

# Introduction to R

Université Côte d'Azur - MSc Programme in Economics

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Introduction

Data structures

# Schedule

- ▶ 08th of September 13-16
- ▶ 15th of September 9-12
- ▶ 22th of September 9-12

# Rules of the game

- ▶ arrive on time
- ▶ 20 minutes break
- ▶ homeworks
- ▶ no book (plenty of open source resources on-line)
- ▶ slides <https://github.com/mattiaguerini/slides-intro-to-R>
- ▶ take home exam (short project)

# Introduction

# What is R

R is both a programming language and software environment for statistical computing, which is free and open-source.

The *R Project* was initiated by Robert Gentleman and Ross Ihaka (University of Auckland) in the early 1990s as a different implementation of the S language.

Since 1997, R has been developed by the *R Development Core Team*.

R is platform independent and can run on Microsoft Windows, Mac OS and Unix/Linux systems.

# Getting Started

To get started, you'll need to install two pieces of software:

- ▶ R, the actual programming language.  
<https://cran.r-project.org>
- ▶ RStudio, an excellent IDE for working with R.  
<https://www.rstudio.com>

Why RStudio?<sup>1</sup>

- ▶ Easier to use (everything is in one space)
- ▶ Many useful integrations (e.g. R-projects, R-markdown, shiny ...)
- ▶ Plenty of shortcuts (alt + shift + k)
- ▶ Plenty of cheatsheets (see top panel)

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<sup>1</sup>You must have installed R before using RStudio.

# Screenshot of RConsole

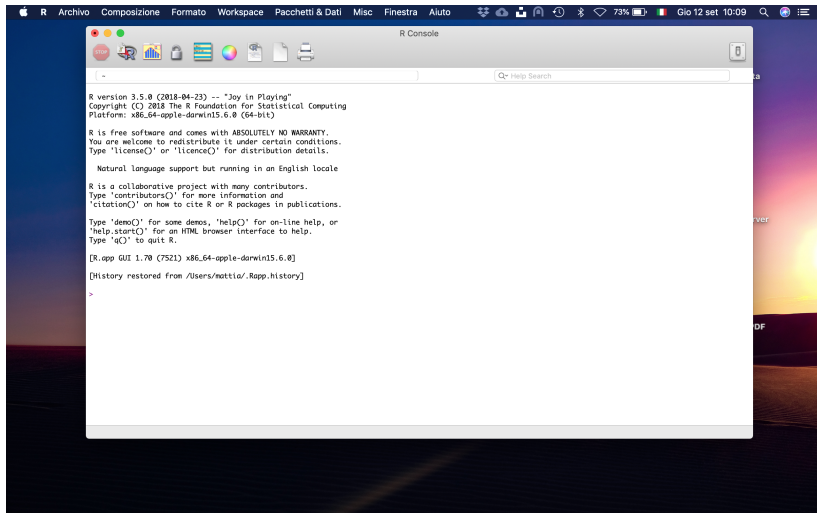


Figure 1: RConsole



# Screenshot of RStudio

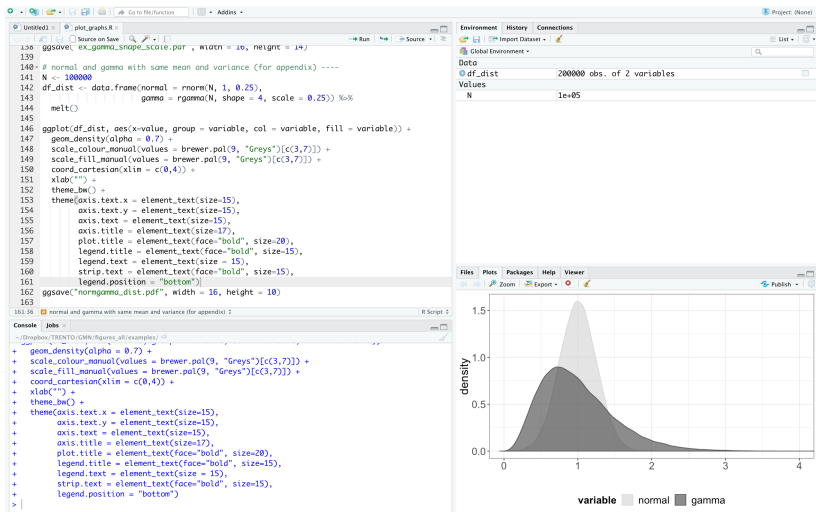


Figure 2: RStudio

# Glossary

- ▶ *command*: user input (text or numbers) that R understands
- ▶ *script*: a sequence of commands collected in a text file, each separated by a new line
- ▶ *environment*: a list of named variables that we have generated/imported by means of a series of commands
- ▶ *history*: the list of past commands thaty we have used
- ▶ *help*: a documentation of all the functions available in R (the user manual)
- ▶ *package*: a collection of additional functions and dataset

# R as a calculator (I)

```
2+2
```

```
## [1] 4
```

```
2-2
```

```
## [1] 0
```

```
2*2
```

```
## [1] 4
```

```
2/2
```

```
## [1] 1
```

## R as a calculator (II)

```
log(1)
```

```
## [1] 0
```

```
exp(1)
```

```
## [1] 2.718282
```

```
log(exp(1))
```

```
## [1] 1
```

```
sqrt(25)
```

```
## [1] 5
```

# The help

```
?log  
help(log)
```

Otherwise:

- ▶ Google your error message
- ▶ Ask for help in Stack Overflow

# Packages

R comes with a number of built-in functions and datasets, but one of the main strengths of R as an open-source project is its package system.

Packages gives you access to additional functions and datasets.

If you want to do something which is not doable with the R basic functions, there is a good chance that there exist a package that will fulfill your needs.

You can install packages using the command  
`install.packages()`

You can load packages using the command `library()`

# Data structures

# Data types

- ▶ Numeric/Double (e.g. 2.5, 1/5, 1.0, ...)
- ▶ Integer (e.g. 1, 2, 3, ...)
- ▶ Complex (e.g.  $1 + 2i$ , ...)
- ▶ Logical (e.g. TRUE, FALSE or NA)
- ▶ Character (e.g. “a”, “paper”, “2 plus 2 = 5”, “TRUE”, ...)
- ▶ Factor/Categorical (“male”, “female”, ...)



# Data structures

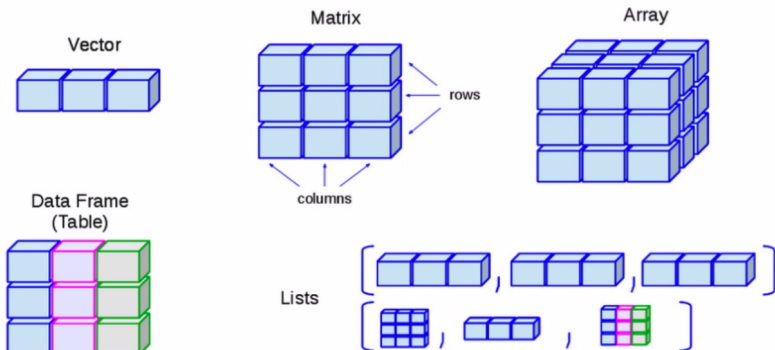


Figure 3: Visualization of data structures

# Vectors (I)

You can create a vector using the command `c()`

```
x <- c(1, 3, 5, 10)
x
```

```
## [1] 1 3 5 10
```

Vectors must contain elements of the same data type.

```
c(1, "intro", TRUE)
```

```
## [1] "1"      "intro" "TRUE"
```

You can measure the length of a vector using the command `length()`

```
length(x)
```

```
## [1] 4
```

## Vectors (II)

It is also possible to easily create sequences

```
1:10
```

```
## [1] 1 2 3 4 5 6 7 8 9 10
```

```
seq(from = 1, to = 2, by = 0.1)
```

```
## [1] 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
```

```
rep("A", times = 5)
```

```
## [1] "A" "A" "A" "A" "A"
```

## Vectors (III)

You can combine different vectors

```
x <- 1:3 # from 1 to 3  
y <- c(10, 15) # 10 and 15  
z <- c(x,y) # x first and then y  
z
```

```
## [1] 1 2 3 10 15
```

And you can repeat vectors (or its elements)

```
z <- rep(y, each=3) # repeat each element 3 times  
z
```

```
## [1] 10 10 10 15 15 15
```

```
z <- rep(y, times=3) # repeat the whole vector 3 times  
z
```

```
## [1] 10 15 10 15 10 15
```

# Subsetting Vectors

```
x <- c(1,5,10,7)
x < 6 # is the element lower than 6?
```

```
## [1] TRUE TRUE FALSE FALSE
```

```
x == 10 # is the element equal to 10?
```

```
## [1] FALSE FALSE TRUE FALSE
```

```
x[2] # which element is in the second position?
```

```
## [1] 5
```

```
x[1:2] # which elements are in the first 2 positions?
```

```
## [1] 1 5
```

```
x[c(1,3,4)] # which elements are in positions 1, 3 and 4?
```

```
## [1] 1 10 7
```

# Vectors' Operations

```
x <- c(1,5,10,7)
x+2 # adds a scalar to all elements
```

```
## [1] 3 7 12 9
```

```
x^2 # what's the square of all elements?
```

```
## [1] 1 25 100 49
```

# Matrices (I)

You can create a matrix using the command `matrix()`

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

```
X
```

```
##      [,1] [,2] [,3]  
## [1,]    1    4    7  
## [2,]    2    5    8  
## [3,]    3    6    9
```

## Matrices (II)

R automatically inserts elements by columns, but we can ask to include by rows

```
X <- matrix(1:9, nrow = 3, ncol = 3, byrow = TRUE)
X
```

```
##      [,1] [,2] [,3]
## [1,]    1    2    3
## [2,]    4    5    6
## [3,]    7    8    9
```

You don't even have to specify the options names

```
X <- matrix(1:8, 2, 4, T)
X
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    2    3    4
## [2,]    5    6    7    8
```



## Matrices (III)

Matrices can also be created by combining vectors

```
X <- cbind(1:4, 6:9) # binds them as columns
X
```

```
##      [,1] [,2]
## [1,]    1    6
## [2,]    2    7
## [3,]    3    8
## [4,]    4    9
```

```
X <- rbind(1:4, 6:9) # binds them as rows
X
```

```
##      [,1] [,2] [,3] [,4]
## [1,]    1    2    3    4
## [2,]    6    7    8    9
```

# Subsetting Matrices

```
X>5 # elements larger than 5
```

```
##      [,1] [,2] [,3] [,4]  
## [1,] FALSE FALSE FALSE FALSE  
## [2,]  TRUE  TRUE  TRUE  TRUE
```

```
X[1,4] # element of first row, fourth column?
```

```
## [1] 4
```

```
X[1,] # element in the first row?
```

```
## [1] 1 2 3 4
```

```
X[,2] # elements in the second columns?
```

```
## [1] 2 7
```

# Matrices' Operations (I)

Let's create two matrices X and Y:

```
x <- c(1,5,4,9)
y <- c(2,4,1,3)
X <- matrix(x, 2, 2)
Y <- matrix(y, 2, 2)
```

X

```
##      [,1] [,2]
## [1,]    1    4
## [2,]    5    9
```

Y

```
##      [,1] [,2]
## [1,]    2    1
## [2,]    4    3
```

## Matrices' Operations (II)

```
X+Y    # element by element (also subtraction is equal)
```

```
##      [,1] [,2]  
## [1,]    3    5  
## [2,]    9   12
```

```
X*Y    # element by element multiplication
```

```
##      [,1] [,2]  
## [1,]    2    4  
## [2,]   20   27
```

```
X%*%Y # matrix multiplication
```

```
##      [,1] [,2]  
## [1,]   18   13  
## [2,]   46   32
```

## Matrices' Operations (III)

```
solve(Y) # inverse
```

```
##      [,1] [,2]  
## [1,]  1.5 -0.5  
## [2,] -2.0  1.0
```

```
t(X) # transpose
```

```
##      [,1] [,2]  
## [1,]    1    5  
## [2,]    4    9
```

# Arrays (I)

```
x <- 1:4  
X <- array(data = x, dim = c(2,3,2))  
X
```

```
## , , 1  
##  
##      [,1] [,2] [,3]  
## [1,]    1    3    1  
## [2,]    2    4    2  
##  
## , , 2  
##  
##      [,1] [,2] [,3]  
## [1,]    3    1    3  
## [2,]    4    2    4
```

# Notes about the Arrays

- ▶ Remember that vectors, matrices and arrays can include only data types of the same kind.
- ▶ A 3D array is basically a combination of matrices each laid on top of other (e.g. write  $N$   $K \times K$  matrices in  $N$  different pages in your notebook)
- ▶ A 4D array is basically a combination of arrays each laid on top of other (e.g. take two notebooks of 3D arrays)
- ▶ A 5D array ...
- ▶ Pay attention to the **recycling rule**  
(<https://cran.r-project.org/doc/manuals/r-devel/R-intro.html#The-recycling-rule>)

# Lists

A list is a one-dimensional heterogeneous data structure.

It is indexed like a vector with a single integer value (or a name), but each element can contain an element of any data type.

```
x <- 1:4  
y <- c("a", "b", "c")  
L <- list(numbers = x, letters = y)  
L
```

```
## $numbers  
## [1] 1 2 3 4  
##  
## $letters  
## [1] "a" "b" "c"
```



# Subsetting Lists

```
L[[1]] # extract the first element
```

```
## [1] 1 2 3 4
```

```
L$numbers # extract the element called numbers
```

```
## [1] 1 2 3 4
```

```
L$letters # extract the element called letters
```

```
## [1] "a" "b" "c"
```

You can even “work” with the subsetting element:

```
L$numbers[1:3] > 2
```

```
## [1] FALSE FALSE TRUE
```

# Data Frames (I)

A `data.frame` is similar to a typical spreadsheet in excel.

There are rows, and there are columns.

A row is typically thought of as an *observation*.

A column is a certain *variable*, characteristic or feature of that observation.

## Data Frames (II)

A data frame is a list of column vectors where:

- ▶ each column has a name
- ▶ each column must contain the same data type, but the different columns can store different data types.
- ▶ each column must be of same length

## Data Frames (III)

```
set.seed(1)
df <- data.frame(id = 1:5,
  name = c("Diego", "Samuel", "Marco", "Javier", "Leonardo"),
  surname = c("Milito", "Eto'o", "Materazzi", "Zanetti", "Bonucci"),
  wage = rnorm(n=5, mean = 10^5, sd = 10^3), # normal random sample
  origin = c("Argentina", "Cameroon", "Italy", "Argentina", "Italy"),
  treble_winner = c(T, T, T, T, F)
)
df
```

##	id	name	surname	wage	origin	treble_winner
## 1	1	Diego	Milito	99373.55	Argentina	TRUE
## 2	2	Samuel	Eto'o	100183.64	Cameroon	TRUE
## 3	3	Marco	Materazzi	99164.37	Italy	TRUE
## 4	4	Javier	Zanetti	101595.28	Argentina	TRUE
## 5	5	Leonardo	Bonucci	100329.51	Italy	FALSE

You can verify the size of the `data.frame` using the command `dim()`

You can get the data type info using the command `str()`

# Subsetting Data Frames (I)

```
df$name # subset a column
```

```
## [1] Diego    Samuel    Marco     Javier    Leonardo  
## Levels: Diego Javier Leonardo Marco Samuel
```

```
df[,c(2,5)] # can also subset like a matrix
```

```
##      name    origin  
## 1   Diego Argentina  
## 2   Samuel  Cameroon  
## 3    Marco     Italy  
## 4   Javier Argentina  
## 5 Leonardo     Italy
```

## Subsetting Data Frames (II)

```
head(df, n=3) # first n observations
```

##	id	name	surname	wage	origin	treble_winner
## 1	1	Diego	Milito	99373.55	Argentina	TRUE
## 2	2	Samuel	Eto'o	100183.64	Cameroon	TRUE
## 3	3	Marco	Materazzi	99164.37	Italy	TRUE

```
tail(df, n=3) # last n observations
```

##	id	name	surname	wage	origin	treble_winner
## 3	3	Marco	Materazzi	99164.37	Italy	TRUE
## 4	4	Javier	Zanetti	101595.28	Argentina	TRUE
## 5	5	Leonardo	Bonucci	100329.51	Italy	FALSE

# Inspecting data frames (I)

R comes with many data bases included. These can be used for learning R.

One of the most famous is the one called `mtcars`.

```
head(mtcars)
```

##		mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
##	Mazda RX4	21.0	6	160	110	3.90	2.620	16.46	0	1	4	4
##	Mazda RX4 Wag	21.0	6	160	110	3.90	2.875	17.02	0	1	4	4
##	Datsun 710	22.8	4	108	93	3.85	2.320	18.61	1	1	4	1
##	Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1
##	Hornet Sportabout	18.7	8	360	175	3.15	3.440	17.02	0	0	3	2
##	Valiant	18.1	6	225	105	2.76	3.460	20.22	1	0	3	1

```
dim(mtcars)
```

```
## [1] 32 11
```

## Inspecting data frames (II)

```
str(mtcars)
```

```
## 'data.frame':    32 obs. of  11 variables:
## $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
## $ cyl : num   6  6  4  6  8  6  8  4  4  6 ...
## $ disp: num  160 160 108 258 360 ...
## $ hp  : num  110 110 93 110 175 105 245 62 95 123 ...
## $ drat: num   3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
## $ wt  : num   2.62 2.88 2.32 3.21 3.44 ...
## $ qsec: num   16.5 17 18.6 19.4 17 ...
## $ vs  : num    0  0  1  1  0  1  0  1  1  1 ...
## $ am  : num    1  1  1  0  0  0  0  0  0  0 ...
## $ gear: num    4  4  4  3  3  3  3  4  4  4 ...
## $ carb: num    4  4  1  1  2  1  4  2  2  4 ...
```

```
names(mtcars)
```

```
## [1] "mpg" "cyl" "disp" "hp" "drat" "wt" "qsec" "vs" "am" "gear"
## [11] "carb"
```



## Subsetting data frames (III)

We are interesting in the cylinders and the weights of inefficient cars (lower than 15 miles per gallon).

```
poll_cars <- mtcars[mtcars$mpg<15, c("cyl", "wt")]  
poll_cars
```

##	cyl	wt
## Duster 360	8	3.570
## Cadillac Fleetwood	8	5.250
## Lincoln Continental	8	5.424
## Chrysler Imperial	8	5.345
## Camaro Z28	8	3.840

## Subsetting data frames (IV)

Alternatively:

```
poll_cars <- subset(mtcars, subset = mpg<15, select = c("cyl", "wt"))  
poll_cars
```

##	cyl	wt
## Duster 360	8	3.570
## Cadillac Fleetwood	8	5.250
## Lincoln Continental	8	5.424
## Chrysler Imperial	8	5.345
## Camaro Z28	8	3.840

# Importing data frames (I)

You can import csv data using:

```
setwd("~/Google Drive/T_2020a_UCA_introR/data/")  
nyc_ab <- read.csv("AB_NYC_2019.csv")
```

where:

- ▶ `setwd()` sets the working directory to the place where the data is saved;
- ▶ `read.csv()` loads the csv file with the specified name.