cse643
Data Mining

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Course Textbook

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DATA MINING

Concepts and Techniques

Morgan Kaufmann

Second or Third Edition

Book 2nd edition and Course Content

We will cover, some in more detail than the others, the following book chapters from the 2nd edition

- Chapter 1 Introduction and overview
- Chapter 2 Preprocessing
- Chapter 3 Data warehouse and OPLAP
- Chapter 5 Association
- Chapter 6 Classification
- Chapter 7 Clustering

Book 2nd Edition and Course Content

- Chapter 8 Stream, series, sequence data
- Chapter 10 Multimedia, text, web data
- Chapter 11 Applications and trends

- We will also cover in some level of detail the following subjects
- Genetic Algorithms
- Types of Neural Networks
- Protein Secondary Structure Prediction
- Descriptive Granularity - DM Model

Book and Course Content

We will cover, some in more detail than the others, the following book chapters from the 3rd edition

- Chapter 1 Introduction
- Chapter 2 Know your Data
- Chapter 3 Data Preprocessing
- Chapter 4 Data Warehousing
- Chapter 6 Mining Frequent Patterns; Association and Correlation: Basic Concepts
- Chapter 7 Advanced Frequent Patterns

Book 3rd Edition and Course Content

- Chapter 8 Classification: Basic Concepts
- Chapter 9 Classification: Advanced Concepts
- Chapter 10 Cluster Analysis: Basic Concepts
- Chapter 13 Trends and Research Frontiers in DM

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Chapter 1: Introduction

- **Data Mining Main Objectives:**
- **Indentification** of data as a source of useful information
- **Use** of discovered information for **competitive advantages** when working in business enviroment

Data – Information - Knowledge

- **Data** – as in databases
- **Information** or **knowledge** is a meta information ABOUT the **patterns hidden** in the data
- **The patterns** must be discovered **automatically**

Why Data Mining?

- **Data explosion problem**

  Automated data collection tools and mature database technology lead to tremendous amounts of data stored in databases, data warehouses and other data repositories

Why Data Mining

- **Data explosion problem**
- We are drowning in data, but starving for knowledge
- **Solution:** Data warehousing and data mining
- **Data Mining:**

  Extraction of interesting knowledge (rules, regularities, patterns, constraints) **from data in large databases**

What is Data Mining?

- There are many activities with the same name: CONFUSSION

- DM: Huge volumes of data
- DM: Potential hidden knowledge
- DM: Process of **discovery** of hidden **patterns** in data

DM: Intuitive Definition

DM is a process to extract previously unknown knowledge from large volumes of data

Requires both new technologies and new methods

Data Mining

- **DM creates models (algorithms):**
- **classification** (chapter 6)
- **association** (chapter 5)
- **prediction** (chapter 6)
- **clustering** (chapter 7)

Data Mining

- **DM** often **presents** the knowledge as a set of rules of the form

  IF.... THEN ...

  In this case it is called a Descriptive DM

- **DM** finds other relationships in data

- **DM** detects deviations

DM: Some Historical Applications

- **Market analysis and management**
  - target marketing, customer relation management, market basket analysis, cross selling, market segmentation
  - **Risk analysis and management**
  - Forecasting, customer retention, improved underwriting, quality control, competitive analysis

DM: Some Historical Applications

- **More Applications**
- Text mining
- News groups, emails, documents
- Web analysis
- Intelligent query answering
- Scientific Applications

DM: Business Advantages

- Data Mining uses collected data to
- **Predict** tendencies and waves
- **Classifiy** new data
- **Find** previously unknown patterns for the use for business advantages
- **Discover** unknown relationships

DM: Technologies

- Many commercially avaible tools
- Many methods (models, algorithms) for the same task
- TOOLS ALONE ARE NOT THE SOLUTION
- **The user must often be able to interpret the results**

DM: Technologies

- One of the **requirements** of DM is:

“the results must be easily comprehensible to the user”

- **Strenght** of Descriptive Methods

- Most often, especially when dealing with statistical methods
- separate analysts are needed to interpret the results (knowledge)
- **Weakness** of Statistical Methods

Data Mining vs Statistics

- Some statistical methods are considered as a part of **Data Mining** i.e.
- they are used as **Data Mining** algorithms, or as a part of **Data Mining** algorithms

- Some, like statistical prediction methods, different types of regression, and clustering methods are now considered as an **integral part** of **Data Mining** research and applications

Bussiness Applications

- Buying patterns
- Fraud detection
- Customer Campaings
- Decision support
- Medical aplications
- Marketing
- and more

Fraud Detection and Management (B1)

- **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

Fraud Detection and Management (B2)

- Examples
  - **auto insurance**: detect characteristics of group of people who stage accidents to collect on insurance
  - **money laundering**: detect characteristics of suspicious money transactions (US Treasury's Financial Crimes Enforcement Network)
  - **medical insurance**: detect characteristics of fraudulent patients and doctors

Fraud Detection and Management (B3)

- **Detecting inappropriate medical treatment**
  - Australian Health Insurance Commission detected that in many cases blanket screening tests were requested (save Australian $1m/yr)
- **Detecting telephone fraud**
  - DM builds telephone call model: destination of the call, duration, time of day or week.
  - Detects 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

Fraud Detection and Management (B4)

- **Retail**
  - Analysts used Data Mining techniques to estimate that 38% of retail shrink is due to dishonest employees
  - and more….

Data Mining vs Data Marketing

- **Data Mining** methods apply to many domains

- **Data Marketing:**
- Applications of Data Mining methods in which the goal is to find buying patterns in Transactional Data Bases

- Association Rules- APRIORI Algorithm

Market Analysis and Management (MA1)

- Data sources for analysis
  - Credit card transactions, loyalty cards, discount coupons, customer complaint calls, plus (public) lifestyle studies
- Target marketing
  - **DM** finds clusters of “model” customers who share the same characteristics: interest, income level, spending habits, etc.

Market Analysis and Management (MA2)

- Determine customer purchasing patterns over time
  - Conversion of single to a joint bank account: when marriage occurs, etc.
- Cross-market analysis
  - **Associations/co-relations** between product sales
  - **Prediction** based on the association information

Market Analysis and Management (MA3)

- Customer profiling
  - DM can tell you what types of customers buy what products (clustering or classification)
- Identifying customer requirements
- identifying the best products for different customers

Corporate Analysis and Risk Management (CA1)

- 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

Corporate Analysis and Risk Management (CA2)

- Competition:
  - monitor competitors and market directions
  - group customers into classes and a class-based pricing procedure
  - set pricing strategy in a highly competitive market

Business Summary

- **Data Mining** helps to improve competitive advantage of organizations in dynamically changing environment;
- it improves clients retention and conversion
- Different **Data Mining** methods are required for different kind of data and different kinds of goals

Scientific Applications

- Networks failure detection
- Controllers
- Geographic Information Systems
- Genome- Bioinformatics
- Intelligent robots
- Intelligent rooms
- etc… etc ….

What is NOT Data Mining

- Once patterns are found Data Mining process is **finished**

- Use of the patterns is not Data Mining
- Monitoring is not Data Mining

- Querries to the database are not DM

Evolution of Database Technology

- 1960s:
  - Data collection, database creation, IMS and network DBMS
- 1970s:
  - Relational data model, relational DBMS implementation

Evolution of Database Technology

- 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 database
  - 2000 ---- **Big Data**

Short History of Data Mining

- **1989 - KDD** term: Knowledge Discovery in Databases appears in (IJCAI Workshop)
- **1991 -** a collection of research papers edited by Piatetsky-Shapiro and Frawley
- **1993 – Association Rule Mining Algorithm APRIORI** proposed by Agraval, Imielinski and Swami

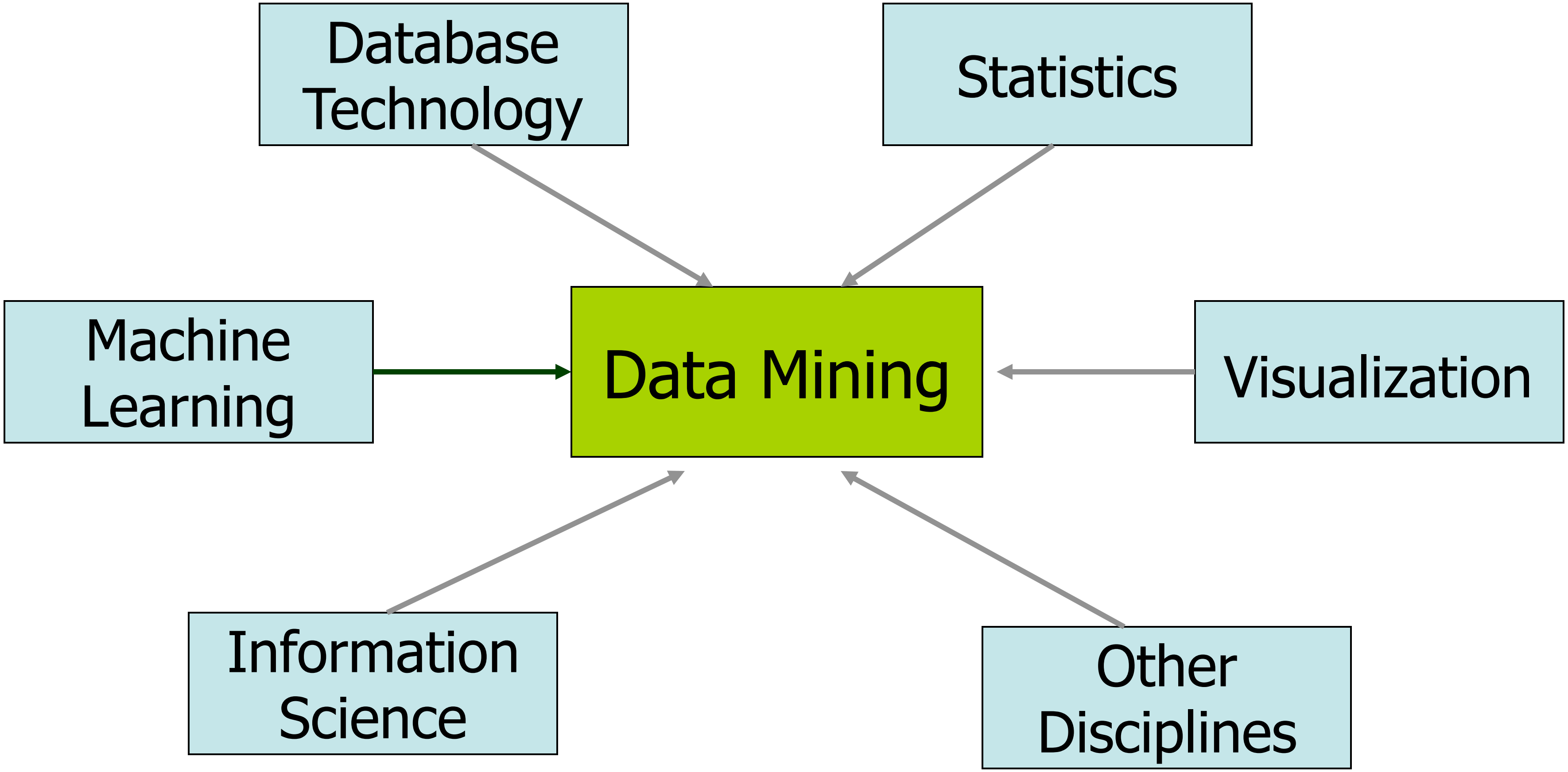
Short History of Data Mining

- **1996 –2000**
- **KDD** evolves as a conjuction of different knowledge areas:

- data bases, machine learning, statistics, artificial intelligence

- **2000- present**
- the term **Data Mining** becomes established and evolves into **Big Data**

Data Mining: Confluence of Multiple Disciplines

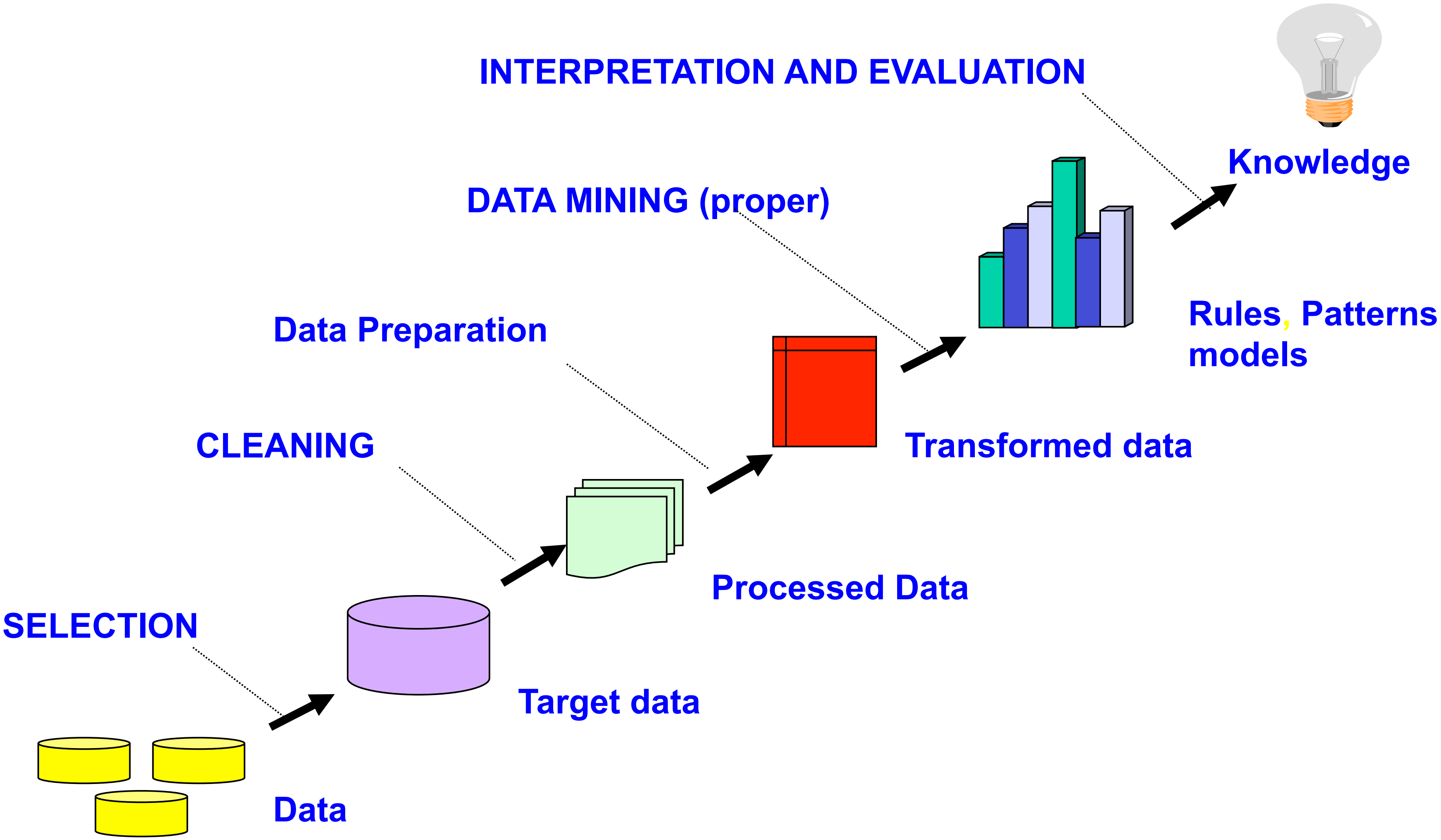


KDD process Definition

[Piatetsky-Shapiro 97]

- KDD is a non trivial process for identification of :
  - Valid
  - New
  - Potentially useful
  - Understandable
  - patterns in data

KDD Process



INTERPRETATION AND EVALUATION

Knowledge

DATA MINING (proper)

Rules, Patterns models

Data Preparation

Transformed data

CLEANING

Processed Data

SELECTION

Target data

Data

DM: Data Mining

- **DM** is a step in the KDD process
- in which algorithms are applied to look for patterns in data

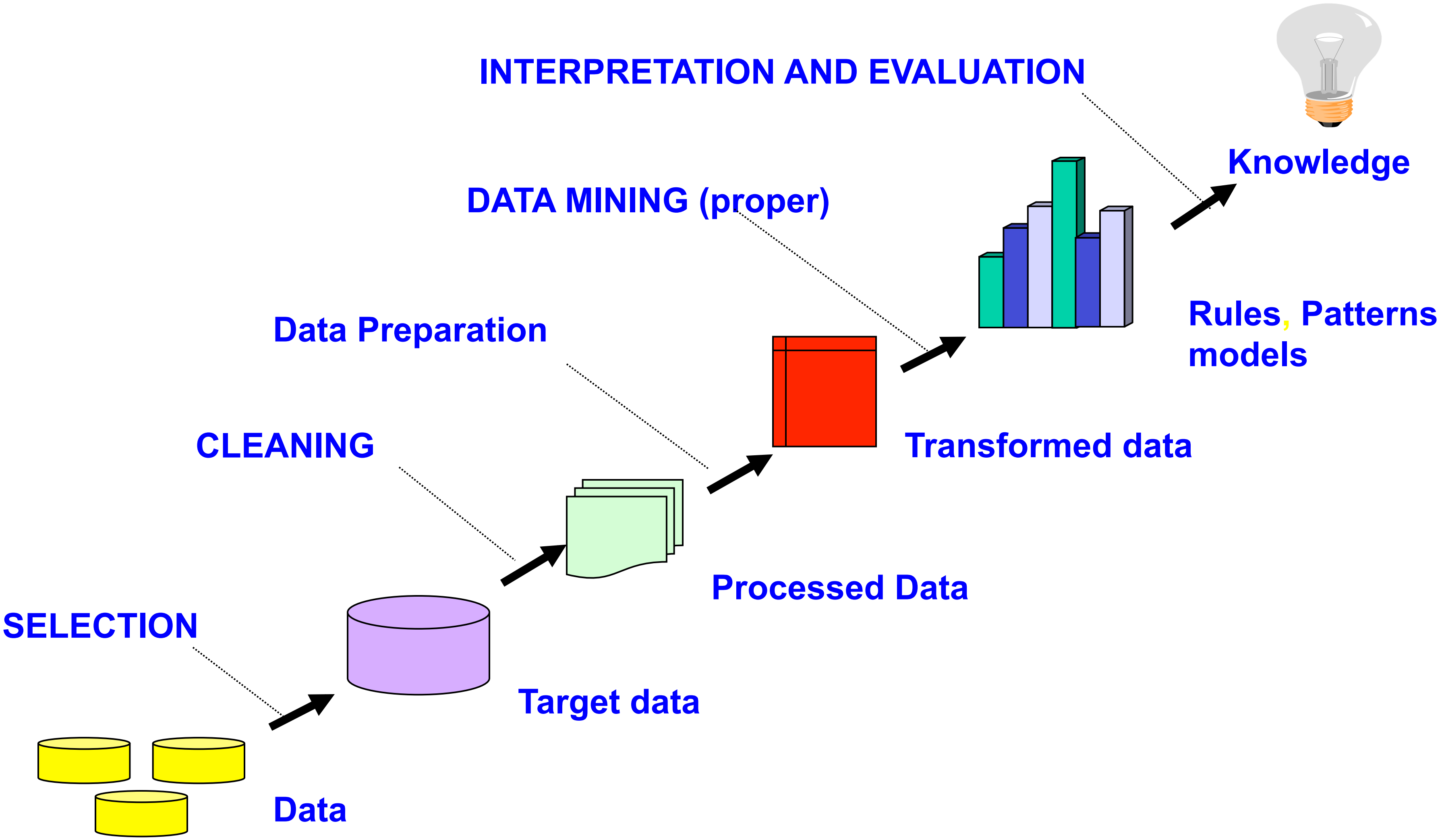
- We use term **DATA MINING PROPER** for DM step in KDD Process
- We usually use term **DM process** term for KDD process

DM: Data Mining Process

- **Rememeber**
- It is necessary to apply first
- the preprocessing operations to clean and preprocess the data in order to obtain significant patterns

- DM Process can be re-iterated- and usually is

Data Mining Process



Data

SELECTION

Target data

CLEANING

Processed Data

Data Preparation

Transformed data

DATA MINING (proper)

Rules, Patterns
models

INTERPRETATION AND EVALUATION

Knowledge

KDD vs DM

- **KDD** was a term used by **academia**
- **DM** was often used as a **commercial** term
- **DM** term is now being used in academia, as it has become a “brand name” for both KDD process and its DM sub-process
- The important point is to see **DM** as a **process** with Data Mining Proper as part of it
- BIG DATA – a new videly use term

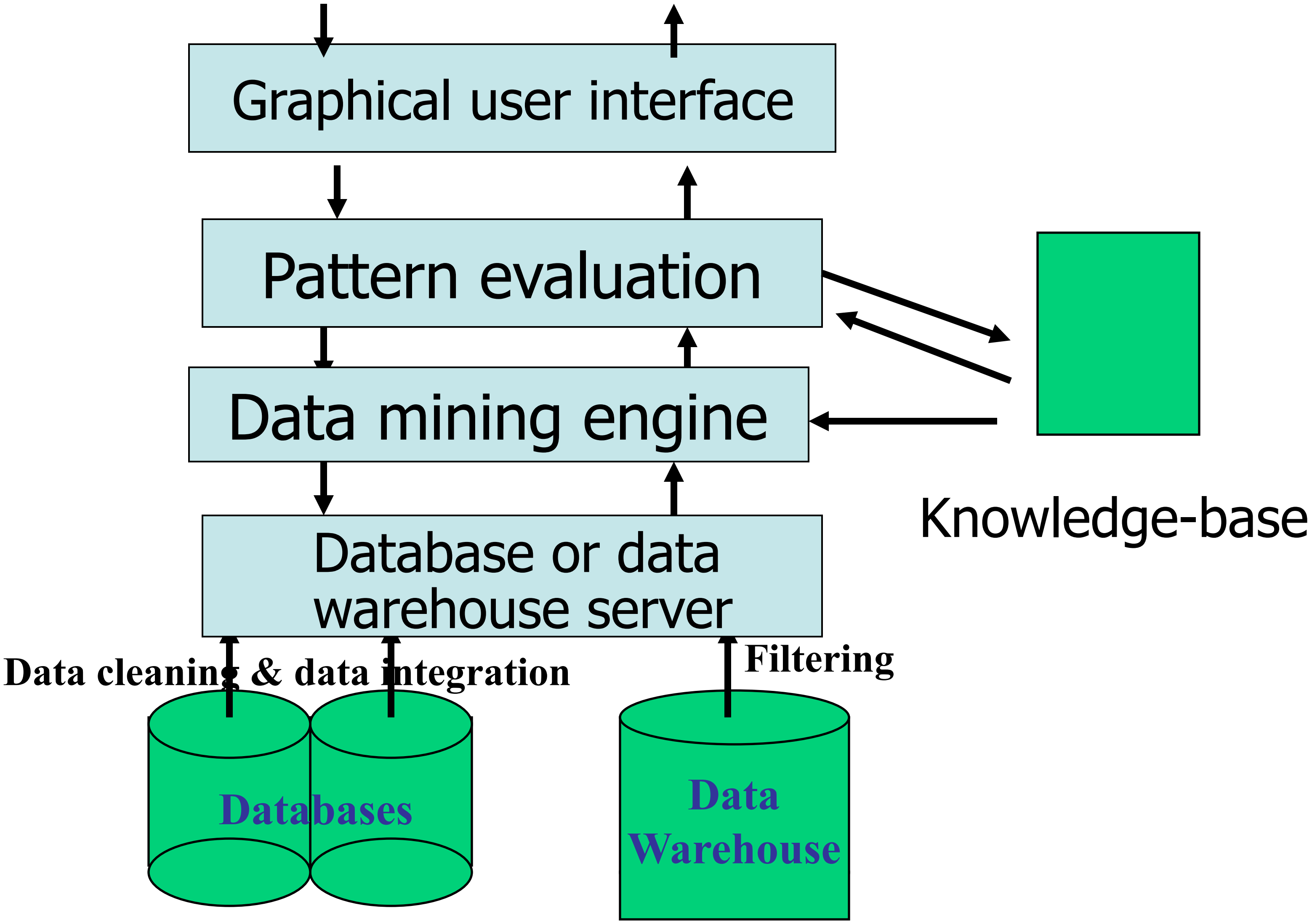
Steps of the DM process

- **Preprocessing:** includes all the operations that have to be performed before a data mining algorithm is applied

- **Data Mining (proper):** knowledge discovery algorithms are applied in order to obtain the patterns

- **Interpretation**: discovered patterns are presented in a proper format and the user decides if it is neccesary to re-iterate the algorthms

Architecture of a Typical Data Mining System
(book slide)



What Kind of Data?

- 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

Descriptive Data Mining: Concept Description

- **Concept** – is defined **semantically** as **any subset of records**
- We often define the **concept** by distinguishing in our database an **attribute c** and **its value v**

- In this case the **concept description** is written **syntactically** as : **c=v**
- We define a concept with the description **c=v** as

CONCEPT = {records: c=v}

Descriptive Data Mining:

Concept Description

- Let **C** be a concept with the description **c=v**, i.e.

  ***C = {records:* c=v}**

- We call such attribute **c** a **class** attribute, or a **decision** attribute, or a **classification** attribute

- The description **c=v** is called a **class**, or **decision** description

Descriptive Data Mining:

Concept, Class Description

- **For example:**
- *climate=wet is a description of the concept of WET CLIMATE and*
- ***WET CLIMAT = {records:** climate=wet**}***
- **We use words:** decision attribute, class attribute, concept attribute
- We talk about decision or class description
-
- REMEMBER: **all definitions are relative to the database we deal with.**

Desctiptive DM

Decision, Concept, Class Characteristics

- Let **C** be a class (concept) with a **description** **c=v**, i.e.

  C = {records: c=v}

- *The class **C** **characteristics** is a set of attributes a1, a2, … ak, and their respective values v1, v2, …. vk that are **characteristic** for a given class **C**, i.e. such that*

- *{records: a1=v1 & a2=v2&…..ak=vk} Λ **C** = non empty set*

- ***Characteristics description** of **C** is then written as*

  a1=v1 & a2=v2&…..ak=vk

Characterization

- ***Describes the process which aim is to find rules that describe characteristic properties of a*** **class (concept)**

- They take the form

  If class **then** characteristics

  If c = v then a2=v2&…..ak=v*k*

C=1 → A=1 & B=3 **25%** (support: there are 25% of the records for which the rule is true)

- C=1 → A=1 & B=4 **17%**
- C=1 → A=0 & B=2 **16%**

Discrimination

- ***It is the process which aim is to find rules that allow us to discriminate the objects (records) belonging to a given concept (one class) from the rest of records***

If characteristics then concept

If a2=v2&…..ak=vk ***then*** **c = v**

- **A=0 & B=1 → C=1 33% 83% (support, confidence: the conditional probability of the concept given the characteristics)**
- **A=2 & B=0 → C=1 27% 80%**
- **A=1 & B=1 → C=1 12% 76%**

Classification - Supervised Learning

- **Classification**
- Finding models (rules) that describe (characterize) or/ and distinguish (discriminate) classes or concepts for future prediction
- **Example:** classify countries based on climate (characteristics)
- classify cars based on gas mileage and use it to predict classification of a new car

Classification Algorithms
Models, Basic Classifiers

- **Decision Trees** (ID3, C4.5) –descriptive
- **Neural Networks-** statistical
- **Bayesian Networks** - statistical
- **Rough Sets** - descriptive
- **Genetic Algorithms** – descriptive or statistical but mainly an optimization method
- **Classification by Association** – descriptive

Classification Algorithms
Models, Basic Classifiers

- **Presentation of results:**
- characteristic and /or discriminant rules
- In case of **descriptive DM**

- converged network (Neural, Bayes) in case of **statistical DM**

Statistical DM, Clustering

- **Statistical Prediction** - predict some unknown or missing numerical values
- **Cluster analysis (statistical)**
  - Class label is unknown
  - Goal: group data to form new classes
  - It is called **unsupervised learning**
  - **For example:** cluster houses to find distribution patterns
  - **Clustering** is based on the principle:
  - **maximizing** the intra-class similarity and **minimizing** the interclass similarity

Statistical DM

- **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 and others

Statistical DM

- **Trend and evolution analysis (statistical)**
  - Trend and deviation: regression analysis
  - Sequential pattern mining, periodicity analysis
  - Similarity-based analysis
- **Other pattern-directed or statistical analyses**

Classification
Supervised Learning

- Given a set of objects (concept, class) described by a **class attribute,** a classification algorithm builds a set of discriminant and /or characterization rules (or other descriptions in case of statistical methods) in order to be able,
- as the next step, to **classify** unknown sets of objects
- This is also called a supervised learning

Classification: Chapter 6

- Decision Trees (ID3, C4.5) – descriptive
- Neural Networks -statistical
- Rough Sets – descriptive
- Bayesian Networks- statistical
- Genetic Algorithms- can be both, but is mainly an optimization method

Association: Chapter 5
Problem Statement

- I={i1, i2, ..., in} a set of **items**
- **Transaction T:** set of items, **T** is subset of **I**
- **Data Base:** set of transactions
- An association rule is an implication of the form : **X-> Y,** where **X, Y** are **disjoint** subsets of **T**
- **Problem: Find association rules that have support and confidence greater that user-specified minimum support and minimun confidence**

Association Rules

- **Confidence:** a rule **X->Y** holds in the database **D** with a confidence c if the c% of transactions in **D** that contain **X** also contain **Y**

- **Support:** a rule **X->Y** has a support s in **D** if s% of transactions contain **XUY**

Association Rules

- Association rules presentation (predicate presentation)

  Multi-dimensional:

  age(X, “20..29”) ^ income(X, “20..29K”) → buys(X, “PC”) [support = 2%, confidence = 60%]

  Single-dimensional:

  – **buys(x, “computer”) → buys(x, “software”)** [1%, 75%]

  Association rules presentation (non-predicate presentation)

  Age = 20..29 /\ income=20..29K → buys=PC (2%, 60%)

  Buys=computer → buys=software (1%,75%)

Clustering- Chapter 7

- Database segmentation
- Given a set of objects (records) the algorithm obtains a division of the objects into clusters in which the distance of objects inside a cluster is minimal and the distance among objects of diferent clusters is maximal
- Unsupervised learning

Other Statistical Methods chapter 6

- Regression
- Temporal Series
- Lazy learners
- Support Vector Machines

.....

Major Issues in Data Mining (1)

Book Slide

- 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

Major Issues in Data Mining (2)

Book Slide

- – 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 (3)

Book Slide

- 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

- **Data mining:** discovering comprehensible, interesting patterns from large amounts of data
- **A natural evolution of database technology, in great demand, with wide applications**
- **A KDD process**, or **DM process** includes data cleaning, data integration, data selection, transformation, data mining proper, pattern evaluation, and knowledge presentation
- **Mining can be performed in a variety of information repositories**

Summary

- **Data mining functionalities**: characterization, discrimination, association, classification, clustering, outlier and trend analysis
- **Classification** of data mining systems
- Major issues in data mining

Preprocesing
Introduction to chapter 2

Preprocesing

- Select, **integrate**, and **clean** the data
- Decide which kind of **patterns** are needed
- Decide which **algorithm** is the best for your **goal**
  It depends on many factors
- Prepare **data** for algorithms
- Different algorithms accept different data format

Implementaion Preparation

- Identify the **problem** to be solved.
- Study **problem** it in detail
- Explore the solution **space**
- Find one acceptable **solution** (feasible to implement)
- Specify the **solution**
- Prepare the data

Preparation

- Remember GIGO! (garbage in gabage out)
- Add some data, if necessary
- Structure the data in a proper form
- Be careful with incomplete and noisy data

Some implementation preparation rules to follow

- Select the **problem**
- Specify the **problem**
- Study the data
- The **problem** must guide the search for tools and technologies
- Search for the **simplest** model (algorithm, method)
- Define for each data the solution is **valid**, where it is **not valid** at all and where it is **valid** with some constraints

Studying the data

- The surrounding world consists of objects (data) and the DM problem is to find the relationships among objects (data)

- The objects (data) are characterized by the following properties:

  attributes, values of attributes

The results (rules, descriptions) are **valid** (true) under certain circumstances (data) and in certain moments (avaible data at the moment)

Measures

- Type of data decides a way in which data are analized and preprocessed
  - Names (attributes)
  - Categories, classes, class attributes
  - Ordered values of attributes
  - Intervals of values of attributes
  - Types of values of attributes

Types of data

- Generally we distinguish:
  - Quantitative Data
  - Qualitative Data
- Bivaluated: often very useful
- Null Values are not applicable
- Missing data usually not acceptable
- NNetworks, and Bayes accept some missing data.

What to take into account

- Eliminate redundant records

- Eliminate out of range values of attributes
- **Decide a generalization level**

- Consistency

Other preprocessing tasks

- Generalization vs specification
- Discretization
- Sampling
- Reducing number of attributes at the preprocessing stage

Summary

- The preprocessing is required and is an **essential** part of the DM process
- If preprocessing is not performed patterns obtained could be of no use
- Preprocessing is a tedious task that could even take more time that DM proper

APPROACHES TO DATA MINING

Aproaches

- **Mathematics**: Consist in the creation of mathematical models, algorithms, methods, to extract rules, regularities and patterns

- Rough Sets is the most precise model

- **Statistics:** They are focused in the creation of statistical models to analise data
- Regression, Bayesian networks, NN, Clustering

Statistical methods

- Numerical data are needed
- Statistical methods are also often used in preprocessing steps to study the sample

- Hypothesis validation and regression analisys are used in data mining steps of the process

Decision trees

- Discovering discriminant rules
- Descriptive Data Mining
- Method: succesive division of the set of data
- This is a classification algorithm
- Works better when attributes

  have a small set of values

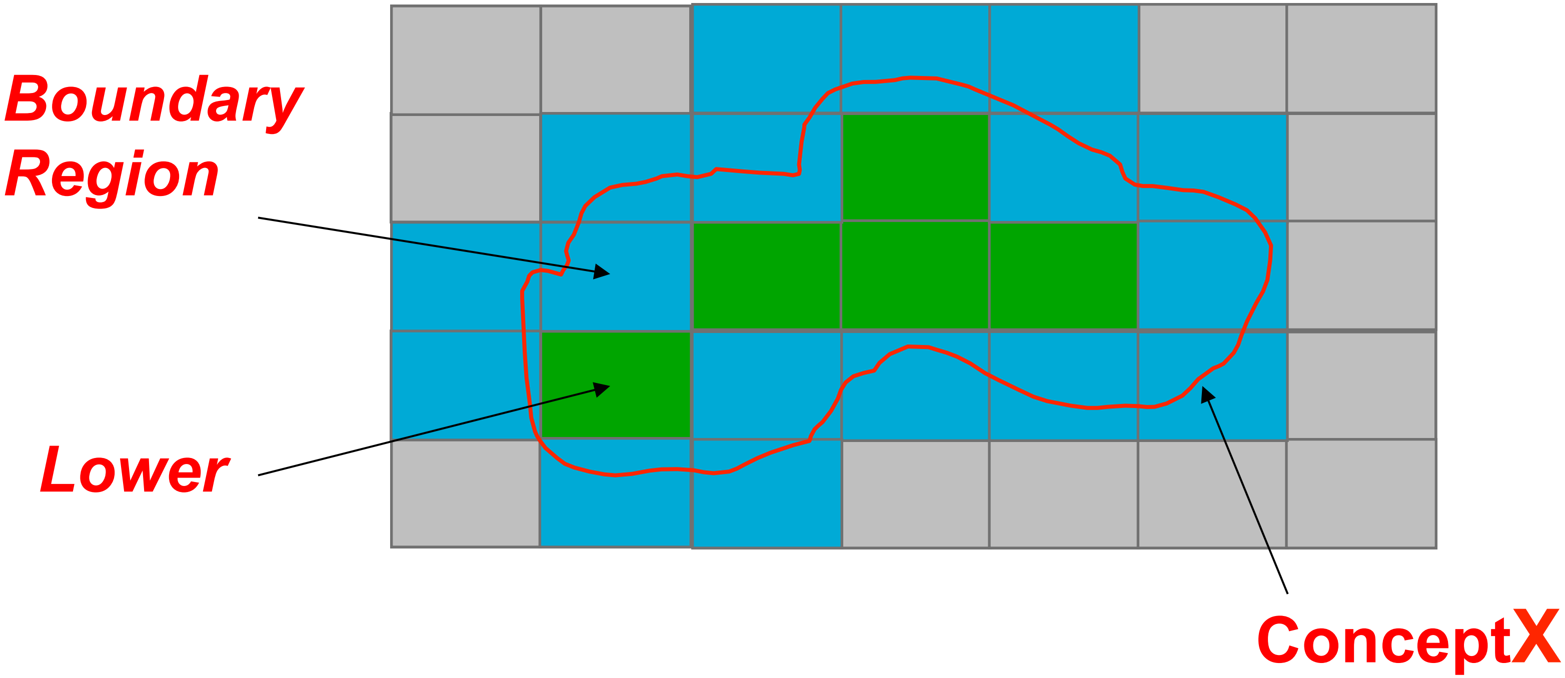
Apriori Algorithm

- Agrawal, Imielinski (IBM S. José. California)
- It is an intuitive and efficient algorithm to extract associations from transactions
- Also used as classification algorithm
- classification by association
- **Method:**
- Iterates until the associations obtained don't have the required support

Rough Sets
Descriptive Classification

- Approximation space A=(U,IND(B)):
  - *Lower Approximation* $\underline{X}_B = \{o \in U / [o] \subseteq X\}$
  - *Upper Approximation* $\overline{X}_B = \{o \in U / [o] \cap X \neq \emptyset\}$
  - *Boundary* Region $\mathrm{Bnd}(\mathrm{X})_{\mathrm{B}} = \overline{X}_B - \underline{X}_B$
  - Positive Region: $\mathrm{POS}_{\mathrm{B}}(\mathrm{D}) = \bigcup\{\overline{X} : X \in IND(D)\}$

Rough Sets



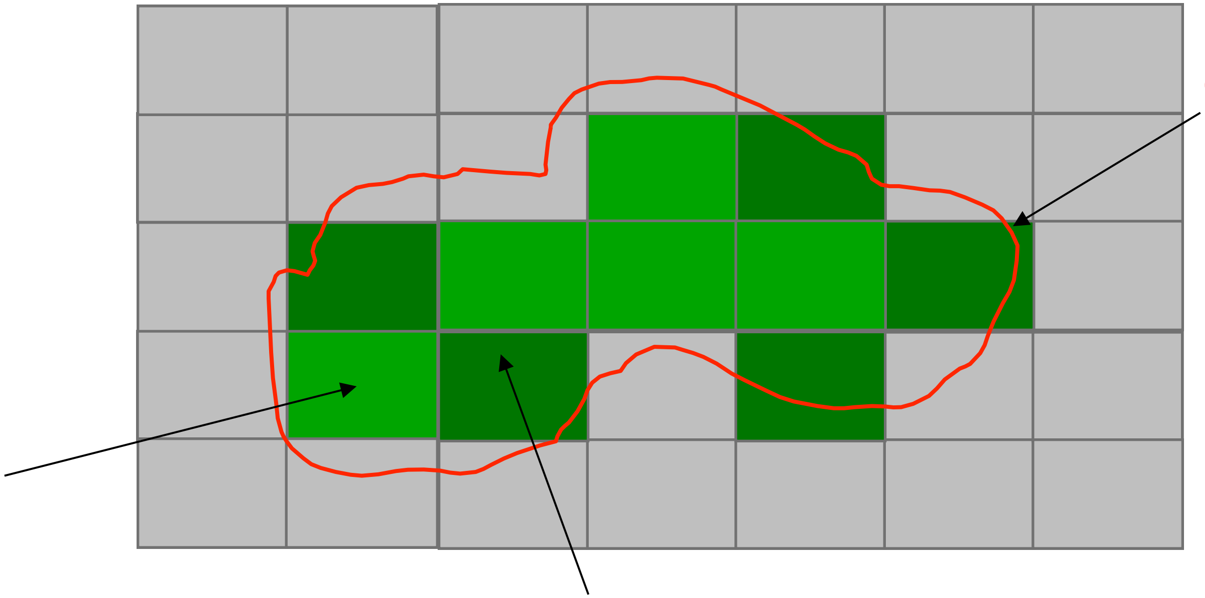
Boundary Region

Lower

ConceptX

Boundary + *Lower* = *Upper*

Variable Precision Rough Set Model



Concept X

Lower

New objects add to the lower

$$c(X,Y) = \begin{cases} 0 & \text{if} \quad card(X) = 0 \\ 1 - card(X \cap Y)/card(X) & \quad\;\; card(X) > 0 \end{cases}$$

Rough Sets in SQL

```
Begin UPPER
setdb(dbName);
exec(conn,”BEGIN”);

“DECLARE clases CLASES FOR
SELECT $C_1$,....,$C_N$, D, COUNT (*) AS cnt
FROM R
GROUP BY $C_1$,....,$C_N$, D
ORDER BY $C_1$,....,$C_N$, D, CNT desc”);

while  not_end_records() do
    equ_class=exec(“FETCH 1 IN cursor”);
    first_decision_value=get_value(equ_class(“D”));
    insert(equ_class,upper[first_decision_value]);
    while (equ_class == exec(“FETCH 1 IN cursor”) do
        decision_value=get_value(equ_class(“D”));
        insert(equ_class,upper[first_decision_value]);
    end while
end while
End UPPER
```

Statistical Methods

- **Neural Network:** statistical CLASSIFICATION algorithm
- the network is trained to obtain classification patterns

- **Clustering:** form groups of objects without any previous hypothesis

Genetic Algorithms

- **Optimization method**
- They should be used when the goal is to find an optimal solution in solution space
- They often are used together with neural netwoks, or other methods to produce more understable (optimal) outputs
- They also are used to find the **optimal set of discriminant and/or characteristic rules** for a given database and a given class

Classification: requirements

- Decision attribute; called also class attribute, concept attribute
- Condition attributes: rest of the attributes or its subset
- Some require numerical data but there are algorithms to deal with any kind of data

Asociation: requirements

- Transactional data
- There is not needed to specify right and left side of the rules
- There are algorithms to tackle any kind of data
- Minimum support
- Maximum number of rules to be obtained

Clustering: requirements

- Set of attributes
- Maximum number of clusters
- Number of iterations
- Mimimun number of elements in any cluster