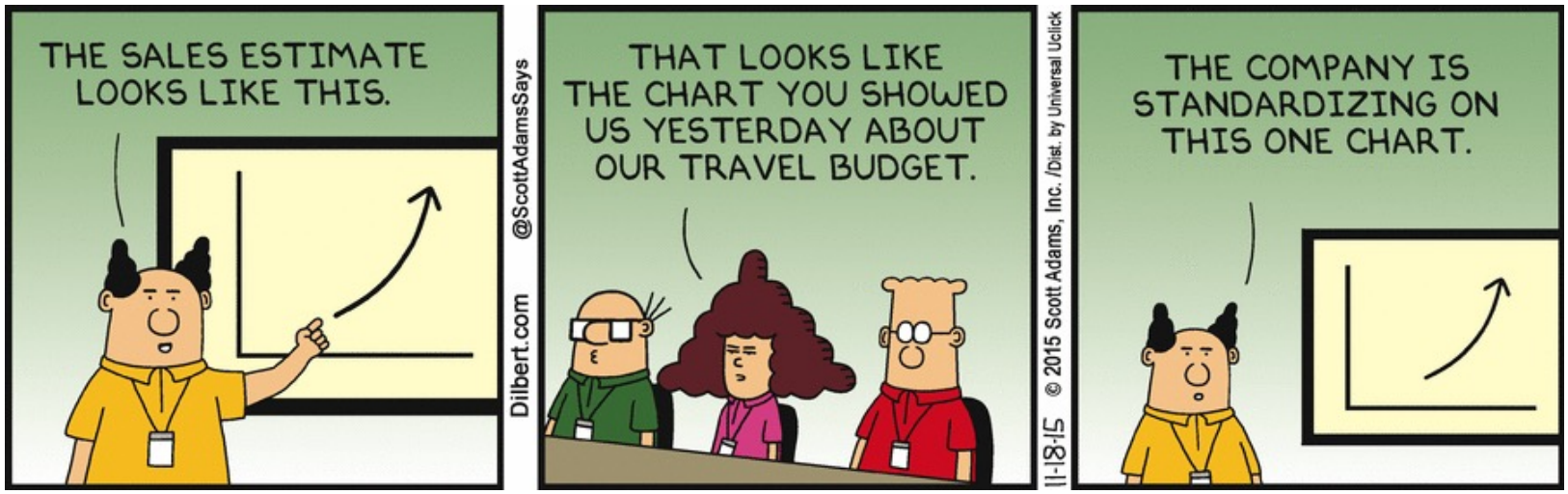
Data Mining: Exploring Data



Lecture Notes for Chapter 2

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Topics

- **Exploratory Data Analysis**
- Summary Statistics
- Visualization

What is Data Exploration?

“A preliminary exploration of the data to better understand its characteristics.”

- Key motivations of data exploration include
  - —Helping to select the right tool for preprocessing or analysis
  - —Making use of humans’ abilities to recognize patterns.
    People can recognize patterns not captured by data analysis tools

- Related to the area of Exploratory Data Analysis (EDA)
  - —Created by statistician John Tukey
  - —Seminal book is "Exploratory Data Analysis" by Tukey
  - —A nice online introduction can be found in Chapter 1 of the NIST Engineering Statistics Handbook
  - —http://www.itl.nist.gov/div898/handbook/index.htm

Topics

- Exploratory Data Analysis
- **Summary Statistics**
- Visualization

Summary Statistics

Summary statistics are numbers that summarize properties of the data

- Summarized properties include location and spread for continuous data

  Examples: location - mean
  spread - standard deviation

- Most summary statistics can be calculated in a single pass through the data

Frequency and Mode

- The frequency of an attribute value is the percentage of time the value occurs in the data set
  - —For example, given the attribute ‘gender’ and a representative population of people, the gender ‘female’ occurs about 50% of the time.
- The mode of an attribute is the most frequent attribute value
- The notions of frequency and mode are typically used with **categorical data.**

Measures of Location: Mean and Median

- For quantitative features.
- The mean is the most common measure of the location of a set of points.
- However, the mean is very sensitive to outliers.
- Thus, the median or a trimmed mean is also commonly used.

$$\text{mean}(x) = \overline{x} = \frac{1}{m}\sum_{i=1}^{m} x_i$$

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

Measures of Spread: Range and Variance

- Range is the difference between the max and min
- The variance or standard deviation is the most common measure of the spread of a set of points.

$$\text{variance}(x) = s_x^2 = \frac{1}{m-1}\sum_{i=1}^{m}(x_i - \overline{x})^2$$

- However, this is also sensitive to outliers, so that other measures are often used.

$$\text{AAD}(x) = \frac{1}{m}\sum_{i=1}^{m}|x_i - \overline{x}|$$

$$\text{MAD}(x) = median\left(\{|x_1 - \overline{x}|, \ldots, |x_m - \overline{x}|\}\right)$$

$$\text{interquartile range}(x) = x_{75\%} - x_{25\%}$$

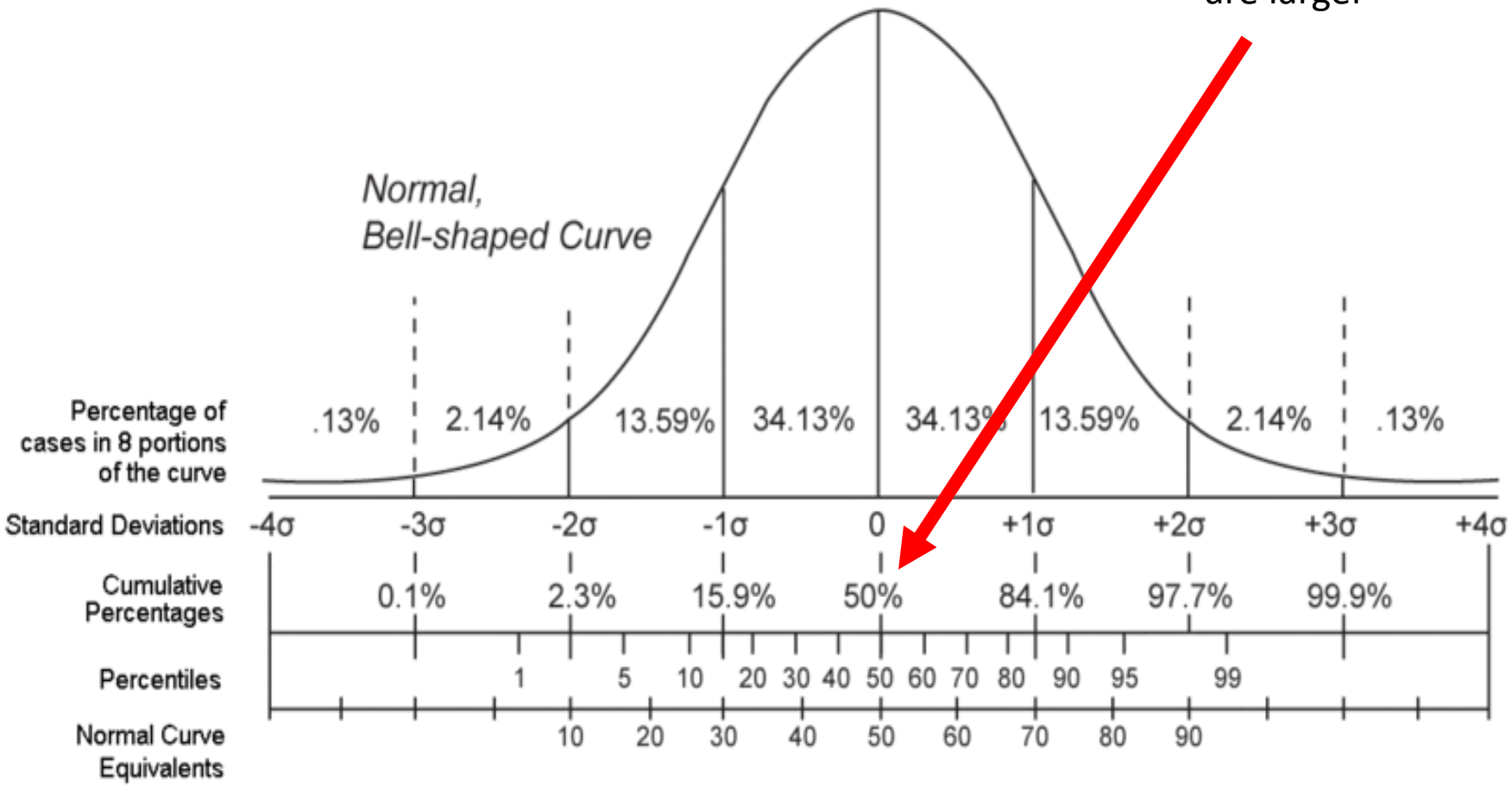
Percentiles

- Given an ordinal or continuous attribute x and a number p between 0 and 100, the p^{th} percentile is a value $x_{p\%}$ of x such that p% of the observed values of x are less than $x_{p\%}$.

- Example: the 50th percentile is the value $x_{50\%}$ such that 50% of all values of x are less than $x_{50\%}$.

Percentiles

Median – 50% of the cases has a smaller value & 50% are larger



Multivariate Summary Statistics

Object	x_1	x_2
1	12	15
2	2	4
...	...	...
m	18	4

- Covariance between features i and j

$$s_{ij} = \frac{1}{m-1} \sum_{k=1}^{m} (x_{ki} - \bar{x}_i)(x_{kj} - \bar{x}_j)$$

- Correlation

$$r_{ij} = \frac{s_{ij}}{s_i s_j}$$

- s_i is the variance of feature i

Topics

- Exploratory Data Analysis
- Summary Statistics
- **Visualization**

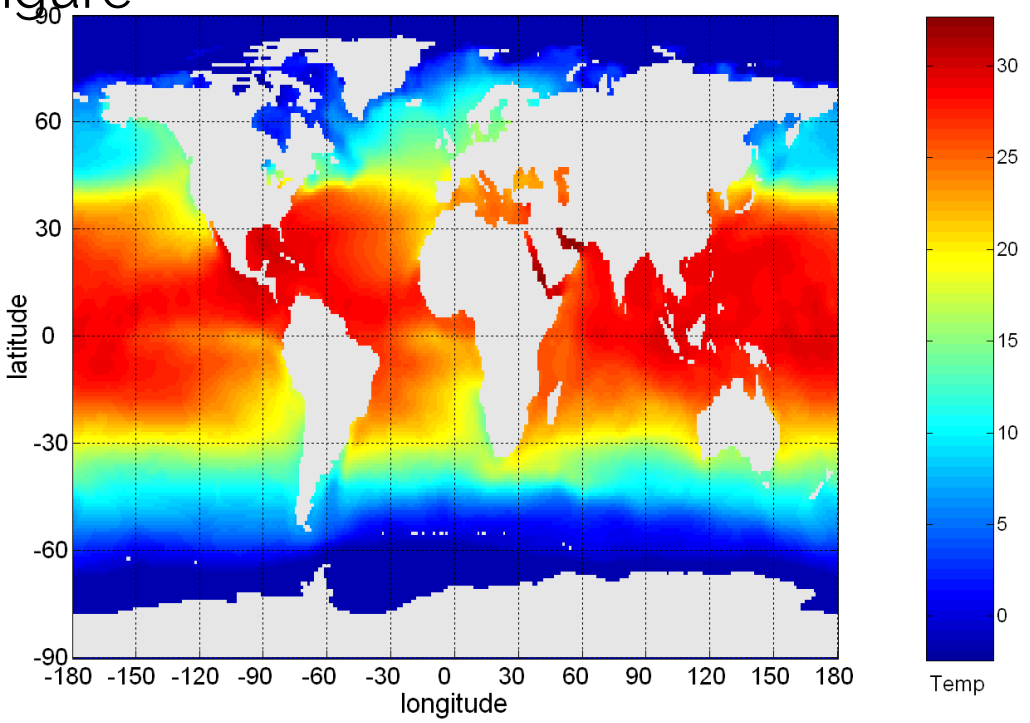
Visualization

- Visualization is the conversion of data into a visual or tabular format so that the characteristics of the data and the **relationships among data items or attributes** can be analyzed or reported.

- Visualization of data is one of the most powerful and appealing techniques for data exploration.
  - —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

Example: Sea Surface Temperature

- The following shows the Sea Surface Temperature (SST) for July 1982
- Tens of thousands of data points are summarized in a single figure



Representation

- Is the mapping of information to a visual format
- Data objects, their attributes, and the relationships among data objects are translated into graphical elements such as points, lines, shapes, and colors.
- Example:
  - Objects are often represented as points
  - Their attribute values can be represented as the position of the points or the characteristics of the points, e.g., color, size, and shape
  - If position is used, then the relationships of points, i.e., whether they form groups or a point is an outlier, is easily perceived.

Arrangement

- Is the placement of visual elements within a display
- Can make a large difference in how easy it is to understand the data
- Example:

	1	2	3	4	5	6
1	0	1	0	1	1	0
2	1	0	1	0	0	1
3	0	1	0	1	1	0
4	1	0	1	0	0	1
5	0	1	0	1	1	0
6	1	0	1	0	0	1
7	0	1	0	1	1	0
8	1	0	1	0	0	1
9	0	1	0	1	1	0

	6	1	3	2	5	4
4	1	1	1	0	0	0
2	1	1	1	0	0	0
6	1	1	1	0	0	0
8	1	1	1	0	0	0
5	0	0	0	1	1	1
3	0	0	0	1	1	1
9	0	0	0	1	1	1
1	0	0	0	1	1	1
7	0	0	0	1	1	1

The Iris Dataset

Many of the exploratory data techniques are illustrated with the Iris Plant data set.

- Included as a demo datasert in many tools (R, scikit-learn, Rapidminer, …).
- Can be obtained from the UCI Machine Learning Repository http://www.ics.uci.edu/~mlearn/MLRepository.html
- From the statistician R.A. Fisher
- 150 flowers, three types (classes).
- Four (non-class) attributes

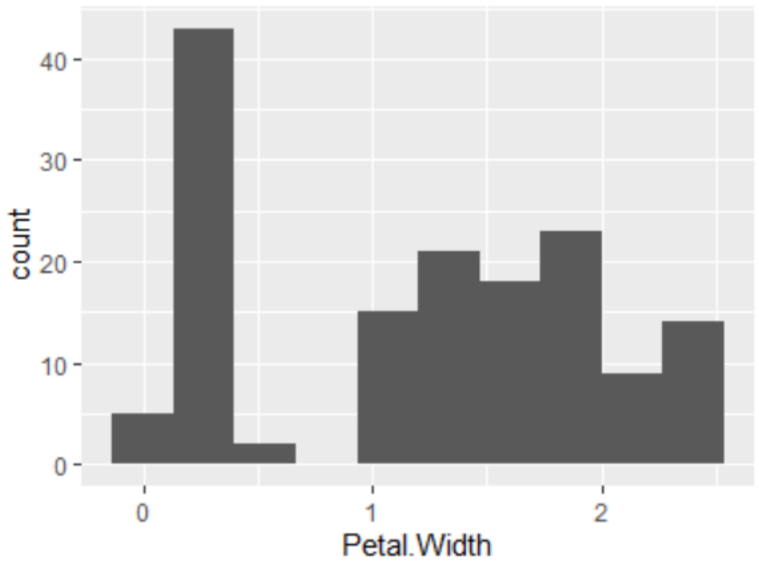
	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
1	5.1	3.5	1.4	0.2	setosa
2	4.9	3.0	1.4	0.2	setosa
3	4.7	3.2	1.3	0.2	setosa

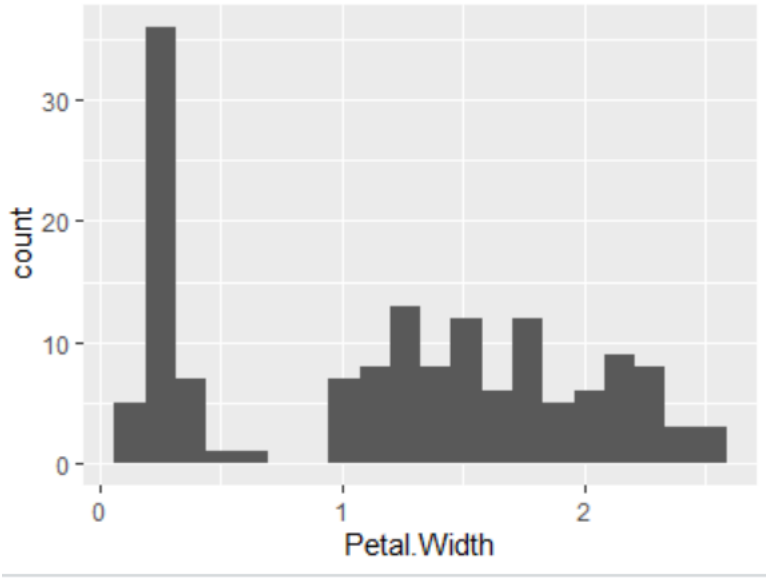
. . .

Distribution: Histograms

- Usually shows the distribution of values of a single variable
- Divide the values into bins and show a bar plot of the number of objects in each bin.
- The height of each bar indicates the number of objects
- Shape of histogram depends on the number of bins

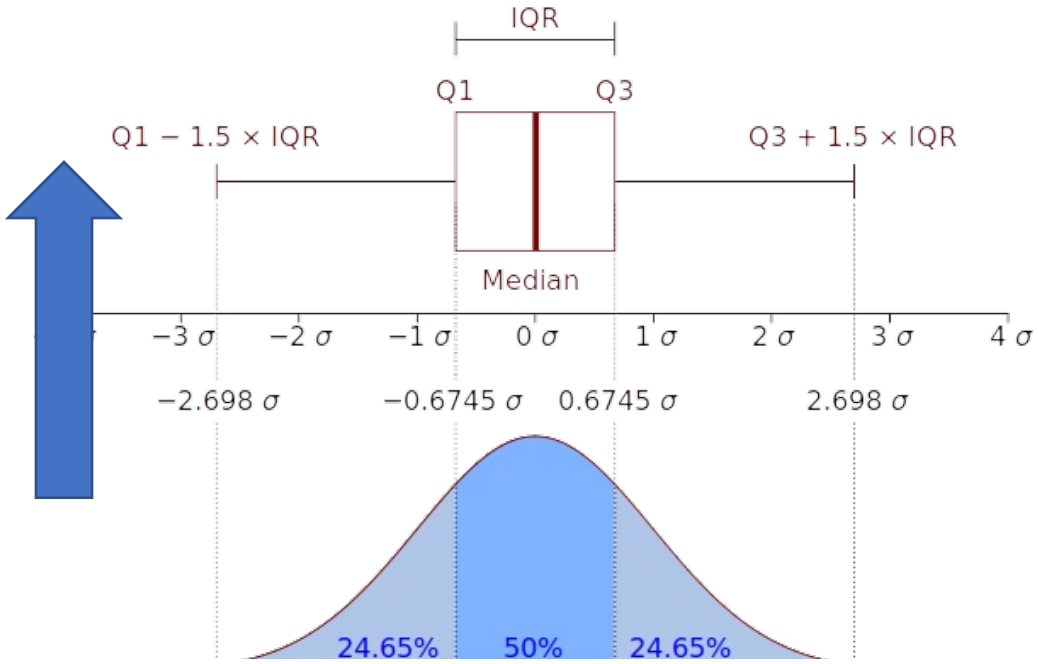
- Example: Petal Width (10 and 20 bins, respectively)



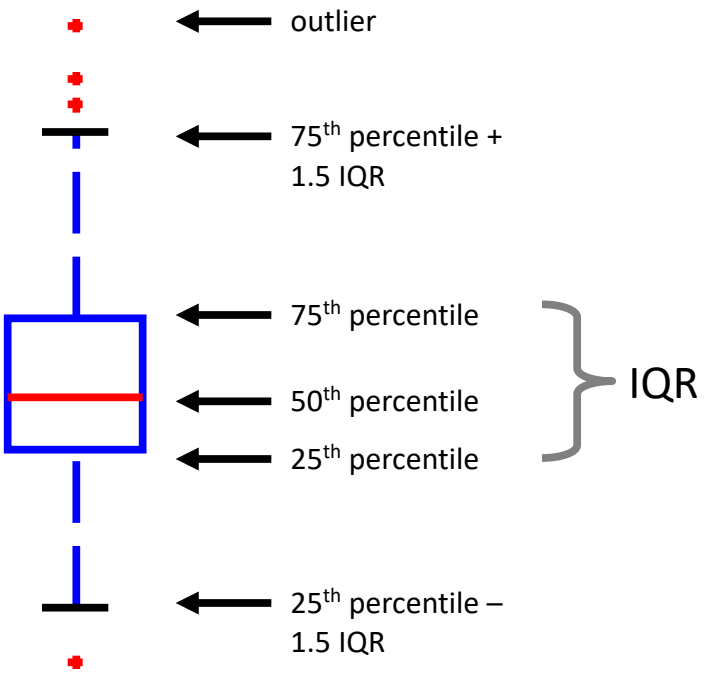


Distribution Box Plots

- Invented by J. Tukey
- Simplified version of a PDF/histogram.

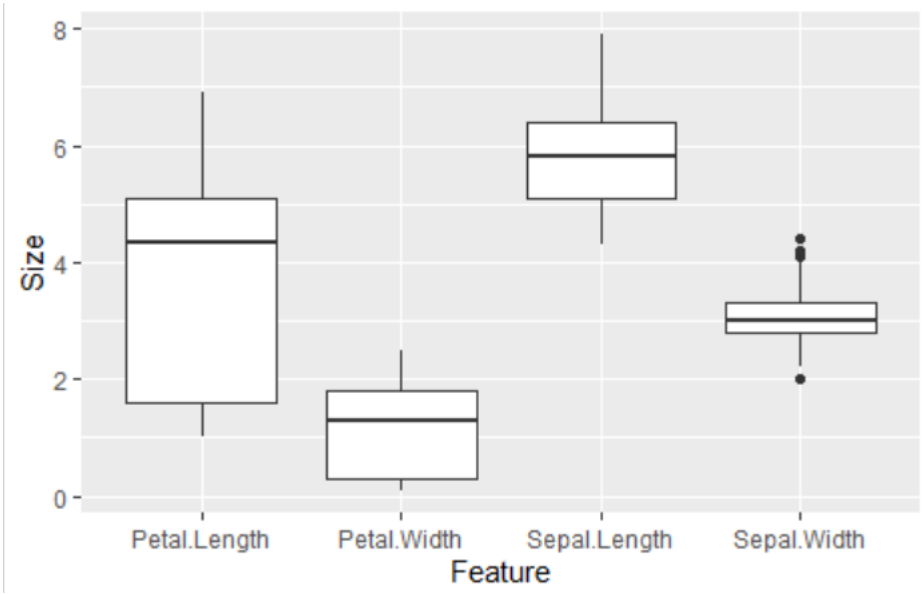


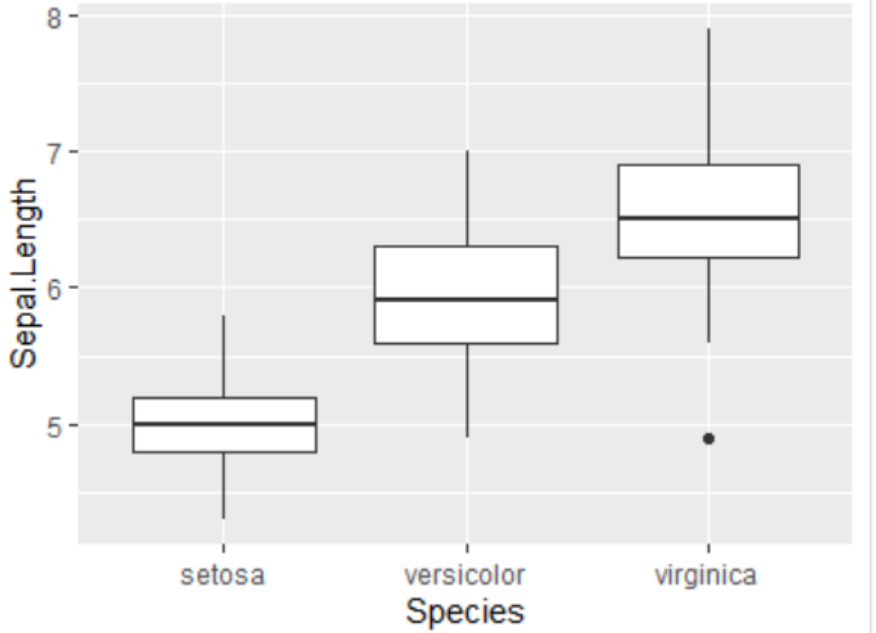
PDF or histogram



Examples of Box Plots

- Box plots can be used to compare attributes or subgroups.





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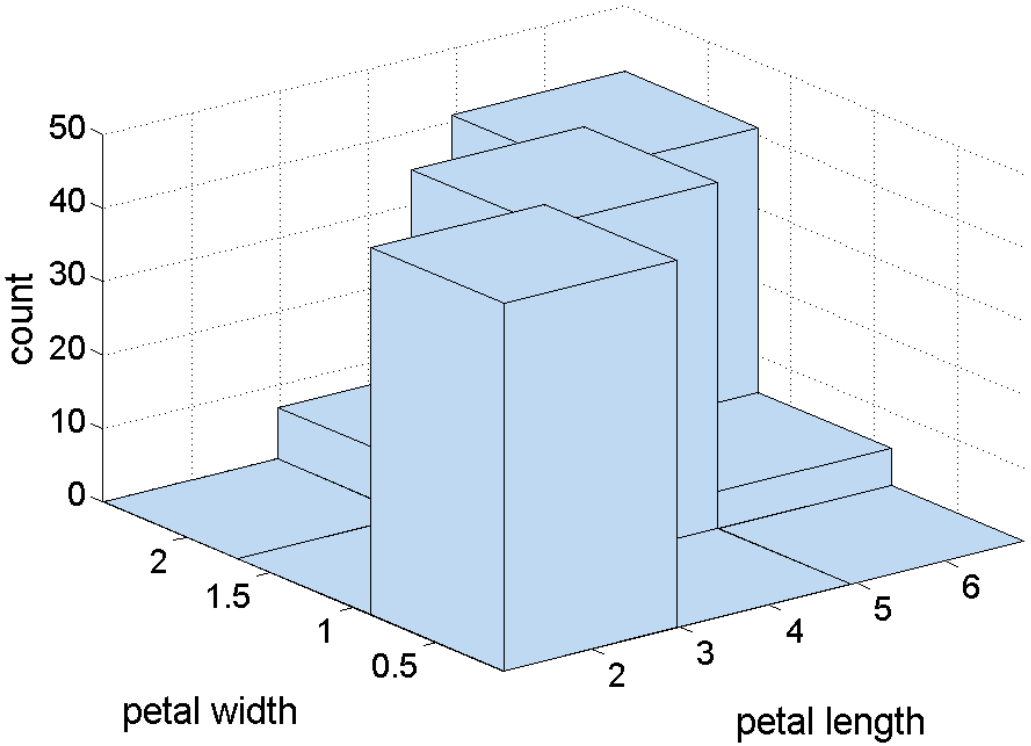
3	4.7	3.2	1.3	0.2	setosa

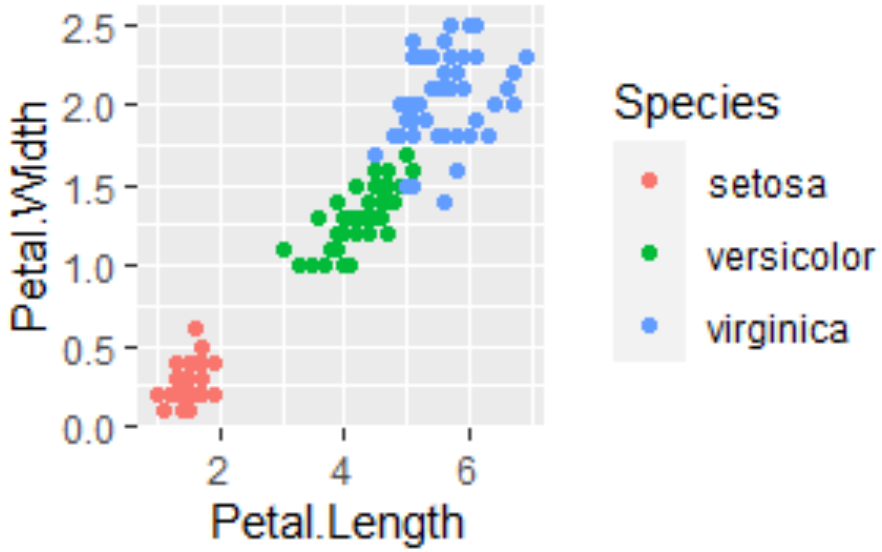
Two-Dimensional Histograms

- Show the joint distribution of the values of two attributes
- Example: petal width and petal length
  - What does this tell us?

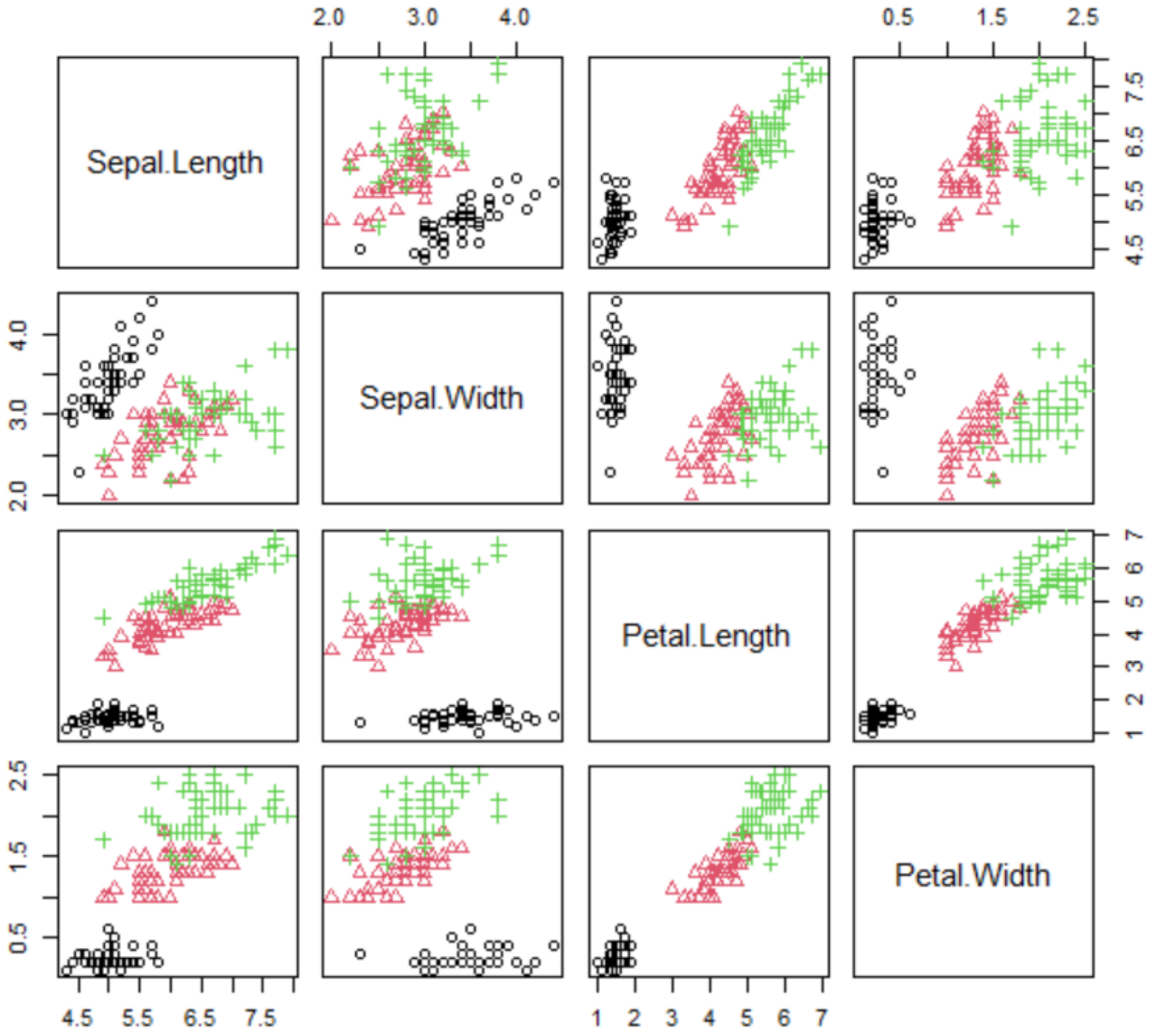


Scatter Plots

- Attributes values determine the position
- Two-dimensional scatter plots most common, but can have three-dimensional scatter plots
- Often additional attributes can be displayed by using the size, shape, and color of the markers that represent the objects

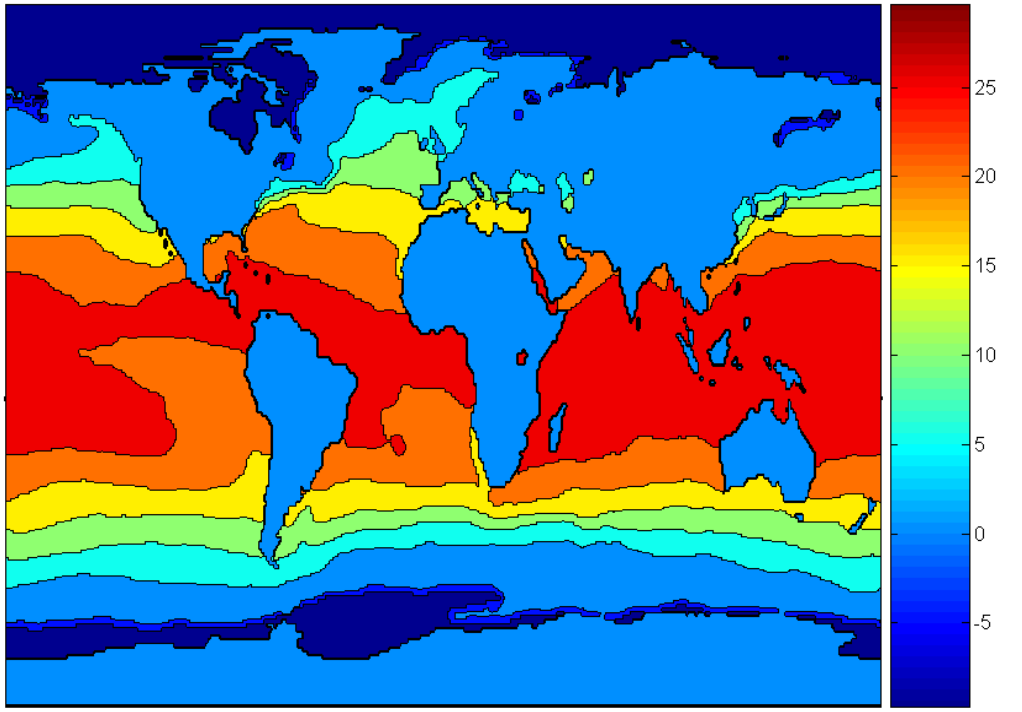


Scatter Plot Array of Iris Attributes



Contour Plots

- Useful when a continuous attribute is measured on a **spatial grid**
- They partition the plane into regions of similar values
- The contour lines that form the boundaries of these regions connect points with equal values
- The most common example is contour maps of elevation
- Can also display temperature, rainfall, air pressure, etc.

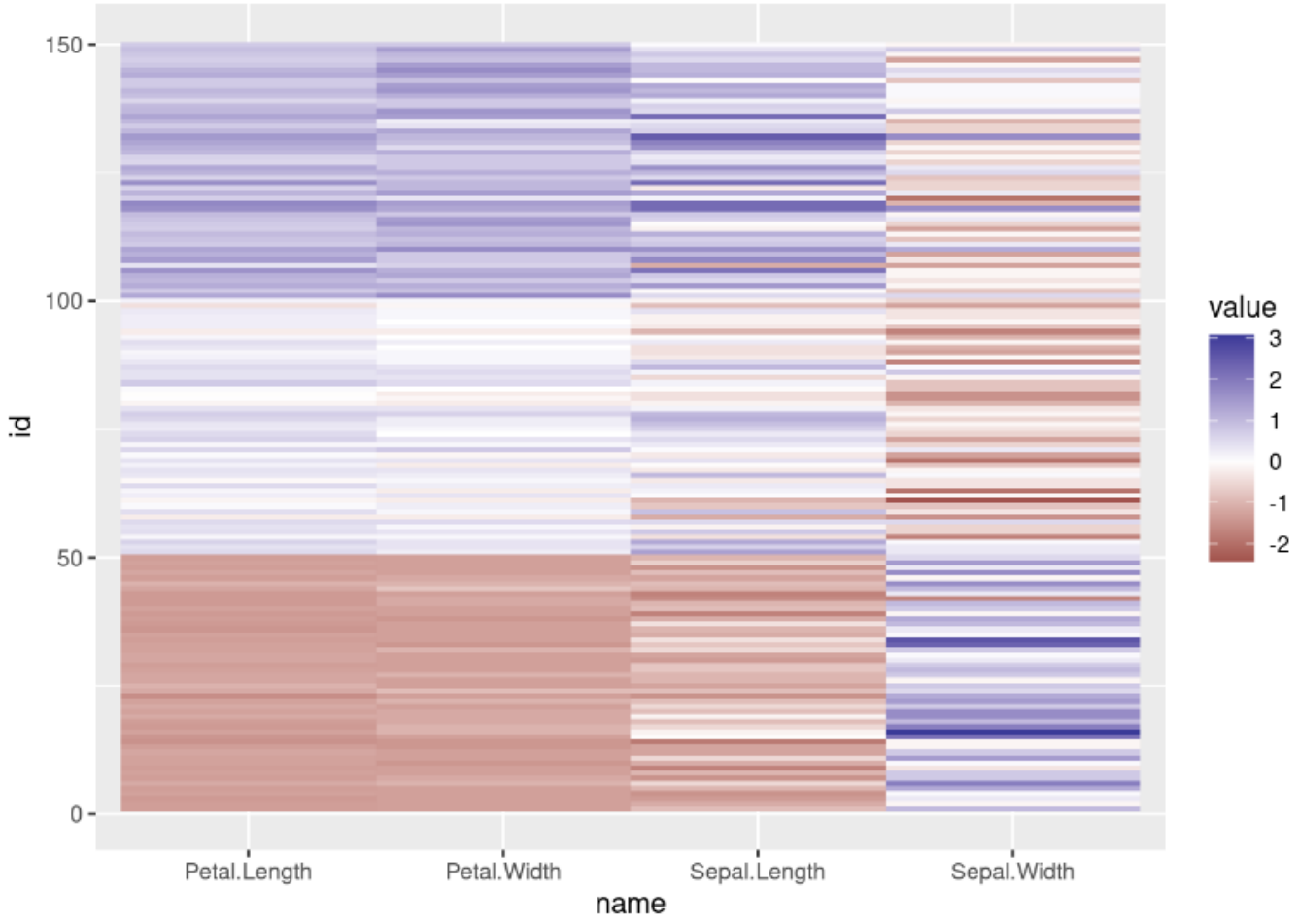


Matrix Plots

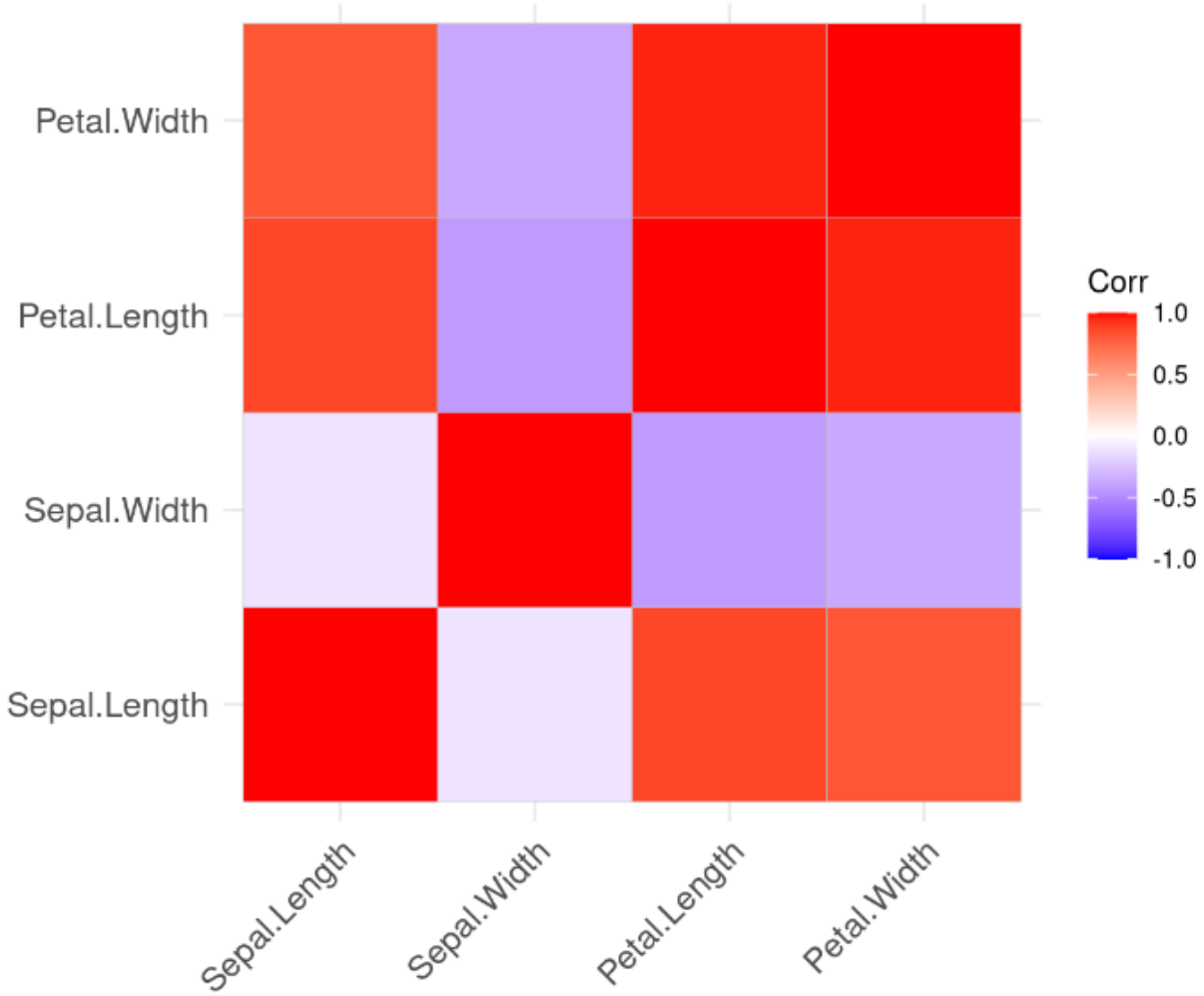
- Can plot a data matrix
- Can be useful when objects are sorted according to class
- Typically, the attributes are normalized to prevent one attribute from dominating the plot
- Plots of similarity or distance matrices can also be useful for visualizing the relationships between objects

Visualization of the Iris Data Matrix

Deviation form feature mean



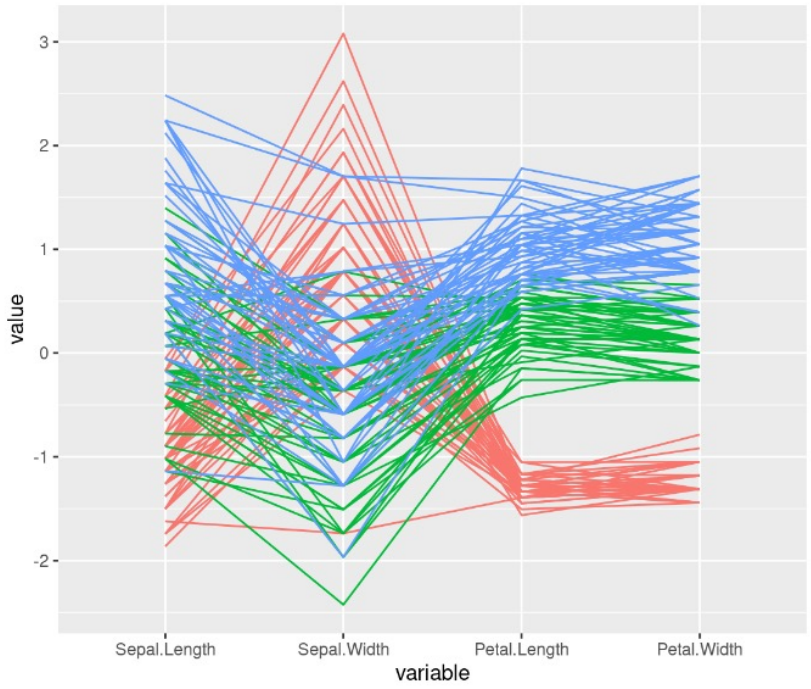
Visualization of the Iris Correlation Matrix

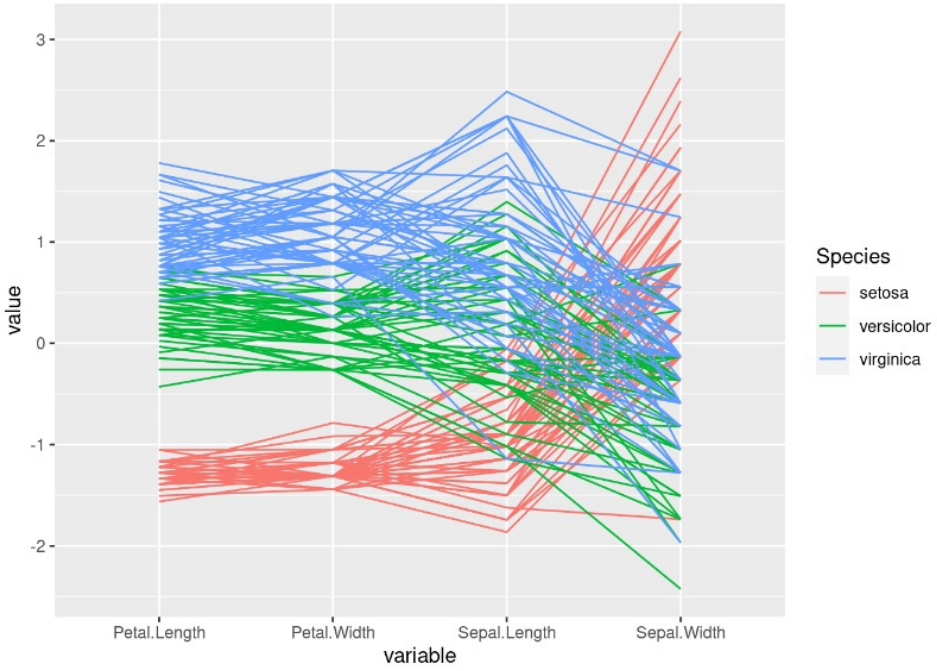


Parallel Coordinates

- Used to plot the attribute values of high-dimensional data
- Instead of using perpendicular axes, use a set of parallel axes
- The attribute values of each object are plotted as a point on each corresponding coordinate axis and the points are connected by a line
- Thus, each object is represented as a line
- Often, the lines representing a distinct class of objects group together, at least for some attributes
- Ordering of attributes is important in seeing such groupings

Parallel Coordinates Plots for Iris Data





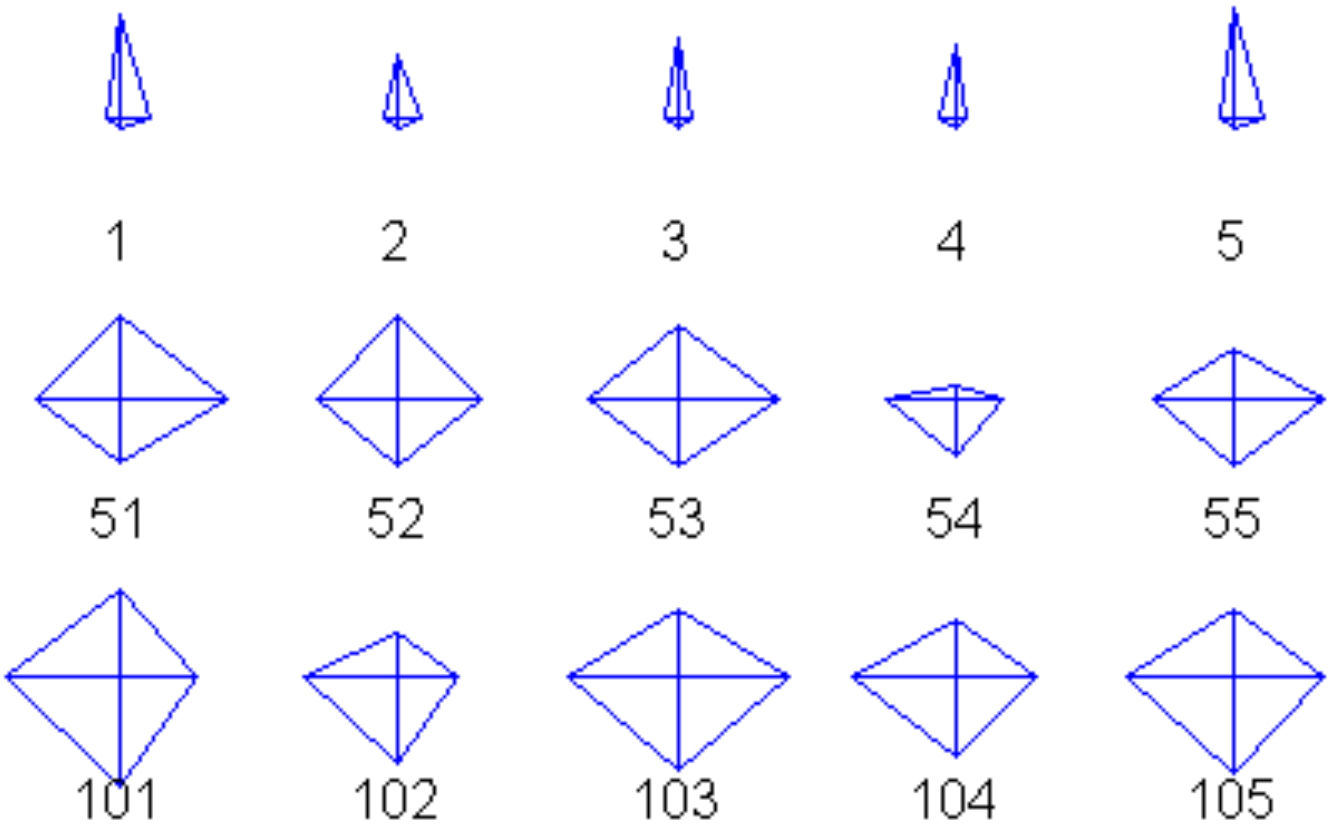
Reordered features

Other Visualization Techniques

- Star Plots
  - —Similar approach to parallel coordinates, but axes radiate from a central point
  - —The line connecting the values of an object is a polygon
- Chernoff Faces
  - —Approach created by Herman Chernoff
  - —This approach associates each attribute with a characteristic of a face
  - —The values of each attribute determine the appearance of the corresponding facial characteristic
  - —Each object becomes a separate face
  - —Relies on human's ability to distinguish faces

Star Plots for Iris Data

- Setosa
- Versicolo
- Virginica



Chernoff Faces for Iris Data

- Setosa
- Versicolor
- Virginica