



CS 412 Intro. to Data Mining

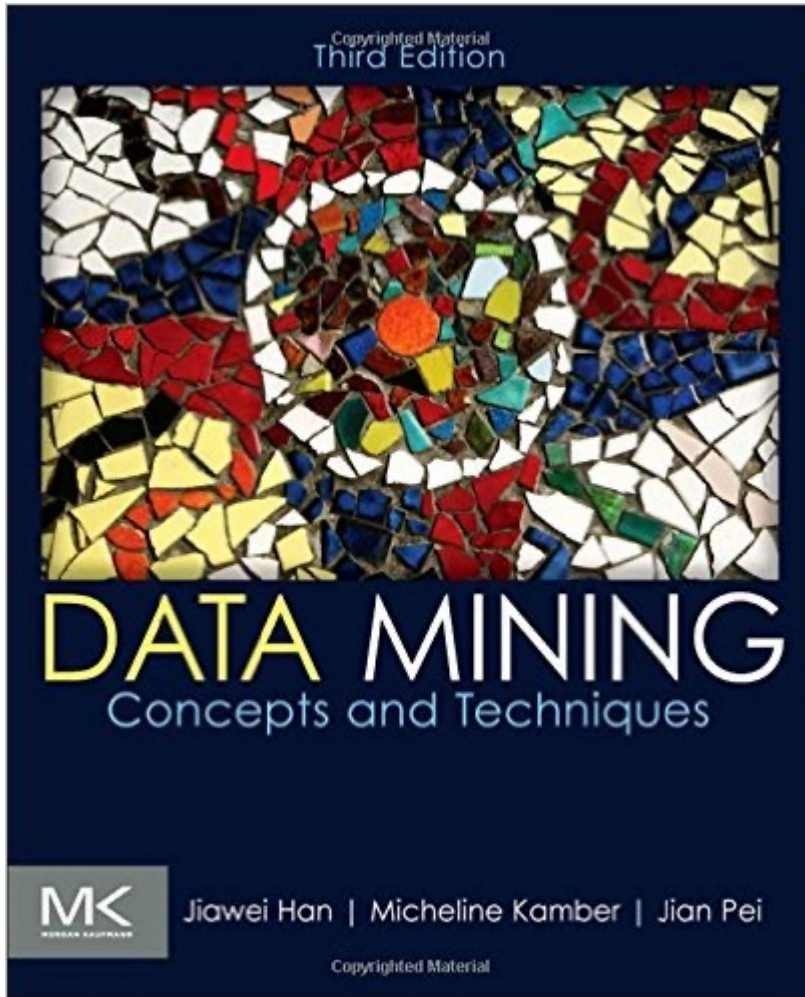
Chapter 1. Introduction

Jiawei Han, Computer Science, Univ. Illinois at Urbana-Champaign, 2017





CS 412. Course Page & Class Schedule



- ❑ Textbook
 - ❑ Jiawei Han, Micheline Kamber and Jian Pei, *Data Mining: Concepts and Techniques (3rd ed)*, Morgan Kaufmann, 2011
- ❑ Class Homepage:
<https://wiki.engr.illinois.edu/display/cs412>
- ❑ Bookmark on course schedule page
- ❑ **Class Schedule: 9:30-10:45 am Tues./Thurs.@1404 SC**
- ❑ Office hours: 10:45-11:30am Tues./Thurs. @2132 SC
- ❑ Lecture media: recorded; but class attendance is critical



Jiawei Han

CS 412. Course Work and Grading

- Assignments, Programming Assignments, and Exams
 - Written Assignments: 15% (three homework assignments expected)
 - Programming assignments: 20% (two programming assignments expected)
 - Midterm exam: 30%
 - Final exam: 35%


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
- ❑ A Brief History of Data Mining and Data Mining Society
- ❑ Summary

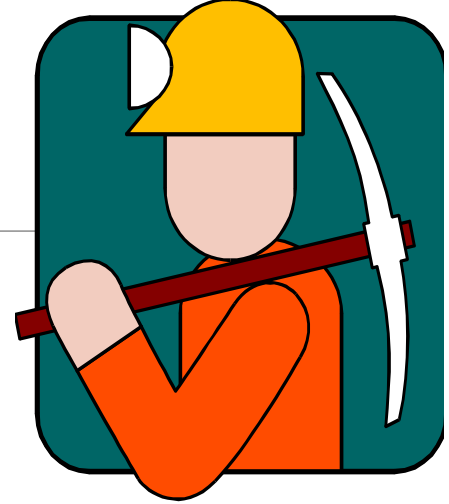
Why Data Mining?

- ❑ 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

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What Is Data Mining?

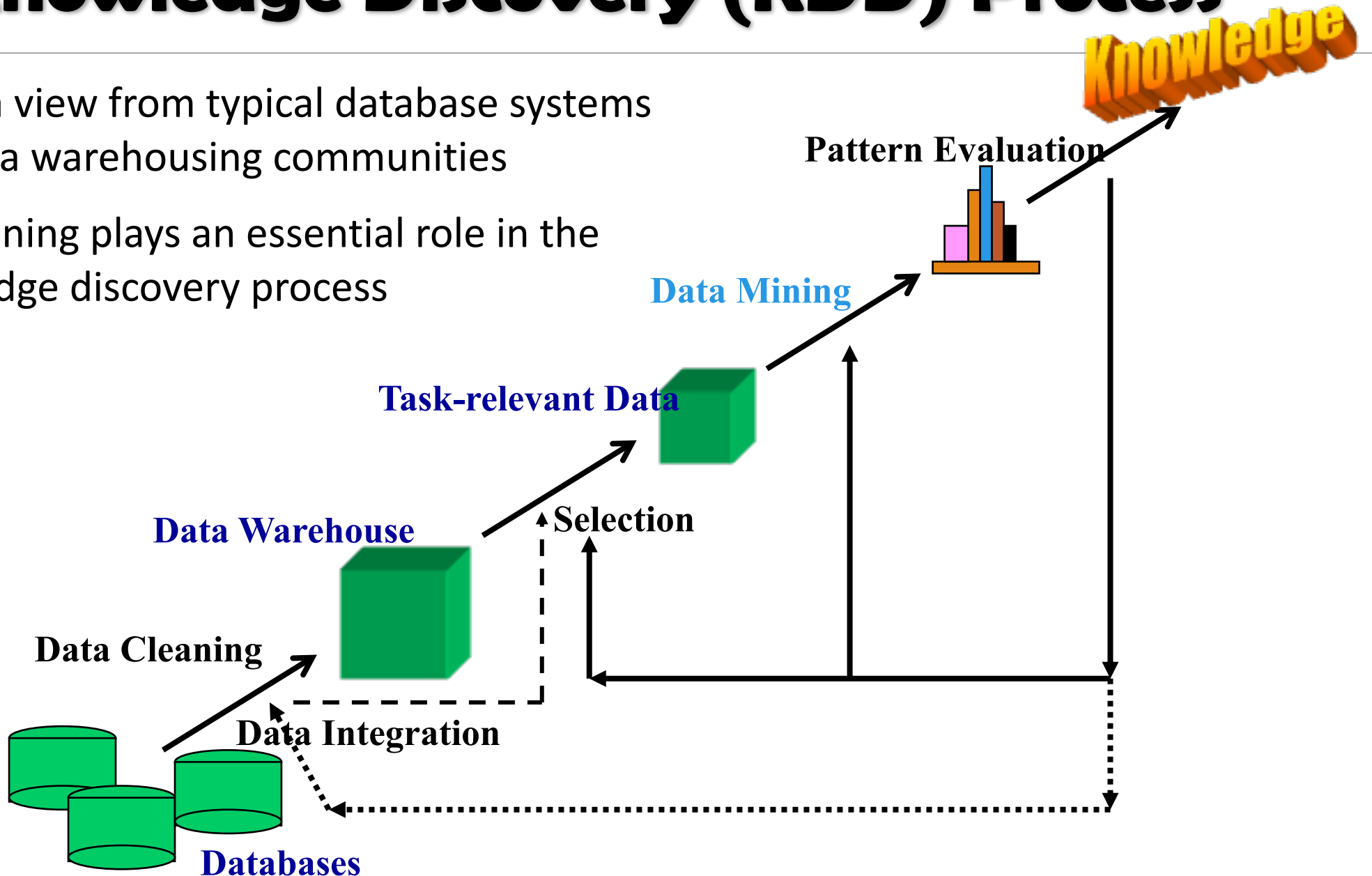


- ❑ Data mining (knowledge discovery from data)
 - ❑ Extraction of interesting (non-trivial, implicit, previously unknown and potentially useful) patterns or knowledge from huge amount of data
 - ❑ Data mining: a misnomer?
- ❑ Alternative names
 - ❑ Knowledge discovery (mining) in databases (KDD), knowledge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

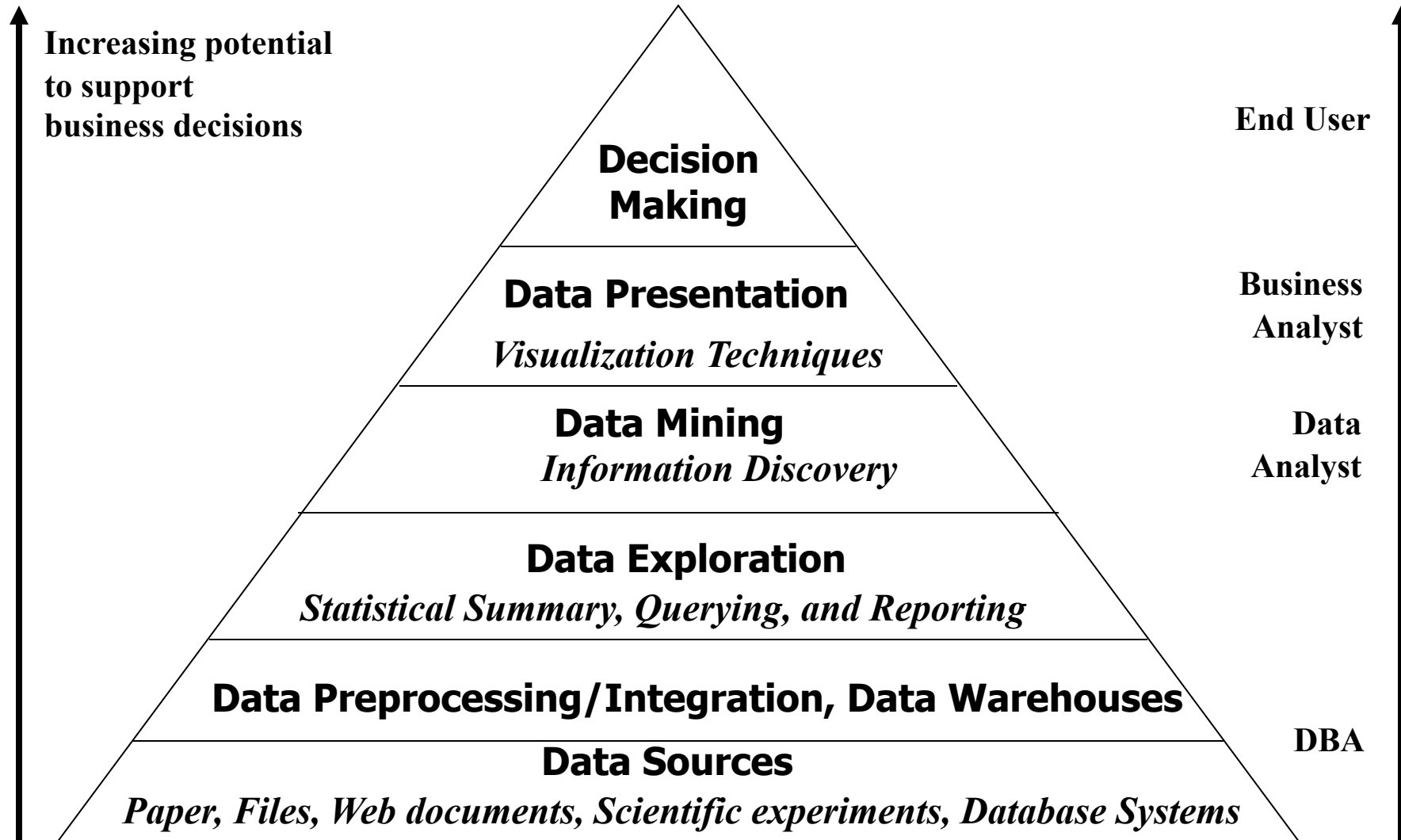
- This is a view from typical database systems and data warehousing communities
- Data mining plays an essential role in the knowledge discovery process



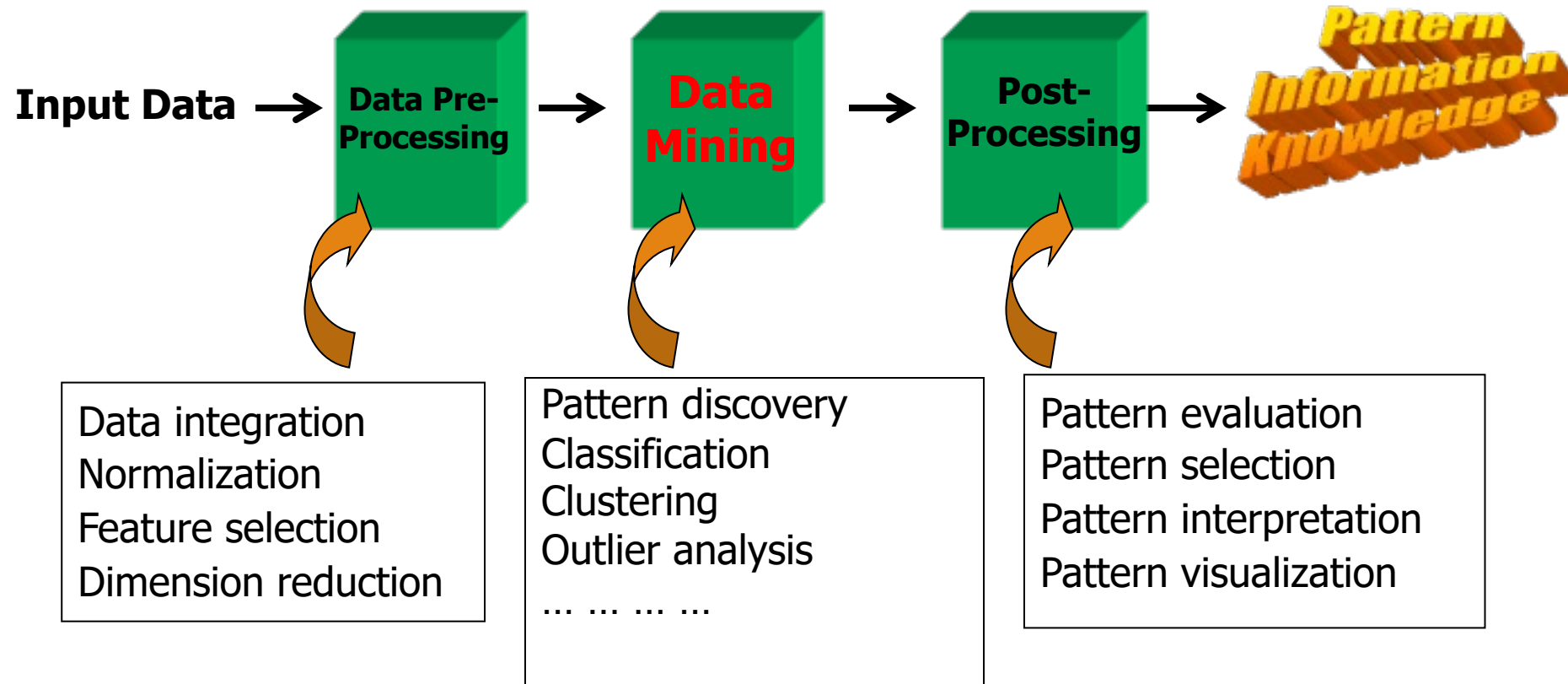
Example: A Web Mining Framework

- ❑ 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 View from ML and Statistics




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

Data Mining vs. Data Exploration

- ❑ Which view do you prefer?
 - ❑ KDD vs. ML/Stat. vs. Business Intelligence
 - ❑ Depending on the data, applications, and your focus

- ❑ Data Mining vs. Data Exploration
 - ❑ Business intelligence view
 - ❑ Warehouse, data cube, reporting but not much mining
 - ❑ Business objects vs. data mining tools
 - ❑ Supply chain example: mining vs. OLAP vs. presentation tools
 - ❑ Data presentation vs. data exploration

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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, 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.

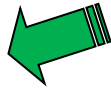
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Data Mining: On What Kinds of Data?

- ❑ Database-oriented data sets and applications
 - ❑ Relational database, data warehouse, transactional database
 - ❑ Object-relational databases, Heterogeneous databases and legacy databases
- ❑ 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 information networks
 - ❑ Spatial data and spatiotemporal data
 - ❑ Multimedia database
 - ❑ Text databases
 - ❑ The World-Wide Web

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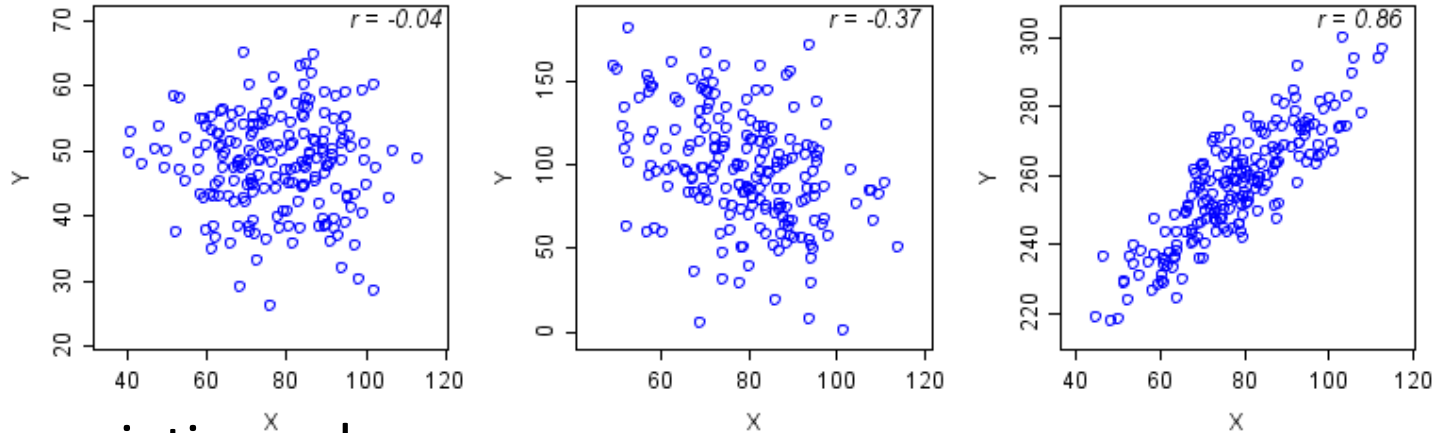
Data Mining Functions: (1) Generalization

- ❑ Information integration and data warehouse construction
 - ❑ Data cleaning, transformation, integration, and multidimensional data model
- ❑ Data cube technology
 - ❑ 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 Functions: (2) Pattern Discovery

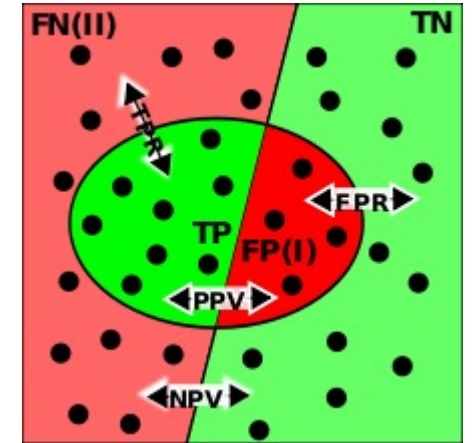
- Frequent patterns (or frequent itemsets)
 - What items are frequently purchased together in your Walmart?
- Association and Correlation Analysis



- A typical association rule
 - Diaper \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?

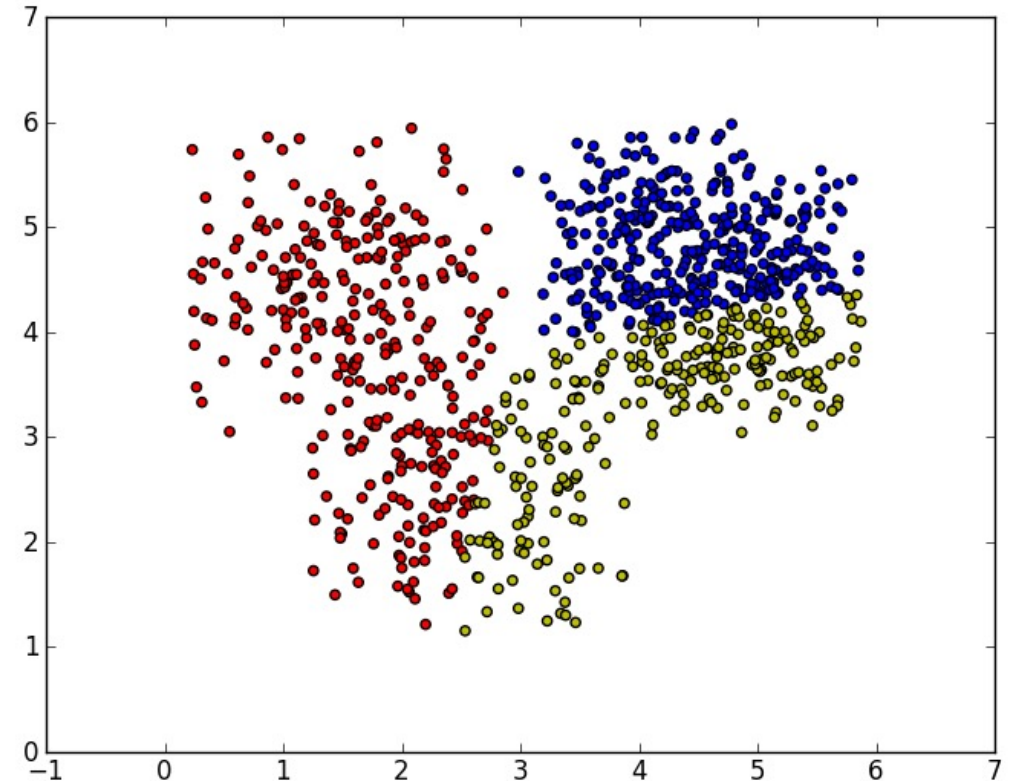
Data Mining Functions: (3) Classification

- ❑ 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, ...



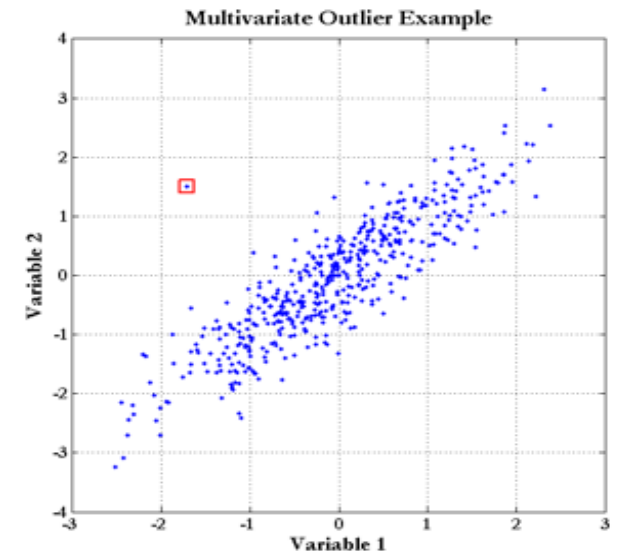
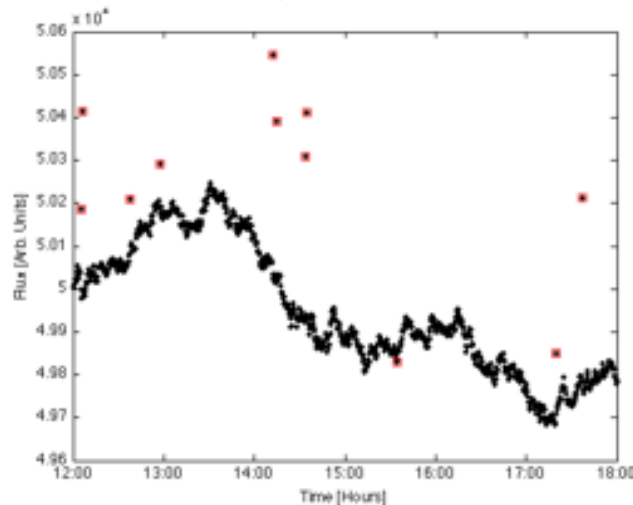
Data Mining Functions: (4) Cluster Analysis

- ❑ 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



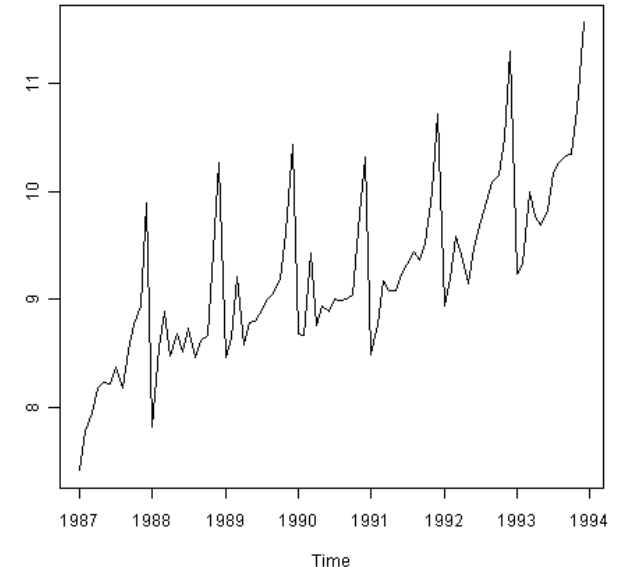
Data Mining Functions: (5) Outlier Analysis

- ❑ 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



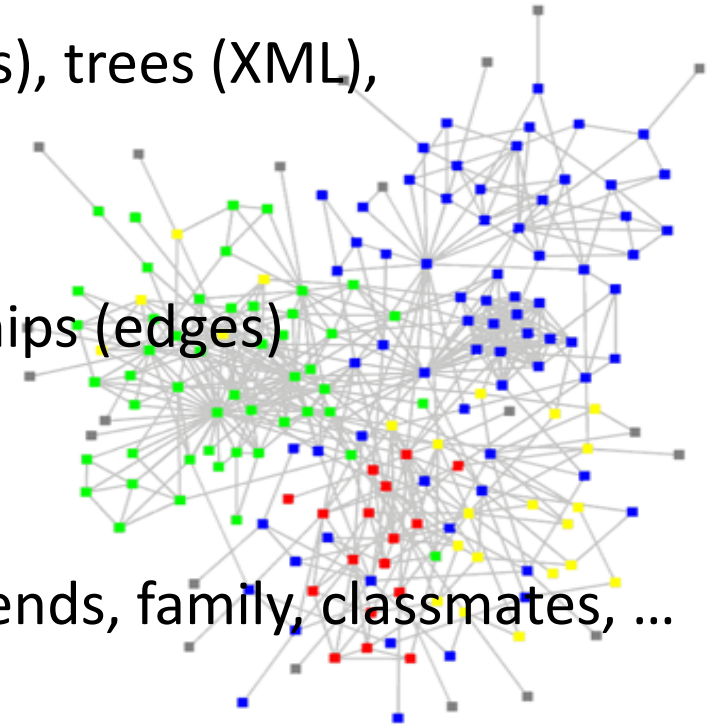
Data Mining Functions: (6) Time and Ordering: Sequential Pattern, Trend and Evolution Analysis

- Sequence, trend and evolution analysis
 - Trend, time-series, and deviation analysis
 - e.g., regression and value prediction
 - Sequential pattern mining
 - e.g., buy digital camera, then buy large 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



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, ...

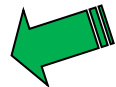


Evaluation of Knowledge

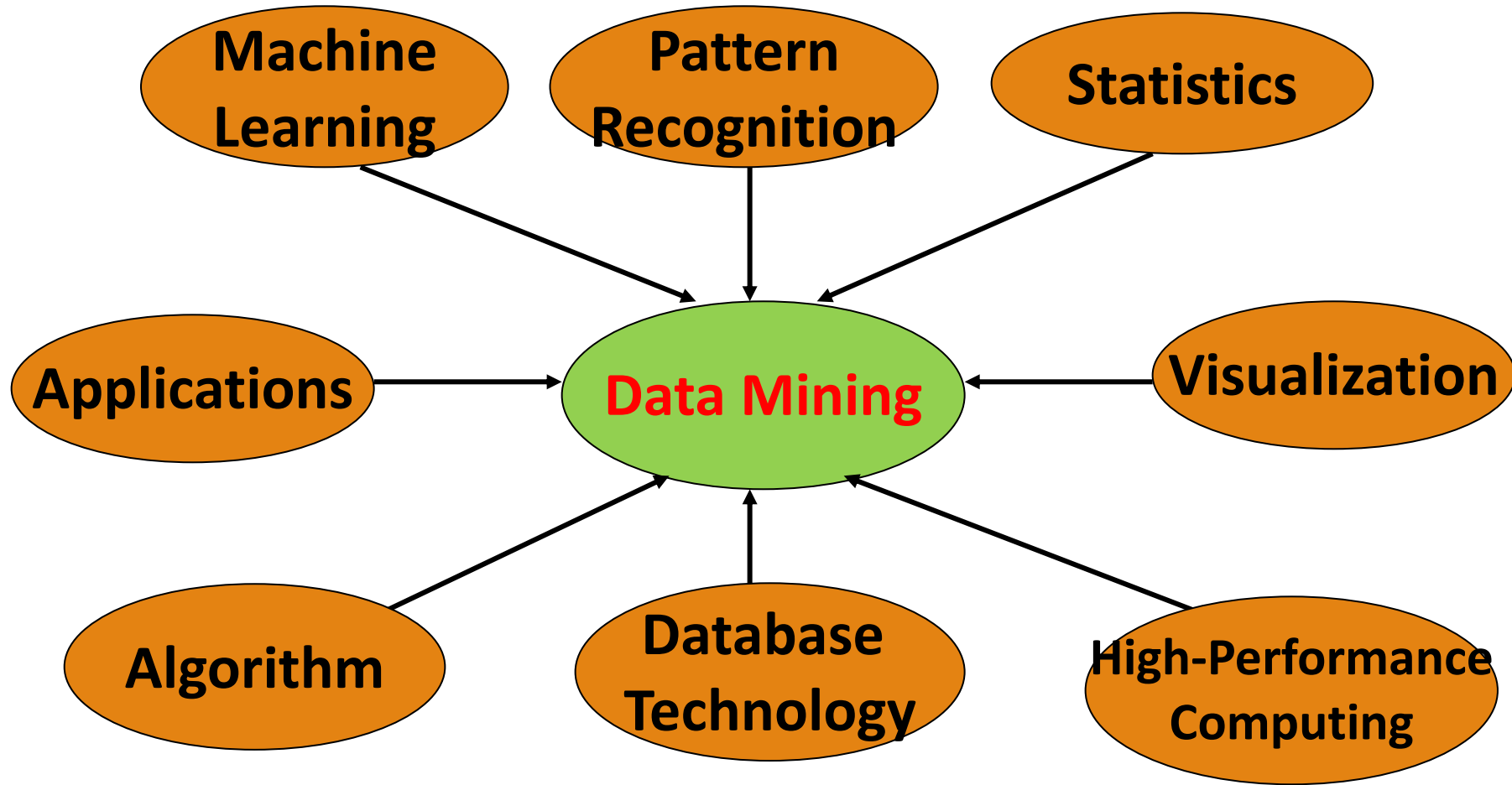
- ❑ Are all mined knowledge interesting?
 - ❑ One can mine tremendous amount of “patterns”
 - ❑ Some may fit only certain dimension space (time, location, ...)
 - ❑ Some may not be representative, may be transient, ...
- ❑ Evaluation of mined knowledge → directly mine only interesting knowledge?
 - ❑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



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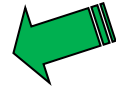
Data Mining: Confluence of Multiple Disciplines



Why Confluence of Multiple Disciplines?

- ❑ Tremendous amount of data
 - ❑ Algorithms must be scalable to handle big 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 and information networks
 - ❑ Spatial, spatiotemporal, multimedia, text and Web data
 - ❑ Software programs, scientific simulations
- ❑ New and sophisticated applications

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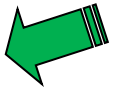
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Applications of Data Mining

- ❑ 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
- ❑ Built-in (invisible data mining) functions in Google, MS, Yahoo!, Linked, Facebook, ...
- ❑ Major dedicated data mining systems/tools
 - ❑ SAS, MS SQL-Server Analysis Manager, Oracle Data Mining Tools)



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Major Issues in Data Mining (1)

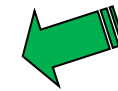
- ❑ Mining Methodology
 - ❑ Mining various and new kinds of knowledge
 - ❑ Mining knowledge in multi-dimensional space
 - ❑ Data mining: An interdisciplinary effort
 - ❑ Boosting the power of discovery in a networked environment
 - ❑ Handling noise, uncertainty, and incompleteness of data
 - ❑ Pattern 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)

- ❑ 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

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A Brief History of Data Mining Society

- ❑ 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)

Conferences and Journals on Data Mining

❑ KDD Conferences

- ❑ ACM SIGKDD Int. Conf. on Knowledge Discovery in Databases and Data Mining (**KDD**)
- ❑ SIAM Data Mining Conf. (**SDM**)
- ❑ (IEEE) Int. Conf. on Data Mining (**ICDM**)
- ❑ European Conf. on Machine Learning and Principles and practices of Knowledge Discovery and Data Mining (**ECML-PKDD**)
- ❑ Pacific-Asia Conf. on Knowledge Discovery and Data Mining (**PAKDD**)
- ❑ Int. Conf. on Web Search and Data Mining (**WSDM**)

■ Other related conferences

- DB conferences: ACM SIGMOD, VLDB, ICDE, EDBT, ICDT, ...
- Web and IR conferences: WWW, SIGIR, WSDM
- ML conferences: ICML, NIPS
- PR conferences: CVPR,

■ Journals

- Data Mining and Knowledge Discovery (DAMI or DMKD)
- IEEE Trans. On Knowledge and Data Eng. (TKDE)
- KDD Explorations
- ACM Trans. on KDD

Where to Find References? DBLP, CiteSeer, Google

❑ Data mining and KDD (SIGKDD)

- ❑ Conferences: ACM-SIGKDD, IEEE-ICDM, SIAM-DM, PKDD, PAKDD, etc.
- ❑ Journal: Data Mining and Knowledge Discovery, KDD Explorations, ACM TKDD

❑ Database systems (SIGMOD)

- ❑ 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,

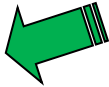
❑ Statistics

- ❑ 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.

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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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- ❑ 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

