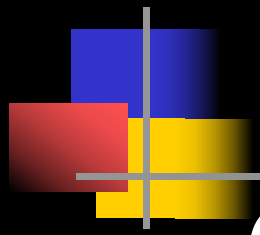


Data Mining: Concepts and Techniques

— Slides for Textbook —

— Chapter 1 —

©Jiawei Han and Micheline Kamber

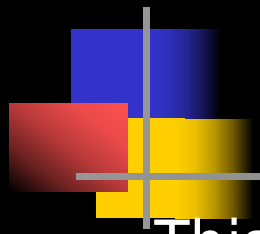
Intelligent Database Systems Research Lab

School of Computing Science

Simon Fraser University, Canada

http://www.cs.sfu.ca

Acknowledgements

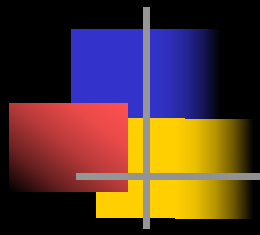


- This work on this set of slides started with my (Han's) tutorial for UCLA Extension course in February 1998
- Dr. Hongjun Lu from Hong Kong Univ. of Science and Technology taught jointly with me a Data Mining Summer Course in Shanghai, China in July 1998. He has contributed many excellent slides to it
- Some graduate students have contributed many new slides in the following years. Notable contributors include Eugene Belchev, Jian Pei, and Osmar R. Zaiane (now teaching in Univ. of Alberta).

CMPT-459-00.3 Course Schedule

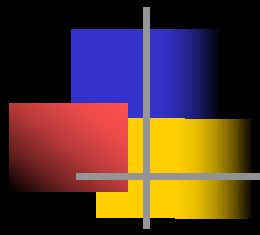
- Chapter 1. Introduction {W1:L2, L3}
- Chapter 2. Data warehousing and OLAP technology for data mining {W2:L1-3, W3:L1-2}
  - Homework # 1 distribution (SQLServer7.0+ DBMiner2.0)
- Chapter 3. Data preprocessing {W3:L3, W4: L1-L2}
- Chapter 4. Data mining primitives, languages and system architectures {W4: L3, W5: L1}
  - Homework #1 due, homework #2 distribution
- Chapter 5. Concept description: Characterization and comparison {W5: L2, L3, W6: L2}
  - W6:L1 Thanksgiving Day
- Chapter 6. Mining association rules in large databases {W6: L3, W7: L1-3, W8: L2}
  - Midterm {W8: L2}
- Chapter 7. Classification and prediction {W8:L3, W9: L1-L3}
- Chapter 8. Clustering analysis {W10: L1-L3}
  - W10: L3 Homework #2 due
- Chapter 9. Mining complex types of data {W11: L2-L3, W12:L1-L3}
  - W11:L1 Remembrance Day, W12:L3 Course project due
- Chapter 10. Data mining applications and trends in data mining {W13: L1-L3}

Where to Find the Set of Slides?



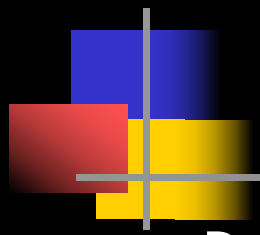
- Tutorial sections (MS PowerPoint files):
  - http://www.cs.sfu.ca/~han/dmbook
- Other conference presentation slides (.ppt):
  - http://db.cs.sfu.ca/ or http://www.cs.sfu.ca/~han
- Research papers, DBMiner system, and other related information:
  - http://db.cs.sfu.ca/ or http://www.cs.sfu.ca/~han

Chapter 1. Introduction



- Motivation: Why data mining?
- What is data mining?
- Data Mining: On what kind of data?
- Data mining functionality
- Are all the patterns interesting?
- Classification of data mining systems
- Major issues in data mining

Motivation: "Necessity is the Mother of Invention"



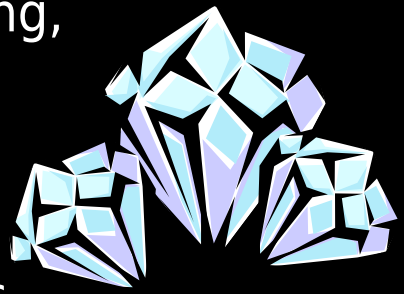
- Data explosion problem
  - Automated data collection tools and mature database technology lead to tremendous amounts of data stored in databases, data warehouses and other information repositories
- We are drowning in data, but starving for knowledge!
- Solution: Data warehousing and data mining
  - Data warehousing and on-line analytical processing
  - Extraction of interesting knowledge (rules, regularities, patterns, constraints) from data in large databases

Evolution of Database Technology
(See Fig. 1.1)

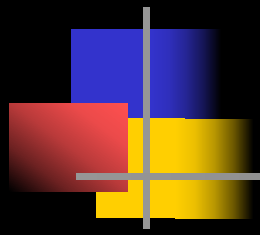
- 1960s:
  - Data collection, database creation, IMS and network DBMS
- 1970s:
  - Relational data model, relational DBMS implementation
- 1980s:
  - RDBMS, advanced data models (extended-relational, OO, deductive, etc.) and application-oriented DBMS (spatial, scientific, engineering, etc.)
- 1990s—2000s:
  - Data mining and data warehousing, multimedia databases, and Web databases

What Is Data Mining?

- Data mining (knowledge discovery in databases):
  - Extraction of interesting (non-trivial, implicit, previously unknown and potentially useful) information or patterns from data in large databases
- Alternative names and their "inside stories":
  - Data mining: a misnomer?
  - Knowledge discovery(mining) in databases (KDD), knowledge extraction, data/pattern analysis, data archeology, data dredging, information harvesting, business intelligence, etc.
- What is not data mining?
  - (Deductive) query processing.
  - Expert systems or small ML/statistical programs

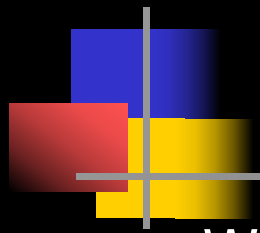


Why Data Mining? — Potential Applications



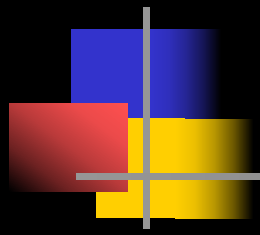
- Database analysis and decision support
  - Market analysis and management
    - target marketing, customer relation management, market basket analysis, cross selling, market segmentation
  - Risk analysis and management
    - Forecasting, customer retention, improved underwriting, quality control, competitive analysis
  - Fraud detection and management
- Other Applications
  - Text mining (news group, email, documents) and Web analysis.
  - Intelligent query answering

Market Analysis and Management (1)



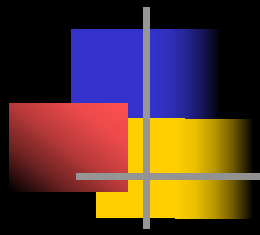
- Where are the data sources for analysis?
  - Credit card transactions, loyalty cards, discount coupons, customer complaint calls, plus (public) lifestyle studies
- Target marketing
  - Find clusters of “model” customers who share the same characteristics: interest, income level, spending habits, etc.
- Determine customer purchasing patterns over time
  - Conversion of single to a joint bank account: marriage, etc.
- Cross-market analysis
  - Associations/co-relations between product sales
  - Prediction based on the association information

Market Analysis and Management (2)



- Customer profiling
  - data mining can tell you what types of customers buy what products (clustering or classification)
- Identifying customer requirements
  - identifying the best products for different customers
  - use prediction to find what factors will attract new customers
- Provides summary information
  - various multidimensional summary reports
  - statistical summary information (data central tendency and variation)

Corporate Analysis and Risk Management



- Finance planning and asset evaluation
  - cash flow analysis and prediction
  - contingent claim analysis to evaluate assets
  - cross-sectional and time series analysis (financial-ratio, trend analysis, etc.)
- Resource planning:
  - summarize and compare the resources and spending
- Competition:
  - monitor competitors and market directions
  - group customers into classes and a class-based pricing procedure
  - set pricing strategy in a highly competitive market

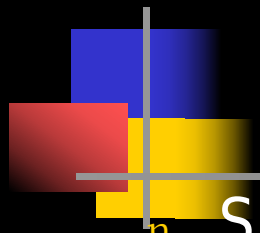
Fraud Detection and Management (1)

- Applications
  - widely used in health care, retail, credit card services, telecommunications (phone card fraud), etc.
- Approach
  - use historical data to build models of fraudulent behavior and use data mining to help identify similar instances
- Examples
  - auto insurance: detect a group of people who stage accidents to collect on insurance
  - money laundering: detect suspicious money transactions (US Treasury's Financial Crimes Enforcement Network)
  - medical insurance: detect professional patients and ring of doctors and ring of references

Fraud Detection and Management (2)

- Detecting inappropriate medical treatment
  - Australian Health Insurance Commission identifies that in many cases blanket screening tests were requested (save Australian $1m/yr).
- Detecting telephone fraud
  - Telephone call model: destination of the call, duration, time of day or week. Analyze patterns that deviate from an expected norm.
  - British Telecom identified discrete groups of callers with frequent intra-group calls, especially mobile phones, and broke a multimillion dollar fraud.
- Retail
  - Analysts estimate that 38% of retail shrink is due to dishonest employees.

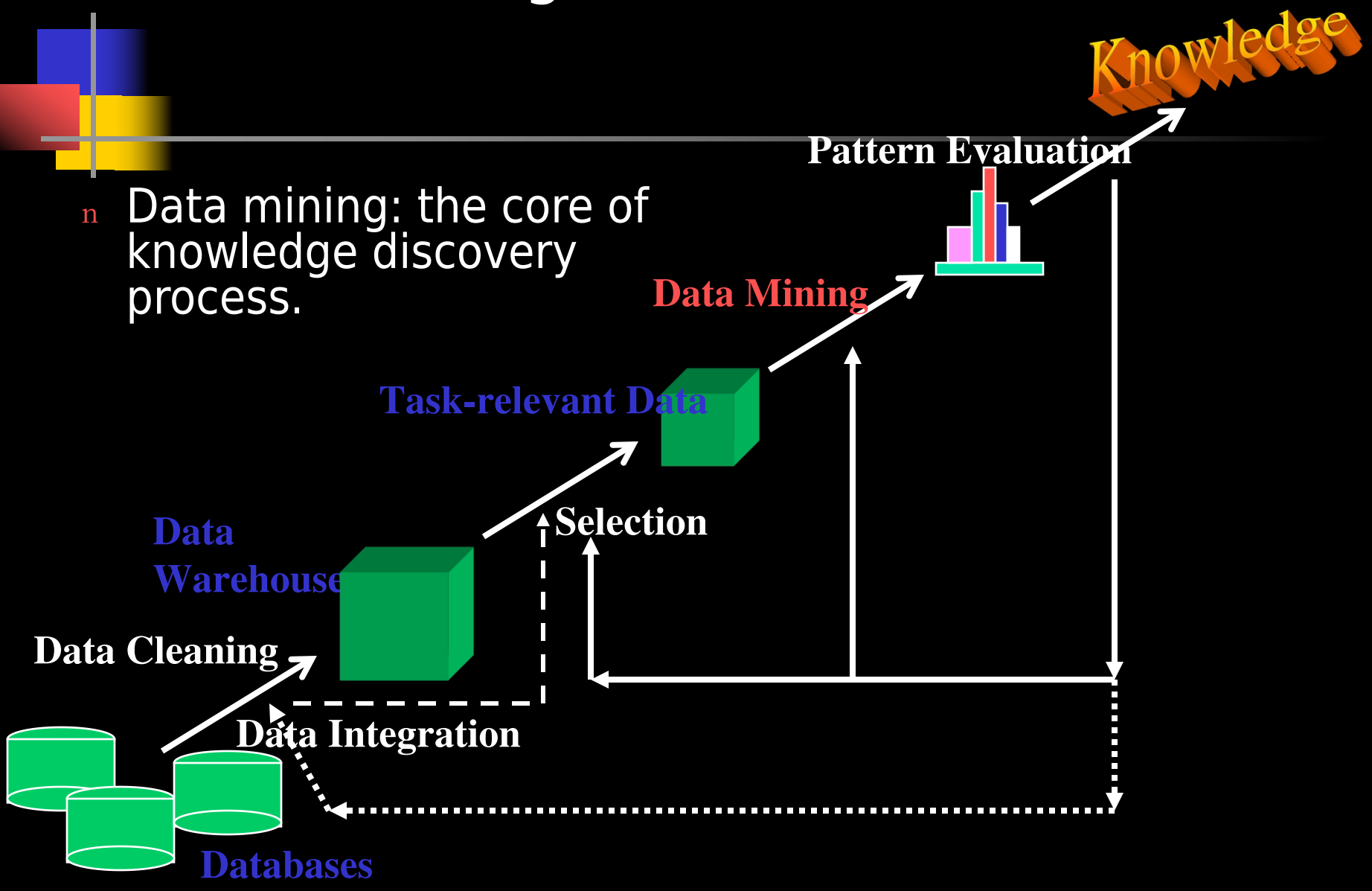
Other Applications



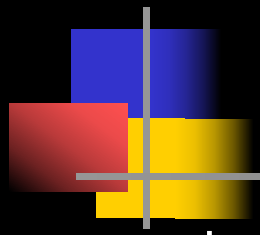
- Sports
  - IBM Advanced Scout analyzed NBA game statistics (shots blocked, assists, and fouls) to gain competitive advantage for New York Knicks and Miami Heat
- Astronomy
  - JPL and the Palomar Observatory discovered 22 quasars with the help of data mining
- Internet Web Surf-Aid
  - IBM Surf-Aid applies data mining algorithms to Web access logs for market-related pages to discover customer preference and behavior pages, analyzing effectiveness of Web marketing, improving Web site organization, etc.

Data Mining: A KDD Process

- Data mining: the core of knowledge discovery process.

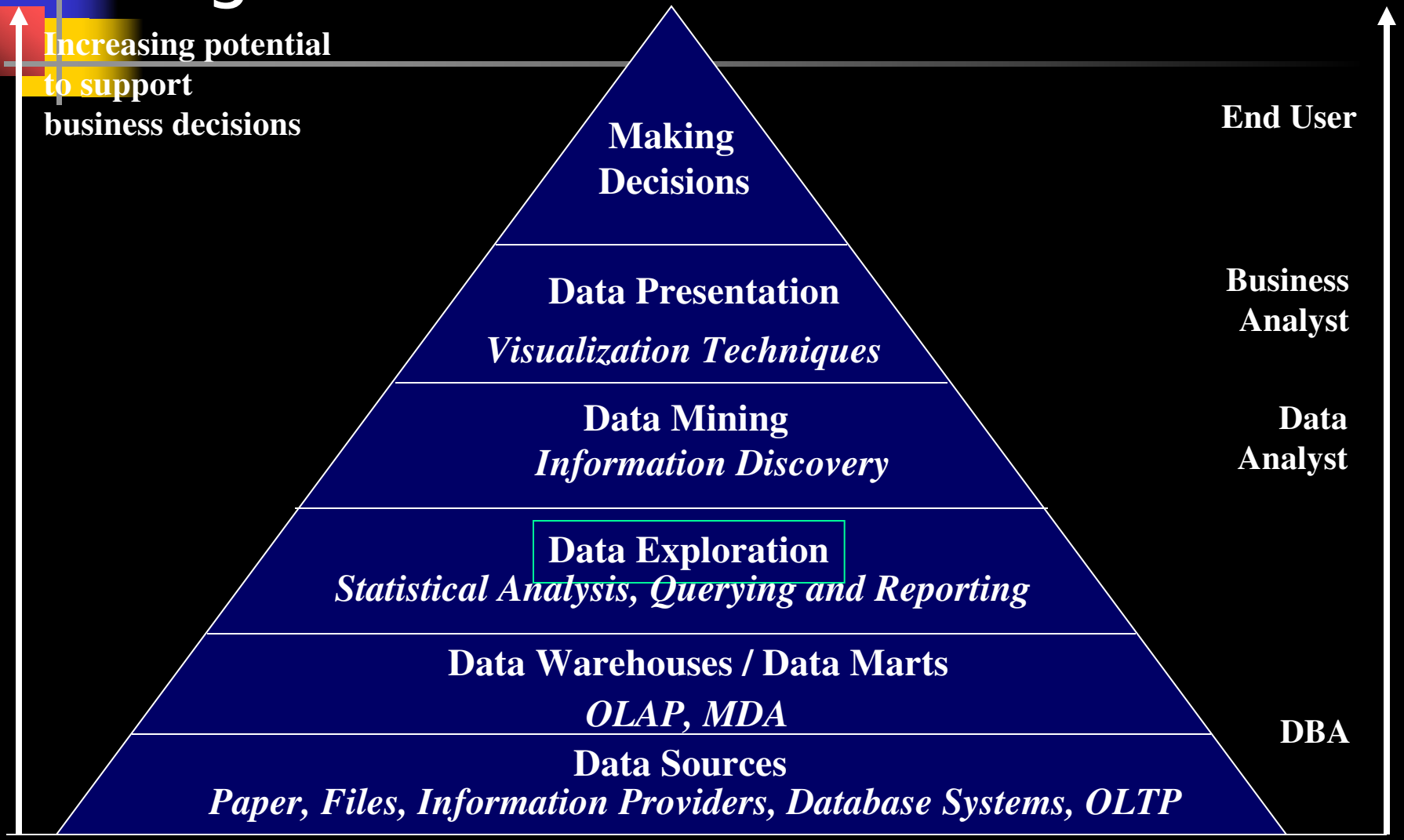


Steps of a KDD Process

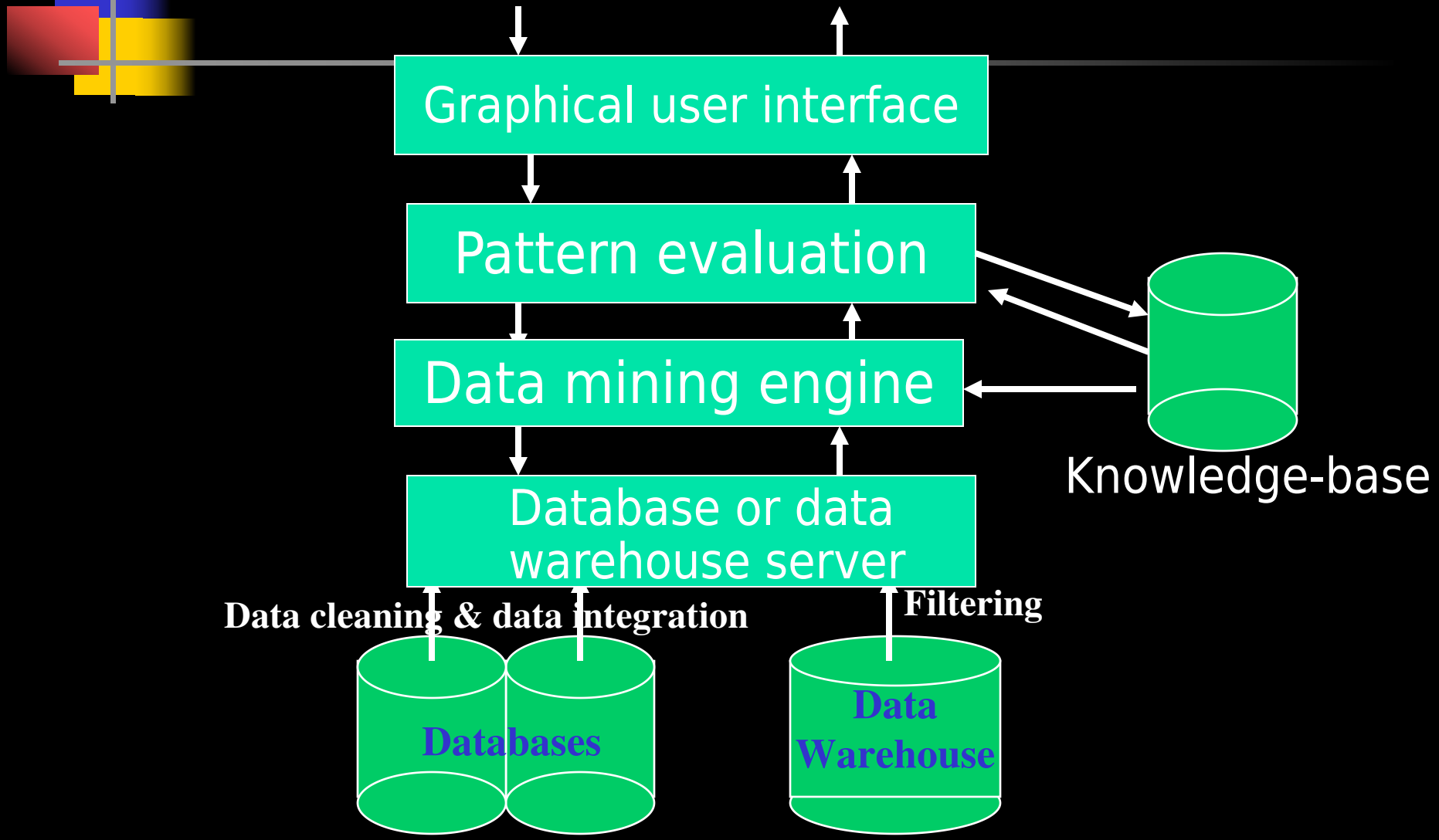


- Learning the application domain:
  - relevant prior knowledge and goals of application
- Creating a target data set: data selection
- Data cleaning and preprocessing: (may take 60% of effort!)
- Data reduction and transformation:
  - Find useful features, dimensionality/variable reduction, invariant representation.
- Choosing functions of data mining
  - summarization, classification, regression, association, clustering.
- Choosing the mining algorithm(s)
- Data mining: search for patterns of interest
- Pattern evaluation and knowledge presentation
  - visualization, transformation, removing redundant patterns, etc.
- Use of discovered knowledge

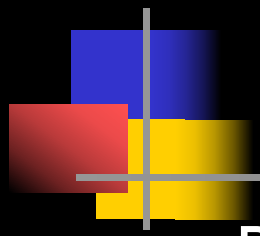
Data Mining and Business Intelligence



Architecture of a Typical Data Mining System

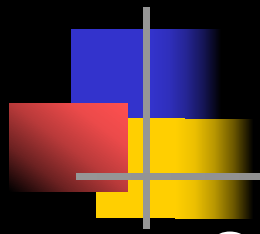


Data Mining: On What Kind of Data?



- Relational databases
- Data warehouses
- Transactional databases
- Advanced DB and information repositories
  - Object-oriented and object-relational databases
  - Spatial databases
  - Time-series data and temporal data
  - Text databases and multimedia databases
  - Heterogeneous and legacy databases
  - WWW

Data Mining Functionalities (1)



- Concept description: Characterization and discrimination
  - Generalize, summarize, and contrast data characteristics, e.g., dry vs. wet regions
- Association (correlation and causality)
  - Multi-dimensional vs. single-dimensional association
  - age(X, “20..29”) ^ income(X, “20..29K”) à buys(X, “PC”) [support = 2%, confidence = 60%]
  - contains(T, “computer”) à contains(x, “software”) [1%, 75%]

Data Mining Functionalities (2)

- Classification and Prediction
  - Finding models (functions) that describe and distinguish classes or concepts for future prediction
  - E.g., classify countries based on climate, or classify cars based on gas mileage
  - Presentation: decision-tree, classification rule, neural network
  - Prediction: Predict some unknown or missing numerical values
- Cluster analysis
  - Class label is unknown: Group data to form new classes, e.g., cluster houses to find distribution patterns
  - Clustering based on the principle: maximizing the intra-class similarity and minimizing the interclass similarity

Data Mining Functionalities (3)

- Outlier analysis
  - Outlier: a data object that does not comply with the general behavior of the data
  - It can be considered as noise or exception but is quite useful in fraud detection, rare events analysis
- Trend and evolution analysis
  - Trend and deviation: regression analysis
  - Sequential pattern mining, periodicity analysis
  - Similarity-based analysis
- Other pattern-directed or statistical analyses

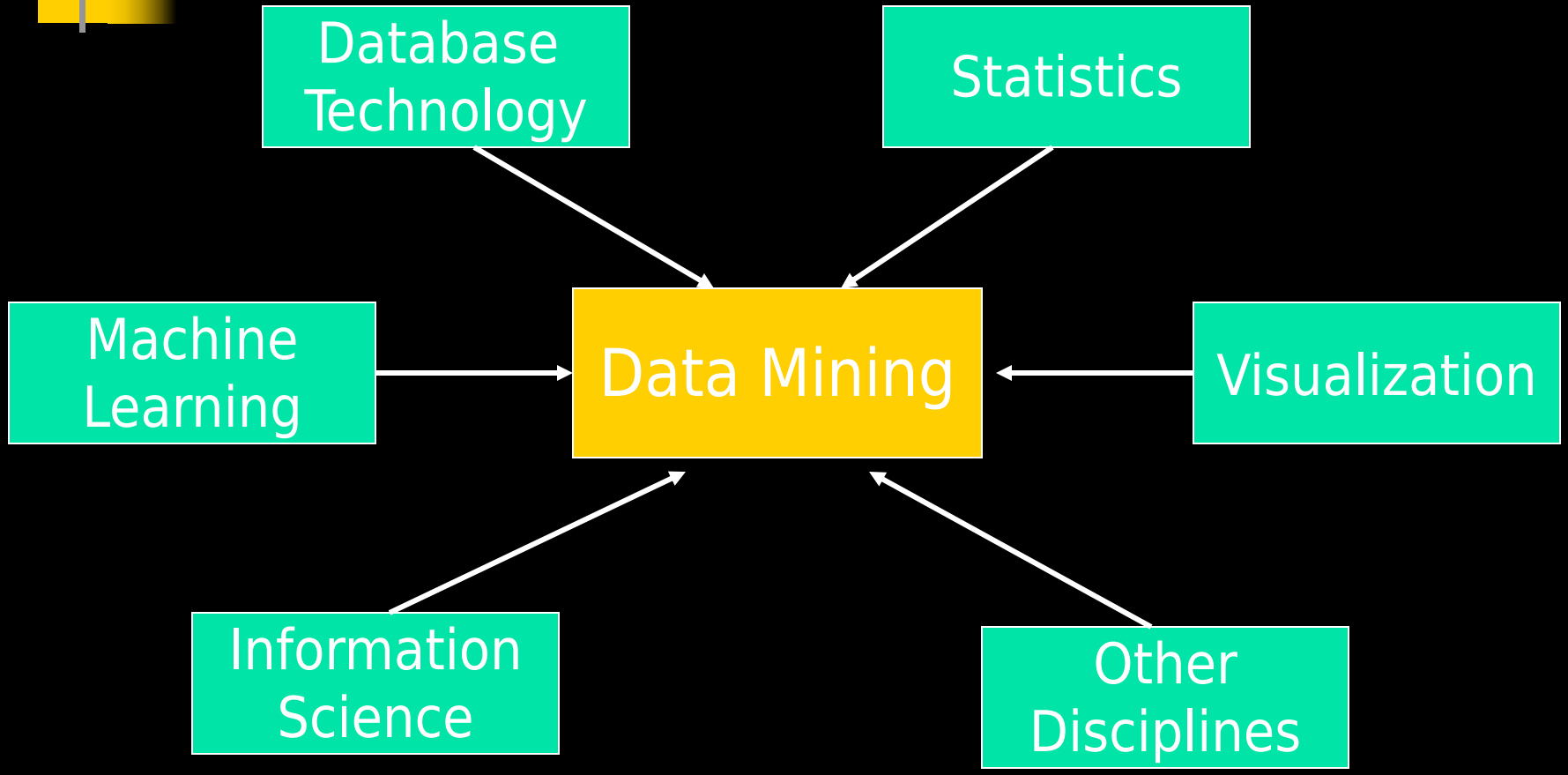
Are All the "Discovered" Patterns Interesting?

- A data mining system/query may generate thousands of patterns, not all of them are interesting.
  - Suggested approach: Human-centered, query-based, focused mining
- **Interestingness measures**: A pattern is interesting if it is easily understood by humans, valid on new or test data with some degree of certainty, potentially useful, novel, or validates some hypothesis that a user seeks to confirm
- **Objective vs. subjective interestingness measures:**
  - Objective: based on statistics and structures of patterns, e.g., support, confidence, etc.
  - Subjective: based on user's belief in the data, e.g., unexpectedness, novelty, actionability, etc.

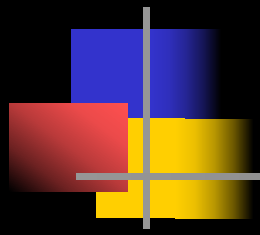
Can We Find All and Only Interesting Patterns?

- Find all the interesting patterns: Completeness
  - Can a data mining system find all the interesting patterns?
  - Association vs. classification vs. clustering
- Search for only interesting patterns: Optimization
  - Can a data mining system find only the interesting patterns?
  - Approaches
    - First general all the patterns and then filter out the uninteresting ones.
    - Generate only the interesting patterns—mining query optimization

Data Mining: Confluence of Multiple Disciplines

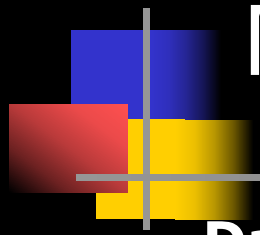


Data Mining: Classification Schemes



- General functionality
  - Descriptive data mining
  - Predictive data mining
- Different views, different classifications
  - Kinds of databases to be mined
  - Kinds of knowledge to be discovered
  - Kinds of techniques utilized
  - Kinds of applications adapted

A Multi-Dimensional View of Data Mining Classification

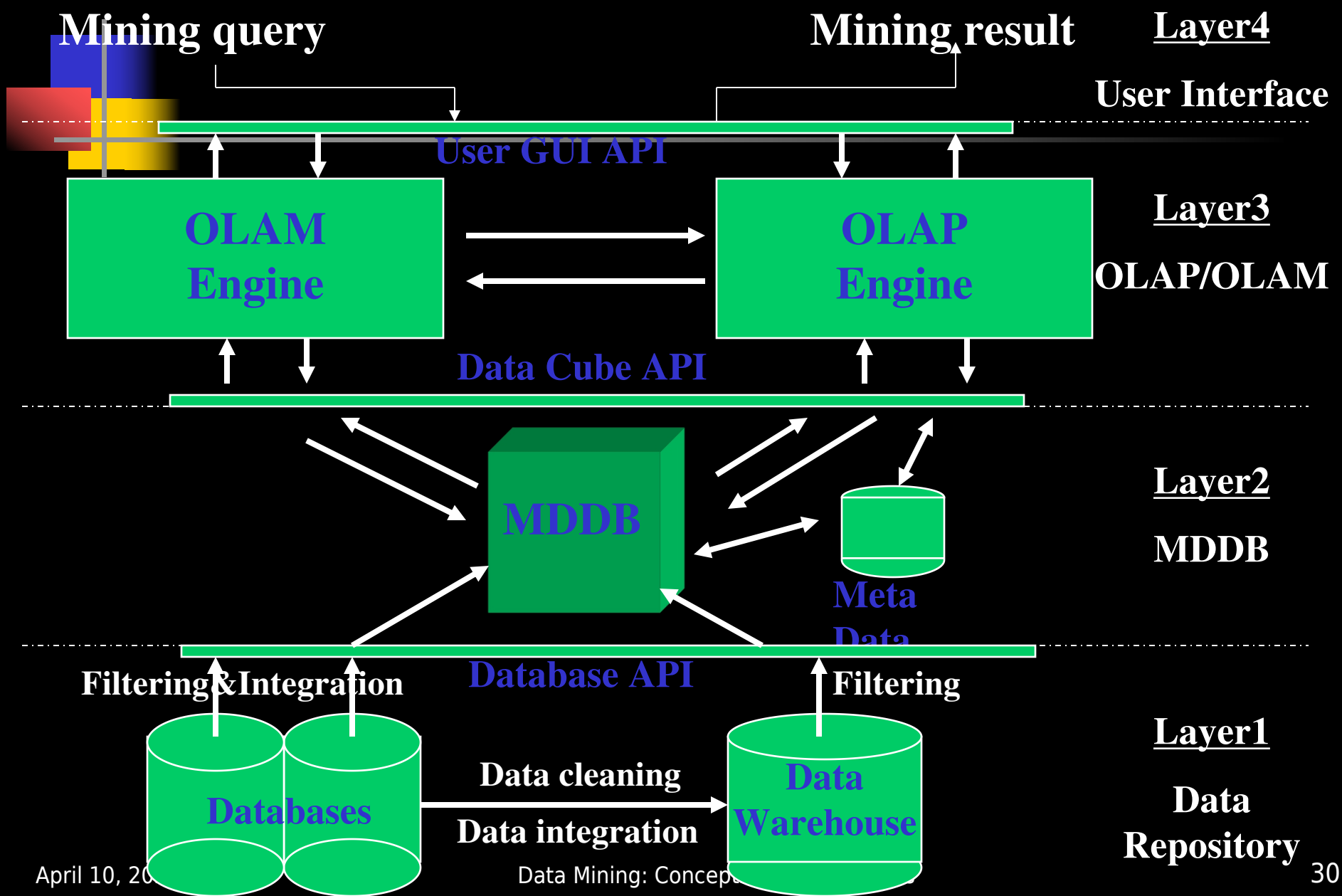


- **Databases to be mined**
  - Relational, transactional, object-oriented, object-relational, active, spatial, time-series, text, multi-media, heterogeneous, legacy, WWW, etc.
- **Knowledge to be mined**
  - Characterization, discrimination, association, classification, clustering, trend, deviation and outlier analysis, etc.
  - Multiple/integrated functions and mining at multiple levels
- **Techniques utilized**
  - Database-oriented, data warehouse (OLAP), machine learning, statistics, visualization, neural network, etc.
- **Applications adapted**
  - Retail, telecommunication, banking, fraud analysis, DNA mining, stock market analysis, Web mining, Weblog analysis, etc.

OLAP Mining: An Integration of Data Mining and Data Warehousing

- **Data mining systems, DBMS, Data warehouse systems coupling**
  - No coupling, loose-coupling, semi-tight-coupling, tight-coupling
- **On-line analytical mining data**
  - integration of mining and OLAP technologies
- **Interactive mining multi-level knowledge**
  - Necessity of mining knowledge and patterns at different levels of abstraction by drilling/rolling, pivoting, slicing/dicing, etc.
- **Integration of multiple mining functions**
  - Characterized classification, first clustering and then association

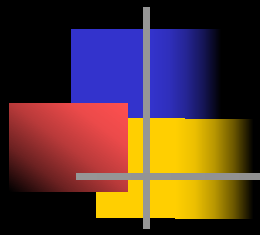
An OLAM Architecture



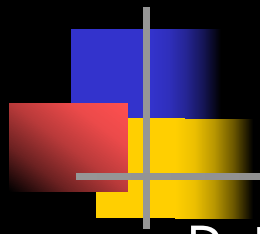
Major Issues in Data Mining (1)

- Mining methodology and user interaction
  - Mining different kinds of knowledge in databases
  - Interactive mining of knowledge at multiple levels of abstraction
  - Incorporation of background knowledge
  - Data mining query languages and ad-hoc data mining
  - Expression and visualization of data mining results
  - Handling noise and incomplete data
  - Pattern evaluation: the interestingness problem
- Performance and scalability
  - Efficiency and scalability of data mining algorithms
  - Parallel, distributed and incremental mining methods

Major Issues in Data Mining (2)



- Issues relating to the diversity of data types
  - Handling relational and complex types of data
  - Mining information from heterogeneous databases and global information systems (WWW)
- Issues related to applications and social impacts
  - Application of discovered knowledge
    - Domain-specific data mining tools
    - Intelligent query answering
    - Process control and decision making
  - Integration of the discovered knowledge with existing knowledge: A knowledge fusion problem
  - Protection of data security, integrity, and privacy



Summary

- Data mining: discovering interesting patterns from large amounts 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 information repositories
- Data mining functionalities: characterization, discrimination, association, classification, clustering, outlier and trend analysis, etc.
- Classification of data mining systems
- Major issues in data mining

A Brief History of Data Mining Society

- 1989 IJCAI Workshop on Knowledge Discovery in Databases (Piatetsky-Shapiro)
  - 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)
- 1998 ACM SIGKDD, SIGKDD'1999-2001 conferences, and SIGKDD Explorations
- More conferences on data mining
  - PAKDD, PKDD, SIAM-Data Mining, (IEEE) ICDM, etc.

Where to Find References?

- Data mining and KDD (SIGKDD member CDROM):
  - Conference proceedings: KDD, and others, such as PKDD, PAKDD, etc.
  - Journal: Data Mining and Knowledge Discovery
- Database field (SIGMOD member CD ROM):
  - Conference proceedings: ACM-SIGMOD, ACM-PODS, VLDB, ICDE, EDBT, DASFAA
  - Journals: ACM-TODS, J. ACM, IEEE-TKDE, JIIS, etc.
- AI and Machine Learning:
  - Conference proceedings: Machine learning, AAAI, IJCAI, etc.
  - Journals: Machine Learning, Artificial Intelligence, etc.
- Statistics:
  - Conference proceedings: Joint Stat. Meeting, etc.
  - Journals: Annals of statistics, etc.
- Visualization:
  - Conference proceedings: CHI, etc.
  - Journals: IEEE Trans. visualization and computer graphics, etc.

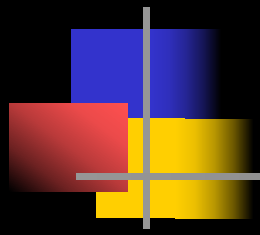
References

- U. M. Fayyad, G. Piatetsky-Shapiro, P. Smyth, and R. Uthurusamy. Advances in Knowledge Discovery and Data Mining. AAAI/MIT Press, 1996.
- J. Han and M. Kamber. Data Mining: Concepts and Techniques. Morgan Kaufmann, 2000.
- T. Imielinski and H. Mannila. A database perspective on knowledge discovery. Communications of ACM, 39:58-64, 1996.
- G. Piatetsky-Shapiro, U. Fayyad, and P. Smith. From data mining to knowledge discovery: An overview. In U.M. Fayyad, et al. (eds.), Advances in Knowledge Discovery and Data Mining, 1-35. AAAI/MIT Press, 1996.
- G. Piatetsky-Shapiro and W. J. Frawley. Knowledge Discovery in Databases. AAAI/MIT Press, 1991.

http://www.cs.sfu.ca/~han

Thank you !!!

CMPT-843 Course Arrangement



- 1st week: full instructor teaching
- 2nd to 11th week: 1/2 graduate student + 1/2 instructor teaching
- 12-13th week: full student graduate project presentation
- Course evaluation:
  - presentation (quality of presentation slides 7% + presentation 8%) 15%
  - midterm exam 35%
  - project (presentation 5% + report 25%) total 30%
  - homework (2): 20%
- Deadline for the selection of your work in the semester:
  - selection of course presentation: at the end of the 1st week
  - selection of the course project: at the end of the 3rd week
  - project proposal due date: at the end of the 4th week
  - homework due dates:
  - project due date: end of the semester
  - Your presentation slides due date: one day before the presentation
  - midterm date: end of the 8th week