POLITECNICO DI MILANO

Data Mining

Data Mining and Text Mining (UIC 583 @ Politecnico di Milano)

Lecture outline

- Why Data Mining?
- What is Data Mining?
- What are the typical tasks?
- What are the primitives?
- What are the typical applications?
- What are the major issues?

Why
Data Mining?

Why Data Mining? "Necessity is the mother of invention"

- Explosive Growth of Data
  - Terabytes of available data
  - Data collections and data availability
  - Major sources of abundant data
- Pressing need for the automated analysis of massive data

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)
  - Global information systems

Examples

- In vitro fertilization
  - Given: embryos described by 60 features
  - Problem: selection of embryos that will survive
  - Data: historical records of embryos and outcome

- Cow culling
  - Given: cows described by 700 features
  - Problem: selection of cows that should be culled
  - Data: historical records and farmers' decisions

Examples

- Customer attrition
  - Given: customer information for the past months
  - Problem: predict who is likely to attrite next month, or estimate customer value
  - Data: historical customer records

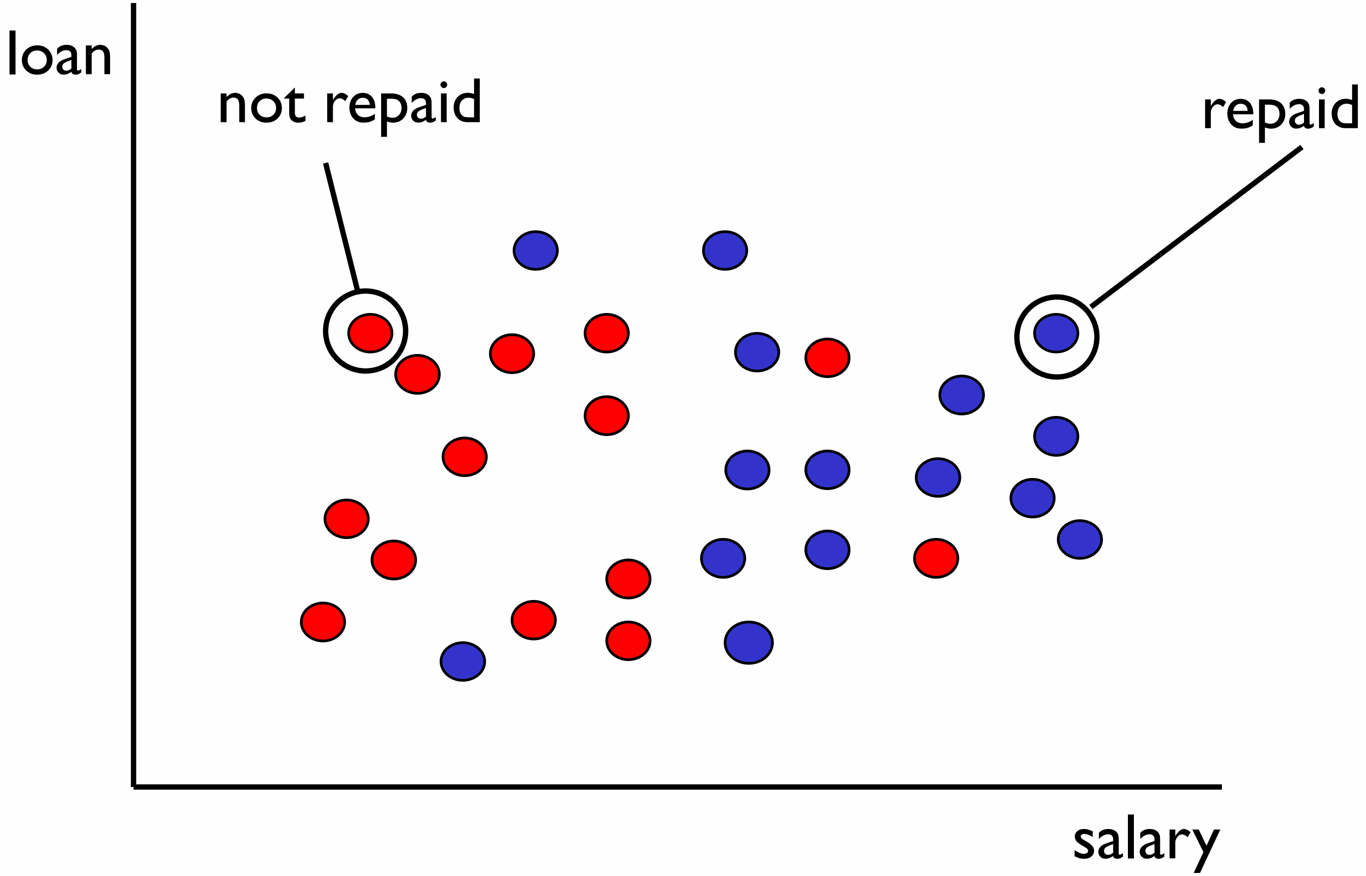
- Credit assessment
  - Given: a loan application
  - Problem: predict whether the bank should approve the loan
  - Data: records from other loans

What is Data Mining?

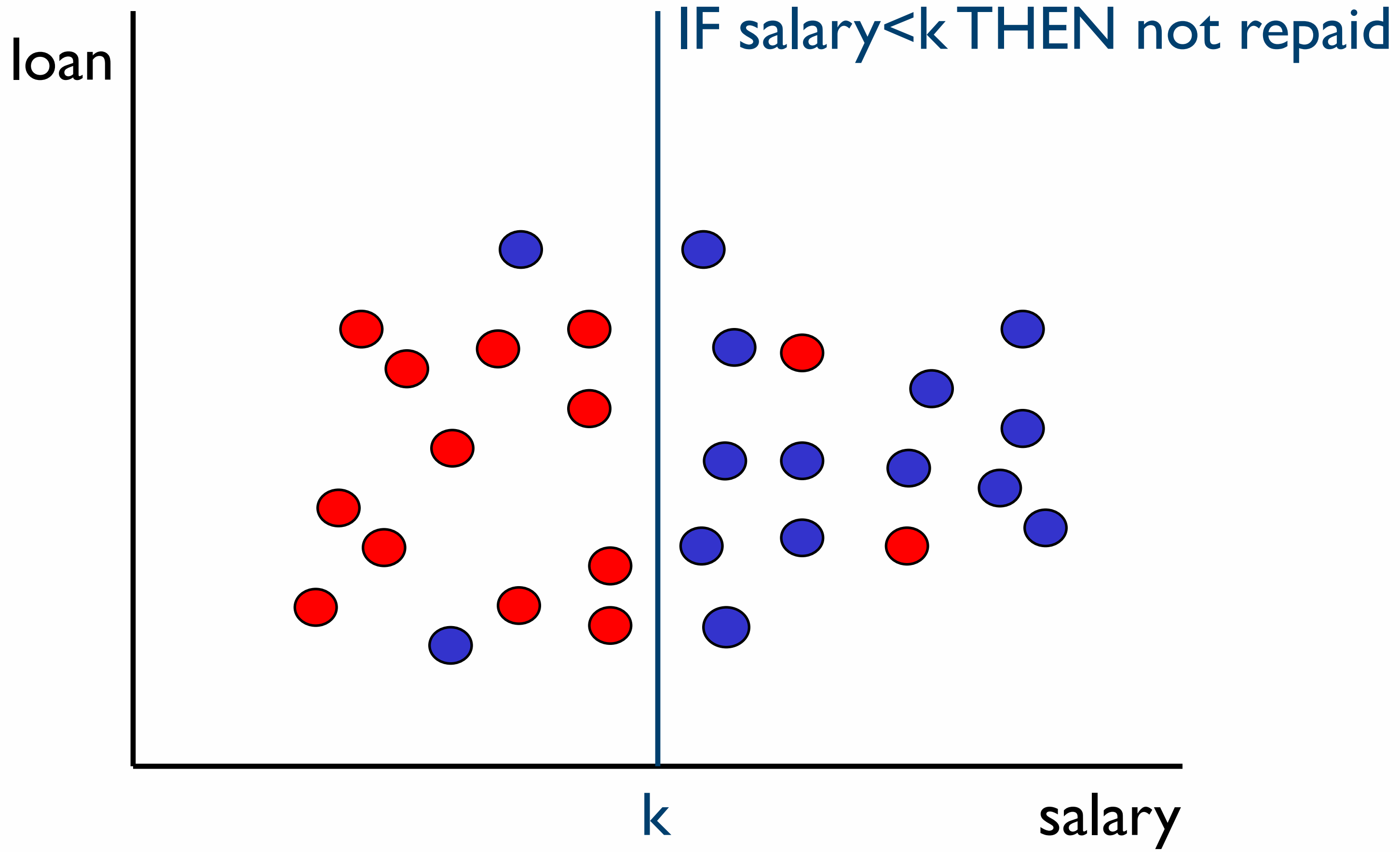
What is Data Mining?

- The non-trivial process of identifying
  - valid
  - novel
  - potentially useful, and
  - ultimately understandable patterns in data.
- Alternative names,
  - Data Fishing, Data Dredging (1960-)
  - Data Mining (1990-), used by DB and business
  - Knowledge Discovery in Databases (1989-), used by AI
  - Business Intelligence, Information Harvesting, Information Discovery, Knowledge Extraction, ...
- Currently, Data Mining and Knowledge Discovery are used interchangeably

Example: Credit Risk



Example: Credit Risk



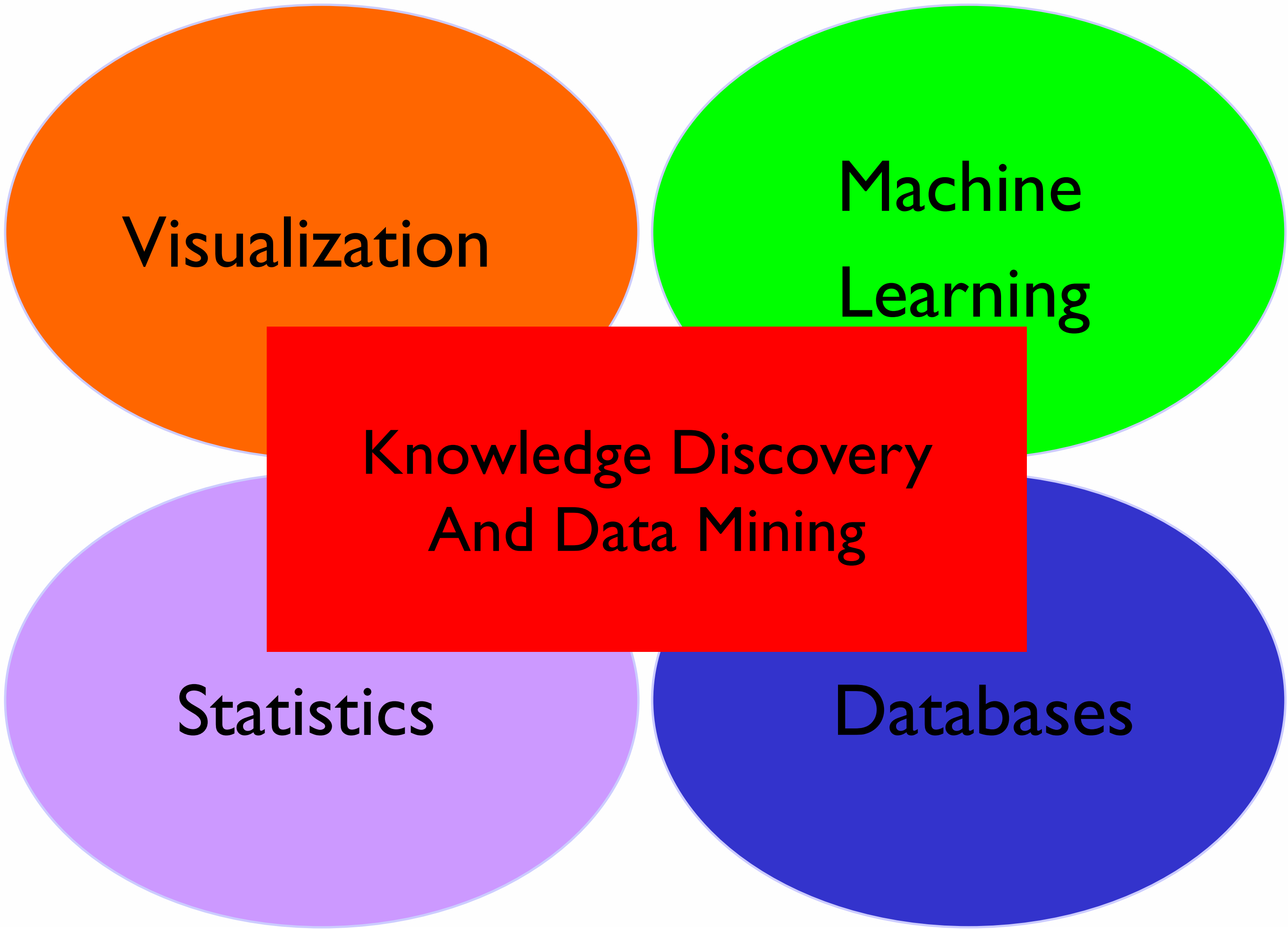
Example: Credit Risk

- Is it valid?
  - The pattern has to be valid with respect to a certainty level (rule true for the 86%)
- Is it novel?
  - The value k should be previously unknown or obvious
- Is it useful?
  - The pattern should provide information useful to the bank for assessing credit risk
- Is it understandable?

What is the general idea?

- Build computer programs that sift through databases automatically, seeking regularities or patterns
- There will be problems
  - Most patterns are banal and uninteresting
  - Most patterns are spurious, inexact, or contingent on accidental coincidences in the particular dataset used
  - Real data is imperfect: Some parts will be garbled, and some will be missing
- Algorithms need to be robust enough to cope with imperfect data and to extract regularities that are inexact but useful

What are the related fields?



Statistics, Machine Learning, and Data Mining

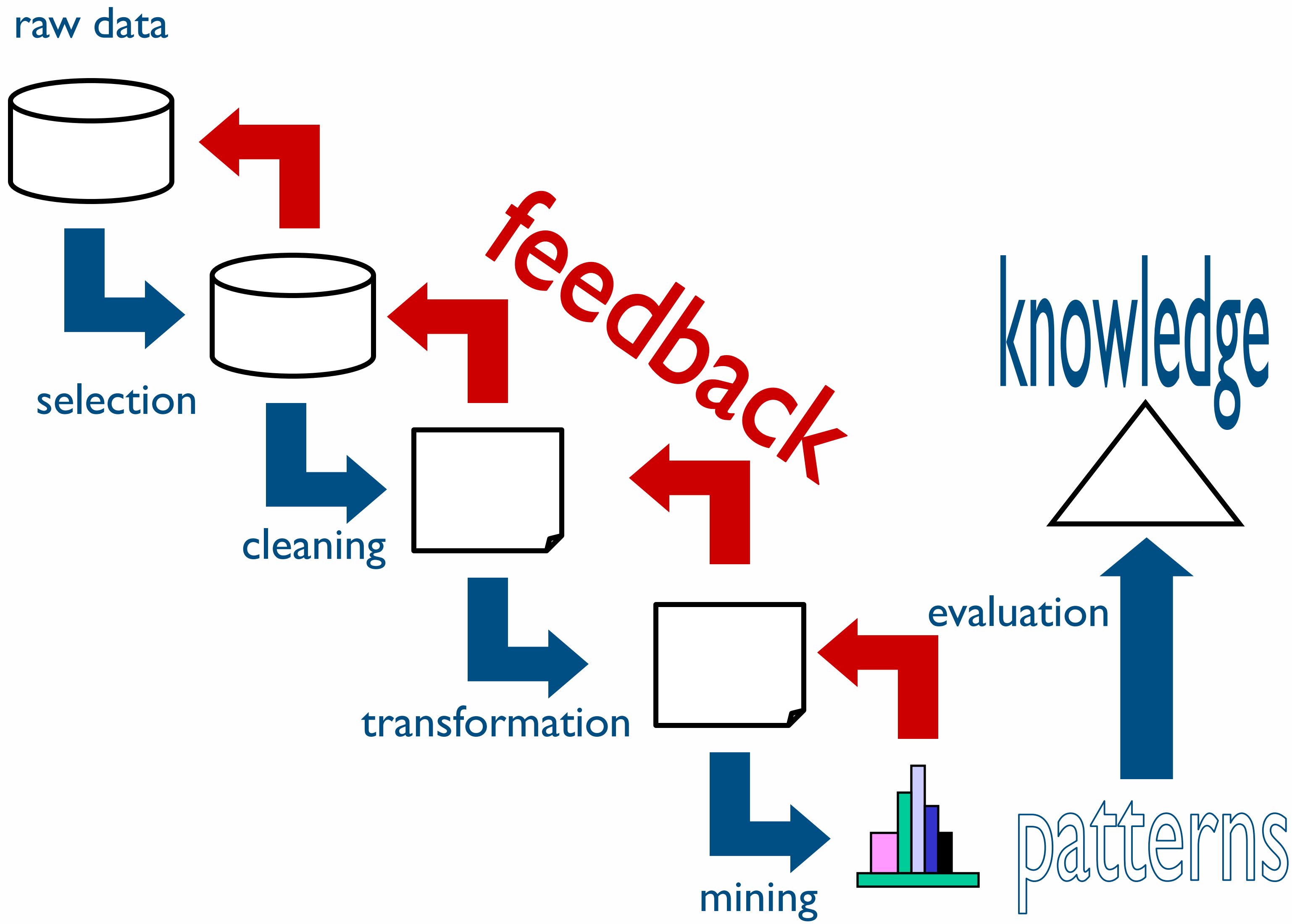
- Statistics:
  - more theory-based, focused on testing hypotheses
- Machine learning
  - more heuristic, focused on building program that learns, more general than Data Mining
- Knowledge Discovery
  - integrates theory and heuristics
  - focus on the entire process of discovery, including data cleaning, learning, integration and visualization
- Data Mining
  - focus on the algorithms to extract patterns from data

Distinctions are blurred!

Why not traditional data analysis?

- Tremendous amount of data
  - High scalability to handle terabytes 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

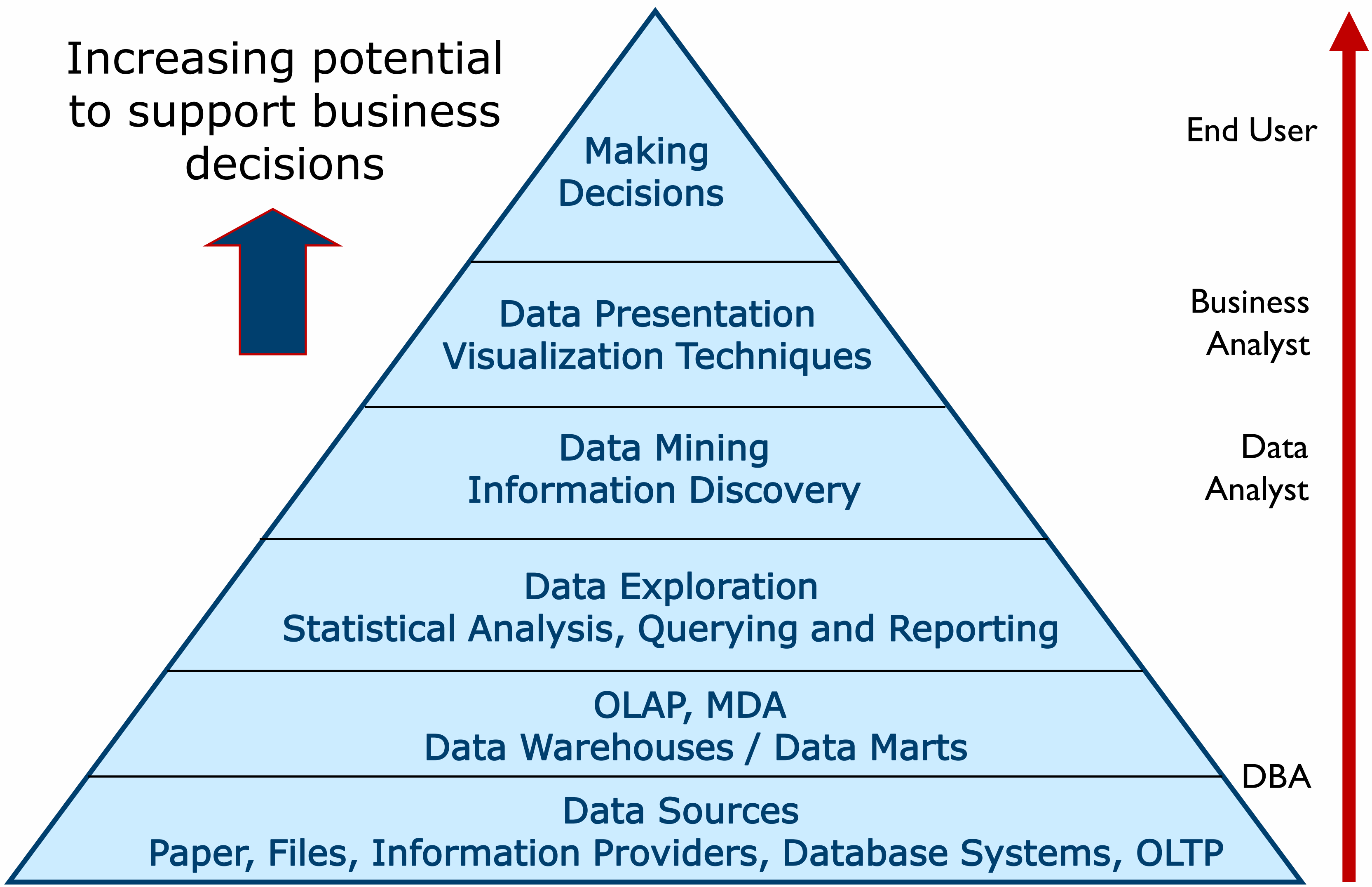
Knowledge Discovery Process



Knowledge Discovery Process
What are the main steps?

- Learning the application domain to extract relevant prior knowledge and goals
- Data selection
- Data cleaning
- Data reduction and transformation
- Mining
  - Select the mining approach: classification, regression, association, clustering, etc.
  - Choosing the mining algorithm(s)
  - Perform mining: search for patterns of interest
- Pattern evaluation and knowledge presentation
  - visualization, transformation, removing redundant patterns, etc.
- Use of discovered knowledge

Knowledge Discovery and Business Intelligence



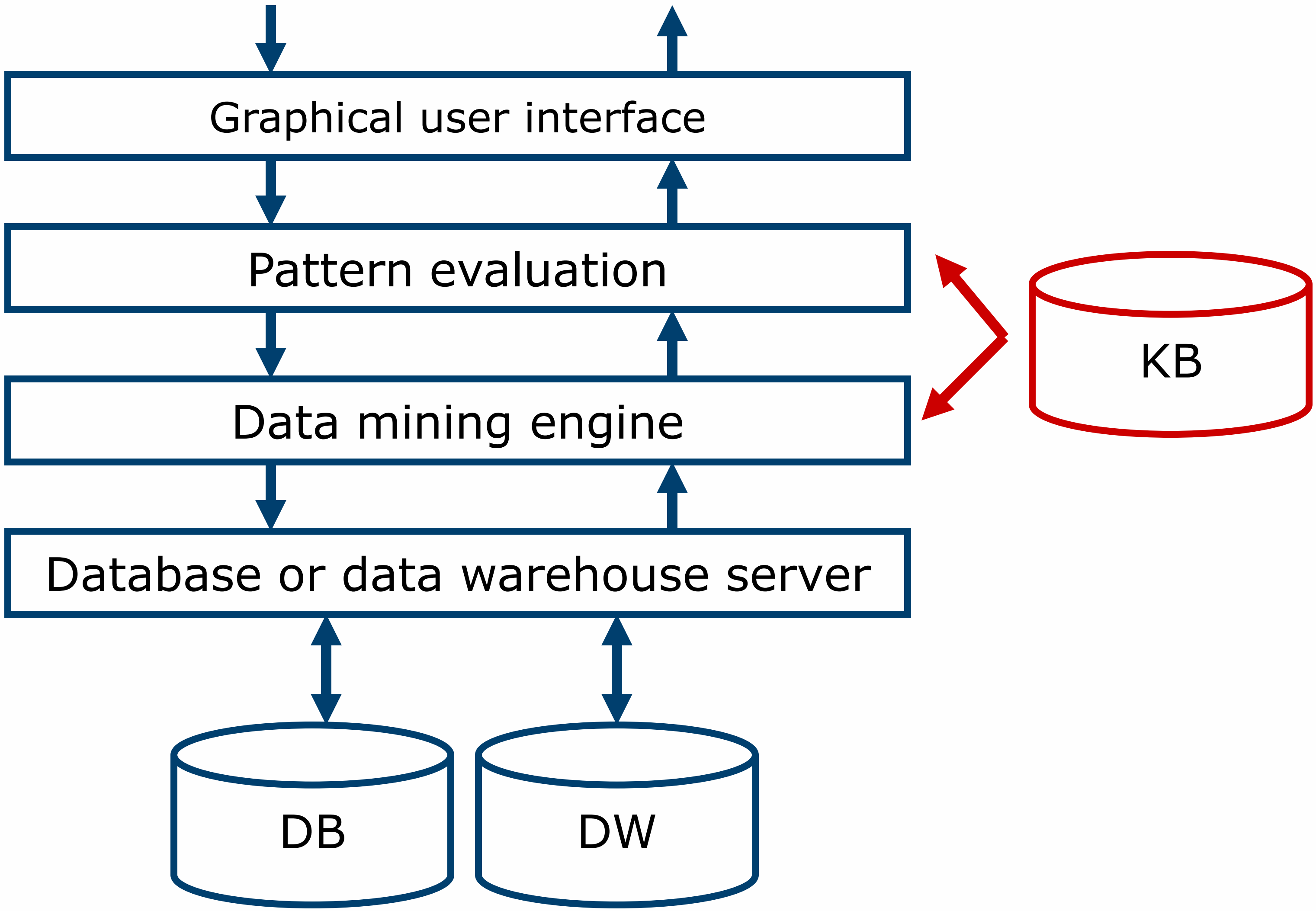
Integration of Data Mining and Data Warehousing

- 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

Coupling Data Mining with Data bases and Datawarehouses

- No coupling—flat file processing, not recommended
- Loose coupling
  - Fetching data from DB/DW
- Semi-tight coupling—enhanced DM performance
  - Provide efficient implement a few data mining primitives in a DB/DW system, e.g., sorting, indexing, aggregation, histogram analysis, multiway join, precomputation of some stat functions
- Tight coupling—A uniform information processing environment
  - DM is smoothly integrated into a DB/DW system, mining query is optimized based on mining query, indexing, query processing methods, etc.

Architecture of a Typical Knowledge Discovery System

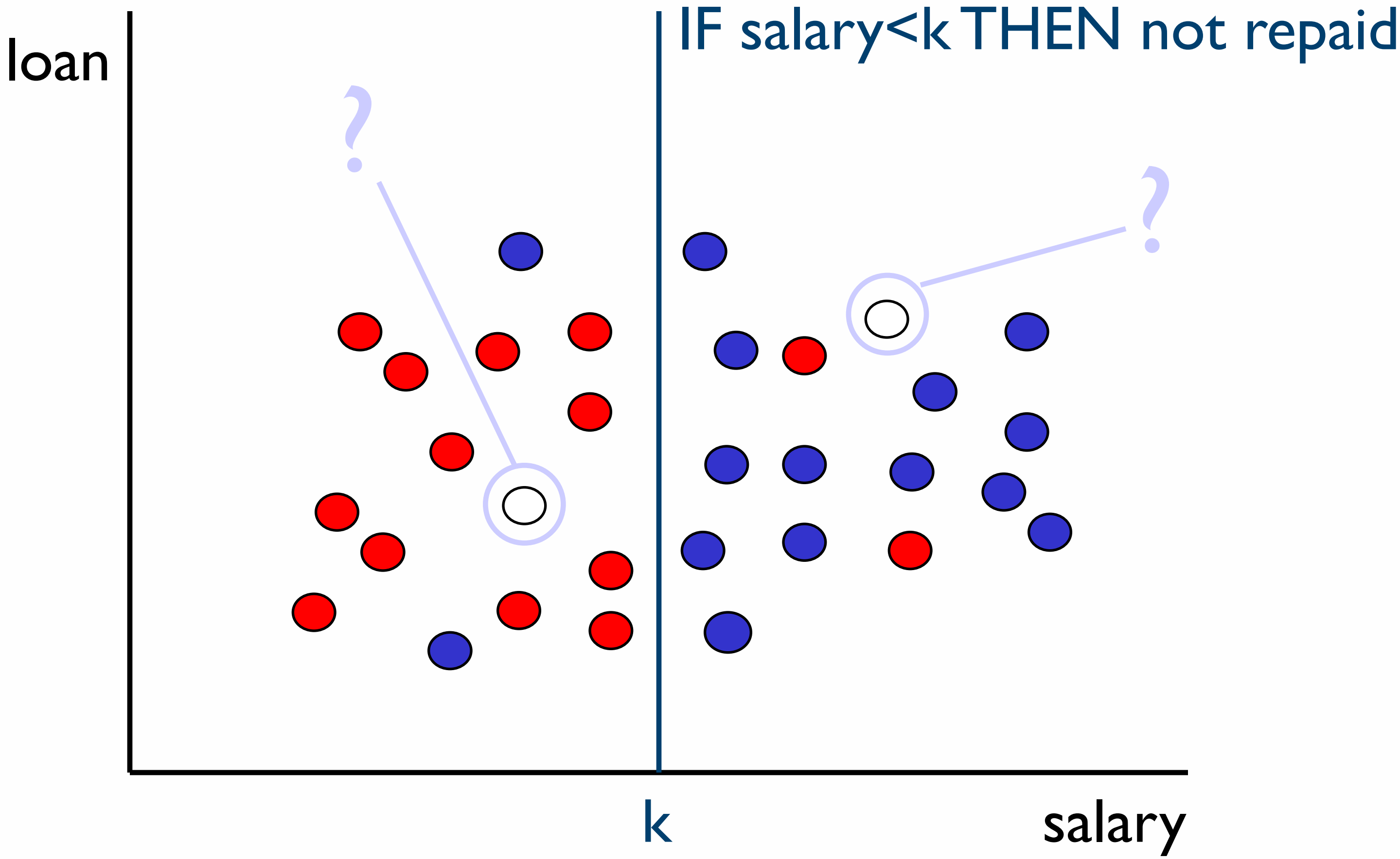


What tasks?

Major Data Mining Tasks

- Classification: predicting an item class
- Clustering: finding clusters in data
- Associations: frequent occurring events…
- Visualization: to facilitate human discovery
- Summarization: describing a group
- Deviation Detection: finding changes
- Estimation: predicting a continuous value
- Link Analysis: finding relationship

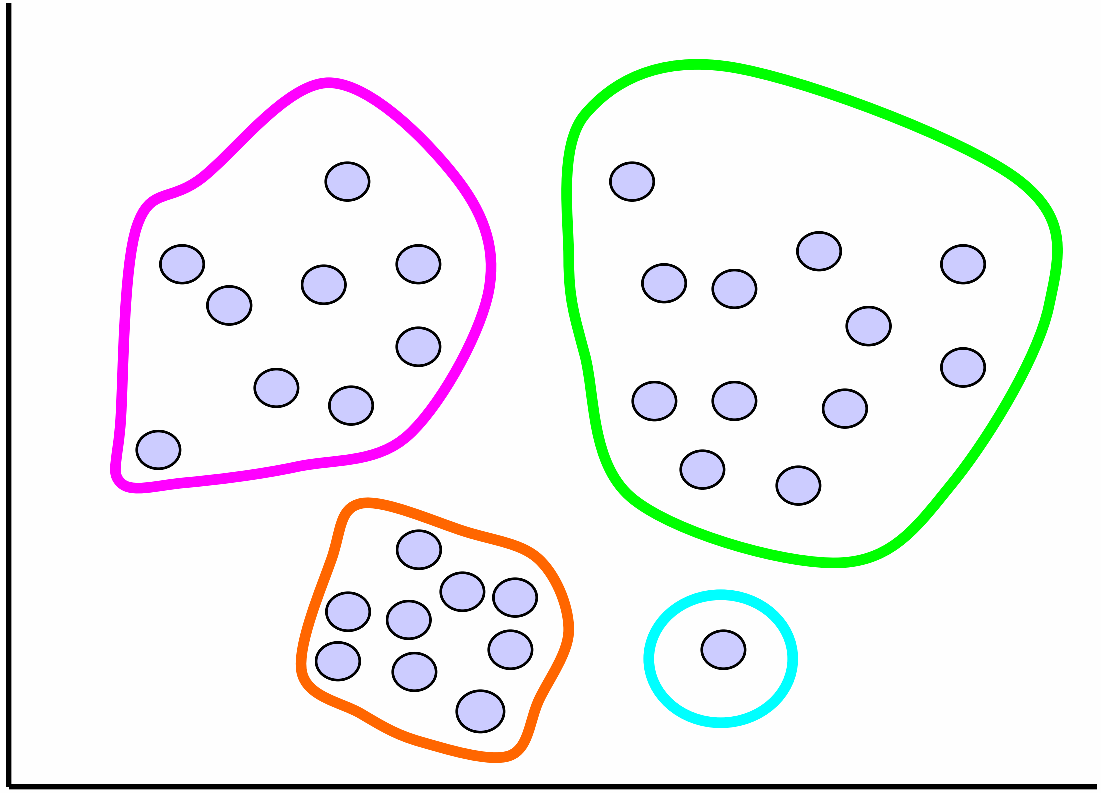
Data Mining Tasks: classification



Data Mining Tasks: classification

- Classification and Prediction
  - Finding models (functions) that describe and distinguish classes or concepts
  - The goal is to describe the data or to make 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 numerical values

Data Mining Tasks: clustering



- Cluster analysis
  - The 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

Bread
Peanuts
Milk
Fruit
Jam

Bread
Jam
Soda
Chips
Milk
Fruit

Steak
Jam
Soda
Chips
Bread

Jam
Soda
Peanuts
Milk
Fruit

Is there something interesting?

Jam
Soda
Chips
Milk
Bread

Fruit
Soda
Chips
Milk

Fruit
Soda
Peanuts
Milk

Fruit
Peanuts
Cheese
Yogurt

Data Mining Tasks: associations

- Association Rule Mining
  - Finds interesting associations and/or correlation relationships among large set of data items.
  - E.g., 98% of people who purchase tires and auto accessories also get automotive services done

Data Mining Tasks: others

- 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
- Text Mining, Graph Mining, Data Streams
- Other pattern-directed or statistical analyses

Are all the "Discovered" Patterns Interesting?

- Data Mining may generate thousands of patterns, not all of them are interesting.

- 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, etc.

Can we find all and only interesting patterns?

- Completeness: Find all the interesting patterns
  - Can a data mining system find all the interesting patterns?
  - Association vs. classification vs. clustering
- Optimization: Search for only interesting patterns:
  - 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 tasks

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

What primitives?

Primitives that Define a Data Mining Task

- Task-relevant data
- Type of knowledge to be mined
- Background knowledge
- Pattern interestingness measurements
- Visualization/presentation of discovered patterns

Primitive 1: Task-Relevant Data

- Database or data warehouse name
- Database tables or data warehouse cubes
- Condition for data selection
- Relevant attributes or dimensions
- Data grouping criteria

Primitive 2: Types of Knowledge to Be Mined

- Characterization
- Discrimination
- Association
- Classification/prediction
- Clustering
- Outlier analysis
- Other data mining tasks

Primitive 3: Background Knowledge

- A typical kind of background knowledge: Concept hierarchies
- Schema hierarchy
  - E.g., Street < City < ProvinceOrState < Country
- Set-grouping hierarchy
  - E.g., {20-39} = young, {40-59} = middle_aged
- Operation-derived hierarchy
  - email address: hagonzal@cs.uiuc.edu
  - login-name < department < university < country
- Rule-based hierarchy
  - LowProfitMargin (X) <= Price(X, P1) and Cost (X, P2) and (P1 - P2) < $50

Primitive 4:
Pattern Interestingness Measure

- Simplicity
- Certainty
- Utility
- Novelty

Primitive 5: Presentation of Discovered Patterns

- Different backgrounds/usages may require different forms of representation
  - E.g., rules, tables, crosstabs, pie/bar chart, etc.
- Concept hierarchy is also important
  - Discovered knowledge might be more understandable when represented at high level of abstraction
  - Interactive drill up/down, pivoting, slicing and dicing provide different perspectives to data
- Different kinds of knowledge require different representation: association, classification, clustering, etc.

What issues?

Major Issues in Data Mining

- Mining methodology
  - Mining different kinds of knowledge from diverse data types, e.g., bio, stream, Web
  - Performance: efficiency, effectiveness, and scalability
  - Pattern evaluation: the interestingness problem
  - Incorporation of background knowledge
  - Handling noise and incomplete data
  - Parallel, distributed and incremental mining methods
  - Integration of the discovered knowledge with existing one: knowledge fusion

- User interaction
  - Data mining query languages and ad-hoc mining
  - Expression and visualization of data mining results
  - Interactive mining of knowledge at multiple levels of abstraction

- Applications and social impacts
  - Domain-specific data mining & invisible data mining
  - Protection of data security, integrity, and privacy

Summary

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
- Data mining functionalities: characterization, discrimination, association, classification, clustering, outlier and trend analysis, etc.
- Data mining systems and architectures
- Major issues in data mining