MONASH University

MONASH BUSINESS SCHOOL

ETC4500/ETC5450
Advanced R programming

Week 5: Reactive programming with targets and renv

Outline

1. Reactive programming
2. Shiny
3. targets
4. Reproducible environments

Outline

Regular (imperative) programming

Consider how code is usually evaluated…

```
a <- 1
b <- 2
x <- a + b
x
```

What is `x`?

```
a <- -1
x
```

What is `x` now?

Regular (imperative) programming

Predictable programming

All programming we've seen so far evaluates code in sequential order, line by line.

Since `x` was not re-evaluated, its value stays the same even when its inputs have changed.

Reactive programming

Within a reactive programming paradigm, objects *react* to changes in their inputs and automatically update their value!

Reactive programming

Within a reactive programming paradigm, objects *react* to changes in their inputs and automatically update their value!

Disclaimer

Reactive programming is a broad and diverse paradigm, we'll focus only on the basic concepts and how they apply in shiny applications.

Reactive programming

We can implement *reactivity* with functions & environments.

```
library(rlang)
react <- function(e) new_function(alist(), expr(eval(!!enexpr(e))))
```

We'll learn how this function works later (metaprogramming).

Reactive programming is also smarter about *'invalidation'*, results are **cached and reused** if the inputs aren't changed.

Reactive programming

How does reactive programming differ?

```
a <- 1
b <- 2
y <- react(a + b)
y()
```

What is `y`?

```
a <- -1
y()
```

What is `y` now?

Reactive programming

(Un)predictable programming?

Reactive programming can be disorienting!

Reactive objects *invalidate* whenever their inputs change, and so its value will be recalculated and stay up-to-date.

Reactive programming

Your turn!

```
a <- 1
b <- 2
y <- react(a + b)
y()
```

When was `a + b` evaluated?

How does this differ from ordinary (imperative) code?

Imperative and declarative programming

Imperative programming

- Specific commands are carried out immediately.
- Usually direct and exact instructions.
- e.g. read in data from this file.

Declarative programming

- Specific commands are carried out when needed.
- Expresses higher order goals / constraints.
- e.g. make sure this dataset is up to date every time I see it.

Imperative and declarative programming

Mastering Shiny: Chapter 3 (Basic Reactivity)

With imperative code you say “Make me a sandwich”.

With declarative code you say “Ensure there is a sandwich in the refrigerator whenever I look inside of it”.

*Imperative code is **assertive**;*
*declarative code is **passive-aggressive**.*

Use cases for reactive programming

! Use-less cases

This paradigm is rarely needed or used in R for data analysis.

Useful cases

Reactive programming is useful for developing user applications (including web apps!).

In R, the shiny package uses reactive programming for writing app interactivity.

Outline

A shiny app

Most shiny apps are organised into several files.

- `ui.R`: The specification of the user interface
- `server.R`: The reactive code that defines app behaviour
- `global.R`: Static global objects used across app
- `www/`: Folder for your web data (images, css, js, etc.)

Simple apps can consist of only an `app.R` script.

Hello *shiny*!

Follow along!

Create a shiny app. Save this code as `app.R`.

```
library(shiny)
ui <- fluidPage(
  textInput("name", "Enter your name: "),
  textOutput("greeting")
)
server <- function(input, output, session) {
  output$greeting <- renderText({
    sprintf("Hello %s", input$name)
  })
}
shinyApp(ui, server)
```

Hello *shiny*!

Follow along!

Launch the app by clicking **Run App**.

Use the text input field and see how the webpage changes.

Look at the server code to see how it ‘reacts’.

Shiny reactivity

Reactivity in shiny comprises of:

- Reactive **sources** (inputs):

  UI inputs `input*()` and values `reactiveValues()`

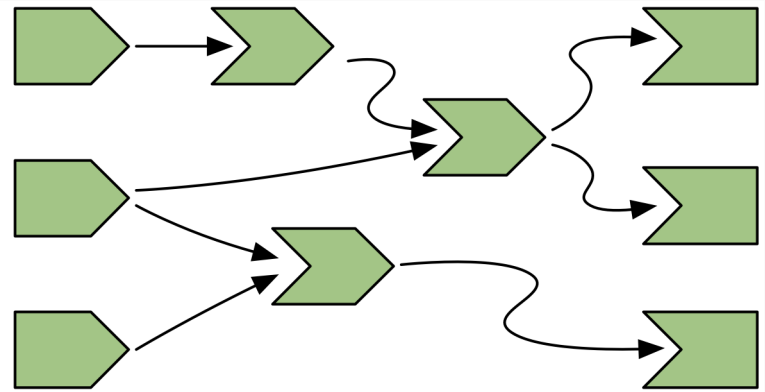
- Reactive **conductors** (intermediates):

  Expressions `reactive()` and events `eventReactive()`

- Reactive **endpoints** (results):

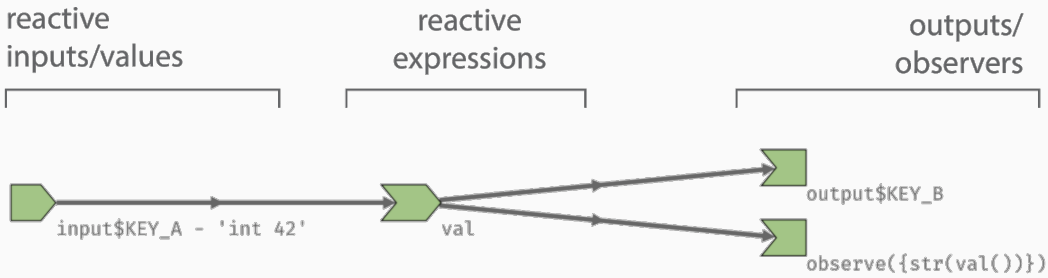
  UI outputs `render*()` and side-effects `observe()`

Reactive graphs



The reactivity of an app can be visualised with a graph.

Reactive graphs



The graph shows relationships between reactive elements.

reactlog

The reactlog package allows you to visualise an app's **reactive graph**.

To **enable logging** of an app's behaviour, run:

```
reactlog::reactlog_enable()
```

Then **start, use, and stop your app** to fill the log.

View the log with:

```
shiny::reactlogShow()
```

Or while your Shiny app is running, press the key combination Ctrl+F3 (Mac: Cmd+F3) to see the reactive log.

Hello *reactlog*!

Follow along!

Create a reactive log of the *hello shiny* app.

Start reactlog, then open the app and enter your name.

Close the app and view the log, see how the app reacts to changes to the input text.

Reactive expressions

Reactive expressions are used in the shiny server as intermediate calculations.

They are expressions wrapped with `reactive()`.

For example:

```
simulation <- reactive(rnorm(input$n_samples))
```

Reactive expressions

Reactive expressions are used in the shiny server as intermediate calculations.

They are expressions wrapped with `reactive()`.

For example:

```
simulation <- reactive(rnorm(input$n_samples))
```

The up-to-date value is obtained with `simulation()`.

Whenever the input ID `n_samples` changes, the reactive expression `simulation` *invalidates*.

Reactive expressions

Follow along!

Use a reactive expression to convert the name to ALLCAPS.

Look at the reactive graph and see how it changes.

Preventing reactivity

Equally important to telling shiny **how** to react to changes, is describing **when** reactions should (not) occur.

Preventing reactivity

Equally important to telling shiny **how** to react to changes, is describing **when** reactions should (not) occur.

The most useful way to prevent reactivity is with `req()`.

It is similar to `stop()`, silently ending the reactive chain.

`req()` *'requires'* inputs to be 'truthy' (not FALSE or empty).

Preventing reactivity

Follow along!

Use `req()` to prevent reactivity until text is entered.

Update `req()` to require at least 3 characters inputted.

Preventing reactivity

Other ways reactivity might be prevented include:

- Event reactivity
  - `eventReactive(rnorm(input$n_samples), input$go)`
  - `observeEvent(input$go, message("Go!"))`
- Rate limiting
  - `throttle(reactive())`: limits update frequency
  - `debounce(reactive())`: waits for changes to stop

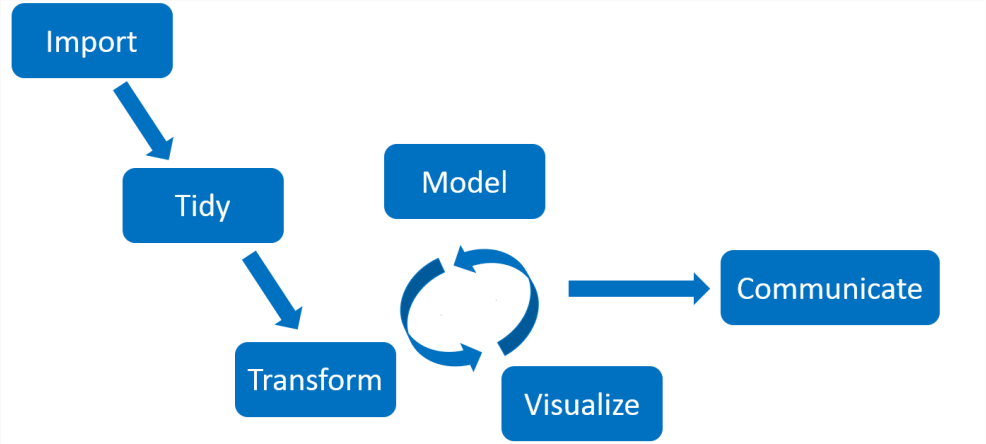
Outline

targets: reproducible computation at scale

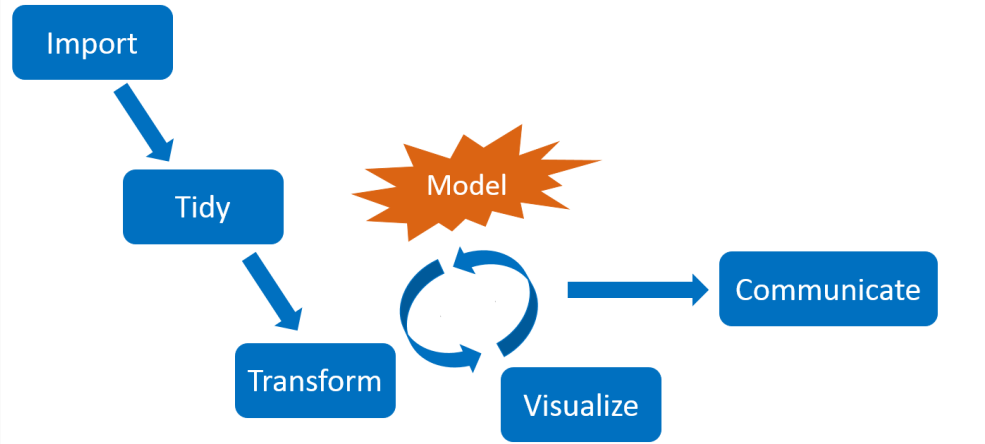
- Supports a clean, modular, function-oriented programming style.
- Learns how your pipeline fits together.
- Runs only the necessary computation.
- Abstracts files as R objects.
- Similar to Makefiles, but with R functions.

Some images from https://wlandau.github.io/targets-tutorial

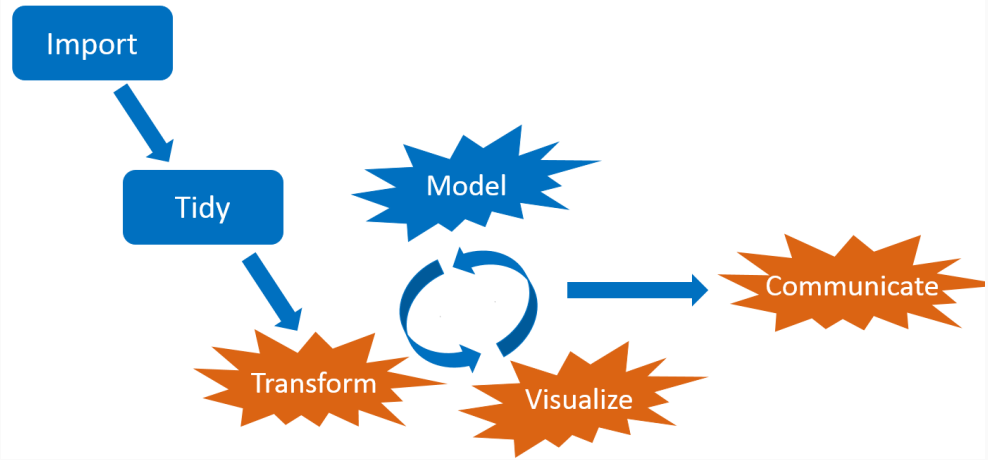
Interconnected tasks



Interconnected tasks



Interconnected tasks



Dilemma: short runtimes or reproducible results?

What do I rerun?

Will the output be reproducible?

Skip to save time?

Skip to save time?

Rerun which models?

Rerun everything?

Rerun everything?

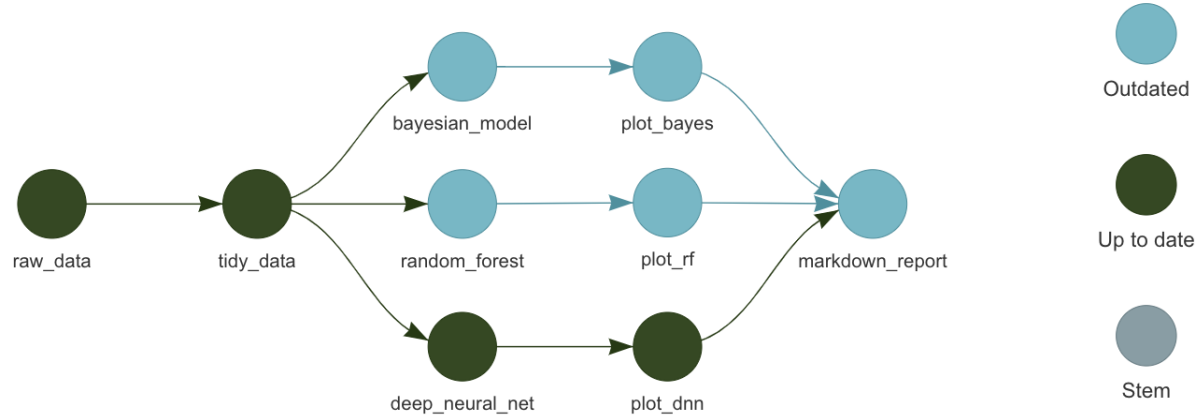
01-import.Rmd

02-tidy.Rmd

03-models.Rmd

04-visualize.Rmd

Let a pipeline tool do the work



- Save time while ensuring computational reproducibility.
- Automatically skip tasks that are already up to date.

Typical project structure

```
_targets.R # Required top-level configuration file.
R/
└── functions.R
data/
└── my_data.csv
```

_targets.R

```
library(targets)
tar_source() # source all files in R folder
tar_option_set(packages = c("tidyverse", "fable"))
list(
  tar_target(my_file, "data/my_data.csv", format = "file"),
  tar_target(my_data, read_csv(my_file)),
  tar_target(my_model, model_function(my_data))
)
```

Generate `_targets.R` in working directory

```
library(targets)
tar_script()
```

Useful targets commands

- `tar_make()` to run the pipeline.
- `tar_make(starts_with("fig"))` to run only targets starting with “fig”.
- `tar_read(object)` to read a target.
- `tar_load(object)` to load a target.
- `tar_load_everything()` to load all targets.
- `tar_manifest()` to list all targets
- `tar_visnetwork()` to visualize the pipeline.
- `tar_destroy()` to remove all targets.
- `tar_outdated()` to list outdated targets.

Debugging

Errored targets to return `NULL` so pipeline continues.

```
tar_option_set(error = "null")
```

Debugging

Errored targets to return `NULL` so pipeline continues.

```
tar_option_set(error = "null")
```

See error messages for all targets.

```
tar_meta(fields = error, complete_only = TRUE)
```

Debugging

Errored targets to return `NULL` so pipeline continues.

```
tar_option_set(error = "null")
```

See error messages for all targets.

```
tar_meta(fields = error, complete_only = TRUE)
```

See warning messages for all targets.

```
tar_meta(fields = warnings, complete_only = TRUE)
```

Debugging

- Try loading all available targets: `tar_load_everything()`. Then run the command of the errored target in the console.
- Pause the pipeline with `browser()`
- Use the debug option: `tar_option_set(debug = "target_name")`
- Save the workspaces:
  - `tar_option_set(workspace_on_error = TRUE)`
  - `tar_workspaces()`
  - `tar_workspace(target_name)`

Random numbers

- Each target runs with its own seed based on its name and the global seed from `tar_option_set(seed = ???)`
- So running only some targets, or running them in a different order, will not change the results.

Folder structure

```
├── .git/
├── .Rprofile
├── .Renviron
├── renv/
├── index.Rmd
├── _targets/
├── _targets.R
├── _targets.yaml
├── R/
├──── functions_data.R
├──── functions_analysis.R
├──── functions_visualization.R
├── data/
└──── input_data.csv
```

targets with quarto

```
library(targets)
library(tarchetypes)                                                    ①
tar_source() # source all files in R folder
tar_option_set(packages = c("tidyverse", "fable"))
list(
  tar_target(my_file, "data/my_data.csv", format = "file"),
  tar_target(my_data, read_csv(my_file)),
  tar_target(my_model, model_function(my_data))
  tar_quarto(report, "file.qmd", extra_files = "references.bib")        ②
  )
```

① Load `tarchetypes` package for quarto support.

② Add a quarto target.

Exercise

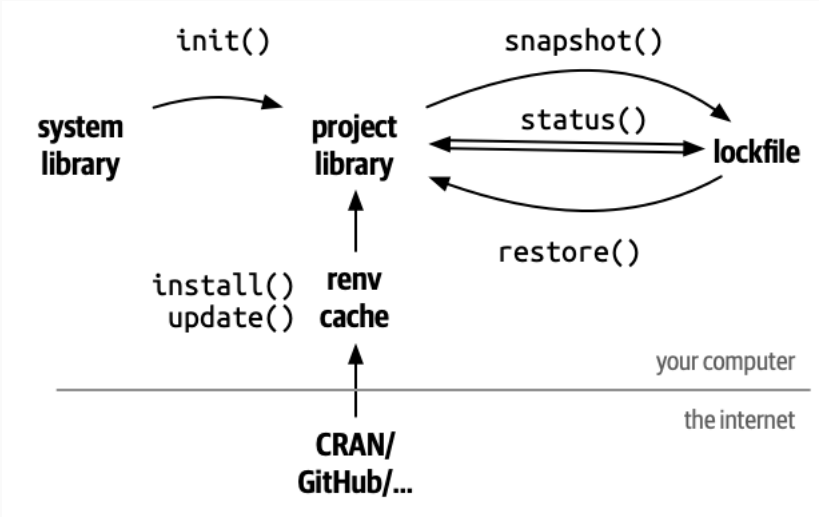
- Add a targets workflow to your quarto document.
- Create a visualization of the pipeline network using `tar_visnetwork()`.

Outline

Reproducible environments

- To ensure that your code runs the same way on different machines and at different times, you need the computing environment to be the same.
  1. Operating system
  2. System components
  3. R version
  4. R packages
- Solutions for 1–4: Docker, Singularity, `containerit`, `rang`
- Solutions for 4: `packrat`, `checkpoint`, `renv`

renv package



renv package

- `renv::init()` : initialize a new project with a new environment. Adds:
  - `renv/library` contains all packages used in project
  - `renv.lock` contains metadata about packages used in project
  - `.Rprofile` run every time R starts.
- `renv::snapshot()` : save the state of the project to `renv.lock`.
- `renv::restore()` : restore the project to the state saved in `renv.lock`.

renv package

- renv uses a package cache so you are not repeatedly installing the same packages in multiple projects.
- `renv::install()` can install from CRAN, Bioconductor, GitHub, Gitlab, Bitbucket, etc.
- `renv::update()` gets latest versions of all dependencies from wherever they were installed from.
- Only R packages are supported, not system dependencies, and not R itself.
- renv is not a replacement for Docker or Singularity.
- `renv::deactivate(clean = TRUE)` will remove the renv environment.