Department of Mathematics
University of Calabria

*Business Intelligence and Analytics*

*(Data Mining)*

# Data Understanding

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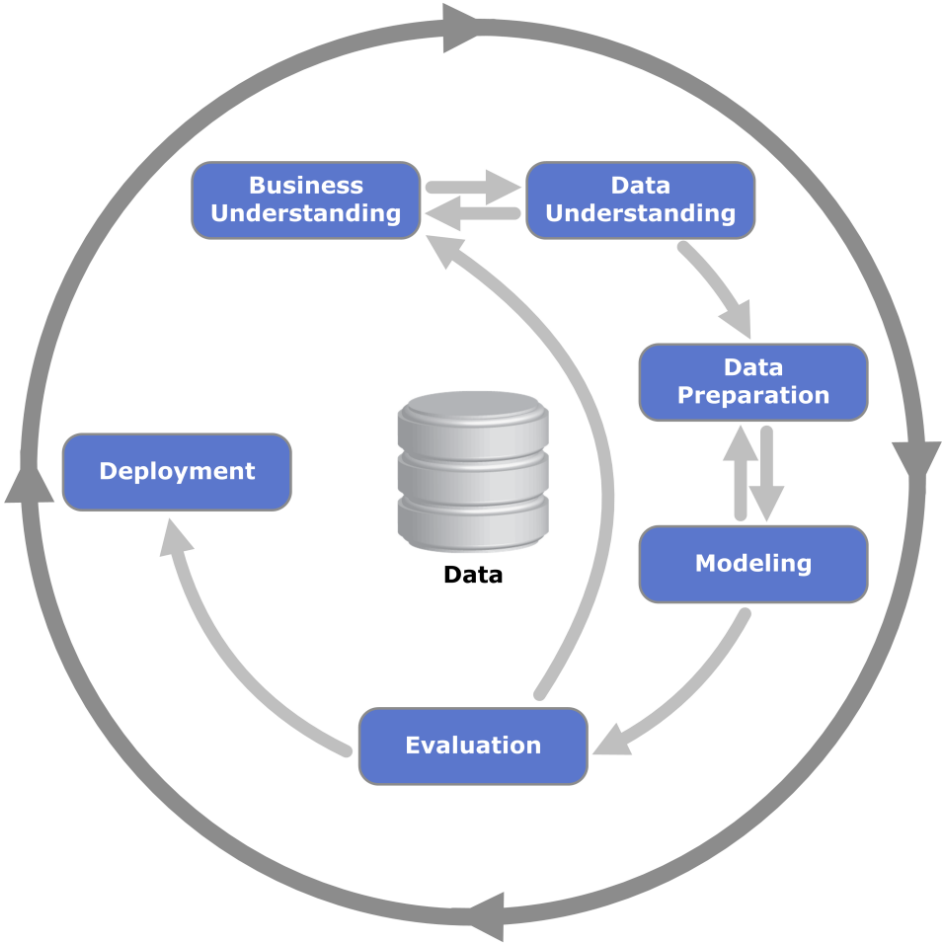
# The Knowledge Discovery Process (CRISP-DM)



# About the Lecture

- Main Source:
  - Tan, Steinbach, Kumar "Introduction to Data Mining"

# Data - Objects and Attributes

- *Data* is a collection of objects
- *Objects* (a.k.a. elements, instances, samples, records, rows, ...) are described by means of a set of attributes
- An *attribute* (a.k.a. field, variable, feature, ...) defines a property, a characteristic or a measure of an object (e.g. eye color, temperature...)

# Data – An example

| ID | Age | Sex | Marital Status | Income | Job | Trustable |
|---|---|---|---|---|---|---|
| 23432 | 34 | male | single | 24000 | bank officer | yes |
| 23433 | 45 | male | - | 36000 | Teacher | yes |
| 23434 | 44 | female | single | 300000 | - | no |
| 23435 | 55 | female | divorced | 35000 | Unemployed | no |
| 23436 | 57 | female | married | 22000 | bank officer | no |

# Attribute Types

- Categorical (Qualitative) Attributes [Discrete attributes]
  - Nominal (e.g. red, yellow, green, blue, …)
  - Binary (e.g. flags: true or false)
  - Ordinal (e.g. low, medium, high)
- Numeric (Quantitative) Attributes [Discrete and Continuous attributes]
  - Interval-scaled (real values in an interval)
  - Ratio-scaled (multiples of a constant)
- More complex data
  - Texts in natural language, Dates, Taxonomy, Graphs, XMLs…

# Categorical Attributes

## Nominal: categories, states, or "names of things"

- Hair_color = {auburn, black, blond, brown, grey, red, white}
- marital status, occupation, ID numbers, zip codes

## Binary

- Nominal attribute with only 2 values (0 and 1)
- They can be:
  - **Balanced**: both outcomes equally important (e.g., gender)
  - **Unbalanced**: outcomes not equally important (e.g., medical test )

## Ordinal

- Values have a meaningful order (ranking) but magnitude between successive values is not known.
- Size = {small, medium, large}, {1,2,3}, grades, army rankings

# Numeric Attributes

- **Quantity** (integer or real-valued)
- **Interval-based**
  - Measured on a continuous range
  - Values have order (e.g., temperature in C˚or F˚)
  - No evident correlation among values
- **Ratio-Scale** (e.g., temperature in Kelvin, length, counts, monetary quantities)
  - Values are multiple of a **unit of measurement**

# Discrete vs. Continuous Attributes

**Discrete Attribute**
(E.g., zip codes, profession, ID numbers, the set of words in a collection of documents )

- Has only a **finite** or **countably infinite** set of values
- Sometime represented as **integer variables**
- Note: Binary attributes are a special case of discrete attributes

**Continuous Attribute**
(E.g., temperature, height, or weight)

- Has **real numbers** as attribute values
- Practically, real values can only be measured and represented using a finite number of digits
- Typically represented as **floating-point variables**

# Properties of Attributes

| Type | Properties | Transformations | Operations |
|---|---|---|---|
| Nominal | Distinctness (= & ≠) | Permutations | Mode, entropy, correlation… |
| Ordinal | Order (< & >) | Order preserving change of values | Median, percentiles…. |
| Interval | Addition (+ & -) | *new_value* = *a* + *old_value* | Mean, St. Dev…. |
| Ratio | Multiplication (* & /) | *new_value* = *a* * *old_value* | Geom. Mean, Harmonic Mean, Pearson's correlat…. |

- Each type possesses all the properties and operations of the attribute types above it

# Types of Data

- The most generic type is the **Record Data**

- Other types:
  - **Text Data** (corpora of documents written in natural language)
  - **Graph Data** (used to represent information from World Wide Web or Molecular Structures)
  - **Ordered Data** (e.g. Spatial Data, Temporal Data, Sequential Data, Genetic Sequence Data)
  - …

# Record Data

- It consists of a collection of records (tuples)
- Each record consists of a fixed set of attributes
- There is no explicit relationship among attributes or records
- Usually stored in flat files or relational databases.

# Record Data – Example

| ID | Age | Sex | Marital Status | Income | Job | Trustable |
|---|---|---|---|---|---|---|
| 23432 | 34 | male | single | 24000 | bank officer | yes |
| 23433 | 45 | male | - | 36000 | Teacher | yes |
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# Record Data- Special Cases

## Transactional Data

- Each record involves a set of items
- Typically used to represent Market Transaction Data

| *TID* | *Items* |
|---|---|
| 1 | Bread, Soda, Milk |
| 2 | Beer, Bread |
| 3 | Beer, Soda, Diaper, Milk |
| 4 | Beer, Bread, Diaper, Milk |
| 5 | Soda, Diaper, Milk |

Equival.

| TID | Bread | Soda | Milk | Beer | Diaper |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 0 | 0 |
| 2 | 1 | 0 | 0 | 1 | 0 |
| 3 | 0 | 1 | 1 | 1 | 1 |
| 4 | 1 | 0 | 1 | 1 | 1 |
| 5 | 0 | 1 | 1 | 0 | 1 |

Binary attributes, but they can also be discrete or continuous

# Record Data-Special Cases

## Data Matrix

- Only *numeric attributes*
- Each record can be thought as a vector in multi-dimensional space
- Can be represented by an ***m x n*** matrix
  - Rows represent the objects and columns the attributes
  - **Advantage:** All standard matrix operations can be applied.
- It can be **sparse:** only non-zero value are important

# Record Data- Special Cases

## Document Data

- Used to represent a set of documents, with their terms (do you remember transactional data?)
- It is a ***sparse data matrix***

| | team | coach | play | ball | score | game | Win | lost | Timeout | season |
|---|---|---|---|---|---|---|---|---|---|---|
| Document 1 | 3 | 0 | 5 | 0 | 2 | 6 | 0 | 2 | 0 | 2 |
| Document 2 | 0 | 7 | 0 | 2 | 1 | 0 | 0 | 3 | 0 | 0 |
| Document 3 | 0 | 1 | 0 | 0 | 1 | 2 | 2 | 0 | 3 | 0 |

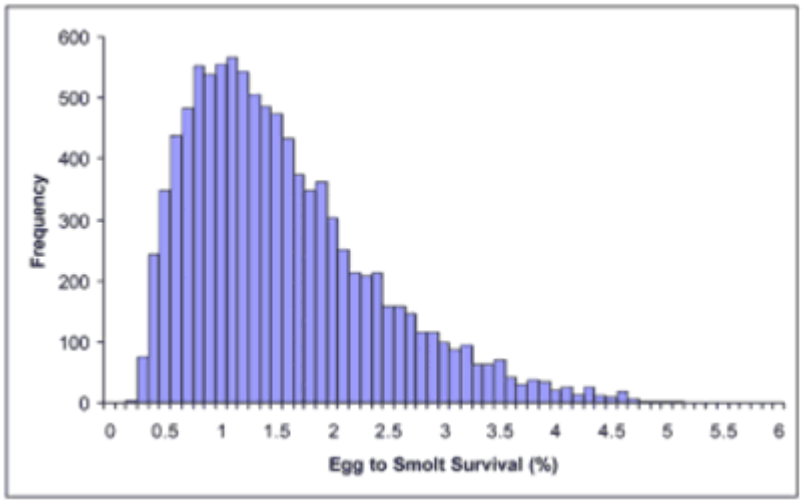
# Exploratory Data Analysis

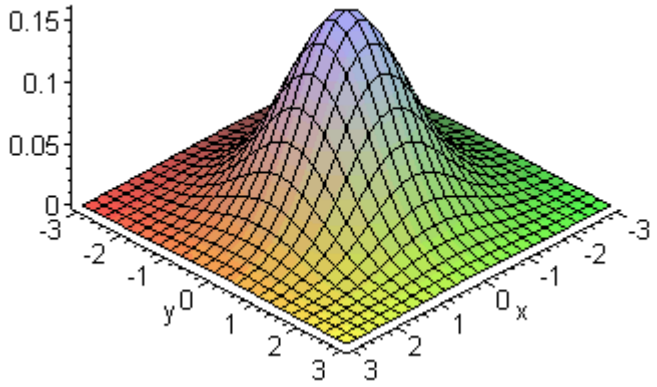
- Exploratory data analysis is an approach to analyzing data sets, to summarize their main characteristics, often with visual methods.

*"Procedures for analyzing data, techniques for interpreting the results of such procedures, ways of planning the gathering of data to make its analysis easier, more precise or more accurate, and all the machinery and results of (mathematical) statistics which apply to analyzing data."*

*John Tukey – "The Future of Data Analysis" - July 1961*

# Exploratory Data Analysis




# Exploratory Data Analysis

- Two approaches:
  - Parametric
    - The distribution, that governs the data, is known
      - Parameter estimation
  - Non-parametric
    - The distribution is unknown
      - Choose a “good” hypothesis and find its parameters

# Measures for categorical attributes

- The **frequency** of an attribute value is the percentage of time the value occurs in the data set
- The **mode** of a an attribute is the most frequent attribute value
- **Variability**
  - Are there (or not) some dominant values?

# Measures for numerical attributes

- Arithmetic mean

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

Incremental version

$$\bar{x}_0 = 0$$

$$\bar{x}_{n+1} = \frac{n(\bar{x}_n + x_{n+1})}{n+1}$$

- Geometric mean

$$\bar{x} = \sqrt[n]{\prod_{i=1}^{n} x_i}$$

Logarithmic version

$$\ln \bar{x} = \frac{1}{n}\sum_{i=1}^{n} \ln x_i$$

# Measures for numerical attributes

- Harmonic mean

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

- The **median** is the middle number of the group when they are ranked in order. (If there are an even number of numbers, the mean of the middle two is taken.)
  - {1, 7, 12, 23, 34, 54, 20678299132168}, the median is 23

# Measures of Dispersion

- **Range** is the difference between maximum and minimum:

$$r = \max\{x_1, \dots, x_n\} - \min\{x_1, \dots, x_n\}$$

- **Variance** $\sigma^2$ and **Standard Deviation** $\sigma$ are the most common measures of dispersion:

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

- Other measures able to mitigate the influence of outliers:

$$AAD = \frac{1}{n}\sum_{i=1}^{n}|x_i - \bar{x}| \qquad MAD = median\{|x_1 - \bar{x}|, \dots, |x_n - \bar{x}|\}$$

# Robust Measure for Dispersion: IQR

- Given an ordinal or continuous attribute $x$ and a number $p \in [0,100]$, the $p$-th ***percentile*** is the value of $x$ such that $p\%$ of the observed values of $x$ are smaller than $x_p$.
  - For instance, the 50th percentile is the value $x_{50\%}$ such that 50% of all values of $x$ are less than $x_{50\%}$.
- **Quartiles** and outliers
  - Quartiles: Q1 (25th percentile), Q3 (75th percentile)
  - Inter-quartile range:

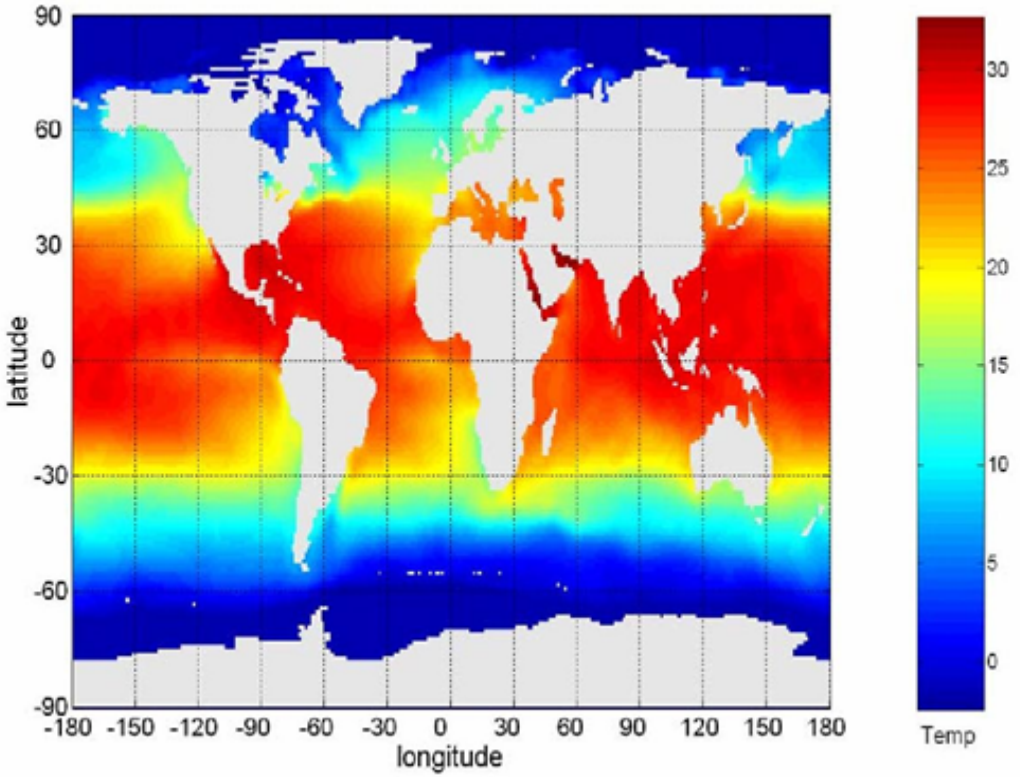
$$\text{IQR} = \text{Q3} - \text{Q1}$$

  - **Outlier**: usually, a value higher/lower than 1.5 x IQR

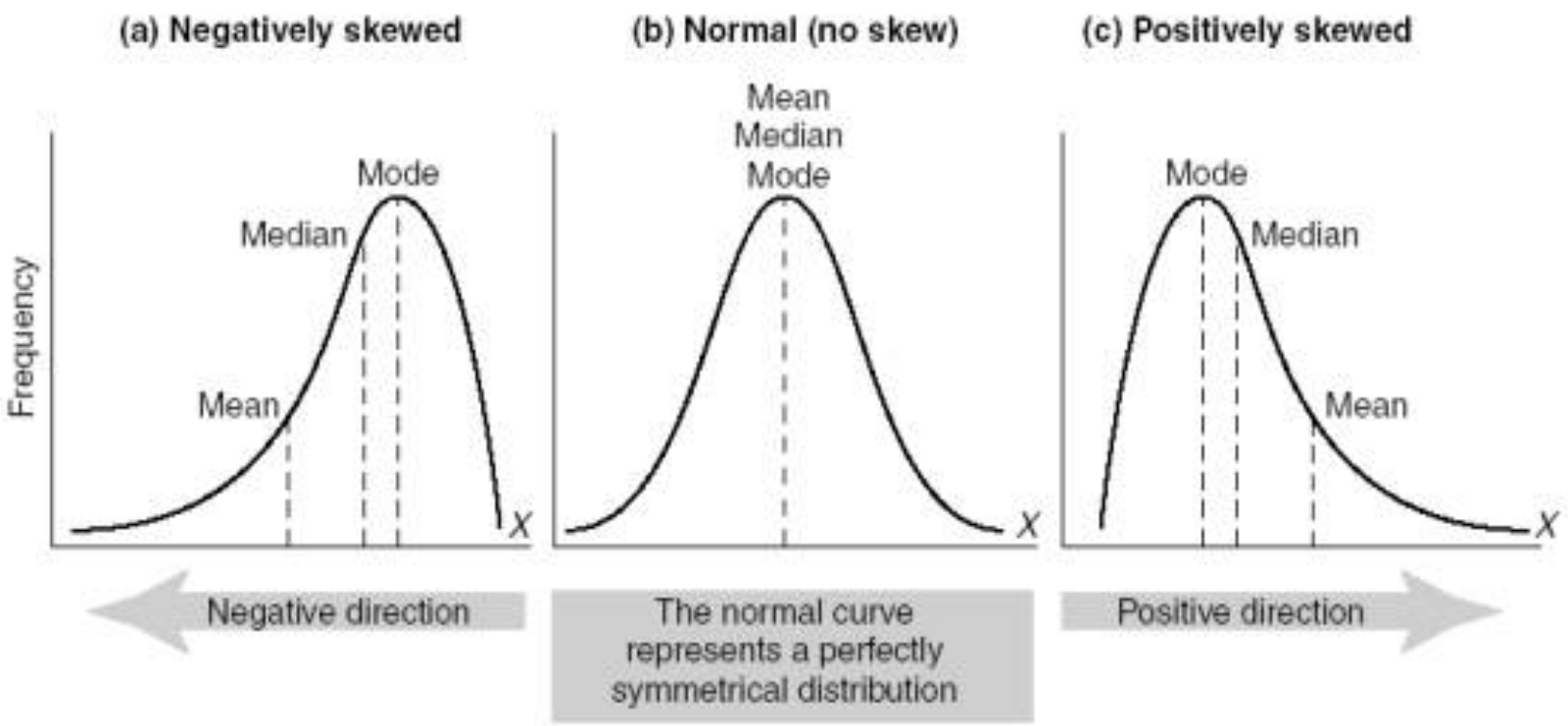
# Visualization

- ***Aim***: To analyze/report the characteristics of the data and the relationships among data items or attributes
- ***Requirement***: Conversion of data into a visual or tabular format.
- Humans have a well developed ability to analyze large amounts of information that is visually presented
  - Can detect general patterns and trends
  - Can detect outliers and unusual patterns

# Visualization – Example



# Normal VS Skewed Distribution



# Visualization – Iris Dataset

- Can be obtained from the UCI Machine Learning Repository

  http://www.ics.uci.edu/~mlearn/MLRepository.html

- From the statistician Douglas Fisher
- Three flower types (classes):
  - Setosa
  - Virginica
  - Versicolour
- Four (non-class) attributes
  - Sepal/Petal Width/Length

Setosa

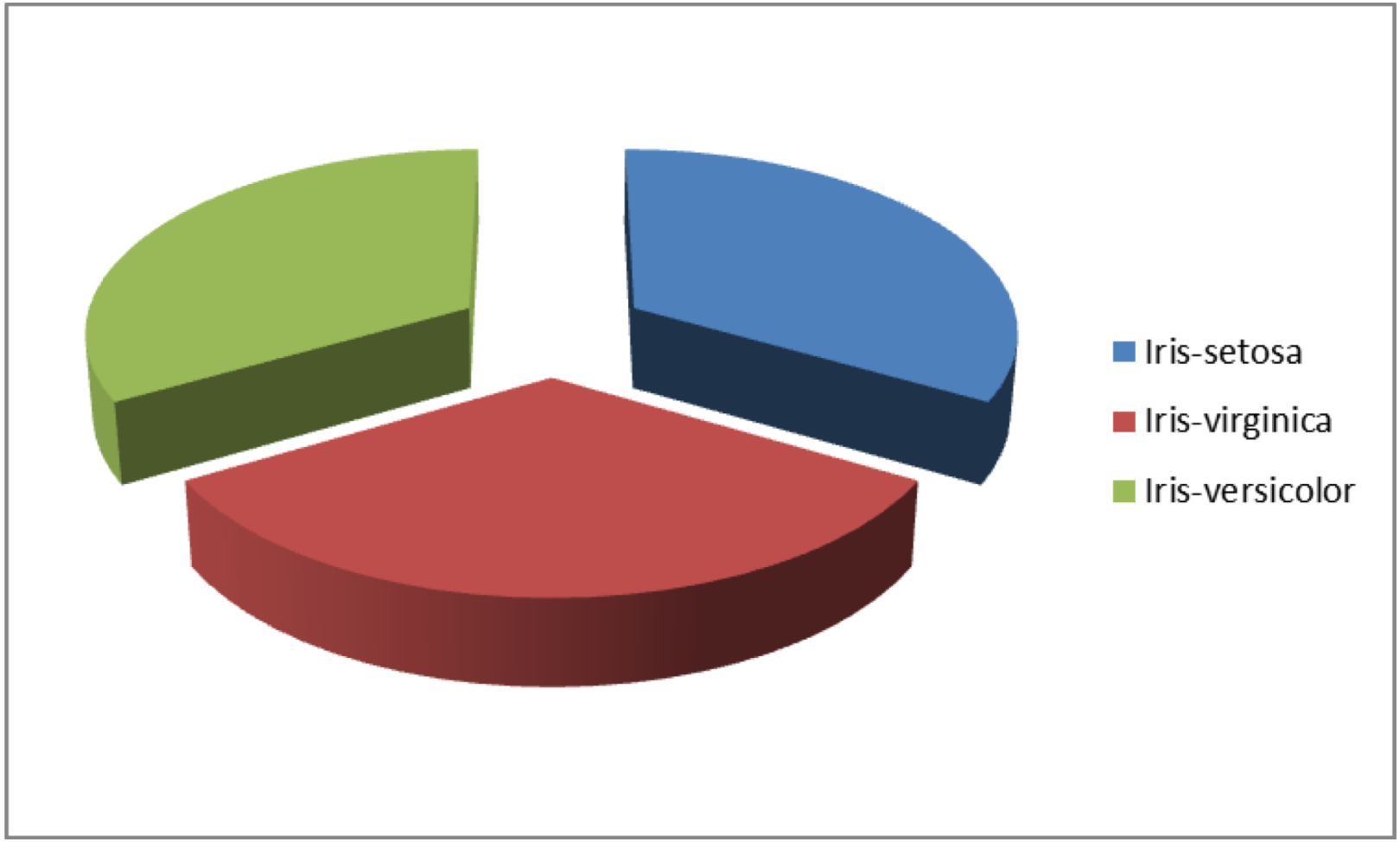

Virginica

Versicolour

# Visualization – Iris Dataset

| sepal length | sepal width | petal length | petal width | class |
|---|---|---|---|---|
| 4.3 | 3 | 1.1 | 0.1 | Iris-setosa |
| 4.4 | 2.9 | 1.4 | 0.2 | Iris-setosa |
| 4.4 | 3 | 1.3 | 0.2 | Iris-setosa |
| 4.9 | 2.4 | 3.3 | 1 | Iris-versicolor |
| 5 | 2 | 3.5 | 1 | Iris-versicolor |
| 5 | 2.3 | 3.3 | 1 | Iris-versicolor |
| 5.8 | 2.7 | 5.1 | 1.9 | Iris-virginica |
| 5.8 | 2.8 | 5.1 | 2.4 | Iris-virginica |
| ..... | ..... | ..... | ..... | ..... |

# Visualization Techniques – Pie Chart

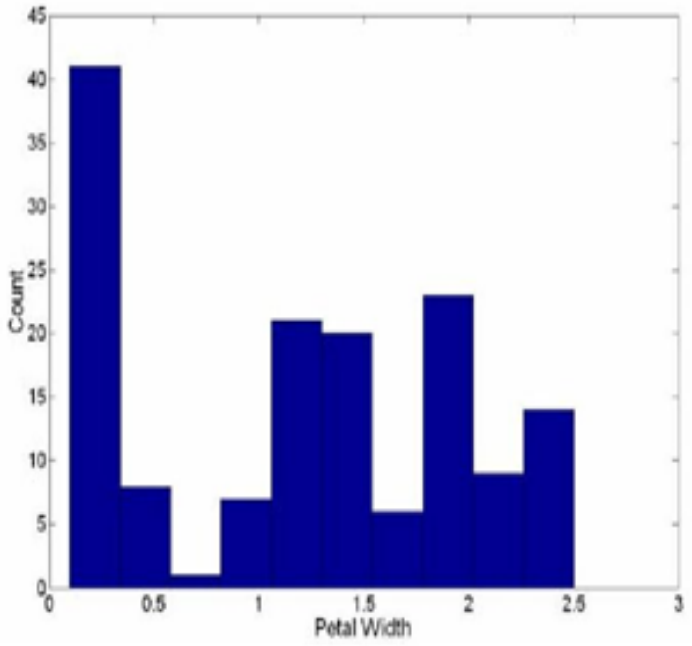


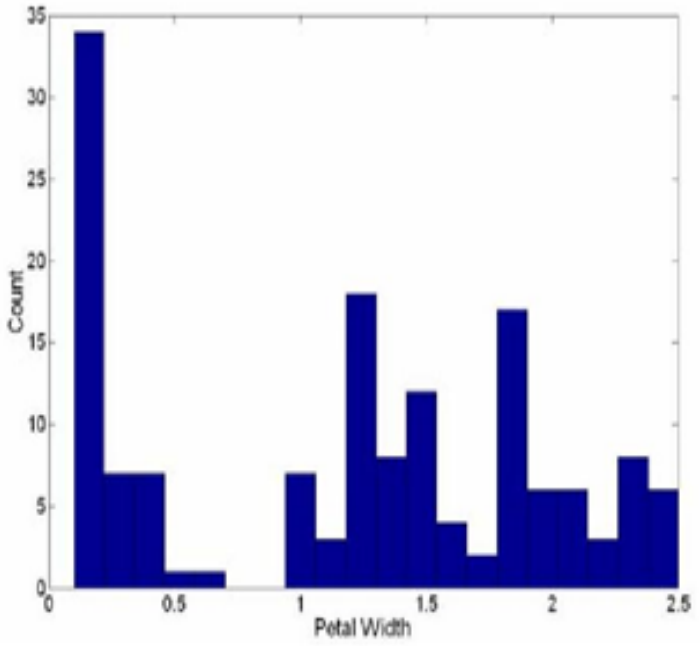
# Visualization Techniques – Histogram

- Usually, a histogram shows the value distribution of a single variable
- It divides the values into bins and shows a bar plot of the number of objects in each bin
- The height of each bar indicates the number of objects
- *The Shape* of a histogram depends on the number of bins

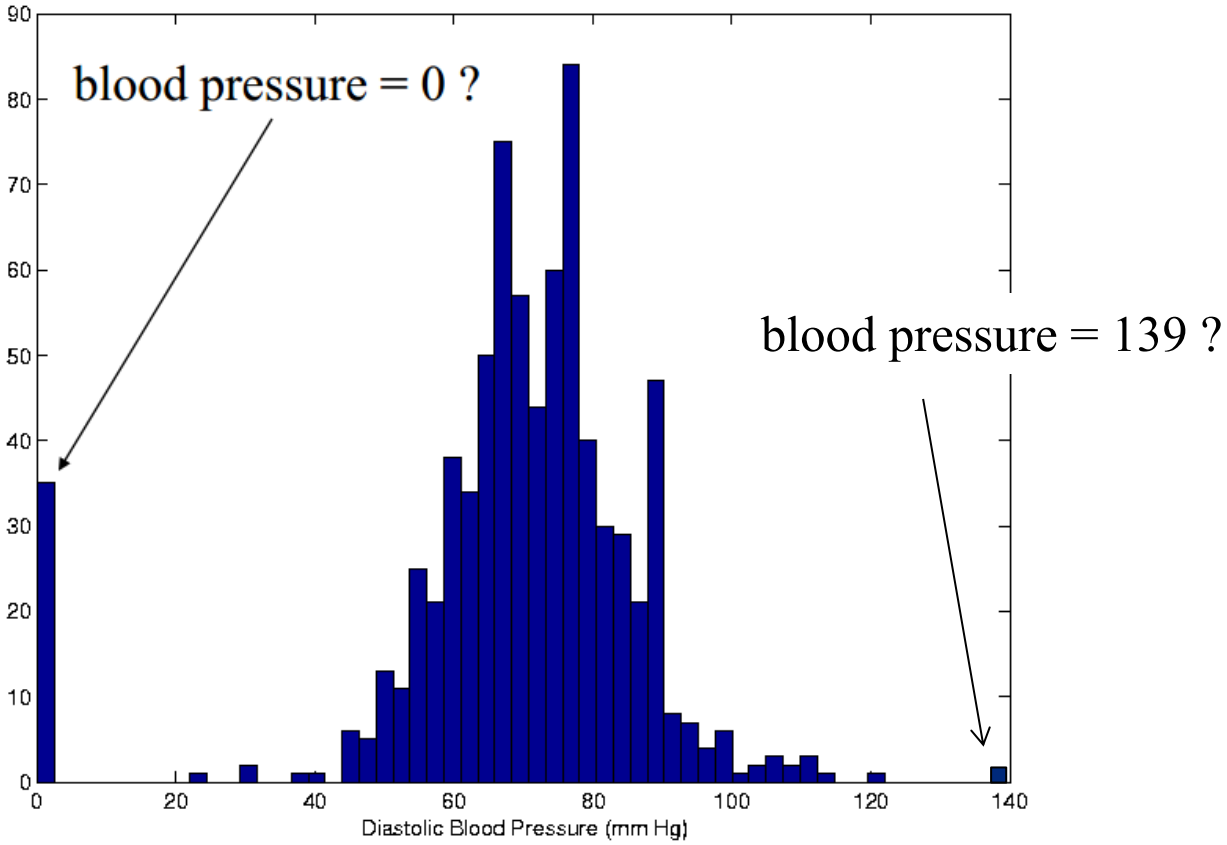
# Histogram – Example

- Petal Width (10 and 20 bins, respectively)



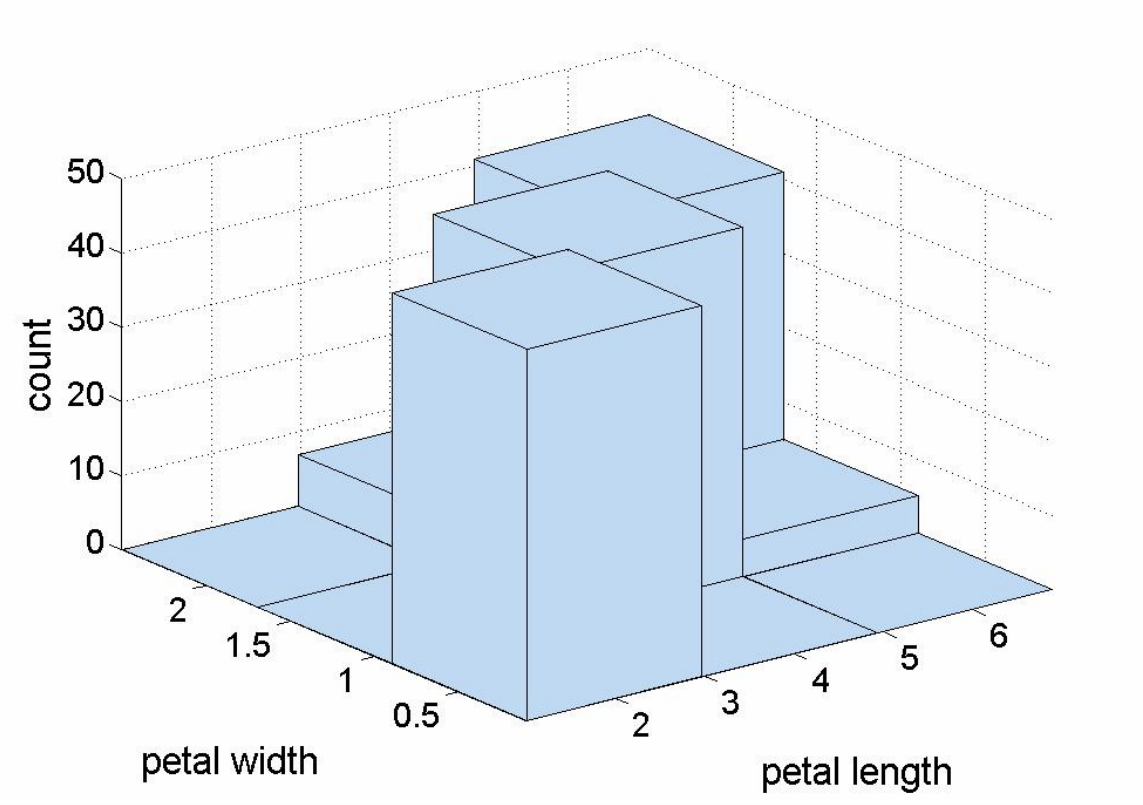



# Histogram – Anomalies and Outliers



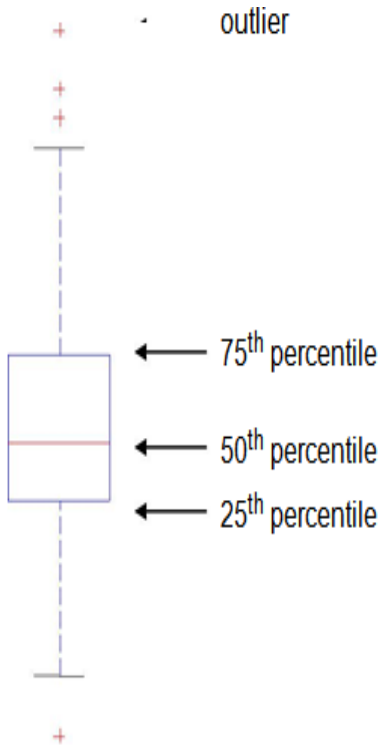
# 2-Dim Histogram

- It shows the joint distribution of two attributes

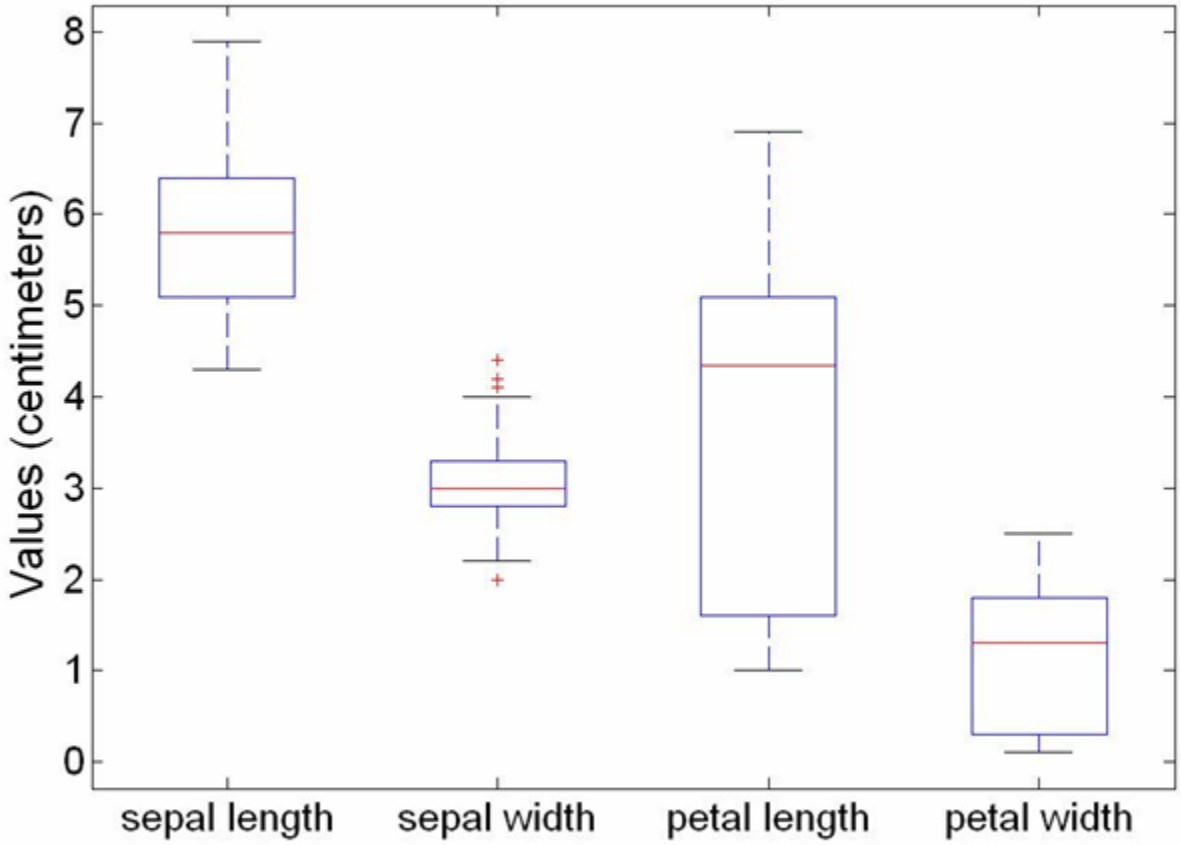


# Visualization Techniques – BoxPlot

- 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



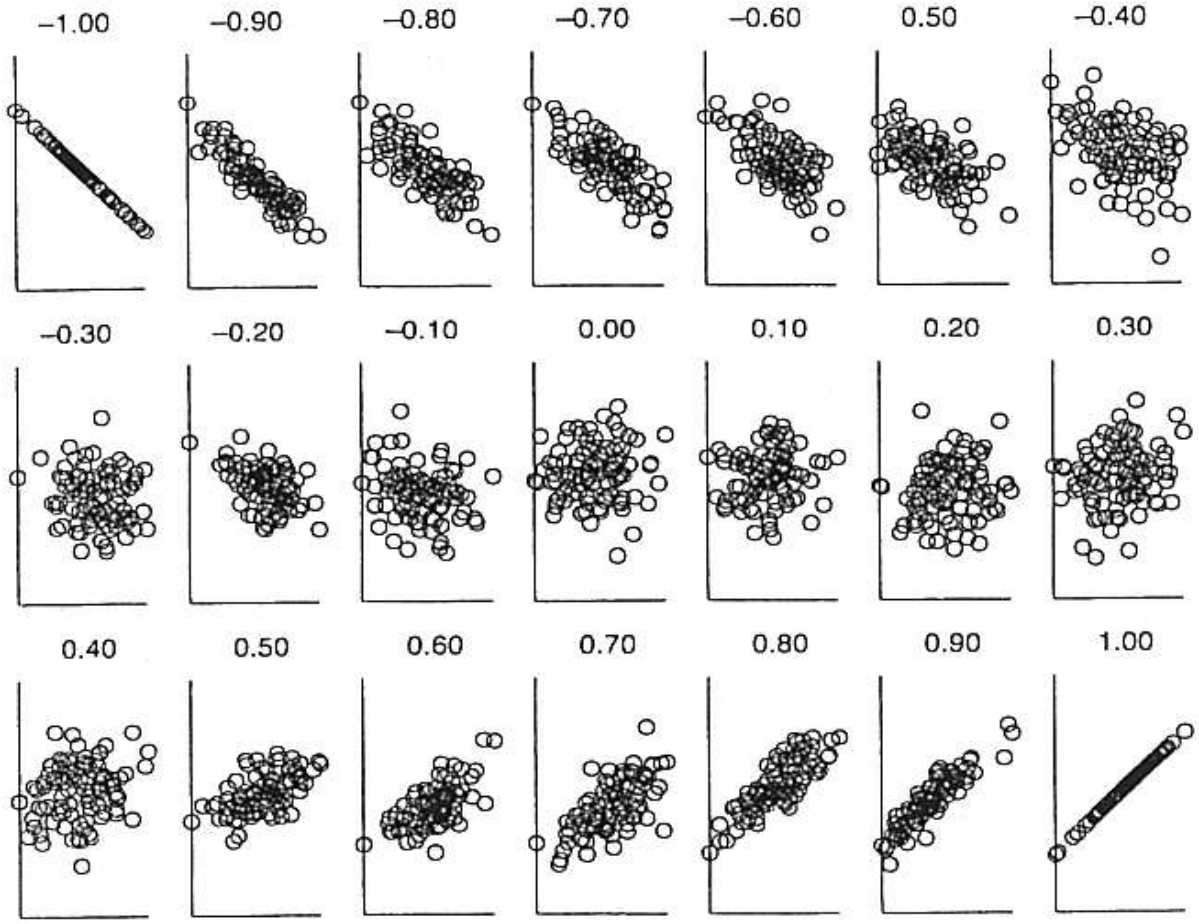
# BoxPlot – Example



# Visualization Techniques – Scatter Plot

- Used to discovery linear correlation between attributes
- Attributes values determine the position
- Additional attributes can be displayed by using the size, shape, and color of the markers that represent the objects
- *Arrays* of scatter plots can compactly summarize the relationships of several pairs of attributes
- The two-dimensional scatter plots are the most common, but we can have *three-dimensional* scatter plots

# Correlation in scatter plots



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# Scatter Plot – Example