Data Mining

About Myself

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Textbook

- Han, J., Kamber , M., & Pei, J. “Data Mining: Concepts and Techniques”, Latest Edition, Morgan Kaufmann

Evaluation Criteria

- Subject to change as per policy

Activity	Evaluation Percentage
Assignments	15
Quizzes	10
Project	10
Mid Term	25
End Term	40

Chapter 1. Introduction

- Why Data Mining?
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining
- What Kinds of Data Can Be Mined?
- What Kinds of Patterns Can Be Mined?
- What Kinds of Technologies Are Used?
- What Kinds of Applications Are Targeted?
- Major Issues in Data Mining

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
- <u>We are drowning in data, but starving for knowledge!</u>
- "Necessity is the mother of invention"—Data mining—Automated analysis of massive data sets

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- A Brief History of Data Mining and Data Mining Society
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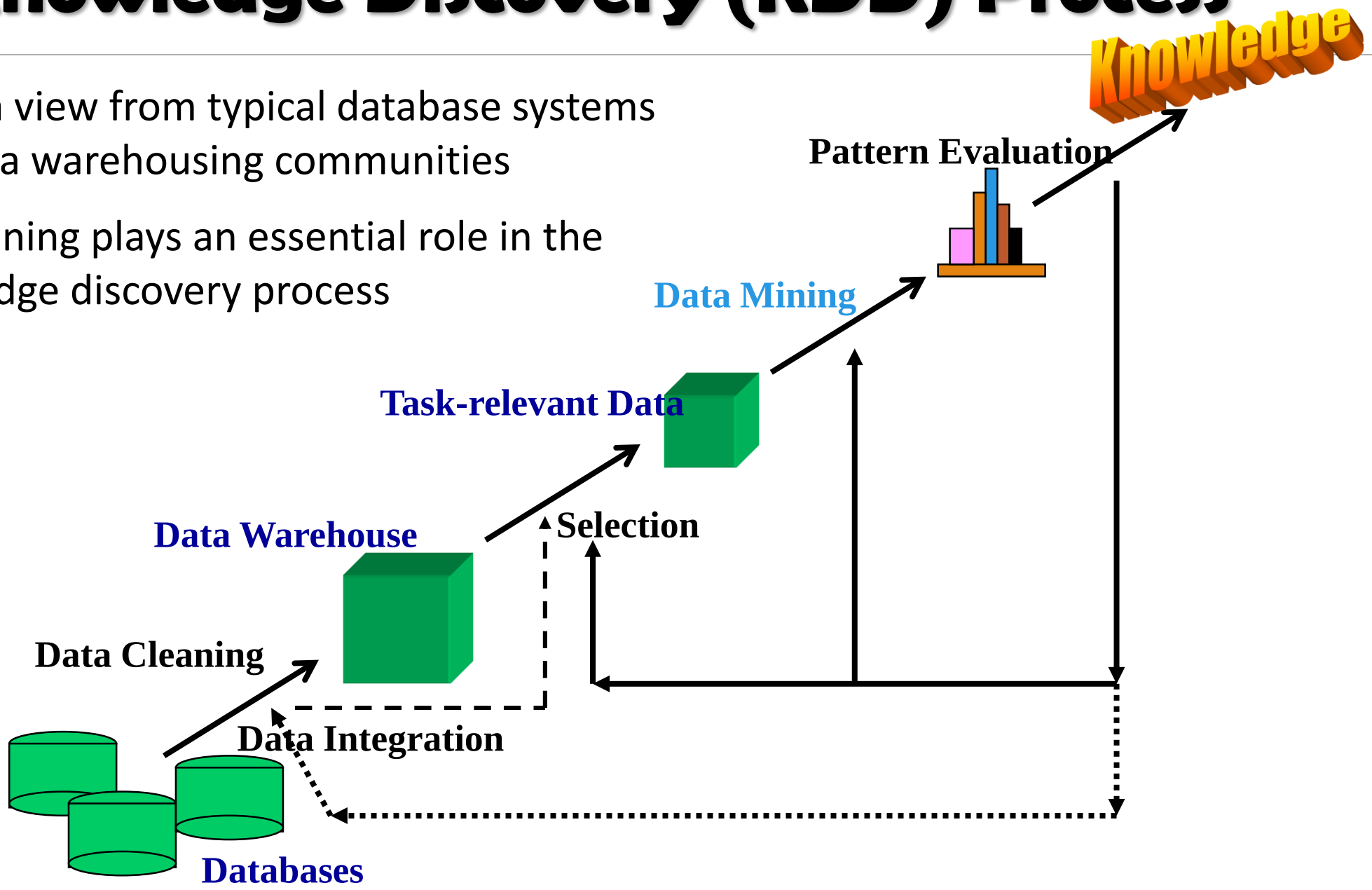
What Is Data Mining?

- Data mining (knowledge discovery from data)
  - Extraction of interesting (non-trivial, hidden, 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"?
  - Simple search and query processing
  - (Deductive) expert systems

Knowledge Discovery (KDD) Process

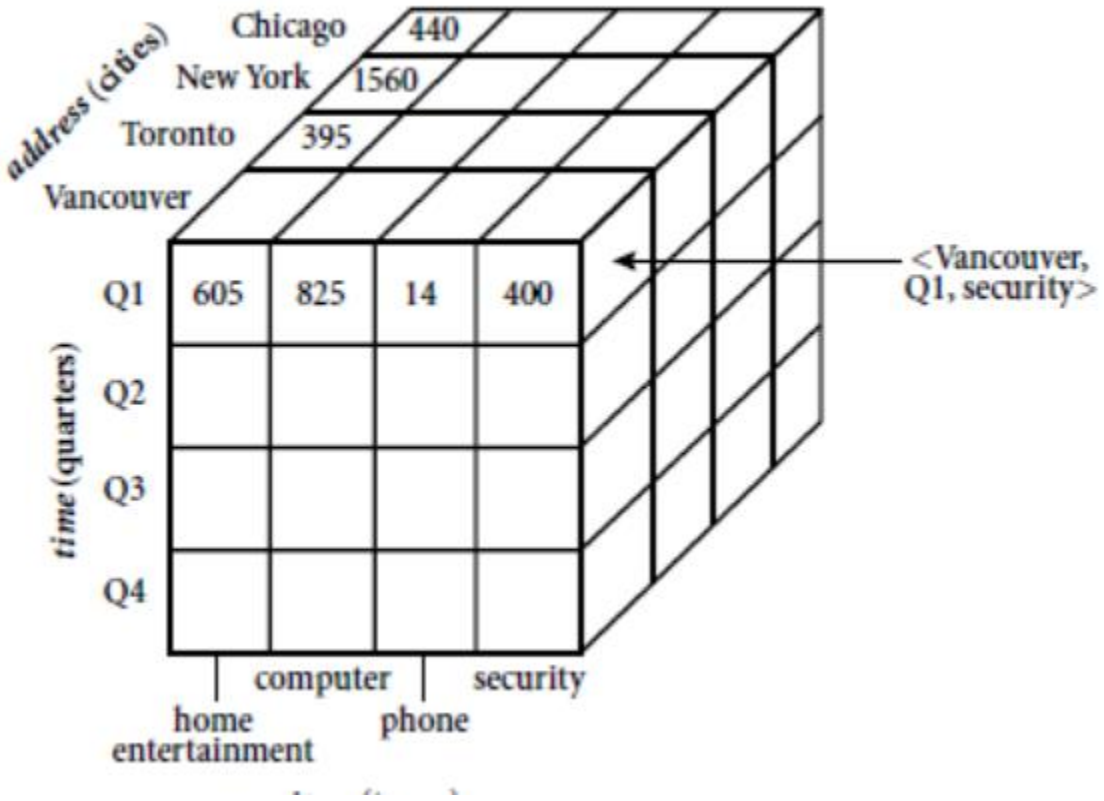
- This is a view from typical database systems and data warehousing communities
- Data mining plays an essential role in the knowledge discovery process



Example: A Web Mining Framework

- 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

Data Cube


address (cities)
Chicago
New York
Toronto
Vancouver
440
1560
395
time (quarters)
Q1
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Q4
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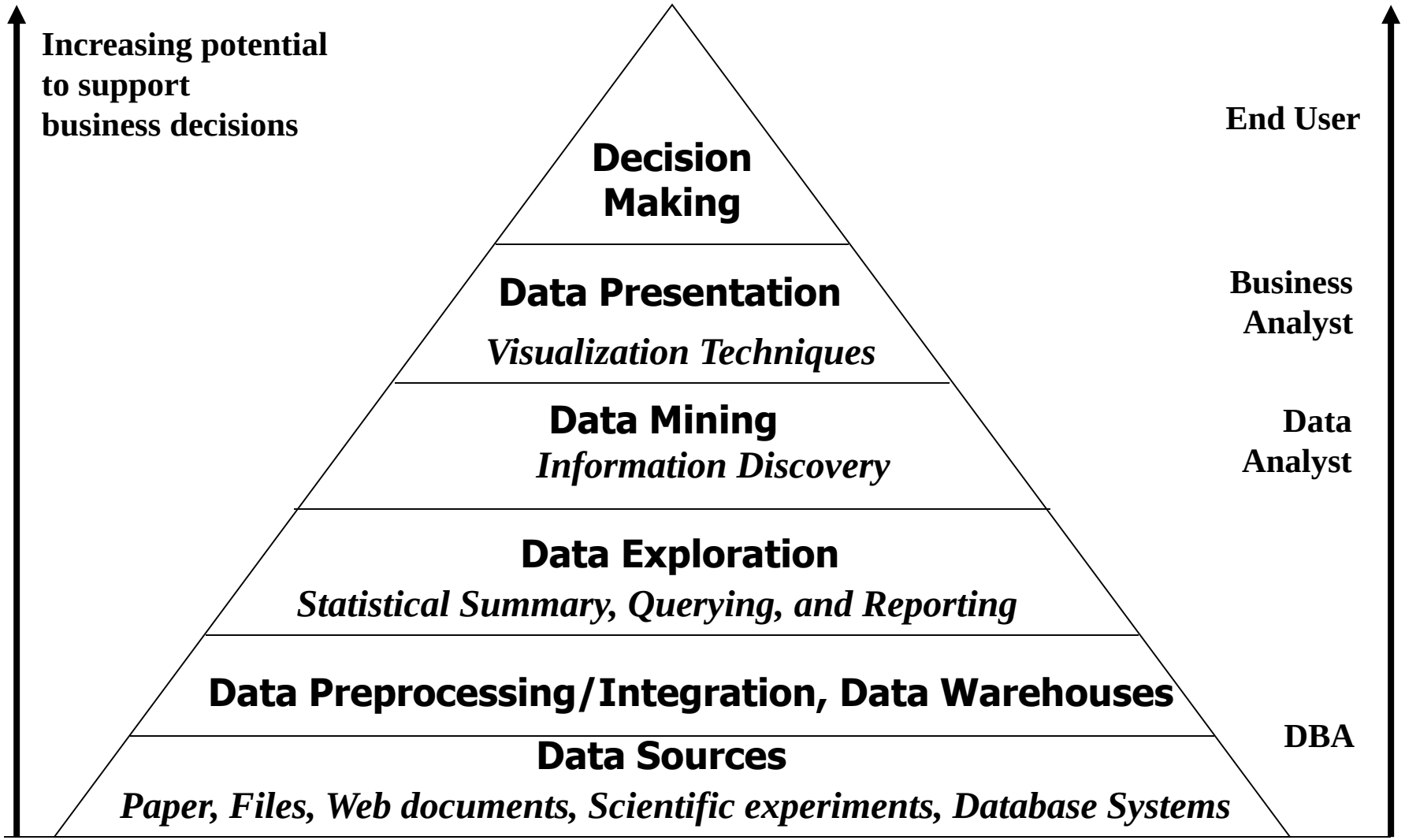
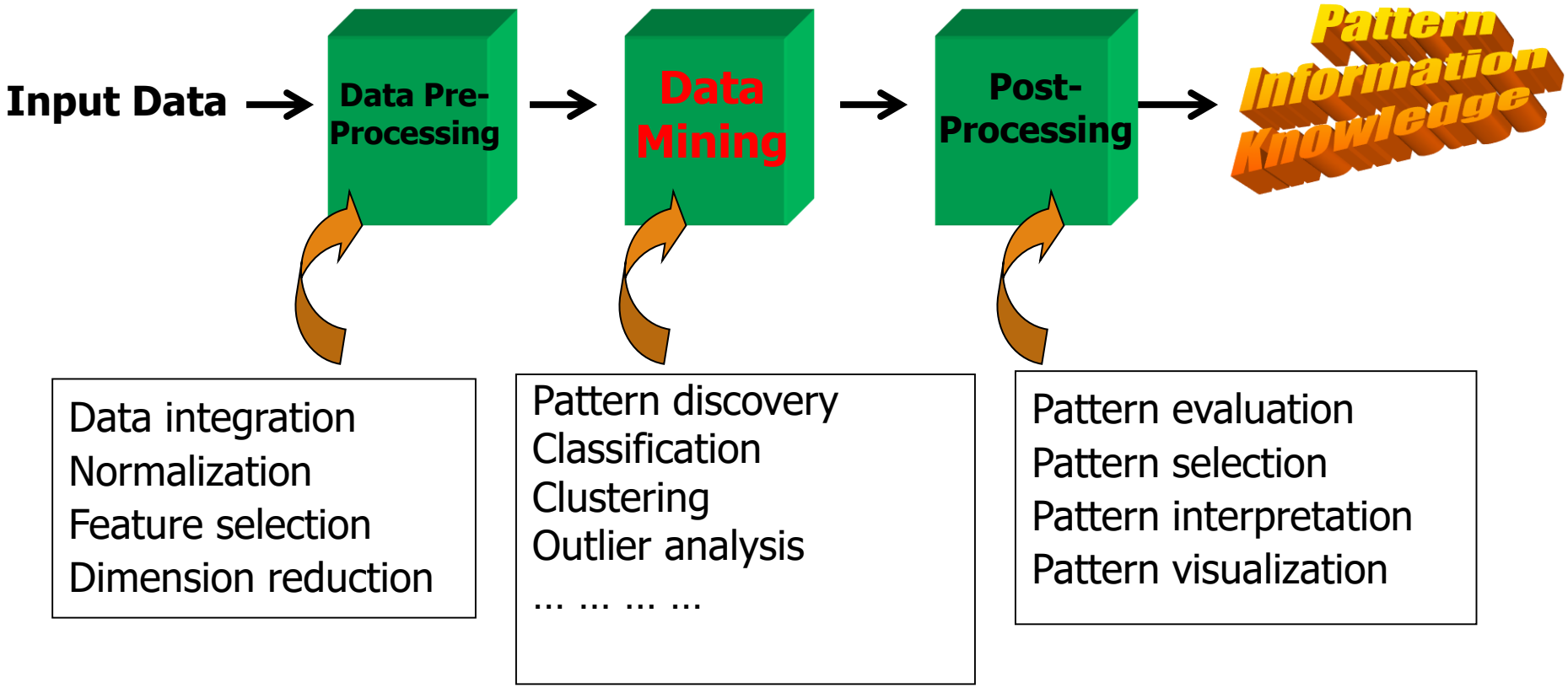
computer
security
home entertainment
phone

Data Mining in Business Intelligence



KDD Process: A View from ML and Statistics



- 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), data warehouse, transactional data, stream (e.g. video), spatiotemporal (e.g. maps), time-series and sequence (e.g. stock), text (customer sentiment) and web, multi-media, graphs & social and information networks
- **Knowledge to be mined (or: Data mining functions)**
  - Characterization (summarization of general features of a target class. E.g. characteristics of software products whose sales were increased by 10% last year)
  - Discrimination (comparison of features of contrasting classes. Eg. Comparing features of dataset where software were increased by 10% Vs. which were decreased by 30%)
  - Association, classification, clustering, trend/deviation, outlier analysis
  - Descriptive (characterize properties of data) vs. predictive data mining (predictions)

Multi-Dimensional View of Data Mining

- **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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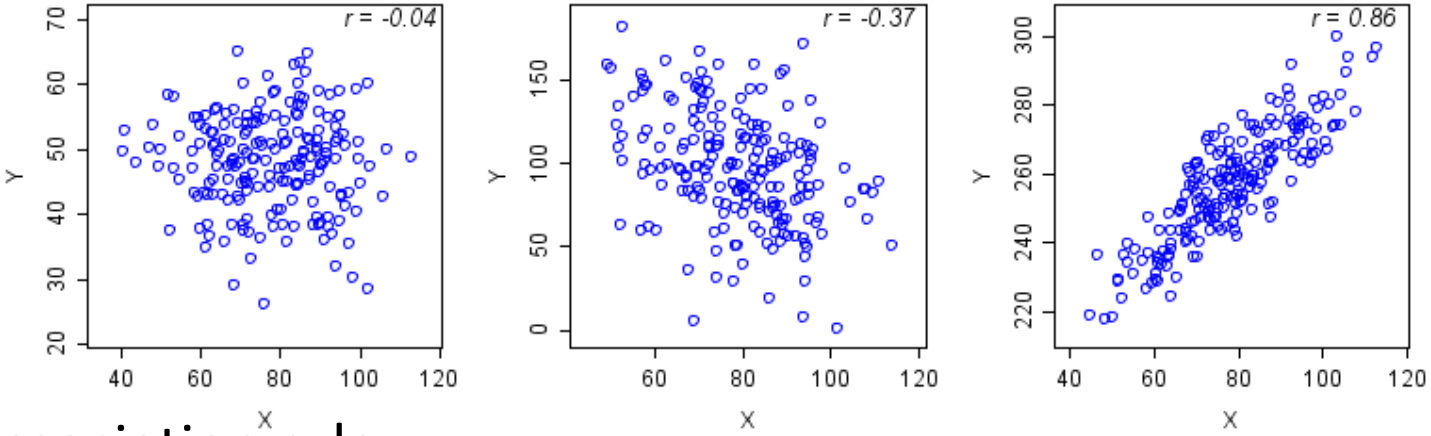
Data Mining Functions: (1) Generalization

- Information integration and data warehouse construction
  - Data cleaning, transformation, integration, and multidimensional data model
- Data cube technology
  - Multidimensional aggregates
  - OLAP (online analytical processing)

- Multidimensional concept description: Characterization and discrimination
  - Generalize, summarize, and contrast data characteristics, e.g., dry vs. wet region

Data Mining Functions: (2) Pattern Discovery

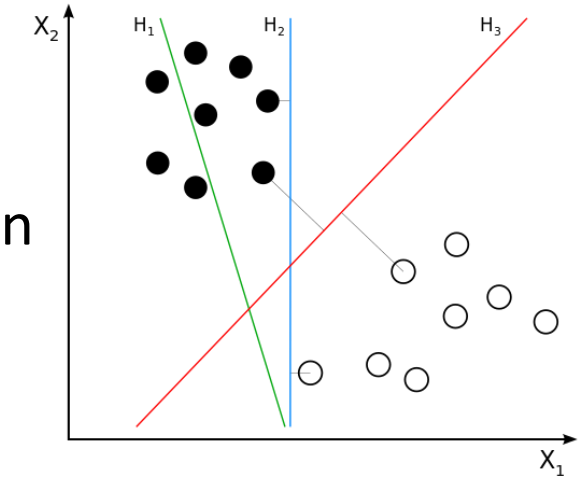
- Frequent patterns (or frequent itemsets)
  - What items are frequently purchased together in your Walmart?
- Association and Correlation Analysis



- A typical association rule
  - Diaper → Juice [0.5%, 75%] (support, confidence) (P(XUY),P(X|Y))
- How to mine such patterns and rules efficiently in large datasets?
- How to use such patterns for classification, clustering, and other applications?

Data Mining Functions: (3) Classification

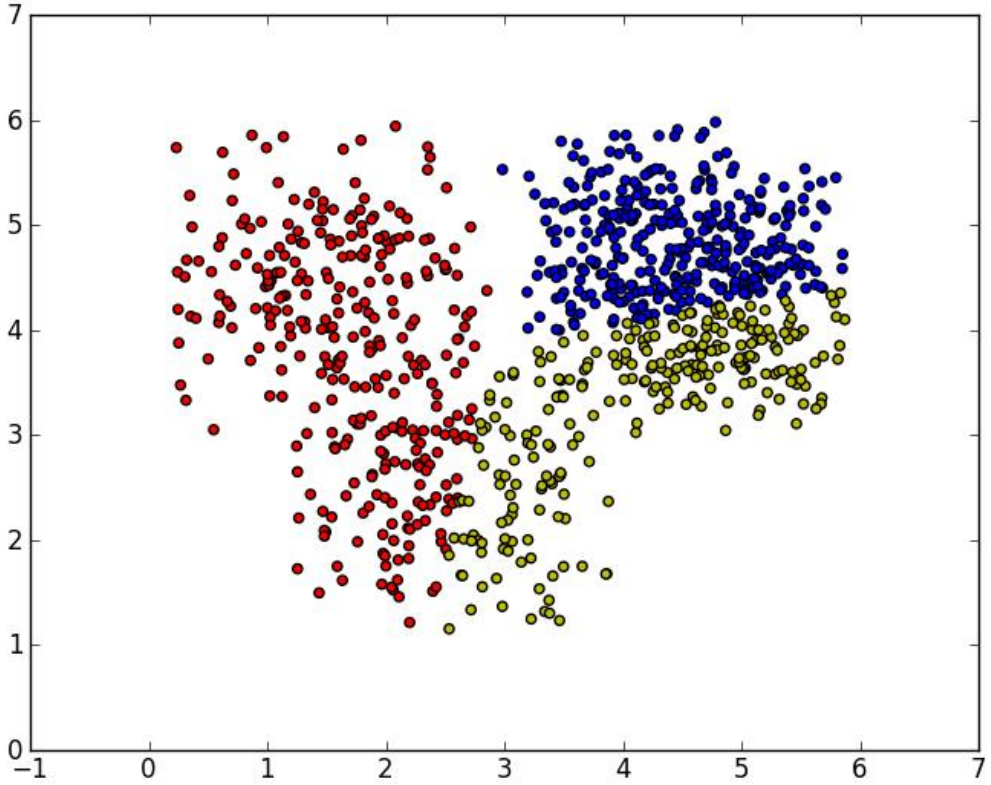
- Classification and label prediction
  - Construct models (functions) based on some training examples
  - Describe and distinguish classes or concepts for future prediction
    - Ex. 1. Classify countries based on (climate)
    - Ex. 2. Classify cars based on (gas mileage)
  - Predict some unknown class 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 diseases, web-pages, …

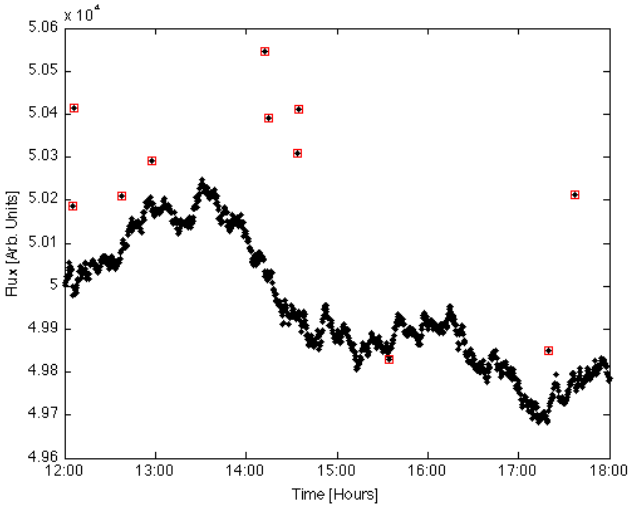
Data Mining Functions: (4) Cluster Analysis

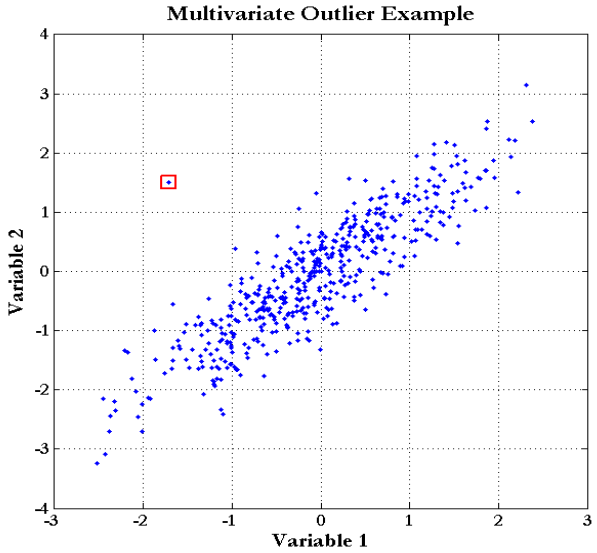
- Unsupervised learning (i.e., Class label is unknown)
- Group data to form new categories (i.e., clusters), e.g., cluster houses to find distribution patterns
- Principle: Maximizing intra-class similarity & minimizing interclass similarity
- Many methods and applications
  - Like market segmentation, community detection, improving search results, ...



Data Mining Functions: (5) Outlier Analysis

- Outlier analysis
  - Outlier: A data object that does not comply with the general behavior of the data
  - Noise or exception?—One person's garbage could be another person's treasure
  - Methods: by product of clustering or regression analysis, …
  - Useful in fraud detection, rare events analysis





Evaluation of Knowledge

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

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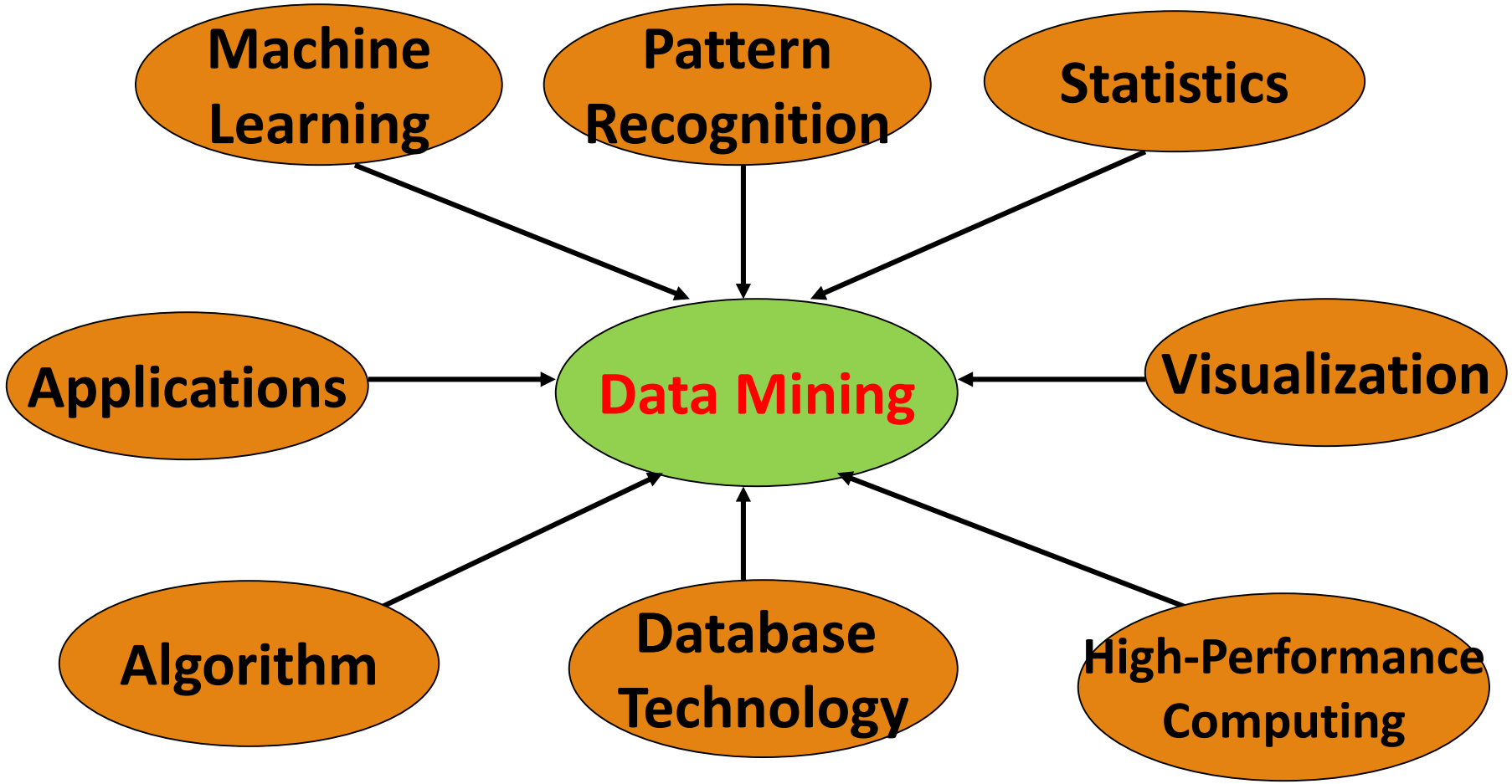
Data Mining: Confluence of Multiple Disciplines



Why Confluence of Multiple Disciplines?

- Tremendous amount of data
  - Algorithms must be scalable to handle big data
- High-dimensionality of data
  - May have tens of thousands of dimensions
- High complexity of data
  - Data streams and sensor data (temp, humidity, air pressure, gps, heart rate etc.)
  - Time-series data, temporal data, sequence data
  - Structure data, graphs, social and information networks
  - Spatial (3D), spatiotemporal (maps), multimedia, text and Web data
  - Software programs, scientific simulations
- New and sophisticated applications

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Applications of Data Mining

- Web page analysis: classification, clustering, ranking
- Recommender systems
- Basket data analysis to targeted marketing
- Biological and medical data analysis
- Data mining and text analysis
- Data mining and social and information network analysis
- Data mining and software engineering (e.g. bug mining, i.e. mining of software bugs in large programs)
- Built-in (invisible data mining) functions in Google, MS, Yahoo!, Linked, Facebook, …

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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 (e.g. cube)
  - 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)

- Efficiency and Scalability
  - Efficiency and scalability of data mining algorithms
  - Parallel and incremental mining methods (dealing with new input data)
- 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 (good use in society vs misuse)
  - Privacy-preserving data mining
  - Invisible data mining (web search engines, internet-based stores)

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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
- Mining can be performed in a variety of data
- Data mining functionalities: characterization, discrimination, association, classification, clustering, trend and outlier analysis, etc.
- Data mining technologies and applications
- Major issues in data mining

Recommended Reference Books

- Charu C. Aggarwal, Data Mining: The Textbook, Springer, 2015
- 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
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- Mohammed J. Zaki and Wagner Meira Jr., Data Mining and Analysis: Fundamental Concepts and Algorithms 2014