

Introduction to R - Part 2

Data Science Skills Day 2022

Anjali Silva, PhD

Summer Undergraduate Data Science Research Program
University of Toronto
03 June 2022



a.silva@utoronto.ca



[anjalisilva.github.io](https://github.com/anjalisilva)



[@Silva_Anjali](https://twitter.com/Silva_Anjali)

Course Description

- Introduction to R - Part 2
Data Science Skills Day
 - The vast amount of data produced by evolving information technology requires tools and skills. Among the many tools, R is a free, open-source language for data sciences. R is a programming language that can aid in the process of data analysis. This course is a beginner level, introductory course for R for data analysis. We will learn about R, RStudio (the environment use to work in R), including installation, and apply R for beginner-level data modeling and visualization. By the end of the course, you'll have a introduction to the flexibility of R, different functionalities, and understand how to apply it for basic data exploration.
 - Friday 10:00 am – 4 pm EST; online - synchronous.

Material

- Instructor Slides:
 - https://github.com/anjalisilva/DSI_IntroductionToR
 - SlideIntroR2022.pdf
 - SlideIntroR2022_part2.pdf

Data Frames

- Data frames are used to store tabular data in R.

data frame

1	"S"	TRUE
7	"A"	FALSE
3	"U"	TRUE

numeric character logical

Figure: Data frames can store different classes of objects in each column. Figure from: <https://datacarpentry.org/r-socialsci/02-starting-with-data/index.html>

Data Frames

- Data frames are used to store tabular data in R.
- Data frames can store different classes of objects in each column.

```
dataFrameExample <- data.frame(  
  numbers = 1:4,  
  sex = c("M", "M", "F", "F"))  
  
dataFrameExample  
class(dataFrameExample) # "data.frame"  
dim(dataFrameExample) # 4 2  
names(dataFrameExample) # "numbers" "sex"
```

Data Frames

- Data frames can be converted to a matrix using `data.matrix()`.

```
dataMatrix <- data.matrix(dataFrameExample)
class(dataMatrix) # "matrix"
dim(dataMatrix) # 4 2
```

Question 14:

Generate the following information into a data frame.

1	numbers	sex	age	height
2	1	M	30	72
3	2	M	31	70
4	3	F	40	65
5	4	F	35	62.4

Question 15:

After generating the data frame, you realize the height is recorded in inches but should be changed to centimeters. How would you do this? Note, 1 inch = 2.54 cm.

	numbers	sex	age	height
1				
2	1	M	30	72
3	2	M	31	70
4	3	F	40	65
5	4	F	35	62.4

Booleans

- TRUE/FALSE or T/F are called “boolean” values.

```
testValue <- FALSE
typeof(testValue)
is.logical(testValue)
```

```
! testValue
```

- “!” is the NOT operator. It returns the opposite of the argument.

Boolean Operators

- Operators $>$ or $<$:

```
a <- c(1:5)
```

```
a
```

```
a < 2 # TRUE FALSE FALSE FALSE FALSE
```

- Equivalence test:

```
a == 2 # FALSE TRUE FALSE FALSE FALSE
```

Boolean Operators

- & symbol is the "AND" operator:

```
a <- 45  
(a > 40) & (a < 50) # TRUE
```

- | symbol is the "OR" operator:

```
b <- 10  
(b < 20) | (b > 5) # TRUE
```


Question 16:

Given the below numeric vector 'numericVec', how can a user check if values are greater than 5?

```
numericVec <- c(1.1, 3, 5.3, 2)
```

Question 17:

Given the below numeric vector 'numericVec', how can a user retrieve the value/s that is/are greater than 5, from the vector?

```
numericVec <- c(1.1, 3, 5.3, 2)
```

Data Import/Export

Data Import/Export

- To see the list of pre-loaded data in R:

```
data(package = "datasets")
```

```
AirPassengers # Example dataset
```

```
head(AirPassengers) # see first few entries
```

```
tail(AirPassengers) # see last few entries
```

Data Slicing

- Let us look at another pre-loaded datasets:

```
women # another dataset (last)
?women
dim(women) # 15  2
class(women) # "data.frame"
head(women) # height and weight information

women$height > 60 # slicing
women[women$height > 60, ] # slicing
```

Data Reading/Writing

- Files can be written using functions like `write.csv()`, `write.table()`:

```
getwd() # file will be saved here
write.csv(x = women, file = "women.csv")
# saving women dataset in current working directory
```

Data Reading/Writing

- Txt files can be read using `read.table("location of the file")` or `read.csv()`

```
womenNew <- read.csv(file = "women.csv", row.names = 1)
womenNew
```

```
head(womenNew) # to view first part of object
tail(womenNew) # to view last part of object
dim(womenNew) # 15 2
womenNew[c(1:5), ] # to view first 5 rows
womenNew[, 1] # to view first column
```

Arithmetic

Arithmetic

- “+” is used for addition:

```
x <- 2.5 + 2
```

```
x # 4.5
```

```
y <- 2:15
```

```
sum(y) # 119
```

```
sum(y[1:3]) # 9
```

Arithmetic

- “-” is used for subtraction:

```
x <- 2.5 - 2  
x # 0.5
```

- “/” is used for division:

```
x <- 2 / 2  
x # 1
```

Arithmetic

- “*” is used for multiplication:

```
x <- 2 * 2  
x # 4
```

- “%*% ” is used for matrix multiplication:

```
a <- matrix(1:6, nrow = 2, ncol = 3) # 2 x 3 matrix  
a  
b <- matrix(7:12, nrow = 3, ncol = 2) # 3 x 2 matrix  
b  
c <- a %*% b  
c # 2 x 2 matrix
```


Any questions?

Writing Functions

- Functions combine a sequence of expressions that are executed to achieve a goal.
- Can be reused without rewriting the sequence of expressions.
- Take input, *function arguments* and generate output, *return value*.
- When writing functions, ask yourself:
 - *What will the user want to modify in this function?*
 - This will help determine *function arguments*.

Function Interface

- Function names cannot begin with a number.
- To run the function:

```
firstFunction(argumentOne = 2, argumentTwo = 3)
```

- To “call” or “invoke” the function, type function name:

```
firstFunction
```

Function Interface

- Default values play a vital role in R functions and influence user's behaviour.
- Default values should be assigned using "=", and not "<=".

```
secondFunction <- function(argOne = 1, argTwo = 3) {  
  cat("\n First argument is", argOne, "\n")  
  cat("\n Second argument is", argTwo, "\n")  
  argThree <- argOne + argTwo  
  
  cat("\n argOne + argTwo is", argThree, "\n")  
  
  return(argThree)  
}
```

Local and Global Variables

- Where variables are defined matters.
- Variables defined within functions are only accessible from within the function.
- Variables declared within a function are called “local”.
- Variables declared outside of functions are called “global”.

Variables

- If variables are defined outside of functions, globally, they hold that value.

```
argOne <- "Hello"
```

```
anotherFunction <- function() {  
  argOne <- 10  
  return(argOne)  
}
```

```
anotherFunction()
```

```
argOne # What would this return?
```


Non-base Functions

- Functions have been written by other authors.
- Non-base functions in R can be utilized by downloading R packages.
- To see all the currently loaded packages:

```
search()
```

Non-base Functions

- Popular repositories for Packages:
 - The Comprehensive R Archive Network (CRAN)
 - Link: <https://cran.r-project.org/web/packages/>
 - Bioconductor
 - Link: <https://www.bioconductor.org/packages/release/bioc/>
 - GitHub
- Depending on the source of Package, downloading instructions may differ.

Example

- User wants to do a cluster analysis of the women built-in dataset.
- Assume the user is interested in performing model-based clustering using Gaussian finite mixture models.
 - Do an R search:
??clustering
 - Google R packages for model-based clustering.
 - Read blogs on clustering.

Example, continue...

- Get to know about R package 'mclust'.
- Visit <https://cran.r-project.org/web/packages/mclust/index.html>.
- Click on Reference manual to see all the functions within the package.
- Download package to R session:

```
# Install package from CRAN, case matters!  
install.packages("mclust")  
library("mclust") # to load and attach
```

Example, continue...

- More details on 'mclust' package (only after downloading):

```
vignette("mclust") # vignette for 'mclust'
```

```
?'mclust-package' # get information on package
```

```
?mclust # get information on package
```

```
ls("package:mclust") # list all functions in package
```

Example, continue...

- Work with 'mclust' package:

```
# Running mclust
```

```
MclustResults <- mclust::Mclust(data = women)
```

```
str(MclustResults) # provide the structure; list of 15  
names(MclustResults)
```

```
MclustResults$G # There are four clusters in the dataset
```

```
# Citing the package
```

```
citation("mclust")
```


Bioconductor

- Bioconductor packages are available from [bioconductor.org](https://www.bioconductor.org).
- URL: <https://www.bioconductor.org/install/>.

```
if (!requireNamespace("BiocManager", quietly = TRUE))  
  install.packages("BiocManager")
```

- Bioconductor packages are listed here:
<https://www.bioconductor.org/packages/release/bioc/>.

Bioconductor

[Home](#)[Install](#)[Help](#)[Developers](#)[About](#)Search: [Home](#) » [Bioconductor 3.11](#) » 3.11 Software Packages

Bioconductor Software Packages

Bioconductor version: Release (3.11)

Package	Maintainer	Title
a4	Tobias Verbeke, Laure Cougnaud	Automated Affymetrix Array Analysis Umbrella Package
a4Base	Tobias Verbeke, Laure Cougnaud	Automated Affymetrix Array Analysis Base Package
a4Classif	Tobias Verbeke, Laure Cougnaud	Automated Affymetrix Array Analysis Classification Package
a4Core	Tobias Verbeke, Laure Cougnaud	Automated Affymetrix Array Analysis Core Package
a4Preproc	Tobias Verbeke, Laure Cougnaud	Automated Affymetrix Array Analysis Preprocessing Package
a4Reporting	Tobias Verbeke, Laure Cougnaud	Automated Affymetrix Array Analysis Reporting Package
ABAEEnrichment	Steffi Grote	Gene expression enrichment in human brain regions
ABarray	Yongming Andrew Sun	Microarray QA and statistical data analysis for Applied Biosystems Genome Survey Microarray (AB1700) gene expression data.
abseqR	Jiahong Fong	Reporting and data analysis functionalities for Rep-Seq datasets of antibody libraries

Packages »

Bioconductor's stable, semi-annual release:

- Analysis [software](#) packages.
- [Annotation](#) packages.
- Illustrative [experiment data](#) packages.
- [Workflow](#) packages.
- Latest [release announcement](#).

Bioconductor is also available via [Docker](#) and [Amazon Machine Images](#).

Development Version »

Bioconductor packages under development:

- Analysis [software](#) packages.
- [Annotation](#) packages
- Illustrative [experiment data](#) packages

Developer Resources:

- [GIT Log](#)

Example

- User is interested in Bioconductor package GenomicFeatures.
- To load package:

```
BiocManager::install("GenomicFeatures")  
library("GenomicFeatures")
```

```
# list all functions in the package  
ls("package:GenomicFeatures")
```

- More about installation:
<https://www.bioconductor.org/install/>.

Bioconductor



Home



Explore



Notifications



Messages



Bookmarks



Lists



Profile



Bioconductor

2,020 Tweets



Following

Bioconductor

@Bioconductor

📍 Roswell Park Cancer Institute bioconductor.org

📅 Joined November 2011

5 Following 7,028 Followers

Any questions?

You are interested in R packages for analyzing Covid-19 data for a project you are doing. So you search Google for such R packages.

You come across a package called 'covid19.analytics' which has a GitHub R package (<https://github.com/mponce0/covid19.analytics>) that was later developed into a CRAN package (<https://cran.r-project.org/web/packages/covid19.analytics/index.html>). How would you download both the GitHub and CRAN package?

R: Graphics

Applying Base Functions

- Package 'graphics' is a standard or base package.

```
library(graphics) # to load and attach
```

```
?AirPassengers
```

```
# Monthly Airline Passenger Numbers 1949-1960
```

```
# plot
```

```
plot(AirPassengers)
```

```
plot(AirPassengers, type = "p")
```

```
plot(AirPassengers, type = "p", main = "Monthly Airline  
Passenger Numbers 1949-1960") # zoom
```

Applying Base Functions

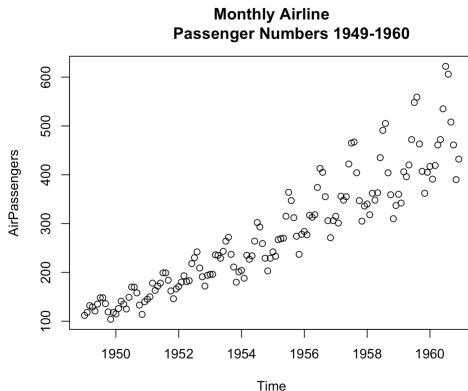


Figure: Plotting AirPassengers dataset as a scatter plot.

Applying Base Functions

- Package 'graphics' is a base package.

```
library(graphics) # to load and attach
```

```
# plot
```

```
plot(AirPassengers)
```

```
plot(AirPassengers, type = "l", main = "Monthly Airline  
Passenger Numbers 1949-1960") # zoom
```


Applying Base Functions

- Package 'graphics' is a base package.

```
library(graphics) # to load and attach
```

```
?AirPassengers
```

```
# Monthly Airline Passenger Numbers 1949-1960
```

```
# To have multiple plots in one overall plot using
```

```
par(mfrow = c(1, 2))
```

```
hist(AirPassengers) # histogram
```

```
boxplot(AirPassengers) # boxplot
```

Applying Base Functions

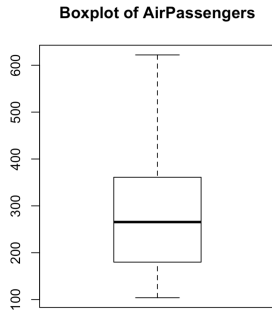
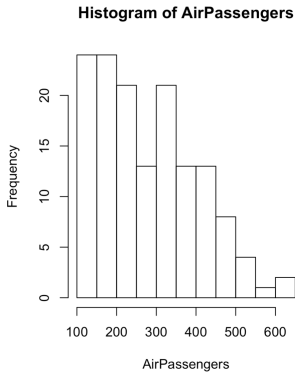


Figure: Output from plotting AirPassengers dataset.

Applying Base Functions

- Package 'graphics' is a base package.

```
library(graphics) # to load and attach
```

```
?iris
```

```
?pairs
```

```
pairs(iris[, c(1:4)], col = iris$Species,  
      main = "Scatter plot of iris dataset")
```

Applying Base Functions

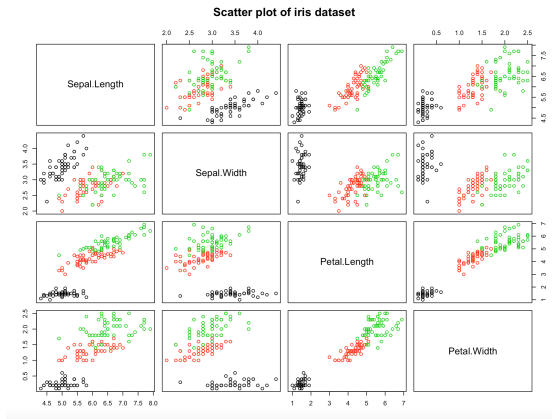


Figure: Output from plotting iris dataset as a pairs plot.

Applying Base Functions

- Package 'graphics' is a base package.

```
library(graphics) # to load and attach
```

```
barplot(as.matrix(iris[, c(1:4)]),  
        legend.text = TRUE,  
        main = "Bar plot of iris dataset")
```

```
# Calculate column sums of iris dataset  
colSums(as.matrix(iris[, c(1:4)]))
```

```
# Sepal.Length  Sepal.Width Petal.Length  Petal.Width  
# 876.5          458.6          563.7          179.9
```

Applying Base Functions

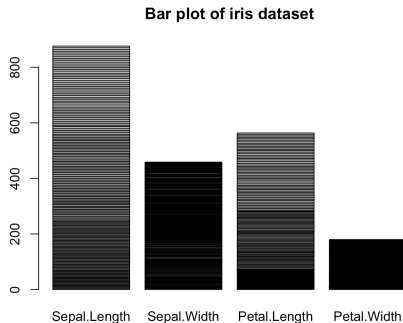


Figure: Output from plotting iris dataset as a bar plot.

R Packages for Plotting

- More resources:
 - R Graphics Cookbook: <https://r-graphics.org/>.
 - sthda:
<http://www.sthda.com/english/wiki/ggplot2-essentials>.

Any questions?

Anscombes quartet is a set of 4 x,y data sets that were published by Francis Anscombe in a 1973 paper Graphs in statistical analysis. This is available as a standard or base dataset in R.

- Obtain the dataset. What is the size of the dataset? Check the column names of the dataset. Summarise the data by calculating the mean, variance, for each column and the correlation between each pair, eg., (x_1, y_1) , (x_2, y_2) , etc. Then create a scatter plot for each x, y pair of data.
- For later reading, original paper:

<https://www.jstor.org/stable/2682899?seq=1>

Question 19: continue...

- Anscombe's quartet has four data sets that have nearly identical descriptive statistics, but very different distributions.

<u>Property</u>	<u>Value</u>
Mean of X (average)	9 in all 4 XY plots
Sample variance of X	11 in all four XY plots
Mean of Y	7.50 in all 4 XY plots
Sample variance of Y	4.122 or 4.127 in all 4 XY plots
Correlation (r)	0.816 in all 4 XY plots

- Original paper:
<https://www.jstor.org/stable/2682899?seq=1>.

Next Steps

Resources

- The R Journal: <https://journal.r-project.org/>
- R for Data Science textbook (free): <https://r4ds.had.co.nz/>.
- Bioconductor Workshops:
<https://www.bioconductor.org/help/events/>
- Coursera offers courses via both paid + free options
 - <https://www.coursera.org/courses?query=bioinformatics>

Resources



R packages for data science

The tidyverse is an opinionated **collection of R packages** designed for data science. All packages share an underlying design philosophy, grammar, and data structures.

Install the complete tidyverse with:

```
install.packages("tidyverse")
```

Figure: Tidyverse R Packages designed for data science. Figure from <https://www.tidyverse.org/>.

Conferences

useR! — International R User Conference



useR! 2022 will be a hybrid conference from June 20 to June 23, with opportunities to participate as an online attendee or to attend in person at Vanderbilt University Medical Center, Nashville, TN, USA. For the latest updates, follow '@_useRconf' on Twitter, or 'user-conf' on LinkedIn.

