Simple Reproducible Analysis with knitr, R Markdown, and RStudio

Melbourne R Users Group (melbURN)

Jeromy Anglim

Melbourne Business School

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- `http://jeromyanglim.blogspot.com`
- `https://github.com/jeromyanglim/rmarkdown-rmeetup-2012`

Outline

Introduction

Markdown

knitr and R Markdown

LaTeX

Conclusion

1 Introduction

2 Markdown

3 knitr and R Markdown

4 LaTeX

5 Conclusion

Motivation: How to create documents?

- Types and distinctions
  - Formal Documents: Journal articles, books, book chapters, theses, consulting reports, etc.
  - Informal documents: preliminary analyses, statistical homework,
  - Online content: web pages, blog posts, forum posts
  - Browser metaphor versus page/slide-based metaphor
- Context
  - When to use reproducible analysis?
  - When to use knitr with R Markdown or LaTeX?

What is *reproducible analysis*?

- Reproducibility varies on a continuum
- One particular form:
  - code transforms raw data and meta-data into processed data,
  - code runs analyses on the data, and
  - code incorporates analyses into a report
- Ideally, the process involves a one-click build
- Public sharing of document, code, and data is optional, but forms part of gold standard of scientific openness
- Goes by many names, particularly "reproducible research", but I prefer "reproducible analysis".

See also: `http://stats.stackexchange.com/a/15006/183`
`https://github.com/jeromyanglim/rmarkdown-rmeetup-2012/issues/11`

Aims of reproducible analysis

- Ability to reproduce analysis
- Increase accuracy
  - Ability to verify analyses are consistent with intentions
  - Ability to review analysis choices
- Increase clarity of communication
- Increased trustworthiness
  - Increased accuracy +
  - Ability for others to verify
- Extensibility
  - Ability to easily modify or re-use existing analyses

Reproducible analysis in R

Typically:

- Combine R and plain text file format to produce documents (e.g., pdfs, HTML documents, etc.)

Popular Instances

- Sweave
- brew
- knitr

see also `http://cran.r-project.org/web/views/ReproducibleResearch.html`

Installation of software used in this talk

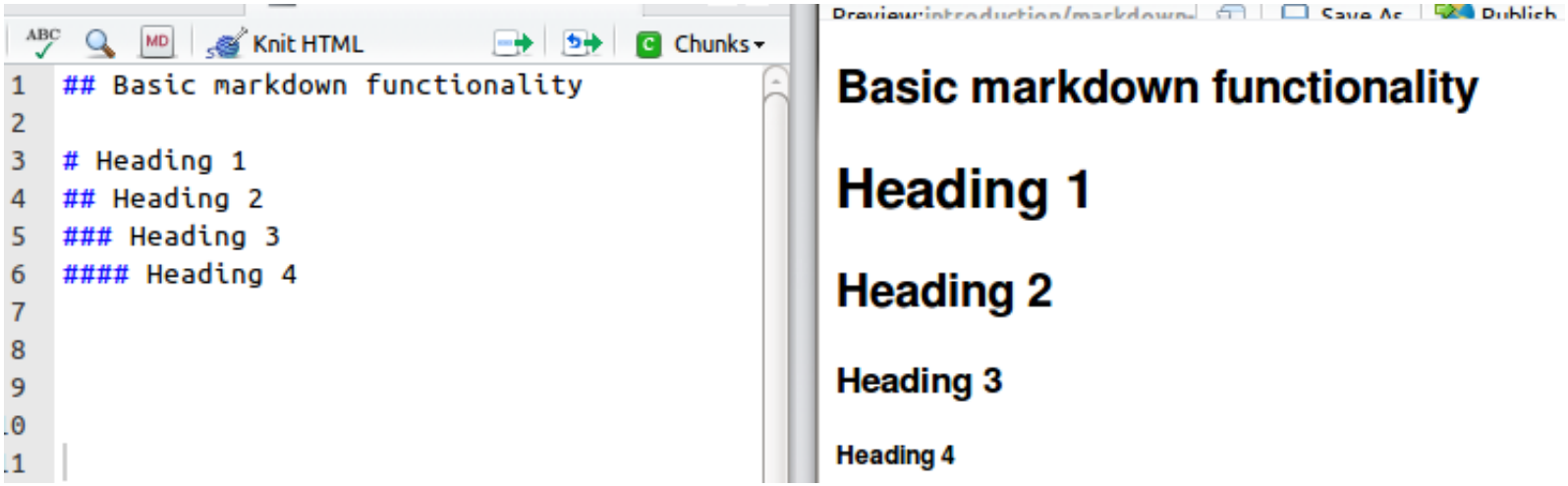
- R: `http://www.r-project.org/`
- R Studio: `http://rstudio.org/`
- In R:
  - `install.packages("knitr)`
  - `install.packages("markdown")`
  - `install.packages("xtable")`
  - `install.packages("ggplot2")`
  - `install.packages("lattice")`
- pandoc:
  - `http://johnmacfarlane.net/pandoc/`
- LaTeX distribution:
  - E.g., TeXLive, MikTeX
    `http://www.latex-project.org/ftp.html`

What is markdown?

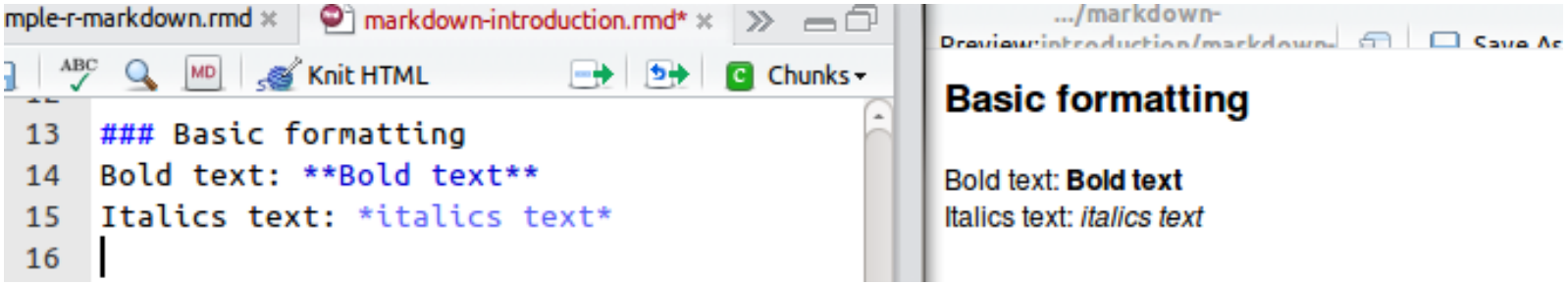
- Simple, readable, intuitive, light-weight markup
- Convert to HTML
- Raw HTML can be interspersed to add functionality
- Various extensions and flaours of markdown
- Popular on websites: e.g., StackOverflow, GitHub, Reddit

see also: `http://daringfireball.net/projects/markdown/`

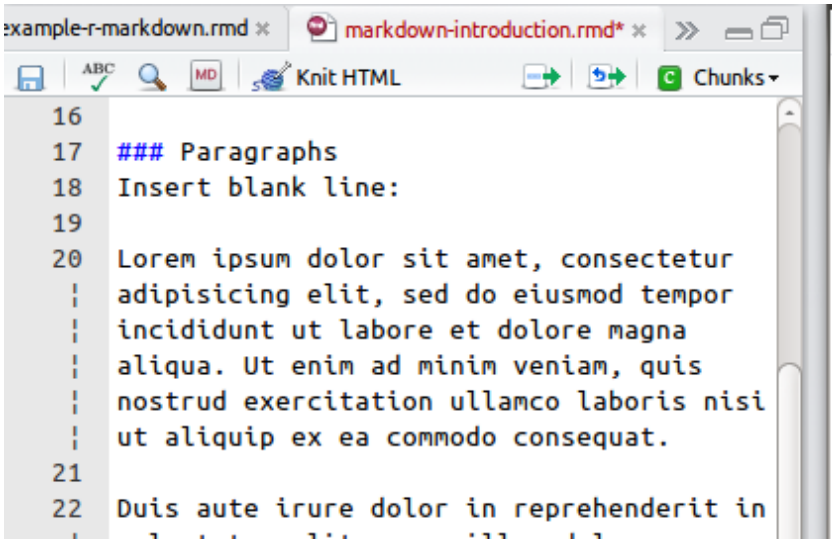
Headings

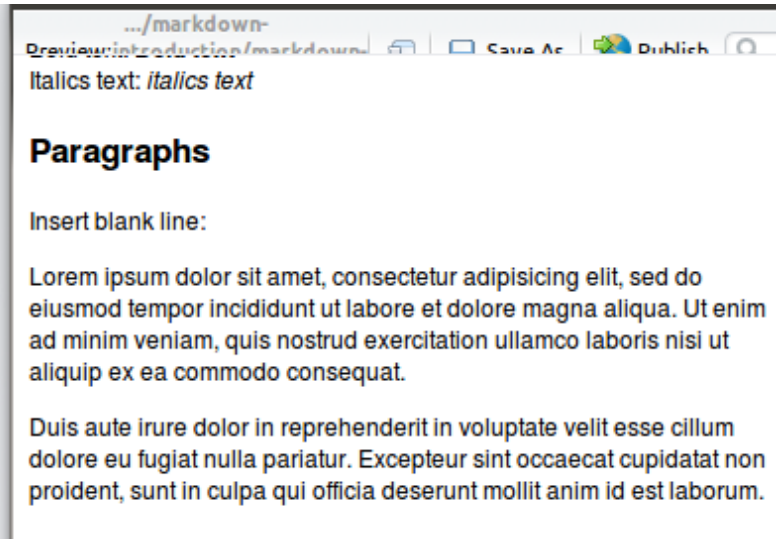

Knit HTML
Chunks
1 ## Basic markdown functionality
2
3 # Heading 1
4 ## Heading 2
5 ### Heading 3
6 #### Heading 4
7
8
9
10
11
Basic markdown functionality
Heading 1
Heading 2
Heading 3
Heading 4

Basic formatting



Paragraphs


example-r-markdown.rmd
markdown-introduction.rmd*
Knit HTML
Chunks
16
17 ### Paragraphs
18 Insert blank line:
19
20 Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat.
21
22 Duis aute irure dolor in reprehenderit in


.../markdown-
Save As
Publish
Italics text: *italics text*
Paragraphs
Insert blank line:
Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat.
Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Dot points


```
### Dot Points
Simple dot points:

* Point 1
* Point 2
* Point 3

and numeric dot points:

1. Number 1
2. Number 2
3. Number 3

and nested dot points:

* A
    * A.1
    * A.2
* B
    * B.1
    * B.2
```

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    - B.1
    - B.2

Equations


```
### Equations
Uses Mathjax to support LaTeX equations.

Inline equations: e.g., $y_i = \alpha + \beta x_i + e_i$.

Displayed equations:

$$
\frac{1}{1+\exp(-x)}
$$
```

Equations

Uses Mathjax to support LaTeX equations.

Inline equations: e.g., $y_i = \alpha + \beta x_i + e_i$.

Displayed equations:

$$\frac{1}{1+\exp(-x)}$$

- Uses MathJaX to render LaTeX (and other) equations
- Inserts MathJaX script reference into HTML header

getting started: `http://jeromyanglim.blogspot.com.au/2010/10/getting-started-with-writing.html`

Hyperlinks


```
### Hyperlinks

* [my RSS feed](http://feeds.feedburner
.com/jeromyanglim).
* <http://www.r-project.org/>
```

Hyperlinks

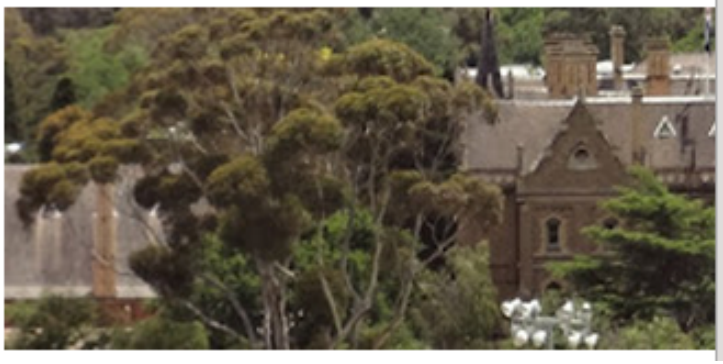
- my RSS feed.
- http://www.r-project.org/

Images


```
### Images

![image description here](figure/buildings.jpg)
```

Images



Code


````
### Code
Inline code between backticks: e.g.,
`print('hello world!')`.

Displayed code can be tab indented or
four space indented:

    ```{r}
    x <- 1:10
    x
    ```
````

Code

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Displayed code can be tab indented or four space indented:

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

Quotes


```
### Quote
Quotes by adding greater than to start of
each line.

> To be, or not to be, that is the
question:
> Whether 'tis nobler in the mind to
suffer
> The slings and arrows of outrageous
fortune,
```

Quote

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> To be, or not to be, that is the question:
> Whether 'tis nobler in the mind to suffer
> The slings and arrows of outrageous fortune,

Tables


```
### Tables
Extended github table functionality:

A   | B      |   C
--- | ---    | ---
1   | Male   | Blue
2   | Female | Pink

Or just write HTML:

<table border="1">
    <tr><td>Cell A1</td>
        <td>Cell B1</td></tr>
    <tr><td>Cell A2</td>
        <td>Cell B2</td></tr>
</table>
```

Tables

Extended github table functionality:

A	B	C
1	Male	Blue
2	Female	Pink

Or just write HTML:

Cell A1	Cell B1
Cell A2	Cell B2

Raw HTML

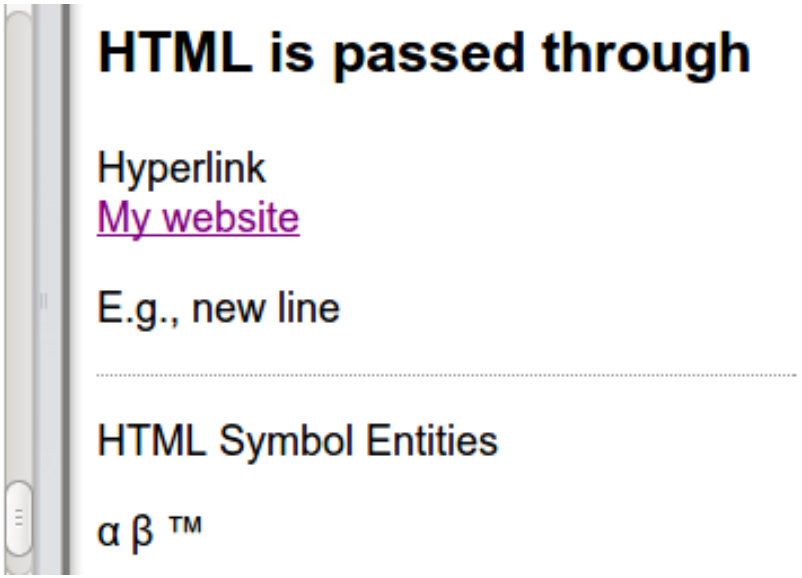

```
### HTML is passed through
Hyperlink
<a href="http://jeromyanglim.blogspot
.com">My website</a>



E.g., new line
<hr />

HTML Symbol Entities

&alpha; &beta; &trade;
```



HTML is passed through

Hyperlink
My website

E.g., new line

HTML Symbol Entities

α β ™

knitr, R Markdown, and R Studio

- knitr: R Package developed by Yihui Xie for weaving R (and other languages) with various markup languages
- R Markdown: A file format that combines R code chunks and markdown text which is converted by knitr into markdown, and other formats (e.g., HTML, pdf, etc.).
- R Studio: Open source, cross-platform IDE for R.

Benefits of knitr

- knitr supports many markups: LaTeX, Markdown, HTML, reStructuredText
- knitr has really nice defaults
- Tidy placement of generated files
- Simplified figure production
  - automatically print ggplot2 and lattice figures
  - print figures by default
  - permit interspersing of figures and console output
- Greater extensibility:
  - output options
  - supports languages other than R
- Simplified caching
- And more: `http://yihui.name/slides/2012-knitr-RStudio.html`

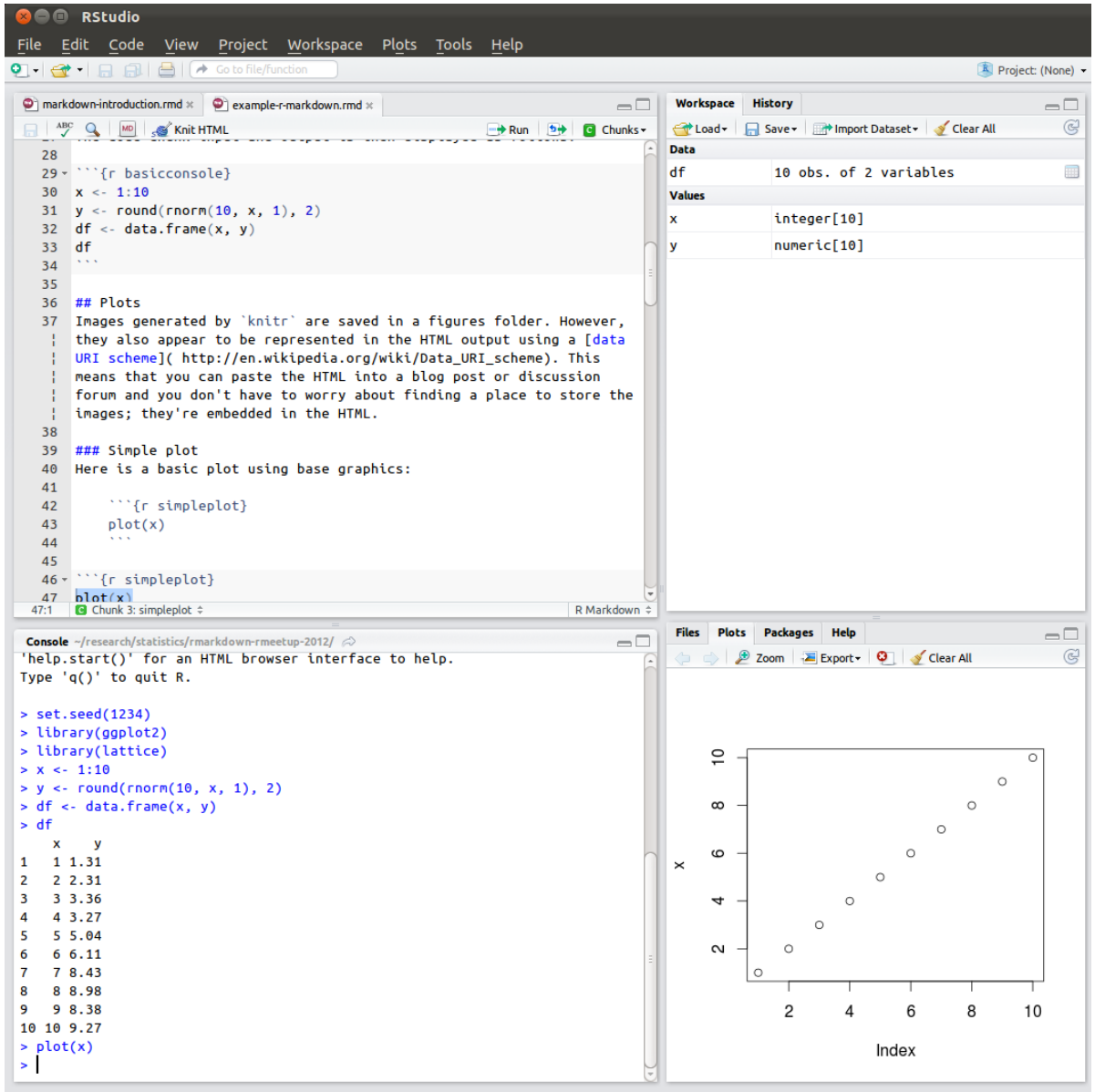
Rstudio

- Benefits of Rstudio as IDE for R
  - Open source
  - Works on Linux, Mac, and Windows
  - Many useful features
  - It just works
  - Tight integration with knitr
- But many other options
  - Emacs with ESS
  - Vim with R plugin
  - Eclipse with StatET
  - etc.

RMarkdown Examples

- *Introduction to R Markdown*
- *Statistics homework example*
- *Analysis of Winter Olympic Medals Example*

Rstudio screenshot



R Code chunks

see http://yihui.name/knitr/options

```
```{r my_chunk_name, some_option='some_value'}
some_r_code
```
```

R Code chunks options

Global options:

```
`r opts_chunk$set(opt = value)` # general form
`r opts_chunk$set(cache=TRUE)` # e.g, global cache
```

Some useful local options

- Hide console input: `echo=FALSE`
- Hide assorted messages: `warning=FALSE, error=FALSE, message=FALSE`
- Hide console output: `results="hide"`
- Display console input as is: `tidy=FALSE`
- Output raw markup: `results="asis"`

Inline R Code

R Markdown	`` `r 2 + 2` ``	`` `r I(2+2)` ``
Markdown	`4`	4
HTML	<code>4</code>	4

Figures

- Support for multiple figures in a code block
  - also see e.g., `par(mfrow=c(2,2))` or `grid.arrange`
- Figures and console output can be interspersed in a code chunk
- Various code chunk options
  - see http://yihui.name/knitr/options
  - `fig.width` and `fig.height`
  - `dev` defaults to pdf for LaTeX and png for HTML/markdown

Tables

- Many options for creating HTML Tables:
  - R packages: `xtable`, `googleVis`, `R2HTML`, `hwriter`
  - markdown extentions: github, pandoc
  - Custom R code
- `xtable` is a reasonable option
- For informal reports just use console output
- css can be added later to control table appearance
- If you require sophisticated tables, you may want to switch to LaTeX

xtable example


```
print(xtable(my_data_frame, caption = "My Caption",
    digits = 3), type = "html",
    caption.placement = "top",
    html.table.attributes =
    "style=\"border: 1px solid black;\"")
```

My Caption

	Mean	SD
A1	2.413	1.408
A2	4.802	1.172
A3	4.604	1.302
A4	4.700	1.480
A5	4.560	1.259

Caching

Basic workflow:

- If knitting is quick, don't cache.
- If knitting takes more than ten seconds add `` `r opts_chunk$set(cache=TRUE)` `` to the top of R Markdown file.
- If caching is causing problems, delete contents of `cache` folder,
- But if caching is causing problems and knitting takes a long time, name R code chunks and use the `dependson` option in knitr (see http://yihui.name/knitr/options). Naming also permits selective deletion of named R code chunks in the cache directory.

R package: `markdown`

- Maintained by Jeffrey Horner; Developed by devloped JJ Allaire, Jeffrey Horner, Vicent Marti, and Natacha Porte
- R Package that creates more options for converting Markdown to HTML
- `markdownToHTML("file.md", "file.html", options=c(...))`
- The default options are `"hard_wrap"`, `"use_xhml"`, `"smartypants"`, `"base64_images"`

Replicating R Studio's `Knit to HTML`


```
require(knitr) # for knitting from rmd to md
require(markdown) # for md to html
knit('test.rmd', 'test.md') # creates md
markdownToHTML('test.md', 'test.html') # create html
browseURL(paste('file://',
    file.path(getwd(),'test.html'),
    sep='')) # open file in browser
```

see `?markdownHTMLOptions` for more options. E.g.,

```
markdownToHTML('test.md', 'test.html',
    options='fragment_only')
```

pandoc

- pandoc is a library and command-line tool for converting between many document formats (e.g., HTML, markdown, pdf, LaTeX, docx; also supports multiple plain text slide formats such as beamer)
- Lots of options
- Often requires thought in order to minimise conversion issues

Example

```
pandoc -s file.html -o file.pdf
```

One-click build

- For simple documents, click `knit to HTML` in RStudio
- For complex documents use a command-line option:
  - e.g., `makefile`, `Rscript`, etc.
  - combine with `pandoc`, `knitr` options, `markdown` options, text manipulation tools (e.g., sed, awk, scripting languages) etc. to flexibly produce a varity of documents

Example of LaTeX

If time permits, show example of knitr with LaTeX

Final thoughts

- knitr and R Markdown
  - It makes reproducible analysis as simple as one click
  - Great tool for:
    - quick analyses for self and colleagues
    - doing homework
    - creating teaching resources
    - blog posts, websites, etc.
  - Scope to make more complex documents, but at a certain point it may be worth exploring other tools
- knitr and R LaTeX
  - Great for journal articles, theses, books (e.g., citations, cross-references, printed works, equations)
- As your needs get more complex
  - pandoc, makefiles, knitr options, markdown package options, scripts, etc.

Links

- knitr: `http://yihui.name/knitr/`
- R Studio: `http://rstudio.org/`
- R Markdown with R Studio: `http://rstudio.org/docs/authoring/using_markdown`
- My Posts `http://jeromyanglim.blogspot.com.au/search/label/reproducible%20research`

Places to ask questions

- R on StackOverflow: `http://stackoverflow.com/questions/tagged/r`
- LaTeX: `http://tex.stackexchange.com/`
- knitr: `https://github.com/yihui/knitr/issues`

Thank You

Questions?