MONASH University

MONASH BUSINESS SCHOOL

ETC4500/ETC5450
Advanced R programming

Week 6: Literate programming with Quarto

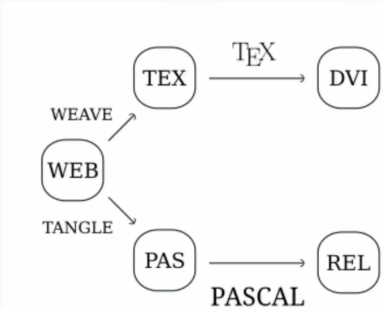
Outline

1. Literate programming
2. roxygen2
3. Rmarkdown
4. Quarto

Outline

Literate programming

- Due to Donald Knuth (Stanford), 1984
- A script or document that contains an explanation of the program logic in a natural language (e.g. English), interspersed with snippets of source code, which can be compiled and rerun.
- Generates two representations from a source file: formatted documentation and “tangled” code.



Literate programming

- As a programming approach, it never quite caught on.
- But it has become the standard approach for reproducible documents.

Literate programming examples

- WEB (combining Pascal and TeX)
- roxygen2 comments
  - technically documentation generation rather than literate programming
  - documentation embedded in code, rather than code embedded in documentation
- Sweave documents
- Jupyter notebooks
- Rmarkdown documents
- Quarto documents

Outline

roxygen2

- roxygen2 documentation are just comments to R.
- roxygen2::roxygenize():
  - generates documentation from these comments in the form of Rd files
  - adds relevant lines to the NAMESPACE file.
- roxygen2::roxygenize() is called by devtools::document().
- Advantage: keeps documentation with the code. More readable, less chance for errors.

Outline

Markdown syntax

Markdown: a “markup” language for formatting text.

- Headings:

```
# Heading 1
## Heading 2
```

- **Bold**: `**bold**`.
- *Italic*: `*italic*`.
- Blockquotes:

```
> blockquote.
```

Markdown and Rmarkdown

- Markdown (markup language):
  - Extension either `.md` or `.markdown`.
  - Used in many places on the web, in note-taking apps, etc.
- Rmarkdown (markup language):
  - an extension of markdown that allows for embedded R code chunks.
  - Extension `.Rmd`.
- Rmarkdown (package):
  - an R package that allows for the conversion of `.Rmd` files to other formats.

Rmarkdown files

- Structure:
  1. YAML header
  2. Markdown content
  3. R code chunks surrounded by ```` ```{r} ```` and ```` ``` ````
  4. Inline R surrounded by `` `r `` and `` ` ``
- Rmarkdown documents can be compiled to HTML, PDF, Word, and other formats
- Compile with `rmarkdown::render("file.Rmd")`

Rmarkdown, knitr and pandoc

- `rmarkdown::render()`
  - Uses `knitr` to run all code chunks, and "knit" the results into a markdown file (replacing R chunks with output).
  - Uses `pandoc` to convert the markdown file to the desired output format.
  - If PDF output is desired, LaTeX then converts the tex file (from pandoc output) to pdf.

knitr functions

- `knitr::knit()`: knits a single Rmd file — runs all code chunks and replaces them with output in a markdown file.
- `knitr::purl()`: extracts all R code from an Rmd file and saves it to a new file.
- `knitr::spin()`: knits a specially formatted R script file into an Rmd file.

Rmarkdown packages

- rmarkdown (to html, pdf, docx, odt, rtf, md, etc.)
- bookdown (to html, pdf, epub)
- blogdown (to html) – uses hugo rather than pandoc
- xaringan (to html) – uses remark.js rather than pandoc
- beamer (to pdf)
- rticles (to pdf)
- tufte (to html, pdf)
- vitae (to pdf)
- distill (to html)
- flexdashboard (to html)

Outline

Quarto

- Generalization of Rmarkdown (not dependent on R)
- Supports R, Python, Javascript and Julia chunks by using either `knitr`, `jupyter` or `ObservableJS` engines.
- More consistent yaml header and chunk options.
- Many more output formats, and many more options for customizing format.
- Heavier reliance on pandoc Lua filters
- Uses pandoc templates for extensions

Choose your engine

Specify the engine in the yaml header:

```
---
engine: knitr
---
```

```
---
engine: jupyter
jupyter: python3
---
```

Default: If any `{r}` blocks found, use `knitr` engine; otherwise use `jupyter` (with kernel determined by first block).

Code chunks

Chunk options use the hash-pipe `#|`

````
```{r}
#| label: fig-chunklabel
#| fig-caption: My figure
#| fig-width: 6
#| fig-height: 4
mtcars |>
  ggplot(aes(x = mpg, y = wt)) +
  geom_point()
```
````

Reference the figure using `@fig-chunklabel`.

Chunk options

- Quarto consistently uses hyphenated options (`fig-width` rather than `fig.width`)
- The Rmarkdown `knitr` options are recognized for backwards compatibility.
- Options that are R expressions need to be prefaced by `!expr`

````
```{r}
#| fig-cap: !expr paste("My figure", 1+1)
```
````

Execute options

- `execute` option in yaml header can be used instead of a `setup` chunk:

```
execute:
  cache: true
  echo: false
  warning: false
```

Some chunk options

- `label`: name of chunk. Useful for cross-references
- `eval`: whether to evaluate the code chunk
- `echo`: whether to display the code chunk
- `output`: whether to show chunk output
- `results: 'asis'` includes the output without markup
- `message`: whether to display messages
- `warning`: whether to display warnings
- `error: true`: continue even if code returns an error.
- `fig-cap`: caption for the figure
- `fig-width`, `fig-height`: width and height of the figure
- `cache`: whether to cache the code chunk
- `dependson`: cache dependencies

Debugging

- The Quarto document is compiled in a different environment from your R console.
- If you get an error, try running all chunks (Ctrl+Alt+R).
- If you can't reproduce the error, check the working directory (add `getwd()` in a chunk).
- Try setting `error: true` on problem chunk to help you diagnose what happens. (But change it back!)
- Look at the intermediate files (`.md` or `.tex`) to see what is happening.

Caching

```
```{r}
#| cache: true
```
```

- When evaluating code chunks, knitr will save the results of chunks with caching to files to be reloaded in subsequent runs.
- Caching is useful when a chunk takes a long time to run.
- It will re-run if the code in the chunk changes in any way (even comments or spacing).
- Beware of inherited objects from earlier chunks. Without explicit dependencies, a chunk will not re-run if inherited objects change.
- Beware of dependence on external files.

Caching

````
```{r}
#| label: chunk1
#| cache = TRUE
x <- 1
```


```{r}
#| label: chunk2
#| cache: true
#| dependson: "chunk1"
y <- x*3
```
````

Caching

Cache will be rebuilt if:

- Chunk options change except `include`
- Any change in the code, even a space or comment
- An explicit dependency changes

Do not cache if:

- setting R options like `options('width')`
- setting knitr options like `opts_chunk$set()`
- loading packages via `library()` if those packages are used by uncached chunks

Caching with random numbers

```
```{r}
#| label: setup
#| include: false
knitr::opts_chunk$set(cache.extra = knitr::rand_seed)
```
```

- `rand_seed` is an unevaluated expression.
- Each chunk will check if `.Random.seed` has been changed since the last run.
- If it has, the chunk will be re-run.

Some caching options

- `cache-comments` If `false`, changing comments does not invalidate the cache.
- `cache-rebuild` Force rebuild of cache.
- `dependson` A character vector of labels of chunks that this chunk depends on.
- `autodep` If `true`, the dependencies are automatically determined. (May not be reliable.)

Caching

Build automatic dependencies among chunks

```
```
execute:
  cache: true
  autodep: true
```
```

Child documents

````
```{r}
#| child: file1.qmd, file2.qmd
```
````

Child documents

```
```{r}
#| child: file1.qmd, file2.qmd
```
```

Conditional inclusion

```
```{r}
#| child: !expr if(condition) 'file1.qmd' else 'file2.qmd'
```
```

Child documents

```
```{r}
#| child: file1.qmd, file2.qmd
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```

Conditional inclusion

```
```{r}
#| child: !expr if(condition) 'file1.qmd' else 'file2.qmd'
```
```

R Script files

```
```{r}
#| file: "Rscript1.R"
```
```

- Better than `source("Rscript1.R")` because output of script included and dependencies tracked.

Other language engines

````
```{python}
print("Hello Python!")
```
````

````
```{stata}
sysuse auto
summarize
```
````

- Python and Stata need to be installed with executables on PATH

Other language engines

```
names(knitr::knit_engines$get())
```

```
 [1] "awk"       "bash"      "coffee"    "gawk"      "groovy"
 [6] "haskell"   "lein"      "mysql"     "node"      "octave"
[11] "perl"      "php"       "psql"      "Rscript"   "ruby"
[16] "sas"       "scala"     "sed"       "sh"        "stata"
[21] "zsh"       "asis"      "asy"       "block"     "block2"
[26] "bslib"     "c"         "cat"       "cc"        "comment"
[31] "css"       "ditaa"     "dot"       "embed"     "eviews"
[36] "exec"      "fortran"   "fortran95" "go"        "highlight"
[41] "js"        "julia"     "python"    "R"         "Rcpp"
[46] "sass"      "scss"      "sql"       "stan"      "targets"
[51] "tikz"      "verbatim"  "ojs"       "mermaid"   "glue"
[56] "glue_sql"  "gluesql"
```

Extensions and templates

- Quarto extensions modify and extend functionality.
- They are stored locally, in the `_extensions` folder alongside the qmd document.
- See https://quarto.org/docs/extensions/ for a list.
- Templates are extensions used to define new output formats.
- Journal templates at https://quarto.org/docs/extensions/listing-journals.html
- Monash templates at https://github.com/quarto-monash

quarto on the command line

- `quarto render` to render a quarto or Rmarkdown document.
- `quarto preview` to preview a quarto or Rmarkdown document.
- `quarto add <gh-org>/<gh-repo>` to add an extension from a github repository.
- `quarto update <gh-org>/<gh-repo>` to update an extension
- `quarto remove <gh-org>/<gh-repo>` to remove an extension
- `quarto list extensions installed`
- `quarto use template <gh-org>/<gh-repo>` to use existing repo as starter template.

Add a custom format

From the CLI: `quarto add quarto-monash/memo`

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New folder/files added

```
├── _extensions
│   └── quarto-monash
│       └── memo
│           └── ...
```

Add a custom format

From the CLI: `quarto add quarto-monash/memo`

New folder/files added

```
├── _extensions
│   └── quarto-monash
│       └── memo
│           └── ...
```

Update YAML

```
---
title: "My new file using the Monash memo format"
format: memo-pdf
---
```

Exercise

- Set up a new project.
- Create a quarto document using an html format.
- Add a code chunk to generate a figure with a caption.
- Reference the figure in the text using `@fig-chunklabel`.
- Add the monash memo extension and generate a pdf output.