Ludwig-Maximilians-Universität München
Lehrstuhl für Datenbanksysteme und Data Mining
Prof. Dr. Thomas Seidl

Knowledge Discovery and Data Mining 1

(Data Mining Algorithms 1)

Winter Semester 2020/21

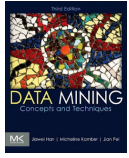
Agenda

Agenda

Textbook / Acknowledgements

The slides used in this course are modified versions of the copyrighted original slides provided by the authors of the adopted textbooks:

- © Jiawei Han, Micheline Kamber, Jian Pei: *Data Mining – Concepts and Techniques*, 3rd ed., Morgan Kaufmann Publishers, 2011.
  http://www.cs.uiuc.edu/~hanj/bk3



- © Martin Ester and Jörg Sander: *Knowledge Discovery in Databases – Techniken und Anwendungen* Springer Verlag, 2000 (in German).

Content of the Course

- Introduction
- Preliminaries – what is data, how to represent data, how to present data
- Classification – supervised learning
- Clustering – unsupervised learning
- Frequent Pattern Mining – itemsets, sequences, processes
- Further topics – outlook

Motivation

- Data Mining = extraction of patterns from data
- Patterns
  - Regularities – examples: frequent itemsets, clusters
  - Irregularities – examples: outliers
- Not all patterns are useful
  - *"all mothers in our database are female"* $\rightsquigarrow$ trivial/known
  - *"bread, butter is frequent"* given *"bread, butter, salt is frequent"* $\rightsquigarrow$ redundant
- Aggregation of data may help: Basic statistics

What is Data Mining?

Knowledge Discovery in Databases (Data Mining)

Extraction of interesting *(non-trivial, implicit, previously unknown and potentially useful)* information or patterns from data in *large databases*

Roots of Data Mining

- Statistics
- Machine Learning
- Database Systems
- Information Visualization

Data Mining and Machine Learning

Descriptive Learning

- Better understanding – data mining
- examples: pattern recognition, clustering, outlier detection

Predictive Learning

- Better forecasts – regression
- examples: traffic prediction, labeling, fraud detection

Prescriptive Learning

- Better actions – artificial intelligence
- examples: predictive maintenance, autonomous driving, medical therapies

Data Mining: Motivation

"Necessity is the mother of invention"

Data Explosion Problem

Tremendous amounts of data caused by

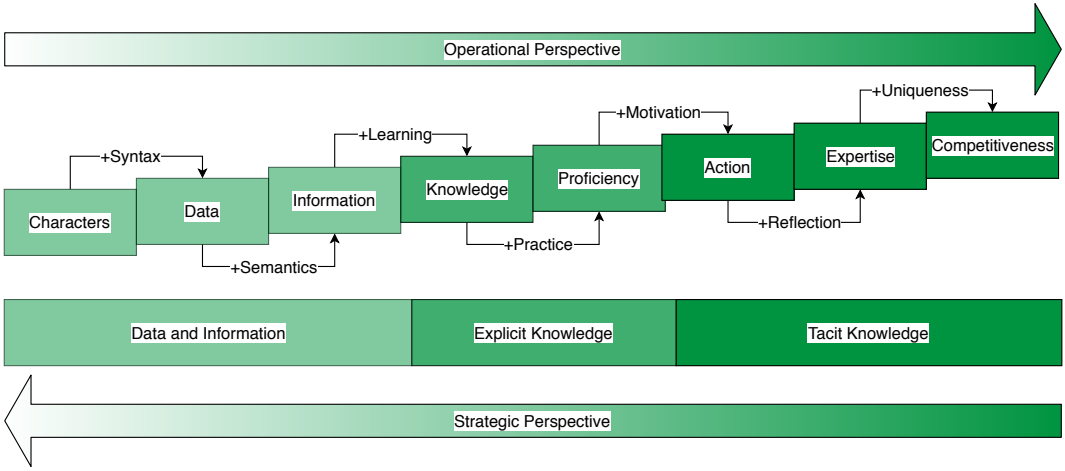
- Automated data collection
- Mature database technology

"We are drowning in data, but starving for knowledge!"

Solution

- Data Warehousing and on-line analytical processing (OLAP)
- Data Mining: Extraction of interesting knowledge (rules, regularities, patterns, constraints) from data in large databases

Data Mining: Motivation



Stairs of Knowledge (K. North) [1]

[1] Stairs of Knowledge: North, K.: Wissensorientierte Unternehmensführung - Wertschöpfung durch Wissen. Gabler, Wiesbaden 1998.

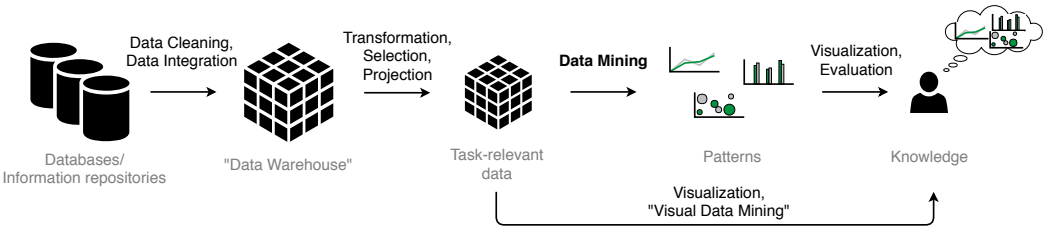
Data Mining: Potential Applications

- Database analysis and decision support
  - *Market analysis and management*:
    target marketing, customer relation management, market basket analysis, cross selling, market segmentation
  - *Risk analysis and management*:
    Forecasting, customer retention ("Kundenbindung"), improved underwriting, quality control, competitive analysis
  - *Fraud detection and management*
- Other Applications:
  - Text mining (news group, email, documents) and Web analysis.
  - Intelligent query answering

Agenda

The Knowledge Discovery Process

- The KDD-Process (Knowledge Discovery in Databases)



- Data Mining:
  - Frequent Pattern Mining
  - Clustering
  - Classification
  - Regression
  - Process Mining
  - ...

KDD Process: Data Cleaning & Integration

- . . . may take 60% of effort
- Integration of data from different sources
  - Mapping of attribute names, e.g. `C_Nr` $\rightarrow$ `O_Id`
  - Joining different tables, e.g. `Table1 = [C_Nr, Info1]` and `Table2 = [O_Id, Info2]`
    $\rightsquigarrow$ `JoinedTable = [O_Id, Info1, Info2]`
- Elimination of inconsistencies
- Elimination of noise
- Computation of missing values (if necessary and possible): Possible strategies e.g. default value, average value, or application specific computations

KDD Process: Focusing on Task-Relevant Data

Task

- Find useful features, dimensionality/variable reduction, invariant representation
- Creating a target data set

Selections

Select the relevant tuples/rows from the database tables, e.g., sales data for the last year

KDD Process: Focusing on Task-Relevant Data

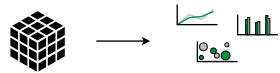
Projections

Select the relevant attributes/columns from the database tables, e.g., (`id`, `name`, `date`, `location`, `amount`) $\rightsquigarrow$ (`id`, `date`, `amount`)

Transformations, e.g.:

- Discretization of numerical attributes, e.g.,
  `amount`: [0, 100] $\rightsquigarrow$ `d_amount`: {low, medium, high}
- Computation of derived tuples/rows and derived attributes:
  - aggregation of sets of tuples, e.g., total amount per months
  - new attributes, e.g., `diff = sales current month - sales previous month`

KDD Process: Basic Data Mining Tasks



Goal

Find patterns of interest

Tasks

- Identify task: Are there labels (in the training data)?
  - *Many* $\rightsquigarrow$ Supervised learning (focus on given concepts)
  - *Some few* $\rightsquigarrow$ Semi-supervised learning (focus on few hidden concepts)
  - *None* $\rightsquigarrow$ Unsupervised learning (many hidden concepts)
- Choose fitting mining algorithm(s)

Basic Mining Tasks: Frequent Itemset Mining

Setting

Given a database of transactions,
e.g.

Transaction ID	Items Bought
2000	A,B,C
1000	A,C
4000	A,D
5000	B,E,F

Motivation

Frequently co-occurring items in the set of transactions indicate correlations or causalities

Examples

- `buys(x, "diapers")` $\Rightarrow$ `buys(x, "beers")` [supp: 0.5%, conf: 60%]
- `major(x, "CS")` $\wedge$ `takes(x, "DB")` $\Rightarrow$ `grade(x,"A")` [supp: 1.0%, conf: 75%]

Basic Mining Tasks: Frequent Itemset Mining

Applications

- Market-basket analysis
- Cross-marketing
- Catalogue design
- Also used as a basis for clustering, classification
- Association rule mining: Determine correlations between different itemsets

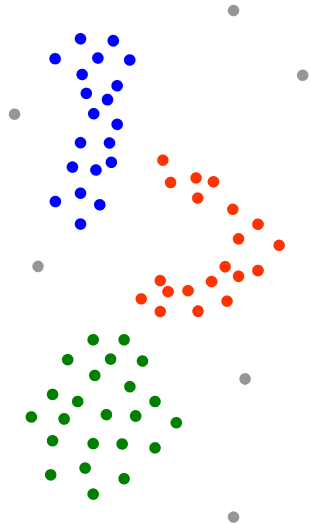
Basic Mining Tasks: Clustering

Setting

- Database of objects O
- Unknown class labels
- Similarity model for objects, often as (dis)similarity function $sim : O \times O \to \mathbb{R}$

Task

Group objects into clusters while maximizing intra-cluster similarity (cohesion) and minimizing inter-cluster similarity (separation)



Basic Mining Tasks: Clustering

Applications

- Customer profiling/segmentation
- Document or image collections
- Web access patterns
- ...

Basic Mining Tasks: Classification

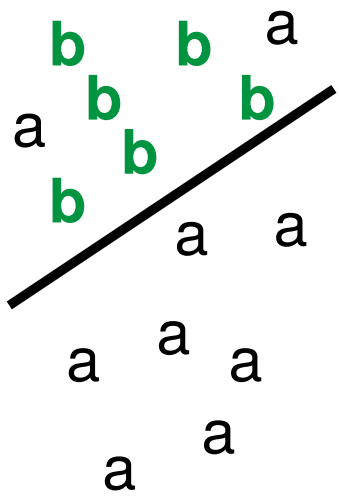
Setting

Class labels are known for a small set of "training data"

Task

Find models/functions/rules (based on attribute values of the training examples) that

- describe and distinguish classes
- predict class membership for "new" objects



Basic Mining Tasks: Classification

Applications

- Classify disease type for tissue samples from gene expression values
- Automatic assignment of categories to large sets of newly observed celestial objects
- Predict unknown or missing values (cf. KDD data cleaning & integration)
- ...

Basic Mining Tasks: Regression

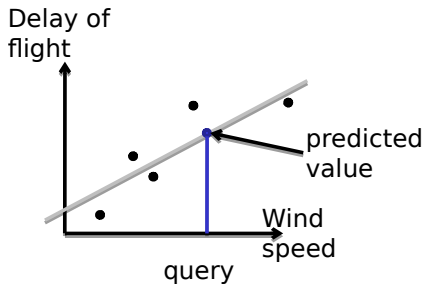
Setting

Numerical output values are known for a small set of "training data"

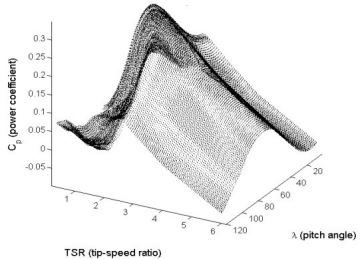
Task

Find models/functions/rules (based on attribute values of the training examples) that

- describe the numerical output values of the training data
- predict the numerical value for "new" objects



Basic Mining Tasks: Regression

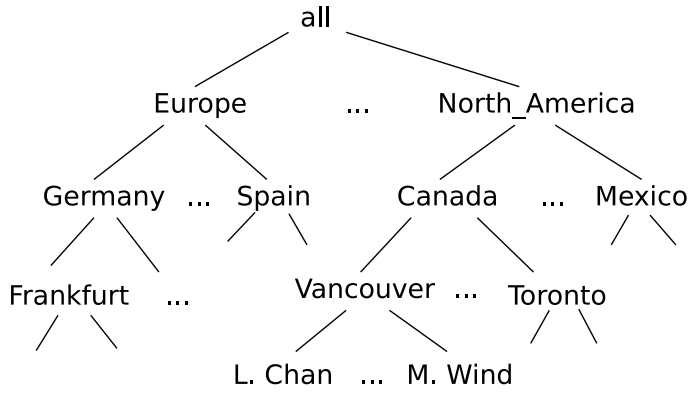


Applications

- Build a model of the housing values, which can be used to predict the price for a house in a certain area
- Build a model of an engineering process as a basis to control a technical system
- ...

Basic Mining Tasks: Generalization Levels

- Generalize, summarize, and contrast data characteristics
- Based on attribute aggregation along concept hierarchies
  - Data cube approach (OLAP)
  - Attribute-oriented induction approach



Basic Mining Tasks: Other Methods

Outlier Detection

Find objects that do not comply with the general behaviour of the data (fraud detection, rare events analysis)

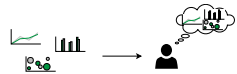
Trends and Evolution Analysis

Sequential patterns (find re-occurring sequences of events)

Methods for special data types, and applications

- Process Mining
- Spatial Data Mining
- Graphs
- ...

KDD Process: Evaluation and Visualization



- Pattern evaluation and knowledge presentation: Visualization, transformation, removing redundant patterns, etc.
- Different stages of visualization:
  - visualization of *data*
  - visualization of data mining *results*
  - visualization of data mining *processes*
  - *interactive* visual data mining
- Different types of 2D/3D plots, charts and diagrams are used, e.g. box-plots, trees, scatterplots, parallel coordinates
- Supports insights and usage of discovered knowledge

Summary

- Data mining = Discovering interesting patterns from large amounts of data
- A natural evolution of database technology, machine learning, statistics, visualization, 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.

References: Where to find scientific publications

	Conference	Journal
Data Mining and KDD	KDD, PKDD, SDM, PAKDD, ICDM, ...	Data Mining and Knowledge Discovery, ...
Database Field	ACM-SIGMOD, ACM-PODS, VLDB, ICDE, EDBT, CIKM, ...	ACM-TODS, J. ACM, IEEE-TKDE, JIIS, VLDBJ, ...
AI and Machine Learning	Machine learning, AAAI, IJCAI, ICLR, ...	Machine Learning, Artificial Intelligence, ...
Statistics	Joint Stat. Meeting, ...	Annals of Statistics, ...
Visualization	CHI (Comp. Human Interaction), ...	IEEE Trans. Visualization and Computer Graphics, ...

Preliminaries: Data

- What is data?
  - Representation of real (or artificial) objects, situations, processes, ...
  - Measured by physical sensors → temperature, humidity, car traffic, speed, color, ...
  - Recorded from digital systems → bank transfers, web browsing, ...
  - Generated by simulations → weather forecast, digital mockups, ...
  - Stored and provided by computers → e.g., on local disk or on remote server
- How to represent data?
  - Numerical and categorical data types
  - Similarity models → allow for pattern mining
  - Data reduction → to increase efficiency
- How to present data?
  - Visualization
  - Privacy aspects