Calculus II

With R

“Statistics is the grammar of science”

Karl Pearson

Adel Ahmadi - Omid SFard

October 2024

Course Objectives

- Familiarity with R Programming Basic
- Numerical and Symbolic Calculations in R
- Plotting Mathematical and Geometric Graphs
- Working with Data and Data Structures in R
- Utilizing Advanced R Packages
- Solving Practical Problems Using R

Grading Breakdown

Total Points: 5 / 20

- 2 Points for Assignments
- 1 Points for Project
- 2 Point for Final Quiz
- 0.5 Extra Point for Attendance and 0.5 Extra Point for Class Participation

Questions related to the projects will be asked at the end of the term. Students will receive their project scores based on their understanding and mastery of the project content.

Why R?

Powerful Statistical Capabilities

Extensive Statistical Libraries

Educational Use

Free and Open Source

Strong Community Support

User-Friendly Interface

Installing R

1. **Download R**

   Visit the Comprehensive R Archive Network (CRAN) at CRAN R Project to download the latest version of R for your operating system (Windows, macOS, or Linux).

2. **Installation Process**

   Follow the installation instructions specific to your operating system.

   Accept the default settings for a smooth installation process.

3. **Install RStudio (Optional but Recommended)**

   Download RStudio from RStudio Website for a more user-friendly interface to work with R.

   Follow the installation instructions for RStudio.

Using Google Colab

1. **Introduction to Google Colab**

   Google Colab is a free, cloud-based Jupyter notebook environment that allows you to write and execute Python and Rcode in your browser

2. **Accessing Google Colab**

   Go to Google Colab

   Sign in with your Google account to access the platform

3. **Creating a New Notebook**

   Click on "File" > "New Notebook" to create a new notebook.

Lets Begin!

Introduction to RStudio Environment

1. What is R Studio?
2. Console
3. Script Editor
4. Environment/History Pane
5. Files/Plots/Packages/Help Pane
6. Benefits of Using RStudio

Writing Our First Program in R

```
# Program 1
number1 <- 10  # Assign value to the first number
number2 <- 5   # Assign value to the second number
sum <- number1 + number2  # Calculate the sum
print(sum)  # Print the result

# Program 2
plot(1:10)
```

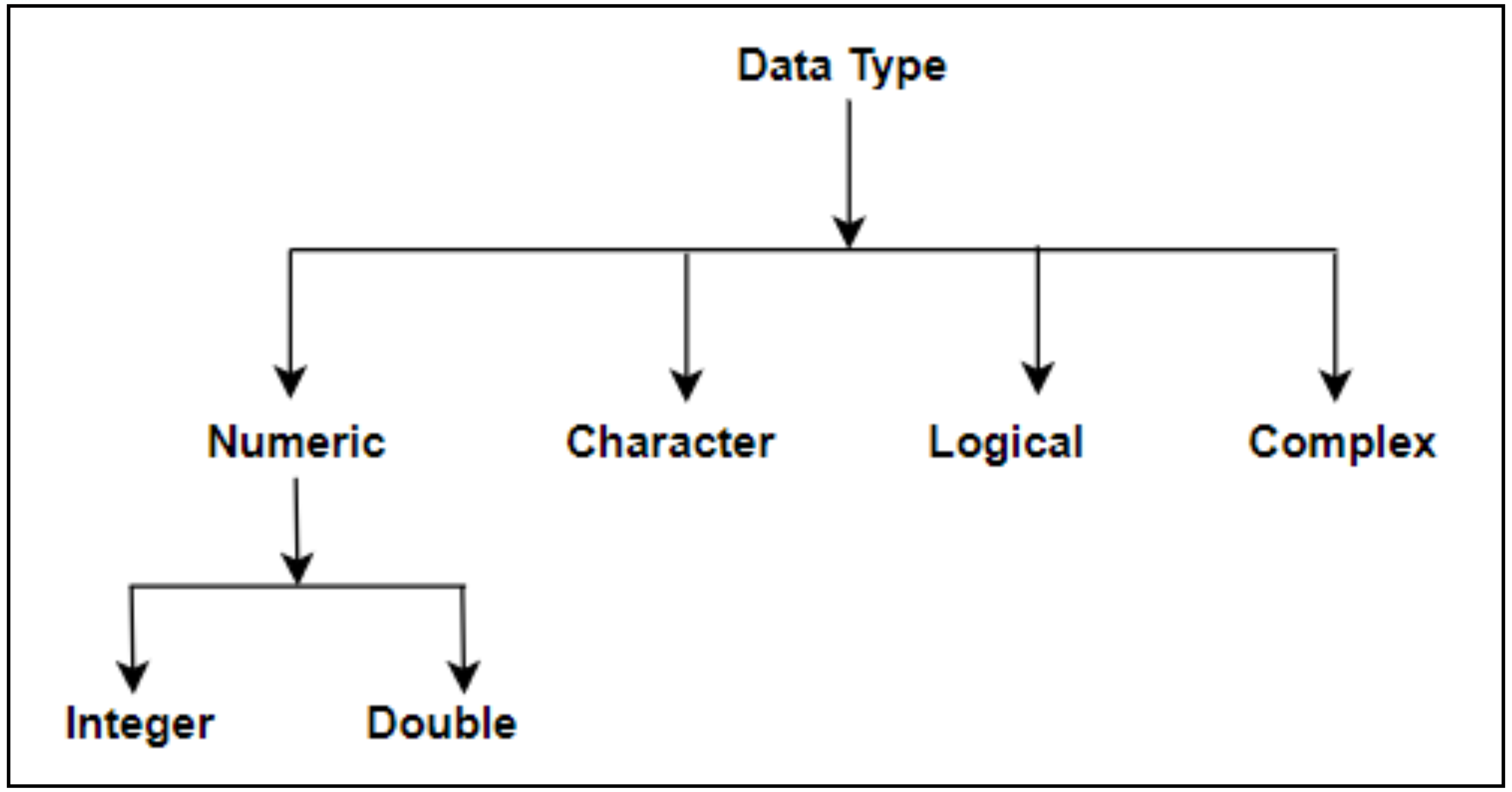
Variable Types

- Numeric
- Integer
- Character (String)
- Logical (Boolean)
- Complex

- Class Function - class()

Type Conversion

- as.numeric()
- as.integer()
- as.complex()



Operators

R divides the operators in below groups:

- Assignment operators
- Arithmetic operators
- Comparison operators
- Logical operators
- Miscellaneous operators

Assignment Operators

- Local assignment (->)(<-)
- Global assignment (->>)(<<-)

```
txt <- "global variable"
my_function <- function() {
  txt = "fantastic"
  paste("R is", txt)
}
my_function()
txt # print txt
```

- Whats the difference?

Arithmetic Operators

- Addition (+)
- Subtraction (-)
- Multplication (*)
- Division (/)
- Exponent (^)
- Modulus (%%)
- Integer Division (%/%)

Comparison Operators

- Equal (==)
- Not equal (!=)
- Greater than (>)
- Less than (<)
- Greater than or equal to (>=)
- Less than or equal to (<=)

Logical Operators

- Element-wise logical AND (&)
- Logical AND (&&)
- Element-wise logical OR (|)
- Logical OR (||)
- Logical not (!)

Miscellaneous Operators

- Creates a sequence of numbers (:)
- Find out if an element belongs to a vector (%in%)
- Matrix multiplication (%*%)

Conditions (If Statements)

- If - else if - else

```
a <- 200
b <- 33
if (b > a) {
  print("b is greater than a")
} else if (a == b) {
  print("a and b are equal")
} else {
  print("a is greater than b")
}
```

- Nested if
- Conditions + Logical operators

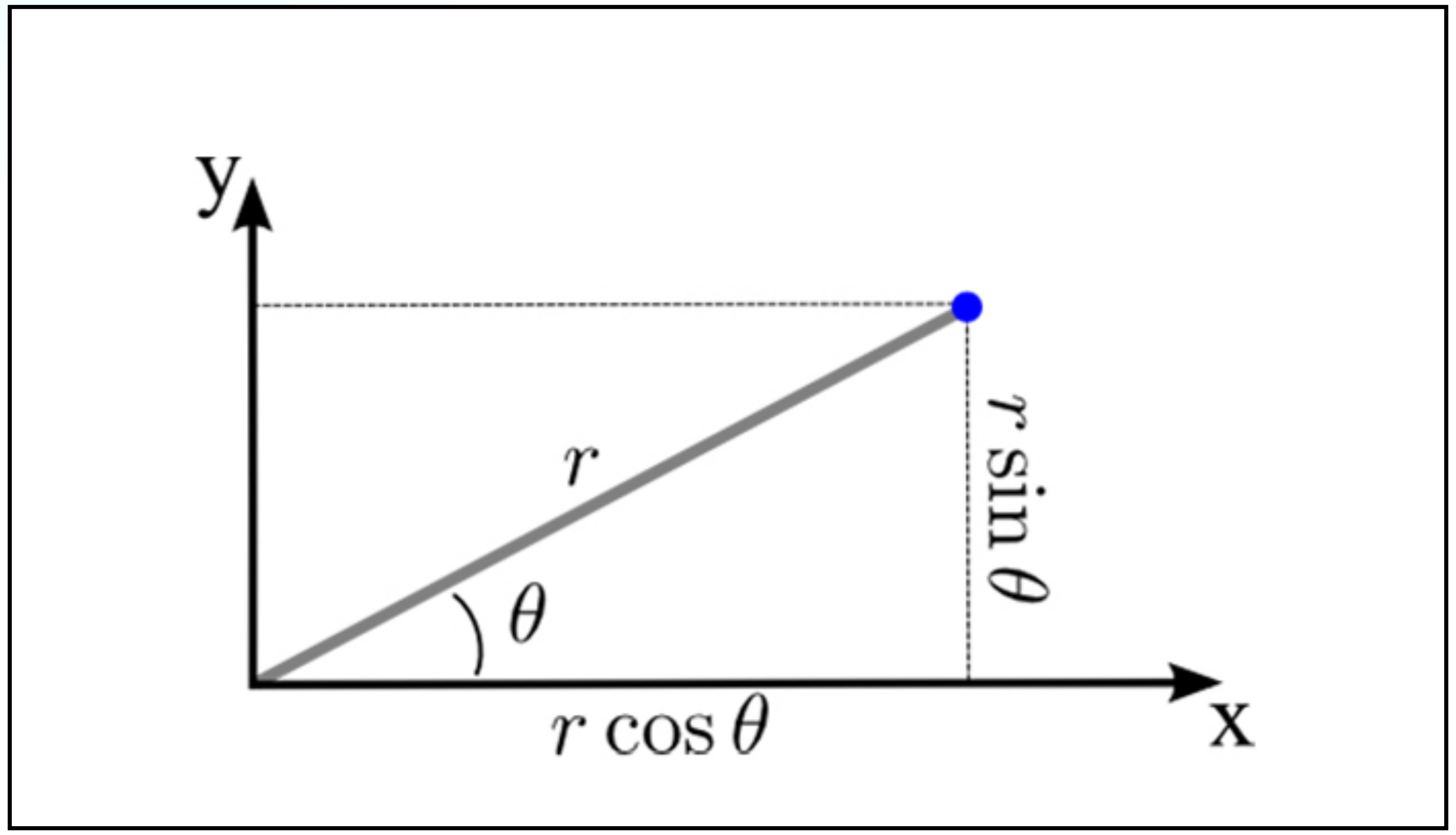
Simple Math

We can use arithmetic operators to perform common basic mathmatical operations of numbers. There are also some built-in math functions like:

- min() and max()
- sqrt()
- abs()
- ceiling() and floor ()
- sin() and cos()

Practical Challenge

- Write an R code to convert polar coordinates to cartesian and vice versa.



Loops

Loops can execute a block of code as long as a condition is satisfied.

R has two loop commands:

- For loop
- While loop

For Loop

For loop is used for iterating over a sequence. With for loops we can execute a block of code, once for each item in a vector, sequence, array, list and etc…

```
# First Loop
for (x in 1:10) {
  print(x)
}

# Second Loop
fruits <- list("apple", "banana", "cherry")
for (x in fruits) {
  print(x)
}
```

While Loop

While loop will execute a block of code as long as a condition is true.

```
i <- 0
while (i < 6) {
  i <- i + 1
  if (i == 3) {
    next
  }
  print(i)
}
```

- What is “next”?

R Functions

A function is a reusable block of code that perform a specified task. Functions in R allow us to organize our code, avoid code repetition and make modular projects.

Functions are defined using function() keyword and can take arguments or inputs and return a value or output.

```
function_name <- function(arg1 , arg2, ...) {
  # Function Codes
  result <- some_operation(arg1 , arg2)
  return(result)
}
function_name
```

A Simple Function

```
# Define a function that calculates the square of a number
square <- function(x) {
  result <- x^2  # Perform the operation
  return(result) # Return the result
}

# Call the function with an argument
print(square(4))  # Output: 16
```

Lets Solve This Challenges!

1. Write two functions to convert radian to degree and vice versa.
2. Write a function to calculate points from input x and y on below parametric curve. (Variable t is parameter and r = 5 is the radus)

$$x = r\,.\,cos(t)$$

$$y = r\,.\,sin(t)$$

Vectors

A vector coniant a list of items with the same type separated by a comma. We use c() keyword to declare vectors.

```
# Example One
# Vector of strings
fruits <- c("banana", "apple", "orange")
# Print fruits
fruits

# Example Two
values = c(TRUE,FALSE,FALSE)
# Print values
values
```

Access and Modify Vectors

- We can access a vector item by its index number inside brackets. Indexes start from 1,2,…,,n.

```
fruits <- c("banana", "apple", "mango")

# Accessing the first item
fruits[1]
```

- We also can change a vector item by its index.

```
fruits <- c("banana", "apple", "orange")

# Change the first item (banana)
fruits[1] = "Mango"
fruits
```

Sort Vectors

- We can use sort() function to sort items alphabetically or numerically.

```
fruits <- c("banana", "apple")
numbers <- c(2, 3, 51, 1, 20, 4)

sort(fruits)  # Sort a string
sort(numbers) # Sort numbers
```

Lists

- Lists in R are like vectors but we can to store many different data types in lists.

```
 # List of strings
thislist <- list("apple", "banana", "cherry",2,TRUE)

# Print the list
thislist
```

List Functions

- Access specific item and change it

```
ls1 <- list("apple", "banana", "cherry")
ls1[1]
ls1[1] <- "blackcurrant"
ls1[1]
# Print the updated list
ls1
```

- Add item to list

```
ls1 <- list("apple", "banana", "cherry")
ls1
ls1 = append(ls1,'mango')
# Print the updated list
ls1
```

List Functions

- Check if item exist in list

```
ls1 <- list("apple", "banana", "cherry","mango")
if ("mango" %in% ls1){
  print('There is mango')
}
```

- Remove from list with index or value

```
ls1 <- list("apple", "banana", "cherry","mango")
# Delete with value
ls2 <- ls1[ls1 != "mango"]
# Delete with index
ls3 <- ls1[-4]
# Print modified lists
ls2
ls3
}
```

List Functions

- Loop through a list

```
ls1 = list("BMW","Mercedes","Hyundai","Lexus")
for(car in ls1){
  print(paste('Car:',car))
}
```

- Join lists

```
ls1 = list("BMW","Mercedes","Hyundai","Lexus")
ls2 = list("Ninja","Honda")
ls3 = c(ls1,ls2)
# Print Joined list
ls3
```

Matrices

Matrix is a two dimensional data with rows and columns. We can use matrix() keyword to create a matrix and specify number of rows and columns with nrow and ncol.

```
m1 = matrix(c(1,2,3,4,5,6,7,8,9),nrow = 3,ncol = 3,byrow = TRUE)
# Printing the matrix
m1
```

- What is “byrow=TRUE”?

Matrix Functions

- Access and change values

```
m1 = matrix(c(1,2,3,4,5,6,7,8,9),nrow = 3,ncol = 3,byrow = TRUE)
# Changing row 1, col 2 index
m1[1,2] = 10
m1
```

- Add rows and columns

```
m1 = matrix(c(1,2,3,4),nrow = 2,ncol = 2,byrow = TRUE)
# Add a column
m2 <- cbind(m1, c("cbind1", "cbind2"))
# Add a row
m3 <- rbind(m1,c("rbind1","rbind2"))
# Printing new matrixes
m2
m3
```

Matrix Functions

- Remove rows and columns

```
m1 = matrix(c(1,2,3,4,5,6),nrow = 2,ncol = 3,byrow = TRUE)
m2 <- m1[-c(1),] # Remove first row
m3 <- m1[,-c(1)] # Remove first column
# Print modified matrices
m2
m3
```

- Loop through a matrix

```
m1 = matrix(c(1,2,3,4,5,6),nrow = 2,ncol = 3,byrow = TRUE)
for(row in 1:nrow(m1)){
 for(col in 1:ncol(m1)){
  print(m1[row,col])
 }
}
```

Arrays

Unlike matrices, arrays can have more than 2 dimensions in R. We use array() function to declare an array and dim keyword to determine array dimensions. Remember that array can only store data with same data types.

```
# An array with more than one dimension created from a vector at first
vector1 = c(1:36)
arr1 <- array(vector1, dim = c(4, 3, 3))
arr1
```

- How can we access and modify array items?

DataFrames

- Data frames are data displayed in a format like table. We can store data with different data types in a data frame but each column in data frame can contain data with same data type. We use data.frame() keyword to declare a data frame.

  ```
  # Create a data frame
  df1 <- data.frame (
    ID = c(1 , 2, 3),
    Name = c("Alex", "John", "Alice"),
    Age = c(60, 30, 45)
  )

  # Print the data frame
  df1
  ```

- What does summary() keyword do?

DataFrame Functions

- Access and modify values

```
# Create a data frame
df1 <- data.frame (
  ID = c(1, 2, 3),
  Name = c("Alex", "John", "Alice"),
  Age = c(60, 30, 45)
)
# Access to values
df1[2]
df1[[2]]
df1$Name
# Modify a value
df1$Name[2] = "Richard"
df1
```

Other functions like add and remove rows and columns, combine data frames and etc.. are like arrays function.

Plotting

We can use plot() function to draw points in a diagram. This function has two main arguments, x-axis and y-axis. For example, you can plot two numbers (1,4) and (2,9) with code below:

```
plot(c(1, 2), c(4, 9))
```

- Plot a simple sequence

```
plot(1:10)
```

- Drawing a line

```
plot(1:10, type=“l")
```

- Labeling the plot

```
plot(1:10, main="Graph 1", xlab="X-axis", ylab="Y-axis")
```