



# **Data Mining: Concepts and Techniques**

# Reference Material



## **1. Data Mining Concepts and Techniques,**

Authors: Jiawei Han, Micheline Kamber, Jian Pei; *Morgan Kauffman Publishing*

## **2. Introduction to Data Mining**

Authors: Pang-Ning Tan; Michael Steinbach; Anuj Karpatne; Vipin Kumar;  
*Pearson Publisher*

## **3. Data Mining: Practical Machine Learning Tools and Techniques with Java implementations**

Authors: Ian H. Witten and Eibe Frank; *Morgan Kauffman Publishing*

## **4. Data Preparation for Data Mining,**

Authors: Dorian Pyle; *Morgan Kauffman Publishing*

# Chapter 1. Introduction

---

- Why Data Mining? 
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining
- What Kind of Data Can Be Mined?
- What Kinds of Patterns Can Be Mined?
- What Technology Are Used?
- What Kind of Applications Are Targeted?
- Major Issues in Data Mining
- A Brief History of Data Mining and Data Mining Society
- Summary


# 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

# Chapter 1. Introduction

---

- Why Data Mining?
- What Is Data Mining? 
- A Multi-Dimensional View of Data Mining
- What Kind of Data Can Be Mined?
- What Kinds of Patterns Can Be Mined?
- What Technology Are Used?
- What Kind of Applications Are Targeted?
- Major Issues in Data Mining
- A Brief History of Data Mining and Data Mining Society
- Summary

# What Is Data Mining?

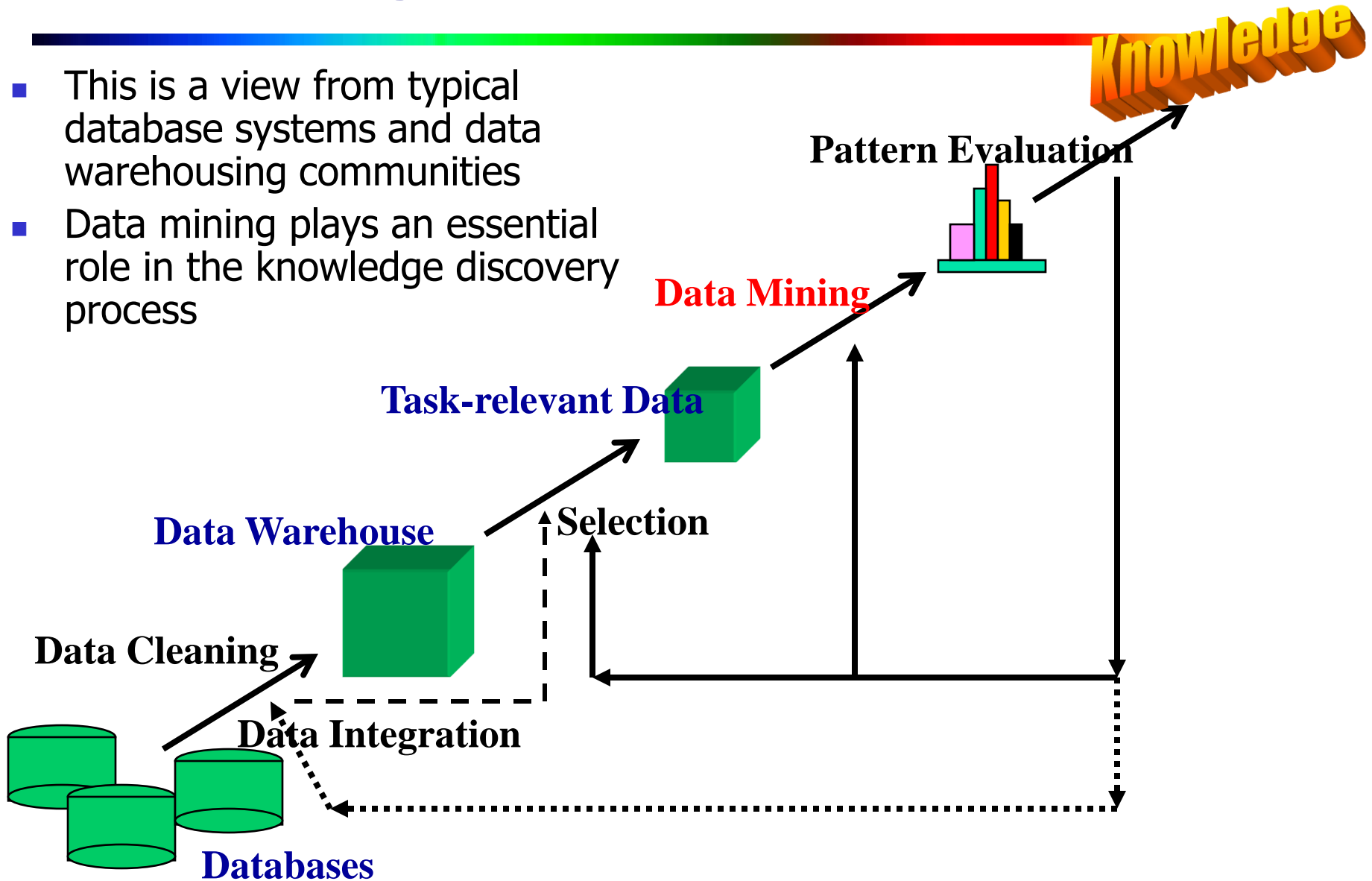


- Data mining (knowledge discovery from data)
  - Extraction of interesting (non-trivial, implicit, previously unknown and potentially useful) patterns or knowledge from huge amount of data
  - Data mining: a misnomer?
- Alternative names
  - Knowledge discovery (mining) in databases (KDD), knowledge 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

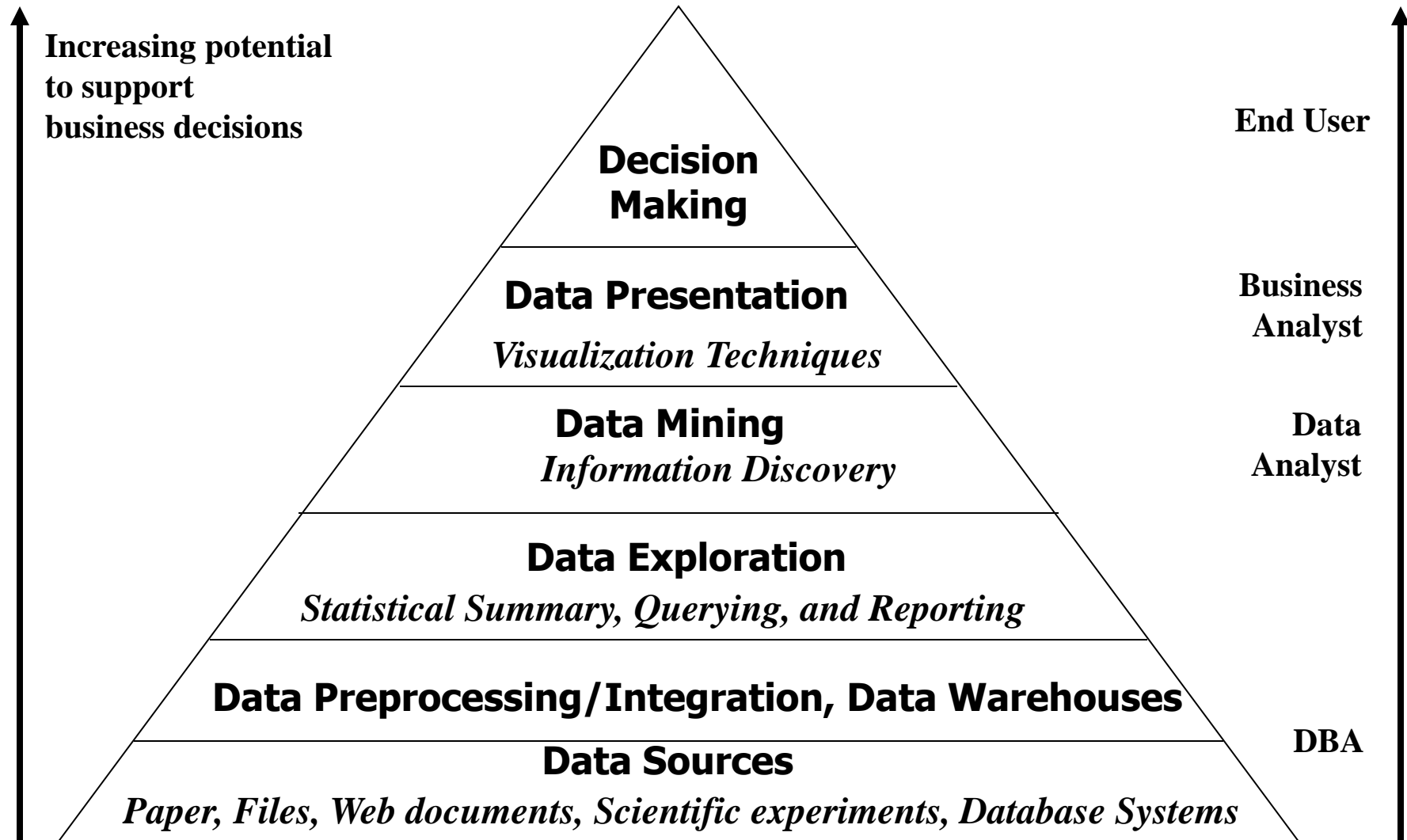


# Example: A Web Mining Framework

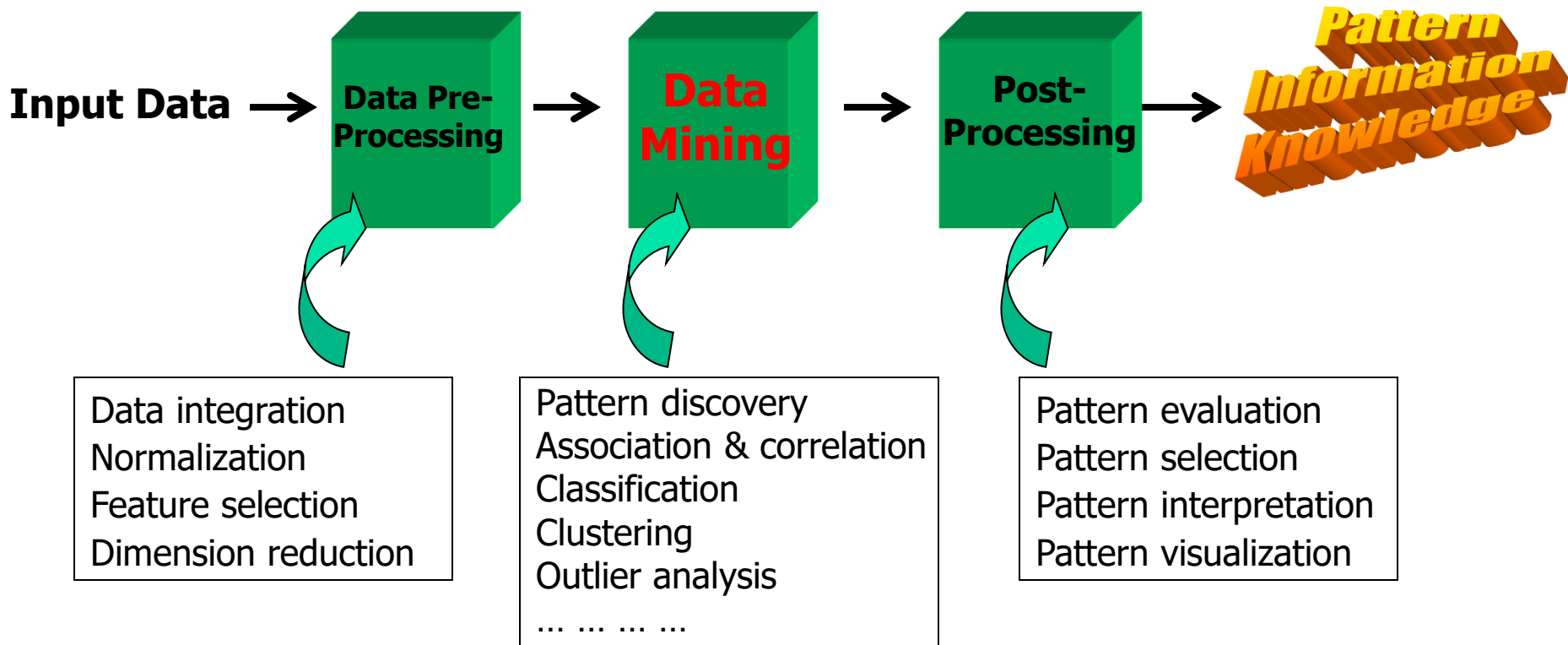
---

- 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 Mining in Business Intelligence




# KDD Process: A Typical View from ML and Statistics



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

# Chapter 1. Introduction

---

- Why Data Mining?
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining 
- What Kind of Data Can Be Mined?
- What Kinds of Patterns Can Be Mined?
- What Technology Are Used?
- What Kind of Applications Are Targeted?
- Major Issues in Data Mining
- A Brief History of Data Mining and Data Mining Society
- Summary

# 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.

# Chapter 1. Introduction

---

- Why Data Mining?
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining
- What Kind of Data Can Be Mined? 
- What Kinds of Patterns Can Be Mined?
- What Technology Are Used?
- What Kind of Applications Are Targeted?
- Major Issues in Data Mining
- A Brief History of Data Mining and Data Mining Society
- Summary

# 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

# Chapter 1. Introduction

---

- Why Data Mining?
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining
- What Kind of Data Can Be Mined?
- What Kinds of Patterns Can Be Mined? 
- What Technology Are Used?
- What Kind of Applications Are Targeted?
- Major Issues in Data Mining
- A Brief History of Data Mining and Data Mining Society
- Summary

# Data Mining Function: (1) Generalization

---

- Information integration and data warehouse construction
  - Data cleaning, transformation, integration, and multidimensional data model
- Data cube technology
  - Scalable methods for computing (i.e., materializing) 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 Function: (2) 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  $\rightarrow$  Beer [0.5%, 75%] (support, confidence)
  - Are strongly associated items also strongly correlated?
- How to mine such patterns and rules efficiently in large datasets?
- How to use such patterns for classification, clustering, and other applications?

# Data Mining Function: (3) 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: (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

# Data Mining Function: (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

# Time and Ordering: Sequential Pattern, Trend and Evolution Analysis

---

- Sequence, trend and evolution analysis
  - Trend, time-series, and deviation analysis: e.g., regression and value prediction
  - Sequential pattern mining
    - e.g., first buy digital camera, then buy large SD memory cards
  - Periodicity analysis
  - Motifs and biological sequence analysis
    - Approximate and consecutive motifs
  - Similarity-based analysis
- Mining data streams
  - Ordered, time-varying, potentially infinite, data streams

# 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, ...

# 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
  - ...

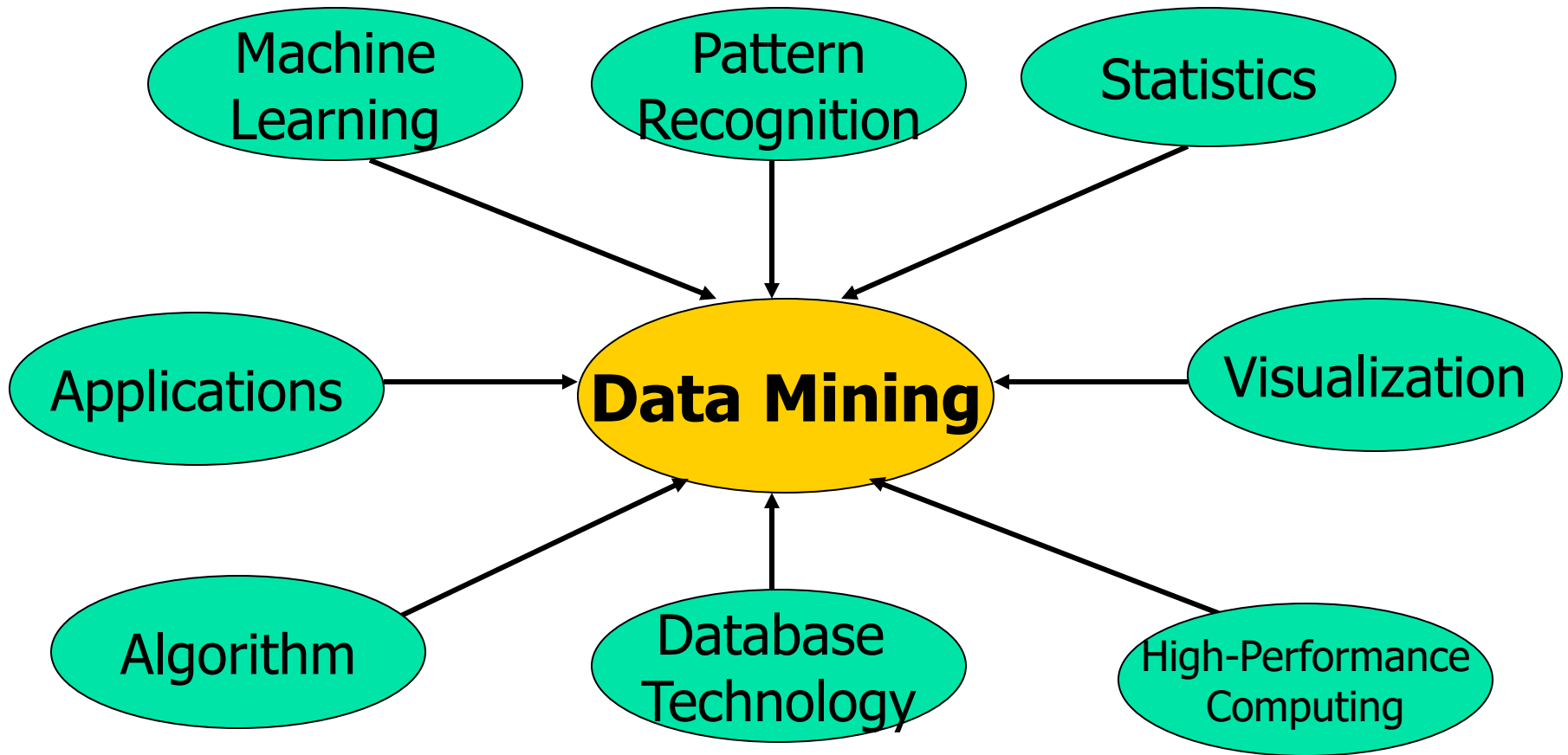
# Chapter 1. Introduction

---

- Why Data Mining?
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining
- What Kind of Data Can Be Mined?
- What Kinds of Patterns Can Be Mined?
- What Technology Are Used? 
- What Kind of Applications Are Targeted?
- Major Issues in Data Mining
- A Brief History of Data Mining and Data Mining Society
- Summary

# Data Mining: Confluence of Multiple Disciplines

---



# Why Confluence of Multiple Disciplines?

---

- Tremendous amount of data
  - Algorithms must be highly scalable to handle such as tera-bytes of data
- High-dimensionality of data
  - Micro-array may have tens of thousands of dimensions
- High complexity of data
  - Data streams and sensor data
  - Time-series data, temporal data, sequence data
  - Structure data, graphs, social networks and multi-linked data
  - Heterogeneous databases and legacy databases
  - Spatial, spatiotemporal, multimedia, text and Web data
  - Software programs, scientific simulations
- New and sophisticated applications

# Chapter 1. Introduction

---

- Why Data Mining?
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining
- What Kind of Data Can Be Mined?
- What Kinds of Patterns Can Be Mined?
- What Technology Are Used?
- What Kind of Applications Are Targeted? 
- Major Issues in Data Mining
- A Brief History of Data Mining and Data Mining Society
- Summary


# 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)
- From major dedicated data mining systems/tools (e.g., SAS, MS SQL-Server Analysis Manager, Oracle Data Mining Tools) to invisible data mining

# Chapter 1. Introduction

---

- Why Data Mining?
- What Is Data Mining?
- A Multi-Dimensional View of Data Mining
- What Kind of Data Can Be Mined?
- What Kinds of Patterns Can Be Mined?
- What Technology Are Used?
- What Kind of Applications Are Targeted?
- Major Issues in Data Mining 
- A Brief History of Data Mining and Data Mining Society
- Summary

# 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)

---

- 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

# 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.

# Summary

---

- Data mining: Discovering interesting patterns and knowledge from massive amount of data
- A natural evolution of database 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, outlier and trend analysis, etc.
- Data mining technologies and applications
- Major issues in data mining

# Recommended Reference Books

- **S. Chakrabarti. Mining the Web: Statistical Analysis of Hypertext 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**
- **U. Fayyad, G. Grinstein, and A. Wierse, Information Visualization in Data Mining and Knowledge Discovery, Morgan Kaufmann, 2001**
- **J. Han and M. Kamber. Data Mining: Concepts and Techniques. Morgan Kaufmann, 3<sup>rd</sup> ed., 2011**
- **D. J. Hand, H. Mannila, and P. Smyth, Principles of Data Mining, MIT Press, 2001**
- **T. Hastie, R. Tibshirani, and J. Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, 2<sup>nd</sup> ed., Springer-Verlag, 2009**
- **B. Liu, Web Data Mining, Springer 2006.**
- **T. M. Mitchell, Machine Learning, McGraw Hill, 1997**
- **G. Piatetsky-Shapiro and W. J. Frawley. Knowledge Discovery in Databases. AAAI/MIT Press, 1991**
- **P.-N. Tan, M. Steinbach and V. Kumar, Introduction to Data Mining, Wiley, 2005**
- **S. M. Weiss and N. Indurkha, 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, 2<sup>nd</sup> ed. 2005**