Dynamic Documents

Using **knitr**

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A very short history of "Literate Programming"

- The name *Literate Programming* (mixing the source code with documentation) was first coined by Knuth [1984].
- `Sweave`, a function that is shipped with base R, was created by Leisch [2002].
- In the following years, `Sweave` gained much attention but showed some shortcomings. Several add on packages to `Sweave` tried to fix these issues (e.g. syntax highlighting, better graphics and more devices, cache)
- **knitr** (vers. 0.1) was released in 01/2012 by Xie [2014, 2015] to enhance (and replace?) `Sweave`.

- We will focus on **knitr** in this tutorial.

Why should one use literate programming?

- Instead of copy and paste output, figures, etc. to your document, they are part of the document.
- It is by far less error prone.

- It is easier to update the report, e.g., if the data changes.
- In summary it is often faster to use literate programming even if it requires more work in the first place.

Getting started

- Open RStudio
- Install **knitr**, e.g., via `install.packages("knitr")`
- Go to `Tools` ▶ `Global Options ...` ▶ `Sweave` and select `knitr` as default.

Basic Idea

The basic idea is to mix code and narratives (aka text). **knitr** can be used in combination with LaTeX, HTML, Markdown etc. To make the code identifiable it is wrapped in special tags. In LaTeX these are:

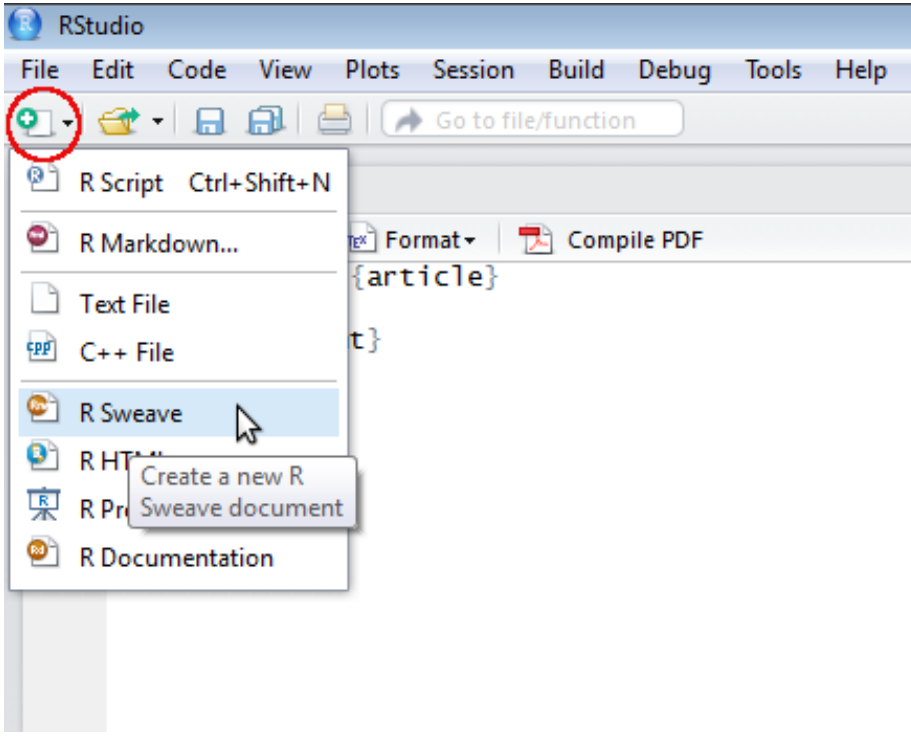
```
<<  options  >>=
code
@
```

Code can also be used in-line by typing `\Sexpr{code}` in LaTeX. The latter is supposed to produce a single (textual) result.

If we run **knitr** on the document, it searches for the special tags, extracts the code, evaluates it and replaces it with the results (depending on the code and on the options).

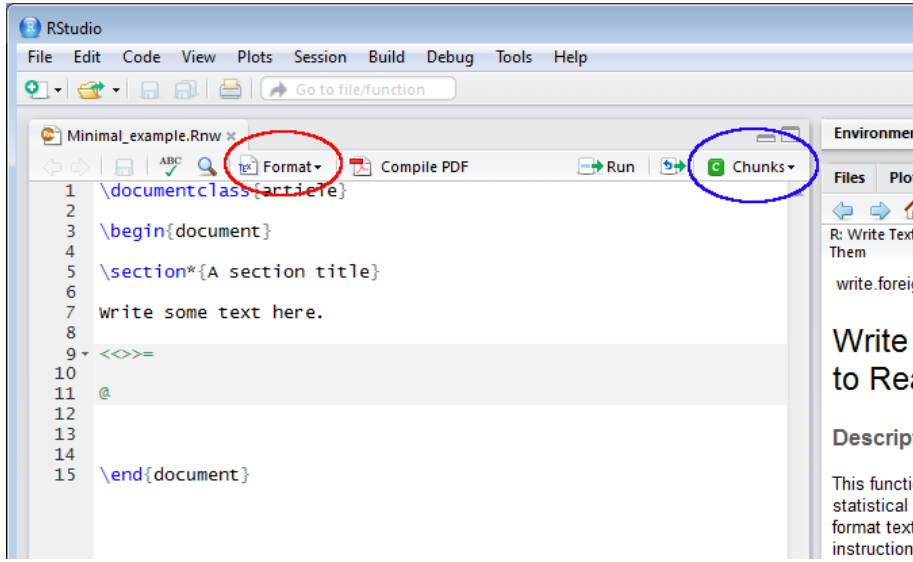
A minimal example in RStudio

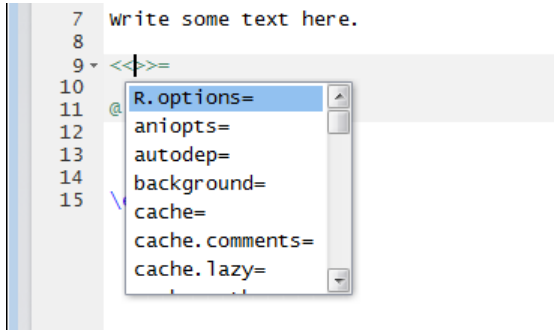
- Go to new file (red circle)
- Select `R Sweave`
- Now we can save this file (use the default file extension `.Rnw` which stands for R noweb) and start working.



A minimal example in RStudio (ctd)

- To insert text simply write some text (after `\begin{document}`)
- To insert text with special markup use the `Format` drop down menu (red circle).
- To insert code, use the `Chunks` drop down menu (blue circle).
- To select chuck options hit the `Tab` key when the cursor is between << and >>=. This works also for auto-completion, i.e., after you started typing an option name.





Chunk options

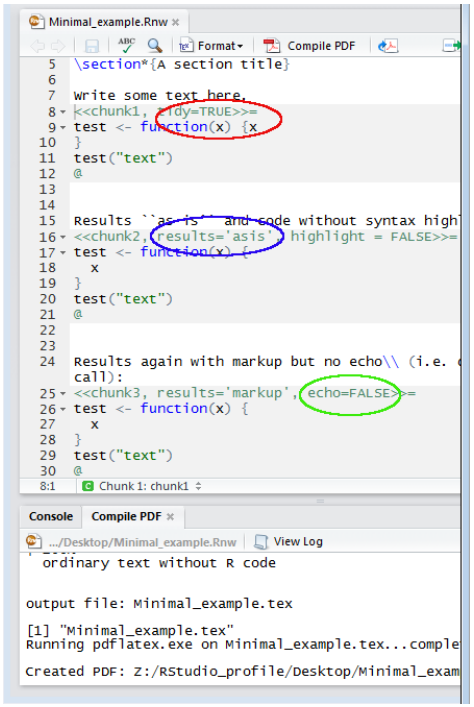
- Chunk options follow the rule: `name = value`.
- The value can be R code itself to allow conditional executions.
- The first option might not have a `name`, in this case it is the chunk label:

```
<<first_chunk, echo=TRUE, results='markup'>>=
print("123")
@
```

- For more on chunk labels and their application see below.

Important chunk options[1]

eval	evaluate the chunk? (`TRUE` / `FALSE`)
tidy	tidy up the code? (`FALSE` / `TRUE` ▶ red circles)
results	type of result, either R-like output (`'markup'`), as is (`'asis'` ▶ blue circles), push everything to the end of the chunk (`'hold'`) or `'hide'` it.
highlight	Use syntax highlighting? (`TRUE` / `FALSE` ▶ green rectangle)
echo	Show R command? (`TRUE` / `FALSE` ▶ green rectangle is missing)
include	Include the chunk in the output? (`TRUE` / `FALSE`)



Details and more options: http://yihui.name/knitr/options/

[1] first option is always the default

Global options

- Errors are reported to the output document.
- Note that the knitr process isn't stopped on errors!
- Reporting of `error`, `warning` and `message` (`TRUE` / `FALSE`) should usually be turned off if one writes a report, at least the last two options.
- One can do this separately for each chunk.
- Better do this globally, i.e., for all chunks.
  One can use global chunk options which are set in a chunk at the beginning of the document (and which will hold from this point onwards):

```
<<init, include=FALSE>>=
opts_chunk$set(warning = FALSE, message = FALSE)
@
```

- Obviously, all other options can be changed globally as well.

(In `Sweave` one needs to use the LaTeX-like command `\SweaveOpts{}`)

Tables as output

- To create tables, one needs to use other packages which return a LaTeX-table, e.g., **xtable** [Dahl, 2014], **Hmisc** [Harrell, 2015], **tables** [Murdoch, 2014].
- Use these packages and their functions in a chunk with option `results='asis'`.

- Easier reporting of descriptive statistics (including figures) and model summaries (with confidence intervals, pretty p-values, ...) is implemented in **papeR** [Hofner, 2015].
- An improved development version can be found on GitHub: http://GitHub.com/hofnerb/papeR.
- To install from GitHub use:

```
library("devtools")
install_github("hofnerb/papeR")
```

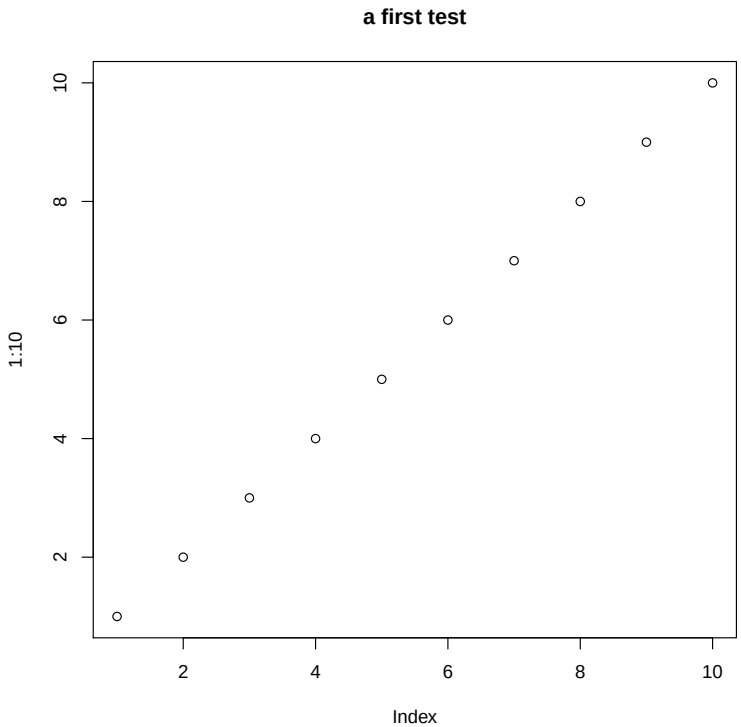
Figures as output

- **knitr** is build to achieve a nice work-flow for graphics.
- Graphics can be created as if you were using the R console directly.
- If a chunk contains a graphic, it is automatically created and inserted in the document.

```
<<test>>=
plot(1:10, main = "a first test")
@
```

- The label is used as file name for the figure.
- Usually one should use `echo = FALSE` for figure chunks.

```
plot(1:10, main = "a first te
```



Important chunk options for figures

fig.path — store the figures here.
defaults to `'figure/'`. Can also be e.g. `'folder/prefix-'`, where `folder` will be automatically created.

fig.width, fig.height — width and height of figure device in inches.
Both default to `7`.

out.width, out.height — width and height of figure in output.
E.g. `out.width='0.8\\textwidth'` (Attention: use `\\`).

fig.show — (how to) show the figure.
`'asis'` / `'hide'` / ...

dev — plotting device.
default depends on the output: `'pdf'` (for LaTeX) or `'png'` (for HTML and Markdown). Interesting device for LaTeX: `'tikz'`.

fig.keep — plots are produced as a sequence. Which plots should be kept and displayed?
`'high'` / `'all'` / `'last'` / ...

Details and more options: http://yihui.name/knitr/options/

Cache

- To speed up computation, one can use cached versions of chunks.
- This can be turned on by

```
<<chunk1, cache=TRUE>>=
plot(1:10, main = "a first test")
@
```

  Per default this option is `FALSE`.

- Code is only executed at the first time and if it is changed.

- What happens if not the code inside the chunk but the data, pre-computed objects (i.e., code in other chunks), the package versions, . . . change?
- Per default, the code chunk is **not** re-evaluated.

Cache – Dependencies

- To define define dependencies to other chunks one can use the option `dependson`. One can either specify a numeric vector such as `1:5` or `c(-1, -2)` or a vector containing the chunk names.
- Dependencies are only possible for cached chunks.
- The (still experimental) option `autodep` tries to automatically determine dependencies if set to `TRUE`.

Cache – Further dependencies

- To cache further changes these need to be included as chunk options.
- **Note:** One can specify arbitrary chunk options.
- To check if the data set has changed on disk, one could use, e.g., the modification time as option

```
<<chunk1, cache=TRUE, data_version=file.info("dataset.csv")$mtime>>=
data <- read.csv("dataset.csv")
@
```

- Similarly, we could also depend on the value of a variable `x` from a different chunk by including, e.g., `cache.dep = x`.

Cache – Random numbers

- Usually, the current state of the variable `.Random.seed` is also part of the cached objects. This helps to make simulations in combination with `cache = TRUE` reproducible.
- All random numbers drawn after the cached chunk will be exactly the same as if the chunk was executed.

- To re-run the cached chunk if the current state of the seed changes (e.g. by drawing another random number before that chunk) one needs to add a dependency on `.Random.seed`

```
<<chunk1, cache=TRUE, cache.seed=.Random.seed>>=
```

or set this global option:

```
opts_chunk$set(cache.seed = rand_seed)
```

Cache – Side effects

- Note that "side effects" are usually not cached.

- E.g. global options (`options()`), graphics options (`par()`) or global **knitr** options (`opts_chunk$set()`) might affect the execution of all following code.

! These settings are, however, not recorded and cached.

- Global options and other functions with side effects (e.g. `setwd()`) need to be set in an un-cached chunk!

For details on `cache` see `http://yihui.name/knitr/demo/cache/`. Please read the notes there as well, as using `cache = TRUE` might have unintended side effects!

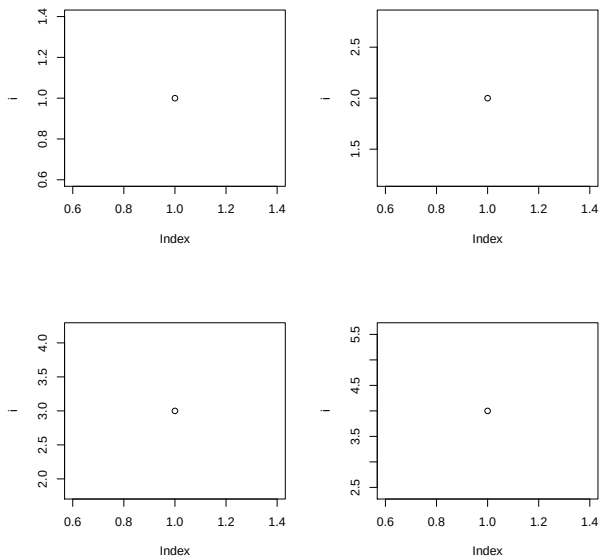
Cross references

Re-using chunks

- Chunks can be easily re-used (to avoid code duplication).
- If a labeled (!) chunk is defined it can be used in any other chunk as follows:

```
<<par, eval = FALSE>>=
par(mfrow = c(2, 2))
@
```

```
<<myfig>>=
<<par>>
for (i in 1:4)
    plot(i)
@
```



Cross references

Re-using chunks

- Code chunks can also be used within another command as long as they are only preceded by spaces.

```
<<mysum, eval = FALSE, echo = FALSE>>=
sum(1:10)
@
```

```
<<total, echo = FALSE>>=
sum(11:20) +
    <<mysum>>
@
```

```
## [1] 210
```

```
<<NOT_WORKING>>=
sum(11:20) + <<mysum>>
@
```

Cross references

Re-using whole chunks

- Code chunks can also be re-used as a whole.
- Same way as above,
- or use an empty chunk with the same label,

```
<<mysum, eval = TRUE>>=
@
```

```
sum(1:10)

## [1] 55
```

- or use the option `ref.label`

```
<<mysum2, ref.label=c("mysum", "total"), tidy=TRUE>>=
@
```

```
sum(1:10)

## [1] 55

sum(11:20) + sum(1:10)

## [1] 210
```

Cross references

Using external `.Rnw` files

- Similar result as `\input{file.tex}` but for **knitr** files.
- External file `external.Rnw` (a mixture of code and narratives):

```
\textbf{This text is an external text.}
A random normal sample:
<<ext_chunk>>=
set.seed(1503)
rnorm(2)
@
```

- We use the chunk option `child` with an empty chunk

```
<<use_external_file, child = "external.Rnw">>=
@
```

This text is an external text. A random normal sample:

```
set.seed(1503)
rnorm(2)
```

```
## [1] -0.2142477  1.2526165
```

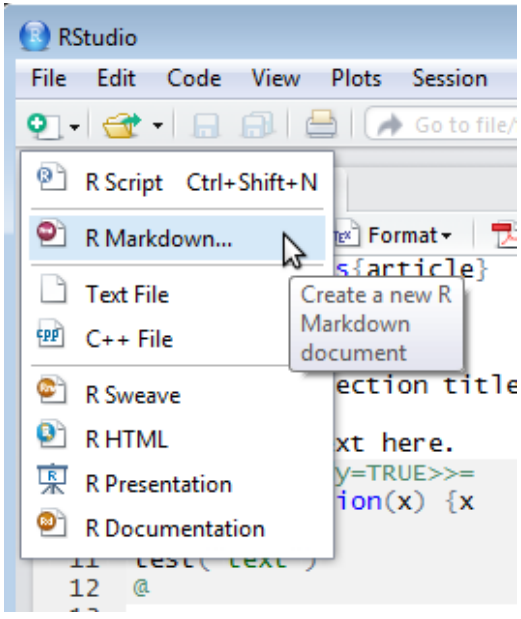
Using `knitr` with `markdown`

- Instead of LaTeX we can use Markdown to write the narratives.
- Markdown is a simple markup language (with many different flavors or dialects).
- For `R markdown` basic syntax see the RStudio help or http://rmarkdown.rstudio.com/authoring_basics.html.
- For further details see http://rmarkdown.rstudio.com/.
- The standard document suffix for markdown is `.md`, for **knitr** type markdown files it becomes `.Rmd`.
- Note that the chunk tags change:

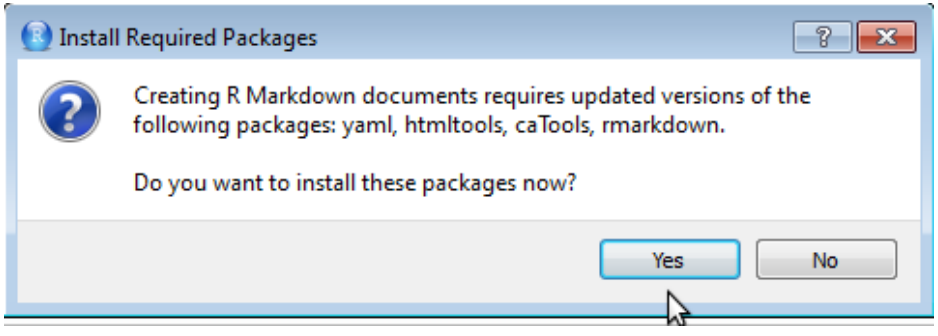
  Open chunk: `<<label, opts>>=` ▶ ```` ```{r label, opts} ````
  Close chunk: `@` ▶ ```` ``` ````
  In-line code: `\Sexpr{code}` ▶ `` `r code` ``

- One can `knit` the `R markdown` files to HTML, PDF or even Word.

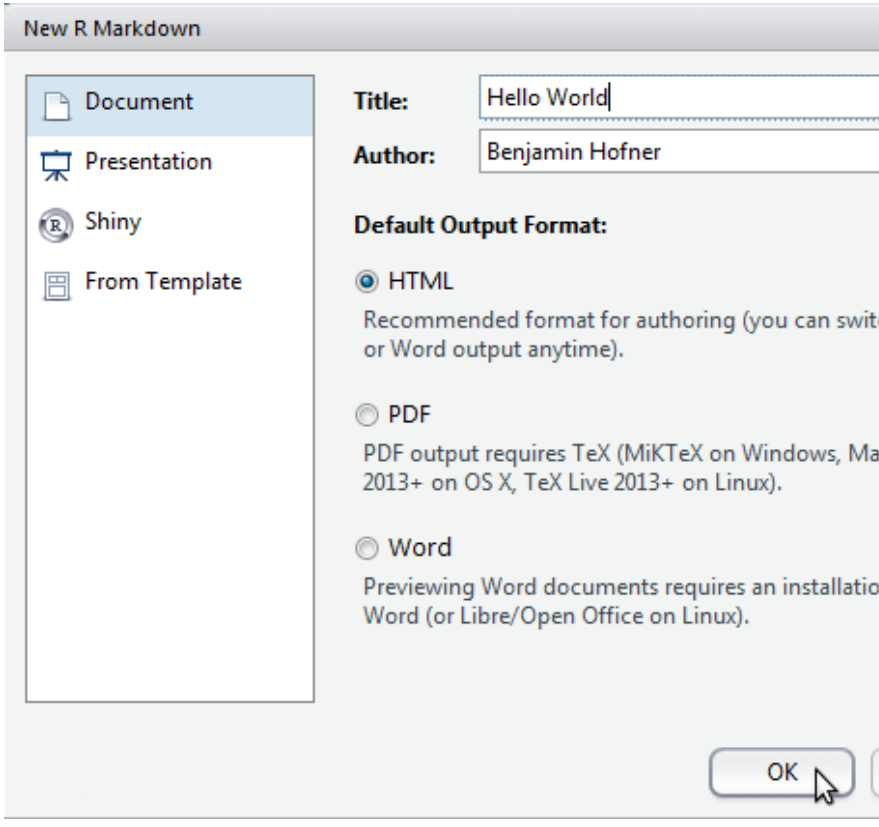
- Open new R Markdown file:



- If doing this for the first time, one needs to install some packages:



- Set up file:



- To knit the file or change the options use these icons:

Further resources & References

- Online manual: http://yihui.name/knitr
- Chunk options: http://yihui.name/knitr/options
- More on Reproducible Research in R: http://cran.r-project.org/web/views/ReproducibleResearch.html

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