Data Mining

Introduction

Organization

- Lectures
  - Mondays and Thursdays from 10:30 to 12:30
  - Lecturer: Mouna Kacimi
  - Office hours: appointment by email
- Labs
  - Thursdays from 14:00 to 16:00
  - Teaching Assistant: Mouna Kacimi
- Course Webpage: http://www.inf.unibz.it/~mkacimi/teaching.shtml
- Textbooks
  - Jiawei Han and Micheline Kamber, "Data Mining: Concepts and Techniques", Second Edition, 2006
  - Pang-Ning Tan, Michael Steinbach, and Vipin Kumar, "Introduction to Data Mining", Pearson Addison Wesley, 2008, ISBN: 0-32-134136-7

Project

- During Lab hours
- The project will be divided into small tasks, a new task every week
- The project can be done individually
- Groups of no more than 2 students are allowed
- You need to know how to program. If you do not know, team up with someone who knows
- You have the option to do a free project on your own: your proposal needs to be approved by the teacher

Exam Procedure

- Requirement: obtain 18 credit points in each of the following:
  - Project
  - Exam

$$\text{Final Grade} = 0.5 \times \text{Project Grade} + 0.5 \times \text{Exam Grade}$$

- Exams
  - Midterm Exam (optional) : 15 points
  - Final Exam
    - Full: 30 points
    - Partial: 15 points

$$\text{Exam Grade} = \left\{ \begin{array}{ll} \text{Midteram Grade+Partial Exam Grade} & \text{if student took the midtem exam} \\ & \\ \text{Full Exam Grade} & \text{if student did not take the midterm exam} \\ & \text{or decided not to consider the midterm exam} \end{array} \right\}$$

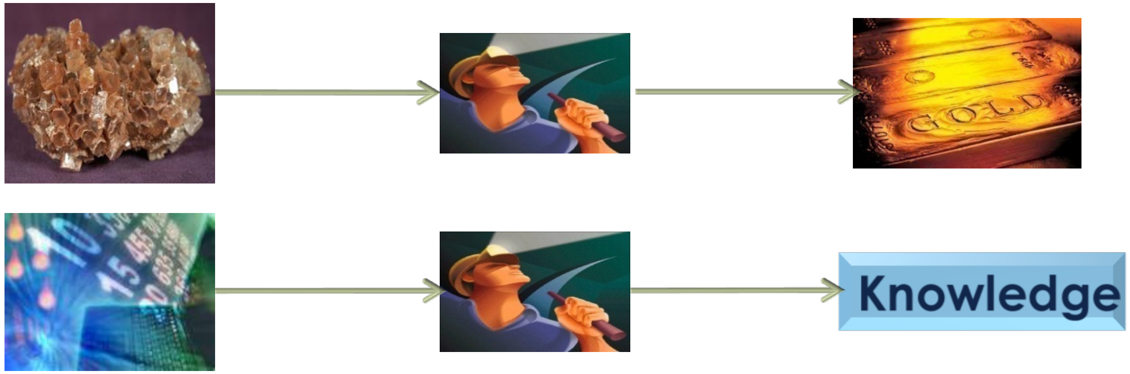
Exam Procedure

- Students must have a successful project to be able to take the final exam
- A successful project remains valid even when the student fails the exam
- If a project is unsuccessful until the day of the exam, its validity expires
- Students can do a new project until the next exam session. In this case, the teaching assistant does not guarantee support for supervising the students.

Road Map

1. Definitions & Motivations
2. Data to be mined
3. Knowledge to be discovered
4. Major Issues in Data Mining

Data Mining: what does it?



Stone

Gold Mining
Not Stone Mining

Data

Knowledge

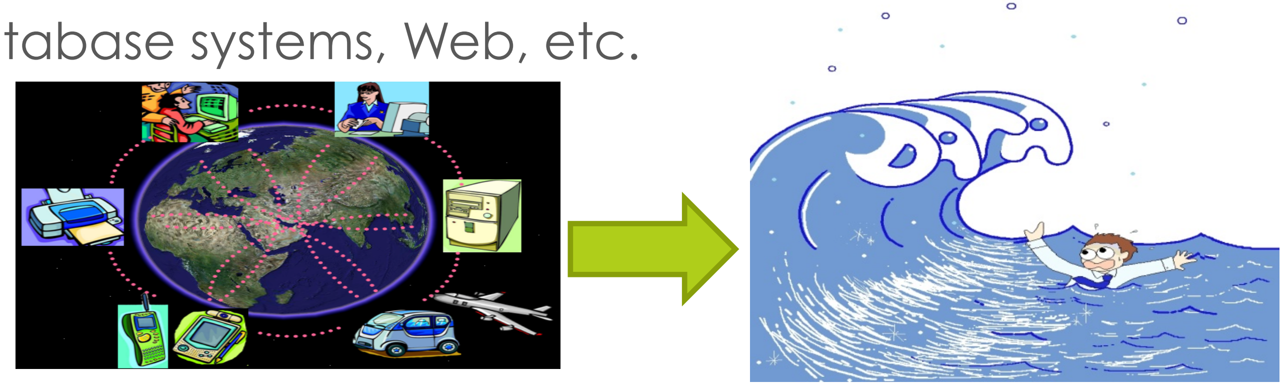
Knowledge Mining?

- 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.

Why Data Mining?

- Explosive Growth of Data: from terabytes to petabytes
- Data Collections and Data Availability
  - Crawlers, database systems, Web, etc.



  - Sources
    - Business: Web, e-commerce, transactions, etc.
    - Science: Remote sensing, bioinformatics, etc.
    - Society and everyone: news, YouTube, etc.
- **Problem**: We are drowning in data, but starving for knowledge!
- **Solution**: Use Data Mining tools for Automated Analysis of massive data sets

What Data Mining is Used For?

Financial Data Analysis

- Banks and Institutions offer a wide variety of banking services
  - Checking and saving accounts for business or individual customers
  - Credit business, mortgage, and automobile loans
  - Investment services (mutual funds)
  - Insurance services and stock investment services

- Financial data is relatively complete, reliable, and of high quality

- What to do with this data?

What Data Mining is Used For?

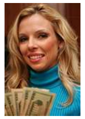
Financial Data Analysis

- Loan Payment Prediction and costumer credit policy analysis
  - Attribute selection and attribute relevance ranking may help identifying important factors and eliminate irrelevant ones
  - Example of factors related to the risk of loan payment
    - Term of the loan
    - Debt ratio
    - Payment to income ratio
    - Customer level income
    - Education level
    - Residence region
  - The bank can adjust its decisions according to the subset of factors selected

What Data Mining is Used For?

Retail Industry

- Collect huge amount of data on sales, customer shopping history, goods transportation, consumption and service, etc.
- Many stores have web sites where you can buy online. Some of them exist only online (e.g., Amazon)
- Data mining helps to
  - Identify costumer buying behaviors
  - Discover customers shopping patterns and trends
  - Improve the quality of costumer service
  - Achieve better costumer satisfaction
  - Design more effective good transportation
  - Reduce the cost of business



What Data Mining is Used For?

- Many different ways of communicating
  - Fax, cellular phone, Internet messenger, images, e-mail, computer and Web data transmission, etc.

- Great demand of data mining to help
  - Understanding the business involved
  - Identifying telecommunication patterns
  - Catching fraudulent activities
  - Making better use of resources
  - Improve the quality of service

Example of a Data Mining Problem

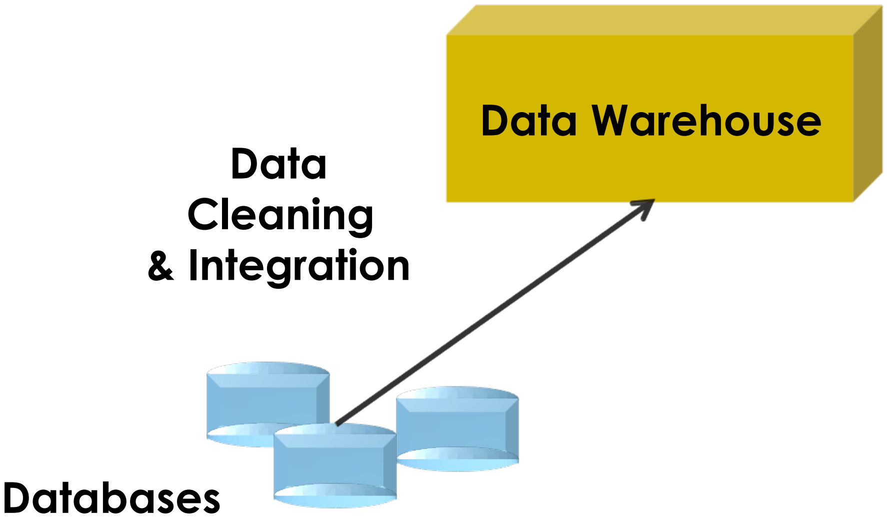
- You want to do advertisement of sport activities for a set of new users on Facebook

- These people do not have explicit information about what they like and no history of past activities

- What you know is:
  - Their age, gender, and location
  - Their friends (not necessarily new users)
  - Messages they exchange with friends

Knowledge Discovery (KDD) Process

- Data Mining as a step in the knowledge discovery process

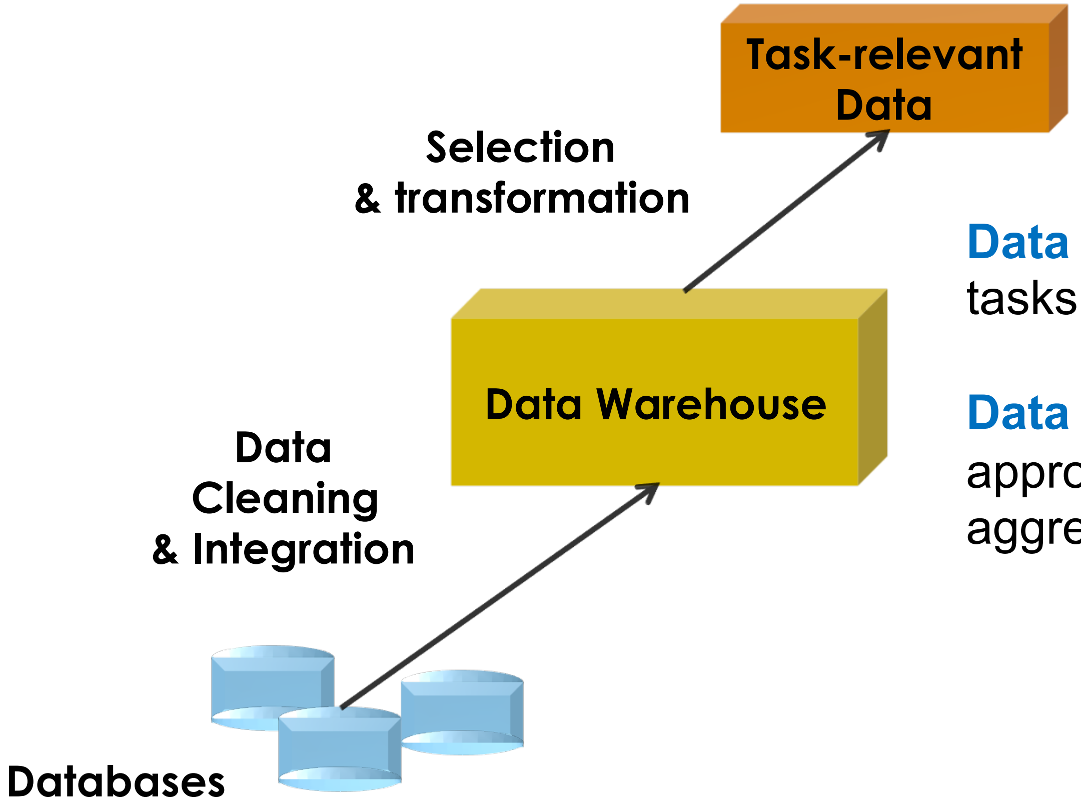


Data Cleaning: Remove noise and inconsistent data

Data Integration: Combine multiple data sources

Knowledge Discovery (KDD) Process

- Data Mining as a step in the knowledge discovery process

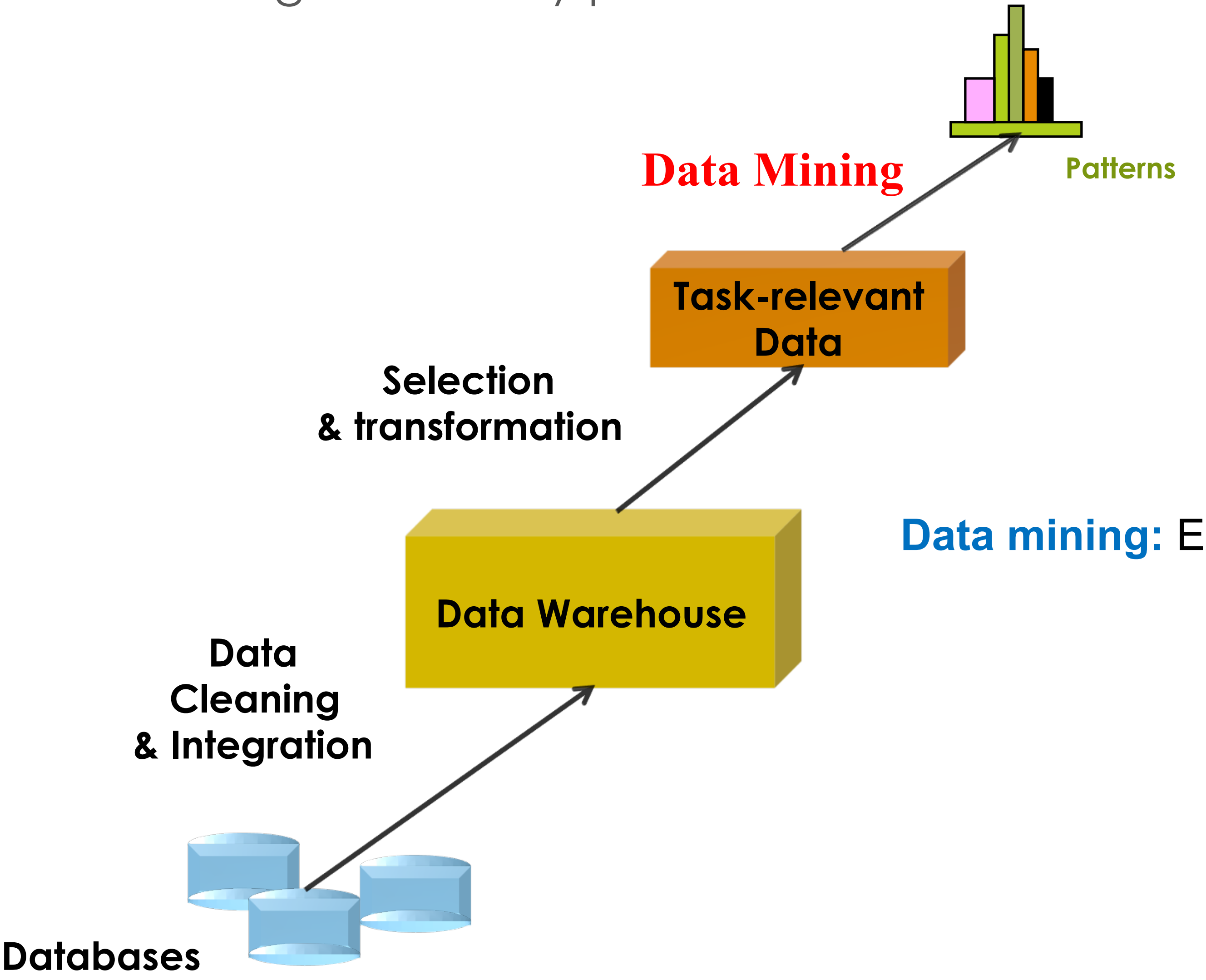


Data Selection: Data relevant to analysis tasks are retrieved form the data

Data transformation: Transform data into appropriate form for mining (summary, aggregation, etc.)

Knowledge Discovery (KDD) Process

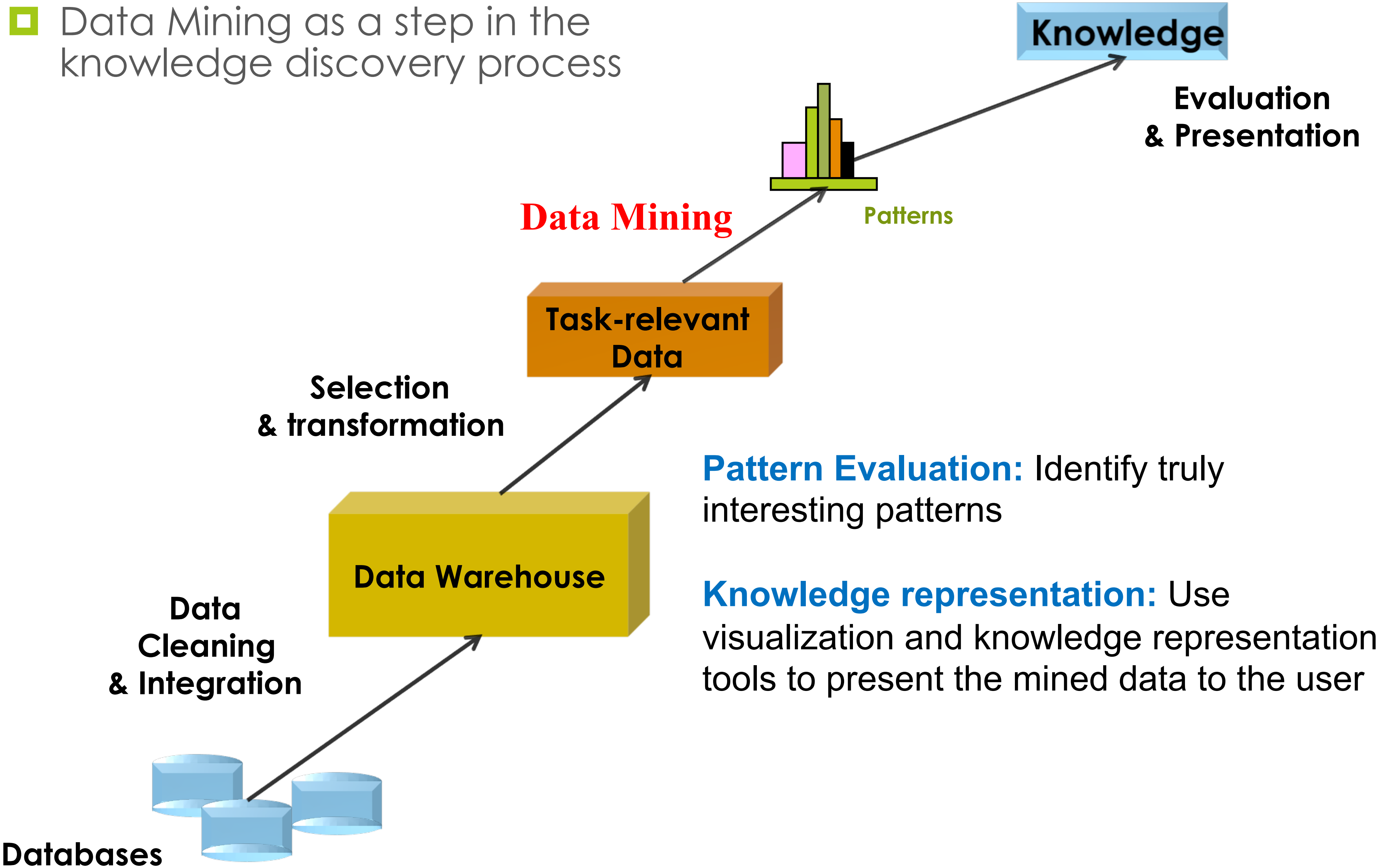
- Data Mining as a step in the knowledge discovery process



Data mining: Extract data patterns

Knowledge Discovery (KDD) Process

- Data Mining as a step in the knowledge discovery process

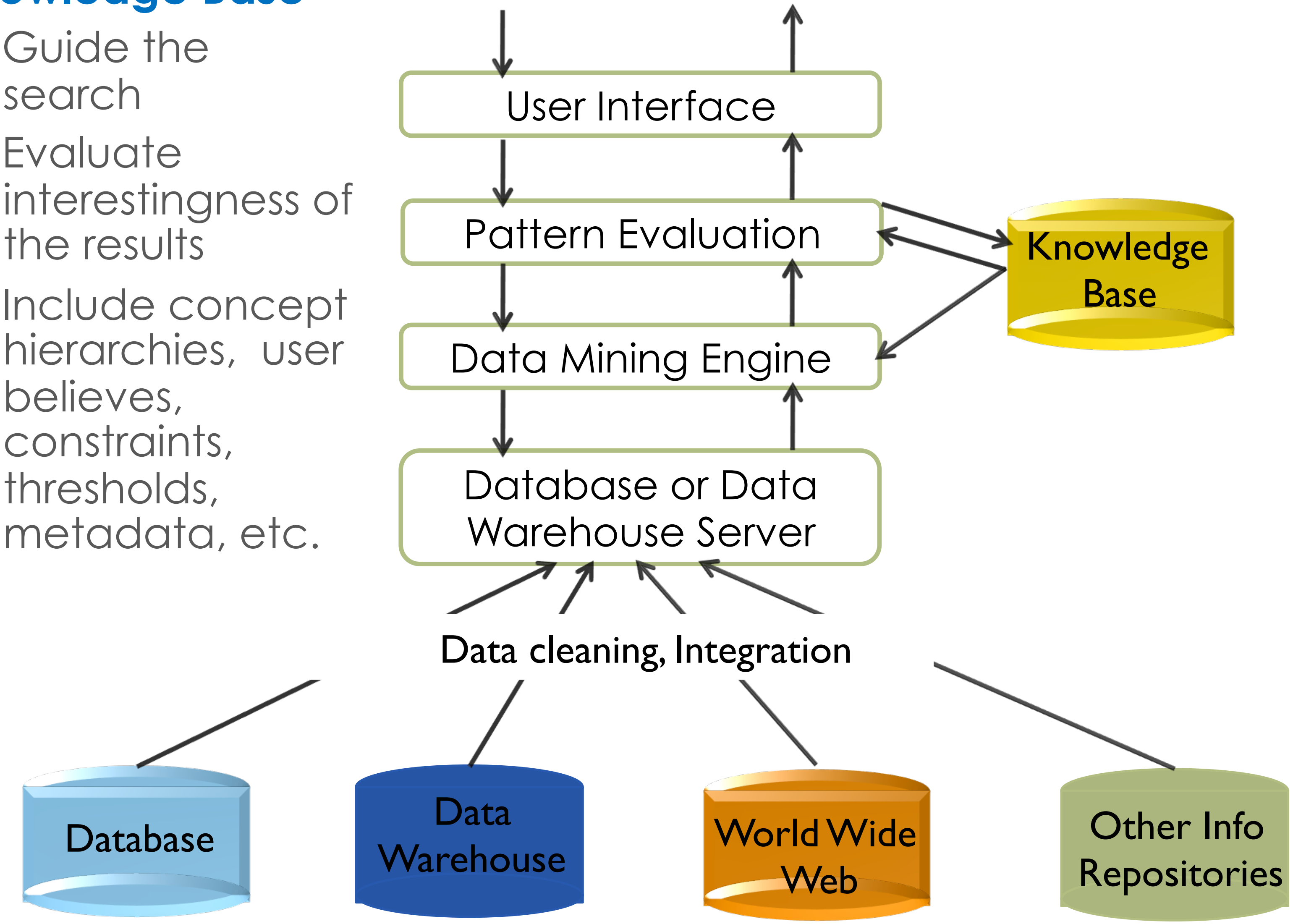

Knowledge
Evaluation & Presentation
Patterns
Data Mining
Task-relevant Data
Selection & transformation
Data Warehouse
Data Cleaning & Integration
Databases

Pattern Evaluation: Identify truly interesting patterns

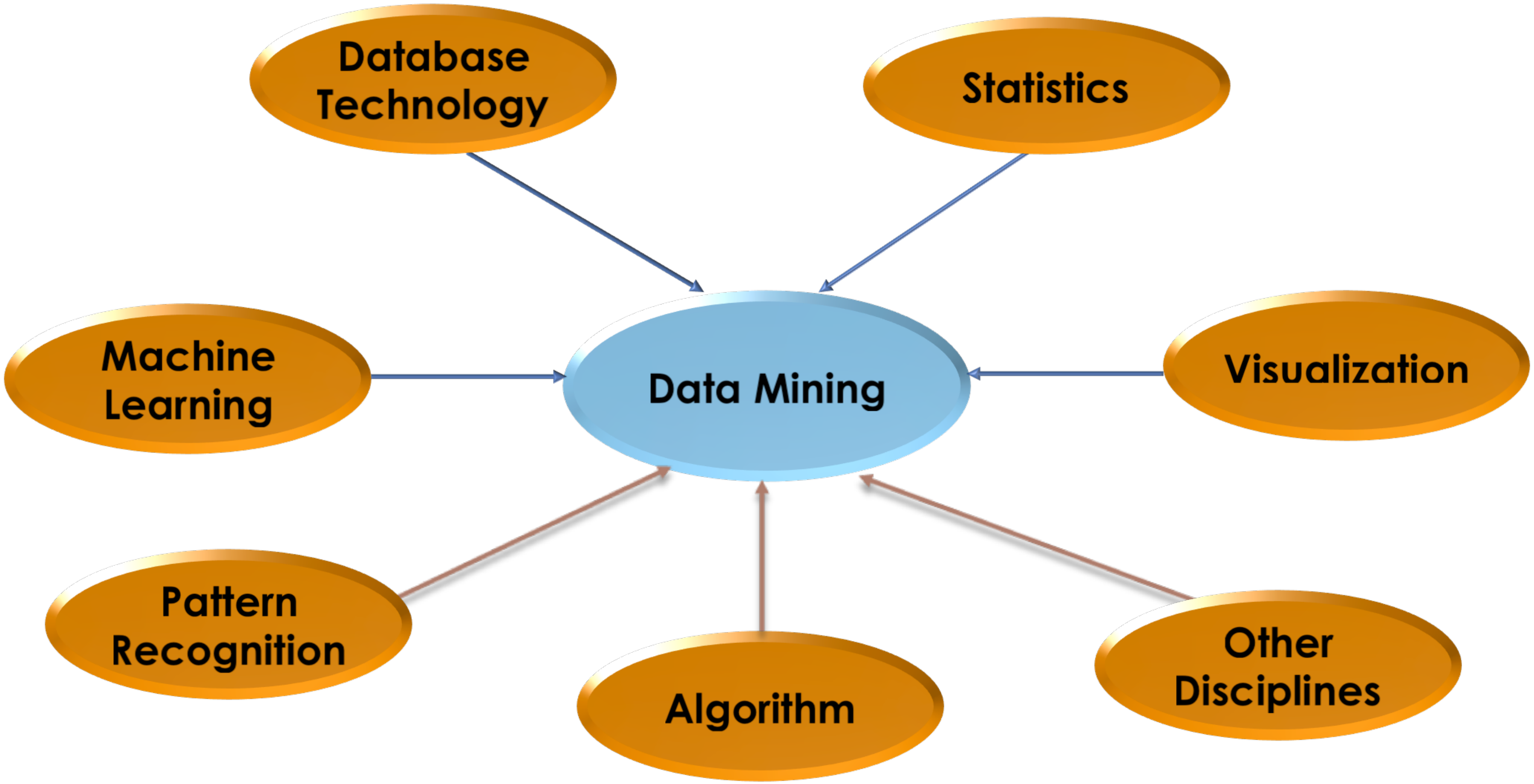
Knowledge representation: Use visualization and knowledge representation tools to present the mined data to the user

Typical Architecture of a DM System

- **Knowledge Base**
  - Guide the search
  - Evaluate interestingness of the results
  - Include concept hierarchies, user believes, constraints, thresholds, metadata, etc.



Confluence of Multiple Disciplines



Database Technology

Statistics

Machine Learning

Data Mining

Visualization

Pattern Recognition

Algorithm

Other Disciplines

Why Confluence of Multiple Disciplines?

- **Tremendous amount of data**
  - Scalable algorithms to handle terabytes of data (e.g., Flickr hits 6 billion images but facebook does that every 2 months http://thenextweb.com/socialmedia/2011/08/05/flickr-hits-6-billion-total-photos-but-facebook-does-that-every-2-months//)
- **High dimensionality of data**
  - Data can have tens of thousands of features (e,g., DNA microarray)
- **High complexity of data**
  - Data can be highly complex, can be of different types, and can include different descriptors
    - Images can be described using text and visual features such as color, texture, contours, etc.
    - Videos can be described using text, images and their descriptors, audio phonemes, etc.
    - Social networks can have a complex structure…
- **New and sophisticated applications**

Different Views of Data Mining

- **Data View**
  - Kinds of data to be mined
- **Knowledge view**
  - Kinds of knowledge to be discovered
- **Method view**
  - Kinds of techniques utilized
- **Application view (seen before)**

Road Map

1. Definitions & Motivations
2. Data to be mined
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4. Major Issues in Data Mining

Data to be Mined

- In principle, data mining should be applicable to any data repository

- This lecture includes examples about:

    - Relational databases
    - Data warehouses
    - Transactional databases
    - Advanced database systems

Relational Databases

- **Database System**
  - Collection of interrelated data, known as **database**
  - A set of software programs that manage and access the data

- **Relational Databases (RD)**
  - A collection of tables. Each one has a unique name
  - A table contains a set of attributes (columns) & tuples (rows).
  - Each object in a relational table has a unique key and is described by a set of attribute values.
  - Data are accessed using database

  queries (SQL): projection, join, etc.

Costumers

cust_Id	Name	age	income
152 …	Anna …	27 …	24000 € …

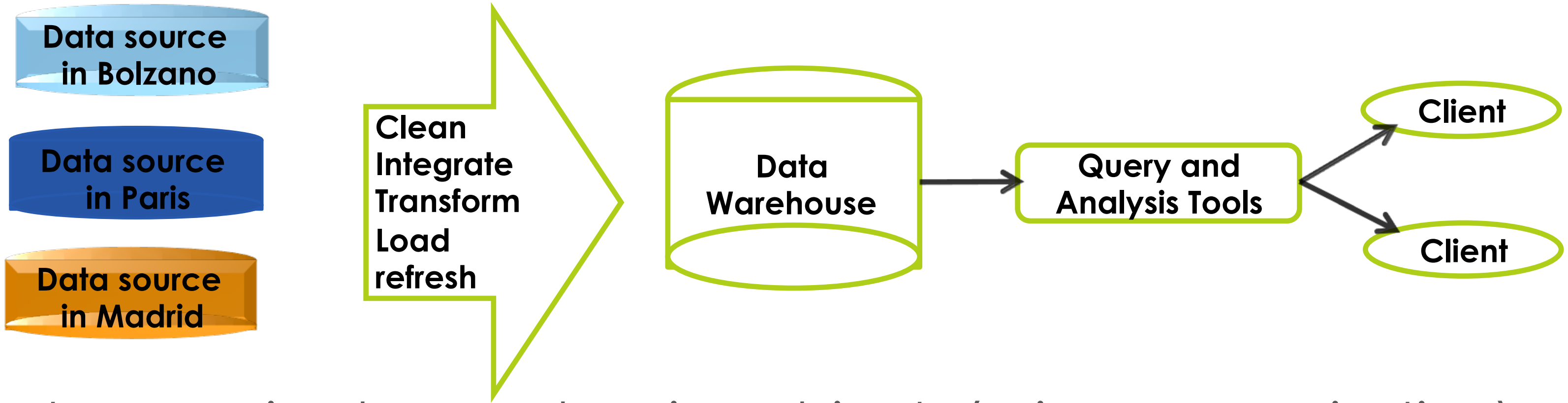
Purchases

trans_Id	cust_Id	method	Amount
T156 …	152 …	Visa …	1357 € …

- **Data Mining applied to RD**
  - Search for trends or data patterns
  - Example: predict the credit risk of costumers based on their income, age and expenses.

Data Warehouses

- A data warehouse (DW) is a repository of information collected from multiple sources, stored under a unified schema.



- Data organized around major subjects (using summarization)
- Multidimensional database structure (e.g., data Cube)
  - Dimension = one attribute or a set of attributes
  - Cell = stores the value of some aggregated measures.
- **Data Mining applied to DW**
  - Data warehouse tools help data analysis
  - Data Mining tools are required to allow more in-depth and automated analysis

Transactional Databases

- A transactional database (TD) consists of a file where each record represents a transaction.
- A transaction includes a unique transaction identifier (trans_id) and a list of the items making the transaction.
- A transaction database may include other tables containing other information regarding the sale (customer_Id, location, etc.)
- Basic analysis (examples)
  - Show me all the items purchased by David Winston?
  - How many transactions include item number 5?

trans_Id	List of items_IDs
T100	I1,I3,I8,I16
T200	I2,I8
…	…

- **Data Mining on TD**
  - Perform a deeper analysis
  - Example: Which items sold well together?
  - Basically, data mining systems can identify frequent sets in transactional databases and perform *market basket data analysis*.

Advanced Database Systems (1)

- Advanced database systems provide tools for handling **complex** data
  - Spatial data (e.g., maps)
  - Engineering design data (e.g., buildings, system components)
  - Hypertext and multimedia data (text, image, audio, and video)
  - Time-related data (e.g., historical records)
  - Stream data (e.g., video surveillance and sensor data)
  - World Wide Web, a huge, widely distributed information repository made available by Internet
- Require **efficient** data structures and **scalable** methods to handle
  - Complex object structures and variable length records
  - Semi structured or unstructured data
  - Multimedia and spatiotemporal data
  - Database schema with complex and dynamic structures

Advanced Database Systems (2)

- **Example: World Wide Web**
  - Provide rich, worldwide, online and distributed information services.
  - Data objects are linked together
  - Problems
    - Data can be highly unstructured
    - Understand the semantic of web pages

- **Data Mining on WWW**
  - Web usage Mining (user access pattern)
    - Improve efficiency and make better marketing decisions
  - Authoritative Web page Analysis
    - Ranking web pages based on their importance
  - Automated Web page clustering and classification
    - Group and arrange web pages based on their content
  - Web community analysis
    - Identify hidden web social networks and observe their evolution

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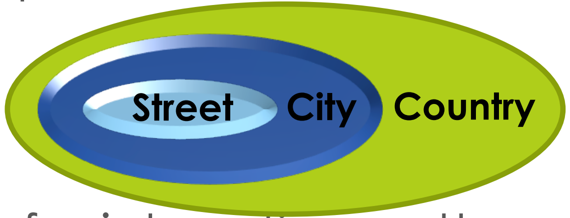
Knowledge to be Discovered

- Data mining functionalities are used to specify the kind of patterns to be found in data mining tasks
- Data mining tasks can be classified into two categories
  - **Descriptive :** Characterize the general properties of the data
  - **Predictive :** Perform inference on the current data to make predictions
- **What to extract?**
  - Users may not have an idea about what kinds of patterns in their data can be interesting
- **What to do?**
  - Have a data mining system that can mine multiple types of patterns to handle different user and application needs.
  - Discover patterns at various granularities (levels of abstraction)
  - Allow users to guide the search for interesting patterns



Example of different granularities

Characterization and Discrimination (1)

- Data can be associated with classes or concepts

Example of data from a store

Classes

printers

computers

Concepts

Big-Spenders

Budget-Spenders

- **Class/Concept descriptions:** describe individual classes and concepts in summarized, concise, and precise way.
  - Data characterization
    - Summarize the data of the class under study (**target class**)
  - Data Discrimination
    - Compare the target class with a set of comparative classes (**contrasting classes**)
  - Data characterization & Discrimination
    - Perform both analysis

Characterization and Discrimination (2)

Data Characterization

- Output: charts, curves, multidimensional data cubes, etc.
- Example

Summarize the characteristics of costumers who spend more than 1000€ →

Costumers profile

- 40-50 years old
- Employed
- excellent credit ratings

Data Discrimination

- Output: similar to characterization + comparative measures
- Example

Compare customers who shop for computer products regularly(more than 2 times a month) with those who rarely shop for such products(less then three times a year) →

Comparative profile

Frequent costumers	Rare costumers
80% •Are between 20 and 40 •Have university education	60% •Are senior or youths •Have no university degree

Frequent Patterns, Associations, Correlations

- **Frequent patterns** are patterns occurring frequently in the data (e.g., item-sets, sub-sequences, and substructures)
  - Frequent item-sets: items that frequently appear together
    - Example in a transactional data set: **bread** and **milk**
  - Frequent Sequential pattern: a frequently occurring subsequence
    - Example in a transactional data set: buy **first PC**, **second digital camera**, **third memory card**

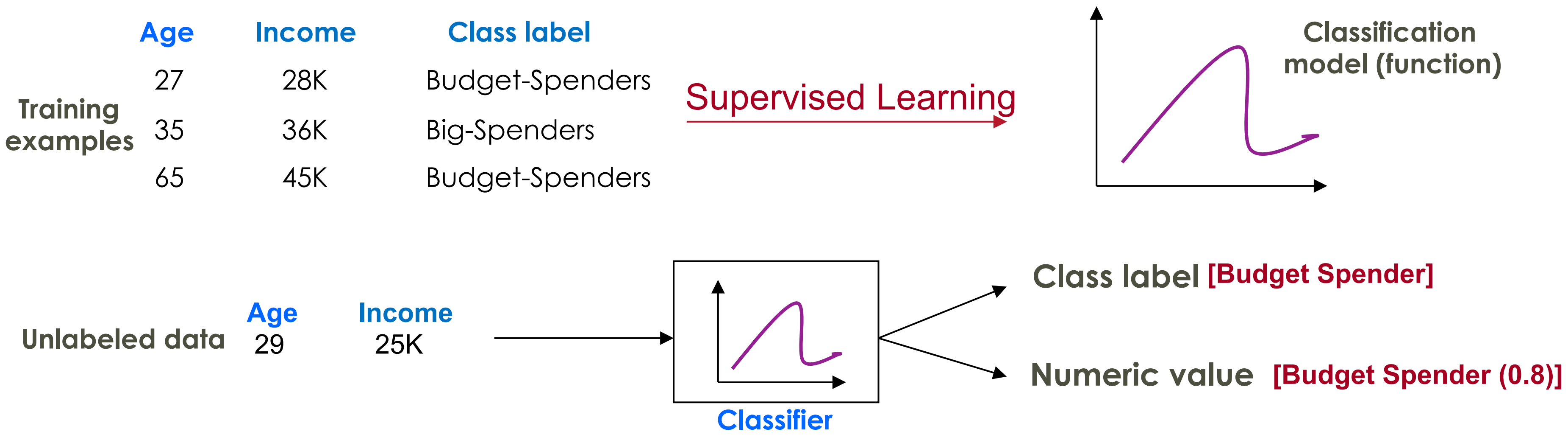
- **Association Analysis**
  - Derive some association rules
    - *buys(X, "computer") ⇒ buys (X, "software") [support =1%, confidence=50%]*
    - *age(X, "20...29") ∧ income(X, "20K...29K") ⇒ buys (X, "CD player")*

      [support =2%, confidence=60%]

- **Correlation Analysis**
  - Uncover interesting statistical correlations between associated attribute-value pairs

Classification & Prediction

- Construct models (functions) based on some training examples
- Describe and distinguish classes or concepts for future prediction
- Predict some unknown class labels



Training examples

Age	Income	Class label
27	28K	Budget-Spenders
35	36K	Big-Spenders
65	45K	Budget-Spenders

Supervised Learning

Classification model (function)

Unlabeled data

Age	Income
29	25K

Classifier

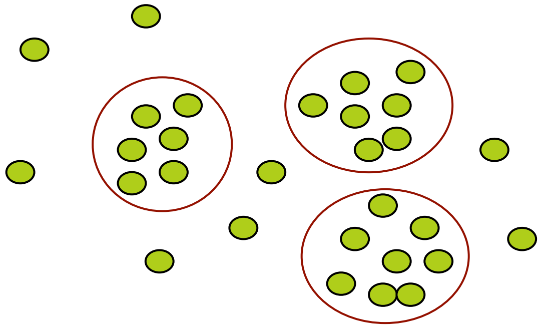
Class label [Budget Spender]

Numeric value [Budget Spender (0.8)]

- **Typical Models**: Decision trees, Bayesian classifiers, Regression, etc.
- **Typical Applications**: Credit card fraud detection, classifying web pages, stars, diseases, etc

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



- **Typical methods**: Hierarchical, density-based, Grid-based, Model-Based, constraint-based , etc.
- **Typical Applications**: WWW, social networks, Marketing, Biology, Library, etc.

Outlier Analysis

- **Outlier**: A data object that does not comply with the general behavior of the data learning (i.e., Class label is unknown)
- Noise or exception? — One person’s garbage could be another person’s treasure

Or

?

- **Typical methods:** Product of clustering or regression analysis, etc
- **Typical Applications:** Useful in fraud detection:
  - How to uncover fraudulent usage of credit card?
  - Detect purchases of extremely large amounts for a given account number in comparison to regular charges incurred by the same account
  - Outliers may also be detected with respect to the location and type of purchase, or the frequency.

Road Map

1. Definitions & Motivations
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Major Challenges of Data Mining

- Efficiency and scalability of data mining algorithms
- Parallel, distributed, stream, and incremental mining methods
- Handling high-dimensionality, noise, uncertainty, and incompleteness of data
- Incorporation of constraints, expert knowledge, and background knowledge in data mining
- Pattern evaluation and knowledge integration
- Mining diverse and heterogeneous kinds of data
- Application-oriented and domain-specific data mining
- Protection of security, integrity, and privacy in data mining

Summary

- Data Mining is a process of extracting knowledge from data
- Data to be mined can be of any type
  - Relational Databases, Advanced databases, etc.
- Knowledge to be discovered
  - Frequent patterns, correlations, associations, classification, prediction, clustering
- Data Mining is interdisciplinary
  - Large amount of complex data and sophisticated applications
- Challenges of data Mining
  - Efficiency, scalability, parallel and distributed mining, handling high dimensionality, handling noisy data, mining heterogeneous data, etc.