# CS6220: DATA MINING TECHNIQUES

## 1: Introduction

**Instructor: Yizhou Sun**

yzsun@ccs.neu.edu

September 9, 2013

# Course Information

- Course homepage: http://www.ccs.neu.edu/home/yzsun/classes/2013Fall_CS6220/index.htm
  - Class schedule
  - Slides
  - Announcement
  - Assignments
  - …
- Piazza: https://piazza.com/northeastern/fall2013/cs6220/home

- Prerequisites
  - CS 5800 or CS 7800, or consent of instructor
  - More generally
    - You are expected to have background knowledge in data structures, algorithms, basic linear algebra, and basic statistics.
    - You will also need to be familiar with at least one programming language, and have programming experiences.

# Meeting Time and Location

- When
  - Tuesdays, 6-9pm
- Where
  - Behrakis Health Sciences Center 310

# Instructor and TA Information

- Instructor: Yizhou Sun
  - Homepage: http://www.ccs.neu.edu/home/yzsun/
  - Email: yzsun@ccs.neu.edu
  - Office: 320 WVH
  - Office hour: Wednesdays 3-5pm
- TA:
  - Moonyoung (Moon) Kang
    - Email: yerihyo@gmail.com
    - Office hours: Tuesdays 2-4pm at 472 WVH
  - Qizhen Ruan
    - Email: ruan.qi@husky.neu.edu
    - Office hours: Mondays 4:30-6:30pm at 102 Main Lab WVH

# Grading

- Homework: 40%
- Midterm exam: 25%
- Course project: 30%
- Participation: 5%

# Grading: Homework

- Homework: 40%
  - Four assignments are expected
    - 2 paper-based assignments
    - 2 program-based assignments
  - Deadline: 11:59pm of the indicated due date via *Blackboard* or class system
    - within 1 hour late: 90% max; within 8 hours late: 60% max; otherwise: 0%
  - No copying or sharing of homework!
    - But you can discuss general challenges and ideas with others

# Grading: Midterm Exam

- Midterm exam: 25%
  - Closed book exam, but you can take a “cheating sheet” of A4 size

# Grading: Course Project

- Course project: 30%
  - Group project (3-4 people for one group)
  - Goal: Choose one interesting problem, formalize it as a data mining task, collect data, provide solutions, and evaluate and compare your solutions.
  - You are expected to submit one project proposal early this semester, and your datasets, code, and a project report at the end of the semester
  - You are expected to present your project at the end of the semester.

# Grading: Participation

- Participation (5%)
  - In-class participation
  - Online participation (piazza)

# Textbook

- Jiawei Han, Micheline Kamber, and Jian Pei. Data Mining: Concepts and Techniques, 3rd edition, Morgan Kaufmann, 2011
- References
  - "Data Mining" by Pang-Ning Tan, Michael Steinbach, and Vipin Kumar (http://www-users.cs.umn.edu/~kumar/dmbook/index.php)
  - "Machine Learning" by Tom Mitchell (http://www.cs.cmu.edu/~tom/mlbook.html)
  - "Introduction to Machine Learning" by Ethem ALPAYDIN (http://www.cmpe.boun.edu.tr/~ethem/i2ml/)
  - "Pattern Classification" by Richard O. Duda, Peter E. Hart, David G. Stork (http://www.wiley.com/WileyCDA/WileyTitle/productCd-0471056693.html)
  - "The Elements of Statistical Learning: Data Mining, Inference, and Prediction" by Trevor Hastie, Robert Tibshirani, and Jerome Friedman (http://www-stat.stanford.edu/~tibs/ElemStatLearn/)
  - "Pattern Recognition and Machine Learning" by Christopher M. Bishop (http://research.microsoft.com/en-us/um/people/cmbishop/prml/)

# Course Content

- By data types:
  - matrix data
  - set data
  - sequence data
  - time series
  - graph and network (Next Semester: Advanced Topics)
- By functions:
  - Classification
  - Clustering
  - Frequent pattern mining
  - Prediction
  - Similarity search
  - Ranking

# Goal of the Course

- Know what is data mining and the basic algorithms
- Know how to apply algorithms to real-world applications
- Provide a starting course for research in data mining

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- Why Data Mining?
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining
  - What Kinds of Data Can Be Mined?
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# 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!
- "Necessity is the mother of invention"—Data mining—Automated analysis of massive data sets

# Big Data Challenges

- Video 1: Big Data Challenges (Ads by DataStax)
  - http://www.youtube.com/watch?v=or6Pse8fxD4

- Video 2: Explaining Big Data
  - http://www.youtube.com/watch?v=7D1CQ_LOizA

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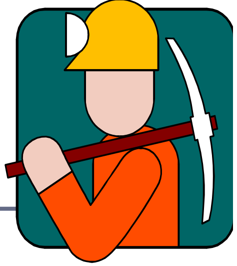
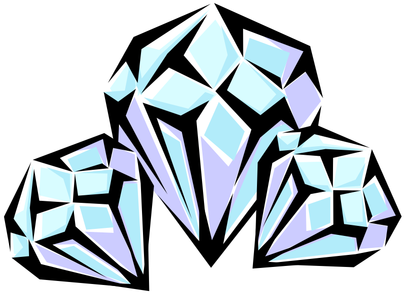
- Major Issues in Data Mining
- A Brief History of Data Mining and Data Mining Society
- Summary

# What Is Data Mining?



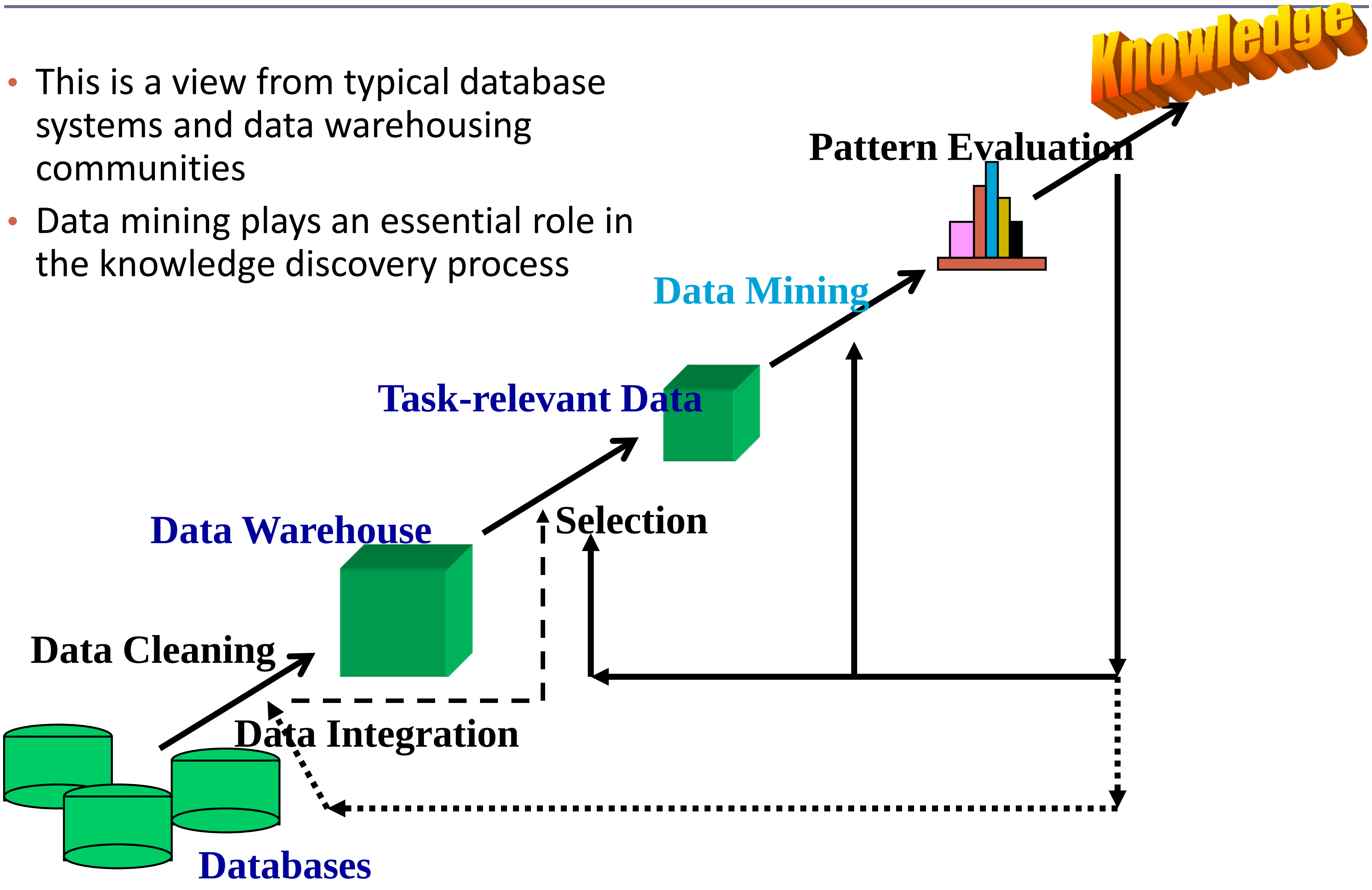
- Data mining (knowledge discovery from data)
  - Extraction of interesting (non-trivial, implicit, previously unknown and potentially useful) patterns or knowledge from huge amount of data

- Alternative names
  - Knowledge discovery (mining) in databases (KDD), knowledge extraction, data/pattern analysis, data archeology, data dredging, information harvesting, business intelligence, etc.

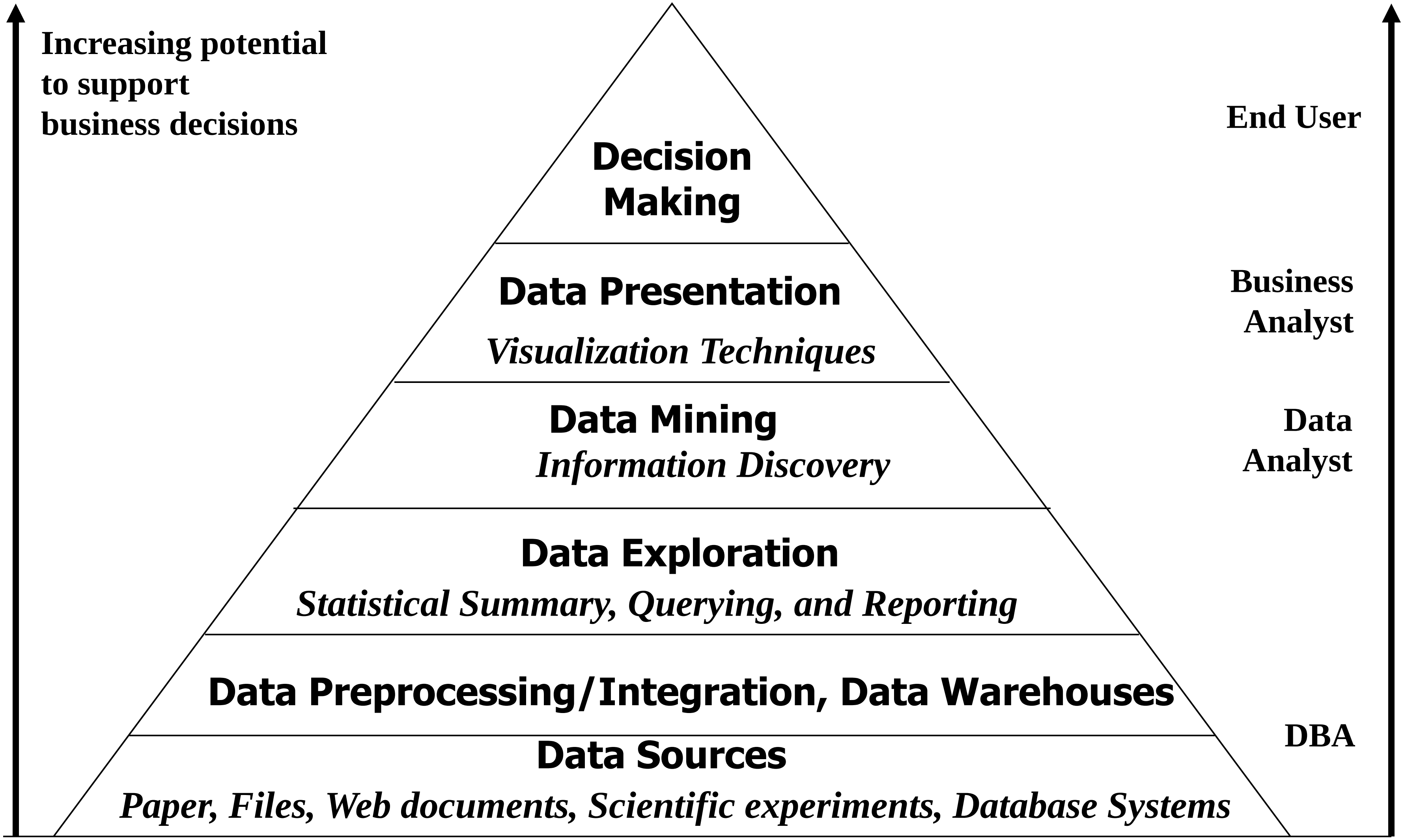


# Knowledge Discovery (KDD) Process

- This is a view from typical database systems and data warehousing communities
- Data mining plays an essential role in the knowledge discovery process



# Data Mining in 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*

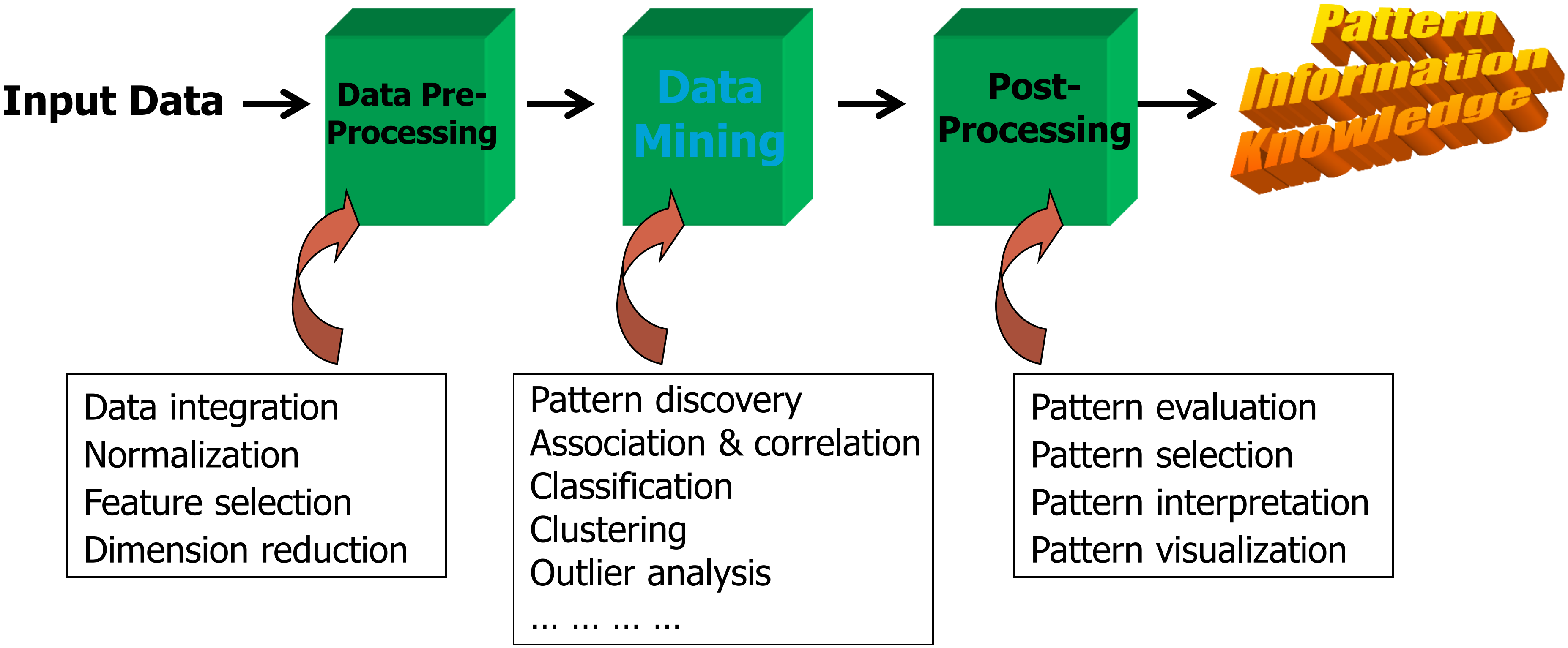
End User

Business Analyst

Data Analyst

DBA

# KDD Process: A Typical View from ML and Statistics



Input Data → Data Pre-Processing → Data Mining → Post-Processing → Pattern Information Knowledge

Data integration
Normalization
Feature selection
Dimension reduction

Pattern discovery
Association & correlation
Classification
Clustering
Outlier analysis
… … … …

Pattern evaluation
Pattern selection
Pattern interpretation
Pattern visualization

- This is a view from typical machine learning and statistics communities

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# Multi-Dimensional View of Data Mining

- **Data to be mined**
  - Database data (extended-relational, object-oriented, heterogeneous, legacy), 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, etc.
  - 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.

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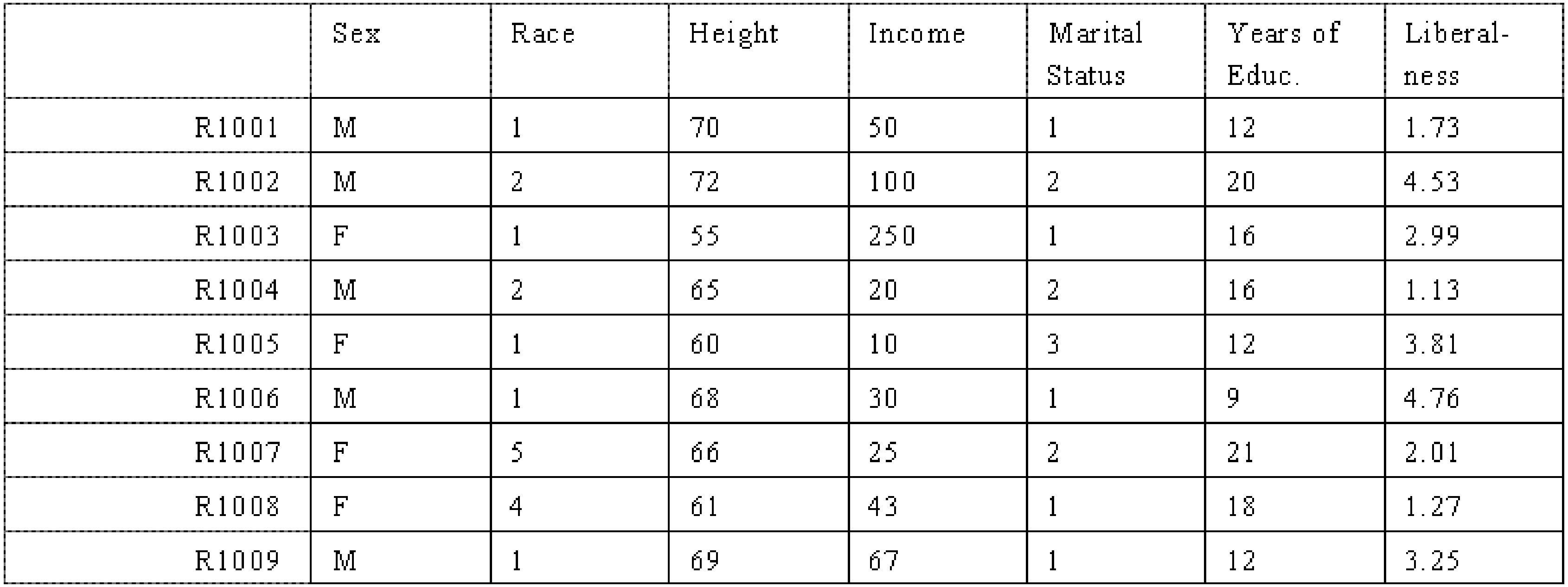
# Data Mining: On What Kinds of Data?

- Database-oriented data sets and applications
  - Relational database, data warehouse, transactional database
- Advanced data sets and advanced applications
  - Data streams and sensor data
  - Time-series data, temporal data, sequence data (incl. bio-sequences)
  - Structure data, graphs, social networks and multi-linked data
  - Object-relational databases
  - Heterogeneous databases and legacy databases
  - Spatial data and spatiotemporal data
  - Multimedia database
  - Text databases
  - The World-Wide Web

# Matrix Data

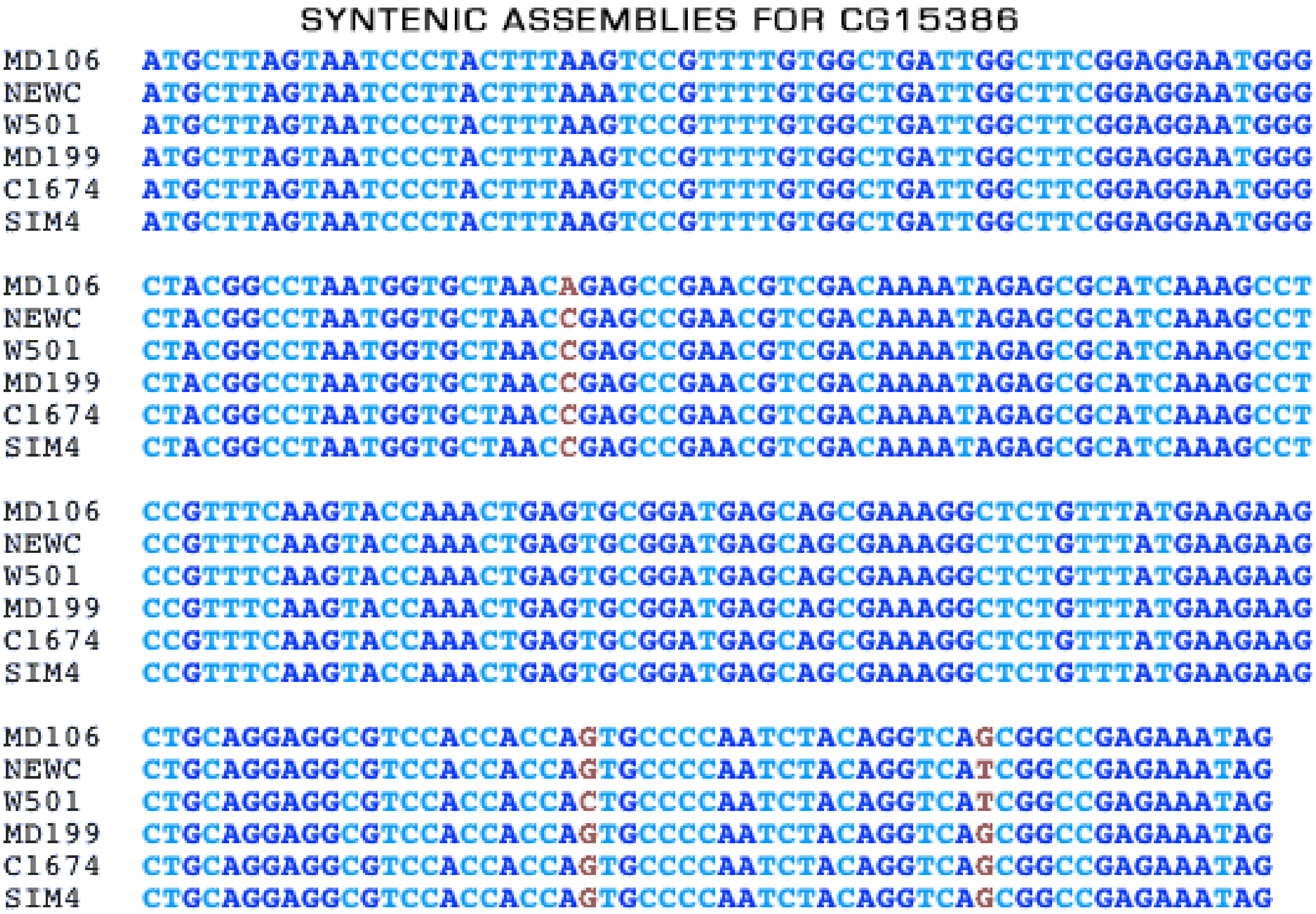


| | Sex | Race | Height | Income | Marital Status | Years of Educ. | Liberal-ness |
|---|---|---|---|---|---|---|---|
| R1001 | M | 1 | 70 | 50 | 1 | 12 | 1.73 |
| R1002 | M | 2 | 72 | 100 | 2 | 20 | 4.53 |
| R1003 | F | 1 | 55 | 250 | 1 | 16 | 2.99 |
| R1004 | M | 2 | 65 | 20 | 2 | 16 | 1.13 |
| R1005 | F | 1 | 60 | 10 | 3 | 12 | 3.81 |
| R1006 | M | 1 | 68 | 30 | 1 | 9 | 4.76 |
| R1007 | F | 5 | 66 | 25 | 2 | 21 | 2.01 |
| R1008 | F | 4 | 61 | 43 | 1 | 18 | 1.27 |
| R1009 | M | 1 | 69 | 67 | 1 | 12 | 3.25 |

# Set Data

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

# Sequence Data



SYNTENIC ASSEMBLIES FOR CG15386

```
MD106   ATGCTTAGTAATCCCTACTTTAAGTCCGTTTTGTGGCTGATTGGCTTCGGAGGAATGGG
NEWC    ATGCTTAGTAATCCTTACTTTAAATCCGTTTTGTGGCTGATTGGCTTCGGAGGAATGGG
W501    ATGCTTAGTAATCCCTACTTTAAGTCCGTTTTGTGGCTGATTGGCTTCGGAGGAATGGG
MD199   ATGCTTAGTAATCCCTACTTTAAGTCCGTTTTGTGGCTGATTGGCTTCGGAGGAATGGG
C1674   ATGCTTAGTAATCCCTACTTTAAGTCCGTTTTGTGGCTGATTGGCTTCGGAGGAATGGG
SIM4    ATGCTTAGTAATCCCTACTTTAAGTCCGTTTTGTGGCTGATTGGCTTCGGAGGAATGGG

MD106   CTACGGCCTAATGGTGCTAACAGAGCCGAACGTCGACAAAATAGAGCGCATCAAAGCCT
NEWC    CTACGGCCTAATGGTGCTAACCGAGCCGAACGTCGACAAAATAGAGCGCATCAAAGCCT
W501    CTACGGCCTAATGGTGCTAACCGAGCCGAACGTCGACAAAATAGAGCGCATCAAAGCCT
MD199   CTACGGCCTAATGGTGCTAACCGAGCCGAACGTCGACAAAATAGAGCGCATCAAAGCCT
C1674   CTACGGCCTAATGGTGCTAACCGAGCCGAACGTCGACAAAATAGAGCGCATCAAAGCCT
SIM4    CTACGGCCTAATGGTGCTAACCGAGCCGAACGTCGACAAAATAGAGCGCATCAAAGCCT

MD106   CCGTTTCAAGTACCAAACTGAGTGCGGATGAGCAGCGAAAGGCTCTGTTTATGAAGAAG
NEWC    CCGTTTCAAGTACCAAACTGAGTGCGGATGAGCAGCGAAAGGCTCTGTTTATGAAGAAG
W501    CCGTTTCAAGTACCAAACTGAGTGCGGATGAGCAGCGAAAGGCTCTGTTTATGAAGAAG
MD199   CCGTTTCAAGTACCAAACTGAGTGCGGATGAGCAGCGAAAGGCTCTGTTTATGAAGAAG
C1674   CCGTTTCAAGTACCAAACTGAGTGCGGATGAGCAGCGAAAGGCTCTGTTTATGAAGAAG
SIM4    CCGTTTCAAGTACCAAACTGAGTGCGGATGAGCAGCGAAAGGCTCTGTTTATGAAGAAG

MD106   CTGCAGGAGGCGTCCACCACCAGTGCCCCAATCTACAGGTCAGCGGCCGAGAAATAG
NEWC    CTGCAGGAGGCGTCCACCACCAGTGCCCCAATCTACAGGTCATCGGCCGAGAAATAG
W501    CTGCAGGAGGCGTCCACCACCACTGCCCCAATCTACAGGTCATCGGCCGAGAAATAG
MD199   CTGCAGGAGGCGTCCACCACCAGTGCCCCAATCTACAGGTCAGCGGCCGAGAAATAG
C1674   CTGCAGGAGGCGTCCACCACCAGTGCCCCAATCTACAGGTCAGCGGCCGAGAAATAG
SIM4    CTGCAGGAGGCGTCCACCACCAGTGCCCCAATCTACAGGTCAGCGGCCGAGAAATAG
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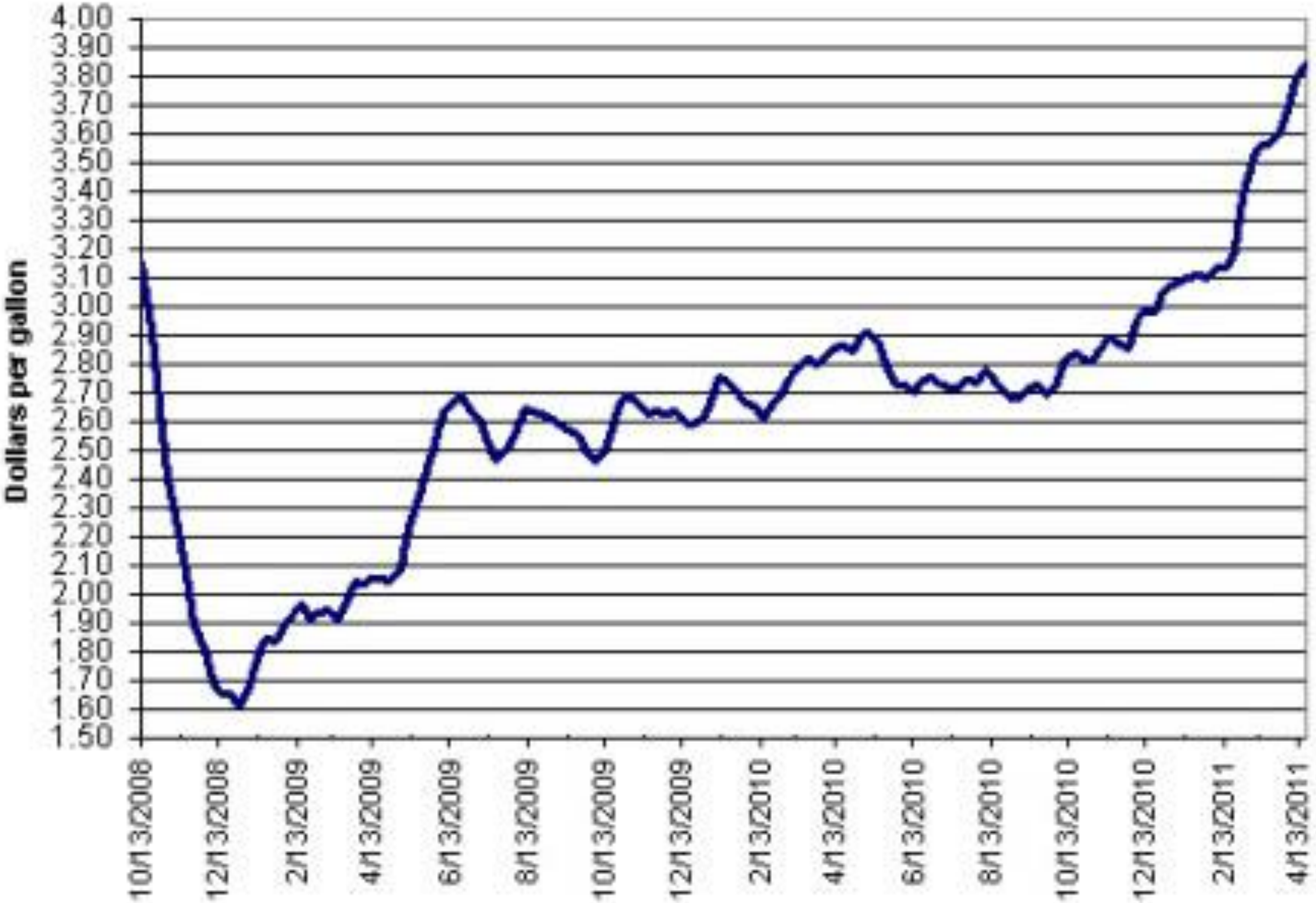
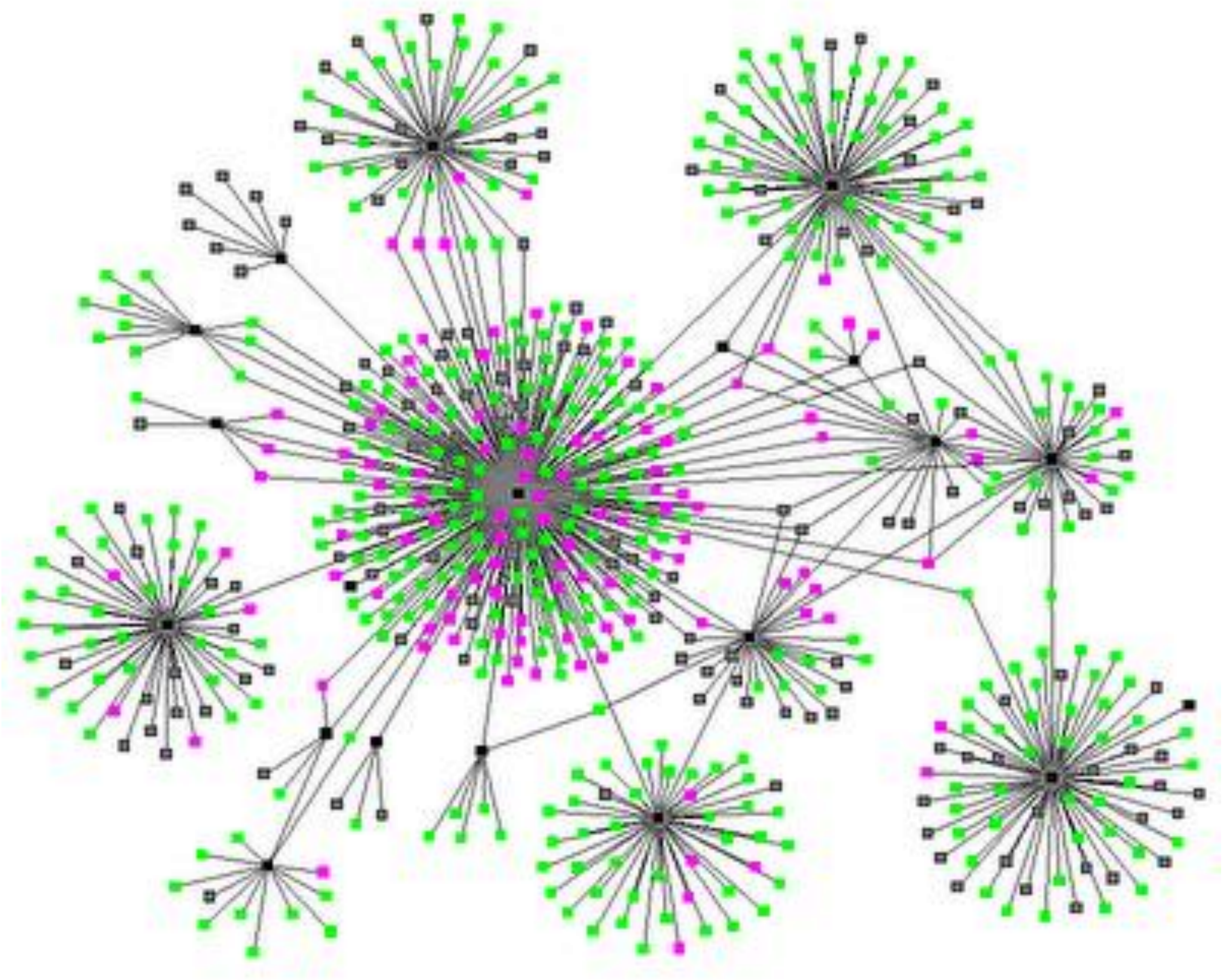
# Time Series

Weekly U.S. Retail Gasoline Prices, Regular Grade



Source: Energy Information Administration

# Graph / Network



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# Data Mining Function: Association and Correlation Analysis

- Frequent patterns (or frequent itemsets)
  - What items are frequently purchased together in your Walmart?
- Association, correlation vs. causality
  - A typical association rule
    - Diaper → Beer [0.5%, 75%] (support, confidence)
  - Are strongly associated items also strongly correlated?

# Data Mining Function: Classification

- Classification and label prediction
    - Construct models (functions) based on some training examples
    - Describe and distinguish classes or concepts for future prediction
        - E.g., classify countries based on (climate), or 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 Function: Cluster Analysis

- 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
- Many methods and applications

# Data Mining Function: Others

- Prediction
- Similarity search
- Ranking
- Outlier detection
- …

# Evaluation of Knowledge

- Are all mined knowledge interesting?
  - One can mine tremendous amount of “patterns” and knowledge
  - Some may fit only certain dimension space (time, location, …)
  - Some may not be representative, may be transient, …
- Evaluation of mined knowledge → directly mine only interesting knowledge?
  - Descriptive vs. predictive
  - Coverage
  - Typicality vs. novelty
  - Accuracy
  - Timeliness
  - …

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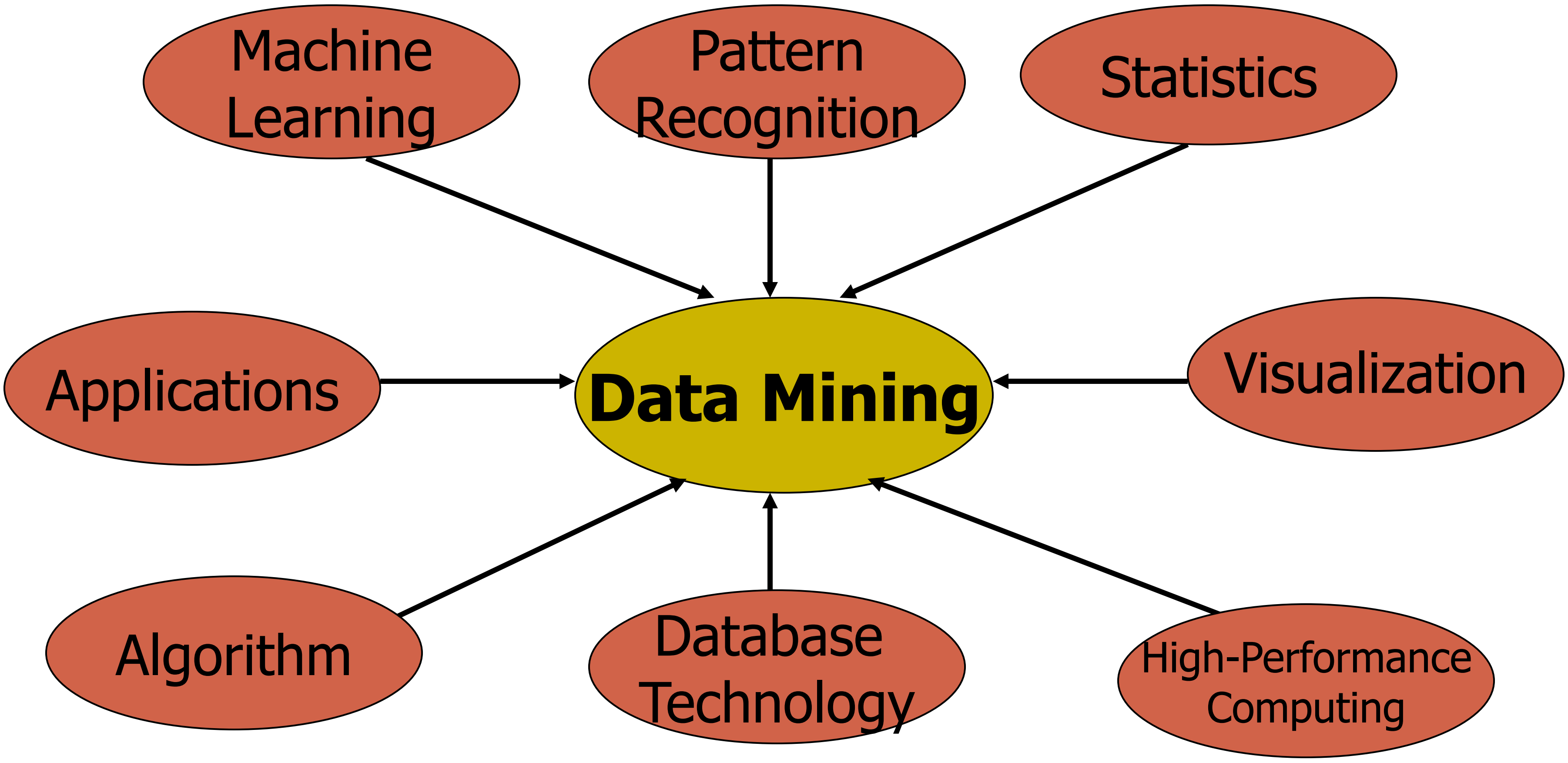
# Data Mining: Confluence of Multiple Disciplines



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# Applications of Data Mining

- Web page analysis: from web page classification, clustering to PageRank & HITS algorithms
- Collaborative analysis & recommender systems
- Basket data analysis to targeted marketing
- Biological and medical data analysis: classification, cluster analysis (microarray data analysis),  biological sequence analysis, biological network analysis
- Data mining and software engineering (e.g., IEEE Computer, Aug. 2009 issue)
- Social media
- Game

# Example

- Street Bump Boston Project
  - http://www.cityofboston.gov/doit/apps/streetbump.asp

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# Major Issues in Data Mining (1)

- 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

# Major Issues in Data Mining (2)

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

# Where to Find References? DBLP, CiteSeer, Google

- Data mining and KDD (SIGKDD: CDROM)
  - Conferences: ACM-SIGKDD, IEEE-ICDM, SIAM-DM, PKDD, PAKDD, etc.
  - Journal: Data Mining and Knowledge Discovery, KDD Explorations, ACM TKDD
- Database systems (SIGMOD: ACM SIGMOD Anthology—CD ROM)
  - Conferences: ACM-SIGMOD, ACM-PODS, VLDB, IEEE-ICDE, EDBT, ICDT, DASFAA
  - Journals: IEEE-TKDE, ACM-TODS/TOIS, JIIS, J. ACM, VLDB J., Info. Sys., etc.
- AI & Machine Learning
  - Conferences: Machine learning (ML), AAAI, IJCAI, COLT (Learning Theory), CVPR, NIPS, etc.
  - Journals: Machine Learning, Artificial Intelligence, Knowledge and Information Systems, IEEE-PAMI, etc.
- Web and IR
  - Conferences: SIGIR, WWW, CIKM, etc.
  - Journals: WWW: 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.

# Recommended Reference Books

- E. Alpaydin. Introduction to Machine Learning, 2nd ed., MIT Press, 2011
- S. Chakrabarti. Mining the Web: Statistical Analysis of Hypertex and Semi-Structured Data. Morgan Kaufmann, 2002
- R. O. Duda, P. E. Hart, and D. G. Stork, Pattern Classification, 2ed., Wiley-Interscience, 2000
- T. Dasu and T. Johnson. Exploratory Data Mining and Data Cleaning. John Wiley & Sons, 2003
- U. M. Fayyad, G. Piatetsky-Shapiro, P. Smyth, and R. Uthurusamy. Advances in Knowledge Discovery and Data Mining. AAAI/MIT Press, 1996
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- P.-N. Tan, M. Steinbach and V. Kumar, Introduction to Data Mining, Wiley, 2005
- S. M. Weiss and N. Indurkhya, Predictive Data Mining, Morgan Kaufmann, 1998
- I. H. Witten and E. Frank, Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations, Morgan Kaufmann, 2nd ed. 2005