Data Mining:

Concepts and Techniques

(3rd ed.)

— Chapter 1 —

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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?
- What Kind 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 zettabytes.
  - 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

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.
- 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 info. management, acquisition, organization, query, and visualization tasks scale almost linearly with data volumes. Data mining is a major new challenge!
- Jim Gray and Alex Szalay, *The World Wide Telescope: An Archetype for Online Science*, Comm. ACM, 45(11): 50-54, Nov. 2002

Evolution of Database Technology

- 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.)
  - 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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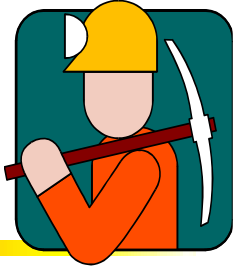
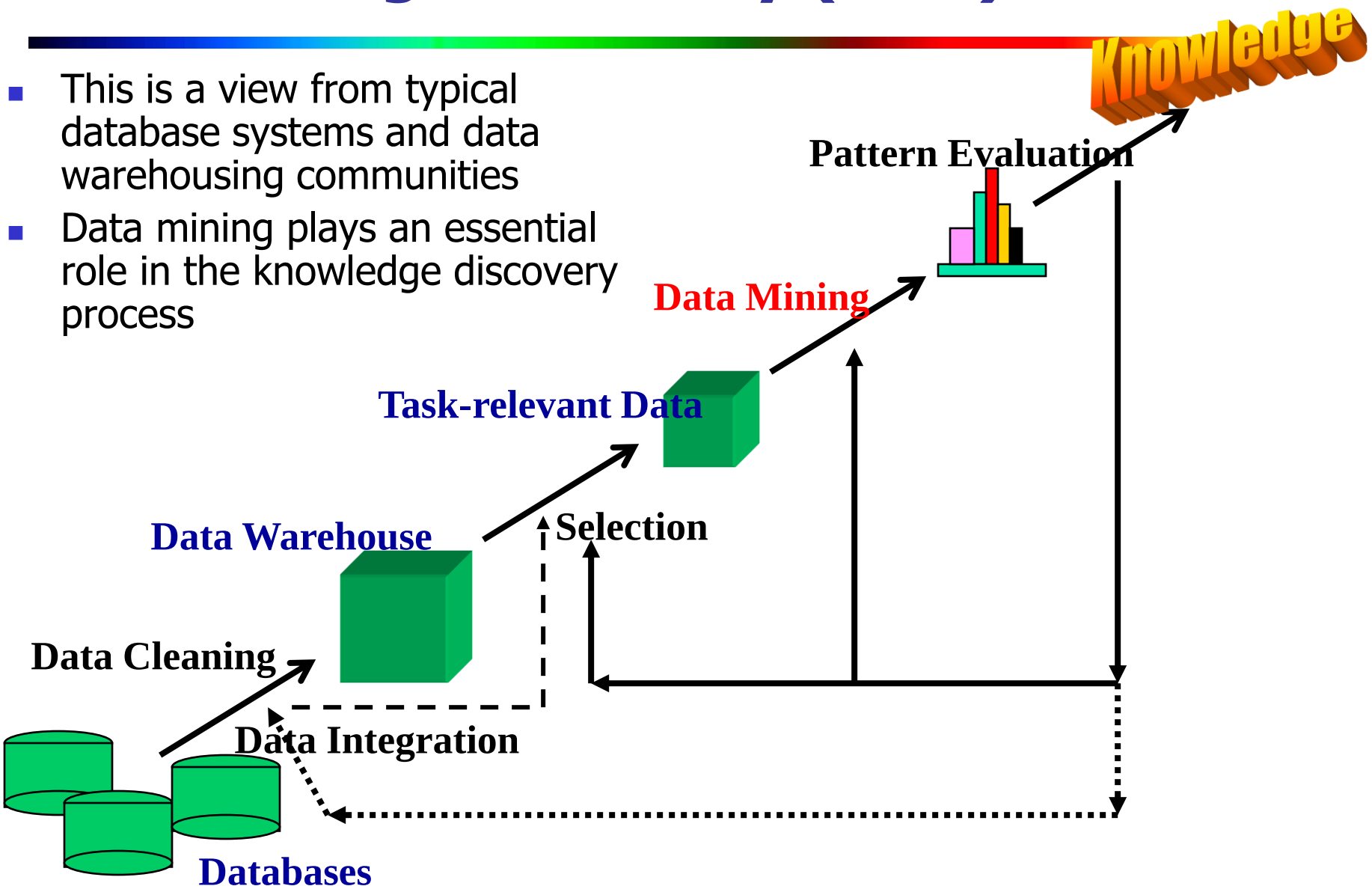
What Is Data Mining?



- 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
  - 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



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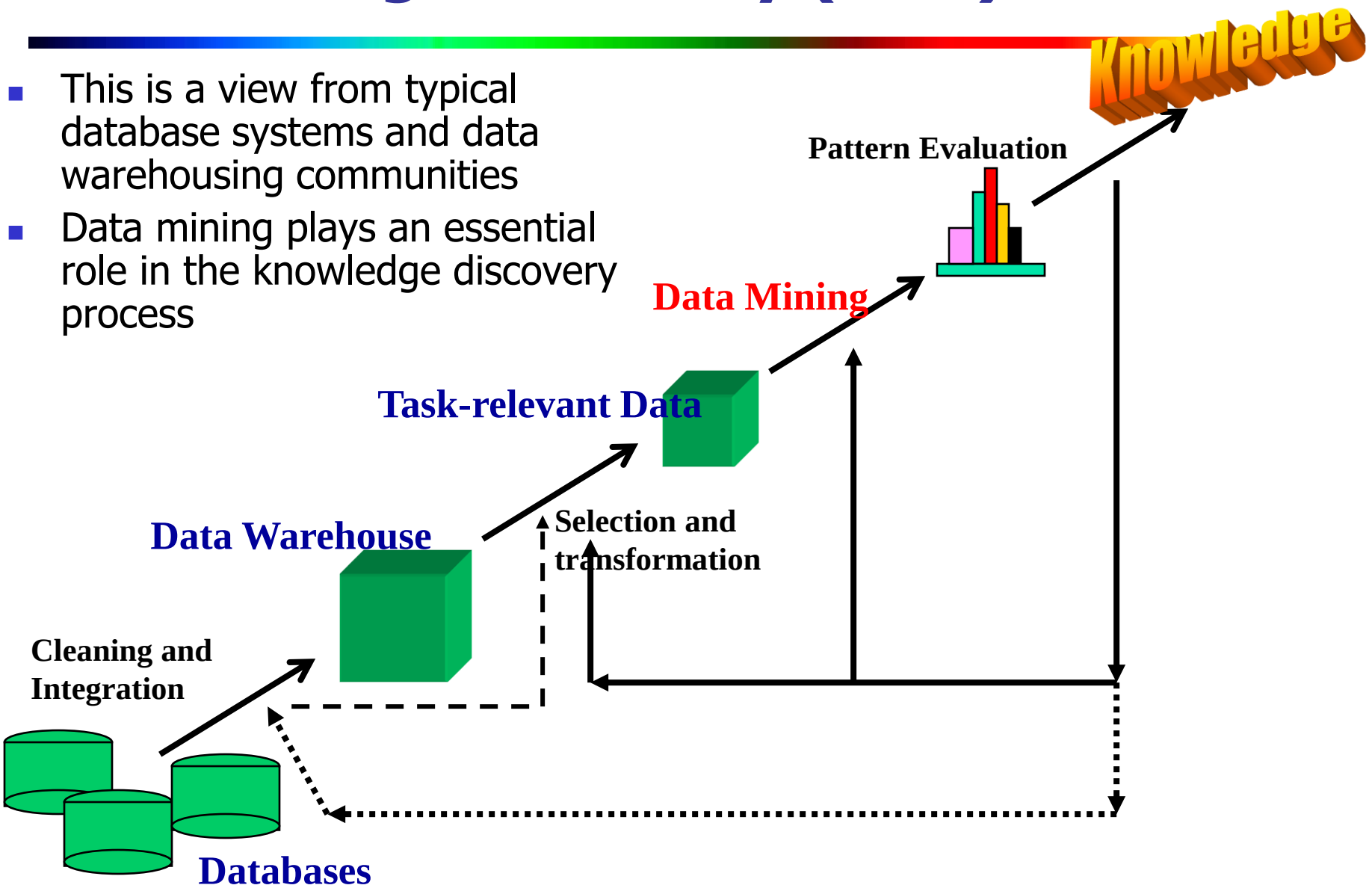
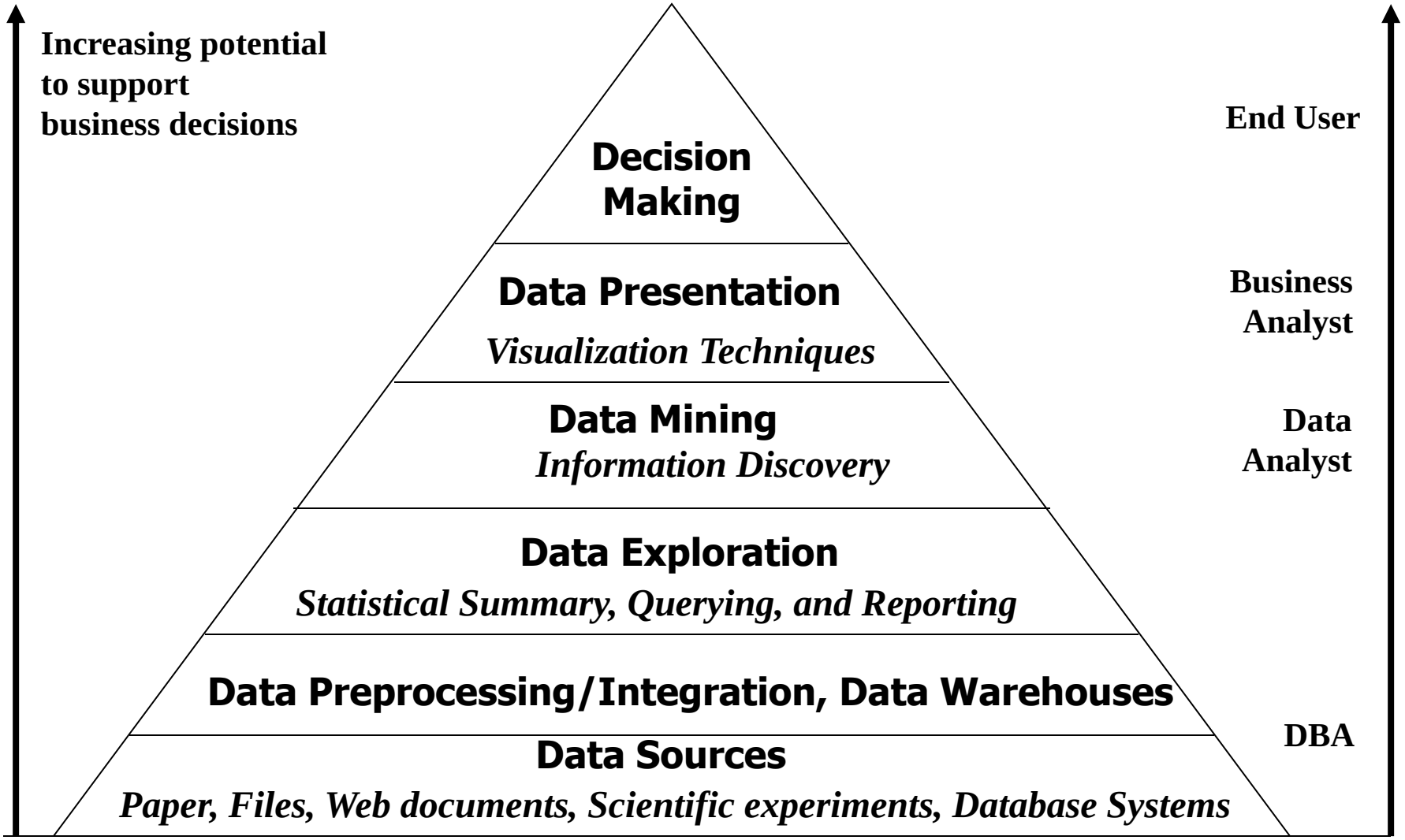


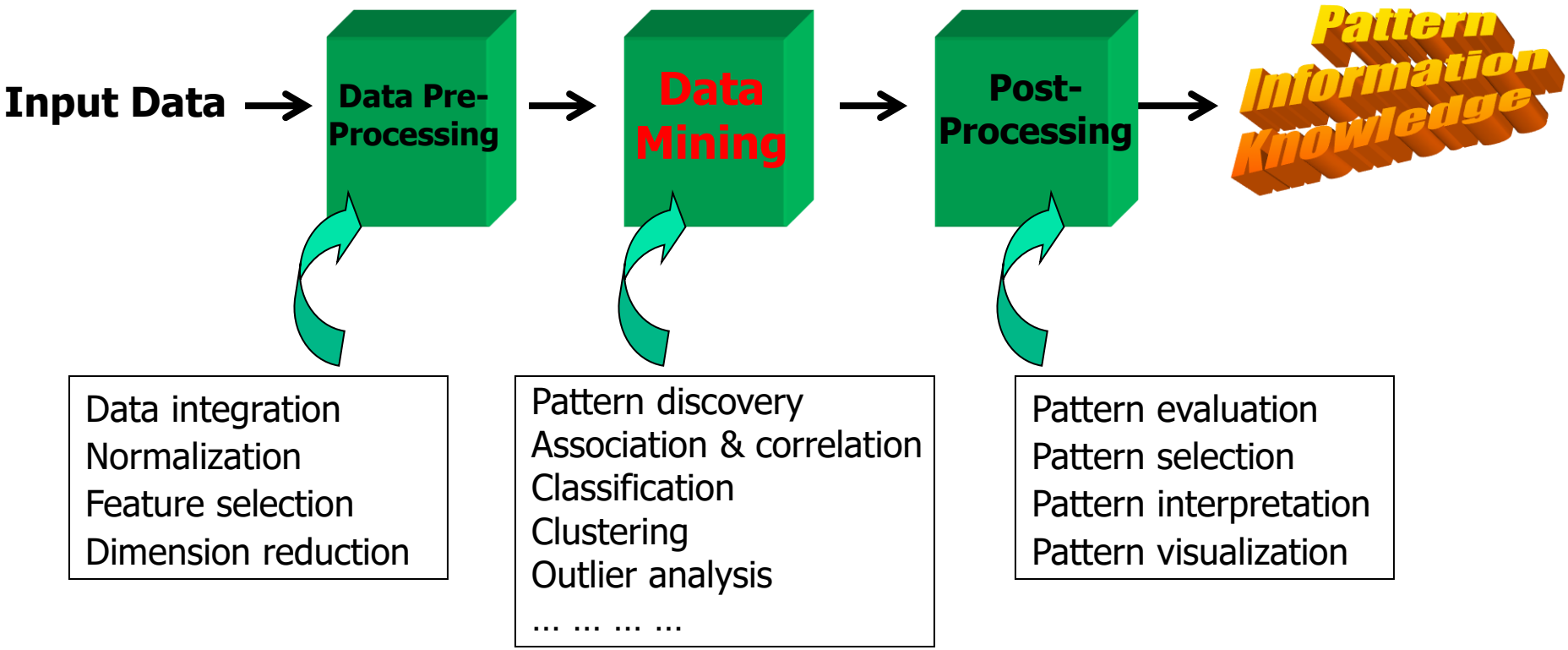
Example: A Web Mining Framework

- 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 (or: 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
- **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

Data Mining: Relational Data

customer *(cust_ID, name, address, age, occupation, annual income, credit information,*

category, . . .)

item *(item_ID, brand, category, type, price, place made, supplier, cost, . . .)*

employee *(empl_ID, name, category, group, salary, commission, . . .)*

branch *(branch_ID, name, address, . . .)*

purchases *(trans_ID, cust_ID, empl_ID, date, time, method paid, amount)*

items_sold *(trans_ID, item_ID, qty)*

works_at *(empl_ID, branch_ID)*

Figure: Relational schema for a relational database, AllElectronics

Data Mining: Transactional Data

- Each record in a transactional database captures a transaction, such as a customer's purchase, a flight booking, or a user's clicks on a web page.
- Because most relational database systems do not support nested relational structures, the transactional database is usually either stored in a flat file in a format similar to the table in the following figure.

trans_ID	*list_of_item_IDs*
T100	I1, I3, I8, I16
T200	I2, I8
...	...

Figure: Fragment of a transactional database for sales at AllElectronics.

- Example of transactional data mining task: Which items sold well together?

Data Mining: Data Warehouse

- Constructed via - data cleaning, data integration, data transformation, data loading, and periodic data refreshing.
- Summarized data. E.g., rather than storing the details of each sales transaction, the data warehouse may store a summary of the transactions per item type for each store, or summarized to a higher level, for each sales region.
- Usually modeled by a multidimensional data structure, called a data cube.
- Each dimension in data cube corresponds to an attribute or a set of attributes in the schema, and each cell stores the value of some aggregate measure such as *count* or *sum(sales amount).*
- By providing multidimensional data views and the precomputation of summarized data, data warehouse systems can provide inherent support for OLAP: Online analytical processing operations.
- Examples of OLAP operations include drill-down and roll-up, which allow the user to view the data at differing degrees of summarization.

Data Mining: Data Warehouse

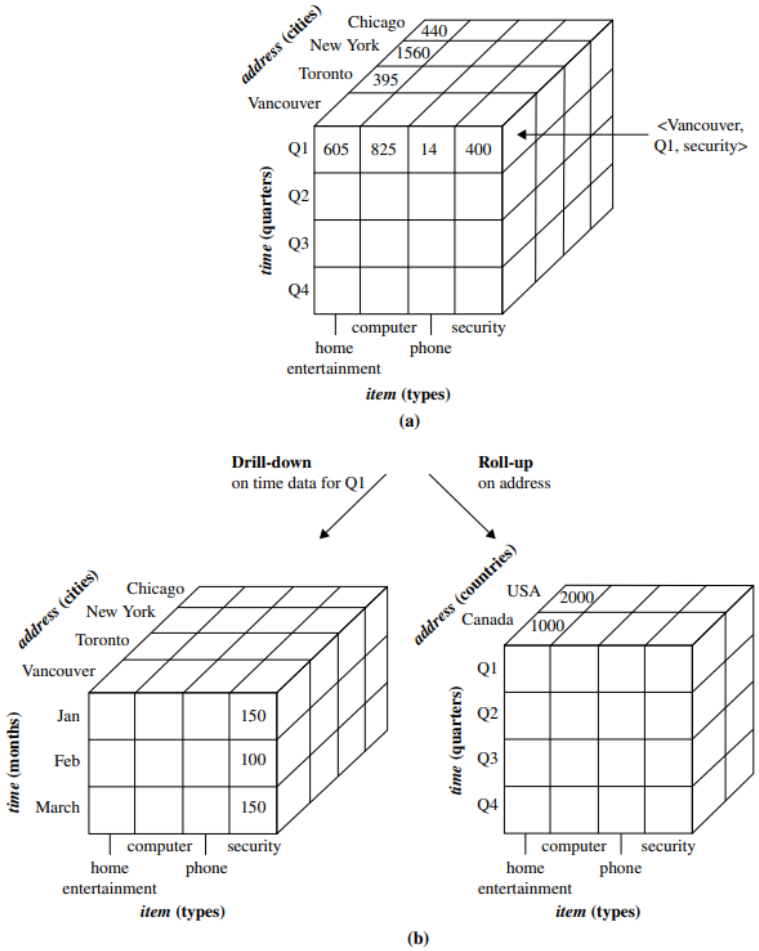

Figure: A multidimensional data cube, commonly used for data warehousing, (a) showing summarized data for AllElectronics and (b) showing summarized data resulting from drill-down and roll-up operations on the cube in (a). For improved readability, only some of the cube cell values are shown.

Data Mining: Other Data

- Time-related or sequence data, data steams, spatial data, engineering design data, hypertext and multimedia data, graph and networked data, and the Web.
- Sequence data: Time-series data, Symbolic sequence data, biological sequence data.
- Spatial data: often refers to geospace-related data stored in geospatial data repositories.
- Spatiotemporal data: Data that relates to both space and time.
  - Examples: discovering the evolutionary history of cities and lands, uncovering weather patterns, predicting earthquakes and hurricanes, and determining global warming trends.
  - Data collected from cell phones, GPS devices, Internet-based map services, weather services, and digital Earth, as well as satellite, RFID, sensor, wireless, and video technologies.
  - Moving-object data
- Web data: web content mining, web structure mining, and web usage mining.