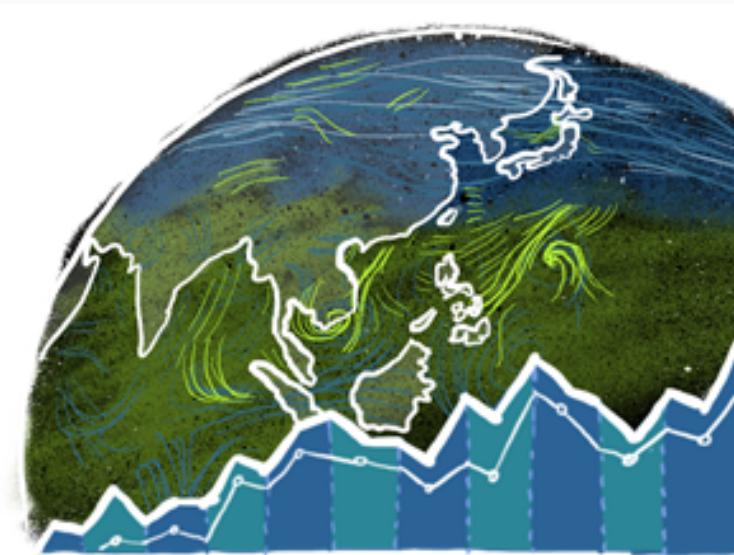


Fundamental of Data Science for ESS



R session 01 - Introduction to R

Daniel Vaulot



Outline

- What is R and why use R ?
- Resources
- Get started
- Fundamentals of R
 - Data objects
 - Vectors
 - Operators
 - Functions
 - Packages
 - Data frames



Introduction

- Who has used R before ?



Introduction

- Who has used R before ?
- What other programming language have you used before ?



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- Who has used R before ?
- What other programming language have you used before ?
- For those who are experts in R



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 - please refrain to answer during this session...
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| Your turn...



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| Your turn...

| Warning



Introduction

Computer languages

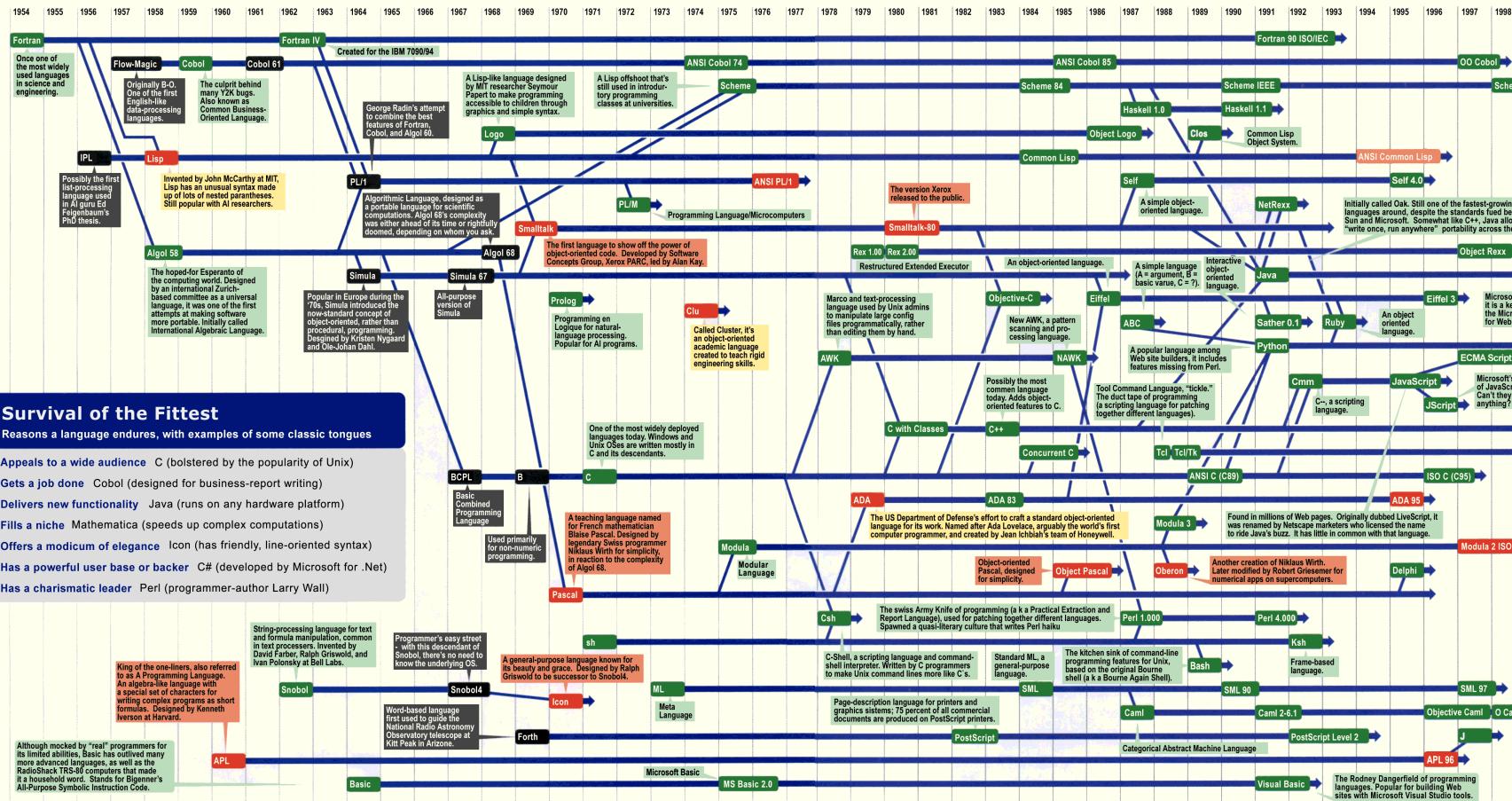
Mother Tongues

Tracing the roots of computer languages through the ages

Just like half of the world's spoken tongues, most of the 2,300-plus computer programming languages are either endangered or extinct. As powerhouses C/C++, Visual Basic, Cobol, Java and other modern source codes dominate our systems, hundreds of older languages are running out of life.

An ad hoc collection of engineers-electronic lexicographers, if you will—aim to save, or at least document the lingo of classic software. They're combing the globe's 9 million developers in search of coders still fluent in these nearly forgotten lingua frangas. Among the most endangered are Ada, APL, B (the predecessor of C), Lsp, Oberon, Smalltalk, and Simula.

Code-raker Grady Booch, Rational Software's chief scientist, is working with the Computer History Museum in Silicon Valley to record and, in some cases, maintain languages by writing new compilers so our ever-changing hardware can grok the code. Why bother? "They tell us about the state of software practice, the minds of their inventors, and the technical, social, and economic forces that shaped history at the time," Booch explains. "They'll provide the raw material for software archaeologists, historians, and developers to learn what worked, what was brilliant, and what was an utter failure." Here's a peek at the strongest branches of programming's family tree. For a nearly exhaustive rundown, check out the Language List at [HTTP://www.informatik.uni-freiburg.de/Misc/list_lang_1st.html](http://www.informatik.uni-freiburg.de/Misc/list_lang_1st.html). — Michael Mendeno



Sources: Paul Boutin; Brent Hailpern, associate director of computer science at IBM Research; The Retrocomputing Museum; Todd Proebsting, senior researcher at Microsoft; Gio Wiederhold, computer scientist, Stanford University

Introduction

History of R

- **Mid 1970s** - S Language for Statistical Computing conceived by John Chambers, Rick Becker, Trevor Hastie, Allan Wilks and others at Bell Labs
- **Early 1990's** - R was first implemented in the early 1990's by Robert Gentleman and Ross Ihaka, both faculty members at the University of Auckland.
- **1995** - Open Source Project
- **1997** - Managed by the R Core Group
- **2000** - First release of R
- **2011** - First release of R studio
- [Historical notes](#) - Paper from 1998



Introduction

Why use R ?

- **Script vs. Menu driven software (e.g. Excel)**

- Can be re-rerun with new data
- Reproducible workflow

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 - Tidy "universe" : tidyverse and ggplot2
 - Very easy to manipulate tables (select columns, create new variables)
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 - R studio
- **Document your data processing**
 - R markdown
 - Create HTML, pdf, presentations

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 - Create HTML, pdf, presentations
- **Share your data and workflow**
 - GitHub

Introduction

What can you do with R ?

Introduction

What can you do with R ?

- **Science**

- Statistics of course...
- Data processing
- Graphics
- Time series analyses
- Maps
- Bioinformatics

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- **But also**

- Teach
- Do a presentation
- Write your CV
- Build a web site
- Write a book
- Much more...

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DANIEL VAULOT

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Daniel Vaulot

Directeur de Recherche (CNRS) - Visiting Professor (NTU)

Station Biologique de Roscoff
CNRS
Sorbonne Université
Nanyang Technological University, Singapore

[Download CV](#)

Interests

- Marine Phytoplankton
- Microbial Ecology
- Polar ecosystems

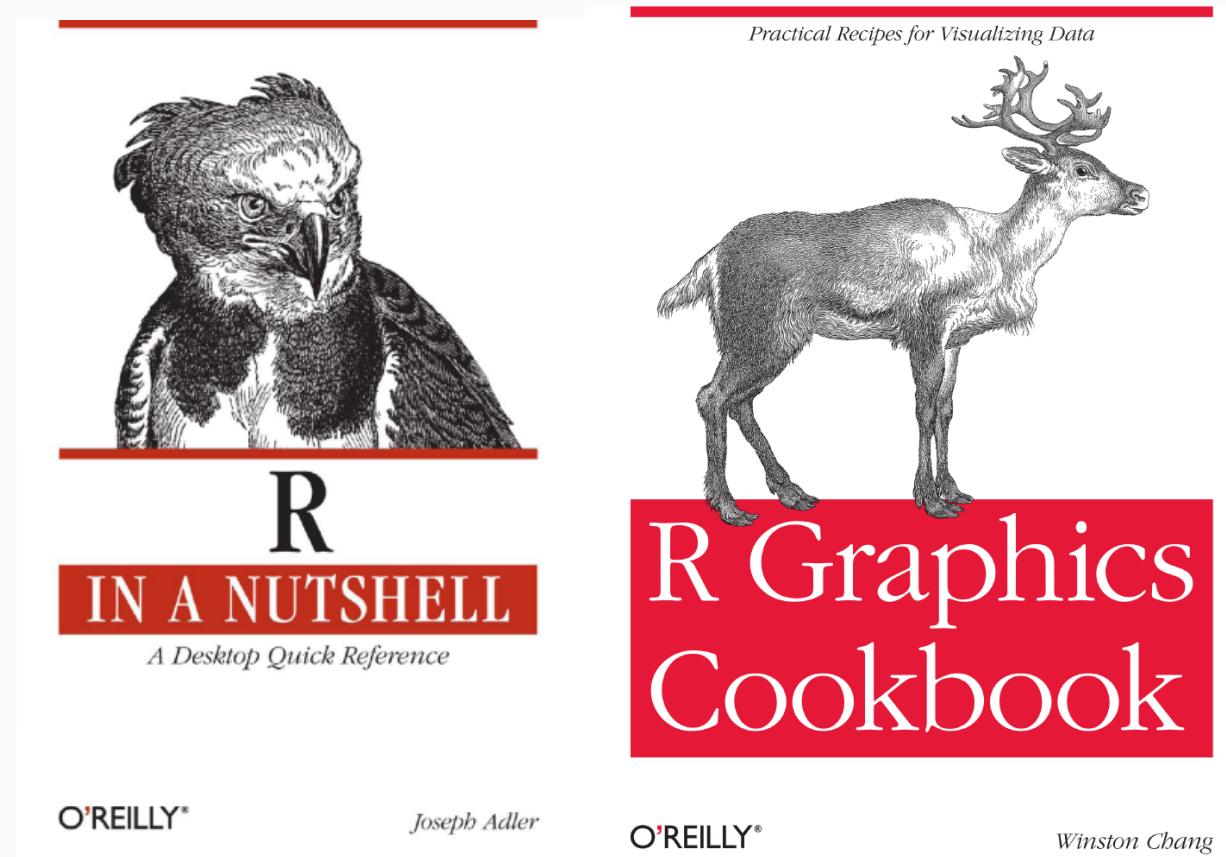
Education

- 🎓 Ingénieur, 1975
Ecole Polytechnique
- 🎓 Ingénieur, 1977
Ecole du Génie Rural et des Eaux et Forêts
- 🎓 PhD in Oceanography, 1985
Massachusetts Institute of Technology

Resources

Books and Manuals



- [R intro](#) : Very good introduction to R, short and clear
- [R in a nutshell](#) : Many many receipes to solve all your questions
- R graphics cook book : very good for graphics

Resources

On line courses and web sites

Home | Interface | Input | Manage | Stats | Adv Stats | Graphs | Adv Graphs | Blog

Search

About Quick-R

Correlations Among Auto Characteristics

Who Survived the Titanic?

R is an elegant and comprehensive statistical and graphical programming language. Unfortunately, it can also have a [steep learning curve](#). I created this website for both current R users, and experienced users

- Coursera
- Pluralsight
- Quick-R, very simple

Resources

Cheat sheets

The screenshot shows the RStudio IDE interface. On the left, the 'Help' menu is open, displaying various resources like 'R Help', 'About RStudio', and 'Check for Updates'. The 'Cheatsheets' option is highlighted with a blue border. Below this, other options include 'RStudio Docs', 'RStudio Support', 'Markdown Quick Reference', 'Roxygen Quick Reference', and 'Diagnostics'. A central panel titled 'RStudio IDE Cheat Sheet' lists several cheat sheets: 'Data Manipulation with dplyr, tidyverse', 'Data Visualization with ggplot2', 'R Markdown Cheat Sheet', 'R Markdown Reference Guide', 'Shiny Web Applications', and 'Package Development with devtools'.

This screenshot displays the 'Data Visualization with ggplot2' cheat sheet. It includes sections for 'Basics', 'Geoms', 'Continuous X, Continuous Y', 'Two Variables', 'Three Variables', and 'Visualizing one variable'. The 'Geoms' section is expanded, showing a grid of icons representing different geometric shapes used in ggplot2, each with its name and a brief description of its parameters. Other sections provide summaries of functions for data manipulation and visualization.

- R basics
- ggplot2
- dplyr

Resources

Forum

The screenshot shows a Stack Overflow question titled "How to sort a dataframe by multiple column(s)?". The question was asked by Christopher DuBois on August 18, 2009, at 21:33. It has 14.7k views, 62 votes, and 104 answers. The question text asks how to sort a data frame by multiple columns, specifically mentioning sorting by column z (descending) then by column b (ascending). Below the question is a code snippet:

```
dd <- data.frame(b = factor(c("Hi", "Med", "Hi", "Low"),
  levels = c("Low", "Med", "Hi"), ordered = TRUE),
  x = c("A", "D", "A", "C"), y = c(8, 3, 9, 2),
  z = c(1, 1, 1, 2))
dd
  b x y z
1 Hi A 8 1
2 Med D 3 1
3 Hi A 9 1
4 Low C 9 2
```

Below the code are tags: r, sorting, dataframe, order, r-faq. The answer section starts with a comment from smcl suggesting the use of the `order()` function directly.

1471 You can use the `order()` function directly without resorting to add-on tools -- see this simpler answer which uses a trick right from the top of the `example(order)` code.

```
R> dd[with(dd, order(-z, b)), ]
  b x y z
4 Low C 9 2
2 Med D 3 1
1 Hi A 8 1
3 Hi A 9 1
```

Edit some 2+ years later: It was just asked how to do this by column index. The answer is to simply pass the desired sorting column(s) to the `order()` function:

```
R> dd[order(-dd[,4], dd[,1]), ]
  b x y z
4 Low C 9 2
```

- <https://stackoverflow.com/>
- <http://r-statistics.co/>
- <https://stats.stackexchange.com/>
- <https://www.r-bloggers.com/>

Let's get started

Setup

- Install R
- Install R studio

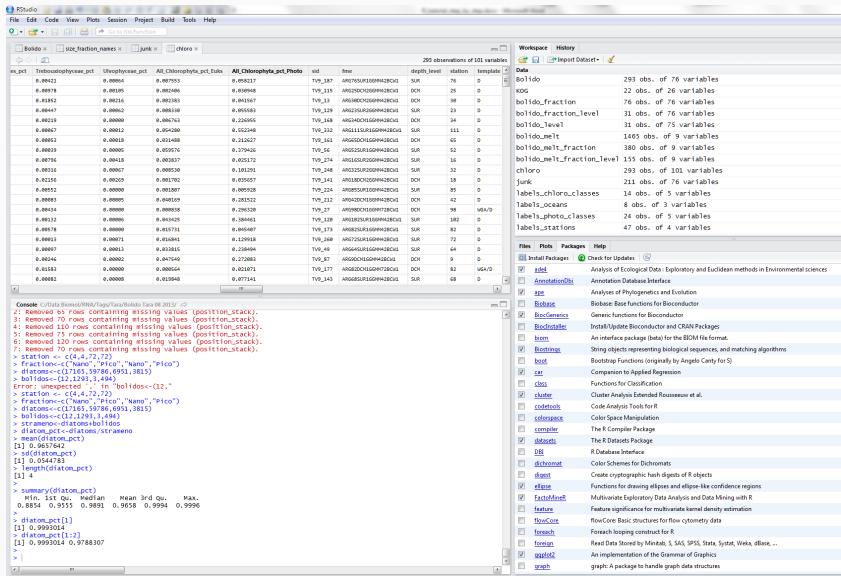
The screenshot shows an RStudio interface with several panes:

- File Explorer:** Shows the project structure with files like "Bolido.RData", "size_fraction_names.RData", "junk.RData", and "chloro.RData".
- Code Editor:** Displays R code for data processing, including reading CSV files, handling missing values, and calculating statistics.
- Data View:** Shows a data frame with 293 observations of 101 variables, including columns like es_pct, Trebouxiophyceae_pct, Ulvophyceae_pct, All_Chlorophyta_pct_Euks, All_Chlorophyta_pct_Photo, sid, fme, depth_level, station, template, and various TV9_ and ARG65SU16G99M42BCW1 entries.
- Environment View:** Shows the global environment with objects like bolido, kog, bolido_fraction, bolido_fraction_level, bolido_level, bolido_melt, bolido_melt_fraction, bolido_melt_fraction_level, chloro, junk, labels_chloro_classes, labels_oceans, labels_photo_classes, and labels_stations.
- Console:** Displays the R code and its output, including error messages and statistical summaries.
- Help:** Shows the help documentation for various packages.
- Project:** Shows the current project is "(None)".

Let's get started

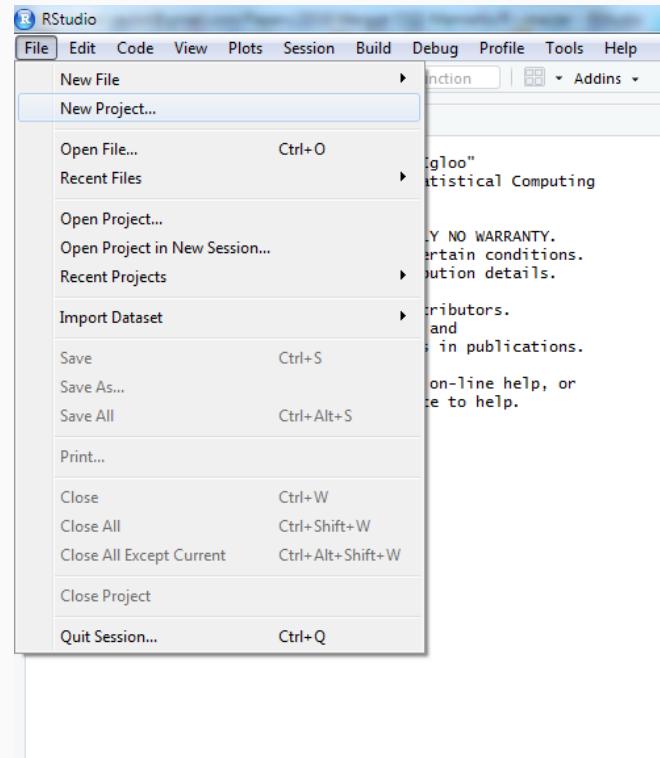
The R studio interface

- **Bottom left**
 - Console
 - **Top left**
 - File editor
 - **Top right**
 - Environment (i.e. R objects)
 - History
 - **Bottom right**
 - Files
 - Plots
 - Packages
 - Help



Let's get started

Create a new project



- Open R studio
- Create new project for the course in a new directory
 - e.g. Data Science Class

Let's get started

Your first script

Two ways to proceed

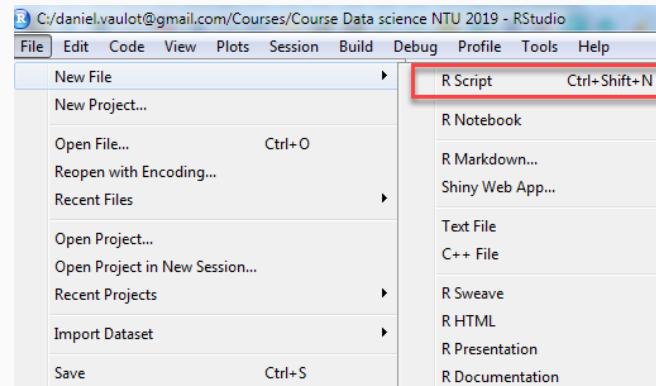
1. Type directly in command window

Let's get started

Your first script

Two ways to proceed

1. Type directly in command window
2. Create a new script



Type in script window, select and execute (CTRL-R)

The R language

Everything in R is an **object**

- Assignment done with `<-`

The R language

Everything in R is an **object**

- Assignment done with `<-`

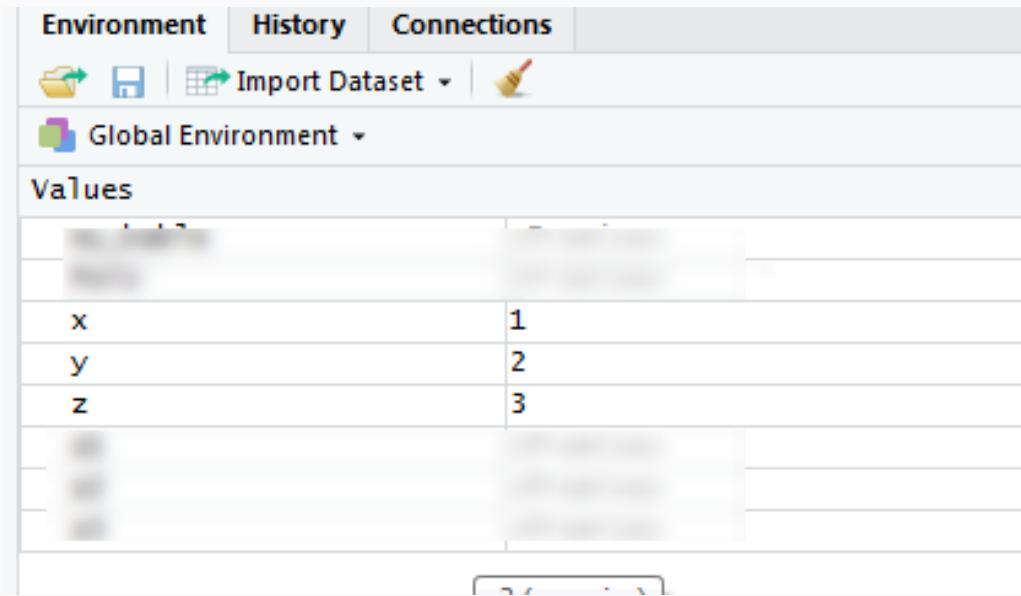
The R language

= can be used instead of <- but refrain from it (not good style)

The R language

= can be used instead of <- but refrain from it (not good style)

You can view the values of the objects in R-studio environment window (top-right)



The screenshot shows the RStudio interface with the 'Environment' tab selected. The 'Global Environment' dropdown is open, showing a list of variables: x, y, and z. The variable 'x' has a value of 1, 'y' has a value of 2, and 'z' has a value of 3.

Value	x	y	z
Type	1	2	3

The R language

R is **case sensitive**

The R language

R is **case sensitive**

The R language

Rules for naming objects

- Use
 - letters
 - numbers
 - the dot
 - the underscore (not the minus sign !)
- Start always with a letter
 - , , , are OK
 - , , are **not** OK

The R language

Use consistent naming

Five conventions

- alllowercase: e.g. adjustcolor
- period.separated: e.g. plot.new
- **underscore_separated**: e.g. numeric_version
- lowerCamelCase: e.g. addTaskCallback
- UpperCamelCase: e.g. SignatureMethod

Prefer third one, much more easy to read

- Use **names** for objects : **last_name**
- Use **verbs** for function : **build_name**
- Think about best order
 - e.g. prefer maybe **name_last** because then you can have name_first, name_full...
 - and you identify that all these objects are related to a name...

R objects

Data types

- **character**: "Daniel", "This is a course in R", 'Donald'
- **numeric**: 2, 15.5, 10e-3
- **integer**: 2L (the L tells R to store this as an integer)
- **date**: 2018-02-25
- **logical**: TRUE, FALSE
- **complex**: 1+4i (complex numbers with real and imaginary parts)

R objects

Data types

- **character**: "Daniel", "This is a course in R", 'Donald'
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- **integer**: 2L (the L tells R to store this as an integer)
- **date**: 2018-02-25
- **logical**: TRUE, FALSE
- **complex**: 1+4i (complex numbers with real and imaginary parts)
- **No data** "NA"
- **Not a number** "NaN" (e.g. division by zero)

R objects

Data structures

- **Vector**
- **List**
- **Matrix**
- **Data frames**
- **Function**

Vectors

The basic R structure is a vector:

Vectors

The basic R structure is a vector:

A vector can with a single element only

Vectors

The basic R structure is a vector:

A vector can with a single element only

Assign a value to a vector

Vectors

Assign several elements

Vectors

Assign several elements



Assign range



Vectors

Assign characters

Assign logical

Vectors

Access specific elements of a vector

First

Vectors

Access specific elements of a vector

First



Range



Vectors

Access specific elements of a vector

First



Range



Remove one element



Vectors

Determine object properties

Apply functions (we will come back to functions latter)

- **typeof()** - what is the object's data type (low-level)?
- **length()** - how long is it? What about two dimensional objects?

Vectors

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Vectors

Determine object properties

Apply functions (we will come back to functions latter)

- **typeof()** - what is the object's data type (low-level)?
- **length()** - how long is it? What about two dimensional objects?

What is the type and length of **PoTU** ?

Operators

Arithmetic Operators

Operator	Description
+	addition
-	subtraction
*	multiplication
/	division
^ or **	exponentiation
x %% y	modulus (x mod y) 5%%2 is 1
x %/% y	integer division 5%/%2 is 2

Operators

Arithmetic Operators

We are performing vector operations !

Operators

Arithmetic Operators

Vector one element



Operators

Arithmetic Operators

Vector several elements



Operators

Arithmetic Operators

Vector several elements

- Several instructions on same line separate by ;
- The hastag # indicate a comment -> Use heavily to document your code

Operators

Arithmetic Operators

Vector several elements

- Several instructions on same line separate by ;
- The hastag # indicate a comment -> Use heavily to document your code

Use the other operators

Operators

Arithmetic Operators

What happens when the vectors have different number of elements ?



Operators

Arithmetic Operators

What happens when the vectors have different number of elements ?



Operators

Arithmetic Operators

What happens when the vectors have different number of elements ?

Equivalent to

The recycling rule...

Operators

Can we add logical ?

Operators

Can we add logical ?

Operators

Can we add logical ?

It does not give an error but...

The resulting variable is transformed to a **numeric**

| How you would show that ?

Operators

Can we add logical ?

It does not give an error but...

The resulting variable is transformed to a **numeric**

How you would show that ?

Operators

Logical Operators

Operator	Description
<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to
==	exactly equal to
!=	not equal to
!x	Not x
x y	x OR y
x & y	x AND y
isTRUE(x)	test if X is TRUE

Operators

Logical Operators



Operators

Logical Operators

Do not mix

- == which is logical operator
- = which is assignment

Operators

Can we add characters ?



Operators

Can we add characters ?

Generates an error

Operators

Can we add characters ?

Generates an error

What can we do ?

Functions

Function perform specific task on objects

- e.g. to concatinate strings we use **paste0()**

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Function perform specific task on objects

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Function perform specific task on objects

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- Functions take **arguments** and return an object called **result**
- To know the arguments use ?



Functions

Function perform specific task on objects

- e.g. to concatinate strings we use **paste0()**

- Functions take **arguments** and return an object called **result**
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What happened ?

Functions

Function perform specific task on objects

- e.g. to concatinate strings we use **paste0()**

- Functions take **arguments** and return an object called **result**
- To know the arguments use ?

What happened ?

- Can go directly to Help panel and type function name

Functions

Help

paste {base} ←

R Documentation

Concatenate Strings

Description

Concatenate vectors after converting to character.

Usage

```
paste(..., sep = " ", collapse = NULL)
paste0(..., collapse = NULL)
```

Arguments ←

... one or more R objects, to be converted to character vectors.

sep a character string to separate the terms. Not [NA_character_](#).

collapse an optional character string to separate the results. Not [NA_character_](#).

Details

`paste` converts its arguments (*via* [as.character](#)) to character strings, and concatenates them (separating them by the string given by `sep`). If the arguments are vectors, they are concatenated term-by-term to give a character vector result. Vector arguments are recycled as needed, with zero-length arguments being recycled to "".

Note that `paste()` coerces [NA_character_](#), the character missing value, to "NA" which may seem undesirable, e.g., when pasting two character vectors, or very desirable, e.g. in `paste("the value of p is ", p)`.

`paste0(..., collapse)` is equivalent to `paste(..., sep = "", collapse)`, slightly more efficiently.

If a value is specified for `collapse`, the values in the result are then concatenated into a single string, with the elements being separated by the value of `collapse`.

Functions

Help

Examples

```
## When passing a single vector, paste0 and paste work like as.character.
paste0(1:12)
paste(1:12)      # same
as.character(1:12) # same

## If you pass several vectors to paste0, they are concatenated in a
## vectorized way.
(nth <- paste0(1:12, c("st", "nd", "rd", rep("th", 9)))))

## paste works the same, but separates each input with a space.
## Notice that the recycling rules make every input as long as the longest input.
paste(month.abb, "is the", nth, "month of the year.")
paste(month.abb, letters)

## You can change the separator by passing a sep argument
## which can be multiple characters.
paste(month.abb, "is the", nth, "month of the year.", sep = "_*_")

## To collapse the output into a single string, pass a collapse argument.
paste0(nth, collapse = ", ")

## For inputs of length 1, use the sep argument rather than collapse
paste("1st", "2nd", "3rd", collapse = ", ") # probably not what you wanted
paste("1st", "2nd", "3rd", sep = ", ")

## You can combine the sep and collapse arguments together.
paste(month.abb, nth, sep = ": ", collapse = "; ")

## Using paste() in combination with strwrap() can be useful
## for dealing with long strings.
(title <- paste(strwrap(
  "Stopping distance of cars (ft) vs. speed (mph) from Ezekiel (1930)",
  width = 30), collapse = "\n")))
plot(dist ~ speed, cars, main = title)
```

Functions

Getting what you want

We would like to write "Donald Trump" but we have :

Can you read the help and suggest a change in the way we call the function ?

Functions

Getting what you want

We would like to write "Donald Trump" but we have :

Can you read the help and suggest a change in the way we call the function ?

Functions

Write your own function

Functions

Write your own function

| If you write 3 times the same piece of code write a function...

Functions

Examples of functions

Most of the time you do not have to write functions because someone has already written one for what you want to do...

- Sum

Functions

Examples of functions

Most of the time you do not have to write functions because someone has already written one for what you want to do...

- Sum



- Normal distribution



Functions

Statistics



Functions

Statistics

- Is the mean close to expected mean ?
- What can be done ?

Functions

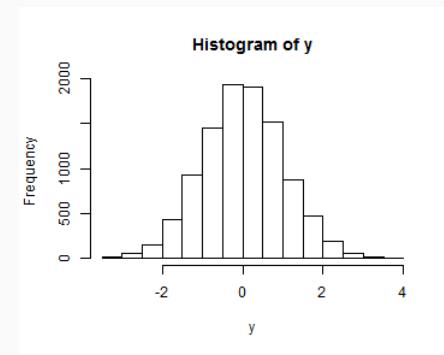
Sample more points... 10,000 instead of 100



Functions

Plot

Histogram

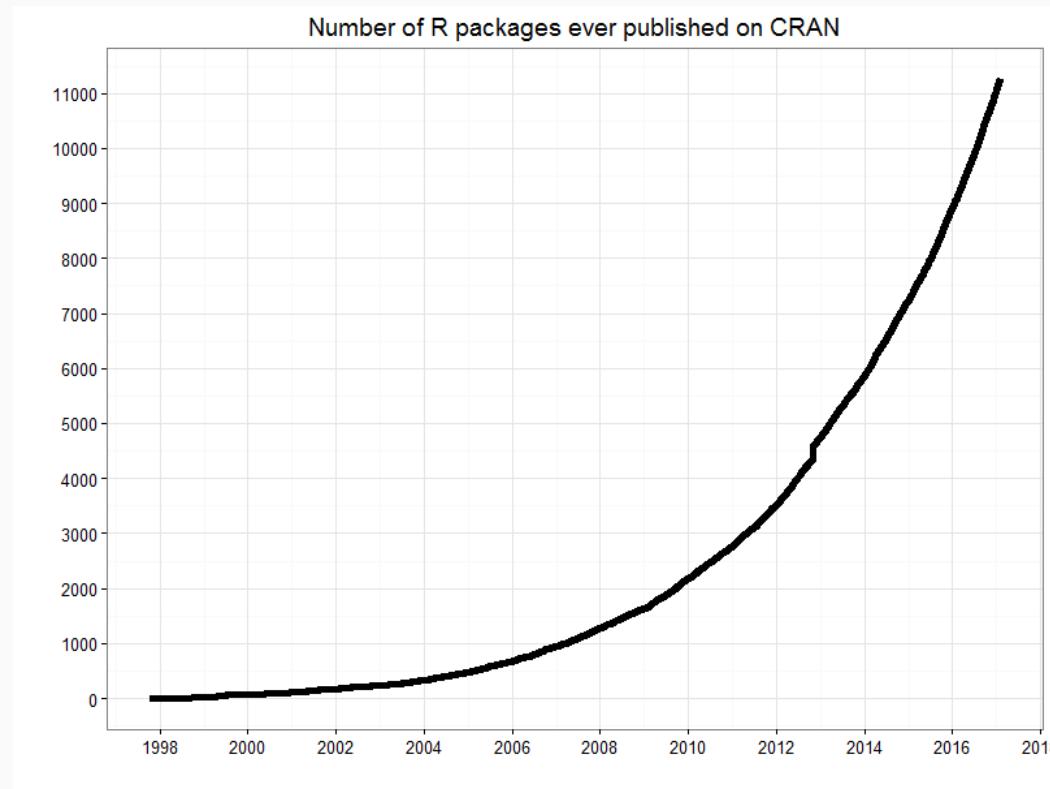


- What is this "library()"

Packages

Packages are set of functions that have a common goal

They are really the strength of R

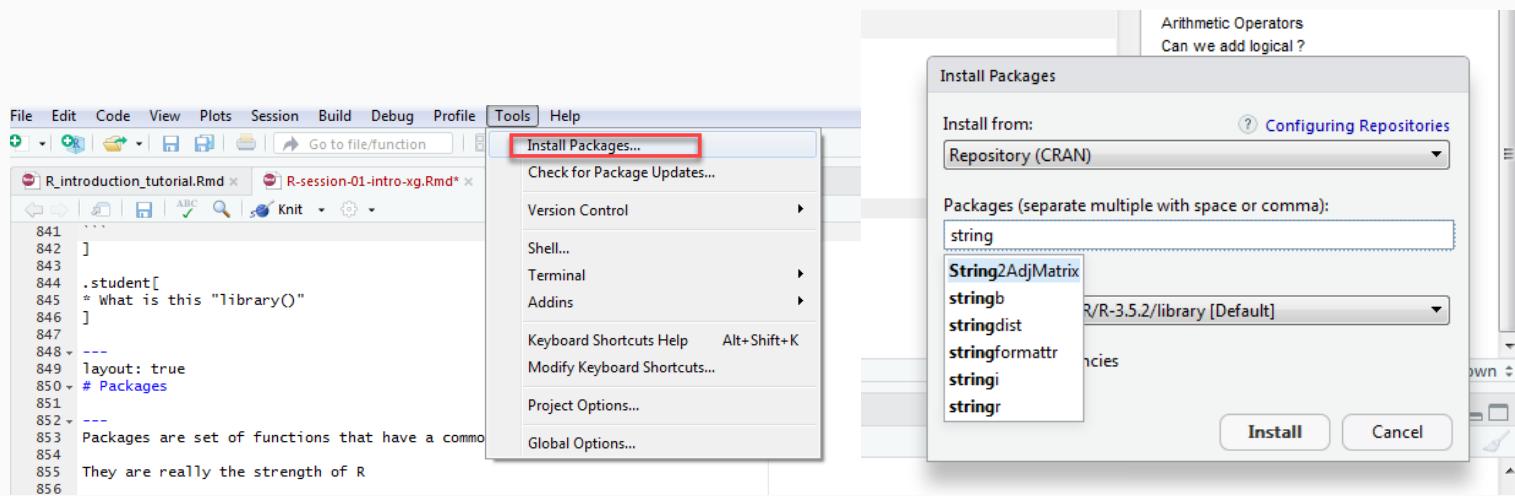


And these are only the "official" packages. You can find more on GitHub

Packages

Installing a package

Download on your computer the package you need



Install package **stringr** (to manipulate strings of characters)

Packages

Using a package

To use functions from the package

- use the syntax



Packages

Using a package

To use functions from the package

- use the syntax



- load the package with the library function



Packages

Using a package

To use functions from the package

- use the syntax

```
library(ggplot2)
```

- load the package with the library function

```
library(ggplot2)
```

| Sometimes functions from different libraries have similar names

Packages

List installed packages

Name	Description	Version
System Library		
<input type="checkbox"/> abind	Combine Multidimensional Arrays	1.4-5
<input type="checkbox"/> addinslist	Discover and Install Useful RStudio Addins	0.2
<input type="checkbox"/> ade4	Analysis of Ecological Data: Exploratory and Euclidean Methods in Environmental Sciences	1.7-13
<input type="checkbox"/> AnnotationDbi	Annotation Database Interface	1.42.1
<input type="checkbox"/> anytime	Anything to 'POSIXct' or 'Date' Converter	0.3.3
<input type="checkbox"/> ape	Analyses of Phylogenetics and Evolution	5.2
<input type="checkbox"/> assertthat	Easy Pre and Post Assertions	0.2.0
<input type="checkbox"/> backports	Reimplementations of Functions Introduced Since R-3.0.0	11.3
<input type="checkbox"/> base64enc	Tools for base64 encoding	0.1-3
<input type="checkbox"/> BH	Boost C++ Header Files	1.66.0-1
<input type="checkbox"/> bib2academic	Convert BibTex to Markdown for the Hugo Academic Theme	0.1.1.99
<input type="checkbox"/> bibtex	Bibtex Parser	0.4.2
<input type="checkbox"/> binb	'binb' is not 'Beamer'	0.0.3
<input type="checkbox"/> bindr	Parametrized Active Bindings	0.1.1
<input type="checkbox"/> bindrcpp	An 'Rcpp' Interface to Active Bindings	0.2.2
<input type="checkbox"/> Biobase	Biobase: Base functions for Bioconductor	2.40.0
<input type="checkbox"/> BiocGenerics	S4 generic functions for Bioconductor	0.26.0
<input type="checkbox"/> BiocInstaller	Install/Update Bioconductor, CRAN, and github Packages	1.30.0
<input type="checkbox"/> BiocManager	Access the Bioconductor Project Package Repository	1.30.4
<input type="checkbox"/> BiocParallel	Bioconductor facilities for parallel evaluation	1.14.2
<input type="checkbox"/> BiocVersion	Set the appropriate version of Bioconductor packages	3.8.0
<input type="checkbox"/> biofiles	An Interface for GenBank/GenPept Flat Files	1.0.0
<input type="checkbox"/> biomaRt	Interface to BioMart databases (e.g. Ensembl, COSMIC, Wormbase and Gramene)	2.36.1

Other objects

- List
- Matrix
- Factors
- **Data frames**

Data frames

What is it ?

- Table mixing different types of columns (an Excel table...)
- However within a column all values are similar, e.g. numeric, logical, character

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- Table mixing different types of columns (an Excel table...)
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- We will not get into the factor at this time, why we set 
- Notice the recycling rule ?

Data frames

Useful functions



Data frames

Useful functions



Data frames

Access specific column

- Use `[]` notation

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Access specific column

- Use `[]` notation

```
df[0]
```

- Use the `[,]` notation

```
df[0:1]
```

```
df[0:1]
```

Data frames

Access specific value

- Use `[]` notation

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Access specific value

- Use `[]` notation

`df[0]`

`df[0][0]`

- Use the `[,]` notation

`df[0][0]`

`df[0][0][0]`

Data frames

Filter the data

| Select lines for which the label is c

Data frames

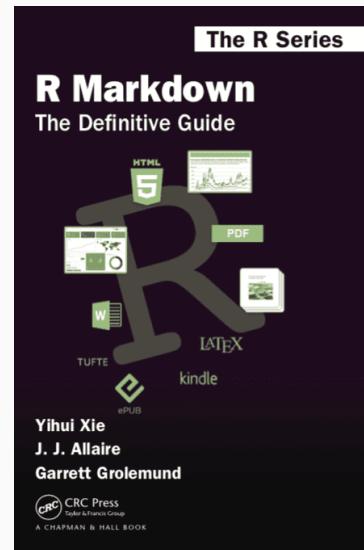
Filter the data

| Select lines for which the label is c

Next time: Markdown

What you will learn :

- Mix text, R code and R output in a single document
- Produce documents as HTML, pdf or even Word from the same template



- Please install the following packages and their dependencies
 - rmarkdown (will install also knitr)
 - tinytex (Latex)
- Read the installation instruction : <https://bookdown.org/yihui/rmarkdown/installation.html>
- Have a look at the book <https://bookdown.org/yihui/rmarkdown>