

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?

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

What Is Data Mining?

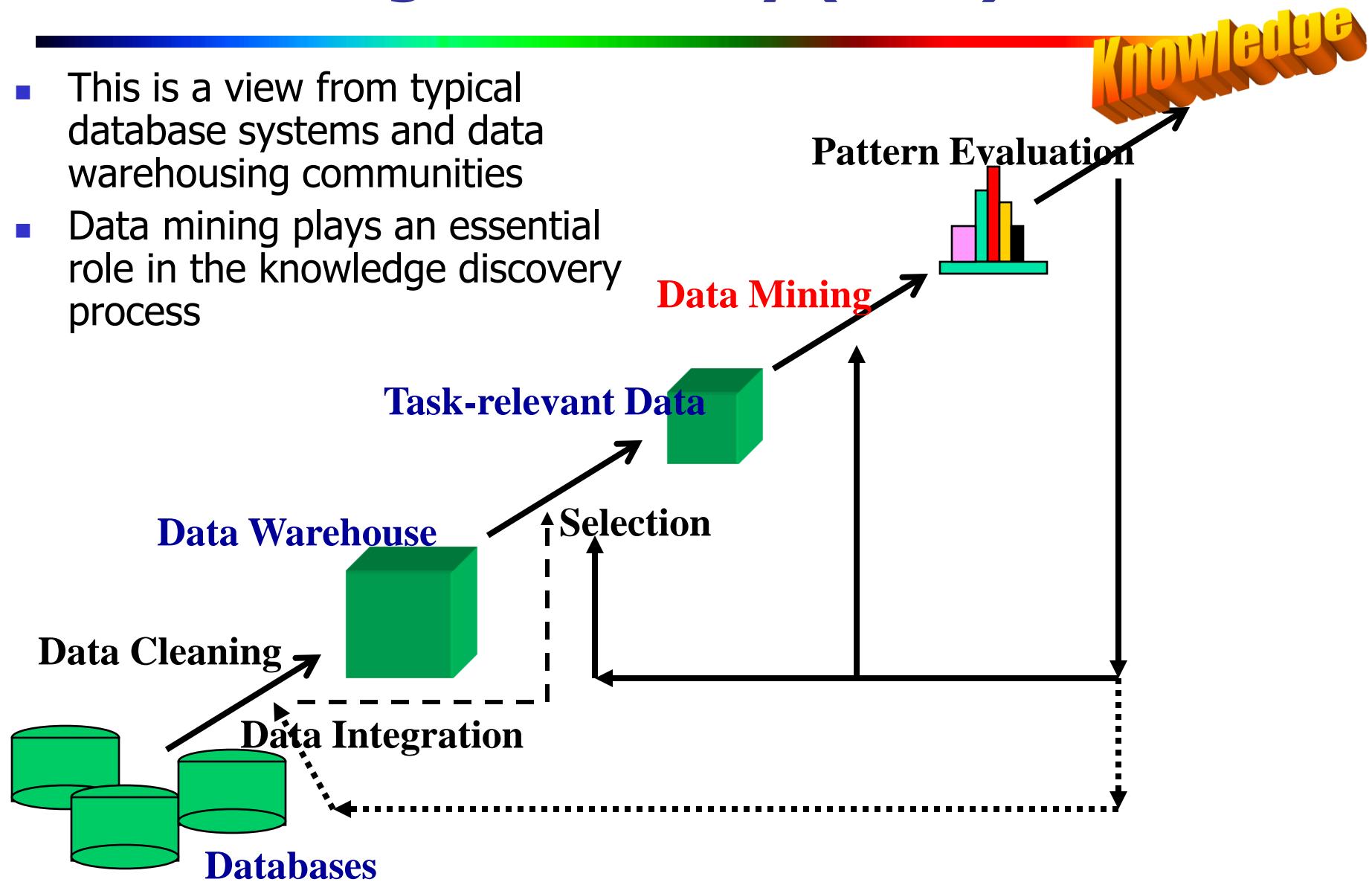


- Data mining (knowledge discovery from data)
 - Extraction of interesting (non-trivial, implicit, previously unknown and potentially useful) patterns or knowledge from huge amount of data
- Alternative names
 - Knowledge discovery (mining) in databases (KDD), knowledge extraction, data/pattern analysis, data archeology, information harvesting, business intelligence, etc.
- Watch out: Is everything “data mining”?
 - Simple search and query processing
 - (Deductive) expert systems



Knowledge Discovery (KDD) Process

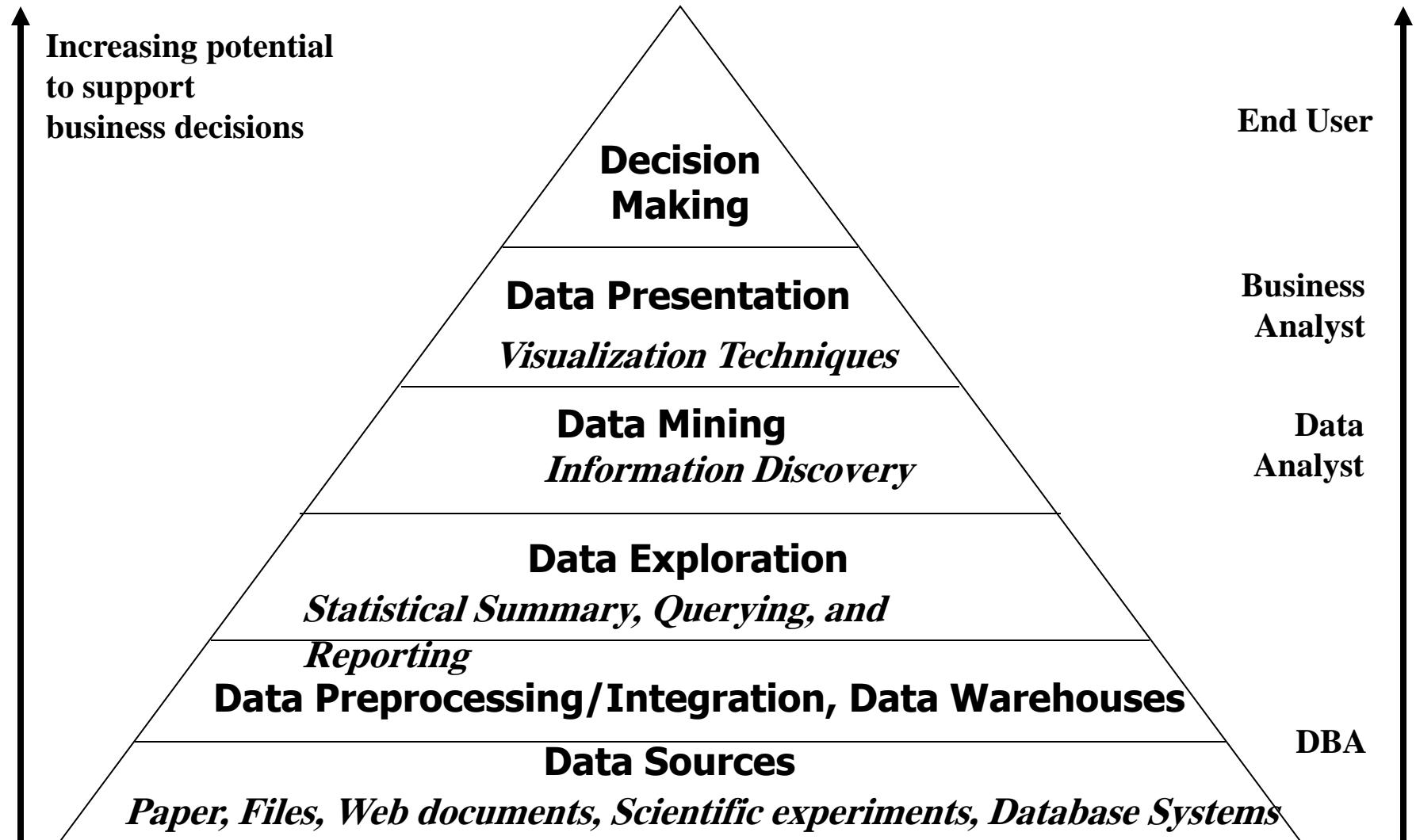
- This is a view from typical database systems and data warehousing communities
- Data mining plays an essential role in the knowledge discovery process



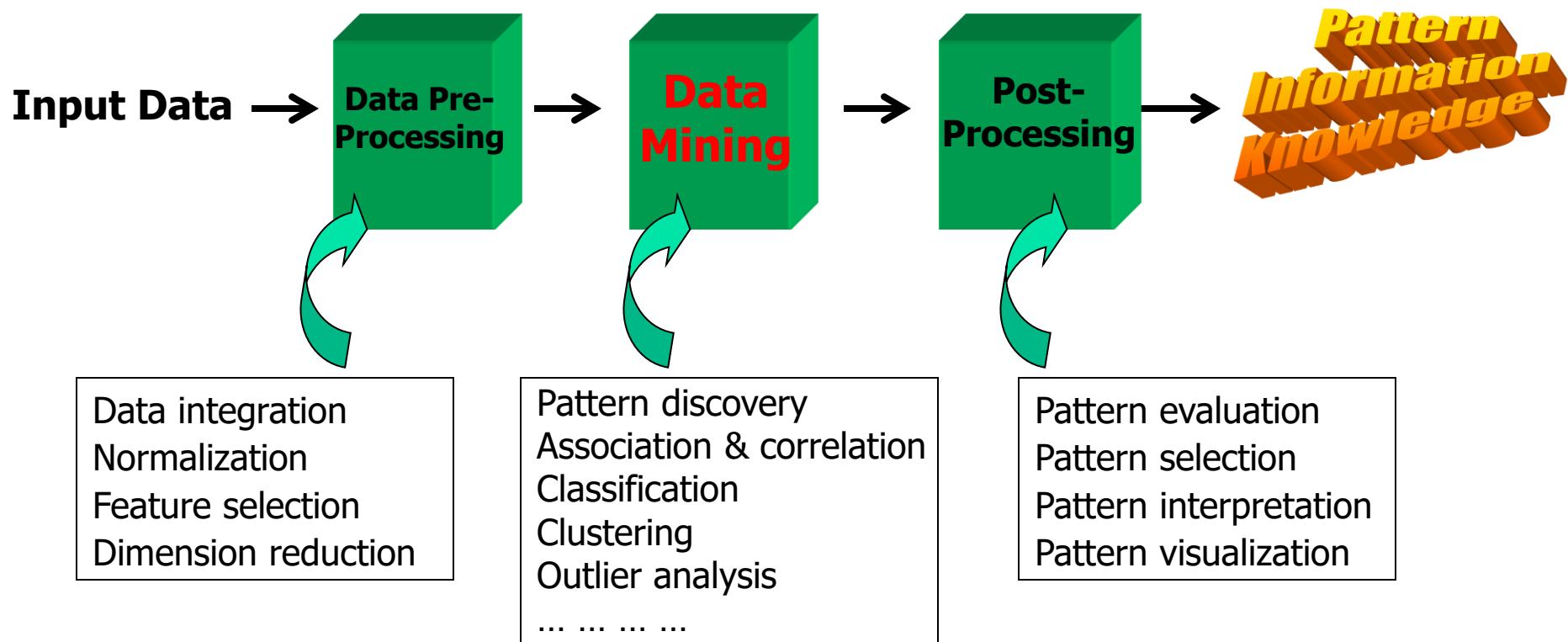
Example: A Web Mining Framework

- 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

Multi-Dimensional View of Data Mining

- **Data to be mined**
 - Database data (extended-relational, object-oriented, heterogeneous, legacy), data warehouse, transactional data, stream
- **Knowledge to be mined (or: Data mining functions)**
 - Association, classification, clustering, trend/deviation, outlier analysis, etc.
 - Descriptive vs. predictive data mining
 - Multiple/integrated functions and mining at multiple levels
- **Techniques utilized**
 - Data warehouse (OLAP), machine learning, statistics, pattern recognition, visualization, etc.
- **Applications adapted**
 - Retail, telecommunication, banking, fraud analysis, bio-data mining, stock market analysis, text mining, Web mining, etc.

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

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

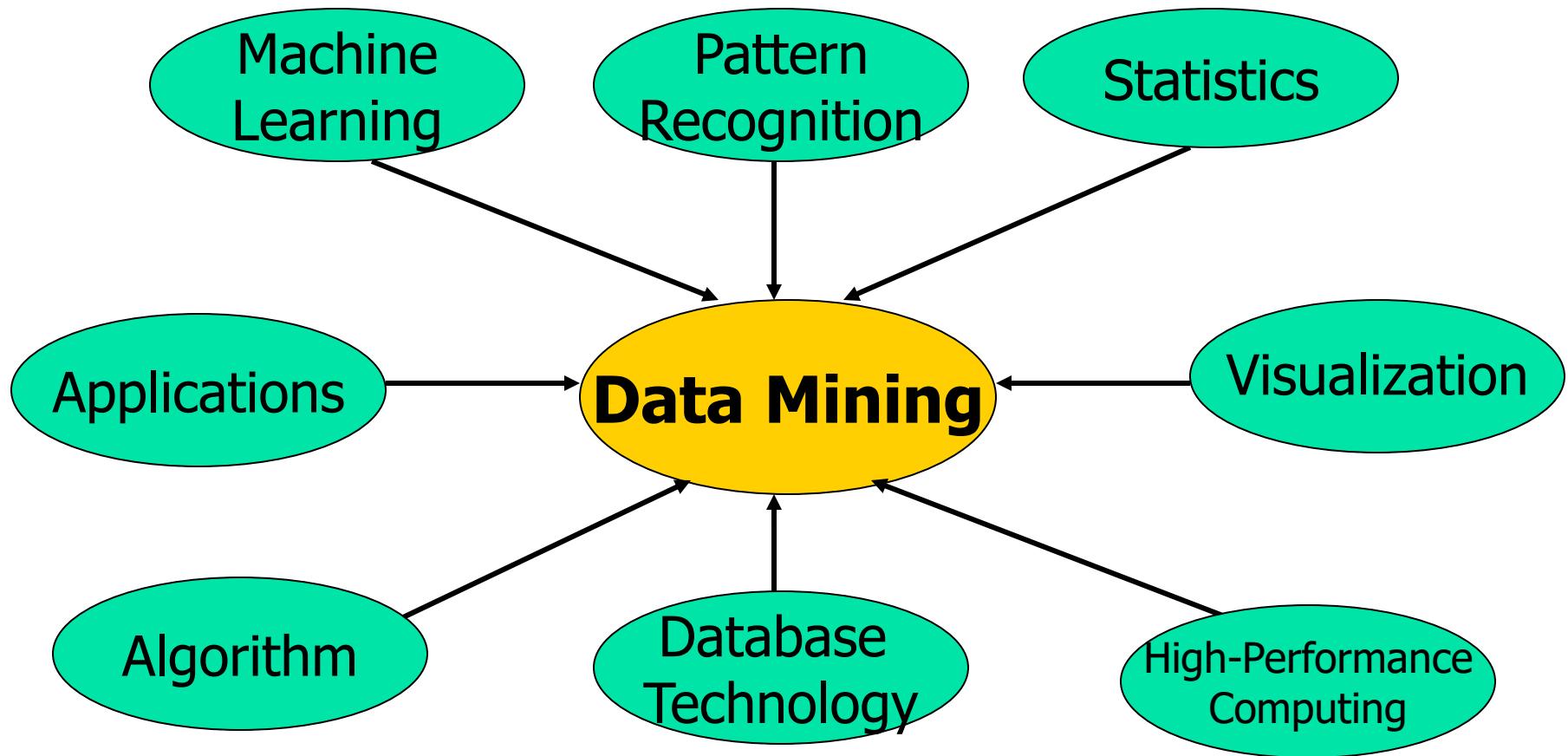
Time and Ordering: Sequential Pattern, Trend and Evolution Analysis

- 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
 - Similarity-based analysis
- Mining data streams
 - Ordered, time-varying, potentially infinite, data streams

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
 - ...

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

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.