

# ETC4500/ETC5450

## Advanced R programming

Week 7: Reactive programming with  
targets and renv



# Outline

- 1 Reactive programming
- 2 Caching
- 3 targets
- 4 Reproducible environments

# Outline

- 1 Reactive programming
- 2 Caching
- 3 targets
- 4 Reproducible environments

# 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.

# 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

- 1 Reactive programming
- 2 Caching
- 3 targets
- 4 Reproducible environments

# Caching: using rds

```
if (file.exists("results.rds")) {  
  res <- readRDS("results.rds")  
} else {  
  res <- compute_it() # a time-consuming function  
  saveRDS(res, "results.rds")  
}
```

# Caching: using rds

```
if (file.exists("results.rds")) {  
  res <- readRDS("results.rds")  
} else {  
  res <- compute_it() # a time-consuming function  
  saveRDS(res, "results.rds")  
}
```

## Equivalently...

```
res <- xfun::cache_rds(  
  compute_it(), # a time-consuming function  
  file = "results.rds"  
)
```



# Caching: using rds

```
compute <- function(...) {  
  xfun::cache_rds(rnorm(6), file = "results.rds", ...)  
}  
compute()
```

```
[1]  1.113 -0.163 -0.557 -0.428 -0.444 -0.503
```

```
compute()
```

```
[1]  1.113 -0.163 -0.557 -0.428 -0.444 -0.503
```

```
compute(rerun = TRUE)
```

```
[1] -0.5011  1.0217  0.1034 -1.7602 -0.0269  2.1689
```

```
compute()
```

```
[1] -0.5011  1.0217  0.1034 -1.7602 -0.0269  2.1689
```

# Caching downloads

You often want to prevent downloads of the same data multiple times.

```
download_data <- function(url) {  
  dest_folder <- tempdir()  
  sanitized_url <- stringr::str_replace_all(url, "/", "_")  
  dest_file <- file.path(dest_folder, paste0(sanitized_url, ".rds"))  
  if (file.exists(dest_file)) {  
    data <- readRDS(dest_file)  
  } else {  
    data <- read_tsv(url, show_col_types = FALSE)  
    saveRDS(data, dest_file)  
  }  
  data  
}  
bulldozers <- download_data("https://robjhyndman.com/data/Bulldozers.csv")
```

# Caching: memoise

Caching stores results of computations so they can be reused.

```
library(memoise)
sq <- function(x) {
  print("Computing square of 'x'")
  x**2
}
memo_sq <- memoise(sq)
memo_sq(2)
```

```
[1] "Computing square of 'x'"
```

```
[1] 4
```

```
memo_sq(2)
```

```
[1] 4
```

# Caching: Rmarkdown

```
```{r import-data, cache=TRUE}  
d <- read.csv('my-precious.csv')  
```  
  
```{r analysis, dependson='import-data', cache=TRUE}  
summary(d)  
```
```

- Requires explicit dependencies or changes not detected.
- Changes to functions or packages not detected.
- Good practice to frequently clear cache to avoid problems.
- targets is a better solution

# Caching: Quarto

```
```{r}
#| label: import-data
#| cache: true
d <- read.csv('my-precious.csv')
```

```{r}
#| label: analysis
#| dependson: import-data
#| cache: true
summary(d)
```
```

- Same problems as Rmarkdown
- targets is a better solution

# Outline

- 1 Reactive programming
- 2 Caching
- 3 targets
- 4 Reproducible environments

# 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.

# Interconnected tasks

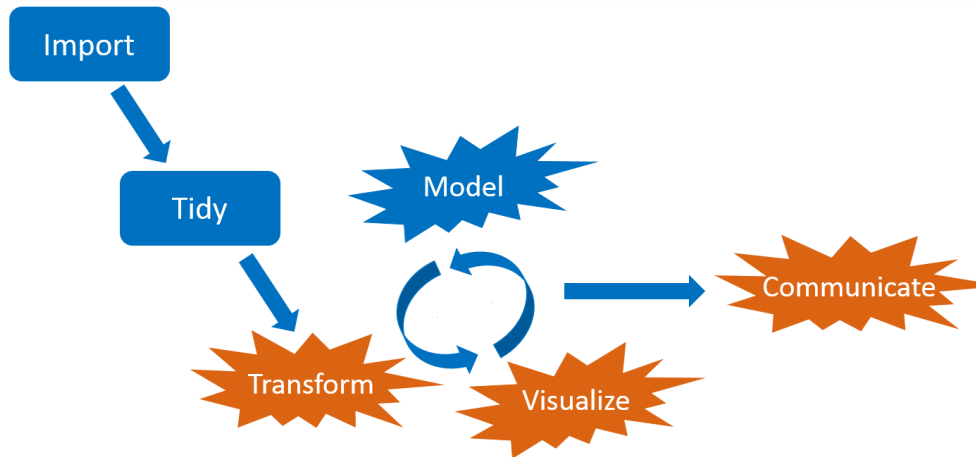




# Interconnected tasks



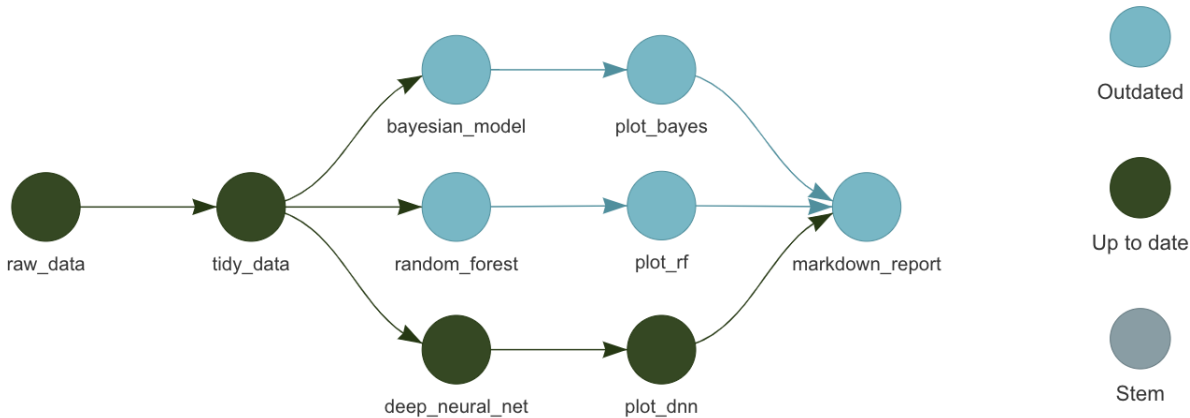
# Interconnected tasks



# Dilemma: short runtimes or reproducible results?



# 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

## no\_targets.R

```
library(tidyverse)
library(fable)
source("R/functions.R")
my_data <- read_csv("data/my_data.csv")
my_model <- model_function(my_data)
```

# Typical project structure

## no\_targets.R

```
library(tidyverse)
library(fable)
source("R/functions.R")
my_data <- read_csv("data/my_data.csv")
my_model <- model_function(my_data)
```

## \_targets.R

```
library(targets)
tar_option_set(packages = c("tidyverse", "fable"))
tar_source() # source all files in R folder
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()
```

# Activity

- Set up a project using targets: `tar_script()`
- Add targets to generate a plot from the `mtcars` dataset, and fit a linear regression model.
- Make the project using `tar_make()`
- Visualize the pipeline using `tar_visnetwork()`



# 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.R with quarto

```
library(targets)
library(tarchetypes)
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")
)
```

①

②

- ① Load tarchetypes package for quarto support.
- ② Add a quarto target.

Replace quarto chunks with `tar_read()` or `tar_load()`.



# Chunk options

## Chunk with regular R code

```
```{r}  
#| label: fig-chunklabel  
#| fig-caption: My figure  
mtcars |>  
  ggplot(aes(x = mpg, y = wt)) +  
  geom_point()  
```
```

# Chunk options

## Chunk with regular R code

```
```{r}
#| label: fig-chunklabel
#| fig-caption: My figure
mtcars |>
  ggplot(aes(x = mpg, y = wt)) +
  geom_point()
```
```

## Chunk with targets

```
```{r}
#| label: fig-chunklabel
#| fig-caption: My figure
tar_read(my_plot)
```
```

# Exercise

Add a quarto document to your targets project that includes the plot and the output from the linear regression model.

# Outline

- 1 Reactive programming
- 2 Caching
- 3 targets
- 4 Reproducible environments

# 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

# Reproducible environments



- Creates project-specific R environments.
- Uses a package cache so you are not repeatedly installing the same packages in multiple projects.
- Does not ensure R itself, system dependencies or the OS are the same.
- Not a replacement for Docker or Apptainer.

# Reproducible environments



- Can use packages from CRAN, Bioconductor, GitHub, Gitlab, Bitbucket, etc.
- `renv::init()` to initialize a new project.
- `renv::snapshot()` to save state of project to `renv.lock`.
- `renv::restore()` to restore project as saved in `renv.lock`.

# renv package





# renv package

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

# Activity

Add renv to your targets project.

# Example paper



Hyndman RJ, Rostami-Tabar B (2024) Forecasting interrupted time series, *Journal of the Operational Research Society*, in press.



[bahmanrostamitabar/  
forecasting\\_interrupted\\_time\\_series](https://github.com/bahmanrostamitabar/forecasting_interrupted_time_series)