



DSC603

DATA MINING

INTRODUCTION

COURSE OBJECTIVES

- Introduces main concepts and tasks of data mining
 - Data manipulation
 - Cleaning techniques,
 - Representation of real-world information as data types.
- Explores approaches to mine knowledge from these data representations.

COURSE OUTLINE

- 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
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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

BRIEF EVOLUTION OF SCIENCES



- Before 1600, **empirical science**
- 1600-1950s, **theoretical science**
 - Each discipline has grown a *theoretical* component. Theoretical models often motivate experiments and generalize our understanding.
- 1950s-1990s, **computational science**
 - Over the last 50 years, most disciplines have grown a third, *computational* branch (e.g. empirical, theoretical, and computational ecology, or physics, or linguistics.)
 - Computational Science traditionally meant simulation. It grew out of our inability to find closed-form solutions for complex mathematical models.

BRIEF EVOLUTION OF SCIENCES

- 1990-now, **data science**
 - The flood of data from new scientific instruments and simulations
 - The ability to economically store and manage petabytes of data online
 - The Internet and computing Grid that makes all these archives universally accessible
 - Scientific information management, acquisition, organization, query, and visualization tasks scale almost linearly with data volumes.
 - **Data mining** is **another** major new challenge!

EVOLUTION OF DATABASE TECHNOLOGY



- 1960s:
 - Data collection, database creation, IMS (Integrated Management System) and network DBMS
- 1970s:
 - Relational data model, relational DBMS implementation
- 1980s:
 - RDBMS, advanced data models (extended-relational, OO, deductive, etc.)
 - Application-oriented DBMS (spatial, scientific, engineering, etc.)
- 1990s:
 - Data mining, data warehousing, multimedia databases, and Web databases
- 2000s
 - Stream data management and mining
 - Data mining and its applications
 - Web technology (XML, data integration) and global information systems

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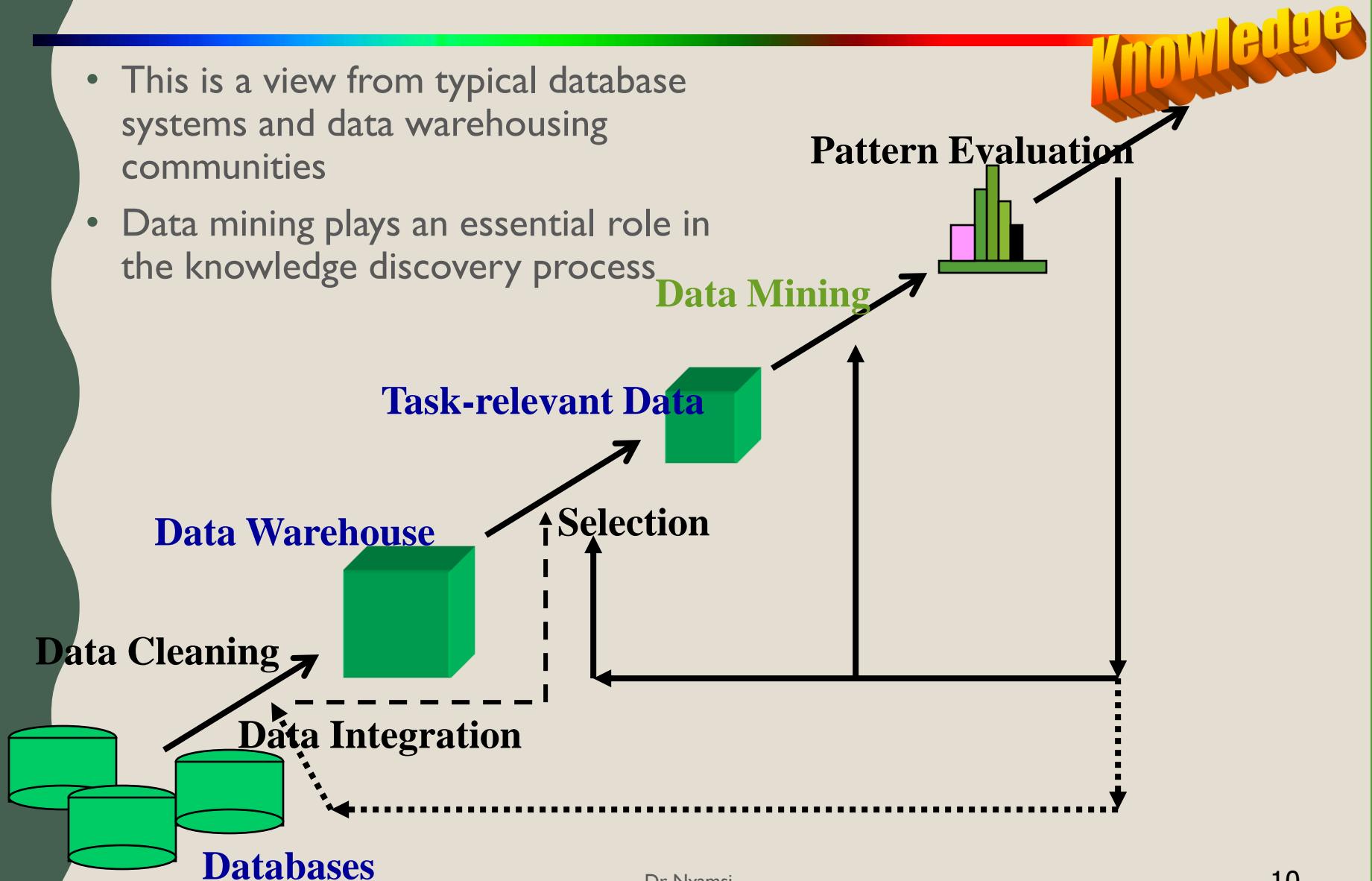
WHAT IS DATA MINING?



- 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
- 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

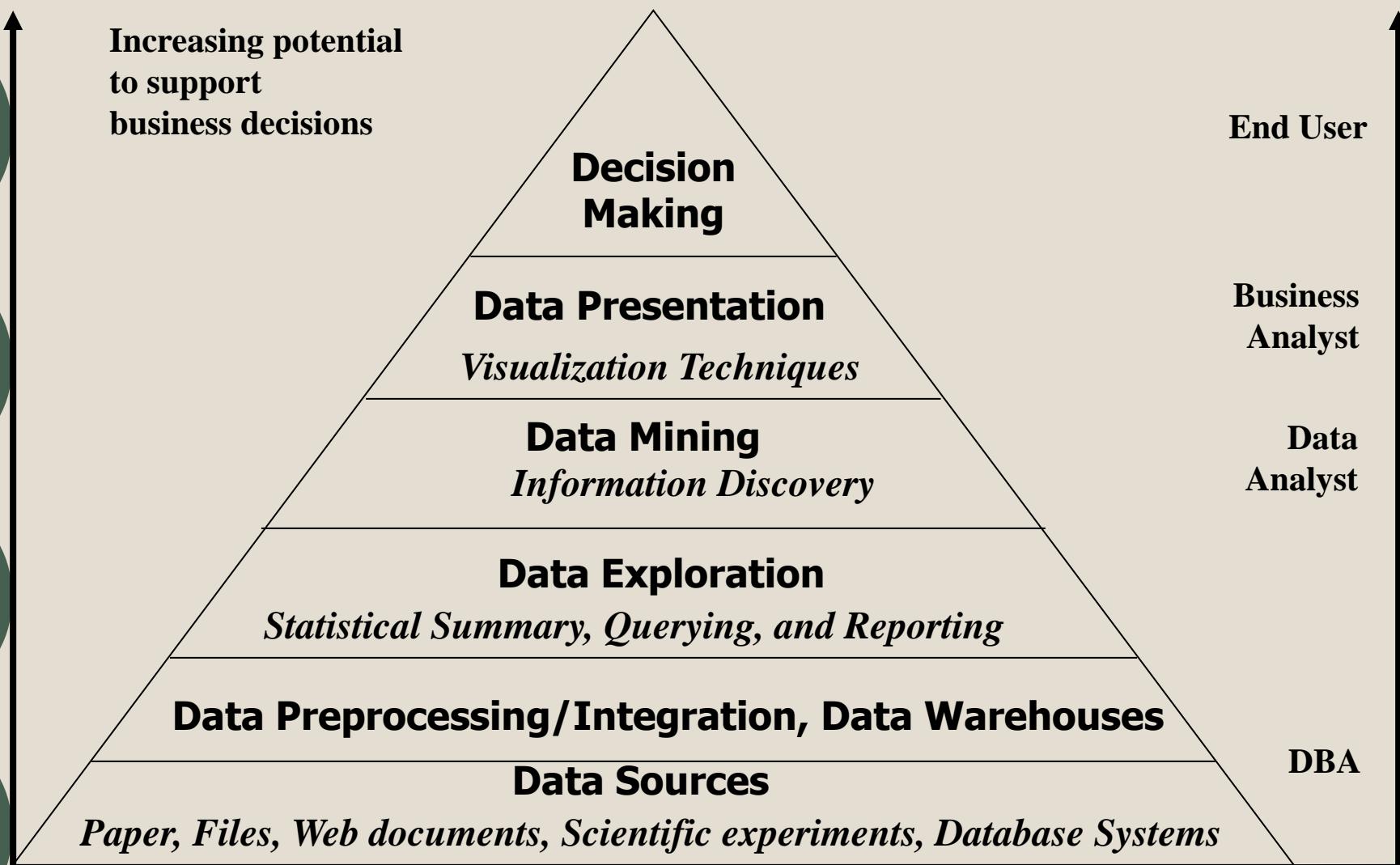
- This is a view from typical database systems and data warehousing communities
- Data mining plays an essential role in the knowledge discovery process



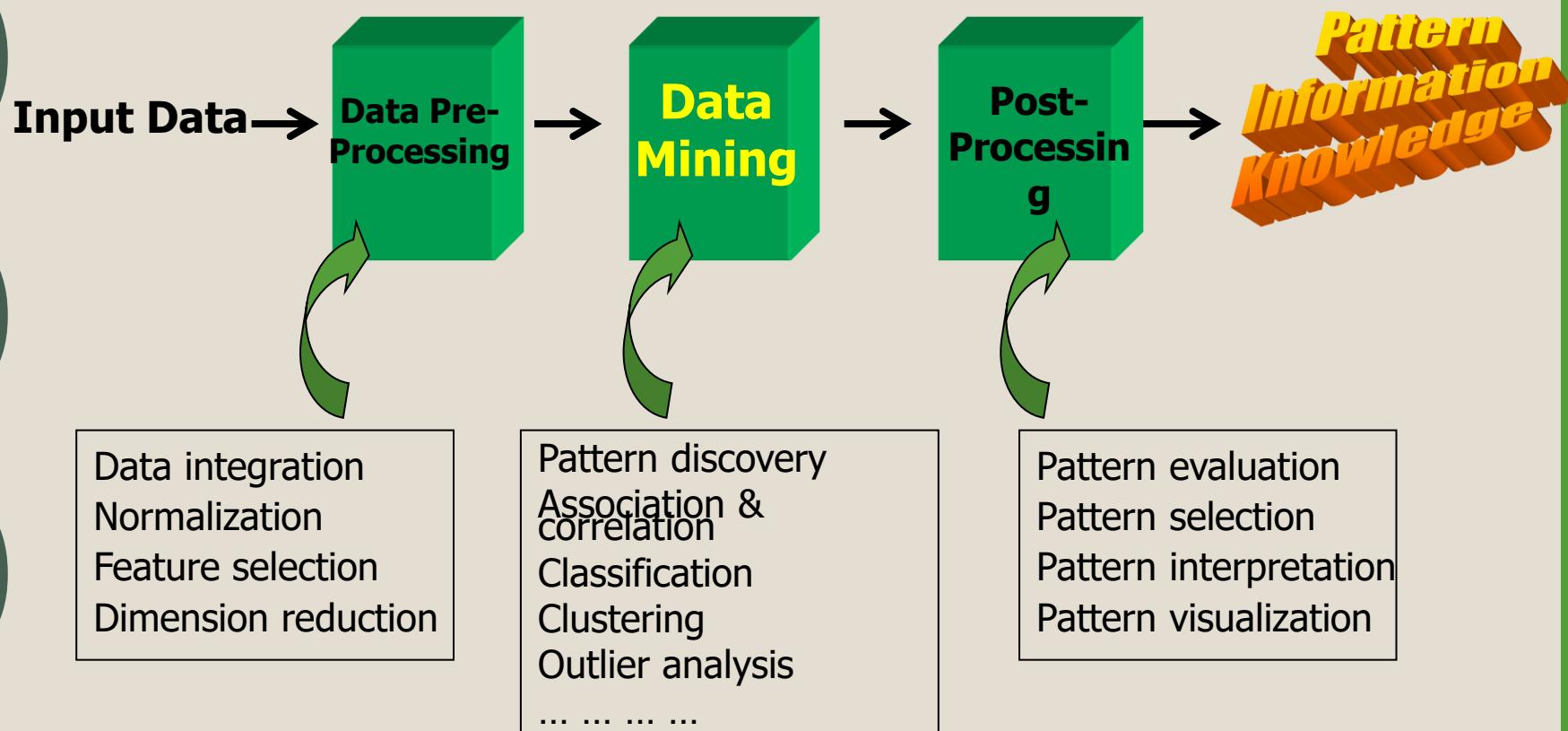
EXAMPLE: A WEB MINING FRAMEWORK

- 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

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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 (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

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: 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

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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 → 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

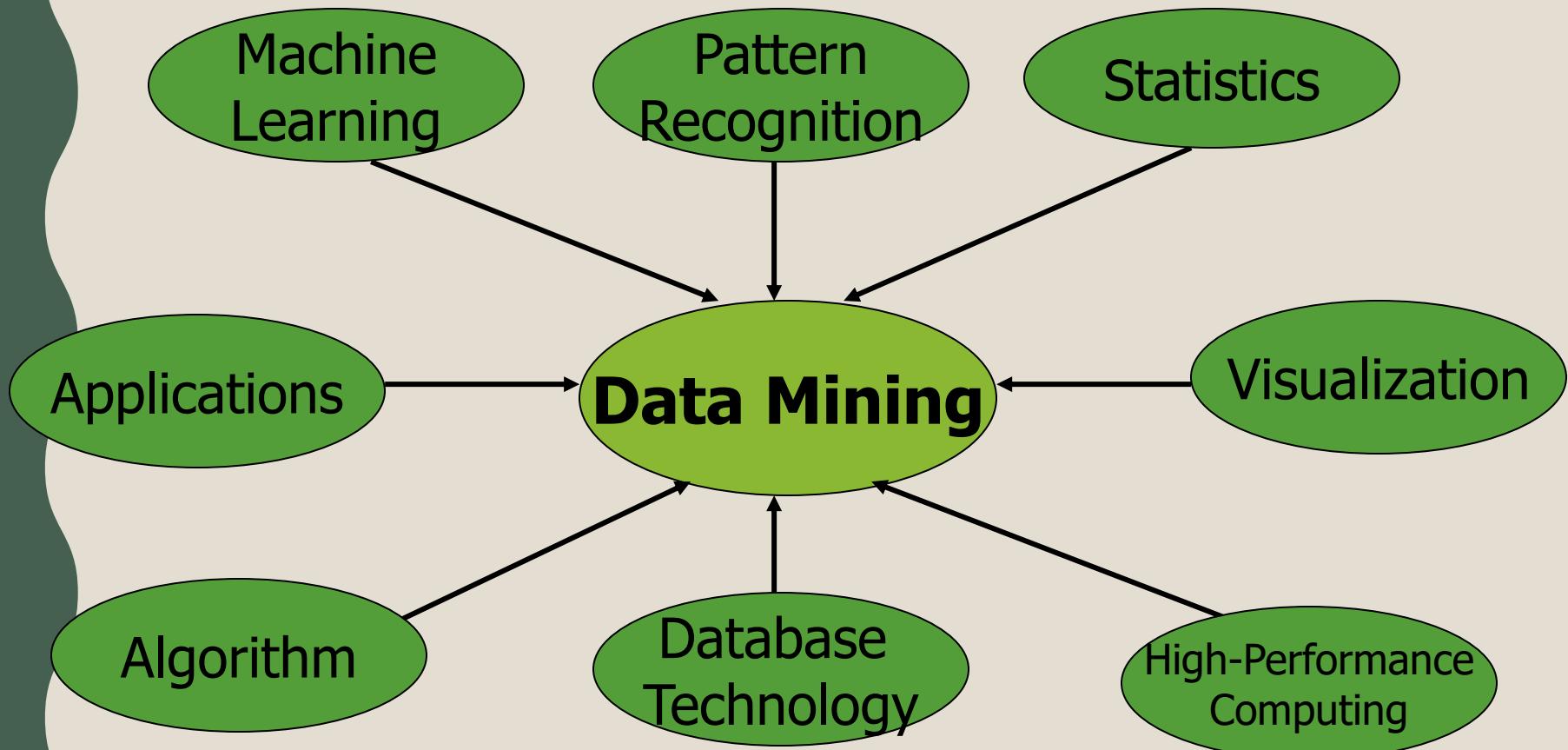


- Are all mined knowledge interesting?
 - One can mine tremendous amount of “patterns” and knowledge
 - Some may fit only certain dimension space (time, location, ...)
 - Some may not be representative, may be transient, ...
- Evaluation of mined knowledge → directly mine only interesting knowledge?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

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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

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

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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), etc.
- ACM Transactions on KDD starting in 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: 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.

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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
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- I. H. Witten and E. Frank, Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations, Morgan Kaufmann, 2nd ed. 2005