Introduction to KDD and data mining

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This presentation was prepared on the basis of the following public materials:

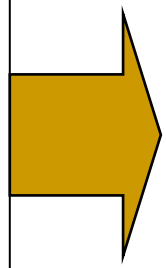
1. Jiawei Han and Micheline Kamber, „Data mining, concept and techniques" http://www.cs.sfu.ca
2. Gregory Piatetsky-Shapiro, „kdnuggest", http://www.kdnuggets.com/data_mining_course/

Lecture plan

- Motivations: why data mining?
- Definitions of data mining?
- Examples of applications
- Data mining systems and functionality
- Methods in data mining
- Data mining: a KDD process
- Data mining issues


Motivation: large scale databases

- Advanced methods in data extraction and data storing techniques
- Growth of many application areas



- More generated data:
  - Bank, telecom, other business transactions ...
  - Scientific data: astronomy, biology, etc
  - Web, text, and e-commerce

Massive data sources

- Huge number of records
  10^6-10^{12} in case of databases about celestial objects (astronomy)
- Huge number of attributes (features, measurements, columns)
  Hundreds of variables in patient records corresponding to results of medical examinations

Motivation

- „We are melting in a ocean of data, but we need a knowledge”
- PROBLEM:
  How to get a useful information/knowledge from large databases?
- SOLUTION: Data wherehouse + data mining

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What Is Data Mining?

An iterative and interactive process of discovering

- novel,
- valid,
- useful,
- comprehensive and
- understandable

patterns and models in

MASSIVE data sources (databases).

- Novel: something we are not aware of
- Valid: generalise to the future
- Useful: some reaction is possible
- Understandable: leading to insight
- Iterative: many steps and many passes
- Interactive: human is a part of the system

What is Data Mining

- Alternative names and their "inside stories":
  - Data mining: a misnomer?
  - Knowledge discovery (mining) in databases (KDD), knowledge extraction, data/pattern analysis, data archeology, data dredging, information harvesting, business intelligence, etc.
- What is not data mining?
  - (Deductive) query processing.
  - Expert systems or small ML/statistical programs

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.) and application-oriented DBMS (spatial, scientific, engineering, etc.)
- 1990s—2000s:
  - Data mining and data warehousing, multimedia databases, and Web databases


Big Data Examples

- Europe's Very Long Baseline Interferometry (VLBI) has 16 telescopes, each of which produces **1 Gigabit/second** of astronomical data over a 25-day observation session
  - storage and analysis a big problem
- AT&T handles billions of calls per day
  - so much data, it cannot be all stored -- analysis has to be done "on the fly", on streaming data

Largest databases in 2003

- Commercial databases:
  - Winter Corp. 2003 Survey: France Telecom has largest decision-support DB, ~30TB; AT&T ~ 26 TB
- Web
  - Alexa internet archive: 7 years of data, 500 TB
  - Google searches 4+ Billion pages, many hundreds TB
  - IBM WebFountain, 160 TB (2003)
  - Internet Archive (www.archive.org),~ 300 TB

5 million terabytes created in 2002

- UC Berkeley 2003 estimate: 5 exabytes (5 million terabytes) of new data was created in 2002.

www.sims.berkeley.edu/research/projects/how-much-info-2003/

- US produces ~40% of new stored data worldwide

Data Growth Rate

- Twice as much information was created in 2002 as in 1999 (~30% growth rate)
- Other growth rate estimates even higher
- Very little data will ever be looked at by a human
- Knowledge Discovery is **NEEDED** to make sense and use of data.


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Data Mining
Application areas

- Science
  - astronomy, bioinformatics, drug discovery, …
- Business
  - advertising, CRM (Customer Relationship management), investments, manufacturing, sports/entertainment, telecom, e-Commerce, targeted marketing, health care, …
- Web:
  - search engines, bots, …
- Government
  - law enforcement, profiling tax cheaters, anti-terror(?)


Data Mining for Customer Modeling

- Customer Tasks:
  - attrition prediction
  - targeted marketing:
    - cross-sell, customer acquisition
  - credit-risk
  - fraud detection
- Industries
  - banking, telecom, retail sales, …


Customer Attrition: Case Study

- Situation: Attrition rate at for mobile phone customers is around 25-30% a year!

Task:

- Given customer information for the past N months, predict who is likely to attrite next month.
- Also, estimate customer value and what is the cost-effective offer to be made to this customer.

Customer Attrition Results

- Verizon Wireless built a customer data warehouse
- Identified potential attriters
- Developed multiple, regional models
- Targeted customers with high propensity to accept the offer
- Reduced attrition rate from over 2%/month to under 1.5%/month (huge impact, with >30 M subscribers)

(Reported in 2003)


Assessing Credit Risk: Case Study

- Situation: Person applies for a loan
- Task: Should a bank approve the loan?
- Note: People who have the best credit don't need the loans, and people with worst credit are not likely to repay. Bank's best customers are in the middle


Credit Risk - Results

- Banks develop credit models using variety of machine learning methods.
- Mortgage and credit card proliferation are the results of being able to successfully predict if a person is likely to default on a loan
- Widely deployed in many countries


Successful e-commerce – Case Study

- A person buys a book (product) at Amazon.com.
- Task: Recommend other books (products) this person is likely to buy
- Amazon does clustering based on books bought:
  - customers who bought "**Advances in Knowledge Discovery and Data Mining**", also bought "**Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations**"
- Recommendation program is quite successful

Unsuccessful e-commerce case study (KDD-Cup 2000)

- Data: clickstream and purchase data from Gazelle.com, legwear and legcare e-tailer
- Q: Characterize visitors who spend more than $12 on an average order at the site
- Dataset of 3,465 purchases, 1,831 customers
- Very interesting analysis by Cup participants
  - thousands of hours - $X,000,000 (Millions) of consulting
- Total sales -- $Y,000
- Obituary: Gazelle.com out of business, Aug 2000

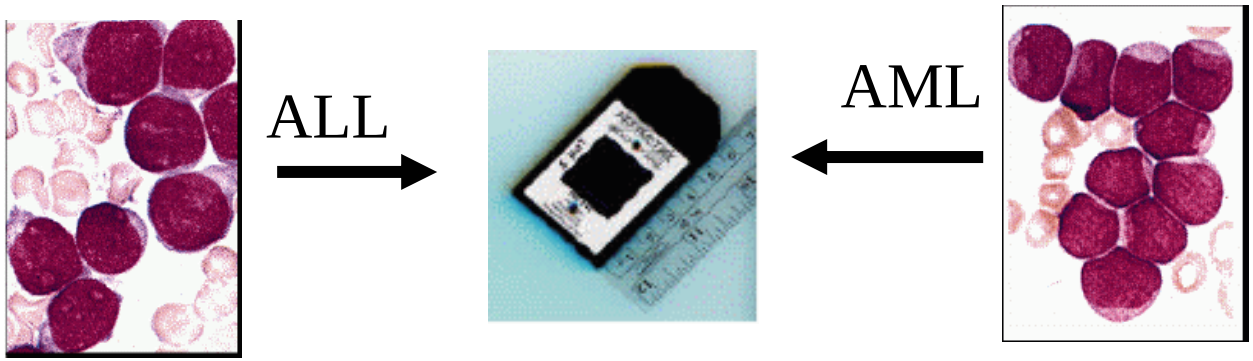

Genomic Microarrays – Case Study

Given microarray data for a number of samples (patients), can we

- Accurately diagnose the disease?
- Predict outcome for given treatment?
- Recommend best treatment?

Example: ALL/AML data

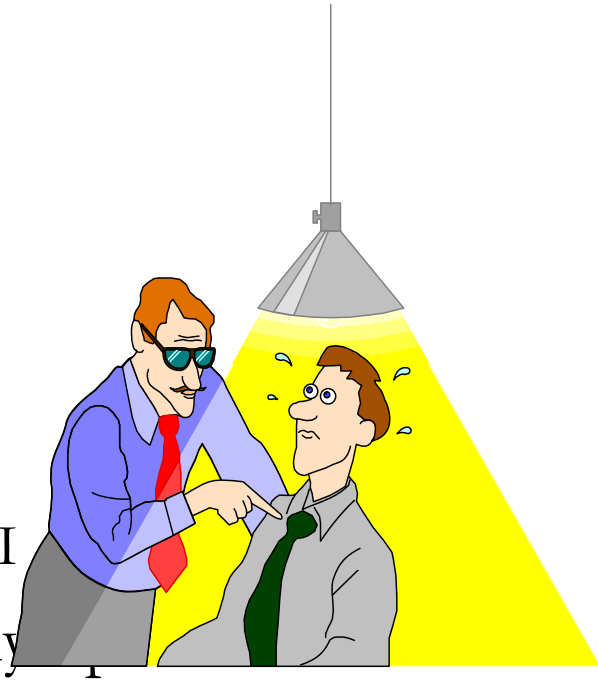
- 38 training cases, 34 test, ~ 7,000 genes
- 2 Classes: Acute Lymphoblastic Leukemia (ALL) vs Acute Myeloid Leukemia (AML)
- Use train data to build diagnostic model



Results on test data:
33/34 correct, 1 error may be mislabeled

Security and Fraud Detection - Case Study

- Credit Card Fraud Detection
- Detection of Money laundering
  - FAIS (US Treasury)
- Securities Fraud
  - NASDAQ KDD system
- Phone fraud
  - AT&T, Bell Atlantic, British Telecom/MCI
- Bio-terrorism detection at Salt Lake Oly
  2002



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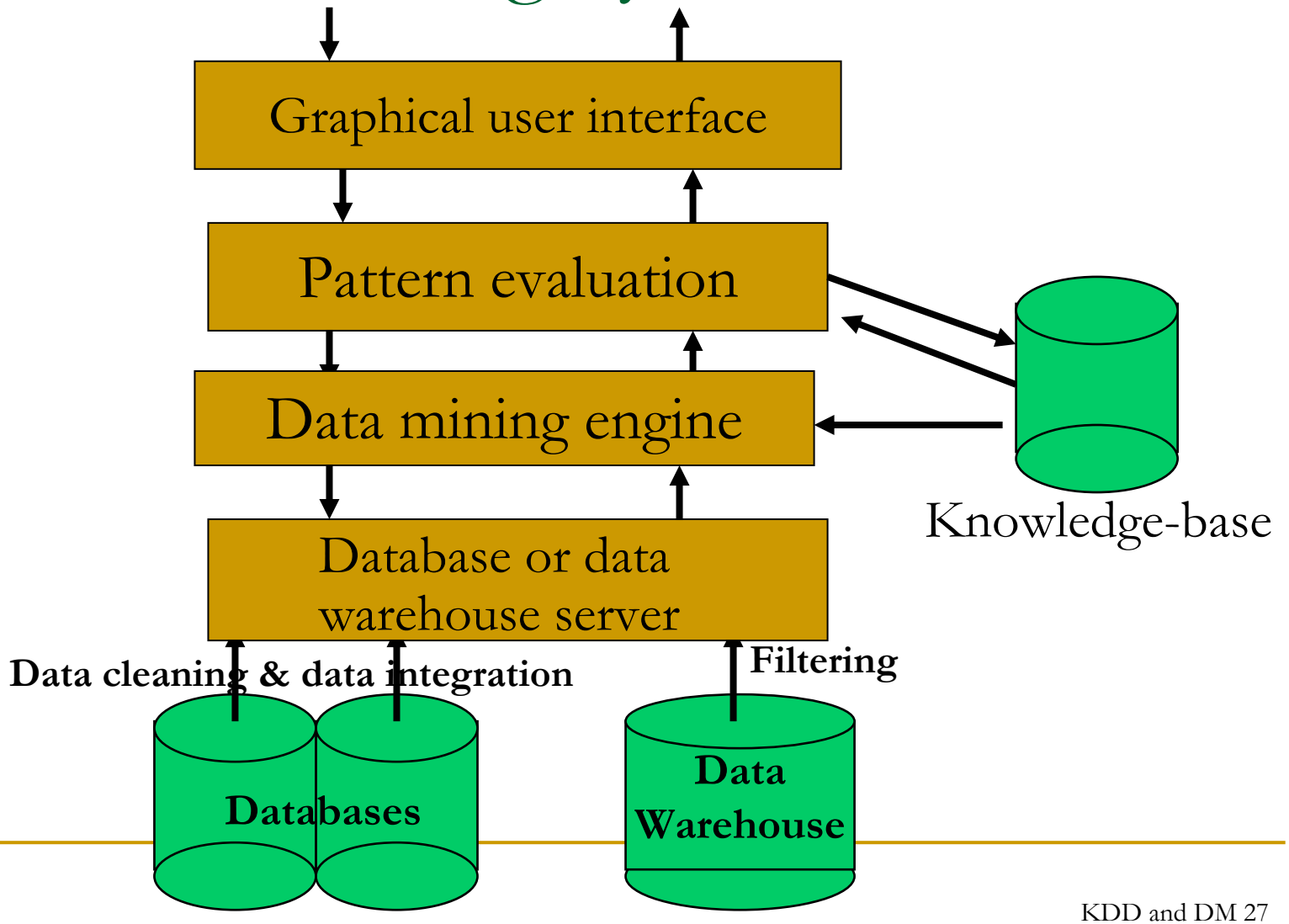
Architecture of a Typical Data Mining System



Data Mining: On 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

Data Mining Functionalities (1)

- Concept description: Characterization and discrimination
  - Generalize, summarize, and contrast data characteristics, e.g., dry vs. wet regions
- Association (correlation and causality)
  - Multi-dimensional vs. single-dimensional association
  - age(X, "20..29") ^ income(X, "20..29K") => buys(X, "PC") [support = 2%, confidence = 60%]
  - contains(T, "computer") => contains(T, "software") [1%, 75%]

Data Mining Functionalities (2)

- Classification and Prediction
  - Finding models (functions) that describe and distinguish classes or concepts for 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 or missing numerical values
- Cluster analysis
  - 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

Data Mining Functionalities (3)

- 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
- Other pattern-directed or statistical analyses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Component of a Data Mining algorithm

- Knowledge representation model
- Evaluation criteria
- Search strategy


Knowledge representation

- Using logical language to describe mined patterns. E.g.,
  - Logical formulas
  - Decision tree
  - Neural networks (!)

Search strategy

- Parameter searching
- Model searching


Are All the "Discovered" Patterns Interesting?

- A data mining system/query may generate thousands of patterns, not all of them are interesting.
  - Suggested approach: Human-centered, query-based, focused mining
- **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, actionability, etc.

Can We Find All and Only Interesting Patterns?

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

Major Data Mining Methods

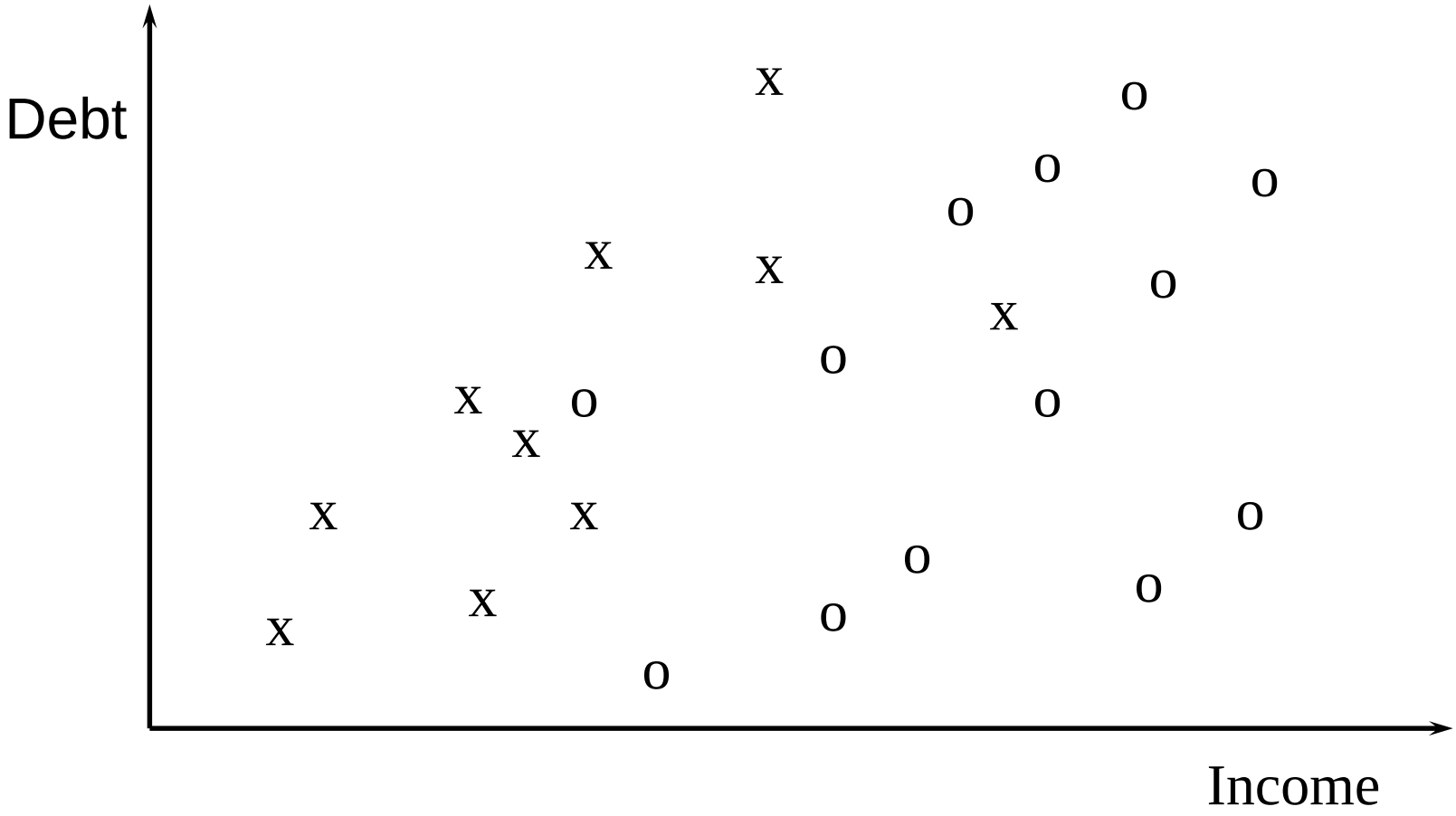
- **Classification:** predicting an item class
- **Clustering:** finding clusters in data
- **Associations:** e.g. A & B & C occur frequently
- **Visualization:** to facilitate human discovery
- **Summarization:** describing a group
- **Deviation Detection**: finding changes
- Estimation: predicting a continuous value
- Link Analysis: finding relationships
- …

Related techniques

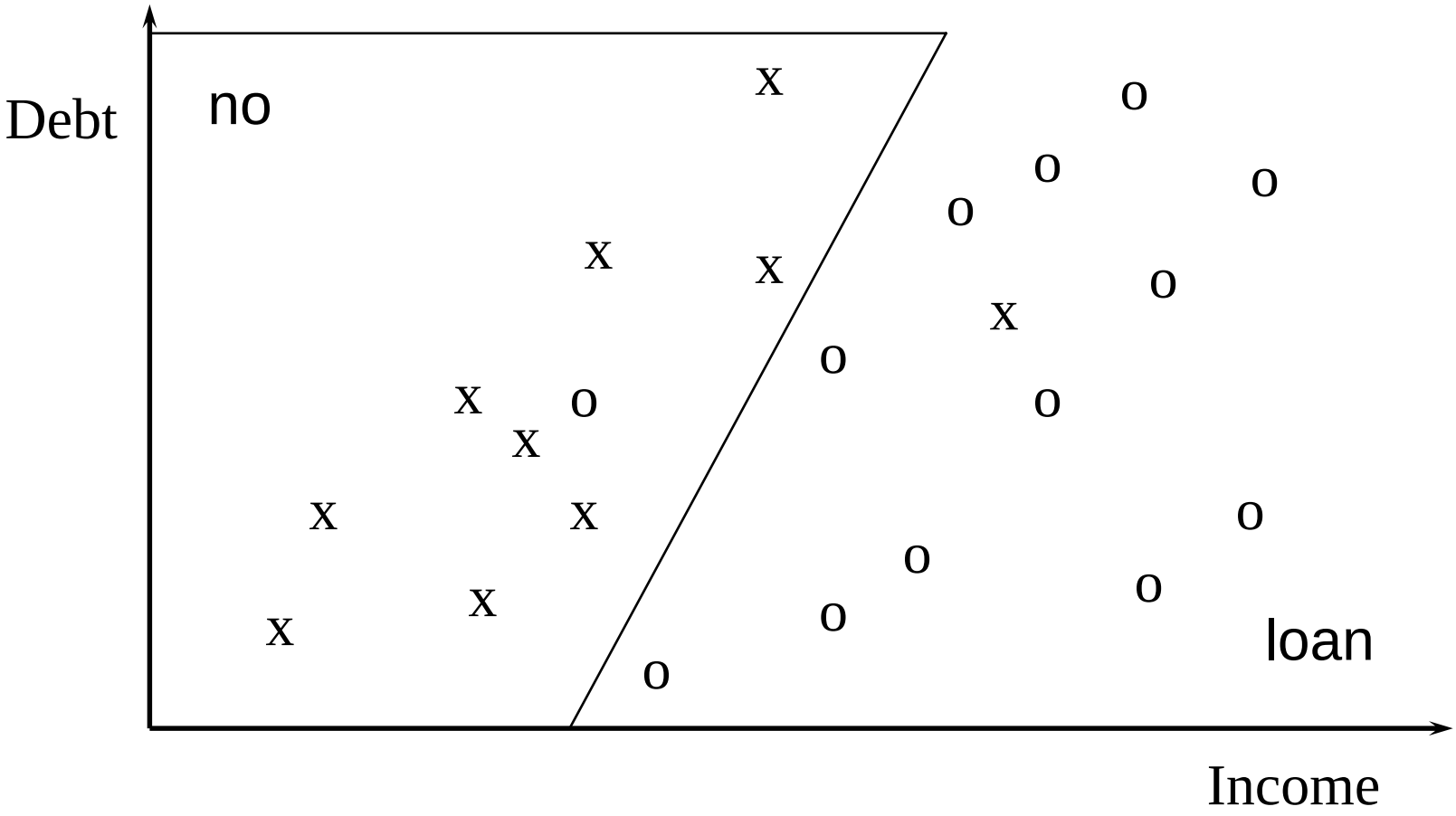
- Neural Networks
- Fuzzy Sets
- Rough Sets
- Time series analysis
- Bayesian Networks
- Decision trees
- Evolutionary programming and GA
- Markov modelling

…….

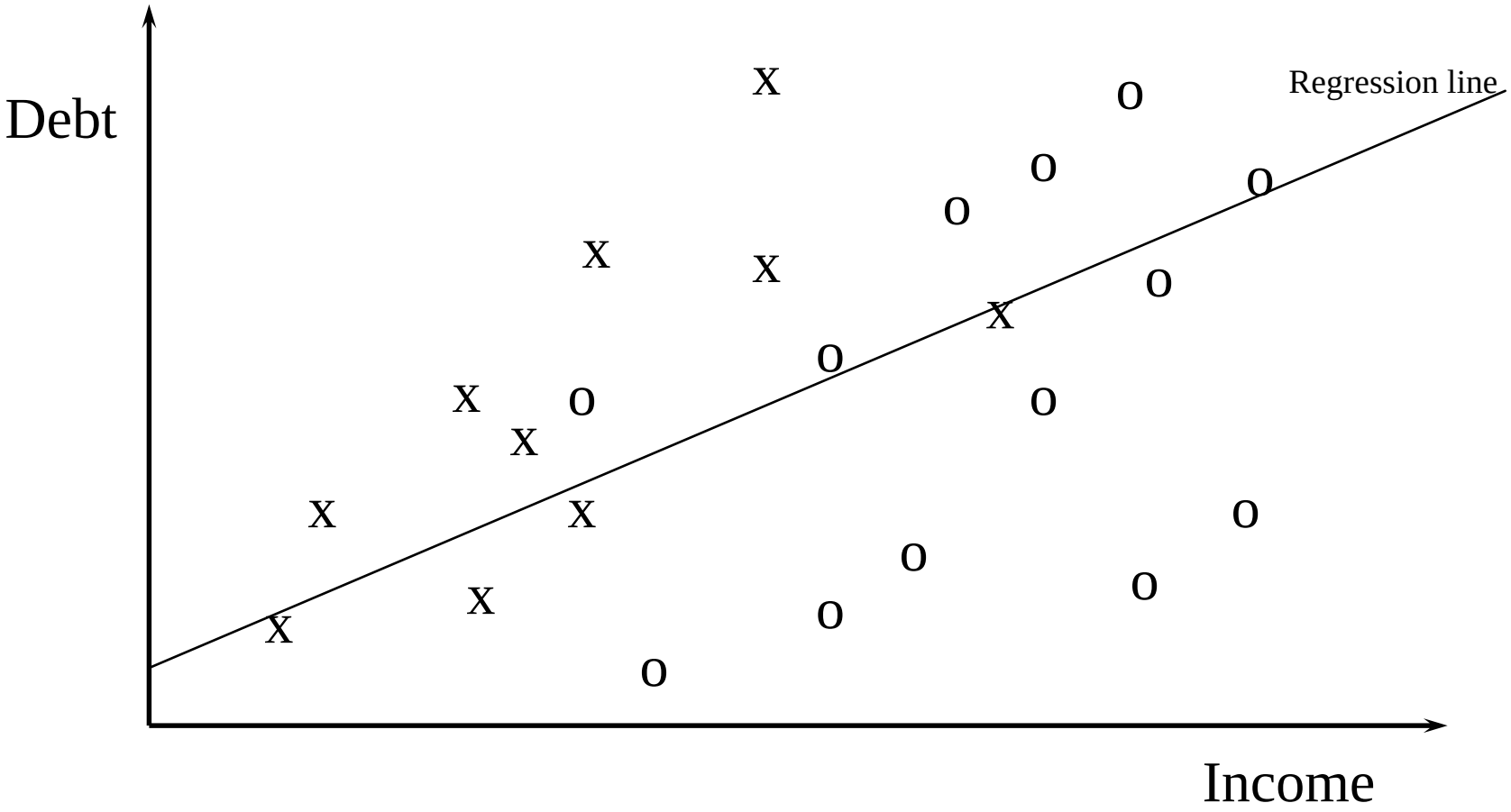

Example



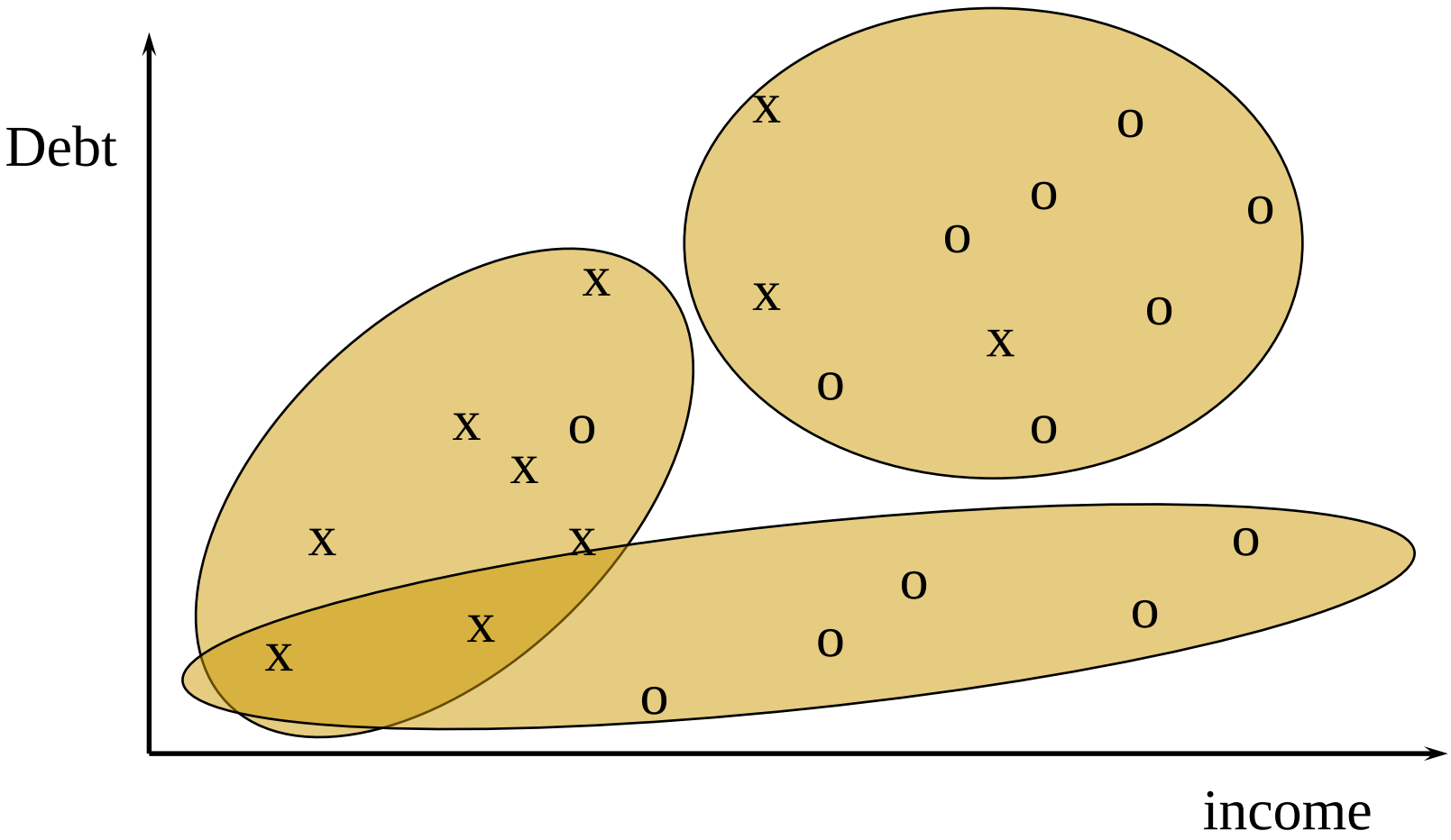
Linear classification



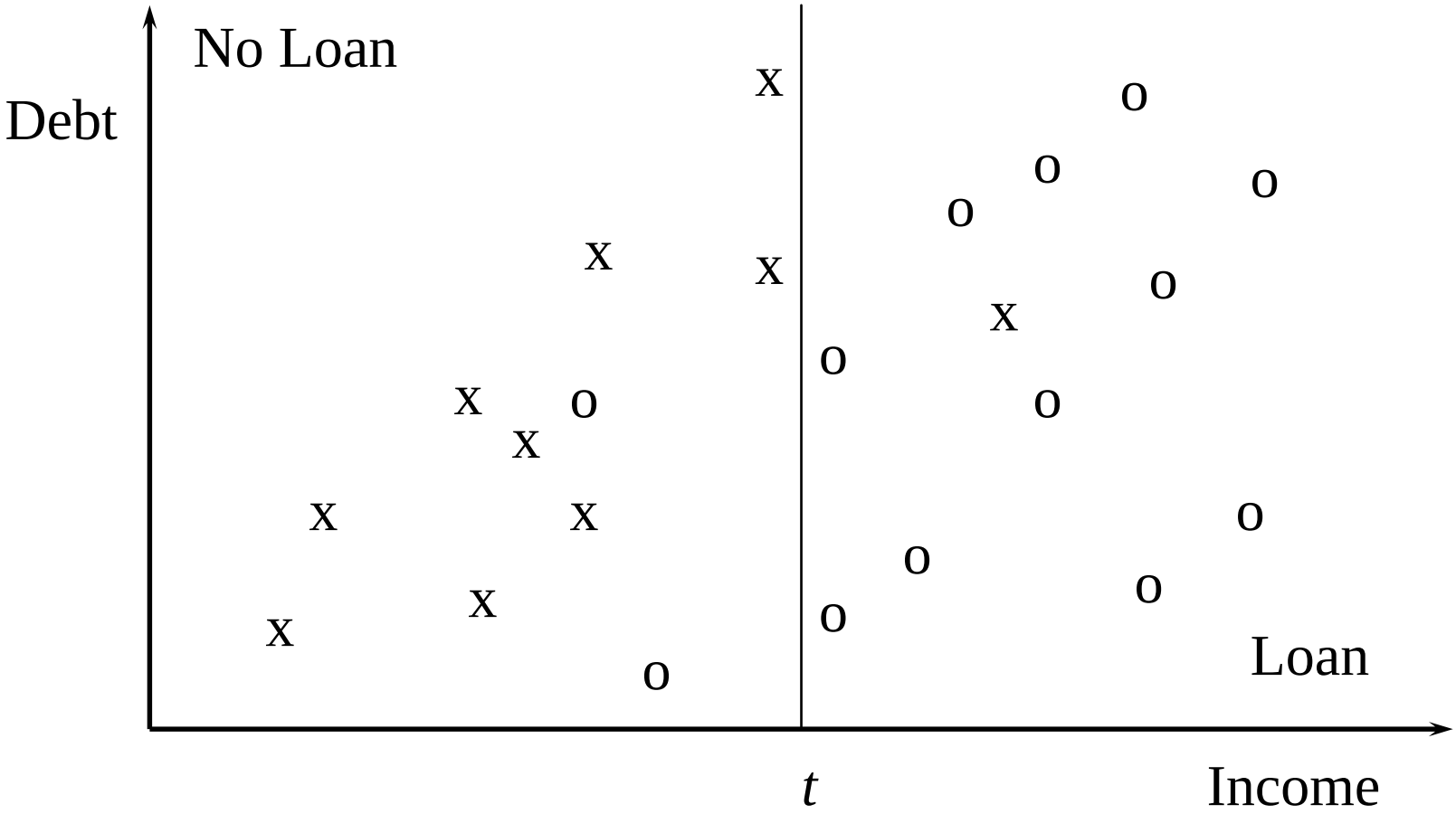
Linear regresion



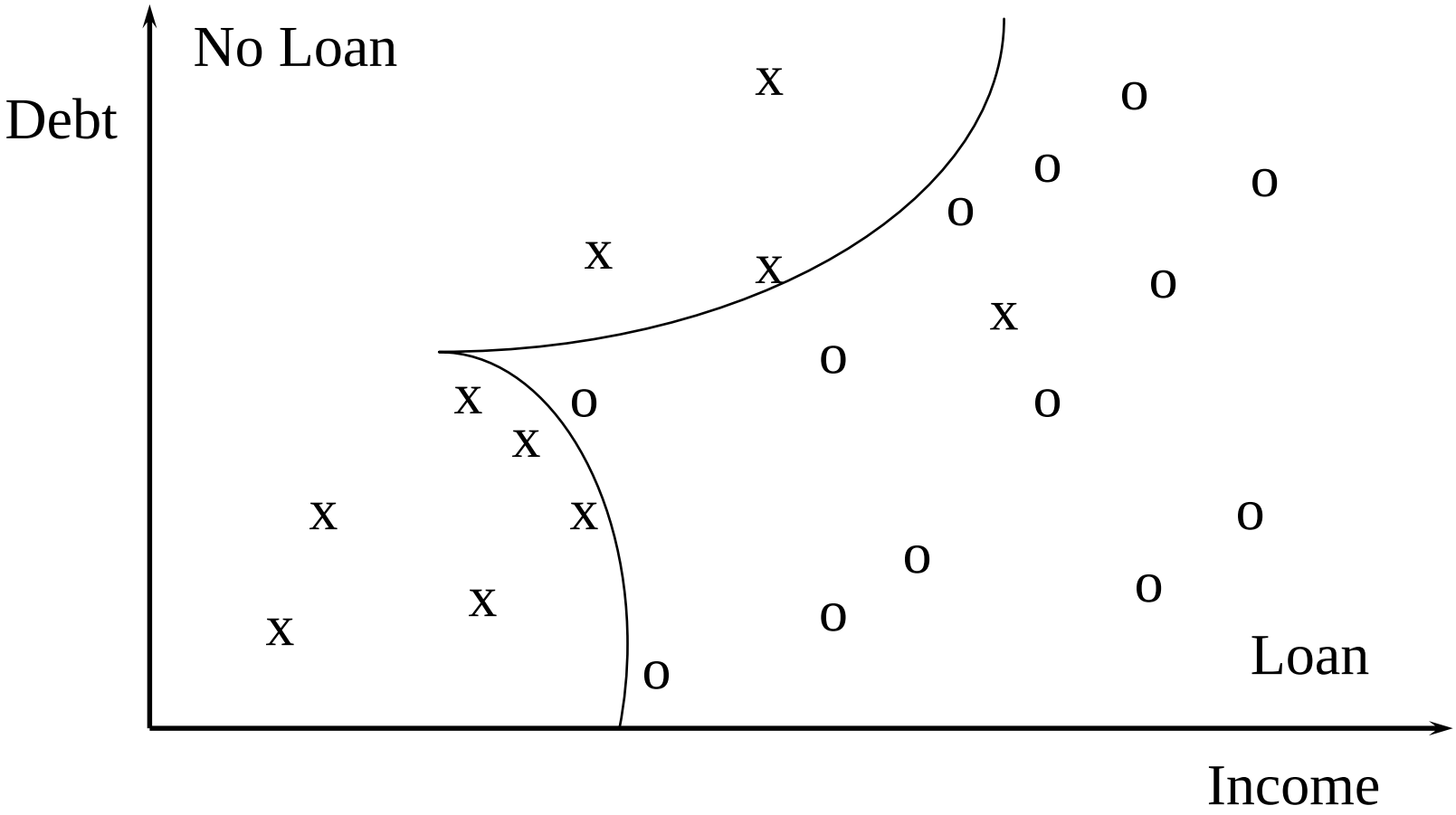
Clustering



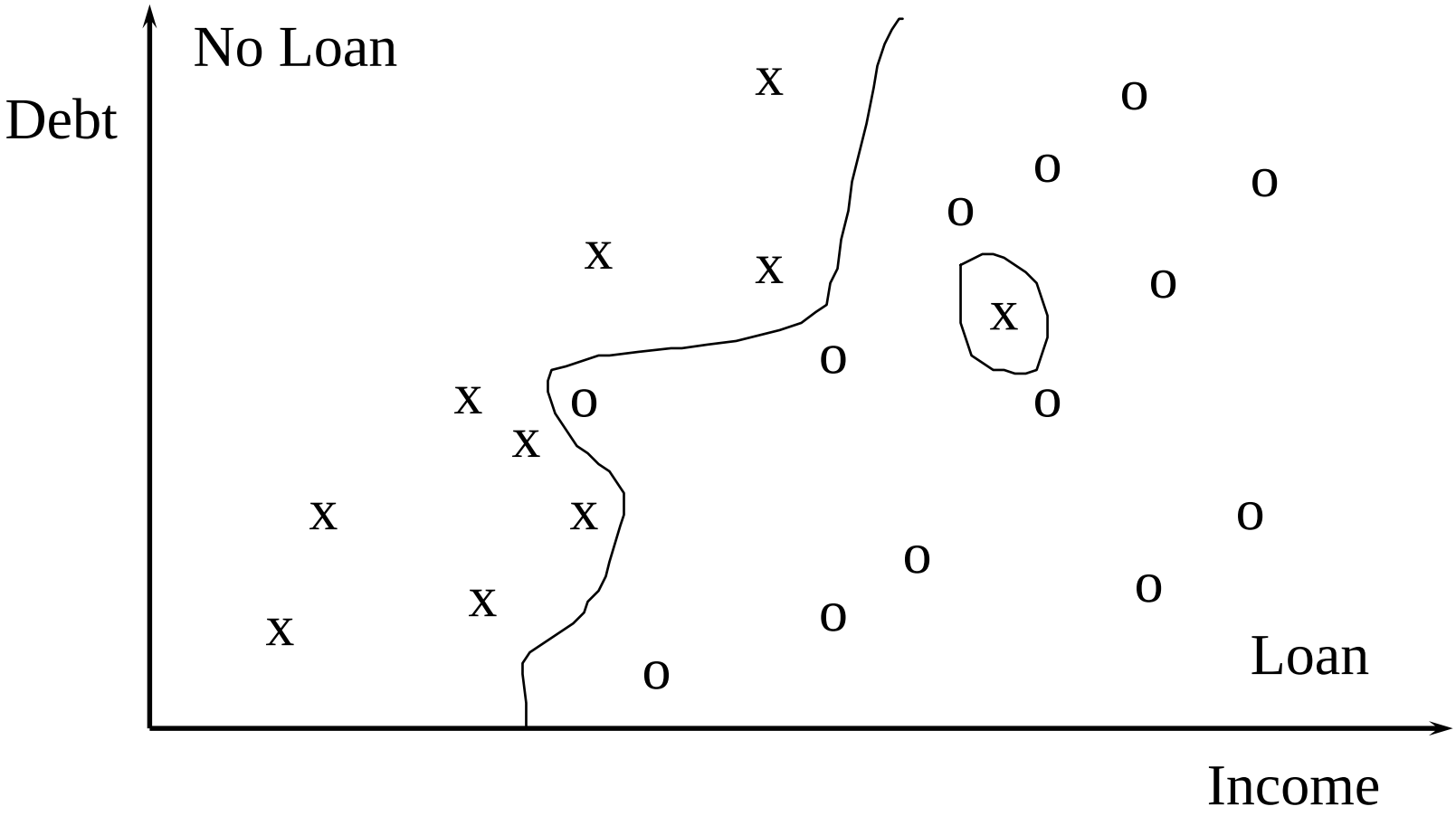
Single threshold (cut)



Nonlinear classifier



Nearest neighbour



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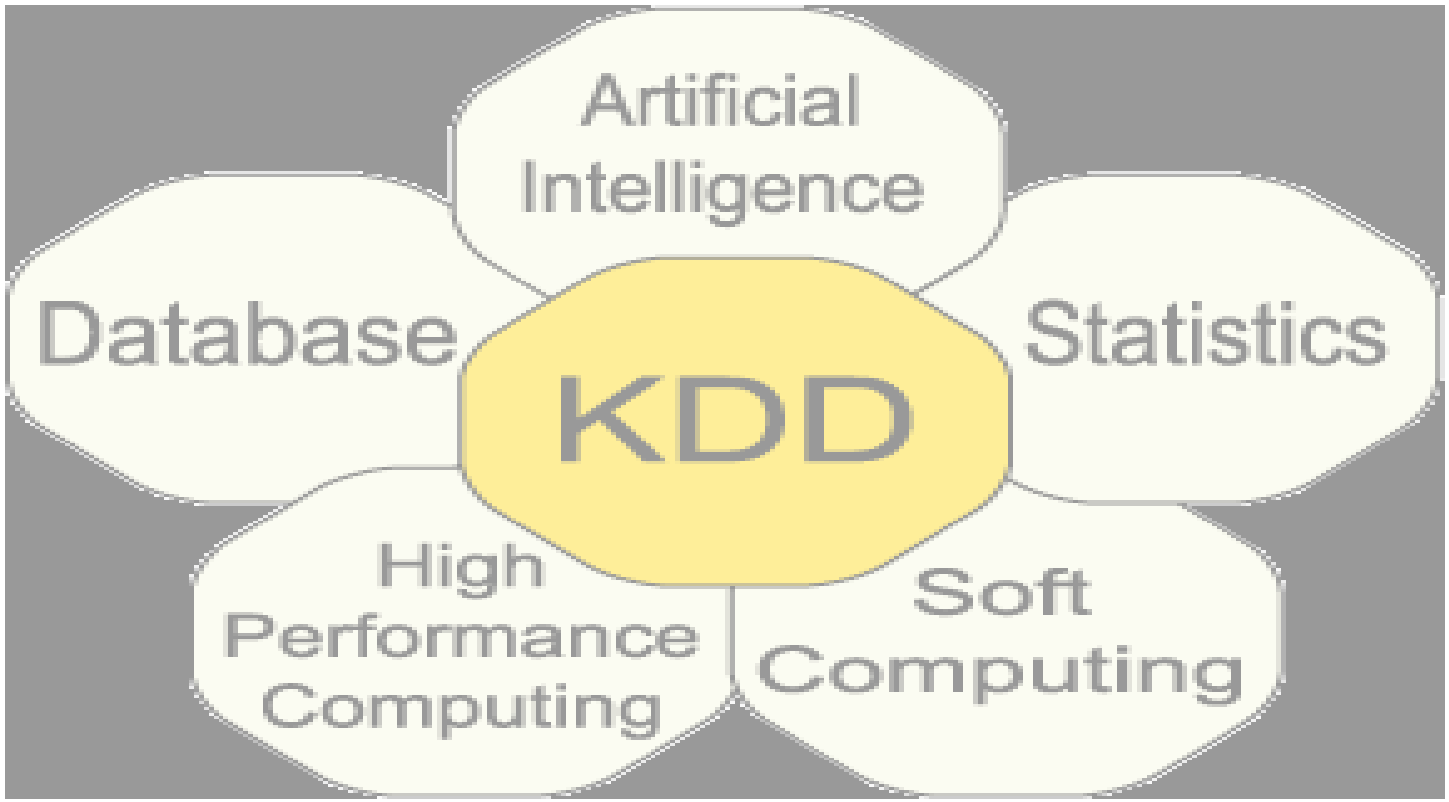
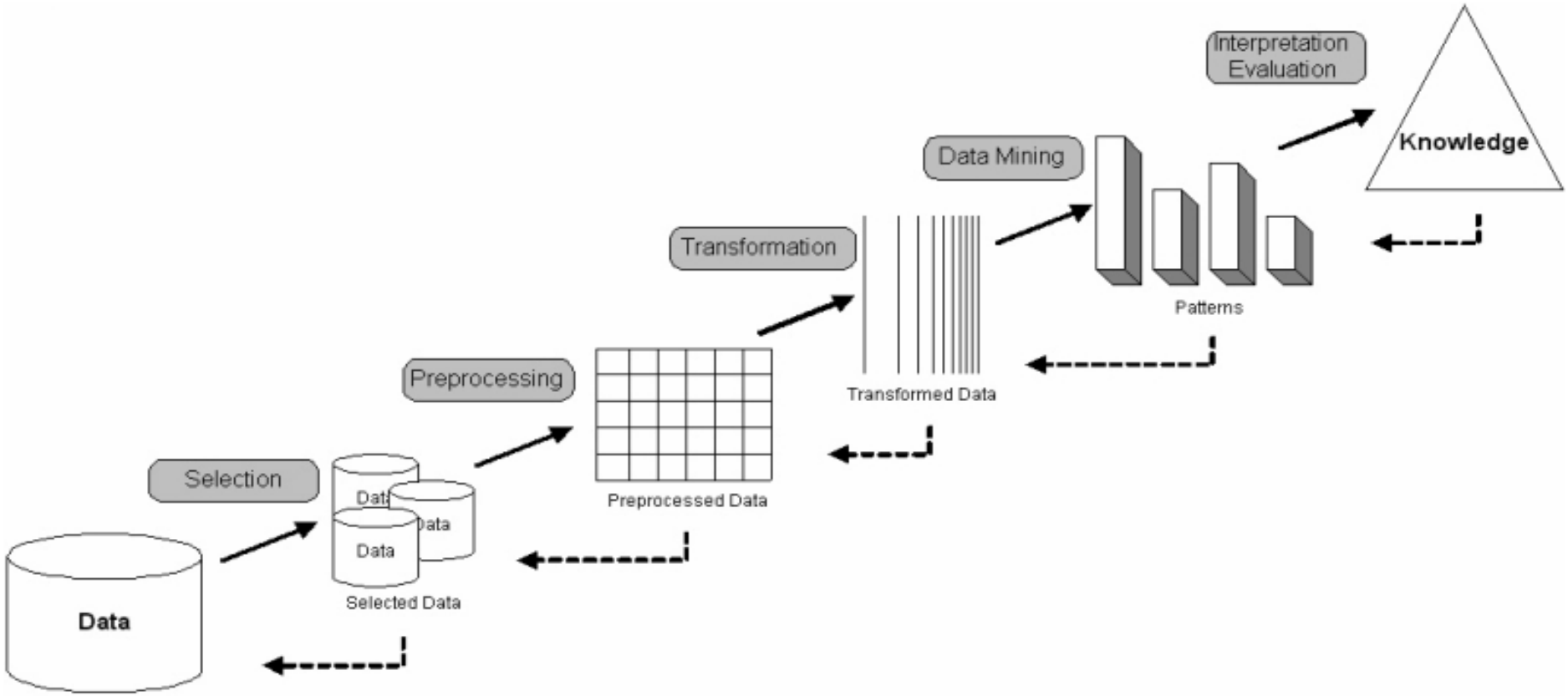
KDD


Artificial Intelligence
Database
KDD
Statistics
High Performance Computing
Soft Computing

Data Mining: a KDD process



Steps of a KDD Process

1. Learning the application domain:
   - relevant prior knowledge and goals of application
2. Creating a target data set: data selection
3. Data cleaning and preprocessing: (may take 60% of effort!)
4. Data reduction and transformation:
   - Find useful features, dimensionality/variable reduction, invariant representation.
5. Choosing functions of data mining
   - summarization, classification, regression, association, clustering.
6. Choosing the mining algorithm(s)
7. Data mining: search for patterns of interest
8. Pattern evaluation and knowledge presentation
   - visualization, transformation, removing redundant patterns, etc.
9. Use of discovered knowledge


The goals of Data Mining

- **Prediction**: To foresee the possible future situation on the basis of previous events.
  Given sales recordings from previous years can we predict what amount of goods we need to have in stock for the forthcoming season?
- **Description**: What is the reason that some events occur?
  What are the reasons for the cars of one producer to sell better that equal products of other producers?
- **Verification**: We think that some relationship between entities occur.
  Can we check if (and how) the thread of cancer is related to environmental conditions?
- **Exception detection**: There may be situations (records) in our databases that correspond to something unusual.
  Is it possible to identify credit card transactions that are in fact frauds?

Classification of Data Mining systems

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


A Multi-Dimensional View of Data Mining Classification

- **Databases to be mined**
  - Relational, transactional, object-oriented, object-relational, active, spatial, time-series, text, multi-media, heterogeneous, legacy, WWW, etc.
- **Knowledge to be mined**
  - Characterization, discrimination, association, classification, clustering, trend, deviation and outlier analysis, etc.
  - Multiple/integrated functions and mining at multiple levels
- **Techniques utilized**
  - Database-oriented, data warehouse (OLAP), machine learning, statistics, visualization, neural network, etc.
- **Applications adapted**
  - Retail, telecommunication, banking, fraud analysis, DNA mining, stock market analysis, Web mining, Weblog analysis, etc.

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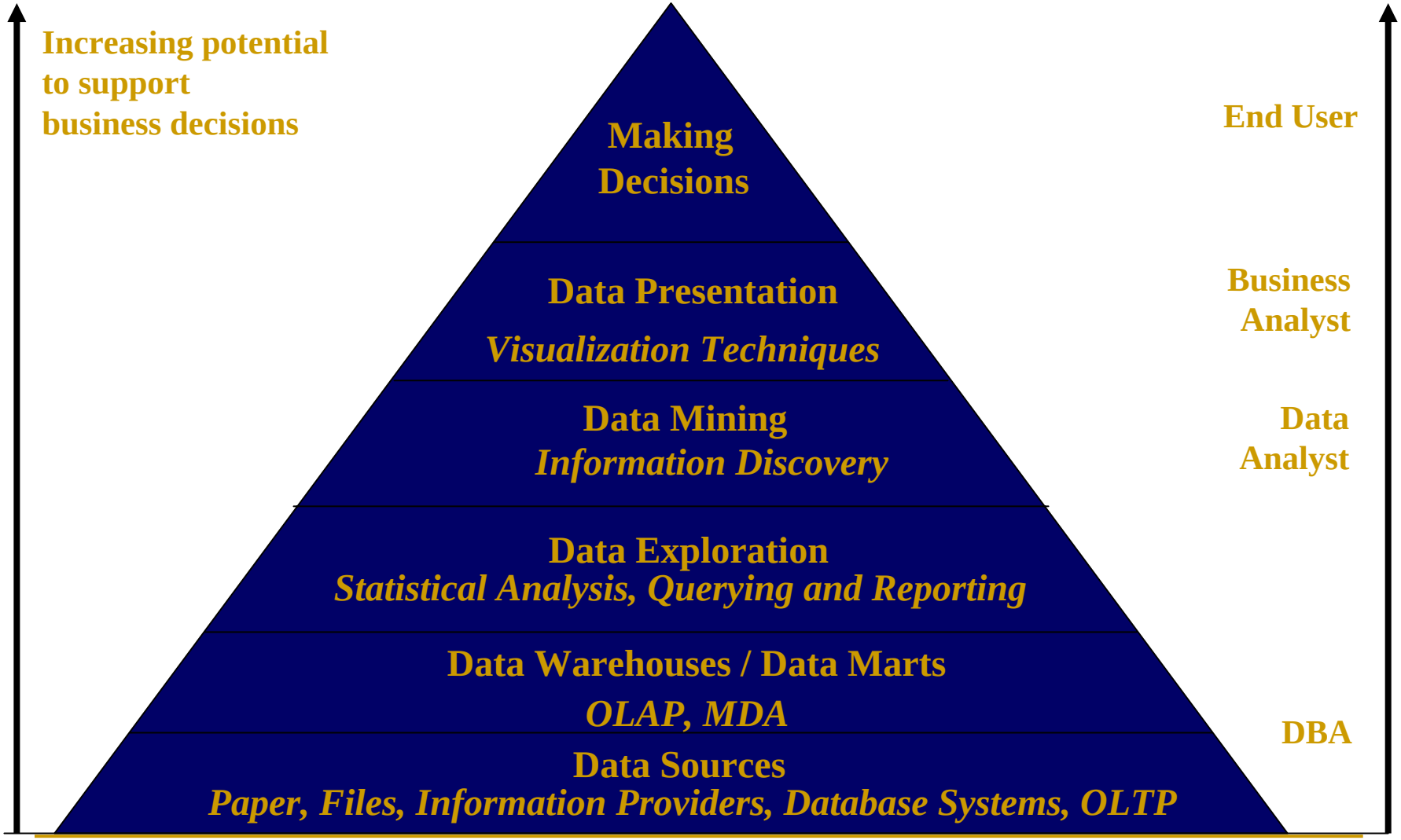
Data Mining and Business Intelligence



Major Issues in Data Mining (1)

- 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
  - 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 (2)

- 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


References

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