R Markdown クックブック日本語版

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2021-01-24 20:56:58 (翻訳作業中の草稿)

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人生で最も驚異すべき料理人, Xie Shaobai と Si Zhinan へ

—Yihui

支えてくれた妻 Caroline と生まれたばかりの愛する Axel へ

—Christophe

生涯学び続けることの楽しさを教えてくれた母へ

—Emily

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はじめに

本書はクリエイティブ・コモンズ表示 - 非営利 - 継承 4.0 国際ライセンス[*1] で提供されています. オリジナルはこちら[*2]で読むことができます.

This is an unofficial Japanese translation of “R Markdown Cookbook” by Xie, Dervieux, and Riederer, which is licensed under CC BY-NC-SA 4.0[*3]. The original is here[*4].

注: 本書は Chapman & Hall/CRC[*5] より出版されます. 本書のオンライン版は (Chapman & Hall/CRC の厚意により) ここで無料で読むことができます. 本書はクリエイティブ・コモンズ表示 - 非営利 - 継承 4.0 国際ライセンス[*6]のもとで提供されています. ご意見は GitHub で[*7] いつでも受け付けています. いつもありがとうございます.

R Markdown は分析とレポート作成を 1 つのドキュメントとして結びつけるパワフルなツールです. 2014 年初頭に **rmarkdown** パッケージ (JJ Allaire Xie McPherson, et al., 2020) が誕生して以来, R Markdown はいくつかの出力フォーマットをサポートするだけの単なるパッケージから, 書籍・ブログ・科学論文・ウェブサイト, そして講義資料の作成までもサポートする拡張性と多様なエコシステムを持つパッケージへと成長を遂げました.

R Markdown: The Definitive Guide[*8] (Xie J.J. Allaire, and Grolemund, 2018) という, ほんの数年前に書かれた情報の詰まったガイドブックがあります. これは **rmarkdown** パッケージやその他の拡張パッケージの組み込みフォーマットのリファレンスを詳説しています. しかし読者や出版社から, どうやって作りたい内容を実現できるのかを見つけまでが大変なので, より実践的で, 面白く役に立つ小規模な使用例を豊富に掲載したものがあればというコメントをいただきました (言い換えるなら, 前書は無機質すぎるということです). これが本書の生まれた経緯です.

[*5] https://www.routledge.com/p/book/9780367563837
[*6] https://creativecommons.org/licenses/by-nc-sa/4.0/deed.ja
[*7] https://github.com/yihui/rmarkdown-cookbook/issues/new
[*8] https://bookdown.org/yihui/rmarkdown/

公式ドキュメントが存在するにも関わらず, R Markdown のユーザーは有名な Q&A フォーラム『スタック・オーバーフロー』でしょっちゅう助けを求めています. 本書の執筆時点では, `r-markdown` タグのついた質問[*9] が 6,000 件以上ありました. この膨大な件数は特定の問題を探すのでない場合, フォーラムの利用が難しくなります. よって R Markdown を使ってできること, あるいはどのすればできるか, ということについての全ての可能性を知ることが難しくなるかもしれません. 本書の狙いはスタック・オーバーフローやその他のオンラインリソース (ブログの投稿やチュートリアル) から有名な質問を取り上げ, 多くのユーザーが毎日こぞって検索している問題に対して最新のソリューションを提供することです. 実際, 本書で扱うトピックを決めるのに役立つよう, 第二著者の Christophe はスタックオーバーフローの日々の最も人気のある投稿をスクレイピングする R Markdown のダッシュボートを作成しました. 幸運にも, 我々のクックブックはこれらの人気の投稿を含むことでより一層役に立つものになったに違いありません.

本書は R Markdown 文書の機能をどう活用するかの多くの例を掲載しています. クックブックとして, このガイドは R Markdown をより効率よく使いたい, そして R Markdown の力をより知りたい新規または初心者ユーザーにおすすめです.

本書の読み方

本書は R Markdown の基礎を理解している読者におすすめです. *R Markdown: The Definitive Guide* (Xie J.J. Allaire, and Grolemund, 2018) の Chapter 2[*10] は R Markdown の基礎を解説しており, 新規ユーザーが読むのにおすすめです. たとえば, 本書では Markdown の構文はカバーしていませんので, 読者が他の手段でそれを学んでいる想定です. 特に, 最低でも一度は Pandoc の完全なマニュアル[*11][*12] に目を通すことを強くお薦めします. このマニュアルはかなり長大ですが, 金脈のようなものでもあります. 全てを覚えておかなくともよいですが, Markdown の機能をどう応用できるか知っていればとても役に立つでしょう. 多くの人々が 3 連続バッククォートを verbatim なコードブロックに書こうとして失敗したり, 子要素を持つリストを作ろうとして失敗したりするのを, 私は数え切れないほど見てきました[*13]. マニュアルに書いてある Markdown の構文を全て読まなければ, 「`N` 連続バッククォートに対して外側に `N + 1` 連続でバッククォートを書く」「子要素を表現するには適切なインデントを」といったことにきっとあなたは気づかないままでしょう.

このクックブックは R Markdown の技術的なリファレンスを網羅することを意図したものではあ

[*9] https://stackoverflow.com/questions/tagged/r-markdown
[*10] https://bookdown.org/yihui/rmarkdown/basics.html
[*11] https://pandoc.org/MANUAL.html
[*12] 訳注: 完全ではありませんが, 日本語訳が公開されています. https://pandoc-doc-ja.readthedocs.io/ja/latest/users-guide.html
[*13] https://yihui.org/en/2018/11/hard-markdown/

りません. 本書は既存の資料に対する補足となることを目的としています. よって, さらに詳細な情報を知るために読者は以下のような本を参考にすることになるでしょう.

- *R Markdown: The Definitive Guide* (Xie J.J. Allaire, and Grolemund, 2018) は **rmarkdown'** パッケージやその他いくつかの拡張パッケージでの R Markdown の出力フォーマットに関する技術的資料です.
- *R for Data Science* (Wickham and Grolemund, 2016b)[*14] の Part V "Communicate".: このパートは上記の "Definitive Guide" よりも技術的なことは少ないので, より平易な R Markdown の入門になるでしょう.
- *Dynamic Documents with R and knitr* (Xie, 2015) は **knitr** パッケージ (Xie, 2020b) の網羅的な入門書です (補足しますと, R Markdown は **knitr** パッケージのサポートする文書形式の 1 つにすぎません). 短縮版を読みたい場合, Karl Broman による最小限のチュートリアル "knitr in a knutshell"[*15] が役に立つでしょう. **訳注**: これらは日本語訳が存在しませんが, Yihui 氏によるドキュメント *knitr Elegant, flexible, and fast dynamic report generation with R*[*16] の日本語訳は既に用意してあります[*17].
- *bookdown: Authoring Books and Technical Documents with R Markdown* (Xie, 2016) は **bookdown** パッケージ (Xie, 2020a) の公式ドキュメントとして書かれた小規模な書籍です. **bookdown** パッケージは長大なフォーマットのドキュメントを R Markdown で簡単に書くために設計されました.
- *blogdown: Creating Websites with R Markdown* (Xie Hill, and Thomas, 2017) は **blogdown** パッケージ (Xie Dervieux, and Presmanes Hill, 2021) によって R Markdown でウェブサイトを作成する方法を紹介してます.

関連性に応じて本書は既存の参考資料を紹介します. それとは別に, R Markdown の公式ウェブサイトにも役立つ情報が多く含まれています: https://rmarkdown.rstudio.com

本書は最初から順に読む必要はありません. 以降の各章はそれより前の章よりも難解になることはありません. 各章と各セクションのうち, 他よりも発展的と思われるものに対しては, タイトルにアスタリスク (*) を付けています. R Markdown でやりたい具体的なタスクがあるとき, あるいは目次に目を通していたら興味のある箇所が見つかった, という使い方が最も効率的な読み方でしょう. いくつかの箇所で相互参照を免れないところがありますが, 用例集を理解するのに必要な予備知識を参照するつもりです.

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*14 本書は https://r4ds.had.co.nz/ で無料公開されています. また, 日本語訳がオライリー・ジャパンより出版されています.

*15 https://kbroman.org/knitr_knutshell/

*16 https://yihui.org/knitr/

*17 https://gedevan-aleksizde.github.io/knitr-doc-ja/

自分で用例集に挑戦したいならば, 本書の完全なソースコードと用例集は Github の `https://github.com/yihui/rmarkdown-cookbook` で自由に見ることができます[*18]. 本書の電子書籍版をお読みの場合, 掲載されているコードをお好きなテキストエディタにコピー & ペーストして実行することになるでしょう.

本書の構成

本書はそれぞれ単独のコンセプトを実演するため, 小規模な「レシピ」に細分化されています. 1 章では必要なソフトウェアツールのインストール方法を紹介しています. 2 章では R Markdown のコンセプトを概観します. 3 章では R Markdown の基本的な構成要素を紹介し, R Markdown 文書と R スクリプトの変換方法を紹介します. 4 章では, 改ページ, 参考文献リストの掲載, 番号付きの図, アニメーション, ダイアグラムといった文書の要素を作成する方法の話をします. 5 章では図の大きさやアラインメントといった文書の整形方法を紹介します. 6 章では LaTeX/PDF のみ出力したい場合に使える豆知識と小ワザを紹介します. 同様に 7 章では HTML ユーザーに対して, 8 章では Word ユーザーに対して豆知識や小ワザを紹介します. 同時に複数の出力フォーマットで生成したい場合 (しょっちゅう小技を駆使します), 9 章の記述が役に立つでしょう. 10 章は, 正直に言えば私が最も気に入らなかった箇所ですが, 私は多くのユーザーが表の作成方法を本当に欲していることを理解しています. 私はゴテゴテした装飾過多な表の専門家ではありませんが, その役に立つパッケージのリストを知ることはできるでしょう. 11 章では, あなたがまだ知らないであろう **knitr** のチャンクオプションのいくつかの応用をお教えします. 12, 13 章は **knitr** の出力とカスタムフック関数の挙動をうまく扱えるようになることの偉大さをお教えしますので, 少し発展的ですがこれまたとても役に立つはずです. 14 章ではいろいろな **knitr** の小ワザを紹介します. 15 章では R Markdown で他のプログラミング言語を扱う例をお見せします. そう, R Markdown は R のためだけのものではありません. また, **knitr** がまだサポートしていない新しい言語でも動作させる方法も紹介します. 16 章は R Markdown とプロジェクトを関連付けて管理するための豆知識を紹介します. 17 はあなたのワークフローを改善する豆知識をいくつか提示します.

本書のレシピはそれぞれ独立した項目になっているので, あなたに決まった目的がなくてもこれらの中から適当に取り上げて読むことができます.

ソフトウェア情報と表記のルール

本書をコンパイルした時点での基本的な R セッション情報は以下のとおりです[*19].

[*18] 訳注: この日本語版のソースコードは `https://github.com/Gedevan-Aleksizde/rmarkdown-cookbook` で見られます.

[*19] 訳注: 日本語版作成にあたって, **rmdja** パッケージ[*20]を使用しています.

```r
xfun::session_info(c(
  'bookdown', 'knitr', 'rmarkdown', 'rmdja', 'xfun'
), dependencies = FALSE)
```

```
## R version 4.0.3 (2020-10-10)
## Platform: x86_64-pc-linux-gnu (64-bit)
## Running under: Ubuntu 20.04.1 LTS
##
## Locale:
##   LC_CTYPE=ja_JP.UTF-8
##   LC_NUMERIC=C
##   LC_TIME=ja_JP.UTF-8
##   LC_COLLATE=ja_JP.UTF-8
##   LC_MONETARY=ja_JP.UTF-8
##   LC_MESSAGES=ja_JP.UTF-8
##   LC_PAPER=ja_JP.UTF-8
##   LC_NAME=C
##   LC_ADDRESS=C
##   LC_TELEPHONE=C
##   LC_MEASUREMENT=ja_JP.UTF-8
##   LC_IDENTIFICATION=C
##
## Package version:
##   bookdown_0.21 knitr_1.30    rmarkdown_2.6
##   rmdja_0.4.3   xfun_0.20
##
## Pandoc version: 2.11.2
```

上記のセッション情報を見て分かるように, 本書では R ソースコードにプロンプト記号 (> や +) を付けたりしません. またテキスト出力は 2 連続ハッシュ `##` でコメントアウトしています. これはコードをコピーして実行する際の利便性のためです (テキスト出力はコメントアウトされているので無視されます). パッケージ名は太字 (例: **rmarkdown**) で表記し, 本文中のコードやファイルネームはタイプライタフォントで表記します (例: `knitr::knit('foo.Rmd')`). 関数名の末尾には括弧を付けます (例: `blogdown::serve_site()`). 二重コロン演算子 `::` はパッケージのオブジェクトへのアクセスを意味します.

“Rmd” は R Markdown のファイル拡張子名であり, 本書では R markdown の略称としても使用します.

謝辞

常のこととして, 初めに本書の執筆作業の自由を与えていただいた雇用主である RStudio 社に感謝の意を表します. 執筆作業が始まってから, 上司である Tareef Kawaf との毎週のミーティング当初 15 分から 5 分に削減され, それから完全になくなりました. 私は複数の友人から所属先で耐えられないほど多くのミーティングがあり, 時間の浪費になっていると聞いていました. 集中力の維持の観点から, 最近友人の一人は「5 分間 Slack をミュートすることができるかもしれないが, **1 日中**ミュートできるものか?」と嘆きました「もちろんできる!」と私は答えました. 私は 1 ヶ月でも好きなだけ Slack をミュートできるようになったようです. 誤解しないでください — Tareef や同僚が邪魔だという意味ではありません. 皆の提供してくれた自由がどれだけ価値あることかを伝えたいだけです.

R Markdown Definitive Guide を刊行したのち, このクックブックを執筆することを思いつきましたが, アイディアはまだ貧弱でした. 困難で高く付く作業でした. 最初に Michael Harper's[*21] の後押しがなければ, この作業にまじめに取り組むことはなかったでしょう. Christophe Dervieux は助けが必要なときにいつも近くにいました. 彼の R と R Markdown のスキルにより作成されたダッシュボード (**flexdashboard** パッケージによるもの) は人々が興味を持つであろうもの, 役に立つであろうトピックを本書に記載する助けになりました. 同時に多数の Github issues を手伝ってくれたため, 最小限の再現例も添付してないバグ報告と格闘する時間を執筆作業に割くことができました. 同様に, Martin Schmelzer, Marcel Schilling, Ralf Stubner をはじめ数名がスタック・オーバーフロー上の R Markdown の質問に答えるのを手伝ってくれました. おそらく意図してのことではないと思いますが, 彼らの努力は私の多くの持ち時間を節約してくれました. 最近のスタック・オーバーフローでは Johannes Friedrich の活動が注意を引きます. これまでに何度か, スタック・オーバーフローの質問を開いたら彼がもう回答していた, ということがありました.

10.3 節では David Keyes が私を救ってくれました. 私は彼のことをあまり知りませんでしたが, 表を作成するためのパッケージをいくつか紹介する すばらしいブログ記事[*22]を彼が書いていたおかげで助かりました. Holtz Yan の R Markdown の豆知識に関する投稿[*23], Nicholas Tierney の本 *R Markdown for Scientists*[*24] Maëlle Salmon の R Markdown の講座[*25], Jennifer Thompson

[*21] http://mikeyharper.uk
[*22] https://rfortherestofus.com/2019/11/how-to-make-beautiful-tables-in-r/
[*23] https://holtzy.github.io/Pimp-my-rmd/
[*24] https://rmd4sci.njtierney.com
[*25] https://github.com/maelle/rmd_course_isglobal

の R Markdown の講座[*26], Emi Tanaka の R Markdown のワークショップ[*27], Alison Hill の R Markdown ワークショップ[*28] (私も講師の 1 人です), Alison Hill と Emi Tanaka's R Markdown のワークショップ[*29] といったそれ以外のオンライン上の資料もまた, たいへん助けになりました.

Maria Bekker-Nielsen Dunbar, Nathan Eastwood, Johannes Friedrich, Krishnakumar Gopalakrishnan, Xiangyun Huang, Florian Kohrt, Romain Lesur, Jiaxiang Li, Song Li, Ulrik Lyngs, Matt Small, Jake Stephen, Atsushi Yasumoto, Hao Zhu, John Zobolas といった人々がプルリクエストを送ったり, issues を埋めたりして多くの人が本書の Github リポジトリに貢献してくれました. 本書の素晴らしい表紙絵は Allison Horst によってデザインされ[*30], 全体のデザインは Kevin Craig によって完成されました.

本書の当初のアイディアの一部は 2018 年の RaukR Summer School で **knitr** のあまり知られていない機能についてのリモート講演で生まれたものでした. 視聴者は **knitr** の機能についてレシピ形式のような手短な入門を好んでいるようでした. 私を招待していただいた, Marcin Kierczak と Sebastian Dilorenzo をはじめとするサマースクールのオーガナイザたちに感謝したいです. Genentech と DahShu.[*31] でものちに同様の講演を行いました. 招待していただいた Michael Lawrence と Yuqing Zhang, そしてフィードバックをくれた視聴者のみなさんにも感謝したいです. Paul Johnson からは 2020 年刊の *The American Statistician* に掲載された *R Markdown: The Definitive Guide* に対するとても有意義な批評をいただきました. 彼がこの本には詳細な例が欠けていると批判してくれたため, この「決定版ガイド」は十分に決定的とはいえないことになりました. 彼の論評には心から称賛と賛意を送ります. この新しいクックブックがこの溝を埋めてくれることを願います.

これは編集者の John Kimmel との仕事で 5 番目になる本です. 彼と Chapman & Hall/CRC のチームとの共同作業は常に喜びに満ちていました. 他の著者たちに **bookdown** が広く利用されるのは **bookdown** の成功だと John が言ってくれるたびに私は興奮しました. 私の以前の著作のプロダクションエディターであった Suzanne Lassandro が, 他にも多くの責任ある立場にあり著者と直接の接点がほとんどなくなった今も, 本書の手助けになるよう熱心に取り組んでいると John から聞いて私は誇りに思いました. Suzanne と校正担当 (Rebecca Condit) は初稿から「たったの」377 箇所の問題を見つけ出してくれました. 実は次の本のミスは 30 箇所くらいだろうという以前の私の予想[*32]は楽観的すぎました. LaTeX の専門家 Shashi Kumar は PDF を印刷する直前の最後の障害となった, 厄介な LaTeX の問題を解決する手助けをしてくれました.

[*26] https://github.com/jenniferthompson/RepResearchRMarkdown
[*27] https://github.com/emitanaka/combine2019
[*28] https://arm.rbind.io
[*29] https://ysc-rmarkdown.netlify.app
[*30] https://github.com/yihui/rmarkdown-cookbook/issues/180
[*31] http://dahshu.org
[*32] https://bookdown.org/yihui/rmarkdown/acknowledgments.html

John は原稿へのフィードバックのために数名の査読を用意してくれました．実質的に 9 人の偉大な査読を得ることになりました．彼らの 1 人は共同著者として迎えられれば良かったのにと思うほど偉大でした！ 9 人の査読との作業は膨大でしたが, 間違いなく苦労に見合った価値がありました．Carl Boettiger, John Blischak, Sharla Gelfand, Johannes Friedrich, Atsushi Yasumoto, そして残りの匿名の査読たちの有意義なフィードバックに感謝の意を送りたいと思います．

本書の最後のパートの作業は私の昔なじみの友人, Dong Guo と Qian Jia が引っ越した後の空き家 (ネット回線なし!) で行いました．私が疲労困憊しとにかく静かな環境を必要としていた時, 家を一時的なオフィスとして使わせてくれた彼らに感謝します．彼らに別れを告げるのは悲しいです．私が, この本を, 彼らの家で, 仕上げられたというのは, 両親とかわいらしい娘をふくむ彼らの家族との良い思い出となるでしょう．

最後に, COVID-19 のパンデミックの下で自宅での 2 人の小さな「超役に立つ同僚」(5 歳と 3 歳) に感謝するという, このユニークな機会を絶対に逃せません．もし 2 人がいなければ, 5 ヶ月は早く刊行できたでしょう．今となっては託児所 (Small Miracle) の先生が懐かしいですし, 料金もきっと高くはないと感じています...

Yihui Xie ネブラスカ州エルクホーンにて

著者について

Yihui が本書のほとんどの文を書きました．これが第一著者であることを正当化する唯一の根拠です．Christophe は全ての Github issues をまとめ, そしていくつかのセクションを書いたというはっきりした貢献があります．Emily は本来は本書の査読者でした．Yihui は彼女と長いコメントでやり取りできるほどの忍耐がないので, 自分でとてもうまく書けたと思っていたものに大量の追加注文を付けられる痛みを分かち合うために (報復のために) 共同著者として招待されました．いいえ, 冗談です．彼女のコメントはとても有意義でしたが, Yihui には提案された全ての改善案に対処する時間がなかったため, 完全に賛意によって彼女を招待しました．

本書で「私」という表現があれば, それは Yihui のことを指します．「我々」ではなく「私」を使うのは, 共著者のことを忘れてしまったからではなく, 完全に Yihui の独自の意見を表明したいことを意味しています．彼は賢く見られたいと思っていますが, 実は愚かであるというのなら愚かなのは自分だけであってほしいと思っています．

Yihui Xie

Yihui Xie (`https://yihui.org`) は RStudio (`https://www.rstudio.com`) のソフトウェアエンジニアです．アイオワ州立大学の統計学部で PhD を取得しました．インタラクティブな統計的グラフィックと統計的コンピューティングに関心があります．活動的な R ユーザーとして, **knitr**, **bookdown**, **blogdown**, **xaringan**, **tinytex**, **rolldown**, **animation**, **DT**, **tufte**, **formatR**, **fun**, **xfun**, **testit**, **mime**, **highr**, **servr**, **Rd2roxygen** といった R パッケージを開発しています．その中でも **animation** パッケージは 2009 年の John M. Chambers Statistical Software Award (ASA) を受賞しています．また, **shiny**, **rmarkdown**, **pagedown**, **leaflet** といったパッケージの開発メンバーにも加わっています．

彼は 2 つの本を書いています, *Dynamic Documents with knitr* (Xie, 2015), と *bookdown: Authoring Books and Technical Documents with R Markdown* (Xie, 2016), です．そして 2 つの本の共著者です, *blogdown: Creating Websites with R Markdown* (Xie Hill, and Thomas, 2017), と *R Markdown: The Definitive Guide* (Xie J.J. Allaire, and Grolemund, 2018) です．

2006 年, 彼は Capital of Statistics (https://cosx.org) を設立しました. これは中国国内の大きな統計学のオンラインコミュニティに成長しました. 彼はまた 2008 年に Chinese R conference を開始し, 以降, 中国での R カンファレンスの企画に関わってきました. アイオワ州立大学での PhD のトレーニングの間に, 彼は学部で Vince Sposito Statistical Computing Award (2011 年) と Snedecor Award (2012)[*33] を受賞しました.

彼はたいていの場合, twitter のメッセージを週に 1 度確認します (https://twitter.com/xieyihui). ほとんどの時間, 彼は Github (https://github.com/yihui) で見かけることができます.

彼には 4 つの趣味があります. 読むこと, 書くこと (ほとんどはブログ), 料理, そしてバドミントンをすることです. 彼は実際食べるより料理する方に関心があります. 食べるのに我慢できないほど好きな料理はそう多くなく, 辛い料理が数少ない一例です. 料理がさらに楽しくなったので, レストランに行くことがまれになっています. レストランに行って「料理はどれくらい辛くしたらよろしいでしょうか」と訊かれれば彼はたいてい「シェフができる限界まで辛くして」と答えます.

Christophe Dervieux

Christophe Dervieux は R コミュニティの活動的なメンバーであり, 現在はフランス在住です. エネルギーと経済に関する修士号を取得しており, R を使った最初の仕事はマーケットデザインに関する経済研究のアナリストです. これは developer advocate および R 管理者となって R の布教と職場での R ユーザーへのサポートをするようになる前のことです.

彼は人々が R を最大限活用できるように手助けすることに関心があり, 彼が RStudio Community で sustainer としてあちこちを渡り歩く姿を, あるいはいくつかの R パッケージの Github issues であなたも目にすることができるでしょう. どちらの場でも, “cderv” という短縮ハンドルネームで彼だと認識できるでしょう.

R 開発者としての彼は, **bookdown**, **rmarkdown**, **knitr** といったいくつかの R パッケージのコントリビューターです. **crrri** パッケージの開発メンバーの一人でもあります. 彼自身のプロジェクトは GitHub (https://github.com/cderv) で確認できますし, ときどき Twitter でアイディアを共有することもあります.

彼は辛い料理は苦手ですが, 毎週バドミントンを楽しんでいます.

[*33] 訳注: Committee of Presidents of Statistical Societies の授与するものではなく, 大学内で学生に授与されるもの

Emily Riederer

Emily Riederer は消費者金融業界でデータサイエンスの仕事をしており, R を使った分析ツールを構築するチームを率い, この業界でオープンサイエンスの文化を育てています. それ以前は, 彼女はチャペルヒルのノースカロライナ大学で数学と統計学を専攻していました.

Emily は頻繁に Twitter (`https://twitter.com/emilyriederer`) や自分のブログ (`https://emily.rbind.io`) で R について議論し, プロジェクトを共有します. その中には GitHub (`https://github.com/emilyriederer`) にある **projmgr** パッケージも含まれます. rOpenSci のパッケージレビュアーとしても活動し, さらに satuRday Chicago R conference の発起メンバーの一人でもあります.

TODO: "satRday" はタイポか?

Emily の他の関心は読書とウェイトリフティングです. 彼女は自分で辛い料理が好きだと考えていますが, 合衆国内にしか住んだことがないため, その言葉が実際に意味するところをよく分かっていないのだと言われています.

第 1 章

インストール方法

R Markdown を使うには R (R Core Team, 2020) と R パッケージである **rmarkdown** (JJ Allaire Xie McPherson, et al., 2020) のインストールが必要です.

```r
# CRAN から rmarkdown パッケージを R にインストール
install.packages("rmarkdown")

# または, 開発版をインストールしたければ GitHub
# からインストール
if (!requireNamespace("remotes")) install.packages("remotes")
remotes::install_github("rstudio/rmarkdown")
```

こだわりのあるテキストエディタや IDE (統合開発環境) がなければ, RStudio IDE (`https://www.rstudio.com`) のインストールも推奨します. RStudio は必須ではないですが, エディタに強力な R Markdown 支援機能があるので平均的なユーザーにとっては作業がより簡単になります. RStudio IDE を使わない選択をしたなら, Markdown を他の形式の文書に変換するために **rmarkdown** が使用する Pandoc(1.1 節参照) をインストールする必要があります.

PDF として作成する必要があるなら, LaTeX (1.2 節) およびいくつかのパッケージ (1.3) のインストールも必要になるかもしれません.

1.1 RStudio IDE にバンドルされていないバージョンの Pandoc を使う

RStudio IDE は特定のバージョンの Pandoc を同梱しているため, RStudio IDE を使用する場合は自分で Pandoc をインストールする必要はありません. しかし同梱されたバージョンが最新でないことはよくありますし, 必要なバージョンでないかもしれません. 別の Pandoc を自分でインストールすることができます. ほとんどの RStudio ユーザーは同梱されたバージョンを使用しているでしょうから, このバージョンの Pandoc は R Markdown での徹底的なテストを乗り越えていることを覚えておいてください. 異なるバージョン (特に新しいバージョン) を使う場合, 他の R Markdown ユーザーや開発者が解決できない問題にぶつかるかもしれません.

Pandoc のサイトに, プラットフォームごとの Pandoc のインストール方法の詳細なインストラクション https://pandoc.org/installing.html があります. 特定のバージョンを使うために Pandoc を自分でインストールしたのなら, `rmarkdown::find_pandoc()` 関数を呼び出して **rmarkdown** パッケージにそのことを知らせることになるでしょう. 例えば以下のように.

```r
# 特定のバージョンを検索
rmarkdown::find_pandoc(version = "2.9.1")

# 特定のディレクトリから検索
rmarkdown::find_pandoc(dir = "~/Downloads/Pandoc")

# 以前発見した Pandoc を無視して再検索する
rmarkdown::find_pandoc(cache = FALSE)
```

上記のコードチャンクのように, Pandoc のバージョンを特定する方法はいくつかあります. デフォルトでは `rmarkdown::find_pandoc()` はお使いのシステムの最新の Pandoc を発見しようとします. 発見できたなら, バージョン情報はキャッシュされ `cache = FALSE` でキャッシュは無効化されます. `pandoc` 実行ファイルの発見されるであろうディレクトリがどこにある可能性があるかは, ヘルプページの `?rmarkdown::find_pandoc` を見てください.

この関数は Rmd 文書内でも外部でも呼び出される可能性があります. あなたのコンピュータにインストールした特定のバージョンの Pandoc で Rmd 文書をコンパイルしたい場合, この関数を文書内のチャンクのどれかで呼び出すことになるでしょう. 例えばセットアップ用のチャンクで以下のように.

```
```{r, setup, include=FALSE}
rmarkdown::find_pandoc(version = '2.9.1')
```
```

1.2 PDF レポートの作成に LaTeX (TinyTeX) をインストールする

R Markdown から PDF 文書を作りたいなら, LaTeX がインストール済みである必要があります. 伝統的な選択肢として MiKTeX, MacTeX, そして TeX Live がありますが, R Markdown ユーザーに対しては TinyTeX[*1] のインストールを推奨します.

TinyTeX は TeX Live をもとにカスタムされた LaTeX ディストリビューションで, 比較的サイズが小さく, それでいて, 特に R ユーザーが使うようなほとんどの機能を備えています. TinyTeX のインストールや起動にはシステム管理者権限は不要です[*2]. TinyTeX は R パッケージの **tinytex** (Xie, 2020c) でインストールできます.

```
tinytex::install_tinytex()
# TinyTeX をアンインストールするなら,
# tinytex::uninstall_tinytex() を実行してください
```

“**tinytex**” は R パッケージのことを指し, “TinyTeX” は LaTeX ディストリビューションを指すことに注意してください. TinyTeX を使う利点は 2 つあります.

1. TinyTeX は (他の LaTeX ディストリビューションと比べて) 軽量であり, クロスプラットフォームでありポータブルです. 例えば USB ドライブや他のポータブルデバイスに TinyTeX のコピーを保存し, 同じオペレーティングシステムの別のコンピュータで使用することができます.

2. R Markdown を PDF へ変換する時, Pandoc はまず Markdown を中間ファイルとして LaTeX 文書に変換します. **tinytex** パッケージは LaTeX 文書を PDF にコンパイルするヘルパー関数を提供します (主な関数は `tinytex::latexmk()` です). TinyTeX を使っていて, インストールされていない LaTeX パッケージが必要ならば, **tinytex** は自動でインストールしようとします. LaTeX ファイルに対するコンパイルも, 全ての相互参照を確実に解決するために十分な回数だけ行おうとします.

[*1] https://yihui.org/tinytex/

[*2] というより, あなたがシステムの唯一のユーザーなら Linux や macOS では TinyTeX を root 権限で (つまり sudo で) インストール**しない**ことをお薦めします.

技術的に詳しい話に興味があるなら, Xie (2019b) の論文と `https://yihui.org/tinytex/faq/` の FAQ を確認するとよいかもしれません.

1.3 足りない LaTeX パッケージをインストールする

文書を LaTeX を通して PDF にコンパイルしたい時, これらのようなエラーに遭遇するかもしれません.

```
! LaTeX Error: File `ocgbase.sty' not found.

!pdfTeX error: pdflatex (file 8r.enc):
  cannot open encoding file for reading

!pdfTeX error: /usr/local/bin/pdflatex (file tcrm0700):
  Font tcrm0700 at 600 not found
```

1.2 節で紹介した TinyTeX を使用しているなら, だいたいの場合このようなエラーに対処する必要はありません. **tinytex** (Xie, 2020c) が自動で対処してくれるからですが, 何らかの理由でこのようなエラーに遭遇した場合でもやはり, `tinytex::parse_install()` で足りない LaTex パッケージをインストールするのは簡単です. この関数は LaTeX ログファイルのパスを引数として, 足りないパッケージの問題を自動的に解決し, CTAN (the Comprehensive TEX Archive Network, `https://ctan.org`) で見つけられたものをインストールしようとします. LaTeX ログファイルは典型的には入力文書ファイルとおなじ基底名と, `.log` という拡張子名を持ちます. このログファイルを見つけられない場合, エラーメッセージをこの関数の `text` 引数に与えることができます. どちらの方法でも動作するはずです.

```
# ログファイルが filename.log だとする
tinytex::parse_install("filename.log")

# または `text` 引数を使う
tinytex::parse_install(
  text = "! LaTeX Error: File `ocgbase.sty' not found."
)
# "ocgx2" パッケージがインストールされる
```

TinyTeX を使わない場合, **tinytex** パッケージはやはりエラーログから LaTeX パッケージ名を解

決しようとします. tinytex::parse_packages() を例えばこのように使用してください.

```
# ログファイル名が filename.log だったとする
tinytex::parse_packages("filename.log")

# または `text` 引数を使う
tinytex::parse_packages(
  text = "! LaTeX Error: File `ocgbase.sty' not found."
)
# "ocgx2" と返ってくるはず
```

パッケージ名が判明したら, あなたの LaTeX ディストリビューションのパッケージマネージャでインストールすることができます.

代わりに MiKTeX を使っているなら, これも自動で足りないパッケージをインストールできます. MikTeX のインストール中に "Always install missing packages on-the-fly" の設定に必ずチェックしてください. この設定をせずにインストールしていても, まだ MiKTeX Console で変更できます[*3].

*3 https://github.com/rstudio/rmarkdown/issues/1285#issuecomment-374340175

第 2 章

概念に関する概観

このテキストの目標は R Markdown を最大限活用するために多くの豆知識と小技を見せることです. 以降の各章ではより効率的で簡潔なコードを書き, 出力をカスタマイズする技術を実演します. これを始める前に, これらを理解し, 覚え, 応用し, 「リミックス」できる助けになるよう, R Markdown の動作がどうなっているかを少しだけ学んでおくと役に立つでしょう. この節では文書を knit する処理と出力を変更する「重要な切り替えレバー」について簡潔に概観します. この資料は後の章の内容理解に必要ではありません (読み飛ばすのは自由です!) が, 全てのピースをどう当てはめるかについて, より豊かなメンタルモデルを構築する助けになるかもしれません.

2.1 レンダリング時に何が起こっているのか

R Markdown はいくつかの異なるプロセスを合わせて文書を作成し, これが R Markdown の全ての部品がどう連動してるかに関する混乱の主な理由です.[*1] 幸運にも, ユーザーが文書を作成できるようになるためにはこれらの処理の内部の挙動を全て理解することは必須ではありません. しかし, 文書の挙動の変えようとするだろうユーザーにとっては, どの部品がどの挙動を担当しているかを理解することは重要です. あなたが検索する適切な範囲を絞れるようになれば, ヘルプを探すのがより簡単になります.

R Markdown 文書に対する基本的なワークフローの構造を図2.1に示します. ステップ (矢印) と, 出力ファイルが生成される前に作成される中間ファイルを強調しています. 全ての処理は `rmarkdown::render()` 関数内で実装されています. 以降は各段階を詳細に説明します.

`.Rmd` 文書は, 文書の本来の形式です. YAML (メタデータ), テキスト (ナラティブ), コードチャンク

[*1] Allison Horst が R Markdown の処理を魔法になぞらえたすばらしいイラストに描き出してくれました (`https://github.com/allisonhorst/stats-illustrations/raw/master/rstats-artwork/rmarkdown_wizards.png`). そして実際のところ, この絵は本書の扉絵に使われました.

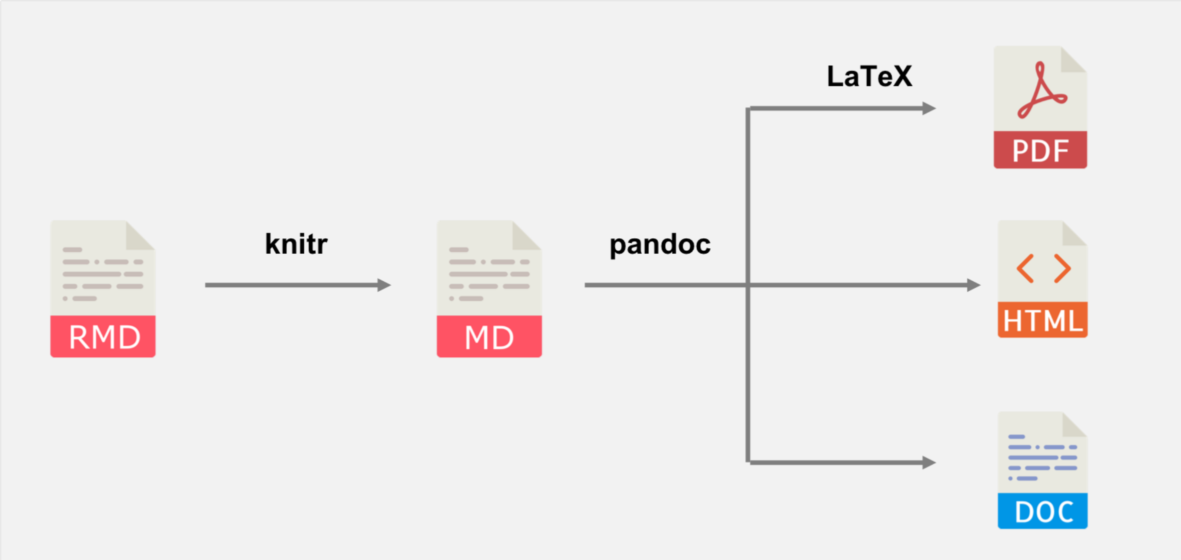

図2.1: R Markdown 文書がどのように最終的な出力文書に変換されるかを表すダイアグラム

を含んでいます.

最初に **knitr** (Xie, 2020b) の `knit()` 関数が `.Rmd` ファイルに埋め込まれた全てのコードを実行することになり, そして出力文書にコードの出力を表示します. 全ての結果は, 一時的に作られた `.md` ファイルに含まれるよう, 適正なマークアップ言語へと変換されます.

その後 `.md` ファイルは, あるマークアップ言語のファイルから別のものへと変換するための多用途なツールである Pandoc によって処理されます. 文書を `output` パラメータで指定された (HTML へ出力する `html_document` のような) 出力形式へ変換するため, 文書の YAML フロントマターで指定されたパラメータを取ります (例: `title`, `author`, `date`).

出力形式が PDF ならば, Pandoc が中間ファイルの `.md` を `.tex` ファイルに変換する時にさらに処理が 1 層, 追加されます. このファイルはその後, 最終的な PDF 文書を形成するため LaTeX によって処理されます. 1.2 節で話したように, **rmarkdown** パッケージは **tinytex** パッケージ Xie (2020c)] の `latexmk()` 関数を呼び出し, これが次々に LaTeX を呼び出して `.tex` をコンパイルし `.pdf` にします.

簡潔にまとめると, `rmarkdown::render()` = `knitr::knit()` + Pandoc (PDF の場合のみ + LaTeX) ということです.

Robin Linacre が https://stackoverflow.com/q/40563479/559676 で R Markdown と **knitr** と Pandoc の関係について良い要約を書いてくれました. この投稿には上記の概観よりも技術的に細かい話も含まれています.

全ての R Markdown 文書が常に Pandoc を通してコンパイルされるわけではないことに注意して

ください．中間ファイル .md は他の Markdown レンダラによってもコンパイルできます．例えば 2 つ例を挙げます．

- **xaringan** パッケージ (Xie, 2020d) は出力された .md をウェブブラウザ上で Markdown コンテンツを表示するための JavaScript ライブラリに渡します．[*2]

- **blogdown** パッケージは (Xie Dervieux, and Presmanes Hill, 2021) .Rmarkdown 文書形式をサポートしています．これは .Rmarkdown を knit して .markdown にし，Markdown 文書は大抵の場合外部のサイトジェネレータによって HTML にレンダリングされます．

2.2 R Markdown の解剖学

R Markdown にいくつかの部品があることを考えながら，我々は 1 レベル深く掘り下げることができます．では，レンダリング作業中にいつどのように処理を変化させるかに注目してみましょう．

2.2.1 YAML メタデータ

YAML metadata (YAML ヘッダとも呼びます) はレンダリング処理の中の多くのステージで処理され，様々な形で最終的な文書に作用することことができます．YAML メタデータは Pandoc，**rmarkdown**，そして **knitr** のそれぞれに読み込まれます．その過程で，メタデータに含まれる情報はコード，コンテンツ，そしてレンダリング処理に影響しうるものです．

典型的な YAML ヘッダはこのように，文書と基本的なレンダリング操作指示に関する基本的なメタデータを含んでいます．

```
---
title: My R Markdown Report
author: Yihui Xie
output: html_document
---
```

この場合，title, author フィールドは Pandoc によって処理され，テンプレート変数の値に設定されます．デフォルトのテンプレートでは，title と author の情報は得られた文書の冒頭に現れます．Pandoc が YAML ヘッダの情報をどう扱うかのより詳細な話は，Pandoc マニュアルの YAML

[*2] 訳注: **xaringan** について日本語で言及している例は少ないですが，次のページが用法・技術的な説明の両面で優れています．https://qiita.com/nozma/items/21c56c7319e4fefceb79

metadata block.[*3] に関するセクションで見られます.[*4]

対照的に output フィールドはレンダリング処理の中で **rmarkdown** が出力フォーマット関数 rmarkdown::html_document() に適用するのに使われます output に指定した出力フォーマットに引数をあたえることで, レンダリング処理に影響させることができます. 例えばこのように書きます.

```yaml
output:
  html_document:
    toc: true
    toc_float: true
```

これは rmarkdown::render() に, rmarkdown::html_document(toc = TRUE, toc_float = TRUE) と指示することと同じです. これらのオプションが何をするのか知るために, あるいは使える他のオプションを知るために, R コンソールで ?rmarkdown::html_document を実行してヘルプページを読むことになるでしょう. output: html_document は output: rmarkdown::html_document と等価であることに注意してください. 出力フォーマットが rmarkdown:: のような修飾子を持たない場合, **rmarkdown** パッケージのものと想定されます. そうでないなら, R パッケージ名のプレフィックスが必要です. 例えば bookdown::html_document2 のような.

17.4 節に書いたように, YAML ヘッダ内でパラメータを選択したのなら, コンテンツとコードにも影響することができます. 簡潔に言うと, R Markdown ドキュメント全体で参照可能な変数や R 評価式をヘッダに含めることができるということです. 例えば以下のヘッダでは start_date と end_date パラメータを定義し, これらは以降の R Markdown 文書内で params というリスト内に反映されます. つまり, R コード内でこれらを使うことができ, params$start_date と params$end_date でアクセスできるということです.

```yaml
---
title: My RMarkdown
author: Yihui Xie
output: html_document
params:
  start_date: '2020-01-01'
```

[*3] https://pandoc.org/MANUAL.html#extension-yaml_metadata_block

[*4] **訳注**: 日本語訳での対応箇所はこちら: https://pandoc-doc-ja.readthedocs.io/ja/latest/users-guide.html#metadata-blocks

```
  end_date: '2020-06-01'
---
```

2.2.2 ナラティブ

TODO: ナラティブ, 訳し方 R Markdown のナラティブテキスト要素は YAML メタデータやコードチャンクよりは理解が簡単でしょう. 典型的には, これはテキストエディタで書いているようなものだと感じられるでしょう. しかし Markdown コンテンツは, どのようにコンテンツが作られるか, どうやって文書の構造がそこから作られるか, の両方に関して, 単純なテキストよりも強力で面白いものに違いありません.

我々のナラティブの多くは人の手で書かれていますが, 多くの R Markdown 文書ではコードと使用される分析を参照することが求められているようです. この理由として, 4 章において, コードがテキストの一部を生成するのを助ける様々な方法が実演されています. 単語を結合してリストにしたり (4.11節), 参考文献リストを書いたり (4.5節) といったやり方です. この変換は `.Rmd` から `.md` への変換と同様に **knitr** で制御されます.

Markdown のテキストは文書の構造も与えることができます. Markdown の構文をこの場で復習するには紙面が足りませんが,[*5] 特に関連深い概念の 1 つとしてセクション (節) ヘッダがあります. これは 1 つ以上の, 対応したレベルの数のハッシュ (#) で表現されます. 例えば, 以下のように.

```
# First-level header

## Second-level header

### Third-level header
```

TODO: section はセクションで統一するか節で統一するか. chapter との兼ね合い

これらのヘッダは **rmarkdown** が `.md` を最終的な出力フォーマットに変換する際に文書全体に構造を与えます. この構造は, いくつかの属性を付与することで節を参照し形成するのに役立ちます. Pandoc 構文は, ヘッダの記述に `{#id}` と続けることで参照を作成することが可能になり, あるいは `{.クラス名}` のように書くこと節に複数のクラスを付与できます. 例えば以下のように.

[*5] Markdown の復習には, 代わりに, https://bookdown.org/yihui/bookdown/markdown-syntax.html をご覧になってください.

```
## Second-level header {#introduction .important .large}
```

例えば ID やクラスで参照するといった, これから学ぶいくつもの方法で, この節にアクセスすることが出来ます. 具体例として, 4.7節では節 ID を使って文書内のどこでも相互参照する方法を実演していますし, 7.6節では小節を認識させる `.tabset` クラスを紹介しています.

R Markdown のテキスト部分で見られる最後の興味深いコンテンツのタイプとして, 特定の出力したいフォーマットに対して「生のコンテンツ」をそのまま書き出す方法, 例えば LaTeX 出力に対して LaTeX コードを直接書く (6.11 節), HTML 出力に対して HTML コードを直接書く, 等 (9.5 節), を挙げます. 生のコンテンツは基本的な Markdown ではできないことが達成できますが, 出力フォーマットが異なるとたいていは無視されることに留意してください. 例えば生の LaTeX コマンドは出力が HTML の場合, 無視されます.

2.2.3 コードチャンク

コードチャンクは R Markdown にとっての心臓の鼓動です. チャンク内のコードは **knitr** によって実行され, 出力は Markdown に翻訳され, レポートは現在のスクリプトとデータに動的に同期します. 各コードチャンクは言語エンジン (15章), ラベル, チャンクオプション (11章), そしてコードで構成されます.

コードチャンクを作ることができるいくつかの mod について理解するためには, **knitr** の処理をあとほんの少しだけ詳しく知ることが有意義です. 各チャンクでは, **knitr** 言語エンジンは 3 つの入力の部品を得ます. knit 環境 (`knitr::knit_global()`), コードの入力, 任意に指定できるラベル, そしてチャンクオプションのリストです. コードチャンクはコードもその出力も整形された表現として返します. 副作用として, knit 環境も修正されます. 例えばコードチャンク内のソースコードを介してこの環境内で新しい変数がつくられます. この処理は図2.2のように表せます.

この処理は以下の方法で修正できます.

- 言語エンジンを変更する
- チャンクオプションを, グローバルあるいはローカル, あるいは特定の言語に対してのみ修正する
- 入出力にさらなる処理を追加するためのフックを使用する

例えば12.1節で, ソースコードの特定行を改ざんする後処理をするフックを加える方法を学ぶことになるでしょう.

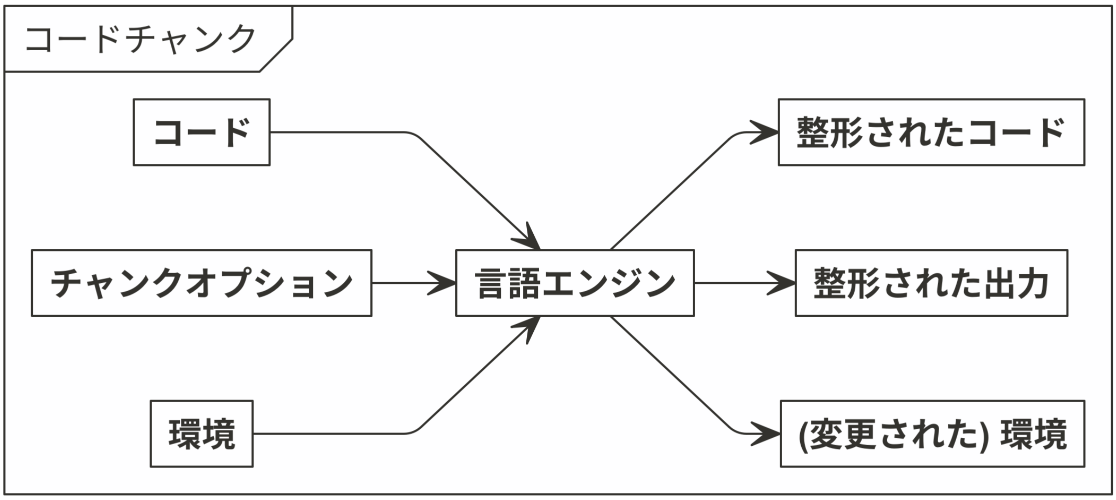

図2.2: 言語エンジンへの入出力フローチャート

コードチャンクは2.2.2節でつぶさに見てきたナラティブのようなクラスと識別子を持ちます．コードチャンクは識別子 (よく「チャンクラベル」と呼ばれます) を言語エンジンの直後に任意で指定することができます．チャンクオプション `class.source` と `class.output` でそれぞれコードブロックとテキスト出力ブロックに対するクラスを設定することもできます (7.3節参照)．例えばチャンクヘッダ ```` ```{r summary-stats, class.output = 'large-text'} ```` はチャンクラベルに `summary-stats` を与え，テキスト出力ブロックに `large-text` というクラスを与えています．チャンクのラベルは 1 つだけですが，クラスは複数持つことができます．

2.2.4　文書の本文

文書を執筆し編集するに際して理解すべき重要なことは，どのようにしてコードとナラティブの小片が文書内のいくつもの節やコンテナを作るのかです．例えばこのような文書があったとします．

````
# タイトル

## X 節

ここから導入文

```{r chunk-x}
x <- 1
````
````

```
print(x)
```
```

### 第 1 小節

ここに詳細な話

### 第 2 小節

ここにさらに詳しい話

## Y 節

ここから新しい節

```{r chunk-y}
y <- 2
print(y)
```
```

この文書を書いていると，それぞれの小片は，テキストとコードを含んだ，独立した節とともに直線上に並んでいるものとみなすかもしれません．しかし実際にしているのは，概念としては図2.3でより細かく描いているように，入れ子 (ネスト) になったコンテナの作成です[*6]

この図に関する 2 つの重要な特徴は (1) テキストやコードのどのセクションも個別のコンテナであり，(2) コンテナは他の別のコンテナを入れ子にできる，ということです．この入れ子は R Markdown 文書を RStudio IDE で執筆し，文書のアウトラインを展開しているとはっきりと分かります．

図2.3では同じレベルのヘッダは同じレベルの入れ子を表していることに注意してください．低レベルのヘッダはより高レベルなヘッダのコンテナ内部にあります．この場合，通常は高レベルの節を「親」といい，低レベルの節を「子」といいます．例えば「小節」は「節」の子です．5.8節で実演するように，ヘッダだけでなく `:::` を使ってまとまりの単位を作ることができます

このテキストで説明されているフォーマットやスタイルのオプションを適用するとき，この構

[*6] 現実に，ここで見えているよりも多くのコンテナがあります．例えば knit されたコードチャンクや，コードと出力がそれぞれ別のコンテナとして存在し，そしてこれらは親要素を共有しています．

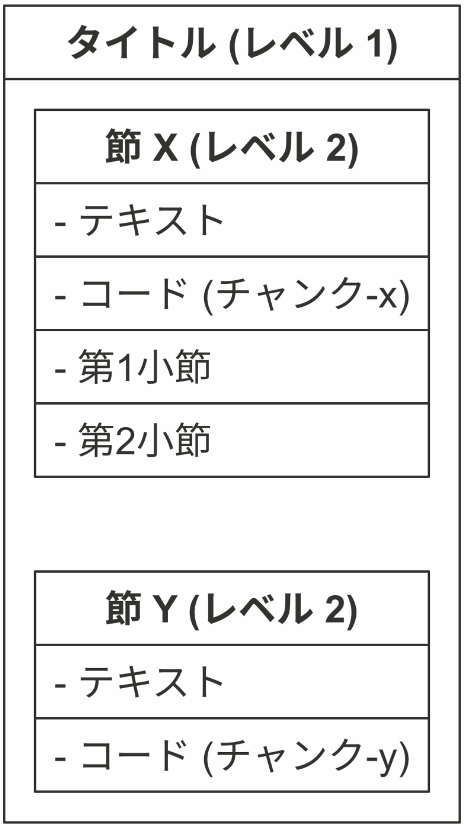

図2.3: 入れ子状のコンテナとして表現された単純な R Markdown 文書の例

造は重要な意味を持ちます．例えば，Pandoc が抽象構文木 (AST) でどのように文書を表現するかを学ぶ時 (4.20節) や，HTML 出力のスタイルを決めるために CSS セレクタを使用する時 (@ref(html-css 節ほか)，入れ子構造の概念が現れます．

フォーマットとスタイルは似たようなタイプのコンテナ (例えばコードブロック) や，あるコンテナ内に全てあるコンテナ (例：「Y 節」以下にある全てのコンテナ) に対して適用できます．加えて2.2.2節で説明したように，同一のクラスをある節に対して同様のものとして扱うために適用することができますし，この場合は共通のクラス名は共通のプロパティ，あるいはこの節に共通の意図を示すようになります．

本書を読みながら，特定の「レシピ」がどんな種類のコンテナに対して作用しているのかを自問し，考えることはあなたにとって有益になるでしょう．

2.3 結果を変更するために, なにを変更できるか?

では, ここまでで概観してきたものを要約し, これから何をすべきかを下見していきましょう.

rmarkdown で R Markdown 文書をレンダリングする処理は **knitr** で `.Rmd` を `.md` で変換する処理, それから (典型的には) Pandoc で `.md` を望む出力に変換する処理で構成されます.

`.Rmd` から `.md` 変換のステップではレポート内の全てのコードの実行と「翻訳」を制御するため, 「コンテンツ」への変更のほとんどは, **knitr** の翻訳するためのコードを伴う `.Rmd` を編集する作業が絡んできます. これらのステップ全体を操作するツールには **knitr** チャンクオプションおよびフックがあります.

`.md` はフォーマットされていないプレーンテキストです. ここで Pandoc の出番です. HTML や PDF, Word といった最終的な出力フォーマットへ変換されます. この途上で構造とスタイルを付与します. この処理ではスタイルシート (CSS), 生 LaTeX または HTML コード, Pandoc テンプレート, Lua フィルタといった様々なツールが助けになります. R Markdown 文書の入れ子構造を理解し, よく考えて識別子とクラスを使うことで, これらのツールを取捨選択して出力の目標となる箇所に応用することができます.

最後に, YAML メタデータはこれらのステップの切り替えに役に立つかも知れません. パラメータの変更はコードがどう動作するかを変更することができ, メタデータの変更はテキストの内容を変化させ, 出力オプションの変更は, 異なる命令のセットをもつ `render()` 関数を与えます.

もちろんこれらは全て大まかな経験則であり, 絶対的な事実として扱うべきでありません. 究極的には, 機能を完璧にきれいに分類することはできません. 本書全体を通じて, 説明されている結果の多くは, しばしば実現のための道筋が複数あり, さらにそのパイプラインの様々なステージの説明に立ち入ることになることが分かるでしょう. 例えば文書内に画像を挿入する作業では, `.Rmd` から `.md` への変換の段階で R コード `knitr::include_graphics()` を使うこともあれば, Markdown 構文 (`![]()`) を直接使うこともあるでしょう. ややこしく思えるかもしれませんし, アプローチごとに異なる利点を持つこともあります. しかし悩まないでください. なんにせよ, あなたの問題を解決する多くの有効な方法が存在し, あなたはそれらから自分にとって最も理にかなうアプローチに従うことができます.

さあこの辺にしておきましょう. 本書の残りの部分で, R Markdown を最大限活用するために我々が説明した, あらゆるコンポネントを変更する方法のより具体的な例を使って絵の下書きに色をつけることができます.

第 3 章

基本

この章では, R Markdown の重要な概念をいくつか提示します. まず「平文」「コード」という R Markdown の基本的なコンポネントを紹介します. 次に, R Markdown 文書をどう R スクリプトへ変換するか, あるいは逆はどうするかを提示します.

もっと基本的な話を求める方は, *R Markdown Definitive Guide* (Xie J.J. Allaire, and Grolemund, 2018) の 2 章を見てください.

3.1 コードチャンクとインライン R コード

R Markdown 文書は平文 (ナラティブ) とコードが混合してできています. Rmd 文書には 2 種類のコード, コードチャンクとインライン (行内) R コードです. 以下は簡単な例です.

````
```{r}
x <- 5  # 円の半径
```

半径 `r x` の円に対し,
その面積は `r pi * x^2` である.
````

コードチャンクはたいていは ```{} で始まり, ``` で終わります. コードチャンク内ではコードを何行でも書いてかまいません. インライン R コードは `r ` という構文を使って文書のナラティブの中に埋め込まれます. 上記の例ではコードチャンク内で円の半径として変数 x を定義し, この円の面積を次のパラグラフで計算しています.

チャンクオプションを通してコードチャンクの挙動と出力をカスタマイズできます (オプションは

カーリー・ブレイス {} 内に与えます). 例のいくつかは11章で見つかるでしょう. コードチャンクに別のプログラミング言語のコードを書くこともあるでしょう (15 章を見てください).

3.2 RStudio のビジュアルエディタで R Markdown を書く

あなたがまだ Markdown の書き方に慣れていないか, Markdown コードを書くのが気に入らないならば, RStudio ver. 1.4 には実験的ですが Markdown 文書用のビジュアルエディタがあります. これは図3.1で示すように Word のような伝統的な WYSIWYG なエディタと似ていると感じるでしょう. この完全なドキュメントは `https://rstudio.github.io/visual-markdown-editing/` で見ることができます.

ビジュアルエディタによって, ヘッダ, 図, 表, 脚注などといった Pandoc でサポートされているほとんどあらゆる Markdown 要素を視覚的に編集できます. あなたは全ての構文を覚えなくてもよいということです. ある要素の構文を忘れた場合, RStudio ツールバー (図3.1参照) を使うかキーボードショートカットを使って要素を追加したり編集したりすることになるでしょう.

あなたが既に Markdown に熟練しているなら, ツールバーを右クリックしてソースモードとビジュアルモードを切り替えられるので, 文書をソースモードのままで書くこともできます.

3.3 R スクリプトをレポートにレンダリングする

年季の入った R を Markdown ユーザーであっても, 別の選択肢があることを見落としているかもしれません. Dean Attali はこれを”**knitr** の隠された至宝[*1] と読んでいます. 純粋な R スクリプトを直接レンダリングできるということです. RStudio IDE をお使いなら, R スクリプトをレンダリングするキーボードショートカットは Rmd 文書を knit するとき (`Ctrl / Cmd + Shift + K`) と同じです.

R スクリプトをレポートにレンダリングすると, まず `knitr::spin()` 関数が呼ばれスクリプトが Rmd ファイルに変換されます. この関数が Dean Attali が「**knitr** の隠された至宝」と呼んでいるものです. レポートには全てのテキストとグラフィックの出力が掲載されます.

レポートの要素を細かく管理したいなら, 以下のようにその助けとなるいくつかの構文があります.

- Roxygen コメントは平文として扱われます. roxygen コメントは `#'` で始まる R コメントで, レポートにナラティブを書くのに役立つかもしれません. コメント内ではあらゆる Markdown 構文を使うことができます.

[*1] `https://deanattali.com/2015/03/24/knitrs-best-hidden-gem-spin/`

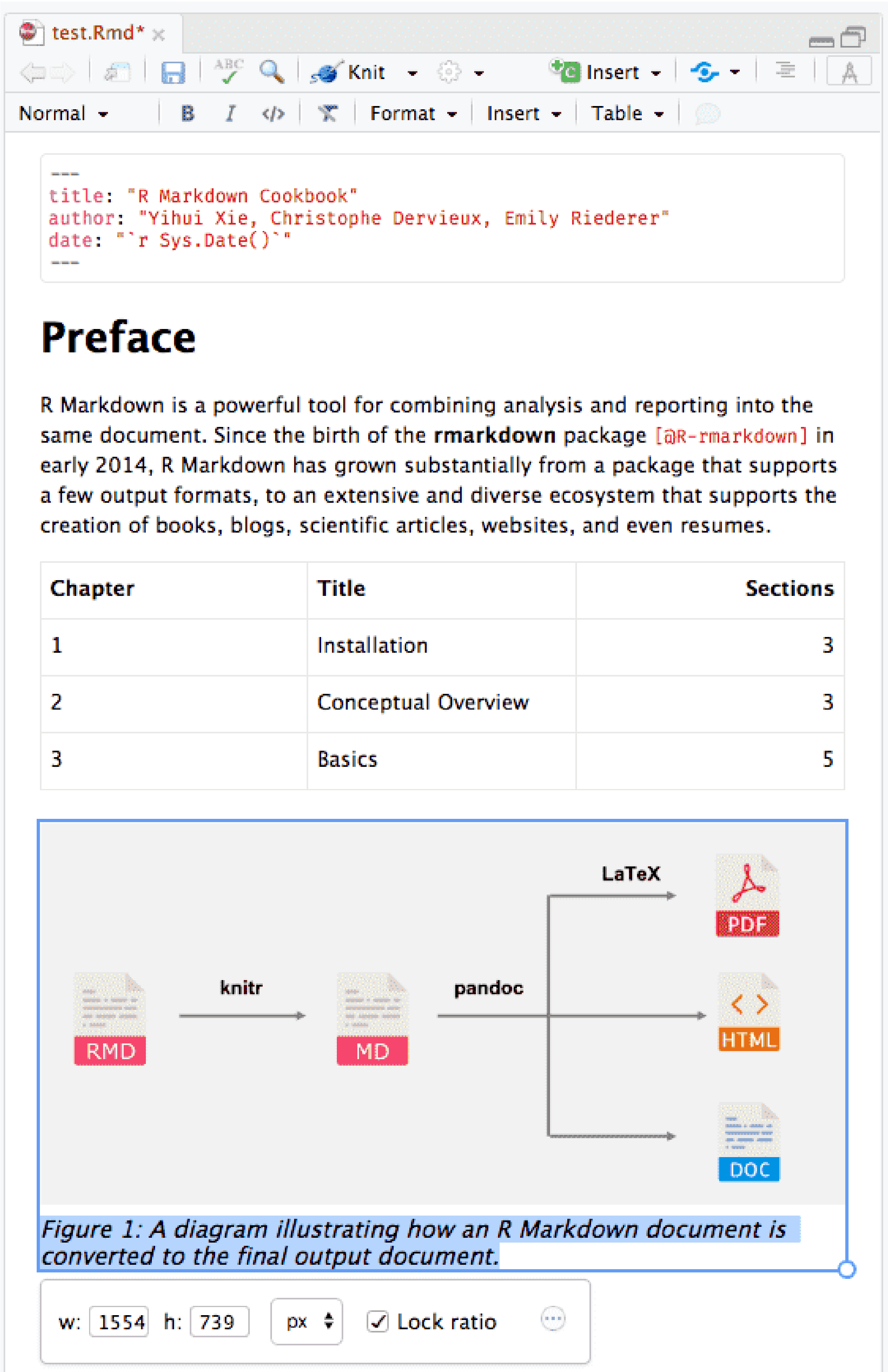

図3.1: RStudio のビジュアル Markdown エディタ

- `#+` で始まるコメントは knitr チャンクヘッダとして扱われます．例えば `#+ label, fig.width=5` というコメントを，`knitr::spin()` は R Markdown の ```` ```{r label, fig.width=5} ```` というチャンクヘッダへ翻訳します．

- `{{ code }}` で囲まれた R コードは R Markdown のインライン R 表現へ翻訳されます．`{{ code }}` は 1 行で書かなければならないことに注意してください．

- YAML フロントマターも，R スクリプトの冒頭の roxigen コメント内に書くことができます．YAML フィールドのインデントによく気をつけてください．YAML のインデントを省くとデータ構造の表現は不正確なものに変わることがあります．例えば `keep_tex: true` というフィールドは，後述する例のように `pdf_document` 以下に 2 つ以上のスペースでインデントするべきです．

- `/*` と `*/` の間の任意のテキストは無視されます (つまり，完全にコメントとして扱われます)

上記のルールの全ての例を表現したのが以下です．

```
#' ---
#' title: "純粋な R script から生成したレポート"
#' output:
#'   pdf_document:
#'     keep_tex: true
#' ---
#'
#' これは `knitr::spin()` によって生成されたレポートです.
#'
#' **knitr** オプションをいくつか試してみましょう:

#+ echo=FALSE, fig.width=7
# これは通常の R コメント文です.
plot(cars)

#' ここにインラインの値を書きましょう. $\pi$ の値は
{{ pi }}
#' であると知られています.
#'
#' 最後に, 全ての roxygen コメントは任意だということを書いておきます.
#' プロットの大きさなど出力要素をコントロールしようと思わない限り
```

```
#' チャンクオプションも必要でありません

# /* C 言語のコメントのように /* と */ の間にコメントを書きましょう:
Sys.sleep(60)
# */
```

このスクリプトがレポートにレンダリングされた時, knitr::spin() はこれを R Markdown へと変換します.

```
---
title: " 純粋な R script から生成したレポート"
output:
  pdf_document:
    keep_tex: true
---

これは `knitr::spin()` によって生成されたレポートです.

**knitr** オプションをいくつか試してみましょう:

```{r echo=FALSE, fig.width=7}
#  これは通常の R コメント文です.
plot(cars)
```

ここにインラインの値を書きましょう. π の値は
`r pi`
であると知られています.

最後に, 全ての roxygen コメントは任意だということを書いておきます.
プロットの大きさなど出力要素をコントロールしようと思わない限り
チャンクオプションも必要でありません
```

このレポート生成方法は, 主に R スクリプトを使って作業していて, 多くのナラティブを必要としないときに特に役立つかもしれません. レポートが実質テキストであるほどの割合のテキストなら,

全てのテキストを roxygen コメントに入れなくてもいいので R Markdown がより良い選択かもしれません.

3.4　Markdown から R script への変換

R Markdown から全ての R コードを取り出したい時, あなたは `knitr::purl()` を呼ぶことができます. 以下は `purl.Rmd` というファイル名の簡単な Rmd の例です.

```
---
title: R コードを取りだすために `purl()` を使いましょう
---

`knitr::purl()` 関数は **knitr** 文書から　R コードチャンクを取り出しコードを R スクリ
↪ プトに保存します.

以下は簡単なチャンクです.

```{r, simple, echo=TRUE}
1 + 1
```

`r 2 * pi` のようなインライン R 表現はデフォルトでは無視されます.

特定のコードチャンクを取り出してほしくない場合は, チャンクオプション `purl = FALSE` を
↪ 設定できます. 例えば以下のように.

```{r, ignored, purl=FALSE}
x = rnorm(1000)
```
```

`knitr::purl("purl.Rmd")` を呼び出したら, 以下の R スクリプト (デフォルトのファイル名は `purl.R`) が生成されます.

```
## ---- simple, echo=TRUE-----------------------------
1 + 1
```

上記の R スクリプトでは, チャンクオプションはコメントとして書かれています. 純粋な R コードが欲しい場合, `documentation = 0` という引数を与えて `knitr::purl()` を呼ぶことになるでしょう. これで以下のような R スクリプトが生成されます.

```
1 + 1
```

テキストも全て維持したい場合 `documentation = 2` 引数を使うことになるでしょう. これは以下のような R スクリプトを生成します.

```
#' ---
#' title: R コードを取りだすために `purl()` を使いましょう
#' ---
#'
#' `knitr::purl()` 関数は **knitr** 文書から R コードチャンクを取り出しコードを R ス
↪ クリプトに保存します.
#'
#' 以下は簡単なチャンクです.
#'
## ---- simple, echo=TRUE-----------------------------
1 + 1

#'
#' `r 2 * pi` のようなインライン R 表現はデフォルトでは無視されます.
#'
#' 特定のコードチャンクを取り出してほしくない場合は, チャンクオプション `purl = FALSE`
↪ を設定できます. 例えば以下のように.
#'
```

`purl = FALSE` というオプションのあるコードチャンクはこの R スクリプトから除外されることに注意してください.

インライン R 表現はデフォルトでは無視されます. R スクリプトにインライン表現も含めたいなら, `knitr::purl()` を呼ぶ前に R のグローバルオプション `options(knitr.purl.inline = TRUE)` を設定する必要があります.

3.5 R Markdown Notebook

R Markdown Definitive Guide (Xie J.J. Allaire, and Grolemund, 2018) の Section 2.2[*2] で言及したように, Rmd 文書をコンパイルする方法はいくつかあります. その 1 つは `html_notebook` という出力形式で R Markdown Notebook を使うことです. 例えば以下のように.

```
---
title: An R Markdown Notebook
output: html_notebook
---
```

RStudio でこの出力形式を使うと, ツールバー上の `knit` ボタンが `Preview` ボタンになります.

notebook を使う主な利点は Rmd 文書を**同じ R セッションで繰り返し**作業できることです. コードチャンクにある緑色の矢印ボタンを押すことでチャンクを個別に随時実行し, エディタ上でテキストやグラフの出力を見ることができます. ツールバー上の `Preview` ボタンを押せば Rmd 文書は, あなたが既に実行したコードチャンクの出力を含む HTML 出力の文書へのみレンダリングされます. `Preview` ボタンは一切のコードチャンクを実行しません. これと比較して, 他の出力形式を使い `knit` ボタンを押せば RStudio は文書全体をコンパイルする (つまり全てのコードチャンクが一気に実行されます) ために R セッションを新規で立ち上げます. これはたいてい, より時間がかかります.

コードチャンクを個別に実行した時に出力が表示されるという RStudio のデフォルトの挙動が気に入らないなら, `Tools -> Global Options -> R Markdown` から "Show output inline for all R Markdown documents" というオプションのチェックを外すことができます. 以降は, コードチャンクを実行すると出力はソースエディタ内ではなく R コンソールに表示されます. このオプションは YAML メタデータで個別の Rmd 文書ごとに設定できます. このように.

```
editor_options:
  chunk_output_type: console
```

*2 https://bookdown.org/yihui/rmarkdown/compile.html

第 4 章

文書の要素

本章では, 改ページ, YAML メタデータ, セクションヘッダ, 引用, 相互参照, 数式, アニメーション, 対話的プロット, ダイアグラム, コメントといった R Markdown 文書の要素をカスタマイズしたり生成したりするのに使える豆知識と小ワザを紹介します.

4.1 改ページ (改段) を挿入する

改ページしたい場合, `\newpage` を文書に挿入できます.[*1] これは LaTeX コマンドですが, **rmarkdown** パッケージは LaTeX 出力フォーマットでも, HTML, Word, ODT などのいくつかの非 LaTeX 出力フォーマットでも認識することができます.[*2]

例えば以下のように.

```
---
title: Breaking pages
output:
  pdf_document: default
  word_document: default
  html_document: default
  odt_document: default
---
```

[*1] **訳注:** 正確には `\newpage` コマンドは改「段」です. 二段組の場合, 次の段に改めるため, 必ずページを改めるわけではありません.

[*2] HTML 出力では, 改ページは HTML ページの出力時のみ意味をなし, それ以外では HTML は単一の連続したページになるため, 改ページを見ることはありません.

```
# 第一節

\newpage

# 第二節
```

これは Pandoc の Lua フィルタ に基づく機能です (4.20 節参照). 技術的なことに興味のある方はこのパッケージの vignettte を見てください.

```r
vignette("lua-filters", package = "rmarkdown")
```

4.2 文書タイトルを動的に設定する

Rmd 文書内のどこでも, YAML メタデータの部分であっても行内 R コード (3.1節) を使うことができます. つまり行内 R コードによって文書のタイトルなどの YAML メタデータの動的生成が可能ということです. 例えばこのように.

```
---
title: " 自動車 `r nrow(mtcars)` 台の分析"
---
```

タイトルが以降の文書内で作成される R の変数に依存する場合, 以下の例のようにその後に YAML セクションを書いて `title` フィールドを加えることになるでしょう.

```
---
author: " 利口なアナリスト"
output: pdf_document
---

我々の市場シェアを頑張って計算してみました.
I just tried really hard to calculate our market share:

```{r}
```
```

```
share <- runif(1)
```
```

---
title: "我々の市場シェアは今や `r round(100 * share, 2)`% です!"
---

これはとても `r if(share > 0.8) "喜ばしい" else "悲しい"` ことです.
```

上記の例では, 変数 share を作成してから文書のタイトルを追加しています. Pandoc は文書内に YAML セクションをいくつ書いても読み込む (そして全てマージする) ことができるため, この例が動作します.

タイトルだけでなくどの YAML フィールドも, パラメータ化されたレポートから動的に生成することができます (17.4 節参照). 例えばこのように.

```
---
title: "`r params$doc_title`"
author: "利口なアナリスト"
params:
  doc_title: "デフォルトのタイトル"
---
```

タイトルが動的なパラメータなら, タイトルだけ異なるレポートのまとまりを簡単に生成できます.

この節ではタイトルを例にしましたが, このアイディアは YAML セクションのどのメタデータのフィールドにも適用可能です.

4.3 R コード内で文書メタデータにアクセスする

Rmd 文書をコンパイルする際に, YAML セクションの全てのメタデータはリストオブジェクト rmarkdown::metadata に保存されます. 例えば rmarkdown::metadata$title は文書のタイトルを与えます. YAML メタデータに与えられた情報をハードコードしなくてすむように, この metadata オブジェクトを R コード内で使うことができます. 例えば **blastula** パッケージ (Richard Iannone and Cheng, 2020) で E メールを送る時, 文書のタイトルをメールの件名に, 著者フィールドを送信者情報に使うことができます.

```
---
title: 重要なレポート
author: John Doe
email: john@example.com
---

重要な分析ができましたので結果をメールで送りたいと思います.

```{r}
library(rmarkdown)
library(blastula)
smtp_send(
  ...,
  from = setNames(metadata$email, metadata$author),
  subject = metadata$title
)
```
```

4.4 番号のない節

ほとんどの出力フォーマットは number_sections オプションをサポートしています. これは true を設定すれば節への付番を有効にできるオプションです. 例えば以下のように.

```
output:
  html_document:
    number_sections: true
  pdf_document:
    number_sections: true
```

特定の節に番号を付けたくないならば, number_sections オプションは true のままにして, その節のヘッダの直後に {-} を加えます. 例えばこのように.

```
# この節には番号がつきません {-}
```

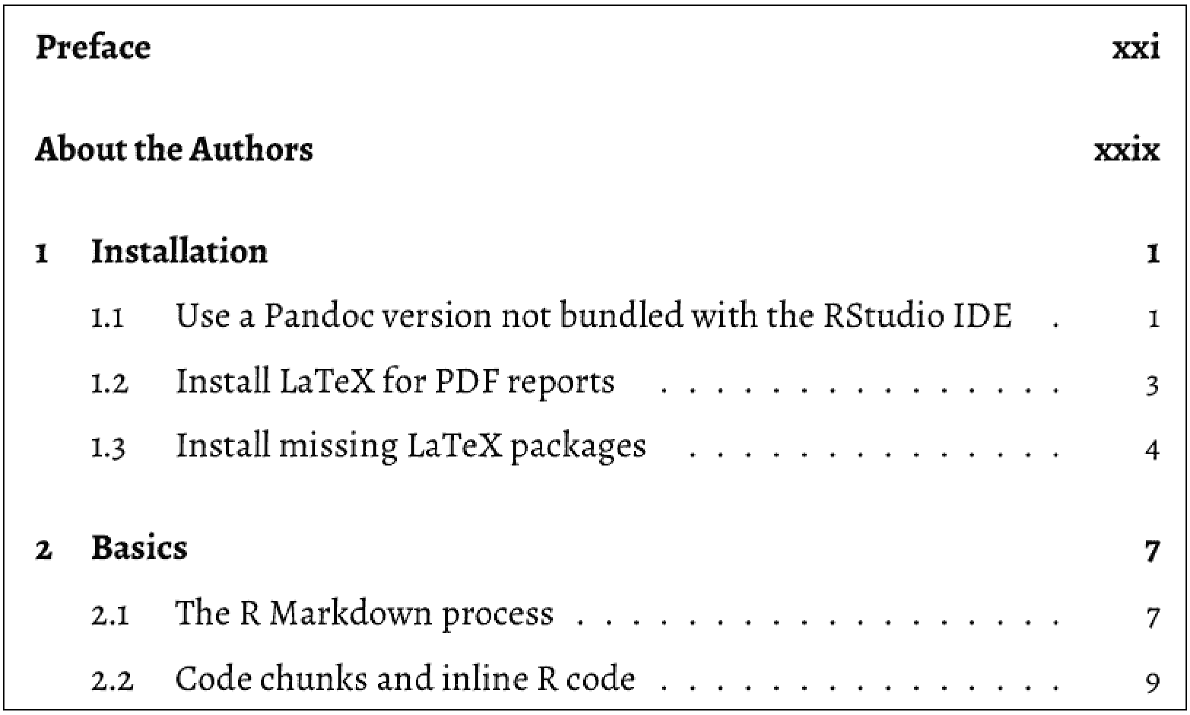
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図4.1: 付番された章とされていない章を示すための目次のスクリーンショット

全く同じことを, `{.unnumbered}` を使ってもできます. 例えば `{.unnumbered #section-id}` のように, 他の属性を追加することもできます. 詳細は https://pandoc.org/MANUAL.html#extension-header_attributes を確認してください.

付番されてない節はしばしば記述に追加の情報を与えるのに使われます. 例えば本書では,「はじめに」と「著者について」の章は本文では含まれないため付番されていません. 図4.1で見られるように, 実際の本文は付番されていない章 2 つの後から始まり, 本文の章は付番されています. TODO: 日本語版が出来たらスクリーンショット撮り直す.

節番号は漸増します. もし付番されている節の後にされていない節が挿入し, その後にさらに付番された節が開始しているなら, 節番号はそこから増加を再開します.

4.5 参考文献と引用

参考文献の目録を出力文書に含める方法の概観として, Xie (2016) の Section 2.8[*3] を見ると良いでしょう. 基本的な使用法として, YAML メタデータの `bibliography` フィールドに文献目録ファイルを指定する必要があります. 例えば BibTeX データベースが `*.bib` という拡張子の付いたプレーンテキストとして与えられているなら, このようにします.

---

*3 https://bookdown.org/yihui/bookdown/citations.html

```yaml
---
output: html_document
bibliography: references.bib
---
```

そしてこのファイルに文献アイテムがこのようなエントリで含まれています.

```bibtex
@Manual{R-base,
  title = {R: A Language and Environment for Statistical
           Computing},
  author = {{R Core Team}},
  organization = {R Foundation for Statistical Computing},
  address = {Vienna, Austria},
  year = {2019},
  url = {https://www.R-project.org},
}
```

文書内 `@key` という構文で文献アイテムを直接引用することができます. `key` の部分エントリの最初の行にある引用キーです. 上記の例なら `@R-base` です. 括弧で囲んで引用したいなら, `[@key]` を使います. 複数のエントリを同時に引用するなら, `[@key-1; @key-2; @key-3]` のようにセミコロンでキーを区切ります. 著者名を表示しないのなら, `[-@R-base]` のように `@` の前にマイナス記号を付けます.

4.5.1 引用スタイルの変更

デフォルトでは Pandoc は Chicago 式の著者名-出版年形式の引用スタイルと参考文献スタイルを使います. 他のスタイルを使うには, メタデータフィールドの `csl` で CSL (Citation Style Language) ファイルを指定します. 例えばこのように.

```yaml
---
output: html_document
bibliography: references.bib
csl: biomed-central.csl
---
```

必要としているフォーマットを見つけるには, Zotero Style Repository,[*4] を使うことをおすすめします．これは必要なスタイルの検索とダウンロードが簡単にできます．

CSL ファイルはカスタマイズされたフォーマット要件に合うようにを修正できます．例えば “et al.” の前に表示する著者の人数を変更できます．これは https://editor.citationstyles.org で使用できるようなビジュアルエディタを使って簡単にできます．

4.5.2 引用していない文献を参考文献に追加する

デフォルトでは参考文献には文書で直接参照されたアイテムのみ表示されます．本文中に実際に引用されていない文献を含めたい場合, notice というダミーのメタデータフィールドを定義し, そこで引用します．

```
---
nocite: |
  @item1, @item2
---
```

4.5.3 全てのアイテムを参考文献に掲載する

文献目録のすべてのアイテムを明示的に言及したくないが, 参考文献には掲載したいというなら, 以下のような構文が使えます．

```
---
nocite: '@*'
---
```

これは全てのアイテムを参考文献として強制的に掲載させます．

4.5.4 参考文献の後に補遺を掲載する (*)

デフォルトでは参考文献は文書全体の最後に掲載されます．しかし参考文献一覧の後に追加のテキストを置きたいこともあるでしょう．一番よくあるのは文書に補遺 (appendix) を含めたいときです．以下に示すように, <div id="refs"></div> を使うことで参考文献一覧の位置を矯正できます．

[*4] https://www.zotero.org/styles

```
# 参考文献

<div id="refs"></div>

# 補遺
```

<div> は HTML タグですが, この方法は PDF など他の出力フォーマットでも機能します.

bookdown パッケージ (Xie, 2020a) を使うことで, 補遺の開始前に special header[*5] `# (APPENDIX) Appendix {-}` の挿入が可能となりさらに改善できます. 例えば以下のように.

```
# 参考文献

<div id="refs"></div>

# (APPENDIX) 補遺 {-}

# 追加情報

これは「補遺 A」になる.

# さらにもう 1 つ

これは「補遺 B」になる.
```

LaTeX/PDF および HTML フォーマットでは補遺の付番スタイルは自動的に変更されます (たいていは A, A.1, A.2, B, B.1, ... という形式です).

4.6 R パッケージの引用を生成する

R パッケージを引用するには, base R の `citation()` を使うことができます. BibTeX 用の引用エントリを生成したいなら, `citation()` の返り値を `toBibtex()` を与えることができます. 例えばこうです.

*5 https://bookdown.org/yihui/bookdown/markdown-extensions-by-bookdown.html#special-headers

```r
toBibtex(citation("xaringan"))
```

```
@Manual{,
  title = {xaringan: Presentation Ninja},
  author = {Yihui Xie},
  year = {2020},
  note = {R package version 0.19},
  url = {https://CRAN.R-project.org/package=xaringan},
}
```

toBibtex() で生成されたエントリを使うには, 出力を .bib ファイルにコピーし, 引用キーを追加しなければなりません (例えば @Manual{, の部分を @Manual{R-xaringan, と書き換える). これは knitr::write_bib() 関数によって自動化できます. この関数は引用エントリを生成し, 自動的にキーを加えてファイルに書き込みます. 例えばこのようにします.

```r
knitr::write_bib(c(.packages(), "bookdown"), "packages.bib")
```

第 1 引数はパッケージ名の文字列ベクトルで, 第 2 引数は .bib ファイルのパスであるべきです. 上記の例では, .packages() は現在の R セッションが読み込んでいる全てのパッケージ名を返します. これらのパッケージのいずれかが更新された (例えば著者, タイトル, 年, あるいはバージョンが変更された) とき, write_bib() は自動的に .bib を更新できます.

引用エントリには 2 つのタイプが選択肢としてあります. 1 つはパッケージの DESCRIPTION ファイルをもとに生成したもので, もう 1 つは, もしパッケージに CITATION ファイルが存在するなら, そこから生成したものです. 前者のタイプは引用キーが R-(パッケージ名) という形式になり (例えば R-knitr), 後者のタイプはパッケージ名と公開年を結合したものがキーとなります (例: knitr2015). もし複数のエントリが同一年にあるなら, 接尾文字が追加されます. 例えば knitr2015a と knitr2015b のように. 前者のタイプはしばしばパッケージ自体を引用 (つまり, ソフトウェアとして) するのに使われますが, 後者のタイプはしばしば論文や書籍のようなパッケージと関連のある出版物として扱われます.

```r
knitr::write_bib(c("knitr", "rmarkdown"), width = 60)
```

```
@Manual{R-knitr,
  title = {knitr: A General-Purpose Package for Dynamic
    Report Generation in R},
  author = {Yihui Xie},
  year = {2020},
  note = {R package version 1.30},
  url = {https://yihui.org/knitr/},
}

@Manual{R-rmarkdown,
  title = {rmarkdown: Dynamic Documents for R},
  author = {JJ Allaire and Yihui Xie and Jonathan McPherson
    and Javier Luraschi and Kevin Ushey and Aron Atkins
    and Hadley Wickham and Joe Cheng and Winston Chang and
    Richard Iannone},
  year = {2020},
  note = {R package version 2.6},
  url = {https://github.com/rstudio/rmarkdown},
}

@Book{knitr2015,
  title = {Dynamic Documents with {R} and knitr},
  author = {Yihui Xie},
  publisher = {Chapman and Hall/CRC},
  address = {Boca Raton, Florida},
  year = {2015},
  edition = {2nd},
  note = {ISBN 978-1498716963},
  url = {https://yihui.org/knitr/},
}

@InCollection{knitr2014,
  booktitle = {Implementing Reproducible Computational
    Research},
  editor = {Victoria Stodden and Friedrich Leisch and Roger
```

```
    D. Peng},
  title = {knitr: A Comprehensive Tool for Reproducible
    Research in {R}},
  author = {Yihui Xie},
  publisher = {Chapman and Hall/CRC},
  year = {2014},
  note = {ISBN 978-1466561595},
  url = {http://www.crcpress.com/product/isbn/
    9781466561595},
}

@Book{rmarkdown2018,
  title = {R Markdown: The Definitive Guide},
  author = {Yihui Xie and J.J. Allaire and Garrett
    Grolemund},
  publisher = {Chapman and Hall/CRC},
  address = {Boca Raton, Florida},
  year = {2018},
  note = {ISBN 9781138359338},
  url = {https://bookdown.org/yihui/rmarkdown},
}

@Book{rmarkdown2020,
  title = {R Markdown Cookbook},
  author = {Yihui Xie and Christophe Dervieux and Emily
    Riederer},
  publisher = {Chapman and Hall/CRC},
  address = {Boca Raton, Florida},
  year = {2020},
  note = {ISBN 9780367563837},
  url = {https://bookdown.org/yihui/rmarkdown-cookbook},
}
```

ファイルパスの引数がないと, `knitr::write_bib()` は上記の例のように引用エントリをコンソールに出力します.

write_bib() は既存の文献目録ファイルを上書きするように設計されていることに注意してください．文献目録に手動で他のエントリを追加したい場合，2 つ目の .bib ファイルを作成して，この例のように bibliography フィールドで参照してください．

```
---
bibliography: [packages.bib, references.bib]
---

```{r, include=FALSE}
knitr::write_bib(file = 'packages.bib')
```
```

上記の例では packages.bib が自動で生成されたもので，手動で変更すべきではありません．それ以外の全ての引用エントリは references.bib に手動で書き込むことができます．

ここまでは R パッケージの引用を生成する方法を 1 つだけ紹介しています．それ以外のタイプの文献を動的に引用を生成するには，**knitcitations** パッケージ (Boettiger, 2021) を確認すると良いでしょう．

4.7 文書内の相互参照

相互参照 はあなたの文書を通して読者を誘導するのに役に立つ方法であり，R Markdown ではこれを自動的に行なえます．これは **bookdown** 本の Chapter 2[*6] で既に説明されていますが，以下で簡潔な説明をします．

相互参照を使用するにあたって，以下が必要になります．

- **bookdown 出力フォーマット**：相互参照は基本となる **rmarkdown** パッケージでは直接提供されず，**bookdown** (Xie, 2020a) による拡張機能として提供されています．よって YAML の output フィールドで **bookdown** のフォーマット (例：html_document2, pdf_document2, word_document2 など) を使用しなければなりません．
- **図 (または表) に対するキャプション**：キャプションのない図は単なる画像として直接埋め込まれるためあめ，付番された図 (figure) にはなりません．
- **ラベルの設定されたコードチャンク**：チャンクによって生成された図を参照するための識別子を提供してくれます．

*6 https://bookdown.org/yihui/bookdown/components.html

これらの条件が合わさって初めて, テキスト内で `\@ref(type:label)` という構文を使って相互参照を作成できます. `label` はチャンクラベルであり, `type` は参照するものの環境 (例:, `tab`, `fig`, `eqn`) です. 以下に例を示します.

```
---
title: 図, 表, 数式を相互参照する
author: bookdown による生成
output:
  bookdown::html_document2: default
  bookdown::pdf_document2: default
---

図 \@ref(fig:cars-plot) を見よ.

```{r cars-plot, fig.cap=" 自動車のデータ", echo=FALSE}
par(mar = c(4, 4, .2, .1))
plot(cars)  # a scatterplot
```

次に数式\@ref(eq:mean) を見よ.

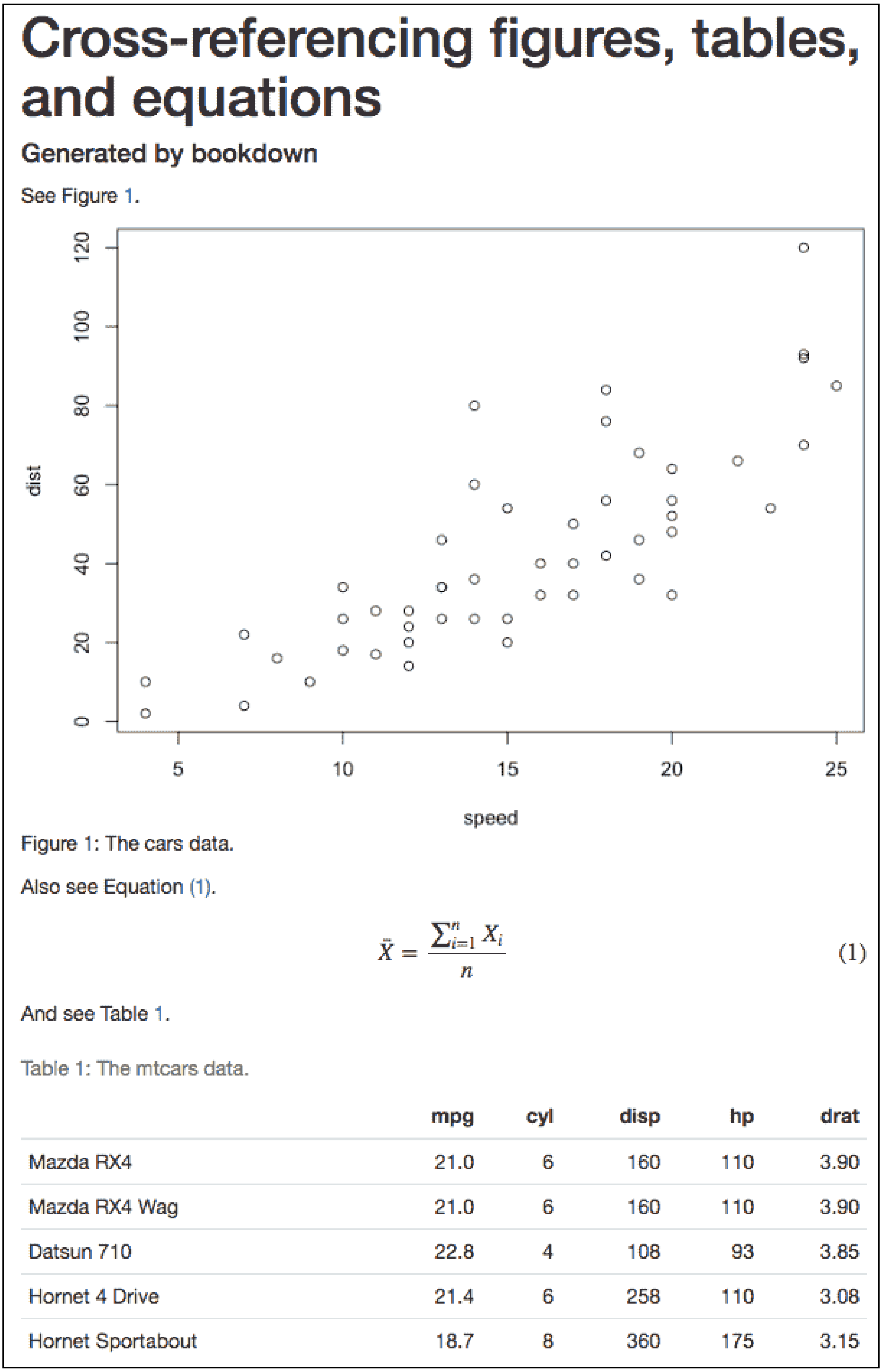
\begin{equation}
\bar{X} = \frac{\sum_{i=1}^n X_i}{n} (\#eq:mean)
\end{equation}

さらに表 \@ref(tab:mtcars) を見よ.

```{r mtcars, echo=FALSE}
knitr::kable(mtcars[1:5, 1:5], caption = "mtcars データ")
```
```

この文書の出力を図 4.2 に示します.

数式, 定理, 節の見出しにも相互参照することができます. これらのタイプの参照は **bookdown** 本の 2.2, 2.6 節でより説明されています.



Cross-referencing figures, tables, and equations

Generated by bookdown

See Figure 1.

Figure 1: The cars data.

Also see Equation (1).

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n} \quad (1)$$

And see Table 1.

Table 1: The mtcars data.

	mpg	cyl	disp	hp	drat
Mazda RX4	21.0	6	160	110	3.90
Mazda RX4 Wag	21.0	6	160	110	3.90
Datsun 710	22.8	4	108	93	3.85
Hornet 4 Drive	21.4	6	258	110	3.08
Hornet Sportabout	18.7	8	360	175	3.15

図4.2: R Markdown 文書内の相互参照の例

4.8 日付を自動的に更新する

出力されたレポートに Rmd 文書がコンパイルされた日付を表示したいなら, YAML メタデータの `date` フィールドに行内 R 評価式を追加し, 現在の日付を得るために `Sys.Date()` or `Sys.time()` 関数を使用できます.

```
date: "`r Sys.Date()`"
```

もっと人間にとって読みやすい, 特定の日次フォーマットを指定したいかもしれません. 例えば以下のようにします.

```
date: "`r format(Sys.time(), '%x')`"
```

例えば 2021 年 1 月 24 日といったコードはあなたが文書を knit するごとに, 日付を動的に生成します. 日付のフォーマットをカスタマイズしたいならば, ご自分でフォーマット文字列を与えて変更できます. いくつか例をお見せしましょう.

- `%Y %B`: 2021 1 月
- `%y/%m/%d`: 21/01/24
- `%b%d (%a)`: 1 月 24 (日)

表 4.1 は POSIXct フォーマットの一覧です.

最後に, 説明的なテキストを日付に含めたいかもしれないときのことを書いておきます. このように R コードの前に「最終コンパイル日」のような何らかの文を追加することができます.

```
date: "最終コンパイル日 `r format(Sys.time(), '%Y/%m/%d')`"
```

4.9 文書に複数の著者を表記する

R Markdown 文書の YAML フロントマターに複数の著者を加える方法は複数あります. 単純に, 全員を同列に並べたい場合, 1 つの文字列を与えることでできます. 例えばこのように.

表4.1: Date and time formats in R.

コード	意味	コード	意味
%a	曜日の略称	%A	曜日の名称
%b	月の略称	%B	月の名称
%c	ロケール依存の時刻	%d	数値表記の日
%H	数値表記の時間 (24 時間)	%I	数値表記の時間 (12 時間)
%j	1 年の何日目か	%m	数値表記の月
%M	数値表記の分	%p	ロケール依存の午前/午後
%S	数値表記の秒	%U	年の何週目か (日曜日始まり)
%w	数値表記の曜日 (0= 日曜日)	%W	年の何週目か (月曜日始まり)
%x	ロケール依存の日付	%X	ロケール依存の時刻
%y	下 2 桁表記の年	%Y	4 桁表記の年
%z	GMT からのオフセット	%Z	タイムゾーン (文字表記)

```
---
title: "無題"
author: "John Doe, Jane Doe"
---
```

別の方法として, 各エントリごとに行を分けたいならば, YAML フィールドにエントリのリストを与えることができます. これは著者ごとに E メールアドレスや所属情報を加えたいときに役に立ちます. 例えばこのように.

```
---
author:
  - John Doe, 組織 1
  - Jane Doe, 組織 2
---
```

追加情報を文書の脚注として追記したい時, Markdown 構文の `^[]` を利用できます. これは著者ごとに連絡先 E メールや住所といった多くの情報を含めたい場合により便利です. 厳密な動作は出力フォーマットに依存します.

```
---
author:
  - John Doe^[組織 1, john@example.org]
  - Jane Doe^[組織 2, jane@example.org]
---
```

特定の R Markdown テンプレートでは YAML に直接追加パラメータを指定することができます. 例えば Distill[*7] 出力フォーマットは url, affiliation, affiliation_url を指定することが可能です. まずは **distill** パッケージ (JJ Allaire Rich Iannone, et al., 2020) をインストールします.

```
install.packages("distill")
```

Distill フォーマットは詳細な著者情報を与えて使うことができます. 例えばこのように.

```
---
title: "R Markdown のための Distill"
author:
  - name: "JJ Allaire"
    url: https://github.com/jjallaire
    affiliation: RStudio
    affiliation_url: https://www.rstudio.com
output: distill::distill_article
---
```

4.10 図のキャプションへの付番

bookdown (Xie, 2020a) 出力フォーマット を, 図のキャプションに図番号を追加するのに使うことができます. 以下はその例です.

```
---
output: bookdown::html_document2
---
```

*7 https://rstudio.github.io/distill/

```
```{r cars, fig.cap = " すごいプロット"}
plot(cars)
```


```{r mtcars, fig.cap = " これもすごいプロット"}
plot(mpg ~ hp, mtcars)
```
```

4.7 節では表や数式といった他の要素でどのように動くか, そして付番された要素をテキスト内で相互参照する方法を実演しています. html_document2 いがいにも, pdf_document2, word_document2 といった他の出力に対する同様のフォーマット関数もあります.

bookdown 以外の R Markdown 出力フォーマットにもこの機能を追加できます. 鍵はこれらが **bookdown** 出力フォーマットの「基本フォーマット」であることです. 例えば, rticles::jss_article フォーマットで図に付番と相互参照をするために以下が使えます.

```
output:
  bookdown::pdf_book:
    base_format: rticles::jss_article
```

bookdown 出力フォーマット関数のヘルプページを読んで, base_format 引数があるかどうか確認してみてください (例: ?bookdown::html_document2).

4.11 単語をコンマ区切りで結合する

文字列ベクトルを人間の読みやすい形で出力したいとします. 例えば x <- c("apple", "banana", "cherry") について, きっとあなたは [1] "apple" "banana" "cherry" のような R が通常プリントする形式で出力をしてほしくないでしょう. あなたは代わりに “apple, banana, and cherry” という文字列がほしいのではないでしょうか. 文字列ベクトルを連結して 1 つにまとめる R 基本関数の paste() があります. 例えば paste(x, collapse = ', ') とすれば, 出力は "apple, banana, cherry" となるでしょう. この方法の問題は (1) 接続詞 “and” が欠けており, (2) ベクトルの要素が 2 つだけの場合はコンマを使うべきでない ("apple, banana" ではなく "apple and banana" という出力になるべき) ということです.

knitr::combine_words() 関数は文字列ベクトルの長さにかかわらず, 要素を連結して文にできます. 基本的に, 単語 1 つに対してはそのまま同じものを返し, “A and B” という 2 つの単語に対し

ては "A and B" と返し，3 つ以上なら "A, B, C, ..., Y, and Z" と言うふうに返します．この関数はさらに出力をカスタマイズするいくつかの引数を持っています．例えば出力される単語をバッククオートで囲みたいなら，`knitr::combine_words(x, before = '``')` を使えば良いでしょう．以下に他の引数についてもさらなる例を示します．これらの出力例から引数の意味がよくわからないのであれば，ヘルプページ `?knitr::combine_words` もご覧ください．

```r
v <- c("apple", "banana", "cherry")
knitr::combine_words(v)
## apple, banana, and cherry
```

```r
knitr::combine_words(v, before = "`", after = "'")
## `apple', `banana', and `cherry'
```

```r
knitr::combine_words(v, sep = "、", and = "そして")
## apple、banana、そして cherry
```

```r
knitr::combine_words(v, sep = " / ", and = "")
## apple / banana / cherry
```

```r
knitr::combine_words(v[1])  # 単語 1 つ
## apple
```

```r
knitr::combine_words(v[1:2])  # 単語 2 つ
## apple and banana
```

```r
knitr::combine_words(LETTERS[1:5])
## A, B, C, D, and E
```

この関数は行内 R 評価式を使うときに特に使いやすいでしょう．例えばこのように．

```
今朝は`r knitr::combine_words(v, sep = '、', and='')`を食べた.
```

4.12 複数の改行コードを維持する

Markdown ユーザは, verbatim 環境 (コードブロック) 以外の場所では空白 (改行コード含む) は大抵の場合意味を持たないことに気づき, 驚くでしょう. 2 つ以上のスペースはスペース 1 つと同じであり, 改行 1 つはスペース 1 つと同じです. LaTeX や HTML を使ったことがあるなら, これらの言語と同じルールであるため驚くことはないかもしれません.

Markdown では, 空白行はしばしば段落などの要素の分離に使われます. 新しい段落に入らずに改行をするには, 末尾にスペース 2 つを追加しなければなりません. 特に詩や歌詞を引用したいときなど, 複数回改行したいときもあるかもしれません. 各行の末尾にスペース 2 つを手動で書き加えるのはうんざりする作業です. `blogdown::quote_poem()` はこの作業を自動でやってくれます. 例えばこのように.

```r
blogdown:::quote_poem(c(" かたつむり", " そろそろ登れ",
  " 富士の山"))
## [1] "> かたつむり  \n そろそろ登れ  \n 富士の山"
```

RStudio IDE と **blogdown** パッケージ (Xie Dervieux, and Presmanes Hill, 2021) をインストールして使っているなら, 改行を維持したいテキストを選択し, ツールバーの "Addins" から RStudio アドインの "Quote Poem" をクリックすることができます. 例えば以下のテキスト (fenced code block 記法内) は末尾にスペースが付いていません.

```
田子の浦ゆ
うち出でてみれば
真白にそ
富士の高嶺に
雪は降りける

--- 山部赤人
```

上記の詩句を選択肢, RStudio アドインの "Quote Poem" をクリックすれば, こう出力されます.

> 田子の浦ゆ
> うち出でてみれば
> 真白にそ
> 富士の高嶺に
> 雪は降りける
>
> — 山部赤人

時に「fenced code block は空白を維持するのに, 詩句をコードブロックに書くのはなぜですか」と質問があります. コードは詩的でありますが, 詩はコードではありません. 「コーディング」という行為にこだわりすぎないでください.

4.13 モデルを数式に変換する

Daniel Anderson らによって開発された **equatiomatic** パッケージ (`https://github.com/datalorax/equatiomatic`) は R で当てはめたモデルに対応する数式を表示する, 便利な自動化の手段を提供します. 簡単な例を以下に示します.

```
fit <- lm(mpg ~ cyl + disp, mtcars)
# 理論モデルを表示
equatiomatic::extract_eq(fit)
```

$$\mathrm{mpg} = \alpha + \beta_1(\mathrm{cyl}) + \beta_2(\mathrm{disp}) + \epsilon$$

```
# 実際の係数を表示
equatiomatic::extract_eq(fit, use_coefs = TRUE)
```

$$\mathrm{mpg} = 34.66 - 1.59(\mathrm{cyl}) - 0.02(\mathrm{disp}) + \epsilon$$

実際の数式を表示するには, チャンクオプション `results = "asis"` (オプションの意味は11.11節参照) が必要です. そうしないと, テキスト出力がそのまま表示されてしまいます.

このパッケージについてより詳しく知りたいならば, ドキュメントを読み, Github 上での開発状況を追ってください.

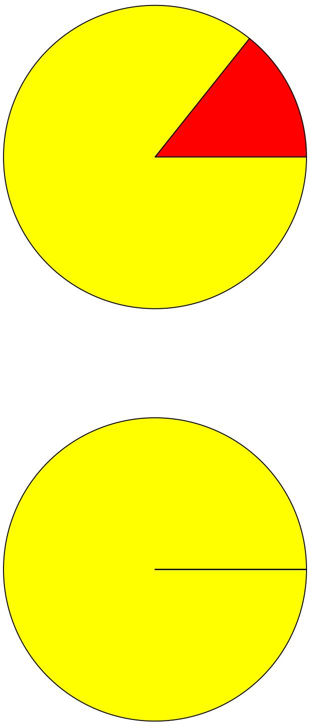


図4.3: パックマンのアニメーション

4.14 複数の R プロットからアニメーションを作成する

1 つのコードチャンクで一連のプロットを生成したとき，これらを結合し 1 つのアニメーションを生成できます．出力フォーマットが HTML なら，これは簡単です．**gifski** パッケージ (Ooms, 2018) をインストールし，チャンクオプション `animation.hook = "gifski"` 設定するだけです．図4.3 はシンプルな「パックマン」のアニメーションで，これは以下のコードで作成しました．

````
```{r, animation.hook="gifski"}
for (i in 1:2) {
  pie(c(i %% 2, 6), col = c('red', 'yellow'), labels = NA)
}
```
````

アニメーションのフォーマットは GIF で，HTML 出力ではうまく動作しますが，LaTeX は GIF を

直接サポートしていません．あなたが本書の PDF または印刷版を読んでいるなら，図4.3 が 2 つの動かない画像になっているのはこれが理由です．本書のオンライン版を読めば，実際のアニメーションが見られるでしょう．

PDF でもアニメーションを動作させることはできますが，事前準備が 2 つ必要です．第 1 に，LaTeX パッケージの **animate**[*8] を読み込む必要があります (方法は6.4節参照)．第 2 に，Acrobat Reader でのみアニメーションを見ることができます．第 2 位に，Acrobat Reader でのみアニメーションの動作を見ることができます．それからチャンクオプション `fig.show = "animate"` で **animate** パッケージ を使いアニメーションを作成できるようにします．以下はその例です．

````
---
title: PDF でのアニメーション
output:
  pdf_document:
    extra_dependencies: animate
---

以下のアニメーションは Acrobat Reader でのみ見ることができます．

```{r, fig.show='animate'}
for (i in 1:2) {
  pie(c(i %% 2, 6), col = c('red', 'yellow'), labels = NA)
}
```
````

アニメーションのイメージフレーム間の表示間隔はチャンクオプション `interval` で設定できます．デフォルトでは `interval = 1` (つまり 1 秒) です．

R パッケージ **animation** (Xie, 2018) には，統計的計算の方法やアイディアを表現するアニメーションの例がいくつか入っています．**gganimate** パッケージ (Pedersen and Robinson, 2020) は **ggplot2** (Wickham Chang, et al., 2020) に基づいた滑らかなアニメーションの作成を可能にします．どちらも R Markdown で動作します．

*8 https://ctan.org/pkg/animate

4.15 ダイアグラムを作成する

ダイアグラムやフローチャートを生成する, R とは独立したプログラム (例: Graphviz) は多くありますが, これらは Rmd 文書内のコードチャンク内で直接管理することができます.

R ではいくつかのパッケージが使用可能ですが, その中で **DiagrammeR** (Richard Iannone, 2020) とその他いくつかを最後に簡単に解説します. 完全なデモは `https://rich-iannone.github.io/DiagrammeR/` で見ることができます. この節では基本的な使用法とダイアグラム内で R コードを使う方法を紹介します.

4.15.1 基本的なダイアグラム

DiagrammeR はいくつかの異なるグラフ言語を使ってグラフを作成する方法を提供します. この節では Graphviz の例を提示しますが,[*9] **DiagrammeR** は純粋に R コードだけでグラフを作ることもできます.

RStudio IDE は Graphviz (`.gv`) および mermaid (`.mmd`) ファイルをネイティブにサポートしています. これらのタイプのファイルを RStudio で編集すると, シンタックスハイライトされるという利点があります. RStudio のツールバーの “Preview” ボタンをクリックすると, ダイアグラムをプレビューすることができます. 図4.4 は, 4 つのステップを表す矩形で構成された, フローチャートの単純な例です. これは以下のコードで生成されています.

```
DiagrammeR::grViz("digraph {
  graph [layout = dot, rankdir = TB]

  node [shape = rectangle]
  rec1 [label = 'ステップ 1. 起床する']
  rec2 [label = 'ステップ 2. コードを書く']
  rec3 [label =  'ステップ 3. ???']
  rec4 [label = 'ステップ 4. 収入を得る']

  # ノード ID でエッジを定義
  rec1 -> rec2 -> rec3 -> rec4
```

[*9] あなたのバックグラウンド次第では, この節は **DiagrammeR** に対する偏った解説になるかもしれません. このパッケージに興味があるなら, パッケージの公式ドキュメントをご覧ください.

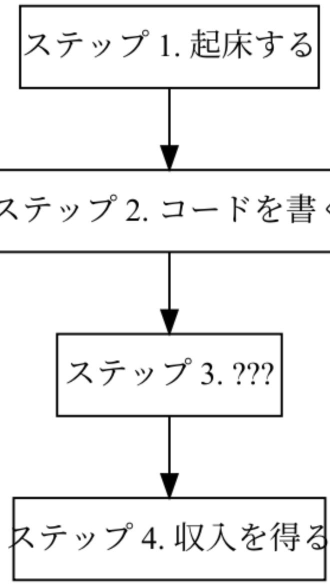


図4.4: プログラマの絵空事を表したダイアグラム

```
  }",
  height = 500)
```

ノードの形状, 色, 線のタイプを定義したり, パラメータを追加したりといったことができる拡張的な操作も用意されています.

4.15.2 図にパラメータを追加する

Graphviz の置換機能は可読性を損なうことなく, R 評価式を Graphviz のグラフ設定に混ぜ込むことができます. @@ を伴う置換を指定すれば, そこに置換される有効な R 評価式が確実にあるようにせねばなりません. 評価式は脚注として置かれ, そして R ベクトルオブジェクトを返すものでなくてはなりません. @@ という記法のすぐ後には数字が続き, これは R 評価式の脚注番号に対応します. 図4.5はダイアグラムへの R コードの埋め込みと評価の例です.

```
DiagrammeR::grViz("
  digraph graph2 {

```

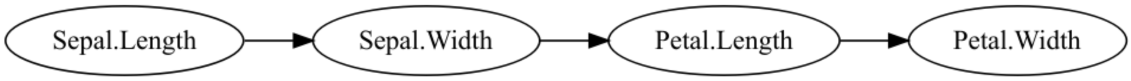


図4.5: R から入力されたパラメータを使用したダイアグラム

```
graph [layout = dot, rankdir = LR]

# node definitions with substituted label text
node [shape = oval]
a [label = '@@1']
b [label = '@@2']
c [label = '@@3']
d [label = '@@4']

a -> b -> c -> d
}

[1]: names(iris)[1]
[2]: names(iris)[2]
[3]: names(iris)[3]
[4]: names(iris)[4]
",
height = 100)
```

4.15.3 その他のダイアグラム作成パッケージ

ダイアグラム作成に使えるパッケージとして, **nomnoml** (de Vries and Luraschi, 2020), **diagram** (Soetaert, 2020), **dagitty** (Textor van der Zander, and Ankan, 2020), **ggdag** (Barrett, 2020), **plantuml** (https://github.com/rkrug/plantuml) といったものを確かめるこ

とになるかもしません.

4.16 特殊文字をエスケープする

Markdown 構文で特殊な意味を持つ文字がいくつかあります. これらの文字を直接使いたい場合, エスケープしなければなりません. 例えばテキストを囲むアンダースコアの組はたいていの場合テキストをイタリック体にします. イタリック体ではなく, アンダースコアをそのまま表示させたいなら, アンダースコアをエスケープする必要があります. 特殊な文字をエスケープする方法は, その直前にバックスラッシュを付けることです. 例えば「`ここは\_ イタリックに\_ したくない.`」というふうに. 同様に, # をセクションヘッダを表してほしくないなら, `\# これは見出しではない`などと書けばよいでしょう.

4.12 節で言及したように, 連続した空白文字は 1 つの正規スペースとして表示されます. 書いたとおりに連続した空白文字を表示させたいならば, 1 つ 1 つにエスケープが必要です. 例えば `ソーシャル \ \ \ ディスタンス維持`というふうに. 空白がエスケープされた時, 空白は「改行しない空白」に変換されます. これは, そのスペースの位置では行が折り返されないということです. 例えば `Mr.\ Dervieux` と言うふうに. TODO: ここもしかして折返しが発生するように調整されてる?

4.17 テキストのコメントアウト

ソース文書内のテキストを最終的な出力文書に表示させないようコメントアウトするのはとても便利です. この用途のため, HTML の構文である `<!-- ここにコメント -->` を使えます. コメントはどの出力形式にも表示されません.

コメントは 1 行でも, 複数行にも広げられます. これは草稿を書くのに便利でしょう.

RStudio を使うなら, 1 行丸ごとコメントアウトするのにキーボードショートカット `Ctrl + Shift + C` (MacOS なら `Command + Shift + C`) を使えます.

4.18 目次から見出しを省略する

目次に特定のセクションの見出しを表示させたくないなら, 見出しに 2 つのクラスを追加できます. `unlisted` と `unnumbered` です. 例えばこのように

```
# 見出し {.unlisted .unnumbered}
```

この機能は Pandoc 2.10 以降のバージョンが必要です. `rmarkdown::pandoc_version()` で

Pandoc のバージョンを確認しましょう. バージョンが 2.10 より古いなら, 新しいバージョンをインストールすることになるでしょう (1.1節参照).

4.19 全てのコードを補遺に置く (*)

対象読者がレポートを読む時, 計算の詳細に強く関心があるのでない限り, あなたはレポートにソースコードブロックを表示させたくないかもしれません. この用途で, チャンクオプション `echo = FALSE` を設定してソースコードを隠し, 読者がプログラムコードで気が散らないようにすることができます. しかしそれでも, ソースコードは再現可能性のある研究のために重要です. 読者はレポートを読み終わった後に計算の正しさを検証したいと思うかも知れません. この場合, 本文中の全てのコードブロックをまとめ, 文書の末尾 (例えば補遺として) に表示するというのは良い考えでしょう.

チャンクオプションの `ref.label` と `knitr::all_labels()` 関数を使い, 文書内の全てのコードチャンクを取り出して 1 つのコードチャンクにまとめる簡単な方法があります. 例えばこのように.

````
# 補遺: 本稿で使ったコード全文

```{r ref.label=knitr::all_labels(), echo=TRUE, eval=FALSE}
```
````

チャンクオプション `ref.label` について詳しく知らないならば, 14.1.3節を読んでください.

`knitr::all_labels()` 関数は文書内の全てのチャンクラベルを返すため, `ref.label = knitr::all_labels()` は全てのソースコードチャンクを回収しこのチャンクに持ってくることを意味します. チャンクオプション `echo = TRUE` (コードを表示させる) と `eval = FALSE` (全てのコードはすでに実行されているため, このコードチャンクは実行してはいけません) を付与すれば, 1 つのコードチャンクに全てのソースコードのコピーを表示させられます.

`ref.label` は任意のチャンクラベルの文字列ベクトルであるため, 補遺に表示するコードチャンクを一部だけにするようにラベルをフィルタリングできます. 以下はその例 (Ariel Muldoon[*10] によるものです) として `setup` と `get-labels` というラベルを排除しています.

```
```{r get-labels, echo = FALSE}
labs = knitr::all_labels()
```

[*10] https://yihui.org/en/2018/09/code-appendix/
```

```
labs = setdiff(labs, c("setup", "get-labels"))
```
```
```{r all-code, ref.label=labs, eval=FALSE}
```
```

`knitr::all_labels()` の引数を使ってコードチャンクをフィルタリングすることもできます. 例えば Rcpp エンジン (`engine == "Rcpp"`) を使用した全てのコードチャンクを得て, かつ文書に表示しない (`echo = FALSE`) ようにするには `knitr::all_labels(engine == "Rcpp", echo == FALSE)` を使えば良いでしょう. どのコードチャンクを補遺に表示したいのか, 正確にコントロールしたいならば, 指定したいコードチャンクに特殊なチャンクオプション `appendix = TRUE` を使い, それらのチャンクのラベルを得るのに `ref.label = knitr::all_labels(appendix == TRUE)` を使えば良いでしょう.

4.20 Pandoc の Lua フィルタから操作する (*)

技術的にはこの節は少し発展的ですが, Markdown の内容が Pandoc 抽象構文木 (AST) にどのように翻訳されるかを一度学べば, Lua というプログラミング言語を使ってどのような Markdown の要素も操作する力を得ることになります.

基本として, Pandoc は Markdown ファイルを読み取り, その内容が AST にパースされます. Pandoc はこの AST を Lua スクリプトを使って修正することを可能にします. AST の意味するものを示すため, 以下のような簡単な Markdown ファイル (`ast.md`) を使います.

```
## 第 1 節

Hello world!
```

このファイルは見出し 1 つとパラグラフ 1 つを持っています. Pandoc がこの内容をパースした後ファイルを JSON 形式に変換すれば, R ユーザーにとっては結果として現れる AST を理解するよりも簡単でしょう.

```
pandoc -f markdown -t json -o ast.json ast.md
```

そして JSON ファイルを R に読み込み, データ構造を書き出します.

この操作をしたら, Markdown の内容は再帰的なリストで表現されていることが分かるでしょう. その構造を以下に表します. ラベル t は “type”, c は “content” を表します. 例として見出しを取り上げてみましょう. タイプは “Header” で, その中身は 3 つの要素が含まれています. 見出しのレベル (2), 属性 (例えば ID が `section-one` であること), そしてテキストの内容です.

```r
xfun:::tree(
  jsonlite::fromJSON('ast.json', simplifyVector = FALSE)
)
```

```
List of 3
 |-blocks            :List of 2
 |  |-:List of 2
 |  |  |-t: chr "Header"
 |  |  |-c:List of 3
 |  |     |-: int 2
 |  |     |-:List of 3
 |  |     |  |-: chr "第1節"
 |  |     |  |-: list()
 |  |     |  |-: list()
 |  |     |-:List of 1
 |  |        |-:List of 2
 |  |           |-t: chr "Str"
 |  |           |-c: chr "第1節"
 |  |-:List of 2
 |     |-t: chr "Para"
 |     |-c:List of 3
 |        |-:List of 2
 |        |  |-t: chr "Str"
 |        |  |-c: chr "Hello"
 |        |-:List of 1
 |        |  |-t: chr "Space"
 |        |-:List of 2
 |           |-t: chr "Str"
 |           |-c: chr "world!"
 |-pandoc-api-version:List of 2
 |  |-: int 1
```

```
|  |-: int 20
|-meta               : Named list()
```

あなたが AST に気づけば, Lua によって修正することができます. Pandoc は組み込みの Lua インタプリタを持っているので, 追加でツールをインストールする必要はありません. Lua スクリプトは Pandoc では「Lua フィルタ」と呼ばれます. 次に見出しのレベルを 1 増やす, 例えばレベル 3 の見出しを 2 に変換する簡単な例を見せます. これは文書のトップレベルの見出しがレベル 2 で, 代わりにレベル 1 から始めたい場合に便利です.

最初に `raise-header.lua` という名前の Lua スクリプトファイルを作ります. これには `Header` という名前の関数が含まれており, “Header” タイプの要素を修正したいということを意味しています (一般に, あるタイプの要素を処理するためにタイプ名を関数名として使うことができます).

```lua
function Header(el)
  -- 見出しのレベルは要素の持つ 'level' 属性でアクセスできます.
  -- 後述の Pandoc ドキュメントを見てください.
  if (el.level <= 1) then
    error("h1 のレベルを上げる方法がわかりません")
  end
  el.level = el.level - 1
  return el
end
```

そしてこのスクリプト Pandoc の `--lua-filter` 引数に与えることができます. 例えばこうです.

```
pandoc -t markdown --atx-headers \
  --lua-filter=raise-header.lua ast.md
```

```
# 第1節

Hello world!
```

`## Section One` を `# Section One` へ変換することに成功したのがお分かりかと思います. この例は些細なものだと思うかも知れませんし, なんでこんなふうに単に正規表現を使って `##` を `#` に置き換えないのかと思うかも知れません.

```r
gsub("^##", "#", readLines("ast.md"))
```

例えば ## が R コード内でコメントに使われていたら, と言うふうに, 正規表現はほとんど常に例外があるため, たいていの場合で, 構造化された文書を操作するのにロバストな手段ではありません. AST は構造化されたデータを与えてくれるので, 確実に意図した要素を修正していることが分かります.

Pandoc の Lua フィルタに関する追加ドキュメントが https://pandoc.org/lua-filters.html にあり, ここで多くの例を見つけることができます. GitHub リポジトリ https://github.com/pandoc/lua-filters のコミュニティで書かれたフィルタを見つけることもできます.

R Markdown の世界では Lua フィルタを活用しているパッケージの例の一部が以下になります (たいていは inst/ ディレクトリにあります)

- **rmarkdown** パッケージ (https://github.com/rstudio/rmarkdown) は改行 (4.1節参照) を挿入するフィルタとカスタムブロック (9.6節参照) を生成するフィルタを含んでいます.
- **pagedown** パッケージ (Xie Lesur, et al., 2020) には脚注を実装するのを助けるフィルタと HTML ページに図のリストを表示するフィルタがあります.
- **govdown** パッケージ (Garmonsway, 2020) には Pandoc の Div による囲みを適切な HTML タグに変換するフィルタがあります.

本書の5.1.2節でも Lua フィルタでテキストの色を変更する方法を紹介する例を見ることができます.

Lua フィルタを (上記のパッケージのように) 導入するために R パッケージを作りたくない R Markdown ユーザーは, これらの Lua スクリプトをコンピュータのどこかに保存し, R Markdown 出力フォーマットの pandoc_args オプションで適用すると良いでしょう. 例えばこのように.

```yaml
---
output:
  html_document:
    pandoc_args:
      - --lua-filter=raise-header.lua
---
```

第 5 章

書式

Markdown 言語の最大の強みは，その簡潔さが初心者にとっても読み書きを非常に簡単にさせていることです．これはオリジナルの Markdown 言語の考案者も次のようにまとめている設計原理の鍵です．

> Markdown 形式の文書は見たままに，タグや整形の指示文でマークアップされず，プレーンテキストとして出力されるべきである．
>
> — John Gruber*1

しかし，これはカスタマイズのコストがかかります．典型的なワードプロセッサの多くの機能は Markdown で直接使うことができません．例えば以下のような機能です．

- テキストの一部のフォントサイズを変更する
- ある単語のフォント色を変更する
- テキストアラインメントを指定する

こういった機能があなたの努力に見合うかどうかはあなたの判断に委ねます．Markdown は，「自然界」はプレーンテキストからなり，(見た目上の) 面白さを欲求して**作為**すべきではない，というストア派哲学をいくらか反映しています．いずれにせよ，この章では R Markdown 文書の見た目や要素のスタイルをカスタマイズをどうやればできるかの豆知識をいくつか提示します．

Markdown 言語の基礎のリマインダが必要ならば，`https://www.rstudio.com/resources/cheatsheets/` にある R Markdown チートシートには基本構文の概観がうまく盛り込まれています． TODO: 翻訳版がないか確認

5.1 フォント色

Markdown 構文にはテキストの色を変更する方法は組み込まれていません. HTML と LaTeX の構文で単語の書式を変更できます.

- HTML では, テキストを タグで囲み CSS で色を設定します. 例えば text というふうに.
- PDF では, LaTeX コマンドの \textcolor{}{} が使えます. これには LaTeX パッケージの **xcolor** が必要で, Pandoc のデフォルトの LaTex テンプレートに含まれています.

PDF でテキストの色を変更する例として, 以下のようなものを挙げます.

```
---
output: pdf_document
---

薔薇は \textcolor{red}{赤い}, 菫は \textcolor{blue}{青い}.
```

上記の例では最初のカーリー・ブレースには指定するテキスト色が含まれ, 2 番めには色を適用したいテキストが含まれています.

R Markdown の文書を複数の出力フォーマットに対してデザインしたいなら, 生の HTML または LaTeX コードは他の出力フォーマットでは無視される (例: LaTeX コードは HTML では無視され, HTML タグは LaTeX 出力時には失われます.) ため文書に埋め込むべきではありません. 次に, この問題に対処する方法を 2 つ提示します.

5.1.1 生の HTML/LaTeX コードを書く関数を使う

knitr パッケージの is_latex_output() および is_html_output() 関数を使って, このように出力フォーマットに依存して適切な構文を挿入するカスタム R 関数を書くことができます.

```
colorize <- function(x, color) {
  if (knitr::is_latex_output()) {
    sprintf("\\textcolor{%s}{%s}", color, x)
  } else if (knitr::is_html_output()) {
    sprintf("<span style='color: %s;'>%s</span>", color,
      x)
```

```
  } else x
}
```

これは行内 R 評価式内で `` `r colorize("文の一部を赤色にする", "red")` `` ように使うことができます. これは 文の一部を赤色にする でしょう (モノクロで印刷されたものを読んでいるなら, 赤色に見えないでしょう).

5.1.2 Lua フィルタを使う (*)

この方法は Lua という他のプログラミング言語が関わるため R ユーザにとっての利点は少ないでしょうが, きわめて強力です. Pandoc の Lua フィルタ(4.20節参照) を使って Markdown 要素をプログラミング的に修正することができます. 以下は使用例の全容です.

```
---
title: "Color text with a Lua filter"
output:
  html_document:
    pandoc_args: ["--lua-filter=color-text.lua"]
  pdf_document:
    pandoc_args: ["--lua-filter=color-text.lua"]
    keep_tex: true
---

First, we define a Lua filter and write it to
the file `color-text.lua`.

```{cat, engine.opts = list(file = "color-text.lua")}
Span = function(el)
  color = el.attributes['color']
  -- if no color attribute, return unchange
  if color == nil then return el end

  -- tranform to <span style="color: red;"></span>
  if FORMAT:match 'html' then
    -- remove color attributes
```
```

```
    el.attributes['color'] = nil
    -- use style attribute instead
    el.attributes['style'] = 'color: ' .. color .. ';'
    -- return full span element
    return el
  elseif FORMAT:match 'latex' then
    -- remove color attributes
    el.attributes['color'] = nil
    -- encapsulate in latex code
    table.insert(
      el.content, 1,
      pandoc.RawInline('latex', '\\textcolor{'..color..'}{')
    )
    table.insert(
      el.content,
      pandoc.RawInline('latex', '}')
    )
    -- returns only span content
    return el.content
  else
    -- for other format return unchanged
    return el
  end
end
```

Now we can test the filter with some text in brackets with
the `color` attribute, e.g.,

> Roses are [red and **bold**]{color="red"} and
> violets are [blue]{color="blue"}.
```

この例では，bracketed_spans という名称の Pandoc Markdown 拡張機能をこっそり使っています．これはテキストに属性を付けて書くことを可能にします．例えば [text]{.class
```

`attribute="value"}` のように．`cat` コードチャンク[*2]内で定義された Lua フィルタは，出力が HTML ならば `<span style="color: ..."></span>` という形でテキストを配置し，LaTeX なら `\textcolor{...}{}` として配置します．`color-text.lua` というファイル名で書き出しコマンドラインオプション `--lua-filter` で有効になった Lua フィルタは出力フォーマットの `pandoc_args` オプションを経由して Pandoc に与えられます．

従来の方法と比較して，Lua フィルタを使う利点はブラケット内でも Markdown 構文が使えることですが，以前の節で紹介した R の `colorize()` 関数は Markdown 構文を使うことが出来ません (例えば `colorize('** 太字 **')` と書いても太字にはなりません)．

5.2 テキストをインデントする

4.12節で話したように，Markdown では空白文字はしばしば意味をなさなくなります．Markdown はまた，デフォルトでインデントの空白を無視します．しかしいくつかの場合ではインデントを維持できます．例えば詩や演説文などです．これらの状況では垂直線 (|) で始まる罫線ブロックを使うことができます．改行と行頭のスペースは出力でも維持されます．例えばこのように[*3]

```
| When dollars appear it's a sign
|   that your code does not quite align
| Ensure that your math
|   in xaringan hath
|   been placed on a single long line
```

出力はこうなります．

> When dollars appear it’s a sign
>   that your code does not quite align
> Ensure that your math
>   in xaringan hath
>   been placed on a single long line

各行は Markdown のソースでは改行コードが使われています (ハードラップ)．連続する行をスペースで始めれば，1 つ前の改行と，この行頭のスペースは通常は無視されます．例えばこのように

---

*2 `cat` コードチャンクを詳しく知らないのなら，15.6節を見てください．ここでは，チャンクを `.lua` ファイルに書き出す便利な方法としてこのエンジンを使っています．そのため Lua スクリプトを `color-text.lua` という別のファイルとして管理しなくてもよいわけです．`cat` エンジンを使いたくなという なら，コードチャンクに Lua コードを埋め込む代わりに Lua コードを正しくコピーして別のファイルに保存することができます．

*3 Claus Ekstrøm: https://yihui.org/en/2018/06/xaringan-math-limerick/ 作のリメリックです．

```
| 採用責任者
| ニンジャ学校,
  ハッカーの大学
| 404 Not Found Road,
  Undefined 0x1234, NA
```

出力はこうなります.

> 採用責任者
> ニンジャの学校, ハッカーの大学
> 404 Not Found Road, Undefined 0x1234, NA

「ニンジャの学校」の直後の改行が無視されているのがわかると思います.

5.3 テキスト出力の幅を制御する

R コードから表示されたテキスト出力の幅が広すぎることがたまにあります. 出力文書のページ幅が固定 (例えば PDF 文書) ならばテキスト出力がページ余白をはみ出すことがあります. その例が図5.1です.

R グローバルオプションの width は R 関数からのテキスト出力の印字幅を制御するのに使うことができます. デフォルトが大きすぎるなら, 値を小さくしてみてください. このオプションは典型的には, おおまかに 1 行ごとの文字数を表しています (東アジア言語は例外です). 例えばこのように.

````
このチャンクの出力は幅広すぎる

```{r}
options(width = 300)
matrix(runif(100), ncol = 20)
```

このチャンクの出力のほうが良い

```{r}
options(width = 60)
matrix(runif(100), ncol = 20)
````
````

```
```
```

全ての R 関数が width オプションを尊重しているわけではありません．このオプションが動作しないなら，唯一の選択は長いテキスト行を折り返しすることです．実際これは html_document 出力フォーマットのデフォルトの挙動です．あなたの使っている HTML 出力フォーマットが長い行の折返しをしないのなら，以下の CSS コード を適用してみてください (解説は7.1節を参照).

```css
pre code {
  white-space: pre-wrap;
}
```

PDF 出力では，行の折返しはよりトリッキーになります．解決策の 1 つは，Pandoc 引数の --listing を使うことで有効になる LaTeX パッケージの **listings** を使うことです．そうしたなら，このパッケージに対するオプションを設定しなければならず，またその設定コードは外部 LaTeX ファイルに含めることができます (方法は6.1節参照) 例えばこのように．

```yaml
---
output:
  pdf_document:
    pandoc_args: --listings
    includes:
      in_header: preamble.tex
---
```

preamble.tex 内では，**listings** パッケージのオプションを設定しています．

```latex
\lstset{
  breaklines=true
}
```

listings によるコードブロックの見た目が気に入らないなら，\lstset{} で他の **listings** オプションを設定することができます．例えば basicstyle=\ttfamily でフォントファミリを変更できます．このパッケージのより詳細な情報はドキュメント https://ctan.org/pkg/listings で見つけることができます．
```

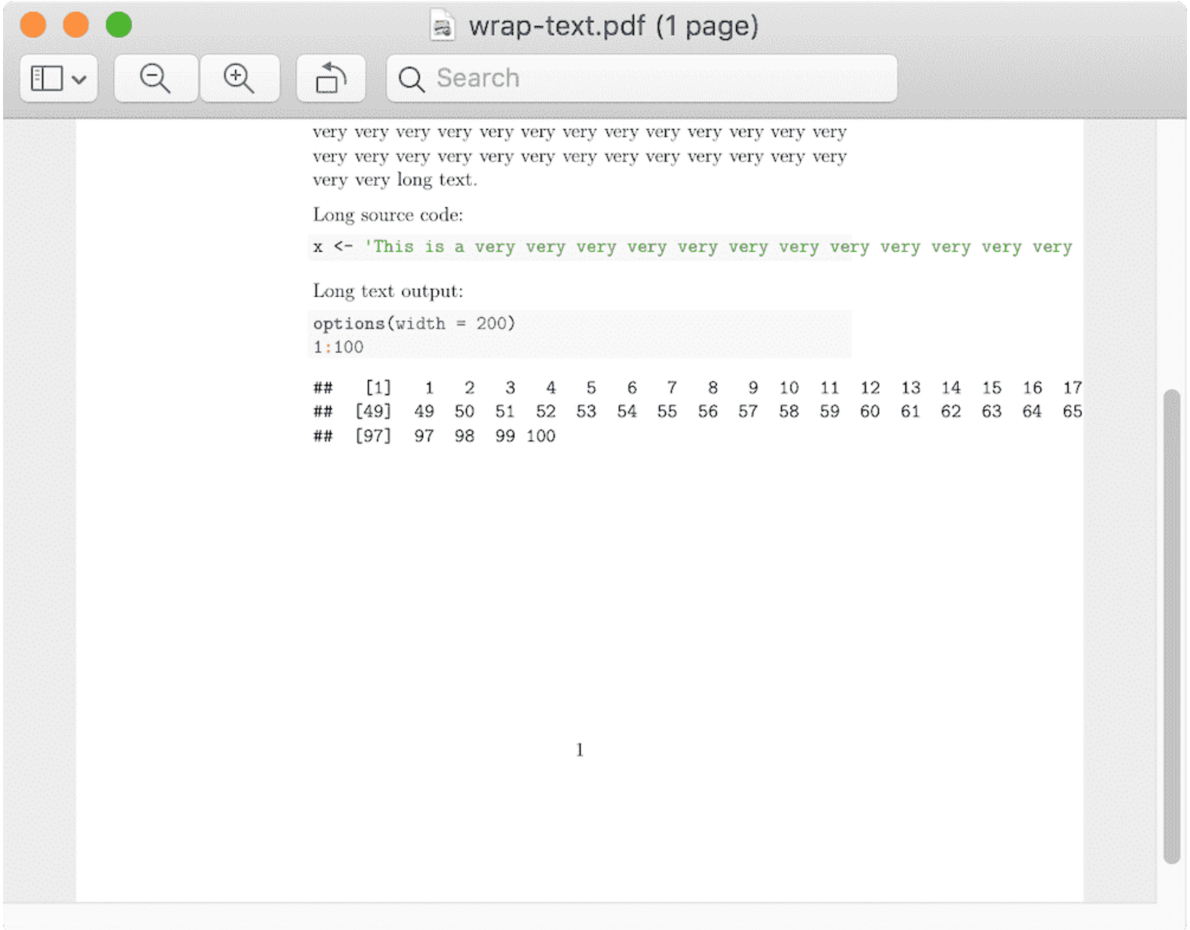


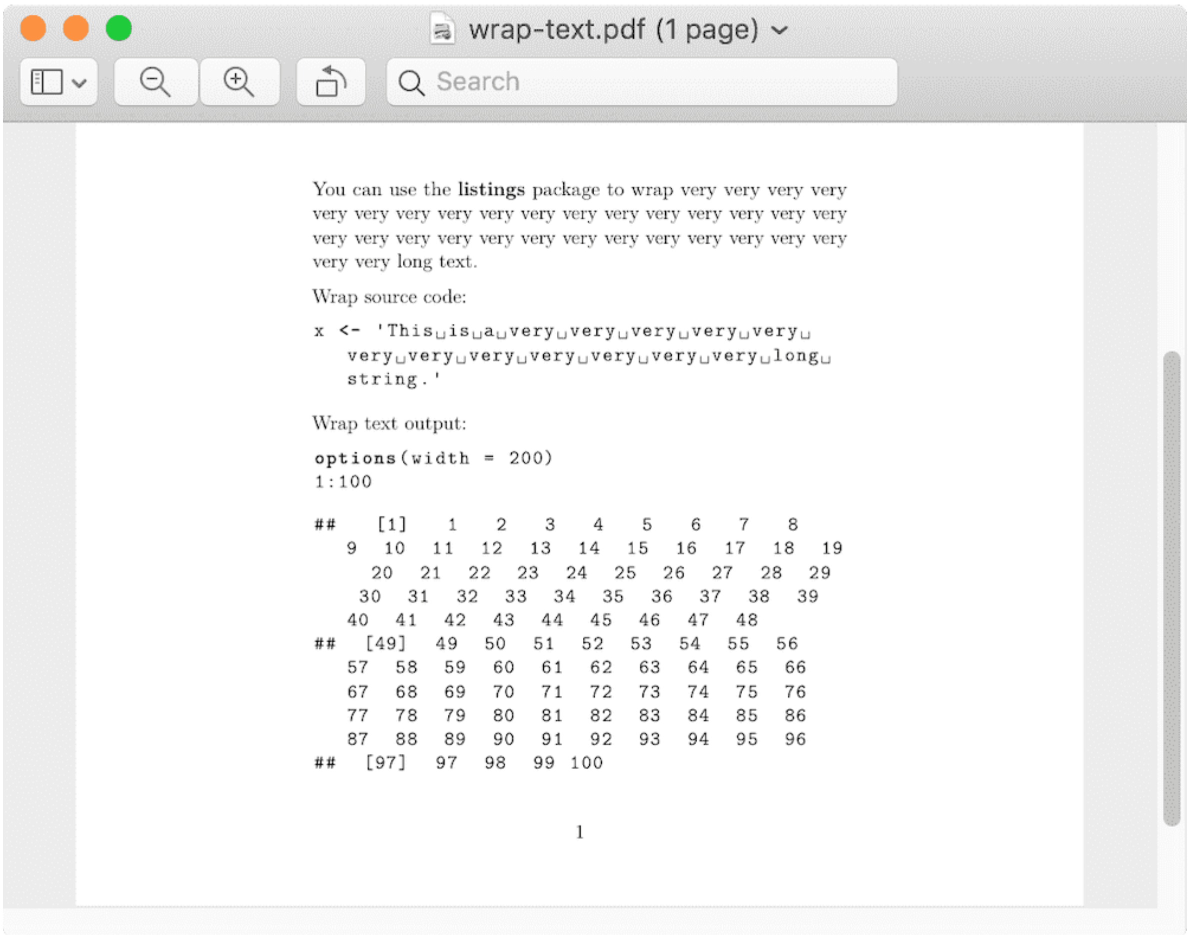
図5.1: 幅が広すぎる通常のテキスト出力

図 5.1 は長い行のあるデフォルトの pdf_document 出力で, ページ余白をはみ出しています. 図5.2 は **listings** パッケージでテキストを折り返したときの PDF 出力です.

訳注: **listings** には多くのオプションがありますが, それだけでデフォルトのシンタックスハイライトを再現するのは難しいです. コードブロックの折返しは **knitr** の styler オプションである程度制御できます. Pandoc は出力ブロックをほとんど表示オプションのない verbatim 環境として出力し, これが問題の主な原因です. フィルタや LaTeX マクロを使うなどしてこの環境を置き換えればデフォルトのシンタックスハイライトと折返しを両立することができます.

5.4 グラフ・画像のサイズを制御する

R が作成するグラフのサイズはチャンクオプション fig.width と fig.height でインチ単位で制御できます. 同様に fig.dim オプション に長さ 2 のベクトルで幅と高さを指定できます. 例えば fig.dim = c(8, 6) は fig.width = 8 と fig.height = 6 を指定したのと同じです. これらのオ



You can use the **listings** package to wrap very very very very very very very very very very very very very very very very very very very very very very very very very very very very very very very very long text.

Wrap source code:

```
x <- 'This␣is␣a␣very␣very␣very␣very␣very␣
   very␣very␣very␣very␣very␣very␣very␣long␣
   string.'
```

Wrap text output:

```
options(width = 200)
1:100

##    [1]   1   2   3   4   5   6   7   8
    9  10  11  12  13  14  15  16  17  18  19
      20  21  22  23  24  25  26  27  28  29
     30  31  32  33  34  35  36  37  38  39
    40  41  42  43  44  45  46  47  48
##   [49]  49  50  51  52  53  54  55  56
    57  58  59  60  61  62  63  64  65  66
    67  68  69  70  71  72  73  74  75  76
    77  78  79  80  81  82  83  84  85  86
    87  88  89  90  91  92  93  94  95  96
##   [97]  97  98  99 100
```

1

図5.2: listings パッケージで折り返されたテキスト出力

プションはグラフの物理的なサイズを設定し，さらに out.width と out.heightを使い出力時に異なるサイズで，例えば out.width = "50%" のように表示することが出来ます．

R コードチャンクで生成されないグラフや画像は，2 通りの方法で掲載できます．

- Markdown 構文 `![キャプション](画像ファイルパス)` を使う．この場合は width, height 属性でサイズを設定できます例えばこのように．

```
次のパラグラフに画像を掲載する．

![良い画像](なんとか.png){width=50%}
```

- コードチャンクで **knitr** 関数 knitr::include_graphics() を使う． そのチャンクで out.width と out.height といったオプションを設定することもできます．例えばこのよ

うに.

R function を使って外部画像ファイルを掲載します

```
```{r, echo=FALSE, out.width="50%", fig.cap=" 良い画像"}
knitr::include_graphics(" なんとか.png")
```
```

上記の例では幅 `50%` が使われており, 画像コンテナの半分の幅にすることを意味します (もし画像がページの子要素ではなく, ページに直接含まれていると仮定すると, これはページ幅の半分を意味します). 特定の出力フォーマットに対してのみ画像を生成することが分かっているのなら, 単位を特定することもできます. たとえば出力フォーマットが HTML なら `300px` と書けるでしょう.

5.5 図のアラインメント

チャンクオプション `fig.align` は図のアラインメントを指定します. 例えば `fig.align = 'center'` で中央揃え, あるいは `fig.align = 'right'` で右揃えができます. このオプションは HTML と LaTeX 出力の両方で機能しますが, 他の出力フォーマット (残念ですが Word といったものは) では機能しないかもしれません. R コードチャンクで描画されたグラフも, `knitr::include_graphics()` で取り込まれた外部イメージに対しても機能します.

5.6 コードチャンクをそのまま (verbatim) 表示

典型的には私達はコードチャンクと行内評価式は **knitr** によってパースされ評価してほしいと思って書きますが, もし **knitr** を使ったチュートリアルを書きたいなら, **knitr** にパース**されない**コードチャンクや行内評価式を生成する必要があり, そしてチャンクヘッダの中身も掲載したいということもあるかもしれません.

不運なことにコードチャンクをさらに別のバッククオートのレイヤで囲むことは出来ませんが, 代わりにチャンクヘッダに `` `r ''` `` を挿入することでソースコード内でコードチャンクを無効化しなければなりません. これは **knitr** によって, **空の文字列**の行内評価式であるものと評価されます. この例ではソース文書内の以下の「コードチャンク」

````
```{r, eval=TRUE}`r ''`
1 + 1
```
````

は出力時にはこのようにレンダリングされます.

~~~~~
```{r, eval=TRUE}
1 + 1
```
~~~~~

空の文字列で置き換えられるため, 行内評価式は消え去ります. しかしこれは第 1 歩にすぎません. 出力時になんらかの無加工のコードを表示するには, Markdown の構文はコードブロックで包まれているべきです (スペース 4 つ分のインデントかバッククオートによる囲みで). 上記の出力を見たいとき, 実際のソースは以下のようになります.

~~~~~
````
```{r, eval=TRUE}`r '''`
1 + 1
```
````
~~~~~

なぜバッククオートが 4 つなのでしょうか. これは N 個のバッククオートを包むには, 少なくとも N+1 個のバッククオートを使わなければならないからです.

5.6.1 行内 R コードをそのまま表示

行内コードをそのまま表示する方法はいくつかあります. 最初の方法は `r の直後で行内式を改行することです. 例えばこのように.

~~~~~
これは出力時に行内 R コードをそのまま表示します `` `r
1+1` ``.
~~~~~

これが出力文書ではこうなっているはずです.

> これは出力時に行内 R コードをそのまま表示します `r 1+1`.

この小技は 2 つの理由で動作します. (1) Markdown パーサはしばしば単独の改行文字を単なるスペース 1 つとして扱う (2 連続の改行は新しい段落を始めることと比べてみてください) ということと, (2) **knitr** は `r をパースするのに直後にスペース 1 つを要求する, つまりここにスペースがないと行内コードとして扱われないということです.

行内 R コードをそのまま表示する別の方法は, R コードを knitr::inline_expr() で包むことです. 例えばこのように.

```
これで出力時に行内 R コードがそのまま表示されます
`` `r knitr::inline_expr("1+1")` ``.
```

私 (Yihui) は 2 つ目の方法をお薦めします．1 つ目の方法は多かれ少なかれ Markdown 構文と **knitr** パーサに対するハック的なものだからです．

5.7 コードブロックに行番号を表示する (*)

`attr.source = ".numberLines"` でソースコードブロックにも行番号を付けることも，`attr.output = ".numberLines"` でテキスト出力ブロックに行番号を付けることもできます (これらのオプションの詳細は11.13節参照)．例えばこのように．

````
```{r, attr.source='.numberLines'}
if (TRUE) {
  x <- 1:10
  x + 1
}
```
````

出力はこうなります．

```
if (TRUE) {
  x <- 1:10
  x + 1
}
```

HTML 出力では，Pandoc が提供するシンタックスハイライト のテーマ を選ぶ必要があることに注意してください．これは出力フォーマットの `highlight` オプションを `default` や `textmate` にすべきではないということを意味します．ヘルプページ `?rmarkdown::html_document` でこのオプションの他の値の一覧を見ることができます．例えばこう設定できます．

```
output:
  html_document:
    highlight: tango
```

bookdown の `gitbook` 出力フォーマットでは, コードの左側の適切な位置に数字を表示するために CSS を多少調整する必要があるかもしれません. 以下は本書で使用しているものです (行番号がページ左余白に近すぎると思ったら, `left` の値を `-0.2em` などに増やして調整してください).[*4]

```css
pre.numberSource code > span > a:first-child::before {
  left: -0.3em;
}
```

revealjs' の `revealjs_presentation` 出力フォーマット (El Hattab and JJ Allaire, 2017) に対しても CSS の調整が必要かもしれません.

```css
.reveal pre code {
  overflow: visible;
}
```

カスタム CSS スタイルを HTML 出力に適用する方法がわからないなら, 7.1節を見てください.

`startFrom` 属性で開始する数字を指定することもできます. 例えばこのように.

````
```{r, attr.source='.numberLines startFrom="5"'}
if (TRUE) {
  1:10
}
```
````

現時点では Word 出力での行番号はサポートしていません.

5.8 多段組み (*)

Pandoc の Markdown はスライドに対する多段レイアウトをサポートしていますが, 他のタイプの文書ではサポートしていません. このレシピでは通常の HTML 文書や LaTeX 文書での多段レイアウトを使う方法を紹介します. これは **knitr** の issue https://github.com/yihui/knitr/issues/1743 での Atsushi Yasumoto の解決策に着想を得ました.

[*4] **訳注**: 日本語版は **rmdja** の出力フォーマットを使用しており, これはデフォルトで行番号を表示し, かつ gitbook に対応した調整を予め搭載しています.

HTML 要素を CSS を使って並べて表示するのは比較的簡単なので, この方法は HTML 出力のみ考慮する必要があるならかなり簡単です. コードチャンクのテキスト出力を並べるだけならば, もっと簡単になります. 以下は 1 つ目の例です.

````
---
output: html_document
---

```{r attr.source="style='display:inline-block;'", collapse=TRUE}
1:10  # 1 から 10 の数列
10:1  # その逆順
```
````

CSS 属性 `display: inline-block;` はコードブロックの出力 (つまり HTML タグの `<pre>` です) をインライン要素として表示すべきという意味です. デフォルトではこれらのブロックはブロックレベル要素 (つまり `display: block;`) として表示され, 行を丸ごと占有します. チャンクオプション `collapse = TRUE` はテキスト出力を R ソースコードブロックと結合することを意味するので, ソースとテキスト出力が同じ `<pre>` ブロックに配置されます.

HTML 出力時に任意の順で横に並べたい場合, Pandoc の fenced `Div`.[*5] を使うことができます. "Div" は HTML タグの `<div>` に由来しますが, 任意のブロックやコンテナと解釈できます. `Div` の開始と終了はは 3 つ以上のコロン (例: `:::`) です. より多くのコロンの `Div` は, よりコロンの少ない `Div` を含むことができます. fanced `Div` の重要で有用な機能は, これに属性を付与できるということです. 例えば CSS 属性 `display: flex;` を外側のコンテナに適用できるので, 内側のコンテナは横並びに配置されます.

```
---
output: html_document
---

:::: {style="display: flex;"}

::: {}
ここは **最初の** Div です.

```

[*5] https://pandoc.org/MANUAL.html#divs-and-spans

```
```{r}
str(iris)
```
:::

::: {}
こっちは右側に配置されるブロックです.

```{r}
plot(iris[, -5])
```
:::

::::
```

上記の例では外側の Div (`::::`) は 2 つの Div (`:::`) を含んでいます. この中にさらに Div を追加することもできます. とても強力な CSS 属性 `display: flex;` (CSS Flexbox) についてもっと知るためには https://css-tricks.com/snippets/css/a-guide-to-flexbox/ というガイドを読むと良いでしょう. CSS グリッド (`display: grid;`) はもっと強力で, 上記の例にも使えます. もし試してみたいなら, `display: flex;` を `display: grid; grid-template-columns: 1fr 1fr; grid-column-gap: 10px;` に置き換えてみてください. グリッドレイアウトについてより知りたいのなら, https://css-tricks.com/snippets/css/complete-guide-grid/ のガイドを見てください.

HTML でも LaTeX でも同じようなレイアウトにしたいのなら, よりトリッキーになります. 以下に HTML, LaTeX そして Beamer で動作する用例の全容を示します.

```
---
output:
  pdf_document:
    latex_engine: lualatex
    keep_tex: true
    includes:
      in_header: columns.tex
  html_document:
```

````
    css: columns.css
  beamer_presentation:
    keep_tex: true
    latex_engine: lualatex
    includes:
      in_header: columns.tex
documentclass: "`r if(knitr::opts_knit$get('rmarkdown.pandoc.to') == 'beamer')
↪   'beamer' else 'ltjsarticle'`"
mainfont: 'Noto Sans CJK JP'
---

# 二段組み

以下は 3 つの子要素の Div を横並びに持つ Div コンテナです．中央の Div は空で，左右の
↪   Div の間に空白を作るためだけに存在します．

:::::: {.cols data-latex=""}

::: {.col data-latex="{0.55\textwidth}"}
```{r, echo=FALSE, fig.width=5, fig.height=4}
par(mar = c(4, 4, .2, .1))
plot(cars, pch = 19)
```
:::

::: {.col data-latex="{0.05\textwidth}"}
\
<!-- 段どうしのセパレータとして機能するだけの空の Div（空白入り）-->
:::

::: {.col data-latex="{0.4\textwidth}"}
左側の図は `cars` データを表しています．


> いろはにほへと ちりぬるを
````

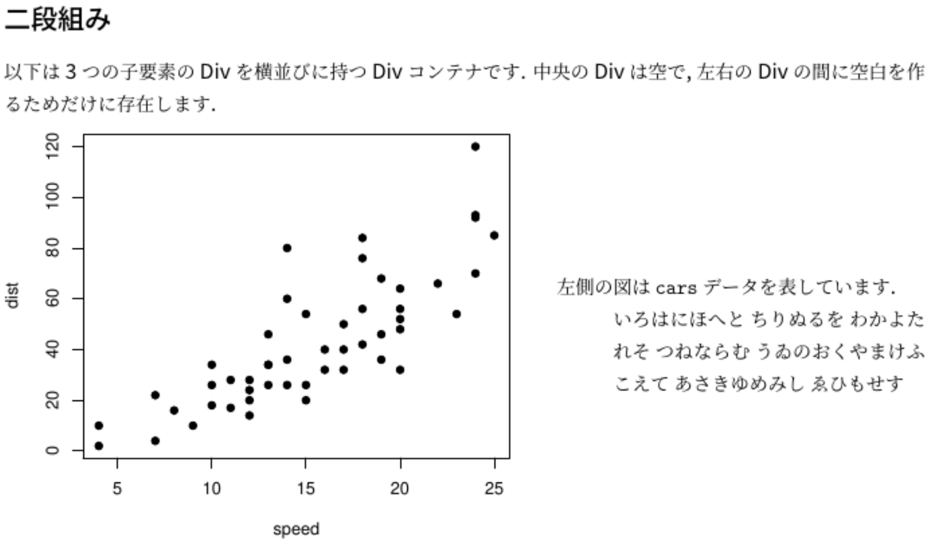


図5.3: HTML, LaTeX, Beamer で動作する二段組み

```
わかよたれそ　つねならむ
うゐのおくやま　けふこえて
あさきゆめみし　ゑひもせす


:::
::::::
```

図5.3 がその出力です. この例では外側の `.cols` クラスを持つ `Div` と, 内側に `.col` クラスを持つ 3 つの `Div` を使っています. HTML 出力では, 外部 CSS ファイル `columns.css` を導入し, その中で Flexbox レイアウトを外側の `Div` に適用しているので, 内側の `Div` が横並びになります.

```
.cols {display: flex; }
```

LaTeX 出力 (pdf_document) では, LaTeX プリアンブルで LaTeX 環境 `cols` と `col` で定義するための `columns.tex` に含まれているダーティーハックについて解説せねばなりません.

```
\newenvironment{cols}[1][]{}{}
```

```
\newenvironment{col}[1]{\begin{minipage}{#1}\ignorespaces}{%
\end{minipage}
\ifhmode\unskip\fi
\aftergroup\useignorespacesandallpars}

\def\useignorespacesandallpars#1\ignorespaces\fi{%
#1\fi\ignorespacesandallpars}

\makeatletter
\def\ignorespacesandallpars{%
  \@ifnextchar\par
    {\expandafter\ignorespacesandallpars\@gobble}%
    {}%
}
\makeatother
```

主に Pandoc が LaTeX 出力では Div に対していつも段落を改めており，この改段を除去しなければならないという理由のため，col 環境は特に複雑です．そうしないと Div を横並びにすることはできません．このハックは https://tex.stackexchange.com/q/179016/9128 から借用しました．

Beamer 出力でも columns.tex で同じハックを適用しています．Pandoc は ::: {.columns}, ::: {.column}, ::: {.incremental} といったスライドショー[*6]用の特別な Div を提供していることに注意してください．これらは特別な意味を持つため，この節で言及されたような方法で Div を LaTeX 環境を変換しようとするなら，これらのタイプの Div を**使わない**ように注意しなければなりません．columns または column ではなく，cols, col という名前の Div タイプを使ったのはこれが理由です．

fenced Div についてより詳しく知りたいなら，9.6節を見てください．

[*6] https://pandoc.org/MANUAL.html#producing-slide-shows-with-pandoc

第 6 章

LaTeX Output

For many authors, the main output of their work will be the PDF report, in which case they can utilize the powerful styling of LaTeX. In this chapter, we discuss approaches that can be used to customize PDF reports, such as including LaTeX code or packages in the preamble, using custom LaTeX templates, adding headers and footers, generating sub-figures, and writing raw LaTeX code in the document body.

We want to offer a note of caution before we start, however. One benefit of R Markdown is the fact that a single source document can create documents with multiple formats. By tailoring your work to a single output format, you may improve the appearance and performance of a single output format, but at the expense of this transferability. This problem is not unique to LaTeX, but all other output formats as well.

6.1 Add LaTeX code to the preamble

The general structure of a LaTeX document is like this:

```
\documentclass{article}
% preamble
\begin{document}
% body
\end{document}
```

That is, you declare the document class in `\documentclass{}`, load certain LaTeX packages and set certain options if necessary in the preamble, and start writing the body of your document after \begin{document}. A Markdown document is mostly the body of the document.

If you want to add anything to the preamble, you have to use the includes option of pdf_document. This option has three sub-options: in_header, before_body, and after_body. Each of them takes one or multiple file paths. The file(s) specified in in_header will be added to the preamble. The files specified in before_body and after_body are added before and after the document body, respectively.

For example, below is a trick that turns hyperlinks in text into footnotes. This trick is useful when the PDF output document is printed on paper, because readers will not be able to click the links (generated from \href{URL}{text}) on paper but can see the URLs in footnotes. This trick displays both the text and URL.

```
% you may want to save a copy of \href before redefining it
% \let\oldhref\href
\renewcommand{\href}[2]{#2\footnote{\url{#1}}}
```

You can save the above code in a file with an arbitrary filename, e.g., preamble.tex. Then include it in the preamble through:

```
output:
  pdf_document:
    includes:
      in_header: "preamble.tex"
```

For this particular trick, you do not really have to implement it by yourself, but can simply set the YAML option links-as-notes to true because it is a built-in feature of Pandoc's default LaTeX template (see Section 6.2).

Another way to add code to the preamble is to pass it directly to the header-includes field in the YAML frontmatter. We will show an example in Section 6.3. The advantage of using header-includes is that you can keep everything in one R Markdown document. However, if your report is to be generated in multiple output formats, we still recommend that you use the includes method, because the header-includes field is unconditional, and will be included in non-LaTeX output documents, too. By comparison, the includes option is only applied to the pdf_document format.

6.2 Pandoc options for LaTeX output

If you are using the default Pandoc template for LaTeX output, there are several options that you may set to adjust the appearance of the PDF output document. We list a few example options below, and you may see https://pandoc.org/MANUAL.html#variables-for-latex for a full list.

```yaml
documentclass: book
classoption:
  - twocolumn
  - landscape
papersize: a5
linestretch: 1.5
fontsize: 12pt
links-as-notes: true
```

The meanings of these options should be clear if you have some knowledge about LaTeX. The `documentclass` option sets the document class, e.g., `article`, `book`, and `report`, etc. The `classoption` is a list of options to be passed to the document class, e.g., you can create a two-column document with the `twocolumn` option,[*1] or the landscape layout with the `landscape` option (the default is the portrait layout). The `papersize` option sets the paper size, e.g., `a4`, `paper`, or `a5`. The `linestretch` option sets the line spacing. The `fontsize` option sets the font size, e.g., `10pt`, `11pt`, or `12pt`. The `links-as-notes` option turns links in text to footnotes, which is useful when the PDF is printed on paper, because readers will not be able to click the links on paper but can see the URLs in footnotes.

Changing fonts can be a little trickier. It depends on which LaTeX engine you are using. If you are using `pdflatex`, which is usually the default engine for most LaTeX-based output formats, you may use the `fontfamily` option to select a LaTeX font package to be loaded in your document to change the font, e.g.,

[*1] This option changes the layout of the whole document, but if you want to switch back to the one-column mode from a certain point, you may insert a command `\onecolumn` at that point. If you want to continue the two-column mode, insert `\twocolumn`.

```yaml
fontfamily: accanthis
output:
  pdf_document:
    latex_engine: pdflatex
```

Then the document will use the font Accanthis.*2 You may see https://tug.org/FontCatalogue/ for a list of many other LaTeX font packages. If your LaTeX distribution is TinyTeX and the required font packages have not been installed, they should be automatically installed when the document is compiled (see Section 1.2).

If you use the LaTeX engine `xelatex` or `lualatex`, you will be able to select fonts that are available on your local computer, and do not have to install additional LaTeX packages. YAML options like `mainfont`, `sansfont`, and `monofont` can be used to specify the main font, sans serif font, and typewriter font, respectively, e.g.,

```yaml
mainfont: Arial
output:
  pdf_document:
    latex_engine: xelatex
```

You can also use some of those LaTeX options when you generate Beamer slides, because a Beamer document is a LaTeX document, too. In addition, Pandoc has provided a few more options for Beamer slides, which can be found at https://pandoc.org/MANUAL.html#variables-for-beamer-slides. For example, you can specify the author affiliation via the `institute` option:

```yaml
---
output: beamer_presentation
institute: "University of Hackers"
---
```

*2 https://tug.org/FontCatalogue/accanthis/

6.3 Add logo to title page

We can use the **titling** LaTeX package to alter our title block to include an image. Below is a full example that shows how to add the R logo (`logo.jpg`) to the title page. The image can be of any format that LaTeX supports (e.g., `jpg`, `png`, or `pdf`).

```
---
title: Adding a Logo to LaTeX Title
author: Michael Harper
date: December 7th, 2018
output: pdf_document
header-includes:
  - \usepackage{titling}
  - \pretitle{\begin{center}
    \includegraphics[width=2in,height=2in]{logo.jpg}\LARGE\\}
  - \posttitle{\end{center}}
---

<!-- Optionally include a page break. This will force the start
of the document to the second page -->

\newpage

This is your report.

```{r, include=FALSE}
# copy the R logo to the current directory
file.copy(file.path(R.home("doc"), "html", "logo.jpg"), '.')
```
```

An example output is shown in Figure 6.1.

An alternative method that does not require a special LaTeX package (**titling**) is to just insert the image in the `title` field using the Markdown syntax. For example:

図**6.1:** A logo on a LaTeX title page.

```
title: |
  ![](logo.jpg){width=1in}
  Adding a Logo to LaTeX Title
```

In this case, you will not need the `header-includes` field in the YAML frontmatter in the first example. Please note that although you cannot see them, there are two trailing spaces after `![](logo.jpg){width=1in}`, which means a line break in Markdown (see Section 4.12). Without the line break, the image and the title would be on the same line, which may not be what you desire.

6.4 Include additional LaTeX packages

The use of additional LaTeX packages can allow for extensive customization of document styling. In addition, several packages such as **kableExtra** (Zhu, 2020) may have LaTeX dependencies for the R package to function. Much like R, we need to load packages within the R Markdown document before we are able to use their functions.

6.4.1 Loading LaTeX packages

We can load additional LaTeX packages using the `extra_dependencies` option within the `pdf_document` YAML settings. This allows us to provide a list of LaTeX packages to be loaded in the intermediate LaTeX output document, e.g.,

```
---
title: "Using more LaTeX packages"
output:
  pdf_document:
    extra_dependencies: ["bbm", "threeparttable"]
---
```

If you need to specify options when loading the package, you can add a second level to the list and provide the options as a list, e.g.,

```
output:
  pdf_document:
    extra_dependencies:
      caption: ["labelfont={bf}"]
      hyperref: ["unicode=true", "breaklinks=true"]
      lmodern: null
```

For those familiar with LaTeX, this is equivalent to the following LaTeX code:

```
\usepackage[labelfont={bf}]{caption}
\usepackage[unicode=true, breaklinks=true]{hyperref}
```

```
\userpackage{lmodern}
```

The advantage of using the `extra_dependencies` argument over the `includes` argument introduced in Section 6.1 is that you do not need to include an external file, so your Rmd document can be self-contained.

6.4.2 Example packages

There is an extensive community for LaTeX, and there are over 4,000 packages available through the Comprehensive TeX Archive Network[*3] (CTAN). Here are some examples of LaTeX packages you could consider using within your report:

- pdfpages[*4]: Include full PDF pages from an external PDF document within your document.
- caption[*5]: Change the appearance of caption subtitles. For example, you can make the figure title italic or bold.
- fancyhdr[*6]: Change the style of running headers of all pages.

6.5 Control the placement of figures

One common frustration with LaTeX is the placement of figures and tables. Unlike in a word processor like Microsoft Word, in which figures are placed directly where the user specifies, LaTeX will attempt to place a figure in a position that does not violate certain typographic rules. In doing so, figures may float away from where they are referenced in the text. This section will explain some background information on how floating environments (such as figures) work and provide several options for customizing their behavior.

6.5.1 Floating environments

By default, figures with captions are generated with the `figure` environment in LaTeX. For example, Pandoc will convert the following Markdown code that contains an image

[*3] https://ctan.org
[*4] https://ctan.org/pkg/pdfpages
[*5] https://ctan.org/pkg/caption
[*6] https://ctan.org/pkg/fancyhdr

```
![This is a figure.](images/cool.jpg)
```

to the LaTeX code:

```
\begin{figure}
  \includegraphics{images/cool.jpg}
  \caption{This is a figure.}
\end{figure}
```

The `figure` environment is a floating environment. You can read a detailed description of floats at https://en.wikibooks.org/wiki/LaTeX/Floats,_Figures_and_Captions. In summary, floats are used as containers for things that cannot be broken over a page, such as tables and figures. If the figure or table cannot be contained in the space left on the current page, LaTeX will try to place it at the top of the next page. If the figure is tall enough, it may occupy the whole next page, even if there is still space left for a few lines of text. The behavior can be controlled by different placement specifiers in square brackets after `\begin{figure}`, e.g., `\begin{figure}[b]`. Below is a list of possible specifiers:

- `h`: Place the float *here*, i.e., approximately at the same point it occurs in the source text.
- `t`: Position at the *top* of the page.
- `b`: Position at the *bottom* of the page.
- `p`: Put on a special *page* for floats only.
- `!`: Override internal parameters LaTeX uses for determining "good" float positions.
- `H`: Place the float at precisely the location in the LaTeX code. This requires the **float** package (`\usepackage{float}`).

These specifiers can be used in conjunction, e.g., `!b` forces LaTeX to place the figure at the bottom of a page. The default behavior is `tbp`. That is, LaTeX will try to position the figure at the top of the page, then at the bottom, and then on a separate page.

6.5.2 Prevent figures from floating

Many users will initially want to prevent figures from floating in their document, replicating the behavior of a traditional word processor. To do this, we must firstly load the LaTeX package **float**. This can be done by including the following line in the YAML:

```
output:
  pdf_document:
    extra_dependencies: ["float"]
```

We can use the chunk option `fig.pos` to control the float behavior. The option value `!H` will prevent any floating within the document. We can set the default behavior for the document so that all chunks have this setting by including the following line in the first code chunk in your R Markdown document:

```
knitr::opts_chunk$set(fig.pos = "!H", out.extra = "")
```

In general, we do not recommend that users force LaTeX to stop floating figures. This solution was included in this book by popular demand,[*7] but there could be some serious side effects when LaTeX is unable to float figures.

6.5.3 Force floats forward

An alternative to forcing all floats to be held is to force floating forward in the text. This can remove a common issue, where a figure is shown at the top of the page before the relevant text comes. This can break the reading flow of a report. We can force the figure to always appear after the text by using the **flafter** LaTeX package as follows:

```
output:
  pdf_document:
    extra_dependencies: ["flafter"]
```

6.5.4 Adjust LaTeX placement rules (*)

LaTeX's own float placement parameters could prevent placements that seem entirely "reasonable" to you—they are notoriously rather conservative. These defaults are displayed in Table 6.1.

[*7] The related Stack Overflow question has been viewed for over 45,000 times: https://stackoverflow.com/q/16626462/559676.

表**6.1:** Default LaTeX float settings.

Command	Description	Default
topfraction	max fraction of page for floats at top	0.7
bottomfraction	max fraction of page for floats at bottom	0.3
textfraction	min fraction of page for text	0.2
floatpagefraction	min fraction of page that should have floats	0.5
topnumber	max number of floats at top of page	2
bottomnumber	max number of floats at bottom of page	1
totalnumber	max number of floats on a page	3

To encourage LaTeX not to move your figures, we can alter these default settings. We could include the following in our LaTeX preamble file, reducing the minimum amount of text required on a page and allow more room for floats:

```
\renewcommand{\topfraction}{.85}
\renewcommand{\bottomfraction}{.7}
\renewcommand{\textfraction}{.15}
\renewcommand{\floatpagefraction}{.66}
\setcounter{topnumber}{3}
\setcounter{bottomnumber}{3}
\setcounter{totalnumber}{4}
```

If we have added these lines to a `.tex` file, we could include this file in the preamble of the LaTeX document using the method introduced in Section 6.1.

6.6 LaTeX sub-figures

Sometimes you may want to include multiple images in a single figure environment. Sub-figures allow us to achieve this by arranging multiple images within a single environment and providing each with its own sub-caption.

Sub-figures require the LaTeX package **subfig**. We can load it via the `extra_dependencies` YAML option within the `pdf_document` output. For example:

```yaml
---
output:
  pdf_document:
    extra_dependencies: "subfig"
---
```

To arrange all plots from a code chunk in sub-figures, you have to use the chunk options `fig.cap` (the caption for the whole figure environment) and `fig.subcap` (a character vector of the captions for sub-figures). For best output, you can also use the following options:

- `fig.ncol`: The number of columns of sub-figures. By default, all plots are arranged in a single row. You can break them into multiple rows.
- `out.width`: The output width of individual plots. You will normally set this to `100%` divided by the number of columns. For example, if you have two plots, the `out.width` option should be equal to or less than `50%`, otherwise the plots may exceed the page margin.

Below is an illustrative example:

```yaml
---
output:
  pdf_document:
    extra_dependencies: "subfig"
---
```

````
```{r, fig.cap='Figure 1', fig.subcap=c('(a)', '(b)', '(c)')}
plot(1:10)
plot(cars, pch = 19)
boxplot(Sepal.Width ~ Species, data = iris)
```
````

The output is shown in Figure 6.2. For the sake of simplicity, we omitted a few chunk options in the chunk header of the above example, including `fig.ncol = 2`, `out.width = "50%"`, `fig.align = "center"`, and the actual long captions.

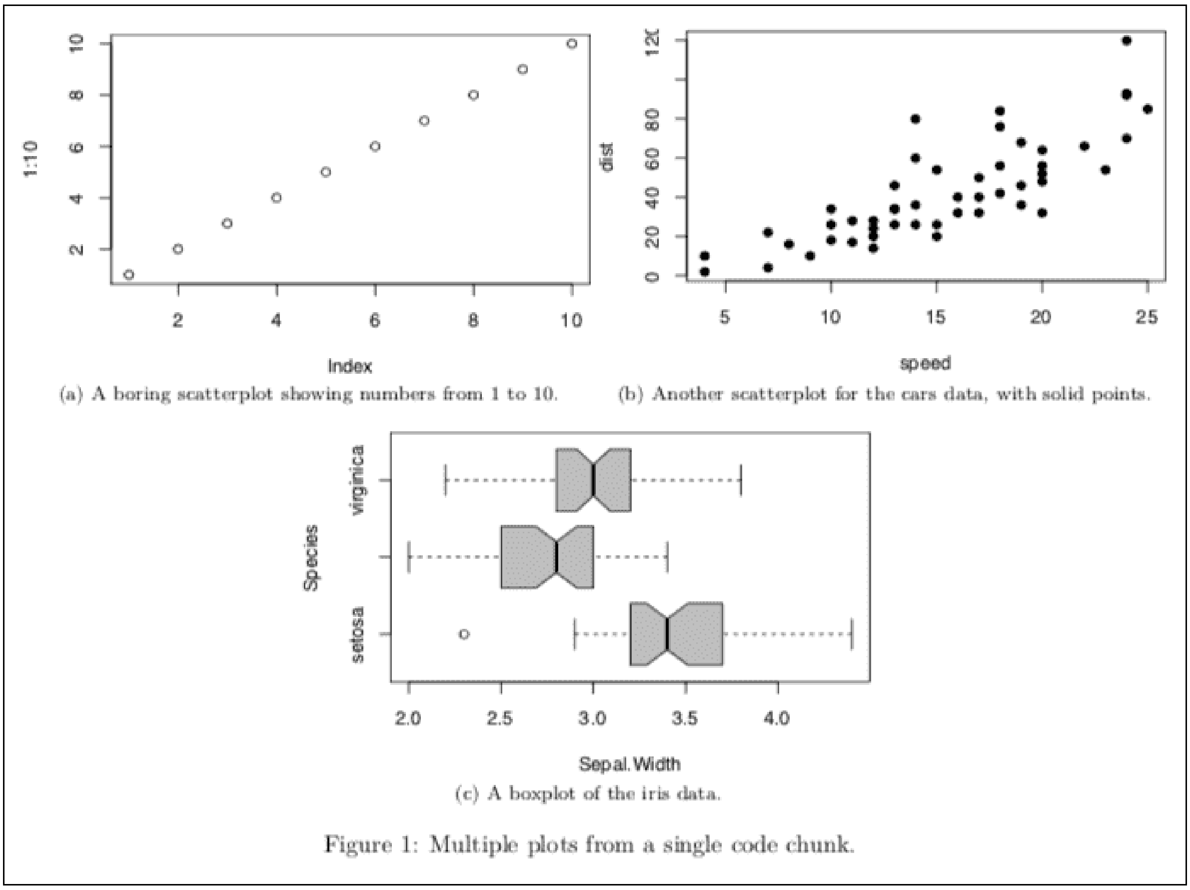


図6.2: An example of one figure environment containing multiple sub-figures.

6.7 Render documents containing Unicode characters

If you run into an error like this:

```
! Package inputenc Error:
  Unicode char \u8: not set up for use with LaTeX.
```

it probably means that you are using the default LaTeX engine, `pdflatex`, to render the (intermediate `.tex`) document to PDF, which was unable to process certain Unicode characters in your document. If that is the case, you may switch to `xelatex` or `lualatex`, e.g.,

```
output:
  pdf_document:
```

```
    latex_engine: xelatex
```

You may also change the LaTeX engine for other document output formats, especially those based on `pdf_document`, such as `bookdown::pdf_document2` and `tufte::tufte_handout`, e.g.,

```
output:
  bookdown::pdf_document2:
    latex_engine: lualatex
  tufte::tufte_handout:
    latex_engine: xelatex
```

6.8 Generate a LaTeX fragment

If you work primarily with pure LaTeX documents, you may still find R Markdown useful. Sometimes it may be more convenient to write in R Markdown and convert the document to a LaTeX fragment, which can be included in other LaTeX documents.

When you render an Rmd document to LaTeX, it generates a full LaTeX document that includes the `\documentclass{}`, `\begin{body}`, and `\end{body}`. A LaTeX fragment is basically the body of a full LaTeX document. To render a LaTeX fragment, you may use the `latex_fragment` output format, e.g.,

```
---
output: latex_fragment
---
```

This will render a `.tex` file, e.g., `foo.Rmd` will render `foo.tex`, and you can use `\input{foo.tex}` to include this fragment in another LaTeX document.

6.9 Add custom headers and footers (*)

The LaTeX package **fancyhdr** has provided several commands to customize the header and footer lines of your document. For a more complete guide, please refer to the full documentation at https://ctan.org/pkg/fancyhdr. To begin with, we must load the package. Then we can change the header style, e.g.,

```
\usepackage{fancyhdr}
\pagestyle{fancy}
```

The package offers three different interfaces, but we will use the commands `\fancyhead` and `\fancyfoot`. The syntax for the formatting is `\fancyhead[selectors]{output text}`, whereby the selectors state the part of the header that we wish to customize. We can use the following selectors for the page locators:

- **E** for even pages
- **O** for odd pages
- **L** for the left side
- **C** for the center
- **R** for the right side

For example, `\fancyhead[LE,RO]{Your Name}` will print the text "Your Name" on the left side of the header for even pages, and the right side for odd pages. We can combine this with additional LaTeX commands to extract details from our document for each page:

- `\thepage`: the number of the current page.
- `\thechapter`: the number of the current chapter.
- `\thesection`: the number of the current section.
- `\chaptername`: the word "Chapter" in English, or its equivalent in the current language, or the text that the author specified by redefining this command.
- `\leftmark`: the name and number of the current top-level structure in uppercase letters.
- `\rightmark`: the name and number of the current next to top-level structure in uppercase letters.

Below is some example LaTeX code that you can add to the preamble using the methods introduced in Section 6.1:

```
\usepackage{fancyhdr}
\pagestyle{fancy}
% center of header
\fancyhead[CO,CE]{Your Document Header}
```

```
% center of footer
\fancyfoot[CO,CE]{And this is a fancy footer}
% page number on the left of even pages and right of odd pages
\fancyfoot[LE,RO]{\thepage}
```

By default, headers and footers will not be displayed on the first page of your PDF document. If we wish to show our footer on the front page, we must include an additional line `\fancypagestyle{plain}{\pagestyle{fancy}}`.

6.10 Use a custom Pandoc LaTeX template (*)

Pandoc converts Markdown to LaTeX through a template. The template is a LaTeX file containing Pandoc variables, and Pandoc will replace these variables with their values. Below is a simple template that only contains a single variable `$body$`:

```
\documentclass{article}
\begin{document}
$body$
\end{document}
```

The value of `$body$` is the LaTeX code generated from the body of the Markdown document. For example, if the body text is `Hello **world**!` in Markdown, the value of `$body$` will be `Hello \textbf{world}!`.

If the LaTeX customization methods in Sections 6.1, 6.2, and 6.4 are not enough for you, you may try to use a custom template instead. A template allows you to use arbitrary LaTeX code in it, and hence is much more flexible. To use a template, include the path of the template in the `template` option of `pdf_document`, e.g.,

```
output:
  pdf_document:
    template: my-template.tex
```

The default LaTeX template of Pandoc can be found at https://github.com/jgm/pandoc/tree/master/data/templates (named `default.latex`). If you want to create your own template, you may want to start with this template.

For the full list of Pandoc variables and their meanings (such as `$body$` and `$title$`), see Pandoc's manual at https://pandoc.org/MANUAL.html#templates. You can also use arbitrary custom variables, which are typically passed to the template from the YAML metadata. If you want to learn by examples, you may take a look at the **MonashEBSTemplates** package (https://github.com/robjhyndman/MonashEBSTemplates), which has provided several custom LaTeX templates. These templates are under the `inst/rmarkdown/templates/*/resources/` directories (here `*` denotes the template names). For example, the template for the output format `MonashEBSTemplates::memo` allows you to use a variable `branding` in the YAML metadata to control whether to include the brand logo of Monash University. This is achieved by an `if` statement in the template that looks like this:

```
$if(branding)$%
\includegraphics[height=1.5cm]{monash2}
\vspace*{-0.6cm}
$else$
\vspace*{-1cm}
$endif$
```

6.11 Write raw LaTeX code

By default, Pandoc will preserve raw LaTeX code in Markdown documents when converting the document to LaTeX, so you can use LaTeX commands or environments in Markdown. However, sometimes your LaTeX code might be too complex for Pandoc to parse, in which case Pandoc will treat the content as normal Markdown. The consequence is that special LaTeX characters may be escaped, e.g., Pandoc may convert a backslash \ to `\textbackslash{}`.

To make sure that Pandoc does not touch the raw LaTeX code in your Markdown document, you may wrap the code in a fenced code block with the attribute `=latex`, e.g.,

````
```{=latex}
\begin{tabular}{ll}
A & B \\
````
````

```
A & B \\
\end{tabular}
```
```

Do not forget the equal sign before `latex`, i.e., it is `=latex` instead of `latex`. This feature requires a Pandoc version higher than 2.0 (check `rmarkdown::pandoc_version()`).

## 6.12 For hardcore LaTeX users (*)

R Markdown is certainly not the best possible document format for authoring or typesetting documents. Simplicity is both its advantage and disadvantage. LaTeX is much more powerful than Markdown in terms of typesetting at the price of more commands to be typed. If typesetting is of much higher priority to you and you are comfortable with using all kinds of LaTeX commands and environments, you can just use pure LaTeX code instead of Markdown to write the whole document.

The **knitr** package supports a variety of source document formats, including but not limited to R Markdown. Below is an example of intermingling R code with pure LaTeX code:

```
\documentclass{article}
\usepackage[T1]{fontenc}

\begin{document}

Here is a code chunk.

<<foo, fig.height=4>>=
1 + 1
par(mar = c(4, 4, .2, .2))
plot(rnorm(100))
@

You can also write inline expressions, e.g. $\pi=\Sexpr{pi}$,
and \Sexpr{1.9910214e28} is a big number.
```
```

```
\end{document}
```

The filename usually has the extension `.Rnw`, e.g., the above file is `latex.Rnw`. The idea is the same but the syntax for writing R code chunks and inline R expressions is different. An R code chunk starts with `<<>>=` (with optional chunk options inside the angle brackets) and ends with `@`. An inline R expression is written in `\Sexpr{}`.

The function `knitr::knit()` can compile an `Rnw` document to a LaTeX (`.tex`) output file, which can be further compiled to PDF through your LaTeX tools such as `pdflatex`. You can also use `knitr::knit2pdf()` to compile `Rnw` to PDF in one step. If you use RStudio, you can hit the `Compile PDF` button on the toolbar. Please note that the default method to compile Rnw documents is through Sweave, and you may want to change it to **knitr** (see the post http://stackoverflow.com/q/27592837/559676 for how to do that).

An `Rnw` document gives you the full power of LaTeX. This could be your last resort if there are typesetting problems that are really difficult to solve in Markdown. However, before you drop Markdown, we would like to remind you of the fact that a custom Pandoc LaTeX template may also be helpful (see Section 6.10).

第 7 章

HTML Output

Compared to LaTeX, HTML may be a little weak in typesetting for paged output. However, it is much more powerful in presenting results, especially when combined with CSS and JavaScript. For example, you can embed interactive applications in HTML, and dynamically modify the appearance and even the content of an HTML page. Some useful yet simple CSS and JavaScript tricks for HTML output are very difficult (and often impossible) to reproduce in LaTeX output.

In this chapter, we introduce techniques to enhance your HTML output from R Markdown, including how to apply custom CSS rules, use custom HTML templates, style or fold code blocks, arrange content in tabs, and embed files on HTML pages.

7.1 Apply custom CSS

We strongly recommend that you learn some CSS and JavaScript if you wish to customize the appearance of HTML documents. Appendix B[*1] of the **blogdown** book (Xie Hill, and Thomas, 2017) contains short tutorials on HTML, CSS, and JavaScript.

For beginners, it is extremely important to understand selectors and precedence of rules in CSS, otherwise you may be confused why your custom CSS rules do not work as expected (they may not have enough precedence).

To include one or multiple custom stylesheets in an Rmd document, you can use the `css` option, e.g.,

[*1] https://bookdown.org/yihui/blogdown/website-basics.html

```yaml
output:
  html_document:
    css: "style.css"
```

To include multiple stylesheets, you may list them in brackets, e.g.,

```yaml
output:
  html_document:
    css: ["style-1.css", "style-2.css"]
```

Alternatively, you can use a css code chunk to embed the CSS rules directly in your Rmd document, e.g.,

````markdown
We embed a `css` code chunk here.

```{css, echo=FALSE}
p {
  font-size: 32px;
}
```
````

The chunk option `echo = FALSE` means the CSS code will not be displayed verbatim in the output, but a `<style>` tag containing the CSS code will be generated to the HTML output file.

7.2 Center section headings

As an application of the methods mentioned in Section 7.1, we can use CSS to adjust the alignment of headings. For example, you may center section headings of level 1, 2, and 3 with the CSS code below:

```css
h1, h2, h3 {
  text-align: center;
}
```

Please see Section 7.1 on how to apply the CSS to your Rmd document.

7.3 Style code blocks and text output

We can customize the style of code chunks and their text output using the chunk options `class.source` and `class.output`, respectively. These options take character vectors of class names (see Section 11.13 for more information). For example, when `class.source = "important"`, the HTML element containing the code chunk in the output will have a class `important`. Then you can define CSS rules for this class.[*2] This can be useful when you want to highlight a certain code chunk or its text output.

By default, the HTML output of R Markdown includes the Bootstrap framework, which makes it easy for you to change the appearance of your code and output, because Bootstrap has predefined some CSS classes for backgrounds:[*3] `"bg-primary"`, `"bg-success"`, `"bg-info"`, `"bg-warning"`, and `"bg-danger"`.

Below is an example using the chunk options `class.source = "bg-danger"` and `class.output = "bg-warning"`, and you can see its output in Figure 7.1.

````
---
title: Change the chunk style
output: html_document
---

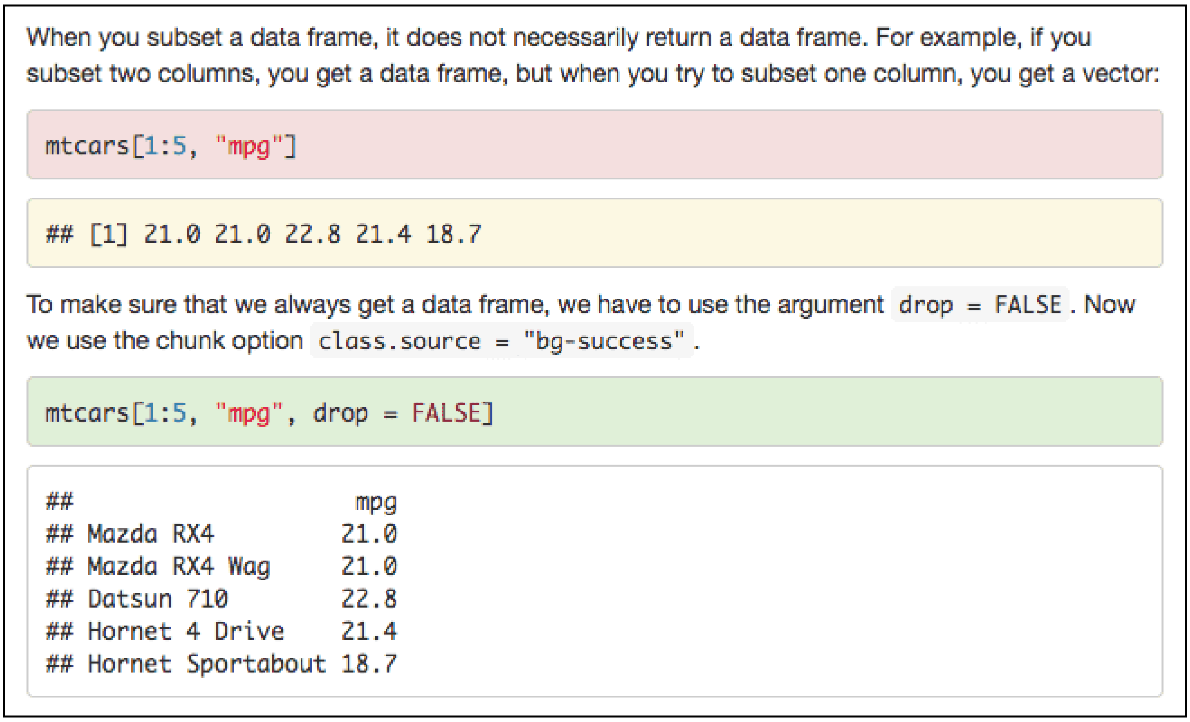
When you subset a data frame, it does not necessarily return
a data frame. For example, if you subset two columns, you get
a data frame, but when you try to subset one column, you get
a vector:

```{r class.source="bg-danger", class.output="bg-warning"}
mtcars[1:5, "mpg"]
```

To make sure that we always get a data frame, we have to use
````

[*2] In this case, the rule would begin `.important` because in CSS, classes are prefixed with a period (`.`).

[*3] https://getbootstrap.com/docs/3.4/css/#helper-classes



When you subset a data frame, it does not necessarily return a data frame. For example, if you subset two columns, you get a data frame, but when you try to subset one column, you get a vector:

```
mtcars[1:5, "mpg"]
```

```
## [1] 21.0 21.0 22.8 21.4 18.7
```

To make sure that we always get a data frame, we have to use the argument `drop = FALSE`. Now we use the chunk option `class.source = "bg-success"`.

```
mtcars[1:5, "mpg", drop = FALSE]
```

```
##                    mpg
## Mazda RX4         21.0
## Mazda RX4 Wag     21.0
## Datsun 710        22.8
## Hornet 4 Drive    21.4
## Hornet Sportabout 18.7
```

図7.1: A code chunk and its text output with background colors defined by Bootstrap.

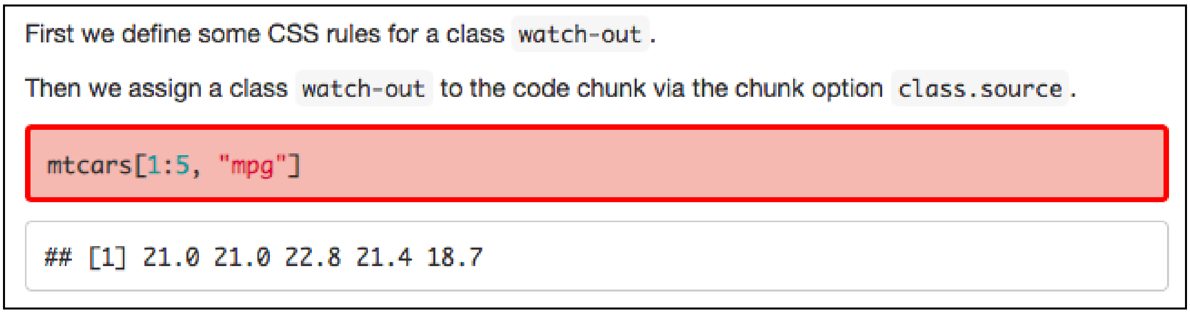
````
the argument `drop = FALSE`. Now we use the chunk option
`class.source = "bg-success"`.

```{r df-drop-ok, class.source="bg-success"}
mtcars[1:5, "mpg", drop = FALSE]
```
````

You can also use arbitrary class names and define CSS rules accordingly. In this case, you will have to include your custom CSS rules using the methods mentioned in Section 7.1. Below is an example:

```
---
title: Assign custom classes to chunks
output: html_document
---

First we define some CSS rules for a class `watch-out`.
```



First we define some CSS rules for a class `watch-out`.

Then we assign a class `watch-out` to the code chunk via the chunk option `class.source`.

```
mtcars[1:5, "mpg"]
```

```
## [1] 21.0 21.0 22.8 21.4 18.7
```

図7.2: A code chunk with a light pink background color and a thick red border.

````
```{css, echo=FALSE}
.watch-out {
  background-color: lightpink;
  border: 3px solid red;
  font-weight: bold;
}
```

Then we assign a class `watch-out` to the code chunk via the
chunk option `class.source`.

```{r class.source="watch-out"}
mtcars[1:5, "mpg"]
```
````

The output style is shown in Figure 7.2.

If you want all code blocks in the document to use the custom style, you can set `class.source` in the global **knitr** options, e.g.,

```
knitr::opts_chunk$set(class.source = "watch-out")
```

You can apply multiple classes to the code blocks. For example, with `class.source = c("important", "warning")`, the code block will have two classes, "important" and "warning."

If you want to decorate individual elements in code blocks instead of the whole blocks, you may consider using the **flair** package (Bodwin and Glanz, 2020). With this package, you can highlight different parts of your code (such as fixed strings, function names, and arguments) with custom styles (e.g., color, font size, and/or font weight).

7.4 Scrollable code blocks (*)

When you have large amounts of code and/or verbatim text output to display on an HTML page, it may be desirable to limit their heights. Otherwise the page may look overwhelmingly lengthy, and it will be difficult for those who do not want to read the details in the code or its text output to skip these parts. There are multiple ways to solve this problem. One solution is to use the `code_folding` option in the `html_document` format. This option will fold code blocks in the output and readers can unfold them by clicking a button (see Section 7.5 for more details).

The other possible solution is to make the code blocks scrollable within a fixed height when they are too long. This can be achieved by the CSS properties `max-height` and `overflow-y`. Below is a full example with the output in Figure 7.3:

````
---
title: Scrollable code blocks
output: html_document
---

```{css, echo=FALSE}
pre {
  max-height: 300px;
  overflow-y: auto;
}

pre[class] {
  max-height: 100px;
}
```

We have defined some CSS rules to limit the height of
````

```
code blocks. Now we can test if these rules work on code
blocks and text output:

```{r}
# pretend that we have a lot of code in this chunk
if (1 + 1 == 2) {
  # of course that is true
  print(mtcars)
  # we just printed a lengthy data set
}
```

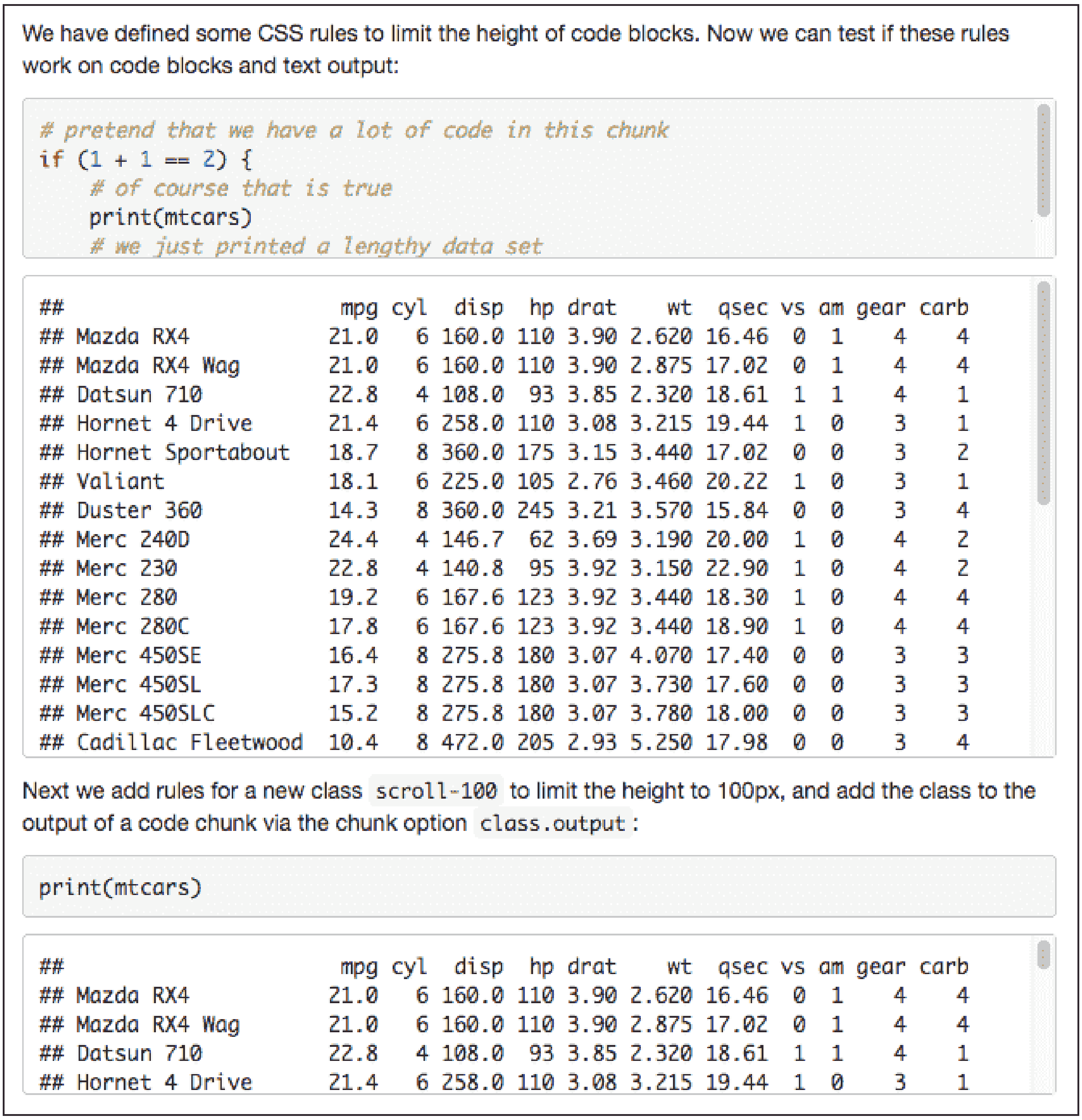
Next we add rules for a new class `scroll-100` to limit
the height to 100px, and add the class to the output of
a code chunk via the chunk option `class.output`:

```{css, echo=FALSE}
.scroll-100 {
  max-height: 100px;
  overflow-y: auto;
  background-color: inherit;
}
```

```{r, class.output="scroll-100"}
print(mtcars)
```
```

In the above example, we defined a global maximum height of 300px for all code blocks. Remember that code blocks are placed in `<pre>` tags in the HTML output. Then we limited the height of `<pre>` blocks to 100px with `class` attributes. That is what the CSS selector `pre[class]` means. By default, text output will be contained in `<pre> </pre>`, and R code blocks are contained in `<pre class="r"> </pre>` (note that the `<pre>` tag has a `class` attribute here).

The height of the text output from the second R code chunk is also 100px. That is because



We have defined some CSS rules to limit the height of code blocks. Now we can test if these rules work on code blocks and text output:

```
# pretend that we have a lot of code in this chunk
if (1 + 1 == 2) {
    # of course that is true
    print(mtcars)
    # we just printed a lengthy data set
```

```
##                      mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4           21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag       21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710          22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## Hornet 4 Drive      21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
## Hornet Sportabout   18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
## Valiant             18.1   6 225.0 105 2.76 3.460 20.22  1  0    3    1
## Duster 360          14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
## Merc 240D           24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## Merc 230            22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
## Merc 280            19.2   6 167.6 123 3.92 3.440 18.30  1  0    4    4
## Merc 280C           17.8   6 167.6 123 3.92 3.440 18.90  1  0    4    4
## Merc 450SE          16.4   8 275.8 180 3.07 4.070 17.40  0  0    3    3
## Merc 450SL          17.3   8 275.8 180 3.07 3.730 17.60  0  0    3    3
## Merc 450SLC         15.2   8 275.8 180 3.07 3.780 18.00  0  0    3    3
## Cadillac Fleetwood  10.4   8 472.0 205 2.93 5.250 17.98  0  0    3    4
```

Next we add rules for a new class `scroll-100` to limit the height to 100px, and add the class to the output of a code chunk via the chunk option `class.output`:

```
print(mtcars)
```

```
##                      mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4           21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag       21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710          22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## Hornet 4 Drive      21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
```

図7.3: Scrollable code blocks using custom CSS.

we assigned a custom class name `scroll-100` to the output, and defined the maximum height to be 100px.

If you want to specify different maximum heights for individual code blocks, you may see the example in Section 12.3.

7.5 Fold all code blocks but show some initially

If code blocks in the output document are potentially distracting to readers, you may choose to fold them initially. Readers can then choose to display them by clicking the fold buttons:

```yaml
output:
  html_document:
    code_folding: hide
```

You can also choose to unfold all code blocks initially (so readers can choose to fold them later):

```yaml
output:
  html_document:
    code_folding: show
```

If you fold all code blocks initially, you can specify certain blocks to be unfolded initially with the chunk option `class.source = "fold-show"`, e.g.,

````
---
title: Hide all code blocks and show some initially
output:
  html_document:
    code_folding: hide
---

```{r}
1  # code is hidden initially
```
````

````
```{r class.source = 'fold-show'}
2  # code is shown initially
```

```{r}
3  # also hidden
```
````

You can also do it the other way around, i.e., show all code blocks but hide some of them initially. For example:

````
---
output:
  html_document:
    code_folding: show
---

```{r}
1  # code is shown initially
```

```{r class.source = 'fold-hide'}
2  # code is hidden initially
```
````

7.6 Put content in tabs

One natural way of organizing parallel sections in an HTML report is to use tabsets. This allows readers to view the content of different sections by clicking the tab titles instead of scrolling back and forth on the page.

To turn sections into tabs, you can add a class attribute `.tabset` to the section header that is one level higher than the headers to be converted to tabs, e.g., adding the `.tabset` attribute to a level-2 header will convert all subsequent level-3 headers to tabs. Below is a full example:

````
---
title: Use tabs to organize content
output: html_document
---

You can turn parallel sections to tabs in `html_document` output.

## Results {.tabset}

### Plots

We show a scatter plot in this section.

```{r, fig.dim=c(5, 3)}
par(mar = c(4, 4, .5, .1))
plot(mpg ~ hp, data = mtcars, pch = 19)
```

### Tables

We show the data in this tab.

```{r}
head(mtcars)
```
````

The output is shown in Figure 7.4. Note that you can only see one tab at a time in reality. In this figure, we actually concatenated two screenshots for you to see both tabs.

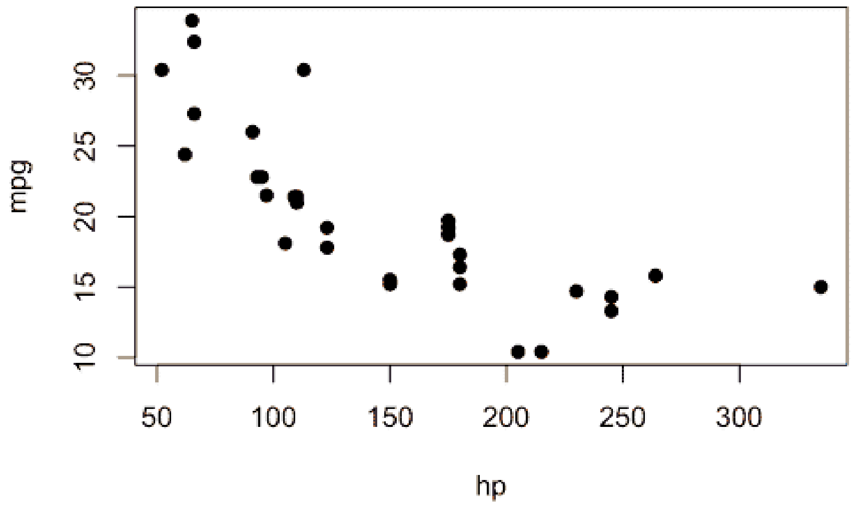
You can add another attribute `.tabset-pills` to the upper-level section header to add a "pill" effect to the tab, and the tab will have a dark blue background.

```
## Results {.tabset .tabset-pills}
```

Plots | Tables

We show a scatter plot in this section.

```
par(mar = c(4, 4, 0.5, 0.1))
plot(mpg ~ hp, data = mtcars, pch = 19)
```



Plots | Tables

We show the data in this tab.

```
head(mtcars)
```

```
##                    mpg cyl disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
## Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
## Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
## Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

図7.4: Turn sections into tabs.

By default, the first tab is active (i.e., displayed). If you want a different tab to be displayed initially, you may add the attribute `.active` to it.

To end the tabset, you need to start a new section header of the upper level. The new section header can be empty, e.g.,

```
## Results {.tabset}

### Tab One

### Tab Two

## {-}

With the above unnumbered (`{-}`) and empty section header,
we can end the tabset and continue to write more paragraphs.
```

7.7 Embed the Rmd source file in the HTML output file

When you share an HTML output page with others, they may want the Rmd source file, too. For example, they may want to change the Rmd source and compile the report by themselves. You can use the option `code_download` to embed a copy of the Rmd source file in the HTML output file:

```yaml
output:
  html_document:
    code_download: true
```

After the option is turned on, the HTML output page will contain a download button, and readers of the page can hit the button to download the Rmd source file.

7.8 Embed arbitrary files in the HTML output file

As mentioned in Section 7.7, we can embed a copy of the Rmd source document in the HTML output file. Sometimes the Rmd source file alone may not be enough to reproduce the report. For example, the report may need an external data file. There is a series of functions in the **xfun** package (Xie, 2021) that enable you to embed arbitrary files in the HTML output file. To use these functions, make sure you have the following R packages available:

```r
xfun::pkg_load2(c("htmltools", "mime"))
```

Then you can use one of the functions `xfun::embed_file()`, `xfun::embed_files()`, or `xfun::embed_dir()` in an R code chunk to embed one or multiple files or an entire directory in the HTML output, e.g.,

````
```{r echo=FALSE}
# a single file
xfun::embed_file('source.Rmd')

# multiple files
xfun::embed_files(c('source.Rmd', 'data.csv'))

# a directory
xfun::embed_dir('data/', text = 'Download full data')
```
````

You can also provide the list of files programmatically, e.g.,

```r
# embed all Rmd and csv files
xfun::embed_files(list.files(".", "[.](Rmd|csv)$"))
```

For multiple files, they are first compressed to a zip file, and the zip file will be embedded. These functions return a link, on which a reader can click on the HTML page to download the embedded file.

You can learn more technical details behind these functions from the help page `?xfun::embed_file` or the blog post at https://yihui.org/en/2018/07/embed-file/. Based on the same idea, the **downloadthis** package (Mattioni Maturana, 2020) has implemented download buttons, so that users can click buttons to download files instead of links. If you prefer using buttons, you may consider using this package.

7.9 Use a custom HTML template (*)

We mentioned LaTeX templates in Section 6.10. You can also specify a custom HTML template for Pandoc to convert Markdown to HTML. Below is a brief example template:

```html
<html>
  <head>
    <title>$title$</title>
    $for(css)$
    <link rel="stylesheet" href="$css$" type="text/css" />
    $endfor$
  </head>
  <body>
  $body$
  </body>
</html>
```

You can see that the template contains a few variables such as `$title$` and `$body$`. You can find the full list of Pandoc variables and their meanings at https://pandoc.org/MANUAL.html#templates.

The template gives you the ultimate power to customize the HTML output. For example, you can include arbitrary CSS stylesheets or JavaScript code or libraries in the `<head>` area. For example, we could use a Boolean variable `draft` to indicate whether the document is a draft or a final version:

```html
<head>
<style type="text/css">
.logo {
  float: right;
}
</style>
</head>

<body>
```

```html
<div class="logo">
$if(draft)$
<!-- use draft.png to show that this is a draft -->
<img src="images/draft.png" alt="Draft mode" />
$else$
<!-- insert the formal logo if this is final -->
<img src="images/logo.png" alt="Final version" />
$endif$
</div>

$body$
</body>
```

Then we can set the variable `draft` to `true` or `false` in the YAML metadata of the Rmd document, e.g.,

```yaml
---
title: "An Important Report"
draft: true
---
```

To apply a template to an Rmd document, you can save the template to a file, and pass the file path to the `template` option of `html_document`, e.g.,

```yaml
output:
  html_document:
    template: my-template.html
```

The **rmarkdown** package uses a custom HTML template shipped with the package, which is different from Pandoc's default template. To use the latter, you can specify `template: null`.

7.10 Include the content of an existing HTML file (*)

With the `includes` option of the `html_document` format (or any other formats that support this option), you can include the content of an existing HTML file in the HTML output document in three possible places: the `<head>` area, the beginning of `<body>`, and the end of `</body>`.

```yaml
output:
  html_document:
    includes:
      in_header: header.html
      before_body: before.html
      after_body: after.html
```

If you are not familiar with HTML, Section 7.9 may help you better understand these options.

With the `in_header` option, you can inject CSS and JavaScript code into the `<head>` tag. With `before_body`, you may include a header that shows a banner or logo. With `after_body`, you can include a footer, e.g.,

```html
<div class="footer">Copyright &copy; John Doe 2020</div>
```

Sometimes you may want to include the content of an external HTML file in an arbitrary place of the body, which can be done with `htmltools::includeHTML()`. You pass the path of the HTML file to this function. It will read the file, and write its content to the output document. You may also use the technique in Section 9.5, e.g.,

`````
````{=html}
```{r, echo=FALSE, results='asis'}
xfun::file_string('file.html')
```
````
`````

Please note that you must not include the content of a full HTML file in another HTML file, but can only include an HTML fragment. A full HTML file contains the `<html>` tag, which cannot be embedded in another `<html>` tag. Below is an invalid HTML document when a full HTML document is included in another HTML document:

```
<html>
  <head>  </head>

  <body>
  Parent HTML file.

  <!-- htmltools::includeHTML() below -->
    <html>
      <head>  </head>
      <body>
      Child HTML file.
      </body>
    </html>
  <!-- included above -->

  </body>
</html>
```

If you run into problems when including an HTML file in an HTML output document, you may check if the HTML file contains the `<html>` tag.

There is an output format `html_fragment` in the **rmarkdown** package, which generates an HTML fragment instead of a full HTML document. If you want to include the compiled results of an Rmd document in another Rmd document, the former Rmd document may use the `html_fragment` format instead of the usual `html_document`.

If you want to include an Rmd or Markdown document instead of an HTML file, you may use child documents introduced in Section 16.4.

7.11 Add a custom browser icon

Section 7.10 demonstrates that we can inject additional code into the HTML head, body, or footer with the `includes` option of the `html_document` format. This technique can be used to add a custom browser icon, called a favicon, to your HTML output.

Favicons are the website logos that are displayed in your browser's address bar, tab title, history, and bookmarks. For example, if you visit the CRAN website (https://cran.r-project.org) in Google Chrome, and look at the browser tab, you will see a small R logo. On mobile devices, favicons are also used in place of an App icon for websites that are pinned to the home screen.

To add a favicon to your HTML document, add the following line of code to a custom header file (such as the file `header.html` mentioned in Section 7.10):

```
<link rel="shortcut icon" href="{path to favicon file}" />
```

Recall that this file can be injected into the document `<head>` area using the YAML metadata:

```
output:
  html_document:
    includes:
      in_header: header.html
```

The path you provide to the `href` attribute in `<link>` should assume the same relative path structure as you would use to reference any other asset (e.g., an image or dataset). For the image itself, most small, square PNG files will work reasonably well. Bear in mind that a typical web browser will often display the image in a 16 x 16 pixel box, so simple designs are better.

If you want to ensure that each browser or platform on which your document is viewed uses a version of your icon with optimal resolution for its specific layout, you may use a service such as https://realfavicongenerator.net to generate a set of favicons and a slightly more complex version of the header HTML code. This service is currently used by the **pkgdown** package's `pkgdown::build_favicon()` function (Wickham and Hesselberth, 2020) to make a set of favicons out of R package logos.

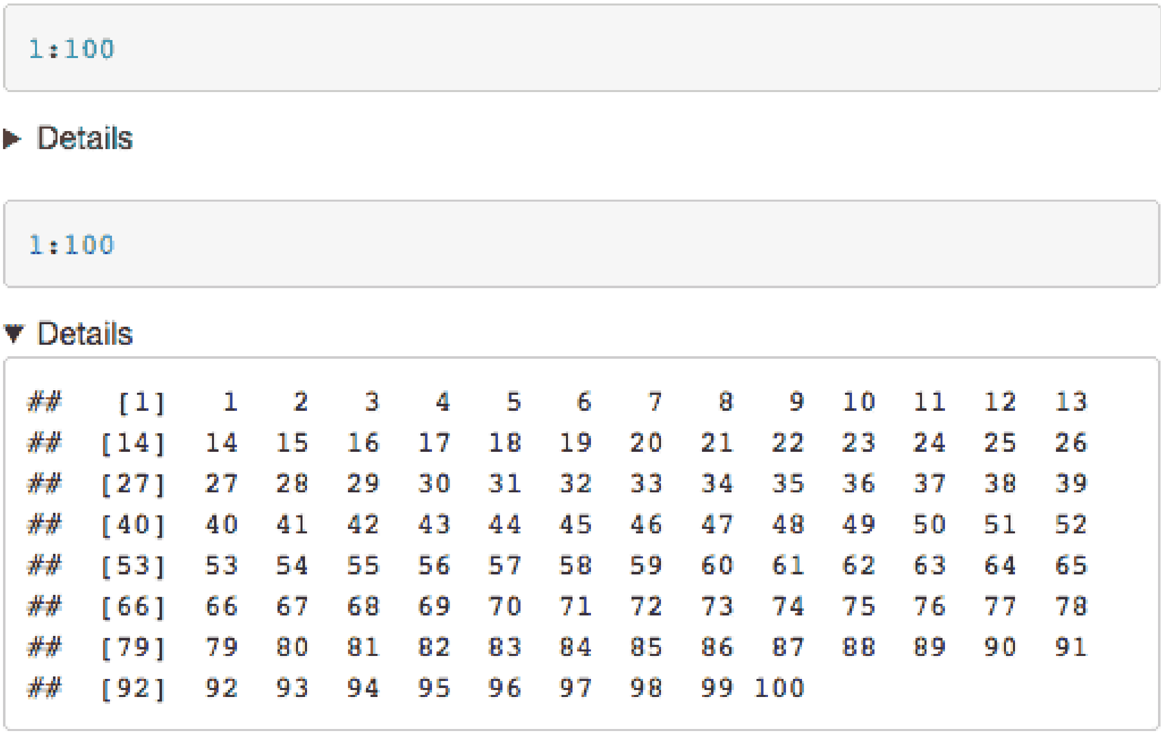


図7.5: Wrap text output in the details element.

7.12 Use the `<details>` disclosure element

As mentioned in Section 7.4, we can fold source code chunks via the option `code_folding: hide` in the `html_document` format. Currently it is not possible to fold output blocks, but we can use some JavaScript tricks to make output foldable, too. This can be useful especially when the output is relatively long but not very important. We can fold it initially, and, if the reader is interested, they can unfold it to view the content. Figure 7.5 shows an example: you may click on the "Details" button to unfold the output.

If you are viewing the HTML version of this book, you can actually see it in action below. If you are reading the PDF or printed version, such an interaction (clicking the "Details" button) is certainly not possible.

```
1:100
```

```
##  [1]   1   2   3   4   5   6   7   8   9  10  11  12
```

```
## [13] 13 14 15 16 17 18 19 20 21 22 23 24
## [25] 25 26 27 28 29 30 31 32 33 34 35 36
## [37] 37 38 39 40 41 42 43 44 45 46 47 48
## [49] 49 50 51 52 53 54 55 56 57 58 59 60
## [61] 61 62 63 64 65 66 67 68 69 70 71 72
## [73] 73 74 75 76 77 78 79 80 81 82 83 84
## [85] 85 86 87 88 89 90 91 92 93 94 95 96
## [97] 97 98 99 100
```

Below is the full source Rmd document that includes the JavaScript code to find output blocks, and wrap them into the <details> tags.

````
---
title: Use the `<details>` disclosure element
output: html_document
---

We show text output inside the `<details>` tags in this
example. We used JavaScript to wrap text output blocks
in `<details></details>`. The JavaScript code needs to
be executed at the end of this document, so it is placed
at the end. Below is a testing code chunk:

```{r}
1:100
```

The actual JavaScript code is below.

```{js, echo=FALSE}
(function() {
  var codes = document.querySelectorAll('pre:not([class])');
  var code, i, d, s, p;
  for (i = 0; i < codes.length; i++) {
    code = codes[i];
    p = code.parentNode;
    d = document.createElement('details');
````
````

```
    s = document.createElement('summary');
    s.innerText = 'Details';
    // <details><summary>Details</summary></details>
    d.appendChild(s);
    // move the code into <details>
    p.replaceChild(d, code);
    d.appendChild(code);
  }
})();
```
```

You may try to adapt the JavaScript code above to your own need. The key is to find out the elements to be wrapped into `&lt;details&gt;`:

```
document.querySelectorAll('pre:not([class])');
```

The CSS selector `pre:not([class])` means all `<pre>` elements without the `class` attribute. You can also select other types of elements. For more about CSS selectors, see https://www.w3schools.com/css/css_selectors.asp. For more about the HTML tags `<details>` and `<summary>`, see https://www.w3schools.com/tags/tag_details.asp.

7.13 Sharing HTML output on the web

One appealing aspect of rendering R Markdown to HTML files is that it is very easy to host these files on the Internet and share them just as one shares any other website. This section briefly summarizes numerous options for sharing the HTML documents that you have created.

7.13.1 R-specific services

RStudio offers a number of services for publishing various types of content created in R Markdown to the Internet. These services make it particularly easy to publish content by using the RStudio IDE or the **rsconnect** package (JJ Allaire, 2019).
```

- **RPubs**[*4] enables free hosting of static single-file R Markdown content. It is easy to publish via the `Publish` button in the RStudio IDE or the `rsconnect::rpubsUpload()` function. Please see the "Getting Started" page (https://rpubs.com/about/getting-started) for more details.
- **ShinyApps.io**[*5] allows for hosting dynamic content that requires a server to run R. For example, one can host interactive R Markdown documents that include Shiny components.[*6] ShinyApps.io is an analog to RPubs for Shiny applications. Apps and interactive R Markdown documents can be published using the push-button in the RStudio IDE or the `rsconnect::deployApp()` function. See the user guide (https://docs.rstudio.com/shinyapps.io/) for more details.
- **bookdown.org**[*7] offers free hosting specifically for books written with the **bookdown** package. You may easily publish static output files of your book using the `bookdown::publish_book()` function.
- **RStudio Connect**[*8] is an enterprise product that organizations may run on their own servers. It can host a wide variety of content created in R (such as R Markdown documents, Shiny apps, and APIs) in a secured environment with document-level access controls, viewership history, and more. Content can be published to RStudio Connect using manual upload, the **rsconnect** package, or with GIT-based deployment.

7.13.2 Static website services

In a few words, a simple static website is composed of any number of HTML files (typically containing an `index.html`, which is the homepage), JavaScript, CSS files, and additional content such as images. This collection of files can be hosted as-is on a web server and rendered in a web browser.

When R Markdown is rendered to the HTML output format, the result may be treated as

---

[*4] https://rpubs.com

[*5] https://www.shinyapps.io

[*6] You may include Shiny components in an R Markdown document by setting the option `runtime: shiny` or `runtime: shiny_prerendered` in the YAML metadata. You will no longer be able to render your document to an HTML document as before; instead, you run your document with `rmarkdown::run()`. To learn more, please refer to Xie J.J. Allaire, and Grolemund (2018) (Chapter 19: https://bookdown.org/yihui/rmarkdown/shiny-documents.html).

[*7] https://bookdown.org/home/about/

[*8] https://rstudio.com/products/connect/

a static website. Websites can range in complexity from a single, standalone HTML file (which is what we get when we use the default `self_contained: true` option), a set of files, or a sophisticated project like a website based on **blogdown** (which relies upon a static website generator). For more details, see Section 2.1 on Static Sites[*9] of the **blogdown** book (Xie Hill, and Thomas, 2017).

As a result, in addition to R-specific services, you may host your HTML document on many freely available static website hosting services. Commonly used options in the R community are:

- **GitHub Pages**[*10] makes it particularly easy to publish Markdown and HTML content straight from a GitHub repository. You may specify whether to host content from either the main branch's root, a `docs/` directory on the main branch, or a specific `gh-pages` branch. Publishing new content can be as simple as pushing new HTML files to your repository via GIT.

- **GitLab Pages**[*11] offers similar functionality to GitHub Pages for GitLab repositories. GitLab deploys content stores in the `public/` directory of a repository. To build and publish content, you must provide a YAML file, `.gitlab-ci.yml` with instructions, but GitLab provides many helpful templates. For an example of hosting rendered HTML content, please see https://gitlab.com/pages/plain-html/-/tree/master.

- **Netlify**[*12] is a platform to build and deploy static website content. It is a popular choice for web content created by the **blogdown** and **pkgdown** packages, but it can host all kinds of HTML files. There are many different publishing options including drag-and-drop, command line, or automated publishing from GitHub and GitLab repositories. Additionally, Netlify offers many helpful features such as website previews in pull requests. See the Netlify documentation (https://docs.netlify.com) or the RStudio webinar "Sharing on Short Notice"[*13] for more details.

[*9] https://bookdown.org/yihui/blogdown/static-sites.html
[*10] https://pages.github.com
[*11] https://docs.gitlab.com/ce/user/project/pages/
[*12] https://www.netlify.com
[*13] https://rstudio.com/resources/webinars/sharing-on-short-notice-how-to-get-your-materials-online-with-r-markdown/

7.14 Improve accessibility of HTML pages

It is important to make your HTML output documents accessible to readers who are visually impaired or blind. These readers often have to use special tools, such as screen readers, to *hear* instead of visually reading your documents. Usually, screen readers can only read out text, but not (raster) images. This means you need to provide enough text hints to screen readers. The good news is that with some small efforts, you can actually greatly enhance the accessibility of your documents. Jonathan Godfrey has provided some tips in the article at `https://r-resources.massey.ac.nz/rmarkdown/` on making accessible R Markdown documents.[*14] Based on this article, we highlight some tips below for the convenience of the readers of this book:

- HTML documents are often more accessible than PDF.

- Try to provide the Rmd source document along with the HTML output document if possible (e.g., Section 7.7 demonstrates one way to do this). In case anything in the HTML document is not accessible, the blind reader may be able to figure it out from the Rmd source, or fix it in the source.

- Provide informative text tags to your graphics. At the useR! conference in 2014, Jonathan explained this issue to me in person. It was the first time that I had learned about the importance of the `alt` attribute of images on web pages.

  To understand this problem, first you have to know that images on web pages are generated by the HTML tag `<img />`. This tag has an `src` attribute, which points to the source of the image, e.g., `<img src="foo_figures/image.png" />`. Sighted readers can see the image, but it is hard for blind users to know anything about the image, because usually screen readers cannot read it, especially when it is a raster image (vector graphics can be better, such as SVG). In this case, it is helpful to provide a text hint, which screen readers can read out to the blind reader. This text hint can be provided in the `alt` attribute of the image, which stands for "alternate text."

  For images generated from code chunks in R Markdown, the `alt` attribute will be generated if you provide the chunk option `fig.cap` (i.e., figure caption). Alternatively, you can insert an image using the Markdown syntax `![]()`. You input the

[*14] JooYoung Seo has also published a post about a few R packages to help visually impaired users at `https://jooyoungseo.com/post/ds4blind/`. It is not directly related to R Markdown, but it can be helpful for you to learn how blind users read graphs.

image path in parentheses, and the `alt` text in square brackets, e.g., `![an informative text](path/to/image.png)`.

The `alt` text is not displayed to sighted readers on an HTML page. However, when you provide the figure caption or alternate text to an image, the `rmarkdown::html_document` format will render a visible figure caption element by default. If you do not want the real figure captions, you can turn off the `fig_caption` option, e.g.,

```
output:
  html_document:
    fig_caption: false
```

In this case, the `alt` attributes will still be generated, but are no longer visible.

- Write mathematical content using the LaTeX syntax (e.g., `$ $` or `$$ $$`) instead of images. By default, R Markdown uses the MathJax library to render math content, and the result is readable to screen readers.

- Get rid of the leading hashes (`##`) in the text output of code chunks by setting the chunk option `comment = ""` (see Section 11.12).

We are not experts on accessibility, so we recommend that you read the original article to learn more details.

7.15 For hardcore HTML users (*)

In Section 6.12, we mentioned that if you feel the constraint of Markdown (due to its simplicity) is too strong, you can embed code chunks in a pure LaTeX document instead of Markdown. Similarly, if you are familiar and comfortable with writing raw HTML code, you can intermingle code chunks with HTML, too. Such documents have the conventional filename extension `.Rhtml`.

In an `Rhtml` document, code chunks are embedded between `<!--begin.rcode` and `end.rcode-->`, and inline R expressions are embedded in `<!--rinline  -->`. Below is a full `Rhtml` example. You can save it to a file named `test.Rhtml`, and use `knitr::knit("test.Rhtml")` to compile it. The output will be an HTML (`.html`) file. In RStudio, you can also hit the `Knit` button on the toolbar to compile the document.

```
<!DOCTYPE html>
<html>
<head>
  <title>A minimal knitr example in HTML</title>
</head>
<body>
<!--begin.rcode
  knitr::opts_chunk$set(fig.width=5, fig.height=5)
  end.rcode-->

  <p>This is a minimal example that shows
  how <strong>knitr</strong> works with pure HTML
  pages.</p>

  <p>Boring stuff as usual:</p>

<!--begin.rcode
    # a simple calculator
    1 + 1
    # boring random numbers
    set.seed(123)
    rnorm(5)
    end.rcode-->

  <p>We can also produce plots (centered by the
  option <code>fig.align='center'</code>):</p>

<!--begin.rcode cars-scatter, fig.align='center'
    plot(mpg ~ hp, data = mtcars)
    end.rcode-->

  <p>Errors, messages and warnings can be put into
  <code>div</code>s with different <code>class</code>es:</p>

<!--begin.rcode
```

```
    sqrt(-1)  # warning
    message('knitr says hello to HTML!')
    1 + 'a'  # mission impossible
    end.rcode-->

  <p>Well, everything seems to be working. Let's ask R what is
  the value of &pi;? Of course it is <!--rinline pi -->.</p>

</body>
</html>
```

第 8 章

Word

To generate a Word document from R Markdown, you can use the output format `word_document`. If you want to include cross-references in the document, you may consider the output format `bookdown::word_document2`, as mentioned in Section 4.7.

```yaml
---
output:
  word_document: default
  bookdown::word_document2: default  # for cross-references
---
```

From our experience, the most frequently asked questions about Word output are:

1. How can I apply a custom Word template to the document?

2. How can I incorporate changes made in Word in the original R Markdown document?

3. How can I style individual document elements?

We will address these questions in this chapter.

8.1 Custom Word templates

You can apply the styles defined in a Word template document to new Word documents generated from R Markdown. Such a template document is also called a "style reference document." The key is that you have to create this template document from Pandoc first, and change the style definitions in it later. Then pass the path of this template to the `reference_docx` option of `word_document`, e.g.,

```yaml
---
output:
  word_document:
    reference_docx: "template.docx"
---
```

As we just mentioned, the document `template.docx` has to be generated from Pandoc. You can create this template from an arbitrary R Markdown document with the `word_document` output format (the actual content of this document does not matter, but it should contain the type of elements of which you want to style). Then open the `.docx` file, and edit the styles.

Figure 8.1 shows that you can open the "Styles" window from the "HOME" tab in Word. When you move the cursor to a specific element in the document, an item in the styles list will be highlighted. If you want to modify the style of any type of element, you can click the drop-down menu on the highlighted item, and you will see a dialog box like Figure 8.2.

After you finish modifying the styles, you can save the document (with a filename that will not be accidentally overwritten), and use it as the template for future Word documents. When Pandoc renders a new Word document with a reference document (template), it will read the styles in the template and apply them to the new document.

You may watch a short video at https://vimeo.com/110804387, or read the article at https://rmarkdown.rstudio.com/articles_docx.html for more detailed instructions on how to create a Word template with custom styles.

Sometimes it may not be straightforward to find the style name for an element. There may be multiple styles applied to the same element, and you will only see one of them highlighted in the list of styles. It may require some guesswork and online searching to figure out the actual style that you want to modify. For example, you have to click the "Manage Styles" button (the third button from left to right at the bottom of the style list in Figure 8.1), and scroll through a large number of style names before you find the "Table" style (see Figure 8.3). Then you can modify this style for your tables (e.g., add borders).

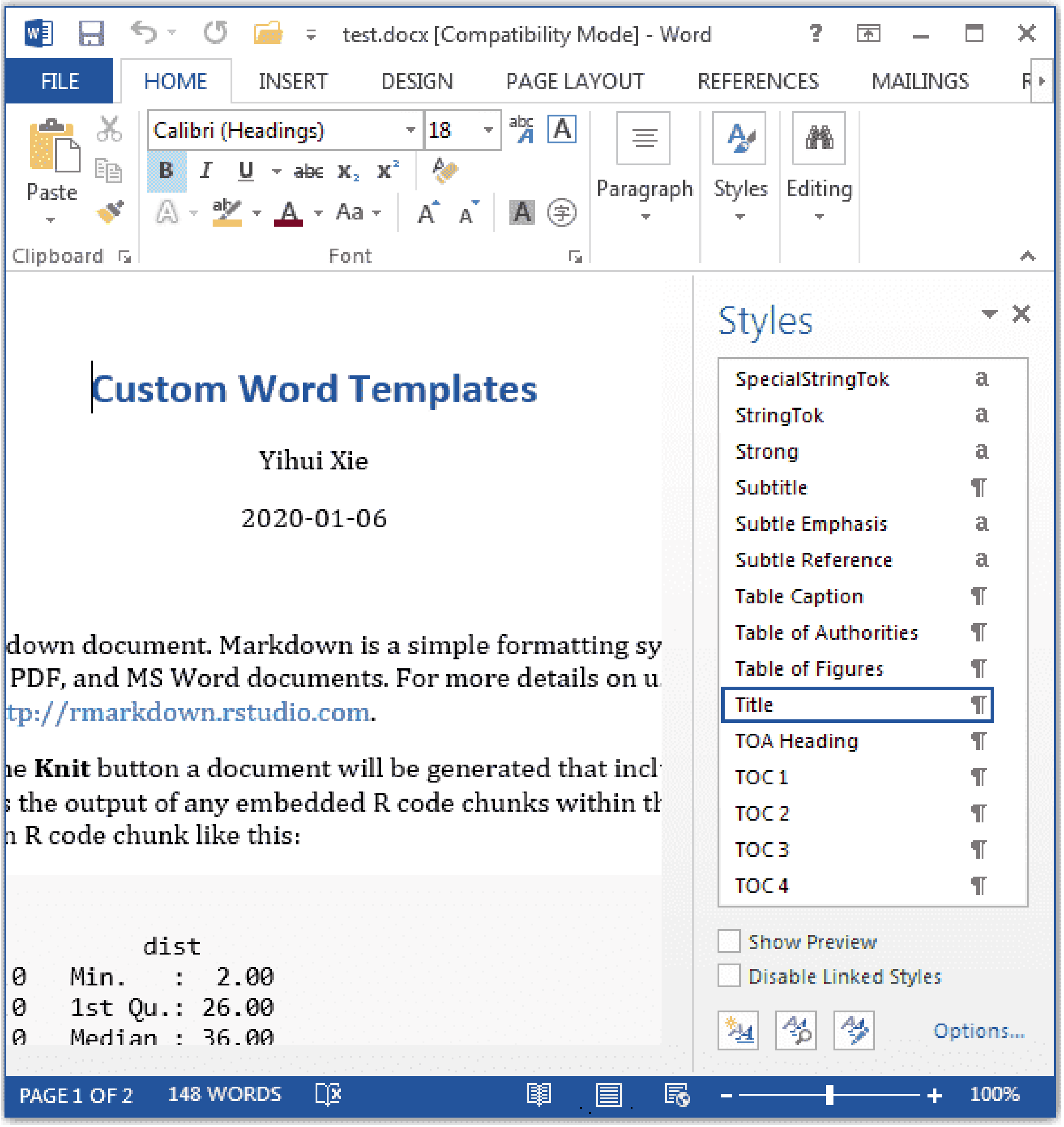


図8.1: Find the styles of a specific document element.

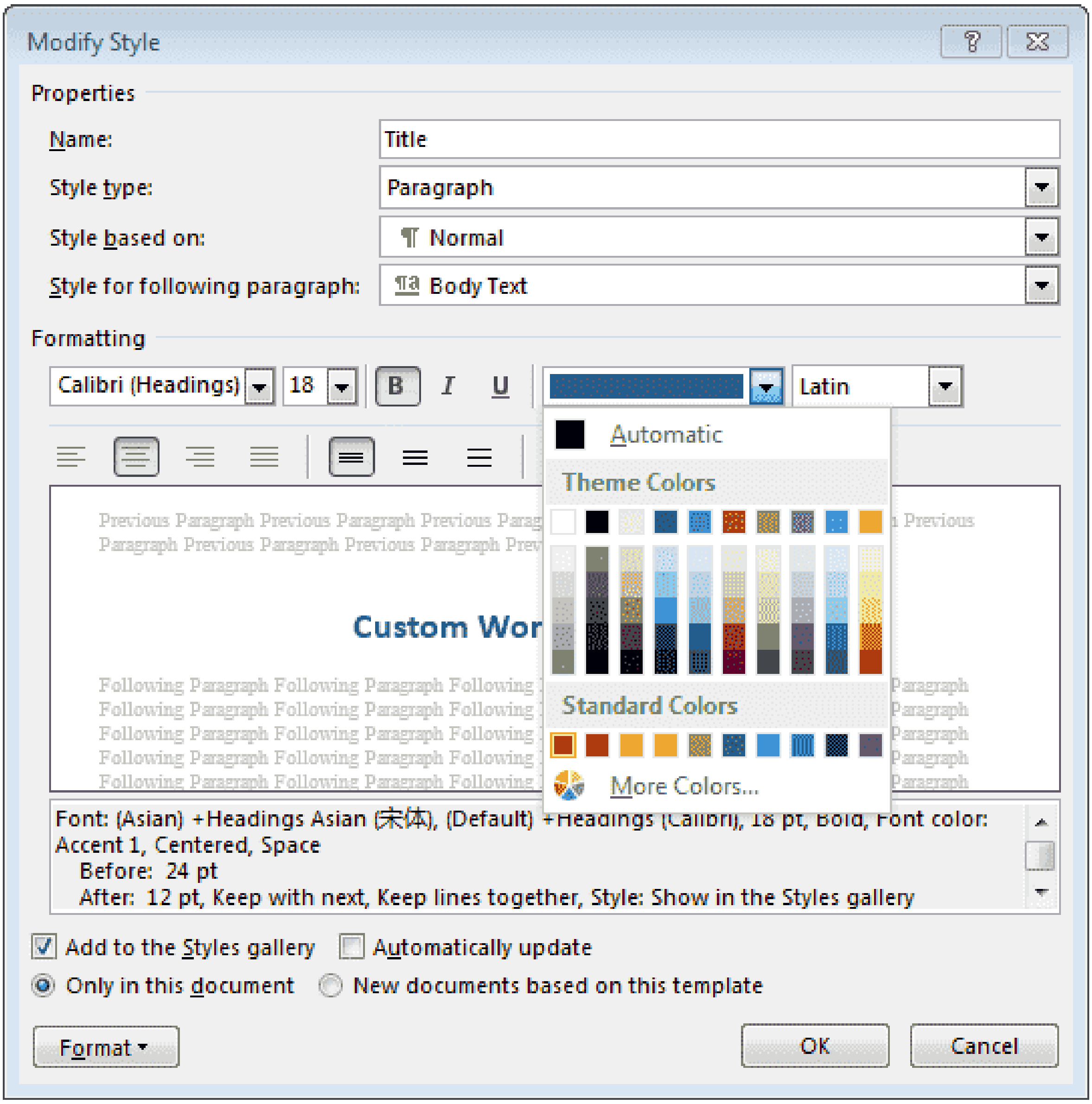


図8.2: Modify the styles of an element in a Word document.

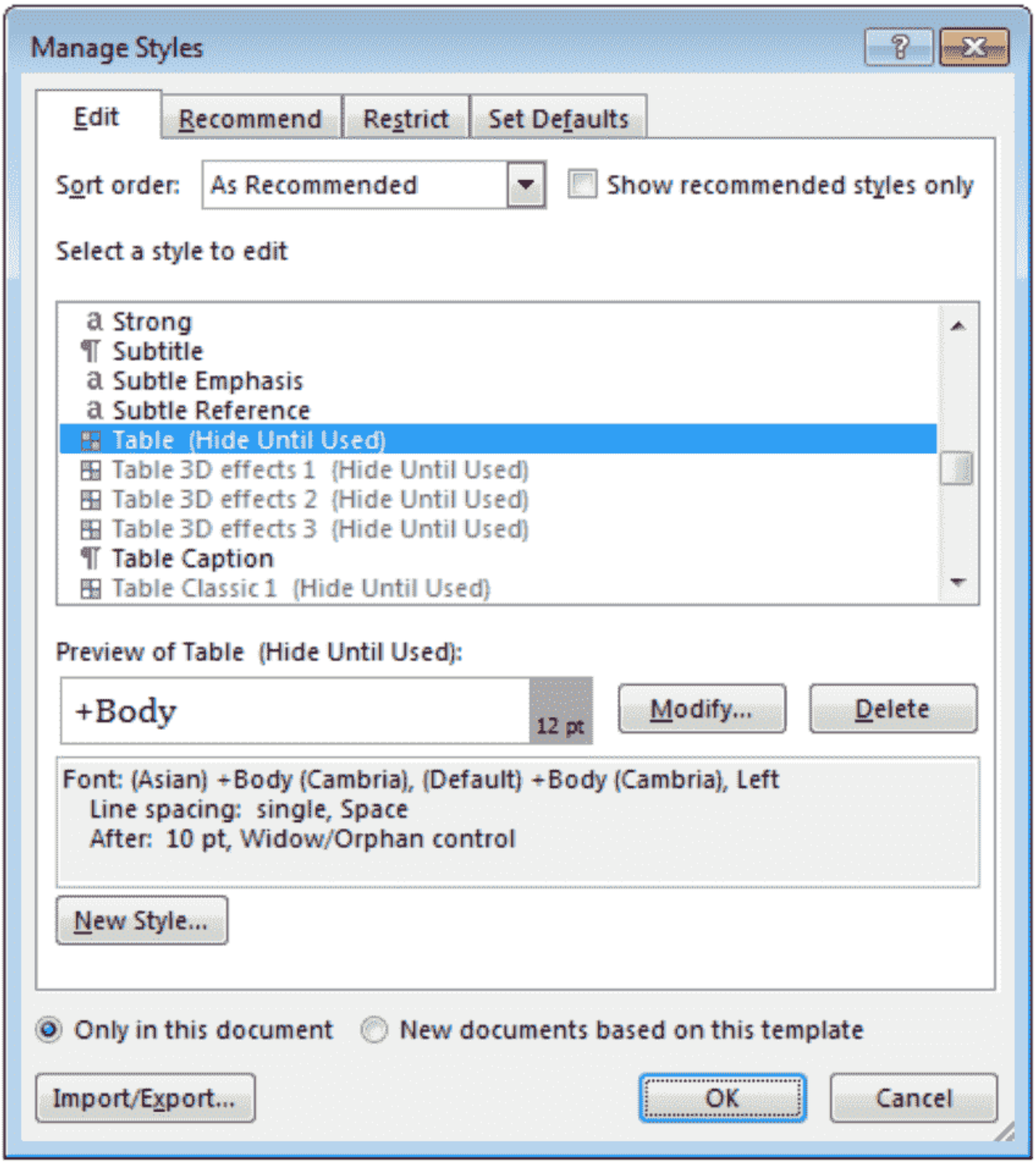


図**8.3:** Modify the styles of tables in a Word document.

8.2 The two-way workflow between R Markdown and Word

While it is easy to generate a Word document from R Markdown, things can be particularly painful when someone else edits the Word document and you have to manually port the changes back to the original R Markdown document. Luckily, Noam Ross has provided a promising solution to this problem. The **redoc** package (https://github.com/noamross/redoc) allows you to generate a Word document, revise the Word document, and convert the revised Word document back to R Markdown. Please note that as of this writing (June 2020), the **redoc** package is still experimental, and more unfortunately, its author has suspended the development. Anyway, if you want to try it out, you can install the package from GitHub:

```r
remotes::install_github("noamross/redoc")
```

Once the package is installed, you may use the output format `redoc::redoc`:

```yaml
---
output: redoc::redoc
---
```

This output format generates a Word document that actually stores the original Rmd document, so the Word document can be converted back to Rmd. Tracked changes in Word will be converted to text written with the CriticMarkup syntax (http://criticmarkup.com). For example, `{++ important ++}` represents the insertion of the word "important" in the text.

You can convert the Word document generated by `redoc::redoc` to Rmd via the function `redoc::dedoc()`, e.g., `redoc::dedoc("file.docx")` will generate `file.Rmd`. In this process, you can decide how to deal with tracked changes in Word via the `track_changes` argument, e.g., you may accept or reject changes, or convert tracked changes to CriticMarkup. We recommend that you use `track_changes = 'criticmarkup'` to avoid the permanent loss of tracked changes.

When editing the Word document, you are expected to edit the parts that are *not* automatically generated by code chunks or inline R expressions in R Markdown. For example, you must not edit a table if it is automatically generated by `knitr::kable()` in a code chunk, because such changes will be lost when you convert Word to Rmd via `dedoc()`. To avoid accidentally editing the automatic results from code chunks, you may set the option `highlight_outputs` to `true` in the `redoc::redoc` format, which means the automatic output will be highlighted in Word (with a background color). You should tell your collaborator that they should not touch these highlighted parts in the Word document.

Again, the **redoc** package is still experimental and its future is unclear at the moment, so the introduction here is intentionally brief. When in doubt, we recommend that you read its documentation on GitHub.

8.3 Style individual elements

Due to the simplicity of Markdown, you can apply some global styles to the Word document (see Section 8.1), but it is not straightforward to style individual elements, such as changing the color of a word, or centering a paragraph.

Continuing his effort to make it easier to work with Office documents in R, David Gohel started to develop the **officedown** package (Gohel and Ross, 2020) in 2018, which aims to bring some **officer** (Gohel, 2021) features into R Markdown. As of this writing, this package is still experimental, although its initial version has been published on CRAN. You may either install it from CRAN or GitHub:

```r
# install from CRAN
install.packages("officedown")

# or GitHub
remotes::install_github("davidgohel/officedown")
```

After the package is installed, you need to load it in your R Markdown document, e.g.,

````
```{r, setup, include=FALSE}
library(officedown)
```
````

There is an output format `rdocx_document` in the **officedown** package, which is based on `rmarkdown::word_document` by default, and has several other features such as styling tables and plots.

The **officedown** package allows you to style specific Word elements via the **officer** package. For example, you can create a style via the function `officer::fp_text()`, and apply the style to a piece of text via `ftext()` an inline R expression:

````
---
title: Style text with officedown
output:
  officedown::rdocx_document: default
---

```{r}
library(officedown)
library(officer)
ft <- fp_text(color = 'red', bold = TRUE)
```

# Test

The **officedown** package is
`r ftext('awesome', ft)`!
````

Besides functions in **officer**, **officedown** also allows you to use some special HTML comments to perform **officer** tasks. For example, the function `officer::block_pour_docx()` can be used to import an external Word document into the current document, and alternatively, you can use the HTML comment in R Markdown:

```
<!---BLOCK_POUR_DOCX{file: 'my-file.docx'}--->
```

That is equivalent to the inline R expression:

```
`r block_pour_docx(file = 'my-file.docx')`
```

Other things you may do with **officedown** and **officer** include the following:

- Insert page breaks.

- Put content in a multi-column layout.

- Change paragraph settings.
- Insert a table of contents.
- Change the orientation of a section (landscape or portrait).

To learn more about **officedown**, please check out its documentation at `https://davidgohel.github.io/officedown/`.

第 9 章

Multiple Output Formats

One main advantage of R Markdown is that it can create multiple output formats from a single source, which could be one or multiple Rmd documents. For example, this book was written in R Markdown, and compiled to two formats: PDF for printing, and HTML for the online version.

Sometimes it can be challenging to make an output element of a code chunk work for all output formats. For example, it is extremely simple to create a rounded and circular image in HTML output with a single CSS rule (`img { border-radius: 50%; }`), but not so straightforward in LaTeX output (typically it will involve TikZ graphics).

Sometimes it is just impossible for an output element to work for all output formats. For example, you can easily create a GIF animation with the **gifski** package (Ooms, 2018) (see Section 4.14), and it will work perfectly for HTML output, but embedding such an animation in LaTeX output is not possible without extra steps of processing the GIF file and using extra LaTeX packages.

This chapter provides a few examples that can work for multiple formats. If a certain feature is only available to a specific output format, we will show you how to conditionally enable or disable it based on the output format.

9.1 LaTeX or HTML output

LaTeX and HTML are two commonly used output formats. The function `knitr::is_latex_output()` tells you if the output format is LaTeX (including Pandoc output formats `latex` and `beamer`). Similarly, the function `knitr::is_html_output` tells you if the output format is HTML.

By default, these Pandoc output formats are considered HTML formats: `markdown`, `epub`, `html`, `html4`, `html5`, `revealjs`, `s5`, `slideous`, and `slidy`. If you do not think a certain Pandoc format is HTML, you may use the `excludes` argument to exclude it, e.g.,

```r
# do not treat markdown as an HTML format
knitr::is_html_output(excludes = "markdown")
## [1] FALSE
```

If a certain output element can only be generated in LaTeX or HTML, you can use these functions to conditionally generate it. For example, when a table is too big on a PDF page, you may include the table in an environment of a smaller font size, but such a LaTeX environment certainly will not work for HTML output, so it should not be included in HTML output (if you want to tweak the font size for HTML output, you may use CSS). Below is a full example:

````
---
title: Render a table in a tiny environment
output:
  pdf_document: default
  html_document: default
---

```{r, setup, include=FALSE}
knitr::opts_chunk$set(echo = FALSE)
options(knitr.table.format = function() {
  if (knitr::is_latex_output()) 'latex' else 'pandoc'
})
```

The LaTeX environment `tiny` is only generated for LaTeX output.

```{r, include=knitr::is_latex_output()}
knitr::asis_output('\n\n\\begin{tiny}')
```

```{r}
````
````

```
knitr::kable(mtcars)
```

```{r, include=knitr::is_latex_output()}
knitr::asis_output('\\end{tiny}\n\n')
```

By comparison, below is the table with the normal font size.

```{r}
knitr::kable(mtcars)
```
```

The key in the above example is the chunk option `include = knitr::is_latex_output()`. That is, the environment `\begin{tiny} \end{tiny}` is only included when the output format is LaTeX. The two tables in the example will look identical when the output format is not LaTeX.

In Section 5.1, we used these functions to change the text color for HTML and LaTeX output. In Section 4.14, we showed an animation example, which also used this trick. The code chunk that generated the animation for HTML output and static images for LaTeX output is like this:

````
```{r animation.hook=if (knitr::is_html_output()) 'gifski'}
for (i in 1:2) {
  pie(c(i %% 2, 6), col = c('red', 'yellow'), labels = NA)
}
```
````

These conditional functions can be used anywhere. You can use them in other chunk options (e.g., `eval` for conditional evaluation of the chunk), or in your R code, e.g.,

````
```{r, eval=knitr::is_html_output(), echo=FALSE}
cat('You will only see me in HTML output.')
```
````
````

````
```{r}
if (knitr::is_latex_output()) {
  knitr::asis_output('\n\n\\begin{tiny}')
}
```
````

9.2 Display HTML widgets

HTML widgets (https://htmlwidgets.org) are typically interactive JavaScript applications, which only work in HTML output. If you knit an Rmd document containing HTML widgets to a non-HTML format such as PDF or Word, you may get an error message like this:

```
Error: Functions that produce HTML output found in document
targeting X output. Please change the output type of this
document to HTML. Alternatively, you can allow HTML output in
non-HTML formats by adding this option to the YAML front-matter
of your rmarkdown file:

  always_allow_html: yes

Note however that the HTML output will not be visible in
non-HTML formats.
```

There is actually a better solution than the one mentioned in the above error message, but it involves extra packages. You can install the **webshot** package (Chang, 2019) in R and also install PhantomJS:

```r
install.packages("webshot")
webshot::install_phantomjs()
```

Then if you knit an Rmd document with HTML widgets to a non-HTML format, the HTML widgets will be displayed as static screenshots. The screenshots are automatically taken in **knitr**. Section 2.10[*1] of the **bookdown** book contains more information on finer control over the screenshots.

9.3 Embed a web page

If you have the **webshot** package (Chang, 2019) and PhantomJS installed (see Section 9.2), you can embed any web page in the output document through knitr::include_url(). When you pass a URL of a web page to this function in a code chunk, it will generate an <iframe> (inline frame) if the output format is HTML, and a screenshot of the web page for other output formats. You can view the actual page in the inline frame. For example, Figure 9.1 should show you my homepage if you are reading the online version of this book, otherwise you will see a static screenshot instead.

```
knitr::include_url("https://yihui.org")
```

Most chunk options related to figures also work for knitr::include_url(), such as out.width and fig.cap.

If you have published a Shiny app publicly on a server, you can use knitr::include_app() to include it, which works in the same way as include_url(). Section 2.11[*2] of the **bookdown** book (Xie, 2016) contains more details about include_app() and include_url().

9.4 Multiple figures side by side

You can place multiple figures side by side using the fig.show="hold" along with the out.width option. In the example below, we have set out.width="50%" (see Figure 9.2 for the output):

````
```{r, figures-side, fig.show="hold", out.width="50%"}
par(mar = c(4, 4, .1, .1))
plot(cars)
plot(mpg ~ hp, data = mtcars, pch = 19)
```
````

[*1] https://bookdown.org/yihui/bookdown/html-widgets.html
[*2] https://bookdown.org/yihui/bookdown/web-pages-and-shiny-apps.html

図9.1: Embed Yihui's homepage as an iframe or screenshot.

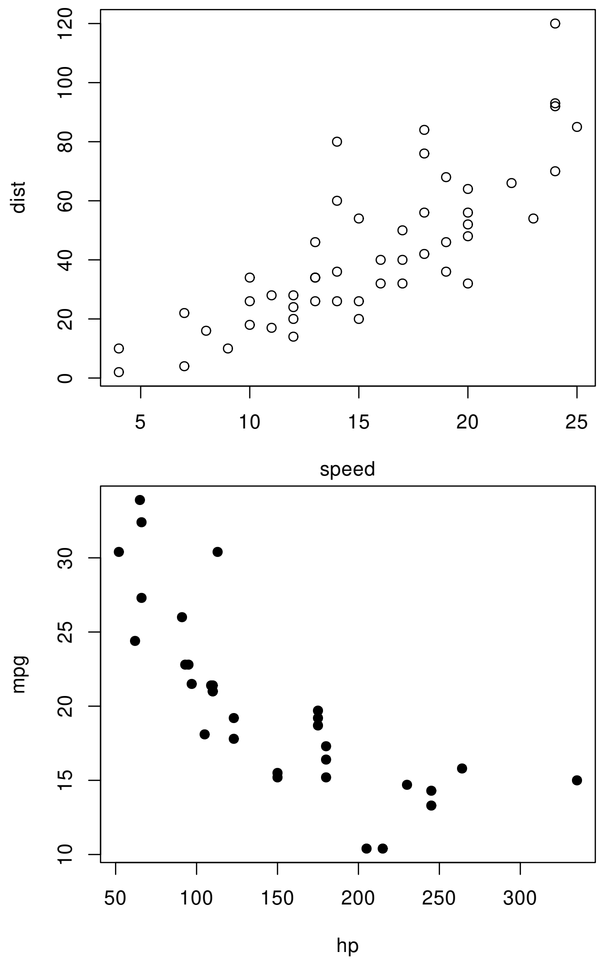


図9.2: Side-by-side figures.

This simple approach works for both PDF and HTML output.

If you want to use sub-figures when there are multiple plots in a figure, you may see Section 6.6, but please note that sub-figures are only supported in LaTeX output.

9.5 Write raw content (*)

The technique introduced in Section 6.11 is actually a general technique. You can protect any complex raw content in Markdown by specifying the content as "raw." For example, if you want to write raw HTML content, you can use the attribute `=html`:

````
```{=html}
<p>Any <strong>raw</strong> HTML content works here.
````
````

```
For example, here is a Youtube video:</p>

<iframe width="100%" height="400"
  src="https://www.youtube.com/embed/s3JldKoA0zw?rel=0"
  frameborder="0" allow="autoplay; encrypted-media"
  allowfullscreen></iframe>
```
```

The attribute name is the Pandoc output format name. If you want to know the output format name, you may check the output of the code chunk below inside an Rmd document:

````
```{r}
knitr:::pandoc_to()
```
````

Please note that raw content is only visible to a specific output format. For example, raw LaTeX content will be ignored when the output format is HTML.

## 9.6 Custom blocks (*)

Section 2.7[*3] of the **bookdown** book mentioned how we can use custom blocks in R Markdown to customize the appearance of blocks of content. This can be a useful way to make some content stand out from your report or book, to make sure that your readers take away the key points from your work. Examples of how these blocks could be used include:

- display a warning message to make sure users are using up-to-date packages before running your analysis;
- add a link at the beginning of your document to your GitHub repository containing the source;
- highlight key results and findings from your analysis.

In this section, we will explain how to create your own custom blocks for both PDF and HTML output. They can both use the same formatting syntax in the R Markdown docu-

[*3] https://bookdown.org/yihui/bookdown/custom-blocks.html
````

ment, but require different configurations.

9.6.1 Syntax

The syntax for custom blocks is based on Pandoc's fenced `Div` blocks.[*4] `Div` blocks are very powerful, but there is a problem at the moment: they mainly work for HTML output and do not work for LaTeX output.

Since version 1.16 of the **rmarkdown** package, it has been possible to convert `Div` blocks to both HTML and LaTeX. For HTML output, all attributes of the block will become attributes of the `<div>` tag. For example, a `Div` can have an ID (after `#`), one or multiple classes (class names are written after `.`), and other attributes. The following `Div` block

```
::: {#hello .greeting .message width="40%"}
Hello **world**!
:::
```

will be converted to the HTML code below:

```html
<div id="hello" class="greeting message" width="40%">
  Hello <strong>world</strong>!
</div>
```

For LaTeX output, the first class name will be used as the LaTeX environment name. You should also provide an attribute named `data-latex` in the `Div` block, which will be the arguments of the environment. This attribute can be an empty string if the environment does not need arguments. We show two simple examples below. The first example uses the `verbatim` environment in LaTeX, which does not have any arguments:

```
::: {.verbatim data-latex=""}
We show some _verbatim_ text here.
:::
```

Its LaTeX output will be:

[*4] https://pandoc.org/MANUAL.html#divs-and-spans

```latex
\begin{verbatim}
We show some \emph{verbatim} text here.
\end{verbatim}
```

When the block is converted to HTML, the HTML code will be:

```html
<div class="verbatim">
We show some <em>verbatim</em> text here.
</div>
```

The second example uses the `center` and `minipage` environments to display some text in a centered box of half of the page width.

```
:::: {.center data-latex=""}

::: {.minipage data-latex="{.5\linewidth}"}
This paragraph will be centered on the page, and
its width is 50% of the width of its parent element.
:::

::::
```

Note that we nested the `minipage` block in the `center` block. You need more colons for a parent block to include a child block. In the above example, we used four colons (you can use five or more) for the `center` block. The two blocks will be converted to the LaTeX code below:

```latex
\begin{center}
\begin{minipage}{.5\linewidth}
This paragraph will be centered on the page, and
its width is 50\% of the width of its parent element.
\end{minipage}
\end{center}
```

It is up to the user to define the appearance of their `<div>` blocks via CSS for the HTML output. Similarly, for LaTeX output, you may use the command `\newenvironment` to define the environment if it has not been defined, or `\renewenvironment` to redefine an existing environment in LaTeX. In the LaTeX definitions, you can decide on the appearance of these blocks in PDF. These customizations will normally be contained in their own files such as `style.css` or `preamble.tex`, and then included within the YAML options:

```
---
output:
  html_document:
    css: style.css
  pdf_document:
    includes:
      in_header: preamble.tex
---
```

Next we will demonstrate a few more advanced custom blocks that use custom CSS rules and LaTeX environments. You may find an additional example in Section 5.8, in which we arranged multiple blocks in a multi-column layout.

9.6.2 Adding a shaded box

First, we show how to include content in a shaded box. The box has a black background with an orange frame with rounded corners. The text in the box is in white.

For HTML output, we define these rules in a CSS file. If you are unfamiliar with CSS, there are plenty of free online tutorials, e.g., https://www.w3schools.com/css/.

```
.blackbox {
  padding: 1em;
  background: black;
  color: white;
  border: 2px solid orange;
  border-radius: 10px;
}
.center {
  text-align: center;
```

```
}
```

For LaTeX output, we create a new environment named `blackbox` and based on the LaTeX package **framed**, with a black background and white text:

```
\usepackage{color}
\usepackage{framed}
\setlength{\fboxsep}{.8em}

\newenvironment{blackbox}{
  \definecolor{shadecolor}{rgb}{0, 0, 0}  % black
  \color{white}
  \begin{shaded}}
 {\end{shaded}}
```

We used the **framed** package in this book because it is fairly lightweight, but it is not possible to draw a colored frame with rounded corners with this package. To achieve the latter, you will need more sophisticated LaTeX packages such as **tcolorbox** (https://ctan.org/pkg/tcolorbox), which offers a set of very flexible options for creating shaded boxes. You can find many examples in its documentation. The LaTeX environment below will create a shaded box of similar appearance to the above CSS example:

```
\usepackage{tcolorbox}

\newtcolorbox{blackbox}{
  colback=black,
  colframe=orange,
  coltext=white,
  boxsep=5pt,
  arc=4pt}
```

Now we can use our custom box in both PDF and HTML output formats. The source code of the box is:

```
:::: {.blackbox data-latex=""}
::: {.center data-latex=""}
**NOTICE!**
:::

Thank you for noticing this **new notice**! Your noticing it has
been noted, and _will be reported to the authorities_!
::::
```

The output is:

NOTICE!

Thank you for noticing this **new notice**! Your noticing it has been noted, and *will be reported to the authorities*!

9.6.3 Including icons

We can make custom blocks even more visually appealing by including images in them. Images can also be an effective way to convey the content of the block. For the following example, we assume that we are working within a directory structure below, which is a simplified version of what is used to build this book:

```
directory/
 ├── your-report.Rmd
 ├── style.css
 ├── preamble.tex
 └── images/
       └── ├── important.png
           ├── note.png
           └── caution.png
```

We show the source code and output of the example before we explain how everything works:

```
::: {.infobox .caution data-latex="{caution}"}
**NOTICE!**

Thank you for noticing this **new notice**! Your noticing it has
been noted, and _will be reported to the authorities_!
:::
```

The output is:

NOTICE!

Thank you for noticing this **new notice**! Your noticing it has been noted, and *will be reported to the authorities*!

For the HTML output, we can add an image to the box through the `background-image` property in CSS. We insert the image into the background, and add enough padding on the left-hand side to avoid the text overlapping with this image. If you are using local images, the file path to the images is provided relative to the CSS file. For example:

```css
.infobox {
  padding: 1em 1em 1em 4em;
  margin-bottom: 10px;
  border: 2px solid orange;
  border-radius: 10px;
  background: #f5f5f5 5px center/3em no-repeat;
}

.caution {
  background-image: url("images/caution.png");
}
```

Note that we used two class names, `.infobox` and `.caution`, on the outer block. The `infobox` class will be used to define the shaded box with a colored border, and the `caution` class will be used to include the image. The advantage of using two classes is that we can define more blocks with different icons without repeating the setup of the shaded box. For example, if we need a `warning` box, we only need to define the following CSS rule without repeating rules in `.infobox`:

```
.warning {
  background-image: url("images/warning.png");
}
```

Then you can create a `warning` box with the Markdown source code below:

```
:::: {.infobox .warning data-latex="warning"}

Include the actual content here.

::::
```

For the PDF output, we can create an `infobox` environment based on the `blackbox` environment defined in the previous example, and add the icon to the left side of the box. There are multiple ways of including images in a LaTeX environment. Here is only one of them (it does not precisely reproduce the box style defined in the CSS above):

```
\newenvironment{infobox}[1]
  {
  \begin{itemize}
  \renewcommand{\labelitemi}{
    \raisebox{-.7\height}[0pt][0pt]{
      {\setkeys{Gin}{width=3em,keepaspectratio}
        \includegraphics{images/#1}}
    }
  }
  \setlength{\fboxsep}{1em}
  \begin{blackbox}
  \item
  }
  {
  \end{blackbox}
  \end{itemize}
```

```
}
```

Below we show more example blocks with different icons:

NOTICE!

Thank you for noticing this **new notice**! Your noticing it has been noted, and *will be reported to the authorities*!

NOTICE!

Thank you for noticing this **new notice**! Your noticing it has been noted, and *will be reported to the authorities*!

NOTICE!

Thank you for noticing this **new notice**! Your noticing it has been noted, and *will be reported to the authorities*!

NOTICE!

Thank you for noticing this **new notice**! Your noticing it has been noted, and *will be reported to the authorities*!

Alternatively, you may use the LaTeX package **awesomebox**[*5] to generate boxes with icons in the PDF output. This package gives you a much larger number of icons to choose from. We give a brief example below: please refer to the package documentation for the possible LaTeX environments and their arguments.

```yaml
---
title: Awesome Boxes
output:
  pdf_document:
    extra_dependencies: awesomebox
---
```

[*5] https://ctan.org/pkg/awesomebox

````
A note box:

::: {.noteblock data-latex=""}
Thank you for noticing this **new notice**! Your noticing it has
been noted, and _will be reported to the authorities_!
:::

We define an R function `box_args()` to generate the arguments
for the box:

```{r}
box_args <- function(
  vrulecolor = 'white',
  hrule = c('\\abLongLine', '\\abShortLine', ''),
  title = '', vrulewidth = '0pt',
  icon = 'Bomb', iconcolor = 'black'
) {
  hrule <- match.arg(hrule)
  sprintf(
    '[%s][%s][\\textbf{%s}]{%s}{\\fa%s}{%s}',
    vrulecolor, hrule, title, vrulewidth, icon, iconcolor
  )
}
```

Pass some arguments to the `awesomeblock` environment through
an inline R expression:

::: {.awesomeblock data-latex="`r box_args(title = 'NOTICE!')`"}
Thank you for noticing this **new notice**!

Your noticing it has been noted, and _will be reported to
the authorities_!
:::
````

第 10 章

Tables

Tables are one of the primary ways in which we can communicate results in a report. You may often desire to tweak their appearance to suit your particular needs. In this chapter, we will introduce techniques that can be used to customize tables. This chapter aims to do the following:

- Show all features of the table-generating function `knitr::kable()`.
- Highlight more advanced customization of tables using the **kableExtra** package (Zhu, 2020).
- Provide a list of other packages that produce tables.

10.1 The function `knitr::kable()`

The `kable()` function in **knitr** is a very simple table generator, and is simple by design. It only generates tables for strictly rectangular data such as matrices and data frames. You cannot heavily format the table cells or merge cells. However, this function does have a large number of arguments for you to customize the appearance of tables:

```
kable(x, format, digits = getOption("digits"), row.names = NA,
  col.names = NA, align, caption = NULL, label = NULL,
  format.args = list(), escape = TRUE, ...)
```

10.1.1 Supported table formats

In most cases, `knitr::kable(x)` may be enough if you only need a simple table for the data object `x`. The `format` argument is automatically set according to the **knitr** source document format. Its possible values are `pipe` (tables with columns separated by pipes), `simple` (Pandoc's simple tables), `latex` (LaTeX tables), `html` (HTML tables), and `rst` (reStructuredText tables). For R Markdown documents, `kable()` uses the `pipe` format for tables by default, which looks like this:

```r
knitr::kable(head(mtcars[, 1:4]), "pipe")
```

```
|                  |  mpg| cyl| disp|  hp|
|:-----------------|----:|---:|----:|---:|
|Mazda RX4         | 21.0|   6|  160| 110|
|Mazda RX4 Wag     | 21.0|   6|  160| 110|
|Datsun 710        | 22.8|   4|  108|  93|
|Hornet 4 Drive    | 21.4|   6|  258| 110|
|Hornet Sportabout | 18.7|   8|  360| 175|
|Valiant           | 18.1|   6|  225| 105|
```

You can also generate simple tables, or tables in HTML, LaTeX, and reStructuredText:

```r
knitr::kable(head(mtcars[, 1:4]), "simple")
```

```
                      mpg   cyl   disp    hp
------------------  -----  ----  -----  ----
Mazda RX4            21.0     6    160   110
Mazda RX4 Wag        21.0     6    160   110
Datsun 710           22.8     4    108    93
Hornet 4 Drive       21.4     6    258   110
Hornet Sportabout    18.7     8    360   175
Valiant              18.1     6    225   105
```

```
knitr::kable(mtcars[1:2, 1:2], "html")
```

```
<table>
 <thead>
  <tr>
   <th style="text-align:left;">   </th>
   <th style="text-align:right;"> mpg </th>
   <th style="text-align:right;"> cyl </th>
  </tr>
 </thead>
<tbody>
  <tr>
   <td style="text-align:left;"> Mazda RX4 </td>
   <td style="text-align:right;"> 21 </td>
   <td style="text-align:right;"> 6 </td>
  </tr>
  <tr>
   <td style="text-align:left;"> Mazda RX4 Wag </td>
   <td style="text-align:right;"> 21 </td>
   <td style="text-align:right;"> 6 </td>
  </tr>
</tbody>
</table>
```

```
knitr::kable(head(mtcars[, 1:4]), "latex")
```

```
\begin{tabular}{l|r|r|r|r}
\hline
  & mpg & cyl & disp & hp\\
\hline
Mazda RX4 & 21.0 & 6 & 160 & 110\\
\hline
Mazda RX4 Wag & 21.0 & 6 & 160 & 110\\
```

```
\hline
Datsun 710 & 22.8 & 4 & 108 & 93\\
\hline
Hornet 4 Drive & 21.4 & 6 & 258 & 110\\
\hline
Hornet Sportabout & 18.7 & 8 & 360 & 175\\
\hline
Valiant & 18.1 & 6 & 225 & 105\\
\hline
\end{tabular}
```

```r
knitr::kable(head(mtcars[, 1:4]), "rst")
```

```
=================  ====  ===  ====  ===
\                   mpg  cyl  disp   hp
=================  ====  ===  ====  ===
Mazda RX4          21.0    6   160  110
Mazda RX4 Wag      21.0    6   160  110
Datsun 710         22.8    4   108   93
Hornet 4 Drive     21.4    6   258  110
Hornet Sportabout  18.7    8   360  175
Valiant            18.1    6   225  105
=================  ====  ===  ====  ===
```

Please note that only the formats `pipe` and `simple` are portable, i.e., they work for any output document format. Other table formats only work for specific output formats, e.g., `format = 'latex'` only works for LaTeX output documents. Using a specific table format will give you more control, at the price of sacrificing portability.

If you only need one table format that is not the default format for a document, you can set the global R option `knitr.table.format`, e.g.,

```r
options(knitr.table.format = "latex")
```

This option can also be a function that returns the format string or `NULL`. In the case of `NULL`, **knitr** will try to automatically decide the appropriate format. For example, we can use the `latex` format only when the output format is LaTeX:

```r
options(knitr.table.format = function() {
  if (knitr::is_latex_output())
    "latex" else "pipe"
})
```

10.1.2 Change column names

The names of columns in a data frame may not be the same as what we want to display to readers. In R, the column names of data often do not use spaces to separate words but dots or underscores instead. This may not feel natural when we read them in a table. We can use the `col.names` argument to replace the column names with a vector of new names. For example, we substitute the dots with spaces in the column names of the `iris` data:

```r
iris2 <- head(iris)
knitr::kable(iris2, col.names = gsub("[.]", " ", names(iris)))
```

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

The `col.names` argument can take an arbitrary character vector (not necessarily the modified column names via functions like `gsub()`), as long as the length of the vector is equal to the number of columns of the data object, e.g.,

```r
knitr::kable(
  iris,
  col.names = c('We', 'Need', 'Five', 'Names', 'Here')
)
```

10.1.3 Specify column alignment

To change the alignment of the table columns, you can use either a vector of values consisting of characters `l` (left), `c` (center), and `r` (right) or a single multi-character string for alignment, so `kable(..., align = c('c', 'l'))` can be shortened to `kable(..., align = 'cl')`. By default, numeric columns are right-aligned, and other columns are left-aligned. Here is an example:

```r
# left, center, center, right, right
knitr::kable(iris2, align = "lccrr")
```

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

10.1.4 Add a table caption

You can add a caption to the table via the `caption` argument, e.g. (see Table 10.1 for the output),

```r
knitr::kable(iris2, caption = "An example table caption.")
```

As we mentioned in Section 4.7, a table can be cross-referenced when it has a caption and the output format is from **bookdown**.

10.1.5 Format numeric columns

You can set the maximum number of decimal places via the `digits` argument (which will be passed to the `round()` function), and other formatting arguments via `format.args` (to be

表10.1: An example table caption.

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

passed to the `format()` function in base R). First we show a few simple examples of `round()` and `format()` so you will understand how the arguments work later in `kable()`:

```r
round(1.234567, 0)
## [1] 1
```

```r
round(1.234567, digits = 1)
## [1] 1.2
```

```r
round(1.234567, digits = 3)
## [1] 1.235
```

```r
format(1000, scientific = TRUE)
## [1] "1e+03"
```

```r
format(10000.123, big.mark = ",")
## [1] "10,000"
```

Then we round and format numbers in a table:

```r
d <- cbind(X1 = runif(3), X2 = 10^c(3, 5, 7), X3 = rnorm(3,
  0, 1000))
```

```r
# at most 4 decimal places
knitr::kable(d, digits = 4)
```

X1	X2	X3
0.8827	1e+03	-479.4422
0.7700	1e+05	284.2424
0.7413	1e+07	-367.3443

```r
# round columns separately
knitr::kable(d, digits = c(5, 0, 2))
```

X1	X2	X3
0.88271	1e+03	-479.44
0.77000	1e+05	284.24
0.74128	1e+07	-367.34

```r
# do not use the scientific notation
knitr::kable(d, digits = 3, format.args = list(scientific = FALSE))
```

X1	X2	X3
0.883	1000	-479.442
0.770	100000	284.242
0.741	10000000	-367.344

```r
# add commas to big numbers
knitr::kable(d, digits = 3, format.args = list(big.mark = ",",
  scientific = FALSE))
```

X1	X2	X3
0.883	1,000	-479.442
0.770	100,000	284.242
0.741	10,000,000	-367.344

10.1.6 Display missing values

By default, missing values (i.e., `NA`) are displayed as the character string `NA` in the table. You can replace them with other values or choose not to display anything (i.e., leave the `NA` cells empty) with the global R option `knitr.kable.NA`, e.g., we make `NA` cells empty in the second table and display `**` in the third table below:

```r
d[rbind(c(1, 1), c(2, 3), c(3, 2))] <- NA
knitr::kable(d)  # NA is displayed by default
```

X1	X2	X3
NA	1e+03	-479.4
0.7700	1e+05	NA
0.7413	NA	-367.3

```r
# replace NA with empty strings
opts <- options(knitr.kable.NA = "")
knitr::kable(d)
```

X1	X2	X3
	1e+03	-479.4
0.7700	1e+05	
0.7413		-367.3

```r
options(knitr.kable.NA = "**")
knitr::kable(d)
```

X1	X2	X3
**	1e+03	-479.4
0.7700	1e+05	**
0.7413	**	-367.3

```r
options(opts)  # restore global R options
```

10.1.7 Escape special characters

If you are familiar with HTML or LaTeX, you know that there are a few special characters in these languages. To generate safe output, `kable()` will escape these special characters by default via the argument `escape = TRUE`, which means all characters will be generated verbatim, and special characters lose their special meanings. For example, > will be substituted with `>` for HTML tables, and _ will be escaped as `\_` for LaTeX tables. If you are an expert and know how to use special characters properly, you may disable this argument via `escape = FALSE`. In the second table below, we include a few LaTeX math expressions that contain special characters `$`, `\`, and `_`:

```r
m <- lm(dist ~ speed, data = cars)
d <- coef(summary(m))
knitr::kable(d)
```

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-17.579	6.7584	-2.601	0.0123
speed	3.932	0.4155	9.464	0.0000

```r
# add a few math expressions to row and column names
rownames(d) <- c("$\\beta_0$", "$\\beta_1$")
colnames(d)[4] <- "$P(T > |t|)$"
knitr::kable(d, escape = FALSE)
```

	Estimate	Std. Error	t value	$P(T > \|t\|)$
β_0	-17.579	6.7584	-2.601	0.0123
β_1	3.932	0.4155	9.464	0.0000

Without `escape = FALSE`, special characters will either be escaped or substituted. For example, `$` is escaped as `\$`, `_` is escaped as `\_`, and `\` is substituted with `\textbackslash{}`:

```r
knitr::kable(d, format = "latex", escape = TRUE)
```

```latex
\begin{tabular}{l|r|r|r|r}
\hline
```

```
  & Estimate & Std. Error & t value & \$P(T > |t|)\$\\
\hline
\$\textbackslash{}beta\_0\$ & -17.579 & 6.7584 & -2.601 & 0.0123\\
\hline
\$\textbackslash{}beta\_1\$ & 3.932 & 0.4155 & 9.464 & 0.0000\\
\hline
\end{tabular}
```

Other common special LaTeX characters include `#`, `%`, `&`, `{`, and `}`. Common special HTML characters include `&`, `<`, `>`, and `"`. You need to be cautious when generating tables with `escape = FALSE`, and make sure you are using the special characters in the right way. It is a very common mistake to use `escape = FALSE` and include `%` or `_` in column names or the caption of a LaTeX table without realizing that they are special.

If you are not sure how to properly escape special characters, there are two internal helper functions in **knitr**. Below are some examples:

```r
knitr:::escape_latex(c("100%", "# a comment", "column_name"))
```

```
## [1] "100\\%"         "\\# a comment" "column\\_name"
```

```r
knitr:::escape_html(c("<address>", "x = \"character\"",
  "a & b"))
```

```
## [1] "&lt;address&gt;"
## [2] "x = &quot;character&quot;"
## [3] "a &amp; b"
```

10.1.8 Multiple tables side by side

You can pass a list of data frames or matrices to `kable()` to generate multiple tables side by side. For example, Table 10.2 contains two tables generated from the code below:

```r
d1 <- head(cars, 3)
d2 <- head(mtcars[, 1:3], 5)
```

表10.2: Two tables placed side by side.

speed	dist
4	2
4	10
7	4

	mpg	cyl	disp
Mazda RX4	21.0	6	160
Mazda RX4 Wag	21.0	6	160
Datsun 710	22.8	4	108
Hornet 4 Drive	21.4	6	258
Hornet Sportabout	18.7	8	360

```
knitr::kable(
  list(d1, d2),
  caption = 'Two tables placed side by side.',
  booktabs = TRUE, valign = 't'
)
```

Please note that this feature only works for HTML and PDF output.

If you want to be able to customize each table individually when placing them side by side, you may use the `kables()` function (the plural form of `kable()`), and pass a list of `kable()` objects to it. For example, we change the column names in the left table and set the number of decimal places to zero in the right table in Table 10.3:

```
# data objects d1 and d2 are from the previous code chunk
knitr::kables(
  list(
    # the first kable() to change column names
    knitr::kable(
      d1, col.names = c('SPEED', 'DISTANCE'), valign = 't'
    ),
    # the second kable() to set the digits option
    knitr::kable(d2, digits = 0, valign = 't')
  ),
  caption = 'Two tables created by knitr::kables().'
)
```

表**10.3:** Two tables created by knitr::kables().

SPEED	DISTANCE
4	2
4	10
7	4

	mpg	cyl	disp
Mazda RX4	21	6	160
Mazda RX4 Wag	21	6	160
Datsun 710	23	4	108
Hornet 4 Drive	21	6	258
Hornet Sportabout	19	8	360

10.1.9 Generate multiple tables from a `for`-loop (*)

One common confusion about `kable()` is that it does not work inside `for`-loops. This problem is not specific to `kable()` but exists in many other packages, too. The reason is a little complicated. In case you are interested in the technicality, it is explained in the blog post "The Ghost Printer behind Top-level R Expressions."[*1]

You may expect the following code chunk to generate three tables, but it will not:

````
```{r}
for (i in 1:3) {
  knitr::kable(head(iris))
}
```
````

You have to explicitly print the `kable()` results, and apply the chunk option `results = 'asis'`, e.g.,

````
```{r, results='asis'}
for (i in 1:3) {
  print(knitr::kable(head(iris)))
}
```
````

In general, when you generate output from a `for`-loop, we recommend that you add a few

[*1] https://yihui.org/en/2017/06/top-level-r-expressions/

line breaks (`\n`) or an HTML comment (`<!-- -->`) after each output element to clearly separate all output elements, e.g.,

````
```{r, results='asis'}
for (i in 1:3) {
  print(knitr::kable(head(iris), caption = 'A caption.'))
  cat('\n\n<!-- -->\n\n')
}
```
````

Without the separators, Pandoc may be fail to detect the individual elements. For example, when a plot is followed immediately by a table, the table will not be recognized:

```
![](logo.png)
                      mpg    cyl    disp    hp
------------------  -----  ----  -----  ----
Mazda RX4            21.0      6    160    110
Mazda RX4 Wag        21.0      6    160    110
```

But it will be if there is a clear separation like this (note that we added an empty line below the image):

```
![](logo.png)

                     mpg   cyl   disp    hp
------------------  -----  ----  -----  ----
Mazda RX4            21.0      6    160    110
Mazda RX4 Wag        21.0      6    160    110
```

or

```
![](logo.png)

<!-- -->
```

```
                     mpg   cyl   disp    hp
-----------------  -----  ----  -----  ----
Mazda RX4           21.0     6    160   110
Mazda RX4 Wag       21.0     6    160   110
```

10.1.10 Customize LaTeX tables (*)

If the only output format you need is LaTeX, there are a few extra options you can use in `kable()`. Note that these options will be ignored in other types of output such as HTML. Unless you have set the table format option globally (see Section 10.1.1), you will have to use the `format` argument of `kable()` explicitly in the examples of this section, e.g.,

```
knitr::kable(iris2, format = "latex", booktabs = TRUE)
```

When you assign a caption to a table (see Section 10.1.4), `kable()` will use the `table` environment to include the table, i.e.,

```
\begin{table}
% the table body (usually the tabular environment)
\end{table}
```

You can change this environment via the `table.envir` argument, e.g.,

```
knitr::kable(cars[1:2, ], format = "latex", table.envir = "figure")
```

```
\begin{figure}
\begin{tabular}{r|r}
\hline
speed & dist\\
\hline
4 & 2\\
\hline
4 & 10\\
```

```
\hline
\end{tabular}
\end{figure}
```

The floating position of the table is controlled by the argument `position`. For example, we can try to force a table to float to the bottom of a page via `position = "!b"`:

```r
knitr::kable(cars[1:2, ], format = "latex", table.envir = "table",
  position = "!b")
```

```latex
\begin{table}[!b]
\begin{tabular}{r|r}
\hline
speed & dist\\
\hline
4 & 2\\
\hline
4 & 10\\
\hline
\end{tabular}
\end{table}
```

When a table has a caption, you can also assign a short caption to it via the `caption.short` argument, e.g.,

```r
knitr::kable(iris2, caption = "A long long long caption!",
  caption.short = "A short one.")
```

The short caption goes into the square brackets of the `\caption[]{}` command in LaTeX, and is often used in the List of Tables of the PDF output document (if the short caption is not provided, the full caption is displayed there).

If you are familiar with the LaTeX package **booktabs**[*2] for publication-quality tables, you

---

[*2] https://ctan.org/pkg/booktabs

can set `booktabs = TRUE`, e.g.,

```r
iris3 <- head(iris, 10)
knitr::kable(iris3, format = "latex", booktabs = TRUE)
```

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
4.6	3.4	1.4	0.3	setosa
5.0	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
4.9	3.1	1.5	0.1	setosa

Please note that when you need additional LaTeX packages such as **booktabs** for an R Markdown document, you have to declare these packages in YAML (see Section 6.4 for how).

Depending on whether the argument `booktabs` is `TRUE` or `FALSE` (default), the table appearance is different. For `booktabs = FALSE`:

- Table columns are separated by vertical lines. You can explicitly remove the vertical lines via the `vline` argument, e.g., `knitr::kable(iris, vline = "")` (the default is `vline = "|"`). You can set this option as a global R option so you do not need to set it for every single table, e.g., `options(knitr.table.vline = "")`.

- The horizontal lines can be defined via arguments `toprule`, `midrule`, `linesep`, and `bottomrule`. Their default values are all `\hline`.

For `booktabs = TRUE`:

- There are no vertical lines in the table, but you can add these lines via the `vline` argument.

- The table only has horizontal lines for the table header and the bottom row. The default argument values are `toprule = "\\toprule"`, `midrule = "\\midrule"`, and bottomrule = "\\bottomrule". A line space is added to every five rows by default. This is controlled by the argument linesep, which defaults to c("", "", "", "", "\\addlinespace"). If you want to add a space to every three rows, you can do this:

```
knitr::kable(iris3, format = "latex", linesep = c("", "",
  "\\addlinespace"), booktabs = TRUE)
```

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
4.6	3.4	1.4	0.3	setosa
5.0	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
4.9	3.1	1.5	0.1	setosa

If you want to remove the line spaces altogether, you may use linesep = ''.

Sometimes your table may be longer than a page. In this case, you can use the argument longtable = TRUE, which uses the LaTeX package **longtable**[*3] to span your table to multiple pages.

Tables are center-aligned by default when they are included in a table environment (i.e., when the table has a caption). If you do not want to center a table, use the argument centering = FALSE.

10.1.11 Customize HTML tables (*)

If you want to customize tables generated via knitr::kable(format = "html"), there is only one extra argument besides the common arguments mentioned in previous sections: table.attr. This argument allows you to add arbitrary attributes to the <table> tag. For example:

[*3] https://ctan.org/pkg/longtable

```r
knitr::kable(mtcars[1:2, 1:2], table.attr = "class=\"striped\"",
  format = "html")
```

```html
<table class="striped">
 <thead>
  <tr>
   <th style="text-align:left;">   </th>
   <th style="text-align:right;"> mpg </th>
   <th style="text-align:right;"> cyl </th>
  </tr>
 </thead>
<tbody>
  <tr>
   <td style="text-align:left;"> Mazda RX4 </td>
   <td style="text-align:right;"> 21 </td>
   <td style="text-align:right;"> 6 </td>
  </tr>
  <tr>
   <td style="text-align:left;"> Mazda RX4 Wag </td>
   <td style="text-align:right;"> 21 </td>
   <td style="text-align:right;"> 6 </td>
  </tr>
</tbody>
</table>
```

We added a class `striped` to the table. However, a class name is not enough to change the appearance of a table. You have to define CSS rules for the class. For example, to make a striped table that has different colors for odd and even rows, you can add a light gray background to even or odd rows:

```css
.striped tr:nth-child(even) { background: #eee; }
```

The above CSS rule means all rows (i.e., the `<tr>` tags) with even row numbers (`:nth-child(even)`) that are children of an element with the `striped` class will have a background

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

図10.1: A striped table created with HTML and CSS.

color #eee.

A little bit of CSS can make a plain HTML table look decent. Figure 10.1 is a screenshot of an HTML table to which the following CSS rules are applied:

```
table {
  margin: auto;
  border-top: 1px solid #666;
  border-bottom: 1px solid #666;
}
table thead th { border-bottom: 1px solid #ddd; }
th, td { padding: 5px; }
thead, tfoot, tr:nth-child(even) { background: #eee; }
```

10.2 The **kableExtra** package

The **kableExtra** package (Zhu, 2020) is designed to extend the basic functionality of tables produced using `knitr::kable()` (see Section 10.1). Since `knitr::kable()` is simple by design (please feel free to read this as "Yihui is lazy"), it definitely has a lot of missing features that are commonly seen in other packages, and **kableExtra** has filled the gap perfectly. The most amazing thing about **kableExtra** is that most of its table features work for both HTML and PDF formats (e.g., making striped tables like the one in Figure 10.1).

This package can be installed from CRAN as usual, or you may try the development version on GitHub (https://github.com/haozhu233/kableExtra):

```r
# install from CRAN
install.packages("kableExtra")

# install the development version
remotes::install_github("haozhu233/kableExtra")
```

It has extensive documentation at https://haozhu233.github.io/kableExtra/, which provides a lot of examples on how the `kable()` output can be customized for either HTML or LaTeX output. We recommend that you read its documentation by yourself, and will only present a handful of examples in this section.

The **kableExtra** package features the pipe operator, `%>%`. You can pipe the `kable()` output to the styling functions of **kableExtra**, e.g.,

```r
library(knitr)
library(kableExtra)
kable(iris) %>%
  kable_styling(latex_options = "striped")
```

10.2.1 Set the font size

The function `kable_styling()` in **kableExtra** allows you to style the whole table. For example, you can specify the alignment of the table on the page, the width, and the font size of the table. Below is an example of using a smaller font size:

```r
kable(head(iris, 5), booktabs = TRUE) %>%
  kable_styling(font_size = 8)
```

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

10.2.2 Style specific rows/columns

The functions `row_spec()` and `column_spec()` can be used to style individual rows and columns, respectively. In the example below, we make the first row bold and italic, add a black background to the second and third rows while changing the font color to white, underline the fourth row and change its typeface, rotate the fifth row, and strike out the fifth column:

```
kable(head(iris, 5), align = 'c', booktabs = TRUE) %>%
  row_spec(1, bold = TRUE, italic = TRUE) %>%
  row_spec(2:3, color = 'white', background = 'black') %>%
  row_spec(4, underline = TRUE, monospace = TRUE) %>%
  row_spec(5, angle = 45) %>%
  column_spec(5, strikeout = TRUE)
```

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~~

Similarly, you can style individual cells with the `cell_spec()` function.

10.2.3 Group rows/columns

Rows and columns can be grouped via the functions `pack_rows()` and `add_header_above()`, respectively. You can also collapse rows via `collapse_rows()`, so one cell can span multiple rows. Below is an example that shows a custom table header with grouped columns:

```
iris2 <- iris[1:5, c(1, 3, 2, 4, 5)]
names(iris2) <- gsub('[.].+', '', names(iris2))
kable(iris2, booktabs = TRUE) %>%
  add_header_above(c("Length" = 2, "Width" = 2, " " = 1)) %>%
```

```r
  add_header_above(c("Measurements" = 4, "More attributes" = 1))
```

Measurements				More attributes
Length		Width		
Sepal	Petal	Sepal	Petal	Species
5.1	1.4	3.5	0.2	setosa
4.9	1.4	3.0	0.2	setosa
4.7	1.3	3.2	0.2	setosa
4.6	1.5	3.1	0.2	setosa
5.0	1.4	3.6	0.2	setosa

For the named vector in `add_header_above()`, the names are the text to be shown in the table header, and the integer values of the vector indicate how many columns a name should span, e.g., `"Length" = 2` means `Length` should span two columns.

Below is an example of `pack_rows()`. The meaning of its `index` argument is similar to the argument of `add_header_above()` as we just explained before.

```r
iris3 <- iris[c(1:2, 51:54, 101:103), ]
kable(iris3[, 1:4], booktabs = TRUE) %>% pack_rows(
  index = c("setosa" = 2, "versicolor" = 4, "virginica" = 3)
)
```

	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width
setosa				
1	5.1	3.5	1.4	0.2
2	4.9	3.0	1.4	0.2
versicolor				
51	7.0	3.2	4.7	1.4
52	6.4	3.2	4.5	1.5
53	6.9	3.1	4.9	1.5
54	5.5	2.3	4.0	1.3
virginica				
101	6.3	3.3	6.0	2.5
102	5.8	2.7	5.1	1.9
103	7.1	3.0	5.9	2.1

10.2.4 Scaling down wide tables in LaTeX

There are a few features that are specific to the HTML or LaTeX output format. For example, landscape pages only make sense in LaTeX, so the `landscape()` function in **kableExtra** only works for LaTeX output. Below we show an example to scale down a table to fit the page (otherwise it would be too wide):

```
tab <- kable(tail(mtcars, 5), booktabs = TRUE)
tab  # original table (too wide)
```

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Lotus Europa	30.4	4	95.1	113	3.77	1.513	16.9	1	1	5	2
Ford Pantera L	15.8	8	351.0	264	4.22	3.170	14.5	0	1	5	4
Ferrari Dino	19.7	6	145.0	175	3.62	2.770	15.5	0	1	5	6
Maserati Bora	15.0	8	301.0	335	3.54	3.570	14.6	0	1	5	8
Volvo 142E	21.4	4	121.0	109	4.11	2.780	18.6	1	1	4	2

```
tab %>%
  kable_styling(latex_options = "scale_down")
```

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Lotus Europa	30.4	4	95.1	113	3.77	1.513	16.9	1	1	5	2
Ford Pantera L	15.8	8	351.0	264	4.22	3.170	14.5	0	1	5	4
Ferrari Dino	19.7	6	145.0	175	3.62	2.770	15.5	0	1	5	6
Maserati Bora	15.0	8	301.0	335	3.54	3.570	14.6	0	1	5	8
Volvo 142E	21.4	4	121.0	109	4.11	2.780	18.6	1	1	4	2

You will not see any differences in the above two tables if you are viewing the HTML version.

10.3 Other packages for creating tables

There are many other R packages that can be used to generate tables. The main reason that I introduced `kable()` (Section 10.1) and **kableExtra** (Section 10.2) is not that they are better than other packages, but because I'm familiar with only them.[*4] Next I will list the packages that I'm aware of but not very familiar with. You can check them out by yourself, and decide which one fits your purpose best.

- **flextable** (Gohel, 2020) and **huxtable** (Hugh-Jones, 2020): If you are looking for a table package that supports the widest range of output formats, **flextable** and **huxtable** are probably the two best choices. They all support HTML, LaTeX, and Office formats, and contain most common table features (e.g., conditional formatting). More information about **flextable** can be found at https://davidgohel.github.io/flextable/, and the documentation of **huxtable** is at https://hughjonesd.github.io/huxtable/.

- **gt** (Richard Iannone Cheng, and Schloerke, 2020): Allows you to compose a table by putting together different parts of the table, such as the table header (title and subtitle), the column labels, the table body, row group labels, and the table footer. Some parts are optional. You can also format numbers and add background shading to cells. Currently **gt** mainly supports HTML output.[*5] You can find more information about it at https://gt.rstudio.com.

[*4] Frankly speaking, I rarely use tables by myself, so I'm not highly motivated to learn how to create sophisticated tables.

[*5] If you need the support for other output formats such as LaTeX and Word, the **gtsummary** package (Sjoberg Curry, et al., 2021) has made some extensions based on **gt** that look very promising: https://github.com/ddsjoberg/gtsummary.

- **formattable** (Ren and Russell, 2021): Provides some utility functions to format numbers (e.g., `percent()` and `accounting()`), and also functions to style table columns (e.g., format the text, annotate numbers with background shading or color bars, or add icons in cells). Like **gt**, this package also primarily supports the HTML format. You can find more information about it from its GitHub project at https://github.com/renkun-ken/formattable.

- **DT** (Xie Cheng, and Tan, 2021): As its author, I think I'm familiar with this package, but I did not introduce it in a separate section because it only supports the HTML format. **DT** is built on top of the JavaScript library **DataTables**, which can turn a static table into an interactive table on an HTML page. You may sort, search, and paginate the table. **DT** also supports formatting the cells, works with Shiny to build interactive applications, and has included a large number of **DataTables** extensions (e.g., you may export the table to Excel, or interactively reorder columns). See the package repository for more information: https://github.com/rstudio/DT.

- **reactable** (Lin, 2020): Similar to **DT**, this package also creates interactive tables based on a JavaScript library. Frankly speaking, it looks better than **DT** in several aspects in my eyes (such as row grouping and aggregation, and embedding HTML widgets). Had **reactable** existed in 2015, I would not have developed **DT**. That said, **reactable** does not contain all the features of **DT**, so you may read its documentation and see which one fits your purpose better: https://glin.github.io/reactable/.

- **rhandsontable** (Owen, 2018): Also similar to **DT**, and has an Excel feel (e.g., you can edit data directly in the table). Visit https://jrowen.github.io/rhandsontable/ to learn more about it.

- **pixiedust** (Nutter, 2020): Features creating tables for models (such as linear models) converted through the **broom** package (Robinson Hayes, and Couch, 2020). It supports Markdown, HTML, and LaTeX output formats. Its repository is at https://github.com/nutterb/pixiedust.

- **stargazer** (Hlavac, 2018): Features formatting regression models and summary statistics tables. The package is available on CRAN at https://cran.r-project.org/package=stargazer.

- **xtable** (Dahl Scott, et al., 2019): Perhaps the oldest package for creating tables—the first release was made in 2000. It supports both LaTeX and HTML formats. The package is available on CRAN at https://cran.r-project.org/package=xtable.

I'm not going to introduce the rest of packages, but will just list them here: **tables** (Murdoch, 2020), **pander** (Daróczi and Tsegelskyi, 2018), **tangram** (Garbett, 2020), **ztable** (Moon, 2020), and **condformat** (Oller Moreno, 2020).

第 11 章

Chunk Options

As illustrated in Figure 2.1, the R package **knitr** plays a critical role in R Markdown. In this chapter and the next three chapters, we show some recipes related to **knitr**.

There are more than 50 chunk options that can be used to fine-tune the behavior of **knitr** when processing R chunks. Please refer to the online documentation at `https://yihui.org/knitr/options/` for the full list of options. For your convenience, we have also provided a copy of the documentation in Appendix A of this book.

In the following sections, we only show examples of applying chunk options to individual code chunks. However, please be aware of the fact that any chunk options can also be applied globally to a whole document, so you do not have to repeat the options in every single code chunk. To set chunk options globally, call `knitr::opts_chunk$set()` in a code chunk (usually the first one in the document), e.g.,

````
```{r, include=FALSE}
knitr::opts_chunk$set(
  comment = "#>", echo = FALSE, fig.width = 6
)
```
````

11.1 Use variables in chunk options

Usually chunk options take constant values (e.g., `fig.width = 6`), but they can actually take values from arbitrary R expressions, no matter how simple or complicated the expressions are. A special case is a variable passed to a chunk option (note that a variable is also an R expression). For example, you can define a figure width in a variable in the beginning of a document, and use it later in other code chunks, so you will be able to easily change the width in the future:

````
```{r}
my_width <- 7
```

```{r, fig.width=my_width}
plot(cars)
```
````

Below is an example of using an `if-else` statement in a chunk option:

````
```{r}
fig_small <- FALSE  # change to TRUE for larger figures
width_small <- 4
width_large <- 8
```

```{r, fig.width=if (fig_small) width_small else width_large}
plot(cars)
```
````

And we have one more example below in which we evaluate (i.e., execute) a code chunk only if a required package is available:

````
```{r, eval=require('leaflet')}
library(leaflet)
leaflet() %>% addTiles()
```
````

In case you do not know it, `require('package')` returns `TRUE` if the package is available (and `FALSE` if not).

11.2 Do not stop on error

Sometimes you may want to show errors on purpose (e.g., in an R tutorial). By default, errors in the code chunks of an Rmd document will halt R. If you want to show the errors without stopping R, you may use the chunk option `error = TRUE`, e.g.,

````
```{r, error=TRUE}
1 + "a"
```
````

You will see the error message in the output document after you compile the Rmd document:

```
Error in 1 + "a":  二項演算子の引数が数値ではありません
```

In R Markdown, `error = FALSE` is the default, which means R should stop on error when running the code chunks.

11.3 Multiple graphical output formats for the same plot

In most cases, you may want one image format for one plot, such as `png` or `pdf`. The image format is controlled by the chunk option `dev` (i.e., the graphical device to render the plots). This option can take a vector of device names, e.g.,

````
```{r, dev=c('png', 'pdf', 'svg', 'tiff')}
plot(cars)
```
````

Only the first format is used in the output document, but the images corresponding to the rest of formats are also generated. This can be useful when you are required to submit figures of different formats additionally (e.g., you have shown a `png` figure in the report but the `tiff` format of the same figure is also required).

Note that by default, plot files are typically deleted after the output document is rendered. To preserve these files, please see Section 16.5.

11.4 Cache time-consuming code chunks

When a code chunk is time-consuming to run, you may consider caching it via the chunk option `cache = TRUE`. When the cache is turned on, **knitr** will skip the execution of this code chunk if it has been executed before and nothing in the code chunk has changed since then. When you modify the code chunk (e.g., revise the code or the chunk options), the previous cache will be automatically invalidated, and **knitr** will cache the chunk again.

For a cached code chunk, its output and objects will be automatically loaded from the previous run, as if the chunk were executed again. Caching is often helpful when loading results is much faster than computing the results. However, there is no free lunch. Depending on your use case, you may need to learn more about how caching (especially cache invalidation[*1]) works, so you can take full advantage of it without confusing yourself as to why sometimes **knitr** invalidates your cache too often and sometimes there is not enough invalidation.

The most appropriate use case of caching is to save and reload R objects that take too long to compute in a code chunk, and the code does not have any side effects, such as changing global R options via `options()` (such changes will not be cached). If a code chunk has side effects, we recommend that you do not cache it.

As we briefly mentioned earlier, the cache depends on chunk options. If you change any chunk options (except the option `include`), the cache will be invalidated. This feature can be used to solve a common problem. That is, when you read an external data file, you may want to invalidate the cache when the data file is updated. Simply using `cache = TRUE` is not enough:

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

You have to let **knitr** know if the data file has been changed. One way to do it is to add another chunk option `cache.extra = file.mtime('my-precious.csv')` or more rigorously, `cache.extra = tools::md5sum('my-precious.csv')`. The former means if the modification time of the file has been changed, we need to invalidate the cache. The latter means if

[*1] https://yihui.org/en/2018/06/cache-invalidation/

the content of the file has been modified, we update the cache. Note that `cache.extra` is not a built-in **knitr** chunk option. You can use any other name for this option, as long as it does not conflict with built-in option names.

Similarly, you can associate the cache with other information such as the R version (`cache.extra = getRversion()`), the date (`cache.extra = Sys.Date()`), or your operating system (`cache.extra = Sys.info()[['sysname']]`), so the cache can be properly invalidated when these conditions change.

We do not recommend that you set the chunk option `cache = TRUE` globally in a document. Caching can be fairly tricky. Instead, we recommend that you enable caching only on individual code chunks that are surely time-consuming and do not have side effects.

If you are not happy with **knitr**'s design for caching, you can certainly cache objects by yourself. Below is a quick example:

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

In this case, the only (and also simple) way to invalidate the cache is to delete the file `results.rds`. If you like this simple caching mechanism, you may use the function `xfun::cache_rds()` introduced in Section 14.9.

11.5 Cache a code chunk for multiple output formats

When caching is turned on via the chunk option `cache = TRUE`, **knitr** will write R objects generated in a code chunk to a cache database, so they can be reloaded the next time. The path to the cache database is determined by the chunk option `cache.path`. By default, R Markdown uses different cache paths for different output formats, which means a time-consuming code chunk will be fully executed for each output format. This may be inconvenient, but there is a reason for this default behavior: the output of a code chunk can be dependent on the specific output format. For example, when you generate a plot, the output for the plot could be Markdown code like `![text](path/to/image.png)` when the output format is word_document, or HTML code like when the output format is html_document.

When a code chunk does not have any side effects (such as plots), it is safe to use the same cache database for all output formats, which can save you time. For example, when you read a large data object or run a time-consuming model, the result does not depend on the output format, so you can use the same cache database. You can specify the path to the database via the chunk option cache.path on a code chunk, e.g.,

````
```{r important-computing, cache=TRUE, cache.path="cache/"}
```
````

By default, cache.path = "INPUT_cache/FORMAT/" in R Markdown, where INPUT is the input filename, and FORMAT is the output format name (e.g., html, latex, or docx).

11.6 Cache large objects

When the chunk option cache = TRUE, cached objects will be lazy-loaded into the R session, which means an object will not be read from the cache database until it is actually used in the code. This can save you some memory when not all objects are used later in the document. For example, if you read a large data object but only use a subset in the subsequent analysis, the original data object will not be loaded from the cache database:

````
```{r, read-data, cache=TRUE}
full <- read.csv("HUGE.csv")
rows <- subset(full, price > 100)
# next we only use `rows`
```

```{r}
plot(rows)
```
````

However, when an object is too large, you may run into an error like this:

```
Error in lazyLoadDBinsertVariable(vars[i], ...
  long vectors not supported yet: ...
Execution halted
```

If this problem occurs, you can try to turn off the lazy-loading via the chunk option `cache.lazy = FALSE`. All objects in this chunk will be immediately loaded into memory.

11.7 Hide code, text output, messages, or plots

By default, **knitr** displays all possible output from a code chunk, including the source code, text output, messages, warnings, and plots. You can hide them individually using the corresponding chunk options.

````
Hide source code:

```{r, echo=FALSE}
1 + 1
```

Hide text output (you can also use `results = FALSE`):

```{r, results='hide'}
print("You will not see the text output.")
```

Hide messages:

```{r, message=FALSE}
message("You will not see the message.")
```

Hide warning messages:

```{r, warning=FALSE}
# this will generate a warning but it will be suppressed
````
````

```
1:2 + 1:3
```

Hide plots:

```{r, fig.show='hide'}
plot(cars)
```

Note that the plot will be generated in the above chunk. It is
just not displayed in the output.
```

One frequently asked question about **knitr** is how to hide package loading messages. For example, when you `library(tidyverse)` or `library(ggplot2)`, you may see some loading messages. Such messages can also be suppressed by the chunk option `message = FALSE`.

You can also selectively show or hide these elements by indexing them. In the following example, we only show the fourth and fifth expressions of the R source code (note that a comment counts as one expression), the first two messages, and the second and third warnings:

````
```{r, echo=c(4, 5), message=c(1, 2), warning=2:3}
# one way to generate random N(0, 1) numbers
x <- qnorm(runif(10))
# but we can just use rnorm() in practice
x <- rnorm(10)
x

for (i in 1:5) message('Here is the message ', i)

for (i in 1:5) warning('Here is the warning ', i)
```
````

You can use negative indices, too. For example, `echo = -2` means to exclude the second expression of the source code in the output.
````

Similarly, you can choose which plots to show or hide by using indices for the `fig.keep` option. For example, `fig.keep = 1:2` means to keep the first two plots. There are a few shortcuts for this option: `fig.keep = "first"` will only keep the first plot, `fig.keep = "last"` only keeps the last plot, and `fig.keep = "none"` discards all plots. Note that the two options `fig.keep = "none"` and `fig.show = "hide"` are different: the latter will generate plots but only hide them, and the former will not generate plot files at all.

For source code blocks in the `html_document` output, if you do not want to completely omit them (`echo = FALSE`), you may see Section 7.5 for how to fold them on the page, and allow users to unfold them by clicking the unfolding buttons.

11.8 Hide everything from a chunk

Sometimes we may want to execute a code chunk without showing any output at all. Instead of using separate options mentioned in Section 11.7, we can suppress the entire output of the code chunk using a single option `include = FALSE`, e.g.,

````
```{r, include=FALSE}
# any R code here
```
````

With `include=FALSE`, the code chunk will be evaluated (unless `eval=FALSE`), but the output will be completely suppressed—you will not see any code, text output, messages, or plots.

11.9 Collapse text output blocks into source blocks

If you feel there is too much spacing between text output blocks and source code blocks in the output, you may consider collapsing the text output into the source blocks with the chunk option `collapse = TRUE`. This is what the output looks like when `collapse = TRUE`:

```
1 + 1
## [1] 2
```

```
1:10
##  [1]  1  2  3  4  5  6  7  8  9 10
```

Below is the same chunk but it does not have the option `collapse = TRUE` (the default is `FALSE`):

```r
1 + 1
```

```
## [1] 2
```

```r
1:10
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10
```

11.10 Reformat R source code

When you set the chunk option `tidy = TRUE`, the R source code will be reformatted by the `tidy_source()` function in the **formatR** package (Xie, 2019a). The `tidy_source()` can reformat the code in several aspects, such as adding spaces around most operators, indenting the code properly, and replacing the assignment operator `=` with `<-`. The chunk option `tidy.opts` can be a list of arguments to be passed to `formatR::tidy_source()`, e.g.,

````
```{r, tidy=TRUE, tidy.opts=list(arrow=TRUE, indent=2)}
# messy R code...
1+            1
x=1:10#some users prefer '<-' as the assignment operator
if(TRUE){
print('Hello world!') # indent by 2 spaces
}
```
````

The output:

```r
# messy R code...
1 + 1
x <- 1:10  #some users prefer '<-' as the assignment operator
```

```r
if (TRUE) {
  print("Hello world!")  # indent by 2 spaces
}
```

In Section 5.3, we mentioned how to control the width of text output. If you want to control the width of the source code, you may try the `width.cutoff` argument when `tidy = TRUE`, e.g.,

````
```{r, tidy=TRUE, tidy.opts=list(width.cutoff=50)}
# a long expression
1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1+1
```
````

The output:

```r
# a long expression
1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 +
  1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 +
  1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 +
  1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1
```

Please read the help page `?formatR::tidy_source` to know the possible arguments, and also see `https://yihui.org/formatR/` for examples and limitations of this function.

Alternatively, you may use the **styler** package (Müller and Walthert, 2020) to reformat your R code if you set the chunk option `tidy = 'styler'`. The R code will be formatted with the function `styler::style_text()`. The **styler** package has richer features than **formatR**. For example, it can align function arguments and works with the pipe operator `%>%`. The chunk option `tidy.opts` can also be used to pass additional arguments to `styler::style_text()`, e.g.,

````
```{r, tidy='styler', tidy.opts=list(strict=FALSE)}
# align the assignment operators
a   <- 1#one variable
````
````

````
abc <- 2#another variable
```
````

By default, `tidy = FALSE` and your R code will not be reformatted.

11.11 Output text as raw Markdown content (*)

By default, text output from code chunks will be written out verbatim with two leading hashes (see Section 11.12). The text is verbatim because **knitr** puts it in fenced code blocks. For example, the raw output of the code `1:5` from **knitr** is:

````
```

## [1] 1 2 3 4 5
```
````

Sometimes you may not want verbatim text output, but treat text output as Markdown content instead. For example, you may want to write out a section header with `cat('# This is a header')`, but the raw output is:

````
```

## # This is a header
```
````

You do not want the text to be in a fenced code block (or the leading hashes). That is, you want the raw output to be exactly the character string passed to `cat()`:

```
# This is a header
```

The solution to this problem is the chunk option `results = 'asis'`. This option tells **knitr** not to wrap your text output in verbatim code blocks, but treat it "as is." This can be particularly useful when you want to generate content dynamically from R code. For example, you may generate the list of column names of the `iris` data from the following code chunk with the option `results = 'asis'`:
```

```r
cat(paste0("- `", names(iris), "`"), sep = "\n")
```

- Sepal.Length
- Sepal.Width
- Petal.Length
- Petal.Width
- Species

The hyphen (`-`) is the syntax for unordered lists in Markdown. The backticks are optional. You can see the verbatim output of the above chunk without the `results = 'asis'` option:

```r
cat(paste0("- `", names(iris), "`"), sep = "\n")
```

```
- `Sepal.Length`
- `Sepal.Width`
- `Petal.Length`
- `Petal.Width`
- `Species`
```

Below is a full example that shows how you can generate section headers, paragraphs, and plots in a `for`-loop for all columns of the `mtcars` data:

````
---
title: Generate content programmatically
---

With the chunk option `results = 'asis'`, you can
write out text as raw Markdown content, which can
also be mixed with plots.

```{r, mtcars-plots, results='asis'}
for (i in names(mtcars)) {
  cat('\n\n# Summary of the variable `', i, '`\n\n')
  x <- mtcars[, i]
  if (length(unique(x)) <= 6) {
    cat('`', i, '` is a categorical variable.\n\n')
````
````

````
    plot(table(x), xlab = i, ylab = 'Frequency', lwd = 10)
  } else {
    cat('Histogram for the continuous variable `', i, '`.\n\n')
    hist(x, xlab = i, main = '')
  }
}
```
````

Please note that we added line breaks (\n) excessively in the code. That is because we want different elements to be separated clearly in the Markdown content. It is harmless to use an excessive number of line breaks between different elements, whereas it can be problematic if there are not enough line breaks. For example, there is much ambiguity in the Markdown text below:

```
# Is this a header?
Is this a paragraph or a part of the header?
![How about this image?](foo.png)
# How about this line?
```

With more empty lines (which could be generated by `cat('\n')`), the ambiguity will be gone:

```
# Yes, a header!

And definitely a paragraph.

![An image here.](foo.png)

# Absolutely another header
```

The `cat()` function is not the only function that can generate text output. Another commonly used function is `print()`. Please note that `print()` is often *implicitly* called to print objects, which is why you see output after typing out an object or value in the R console. For example, when you type `1:5` in the R console and hit the `Enter` key, you see the output because R actually called `print(1:5)` implicitly. This can be highly confusing when you
```

fail to generate output inside an expression (such as a `for`-loop) with objects or values that would otherwise be correctly printed if they were typed in the R console. This topic is quite technical, and I have written the blog post “The Ghost Printer behind Top-level R Expressions”[*2] to explain it. If you are not interested in the technical details, just remember this rule: if you do not see output from a `for`-loop, you should probably print objects explicitly with the `print()` function.

11.12 Remove leading hashes in text output

By default, R code output will have two hashes `##` inserted in front of the text output. We can alter this behavior through the `comment` chunk option, which defaults to a character string `"##"`. We can use an empty string if we want to remove the hashes. For example:

````
```{r, comment=""}
1:100
```
````

Of course, you can use any other character values, e.g., `comment = "#>"`. Why does the `comment` option default to hashes? That is because `#` indicates comments in R. When the text output is commented out, it will be easier for you to copy all the code from a code chunk in a report and run it by yourself, without worrying about the fact that text output is not R code. For example, in the code chunk below, you can copy all four lines of text and run them safely as R code:

```r
1 + 1
## [1] 2
```

```r
2 + 2
## [1] 4
```

If you remove the hashes via `comment = ""`, it will not be easy for you to run all the code, because if you copy the four lines, you will have to manually remove the second and fourth lines:

[*2] https://yihui.org/en/2017/06/top-level-r-expressions/

```
1 + 1
[1] 2
```

```
2 + 2
[1] 4
```

One argument in favor of `comment = ""` is that it makes the text output look familiar to R console users. In the R console, you do not see hashes in the beginning of lines of text output. If you want to truly mimic the behavior of the R console, you can actually use `comment = ""` in conjunction with `prompt = TRUE`, e.g.,

````
```{r, comment="", prompt=TRUE}
1 + 1
if (TRUE) {
  2 + 2
}
```
````

The output should look fairly familiar to you if you have ever typed and run code in the R console, since the source code contains the prompt character > and the continuation character +:

```
> 1 + 1
[1] 2
```

```
> if (TRUE) {
+   2 + 2
+ }
[1] 4
```

11.13 Add attributes to text output blocks (*)

In Section 7.3, we showed some examples of styling source and text output blocks based on the chunk options `class.source` and `class.output`. Actually, there is a wider range of similar options in **knitr**, such as `class.message`, `class.warning`, and `class.error`. These options can be used to add class names to the corresponding text output blocks, e.g., `class.error` adds classes to error messages when the chunk option `error = TRUE` (see Section 11.2). The most common application of these options may be styling the output blocks with CSS rules defined according to the class names, as demonstrated by the examples in Section 7.3.

Typically, a text output block is essentially a fenced code block, and its Markdown source looks like this:

````
```{.className}
lines of output
```
````

When the output format is HTML, it is usually[*3] converted to:

```html
<pre class="className">
<code>lines of output</code>
</pre>
```

The `class.*` options control the `class` attribute of the `<pre>` element, which is the container of the text output blocks that we mentioned above.

In fact, the class is only one of the possible attributes of the `<pre>` element in HTML. An HTML element may have many other attributes, such as the width, height, and style, etc. The chunk options `attr.*`, including `attr.source`, `attr.output`, `attr.message`, `attr.warning`, and `attr.error`, allow you to add arbitrary attributes to the text output blocks. For example, with `attr.source = 'style="background: pink;"'`, you may change the background color of source blocks to pink. The corresponding fenced code block will be:

[*3] It could also be converted to `<div class="className"></div>`. You may view the source of the HTML output document to make sure.

````
```{style="background: pink;"}
...
```
````

And the HTML output will be:

```html
<pre style="background: pink;">
...
</pre>
```

You can find more examples in Section 5.7 and Section 12.3.

As a technical note, the chunk options `class.*` are just special cases of `attr.*`, e.g., `class.source = 'numberLines'` is equivalent to `attr.source = '.numberLines'` (note the leading dot here), but `attr.source` can take arbitrary attribute values, e.g., `attr.source = c('.numberLines', 'startFrom="11"')`.

These options are mostly useful to HTML output. There are cases in which the attributes may be useful to other output formats, but these cases are relatively rare. The attributes need to be supported by either Pandoc (such as the `.numberLines` attribute, which works for both HTML and LaTeX output), or a third-party package (usually via a Lua filter, as introduced in Section 4.20).

11.14 Post-process plots (*)

After a plot is generated from a code chunk, you can post-process the plot file via the chunk option `fig.process`, which should be a function that takes the file path as the input argument and returns a path to the processed plot file. This function can have an optional second argument `options`, which is a list of the current chunk options.

Below we show an example of adding an R logo to a plot using the extremely powerful **magick** package (Ooms, 2020). If you are not familiar with this package, we recommend that you read its online documentation or package vignette, which contains lots of examples. First, we define a function `add_logo()`:

```r
add_logo <- function(path, options) {
  # the plot created from the code chunk
  img <- magick::image_read(path)
  # the R logo
  logo <- file.path(R.home("doc"), "html", "logo.jpg")
  logo <- magick::image_read(logo)
  # the default gravity is northwest, and users can change
  # it via the chunk option magick.gravity
  if (is.null(g <- options$magick.gravity))
    g <- "northwest"
  # add the logo to the plot
  img <- magick::image_composite(img, logo, gravity = g)
  # write out the new image
  magick::image_write(img, path)
  path
}
```

Basically the function takes the path of an R plot, adds an R logo to it, and saves the new plot to the original path. By default, the logo is added to the upper-left corner (northwest) of the plot, but users can customize the location via the custom chunk option `magick.gravity` (this option name can be arbitrary).

Now we apply the above processing function to the code chunk below with chunk options `fig.process = add_logo` and `magick.gravity = "northeast"`, so the logo is added to the upper-right corner. See Figure 11.1 for the actual output.

```r
par(mar = c(4, 4, 0.1, 0.1))
hist(faithful$eruptions, breaks = 30, main = "", col = "gray",
  border = "white")
```

After you get more familiar with the **magick** package, you may come up with more creative and useful ideas to post-process your R plots.

Finally, we show one more application of the `fig.process` option. The `pdf2png()` function below converts a PDF image to PNG. In Section 11.15, we have an example of using the `tikz` graphical device to generate plots. The problem is that this device generates PDF

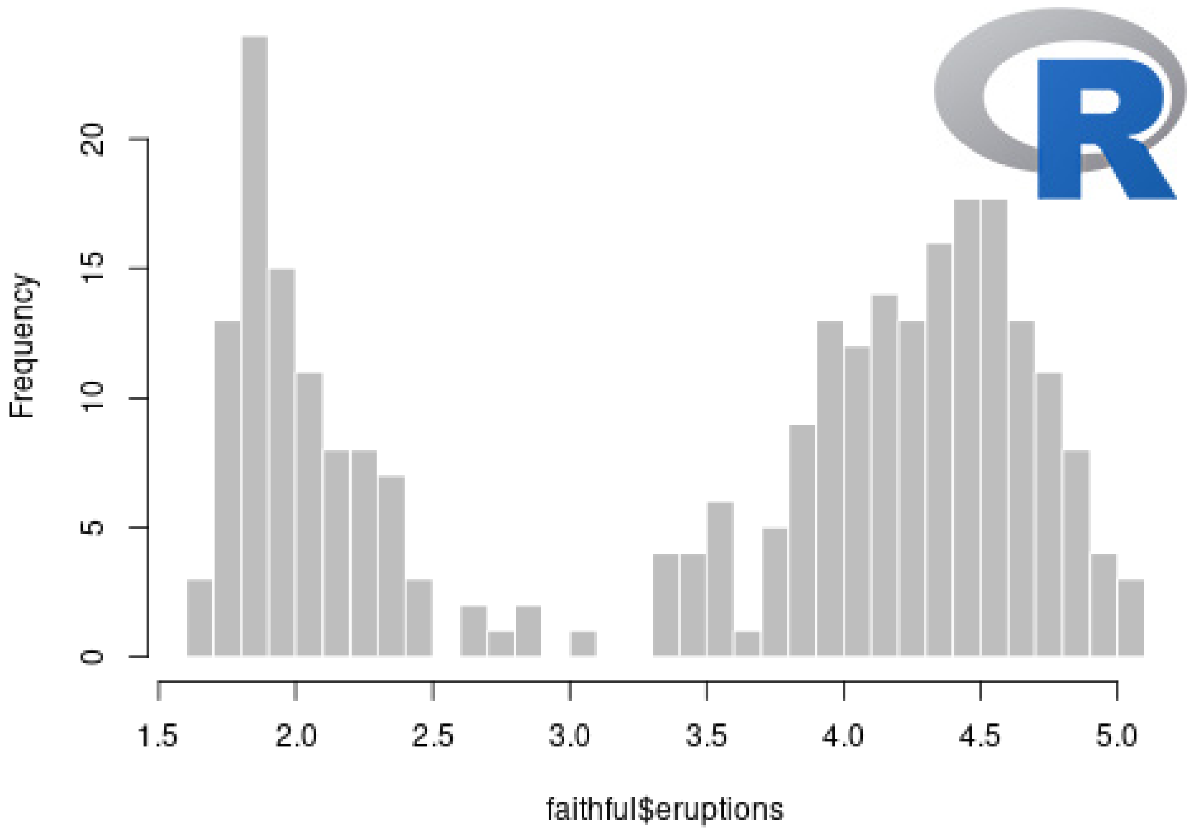


図11.1: Add the R logo to a plot via the chunk option fig.process.

plots, which will not work for non-LaTeX output documents. With the chunk options `dev = "tikz"` and `fig.process = pdf2png`, we can show the PNG version of the plot in Figure 11.2.

```
pdf2png <- function(path) {
  # only do the conversion for non-LaTeX output
  if (knitr::is_latex_output())
    return(path)
  path2 <- xfun::with_ext(path, "png")
  img <- magick::image_read_pdf(path)
  magick::image_write(img, path2, format = "png")
  path2
}
```

11.15 High-quality graphics (*)

The **rmarkdown** package has set reasonable default graphical devices for different output formats. For example, HTML output formats use the `png()` device, so **knitr** will generate PNG plot files, and PDF output formats use the `pdf()` device, etc. If you are not satisfied with the quality of the default graphical devices, you can change them via the chunk option `dev`. All possible devices supported by **knitr** are: `"bmp"`, `"postscript"`, `"pdf"`, `"png"`, `"svg"`, `"jpeg"`, `"pictex"`, `"tiff"`, `"win.metafile"`, `"cairo_pdf"`, `"cairo_ps"`, `"quartz_pdf"`, `"quartz_png"`, `"quartz_jpeg"`, `"quartz_tiff"`, `"quartz_gif"`, `"quartz_psd"`, `"quartz_bmp"`, `"CairoJPEG"`, `"CairoPNG"`, `"CairoPS"`, `"CairoPDF"`, `"CairoSVG"`, `"CairoTIFF"`, `"Cairo_pdf"`, `"Cairo_png"`, `"Cairo_ps"`, `"Cairo_svg"`, `"svglite"`, `"ragg_png"`, and `"tikz"`.

Usually, a graphical device name is also a function name. If you want to know more about a device, you can read the R help page. For example, you can type `?svg` in the R console to know the details about the `svg` device, which is included in base R. Note that the `quartz_XXX` devices are based on the `quartz()` function, and they are only available on macOS. The `CairoXXX` devices are from the add-on R package **Cairo** (Urbanek and Horner, 2020), the `Cairo_XXX` devices are from the **cairoDevice** package (Lawrence, 2020), the `svglite` device is from the **svglite** package (Wickham Henry, et al., 2020), and `tikz` is a device in the **tikzDevice** package (Sharpsteen and Bracken, 2020). If you want to use devices from an add-on package, you have to install the package first.

Usually, vector graphics have higher quality than raster graphics, and you can scale vector graphics without loss of quality. For HTML output, you may consider using `dev = "svg"` or `dev = "svglite"` for SVG plots. Note that SVG is a vector graphics format, and the default `png` device produces a raster graphics format.

For PDF output, if you are really picky about the typeface in your plots, you may use `dev = "tikz"`, because it offers native support for LaTeX, which means all elements in a plot, including text and symbols, are rendered in high quality through LaTeX. Figure 11.2 shows an example of writing LaTeX math expressions in an R plot rendered with the chunk option `dev = "tikz"`.

```r
par(mar = c(4, 4, 2, .1))
curve(dnorm, -3, 3, xlab = '$x$', ylab = '$\\phi(x)$',
      main = 'The density function of $N(0, 1)$')
```

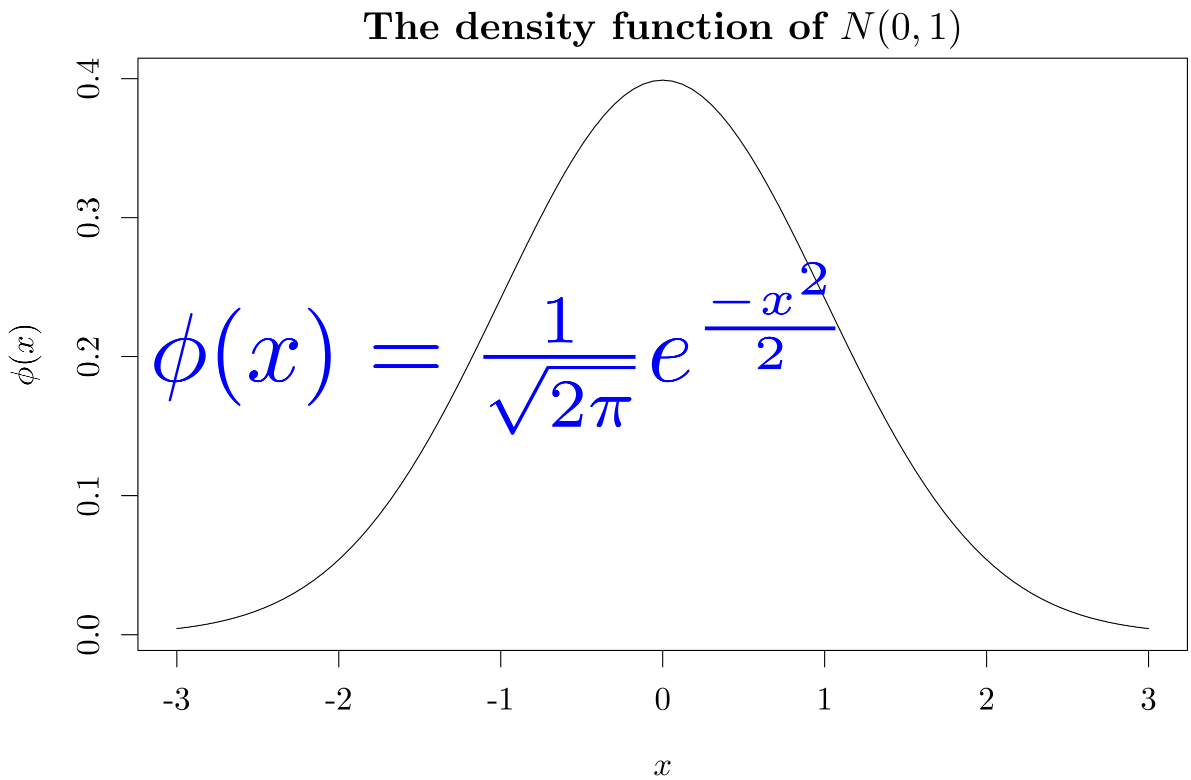


図11.2: A plot rendered via the tikz device.

```
text(-1, .2, cex = 3, col = 'blue',
  '$\\phi(x)=\\frac{1}{\\sqrt{2\\pi}}e^{\\frac{-x^2}{2}}$')
```

Note that base R actually supports math expressions, but they are not rendered via LaTeX (see `?plotmath` for details). There are several advanced options to tune the typesetting details of the `tikz` device. You may see `?tikzDevice::tikz` for the possibilities. For example, if your plot contains multibyte characters, you may want to set the option:

```
options(tikzDefaultEngine = "xetex")
```

That is because `xetex` is usually better than the default engine `pdftex` in processing multibyte characters in LaTeX documents.

There are two major disadvantages of the `tikz` device. First, it requires a LaTeX installation, but this may not be too bad (see Section 1.2). You also need a few LaTeX packages, which can be easily installed if you are using TinyTeX:

```r
tinytex::tlmgr_install(c("pgf", "preview", "xcolor"))
```

Second, it is often significantly slower to render the plots, because this device generates a LaTeX file and has to compile it to PDF. If you feel the code chunk is time-consuming, you may enable caching by the chunk option `cache = TRUE` (see Section 11.4).

For Figure 11.2, we also used the chunk option `fig.process = pdf2png`, where the function `pdf2png` is defined in Section 11.14 to convert the PDF plot to PNG when the output format is not LaTeX. Without the conversion, you may not be able to view the PDF plot in the online version of this book in the web browser.

11.16 Step-by-step plots with low-level plotting functions (*)

For R graphics, there are two types of plotting functions: high-level plotting functions create new plots, and low-level functions add elements to existing plots. You may see Chapter 12 ("Graphical procedures") of the R manual *An Introduction to R*[*4] for more information.

By default, **knitr** does not show the intermediate plots when a series of low-level plotting functions are used to modify a previous plot. Only the last plot on which all low-level plotting changes have been made is shown.

It can be useful to show the intermediate plots, especially for teaching purposes. You can set the chunk option `fig.keep = 'low'` to keep low-level plotting changes. For example, Figure 11.3 and Figure 11.4 are from a single code chunk with the chunk option `fig.keep = 'low'`, although they appear to be from two code chunks. We also assigned different figure captions to them with the chunk option `fig.cap = c('A scatterplot ...', 'Adding a regression line...')`.

```r
par(mar = c(4, 4, 0.1, 0.1))
plot(cars)
```

```r
fit <- lm(dist ~ speed, data = cars)
abline(fit)
```

[*4] https://cran.r-project.org/doc/manuals/r-release/R-intro.html

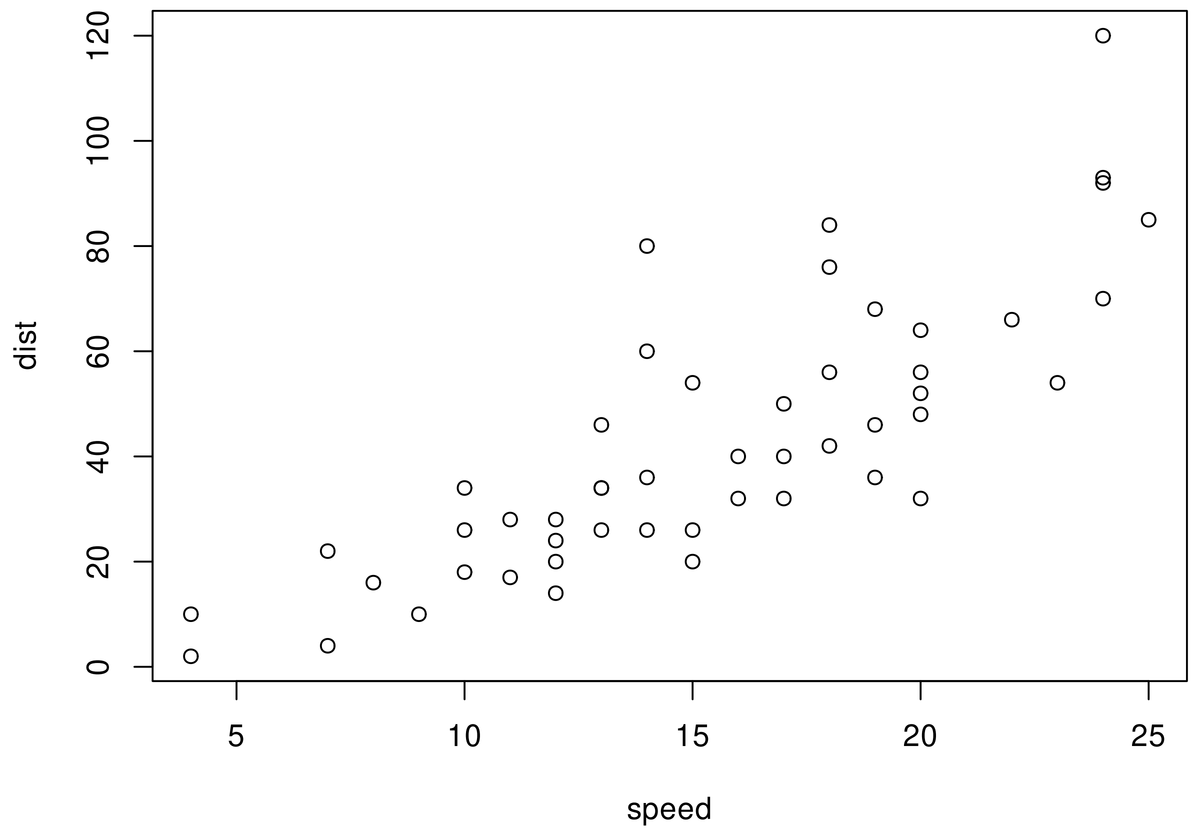


図11.3: A scatterplot of the cars data.

If you want to keep modifying a plot in a *different* code chunk, please see Section 14.5.

11.17 Customize the printing of objects in chunks (*)

By default, objects in code chunks are printed through the `knitr::knit_print()` function, which is by and large just `print()` in base R. The `knit_print()` function is an S3 generic function, which means you can extend it by yourself by registering S3 methods on it. The following is an example that shows how to automatically print data frames as tables via `knitr::kable()`:

```
---
title: Use a custom `knit_print` method to print data frames
---
```

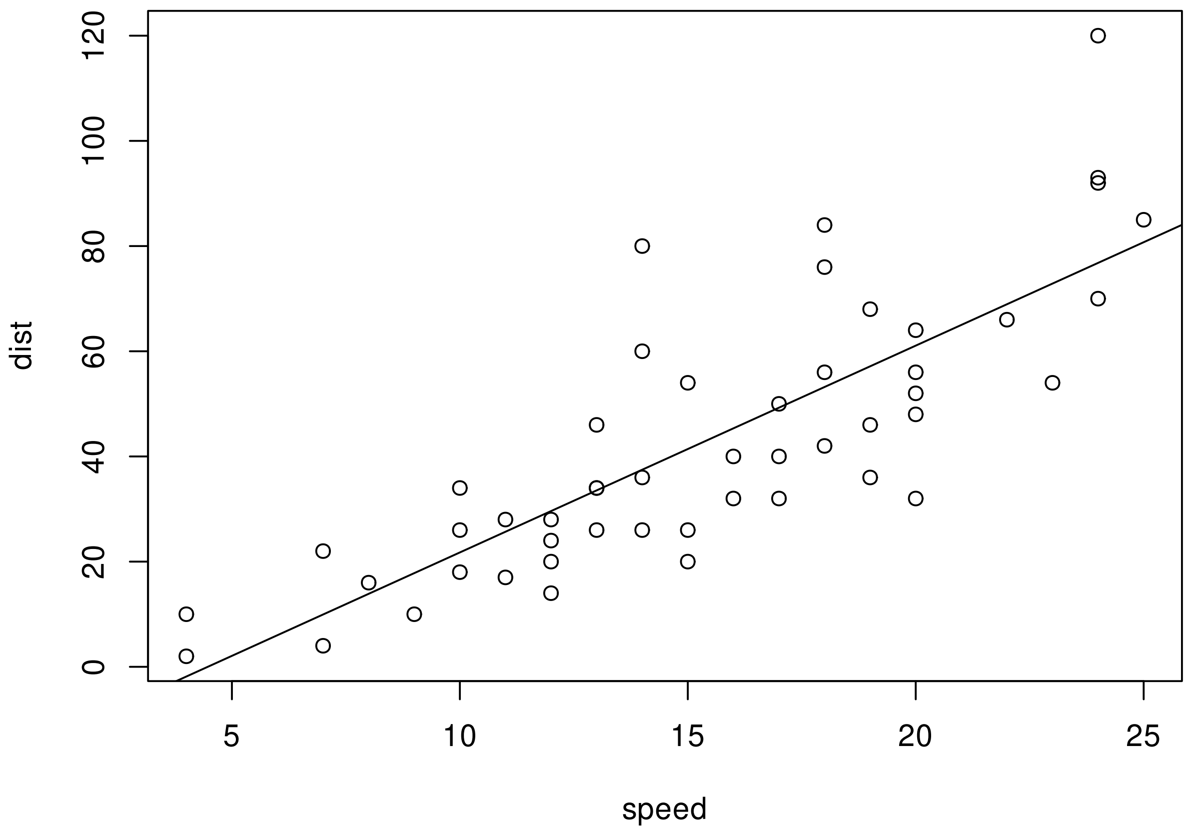


図11.4: Adding a regression line to an existing scatterplot.

````
First, we define a `knit_print` method, and register it:

```{r}
knit_print.data.frame = function(x, ...) {
  res = paste(c("", "", knitr::kable(x)), collapse = "\n")
  knitr::asis_output(res)
}

registerS3method(
  "knit_print", "data.frame", knit_print.data.frame,
  envir = asNamespace("knitr")
)
```
````

````md
Now we can test this custom printing method on data frames.
Note that you no longer need to call `knitr::kable()`
explicitly.

```{r}
head(iris)
```

```{r}
head(mtcars)
```
````

You can learn more about the `knit_print()` function in the **knitr** package vignette:

```r
vignette("knit_print", package = "knitr")
```

The **printr** package (Xie, 2017) has provided a few S3 methods to automatically print R objects as tables if possible. All you need is `library(printr)` in an R code chunk, and all methods will be automatically registered.

If you find this technique too advanced for you, some R Markdown output formats such as `html_document` and `pdf_document` also provide an option `df_print`, which allows you to customize the printing behavior of data frames. For example, if you want to print data frames as tables via `knitr::kable()`, you may set the option:

```yaml
---
output:
  html_document:
    df_print: kable
---
```

Please see the help pages of the output format functions (e.g., `?rmarkdown::html_document`) to determine whether an output format supports the `df_print` option and, if so, what the possible values are.

In fact, you can completely replace the printing function `knit_print()` through the chunk option `render`, which can take any function to print objects. For example, if you want to print objects using the **pander** package, you may set the chunk option `render` to the function `pander::pander()`:

```
```{r, render=pander::pander}
iris
```
```

The `render` option gives you complete freedom on how to print your R objects.

11.18 Option hooks (*)

Sometimes you may want to change certain chunk options dynamically according to the values of other chunk options. You may use the object `opts_hooks` to set up an *option hook* to do it. An option hook is a function associated with the option and to be executed when a corresponding chunk option is not `NULL`. This function takes the list of options for the current chunk as the input argument, and should return the (potentially modified) list. For example, we can tweak the `fig.width` option so that it is always no smaller than `fig.height`:

```r
knitr::opts_hooks$set(fig.width = function(options) {
  if (options$fig.width < options$fig.height) {
    options$fig.width <- options$fig.height
  }
  options
})
```

Because `fig.width` will never be `NULL`, this hook function is always executed before a code chunk to update its chunk options. For the code chunk below, the actual value of `fig.width` will be 6 instead of the initial 5 if the above option hook has been set up:

```
```{r fig.width = 5, fig.height = 6}
plot(1:10)
```
```

As another example, we rewrite the last example in Section 11.12 so we can use a single chunk option `console = TRUE` to imply `comment = ""` and `prompt = TRUE`. Note that `console` is not a built-in **knitr** chunk option but a custom and arbitrary option name instead. Its default value will be `NULL`. Below is a full example:

````
```{r, include=FALSE}
knitr::opts_hooks$set(console = function(options) {
  if (isTRUE(options$console)) {
    options$comment <- ''; options$prompt <- TRUE
  }
  options
})
```

Default output:

```{r}
1 + 1
if (TRUE) {
  2 + 2
}
```

Output with `console = TRUE`:

```{r, console=TRUE}
1 + 1
if (TRUE) {
  2 + 2
}
```
````

The third example is about how to automatically add line numbers to any output blocks, including source code blocks, text output, messages, warnings, and errors. We have mentioned in Section 5.7 how to use chunk options such as `attr.source` and `attr.output` to add line numbers. Here we want to use a single chunk option (`numberLines` in this example) to control the blocks to which we want to add line numbers.

```r
knitr::opts_hooks$set(
  numberLines = function(options) {
    attrs <- paste0("attr.", options$numberLines)
    options[attrs] <- lapply(options[attrs], c, ".numberLines")
    options
  }
)

knitr::opts_chunk$set(
  numberLines = c(
    "source", "output", "message", "warning", "error"
  )
)
```

Basically, the option hook `numberLines` appends the attribute `.numberLines` to output blocks, and the chunk option `numberLines` set via `opts_chunk$set()` makes sure that the option hook will be executed.

With the above setup, you can use the chunk option `numberLines` on a code chunk to decide which of its output blocks will have line numbers, e.g., `numberLines = c('source', 'output')`. Specifying `numberLines = NULL` removes line numbers completely.

You may wonder how this approach differs from setting the chunk options directly, e.g., just `knitr::opts_chunk$set(attr.source = '.numberLines')` like we did in Section 5.7. The advantage of using the option hooks here is that they only *append* the attribute `.numberLines` to chunk options, which means they will not *override* existing chunk option values, e.g., the source code block of the chunk below will be numbered (with the above setup), and the numbers start from the second line:

````
```{r, attr.source='startFrom="2"'}
# this comment line will not be numbered
1 + 1
```
````

It is equivalent to:

````
```{r, attr.source=c('startFrom="2"', '.numberLines'}
# this comment line will not be numbered
1 + 1
```
````

第 12 章

Output Hooks (*)

With the **knitr** package, you have control over every piece of output from your code chunks, such as source code, text output, messages, and plots. The control is achieved through "output hooks." Output hooks are a series of functions that take a piece of output as the input (typically a character vector), and return a character vector to be written to the output document. This may not be easy to understand for now, but hopefully you can see the idea more clearly with a small example below explaining how the output of a simple code chunk is rendered through **knitr**'s output hooks.

Consider this code chunk with one line of code:

````
```{r}
1 + 1
```
````

After **knitr** evaluates the code chunk, it gets two output elements, and both are stored as character strings: the source code `"1 + 1"`, and the text output `"[1] 2"`. These character strings will be further processed by chunk hooks for the desired output format. For example, for Markdown documents, **knitr** will wrap the source code in a fenced code block with a language name. This is done through the `source` hook, which more or less looks like this function:

```r
# for the above case, `x` is a character string '1 + 1'
function(x, options) {
  # the little 'r' here indicates the language name
```

````
  paste(c("```r", x, "```"), collapse = "\n")
}
````

Similarly, the text output is processed by the `output` hook that looks like this function:

````
function(x, options) {
  paste(c("```", x, "```"), collapse = "\n")
}
````

So the final output of the above code chunk is:

````
```r
1 + 1
```

```
[1] 2
```
````

The actual hooks are more complicated than the two functions above, but the idea is the same. You may obtain the actual hooks from the object `knit_hooks` via the `get()` method, e.g.,

```
# for meaningful output, the code below should be
# executed *inside* a code chunk of a knitr document
knitr::knit_hooks$get("source")
knitr::knit_hooks$get("output")
# or knitr::knit_hooks$get(c('source', 'output'))
```

Unless you are truly interested in making contributions to the **knitr** package, we do not recommend that you read the source code of these built-in hooks. If you are interested, this code can be found in the scripts named in the form `hooks-*.R` at https://github.com/yihui/knitr/tree/master/R (e.g., `hooks-md.R` contains hooks for R Markdown documents). As a **knitr** user, it usually suffices if you know how to create custom output hooks by taking advantage of the built-in hooks. You will learn that in several examples in this chapter, and we show the basic idea below.

A custom output hook is registered through the `set()` method of `knit_hooks`. Because this method will override the existing default hook, we recommend that you save a copy of an existing hook, process the output elements in your own way, and pass the results to the default hook. The usual syntax is:

```r
# using local() is optional here (we just want to avoid
# creating unnecessary global variables like `hook_old`)
local({
  hook_old <- knitr::knit_hooks$get("NAME")  # save the old hook
  knitr::knit_hooks$set(NAME = function(x, options) {
    # now do whatever you want to do with x, and pass the
    # new x to the old hook
    hook_old(x, options)
  })
})
```

Here, `NAME` is the name of the hook, which can be one of the following values:

- `source`: processing the source code.
- `output`: processing text output.
- `warning`: processing warnings (usually from `warning()`).
- `message`: processing messages (usually from `message()`).
- `error`: processing error messages (usually from `stop()`).
- `plot`: processing plot file paths.
- `inline`: processing output from inline R expressions.
- `chunk`: processing output from the whole chunk.
- `document`: processing the whole document.

The meaning of the argument `x` in the hook functions is explained in the above list. For the `options` argument of a hook, it denotes the chunk options (as a list) for the current code chunk. For example, if you set `foo = TRUE` on a chunk, you can obtain its value via `options$foo` in the hook. The `options` argument is not available to the `inline` and `document` hooks.

Output hooks give you the ultimate control over every single piece of your chunk and document output. Compared with chunk options, which often have predefined purposes, output hooks can be much more powerful since they are user-defined functions, and you can do anything you want in functions.

12.1 Redact source code

Sometimes we may not want to fully display our source code in the report. For example, you may have a password in a certain line of code. We mentioned in Section 11.7 that you can use the chunk option `echo` to select which expressions in the R code to display (e.g., show the second expression via `echo = 2`). In this section, we provide a more flexible method that does not require you to specify the indices of expressions.

The basic idea is that you add a special comment to the code (e.g., `# SECRET!!`). When this comment is detected in a line of code, you omit that line. Below is a full example using the `source` hook:

````
---
title: Using the `source` hook to hide certain lines of code
---

First, we set up a `source` hook to exclude the lines of code
that contain the string `# SECRET!!` at the end.

```{r, include=FALSE}
local({
  hook_source <- knitr::knit_hooks$get('source')
  knitr::knit_hooks$set(source = function(x, options) {
    x <- x[!grepl('# SECRET!!$', x)]
    hook_source(x, options)
  })
})
```
````

````
Now we can test the new hook. When you knit this document, you
will not see the lines with the special comment `# SECRET!!`.

```{r}
1 + 1  # normal code to be displayed

# please use your real username and password
auth <- httr::authenticate("user", "passwd")
auth <- httr::authenticate("yihui", "horsebattery")  # SECRET!!
httr::GET("http://httpbin.org/basic-auth/user/passwd", auth)
```
````

The key part in the above source hook is this line, which matches the trailing comment `# SECRET!!` in the source code vector `x` via `grepl()` and exclude the matches:

```r
x <- x[!grepl("# SECRET!!$", x)]
```

Precisely speaking, the above hook will exclude whole *expressions* containing the trailing comment `# SECRET!!`, instead of individual lines, because `x` is actually a vector of R expressions. For example, for the code chunk below:

```r
1 + 1
if (TRUE) {
  # SECRET!!
  1:10
}
```

The value of `x` in the `source` hook is:

```r
c("1 + 1", "if (TRUE) { # SECRET!!\n  1:10\n}")
```

If you want to hide lines instead of expressions of R code, you will have to split `x` into individual lines. You may consider using the function `xfun::split_lines()`. The body of the hook function will be:

```
x <- xfun::split_lines(x)  # split into individual lines
x <- x[!grepl("# SECRET!!$", x)]
x <- paste(x, collapse = "\n")  # combine into a single string
hook_source(x, options)
```

This example shows you how to manipulate the source code string, and `grepl()` is certainly not the only choice of string manipulation. In Section 12.2, we will show another example.

12.2 Add line numbers to source code

In this section, we show an example of defining a `source` hook to add line numbers as comments to the source code. For example, for this code chunk:

````
```{r}
if (TRUE) {
  x <- 1:10
  x + 1
}
```
````

We want the output to be:

```
if (TRUE) {    # 1
  x <- 1:10    # 2
  x + 1        # 3
}              # 4
```

The full example is below:

```
---
title: Add line numbers to source code
---

We set up a `source` hook to add line numbers to the source
```

````
code. The numbers appear in comments at the end of each line.

```{r, include=FALSE}
local({
  hook_source <- knitr::knit_hooks$get('source')
  knitr::knit_hooks$set(source = function(x, options) {
    x <- xfun::split_lines(x)
    n <- nchar(x, 'width')
    i <- seq_along(x)  # line numbers
    n <- n + nchar(i)
    s <- knitr:::v_spaces(max(n) - n)
    x <- paste(x, s, '  # ', i, sep = '', collapse = '\n')
    hook_source(x, options)
  })
})
```

Now we can test the new hook. When you knit this document, you
will see line numbers in trailing comments.

```{r}
if (TRUE) {
  x <- 1:10
  x + 1
}
```
````

The main trick in the above example is to determine the number of spaces needed before the comment on each line, so the comments can align to the right. The number depends on the widths of each line of code. We leave it to readers to digest the code in the hook function. Note that an internal function `knitr:::v_spaces()` is used to generate spaces of specified lengths, e.g.,

```r
knitr:::v_spaces(c(1, 3, 6, 0))
```

```
## [1] " "      "   "    "      " ""
```

The method introduced in Section 5.7 may be the actual way in which you want to add line numbers to source code. The syntax is cleaner, and it works for both source code and text output blocks. The above `source` hook trick mainly aims to show you one possibility of manipulating the source code with a custom function.

12.3 Scrollable text output

In Section 7.4, we showed how to restrict the heights of code blocks and text output blocks via CSS. In fact, there is a simpler method with the chunk options `attr.source` and `attr.output` to add the `style` attribute to the fenced code blocks in the Markdown output (see Section 11.13 for more information on these options). For example, for this code chunk with the `attr.output` option:

````
```{r, attr.output='style="max-height: 100px;"'}
1:300
```
````

Its Markdown output will be:

````
```r
1:300
```

```{style="max-height: 100px;"}
##   [1]   1   2   3   4   5   6   7   8   9  10
##  [11]  11  12  13  14  15  16  17  18  19  20
##  ... ...
```
````

Then the text output block will be converted to HTML by Pandoc:

```
<pre style="max-height: 100px;">
<code>##  [1]  1  2  3  4  5  6  7  8  9 10
## [11] 11 12 13 14 15 16 17 18 19 20
## ... ...</code>
</pre>
```

To learn more about Pandoc's fenced code blocks, please read its manual at https://pandoc.org/MANUAL.html#fenced-code-blocks.

The `attr.source` and `attr.output` options have made it possible for us to specify maximum heights for individual code chunks. However, the syntax is a little clunky, and requires a better understanding of CSS and Pandoc's Markdown syntax. Below we show an example of a custom `output` hook that works with a custom chunk option `max.height`, so you will only need to set the chunk option like `max.height = "100px"` instead of `attr.output = 'style="max-height: 100px;"'`. In this example, we only manipulate the `options` argument, but not the `x` argument.

````
---
title: Scrollable code blocks
output:
  html_document:
    highlight: tango
---

We set up an `output` hook to add a `style` attribute to the
text output when the chunk option `max.height` is set.

```{r, include=FALSE}
options(width = 60)
local({
  hook_output <- knitr::knit_hooks$get('output')
  knitr::knit_hooks$set(output = function(x, options) {
    if (!is.null(options$max.height)) options$attr.output <- c(
      options$attr.output,
      sprintf('style="max-height: %s;"', options$max.height)
````
````

````
    )
    hook_output(x, options)
  })
})
```

Without the `max.height` option, you will see the full output,
e.g.,

```{r}
1:100
```

Now we set `max.height` to `100px`. You will see a scrollbar
in the text output because its height is larger than 100px.

```{r, max.height='100px'}
1:100
```

Essentially the `max.height` option is converted to the
`attr.output` option. It works even if the `attr.output`
option is present, i.e., it will not override the
`attr.output` option, e.g., we show line numbers on the left
side of the text output via the `.numberLines` attribute:

```{r, max.height='100px', attr.output='.numberLines'}
1:100
```
````

Figure 12.1 shows the output. Note that in the last code chunk with the chunk option `attr.output`, the option will not be overridden by `max.height` because we respect existing attributes by combining them with the `style` attribute generated by `max.height`:
````

```r
options$attr.output <- c(
  options$attr.output,
  sprintf('style="max-height: %s;"', options$max.height)
)
```

You can use a similar trick in the `source` hook to limit the height of source code blocks.

12.4 Truncate text output

When the text output from a code chunk is lengthy, you may want to only show the first few lines. For example, when printing a data frame of a few thousand rows, it may not be helpful to show the full data, and the first few lines may be enough. Below we redefine the `output` hook so that we can control the maximum number of lines via a custom chunk option `out.lines`:

```r
# save the built-in output hook
hook_output <- knitr::knit_hooks$get("output")

# set a new output hook to truncate text output
knitr::knit_hooks$set(output = function(x, options) {
  if (!is.null(n <- options$out.lines)) {
    x <- xfun::split_lines(x)
    if (length(x) > n) {
      # truncate the output
      x <- c(head(x, n), "....\n")
    }
    x <- paste(x, collapse = "\n")
  }
  hook_output(x, options)
})
```

The basic idea of the above hook function is that if the number of lines of the text output is greater than the threshold set in the chunk option `out.lines` (stored in the variable `n` in the function body), we only keep the first `n` lines and add an ellipsis (`....`) to indicate the output is truncated.

Without the `max.height` option, you will see the full output, e.g.,

```
1:100
```

```
##   [1]   1   2   3   4   5   6   7   8   9  10  11  12  13
##  [14]  14  15  16  17  18  19  20  21  22  23  24  25  26
##  [27]  27  28  29  30  31  32  33  34  35  36  37  38  39
##  [40]  40  41  42  43  44  45  46  47  48  49  50  51  52
##  [53]  53  54  55  56  57  58  59  60  61  62  63  64  65
##  [66]  66  67  68  69  70  71  72  73  74  75  76  77  78
##  [79]  79  80  81  82  83  84  85  86  87  88  89  90  91
##  [92]  92  93  94  95  96  97  98  99 100
```

Now we set `max.height` to `100px`. You will see a scrollbar in the text output because its height is larger than 100px.

```
1:100
```

```
##   [1]   1   2   3   4   5   6   7   8   9  10  11  12  13
##  [14]  14  15  16  17  18  19  20  21  22  23  24  25  26
##  [27]  27  28  29  30  31  32  33  34  35  36  37  38  39
##  [40]  40  41  42  43  44  45  46  47  48  49  50  51  52
##  [53]  53  54  55  56  57  58  59  60  61  62  63  64  65
```

Essentially the `max.height` option is converted to the `attr.output` option. It works even if the `attr.output` option is present, i.e., it will not override the `attr.output` option, e.g., we show line numbers on the left side of the text output via the `.numberLines` attribute:

```
1:100
```

```
1 ##   [1]   1   2   3   4   5   6   7   8   9  10  11  12  13
2 ##  [14]  14  15  16  17  18  19  20  21  22  23  24  25  26
3 ##  [27]  27  28  29  30  31  32  33  34  35  36  37  38  39
4 ##  [40]  40  41  42  43  44  45  46  47  48  49  50  51  52
5 ##  [53]  53  54  55  56  57  58  59  60  61  62  63  64  65
```

図12.1: An example of scrollable text output, with its height specified in the chunk option max.height.

Now we can test the new `output` hook by setting the chunk option `out.lines = 4` on the chunk below:

```
print(cars)
```

```
##    speed dist
## 1      4    2
## 2      4   10
## 3      7    4
....
```

And you see four lines of output as expected. Since we have stored the original `output` hook in `hook_output`, we can restore it by calling the `set()` method again:

```
knitr::knit_hooks$set(output = hook_output)
```

As an exercise for readers, you may try to truncate the output in a different way: given the chunk option `out.lines` to determine the maximum number of lines, can you truncate the output in the middle instead of the end? For example, if `out.lines = 10`, you extract the first and last five lines, and add `....` in the middle like this:

```
##    speed dist
## 1      4    2
## 2      4   10
## 3      7    4
## 4      7   22
....
## 46    24   70
## 47    24   92
## 48    24   93
## 49    24  120
## 50    25   85
```

Please note that the last line in the output (i.e., the argument `x` of the hook function) might be an empty line, so you may need something like `c(head(x, n/2), '....', tail(x, n/2 + 1))` (`+ 1` to take the last empty line into account).

12.5 Output figures in the HTML5 format

By default, plots in R Markdown are included in the tag `<img src="..." />` in a `<p>` or `<div>` tag in the HTML output. This example below shows how to use the HTML5 `<figure>` tag to display plots.

````
---
title: Output figures in `<figure>` tags
output: html_document
---

Given a plot file path `x` and a figure caption in the chunk
option `options$fig.cap`, we want to write the plot in the
HTML5 tag in this form:

```html
<figure>
  <img src="PATH" alt="CAPTION" />
  <figcaption>CAPTION</figcaption>
</figure>
```

Now we redefine the `plot` hook (only when the output format
is HTML):

```{r}
if (knitr::is_html_output()) knitr::knit_hooks$set(
  plot = function(x, options) {
    cap  <- options$fig.cap  # figure caption
    tags <- htmltools::tags
    as.character(tags$figure(
      tags$img(src = x, alt = cap),
      tags$figcaption(cap)
    ))
  }
````
````

```
)
```

The plot from the code chunk below will be placed in the
`<figure>` tag:

```{r, fig.cap='A scatterplot for the cars data.'}
par(mar = c(4.5, 4.5, .2, .2))
plot(cars, pch = 19, col = 'red')
```

We add some CSS styles to "see" the `<figure>` and
`<figcaption>` tags better (the `figure` has a dashed
border, and the caption has a light pink background):

```{css, echo=FALSE}
figure {
  border: 2px dashed red;
  margin: 1em 0;
}
figcaption {
  padding: .5em;
  background: lightpink;
  font-size: 1.3em;
  font-variant: small-caps;
}
```
````

The figure output is shown in Figure 12.2. Note that we actually overrode the default `plot` hook in this example, while most other examples in this chapter build custom hooks on top of the default hooks. You should completely override default hooks only when you are sure you want to ignore some built-in features of the default hooks. For example, the `plot` hook function in this case did not consider possible chunk options like `out.width = '100%'` or `fig.show = 'animate'`.

This example shows you what you can possibly do with the plot file path `x` in the `plot` hook.
````

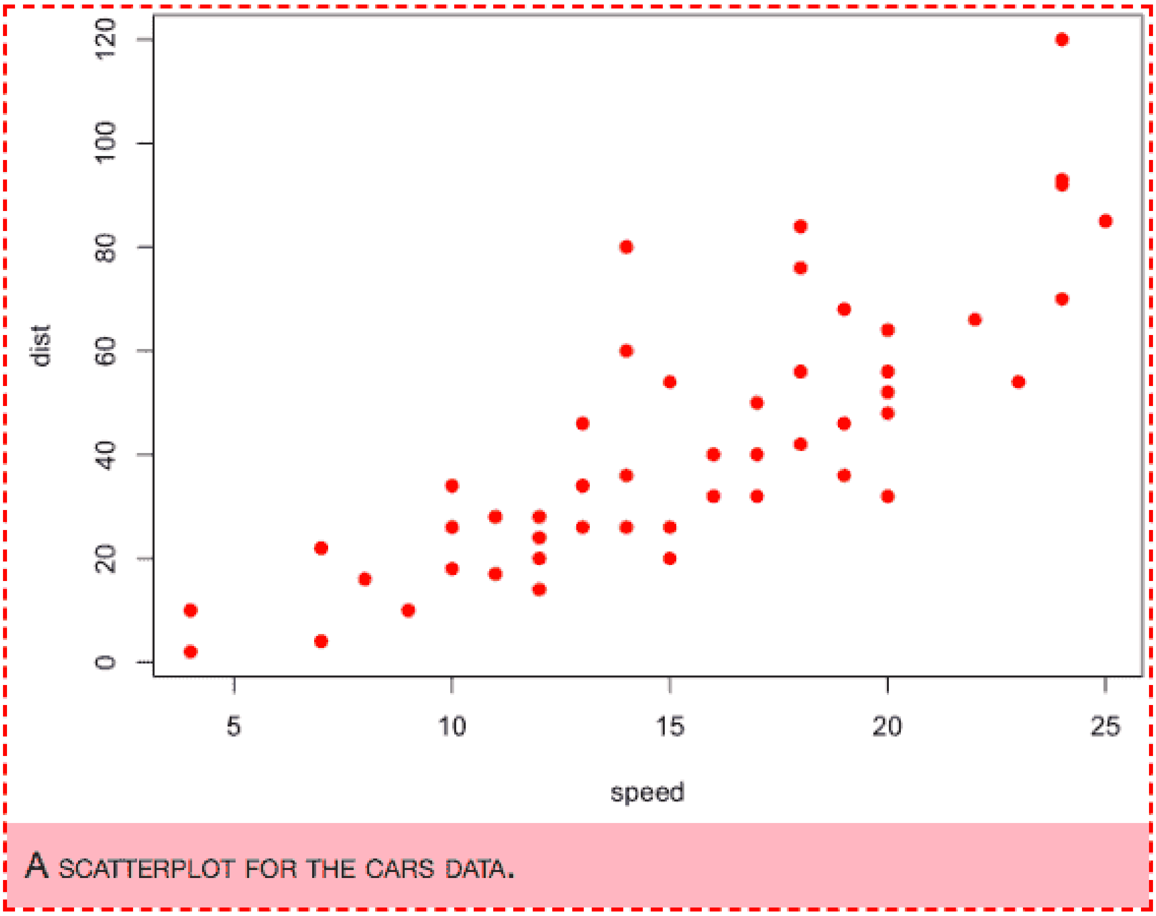


図12.2: A figure in the HTML5 figure tag.

If all you need is to customize the style of figures, you do not have to use the HTML5 tags. Usually the default `plot` hook will output images in the HTML code like this:

```
<div class="figure">
  <img src="PATH" />
  <p class="caption">CAPTION</p>
</div>
```

So you can just define css rules for `div.figure` and `p.caption`.

第 13 章

Chunk Hooks (*)

A chunk hook is a function that is triggered by a chunk option when the value of this chunk option is not NULL. Chunk hooks provide a way for you to execute additional tasks beyond running the code in a chunk. For example, you may want to post-process plots (e.g., Section 13.1 and Section 13.2), or record the time taken by a code chunk (Section 13.3). Such tasks may not be essential to the computing or analysis in the report, but they can be useful for other purposes (e.g., enhance plots or help you identify the most time-consuming chunks).

You can use chunk hooks purely for their side effects (e.g., only printing out certain information to the console), or for their returned values, which will be written to the output document if the value is a character value.

Like output hooks (see Chapter 12), chunk hooks are also registered via the object `knitr::knit_hooks`. Please note that the names of output hooks are reserved by **knitr**, so you must not use these names for your custom chunk hooks:

```
names(knitr:::.default.hooks)
```

```
##  [1] "source"          "output"
##  [3] "warning"         "message"
##  [5] "error"           "plot"
##  [7] "inline"          "chunk"
##  [9] "text"            "evaluate.inline"
## [11] "evaluate"        "document"
```

A chunk hook is associated with a chunk option of the same name. For example, you can register a chunk hook with the name `greet`:

```r
knitr::knit_hooks$set(greet = function(before) {
  if (before)
    "Hello!" else "Bye!"
})
```

We will explain the arguments of the hook function in a moment. Now we set the chunk option `greet = TRUE` for the chunk below:

````
```{r, greet=TRUE}
1 + 1
```
````

And you will see that "Hello!" appears before the chunk, and "Bye!" appears after the chunk in the output below (which is because they are character values):

> Hello!
>
> ```r
> 1 + 1
> ```
>
> ```
> ## [1] 2
> ```
>
> Bye!

A chunk hook function can possibly take four arguments: `before`, `options`, `envir`, and `name`. In other words, it can be of this form:

```r
function(before, options, envir, name) {

}
```

All four arguments are optional. You can have four, three, two, one, or even no arguments. In the above example, we used one argument (i.e., `before`). The meanings of these arguments are:

- `before`: Whether the chunk hook is currently being executed before or after the code chunk itself is executed. Note that a chunk hook is executed twice for every code chunk (once before with `hook(before = TRUE)` and once after with `hook(before = FALSE)`).

- `options`: The list of chunk options for the current code chunk, e.g., `list(fig.width = 5, echo = FALSE, ...)`.
- `envir`: The environment in which the chunk hook is evaluated.
- `name`: The name of the chunk option that triggered the chunk hook.

As we mentioned in the beginning of this chapter, non-character values returned by chunk hooks are silently ignored, and character values are written to the output document.

13.1 Crop plots

The chunk hook `knitr::hook_pdfcrop()` can be used to crop PDF and other types of plot files, i.e., remove the extra margins in plots. To enable it, set this hook via `knit_hooks$set()` in a code chunk, and turn on the corresponding chunk option, e.g.,

```
knitr::knit_hooks$set(crop = knitr::hook_pdfcrop)
```

Then you can use the chunk option `crop = TRUE` to crop plots in a code chunk.

The hook `hook_pdfcrop()` calls the external program `pdfcrop` to crop PDF files. This program often comes with a LaTeX distribution (e.g., TeX Live or MiKTeX). You can check if it is available in your system via:

```
# if the returned value is not empty, it is available
Sys.which("pdfcrop")
```

```
##                    pdfcrop
## "/usr/local/bin/pdfcrop"
```

If you are using the LaTeX distribution TinyTeX (see Section 1.2), and `pdfcrop` is not available in your system, you may install it via `tinytex::tlmgr_install('pdfcrop')`.

For non-PDF plot files such as PNG or JPEG files, this hook function calls the R package **magick** (Ooms, 2020) for cropping. You need to make sure this R package has been installed. Figure 13.1 shows a plot that is not cropped, and Figure 13.2 shows the same plot but has been cropped.

13.2 Optimize PNG plots

If you have installed the program OptiPNG (http://optipng.sourceforge.net), you may use the hook `knitr::hook_optipng()` to optimize PNG plot files to a smaller size without losing the image quality.

```
knitr::knit_hooks$set(optipng = knitr::hook_optipng)
```

After you set up this hook, you can use the chunk option `optipng` to pass command-line arguments to OptiPNG, e.g., `optipng = '-o7'`. These command-line arguments are optional, which means you can just use `optipng = ''` to enable the hook for a code chunk. Please see the user manual on the website of OptiPNG to know the possible arguments.

Note that macOS users can easily install OptiPNG with Homebrew (https://brew.sh): `brew install optipng`.

13.3 Report how much time each chunk takes to run

By default, **knitr** provides a text-based progress bar to show you the knitting progress. If you want more precise timing information about the chunks, you may register a custom chunk hook to record the time for each chunk. Here is an example hook:

```
knitr::knit_hooks$set(time_it = local({
  now <- NULL
  function(before, options) {
    if (before) {
      # record the current time before each chunk
      now <<- Sys.time()
    } else {
      # calculate the time difference after a chunk
      res <- difftime(Sys.time(), now)
      # return a character string to show the time
      paste("Time for this code chunk to run:", res)
```

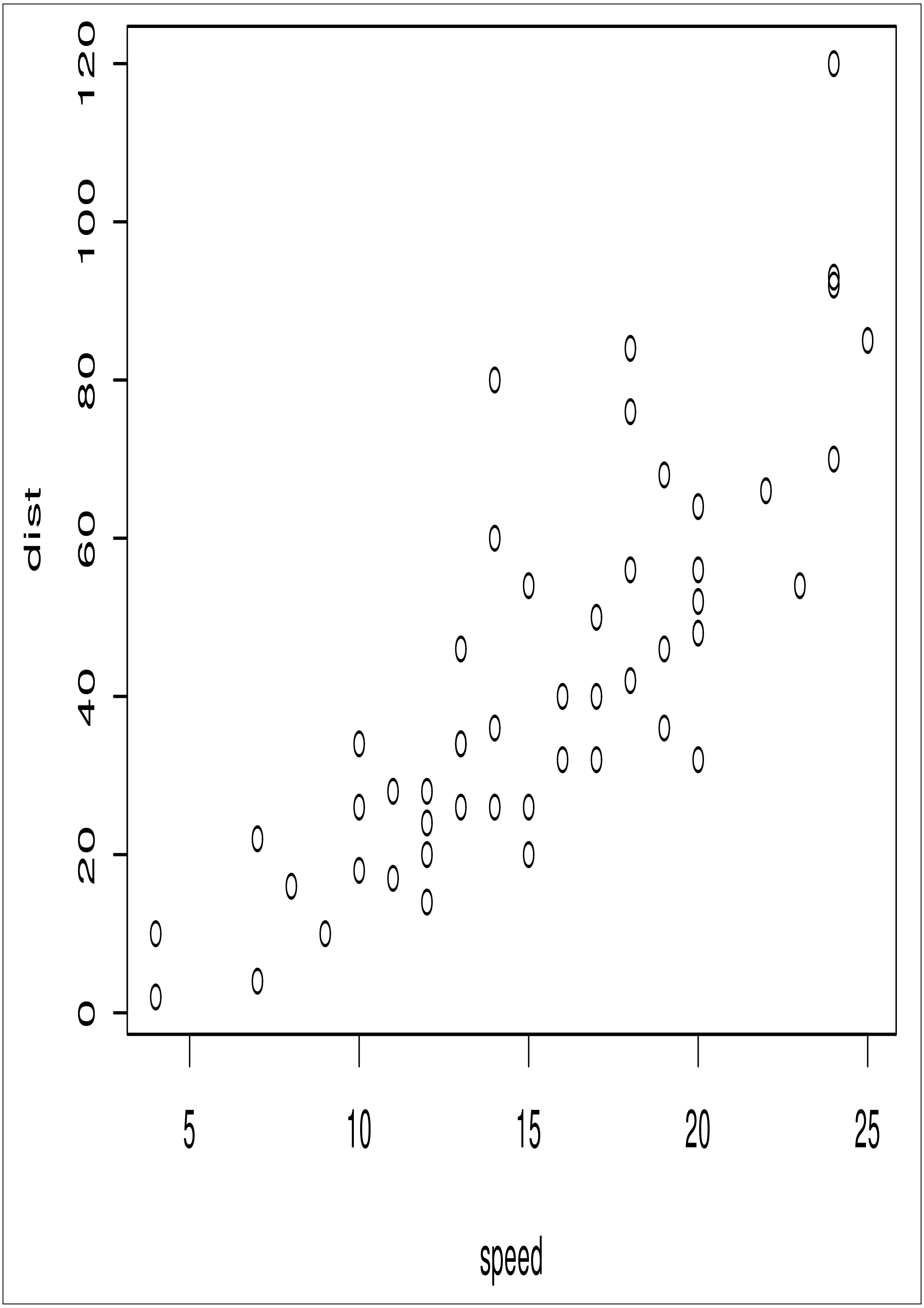


図13.1: A plot that is not cropped.

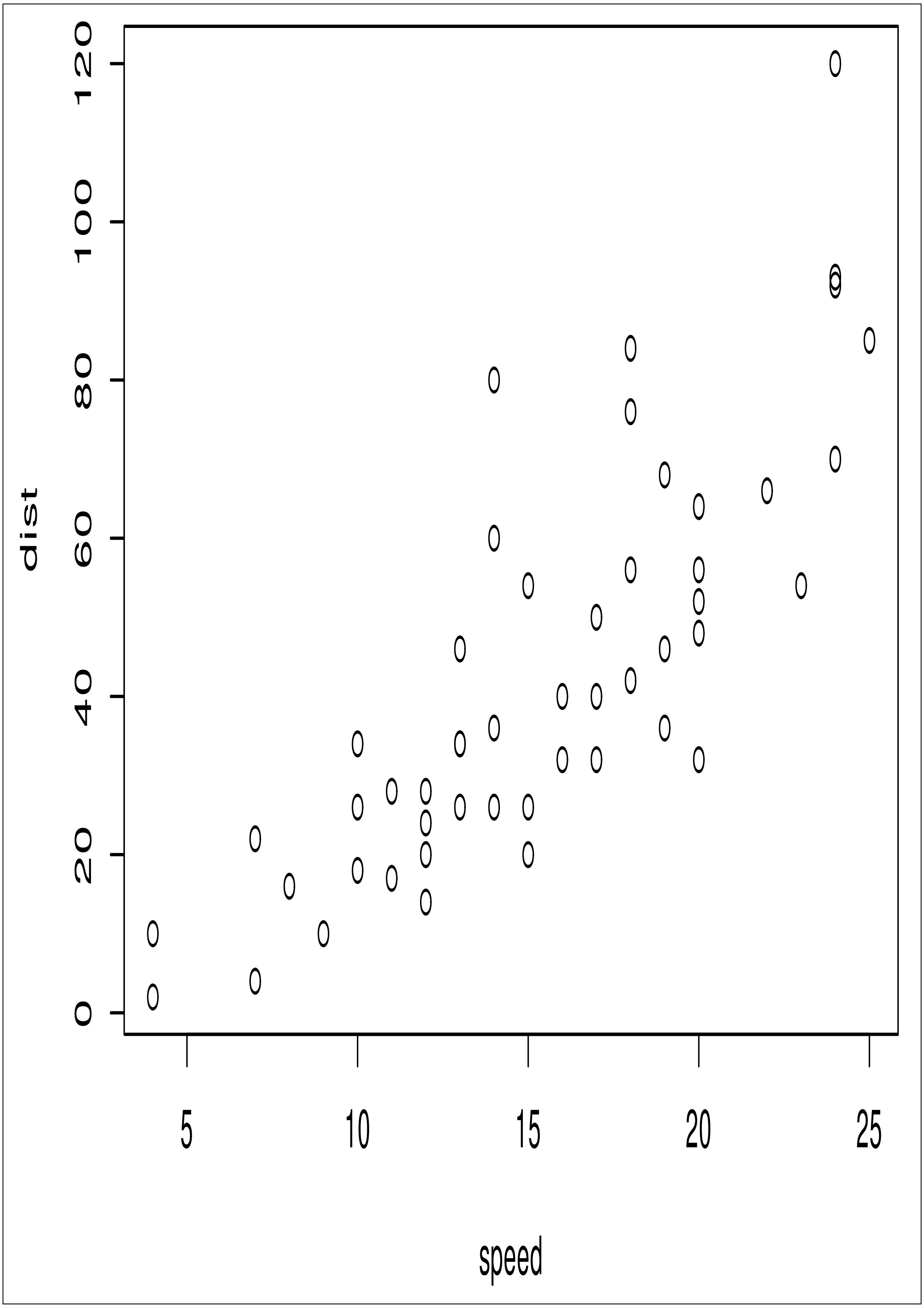


図13.2: A plot that is cropped.

```
    }
  }
}))
```

Then you can time a chunk with the chunk option `time_it`, e.g.,

````
```{r, time_it = TRUE}
Sys.sleep(2)
```
````

If you want to time all code chunks, you can certainly set the option globally: `knitr::opts_chunk$set(time_it = TRUE)`.

In the above hook function, you can also output more information from the chunk options (i.e., the `options` argument of the function). For example, you may print out the chunk label in the returned value:

```
paste("Time for the chunk", options$label, "to run:", res)
```

Or you may record the time without printing it out in the hook:

```
all_times <- list()  # store the time for each chunk
knitr::knit_hooks$set(time_it = local({
  now <- NULL
  function(before, options) {
    if (before) {
      now <<- Sys.time()
    } else {
      res <- difftime(Sys.time(), now)
      all_times[[options$label]] <<- res
    }
  }
}))
```

Then you can access all the time information in the object `all_times`. This object is a named list with the names being chunk labels, and element values being the execution time for each chunk.

Lastly, as a technical note, we want to explain the use of the `local()` function in the previous hooks because some readers may not be familiar with it. This function allows you to run code in a "local" environment. The main benefit is that variables created in the code are local to that environment, so they will not pollute the outer environment (usually the global environment). For example, we created a variable `now` in `local()`, and used it in the `time_it` hook function. In the hook function, we update the value of `now` via the double arrow `<<-` instead of the normal assignment operator `<-`. This is because `<<-` assigns a value to a variable in the parent environment (which is the environment in `local()` in this case), and `<-` can only assign values to variables in the current environment. Before each code chunk is evaluated, the local variable `now` records the current time. After each code chunk is evaluated, we calculate the time difference between the current time and `now`. Note that `local()` returns the last value in the expression passed to it, which is a (hook) function in this case. In short, `local()` can make your workspace cleaner by not exposing variables that are only used locally but unused in the global environment. If you do not mind creating a variable `now` in the global environment, you can choose not to use `local()`.

13.4 Show the chunk header in the output

Sometimes you may want to show the original code chunk header to your readers. For example, when you write an R Markdown tutorial, you may want to show both the chunk output and the chunk options that you used to generate the output, so your readers can learn how to do it by themselves.

The original chunk options are actually stored as a character string in the chunk option `params.src`. After you know this, you may write a chunk hook to add `params.src` to the output. Below is a full example:

````
---
title: Show chunk headers in the output
---

Set up a chunk hook named `wrapper` to wrap the chunk
output inside the original chunk header and footer.

```{r, setup, include=FALSE}
````
````

````
knitr::knit_hooks$set(wrapper = function(before, options) {
  # the original chunk might be indented
  if (is.null(indent <- options$indent)) indent <- ''

  # hide the wrapper=TRUE option
  opts <- gsub(', wrapper=TRUE', '', options$params.src)

  if (before) {
    # add the header
    sprintf('\n\n%s````\n```{r,%s}\n````\n', indent, opts)
  } else {
    # add the footer
    sprintf('\n\n%s````\n```\n````\n', indent)
  }
})
```

Now we apply the hook via the chunk option `wrapper=TRUE`.
Remember to put `wrapper=TRUE` at the end of the header, and
it has to be `wrapper=TRUE` precisely (e.g., not `wrapper=T`),
following a comma and a space, unless you adjust the `gsub()`
call in the above hook.

```{r, test-label, collapse=TRUE, wrapper=TRUE}
1 + 1
plot(cars)
```

You should see the original chunk header appear in
the output. The hook should also work when the chunk
is indented, e.g.,

- One bullet.

  ```{r, eval=TRUE, wrapper=TRUE}
````

```
  2 + 2
  ```

- Another bullet.
```

Basically, we restored the chunk header from `options$params.src` by putting this string inside ```` ```{r, } ````. Then we wrapped this line in a pair of four backticks, so it can be displayed verbatim in the output. Note that the original code chunk might be indented (e.g., when it is nested in a list item), so we also need to add the proper indentation, which is stored in the chunk option `options$indent`.

The output of the bullet list at the end of the above example will be like this:

> - One bullet.
>
>   ```` ```{r, eval=TRUE} ````
>
>   ```r
>   2 + 2
>   ```
>
>   ```
>   ## [1] 4
>   ```
>
>   ```` ``` ````
>
> - Another bullet.

You can see that the code chunk was evaluated, and the chunk header was also added.

13.5 Embed an interactive 3D plot with rgl

The **rgl** package (Adler and Murdoch, 2021) can be used to generate interactive 3D plots. These plots can still be interactive if they are saved to the WebGL format, which can be done through a hook function `rgl::hook_webgl()`. Below is an example that shows you how to set up **rgl** and **knitr** so 3D plots can be saved while preserving the interactivity:

```
---
title: Embed 3D plots with rgl
output: html_document
```
```

````
---

Set up a hook to save **rgl** plots:

```{r, setup}
library(rgl)
knitr::knit_hooks$set(webgl = hook_webgl)
```

See if it works for this 3D plot after we enable the hook
via the chunk option `webgl = TRUE`:

```{r, test-rgl, webgl=TRUE}
x <- sort(rnorm(1000))
y <- rnorm(1000)
z <- rnorm(1000) + atan2(x,y)
plot3d(x, y, z, col = rainbow(1000))
```
````

You should get an interactive 3D scatterplot like Figure 13.3 after you compile this example. Note that the interactive plots only work when the output format is HTML.

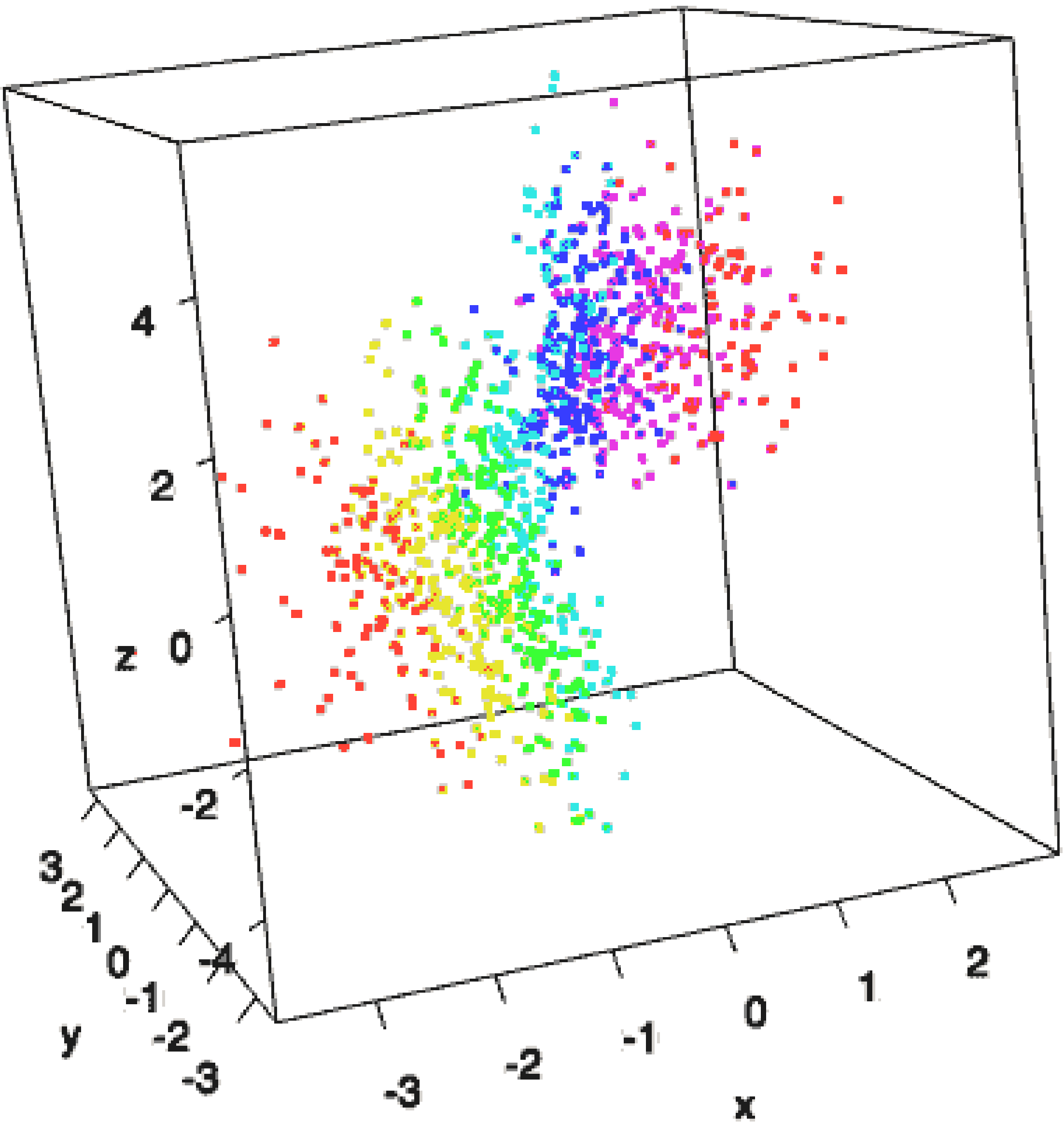


図13.3: A 3D scatterplot generated from the rgl package.

第 14 章

Miscellaneous knitr Tricks

Besides chunk options (Chapter 11), output hooks (Chapter 12), and chunk hooks (Chapter 13), there are other useful functions and tricks in **knitr**. We introduce these tricks in this chapter, such as how to reuse code chunks, exit knitting early, display a plot in a custom place, and so on.

14.1 Reuse code chunks

You can freely reuse code chunks anywhere in your source document without cut-and-paste. The key is to label your code chunks, so you can refer to them with labels in other places. There are three ways to reuse code chunks.

14.1.1 Embed one chunk in another chunk (*)

You can embed one code chunk in another code chunk by enclosing its label in <<>>. Then **knitr** will automatically expand the string `<<label>>` to the actual code. For example, you can create an R function in this way:

````
We define a function to convert Fahrenheit to Celsius.

```{r, f2c}
F2C <- function(x) {
  <<check-arg>>
  <<convert>>
````
````

````
}
```

First, we check if the input value is numeric:

```{r, check-arg, eval=FALSE}
  if (!is.numeric(x)) stop("The input must be numeric!")
```

Then we do the actual conversion:

```{r, convert, eval=FALSE}
  (x - 32) * 5/ 9
```
````

This is based on one of the main ideas of Literate Programming,[*1] which was proposed by Donald Knuth. The advantage of this technique is that you can split (complex) code into smaller parts, write each part in a separate code chunk, and explain them with narratives. All parts can be composed into the main code chunk to be executed.

For the above example, the first code chunk (with the label `f2c`) will become:

````
```{r, f2c}
F2C <- function(x) {
  if (!is.numeric(x)) stop("The input must be numeric!")
  (x - 32) * 5/ 9
}
```
````

You can embed an arbitrary number of other code chunks in one code chunk. The embedding can also be recursive. For example, you may embed chunk A in chunk B, and chunk B in chunk C. Then chunk C will include code from chunk A via chunk B.

The marker `<<label>>` does not have to be on a separate line. It can be embedded anywhere in a code chunk.

[*1] https://en.wikipedia.org/wiki/Literate_programming
````

14.1.2 Use the same chunk label in another chunk

If you want to use exactly the same code chunk two or more times, you may define the chunk with a label, and create more code chunks with the same label but leave the chunk content empty, e.g.,

````
Here is a code chunk that is not evaluated:

```{r, chunk-one, eval=FALSE}
1 + 1
2 + 2
```

Now we actually evaluate it:

```{r, chunk-one, eval=TRUE}
```
````

We used the chunk label "chunk-one" twice in the above example, and the second chunk just reuses code from the first chunk.

We recommend that you do not use this method to run a code chunk more than once to generate plots (or other files), because plot files created from a later chunk may overwrite files from a previous chunk. It is okay if only one of such chunks uses the chunk option `eval = TRUE`, and all other chunks use `eval = FALSE`.

14.1.3 Use reference labels (*)

The chunk option `ref.label` takes a vector of chunk labels to retrieve the content of these chunks. For example, the code chunk with the label `chunk-a` is the combination of `chunk-c` and `chunk-b` below:

````
```{r chunk-a, ref.label=c('chunk-c', 'chunk-b')}
```
````

````
```{r chunk-b}
# this is the chunk b
1 + 1
```

```{r chunk-c}
# this is the chunk c
2 + 2
```
````

In other words, `chunk-a` is essentially this:

````
```{r chunk-a}
# this is the chunk c
2 + 2
# this is the chunk b
1 + 1
```
````

The chunk option `ref.label` has provided a very flexible way of reorganizing code chunks in a document without resorting to cut-and-paste. It does not matter if the code chunks referenced are before or after the code chunk that uses `ref.label`. An early code chunk can reference a later chunk.

There is an application of this chunk option in Section 4.19.

14.2 Use an object before it is created (*)

All code in a **knitr** document, including the code in code chunks and inline R expressions, is executed in linear order from beginning to end. In theory, you cannot use a variable before it is assigned a value. However, in certain cases, we may want to mention the value of a variable earlier in the document. For example, it is common to present a result in the abstract of an article, but the result is actually computed later in the document. Below is an example that illustrates the idea but will not compile:

```
---
title: An important report
abstract: >
  In this analysis, the average value of
  `x` is `r mx`.
---

We create the object `mx` in the following chunk:

```{r}
x <- 1:100
mx <- mean(x)
```
```

To solve this problem, the value of the object has to be saved somewhere and loaded the next time when the document is compiled. Please note that this means the document has to be compiled at least twice. Below is one possible solution using the `saveRDS()` function:

````
```{r, include=FALSE}
mx <- if (file.exists('mean.rds')) {
  readRDS('mean.rds')
} else {
  "The value of `mx` is not available yet"
}
```

---
title: An important report
abstract: >
  In this analysis, the average value of
  `x` is `r mx`.
---

We create the object `mx` in the following chunk:
````

````
```{r}
x <- 1:100
mx <- mean(x)
saveRDS(mx, 'mean.rds')
```
````

The first time you compile this document, you will see the phrase "The value of `mx` is not available yet" in the abstract. Later, when you compile it again, you will see the actual value of `mx`.

The function `knitr::load_cache()` is an alternative solution, which allows you to load the value of an object from a specific code chunk after the chunk has been cached. The idea is similar to the above example, but it will save you the effort of manually saving and loading an object, because the object is automatically saved to the cache database, and you only need to load it via `load_cache()`. Below is the simplified example:

````
---
title: An important report
abstract: >
  In this analysis, the average value of
  `x` is `r knitr::load_cache('mean-x', 'mx')`.
---

We create the object `mx` in the following chunk:

```{r mean-x, cache=TRUE}
x <- 1:100
mx <- mean(x)
```
````

In this example, we added a chunk label `mean-x` to the R code chunk (which is passed to the `load_cache()` function), and cached it using the chunk option `cache = TRUE`. All objects in this code chunk will be saved to the cache database. Again, you will have to compile this document at least twice, so the object `mx` can be correctly loaded from the cache database. If the value of `mx` is not going to be changed in the future, you do not need to compile the document one more time.

If you do not specify the object name in the second argument to `load_cache()`, the whole cache database will be loaded into the current environment. You can then use any objects that were in the cache database before these objects are created later in the document, e.g.,

```r
knitr::load_cache("mean-x")
x  # the object `x`
mx  # the object `mx`
```

14.3 Exit knitting early

Sometimes we may want to exit knitting early and not at the end of the document. For example, we may be working on some analysis and only wish to share the first half of the results, or we may still be working on code at the bottom that is not yet complete. In these situations, we could consider using the `knit_exit()` function in a code chunk, which will end the knitting process after that chunk.

Below is a simple example, where we have a very simple chunk followed by a more time-consuming one:

````
```{r}
1 + 1
knitr::knit_exit()
```

You will only see the above content in the output.

```{r}
Sys.sleep(100)
```
````

Normally you have to wait for 100 seconds, but since we have called `knit_exit()`, the rest of the document will be ignored.

14.4 Generate a plot and display it elsewhere

Normally plots generated in a code chunk are displayed beneath the code chunk, but you can choose to show them elsewhere and (optionally) hide them in the code chunk. Below is an example:

````
We generate a plot in this code chunk but do not show it:

```{r cars-plot, dev='png', fig.show='hide'}
plot(cars)
```

After another paragraph, we introduce the plot:

![A nice plot.](`r knitr::fig_chunk('cars-plot', 'png')`)
````

In the code chunk, we used the chunk option `fig.show='hide'` to hide the plot temporarily. Then in another paragraph, we called the function `knitr::fig_chunk()` to retrieve the path of the plot file, which is usually like `test_files/figure-html/cars-plot-1.png`. You need to pass the chunk label and the graphical device name to `fig_chunk()` for it to calculate the plot file path.

You may see https://stackoverflow.com/a/46305297/559676 for an application of `fig_chunk()` to **blogdown** websites. This function works for any R Markdown output formats. It can be particularly helpful for presenting plots on slides, because the screen space is often limited on slide pages. You may present code on a slide, and reveal the plot on a different slide.

14.5 Modify a plot in a previous code chunk

By default, **knitr** opens a new graphical device to record plots for each new code chunk. This brings a problem: you cannot easily modify a plot from a previous code chunk, because the previous graphical device has been closed. This is usually problematic for base R graphics (not so for grid graphics such as those created from **ggplot2** (Wickham Chang, et al., 2020) because plots can be saved to R objects). For example, if we draw a plot in one code chunk, and add a line to the plot in a later chunk, R will signal an error saying that a high-level plot has not been created, so it could not add the line.

If you want the graphical device to remain open for all code chunks, you may set a **knitr** package option in the beginning of your document device:

```
knitr::opts_knit$set(global.device = TRUE)
```

Please note that it is `opts_knit` instead of the more frequently used `opts_chunk`. You may see the Stack Overflow post https://stackoverflow.com/q/17502050 for an example.

When you no longer need this global graphical device, you can set the option to `FALSE`. Here is a full example:

````
---
title: "Using a global graphical device to record plots"
---

First, turn on a global graphical device:

```{r, include=FALSE}
knitr::opts_knit$set(global.device = TRUE)
```

Draw a plot:

```{r}
par(mar = c(4, 4, 0.1, 0.1))
plot(cars)
```

Add a line to the plot in the previous code chunk:

```{r}
fit <- lm(dist ~ speed, data = cars)
abline(fit)
```
````

```
No longer use the global device:

```{r, include=FALSE}
knitr::opts_knit$set(global.device = FALSE)
```

Draw another plot:

```{r}
plot(pressure, type = 'b')
```
```

14.6 Save a group of chunk options and reuse them (*)

If you frequently use some chunk options, you may save them as a group and reuse them later only using the group name. This can be done with `knitr::opts_template$set(name = list(options))`. Then you can use the chunk option `opts.label` to refer to the group name. For example:

````
```{r, setup, include=FALSE}
knitr::opts_template$set(fullwidth = list(
  fig.width = 10, fig.height = 6,
  fig.retina = 2, out.width = '100%'
))
```

```{r, opts.label='fullwidth'}
plot(cars)
```
````

With `opts.label = 'fullwidth'`, **knitr** will read chunk options from `knitr::opts_template`, and apply them to the current chunk. This can save you some typing effort. If a chunk option is to be used globally in a document, you should consider setting it globally (see

Chapter 11).

You can override options read from `opts.label`, e.g., if you set `fig.height = 7` in the chunk below, the actual `fig.height` will be `7` instead of `6`.

````
```{r, opts.label='fullwidth', fig.height=7}
plot(cars)
```
````

You can save an arbitrary number of grouped options, e.g., `knitr::opts_template$set(group1 = list(...), group2 = list(...))`.

14.7 Use `knitr::knit_expand()` to generate Rmd source

The function `knitr::knit_expand()` "expands" an expression in `{{ }}` (by default) to its value, e.g.,

```r
knitr::knit_expand(text = "The value of `pi` is {{pi}}.")
## [1] "The value of `pi` is 3.14159265358979."
```

```r
knitr::knit_expand(
  text = "The value of `a` is {{a}}, so `a + 1` is {{a+1}}.",
  a = round(rnorm(1), 4)
)
## [1] "The value of `a` is 0.2198, so `a + 1` is 1.2198."
```

This means that if you have an Rmd document that contains some dynamic parts in `{{ }}`, you may apply `knit_expand()` on the document, and then call `knit()` to compile it. For example, here is a template document named `template.Rmd`:

````
# Regression on {{i}}

```{r lm-{{i}}}
lm(mpg ~ {{i}}, data = mtcars)
```
````

We can build linear regression models using `mpg` against all other variables one by one in the `mtcars` dataset:

````
```{r, echo=FALSE, results='asis'}
src = lapply(setdiff(names(mtcars), 'mpg'), function(i) {
  knitr::knit_expand('template.Rmd')
})
res = knitr::knit_child(text = unlist(src), quiet = TRUE)
cat(res, sep = '\n')
```
````

If you find it difficult to understand this example, please see Section 11.11 for the meaning of the chunk option `results = 'asis'`, and Section 16.4 for the usage of `knitr::knit_child()`.

14.8 Allow duplicate labels in code chunks (*)

By default, **knitr** does not allow duplicate code chunk labels in the document. Duplicate labels will result in an error when the document is knitted. This occurs most frequently when a code chunk is copied and pasted within a document. You may have seen an error message like this:

```
processing file: myfile.Rmd
Error in parse_block(g[-1], g[1], params.src, markdown_mode) :
  Duplicate chunk label 'cars'
Calls: <Anonymous> ... process_file -> split_file -> lapply ->
  FUN -> parse_block
Execution halted
```

However, there are scenarios where we may wish to allow duplicate labels. For example, if we have one parent document `parent.Rmd` in which we knit the child document multiple times, it will fail:

```
# settings
```

```
settings <- list(...)

# run once
knit_child("useful_analysis.Rmd")

# new settings
settings <- list(...)

# run again
knit_child("useful_analysis.Rmd")
```

In this scenario, we can allow duplicate labels by setting this global option in R *before* the child document is knitted:

```
options(knitr.duplicate.label = "allow")
```

If you want to allow duplicate labels in the main document instead of the child document, you have to set this option *before* `knitr::knit()` is called. One possible way to achieve that is to set the option in your `~/.Rprofile` file (see the help page `?Rprofile` for more information).

You should set this option with caution. As with most error messages, they are there for a reason. Allowing duplicate chunks can create silent problems with figures and cross references. For example, in theory, if two code chunks have the same label and both chunks generate plots, their plot files will overwrite each other (without error or warning messages), because the filenames of plots are determined by the chunk labels. With the option `knitr.duplicate.label = "allow"`, **knitr** will silently change the duplicate labels by adding numeric suffixes. For example, for the two code chunks:

````
```{r, test}
plot(1:10)
```


```{r, test}
plot(10:1)
````
````

````
```
````

The second label will be silently changed to `test-1`. This may avoid overwriting the plot from the chunk with the label `test`, but it also makes the chunk label unpredictable, so you may have difficulties in cross-referencing figures (see Section 4.7), because the cross references are also based on chunk labels.

14.9 A more transparent caching mechanism

If you feel the caching mechanism of **knitr** introduced in Section 11.4 is too complicated (it is!), you may consider a simpler caching mechanism based on the function `xfun::cache_rds()`, e.g.,

```r
xfun::cache_rds({
  # write your time-consuming code in this expression
})
```

The tricky thing about **knitr**'s caching is how it decides when to invalidate the cache. For `xfun::cache_rds()`, it is much clearer: the first time you pass an R expression to this function, it evaluates the expression and saves the result to a `.rds` file; the next time you run `cache_rds()` again, it reads the `.rds` file and returns the result immediately without evaluating the expression again. The most obvious way to invalidate the cache is to delete the `.rds` file. If you do not want to manually delete it, you may call `xfun::cache_rds()` with the argument `rerun = TRUE`.

When `xfun::cache_rds()` is called inside a code chunk in a **knitr** source document, the path of the `.rds` file is determined by the chunk option `cache.path` and the chunk label. For example, for a code chunk with the chunk label `foo` in the Rmd document `input.Rmd`:

````
```{r, foo}
res <- xfun::cache_rds({
  Sys.sleep(3)
  1:10
})
```
````
````

The path of the `.rds` file will be of the form `input_cache/FORMAT/foo_HASH.rds`, where `FORMAT` is the Pandoc output format name (e.g., `html` or `latex`), and `HASH` is an MD5 hash that contains 32 hexadecimal digits (consisting a-z and 0-9), e.g., `input_cache/html/foo_7a3f22c4309d400eff95de0e8bddac71.rds`.

As documented on the help page `?xfun::cache_rds`, there are two common cases in which you may want to invalidate the cache: 1) the code in the expression to be evaluated has changed; 2) the code uses an external variable, and the value of that variable has changed. Next we will explain how these two ways of cache invalidation work, as well as how to keep multiple copies of the cache corresponding to different versions of the code.

14.9.1 Invalidate the cache by changing code in the expression

When you change the code in `cache_rds()` (e.g., from `cache_rds({x + 1})` to `cache_rds({x + 2})`), the cache will be automatically invalidated and the expression will be re-evaluated. However, please note that changes in white spaces or comments do not matter. Or generally speaking, as long as the change does not affect the parsed expression, the cache will not be invalidated. For example, the two expressions passed to `cache_rds()` below are essentially identical:

```r
res <- xfun::cache_rds({
  Sys.sleep(3  );
  x<-1:10;  # semi-colons won't matter
  x+1;
})

res <- xfun::cache_rds({
  Sys.sleep(3)
  x <- 1:10  # a comment
  x +
    1  # feel free to make any changes in white spaces
})
```

Hence if you have executed `cache_rds()` on the first expression, the second expression will be able to take advantage of the cache. This feature is helpful because it allows you make cosmetic changes in your code without invalidating the cache.

If you are not sure if two versions of code are equivalent, you may try the `parse_code()` below:

```
parse_code <- function(expr) {
  deparse(substitute(expr))
}
# white spaces and semi-colons do not matter
parse_code({x+1})
```

```
## [1] "{"         "    x + 1" "}"
```

```
parse_code({ x   +    1; })
```

```
## [1] "{"         "    x + 1" "}"
```

```
# left arrow and right arrow are equivalent
identical(parse_code({x <- 1}), parse_code({1 -> x}))
```

```
## [1] TRUE
```

14.9.2 Invalidate the cache by changes in global variables

There are two types of variables in an expression: global variables and local variables. Global variables are those created outside the expression, and local variables are those created inside the expression. If the value of a global variable in the expression has changed, your cached result will no longer reflect the result that you would obtain by running the expression again. For example, in the expression below, if `y` has changed, you are most likely to want to invalidate the cache and rerun the expression, otherwise you still get the result from the old value of `y`:

```
y <- 2

res <- xfun::cache_rds({
  x <- 1:10
```

```r
  x + y
})
```

To invalidate the cache when `y` has changed, you may let `cache_rds()` know through the `hash` argument that `y` needs to be considered when deciding if the cache should be invalidated:

```r
res <- xfun::cache_rds({
  x <- 1:10
  x + y
}, hash = list(y))
```

When the value of the `hash` argument is changed, the 32-digit hash in the cache filename (as mentioned earlier) will change accordingly, therefore the cache will be invalidated. This provides a way to specify the cache's dependency on other R objects. For example, if you want the cache to be dependent on the version of R, you may specify the dependency like this:

```r
res <- xfun::cache_rds({
  x <- 1:10
  x + y
}, hash = list(y, getRversion()))
```

Or if you want the cache to depend on when a data file was last modified:

```r
res <- xfun::cache_rds({
  x <- read.csv("data.csv")
  x[[1]] + y
}, hash = list(y, file.mtime("data.csv")))
```

If you do not want to provide this list of global variables to the `hash` argument, you may try `hash = "auto"` instead, which tells `cache_rds()` to try to figure out all global variables automatically and use a list of their values as the value for the `hash` argument, e.g.,

```r
res <- xfun::cache_rds({
  x <- 1:10
  x + y + z  # y and z are global variables
}, hash = "auto")
```

This is equivalent to:

```r
res <- xfun::cache_rds({
  x <- 1:10
  x + y + z  # y and z are global variables
}, hash = list(y = y, z = z))
```

The global variables are identified by `codetools::findGlobals()` when `hash = "auto"`, which may not be completely reliable. You know your own code the best, so we recommend that you specify the list of values explicitly in the `hash` argument if you want to be completely sure which variables can invalidate the cache.

14.9.3 Keep multiple copies of the cache

Since the cache is typically used for time-consuming code, perhaps you should invalidate it conservatively. You might regret invalidating the cache too soon or aggressively, because if you should need an older version of the cache again, you would have to wait for a long time for the computing to be redone.

The `clean` argument of `cache_rds()` allows you to keep older copies of the cache if you set it to `FALSE`. You can also set the global R option `options(xfun.cache_rds.clean = FALSE)` if you want this to be the default behavior throughout the entire R session. By default, `clean = TRUE` and `cache_rds()` will try to delete the older cache every time. Setting `clean = FALSE` can be useful if you are still experimenting with the code. For example, you can cache two versions of a linear model:

```r
model <- xfun::cache_rds({
  lm(dist ~ speed, data = cars)
}, clean = FALSE)

```

```r
model <- xfun::cache_rds({
  lm(dist ~ speed + I(speed^2), data = cars)
}, clean = FALSE)
```

After you decide which model to use, you can set `clean = TRUE` again, or delete this argument (so the default `TRUE` is used).

14.9.4 Comparison with **knitr**'s caching

You may wonder when to use **knitr**'s caching (i.e., set the chunk option `cache = TRUE`), and when to use `xfun::cache_rds()` in a **knitr** source document. The biggest disadvantage of `xfun::cache_rds()` is that it does not cache side effects (but only the value of the expression), whereas **knitr** does. Some side effects may be useful, such as printed output or plots. For example, in the code below, the text output and the plot will be lost when `cache_rds()` loads the cache the next time, and only the value `1:10` will be returned:

```r
xfun::cache_rds({
  print("Hello world!")
  plot(cars)
  1:10
})
```

By comparison, for a code chunk with the option `cache = TRUE`, everything will be cached:

````
```{r, cache=TRUE}
print("Hello world!")
plot(cars)
1:10
```
````

The biggest disadvantage of **knitr**'s caching (and also what users complain most frequently about) is that your cache might be inadvertently invalidated, because the cache is determined by too many factors. For example, any changes in chunk options can invalidate the cache,[*2] but some chunk options may not be relevant to the computing. In the code chunk below, changing the chunk option `fig.width = 6` to `fig.width = 10` should not invalidate the cache, but it will:

````
```{r, cache=TRUE, fig.width=6}
# there are no plots in this chunk
x <- rnorm(1000)
mean(x)
```
````

Actually, **knitr** caching is quite powerful and flexible, and its behavior can be tweaked in many ways. As its author, I often doubt if it is worth introducing these lesser-known features, because you may end up spending much more time on learning and understanding how the cache works than the time the actual computing takes.

In case it is not clear, `xfun::cache_rds()` is a general way for caching the computing, and it works anywhere, whereas **knitr**'s caching only works in **knitr** documents.

[*2] This is the default behavior, and you can change it. See https://yihui.org/knitr/demo/cache/ for how you can make the cache more granular, so not all chunk options affect the cache.

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Other Languages

Besides the R language, many other languages are supported in R Markdown through the **knitr** package. The language name is indicated by the first word in the curly braces after the three opening backticks. For example, the little `r` in ```` ```{r} ```` indicates that the code chunk contains R code, and ```` ```{python} ```` is a Python code chunk. In this chapter, we show a few languages that you may not be familiar with.

In **knitr**, each language is supported through a language engine. Language engines are essentially functions that take the source code and options of a chunk as the input, and return a character string as the output. They are managed through the object `knitr::knit_engines`. You may check the existing engines via:

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

```
##  [1] "awk"       "bash"      "coffee"    "gawk"
##  [5] "groovy"    "haskell"   "lein"      "mysql"
##  [9] "node"      "octave"    "perl"      "psql"
## [13] "Rscript"   "ruby"      "sas"       "scala"
## [17] "sed"       "sh"        "stata"     "zsh"
## [21] "highlight" "Rcpp"      "tikz"      "dot"
## [25] "c"         "cc"        "fortran"   "fortran95"
## [29] "asy"       "cat"       "asis"      "stan"
## [33] "block"     "block2"    "js"        "css"
## [37] "sql"       "go"        "python"    "julia"
## [41] "sass"      "scss"
```

At the moment, most code chunks of non-R languages are executed independently. For example, all `bash` code chunks in the same document are executed separately in their own sessions, so a later `bash` code chunk cannot use variables created in a previous `bash` chunk, and the changed working directory (via `cd`) will not be persistent across different `bash` chunks. Only R, Python, and Julia code chunks are executed in the same session. Please note that all R code chunks are executed in the same R session, and all Python code chunks are executed in the same Python session, etc. The R session and the Python session are two different sessions, but it is possible to access or manipulate objects of one session from another session (see Section 15.2).

Section 2.7[*1] of the *R Markdown Definitive Guide* (Xie J.J. Allaire, and Grolemund, 2018) shows examples of using Python, Shell, SQL, Rcpp, Stan, JavaScript, CSS, Julia, C, and Fortran code in R Markdown. In this chapter, we will show more language engines, and you may find more examples in the repository at https://github.com/yihui/knitr-examples (look for filenames that contain the word "engine").

First, let's reveal how a language engine works by registering a custom language engine.

15.1 Register a custom language engine (*)

You can register a custom language engine via the method `knitr::knit_engines$set()`. It accepts a function as its input, e.g.,

```
knitr::knit_engines$set(foo = function(options) {
  # the source code is in options$code; just do whatever
  # you want with it
})
```

This registers the `foo` engine, and you will be able to use a code chunk that starts with ` ```{foo}`.

The engine function has one argument, `options`, which is a list of chunk options of the code chunk. You can access the source code of the chunk as a character vector in `options$code`. For example, for the code chunk:

[*1] https://bookdown.org/yihui/rmarkdown/language-engines.html

````
```{foo}
1 + 1
2 + 2
```
````

The code element of options would be a character vector `c('1 + 1', '2 + 2')`.

Language engines do not really have to deal with computer languages, but can process any text in a code chunk. First, we show a simple example of an engine that converts the content of a code chunk to uppercase:

```r
knitr::knit_engines$set(upper = function(options) {
  code <- paste(options$code, collapse = "\n")
  if (options$eval)
    toupper(code) else code
})
```

The key is that we apply the function `toupper` to the "code," and return the result as a single character string (by concatenating all lines of code by `\n`). Note that `toupper()` is applied only when the chunk option `eval = TRUE`, otherwise the original string is returned. This shows you how to make use of chunk options like `eval` inside the engine function. Similarly, you may consider adding `if (options$results == 'hide') return()` to the function body to hide the output when the chunk option `results = 'hide'`. Below is an example chunk that uses the `upper` engine, with its output:

> ````
> ```{upper}
> Hello, **knitr** engines!
> ```
> ````
>
> HELLO, **KNITR** ENGINES!

Next we show an example of an alternative Python engine[*2] named `py`. This engine is implemented by simply calling the `python` command via the R function `system2()`:

[*2] In practice, you should use the built-in `python` engine instead, which is based on the **reticulate** package and supports Python code chunks much better (see Section 15.2).

```r
knitr::knit_engines$set(py = function(options) {
  code <- paste(options$code, collapse = '\n')
  out  <- system2(
    'python', c('-c', shQuote(code)), stdout = TRUE
  )
  knitr::engine_output(options, code, out)
})
```

To fully understand the above engine function, you need to know the following:

1. Given Python code as a character string (`code` in the above function), we can execute the code via a command-line call `python -c 'code'`. That is what `system2()` does. We collect the (text) output by specifying `stdout = TRUE` in `system2()`.
2. You can pass the chunk options, source code, and text output to the function `knitr::engine_output()` to generate the final output. This function deals with common chunk options like `echo = FALSE` and `results = 'hide'`, so you do not need to take care of these cases.

A lot of language engines in **knitr** are defined in this way (i.e., using `system2()` to execute commands corresponding to languages). If you are curious about the technical details, you may check out the source code of most language engines in the R source code here: https://github.com/yihui/knitr/blob/master/R/engine.R.

Now we can use the new engine `py`, e.g.,

````
```{py}
print(1 + 1)
```
````

```
## 2
```

You can even override existing language engines in **knitr** via `knitr::knit_engines$set()`, if you are sure that your versions are necessary or better than the existing ones. Usually we do not recommend that you do this because it may surprise users who are familiar with existing engines, but we want to make you aware of this possibility anyway.

15.2 Run Python code and interact with Python

We know you love Python, so let's make it super clear: R Markdown and **knitr** do support Python.

To add a Python code chunk to an R Markdown document, you can use the chunk header `` ```{python} ``, e.g.,

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

You can add chunk options to the chunk header as usual, such as `echo = FALSE` or `eval = FALSE`. Plots drawn with the **matplotlib** package in Python are also supported.

The Python support in R Markdown and **knitr** is based on the **reticulate** package (Ushey JJ Allaire, and Tang, 2020), and one important feature of this package is that it allows two-way communication between Python and R. For example, you may access or create Python variables from the R session via the object `py` in **reticulate**:

````
```{r, setup}
library(reticulate)
```

Create a variable `x` in the Python session:

```{python}
x = [1, 2, 3]
```

Access the Python variable `x` in an R code chunk:

```{r}
py$x
```
````

````
Create a new variable `y` in the Python session using R,
and pass a data frame to `y`:

```{r}
py$y <- head(cars)
```

Print the variable `y` in Python:

```{python}
print(y)
```
````

For more information about the **reticulate** package, you may see its documentation at https://rstudio.github.io/reticulate/.

15.3 Execute content conditionally via the `asis` engine

As its name indicates, the `asis` engine writes out the chunk content as is. The advantage of using this engine is that you can include some content conditionally—the display of the chunk content is decided by the chunk option `echo`. When `echo = FALSE`, the chunk will be hidden. Below is a simple example:

````
```{r}
getRandomNumber <- function() {
  sample(1:6, 1)
}
```

```{asis, echo = getRandomNumber() == 4}
According to https://xkcd.com/221/, we just generated
a **true** random number!
```
````

The text in the asis chunk will be displayed only if the condition `getRandomNumber() == 4` is (randomly) true.

15.4 Execute Shell scripts

You can run Shell scripts via the `bash` or `sh` or `zsh` engine, depending on which shell you prefer. Below is a `bash` example, with the chunk header ```` ```{bash} ````:

```
ls *.Rmd | head -n 5
```

```
## 00-authors.Rmd
## 01-installation.Rmd
## 02-overview.Rmd
## 03-basics.Rmd
## 04-content.Rmd
```

Please note that `bash` is invoked with the R function `system2()`. It will ignore profile files like `~/.bash_profile` and `~/.bash_login`, in which you may have defined command aliases or modified environment variables like the `PATH` variable. If you want these profile files to be executed just like when you use the terminal, you may pass the argument `-l` to `bash` via `engine.opts`, e.g.,

````
```{bash, engine.opts='-l'}
echo $PATH
```
````

If you want to enable the `-l` argument globally for all `bash` chunks, you may set it in the global chunk option in the beginning of your document:

```
knitr::opts_chunk$set(engine.opts = list(bash = "-l"))
```

You can also pass other arguments to `bash` by providing them as a character vector to the chunk option `engine.opts`.

15.5 Visualization with D3

The R package **r2d3** (Strayer Luraschi, and JJ Allaire, 2020) is an interface to D3 visualizations. This package can be used in R Markdown documents as well as other applications (e.g., Shiny). To use it in R Markdown, you can either call its function `r2d3()` in a code chunk, or use its `d3` engine. The latter requires you to understand the D3 library and JavaScript, which are beyond the scope of this book, and we will leave it to readers to learn them. Below is an example of using the `d3` engine to draw a bar chart:

````
---
title: Generate a chart with D3
output: html_document
---

First, load the package **r2d3** to set up the `d3` engine
for **knitr** automatically:

```{r setup}
library(r2d3)
```

Now we can generate data in R, pass it to D3, and draw
the chart:

```{d3, data=runif(30), options=list(color='steelblue')}
svg.selectAll('rect')
  .data(data)
  .enter()
    .append('rect')
      .attr('width', function(d) { return d * 672; })
      .attr('height', '10px')
      .attr('y', function(d, i) { return i * 16; })
      .attr('fill', options.color);
```
````

15.6 Write the chunk content to a file via the `cat` engine

Sometimes it could be useful to write the content of a code chunk to an external file, and use this file later in other code chunks. Of course, you may do this via the R functions like `writeLines()`, but the problem is that when the content is relatively long, or contains special characters, the character string that you would pass to `writeLines()` may look awkward. Below is an example of writing a long character string to a file `my-file.txt`:

```
writeLines("This is a long character string.
It has multiple lines. Remember to escape
double quotes \"\", but 'single quotes' are OK.
I hope you not to lose your sanity when thinking
about how many backslashes you need, e.g., is it
'\t' or '\\t' or '\\\\t'?",
  con = "my-file.txt")
```

This problem has been greatly alleviated since R 4.0.0, because R started to support raw strings in `r"( )"` (see the help page `?Quotes`), and you do not need to remember all the rules about special characters. Even with raw strings, it can still be a little distracting for readers to see a long string written to a file explicitly in a code chunk.

The `cat` engine in **knitr** has provided a way for you to present text content in a code chunk and/or write it to an external file, without thinking about all the rules about R's character strings (e.g., you need double backslashes when you need a literal backslash).

To write the chunk content to a file, specify the file path in the chunk option `engine.opts`, e.g., `engine.opts = list(file = 'path/to/file')`. Under the hood, the list of values specified in `engine.opts` will be passed to the function `base::cat()`, and `file` is one of the arguments of `base::cat()`.

Next we will present three examples to illustrate the use of the `cat` engine.

15.6.1 Write to a CSS file

As shown in Section 7.3, you can embed a `css` code chunk in an Rmd document to style elements with CSS. An alternative way is to provide a custom CSS file to Pandoc via the css option of some R Markdown output formats such as `html_document`. The `cat` engine can be used to write this CSS file from Rmd.

This example below shows how to generate a file `custom.css` from a chunk in the document, and pass the file path to the css option of the `html_document` format:

````
---
title: "Create a CSS file from a code chunk"
output:
  html_document:
    css: custom.css
---

The chunk below will be written to `custom.css`, which
will be used during the Pandoc conversion.

```{cat, engine.opts = list(file = "my_custom.css")}
h2 {
  color: blue;
}
```

## And this title will blue
````

The only difference between the css code chunk approach and this approach is that the former approach writes the CSS code in place (i.e., in the place of the code chunk), which is inside the <body> tag of the output document, and the latter approach writes CSS to the <head> area of the output document. There will not be any practical visual differences in the output document.

15.6.2 Include LaTeX code in the preamble

In Section 6.1, we introduced how to add LaTeX code to the preamble, which requires an external `.tex` file. This file can also be generated from Rmd, and here is an example:

````
---
title: "Create a .tex file from a chunk"
author: "Jane Doe"
classoption: twoside
output:
  pdf_document:
    includes:
      in_header: preamble.tex
---

# How it works

Write a code chunk to a file `preamble.tex` to define
the header and footer of the PDF output document:

```{cat, engine.opts=list(file = 'preamble.tex')}
\usepackage{fancyhdr}
\usepackage{lipsum}
\pagestyle{fancy}
\fancyhead[CO,CE]{This is fancy header}
\fancyfoot[CO,CE]{And this is a fancy footer}
\fancyfoot[LE,RO]{\thepage}
\fancypagestyle{plain}{\pagestyle{fancy}}
```

\lipsum[1-15]

# More random content

\lipsum[16-30]
````

In the LaTeX code in the cat code chunk above, we have defined the header and footer of the PDF document. If we also want to show the author name in the footer, we can append the author information to `preamble.tex` in another `cat` code chunk with options `engine.opts = list(file = 'preamble.tex', append = TRUE)` and `code =`

`sprintf('\\fancyfoot[LO,RE]{%s}', rmarkdown::metadata$author)`. To understand how this works, recall that we mentioned earlier in this section that `engine.opts` is passed to `base::cat()` (so `append = TRUE` is passed to `cat()`), and you may understand the chunk option `code` by reading Section 16.2.

15.6.3 Write YAML data to a file and also display it

By default, the content of the `cat` code chunk will not be displayed in the output document. If you also want to display it after writing it out, set the chunk option `class.source` to a language name. The language name is used for syntax highlighting. In the example below, we specify the language to be `yaml`:

````
```{cat, engine.opts=list(file='demo.yml'), class.source='yaml'}
a:
  aa: "something"
  bb: 1
b:
  aa: "something else"
  bb: 2
```
````

Its output is displayed below, and it also generated a file `demo.yml`.

```yaml
a:
  aa: "something"
  bb: 1
b:
  aa: "something else"
  bb: 2
```

To show the file `demo.yml` is really generated, we can try to read it into R with the **yaml** package (J. Stephens Simonov, et al., 2020):

```r
xfun::tree(yaml::read_yaml("demo.yml"))
```

```
## List of 2
```

```
##  |-a:List of 2
##  |  |-aa: chr "something"
##  |  |-bb: int 1
##  |-b:List of 2
##     |-aa: chr "something else"
##     |-bb: int 2
```

15.7 Run SAS code

You may run SAS (https://www.sas.com) code using the sas engine. You need to either make sure the SAS executable is in your environment variable PATH, or (if you do not know what PATH means) provide the full path to the SAS executable via the chunk option engine.path, e.g., engine.path = "C:\\Program Files\\SASHome\\x86\\SASFoundation\\9.3\\sas.exe". Below is an example to print out "Hello World":

````
```{sas}
data _null_;
put 'Hello, world!';
run;
```
````

15.8 Run Stata code

You can run Stata (https://www.stata.com) code with the stata engine if you have installed Stata. Unless the stata executable can be found via the environment variable PATH, you need to specify the full path to the executable via the chunk option engine.path, e.g., engine.path = "C:/Program Files (x86)/Stata15/StataSE-64.exe". The following is a quick example:

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

The stata engine in **knitr** is quite limited. Doug Hemken has substantially extended it in the **Statamarkdown** package, which is available on GitHub at https://github.com/Hemken/Statamarkdown. You may find tutorials about this package by searching online for "Stata R Markdown."

15.9 Create graphics with Asymptote

Asymptote (https://asymptote.sourceforge.io) is a powerful language for vector graphics. You may write and run Asymptote code in R Markdown with the `asy` engine if you have installed Asymptote (see its website for instructions on the installation). Below is an example copied from the repository https://github.com/vectorgraphics/asymptote, and its output is shown in Figure 15.1:

```
import graph3;
import grid3;
import palette;
settings.prc = false;

currentprojection=orthographic(0.8,1,2);
size(500,400,IgnoreAspect);

real f(pair z) {return cos(2*pi*z.x)*sin(2*pi*z.y);}

surface s=surface(f,(-1/2,-1/2),(1/2,1/2),50,Spline);

surface S=planeproject(unitsquare3)*s;
S.colors(palette(s.map(zpart),Rainbow()));
draw(S,nolight);
draw(s,lightgray+opacity(0.7));

grid3(XYZgrid);
```

Note that for PDF output, you may need some additional LaTeX packages, otherwise you may get an error that looks like this:

```
! LaTeX Error: File `ocgbase.sty' not found.
```

If such an error occurs, please see Section 1.3 for how to install the missing LaTeX pack-

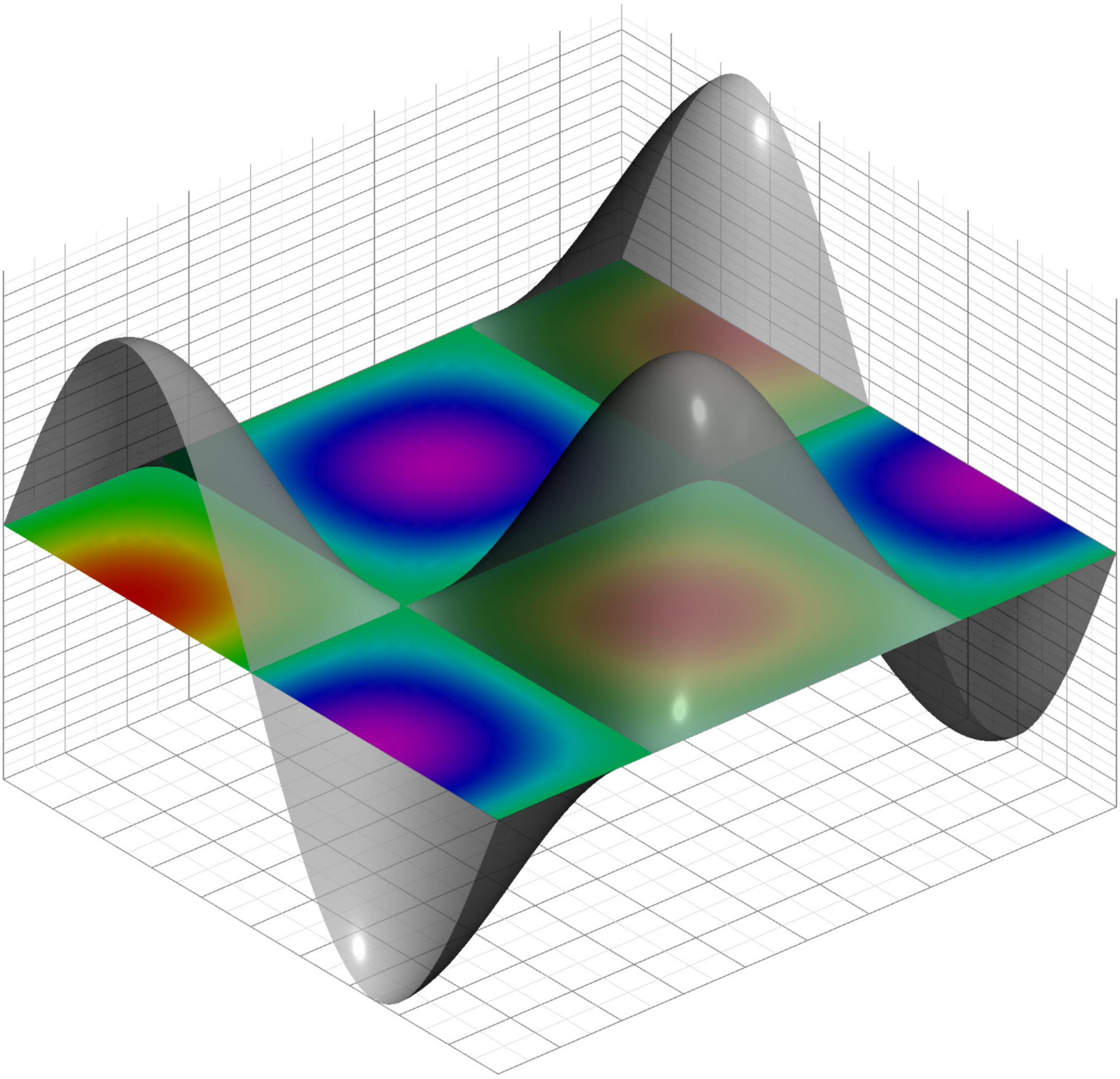

図15.1: A 3D graph made with Asymptote.

ages.

In the `asy` chunk above, we used the setting `settings.prc = false`. Without this setting, Asymptote generates an interactive 3D graph when the output format is PDF. However, the interactive graph can only be viewed in Acrobat Reader. If you use Acrobat Reader, you can interact with the graph. For example, you can rotate the 3D surface in Figure 15.1 with your mouse.

15.9.1 Generate data in R and read it in Asymptote

Now we show an example in which we first save data generated in R to a CSV file (below is an R code chunk):

```
x <- seq(0, 5, l = 100)
y <- sin(x)
writeLines(paste(x, y, sep = ","), "sine.csv")
```

Then read it in Asymptote, and draw a graph based on the data as shown in Figure 15.2 (below is an asy code chunk):

```
import graph;
size(400,300,IgnoreAspect);
settings.prc = false;

// import data from csv file
file in=input("sine.csv").line().csv();
real[][] a=in.dimension(0,0);
a=transpose(a);

// generate a path
path rpath = graph(a[0],a[1]);
path lpath = (1,0)--(5,1);

// find intersection
pair pA=intersectionpoint(rpath,lpath);

// draw all
draw(rpath,red);
draw(lpath,dashed + blue);
dot("$\delta$",pA,NE);
xaxis("$x$",BottomTop,LeftTicks);
yaxis("$y$",LeftRight,RightTicks);
```

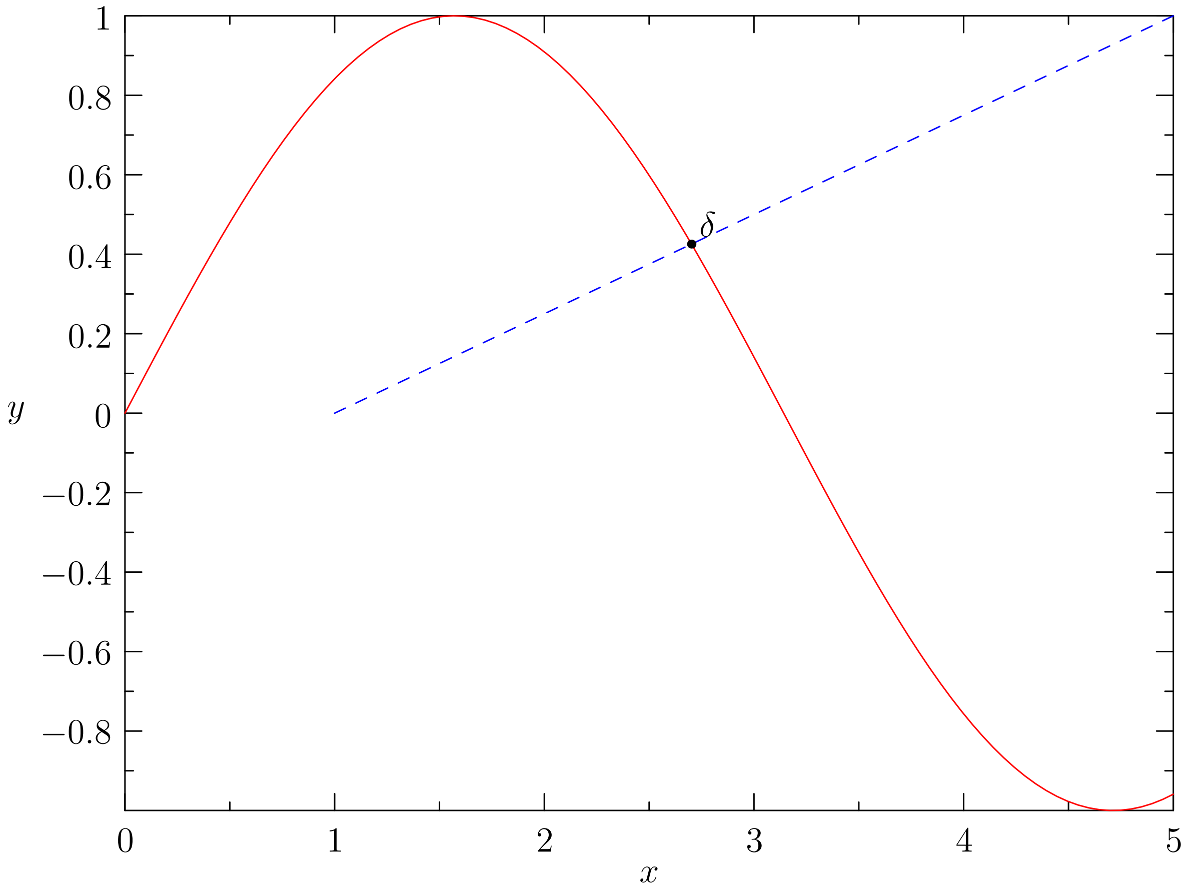

図15.2: Pass data from R to Asymptote to draw a graph.

15.10 Style HTML pages with Sass/SCSS

Sass (`https://sass-lang.com`) is a CSS extension language that allows you to create CSS rules in much more flexible ways than you'd do with plain CSS. Please see its official documentation if you are interested in learning it.

The R package **sass** (Cheng Mastny, et al., 2020) can be used to compile Sass to CSS. Based on the **sass** package, **knitr** includes two language engines: `sass` and `scss` (corresponding to the Sass and SCSS syntax, respectively) to compile code chunks to CSS. Below is a `scss` code chunk, with the chunk header ```` ```{scss} ````:

```
$font-stack: "Comic Sans MS", cursive, sans-serif;
$primary-color: #00FF00;
```

```

.book.font-family-1 {
  font: 100% $font-stack;
  color: $primary-color;
}
```

You can also use the sass engine, and the Sass syntax is slightly different with the SCSS syntax, e.g.,

````
```{sass}
$font-stack: "Comic Sans MS", cursive, sans-serif
$primary-color: #00FF00

.book.font-family-1
  font: 100% $font-stack
  color: $primary-color
```
````

If you are reading the HTML version of this section,[*3] you will notice that the font for this page has been changed to Comic Sans, which might be surprising, but please do not panic—you are not having a stroke.[*4]

The sass/scss code chunks are compiled through the `sass::sass()` function. Currently you can customize the output style for the CSS code via the chunk option `engine.opts`, e.g., `engine.opts = list(style = "expanded")`. The default style is "compressed." If you are not sure what this means, please refer to the help page `?sass::sass_options` and look for the `output_style` argument.

[*3] https://bookdown.org/yihui/rmarkdown-cookbook/eng-sass.html
[*4] https://twitter.com/andrewheiss/status/1250438044542361600

第 16 章

Managing Projects

When you work on larger projects or reports, you may not want to put all text and code in a single R Markdown document, but organize them in smaller units instead. In this chapter, we introduce tips on how to organize multiple files related to R Markdown.

16.1 Source external R scripts

If your R Markdown document has a large amount of code, you may consider putting some code in external R scripts, and run these scripts via `source()` or `sys.source()`, e.g.,

````
```{r, include=FALSE}
source("your-script.R", local = knitr::knit_global())
# or sys.source("your-script.R", envir = knitr::knit_global())
```
````

We recommend that you use the argument `local` in `source()` or `envir` in `sys.source()` explicitly to make sure the code is evaluated in the correct environment, i.e., `knitr::knit_global()`. The default values for them may not be the appropriate environment: you may end up creating variables in the wrong environment, and being surprised that certain objects are not found in later code chunks.

Next in the R Markdown document, you can use objects created in these scripts (e.g., data objects or functions). This way will not only make your R Markdown document cleaner, but also make it more convenient for you to develop R code (e.g., debugging R code is often easier with pure R scripts than R Markdown).

Note that we used `include = FALSE` in the above example because we only want to execute the script without showing any output. If you do want output, you may remove this chunk option, or use the options in Section 11.7 to selectively hide or show different types of output.

16.2 Read external scripts into a chunk

There is a disadvantage of the `source()` method in Section 16.1. That is, you will not be able to see the source code by default. You can use `source(..., echo = TRUE)`, but the source code will not be properly syntax highlighted. Besides, you need to be careful about the `local` argument of `source()`, as mentioned in Section 16.1. In this section, we introduce an alternative method that does not have these problems.

Basically, when you have one or more external scripts, you may read them and pass the content to the `code` option of a chunk. The `code` option can take a character vector and treat it as the content of the code chunk. Below we show a few examples.

- The `code` option can take a character vector of source code. For example:

````
```{r, code=c('1 + 1', 'if (TRUE) plot(cars)')}
```
````

- You can also read an external file:

````
```{r, code=xfun::read_utf8('your-script.R')}
```
````

- You can read as many scripts as you want:

````
```{r, include=FALSE}
read_files <- function(files) {
  unlist(lapply(files, xfun::read_utf8))
}
```

```{r, code=read_files(c('one.R', 'two.R'))}
````
````

```
```
```

You can read scripts of other languages, too. See Chapter 15 for how to use other languages in R Markdown. Here are a few more examples on non-R code.

- Read a Python script:

````
```{python, code=xfun::read_utf8('script.py')}
```
````

- Read a C++ file:

````
```{Rcpp, code=xfun::read_utf8('file.cpp')}
```
````

With the code option, you can develop complicated code in your favorite editor, and read it into a code chunk of an R Markdown document.

## 16.3 Read multiple code chunks from an external script (*)

In Section 16.2, we introduced a way to read code into a single code chunk. In this section, we introduce one method to read multiple code chunks from an external script. The key is that you need to label the code in the script, and you can use the same labels in the code chunks in your R Markdown document, so the code in the external script can be mapped to the code chunks via the function `knitr::read_chunk()`. To label a block of code in a script, you write the label after `## ----` (optionally, you can add a series of dashes to the end of this line). One script can contain multiple labeled code blocks, e.g.,

```
## ---- test-a --------
1 + 1

## ---- test-b --------
if (TRUE) {
  plot(cars)
}
```
```

We assume that the filename of the above script is `test.R`. In the R Markdown document, we can read it via `knitr::read_chunk()`, and use the code in code chunks with the labels, e.g.,

````
Read an external script:

```{r, include=FALSE, cache=FALSE}
knitr::read_chunk('test.R')
```

Now we can use the code, e.g.,

```{r, test-a, echo=FALSE}
```

```{r, test-b, fig.height=4}
```
````

Note that we use `knitr::read_chunk()` mainly for its side effect, so please make sure the code chunk in which you call this function is not cached (see Section 11.4 for the explanation).

Like methods introduced in Section 16.1 and Section 16.2, this method also gives you the flexibility of developing code in a separate environment.

16.4 Child documents (*)

When you feel an R Markdown document is too long, you may consider splitting it into shorter documents, and include them as child documents of the main document via the chunk option `child`. The `child` option takes a character vector of paths to the child documents, e.g.,

````
```{r, child=c('one.Rmd', 'two.Rmd')}
```
````

Since **knitr** chunk options can take values from arbitrary R expressions, one application of the `child` option is the conditional inclusion of a document. For example, if your report has an appendix containing technical details that your boss may not be interested in, you may use a variable to control whether this appendix is included in the report:

````
Change `BOSS_MODE` to `TRUE` if this report is to be read
by the boss:

```{r, include=FALSE}
BOSS_MODE <- FALSE
```

Conditionally include the appendix:

```{r, child=if (!BOSS_MODE) 'appendix.Rmd'}
```
````

Or if you are writing a news report on a football game that has not taken place yet, you may include different child documents depending on the outcome, e.g., `child = if (winner == 'brazil') 'brazil.Rmd' else 'germany.Rmd'`. Then as soon as the game (between Germany and Brazil) is finished, you can publish your report.

Another way to compile child documents is the function `knitr::knit_child()`. You can call this function in an R code chunk or an inline R expression, e.g.,

````
```{r, echo=FALSE, results='asis'}
res <- knitr::knit_child('child.Rmd', quiet = TRUE)
cat(res, sep = '\n')
```
````

The function `knit_child()` returns a character vector of the knitted output, which we can write back to the main document with `cat()` and the chunk option `results = 'asis'`.

You can even use a child document as a template, and call `knit_child()` on it repeatedly with different parameters. In the example below, we run a regression using `mpg` as the response variable and each of the rest of variables in the `mtcars` data as the explanatory variable.

~~~~
```{r, echo=FALSE, results='asis'}
res <- lapply(setdiff(names(mtcars), 'mpg'), function(x) {
  knitr::knit_child(text = c(
    '## Regression on "`r x`"',
    '',
    '```{r}',
    'lm(mpg ~ ., data = mtcars[, c("mpg", x)])',
    '```',
    ''
  ), envir = environment(), quiet = TRUE)
})
cat(unlist(res), sep = '\n')
```
~~~~

To make the above example self-contained, we used the `text` argument of `knit_child()` instead of a file input to pass the R Markdown content to be knitted. You can certainly write the content to a file, and pass a path to `knit_child()` instead. For example, you can save the content below to a file named `template.Rmd`:

~~~~
## Regression on "`r x`"

```{r}
lm(mpg ~ ., data = mtcars[, c("mpg", x)])
```
~~~~

And knit the file instead:

```
res <- lapply(setdiff(names(mtcars), 'mpg'), function(x) {
  knitr::knit_child(
    'template.Rmd', envir = environment(), quiet = TRUE
  )
})
cat(unlist(res), sep = '\n')
```

16.5 Keep the plot files

Most R Markdown output formats use the option `self_contained = TRUE` by default. This causes R plots to be embedded in the output documents, so we do not need the intermediate plot files when viewing the output documents. As a consequence, the plot folder (which typically has a suffix `_files`) will be deleted after the Rmd document is rendered.

Sometimes you may want to keep the plot files. For example, some academic journals require authors to submit figures files separately. For R Markdown, there are three ways to avoid the automatic deletion of these files:

1. Use the option `self_contained = FALSE` if the output format supports this option, e.g.,

   ```
   output:
     html_document:
       self_contained: false
   ```

   However, this means the plot files will not be embedded in the output document. If this is not what you want, you may consider the next two methods.

2. Enable caching for at least one code chunk (see Section 11.4). When caching is enabled, R Markdown will not delete the plot folder.

3. Use the option `keep_md = TRUE` if the output format supports this option, e.g.,

   ```
   output:
     word_document:
       keep_md: true
   ```

   When you ask R Markdown to preserve the intermediate Markdown output file, it will also preserve the plot folder.

16.6 The working directory for R code chunks

By default, the working directory for R code chunks is the directory that contains the Rmd document. For example, if the path of an Rmd file is `~/Downloads/foo.Rmd`, the working directory under which R code chunks are evaluated is `~/Downloads/`. This means when you refer to external files with relative paths in code chunks, you need to know that these paths are relative to the directory of the Rmd file. With the aforementioned Rmd example file, `read.csv("data/iris.csv")` in a code chunk means reading the CSV file `~/Downloads/data/iris.csv`.

When in doubt, you can add `getwd()` to a code chunk, compile the document, and check the output from `getwd()`.

Sometimes you may want to use another directory as the working directory. The usual way to change the working directory is `setwd()`, but please note that `setwd()` is not persistent in R Markdown (or other types of **knitr** source documents), which means `setwd()` only works for the current code chunk, and the working directory will be restored after this code chunk has been evaluated.

If you want to change the working directory for all code chunks, you may set it via a `setup` code chunk in the beginning of your document:

````
```{r, setup, include=FALSE}
knitr::opts_knit$set(root.dir = '/tmp')
```
````

This will change the working directory of all subsequent code chunks.

If you use RStudio, you can also choose the working directory from the menu `Tools -> Global Options -> R Markdown` (see Figure 16.1). The default working directory is the directory of the Rmd file, and there are two other possible choices: you may use the current working directory of your R console (the option "Current"), or the root directory of the project that contains this Rmd file as the working directory (the option "Project").

In RStudio, you may also knit an individual Rmd document with a specific working directory, as shown in Figure 16.2. After you change the "Knit Directory" and click the "Knit" button, **knitr** will use the new working directory to evaluate your code chunks. All these

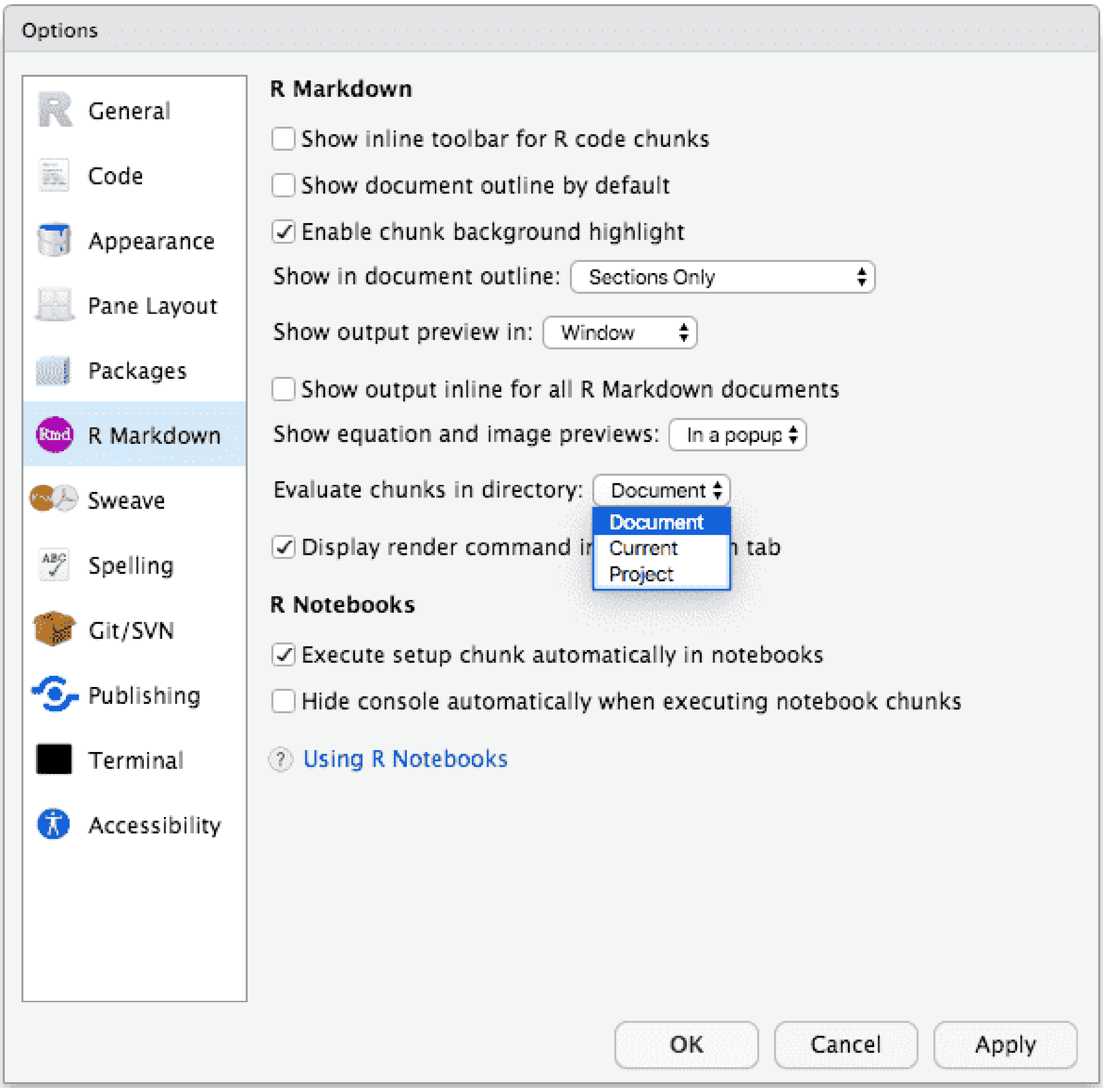

図16.1: Change the default working directory for all R Markdown documents in RStudio.

settings boil down to `knitr::opts_knit$set(root.dir = ...)` as we mentioned earlier, so if you are not satisfied by any of these choices, you can specify a directory by yourself with `knitr::opts_knit$set()`.

There is no absolutely correct choice for the working directory. Each choice has its own pros and cons:

- If you use the Rmd document directory as the working directory for code chunks (**knitr**'s default), you assume that file paths are relative to the Rmd document. This is similar to how web browsers handle relative paths, e.g., for an image `<img`

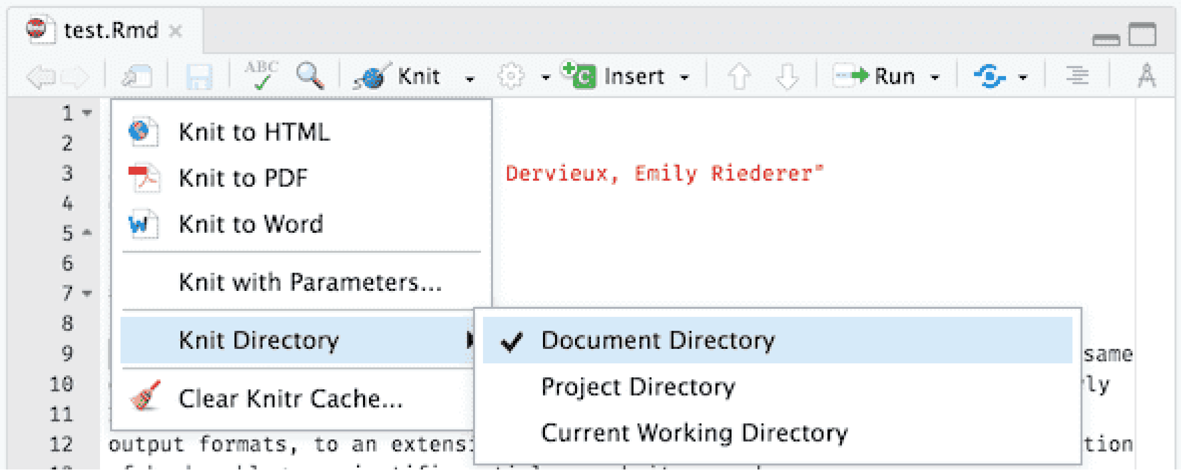

図16.2: Knit an Rmd document with other possible working directories in RStudio.

`src="foo/bar.png" />` on an HTML page `https://www.example.org/path/to/page.html`, your web browser will try to fetch the image from `https://www.example.org/path/to/foo/bar.png`. In other words, the relative path `foo/bar.png` is relative to the directory of the HTML file, which is `https://www.example.org/path/to/`.

The advantage of this approach is that you can freely move the Rmd file *together with* its referenced files anywhere, as long as their relative locations remain the same. For the HTML page and image example above, the files `page.html` and `foo/bar.png` could be moved together to a different directory, such as `https://www.example.org/another/path/`, and you will not need to update the relative path in the `src` attribute of `<img />`.

Some users like to think of relative paths in Rmd documents as "relative to the working directory of the R console," as opposed to "relative to the Rmd file." Therefore **knitr**'s default working directory feels confusing. The reason that I did not use the working directory of the R console as the default when I designed **knitr** was that users could use `setwd()` to change the working directory at any time. This working directory is not guaranteed to be stable. Each time a user calls `setwd()` in the console, there is a risk that the file paths in the Rmd document may become invalid. It could be surprising that the file paths depend on an external factor (`setwd()`), which is out of the control of the Rmd file. If you treat the Rmd file as "the center of the universe" when thinking of relative paths, the paths inside the Rmd file may be stabler.

Furthermore, if you do not want to think too hard on relative paths, you may enter a path in RStudio using its autocomplete, as shown in Figure 16.3. RStudio will try to autocomplete a path relative to the Rmd file.

- Using the working directory of the R console can be a good choice for knitting documents programmatically or interactively. For example, you may knit a document multiple times in a loop, and use a different working directory each time to read a different data file (with the same filename) in that directory. This type of working directory is advocated by the **ezknitr** package (Attali, 2016), which essentially uses `knitr::opts_knit$set(root.dir)` to change the working directory for code chunks in **knitr**.

- Using the project directory as the working directory requires an obvious assumption: you have to use a project (e.g., an RStudio project or a version control project) in the first place, which could be a disadvantage of this approach. The advantage of this type of working directory is that all relative paths in any Rmd document are relative to the project root directory, so you do not need to think where your Rmd file is located in the project or adjust the relative paths of other files accordingly. This type of working directory is advocated by the **here** package (Müller, 2020), which provides the function `here::here()` to return an absolute path by resolving a relative path passed to it (remember that the relative path is relative to the project root). The disadvantage is that when you move the referenced file together with the Rmd file to another location in the project, you need to update the referenced path in the Rmd document. When you share the Rmd file with other people, you also have to share the whole project.

  These types of paths are similar to absolute paths without the protocol or domain in HTML. For example, an image `<img src="/foo/bar.png" />` on the page `https://www.example.org/path/to/page.html` refers to the image under the root directory of the website, i.e., `https://www.example.org/foo/bar.png`. The leading `/` in the `src` attribute of the image indicates the root directory of the website. If you want to learn more (or further confuse yourself) about absolute and relative paths in HTML, please see Appendix B.1 of the **blogdown** book[*1] (Xie Hill, and Thomas, 2017).

The working directory pain mainly arises from this question when dealing with relative paths: *relative to what?* As we mentioned earlier, different people have different preferences, and there is not an absolutely right answer.

[*1] https://bookdown.org/yihui/blogdown/html.html

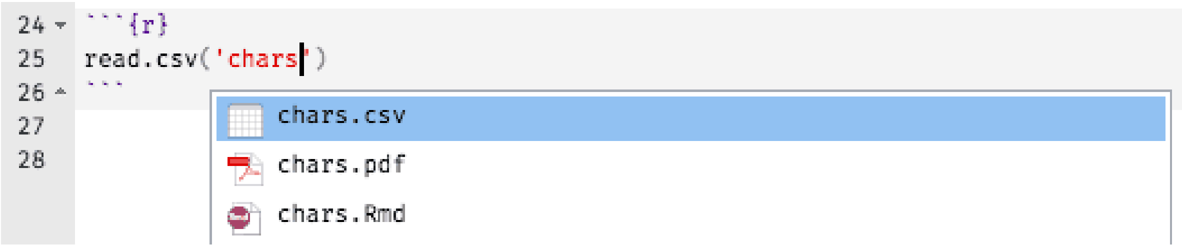

図16.3: Autocomplete file paths in an Rmd document in RStudio.

16.7 R package vignettes

If you have experience in developing R packages, or your project requires clear documentation and rigorous tests for custom functions written in the project, you may consider organizing the project as an R package. If you do not know how to create an R package, you can easily get started in the RStudio IDE by clicking the menu `File -> New Project`, and selecting the project type to be an R package.

There are a lot of benefits of using an R package to manage a project. For example, you can place datasets in the `data/` folder, write R code under `R/`, generate documentation (e.g., using the **roxygen2** package (Wickham Danenberg, et al., 2020)) to `man/`, and add unit tests to `test/`. When it comes to the R Markdown reports, you can write them as package vignettes under `vignettes/`. In the vignettes, you can load datasets and call functions in the package. When you build the package (via the command `R CMD build` or RStudio), vignettes will be automatically compiled.

To create a package vignette in R Markdown, the easiest way is through the RStudio menu `File -> New File -> R Markdown -> From Template` (see Figure 16.4). Then you select "Package Vignette" from the **rmarkdown** package, and you will get a vignette template. After changing the title, author, and other metadata of the template, you can start writing the content of your report.

Alternatively, you can install the package **usethis** (Wickham and Bryan, 2020) and use its function `usethis::use_vignette()` to create a vignette skeleton. Below is what the YAML frontmatter of a package vignette typically looks like:

```
---
title: "Vignette Title"
```

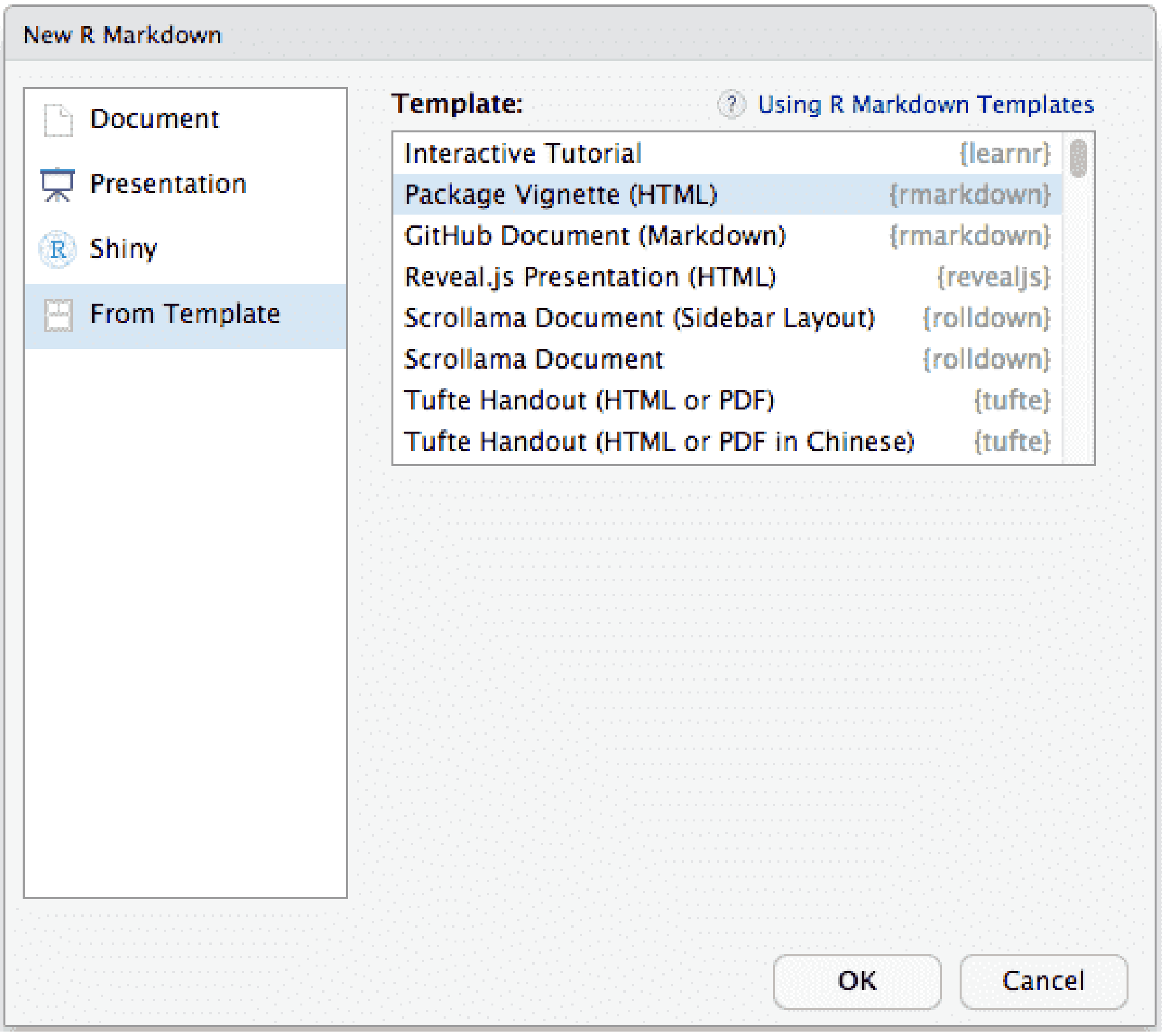

図16.4: Create a package vignette in RStudio.

```
author: "Vignette Author"
output: rmarkdown::html_vignette
vignette: >
  %\VignetteIndexEntry{Vignette Title}
  %\VignetteEngine{knitr::rmarkdown}
  %\VignetteEncoding{UTF-8}
---
```

Note that you need to change the vignette title in both the `title` field and the `\VignetteIndexEntry{}` command. Besides the above information in the vignette, you also need to do two more things in your package `DESCRIPTION` file:

1. Specify `VignetteBuilder: knitr` in the `DESCRIPTION` file.

2. Add `Suggests: knitr, rmarkdown` in `DESCRIPTION`.

The vignette output format does not have to be HTML. It can also be PDF, so you can use `output: pdf_document`, too. Any other output formats that create HTML or PDF are also okay, such as `beamer_presentation` and `tufte::tufte_html`. However, currently, R only recognizes HTML and PDF vignettes.

16.8 R Markdown templates in R packages

Figure 16.4 of Section 16.7 illustrates the process of retrieving the editable Package Vignette (HTML) template from the **rmarkdown** package. This R Markdown file is pre-populated with the appropriate metadata for an R package vignette.

Similarly, any package may include R Markdown templates that package users can access through the RStudio IDE (as shown in the figure) or across any platform with the `rmarkdown::draft()` function.

16.8.1 Template use-cases

Templates are a useful way to share custom structure, style, and content. There are many excellent examples of this "in the wild."

Many templates add structure and style by pre-populating the YAML metadata. We already saw an example of this with the **rmarkdown** package's Package Vignette (HTML) template. Similarly, the **rmdformats** package (Barnier, 2020) provides a number of templates that pass different custom styling functions to the `output` option.

Other templates demonstrate document structures that the packages require. For example, the **pagedown** package (Xie Lesur, et al., 2020) includes numerous templates for posters, resumes, and other page layouts. Similarly, the **xaringan** package's Ninja Presentation template (Xie, 2020d) demonstrates the syntax for many different slide formatting options.

Templates may also demonstrate package features and syntax. For example, both the **flexdashboard** package (Richard Iannone JJ Allaire, and Borges, 2020) and the **learnr** package (Schloerke JJ Allaire, and Borges, 2020) include templates with code chunks that call functions from the packages to create a sample dashboard or tutorial, respectively.

Similarly, templates may also include boilerplate content. For example, the **rticles** package (JJ Allaire Xie R Foundation, et al., 2021) provides many such templates to align R Markdown output to the required style and content guidelines of different academic journals. Boilerplate content is also useful in organizational settings, such as a team generating quarterly reports.

16.8.2 Template setup

The **usethis** package (Wickham and Bryan, 2020) has a helpful function for creating templates. Running `usethis::use_rmarkdown_template("Template Name")` will automatically create the required directory structure and files (you should provide your own Template Name).

If you wish to set up your template manually instead, create a subdirectory of the `inst/rmarkdown/templates` directory. Within this directory, you need to save at least two files:

1. A file named `template.yaml`, which gives the RStudio IDE basic metadata such as a human-readable name for the template. At a minimum, this file should have the `name` and `description` fields, e.g.,

   ```
   name: Example Template
   description: What this template does
   ```

   You may include `create_dir: true` if you want a new directory to be created when the template is selected. This is useful if your template relies upon additional resources. For example, the **learnr** package template[*2] sets `create_dir: true`, whereas the **flexdashboard** package template[*3] uses the default `create_dir: false`. You may attempt to open both of these templates in RStudio to notice the different user prompts.

2. An R Markdown document saved under `skeleton/skeleton.Rmd`. This may contain

*2 https://github.com/rstudio/learnr/blob/master/inst/rmarkdown/templates/tutorial/template.yaml

*3 https://github.com/rstudio/flexdashboard/blob/master/inst/rmarkdown/templates/flex_dashboard/template.yaml anything you wish to put in an R Markdown document.

Optionally, the `skeleton` folder may also include additional resources like style sheets or images used by your template. These files will be loaded to the user's computer along with the template.

For more details on building custom R Markdown templates, please refer to the RStudio Extensions[*4] website and the Document Templates chapter[*5] of the *R Markdown Definitive Guide* (Xie J.J. Allaire, and Grolemund, 2018).

16.9 Write books and long-form reports with **bookdown**

The **bookdown** package (Xie, 2020a) is designed for creating long-form documents that are composed of multiple R Markdown documents. For example, if you want to write a book, you can write each chapter in its own Rmd file, and use **bookdown** to compile these Rmd files into a book.

For RStudio users, the easiest way to get started is to create a **bookdown** project with the IDE by selecting `File -> New Project -> New Directory -> Book Project using bookdown`, as you can see from Figure 16.5.

If you do not use RStudio or if you prefer to work from the console, you may produce the same result by calling the function `bookdown:::bookdown_skeleton('your-book-dir')`.

To demonstrate the usage, we provide a minimal example consisting of three files within the same directory:

```
directory
  |- index.Rmd
  |- 01-intro.Rmd
  |- 02-analysis.Rmd
```

Below we show the content of each file and explain their roles.

- **index.Rmd**:

[*4] https://rstudio.github.io/rstudio-extensions/rmarkdown_templates.html
[*5] https://bookdown.org/yihui/rmarkdown/document-templates.html

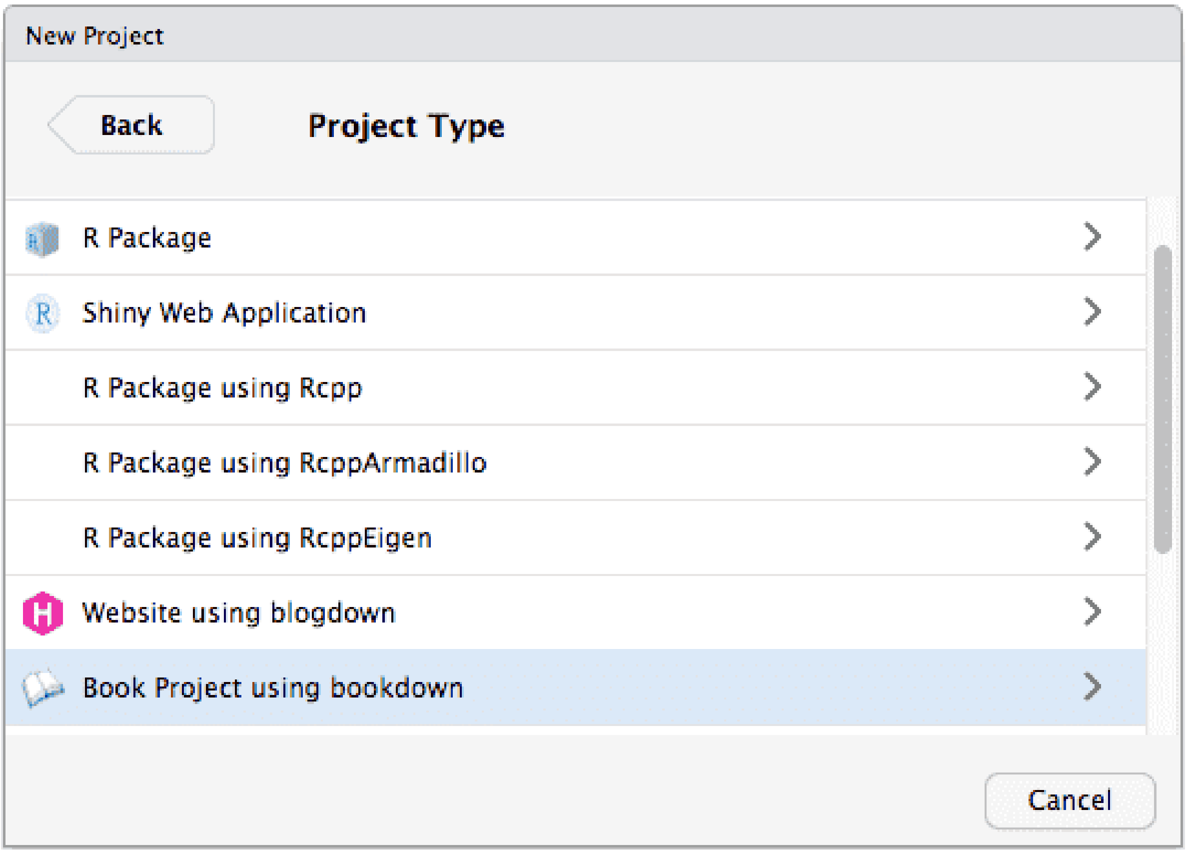

図**16.5:** Create a bookdown project in RStudio.

```
---
title: "A Minimal bookdown Project"
site: bookdown::bookdown_site
output: bookdown::gitbook
---

# Preface {-}

Some content
```

The first file is typically called `index.Rmd`. It should be the only Rmd file in which you provide the YAML frontmatter. It should also include a special YAML field `site: bookdown::bookdown_site`, so that **rmarkdown** knows to use **bookdown** to build all Rmd files, instead of rendering a single Rmd file. You can use any **bookdown** output formats, such as `bookdown::gitbook`, `bookdown::pdf_book`, `bookdown::word_document2`, and `bookdown::epub_book`.

The next two Rmd files are two chapters:

- **01-intro.Rmd:**

```
# Chapter 1

This is chapter 1.
```

- **02-analysis.Rmd**:

```
# Chapter 2

This is chapter 2.
```

To render these Rmd files, you should call `bookdown::render_book('index.Rmd')` instead of `rmarkdown::render()`. Under the hood, **bookdown** merges all Rmd files into a single Rmd by default and compiles it. Files are merged in alphabetical order. That is why we added numeric prefixes to filenames in the above example.

There are a lot of settings that you can customize for a **bookdown** project. For a more comprehensive overview of **bookdown**, you may see Chapter 18 the **rmarkdown** book (Xie J.J. Allaire, and Grolemund, 2018). For the full documentation, see the **bookdown** book (Xie, 2016).

16.10 Build websites with **blogdown**

If you want build a website based on R Markdown, you may consider using the **blogdown** package (Xie Dervieux, and Presmanes Hill, 2021). The easiest way to get started is to use the RStudio menu `File -> New Project -> New Directory -> Website using blogdown`, as you can see from Figure 16.5. If you have never used **blogdown** before, you may use the default settings in the dialog box, otherwise you can customize things like the website theme. If you do not use RStudio, you may call the function `blogdown::new_site()` under an empty directory to create a new website.

A website project may contain any number of Rmd documents. They could either be normal pages or blog posts. R Markdown makes it easier for you to maintain your website because the results on your website are automatically and dynamically generated.

We recommend that you read Chapter 1[*6] of the **blogdown** book (Xie Hill, and Thomas, 2017) for an overview of this package as well as the basic workflow of maintaining a website.

[*6] https://bookdown.org/yihui/blogdown/get-started.html

第 17 章

Workflow

In this chapter, we introduce some tips on working with individual R Markdown documents as well as running your R Markdown projects. You may also check out Chapter 30[*1] of the book *R for Data Science* (Wickham and Grolemund, 2016a), which briefly introduces some tips on using analysis notebooks (including R Markdown documents). Nicholas Tierney also discusses the workflow in the book *R Markdown for Scientists*.[*2]

17.1 Use RStudio keyboard shortcuts

The R Markdown format can be used with any editor of your choice, as long as R, the **rmarkdown** package, and Pandoc are installed. However, RStudio is deeply integrated with R Markdown, so you can work with R Markdown smoothly.

Like any IDE (Integrated Development Environment), RStudio has keyboard shortcuts. A full list can be found under the menu `Tools -> Keyboard Shortcuts Help`. Some of the most useful shortcuts related to R Markdown are summarized in Table 17.1.

Additionally, you can press `F7` to spell-check your document. You can also restart the R session by `Ctrl + Alt + F10` (or `Command + Option + F10` on macOS). Restarting regularly is helpful for reproducibility, because results are more likely to be reproducible if they are computed from a new R session. This can also be done through the drop-down menu Restart R and Run All Chunks behind the Run button on the toolbar.

[*1] https://r4ds.had.co.nz/r-markdown-workflow.html
[*2] https://rmd4sci.njtierney.com/workflow.html

表17.1: RStudio keyboard shortcuts related to R Markdown.

Task	Windows & Linux	macOS
Insert R chunk	Ctrl+Alt+I	Command+Option+I
Preview HTML	Ctrl+Shift+K	Command+Shift+K
Knitr document (knitr)	Ctrl+Shift+K	Command+Shift+K
Compile Notebook	Ctrl+Shift+K	Command+Shift+K
Compile PDF	Ctrl+Shift+K	Command+Shift+K
Run all chunks above	Ctrl+Alt+P	Command+Option+P
Run current chunk	Ctrl+Alt+C	Command+Option+C
Run current chunk	Ctrl+Shift+Enter	Command+Shift+Enter
Run next chunk	Ctrl+Alt+N	Command+Option+N
Run all chunks	Ctrl+Alt+R	Command+Option+R
Go to next chunk/title	Ctrl+PgDown	Command+PgDown
Go to previous chunk/title	Ctrl+PgUp	Command+PgUp
Show/hide document outline	Ctrl+Shift+O	Command+Shift+O
Build book, website, ...	Ctrl+Shift+B	Command+Shift+B

17.2 Spell-check R Markdown

If you use the RStudio IDE, you can press the `F7` key or click the menu `Edit -> Check Spelling` to spell-check an Rmd document. Real-time spell checking has become available in RStudio v1.3, so you no longer need to manually trigger spell checking with this version or a later version of RStudio.

If you do not use RStudio, the **spelling** package (Ooms and Hester, 2020) has a function `spell_check_files()`, which can check the spelling of common document formats, including R Markdown. When spell checking Rmd documents, it will skip code chunks and only check ordinary text.

17.3 Render R Markdown with `rmarkdown::render()`

If you do not use RStudio or any other IDE, you need to know this fact: R Markdown documents are rendered through the function `rmarkdown::render()`. This means you can programmatically render an R Markdown document in any R script. For example, you could render a series of reports in a for-loop for each state of a country:

```r
for (state in state.name) {
  rmarkdown::render(
    'input.Rmd', output_file = paste0(state, '.html')
  )
}
```

The output filename will be different for each state. You can also make use of the state variable in the document input.Rmd, e.g.,

```
---
title: "A report for `r state`"
output: html_document
---

The area of `r state` is `r state.area[state.name == state]`
square miles.
```

You may read the help page ?rmarkdown::render to know other possible arguments. Here we just want to mention two of them, i.e., the clean and envir arguments.

The former (clean) is particularly helpful for debugging when anything goes wrong with the Pandoc conversion. If you call rmarkdown::render(..., clean = FALSE), all intermediate files will be preserved, including the intermediate .md file knitted from the .Rmd file. If Pandoc signals an error, you may start debugging from this .md file.

The latter (envir) offers a way to render a document with the guarantee of an empty new environment when you call rmarkdown::render(..., envir = new.env()), so objects created in your code chunks will stay inside this environment, without polluting your current global environment. On the other hand, if you prefer rendering the Rmd document in a new R session so that objects in your current R session will not pollute your Rmd document, you may call rmarkdown::render in xfun::Rscript_call(), e.g.,

```r
xfun::Rscript_call(
```

```r
  rmarkdown::render,
  list(input = 'my-file.Rmd', output_format = 'pdf_document')
)
```

This method is similar to clicking the `Knit` button in RStudio, which also renders the Rmd document in a new R session. In case you need to render an Rmd document inside another Rmd document, we strongly recommend that you use this method instead of directly calling `rmarkdown::render()` in a code chunk, because `rmarkdown::render()` creates and relies on a lot of side effects internally, which may affect rendering other Rmd documents in the same R session.

The second argument of `xfun::Rscript_call()` takes a list of arguments to be passed to `rmarkdown::render()`. In fact, `xfun::Rscript_call` is a general-purpose function to call any R function (with arguments optionally) in a new R session. Please see its help page if you are interested.

17.4 Parameterized reports

In Section 17.3, we mentioned one way to render a series of reports in a `for`-loop. In fact, `rmarkdown::render()` has an argument named `params` specifically designed for this task. You can parameterize your report through this argument. When you specify parameters for a report, you can use the variable `params` in your report. For example, if you call:

```r
for (state in state.name) {
  rmarkdown::render('input.Rmd', params = list(state = state))
}
```

then in `input.Rmd`, the object `params` will be a list that contains the `state` variable:

```markdown
---
title: "A report for `r params$state`"
output: html_document
---

The area of `r params$state` is
```

```
`r state.area[state.name == params$state]`
square miles.
```

Another way to specify parameters for a report is to use the YAML field `params`, e.g.,

```yaml
---
title: Parameterized reports
output: html_document
params:
  state: Nebraska
  year: 2019
  midwest: true
---
```

Note that you can include as many parameters in the `params` YAML field or the `params` argument of `rmarkdown::render()`. If both the YAML field and the argument are present, the parameter values in the argument will override the corresponding parameters in YAML. For example, when we call `rmarkdown::render(..., params = list(state = 'Iowa', year = 2018)` on the previous example that has the `params` field, `params$state` will become `Iowa` (instead of `Nebraska`) and `params$year` will become `2018` (instead of `2019`) in the R Markdown document.

When rendering the same R Markdown document to a series of reports, you need to adjust the `output_file` argument of `rmarkdown::render()`, to make sure each report has its unique filename. Otherwise, you will accidentally override certain report files. For example, you can write a function to generate a report for each state and each year:

```r
render_one <- function(state, year) {
  # assuming the output format of input.Rmd is PDF
  rmarkdown::render(
    'input.Rmd',
    output_file = paste0(state, '-', year, '.pdf'),
    params = list(state = state, year = year),
    envir = parent.frame()
  )
```

```
}
```

Then you can use nested `for`-loops to generate all reports:

```
for (state in state.name) {
  for (year in 2000:2020) {
    render_one(state, year)
  }
}
```

At the end, you will get a series of report files like `Alabama-2000.pdf`, `Alabama-2001.pdf`, …, `Wyoming-2019.pdf`, and `Wyoming-2020.pdf`.

For parameterized reports, you can also input parameters interactively through a graphical user interface (GUI) created from Shiny. This requires you to provide a `params` field in YAML, and **rmarkdown** will automatically create the GUI using the appropriate input widgets for each parameter (e.g., a checkbox will be provided for a Boolean parameter).

To start the GUI, you can call `rmarkdown::render()` with `params = 'ask'` if you do not use RStudio:

```
rmarkdown::render("input.Rmd", params = "ask")
```

If you use RStudio, you can click the menu `Knit with Parameters` behind the `Knit` button. Figure 17.1 shows an example GUI for parameters.

For more information on parameterized reports, you may read Chapter 15[*3] of the *R Markdown Definitive Guide* (Xie J.J. Allaire, and Grolemund, 2018).

17.5 Customize the `Knit` button (*)

When you click the `Knit` button in RStudio, it will call the `rmarkdown::render()` function in a new R session and output a file of the same base name as the input file in the same directory. For example, knitting `example.Rmd` with the output format `html_document` will create an output file `example.html`.

[*3] https://bookdown.org/yihui/rmarkdown/parameterized-reports.html

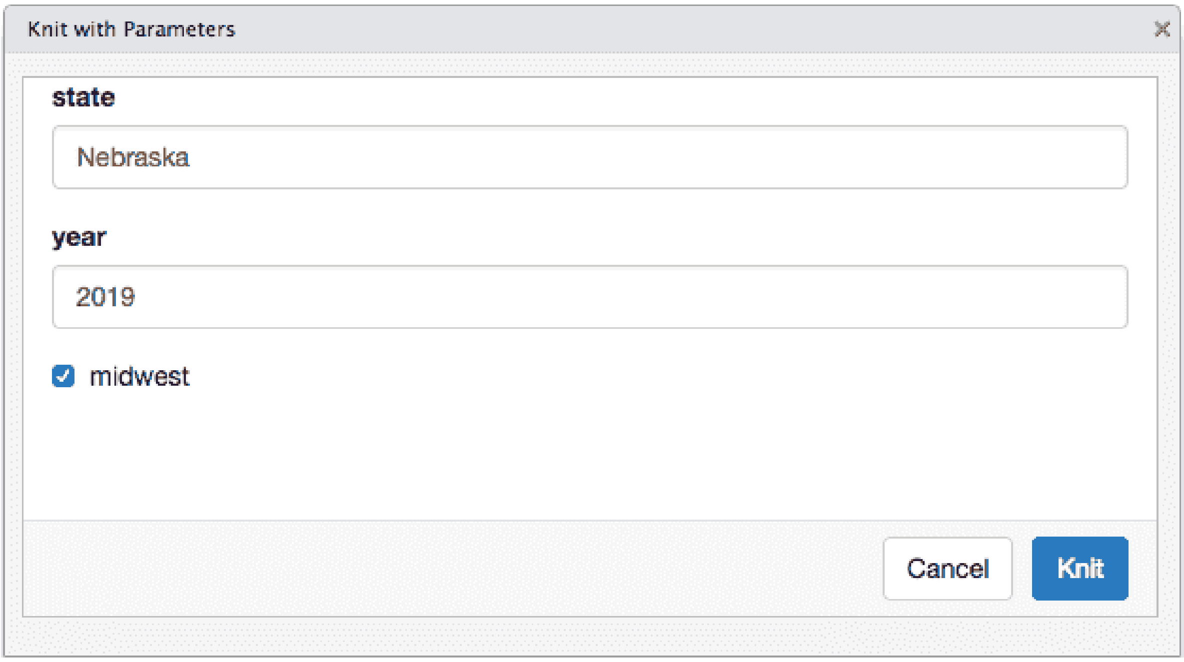

図17.1: Knit an R Markdown document with parameters that you can input from a GUI.

There may be situations in which we want to customize how the document is rendered. For example, perhaps we would like the rendered document to contain the current date, or would like to output the compiled report into a different directory. Although we can achieve these goals by calling `rmarkdown::render()` (see Section 17.3) with the appropriate `output_file` argument, it can be inconvenient to have to rely on a custom call to `rmarkdown::render()` to compile your report.

It is possible to control the behavior of the `Knit` button by providing the `knit` field within the YAML frontmatter of your document. The field takes a function with the main argument `input` (the path to the input Rmd document) and other arguments that are currently ignored. You can either write the source code of the function directly in the `knit` field, or put the function elsewhere (e.g., in an R package) and call the function in the `knit` field. If you routinely need the custom `knit` function, we would recommend that you put it in a package, instead of repeating its source code in every single R Markdown document.

If you store the code directly within YAML, you must wrap the entire function in parentheses. If the source code has multiple lines, you have to indent all lines (except the first line) by at least two spaces. For example, if we want the output filename to include the date on which it is rendered, we could use the following YAML code:

```
---
knit: (function(input, ...) {
    rmarkdown::render(
      input,
      output_file = paste0(
        xfun::sans_ext(input), '-', Sys.Date(), '.html'
      ),
      envir = globalenv()
    )
  })
---
```

For example, if we knit `example.Rmd` on 2019-07-29, the output filename will be `example-2019-07-29.html`.

While the above approach looks simple and straightforward enough, embedding a function directly in your YAML may make it difficult for you to maintain it, unless the function is only to be used once with a single R Markdown document. In general, we would recommend using an R package to maintain such a function, e.g., you may create a function `knit_with_date()` in a package:

```r
#' Custom Knit function for RStudio
#'
#' @export
knit_with_date <- function(input, ...) {
  rmarkdown::render(
    input,
    output_file = paste0(
        xfun::sans_ext(input), '-', Sys.Date(), '.',
        xfun::file_ext(input)
    ),
    envir = globalenv()
  )
}
```

If you add the above code to a package named **myPackage**, you will be able to refer to your custom `knit` function using the following YAML setting:

```yaml
---
knit: myPackage::knit_with_date
---
```

You may refer to the help page `?rmarkdown::render` to find out more ideas on how you could customize your `knit` function behind the `Knit` button in RStudio.

17.6 Collaborate on Rmd documents through Google Drive

Based on the **googledrive** package (D'Agostino McGowan and Bryan, 2020), Emily Kothe provided a few wrapper functions in the **rmdrive** package, which is currently available only on GitHub at https://github.com/ekothe/rmdrive. At the time of writing, it still lacks rich documentation, so I recommend that you try Janosch Linkersdörfer's fork instead: https://github.com/januz/rmdrive (which is based on Ben Marwick's fork—if you still have not learned GIT, you may be motivated by these examples of freely forking and improving other people's GIT repositories).

The workflow with **rmdrive** is outlined below:

1. We assume there is a main author or contributor of the project, who is capable of using version control tools like GIT. The main author writes the initial version of the Rmd document, and uploads it to Google Drive via the `upload_rmd()` function.

2. The Rmd document in Google Drive is shared with other collaborators, who can make or suggest changes in Google Document.

3. The main author can accept suggested changes, and download/preview the Rmd document locally via `render_rmd()`. Other collaborators can also do this by themselves if they have modified code chunks and want to see the new results.

4. If satisfied, the main author can commit changes to the GIT repository.

The collaborative editing can be either synchronous or asynchronous in Google Drive. Multiple people can edit the same document at the same time, or wait for other people to finish their editing first.

There is also a function `udpate_rmd()` in the package, which allows you to edit the Rmd document locally, and upload the local Rmd document to Google Drive. You probably should never want to run this function, because it will completely overwrite the document in Google Drive. The main author may want to warn collaborators about this in advance. Ideally, all collaborators should only edit the document in Google Drive and not locally. It is okay to preview the edited document locally via `render_rmd()`, though (note that `render_rmd()` automatically downloads the document before rendering it).

17.7 Organize an R Markdown project into a research website with **workflowr**

The **workflowr** package (J. Blischak Carbonetto, and M. Stephens, 2020; J. D. Blischak Carbonetto, and M. Stephens, 2019) can help you organize a (data analysis) project with a project template and the version control tool GIT. Every time you make a change to the project, you can log the change, and **workflowr** can build a website corresponding to that particular version of your project. This means that you will be able to view the full history of your analysis results. Although this package uses GIT as the backend for version control, you do not really have to be familiar with GIT. The package provides R functions that do the GIT operations under the hood, and you only need to call these R functions. Furthermore, **workflowr** automates best practices for reproducible code. Each time an R Markdown document is rendered, **workflowr** automatically sets a seed with `set.seed()`, records the session information with `sessionInfo()`, and scans for absolute file paths, etc. Please see the package documentation[*4] for how to get started and more information.

The main author of **workflowr**, John Blischak, has also put together a non-exhaustive list of R packages and guides related to the workflow of R projects, which can be found in this GitHub repo: https://github.com/jdblischak/r-project-workflows.

17.8 Send emails based on R Markdown

With the **blastula** package (Richard Iannone and Cheng, 2020), you can render an Rmd document to the email body and send the email. To render an Rmd document to an email, the document needs to use the output format `blastula::blastula_email`, e.g.,

[*4] https://jdblischak.github.io/workflowr/

```
---
title: Weekly Report
output: blastula::blastula_email
---

Dear Boss,

Below is an analysis of the `iris` data:

```{r}
summary(iris)
plot(iris[, -5])
```

Please let me know if it is not boring enough.

Sincerely,
John
```

This Rmd document should be rendered via the function `blastula::render_email()`, and the output can be passed to `blastula::smtp_send()`, which will send out the email. Note that `smtp_send()` needs an email server as well as your credentials.

If you use RStudio Connect, you can find more examples at https://solutions.rstudio.com/examples/blastula-overview/, including automated, conditional, and parameterized emails.

付録 A

knitr's Chunk and Package Options

The **knitr** package provides a lot of chunk options for customizing nearly all components of code chunks, such as the source code, text output, plots, and the language of the chunk. It also offers some options at the package level to customize the knitting process. This appendix describes all chunk options and package options available in **knitr**. The default values of these options are in parentheses in the list items.

A.1 Chunk options

Chunk options are written in chunk headers. The syntax for chunk headers depends on the document format, e.g., for `.Rnw` documents (R + LaTeX), chunk headers are written with << >>=, and for `.Rmd` documents, chunk headers are written with `` ```{r} ``. The examples below are primarily for `.Rmd` documents (R Markdown), but in most cases, the chunk options can be used with any document format.

Chunk options are written in the form `tag=value` like this:

````
```{r, my-chunk, echo=FALSE, fig.height=4, dev='jpeg'}
```
````

A special chunk option is the chunk label (e.g., `my-chunk` in the above example). Only the chunk label does not need a `tag` (i.e., you only provide the `value`). If you prefer the form `tag=value`, you could also use the chunk option `label` explicitly, e.g.,

```
```{r, label='my-chunk'}
```
```

The chunk label for each chunk is assumed to be unique within the document. This is especially important for cache and plot filenames, because these filenames are based on chunk labels. Chunks without labels will be assigned labels like `unnamed-chunk-i`, where `i` is an incremental number.

You may use `knitr::opts_chunk$set()` to change the default values of chunk options in a document. For example, you may put this in the first code chunk of your document:

````
```{r, setup, include=FALSE}
knitr::opts_chunk$set(
  comment = '', fig.width = 6, fig.height = 6
)
```
````

Below are a few more tips about chunk options:

1. The chunk header must be written on one line. You must not break the line.
2. Try to avoid spaces, periods (`.`), and underscores (`_`) in chunk labels and paths. If you need separators, you are recommended to use hyphens (`-`) instead. For example, `setup-options` is a good label, whereas `setup.options` and `chunk 1` are bad; `fig.path = 'figures/mcmc-'` is a good path for figure output, and `fig.path = 'markov chain/monte carlo'` is bad.
3. All option values must be *valid R expressions*. You may think of them as values to be passed to function arguments.
    - For example, options that take *character* values must be quoted, e.g., `results = 'asis'` and `out.width = '\\textwidth'` (remember that a literal backslash needs double backslashes).
    - In theory, the chunk label should be quoted, too. However, for the sake of convenience, it will be automatically quoted if you did not (e.g., ` ```{r, 2a} ` will parsed as ` ```{r, '2a'} `).
    - You can write arbitrarily complicated expressions as long as they are valid R code.

Below is a list of chunk options in **knitr** documented in the format "`option`: (`default value`; type of value)".

A.1.1 Code evaluation

- `eval`: (`TRUE`; logical or numeric) Whether to evaluate the code chunk. It can also be a numeric vector to choose which R expression(s) to evaluate, e.g., `eval = c(1, 3, 4)` will evaluate the first, third, and fourth expressions, and `eval = -(4:5)` will evaluate all expressions except the fourth and fifth.

A.1.2 Text output

- `echo`: (`TRUE`; logical or numeric) Whether to display the source code in the output document. Besides `TRUE`/`FALSE`, which shows/hides the source code, we can also use a numeric vector to choose which R expression(s) to echo in a chunk, e.g., `echo = 2:3` means to echo only the 2nd and 3rd expressions, and `echo = -4` means to exclude the 4th expression.
- `results`: (`'markup'`; character) Controls how to display the text results. Note that this option only applies to normal text output (not warnings, messages, or errors). The possible values are as follows:
  - `markup`: Mark up text output with the appropriate environments depending on the output format. For example, for R Markdown, if the text output is a character string `"[1] 1 2 3"`, the actual output that **knitr** produces will be:

    ````
    ```
    [1] 1 2 3
    ```
    ````

    In this case, `results='markup'` means to put the text output in fenced code blocks (` ``` `).
  - `asis`: Write text output as-is, i.e., write the raw text results directly into the output document without any markups.

````
```{r, results='asis'}
cat("I'm raw **Markdown** content.\n")
```
````

  - `hold`: Hold all pieces of text output in a chunk and flush them to the end of the chunk.

  - `hide` (or `FALSE`): Hide text output.

- `collapse`: (`FALSE`; logical) Whether to, if possible, collapse all the source and output blocks from one code chunk into a single block (by default, they are written to separate blocks). This option only applies to Markdown documents.

- `warning`: (`TRUE`; logical) Whether to preserve warnings (produced by `warning()`) in the output. If `FALSE`, all warnings will be printed in the console instead of the output document. It can also take numeric values as indices to select a subset of warnings to include in the output. Note that these values reference the indices of the warnings themselves (e.g., `3` means "the third warning thrown from this chunk") and not the indices of which expressions are allowed to emit warnings.

- `error`: (`TRUE`; logical) Whether to preserve errors (from `stop()`). By default, the code evaluation will not stop even in case of errors! If we want to stop on errors, we need to set this option to `FALSE`. Note that R Markdown has changed this default value to `FALSE`. When the chunk option `include = FALSE`, **knitr** will stop on error, because it is easy to overlook potential errors in this case.

- `message`: (`TRUE`; logical) Whether to preserve messages emitted by `message()` (similar to the option `warning`).

- `include`: (`TRUE`; logical) Whether to include the chunk output in the output document. If `FALSE`, nothing will be written into the output document, but the code is still evaluated and plot files are generated if there are any plots in the chunk, so you can manually insert figures later.

- `strip.white`: (`TRUE`; logical) Whether to remove blank lines in the beginning or end of a source code block in the output.

- `class.output`: (`NULL`; character) A vector of class names to be added to the text output blocks. This option only works for HTML output formats in R Markdown.

For example, with `class.output = c('foo', 'bar')`, the text output will be placed in `<pre class="foo bar"></pre>`.

- `class.message`/`class.warning`/`class.error`: (`NULL`; character) Similar to `class.output`, but applied to messages, warnings, and errors in R Markdown output. Please see Section A.1.3 for `class.source`, which applies similarly to source code blocks.

- `attr.output`/`attr.message`/`attr.warning`/`attr.error`: (`NULL`; character) Similar to the `class.*` options above, but for specifying arbitrary fenced code block attributes for Pandoc; `class.*` is a special application of `attr.*`, e.g., `class.source = 'numberLines'` is equivalent to `attr.source = '.numberLines'`, but `attr.source` can take arbitrary attribute values, e.g., `attr.source = c('.numberLines', 'startFrom="11"')`.

- `render`: (`knitr::knit_print`; `function(x, options, ...)`) A function to print the visible values in a chunk. The value passed to the first argument of this function (i.e., `x`) is the value evaluated from each expression in the chunk. The list of current chunk options is passed to the argument `options`. This function is expected to return a character string. For more information, check out the package vignette about custom chunk rendering: `vignette('knit_print', package = 'knitr')`.

- `split`: (`FALSE`; logical) Whether to split the output into separate files and include them in LaTeX by `\input{}` or HTML by `<iframe></iframe>`. This option only works for `.Rnw`, `.Rtex`, and `.Rhtml` documents.

A.1.3 Code decoration

- `tidy`: (`FALSE`) Whether to reformat the R code. Other possible values are as follows:

  - `TRUE` (equivalent to `tidy = 'formatR'`): Call the function `formatR::tidy_source()` to reformat the code.
  - `'styler'`: Use `styler::style_text()` to reformat the code.
  - A custom function of the form `function(code, ...) {}` to return the reformatted code.
  - If reformatting fails, the original R code will not be changed (with a warning).

- `tidy.opts`: (`NULL`; list) A list of options to be passed to the function determined by the `tidy` option, e.g., `tidy.opts = list(blank = FALSE, width.cutoff = 60)` for `tidy = 'formatR'` to remove blank lines and try to cut the code lines at 60 characters.

- `prompt`: (`FALSE`; logical) Whether to add the prompt characters in the R code. See prompt and continue on the help page ?base::options. Note that adding prompts can make it difficult for readers to copy R code from the output, so prompt = FALSE may be a better choice. This option may not work well when the chunk option engine is not R (#1274[*1]).

- comment: ('##'; character) The prefix to be added before each line of the text output. By default, the text output is commented out by ##, so if readers want to copy and run the source code from the output document, they can select and copy everything from the chunk, since the text output is masked in comments (and will be ignored when running the copied text). Set comment = '' remove the default ##.
- highlight: (TRUE; logical) Whether to syntax highlight the source code.
- class.source: (NULL; character) Class names for source code blocks in the output document. Similar to the class.* options for output such as class.output.
- attr.source: (NULL; character) Attributes for source code blocks. Similar to the attr.* options for output such as attr.output.
- size: ('normalsize'; character) Font size of the chunk output from .Rnw documents. See this page[*2] for possible sizes.
- background: ('#F7F7F7'; character) Background color of the chunk output of .Rnw documents.
- indent: (character) A string to be added to each line of the chunk output. Typically it consists of white spaces. This option is assumed to be read-only, and **knitr** sets its value while parsing the document. For example, for the chunk below, indent is a character string of two spaces:

```
```{r}
rnorm(10)
```
```

[*1] https://github.com/yihui/knitr/issues/1274
[*2] https://www.overleaf.com/learn/latex/Font_sizes,_families,_and_styles

A.1.4 Cache

- `cache`: (`FALSE`; logical) Whether to cache a code chunk. When evaluating code chunks for the second time, the cached chunks are skipped (unless they have been modified), but the objects created in these chunks are loaded from previously saved databases (`.rdb` and `.rdx` files), and these files are saved when a chunk is evaluated for the first time, or when cached files are not found (e.g., you may have removed them by hand). Note that the filename consists of the chunk label with an MD5 digest of the R code and chunk options of the code chunk, which means any changes in the chunk will produce a different MD5 digest, and hence invalidate the cache. See more information on this page.[*3]

- `cache.path`: (`'cache/'`; character) A prefix to be used to generate the paths of cache files. For R Markdown, the default value is based on the input filename, e.g., the cache paths for the chunk with the label `FOO` in the file `INPUT.Rmd` will be of the form `INPUT_cache/FOO_*.*`.

- `cache.vars`: (`NULL`; character) A vector of variable names to be saved in the cache database. By default, all variables created in the current chunks are identified and saved, but you may want to manually specify the variables to be saved, because the automatic detection of variables may not be robust, or you may want to save only a subset of variables.

- `cache.globals`: (`NULL`; character) A vector of the names of variables that are not created from the current chunk. This option is mainly for `autodep = TRUE` to work more precisely—a chunk `B` depends on chunk `A` when any of `B`'s global variables are `A`'s local variables. In case the automatic detection of global variables in a chunk fails, you may manually specify the names of global variables via this option (see #1403[*4] for an example).

- `cache.lazy`: (`TRUE`; logical) Whether to `lazyLoad()` or directly `load()` objects. For very large objects, lazyloading may not work, so `cache.lazy = FALSE` may be desirable (see #572[*5]).

- `cache.comments`: (`NULL`; logical) If `FALSE`, changing comments in R code chunks will

[*3] https://yihui.org/knitr/demo/cache/
[*4] https://github.com/yihui/knitr/issues/1403
[*5] https://github.com/yihui/knitr/issues/572

not invalidate the cache database.

- `cache.rebuild`: (`FALSE`; logical) If `TRUE`, reevaluate the chunk even if the cache does not need to be invalidated. This can be useful when you want to conditionally invalidate the cache, e.g., `cache.rebuild = !file.exists("some-file")` can rebuild the chunk when `some-file` does not exist (see #238[*6]).

- `dependson`: (`NULL`; character or numeric) A character vector of chunk labels to specify which other chunks this chunk depends on. This option applies to cached chunks only—sometimes the objects in a cached chunk may depend on other cached chunks, so when other chunks are changed, this chunk must be updated accordingly.

  - If `dependson` is a numeric vector, it means the indices of chunk labels, e.g., `dependson = 1` means this chunk depends on the first chunk in the document, and `dependson = c(-1, -2)` means it depends on the previous two chunks (negative indices stand for numbers of chunks before this chunk, and note they are always relative to the current chunk).
  - Please note this option does not work when set as a global chunk option via `opts_chunk$set()`; it must be set as a local chunk option.

- `autodep`: (`FALSE`; logical) Whether to analyze dependencies among chunks automatically by detecting global variables in the code (may not be reliable), so `dependson` does not need to be set explicitly.

A.1.5 Plots

- `fig.path`: (`'figure/'`; character) A prefix to be used to generate figure file paths. `fig.path` and chunk labels are concatenated to generate the full paths. It may contain a directory like `figure/prefix-`; the directory will be created if it does not exist.

- `fig.keep`: (`'high'`; character) How plots in chunks should be kept. Possible values are as follows:

  - `high`: Only keep high-level plots (merge low-level changes into high-level plots).
  - `none`: Discard all plots.
  - `all`: Keep all plots (low-level plot changes may produce new plots).
  - `first`: Only keep the first plot.
  - `last`: Only keep the last plot.

[*6] https://github.com/yihui/knitr/issues/238

- If set to a numeric vector, the values are indices of (low-level) plots to keep.

Low-level plotting commands include `lines()` and `points()`, etc. To better understand `fig.keep`, consider the following chunk:

```
```{r, test-plot}
plot(1)         # high-level plot
abline(0, 1)    # low-level change
plot(rnorm(10)) # high-level plot
# many low-level changes in a loop (a single R expression)
for(i in 1:10) {
    abline(v = i, lty = 2)
}
```
```

Normally this produces 2 plots in the output (because `fig.keep = 'high'`). For `fig.keep = 'none'`, no plots will be saved. For `fig.keep = 'all'`, 4 plots are saved. For `fig.keep = 'first'`, the plot produced by `plot(1)` is saved. For `fig.keep = 'last'`, the last plot with 10 vertical lines is saved.

- `fig.show`: (`'asis'`; character) How to show/arrange the plots. Possible values are as follows:
  - `asis`: Show plots exactly in places where they were generated (as if the code were run in an R terminal).
  - `hold`: Hold all plots and output them at the end of a code chunk.
  - `animate`: Concatenate all plots into an animation if there are multiple plots in a chunk.
  - `hide`: Generate plot files but hide them in the output document.
- `dev`: (`'pdf'` for LaTeX output and `'png'` for HTML/Markdown; character) The graphical device to generate plot files. All graphics devices in base R and those in **Cairo**, **cairoDevice**, **svglite**, **ragg**, and **tikzDevice** are supported, e.g., `pdf`, `png`, `svg`, `jpeg`, `tiff`, `cairo_pdf`, `CairoJPEG`, `CairoPNG`, `Cairo_pdf`, `Cairo_png`, `svglite`, `ragg_png`, `tikz`, and so on. See `names(knitr:::auto_exts)` for the full list. Besides these devices, you can also provide a character string that is the name of a function of the form `function(filename, width, height)`. The units for the image size are *always* inches (even for bitmap devices, in which DPI is used to convert between pixels and inches).

The chunk options `dev`, `fig.ext`, `fig.width`, `fig.height`, and `dpi` can be vectors (shorter ones will be recycled), e.g., `dev = c('pdf', 'png')` creates a `PDF` and a `PNG` file for the same plot.

- `dev.args`: (`NULL`; list) More arguments to be passed to the device, e.g., `dev.args = list(bg = 'yellow', pointsize = 10)` for `dev = 'png'`. This option depends on the specific device (see the device documentation). When `dev` contains multiple devices, `dev.args` can be a list of lists of arguments, and each list of arguments is passed to each individual device, e.g., `dev = c('pdf', 'tiff'), dev.args = list(pdf = list(colormodel = 'cmyk', useDingats = TRUE), tiff = list(compression = 'lzw'))`.
- `fig.ext`: (`NULL`; character) File extension of the figure output. If `NULL`, it will be derived from the graphical device; see `knitr:::auto_exts` for details.
- `dpi`: (`72`; numeric) The DPI (dots per inch) for bitmap devices (`dpi * inches = pixels`).
- `fig.width`, `fig.height`: (both are `7`; numeric) Width and height of the plot (in inches), to be used in the graphics device.
- `fig.asp`: (`NULL`; numeric) The aspect ratio of the plot, i.e., the ratio of height/width. When `fig.asp` is specified, the height of a plot (the chunk option `fig.height`) is calculated from `fig.width * fig.asp`.
- `fig.dim`: (`NULL`; numeric) A numeric vector of length 2 to provide `fig.width` and `fig.height`, e.g., `fig.dim = c(5, 7)` is a shorthand of `fig.width = 5, fig.height = 7`. If both `fig.asp` and `fig.dim` are provided, `fig.asp` will be ignored (with a warning).
- `out.width`, `out.height`: (`NULL`; character) Width and height of the plot in the output document, which can be different with its physical `fig.width` and `fig.height`, i.e., plots can be scaled in the output document. Depending on the output format, these two options can take special values. For example, for LaTeX output, they can be `.8\\linewidth`, `3in`, or `8cm`; for HTML, they may be `300px`. For `.Rnw` documents, the default value for `out.width` will be changed to `\\maxwidth`, which is defined on this page.[*7] It can also be a percentage, e.g., `'40%'` will be translated to `0.4\linewidth` when the output format is LaTeX.
- `out.extra`: (`NULL`; character) Extra options for figures. It can be an arbitrary string, to be inserted in `\includegraphics[]` in LaTeX output (e.g., `out.extra = 'angle=90'`

[*7] https://yihui.org/knitr/demo/framed/

to rotate the figure by 90 degrees), or `<img />` in HTML output (e.g., `out.extra = 'style="border:5px solid orange;"'`).

- `fig.retina`: (`1`; numeric) This option only applies to HTML output. For Retina displays,[*8] setting this option to a ratio (usually 2) will change the chunk option `dpi` to `dpi * fig.retina`, and `out.width` to `fig.width * dpi / fig.retina` internally. For example, the physical size of an image is doubled, and its display size is halved when `fig.retina = 2`.

- `resize.width`, `resize.height`: (`NULL`; character) The width and height to be used in `\resizebox{}{}` in LaTeX output. These two options are not needed unless you want to resize TikZ graphics, because there is no natural way to do it. However, according to the **tikzDevice** authors, TikZ graphics are not meant to be resized, to maintain consistency in style with other text in LaTeX. If only one of them is `NULL`, `!` will be used (read the documentation of **graphicx** if you do not understand this).

- `fig.align`: (`'default'`; character) Alignment of figures in the output document. Possible values are `default`, `left`, `right`, and `center`. The default is not to make any alignment adjustments.

- `fig.link`: (`NULL`; character) A link to be added onto the figure.

- `fig.env`: (`'figure'`; character) The LaTeX environment for figures, e.g., you may set `fig.env = 'marginfigure'` to get `\begin{marginfigure}`. This option requires `fig.cap` be specified.

- `fig.cap`: (`NULL`; character) A figure caption.

- `fig.alt`: (`NULL`; character) The alternative text to be used in the `alt` attribute of the `<img>` tags of figures in HTML output. By default, the chunk option `fig.cap` will be used as the alternative text if provided.

- `fig.scap`: (`NULL`; character) A short caption. This option is only meaningful to LaTeX output. A short caption is inserted in `\caption[]`, and usually displayed in the "List of Figures" of a PDF document.

- `fig.lp`: (`'fig:'`; character) A label prefix for the figure label to be inserted in `\label{}`. The actual label is made by concatenating this prefix and the chunk label, e.g., the figure label for `` ```{r, foo-plot} `` will be `fig:foo-plot` by default.

[*8] http://en.wikipedia.org/wiki/Retina_Display

- `fig.pos`: (`''`; character) A character string for the figure position arrangement to be used in `\begin{figure}[]`.

- `fig.subcap`: (`NULL`) Captions for subfigures. When there are multiple plots in a chunk, and neither `fig.subcap` nor `fig.cap` is `NULL`, `\subfloat{}` will be used for individual plots (you need to add `\usepackage{subfig}` in the preamble). See 067-graphics-options.Rnw[*9] for an example.

- `fig.ncol`: (`NULL`; integer) The number of columns of subfigures; see this issue[*10] for examples (note that `fig.ncol` and `fig.sep` only work for LaTeX output).

- `fig.sep`: (`NULL`; character) A character vector of separators to be inserted among subfigures. When `fig.ncol` is specified, `fig.sep` defaults to a character vector of which every N-th element is `\newline` (where `N` is the number of columns), e.g., `fig.ncol = 2` means `fig.sep = c('', '', '\\newline', '', '', '\\newline', '', ...)`.

- `fig.process`: (`NULL`; function) A function to post-process figure files. It should take the path of a figure file, and return the (new) path of the figure to be inserted in the output. If the function contains the `options` argument, the list of chunk options will be passed to this argument.

- `fig.showtext`: (`NULL`; logical) If `TRUE`, call `showtext::showtext_begin()` before drawing plots. See the documentation of the **showtext**[*11] package for details.

- `external`: (`TRUE`; logical) Whether to externalize tikz graphics (pre-compile tikz graphics to PDF). It is only used for the `tikz()` device in the **tikzDevice** package (i.e., when `dev='tikz'`), and it can save time for LaTeX compilation.

- `sanitize`: (`FALSE`; character) Whether to sanitize tikz graphics (escape special LaTeX characters). See the documentation of the **tikzDevice** package.

There are two hidden options that are not designed to be set by users: `fig.cur` (the current figure number or index when there are multiple figures), and `fig.num` (the total number of figures in a chunk). The purpose of these two options is to help **knitr** deal with the filenames of multiple figures as well as animations. In some cases, we can make use of them to write animations into the output using plot files that are saved manually (see the

[*9] https://github.com/yihui/knitr-examples/blob/master/067-graphics-options.Rnw
[*10] https://github.com/yihui/knitr/issues/1327#issuecomment-346242532
[*11] http://cran.rstudio.com/package=showtext

graphics manual[*12] for examples).

A.1.6 Animation

- `interval`: (`1`; numeric) Time interval (number of seconds) between animation frames.
- `animation.hook`: (`knitr::hook_ffmpeg_html`; function or character) A hook function to create animations in HTML output; the default hook uses FFmpeg to convert images to a WebM video.
  - Another hook function is `knitr::hook_gifski` based on the **gifski**[*13] package to create GIF animations.
  - This option can also take a character string `'ffmpeg'` or `'gifski'` as a shorthand of the corresponding hook function, e.g., `animation.hook = 'gifski'` means `animation.hook = knitr::hook_gifski`.
  - `aniopts`: (`'controls,loop'`; character) Extra options for animations; see the documentation of the LaTeX **animate** package.[*14]
- `ffmpeg.bitrate` (`1M`; character) To be passed to the `-b:v` argument of FFmpeg to control the quality of WebM videos.
- `ffmpeg.format` (`webm`; character) The video format of FFmpeg, i.e., the filename extension of the video.

A.1.7 Code chunk

- `code`: (`NULL`; character) If provided, it will override the code in the current chunk. This allows us to programmatically insert code into the current chunk. For example, `code = readLines('test.R')` will use the content of the file `test.R` as the code for the current chunk.
- `ref.label`: (`NULL`; character) A character vector of labels of the chunks from which the code of the current chunk is inherited (see the demo for chunk references[*15]).

[*12] https://github.com/yihui/knitr/releases/download/doc/knitr-graphics.pdf
[*13] https://cran.r-project.org/package=gifski
[*14] http://ctan.org/pkg/animate
[*15] https://yihui.org/knitr/demo/reference/

A.1.8 Child documents

- `child`: (`NULL`; character) A character vector of paths of child documents to be knitted and input into the main document.

A.1.9 Language engines

- `engine`: (`'R'`; character) The language name of the code chunk. Possible values can be found in `names(knitr::knit_engines$get())`, e.g., `python`, `sql`, `julia`, `bash`, and `c`, etc. The object `knitr::knit_engines` can be used to set up engines for other languages.
- `engine.path`: (`NULL`; character) The path to the executable of the `engine`. This option makes it possible to use alternative executables in your system, e.g., the default `python` may be at `/usr/bin/python`, and you may set `engine.path = '~/anaconda/bin/python'` to use a different version of Python.

  `engine.path` can also be a list of paths, which makes it possible to set different engine paths for different engines, e.g.,

  ```
  knitr::opts_chunk$set(engine.path = list(
    python = '~/anaconda/bin/python',
    ruby = '/usr/local/bin/ruby'
  ))
  ```

  The names of the list correspond to the names of the engines.

A.1.10 Option templates

- `opts.label`: (`NULL`; character) The label of options set in `knitr::opts_template` (see `?knitr::opts_template`). This option can save some typing effort for sets of frequently used chunk options.

A.1.11 Extracting source code

- `purl`: (`TRUE`; logical) When running `knitr::purl()` to extract source code from a source document, whether to include or exclude a certain code chunk.

A.1.12 Other chunk options

- `R.options`: (`NULL`; list) Local R options for a code chunk. These options are set temporarily via `options()` before the code chunk, and restored after the chunk.

A.2 Package options

The package options can be changed using the object `knitr::opts_knit`[*16] (*not to be confused with* `knitr::opts_chunk`). For example:

```
knitr::opts_knit$set(progress = TRUE, verbose = TRUE)
```

See `?knitr::opts_knit` for the alternative approach to setting package options using the R base function `options()`.

Available package options are as follows:

- `aliases`: (`NULL`; character) A named character vector to specify the aliases of chunk options, e.g., `c(h = 'fig.height', w = 'fig.width')` tells **knitr** that the chunk option `h` really means `fig.height`, and `w` is an alias for `fig.width`. This option can be used to save some typing effort for long option names.

- `base.dir`: (`NULL`; character) An absolute directory under which the plots are generated.

- `base.url`: (`NULL`; character) The base URL of images on HTML pages.

- `concordance`: (`FALSE`; logical) Whether to write a concordance file to map the output line numbers to the input line numbers. This enables one to navigate from the output to the input, and can be helpful especially when a TeX error occurs. This feature is only for `.Rnw` documents, and implemented in RStudio.

[*16] https://yihui.org/knitr/objects/

- `eval.after`: (`c('fig.cap', 'fig.alt')`; character) A character vector of option names. These options will be evaluated *after* a chunk has been evaluated, and all other options will be evaluated before a chunk. For example, for `fig.cap = paste('p-value is', t.test(x)$p.value)`, it will be evaluated after the chunk according to the value of `x` if `eval.after = 'fig.cap'`.

- `global.par`: (`FALSE`; logical) If `TRUE`, the `par()` settings from the previous code chunk will be preserved and applied to the next code chunk (of course, this only applies to base R graphics). By default, **knitr** opens a new graphical device to record plots and close it after evaluating the code, so `par()` settings will be discarded.

- `header`: (`NULL`; character) The text to be inserted into the output document before the document begins (e.g., after `\documentclass{article}` in LaTeX, or after `<head>` in HTML). This is useful for defining commands and styles in the LaTeX preamble or HTML header. The beginning of document is found using the pattern defined in `knitr::knit_patterns$get('document.begin')`. This option is only for `.Rnw` and `.Rhtml` documents.

- `label.prefix`: (`c(table = 'tab:')`; character) The prefix for labels. Currently only the prefix for table labels generated by `knitr::kable()` is supported.

- `latex.options.color`, `latex.options.graphicx` (`NULL`): Options for the LaTeX packages **color** and **graphicx**, respectively. These options are only for `.Rnw` documents.

- `out.format`: (`NULL`; character) Possible values are `latex`, `sweave`, `html`, `markdown`, and `jekyll`. It will be automatically determined based on the input file, and this option will affect the set of hooks to be set (see `?knitr::render_latex` for example). Note this option has to be set *before* `knitr::knit()` runs (it will not work if you set it inside the document).

- `progress`: (`TRUE`; logical) Whether to display a progress bar when running `knitr::knit()`.

- `root.dir`: (`NULL`; character) The root directory when evaluating code chunks. If `NULL`, the directory of the input document will be used.

- `self.contained`: (`TRUE`; logical) Whether the output document should be self-contained (TeX styles to be written in the `.tex` document, and CSS styles to be written in the `.html` document). This option only applies to `.Rnw` and `.Rhtml` documents.

- `unnamed.chunk.label`: (`unnamed-chunk`; character) The label prefix for unnamed chunks.
- `upload.fun`: (`identity`; function) A function that takes a file path, processes the file, and returns a character string when the output format is HTML or Markdown. Typically, it is a function to upload an image and return the link to the image, e.g., `knitr::opts_knit$set(upload.fun = knitr::imgur_upload)` can upload a file to http://imgur.com (see `?knitr::imgur_upload`).
- `verbose`: (`FALSE`; logical) Whether to show verbose information (e.g., R code in each chunk and message logs), or only show chunk labels and options.

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[*18] https://github.com/rstudio/rsconnect
[*19] https://github.com/rstudio/rmarkdown
[*20] https://github.com/rstudio/rticles
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