# INTRODUCTORY APPLIED MACHINE LEARNING

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Today:

- Types of data
- Data visualization

# About Your Project…

- UCI machine learning repository:

https://archive.ics.uci.edu/ml/index.php

# Outline

- Goal of the lecture
- Types of data
- Data preprocessing
- Measures of similarity
- The Iris data set
- Descriptive statistics
- Visualization

# Goals

- After this, you should be able to:
  - Understand data types and data acronyms
  - Calculate similarity between data points
  - Use basic descriptive statistics
  - Visualize data

# What is Data?

- Collection of data objects and their attributes
- An attribute is a property or characteristic of an object
  - Examples: eye color of a person, temperature, etc.
  - Attribute is also known as variable or feature
- A collection of attributes describe an object
  - Object is also known as case, sample, entity, or instance

Attributes

Objects

| *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 |

# Attribute Values

- Attribute values are numbers or symbols assigned to an attribute
- Discrete attribute
  - Has only a finite or countably infinite set of values
  - Examples: zip codes or counts
  - Often represented as integer variables
- Continuous attribute
  - Has real numbers as attribute values
  - Examples: temperature, height, or weight
  - Typically represented as floating-point variables

# Types of Data Sets

- Record
  - Data matrix
  - Document data
  - Transaction data
- Graph
  - World wide web
  - Molecular structures
- Ordered
  - Spatial data
  - Temporal data
  - Sequential data
  - Genetic sequence data

# Record Data

- Data that consists of a collection of records, each of which consists of a fixed set of attributes

| *Tid* | Refund | Marital Status | Taxable Income | Cheat |
|---|---|---|---|---|
| 1 | Yes | Single | 125K | No |
| 2 | No | Married | 100K | No |
| 3 | No | Single | 70K | No |
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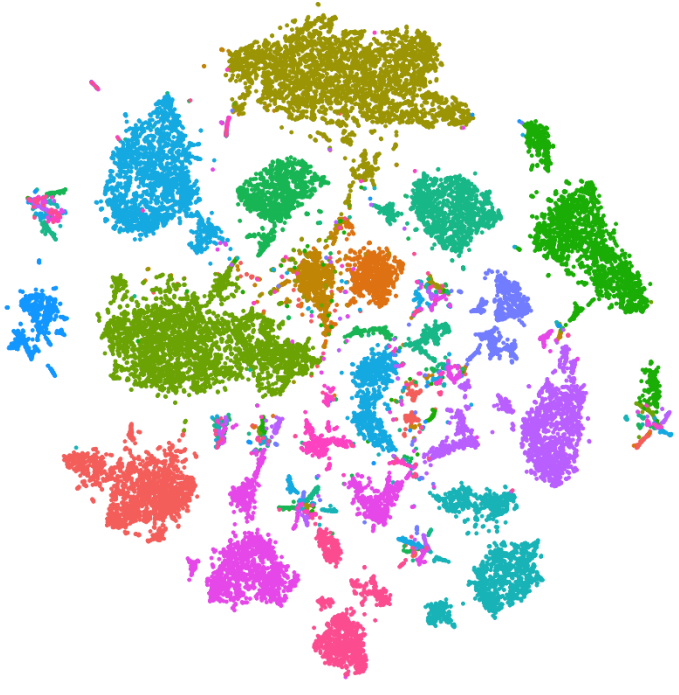
| 10 | No | Single | 90K | Yes |

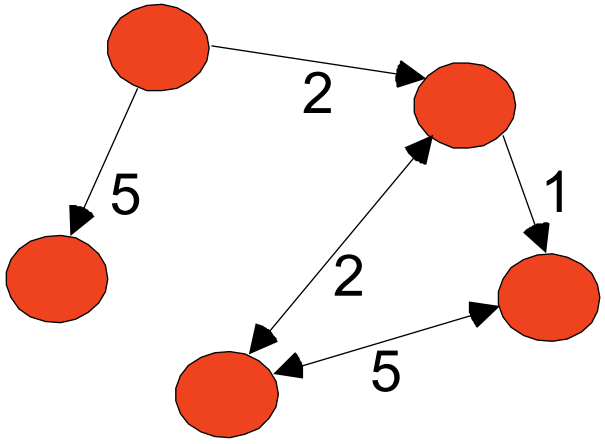
# Record Data in High Dimension

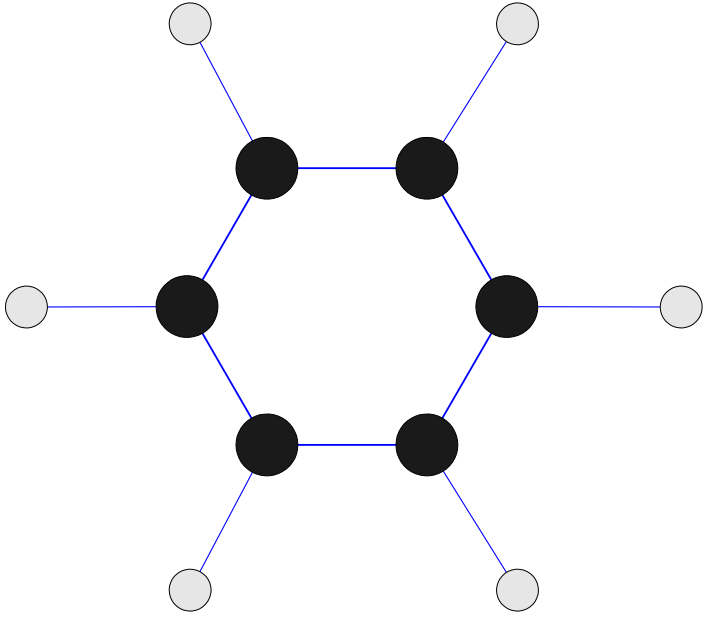
- If data objects have the same fixed set of numeric attributes, the data objects can be thought of as points in a multi-dimensional space



# Graph Data

- Examples: Generic graph and chemical structure ($C_6H_6$)

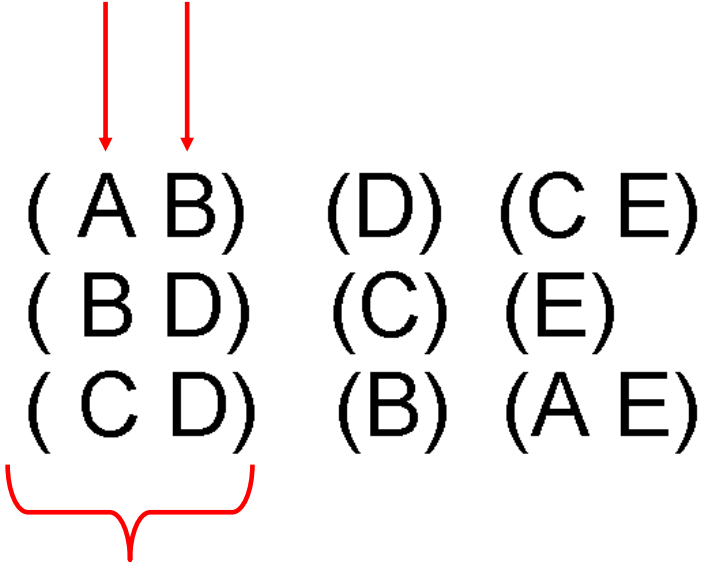


# Ordered Data

- Sequences of transactions

Items/Events




```
GGTTCCGCCTTCAGCCCCGCGCC
CGCAGGGCCCGCCCCGCGCCGTC
GAGAAGGGCCCGCCTGGCGGGCG
GGGGGAGGCGGGGCCGCCCGAGC
CCAACCGAGTCCGACCAGGTGCC
CCCTCTGCTCGGCCTAGACCTGA
GCTCATTAGGCGGCAGCGGACAG
GCCAAGTAGAACACGCGAAGCGC
TGGGCTGCCTGCTGCGACCAGGG
```

# Data Preprocessing – Sampling

- Sampling is the main technique employed for data selection
- It is often used for both the preliminary investigation of the data and the final data analysis
- Statisticians sample because obtaining the entire set of data of interest is too expensive or time consuming
- Sampling is used in machine learning because processing the entire set of data of interest is too expensive or time consuming

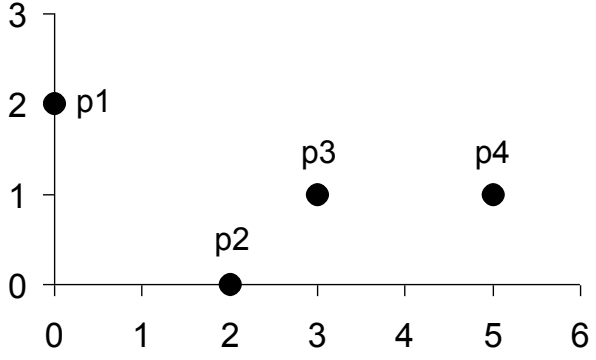
# Measures of Similarity

- The Euclidean distance between two data points $\boldsymbol{p} = [p_k]$ and $\boldsymbol{q} = [q_k]$ is defined as

$$d(\boldsymbol{p}, \boldsymbol{q}) = \sqrt{\sum_{k=1}^{M} (p_k - q_k)^2} \in \Re$$

where $M \in \aleph$ is the number of dimensions (attributes) and $p_k$ and $q_k$ are, respectively, the $k$th attributes (components) of data objects $\boldsymbol{p}$ and $\boldsymbol{q}$

# Examples of Euclidean Distance




| point | x | y |
|---|---|---|
| p1 | 0 | 2 |
| p2 | 2 | 0 |
| p3 | 3 | 1 |
| p4 | 5 | 1 |

Distance Matrix

| | p1 | p2 | p3 | p4 |
|---|---|---|---|---|
| p1 | 0 | 2.828 | 3.162 | 5.099 |
| p2 | 2.828 | 0 | 1.414 | 3.162 |
| p3 | 3.162 | 1.414 | 0 | 2 |
| p4 | 5.099 | 3.162 | 2 | 0 |

# Minkowski Distance

- Minkowski distance is a generalization of Euclidean distance

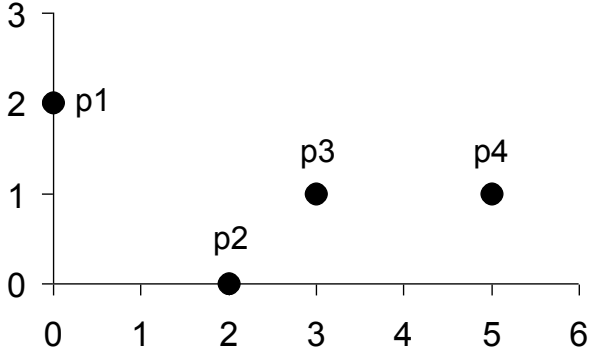
$$d(\boldsymbol{p}, \boldsymbol{q}) = \left( \sum_{k=1}^{M} |p_k - q_k|^r \right)^{\frac{1}{r}} \in \Re$$

where $r \in \aleph$ is a parameter, $M$ is the number of dimensions (attributes), and $p_k$ and $q_k$ are, respectively, the $k$th attributes (components) data objects $\boldsymbol{p}$ and $\boldsymbol{q}$

# Common Minkowski Distance

- $r = 1$: City block ($L_1$ norm)
- $r = 2$: Euclidean distance ($L_2$ norm)
- $r \to \infty$: "supremum" ($L_\infty$ norm)

# Examples of Minkowski Distance




| point | x | y |
|---|---|---|
| p1 | 0 | 2 |
| p2 | 2 | 0 |
| p3 | 3 | 1 |
| p4 | 5 | 1 |

Distance Matrix

| L1 | p1 | p2 | p3 | p4 |
|---|---|---|---|---|
| p1 | 0 | 4 | 4 | 6 |
| p2 | 4 | 0 | 2 | 4 |
| p3 | 4 | 2 | 0 | 2 |
| p4 | 6 | 4 | 2 | 0 |

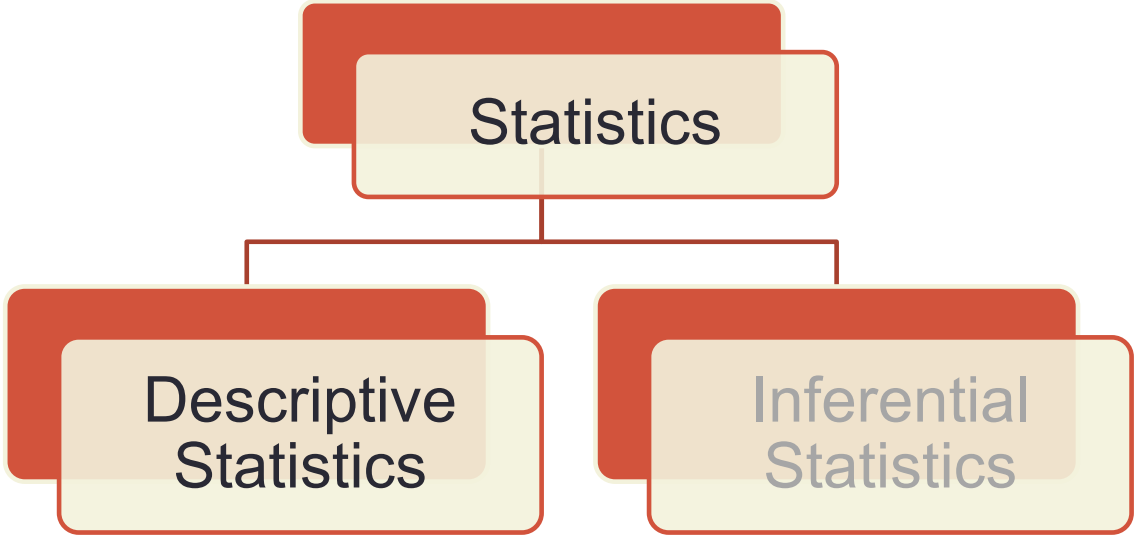
| L2 | p1 | p2 | p3 | p4 |
|---|---|---|---|---|
| p1 | 0 | 2.828 | 3.162 | 5.099 |
| p2 | 2.828 | 0 | 1.414 | 3.162 |
| p3 | 3.162 | 1.414 | 0 | 2 |
| p4 | 5.099 | 3.162 | 2 | 0 |

| $L_\infty$ | p1 | p2 | p3 | p4 |
|---|---|---|---|---|
| p1 | 0 | 2 | 3 | 5 |
| p2 | 2 | 0 | 1 | 3 |
| p3 | 3 | 1 | 0 | 2 |
| p4 | 5 | 3 | 2 | 0 |

# Common Properties of a Distance

- Positive definiteness: $d(\boldsymbol{p}, \boldsymbol{q}) \geq 0$ for all $\boldsymbol{p}$ and $\boldsymbol{q}$ and $d(\boldsymbol{p}, \boldsymbol{q}) = 0$ only if $\boldsymbol{p} = \boldsymbol{q}$
- Symmetry: $d(\boldsymbol{p}, \boldsymbol{q}) = d(\boldsymbol{q}, \boldsymbol{p})$ for all $\boldsymbol{p}$ and $\boldsymbol{q}$
- Triangle inequality: $d(\boldsymbol{p}, \boldsymbol{t}) \leq d(\boldsymbol{p}, \boldsymbol{q}) + d(\boldsymbol{q}, \boldsymbol{t})$ for all points $\boldsymbol{p}$, $\boldsymbol{q}$, and $\boldsymbol{t}$, where $d(\boldsymbol{p}, \boldsymbol{q})$ is the distance (dissimilarity) between points $\boldsymbol{p}$ and $\boldsymbol{q}$
- A distance that satisfies these properties is a metric

# Statistical Methodologies



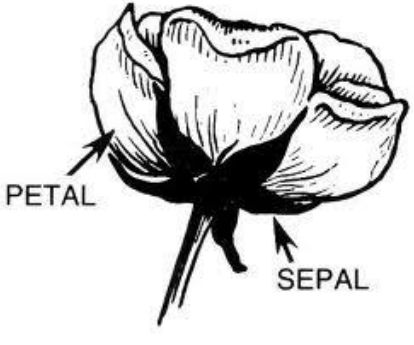

Numerical and graphical methods to look for patterns, to summarize the information in a data set

# The Iris Data Set

- Can be obtained from the UCI Machine Learning Repository http://www.ics.uci.edu/~mlearn/MLRepository.html
- Matlab command:

```
>load fisheriris.mat
```

- From the statistician Douglas Fisher
- Three flower types (classes): Setosa, Virginica, Versicolour
- Four (non-class) attributes: Sepal width and length, Petal width and length



# Mean, Median, and Variance

- The mean is the most common measure of the location of a set of points, though it is very sensitive to outliers

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

- The median is also commonly used

$$median(x) = \begin{cases} x_{(r+1)} & \text{if } m \text{ is odd, i. e., } m = 2r+1 \\ \frac{1}{2}\left(x_{(r)} + x_{(r+1)}\right) & \text{if } m \text{ is even, i. e., } m = 2r \end{cases}$$

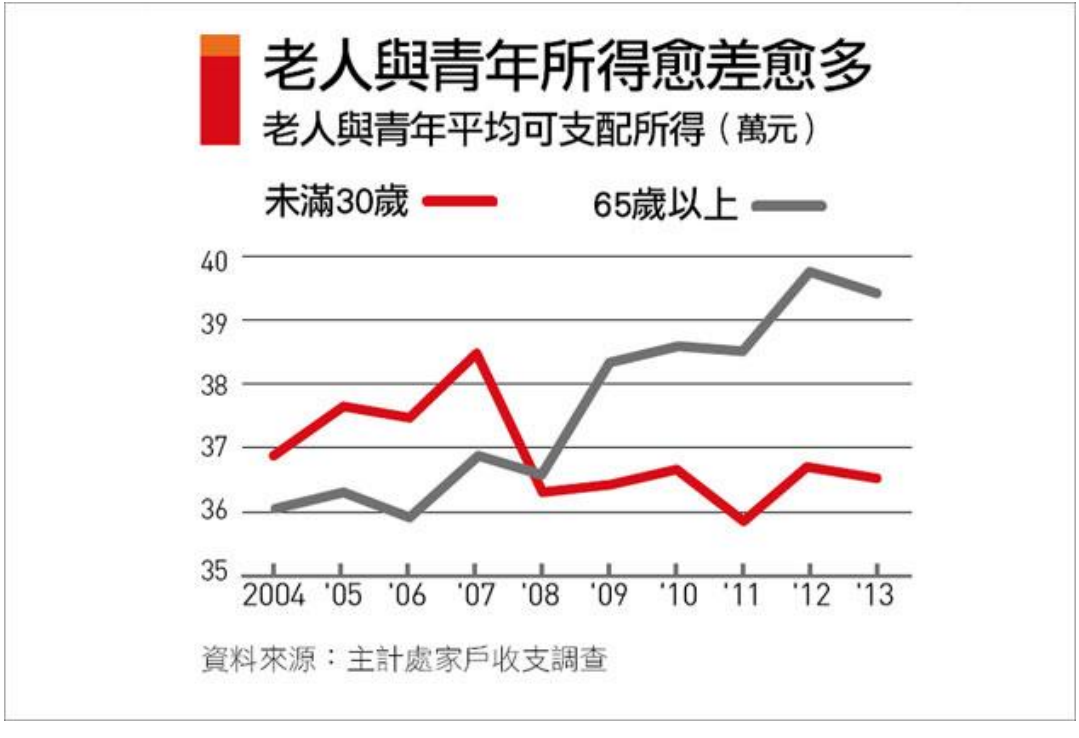
- The variance is the most common measure of the spread of a set of points

$$\text{Var}(x) = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2$$

# Visualization

- Humans have a well developed ability to analyze large amounts of information that is presented visually
- Can detect general patterns and trends
- Can detect outliers and unusual patterns

# The Powerfulness of Visualization

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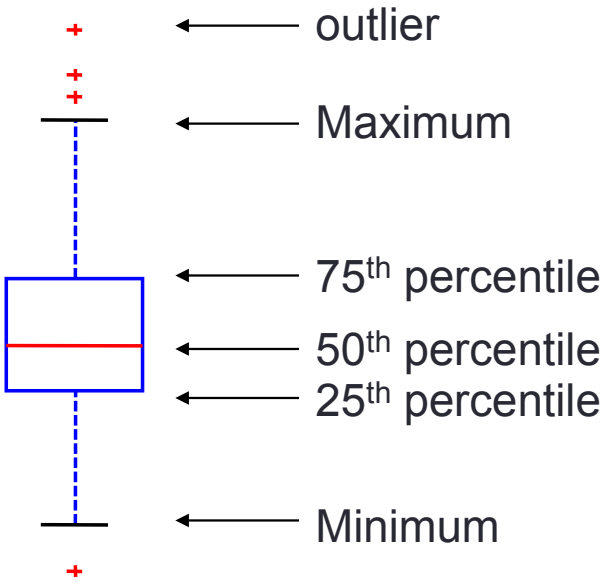
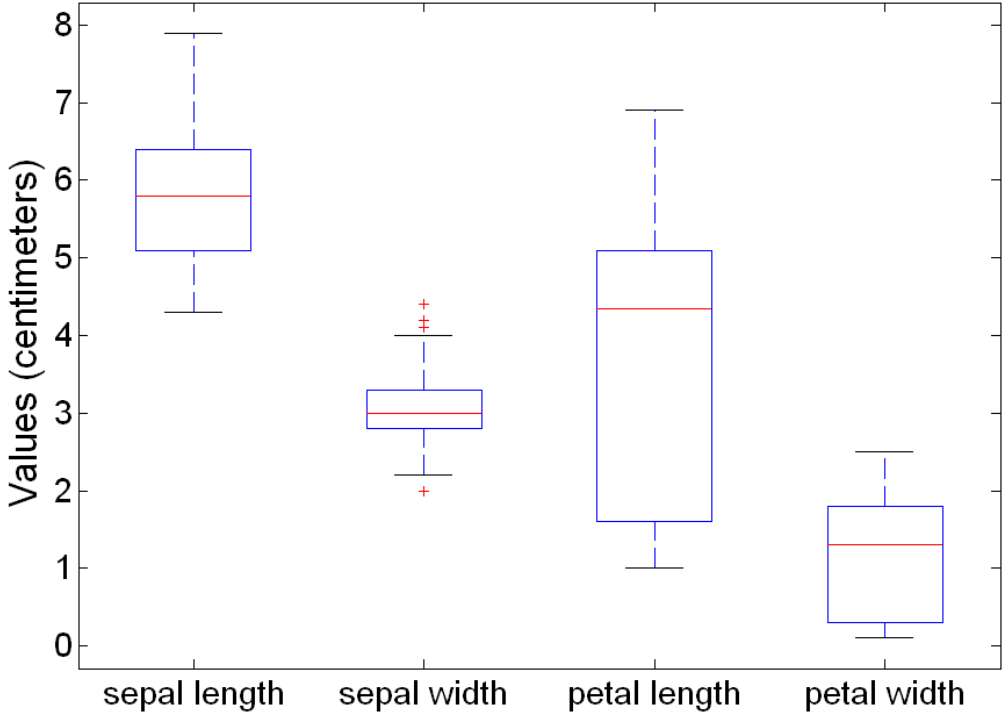
# Visualization Techniques: Box Plots

- Invented by J. Tukey
- A way of displaying the distribution of data
- Following figure shows the basic part of a box plot



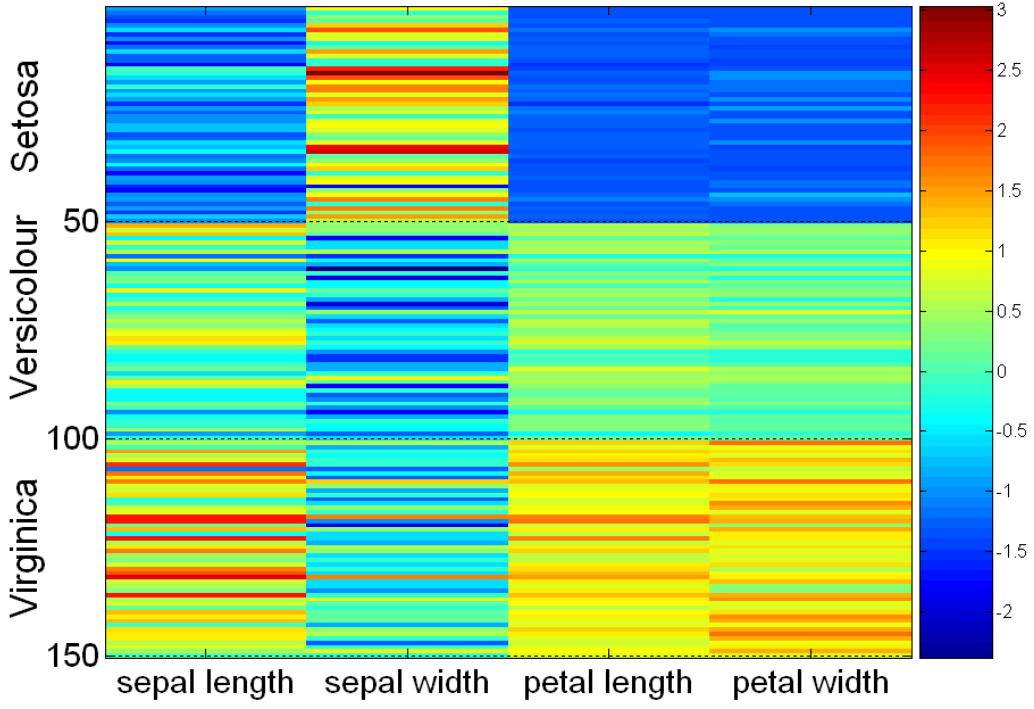
# Example of Box Plots

- Box plots can be used to compare attributes



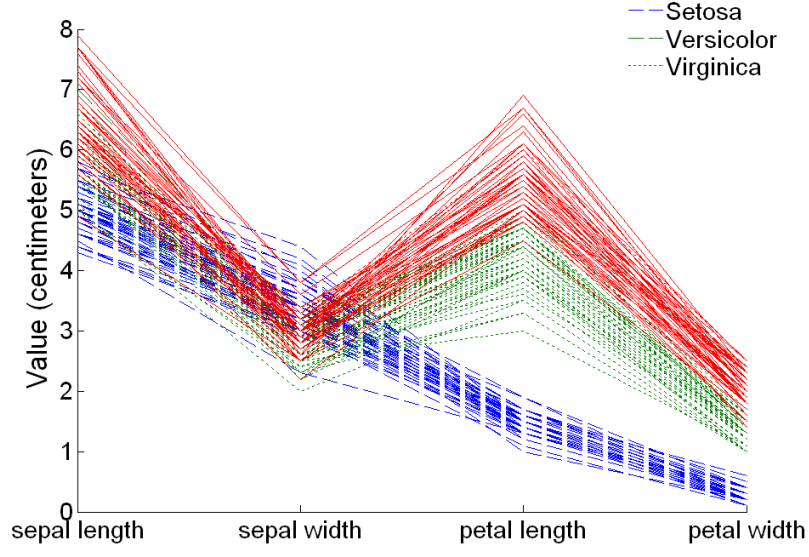
# Visualization Techniques: Matrix Plots

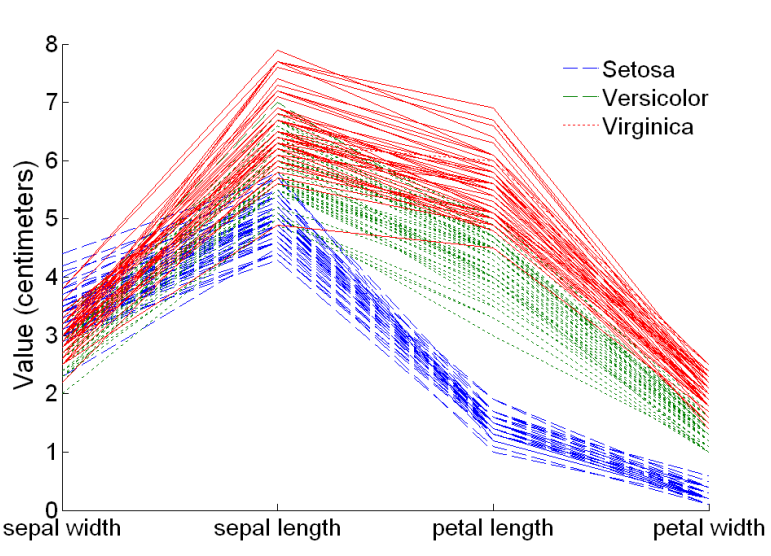
- Display three variables on a 2D plot
- This can be useful when objects are sorted according to class



# Visualization Techniques: Parallel Coordinates

- Used to plot the attribute values of high-dimensional data
- The attribute values of each object are plotted as a point on each corresponding coordinate axis and the points are connected by a line



# Summary

- For many machine-learning applications, a first step is identifying data type
- Norm is a metric to measure distance between data points
- Data visualization makes data analytics more effective

# References


- P. Tan, M. Steinbach, and V. Kumar, *Introduction to Data Mining*