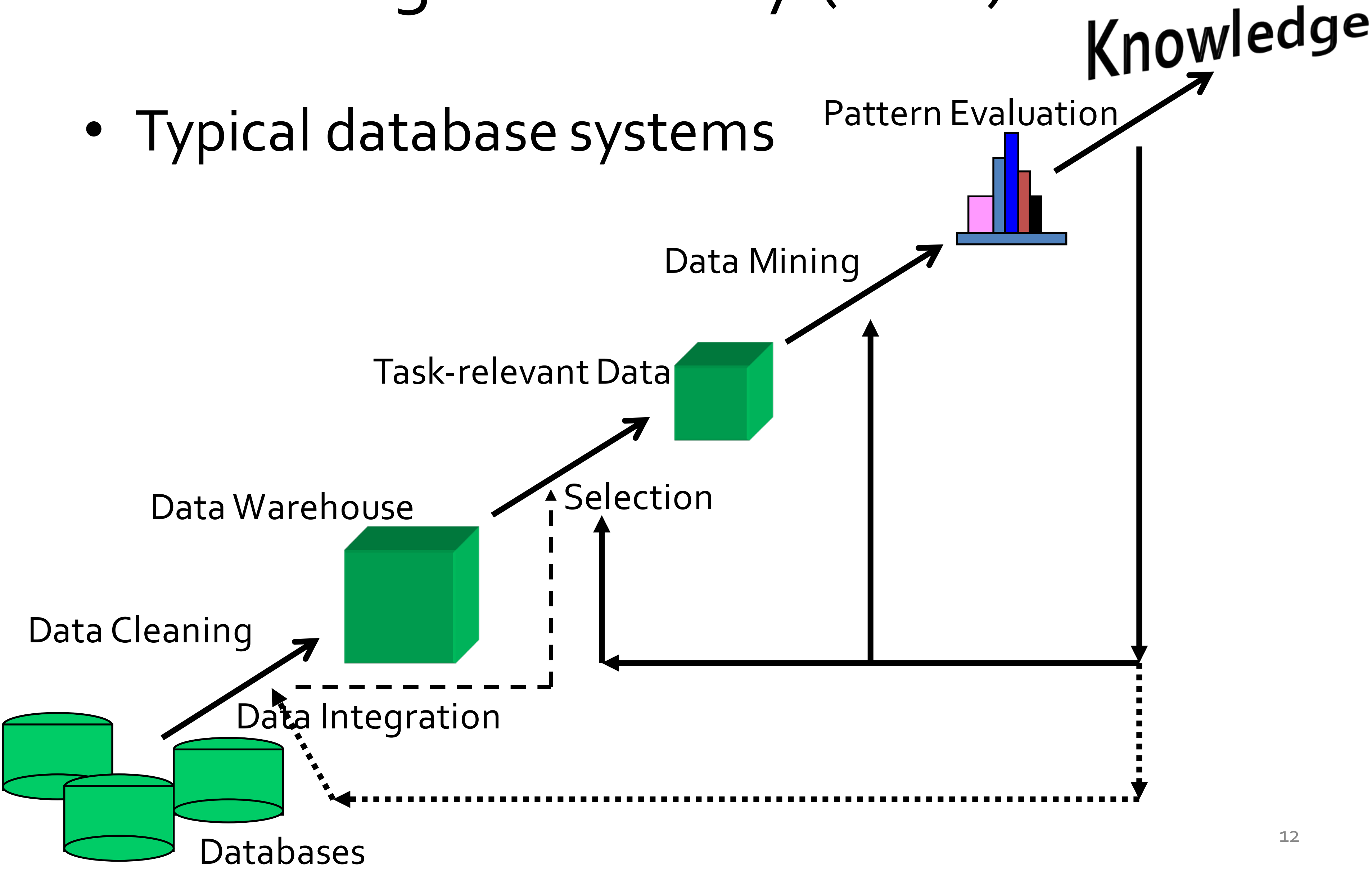
- The Explosive Growth of Data: from terabytes to petabytes
  - Data collection and data availability
    - Automated data collection tools, database systems, Web, computerized society
  - Major sources of abundant data
    - Business: Web, e-commerce, transactions, stocks, …
    - Science: Remote sensing, bioinformatics, scientific simulation, …
    - Society and everyone: news, digital cameras, YouTube
- We are drowning in data, but starving for knowledge!

What is Data Mining?

- Data mining (knowledge discovery from data)
  - Extraction of interesting (non-trivial, implicit, previously unknown and potentially useful) patterns or knowledge from huge amount of data
- Alternative names
  - Knowledge discovery (mining) in databases (KDD), knowledge extraction, data/pattern analysis, data archeology, data dredging, information harvesting, business intelligence, etc.
- Watch out: Is everything "data mining"?

Knowledge Discovery (KDD) Process

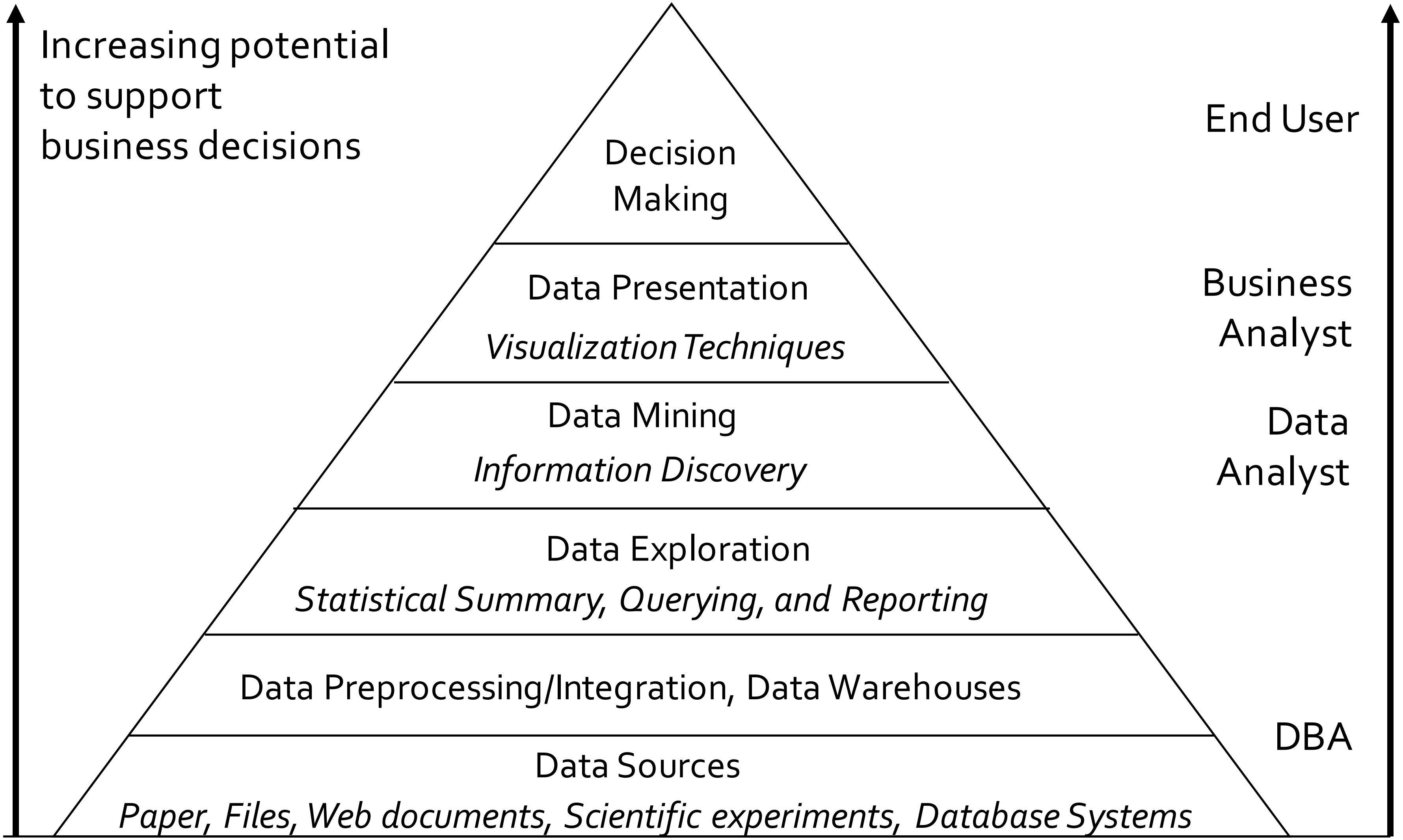
- Typical database systems



Example: Web Mining

- Web mining usually involves
  - Data cleaning
  - Data integration from multiple sources
  - Warehousing the data
  - Data cube construction
  - Data selection for data mining
  - Data mining
  - Presentation of the mining results
  - Patterns and knowledge to be used or stored into knowledge-base

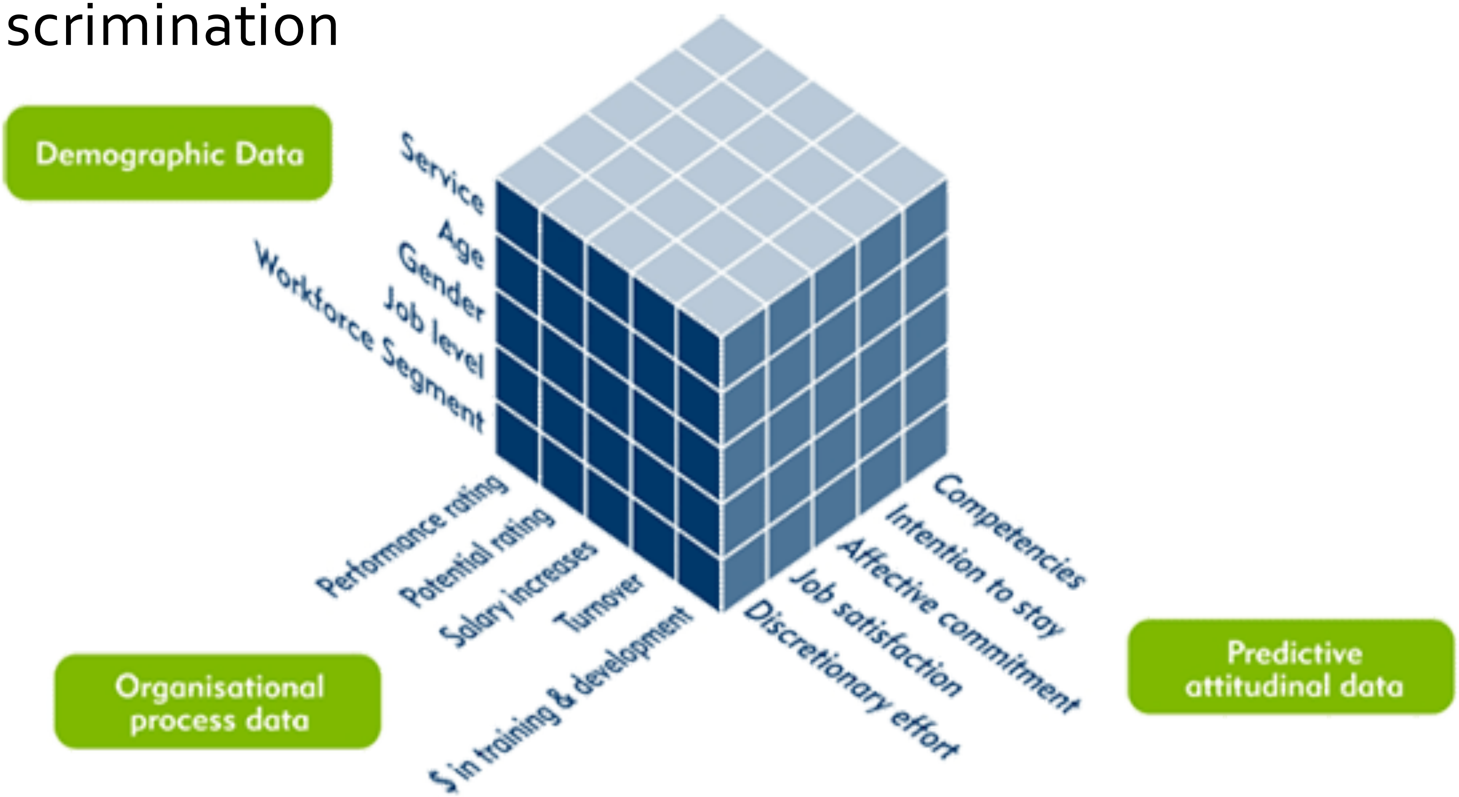
Example: Business Intelligence



Increasing potential to support business decisions
Decision Making
Data Presentation
Visualization Techniques
Data Mining
Information Discovery
Data Exploration
Statistical Summary, Querying, and Reporting
Data Preprocessing/Integration, Data Warehouses
Data Sources
Paper, Files, Web documents, Scientific experiments, Database Systems
End User
Business Analyst
Data Analyst
DBA

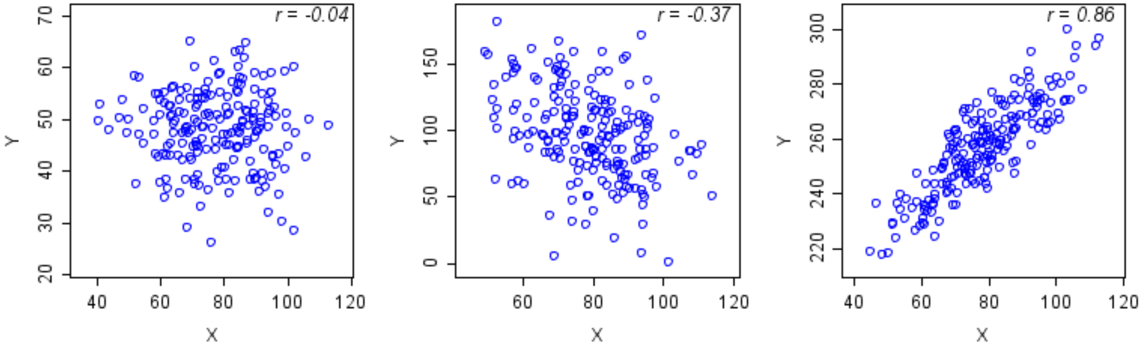
Data Mining Functions: (1) Generalization

- Information integration and data warehouse construction
- Data cube technology
- Multidimensional concept description: Characterization and discrimination



Data Mining Functions: (2) Pattern Discovery

- Frequent patterns (or frequent itemsets)
  - What items are frequently purchased together in your Walmart?
- A typical association rule
  - Diaper → Beer [0.5%, 75%] (support, confidence)
  - **Support:** the proportion of transactions in the dataset which contains the itemset (Diaper, Beer).
  - **Confidence:** the proportion of the transactions that contains Diaper which also contains Beer.
- **Association** and **Correlation** Analysis

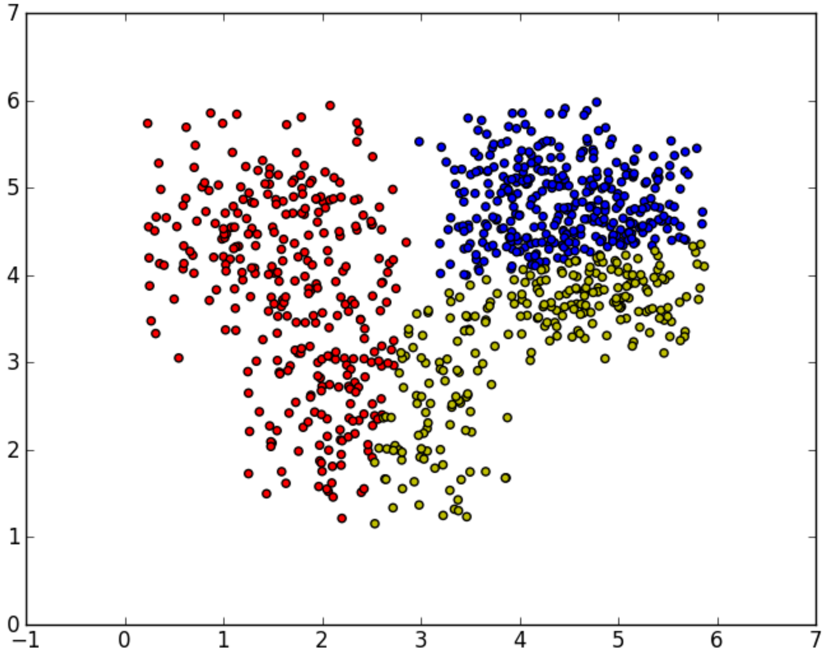


Data Mining Functions: (3) Classification

- Classification and label prediction
  - Construct models (functions) based on some **training** examples
  - Describe and distinguish classes or concepts for future prediction
    - Ex. 1. Classify countries based on (climate)
    - Ex. 2. Classify cars based on (gas mileage)
  - Predict some unknown **class labels**
- Typical methods
  - Decision trees, naïve Bayesian classification, support vector machines, neural networks, rule-based classification, pattern-based classification, logistic regression, …
- Typical applications:
  - Credit card fraud detection, direct marketing, classifying stars, diseases, web-pages, …

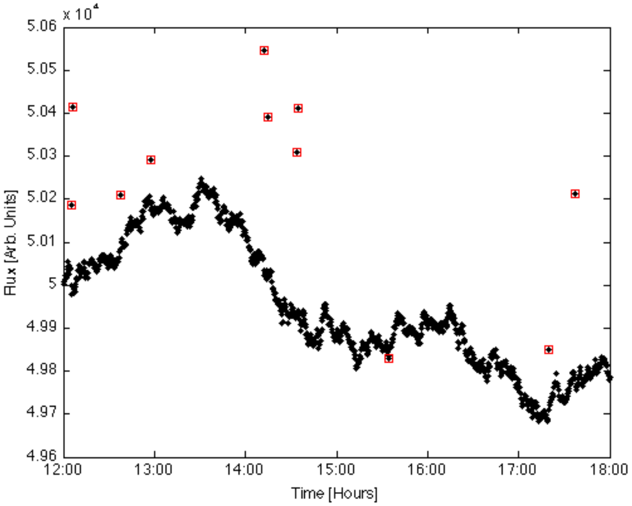
Data Mining Functions: (4) Clustering

- Unsupervised learning (i.e., class label is unknown)
- Group data to form new categories (i.e., clusters), e.g., cluster houses to find distribution patterns
- Principle: Maximizing intra-class similarity & minimizing interclass similarity



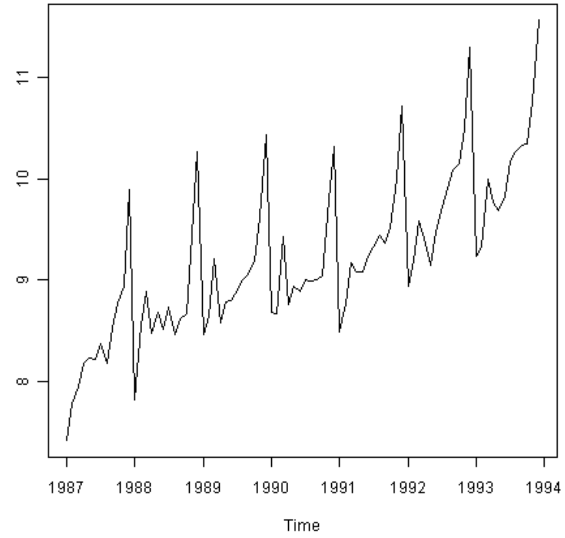
Data Mining Functions: (5) Outlier Analysis

- Outlier analysis
  - Outlier: A data object that does not comply with the general behavior of the data
  - Methods: by product of clustering or regression analysis…
  - Useful in fraud detection, rare events analysis



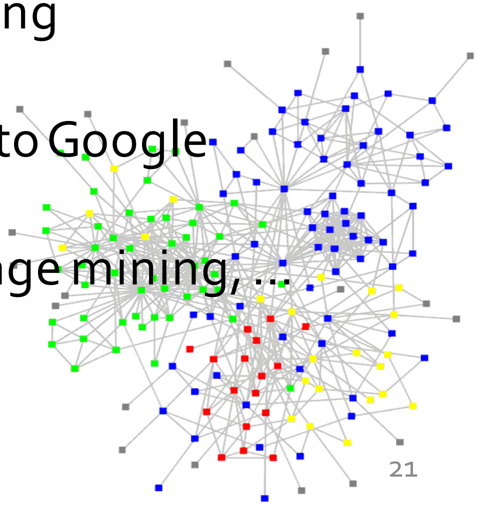
Data Mining Functions: (6) Sequential Pattern, Evolution Analysis

- Sequence, trend and evolution analysis
  - Trend, time-series, and deviation analysis
    - e.g., regression and value prediction
  - Sequential pattern mining
    - e.g., buy digital camera, then buy large memory cards
  - Periodicity analysis
  - Motifs and biological sequence analysis
    - Approximate and consecutive motifs
  - Similarity-based analysis



Data Mining Functions: (7) Structure and Network Analysis

- Graph mining
  - Finding frequent subgraphs (e.g., chemical compounds), trees (XML), substructures (web fragments)
- Information network analysis
  - Social networks: actors (objects, nodes) and relationships (edges)
    - e.g., author networks in CS, terrorist networks
  - Multiple heterogeneous networks
    - A person could be multiple information networks: friends, family, classmates, …
  - Links carry a lot of semantic information: Link mining
- Web mining
  - Web is a big information network: from PageRank to Google
  - Analysis of Web information networks
    - Web community discovery, opinion mining, usage mining, …



Syllabus

- Intro (1)
- Know Your Data (2): Assign. 1
- **Data Preprocessing** (2.5)
- **Data Warehousing** & OLAP (1.5): Assign. 2
- **Data Cube** Tech (2)
- Mining **Frequent Patterns and Associations** (3+5): Assign. 3 and Midterm Exam
- **Classification** (3.5+3.5): Assign. 4 and Assign. 5
- **Cluster** Analysis (4): Final Exam

Discussion

Choose one company:
Amazon, Yahoo!, Walmart, Google, Facebook, Twitter, Snapchat, Bloomberg, CNN…

Answer:
Given what data,

- What to find?
- Why?
- How?

Applications

- Web page analysis: classification, clustering, ranking
- Collaborative analysis & recommender systems
- Basket data analysis to targeted marketing
- Biological and medical data analysis
- Data mining and software engineering
- Data mining and text analysis
- Data mining and social and information network analysis

Multidimensional View of Data Mining

- **Data to be mined**
  - Database data (extended-relational, object-oriented, heterogeneous), data warehouse, transactional data, stream, spatiotemporal, time-series, sequence, text and web, multi-media, graphs & social and information networks
- **Knowledge to be mined (or: Data mining functions)**
  - Characterization, discrimination, association, classification, clustering, trend/deviation, outlier analysis, …
  - Descriptive vs. predictive data mining
  - Multiple/integrated functions and mining at multiple levels
- **Techniques utilized**
  - Data-intensive, data warehouse (OLAP), machine learning, statistics, pattern recognition, visualization, high-performance, etc.
- **Applications adapted**
  - Retail, telecommunication, banking, fraud analysis, bio-data mining, stock market analysis, text mining, Web mining, etc.

Amazon, Yahoo!, Walmart, Google, Facebook, Twitter, Snapchat, Bloomberg, CNN…

Research Challenges

- Mining Methodology
  - Mining various and new kinds of knowledge
  - Mining knowledge in **multi-dimensional** space
  - Data mining: An **interdisciplinary** effort
  - Boosting the power of discovery in a networked environment
  - Handling **noise, uncertainty, and incompleteness** of data
  - **Pattern evaluation** and pattern- or constraint-guided mining
- User Interaction
  - **Interactive** mining
  - Incorporation of **background knowledge**
  - **Presentation and visualization** of data mining results

Research Challenges (cont.)

- Efficiency and Scalability
  - **Efficiency and scalability** of data mining algorithms
  - **Parallel, distributed, stream, and incremental** mining methods
- Diversity of data types
  - Handling **complex** types of data
  - Mining **dynamic, networked, and global** data repositories
- Data mining and society
  - **Social** impacts of data mining
  - **Privacy-preserving** data mining
  - **Invisible** data mining

History

- 1989 IJCAI Workshop on Knowledge Discovery in Databases
  - Knowledge Discovery in Databases (G. Piatetsky-Shapiro and W. Frawley, 1991)
- 1991-1994 Workshops on Knowledge Discovery in Databases
  - Advances in Knowledge Discovery and Data Mining (U. Fayyad, G. Piatetsky-Shapiro, P. Smyth, and R. Uthurusamy, 1996)
- 1995-1998 International Conferences on Knowledge Discovery in Databases and Data Mining (KDD'95-98)
  - Journal of Data Mining and Knowledge Discovery (1997)
- ACM SIGKDD conferences since 1998 and SIGKDD Explorations
- More conferences on data mining
  - PAKDD (1997), PKDD (1997), SIAM Data Mining (2001), (IEEE) ICDM (2001), WSDM (2008), etc.
- ACM Transactions on KDD (2007)

Venues

- Data mining and KDD (SIGKDD)
  - Conferences: ACM SIGKDD, IEEE ICDM, SIAM DM, PKDD, PAKDD, etc.
  - Journal: Data Mining and Knowledge Discovery, KDD Explorations, IEEE TKDE, ACM TKDD
- Database systems (SIGMOD)
  - Conferences: ACM SIGMOD, ACM-PODS, VLDB, IEEE ICDE, EDBT, ICDT, DASFAA
  - Journals: ACM TODS/TOIS, JIIS, J. ACM, VLDB J., Info. Sys., etc.
- AI & Machine Learning
  - Conferences: ICML, AAAI, IJCAI, COLT (Learning Theory), CVPR, NIPS, etc.
  - Journals: Machine Learning, Artificial Intelligence, IEEE PAMI, etc.
- Web and IR
  - Conferences: SIGIR, WWW, CIKM, etc.
  - Journals: Internet and Web Information Systems
- Statistics
  - Conferences: Joint Stat. Meeting, etc.
  - Journals: Annals of statistics, etc.
- Visualization
  - Conference proceedings: CHI, ACM SIGGraph, etc.
  - Journals: IEEE Trans. visualization and computer graphics, etc.

Summary

- Data mining: Discovering interesting patterns and knowledge from massive amount of data
- A natural evolution of science and information technology, in great demand, with wide applications
- A KDD process includes data cleaning, data integration, data selection, transformation, data mining, pattern evaluation, and knowledge presentation
- Data mining functionalities: characterization, discrimination, association, classification, clustering, trend and outlier analysis, …
- Data mining technologies and applications
- Research challenges in data mining

References

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- E. Alpaydin. Introduction to Machine Learning, 2nd ed., MIT Press, 2011
- R. O. Duda, P. E. Hart, and D. G. Stork, Pattern Classification, 2ed., Wiley-Interscience, 2000
- U. Fayyad, G. Grinstein, and A. Wierse, Information Visualization in Data Mining and Knowledge Discovery, Morgan Kaufmann, 2001
- J. Han, M. Kamber, and J. Pei, Data Mining: Concepts and Techniques. Morgan Kaufmann, 3rd ed. , 2011
- T. Hastie, R. Tibshirani, and J. Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, 2nd ed., Springer, 2009
- T. M. Mitchell, Machine Learning, McGraw Hill, 1997
- P.-N. Tan, M. Steinbach and V. Kumar, Introduction to Data Mining, Wiley, 2005 (2nd ed. 2016)
- I. H. Witten and E. Frank, Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations, Morgan Kaufmann, 2nd ed. 2005
- Mohammed J. Zaki and Wagner Meira Jr., Data Mining and Analysis: Fundamental Concepts and Algorithms 2014

Discussion

- Given a **task** – design a machine that can find the only outlier from a set of concepts, …
  - Q: apple, banana, eggplant, strawberry
  - A: eggplant
  - How?

Discussion

- Given self-introductory one-minute one-page text **data** of your classmates, …
  - Q:?
  - A:?
  - How?

Write down your self-intro and what you want to do