

Basics of R Programming for Statistics

Mahesh Divakaran

Amity University, Lucknow

2024-09-28

What is R?

R is an open-source environment for statistical computing and visualisation. It is based on the S language developed at Bell Laboratories in the 1980's [20], and is the product of an active movement among statisticians for a powerful, programmable, portable, and open computing environment, applicable to the most complex and sophisticated problems, as well as “routine” analysis, without any restrictions on access or use.

What is R?

Here is a description from the R Project home page:

“R is an integrated suite of software facilities for data manipulation, calculation and graphical display. It includes:

- an effective data handling and storage facility,
- a suite of operators for calculations on arrays, in particular matrices,
- a large, coherent, integrated collection of intermediate tools for data analysis,
- graphical facilities for data analysis and display either on-screen or on hardcopy, and
- a well-developed, simple and effective programming language which includes conditionals, loops, user-defined recursive functions and input and output facilities.”

Advantages of R

- **Open Source & Free**

R is an open-source programming language available free of cost, which encourages wide community support and rapid updates.

- **Comprehensive Statistical Analysis**

Provides a rich ecosystem of libraries and packages for statistical analysis, data visualization, and machine learning.

- **Data Visualization**

Known for its powerful data visualization libraries (like ggplot2, lattice, etc.), R is great for producing publication-quality plots.

- **Extensible**

Easy to extend with custom functions, as well as C++ integration for performance optimization.

- **Cross-Platform**

Runs on multiple operating systems like Windows, Mac, and Linux, making it flexible for users on different platforms.

Disadvantages of R

- **Memory Intensive**

R stores objects in memory, which can become an issue with large datasets as it may lead to memory limitations.

- **Steep Learning Curve**

Beginners might find R challenging to learn, especially compared to languages like Python.

- **Slower Than Compiled Languages**

Being an interpreted language, R tends to be slower than compiled languages like C++ or Java.

- **Less Friendly for Big Data**

Without specific packages (e.g., `data.table`, `SparkR`), R is not as efficient for handling large datasets compared to Python or Hadoop/Spark.

- **Complexity in Package Management**

Managing and installing packages can sometimes lead to compatibility issues between different libraries and R versions.

Data Types in R

- **Numeric**

Represents real numbers or decimal values. E.g., 5.2, 3.14

- **Integer**

Whole numbers. E.g., 10L (Note the 'L' indicating integer in R)

- **Logical**

Represents Boolean values. E.g., TRUE, FALSE

- **Character**

Text data or strings. E.g., "Hello World"

- **Factor**

Categorical data with defined levels. E.g., `factor(c("Low", "Medium", "High"))`

- **Complex**

Numbers with imaginary components. E.g., $2+3i$

- **Raw**

Used to store raw bytes.

Basics of Vector, Matrix, and Data Frame

- **Vector**

A one-dimensional array that holds data of the same type.

Example: `v <- c(1, 2, 3, 4)`

- **Matrix**

A two-dimensional array where all elements are of the same data type.

Example: `m <- matrix(1:9, nrow=3, ncol=3)`

- **Data Frame**

A table or a two-dimensional array-like structure where columns can have different data types.

Example: `df <- data.frame(name=c("A", "B"), age=c(25, 30))`

Basic Functions in R

- **seq()**

Generates a sequence of numbers.

Example: `seq(1, 10, by=2)` # Generates 1, 3, 5, 7, 9

- **rep()**

Repeats elements of a vector.

Example: `rep(1:3, times=2)` # Generates 1, 2, 3, 1, 2, 3

- **scan()**

Reads input from the console or a file.

Example: `scan()` # Prompts user for input

- **factor()**

Converts a vector to a factor, which is used to handle categorical data.

Example: `factor(c("Low", "Medium", "High"))`

- **table()**

Creates a contingency table of counts for factor data.

Example: `table(factor(c("A", "B", "A", "C")))`

Sampling and Frequency Tables

- **Sampling** is the process of selecting a subset of data from a population to estimate characteristics of the whole population.
- **Frequency Tables** show how often values in a dataset occur. There are two types:
 - **Ungrouped Frequency Tables:** Lists each unique value and its frequency.
 - **Grouped Frequency Tables:** Divides the data into intervals (bins) and counts the frequency of data within each bin.

Forming Frequency Tables

Ungrouped Frequency Table using table()

- **Example:**

```
data <- c(1, 2, 2, 3, 3, 3, 4, 4, 5)
ungrouped_table <- table(data)
print(ungrouped_table)
```

data

1 2 3 4 5

1 2 3 2 1

Forming Frequency Tables

Grouped Frequency Table using cut() and table()

```
data <- c(1, 2, 2, 3, 3, 3, 4, 4, 5)
grouped_data <- cut(data, breaks=3)
grouped_table <- table(grouped_data)
print(grouped_table)
```

```
grouped_data
(0.996,2.33]  (2.33,3.67]  (3.67,5]
           3           3           3
```

Simple Random Sampling (SRS)

- **SRSWR (Simple Random Sampling With Replacement)**
Each selected unit is replaced back into the population before the next draw.
- **SRSWOR (Simple Random Sampling Without Replacement)**
Once a unit is selected, it is not replaced back into the population for future draws.

SRSWR Example using sample()

- **Example:**

```
population <- 1:10  
srswr_sample <- sample(population, size=5, replace=TRUE)  
print(srswr_sample)
```

```
[1]  2 10  2  1  9
```

SRSWOR Example using sample()

- **Example:**

```
population <- 1:10  
srswor_sample <- sample(population, size=5, replace=FALSE)  
print(srswor_sample)
```

```
[1] 2 6 4 3 9
```

This will give a sample of 5 numbers without replacement from the population.

Measures of Central Tendency

- **Central Tendency** refers to the statistical measures that identify a single value as representative of an entire dataset.
- The three most common measures are:
 - **Mean**: The average value of the dataset.
 - **Median**: The middle value when the data is arranged in order.
 - **Mode**: The value that appears most frequently in the dataset.
- **Use in R:**

```
data <- c(1, 2, 3, 4, 4, 5, 6)
mean(data)    # Mean
median(data)  # Median
```

Descriptive Measures

- **sum()**: Returns the sum of all elements in the vector.

```
sum(c(1, 2, 3, 4, 5)) # 15
```

```
[1] 15
```

- **sort()**: Sorts the elements of a vector in ascending or descending order.

```
sort(c(5, 2, 8, 1, 3)) # 1, 2, 3, 5, 8
```

```
[1] 1 2 3 5 8
```

- **min()**: Returns the minimum value from the dataset.

```
min(c(1, 2, 3, 4, 5)) # 1
```

```
[1] 1
```


Descriptive Measures

- **max()**: Returns the maximum value from the dataset.

```
max(c(1, 2, 3, 4, 5)) # 5
```

```
[1] 5
```

- **length()**: Returns the number of elements in the vector.

```
length(c(1, 2, 3, 4, 5)) # 5
```

```
[1] 5
```

Mean, Median, and Mode

- **Mean:** Sum of the data divided by the number of values.

```
data <- c(1, 2, 3, 4, 4, 5, 6)
mean(data) # 3.57
```

```
[1] 3.571429
```

- **Median:** The middle value when the data is sorted.

```
median(data) # 4
```

```
[1] 4
```

Mean, Median, and Mode

- **Mode:** The value that appears most frequently.

```
mode_func <- function(x) {  
  uniq_x <- unique(x)  
  uniq_x[which.max(tabulate(match(x, uniq_x)))]  
}  
mode_func(data) # 4
```

```
[1] 4
```

Geometric Mean

- **Geometric Mean:** The n th root of the product of all values.
 - Used in datasets that involve rates of growth.
- **Formula:**

$$G = \left(\prod_{i=1}^n x_i \right)^{1/n}$$

- **Use in R:**

```
data <- c(1, 2, 3, 4, 5)
geometric_mean <- prod(data)^(1/length(data))
print(geometric_mean) # 2.605
```

```
[1] 2.605171
```

Harmonic Mean

- **Harmonic Mean:** The reciprocal of the arithmetic mean of the reciprocals.
 - Used when dealing with rates or ratios.
- **Formula:**

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

- **Use in R:**

```
data <- c(1, 2, 3, 4, 5)
harmonic_mean <- length(data) / sum(1 / data)
print(harmonic_mean) # 2.189
```

```
[1] 2.189781
```

Measures of Dispersion

- **Dispersion** describes the spread of the data around a central value.
- The common measures of dispersion include:
 - **Range**
 - **Mean Deviation**
 - **Interquartile Range (IQR)**
 - **Quartile Deviation**
 - **Standard Deviation (SD)**
 - **Variance**
 - **Coefficient of Variation (CV)**
 - **Quantiles**
 - **Summary Statistics**

Range

- **Range:** The difference between the maximum and minimum values in a dataset. A simple measure, but sensitive to outliers.

- Formula:

$$\text{Range} = \text{Max} - \text{Min}$$

- **Use in R:**

```
data <- c(3, 7, 2, 9, 5)
range_value <- max(data) - min(data)
print(range_value) # 7
```

```
[1] 7
```

Mean Deviation

- **Mean Deviation:** The average of the absolute deviations from the mean or median.
- **Formula:**

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

- **Use in R:**

```
data <- c(3, 7, 2, 9, 5)
mean_deviation <- mean(abs(data - mean(data)))
print(mean_deviation) # 2.4
```

```
[1] 2.24
```


Interquartile Range (IQR)

- **IQR:** The difference between the third quartile (Q3) and the first quartile (Q1), representing the middle 50% of the data. Less sensitive to outliers than the range.
 - Formula:

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

- **Use in R:**

```
data <- c(3, 7, 2, 9, 5)
iqr_value <- IQR(data)
print(iqr_value) # 4
```

```
[1] 4
```

Quartile Deviation

- **Quartile Deviation (QD):** Half of the Interquartile Range (IQR). It is also called the semi-interquartile range.

- Formula:

$$QD = \frac{Q3 - Q1}{2}$$

- **Use in R:**

```
data <- c(3, 7, 2, 9, 5)
qd_value <- IQR(data) / 2
print(qd_value) # 2
```

[1] 2

Standard Deviation (SD)

- **Standard Deviation:** Measures the average distance of each data point from the mean. Widely used to describe variability in data.

- Formula:

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

- Use in R:

```
data <- c(3, 7, 2, 9, 5)
sd_value <- sd(data)
print(sd_value) # 2.607
```

```
[1] 2.863564
```

Variance

- **Variance:** The square of the standard deviation, representing the average squared deviation from the mean. Gives more weight to larger deviations.

- Formula:

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

- Use in R:

```
data <- c(3, 7, 2, 9, 5)
variance_value <- var(data)
print(variance_value) # 6.8
```

```
[1] 8.2
```

Coefficient of Variation (CV)

- **CV:** The ratio of the standard deviation to the mean, expressed as a percentage. Useful for comparing the relative variability between datasets with different units or means.
 - Formula:

$$CV = \frac{SD}{\bar{x}} \times 100$$

- **Use in R:**

```
data <- c(3, 7, 2, 9, 5)
cv_value <- (sd(data) / mean(data)) * 100
print(cv_value) # 52.71
```

```
[1] 55.06854
```

Quantiles

- **Quantiles:** Cut points dividing the dataset into equal-sized intervals (e.g., quartiles, percentiles).
 - **Use in R:**

```
data <- c(3, 7, 2, 9, 5)
quantiles <- quantile(data)
print(quantiles)
```

0%	25%	50%	75%	100%
2	3	5	7	9

Summary

- **Summary:** Provides a quick overview of key statistics, including min, Q1, median, Q3, and max.
 - **Use in R:**

```
summary(data)
```

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
2.0	3.0	5.0	5.2	7.0	9.0

Moments, Skewness, and Kurtosis

- **Moments:** Statistical measures used to understand the shape of a distribution. They help calculate skewness and kurtosis.
 - **Raw Moments:** Measures relative to the origin.
 - **Central Moments:** Measures relative to the mean.
- **Skewness:** A measure of asymmetry in the distribution.
 - Positive skewness: Data skewed to the right.
 - Negative skewness: Data skewed to the left.
- **Kurtosis:** A measure of the “tailedness” or peakedness of the distribution.
 - High kurtosis: More outliers (leptokurtic).
 - Low kurtosis: Fewer outliers (platykurtic).

Raw Moments

- **Raw Moments:** Measures based on deviations from zero. The raw moments help understand the general shape of the data distribution.
 - The k-th raw moment is given by:

$$M_k = \frac{1}{n} \sum_{i=1}^n x_i^k$$

- **Example in R:**

```
data <- c(2, 4, 6, 8, 10)
raw_moment_2 <- mean(data^2) # Second raw moment
print(raw_moment_2) # 44
```

```
[1] 44
```

Central Moments

- **Central Moments:** Measures based on deviations from the mean. The second central moment is the variance, and the third and fourth moments are related to skewness and kurtosis.
 - The k-th central moment is given by:

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

- **Example in R:**

```
data <- c(2, 4, 6, 8, 10)
central_moment_2 <- mean((data - mean(data))^2) # Second central moment (Var)
print(central_moment_2) # 8
```

[1] 8

Skewness

- **Skewness:** Measures the asymmetry of the distribution relative to the mean. A skewness value of 0 indicates a symmetric distribution.

- Formula:

$$\text{Skewness} = \frac{1}{n} \sum_{i=1}^n \left(\frac{x_i - \bar{x}}{\sigma} \right)^3$$

- **Interpretation:**

- Skewness > 0 : Positively skewed (right-tailed).
- Skewness < 0 : Negatively skewed (left-tailed).
- Skewness $= 0$: Symmetric distribution.

Skewness

- **Example in R:**

```
library(e1071) # For skewness function  
data <- c(2, 4, 6, 8, 10)  
skewness_value <- skewness(data)  
print(skewness_value) # 0
```

```
[1] 0
```

Kurtosis

- **Kurtosis:** Measures the “tailedness” or peak of the distribution.
 - Formula:

$$\text{Kurtosis} = \frac{1}{n} \sum_{i=1}^n \left(\frac{x_i - \bar{x}}{\sigma} \right)^4$$

- **Interpretation:**
 - **High Kurtosis** (> 3): Leptokurtic (sharp peak, heavy tails).
 - **Low Kurtosis** (< 3): Platykurtic (flat peak, light tails).
 - **Normal Kurtosis** ($= 3$): Mesokurtic.

Kurtosis

- Example in R:

```
library(e1071) # For kurtosis function
data <- c(2, 4, 6, 8, 10)
kurtosis_value <- kurtosis(data)
print(kurtosis_value) # -1.3
```

```
[1] -1.912
```

Moment Measures of Skewness and Kurtosis

- **Moment-Based Skewness:**



$$\text{Skewness} = \frac{\mu_3}{\sigma^3}$$

- Third central moment μ_3 represents the asymmetry.

- **Moment-Based Kurtosis:**



$$\text{Kurtosis} = \frac{\mu_4}{\sigma^4}$$

- Fourth central moment μ_4 indicates how sharp or flat the distribution is.

Moment Measures of Skewness and Kurtosis

- **Example in R** (using moments):

```
data <- c(2, 4, 6, 8, 10)
third_moment <- mean((data - mean(data))^3)
fourth_moment <- mean((data - mean(data))^4)

skewness_moment <- third_moment / (sd(data)^3)
kurtosis_moment <- fourth_moment / (sd(data)^4)
```


Moment Measures of Skewness and Kurtosis

- **Example in R** (using moments):

```
print(skewness_moment) # 0
```

```
[1] 0
```

```
print(kurtosis_moment) # 1.875
```

```
[1] 1.088
```

Graphical Methods

- **Bar Plots:**

- Simple and Multiple (Side by Side and Subdivided).
- Useful for comparing categorical data.
- `barplot()` function in R.

- **Pie Chart:**

- Displays the proportion of categories.
- `pie()` function.

- **Histogram:**

- Shows the distribution of continuous data.
- `hist()` function.

- **Scatter Plot:**

- Visualizes relationships between two variables.
- `plot()` function.

- **Line Plot:**

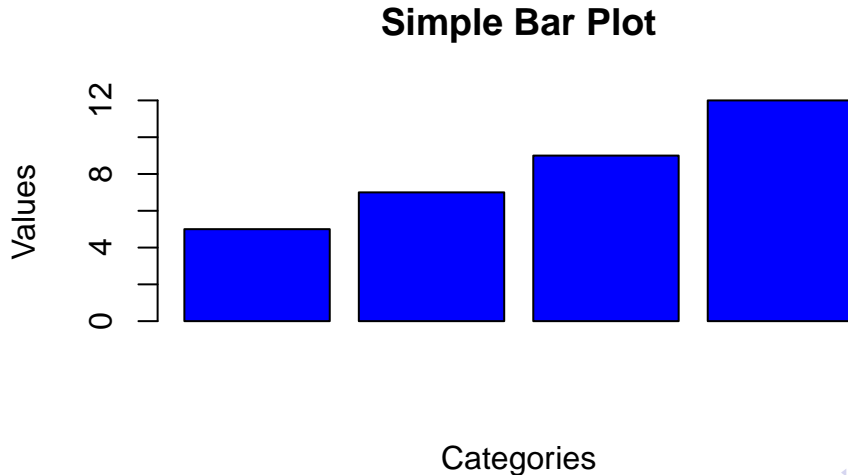
- Adds lines to a scatter plot to show trends.
- `lines()` function.

Simple Bar Plot

- **Bar Plots** are used to display categorical data with rectangular bars.
- **Syntax in R:**

```
data <- c(5, 7, 9, 12)
barplot(data, main="Simple Bar Plot", xlab="Categories",
        ylab="Values", col="blue")
```

Simple Bar Plot



Multiple Bar Plot (Side by Side)

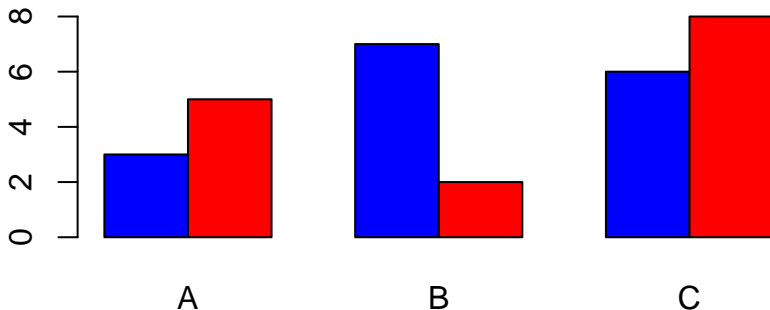
- **Multiple Bar Plot:** Displays multiple sets of data side by side for comparison.
- **Syntax in R:**

```
data <- matrix(c(3, 5, 7, 2, 6, 8), nrow=2)
barplot(data, beside=TRUE, main="Side by Side Bar Plot", col=c("blue", "red"))
```

Multiple Bar Plot (Side by Side)

- Syntax in R:

Side by Side Bar Plot



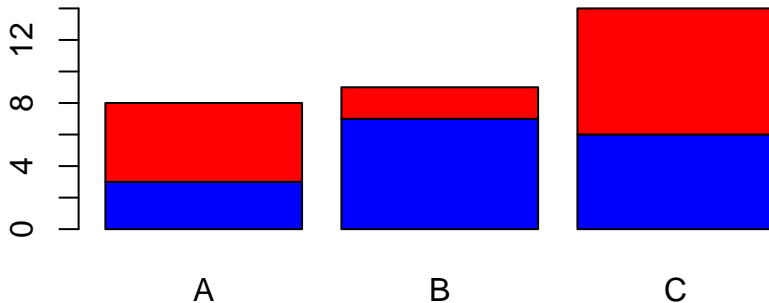
Multiple Bar Plot (Subdivided)

- **Subdivided Bar Plot:** Bars are stacked on top of each other to show the cumulative total.
- **Syntax in R:**

```
data <- matrix(c(3, 5, 7, 2, 6, 8), nrow=2)
barplot(data, beside=FALSE, main="Subdivided Bar Plot", col=c("blue", "red"))
```

Multiple Bar Plot (Subdivided)

Subdivided Bar Plot

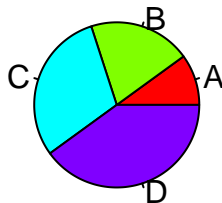


Pie Chart

- **Pie Chart:** A circular chart divided into sectors to show relative proportions of categories.
- **Syntax in R:**

```
data <- c(10, 20, 30, 40)
labels <- c("A", "B", "C", "D")
pie(data, labels=labels, main="Pie Chart", col=rainbow(4))
```

Pie Chart

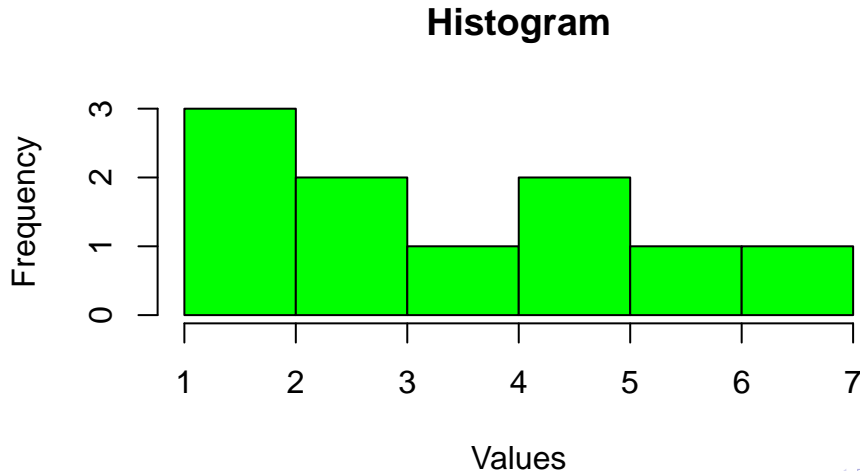


Histogram

- **Histogram:** Displays the distribution of continuous data by dividing it into bins.
- **Syntax in R:**

```
data <- c(1, 2, 2, 3, 3, 4, 5, 5, 6, 7)
hist(data, main="Histogram", xlab="Values", col="green", breaks=5)
```

Histogram

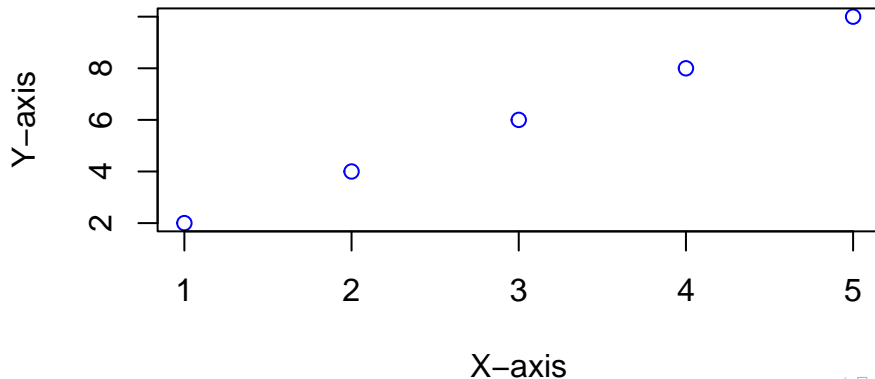


Plot Function

- **plot()**: Used for basic 2D plotting in R.
- **Syntax in R:**

```
x <- c(1, 2, 3, 4, 5)
y <- c(2, 4, 6, 8, 10)
plot(x, y, type="p", main="Simple Scatter Plot", xlab="X-axis", ylab="Y-axis")
```

Simple Scatter Plot

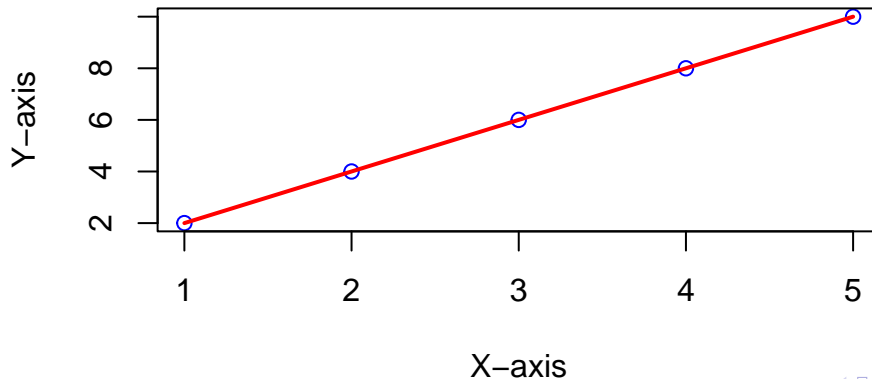


Lines Function

- **lines()**: Adds lines to an existing plot. The lines() function draws lines connecting the data points on the existing plot.
- **Syntax in R:**

```
x <- c(1, 2, 3, 4, 5)
y <- c(2, 4, 6, 8, 10)
plot(x, y, type="p", main="Plot with Lines", xlab="X-axis", ylab="Y-axis", col="red", lwd=2)
```

Plot with Lines



Probability Distributions

- Probability distributions describe the likelihood of various outcomes in random events.
- Common distributions:
 - **Binomial**
 - **Poisson**
 - **Normal**
 - **Chi-square**
 - **t-distribution**
 - **F-distribution**
- In R, these distributions are evaluated using:
 - `d` (density function),
 - `p` (cumulative distribution function),
 - `q` (quantile function),
 - `r` (random variates).

Binomial Distribution

- **Binomial distribution** models the number of successes in a fixed number of independent Bernoulli trials.
 - Parameters: (n) (number of trials), (p) (probability of success).
- **R Functions:**
 - `dbinom(x, size, prob)`: Probability mass function (PMF).
 - `pbinom(q, size, prob)`: Cumulative distribution function (CDF).
 - `qbinom(p, size, prob)`: Quantile function.
 - `rbinom(n, size, prob)`: Random variates.

Binomial Distribution

- Example:

```
dbinom(3, size=10, prob=0.5) # P(X=3) for 10 trials, p=0.5
```

```
[1] 0.1171875
```

```
pbinom(3, size=10, prob=0.5) # P(X<=3)
```

```
[1] 0.171875
```

```
rbinom(5, size=10, prob=0.5) # Generate 5 random binomial variates
```

```
[1] 2 5 5 5 6
```

Poisson Distribution

- **Poisson distribution** models the number of events occurring in a fixed interval of time or space.
 - Parameter: λ (average number of events).
- **R Functions:**
 - `dpois(x, lambda)`: PMF.
 - `ppois(q, lambda)`: CDF.
 - `qpois(p, lambda)`: Quantile function.
 - `rpois(n, lambda)`: Random variates.

Poisson Distribution

- Example:

```
dpois(2, lambda=5) # P(X=2) when lambda=5
```

```
[1] 0.08422434
```

```
ppois(2, lambda=5) # P(X<=2)
```

```
[1] 0.124652
```

```
rpois(5, lambda=5) # Generate 5 random Poisson variates
```

```
[1] 2 7 4 7 4
```

Normal Distribution

- **Normal distribution** (Gaussian distribution) is the most common continuous distribution, defined by mean () and standard deviation ().
 - Parameters: () (mean), () (standard deviation).
- **R Functions:**
 - `dnorm(x, mean, sd)`: Probability density function (PDF).
 - `pnorm(q, mean, sd)`: CDF.
 - `qnorm(p, mean, sd)`: Quantile function.
 - `rnorm(n, mean, sd)`: Random variates.

Normal Distribution

- **Example:**

```
dnorm(0, mean=0, sd=1) # P(X=0) for standard normal
```

```
[1] 0.3989423
```

```
pnorm(1.96, mean=0, sd=1) # P(X≤1.96) for standard normal
```

```
[1] 0.9750021
```

```
rnorm(5, mean=0, sd=1) # Generate 5 random normal variates
```

```
[1] 0.1913023 0.3700542 0.4466955 0.8612854 -0.2403063
```

Chi-Square Distribution

- **Chi-square distribution** is commonly used in hypothesis testing and confidence intervals for variance.
 - Parameter: (k) (degrees of freedom).
- **R Functions:**
 - `dchisq(x, df)`: PDF.
 - `pchisq(q, df)`: CDF.
 - `qchisq(p, df)`: Quantile function.
 - `rchisq(n, df)`: Random variates.

Chi-Square Distribution

- Example:

```
dchisq(3, df=2) # P(X=3) for chi-square with 2 degrees of freedom
```

```
[1] 0.1115651
```

```
pchisq(3, df=2) # P(X<=3)
```

```
[1] 0.7768698
```

```
rchisq(5, df=2) # Generate 5 random chi-square variates
```

```
[1] 0.3335482 2.7121005 0.9832046 5.1356148 0.3043009
```

t-Distribution

- **t-distribution** is used in hypothesis testing and confidence intervals when the sample size is small.
 - Parameter: (df) (degrees of freedom).
- **R Functions:**
 - `dt(x, df)`: PDF.
 - `pt(q, df)`: CDF.
 - `qt(p, df)`: Quantile function.
 - `rt(n, df)`: Random variates.

t-Distribution

- Example:

```
dt(1.96, df=10) # P(T=1.96) for t-distribution with 10 degrees of freedom
```

```
[1] 0.06509475
```

```
pt(1.96, df=10) # P(T<=1.96)
```

```
[1] 0.9607819
```

```
rt(5, df=10) # Generate 5 random t-distribution variates
```

```
[1] 1.099664 -2.209731 3.052028 -1.743828 -1.006695
```

F-Distribution

- **F-distribution** is used to compare two variances (ANOVA).
 - Parameters: (df_1) (numerator degrees of freedom), (df_2) (denominator degrees of freedom).
- **R Functions:**
 - `df(x, df1, df2)`: PDF.
 - `pf(q, df1, df2)`: CDF.
 - `qf(p, df1, df2)`: Quantile function.
 - `rf(n, df1, df2)`: Random variates.

F-Distribution

- Example:

```
df(1, df1=5, df2=10) # P(F=1) for F-distribution with 5 and 10 df
```

```
[1] 0.4954798
```

```
pf(1, df1=5, df2=10) # P(F<=1)
```

```
[1] 0.5348806
```

```
rf(5, df1=5, df2=10) # Generate 5 random F-distribution variates
```

```
[1] 0.2574528 0.8305793 1.3581035 0.7036134 2.5168916
```

Covariance for Bivariate Data

- **Covariance** measures the relationship between two variables and how they vary together. Covariance helps determine the direction of the linear relationship between variables.
 - Formula:

$$\text{Cov}(X, Y) = \frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})$$

- **R Function:**
 - `cov(x, y)`: Computes covariance between x and y.

Covariance for Bivariate Data

- **Example:**

```
x <- c(2, 4, 6, 8)
y <- c(3, 7, 5, 10)
cov(x, y) # Covariance between x and y
```

```
[1] 6.333333
```

Pearson's and Spearman's Correlation Coefficient

- **Pearson's Correlation:** Measures the strength and direction of the linear relationship between two continuous variables.

- Formula:

$$r = \frac{\text{Cov}(X, Y)}{\sigma_X \sigma_Y}$$

- **Spearman's Correlation:** A non-parametric measure of rank correlation (monotonic relationships).
- **R Function:**
 - `cor(x, y, method="pearson")`: Pearson's correlation.
 - `cor(x, y, method="spearman")`: Spearman's correlation.

Pearson's and Spearman's Correlation Coefficient

Pearson's r ranges from -1 to 1, indicating perfect negative or positive correlation, while Spearman's measures the strength of monotonic relationships. - **Example:**

```
x <- c(2, 4, 6, 8)
y <- c(3, 7, 5, 10)
cor(x, y, method="pearson") # Pearson's correlation
```

```
[1] 0.8214416
```

```
cor(x, y, method="spearman") # Spearman's correlation
```

```
[1] 0.8
```

Linear Regression Models

- **Linear Regression:** Models the relationship between a dependent variable and one or more independent variables using a linear equation.

- Formula:

$$y = \beta_0 + \beta_1 x + \epsilon$$

- β_0 : Intercept, β_1 : Slope.
- **Fitting a Linear Model in R:**
 - `lm(y ~ x)`: Fits a simple linear regression model.

Linear Regression Models

- **Example:**

```
x <- c(2, 4, 6, 8)
y <- c(3, 7, 5, 10)
model <- lm(y ~ x)
summary(model) # Displays the model summary
```

Call:

```
lm(formula = y ~ x)
```

Residuals:

1	2	3	4
-0.4	1.7	-2.2	0.9

Thank You!

- Thank you for your attention!
- Feel free to reach out with any questions.

Contact:

- **Email:** mahesh.divakaran01@gmail.com
- **LinkedIn:** linkedin.com/in/imaheshdivakaran