A Data Science Lab Project Template in R Markdown

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Abstract

This is a template mainly designed for data science lab projects. In this template, we review most common components in a single R Markdown document with the power of the **bookdown** package and demonstrate their basic usage by examples.

Keywords: Template; R Markdown; **bookdown**; **knitr**; **Pandoc**

1 Introduction

This document is designed as a template for data science lab projects. However, it can actually be used as a general template in R Markdown for a single document.

The motivation of setting up a template in R Markdown is due to its simple syntax and flexible output format with the help of **pandoc**. In addition, it is in favor of reproducible studies, which have been receiving increasing attention in modern research.

Instead of providing a minimal but non-informative template framework, we review most of the basic syntax of writing a single R Markdown document with the power of **bookdown** (Xie, 2017) by examples. However, this is not intended as a tutorial of the R Markdown or **bookdown** package. Readers are encouraged to skim the PDF or HTML output, and have a closer look at the source document of this template directly.

The rest of this project template is organized as follows: In Section 2, we briefly discuss cross-referencing in R Markdown, which now has a better support from package **bookdown** (Xie, 2016) than package **rmarkdown** (Allaire et al., 2016). In Section 3 and Section 4, we present examples of writing mathematical equations, and mathematical environments of theorem, lemma, and definition, etc., respectively. Some examples for reproducing figures and including existing figures are given in Section 5. The generation of tables and other R objects is discussed in Section 6. A brief demonstration of a code chunk is given in Section 7. At last but not least, in Section 9, we point readers to some external resources for further reading and more advanced usage of **bookdown**.

2 Cross-Reference by bookdown

Cross-reference of mathematical equations, tables, and figures used to be a challenge when using R markdown. Usually extra package, such as **kfigr** (Koohafkan, 2015), and extra effort were needed for automatic and satisfactory cross-referencing. Fortunately, the arrival of package **bookdown** provides a much easier and more consistent syntax for cross-referencing.

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Table 1: Theorem environments in **bookdown**.

Environment	Printed Name	Label Prefix
theorem	Theorem	thm
lemma	Lemma	lem
definition	Definition	def
corollary	Corollary	cor
proposition	Proposition	prp
example	Example	ex

3 Math Equations

Inline math expressions are quoted by `$` in the source document, which is consistent with the syntax of LaTeX. For instance, x_i^2, $\sin(x)$, θ are inline expressions. The equations can be simply quoted by `$$` if no cross-reference is needed, where regular LaTeX commands under the math environment can be used. For equations that need cross-referencing, LaTeX environments for mathematical equations, such as `equation`, `align`, can be used directly. For example, Equation (1) is the well-known Euler's identity.

$$e^{i\theta} = \cos(\theta) + i\sin(\theta). \tag{1}$$

4 Math Theorem Environments

The mathematical theorem can be put inside a `theorem` chunk followed by its label. For example, the Central Limit Theorem (CLT) is presented in Theorem 4.1.

Theorem 4.1. ***(Central Limit Theorem)*** *Let $X_1, \ldots, X_n$ be independent, identically distributed (i.i.d.) random variables with finite expectation μ, and positive, finite variance σ^2, and set $S_n = X_1 + X_2 + \cdots + X_n$, $n \geq 1$. Then*

$$\frac{\bar{S}_n - n\mu}{\sigma\sqrt{n}} \xrightarrow{L} N(0,1) \text{ as } n \to \infty.$$

All the available theorem environments for mathematical theorem, lemma, definition, etc, and their label prefix designed for cross-referencing are summarized in Table 1.

The First Borel-Cantelli Lemma is given inside the `lemma` environment as shown in Lemma 4.1.

Lemma 4.1. ***(First Borel-Cantelli Lemma)*** *Let $\{A_n\}_{n\geq 1}$ be a sequence of events with*

$$\sum_n P(A_n) < \infty.$$

Then

$$P(A_n \text{ i.o.}) = P(\limsup_{n\to\infty}) = 0.$$

Definition 4.1 demonstrates the use of the definition environment.

Definition 4.1. This is a definition.

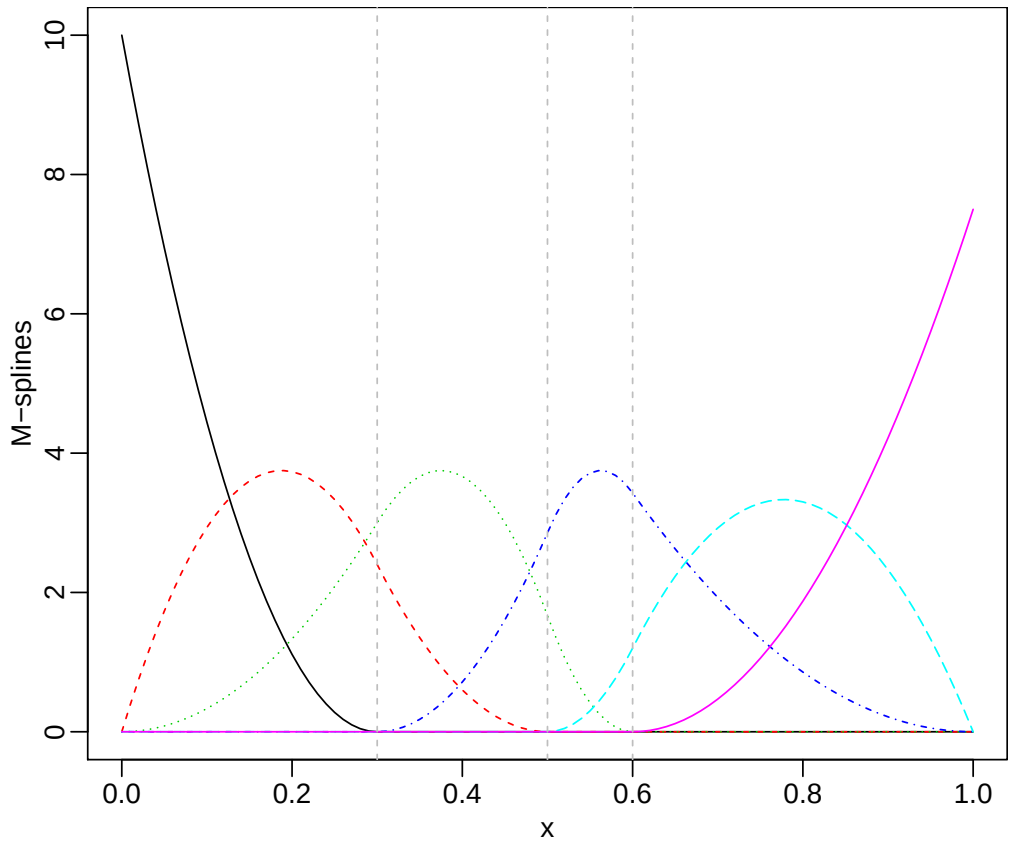

Figure 1: Quadratic M-spline Bases with three internal knots.

5 Figures

Figures can be generated by a code chunk within the source document. For example, quadratic M-splines (Ramsay, 1988) with three internal knots generated by **splines2** package (Wang and Yan, 2017) are plotted by the following R code chunk. The resulting plot is shown in Figure 1.

```
x <- seq.int(0, 1, 0.01)
knots <- c(0.3, 0.5, 0.6)
msMat <- mSpline(x, knots = knots, degree = 2, intercept = TRUE)
par(mar = c(2.5, 2.5, 0, 0), mgp = c(1.5, 0.5, 0))
matplot(x, msMat, type = "l", ylab = "M-splines")
abline(v = knots, lty = 2, col = "gray")
```

It is possible that we may not wish to regenerate a plot from R code. Instead of reproducing plots on the fly, we may also include an existing figure in the document by the function `knitr::include_graghics`. Suppose we have already generated a quadratic I-splines by function `splines2::iSpline` and saved the plot under directory `figs`. Then we may skip the regeneration step and include the existing plot directly as follows:

```
knitr::include_graphics("figs/iSpline.png")
```

We may set the chunk option `echo = FALSE` so that the code chunk generating the plots are excluded

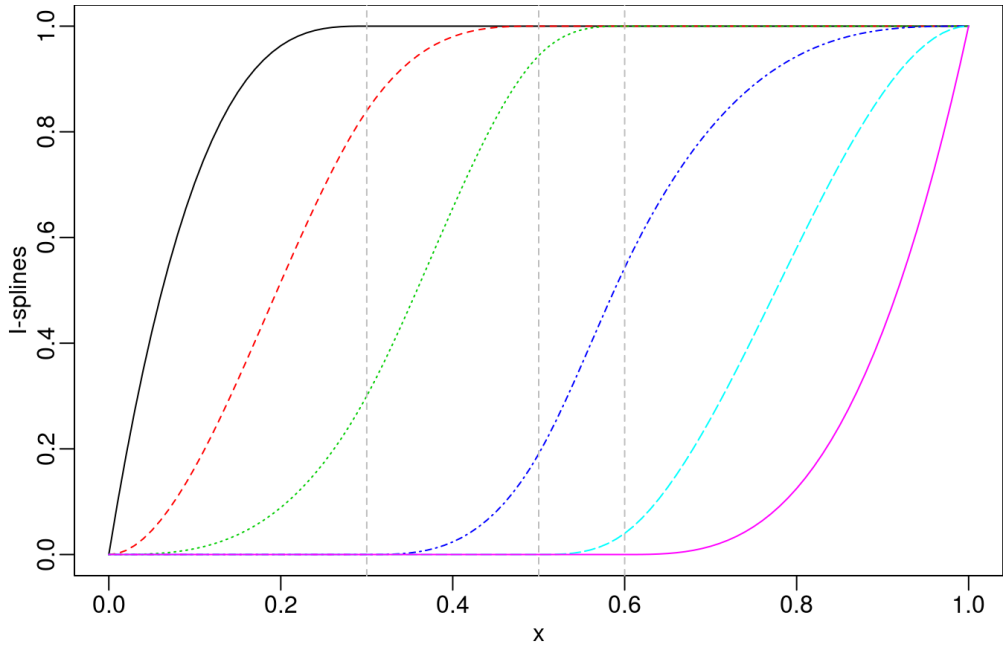

Figure 2: Quadratic I-spline Bases with three internal knots.

Table 2: First six rows of the iris data in package **datasets**.

Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
5.1	3.5	1.4	0.2	setosa
4.9	3.0	1.4	0.2	setosa
4.7	3.2	1.3	0.2	setosa
4.6	3.1	1.5	0.2	setosa
5.0	3.6	1.4	0.2	setosa
5.4	3.9	1.7	0.4	setosa

from the output. Also, the chunk option `cache` can be set to be `TRUE` for time-consuming code chunks once the code chunk is unlikely to be modified.

6 Tables and Other R objects

Tables can be similarly generated by a code chunk within the source document. Table 1 was, in fact, generated by function `knitr::kable`. Another simple example of table generation by `knitr::kable` is given in the following code chunk. Table 2 is the resulting table.

```
knitr::kable(head(iris), booktabs = TRUE,
             caption = 'First six rows of the iris data in package datasets.')
```

There are other R packages that can be of tremendous help in generating Markdown source of table and other R objects. For example, package **xtable** (Dahl, 2016) provides a more sophisticated support for generation of table source for LaTeX and HTML; package **pander** (Daróczi and Tsegelskyi,

2015) provides functions printing a variety of R objects in **pandoc**'s Markdown; package **stargazer** (Hlavac, 2015) produces LaTeX code, HTML code and SCII text for well-formatted tables for results from regression models. See CRAN task view on reproducible research for a more comprehensive package list.

7 Code Chunk

In addition to R, the code chunk can be written in a variety of other languages, such as Bash, Python, SAS, etc., by specifying the chunk option `engine`. The following code chunk is one toy example written in Python 3.

```
foo = "Hello " + "world!"
print("The length of '" + foo + "'" + ' is %d.' % len(foo))
```

```
>>>  The length of 'Hello world!' is 12.
```

We may set the chunk option `eval = FALSE` if we only want to present the code without evaluation.

8 Shiny Apps

Package **shiny** (Chang et al., 2017) is a great tool providing readers with an interactive way to explore data and results. We may easily build Shiny applications on our own, deploy, and share it online at shinyapps.io by package **rsconnect** (Allaire, 2016). In addition to building regular applications by **Shiny**, package **miniUI** (Cheng, 2016) provides layout function designed for Shiny applications with appropriate size on small screens.

We may embed Shiny applications in the document by `knitr::include_app`, which is mainly designed for HTML output. For PDF output, a screenshot taken by package **webshot** (Chang, 2016) will be embedded instead. **webshot** provides argument `zoom` for a possible high resolution screenshot. (However, if the resolution is still not satisfactory, we may take a screenshot and include it manually by `knitr::include_graphics`.)

An example Shiny application visualizing different kind of spline bases is given in Figure 3.

```
knitr::include_app("https://wenjie-stat.shinyapps.io/minisplines2/", "600px")
```

9 Summary and Discussion

In summary, we provided this project template and reviewed the basic syntax of writing a single R Markdown document with the power and love of **bookdown**.

Xie (2017) provided a thorough introduction to **bookdown** including more advanced components, such as HTML widgets, and their usage. What's more, the manual of **Pandoc** gives all the available options that can be specified through YAML metadata section.

The template source and other associated files, such as BibTeX file, are available at the GitHub repository named datalab-templates.

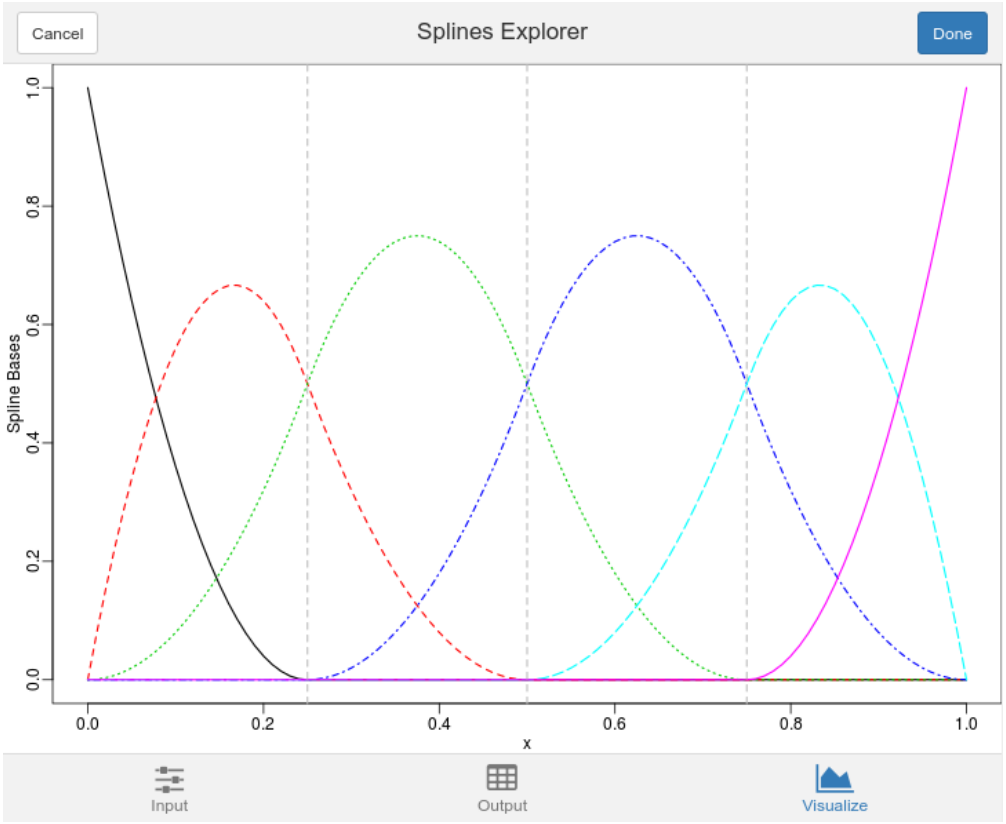

Figure 3: An example Shiny app visualizing different spline bases available at https://wenjie-stat.shinyapps.io/minisplines2.

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