Data Mining   a.a. 2009/10

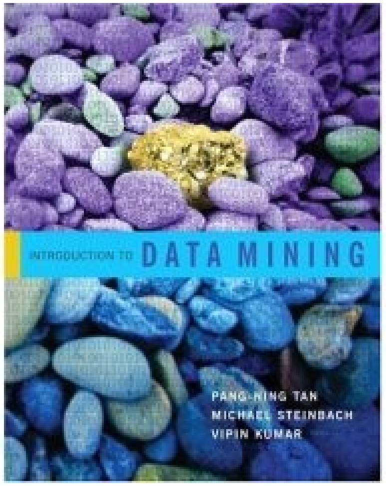
Introduzione

Data Mining

- **Acronimo: DM**
- **Orario:**
  - **Martedì 14-16 aula B1**
  - **Giovedi 11-13 aula B1**
- **Docente:**
  - **Mirco Nanni, ISTI-CNR, mirco.nanni@isti.cnr.it**
- **Pagina web (wiki):**
  - **http://www.cli.di.unipi.it/doku/doku.php/dm/**

Data Mining

- **Testo di riferimento**



Pang-Ning Tan, Michael Steinbach, Vipin Kumar

Introduction to DATA MINING

Addison Wesley, ISBN 0-321-32136-7, 2006

- **Altri riferimenti**
  - Jiawei Han, Micheline Kamber. Data Mining: Concepts and Techniques. Morgan Kaufmann Publishers, 2000
  - David J. Hand, Heikki Mannila and Padhraic Smyth. Principles of Data Mining. MIT Press, 2001.
  - Barry Linoff. Data Mining Techniques for Marketing Sales and Customer Support. John Wiles & Sons, 2002

- **I lucidi utilizzati nelle lezioni saranno resi disponibili attraverso il wiki del corso**

Censimento studenti

Laurea spec./magistrale	#
Spec. Informatica	
Magistrale “	
Spec. Tecnologie Informatiche	2
Spec. Inf. per Ec. e Azienda	3
Magistrale “	
Spec. Informatica Umanistica	7
(Erasmus → Scienze comunicazione) (Triennale)	1
Informatica (Triennale)	2

Laurea provenienza	#
Informatica	6
Informatica Umanistica	7
Informatica Applicata	

Contenuti del corso

- Una parte preliminare dove si introducono i concetti essenziali del **processo di estrazione** della conoscenza: studio e preparazione dei dati, forme dei dati, misure e similarità dei dati

- Una parte centrale dove si introducono le principali **tecniche di datamining** (regole associative, classificazione e clustering). Di queste tecniche si studieranno gli aspetti formali e implementativi;

- Una parte più metodologica dove si visiteranno alcuni **casi di studio** nell'ambito del marketing, del supporto alla gestione clienti e dell'evasione fiscale

- L'ultima parte del corso ha l'obiettivo di introdurre **aspetti avanzati**, quali tecniche di data mining su dati complessi ed aspetti di privacy

Contenuti del corso in dettaglio

- **Introduzione e Concetti Basici**
  - Il processo di knowledge discovery
  - Esempi di applicazioni (Evasione fiscale, Business Intelligence)
- **Il processo di estrazione della conoscenza**
  - Le fasi iniziali: preparazione e pulizia dei dati
- **Introduzione alle tecniche di base**
  - Regole Associative
  - Alberi di decisione
  - Clustering

Contenuti del corso in dettaglio

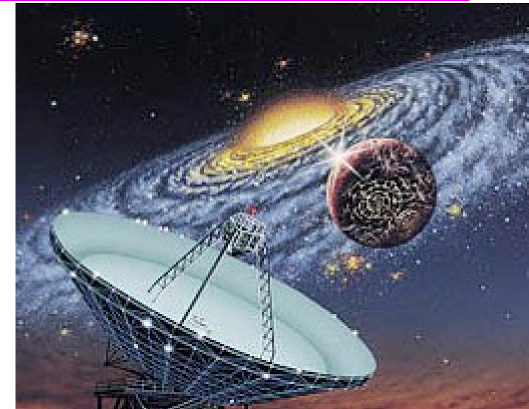
- **Algoritmi di Base**
  - **Regole associative: algoritmo Apriori e varianti**
  - **Alberi di Decisione: C4.5**
  - **Clustering: K-Means, Hierarchical & Density-based**
- **Argomenti avanzati**
  - **Metodi e modelli alternativi**
  - **Dati complessi (serie temporali, ecc.)**
  - **Problemi di privacy**

Why Mine Data? Commercial Viewpoint

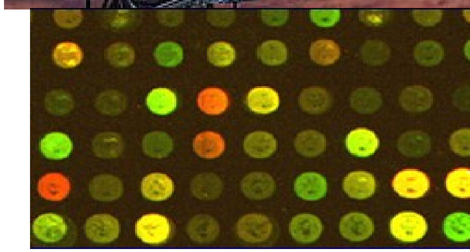
- Lots of data is being collected and warehoused
  - Web data, e-commerce
  - purchases at department/ grocery stores
  - Bank/Credit Card transactions

- Computers have become cheaper and more powerful
- Competitive Pressure is Strong
  - Provide better, customized services for an *edge* (e.g. in Customer Relationship Management)

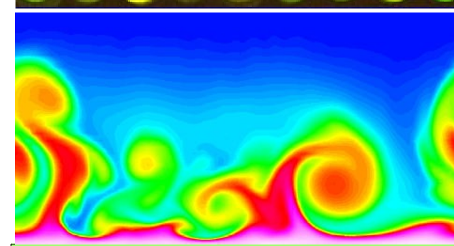
Why Mine Data? Scientific Viewpoint



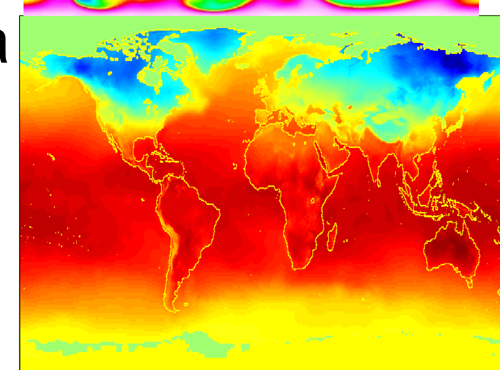
- Data collected and stored at enormous speeds (GB/hour)
  - remote sensors on a satellite
  - telescopes scanning the skies



  - microarrays generating gene expression data



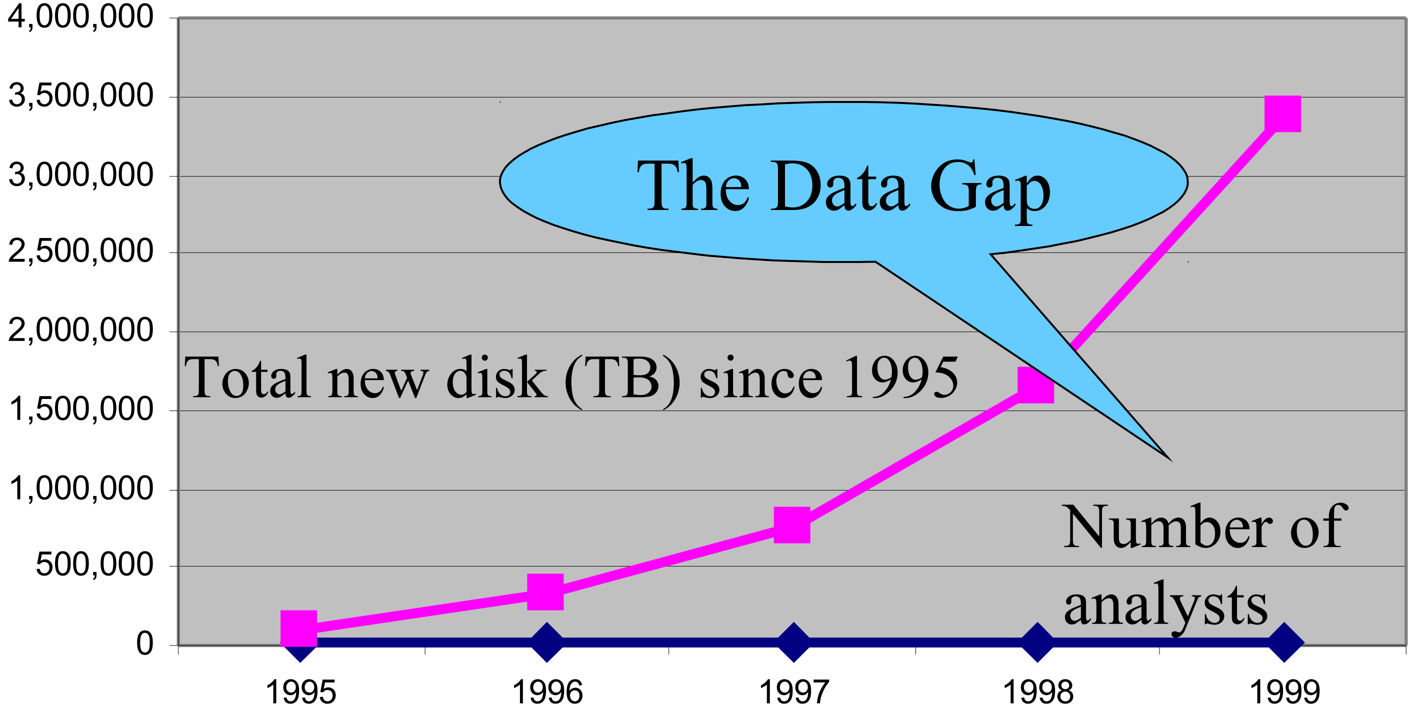
  - scientific simulations generating terabytes of data



- Traditional techniques infeasible for raw data
- Data mining may help scientists
  - in classifying and segmenting data
  - in Hypothesis Formation

Mining Large Data Sets - Motivation

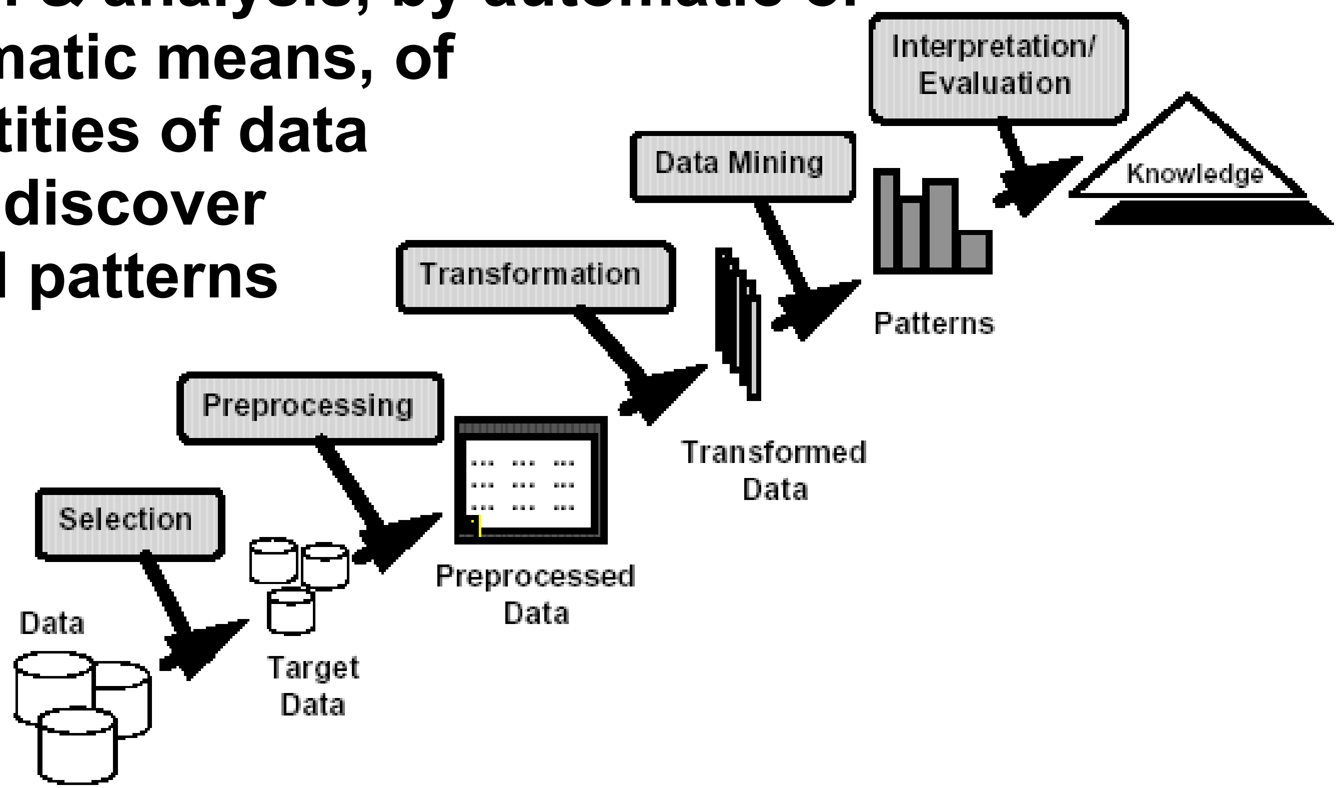
- There is often information “hidden” in the data that is not readily evident
- Human analysts may take weeks to discover useful information
- Much of the data is never analyzed at all



From: R. Grossman, C. Kamath, V. Kumar, “Data Mining for Scientific and Engineering Applications”

What is Data Mining?

- **Many Definitions**
  - Non-trivial extraction of implicit, previously unknown and potentially useful information from data
  - Exploration & analysis, by automatic or semi-automatic means, of large quantities of data in order to discover meaningful patterns



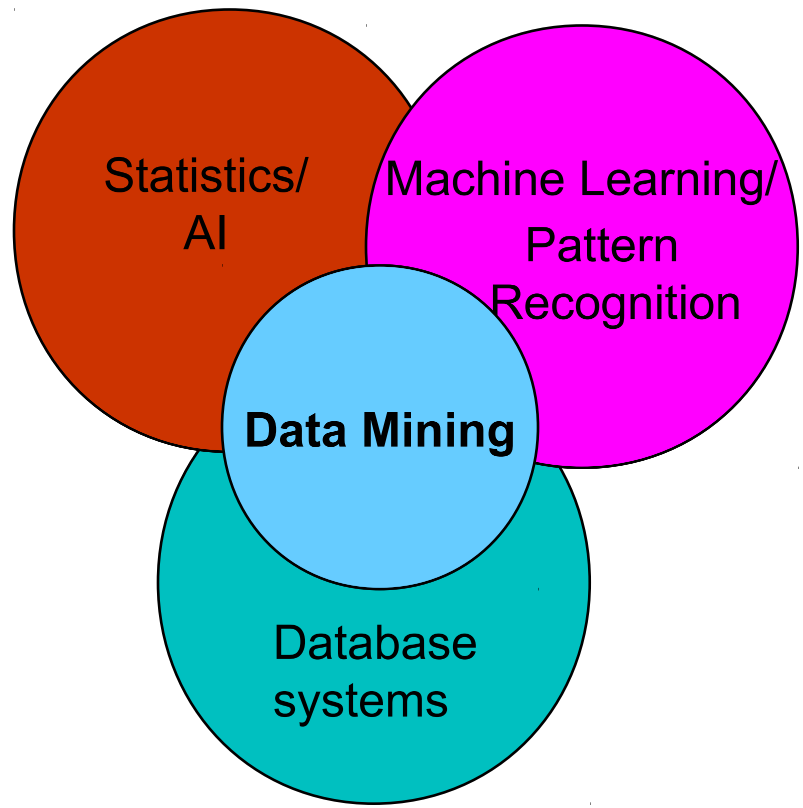
What is (not) Data Mining?

- **What is not Data Mining?**
  - Look up phone number in phone directory
  - Query a Web search engine for information about "Amazon"

- **What is Data Mining?**
  - Certain names are more prevalent in certain US locations (O'Brien, O'Rurke, O'Reilly… in Boston area)
  - Group together similar documents returned by search engine according to their context (e.g. Amazon rainforest, Amazon.com,)

Origins of Data Mining

- Draws ideas from machine learning/AI, pattern recognition, statistics, and database systems
- Traditional Techniques may be unsuitable due to
  - Enormity of data
  - High dimensionality of data
  - Heterogeneous, distributed nature of data



Data Mining Tasks

- Prediction Methods
  - Use some variables to predict unknown or future values of other variables.

- Description Methods
  - Find human-interpretable patterns that describe the data.

From [Fayyad, et.al.] Advances in Knowledge Discovery and Data Mining, 1996

Data Mining Tasks...

- Predictive
  - Classification
  - Regression
  - Deviation Detection
- Descriptive
  - Association Rule Discovery
  - Sequential Pattern Discovery
  - Clustering

Classification: Definition

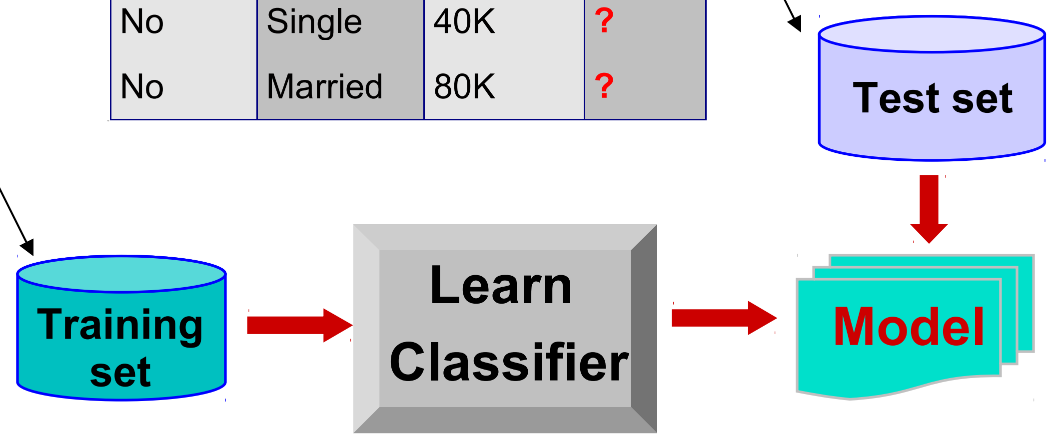
- Given a collection of records (*training set*)
  – Each record contains a set of *attributes*, one of the attributes is the *class*.
- Find a *model* for class attribute as a function of the values of other attributes.
- Goal: <u>previously unseen</u> records should be assigned a class as accurately as possible.
  – A *test set* is used to determine the accuracy of the model. Usually, the given data set is divided into training and test sets, with training set used to build the model and test set used to validate it.

Classification Example

categorical categorical continuous class

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

Refund	Marital Status	Taxable Income	Cheat
No	Single	75K	?
Yes	Married	50K	?
No	Married	150K	?
Yes	Divorced	90K	?
No	Single	40K	?
No	Married	80K	?



Classification: Application 1

- Direct Marketing
  - Goal: Reduce cost of mailing by *targeting* a set of consumers likely to buy a new cell-phone product.
  - Approach:
    - Use the data for a similar product introduced before.
    - We know which customers decided to buy and which decided otherwise. This *{buy, don't buy}* decision forms the *class attribute*.
    - Collect various demographic, lifestyle, and company-interaction related information about all such customers.
      - Type of business, where they stay, how much they earn, etc.
    - Use this information as input attributes to learn a classifier model.

From [Berry & Linoff] Data Mining Techniques, 1997

Classification: Application 2

- Fraud Detection
  - Goal: Predict fraudulent cases in credit card transactions.
  - Approach:
    - Use credit card transactions and the information on its account-holder as attributes.
      - When does a customer buy, what does he buy, how often he pays on time, etc
    - Label past transactions as **fraud** or **fair** transactions. This forms the class attribute.
    - Learn a model for the class of the transactions.
    - Use this model to detect fraud by observing credit card transactions on an account.

Classification: Application 3

- Customer Attrition/Churn:
  - Goal: To predict whether a customer is likely to be lost to a competitor.
  - Approach:
    - Use detailed record of transactions with each of the past and present customers, to find attributes.
      - How often the customer calls, where he calls, what time-of-the day he calls most, his financial status, marital status, etc.
    - Label the customers as **loyal** or **disloyal**.
    - Find a model for loyalty.

From [Berry & Linoff] Data Mining Techniques, 1997

Classification: Application 4

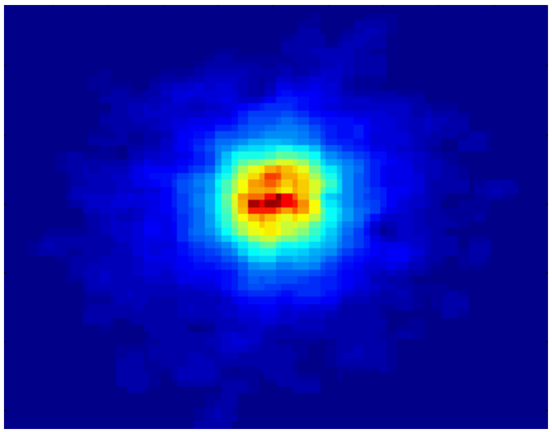
- Sky Survey Cataloging
  - Goal: To predict class (star or galaxy) of sky objects, especially visually faint ones, based on the telescopic survey images (from Palomar Observatory).
    - 3000 images with 23,040 x 23,040 pixels per image.
  - Approach:
    - Segment the image.
    - Measure image attributes (features) - 40 of them per object.
    - Model the class based on these features.
    - Success Story: Could find 16 new high red-shift quasars, some of the farthest objects that are difficult to find!

From [Fayyad, et.al.] Advances in Knowledge Discovery and Data Mining, 1996

Classifying Galaxies

Courtesy: http://aps.umn.edu

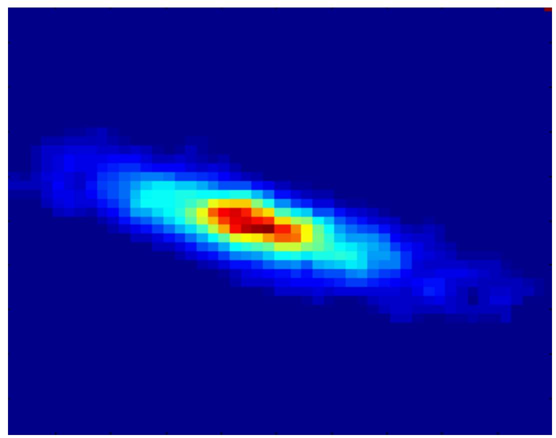
Early



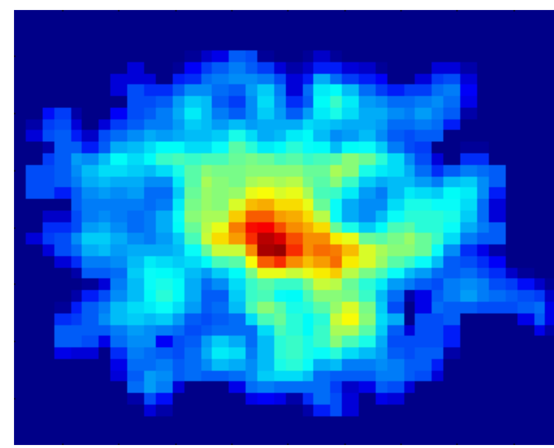
Class:
- Stages of Formation

Attributes:
- Image features,
- Characteristics of light waves received, etc.

Intermediate



Late



Data Size:
- 72 million stars, 20 million galaxies
- Object Catalog: 9 GB
- Image Database: 150 GB

Clustering Definition

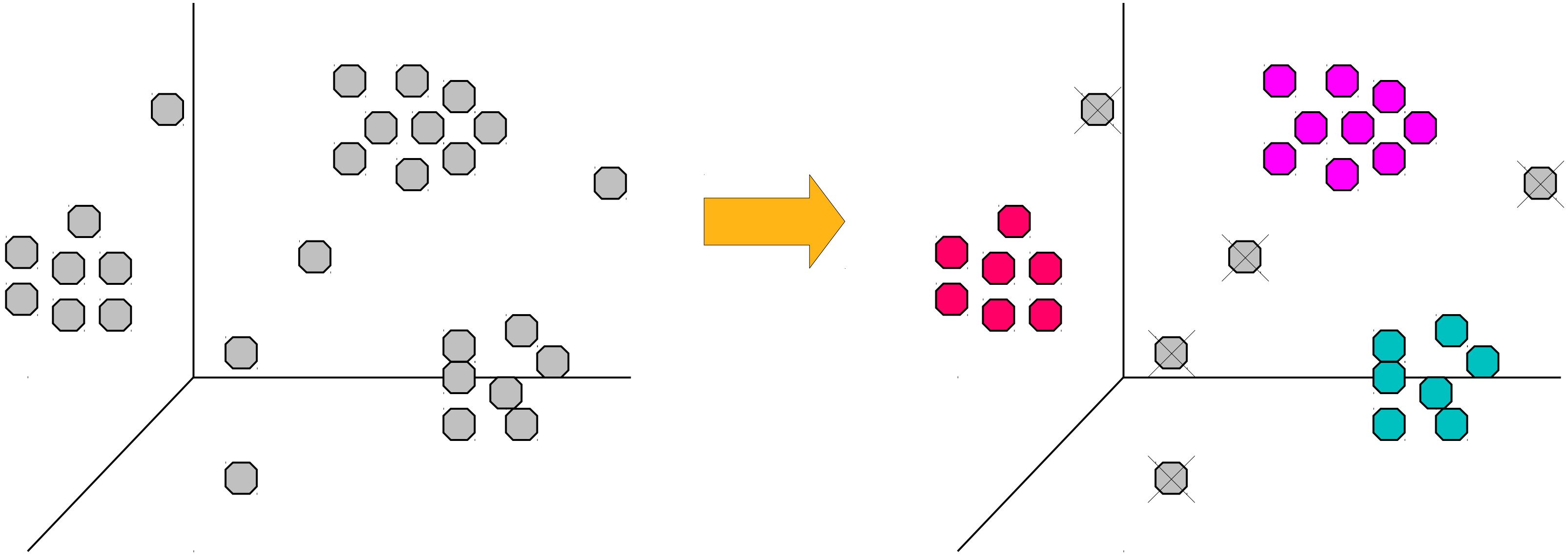
- Given a set of data points, each having a set of attributes, and a similarity measure among them, find clusters such that
  - Data points in one cluster are more similar to one another.
  - Data points in separate clusters are less similar to one another.
- Similarity Measures:
  - Euclidean Distance if attributes are continuous.
  - Other Problem-specific Measures.

Illustrating Clustering

Euclidean Distance-based Clustering in 3-D space.

Intracluster distances are minimized

Intercluster distances are maximized



Clustering: Application 1

- Market Segmentation
  - Goal: subdivide a market into distinct subsets of customers where any subset may conceivably be selected as a market target to be reached with a distinct marketing mix.
  - Approach:
    - Collect different attributes of customers based on their geographical and lifestyle related information.
    - Find clusters of similar customers.
    - Measure the clustering quality by observing buying patterns of customers in same cluster vs. those from different clusters.

Clustering: Application 2

- Document Clustering
  - Goal: To find groups of documents that are similar to each other based on the important terms appearing in them.
  - Approach: To identify frequently occurring terms in each document. Form a similarity measure based on the frequencies of different terms. Use it to cluster.
  - Gain: Information Retrieval can utilize the clusters to relate a new document or search term to clustered documents.

Illustrating Document Clustering

- Clustering Points: 3204 Articles of Los Angeles Times.
- Similarity Measure: How many words are common in these documents (after some word filtering).

Category	***Total Articles***	***Correctly Placed***
Financial	555	364
Foreign	341	260
National	273	36
Metro	943	746
Sports	738	573
Entertainment	354	278

Clustering of S&P 500 Stock Data

- Observe Stock Movements every day.
- Clustering points: Stock-{UP/DOWN}
- Similarity Measure: Two points are more similar if the events described by them frequently happen together on the same day.

	Discovered Clusters	*Industry Group*
1	Applied-Matl-DOWN,Bay-Network-Down,3-COM-DOWN, Cabletron-Sys-DOWN,CISCO-DOWN,HP-DOWN, DSC-Comm-DOWN,INTEL-DOWN,LSI-Logic-DOWN, Micron-Tech-DOWN,Texas-Inst-Down,Tellabs-Inc-Down, Natl-Semiconduct-DOWN,Oracl-DOWN,SGI-DOWN, Sun-DOWN	Technology1-DOWN
2	Apple-Comp-DOWN,Autodesk-DOWN,DEC-DOWN, ADV-Micro-Device-DOWN,Andrew-Corp-DOWN, Computer-Assoc-DOWN,Circuit-City-DOWN, Compaq-DOWN, EMC-Corp-DOWN, Gen-Inst-DOWN, Motorola-DOWN,Microsoft-DOWN,Scientific-Atl-DOWN	Technology2-DOWN
3	Fannie-Mae-DOWN,Fed-Home-Loan-DOWN, MBNA-Corp-DOWN,Morgan-Stanley-DOWN	Financial-DOWN
4	Baker-Hughes-UP,Dresser-Inds-UP,Halliburton-HLD-UP, Louisiana-Land-UP,Phillips-Petro-UP,Unocal-UP, Schlumberger-UP	Oil-UP

Association Rule Discovery: Definition

- Given a set of records each of which contains some number of items from a given collection;
  - Produce dependency rules which will predict occurrence of an item based on occurrences of other items.

TID	*Items*
1	**Bread, Coke, Milk**
2	**Beer, Bread**
3	**Beer, Coke, Diaper, Milk**
4	**Beer, Bread, Diaper, Milk**
5	**Coke, Diaper, Milk**

Rules Discovered:
{Milk} --> {Coke}
{Diaper, Milk} --> {Beer}

Association Rule Discovery: Application 1

- Marketing and Sales Promotion:
  - Let the rule discovered be

    {Bagels, … } --> {Potato Chips}
  - Potato Chips as consequent => Can be used to determine what should be done to boost its sales.
  - Bagels in the antecedent => Can be used to see which products would be affected if the store discontinues selling bagels.
  - Bagels in antecedent *and* Potato chips in consequent => Can be used to see what products should be sold with Bagels to promote sale of Potato chips!

Association Rule Discovery: Application 2

- Supermarket shelf management.
  - Goal: To identify items that are bought together by sufficiently many customers.
  - Approach: Process the point-of-sale data collected with barcode scanners to find dependencies among items.
  - A classic rule --
    - If a customer buys diaper and milk, then he is very likely to buy beer.
    - So, don’t be surprised if you find six-packs stacked next to diapers!

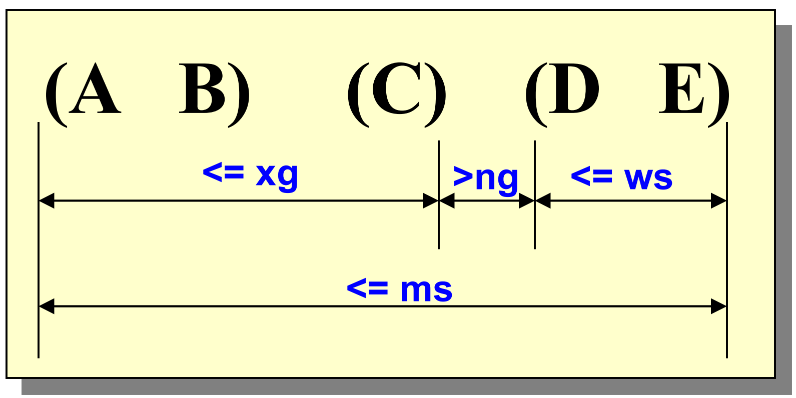
Association Rule Discovery: Application 3

- Inventory Management:
  - Goal: A consumer appliance repair company wants to anticipate the nature of repairs on its consumer products and keep the service vehicles equipped with right parts to reduce on number of visits to consumer households.
  - Approach: Process the data on tools and parts required in previous repairs at different consumer locations and discover the co-occurrence patterns.

Sequential Pattern Discovery: Definition

- Given is a set of objects, with each object associated with its own timeline of events, find rules that predict strong sequential dependencies among different event
- Rules are formed by first discovering patterns. Event occurrences in the patterns are governed by timing constraints.

(A B) (C) ⟶ (D E)



Sequential Pattern Discovery: Examples

- In telecommunications alarm logs,
  - (Inverter_Problem Excessive_Line_Current)

    (Rectifier_Alarm) --> (Fire_Alarm)
- In point-of-sale transaction sequences,
  - Computer Bookstore:

    (Intro_To_Visual_C) (C++_Primer) -->
    (Perl_for_dummies,Tcl_Tk)
  - Athletic Apparel Store:

    (Shoes) (Racket, Racketball) --> (Sports_Jacket)

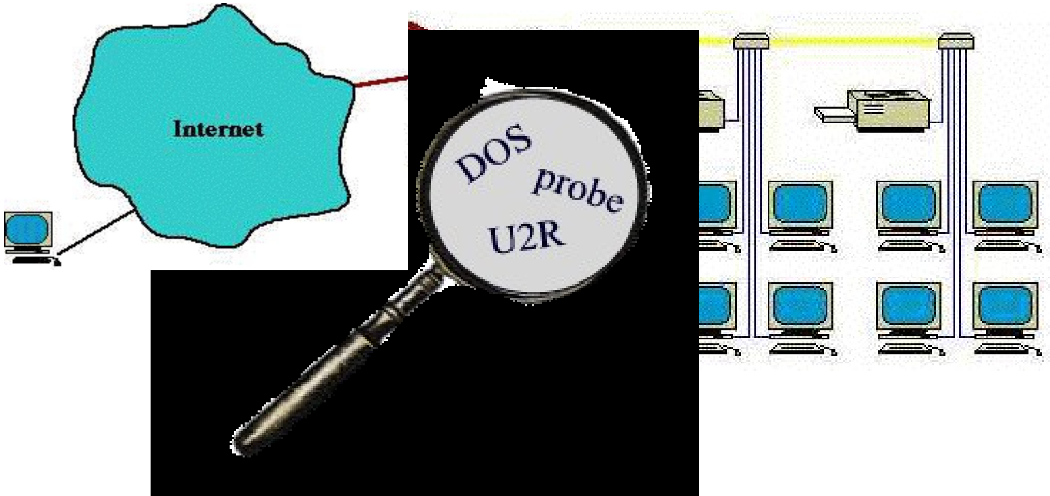
Regression

- Predict a value of a given continuous valued variable based on the values of other variables, assuming a linear or nonlinear model of dependency.
- Greatly studied in statistics, neural network fields.
- Examples:
  – Predicting sales amounts of new product based on advetising expenditure.
  – Predicting wind velocities as a function of temperature, humidity, air pressure, etc.
  – Time series prediction of stock market indices.

Deviation/Anomaly Detection

- Detect significant deviations from normal behavior
- Applications:
  - Credit Card Fraud Detection

  - Network Intrusion Detection



Typical network traffic at University level may [redacted] *ections per day*

Challenges of Data Mining

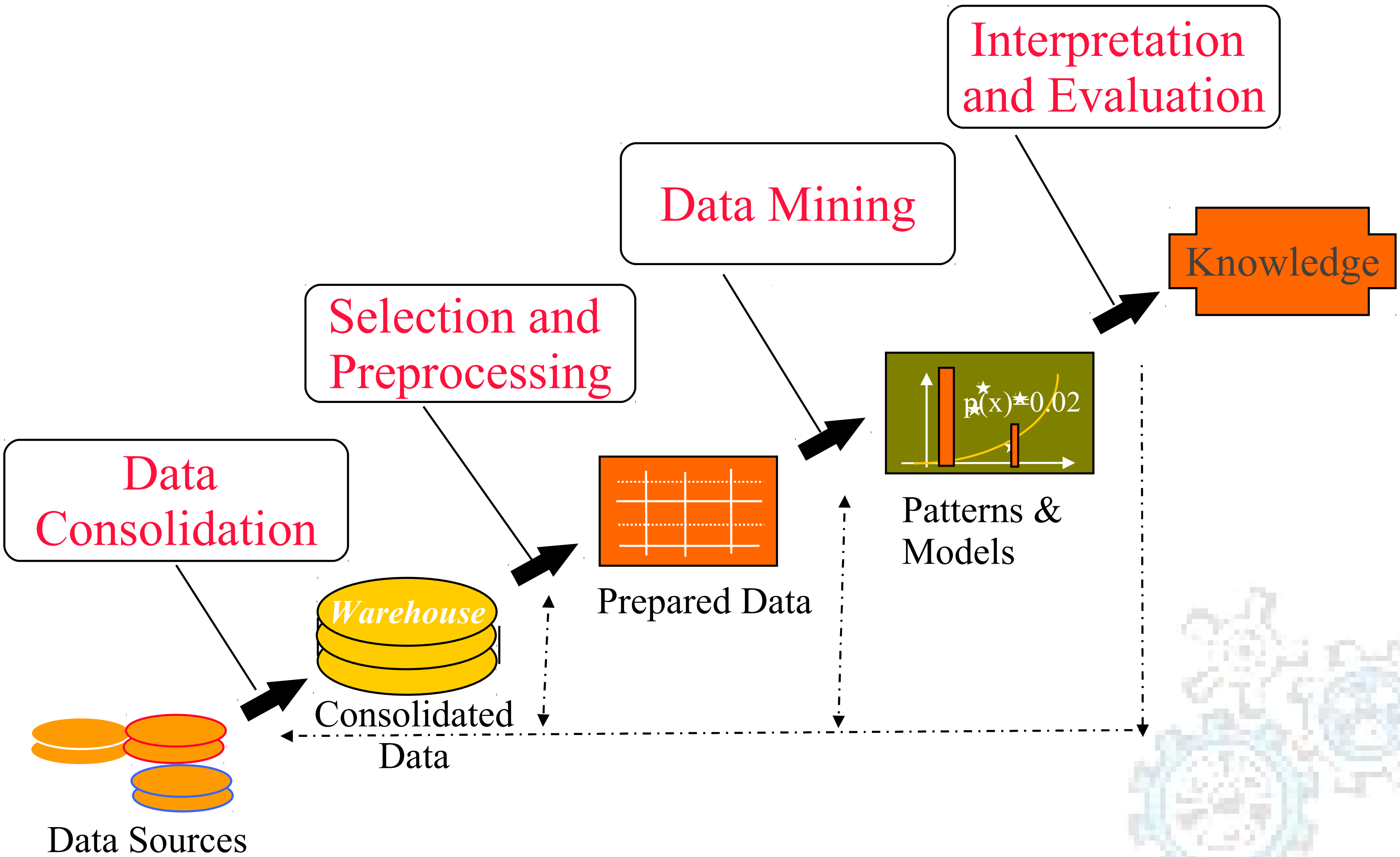
- Scalability
- Dimensionality
- Complex and Heterogeneous Data
- Data Quality
- Data Ownership and Distribution
- Privacy Preservation
- Streaming Data

The KDD process
(Knowledge Discovery in Databases)

- **The selection and processing of data for:**
  - **the identification of novel, accurate, and useful patterns, and**
  - **the modeling of real-world phenomena.**

- **Data mining is a major component of the KDD process - automated discovery of patterns and the development of predictive and explanatory models.**

The KDD process

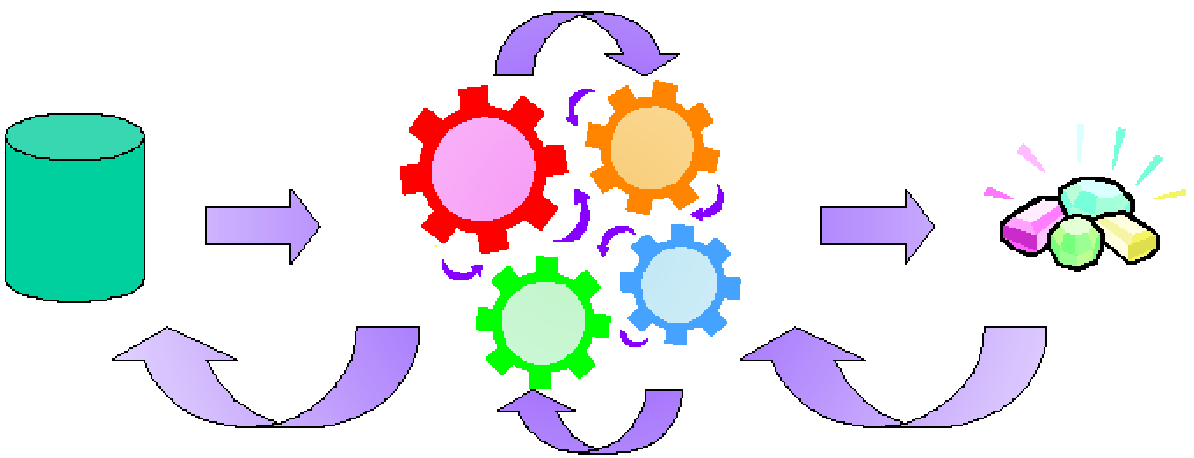


The steps of the KDD process

- Learning the application domain:
  - relevant prior knowledge and goals of application
- Data consolidation: Creating a target data set
- Selection and Preprocessing
  - *Data cleaning* : (may take 60% of effort!)
  - *Data reduction and projection*:
    - find useful features, dimensionality/variable reduction, invariant representation.
- Choosing functions of data mining
  - classification, regression, association, clustering.
- Choosing the mining algorithm(s)
- Data mining: search for patterns of interest
- Interpretation and evaluation: analysis of results.
  - *visualization, transformation, remove redundant patterns*
- Use of discovered knowledge

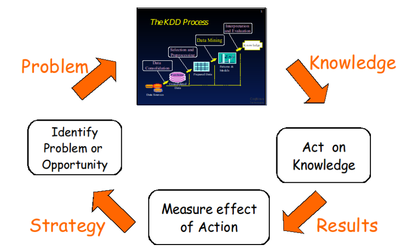
The KDD Process in Practice

- KDD is an Iterative Process
  - art + engineering rather than science

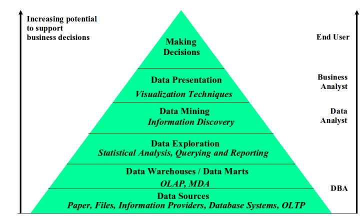


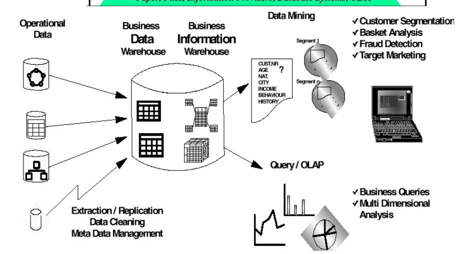
The KDD Process in real applications

- KDD as part of a virtuous cycle

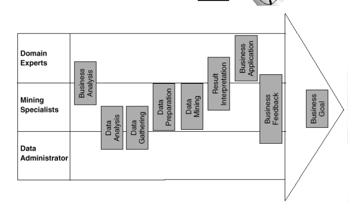


- KDD/DM in the Business intelligence process



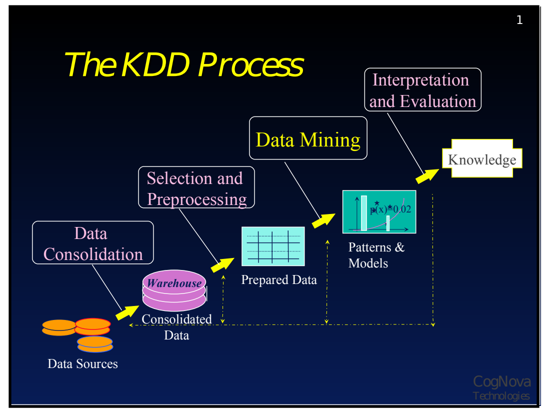


- Roles in the KDD process



- An environment for KDD and BI

The *virtuous cycle*



Problem

Knowledge

Identify Problem or Opportunity

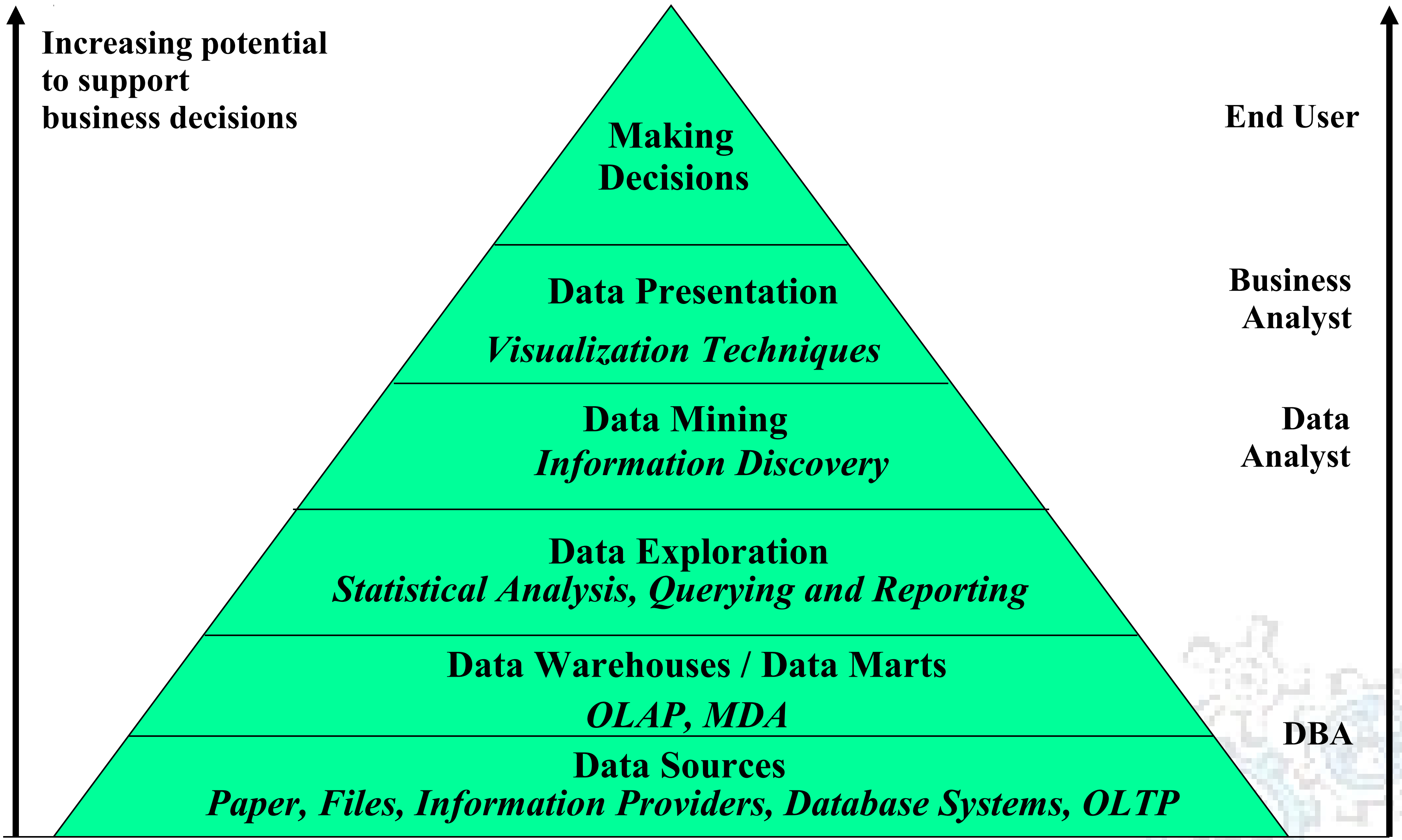
Act on Knowledge

Measure effect of Action

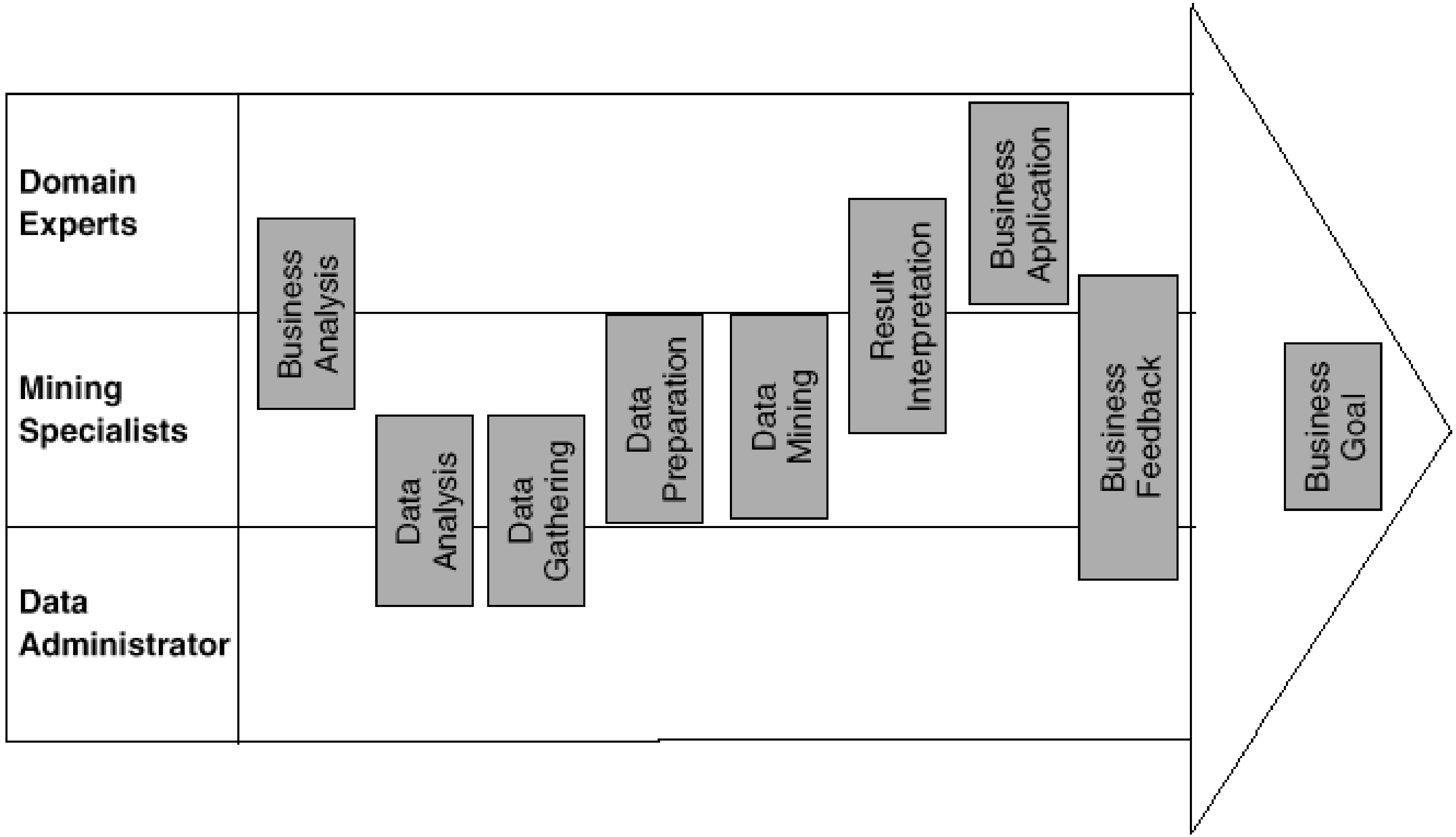
Strategy

Results

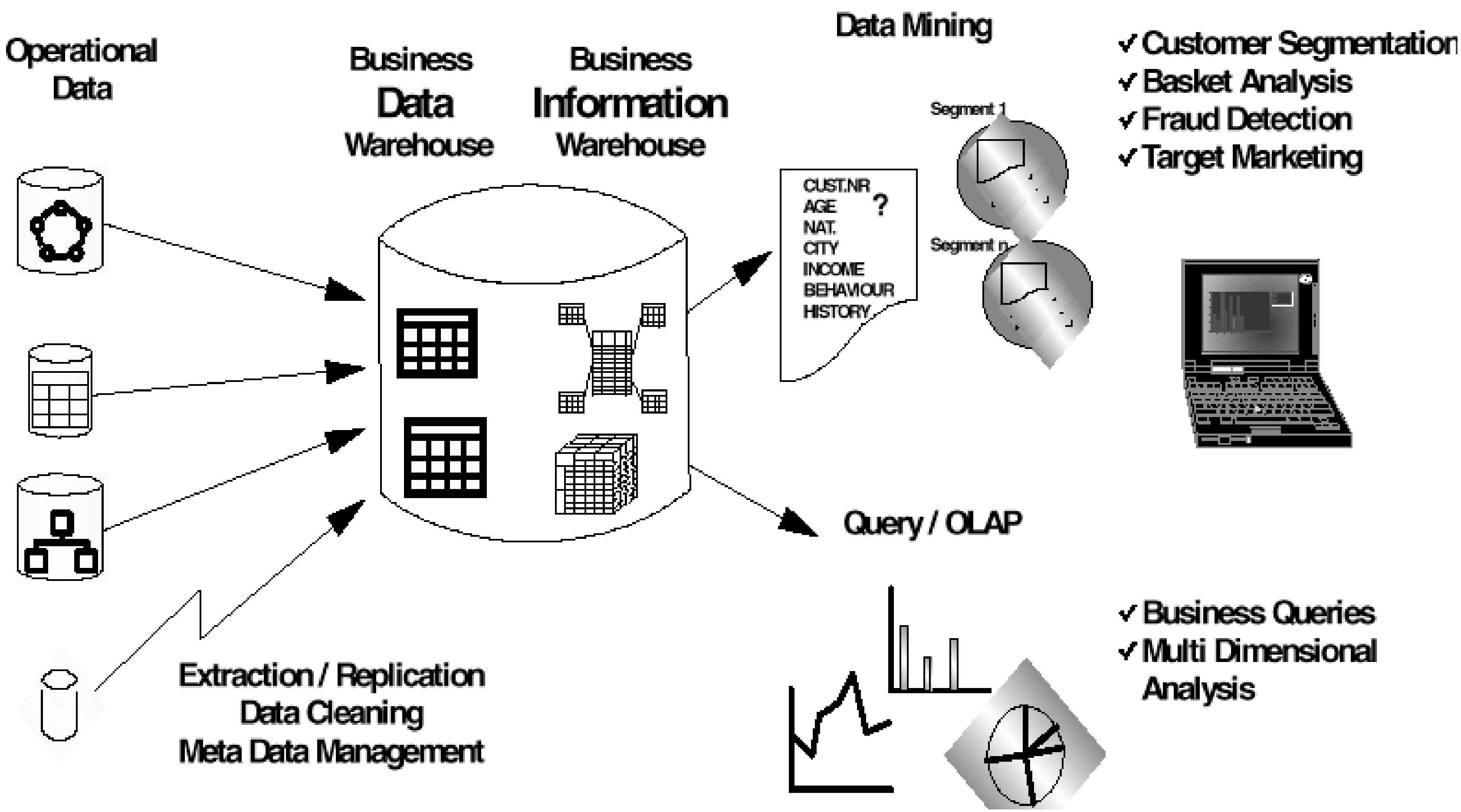
Data mining and business intelligence



Roles in the KDD process



A business intelligence environment



Examples of DM projects

Competitive Intelligence

Health care

L'Oreal, a case-study on competitive intelligence:

Source: DM@CINECA

http://open.cineca.it/datamining/dmCineca/

A small example

- Domain: technology watch - a.k.a. competitive intelligence
  - Which are the emergent technologies?
  - Which competitors are investing on them?
  - In which area are my competitors active?
  - Which area will my competitor drop in the near future?
- Source of data:
  - public (on-line) databases

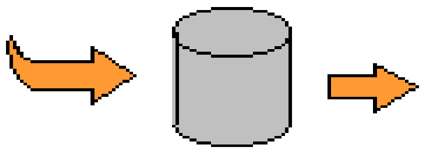
The Derwent database

- Contains all patents filed worldwide in last 10 years
- Searching this database by keywords may yield thousands of documents
- Derwent documents are semi-structured: many long text fields

- Goal: analyze Derwent documents to build a model of competitors' strategy

Structure of Derwent documents

Raccolta dei Documenti



esempio di documento brevettuale

1/3881 - (C) Derwent Info 1994

AN: 94-364398 [45]

TI: Television with function for enlarging picture by variation of deflect ion frequency - has microprocessor for controlling system synchronous signal output, horizontal and vertical frequency drive circuit, sync. signal counter, signal detector.

DC: W03

PA: (GLDS) GOLDSTAR CO LTD

IN: O.KEITH

NP: 1

PR: 88KR-011143 880831

IC: H04N-005/262;C08J-005/18;G11B-005/704

PN: KR940043 B1 940120 DW9445

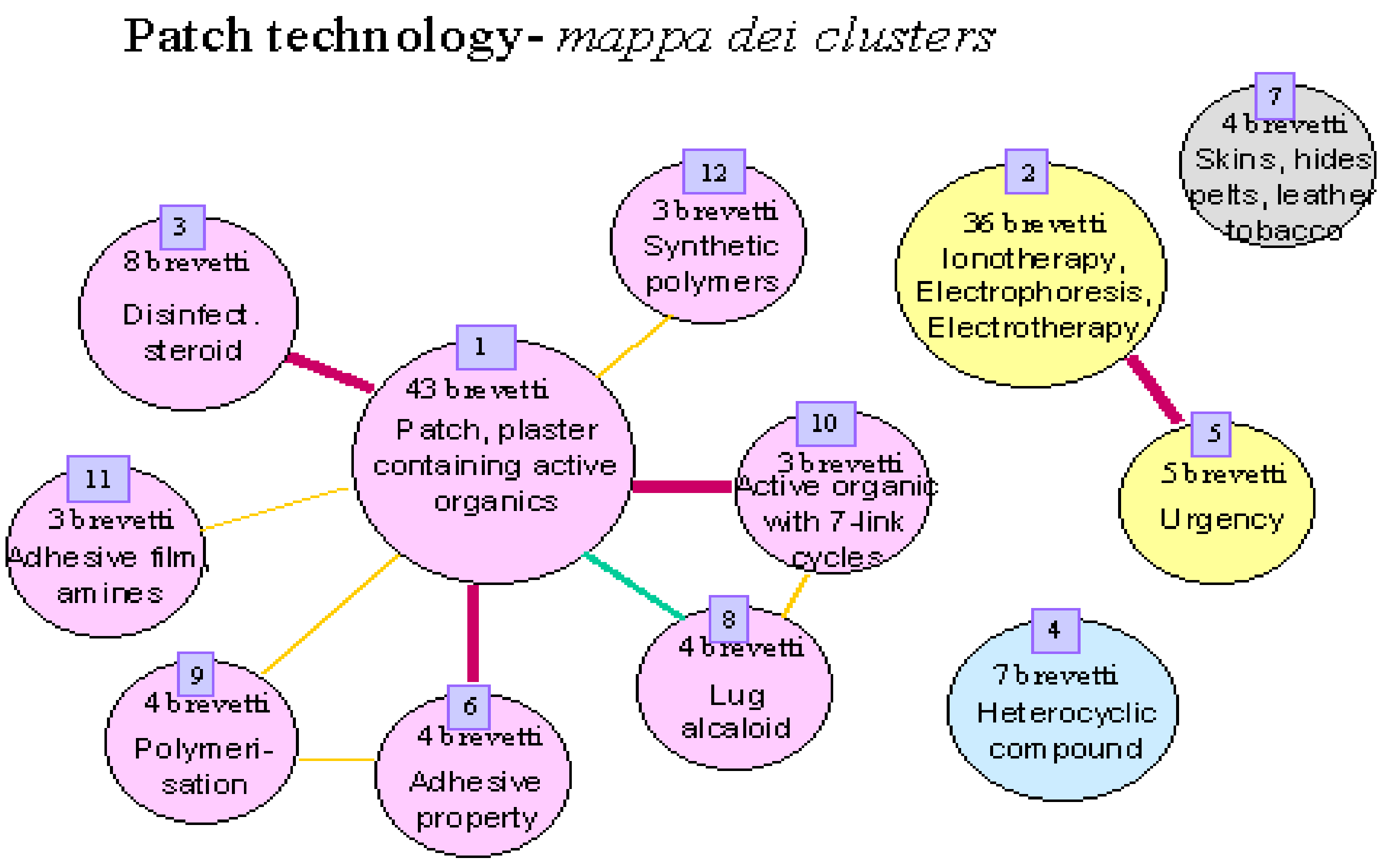
AB: .... abstract ....

Example dataset

- Patents in the area: patch technology (cerotto medicale)
  - 105 companies from 12 countries
  - 94 classification codes
  - 52 Derwent codes

Clustering output

- Clusters patents with similar sets of keywords in the same group
- Groups are linked if they share some keywords



Zoom on cluster 2

Patch technology- *descrizione del cluster n.2*

Classificazione Internazionale:

A61N-001/30 Electrotherapy; Appliances of electrical power by contact electrodes; Ionotherapy or electrophorese devices
A61M-037/00 Therapeutic patch

Classificazione Derwent:

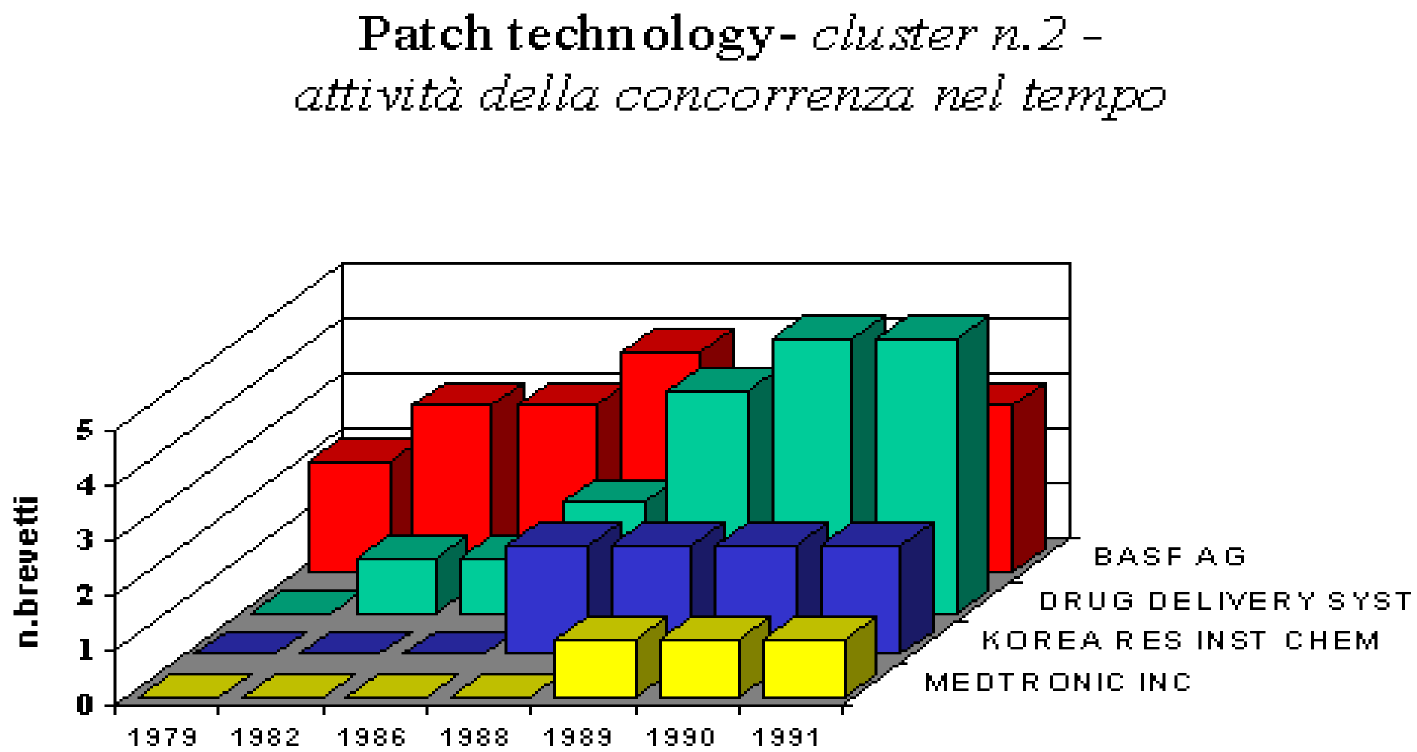
S05 Electromedical
P34 Health, Electrotherapy

Società proprietarie:

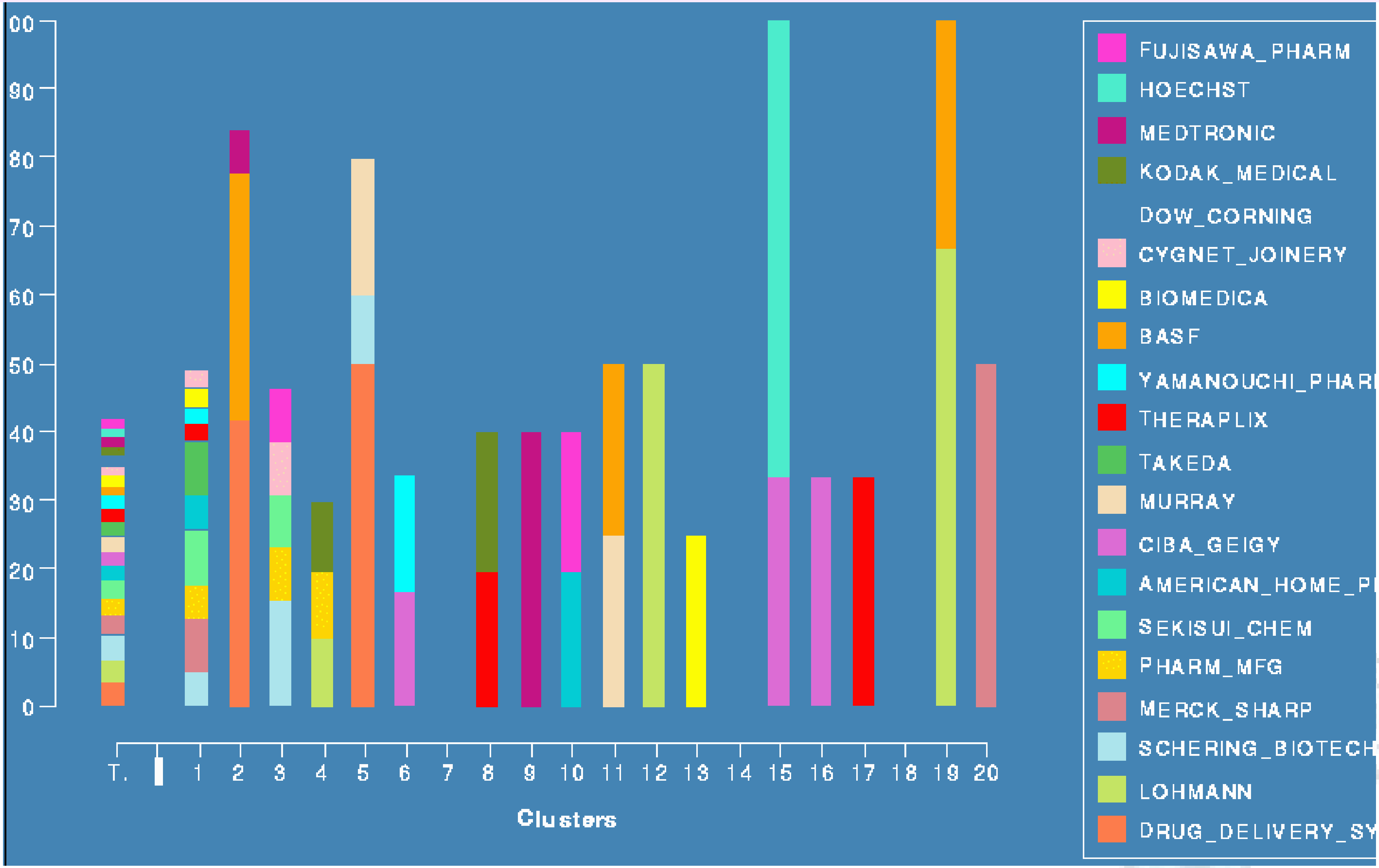
🇺🇸	DRUG DELIVERY SYST	42%
🇩🇪	BASF AG	36%
🇰🇷	KOREA RES INST CHEM	16%
🇺🇸	MEDTRONIC INC	6%

Anno	n. brevetti
1979	2
1982	4
1986	4
1988	8
1989	10
1990	11
1991	11

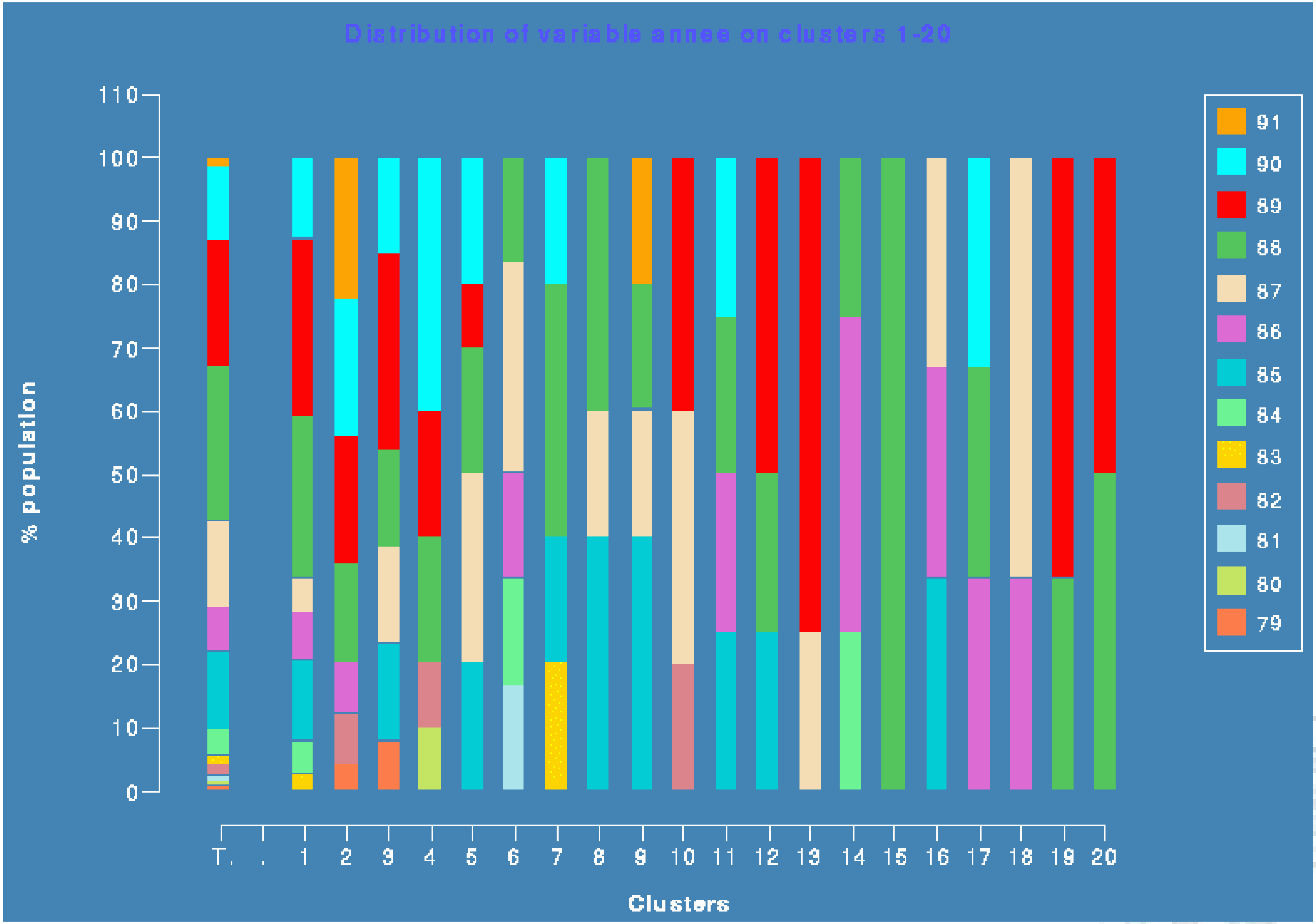
Zoom on cluster 2 - profiling competitors



Activity of competitors in the clusters



Temporal analysis of clusters



Atherosclerosis prevention study

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U nemocnice 2, Prague 2
(head. Prof. M. Aschermann, MD, SDr, FESC)

Atherosclerosis prevention study:

- The STULONG 1 data set is a real database that keeps information about the study of the development of atherosclerosis risk factors in a population of middle aged men.

- Used for Discovery Challenge at PKDD 00-02-03-04

Atherosclerosis prevention study:

- Study on 1400 middle-aged men at Czech hospitals
  - Measurements concern development of cardiovascular disease and other health data in a series of exams
- The aim of this analysis is to look for associations between medical characteristics of patients and death causes.
- Four tables
  - Entry and subsequent exams, questionnaire responses, deaths

The input data

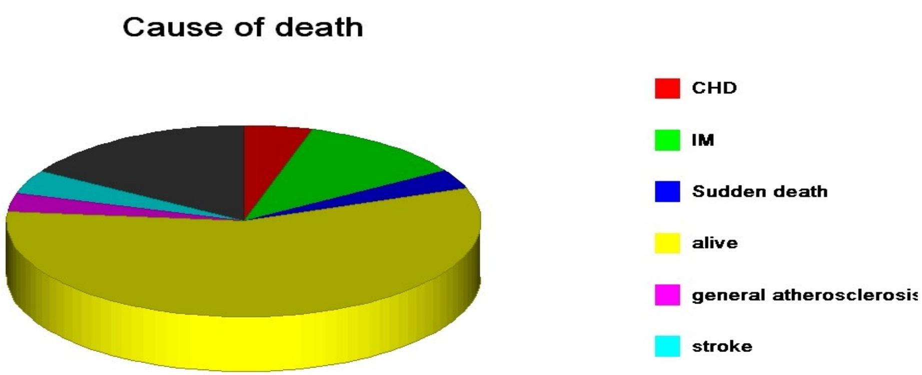
Data from Entry and Exams		
General characteristics	**Examinations**	**habits**
Marital status	Chest pain	Alcohol
Transport to a job	Breathlesness	Liquors
Physical activity in a job	Cholesterol	Beer 10
Activity after a job	Urine	Beer 12
Education	Subscapular	Wine
Responsibility	Triceps	Smoking
Age		Former smoker
Weight		Duration of smoking
Height		Tea
		Sugar
		Coffee

The input data

DEATH CAUSE	PATIENTS	%
myocardial infarction	80	20.6
coronary heart disease	33	8.5
stroke	30	7.7
other causes	79	20.3
sudden death	23	5.9
unknown	8	2.0
tumorous disease	114	29.3
general atherosclerosis	22	5.7
TOTAL	389	100.0

Data selection

- When joining "Entry" and "Death" tables we implicitely create a new attribute "Cause of death", which is set to "alive" for subjects present in the "Entry" table but not in the "Death" table.
- We have only 389 subjects in death table.



The prepared data

Patient	General characteristics		Examinations		Habits		Cause of death
	Activity after work	Education	Chest pain	…	Alcohol	…..	
1	moderate activity	university	not present		no		Stroke
2	great activity		not ischaemic		occasionally		myocardial infarction
3	he mainly sits		other pains		regularly		tumorous disease
……	……..	……..	………..	..	…	……	alive
389	he mainly sits		other pains		regularly		tumorous disease

Descriptive Analysis/ Subgroup Discovery /Association Rules

Are there strong relations concerning death cause?

General characteristics (?) $\Rightarrow$ Death cause (?)

Examinations (?) $\Rightarrow$ Death cause (?)

Habits (?) $\Rightarrow$ Death cause (?)

Combinations (?) $\Rightarrow$ Death cause (?)

Example of extracted rules

Education(university) & Height<176-180>

⇒

Death cause (tumouros disease), ***16 ; 0.62***

- **It means that on tumorous disease have died 16, i.e. 62% of patients with university education and with height 176-180 cm.**

Example of extracted rules

Physical activity in work(he mainly sits) & Height<176-180>

$\Rightarrow$

Death cause (tumouros disease), ***24; 0.52***

- **It means that on tumorous disease have died 24 i.e. 52% of patients that mainly sit in the work and whose height is 176-180 cm.**

Example of extracted rules

Education(university) & Height<176-180>

$\Rightarrow$

Death cause (tumouros disease),

16; 0.62; +1.1;

- **the** relative frequency **of patients who died on tumorous disease among patients with university education and with height 176-180 cm is 110 per cent higher than the relative frequency of patients who died on tumorous disease among all the 389 observed patients**