

# COMP 482: Data Mining

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Department of Computer Science and Engineering  
Kathmandu University

# Prerequisites

- Basic knowledge of algorithms
- Reasonable programming skill
  - C++, Java, Python, R will be helpful
- Basic linear algebra
- Basic probability and statistics
- Familiarity with databases

# What will you learn?

- Basic concepts and techniques of data mining
- Common approaches for data preprocessing, feature generation/selection, and data wrangling
- Basic tools to apply basic data mining / machine learning algorithms
- Effective visualization techniques to describe data

# Contents

1. Introduction to Data Mining
2. Data Warehouse and OLAP
3. Data Preprocessing
4. Data Mining Knowledge Representation
5. Attribute-oriented Analysis
6. Data Mining Algorithms: Association Rules
7. Data Mining Algorithms: Classification
8. Data Mining Algorithms: Prediction
9. Data Mining Algorithms: Clustering
10. Data Mining Algorithms: Outlier Detection

# Communication

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Canvas: <https://canvas.instructure.com/courses/4927354>

# Evaluation

- Internal evaluation
  - Assignments (Theoretical and Practical) - 20%
  - Quizzes - 10%
  - Exams - 30%
  - Mini Project - 25%
  - Viva - 15%
- End-semester exam

# Books

1. Han, J., Pei, J., & Kamber, M. (2011). *Data mining: concepts and techniques* (3rd ed.). Elsevier.
2. Witten, I. H., Frank, E., Hall, M. A., & Pal, C. J. (2016). *Data Mining: Practical machine learning tools and techniques* (4th ed.). Morgan Kaufmann.
3. Tan, P.-N., Steinbach, M., Karpatne, A., Kumar, V. (2019). *Introduction to Data Mining* (2nd ed.). Pearson.

# Chapter 1: Introduction to Data Mining





# Increase in Internet users a global phenomenon

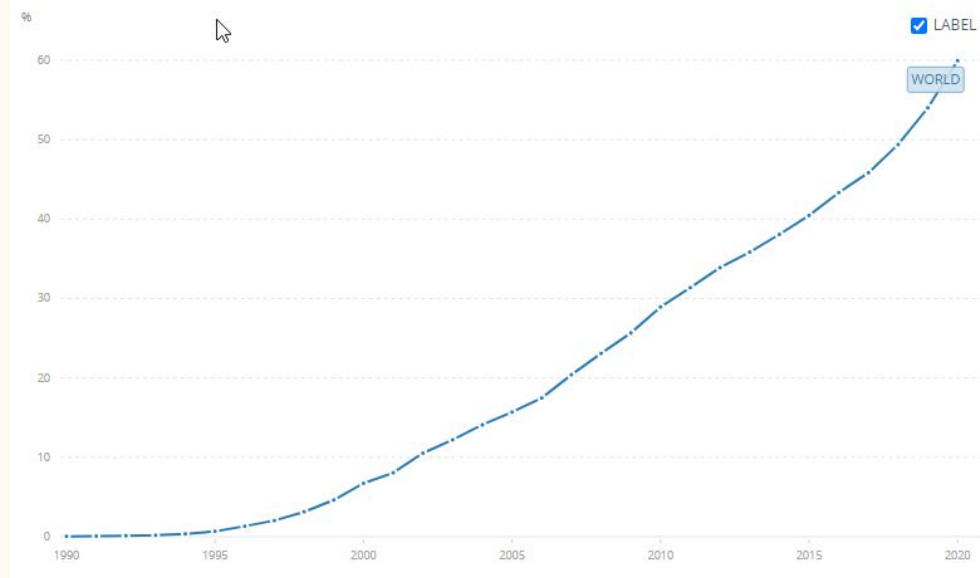


Fig: Individuals using the Internet (% of population)  
(Source: <https://data.worldbank.org/indicator/IT.NET.USER.ZS>)

# Increase in websites

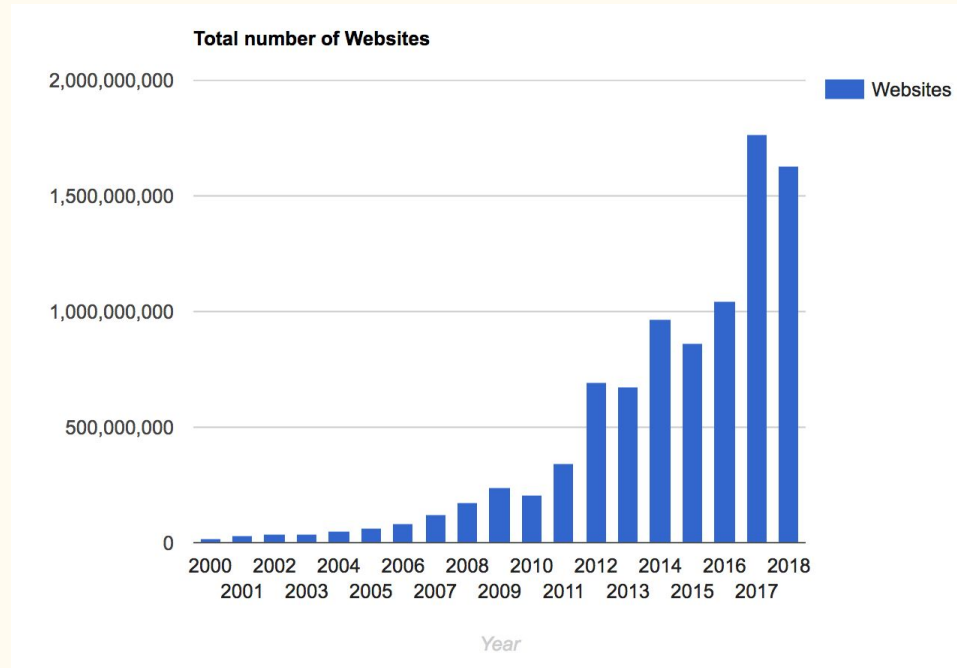


Fig: Total number of websites by year

(Source: <https://www.internetlivestats.com/total-number-of-websites/>)

# Abundance of data

Computerization of our society, and fast development of technologies for collecting, disseminating, processing, and analyzing data resulted in a tremendous volume of data day by day.

## **Sources of data:**

- Online data: Internet users' activities (browsing, searching, blogging, sharing photos/videos, online volunteering/collaboration, surveying etc.), e-commerce, social networks, etc.
- Offline data: environmental, biological, and economical studies, business, medical/health data (e.g., medical records, patient monitoring, medical imaging etc.), various applications etc.

# What is Data Mining?

Data mining is defined as the process of **discovering patterns** in data, automatically or semi-automatically, in **large quantities of data**. The patterns discovered must be **meaningful** in that they lead to some advantage, usually an economic one. [Witten et al. 2011]

Data mining is the process of discovering insightful, interesting, and novel **patterns**, as well as descriptive, understandable, and predictive models from **large-scale data**. [Zaki et al. 2014]

Data mining is the process of discovering interesting **patterns** and **knowledge** from **large amounts of data**. [Han et al. 2012]

# What is pattern/knowledge?

A kind of summary of the input data, which may be used in further analysis

Examples of patterns

1. Groups of data records,
2. Unusual records
3. Dependencies etc.

An interesting pattern represents **knowledge**

# Interestingness of the extracted patterns

A pattern is interesting if it is

1. **Understandable:** humans should be able to interpret the pattern
2. **Valid:** hold on new or test data with some degree of certainty
3. **Potentially useful:** should be possible to act on the item
4. **Novel/unexpected:** non-obvious to the system

# What is not data mining?

- Finding a certain person in an employee database
- Computing the minimum, maximum, sum, count or average values based on table/tables columns
- Using a search engine to find your name occurrences on the web etc.

# Interestingness of the extracted patterns

...the curse of big data is the fact that when you search for patterns in very, very large data sets with billions or trillions of data points and thousands of metrics, you are bound to identify coincidences that have no predictive power.”

The curse of big data: Vincent Granville

## **Bonferroni's principle**

Roughly, if you look in more places for interesting patterns than your amount of data will support, you are bound to find crap [Leskovec et al. 2014]



# Data Mining

Other names [Han et al. 2012]:

1. Knowledge discovery from data (KDD)
2. Knowledge mining from data
3. Knowledge extraction
4. Data / pattern analysis
5. Data archaeology
6. Data dredging etc.

# Knowledge discovery process

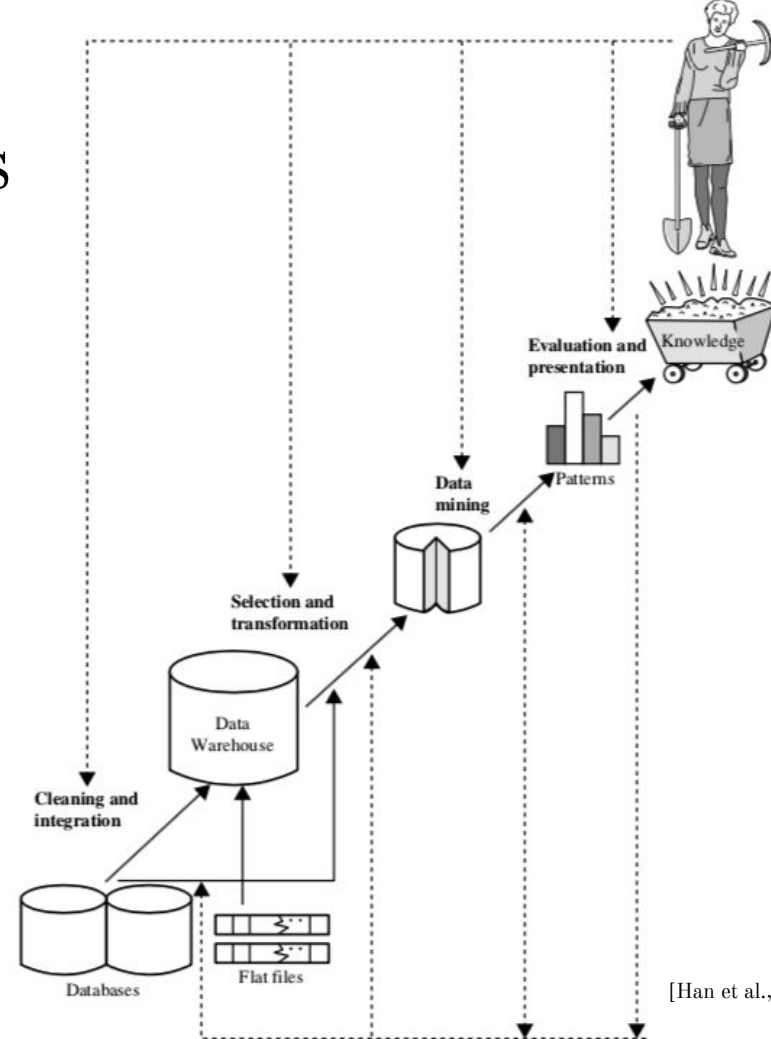
## 1. Data preprocessing

- Data cleaning
- Data integration
- Data selection
- Data transformation

## 2. Data mining

## 3. Data post-processing

- Pattern evaluation
- Pattern interpretation
- Knowledge representation / Visualization



# Knowledge discovery process

- Data selection
  - Selecting a data set, or focusing on a subset of variables, or data samples, on which discovery is to be performed
- Data cleaning and preprocessing
  - Removal of noise or outliers
  - Collecting necessary information to model or account for noise
  - Strategies for handling missing data fields
  - Accounting for time sequence information and known changes

# Knowledge discovery process

- Data transformation
  - Transforming data into forms appropriate for mining
  - Dimensionality reduction
- Data mining
  - Applying intelligent methods to extract data patterns
- Interpretation, presentation, and evaluation
  - Using visualization and knowledge representation techniques to present mined knowledge to users

# What kinds of data can be mined?

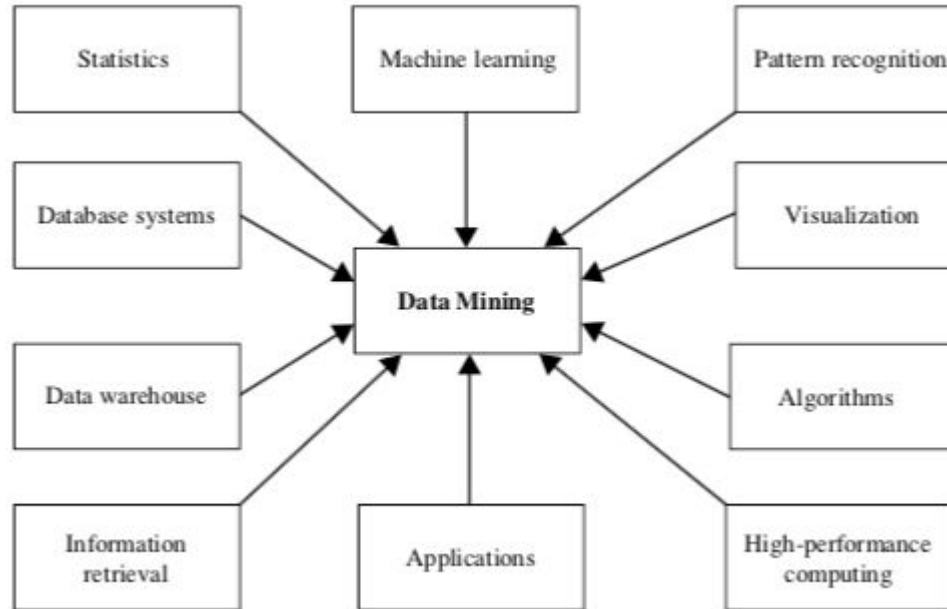
- Database data
  - Data stored in databases
- Data warehouses
  - A repository of information collected from multiple sources, stored under a unified schema, and usually residing at single site
  - Maintained separately from the operational databases
  - Constructed via a process of data cleaning, data integration, data transformation, data loading, and periodic data refreshing
- Transactional data
- Other kinds of data
  - Time-related or sequence data (e.g., historical records, biological sequence data etc.)
  - Data streams (e.g., video surveillance data)
  - Spatial data (e.g., maps)
  - Hypertext, multimedia data etc.

# Data mining tasks

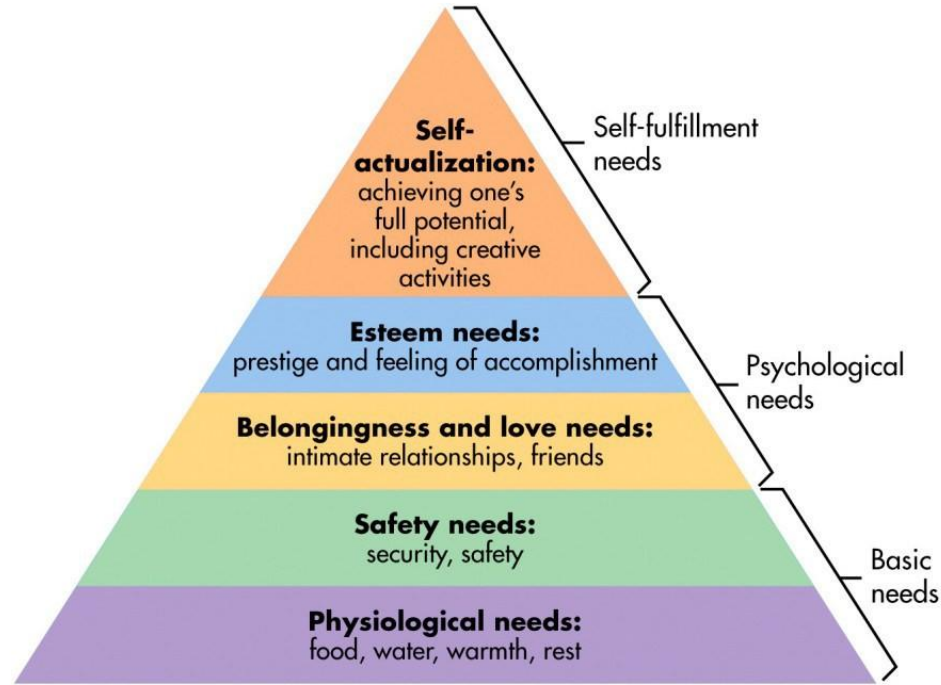
Two "high-level" primary goals of data mining, in practice:

- **Description**
  - Find human-interpretable patterns that describe the data
  - Example: Clustering, association rules etc.
- **Prediction**
  - Use some variables to predict unknown or future values of other variables
  - Example: Classification, recommender systems etc.

# Technologies adopted



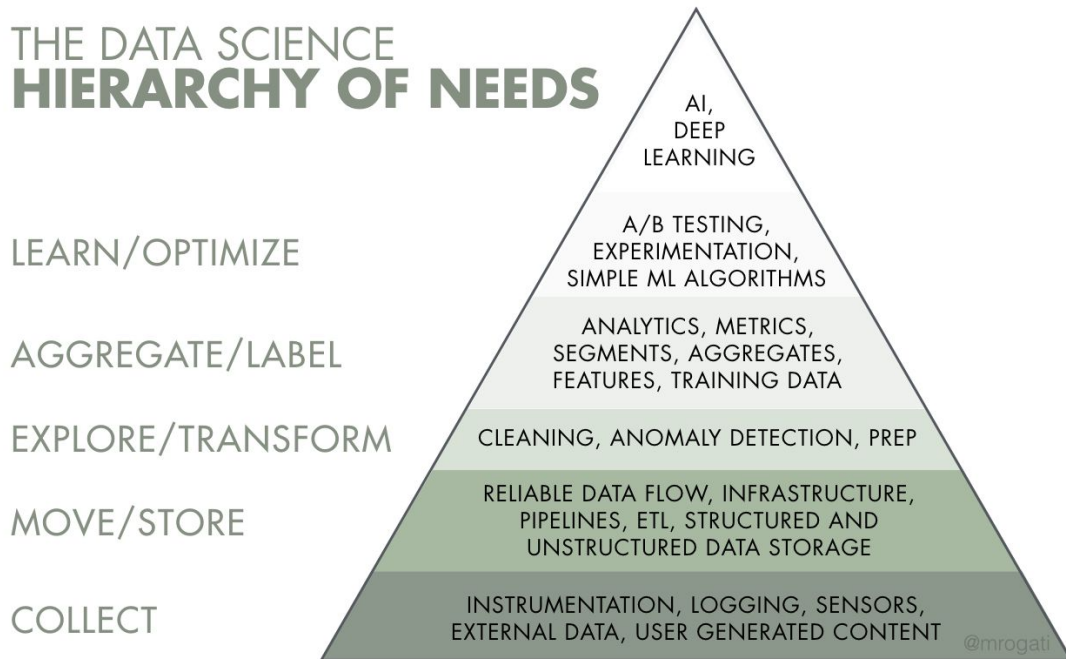
# Maslow's Hierarchy of Needs



<https://www.simplypsychology.org/maslow.html>



# The Data Science Hierarchy of Needs



<https://hackernoon.com/the-ai-hierarchy-of-needs-18f111fcc007>

# Tools

- Orange
- Weka
- TANAGRA
- RapidMiner
- SAS Enterprise Miner
- KNIME
- KEEL
- IBM SPSS Modeler
- Coheris SPAD
- R
- Matlab, Octave etc.

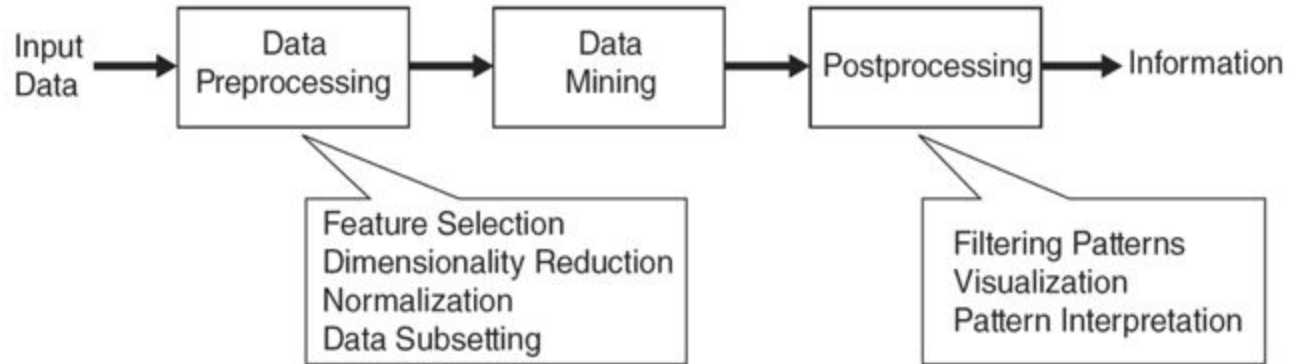
For more, check <https://www.kdnuggets.com/software/index.html>

# Data repositories

- [UCI KDD repository](#)
- [UCI machine learning repository](#)
- [Yahoo sandbox datasets](#)
- [Yelp academic datasets](#)
- [Kaggle datasets](#)

For more, check <https://www.kdnuggets.com/datasets/index.html>

# Knowledge Discovery Process (Revisited)



[Tan et al., 2016]

# Input

Data can often be represented or abstracted as an  **$n \times d$  data matrix** (aka a **matrix of instances versus attributes**, or a **single relation** or a **flat file**), with  $n$  rows and  $d$  columns.

$$\mathbf{D} = \left( \begin{array}{c|cccc} & X_1 & X_2 & \cdots & X_d \\ \hline \mathbf{x}_1 & x_{11} & x_{12} & \cdots & x_{1d} \\ \mathbf{x}_2 & x_{21} & x_{22} & \cdots & x_{2d} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \mathbf{x}_n & x_{n1} & x_{n2} & \cdots & x_{nd} \end{array} \right)$$

Where  $\mathbf{x}_i$  denotes the  $i^{\text{th}}$  row, which is a  $d$ -tuple given as  $\mathbf{x}_i = (x_{i1}, x_{i2}, \dots, x_{id})$

And  $X_j$  denotes the  $j^{\text{th}}$  column, which is an  $n$ -tuple given as  $X_j = (x_{1j}, x_{2j}, \dots, x_{nj})$

# Input

$$\mathbf{D} = \begin{pmatrix} & X_1 & X_2 & \cdots & X_d \\ \mathbf{x}_1 & x_{11} & x_{12} & \cdots & x_{1d} \\ \mathbf{x}_2 & x_{21} & x_{22} & \cdots & x_{2d} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \mathbf{x}_n & x_{n1} & x_{n2} & \cdots & x_{nd} \end{pmatrix}$$

Depending on the application domain, rows may be referred to as *entities*, *instances*, *records*, *examples*, *transactions*, *objects*, *feature-vectors*, *tuples*, and so on.

Likewise, columns may also be called *attributes*, *properties*, *features*, *dimensions*, *variables*, *fields*, and so on.

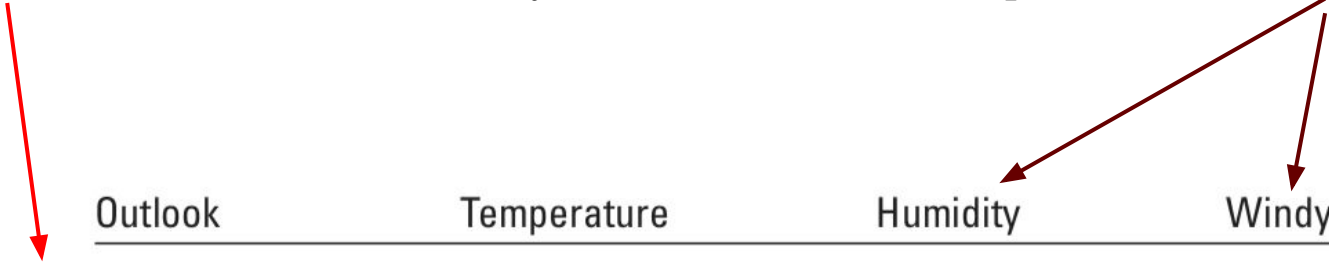
The number of instances  $n$  is referred to as the **size** of the data.

The number of attributes  $d$  is called the **dimensionality** of the data.

Problems often involve relationships between objects rather than separate, independent instances. Mining such data = **relational data mining**

# Input: Example

**Instance** is characterized by the values of a set of predetermined **attributes**



Outlook	Temperature	Humidity	Windy	Play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no

# Input: Attributes

- **Continuous / numeric:** measures numbers, either real or integer valued.  
Example: temperature and humidity in the following dataset
- **Nominal / categorical / enumerated / discrete:** takes on values in a prespecified, finite set of possibilities. Example: outlook

Outlook	Temperature	Humidity	Windy	Play
sunny	85	85	false	no
sunny	80	90	true	no
overcast	83	86	false	yes
rainy	70	96	false	yes
rainy	68	80	false	yes
rainy	65	70	true	no
overcast	64	65	true	yes

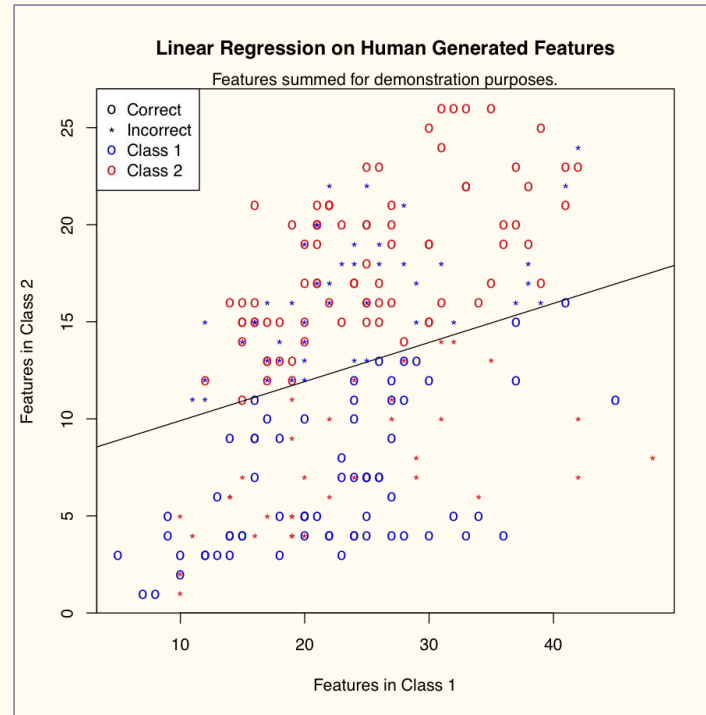


# Output

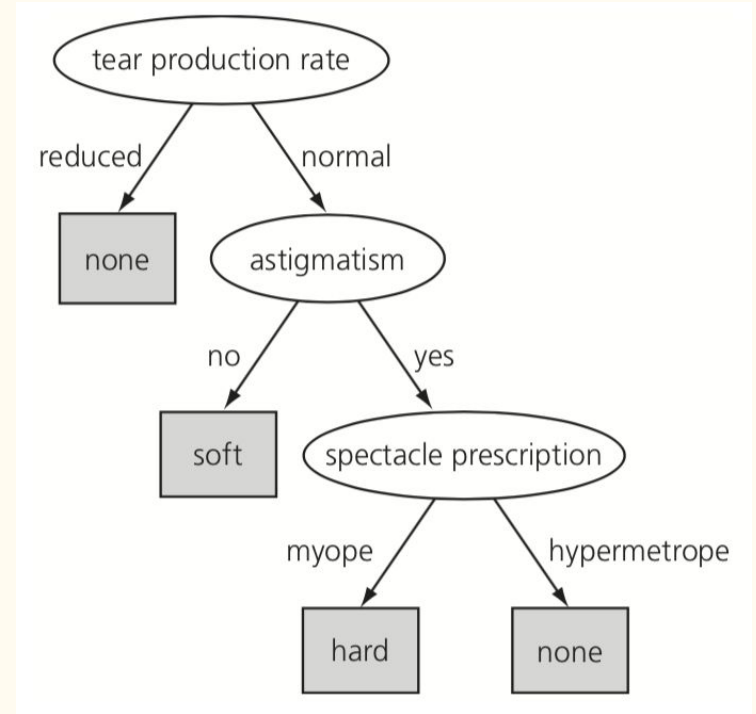
Common ways of representing the output:

- Linear models
- Trees
- Rules
  - Classification rules
  - Association rules
- Clusters

# Output: Linear models



# Output: Trees



# Output: Rules

## Classification rules:

- A popular alternative to decision trees
- Contains two parts:
  - Antecedent: a series of tests just like the tests at nodes in decision trees
  - Consequent: gives the class or classes that apply to instances covered by that rule

```
If outlook = sunny and humidity = high then play = no
If outlook = rainy and windy = true      then play = no
If outlook = overcast                    then play = yes
If humidity = normal                     then play = yes
If none of the above                     then play = yes
```

# Output: Rules

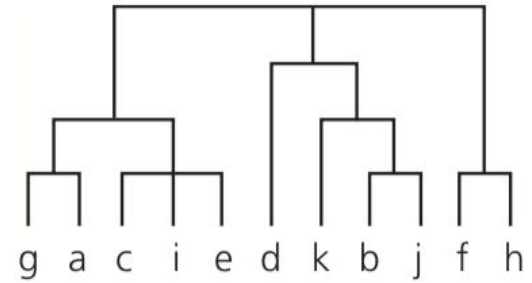
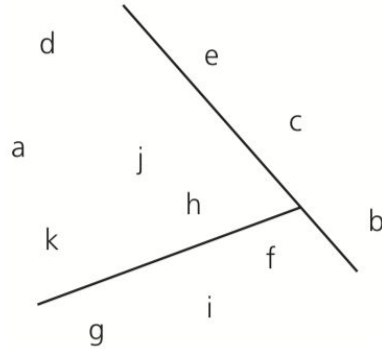
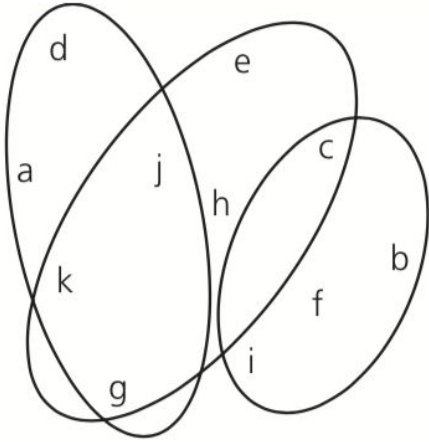
## Association rules

- Unlike classification rules, association rules can predict any attribute, not just the class

```
If windy = false and play = no then outlook = sunny  
                                and humidity = high
```

# Output: Clusters

Clustering involves associating a cluster number with each instance



# Use of data mining in real-world

## **“Diapers and beer”**

Observation that customers who buy diapers are more likely to buy beer than average allowed supermarkets to place beer and diapers nearby, knowing many customers would walk between them. Placing potato chips between increased sales of all three items.

**Decision trees** constructed from bank-loan histories to produce algorithms to decide whether to grant a loan.

Alibaba established **a model for monitoring, analyzing and cracking down on counterfeit goods systems** and is currently in use when cooperating with the police to boycott counterfeit goods.

# Use of data mining in real-world

**Patterns of travellers' behavior** mined to manage the sale of discounted seats on planes, rooms in hotels, etc.

Data mining is also used to **forecast crime scenes**, and to make strategies for reducing crime rates.

Sources:

<https://www.octoparse.com/blog/data-mining-explained-with-10-interesting-stories>

<http://infolab.stanford.edu/~ullman/mining/allnotes.pdf>

More data mining success stories:

[http://dml.cs.byu.edu/~cgc/docs/mldm\\_tools/Reading/DMSuccessStories.html](http://dml.cs.byu.edu/~cgc/docs/mldm_tools/Reading/DMSuccessStories.html)



# Data mining and ethics

- The use of data—particularly data about people—for data mining has serious ethical implications
- Data mining is frequently used to discriminate
- Certain kinds of discrimination (racial, sexual, religious, and so on) are not only unethical but also illegal
  - However, it depends on the application
  - Using sexual and racial information for medical diagnosis is certainly ethical, but using the same information when mining loan payment behavior is not

# Data mining and ethics

## Machine bias

- Biased data  $\Rightarrow$  biased models
  - Google's face recognition software tagged a lot of black faces as gorillas
  - On LinkedIn, high-paying jobs were not displayed as frequently for women as they were for men
  - There were fewer Pokémon locations in primarily black neighborhoods
  - More: <https://github.com/MachineBias/machinebias.github.io>
- Ensure that the data is checked for bias: no simple task

# Data mining and ethics

## Privacy

- Privacy-preserving data mining (PPDM): The philosophy of PPDM is to observe data sensitivity and preserve people's privacy while performing successful data mining

## General Data Protection Regulation (GDPR) compliance

- GDPR directly impacts any company handling EU residents' personal data



# References

Han, J., Pei, J., & Kamber, M. (2011). Data mining: concepts and techniques (3rd ed.). Elsevier.

Tan, P.-N., Steinbach, M., Karpatne, A., Kumar, V. (2019). Introduction to Data Mining (2nd ed.). Pearson.

Witten, I. H., Frank, E., Hall, M. A., & Pal, C. J. (2016). Data Mining: Practical machine learning tools and techniques (4th ed.). Morgan Kaufmann.

Zaki, M. J., Meira, W. (2014). Data Mining and Analysis: Fundamental Concepts and Algorithms. Cambridge University Press.