Literate Programming

Reproducible Computing

@ JSM 2019

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Literate Programming

Donald Knuth "Literate Programming (1983)"

"Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do."

"The practitioner of literate programming [...] strives for a program that is comprehensible because its concepts have been introduced in an order that is best for human understanding, using a mixture of formal and informal methods that reinforce each other."

- These ideas have been around for years!
- And tools for putting them to practice have also been around
- But they have never been as accessible as the current tools: R Markdown, Jupyter, etc.

What is Markdown?

- Markdown is a lightweight markup language for creating HTML (or XHTML) documents.
- Markup languages are designed to produce documents from human readable text (and annotations).
- Some of you may be familiar with LaTeX. This is another (less human friendly) markup language for creating pdf documents.
- Why I love Markdown:
  - Simple syntax means easy to learn and use.
  - Focus on **content**, rather than **coding** and **debugging**.
  - Allows for easy web authoring.
  - Once you have the basics down, you can get fancy and customize everything (via HTML, JavaScript, and CSS).

Sample Markdown document

```
### Unordered List
* Item 1
* Item 2
  * Item 2a
  * Item 2b

### Ordered List
1. Item 1
2. Item 2
3. Item 3
   * Item 3a
   * Item 3b

```

Unordered List

- Item 1
- Item 2
  - Item 2a
  - Item 2b

Ordered List

1. Item 1
2. Item 2
3. Item 3
   - Item 3a
   - Item 3b

What is R Markdown?

Well, it's R + Markdown:

- Ease of Markdown syntax
- Rendering of R code to produce output and plots
- Ability to include LaTeX: e.g. $\hat{y} = \beta_0 + \beta_1 \times x$

Sample R Markdown document

example.Rmd

Knit HTML | Run

```
---
title: "Sample R Markdown document"
author: "Mine Cetinkaya-Rundel"
date: "January 11, 2016"
output: html_document
---

## R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring
HTML, PDF, and MS Word documents. For more details on using R Markdown see
<http://rmarkdown.rstudio.com>.

When you click the **Knit** button a document will be generated that includes both
content as well as the output of any embedded R code chunks within the document. You
can embed an R code chunk like this:

```{r cars}
summary(cars)
```

Including Plots

You can also embed plots, for example:

```{r pressure, echo=FALSE, fig.height=3, fig.width=5}
plot(pressure)
```

Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing
of the R code that generated the plot.
```

22:55 Chunk 2: pressure — R Markdown

Console

Environment | History

Files | Plots | Packages | Help | Viewer

Publish

Sample R Markdown document

Mine Cetinkaya-Rundel

January 11, 2016

R Markdown

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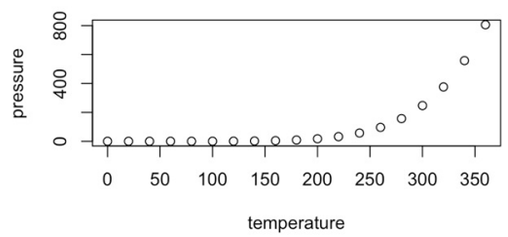
```
summary(cars)
```

```
##      speed           dist
##  Min.   : 4.0   Min.   :  2.00
##  1st Qu.:12.0   1st Qu.: 26.00
##  Median :15.0   Median : 36.00
##  Mean   :15.4   Mean   : 42.98
##  3rd Qu.:19.0   3rd Qu.: 56.00
##  Max.   :25.0   Max.   :120.00
```

Including Plots

You can also embed plots, for example:



Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R code that generated the plot.

Another R Markdown document

This presentation!

R Markdown

It's your lucky day!

You got some data.

- `WorldCupMatches-01.csv`: Match info for each game in pre-2000 World Cups
- Codebook in data/README.md
- Ultimate goal: Visualize the total number of goals for each World Cup over time.

Open `world-cup-goals.Rmd`. Knit the document. Then, update the **yaml** with your information, and knit again.

The YAML

YAML: Yet another Markdown language

- Fields like `title`, `subtitle`, `author`, `date`
- You can also change `output` formats: `html_document` for web authoring, `github_document` for markdown document easily viewable on GitHub, `pdf_document` for PDF (requires TeX), `word_document` for MS Word (requires Word)
- Can use inline R code in values (see `date`)

Chunk options

- Turn off messages with `message = FALSE`
- Turn off warnings with `warning = FALSE`
- Hide code with `echo = FALSE`
- Exclude chunk from doc with `include = FALSE` to prevent code and results from appearing in the finished file. Code in the chunk will still be ran, and the results can be used by other chunks.
- Display error messages in document with `error = TRUE`, as opposed to stopping render when errors occur `error = FALSE`, which is the default
- Set these per chunk or globally in a `setup` chunk on top of the document with `knitr::opts_chunk$set(...)`

cache - cache results for future knits (default = FALSE)

cache.path - directory to save cached results in (default = "cache/")

child - file(s) to knit and then include (default = NULL)

collapse - collapse all output into single block (default = FALSE)

comment - prefix for each line of results (default = '##')

dependson - chunk dependencies for caching (default = NULL)

echo - Display code in output document (default = TRUE)

engine - code language used in chunk (default = 'R')

error - Display error messages in doc (TRUE) or stop render when errors occur (FALSE) (default = FALSE)

eval - Run code in chunk (default = TRUE)

fig.align - 'left', 'right', or 'center' (default = 'default')

fig.cap - figure caption as character string (default = NULL)

fig.height, fig.width - Dimensions of plots in inches

highlight - highlight source code (default = TRUE)

include - Include chunk in doc after running (default = TRUE)

message - display code messages in document (default = TRUE)

results (default = 'markup')
'asis' - passthrough results
'hide' - do not display results
'hold' - put all results below all code

tidy - tidy code for display (default = FALSE)

warning - display code warnings in document (default = TRUE)

Options not listed above: R.options, aniopts, autodep, background, cache.comments, cache.lazy, cache.rebuild, cache.vars, dev, dev.args, dpi, engine.opts, engine.path, fig.asp, fig.env, fig.ext, fig.keep, fig.lp, fig.path, fig.pos, fig.process, fig.retina, fig.scap, fig.show, fig.showtext, fig.subcap, interval, out.extra, out.height, out.width, prompt, purl, ref.label, render, size, split, tidy.opts

Not so lucky after all

Turns out there is an error in the data you received: The number of `home_team_goals` in 1998 by Brazil (in the game vs. Denmark played on 03 Jul 1998) should be 3, not 0. Implement a fix and redo the analysis.

More data!

And now you received more data: World Cup matches post-2000. The data are in `data/WorldCupMatches-02.csv`. Redo the analysis combining data from both files.

Tips

- Make sure RStudio and the `rmarkdown` package (and its dependencies) are up-to-date.
- Get rid of your `.Rprofile`, especially if you have anything in there relating to `knitr`, `markdown`, `rmarkdown`, and RStudio.
- Set a global option for `error = TRUE` (or for a given chunk) so that your document renders even when there are errors.
- Don’t try to change working directory within an R Markdown document. (If you do still decide to use setwd in a code chunk, beware that the new working directory will only apply to that specific code chunk, and any following code chunks will revert back to use the original working directory.)