Developing an R package: a tutorial

The essentials to write your package

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Getting started

R packages to help you create R packages

- `usethis`: to automate package and project creation/configuration/setup
- `devtools`: complete collection of development tools
- `roxygen2`: to document your code and generate help pages
- `lintr` to review your code ("adherence to a given style, syntax errors and possible semantic issues")

Note

- If you are not working from Rstudio, you will not benefit from all its functionality but it is possible to do everything from the R command line.
- In R: `pkg::fun()` refers to the function `fun()` defined in the package `pkg`.

Setup your environment

- install R packages providing development tools[1]: `devtools`, `usethis`, `roxygen2`, `lintr`

```
install.packages(c("devtools", "usethis", "roxygen2", "lintr"))
```

- for a more complete setup: see `https://r-pkgs.org/setup.html`

[1] `devtools` may require to install additional system libraries depending on your OS, a quick search on the web will help you if you encounter any error.

Create a package

- Initialize a package template:

```
usethis::create_package("mypkg")
```

- Directly from Rstudio (equivalent): File - New Project - New directory - R package
- **Attention**: if you want to initialize an R package without initializing an Rstudio project[2], use:

```
usethis::create_package("mypkg1", rstudio = FALSE, open = FALSE)
```

[2] e.g. because you want to create your package in an existing Rstudio project, or you don't use Rstudio

Rstudio project

- Project specific configuration, workspace, history
- Isolated R environment for the project
- RStudio project management feature (e.g. `git` management)
- More information regarding Rstudio project at `https://r-pkgs.org/workflows101.html#projects`

The “old-fashion” built-in R function to create package

(for more advanced users)

```
## two functions and two "data sets" :
f <- function(x, y) x+y
g <- function(x, y) x-y
d <- data.frame(a = 1, b = 2)
e <- rnorm(1000)
## automatically "fill" the package
package.skeleton(list = c("f","g","d","e"), name = "mypkg2")
```

Attention: using `package.skeleton()` creates a package that is not ready “out-of-the-box”, you will have to edit and fix the help pages (e.g. by using `roxygen2`, c.f. later).

Naming your package

- three formal requirements:
  - "The name can only consist of letters, numbers, and periods, i.e., .."
  - "It must start with a letter."
  - "It cannot end with a period."
- Advice: use a catchy name or acronym with a link to your package functionality
- Check if the name you chose is not already used to name a package with the `available` package
- More details on naming convention at `https://r-pkgs.org/workflows101.html#naming`

Always choose a license!

- It governs the possibility to use, modify or redistribute a software
- It helps to identify clear authorship/copyright[3]
- Without a license: fuzzy and unclear (generally "all rights reserved" but you are never sure[4])

[3] depending on legal consideration, varying from one country to another
[4] "Was it forgotten or a deliberate choice?"

Different types of license

- Use a software-specific license for software and a content-specific license for data[5]
- **Recommandation:** favor free[6] and open-source licenses (versus proprietary or closed licenses), either **permissive** or **with copyleft**

[5] e.g. Creative Commons license are for contents and not for software
[6] as in "*libre*" and not as in "gratis" (proprietary software can be gratis)

How to choose a license?

See `https://r-pkgs.org/license.html` (and functions `usethis::use_XX_license()`[7] from the `usethis` package)

Additional resources on software license:

- `https://choosealicense.com`
- `https://opensource.org/licenses`
- `https://www.gnu.org/licenses/license-list.en.html`

[7] e.g. `use_mit_license()` or `use_gpl_license()`

R package structure

Files and sub-directories (1)

Empty package:

```
mypkg
+-- DESCRIPTION
+-- NAMESPACE
+-- R
    +-- (empty)
```

More complete package:

```
mypkg2
+-- data
|   +-- d.rda
|   +-- e.rda
+-- DESCRIPTION
+-- man
|   +-- d.Rd
|   +-- e.Rd
|   +-- f.Rd
|   +-- g.Rd
|   +-- mypkg2-package.Rd
+-- NAMESPACE
+-- R
    +-- f.R
    +-- g.R
```

Files and sub-directories (2)

- Meta-data files: `DESCRIPTION` and `NAMESPACE` (c.f. later)
- `R` sub-directory: where to store R source files implementing the function included in your package
- `man` sub-directory: where to store the mandatory help pages
- `src` sub-directory (optional): where to store code to be compiled (written in other languages, not in R) included in your package
- `data` sub-directory (optional): where to store data files attached to your package

R source code (1)

The `R` sub-directory:

- Write your code as functions
- Save your code implementing functions in R source code files[8]
- Group related functions in the same file
- Create and edit source code files manually or with `usethis::use_r("name")`
- See R code formatting convention
- Check your code formatting with the `lintr` package and `lintr::lint_package()`

[8] with `.R` extension

R source code (2)

Debugging-friendly advice:

- Avoid very long functions (split long functions into several shorter ones)
- Factorize re-used code into specific functions (avoid copying-pasting chunk of codes several time)

From R scripts to R functions

Scripting:

```
# data
a = 7
b = 3
# intermediate operations
tmp1 = 2 * a
tmp2 = b / 6
# final computations
c = tmp1 + tmp2
```

Objective: simplify your code by "hiding" intermediate steps into a function

Implementing functions in your package:

```
myFun <- function(x, y) {
    tmp1 = 2 * x
    tmp2 = y / 6
    return(tmp1 + tmp2)
}
```

In a script using your package:

```
library(mypkg)
# data
a = 7
b = 3
# computations
c = myFun(a,b)
d = myFun(10, 3)
```

Meta-data files

- `DESCRIPTION`: a structured text file giving information about your package (title, description, authors, license, dependencies, etc.)
- `NAMESPACE`: a text file indicating[9] names of R objects (functions, datasets) that are imported in your package (from other packages), and/or exported by your package (to be usable when you install your package)

[9] and/or the name of the dynamic library related to compiled codes to be used in your package if relevant

DESCRIPTION file (1)

- Can be edited manually, or created and modified with `usethis::use_description()` and other `usethis::use_XXX()`
- Setup your package requirements and dependencies (c.f. later)
- More details at `https://r-pkgs.org/description.html`
- **Important**: package versioning

DESCRIPTION file (2)

Example:

```
Package: mypkg
Title: What the Package Does (One Line, Title Case)
Version: 0.0.0.9000
Authors@R:
    person(given = "First",
           family = "Last",
           role = c("aut", "cre"),
           email = "first.last@example.com",
           comment = c(ORCID = "YOUR-ORCID-ID"))
Description: What the package does (one paragraph).
License: `use_mit_license()`, `use_gpl3_license()` or friends to pick a
    license
Encoding: UTF-8
LazyData: true
Roxygen: list(markdown = TRUE)
RoxygenNote: 7.1.1
```

NAMESPACE file

Can be created with `usethis::use_namespace()`, or edited manually, or (better) **automatically updated** thanks to `roxygen2` inline documentation (c.f. later)

Example:

```
# Generated by roxygen2: do not edit by hand

importFrom(stats, runif)
export(my_function)
```

Data in your package

- Binary R data file (`.Rda` or `.Rdata` file) can be stored in the `data` sub-directory
- Raw data can be stored in the `inst` sub-directory and found after installation with the `system.file()` function[10] (**important**: you do not need to search for the `inst` sub-directory, just anything in it)

```
system.file(filename, package = "mypkg")
system.file(dirname, package = "mypkg")
system.file(package = "mypkg") # package root directory
```

- More at `https://r-pkgs.org/data.html`

[10] any other file or sub-directory shipped with a package can be found likewise

help/man pages

- Available with the R commands `?function_name` (e.g. `?rnorm`) or `help(function_name)`
- Content:
  - usage description and functioning details
  - input arguments and return value description
  - function authorship
  - link to related functions
  - bibliographic reference
  - minimum working examples
- Encoded in `.Rd` files in the `man` sub-directory: structured text files with a specific syntax

Document your code and generate help page at once

- Avoid creating and editing `.Rd` file manually (laborious)
- Good practice: **DOCUMENT YOUR CODE** (with inline comments) for other and YOUR FUTURE SELF
- Inline code documentation with `roxygen2` based on tags identified with `@`

Document your code and your package with roxygen2 (1)

Inline code documentation (identified with `#'` comment characters):

```
#' Add together two numbers
#'
#' @param x A number
#' @param y A number
#' @return The sum of \code{x} and \code{y}
#' @author Anonymous
#' @examples
#' add(1, 1)
#' add(10, 1)
#' @export
add <- function(x, y) {
  x + y
}
```

Corresponding `.Rd` file:

```
% Generated by roxygen2 (3.2.0): do not edit by hand
\name{add}
\alias{add}
\title{Add together two numbers}
\usage{
add(x, y)
}
\arguments{
  \item{x}{A number}

  \item{y}{A number}
}
\value{
The sum of \code{x} and \code{y}
}
\description{
Add together two numbers
}
\examples{
add(1, 1)
add(10, 1)
}
```

Document your code and your package with roxygen2 (2)

- **Generate the man pages** (and update `NAMESPACE` file) with `devtools::document()` or in Rstudio interface (Build panel - More - Document[11])
- Identify exported functions[12] with the tag `@export` (automatically added to the `NAMESPACE` file)
- Identify imported functions[13] with the tag `@importFrom package function` (automatically added to the `NAMESPACE` file)

[11] keyboard shortcut: `CTRL + SHIFT + D`
[12] your functions that will be available to users
[13] functions from other packages that you use

Document your code and your package with roxygen2 (4)

More complete example:

```
#' A function to do some stuff
#' @description
#' Do some stuff
#' @details
#' I do the stuff in a complicated way.
#' @param x A number
#' @param y A number
#' @return what the function is returning
#' @author Someone
#' @importFrom stats rnorm
#' @seealso [mypkg::my_other_fun()]
#' @examples
#' add(1, 1)
#' add(10, 1)
#' @export
my_fun <- function(x, y) {
    tmp = rnorm(7)
    ...
}
```

Tips:

- add `Roxygen: list(markdown = TRUE)` to the `DESCRIPTION` file to use markdown syntax in documentation chunks or run `usethis::use_roxygen_md()` (possible conversion from existing standard `roxygen2` syntax with `roxygen2md` package)

- internal functions (only used by other functions in your package, and not to be available for users) can be tagged with `@keywords internal` and (and without `@export` tag)

Document your code and your package with roxygen2 (5)

References:

- More details at `https://r-pkgs.org/man.html`
- `roxygen2` cheat sheet
- Help to format your documentation chunks at `https://roxygen2.r-lib.org/articles/rd-formatting.html` and `https://roxygen2.r-lib.org/articles/rd.html`

Manage your dependencies (1)

Several fields in the `DESCRIPTION` file:

- `Depends: R (>= 3.1.0)`: the minimal R version required by your package
- `Imports: ...`: packages (with optional minimal versions) required for your package to work
- `Suggests: ...` (optional): additional packages (with optional minimal versions) that are not necessary for your package to work but that would improve the user experience with your package
- Additional (optional) fields: `LinkingTo` (useful if external codes needs to be compiled and linked against external library), `OS_type: unix` (to specify which OS are supported[14]), `SystemRequirements: C++11` (to specify additional external system requirements[15])

[14] here it means that Windows is not supported

[15] here a C++ compiler compatible with C++11 standard

Manage your dependencies (2)

Example:

```
Depends: R (>= 3.1.0)
LinkingTo:
    Rcpp (>= 1.0.1),
    RcppEigen (>= 0.3.3.5)
Imports:
    Rcpp (>= 1.0.1),
    openssl
Suggests:
    testthat (>= 2.1.0)
SystemRequirements: C++11
```

Manage your dependencies (3)

- `usethis::use_package()` to update `Imports` or `Suggests` fields
- More details at `https://r-pkgs.org/description.html#dependencies`

Manage your dependencies (4)

Imported objects (functions, dataset) should be declared in the `NAMESPACE` file

$\rightarrow$ automatically manage thanks to `roxygen2`

Other (optional) files and sub-directories (1)

- `README`[16], `LICENSE` (depending on the license your choose), `COPYRIGHT` (to detail authorship, copyright associated to the package content)
- `src`: source codes to be compiled (c.f. later)
- `inst` to store additional files (e.g. required for tests, vignettes, etc.), raw data, etc.
- `tests` to write automatic tests (c.f. later)

[16] possible format: `.md` or `.Rmd` (Rmarkdown), see `usethis::use_readme_md()` or `usethis::use_readme_rmd()`

Other (optional) files and sub-directories (2)

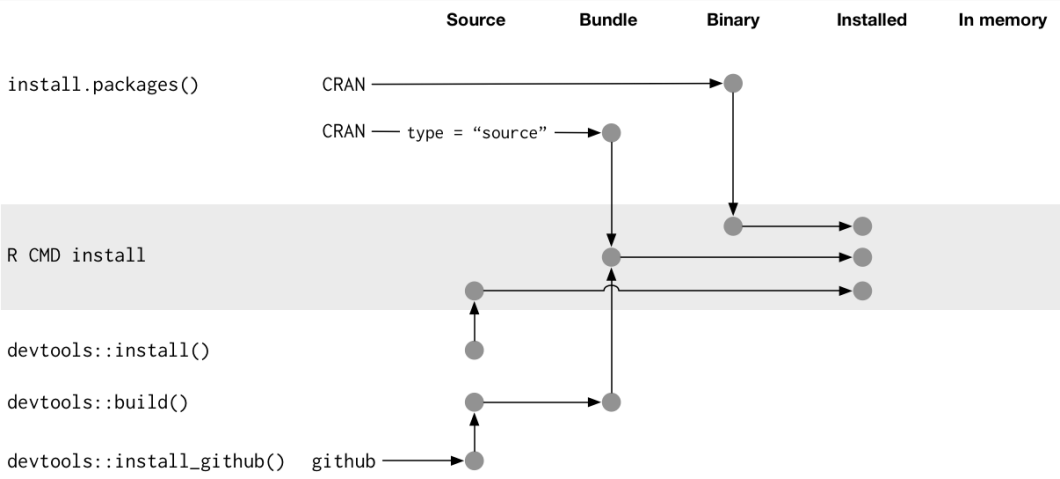
- More details at `https://r-pkgs.org/misc.html`
- Non-standard files can be present in your project but not shipped in your package: you should create a `.Rbuildignore` file

Workflow

Package state

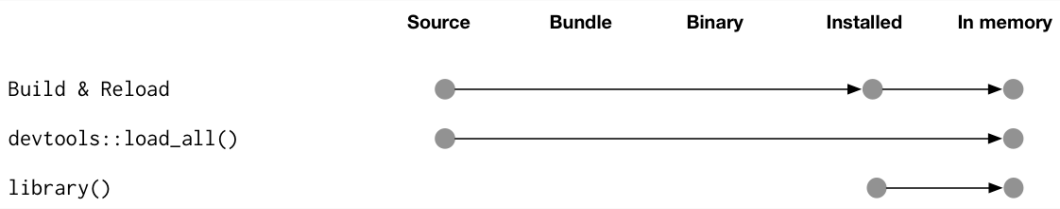
- **source:** what you are writing
- **bundled:** a single-file compressed version containing your package source (how package are shipped by the CRAN for installation)
- **binary:** a single-file binary version of your package containing compiled library (if relevant), mainly used by the CRAN to ship package for installation on Windows
- **installed:** available as a library on your system, i.e. the package files and sub-directories (along with library files if compilation was needed) have been copied somewhere on your computer
- **in-memory:** loaded and ready to use (after calling `library(mypkg)`)

Dev workflow (building and installing a package)



Ref: https://r-pkgs.org/package-structure-state.html

Dev workflow (loading a package)



Ref: https://r-pkgs.org/workflows101.html#load-all

load

Load your package for a test drive (manual test) without building/installing it

- `devtools::load_all()`
- in Rstudio interface (Build panel - More - Load all[17])

Development cycle: write code, test it, correct your code, test it, etc.

[17] keyboard shortcut: `CTRL + SHIFT + L`

document (reminder)

Generate the man pages (and update `NAMESPACE` file)

- `devtools::document()`
- in Rstudio interface (Build panel More - Document[18])

[18] keyboard shortcut: `CTRL + SHIFT + D`

build

Prepare your package for installation (and distribution)

- `devtools::build()`
- in Rstudio interface (Build panel - More - "Build source package")
- R built-in shell command line tool[19]: `R CMD build mypkg`
- Create a `.tar.gz` archive files containing the sources (or a `.zip` file if you use "Build binary package") ready for installation

[19] `R.exe` on Windows

check

Verify that your **package is functional** and that your **package structure is correct**

- `devtools::check()`
- in Rstudio interface (Build panel - Check)
- R built-in shell command line tool[20]: `R CMD check mypkg_1.0.0.tag.gz`
- **Verbose output**: often clearly identify problems (and suggest fixes)
- More details at `https://r-pkgs.org/r-cmd-check.html`

[20] `R.exe` on Windows

usethis (exhaustive tour)

See `https://usethis.r-lib.org/reference/index.html`

Possible to write every files manually for more advanced users.

devtools (exhaustive tour)

See `https://devtools.r-lib.org/reference/index.html`

(`devtools` exports several functions from other development-oriented packages)