

# Chapter II: Data

## Knowledge Discovery in Databases

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## Chapter II: Getting to know your data

This is our agenda for this lecture:

**Data objects and attribute types.**

Basic statistical descriptions of data.

Data visualization.

Measuring data similarity and dissimilarity.

Summary.

## Types of data sets

### Records:

Relational records.

Data matrix, e.g. numerical matrix, crosstabs.

Document data: text documents, **term-frequency vectors**.

**Transaction data.**

	team	couch	play	ball	score	game
Document1	3	0	5	0	2	6
Document2	0	7	0	2	1	0
Document3	0	1	0	0	1	2

### Graph and network:

World wide web.

Social of information networks.

Molecular structures.

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

## Types of data sets

### Ordered data:

- Video data: sequences of images.
- Temporal data: time series.
- Sequential data: transaction sequences.
- Genetic sequence data.

### Spatial, image and multimedia:

- Spatial data: maps.
- Image data.
- Video data.

## Important characteristics of structured data

### **Dimensionality:**

Curse of dimensionality (sparse high-dimensional data spaces).

### **Sparsity:**

Only presence counts.

### **Resolution:**

Patterns depend on the scale.

### **Distribution:**

Centrality and dispersion.

## Data objects

**Data sets are made up of data objects.**

**A data object represents an entity.**

Examples:

Sales database: customers, store items, sales.

Medical database: patients, treatments.

University database: students, professors, courses.

They are also called:

Samples, examples, instances, data points, objects, tuples, ...

**Data objects are described by attributes:**

Database rows → data objects.

Columns → attributes.

## Attributes

### Attribute:

Sometimes also in other context: field, dimension, feature, variable, ...

A data field encodes the property of an entity or feature of a data object.

E.g. customer\_ID, name, address.

### Types:

- Nominal.

- Binary.

- Ordinal.

- Numerical:

  - Interval scaled.

  - Ratio scaled.

## Attribute types

### Nominal:

Categories, states, or "names of things".

E.g. `hair_color = {auburn, black, blond, brown, grey, red, white}`.

Other examples: `marital status`, `occupation`, `ID`, `ZIP code`.

### Binary:

Nominal attribute with only two states (0 and 1).

**Symmetric binaries:** both outcomes equally important, such as gender.

**Asymmetric binary:** outcomes not equally important.

E.g. medical test (positive vs. negative).

Convention: assign 1 to most important outcome (e.g. HIV positive).

### Ordinal:

Values have a meaningful order (ranking),

but magnitude between successive values is not known.

E.g. `size = {small, medium, large}`, grades, army rankings.



## Numerical attribute types

**Numerical: Quantity (integer- or real-valued).**

**Interval scaled:**

Measured on a scale of **equally sized** units.

Values have order.

E.g. temperature in *C* or *F*, calendar dates.

No true zero-point.

**Ratio scaled:**

Inherent **zero point**.

We can speak of values as being an order of magnitude larger than the unit of measurement.

E.g. 10K is twice as high as 5K.

E.g. temperature in Kelvin, length, counts, monetary quantities.

## Discrete vs. continuous attributes

### Discrete attribute:

Has finite or countably infinite elements.

E.g. ZIP code, profession, or the set of words in a collection of documents.

Sometimes represented as integer variables.

Note: Binary attributes are a special case of discrete attributes.

### Continuous attribute:

Has real numbers as attribute values.

E.g. temperature, height, or weight.

Practically, real values can only be measured and represented using a finite number of digits.

Continuous attributes are typically represented as floating-point variables.

## Chapter II: Getting to know your data

Data objects and attribute types.

**Basic statistical descriptions of data.**

Data visualization.

Measuring data similarity and dissimilarity.

Summary.

## Basic statistical descriptions of data

### Motivation:

To better understand the data: central tendency, variation and spread.

### Data dispersion characteristics:

Median, max, min, quantiles, outliers, variance etc.

### Numerical dimensions correspond to sorted intervals.

Data dispersion: analyzed with multiple granularities of precision.

Boxplot or quantile analysis on sorted intervals

### Dispersion analysis on computed measures.

Folding measures into numerical dimensions.

Boxplot or quantile analysis on the transformed cube.

## Measuring the central tendency

### Mean:

$N$  denotes the amount of samples within the data set.

The **sample mean** is given by

$$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i.$$

While the **population mean** is defined by

$$\mu = \sum x \cdot p(x|\theta) \dots$$

## Measuring the central tendency (2)

### Median:

The median  $\tilde{m}$  minimizes the sum of absolute deviations for any  $x$  of a sample  $X$ :

$$\sum_{i=1}^n |\tilde{x} - x_i| \leq \sum_{i=1}^n |x - x_i|. \quad (1)$$

Age	Frequency
1 – 5	200
6 – 15	450
16 – 20	300
21 – 50	1500
51 – 80	700
81 – 110	44

## Measuring the central tendency (3)

### Median for interval grouped data:

Let  $n$  be the total amount of data points,  $n_i$  the respective number of the  $i$ th group and  $l_i$  or  $u_i$  the lower or upper interval limit. We determine the group to which the median belongs and denote it as  $m$ th group. It is determined by

$$\sum_{k=1}^{m-1} n_k < \frac{n}{2}, \text{ but } \sum_{k=1}^m n_k \geq \frac{n}{2}. \quad (2)$$

Age	Frequency
1 – 5	200
6 – 15	450
16 – 20	300
21 – 50	1500
51 – 80	700
81 – 110	44

If there is no information about the underlying distribution, we just assume that data is equally distributed and use linear interpolation to estimate the median:

$$\tilde{x} = l_m + \frac{\frac{n}{2} - \sum_{k=1}^{m-1} n_k}{n_m} \cdot (u_m - l_m). \quad (3)$$

## Measuring the central tendency (3)

### Mode:

Value that occurs most frequently within the data set.

Can be unimodal, bimodal, trimodal etc.

Empirical formula:

$$\bar{x} - \text{mode} \approx 3(\bar{x} - \tilde{x}). \quad (4)$$

Age	Frequency
1 — 5	200
6 — 15	450
16 — 20	300
21 — 50	1500
51 — 80	700
81 — 110	44



## Example of mode, median and mean



$$f(x|\mu, \sigma) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(x - \mu)^2}{2\sigma^2}\right). \quad (5)$$

## Example of mode, median and mean

### Quartiles, outliers and boxplots:

**Quartiles:**  $Q_1$  (25<sup>th</sup> percentile),  $Q_3$  (75<sup>th</sup> percentile).

**Inter quartile range:**  $IQR = Q_3 - Q_1$ .

Five number summary: min,  $Q_1$ , median,  $Q_3$ , max.

**Boxplot:** ends of the box are the quartiles;  
median is marked; add whiskers and plot outliers individually.

**Outlier:** usually assigned to values higher/lower than  $1.5 \cdot IQR$ .

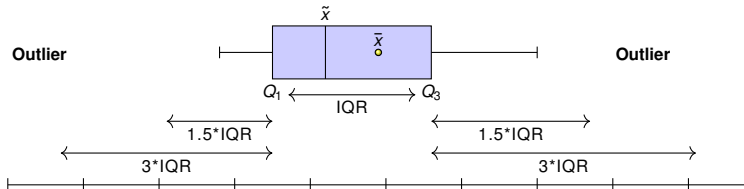
### Variance $\sigma^2$ and standard deviation $\sigma$ :

Empirical sample variance:  $\overline{\sigma^2} = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2$

Empirical population variance:  $\sigma^2 = \frac{1}{N} \sum_{i=1}^n (x_i - \mu)^2$ .

Standard deviation is the square root  $\sigma = \sqrt{\sigma^2}$ .

## Boxplot analysis



### Five number summary of a distribution:

Minimum,  $Q_1$ , median,  $Q_3$ , maximum.

### Boxplot:

Data is represented with a box.

The ends of the box are at the first and third quartiles, i.e. the height of the box is IQR.

The median is marked by a line within the box.

Whiskers: two lines outside the box extended to minimum and maximum.

Outliers: points beyond a specified outlier threshold, plotted individually.

Thank you for your attention.

**Any questions about the second chapter?**

Ask them now, or again, drop me a line:

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