



# Data Mining: Concepts and Techniques

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— Chapter 1 —



# Chapter 1. Introduction

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- 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



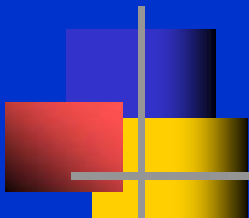
# Motivation: “Necessity is the Mother of Invention”

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- 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)

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- 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

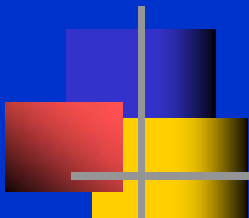


# What Is Data Mining?

- 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:
  - 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

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



# Market Analysis and Management (1)

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- 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)



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- 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

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- 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)

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## ■ 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)

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- 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

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## ■ Sports

- IBM Advanced Scout analyzed NBA game statistics (shots blocked, assists, and fouls) to gain competitive advantage for New York Knicks and Miami Heat

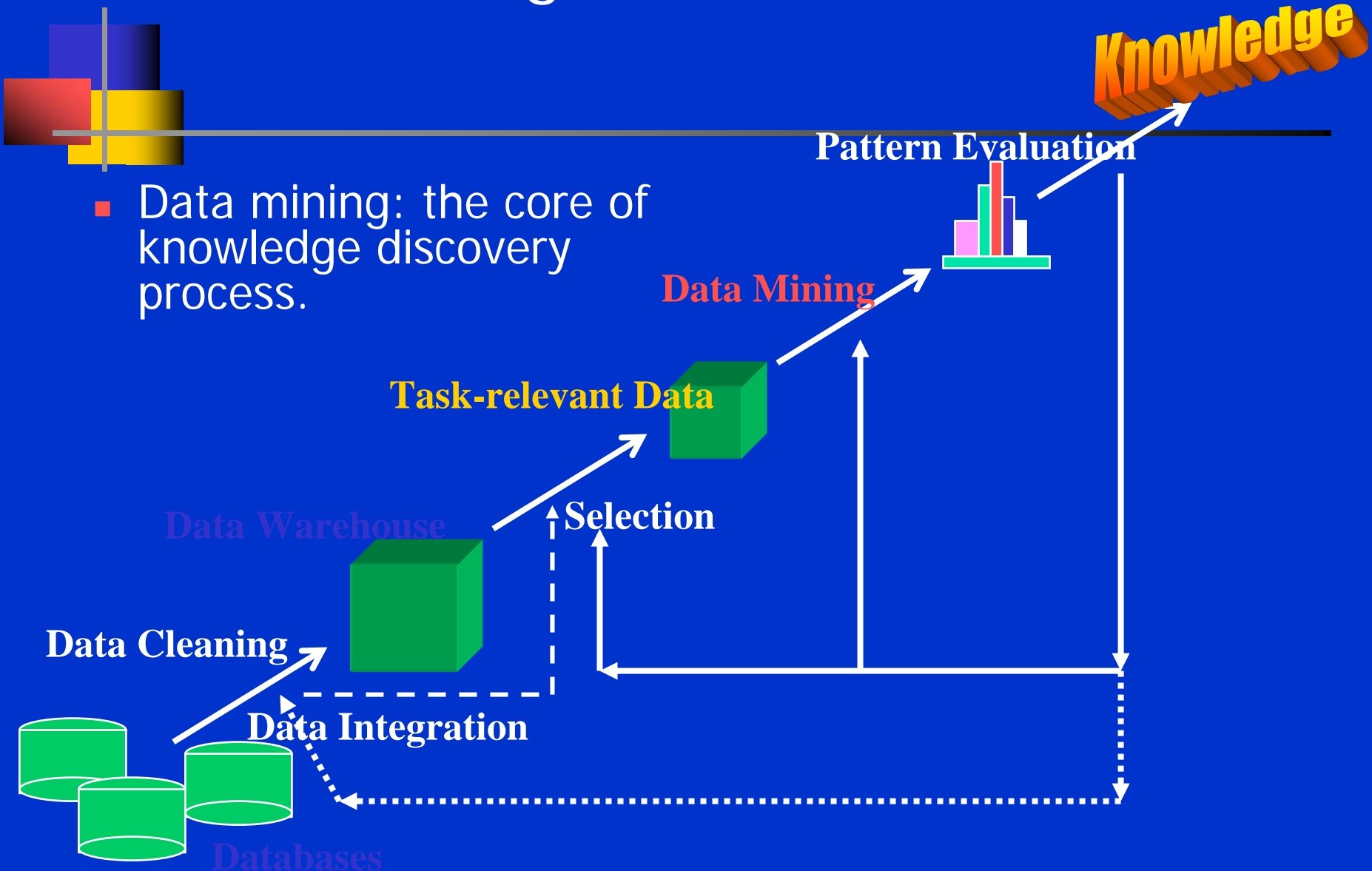
## ■ Astronomy

- 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, analyze effectiveness of Web marketing, improve Web site organization, etc.

# Data Mining: A KDD Process

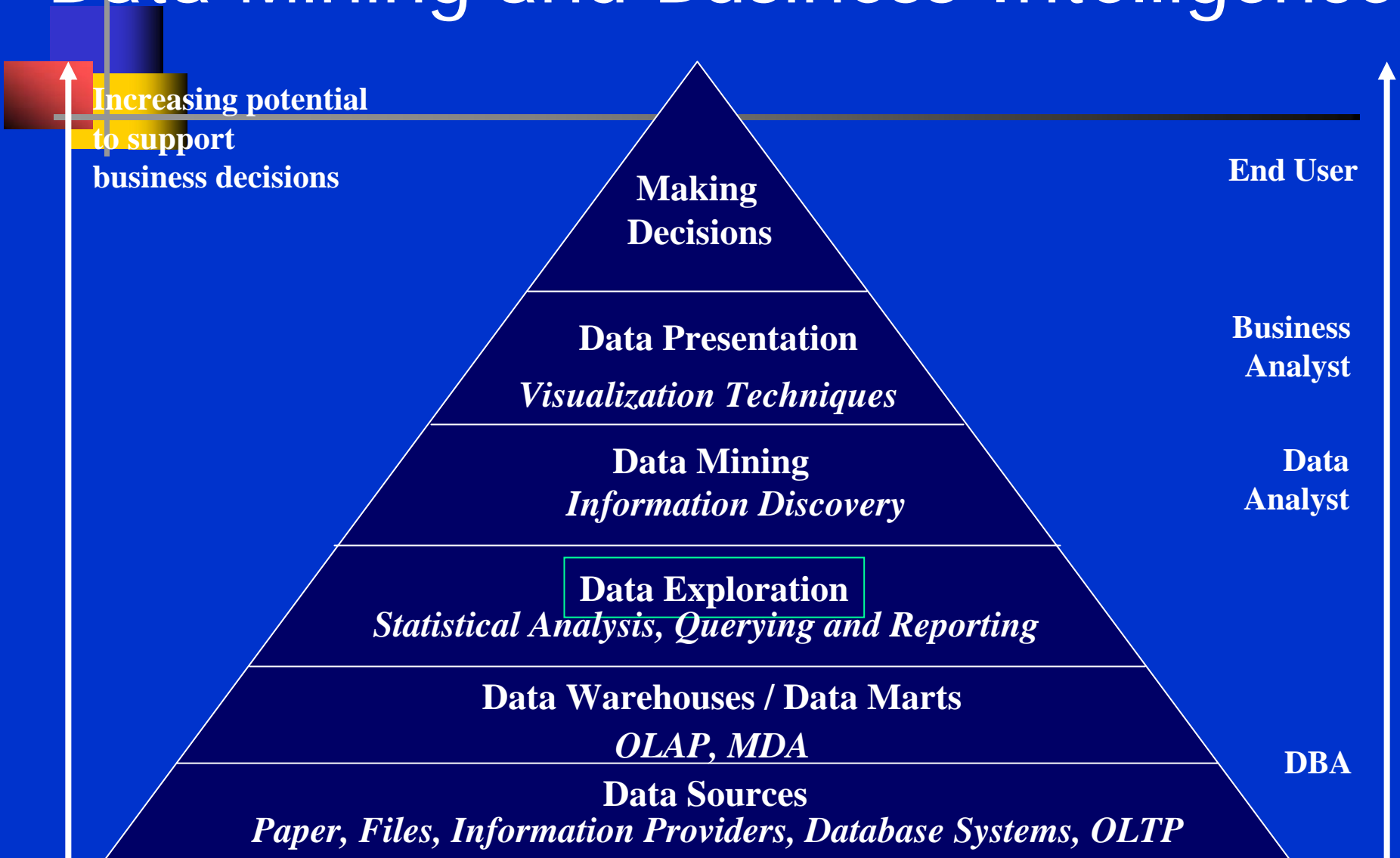


# Steps of a KDD Process

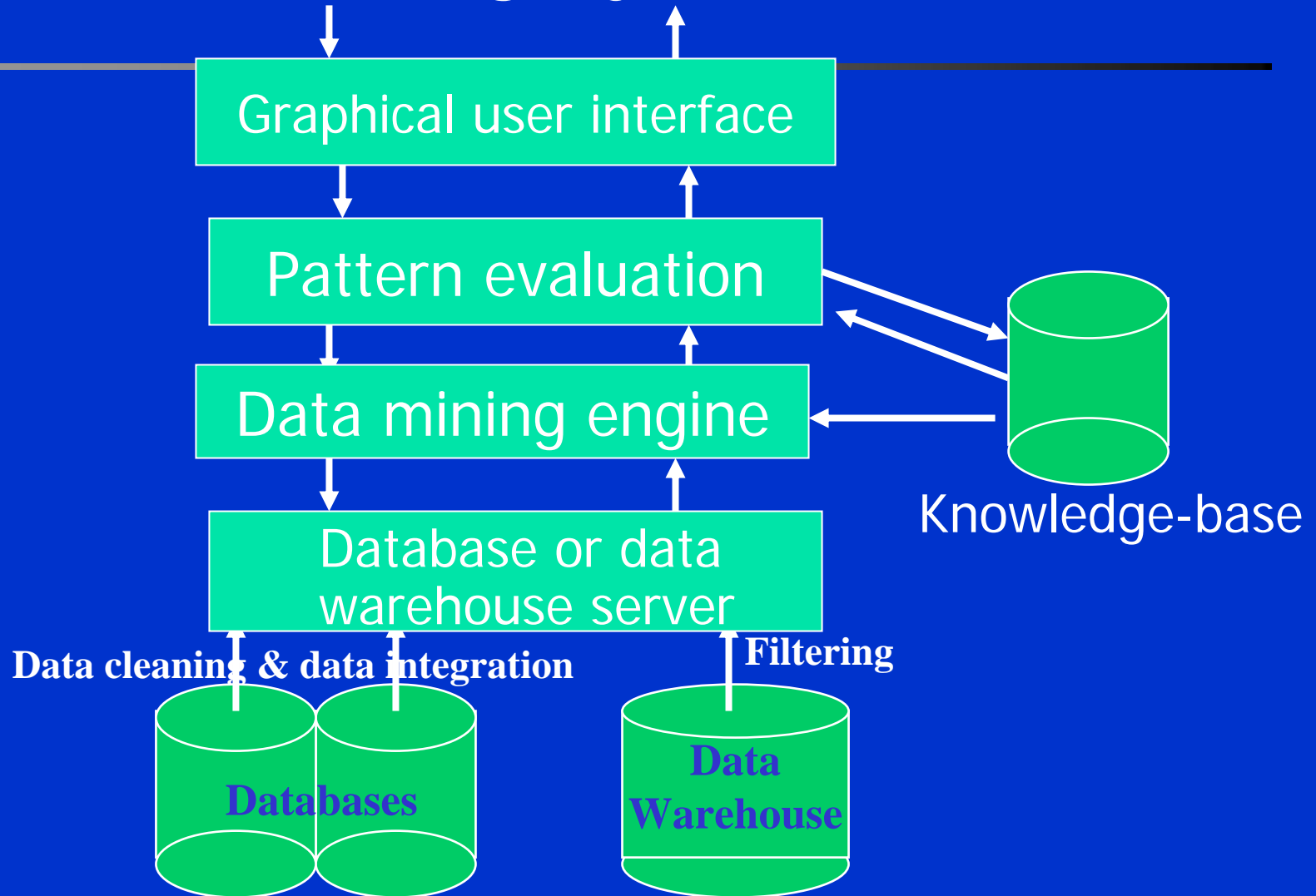


- Learning the application domain:
  - relevant prior knowledge and goals of application
- Creating a target data set: data selection
- Data cleaning and preprocessing: (may take 60% of effort!)
- Data reduction and transformation:
  - Find useful features, dimensionality/variable reduction, invariant 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?

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- 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)

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- 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
  - $\text{age}(X, "20..29") \wedge \text{income}(X, "20..29K") \rightarrow \text{buys}(X, "PC")$  [support = 2%, confidence = 60%]
  - $\text{contains}(T, "computer") \rightarrow \text{contains}(x, "software")$  [1%, 75%]



# Data Mining Functionalities (2)

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## ■ 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)

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## ■ 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.

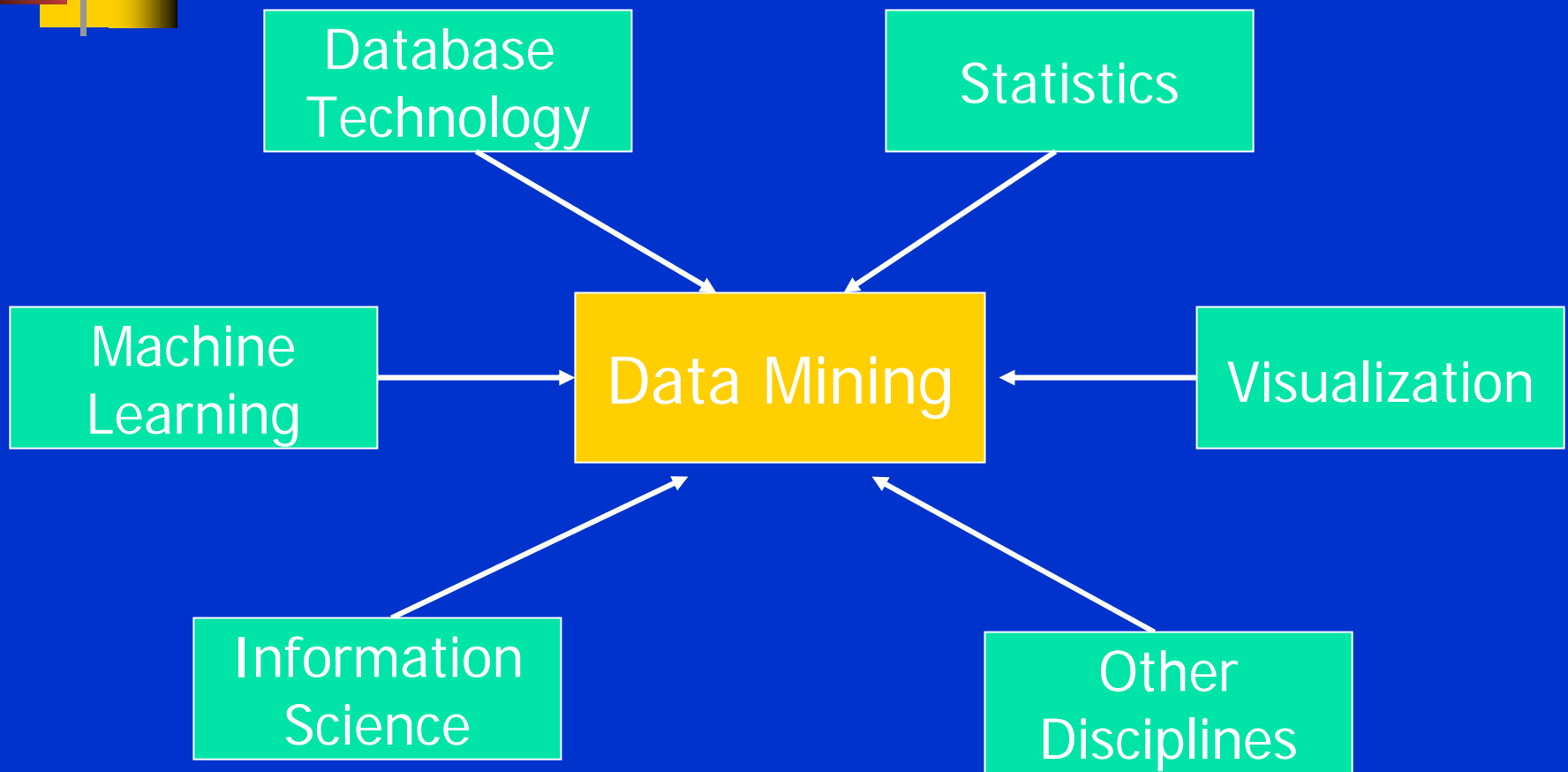


# Can We Find All and Only Interesting Patterns?

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- 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 generate 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

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- 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

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- **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.



# Major Issues in Data Mining (1)

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- 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)

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- 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

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- 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

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- 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-current International Conferences on Knowledge Discovery in Databases and Data Mining
  - Journal of Data Mining and Knowledge Discovery (1997)
- 1998 ACM SIGKDD, SIGKDD'1999-current conferences
- More conferences on data mining
  - PAKDD, PKDD, SIAM-Data Mining, (IEEE) ICDM, etc.