Introduction to Data Mining

Huiping Cao
Dept. of Computer Science
New Mexico State University

Instructor information

- Dr. Huiping Cao
- Email: hcao@nmsu.edu
- My webpage: http://www.cs.nmsu.edu/~hcao
- Tel: 575-646-4600 (office)
- Personal Zoom Meeting link: https://nmsu.zoom.us/j/8549600124

Why this course?

- According to a McKinsey report[1], McKinsey predicts a great effect of big data in employment, where 140, 000 – 190,000 workers with "deep analytical" experience will be needed in the U.S.; furthermore, 1.5 million managers will need to become data-literate.

- 1. M. Manyika et al. Big Data: The next frontier for innovation, competition, and productivity. McKinsey Global Institute. May 2011.

8 Most In-Demand Jobs Every Company Will Be Hiring For in 2021

1. Data analysts will be in demand.

According to the report, data analysts will become increasingly more important in all industries by 2020.

Survey respondents said they expect to have a greater demand for data analysts because they will need help making sense of all of the data generated by technological disruptions.

2. In fact, computer and mathematical jobs as a whole will also continue to get a boost.

Jobs that fall under the computer and mathematical occupations will grow.

These occupations include computer programmers, software developers, information security analysts, and more.

Forbes

Jun 11, 2021, 09:44am EDT | 5,237 views

The Data Analytics Profession And Employment Is Exploding—Three Trends That Matter

learning engineers. The U.S. Bureau of Labor Statistics sees strong growth for data science jobs skills in its prediction that the data science field will grow about 28% through 2026. Also, as technology improves, companies have been able to increase the sophistication of their data operations and analysis. Increasingly, that means inserting artificial intelligence (AI) capabilities into the business processes of regular companies (i.e. non-tech giants). And that means demand for data scientists (average salary in USA $111,100) and related positions (research scientists and machine learning engineer) will also

NewEngineer

Ranking

8 of the Most In-Demand Engineering Jobs for 2021

By Dean McClements

01 June 2021

1. Data Science & Machine Learning

Software engineering has seen continuous growth ove
signs of it stopping. Data science is a branch of softwa

- Average starting salary: $89,000
- Average mid-level salary: $107,000
- Average late career salary: $120,000

So, without further ado, here are 2021's most in-demand engineering jobs and the salary potential one should expect from each.

1. Data Science & Machine Learning. ...
2. Automation & Robotics Engineer. ...
3. Mechanical Engineer. ...
4. Civil Engineer. ...
5. Electrical Engineer. ...
6. Alternative Energy Engineer. ...
7. Mining Engineer. ...
8. Project Engineer.

Course description & topic list

- Course description
  - Techniques for exploring large data sets and discovering patterns in them. Data mining **concepts**, **metrics** to measure its effectiveness. Methods in **classification, clustering, frequent pattern analysis**. Selected topics from current advances in data mining.
- Course topic list
  - (a) Data, Data pre-processing, proximity
  - (b) Regression: linear
  - (c) Classification
  - (d) Clustering
  - (e) Association analysis
  - (f) Anomaly detection

Course objectives

- Upon completion of this course, students will:
  - LO1: Explain and recognize different **data mining tasks** such as data pre-processing, visualization, classification, regression, clustering, association rules, and anomaly detection
  - LO2: **Apply** classical data-mining/machine-learning algorithms for classification, clustering, association rules, and anomaly detection
  - LO3: **Evaluate and compare** the performance of different data-mining/machine-learning algorithms
  - LO4: **Utilize** data mining algorithms to analyze data in real applications using **a data mining tool**

Syllabus & Canvas

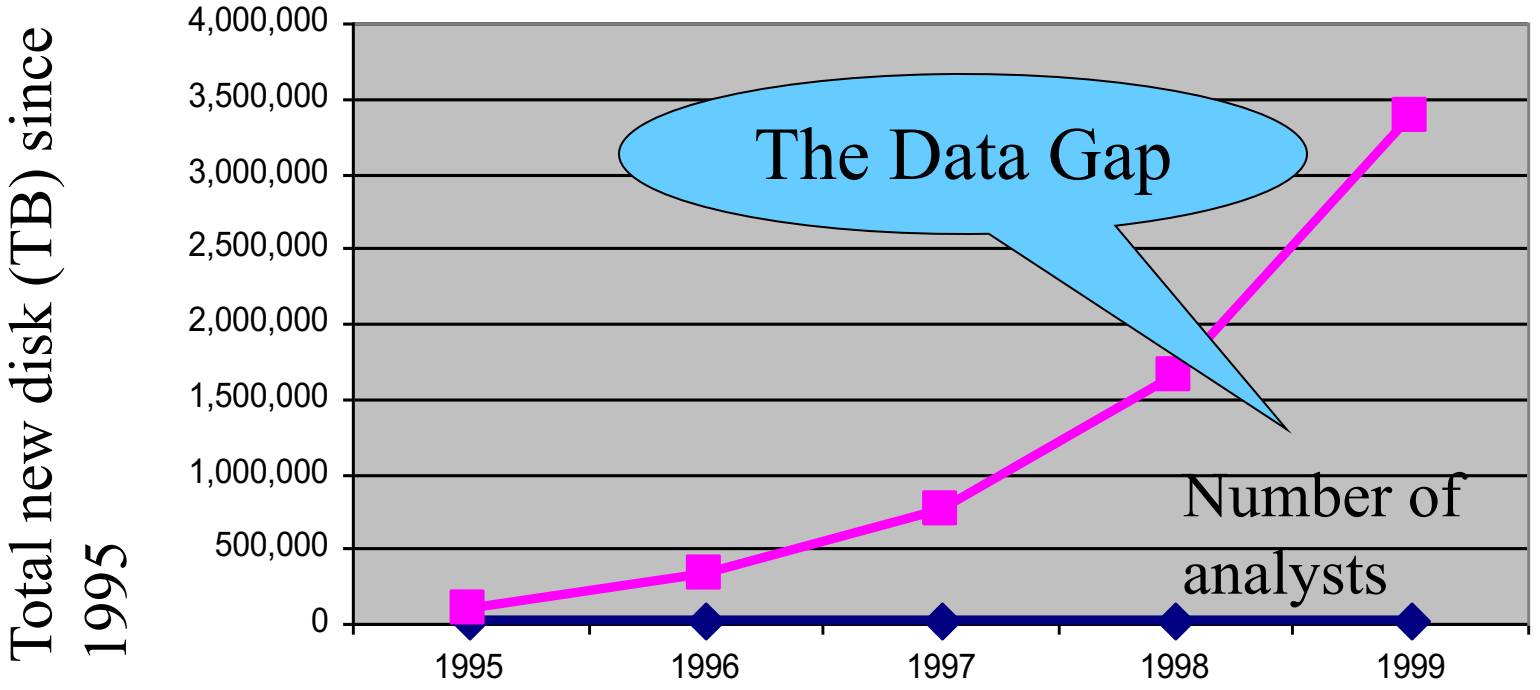
- Go through Syllabus
- Go through Canvas course

Outline

1. Motivations
2. What is data mining
3. Origins of data mining
4. Typical data mining tasks
5. Challenges

Motivation

- Vast amount
- 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"

Data growth

- Worldwide information is more than doubling every two years
- 1.8 zettabytes or 1.8 trillion gigabytes projected to be created and replicated in 2011

Courtesy of Zdnet
http://www.zdnetasia.com/data-volume-to-hit-1-8zb-in-2011-62301103.htm

Data amount: Astronomy

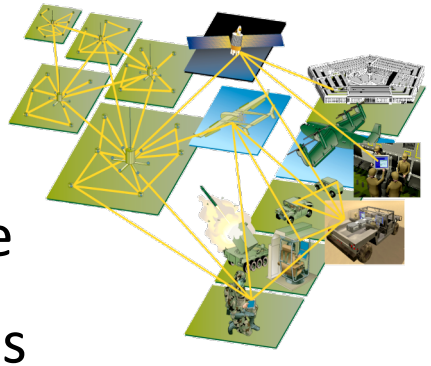
- The Solar and Heliospheric Observatory (SOHO; soho.nascom.nasa.gov), launched in 1995, transmits approximately 200 Mbytes of imagery per day [MDC+09];
- The Solar Dynamics Observatory (SDO; sdo.gsfc.nasa.gov), launched in early 2010, sends about 2 Tbytes of images per day [MDC+09]
- The Advanced Technology Solar Telescope (ATST; atst.nso.edu), which will be in operation from about 2017, will collect approximately 20 Tbytes of imagery per day.

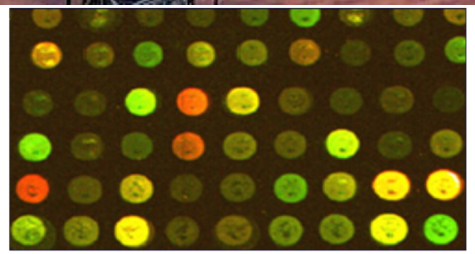
Applications: Business

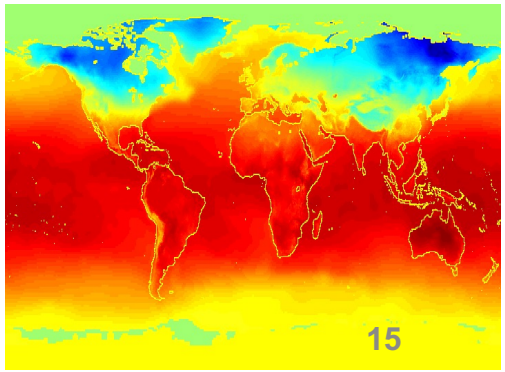
- Product Promotion
  - https://www.kaggle.com/c/springleaf-marketing-response
  - Offer customers loans using direct mails
  - Focus on the customers who are likely to respond and be good candidates for their services
  - Using a large set of anonymized features, predict which customers will respond to a direct mail offer.
- Coupon Purchase Prediction
  - https://www.kaggle.com/c/coupon-purchase-prediction
  - Using past purchase and browsing behavior, predict which coupons a customer will buy in a given period of time. The resulting models will be used to improve a recommendation system, so they can make sure their customers don't miss out on their next favorite thing.

Applications - Science

- Data collected and stored at enormous speed
  - remote sensors on a satellite
  - telescopes scanning the skies
  - microarrays generating gene expression data
  - scientific simulations generating terabytes of data
- Data mining may help scientists
  - in classifying and segmenting data
  - in hypothesis formation





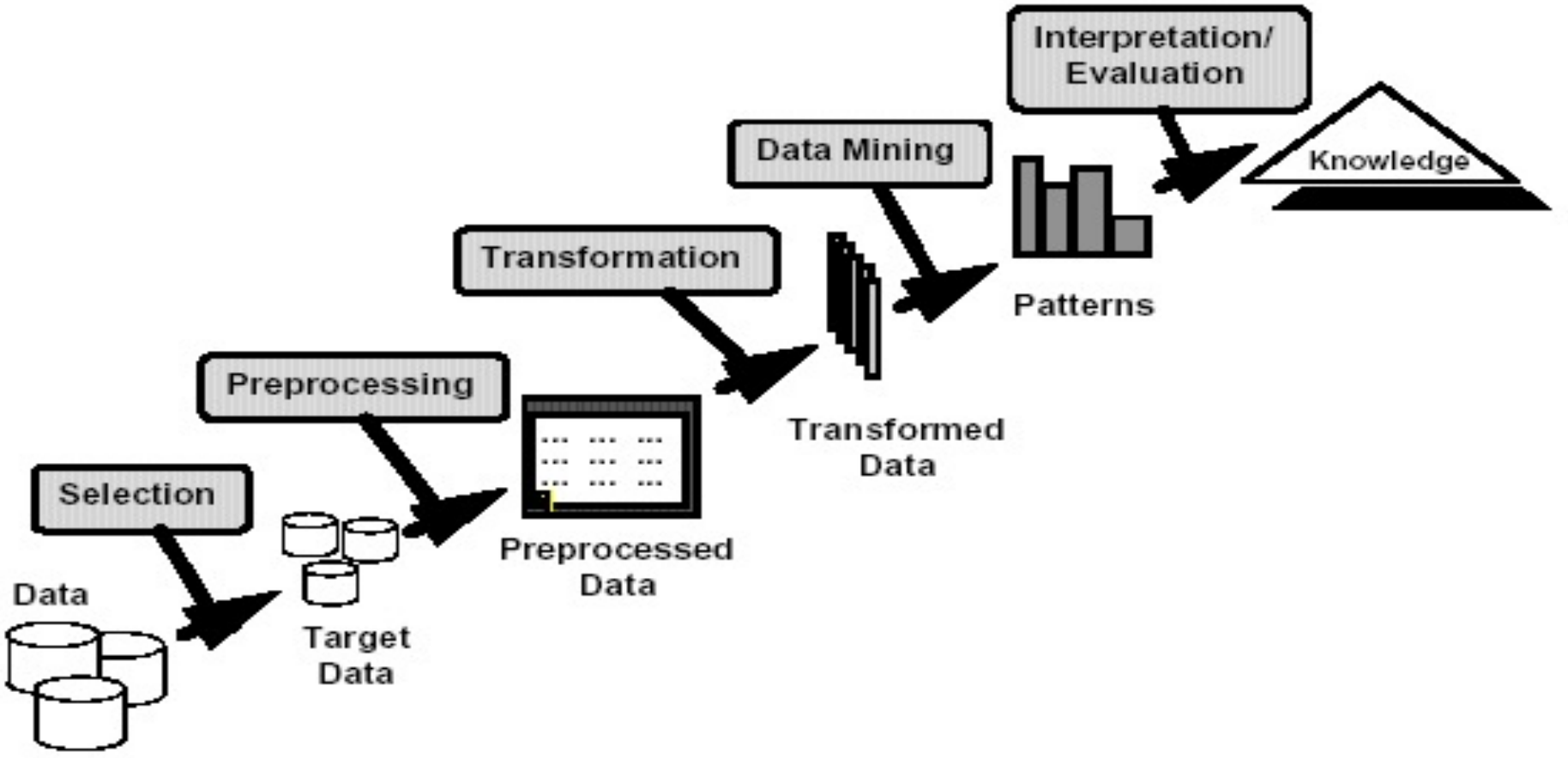


What is Data Mining

- 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 Data Mining (cont.)

- Knowledge discovery

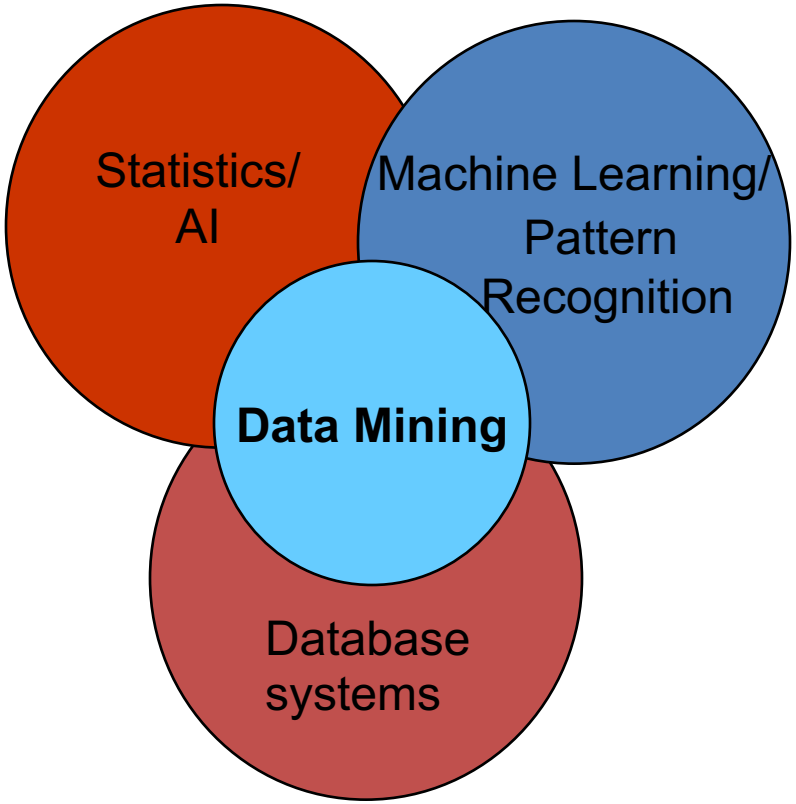


What is not Data Mining (cont.)

- Discovering useful knowledge from large amount of data is data mining?
  - Not really
- Information retrieval
  - Look up phone number in phone directory
  - Query a Web search engine for information about "Amazon"

Origins of Data Mining

- Traditional Techniques may be unsuitable
  - Enormity of data
  - High dimensionality of data
  - Heterogeneous, distributed nature of data



Typical Data Mining Tasks

- Classification [Predictive]
- Regression [Predictive]
- Cluster Analysis [Descriptive]
- Association Analysis [Descriptive]
- Anomaly Detection [Predictive]

Data Mining Tasks

- Prediction Methods
  - Use some variables to predict unknown or future values of other variables.
    - Target, dependent variable
    - Explanatory, independent variable
- Description Methods
  - Find human-interpretable patterns that describe the data.

Classification

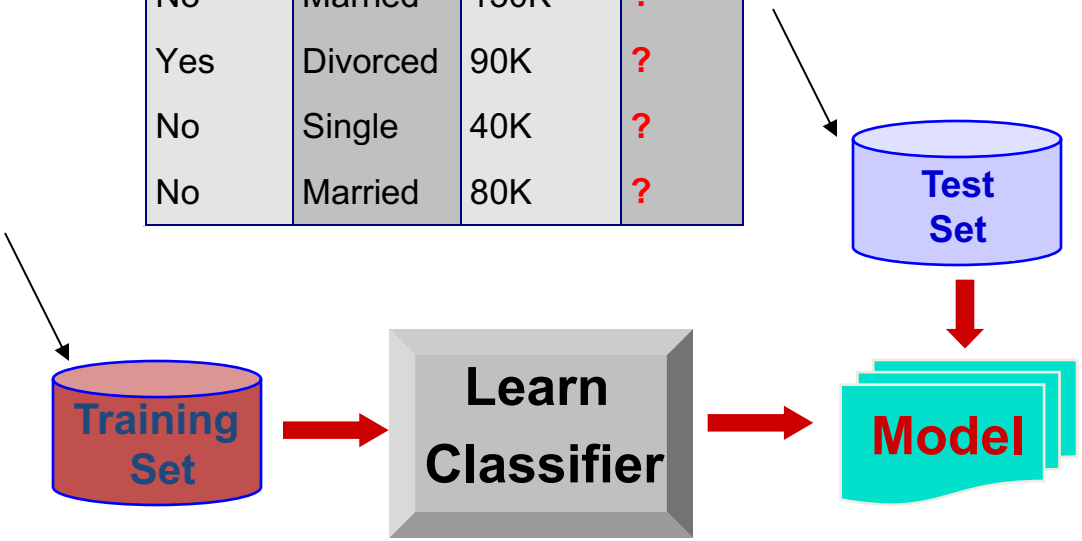
- Given a collection of records (**training set**)
  - Each record contains a **set of attributes**, one of the attributes is the **class**.
- Find a **model** for class attribute as a function of the values of other attributes.
- Goal: **previously unseen record**s should be assigned a class as accurately as possible.
  - A test set is used to determine the accuracy of the model.
- Examples
  - Credit card fraud detection
  - Disturbance classification
  - Animal category.

Classification Example

categorical categorical continuous class

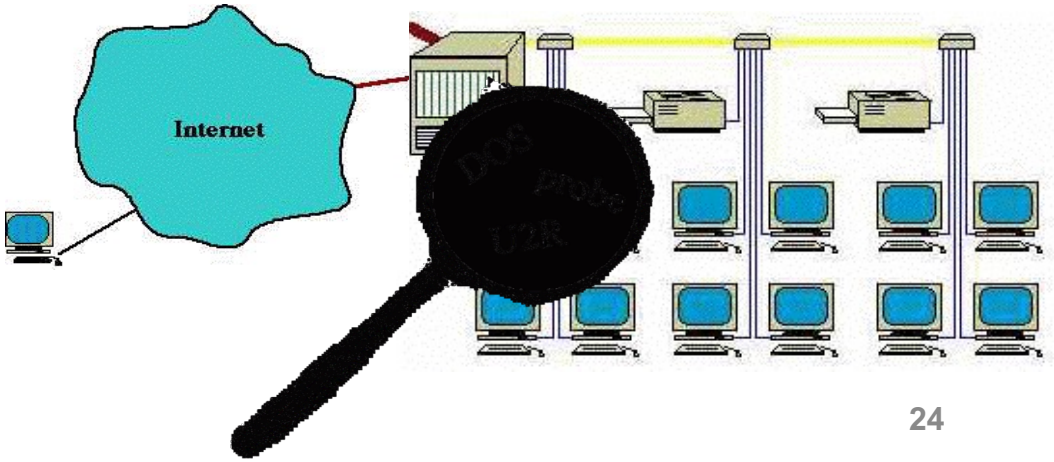
Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

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



Deviation/Anomaly Detection

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



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.
- Extensively studied in statistics, neural network fields.
- **Applications**
  - Predicting sales amounts of new product based on advertising expenditure.
  - Predicting power generation as a function of temperature, humidity, air pressure, etc.
  - Time series prediction of stock market indices.

Regression Example

- Predict house price given 76 explanatory variables
  - https://www.kaggle.com/c/house-prices-advanced-regression-techniques

Bedroom number	Area	YearBuiltt	Price
3	856	2003	208500
3	1262	1976	181500
4	920	2002	223500
…	…	…	…

Bedroom number	Area	YearBuiltt	Price
2	900	2000	???
3	1000	1980	???

Cluster Analysis

- What if I do not have training data?
- But I still want to categorize the data somehow…

Clustering: Application

- Document Clustering:
  - Goal: To find **groups of documents** that are similar to each other based on the important terms appearing in them.

Clustering Definition

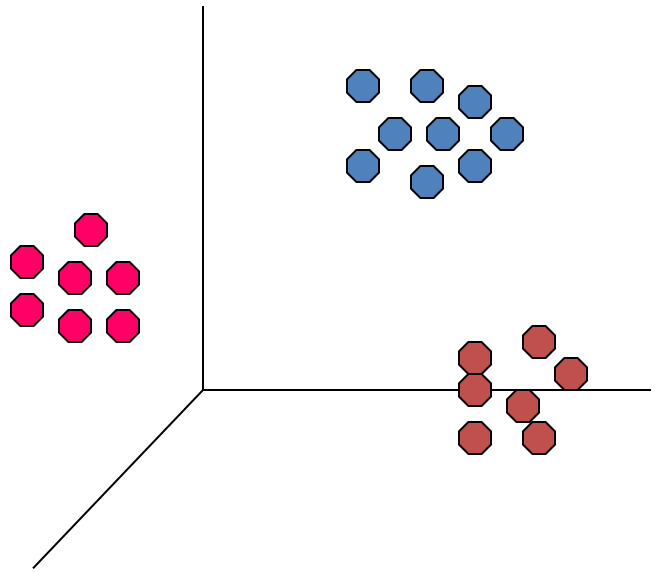
- Given a set of **data points**, each having a set of attributes, and a **similarity measure** among them, find clusters such that
  - Data points in one cluster are more similar to one another.
  - Data points in separate clusters are less similar to one another.
- Similarity measures:
  - Euclidean 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



Association Rule Discovery: Definition

- Given a set of records each of which contain 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

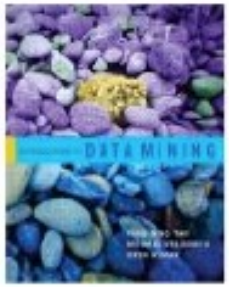
Rules Discovered:

{Milk} --> {Coke}

{Diaper, Milk} --> {Beer}

Association rule discovery: Application

Frequently Bought Together



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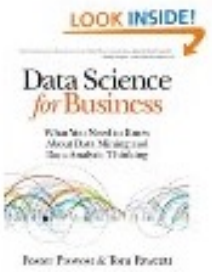

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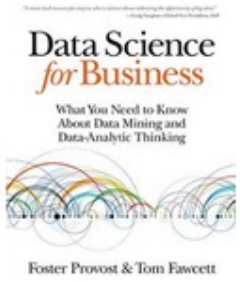

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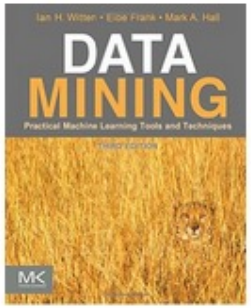

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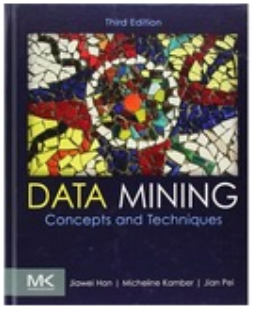

Data Mining: Concepts and Techniques, Third Edition (The Morgan Kaufmann…
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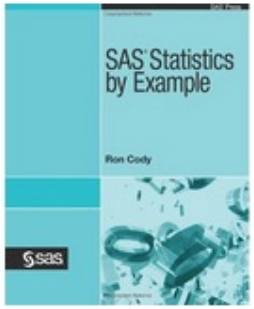

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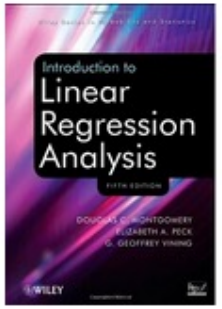

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Types of data

- Relational tables (e.g., customers)
- Time series (e.g., voltage waveforms, speech)
- Images (e.g., CT scan)
- Text (e.g., documents)
- Graphs (e.g., social networks)

Challenges of Data Mining

- Scalability
- Dimensionality
- Complex and heterogeneous Data
- Data distribution
  - Communication, result consolidation, security
- Privacy preserving

Reading

- H. V. Jagadish, Johannes Gehrke, Alexandros Labrinidis, Yannis Papakonstantinou, Jignesh M. Patel, Raghu Ramakrishnan, Cyrus Shahabi: **Big data and its technical challenges**. Commun. ACM (CACM) 57(7):86-94 (2014)
- Vasant Dhar: **Data science and prediction**. Commun. ACM (CACM) 56(12):64-73 (2013)

References (1)

- Journals
  - TDKE, DMKD, DKE, KAIS
  - VLDBJ, IS (domain-specific)
- Conferences
  - Data mining: KDD, ICDM, SDM, PAKDD, PKDD
  - Artificial intelligence: IJCAI, AAAI, UAI
  - Databases: SIGMOD, VLDB, ICDE, EDBT
  - Machine learning: NeurIPS, ICML
  - Information retrieval: SIGIR
  - Misc: WWW, CIKM

References (2)

- **Python**: https://www.python.org/
- **WEKA**: http://www.cs.waikato.ac.nz/ml/weka/
- **R**: http://www.r-project.org/
- **RapidMiner**: http://rapidminer.com/products/rapidminer-studio/
- **Apache Hahout**: a scalable machine learning library https://mahout.apache.org/

- **MATLAB**: http://www.mathworks.com/
- **SPSS**: http://www-01.ibm.com/software/analytics/spss/
- **SAS** (Statistical Analysis System): http://www.sas.com/
- **STATA** (Data Analysis and Statistical Software): http://www.stata.com/
- **Database** management systems

- **Kaggle** competition: https://www.kaggle.com/competitions

References (3)

- [MDC+09]Daniel Muller, George Dimitoglou, Benjamin Caplins, etc.: **Jhelioviewer**: Visualizing Large Sets of Solar Images Using JPEG 2000. In Vol. 11(5), Computing in Science & Engineering, 2009:38-47.