Using the right tools for doing right research

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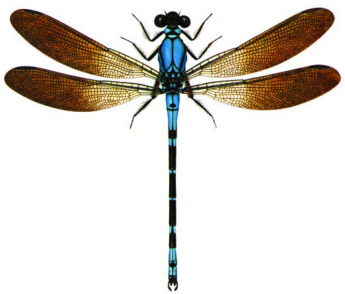


Typical case #1

New data to be incorporated, or mistake in source data

1. Add data to spreadsheet or correct mistake
2. Re-run analyses, involving thousands of clicks
3. Update figures, with a lot of frustration about formatting
4. Update tables, endless copy & paste operations
5. Update numbers in report – Have you missed one?

Waste of time, stressful moment, ending up with a vague feeling of having forgotten to update something...

Typical case #2

Accidental deletion or bad direction

- You realise at some stage that you deleted some data or some text a while ago and that you kept working in a wrong direction.
- You wish you could go back in time to a previous version of your work
- The deleted part might be lost forever, or at least requires to re-do everything since the mistake.

Waste of time and frustration! But you learn from your mistake, and since then, you keep a different version of everything every time you change something.

Typical case #3

Coming back to an old project

- The review of a submitted paper comes back and requires you to do additional analyses
- You open your project folder only to discover 20-odd different versions of the data
- Which one did you use?
- After being fairly confident of the correct one to use, you re-do the analyses, and find different results!
- Eventually, you manage by trial and error to find the same results and keep going.

Waste of time, ending up unsatisfied and not very confident about the results.

Typical case #4

Changing computer

- After spending a lot of time perfecting the formatting of your thesis, presentation, or article, you realise your document looks quite different on another computer

Panic and frustration...

Typical case #5

Changing institution

- After finally getting into grip with a given software, you change institution and you realise they use a different software. Unfortunately, you cannot get your favourite one because the license is too expensive.

Waste of time re-learning a new software, never becoming a master at a given one

Typical case #6

Auditing

- You work on a sensitive issue, e.g. an endangered species at risk of a proposed development project.
- The “bad guys” do not really like your results, preventing their project to be approved.
- In the environmental court, it is agreed that your project gets audited, requiring you to show that you get the same results from the same data.

... Can you?

Typical case #7

Teaching

- A workmate asks you to show him/her how you do a certain analysis.
- You sit at a computer with him/her, and start explaining: “You go to this menu, and click there, then there, then you go there and type in that, and then you click on this, etc.”
- It takes quite a while, as your workmate writes down the whole complicated process.
- He/she gets back to you later, because his/her version of the program is slightly different and he/she cannot find a certain item in the menus.

... (sigh) ...

Let’s dream that...

- all these problems could be solved,
- you could focus on content and process rather than formatting and eye-candy,
- all the tools to solve these problems and do proper research are free,
- on the way of solving these problems, you acquire great skills that would make you find a job very easily.

Well, yes, it is possible!

Research

Research should:

- be reproducible
- be transparent
- have a functional work flow

Sounds trivial, but it is rarely the case!

Scripting power

- Everything is written, no lost clicks
- Reproducible and transparent
- Easily changed
- Code is re-usable
- Repetitive tasks are done using loops
- Generally quicker than clicks and navigating menus
- Don’t Repeat Yourself (DRY) philosophy

Open-source software

- Free!
- Generally quite portable between operating systems
- Huge community for support, bug checking and fixing, for new developments
- Transparent with a non-restrictive license, allowing easy communications between programs.

Main jobs

- Data preparation, exploration, analysis, and plotting
- Reporting
- Bibliography
- Work flow
- Version control
- Distribution

Data preparation, exploration, analysis and plotting

- NZ product!
- Software environment for statistical computing and graphics
- Programming language, but easy to learn
- Works on all systems (Windows, Mac, Linux, ...)
- Increasing popularity, real threat to commercial products (e.g. SAS, SPSS)
- Evolves fast, expandable with thousands of available packages

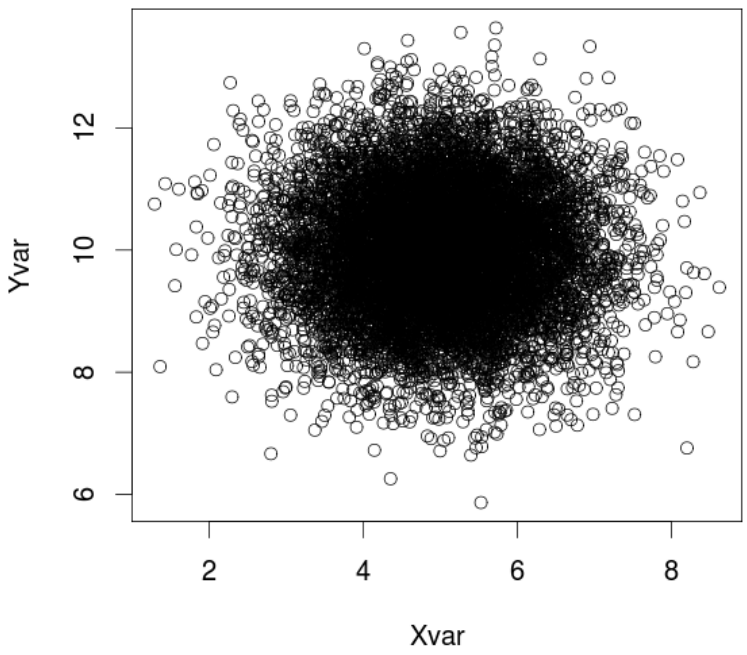
R language

Example

```
## Load data
dat <- read.csv("file-with-data.csv")

## Data manipulation
dat$var3 <- dat$var1 + dat$var2

## Plot
plot(Xvar, Yvar)
```



R language

Fitting a linear model

```
mod <- lm(dep ~ var1 + var2)
summary(mod)
```

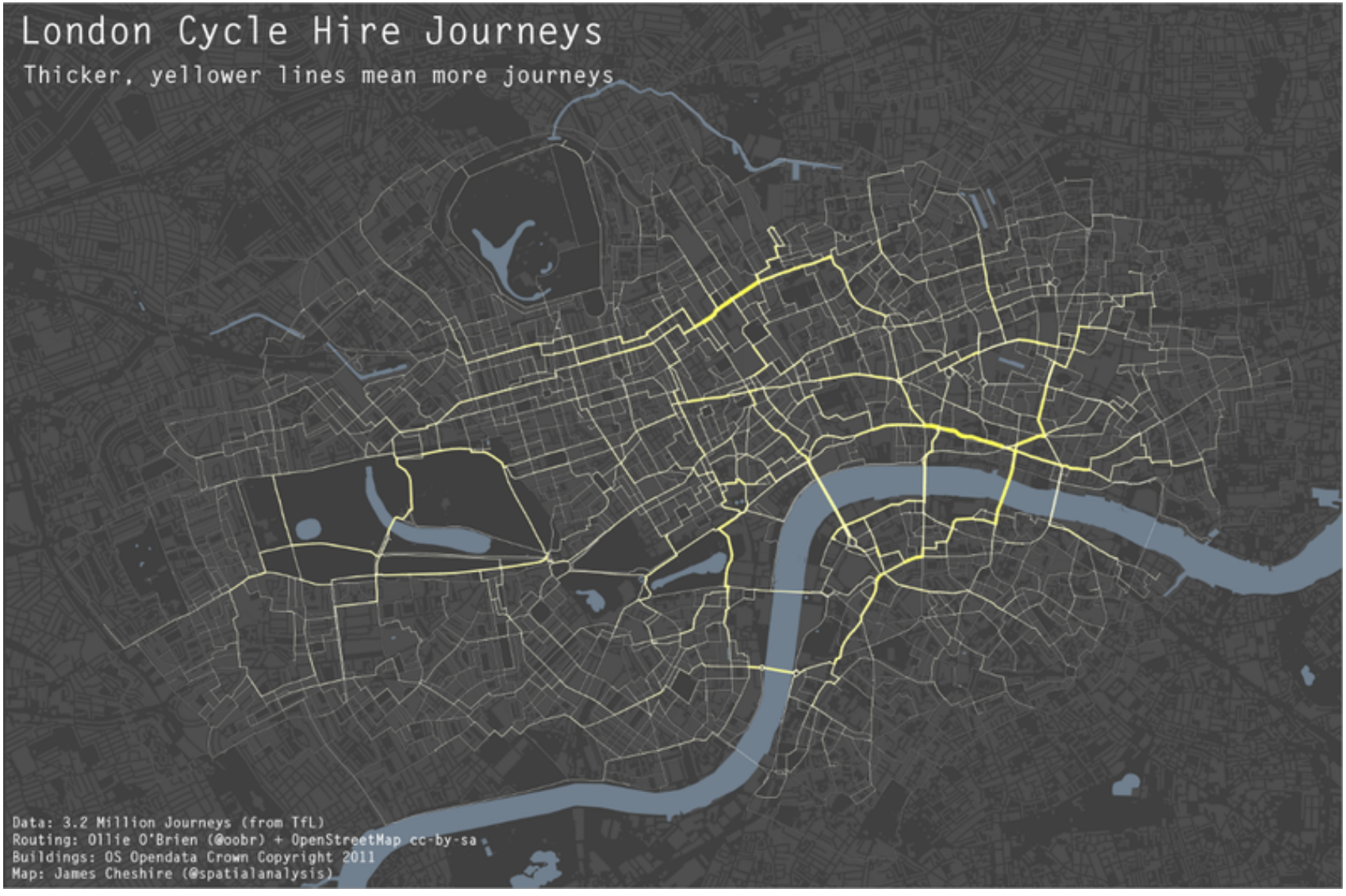
```
Call:
lm(formula = indep ~ var1 + var2)

Residuals:
    Min      1Q  Median      3Q     Max
-7.8060 -1.3795 -0.0133  1.3950  8.2858

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.21056    0.23224   0.907   0.3646
var1         4.95934    0.02074 239.112   <2e-16 ***
var2         0.04883    0.02062   2.368   0.0179 *
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Residual standard error: 2.083 on 9997 degrees of freedom
Multiple R-squared: 0.8512, Adjusted R-squared: 0.8511
F-statistic: 2.859e+04 on 2 and 9997 DF,  p-value: < 2.2e-16
```

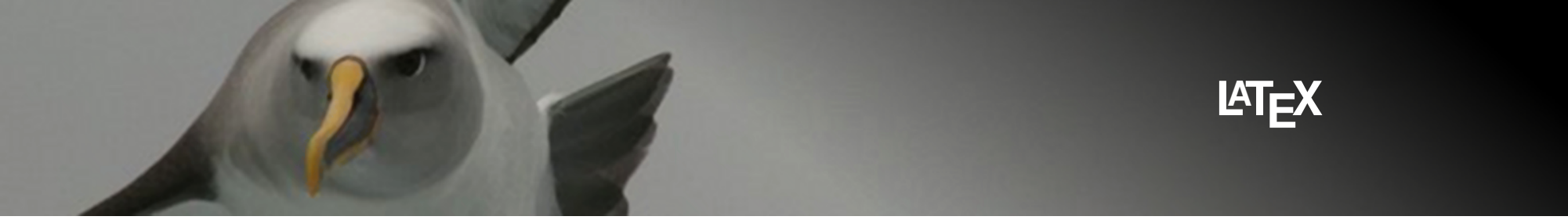
R: advanced graphics



Reporting

LaTeX

- Compiled documents, not WYSIWYG
- Very common
- Most scientific journals provide their own template
- Beautiful typesetting
- Takes care of formatting automatically
- Maths formulae are easy to write
- Easy PDF creation with pdflatex
- Creation of presentations using Beamer (like this one)




```
the stochastic population growth rate ($\lambda_{s}$) may be found via
simulation using the following formula \citep{caswell_matrix_2001}
\[
\lambda_{s} = \exp \Big( \frac{1}{T} \big( \ln(N_{T}) -
  \ln(N_{0}) \big) \Big)
\]
with $N_{i}$ being the population size at time $i$, and $T$ the number
of time steps in the model. This formula is simply the geometric mean
of the population growth rate at each time step ($\lambda_{t \to t+1}
= N_{t+1}/N_{t}$). Similarly, the number of survivors after $T$ time
```

---

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$$\lambda_s = \exp\left(\frac{1}{T}\big(\ln(N_T) - \ln(N_0)\big)\right)$$

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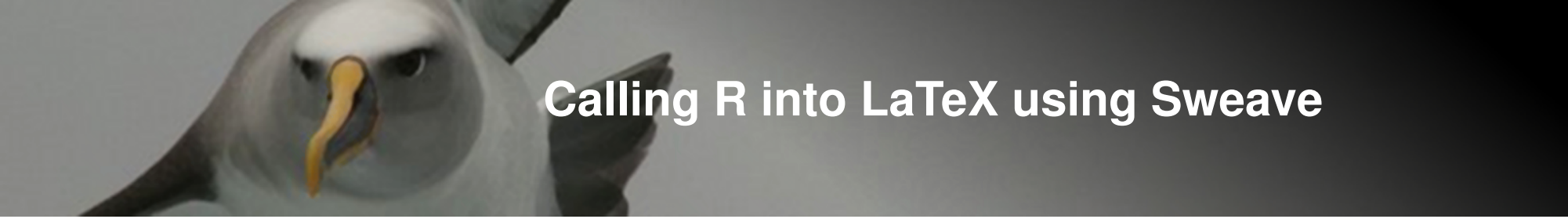


Calling R into LaTeX using Sweave

- Sweave lets data and tables from R to be included in LaTeX documents
- Why copying and pasting data manually when you can call them directly?
- Enormous time saver
- Chances of mistakes are minimal
- Initial data can be changed, the changes will be automatically reflected in the report

Calling R into LaTeX using Sweave

Example

```
\SweaveOpts{echo=FALSE, results=tex, prefix.string=sweave/fig}

<<load>>=
dat <- read.csv("file-with-data.csv")
minsize <- min(dat$popsize)
maxsize <- max(dat$popsize)
@

The population size varied between \Sexpr{minsize} and \Sexpr{maxsize}.
```

Bibliography in LaTeX

Including references is easy with BibTeX! References are stored in a text file (e.g.: refs.bib):

```
@article{richard_cost_2010,
    title = "Cost distance modelling of landscape connectivity
             and gap-crossing ability using radio-tracking data",
    volume = "47",
    number = "3",
    journal = "Journal of Applied Ecology",
    author = "Richard, Yvan and Armstrong, Doug P",
    year = "2010",
    pages = "603--610",
    },
```

Then each reference is called in the LaTeX document by its tag:

```
... is a powerful tool to analyse movements \cite{richard_cost_2010}.
```

Bibliography in LaTeX

- BibTeX format is very common
- References in this format can be downloaded from Google Scholar, imported from Zotero, and from journals web site
- Templates exist for all journals
- No more corrupted EndNote databases...

Workflow management

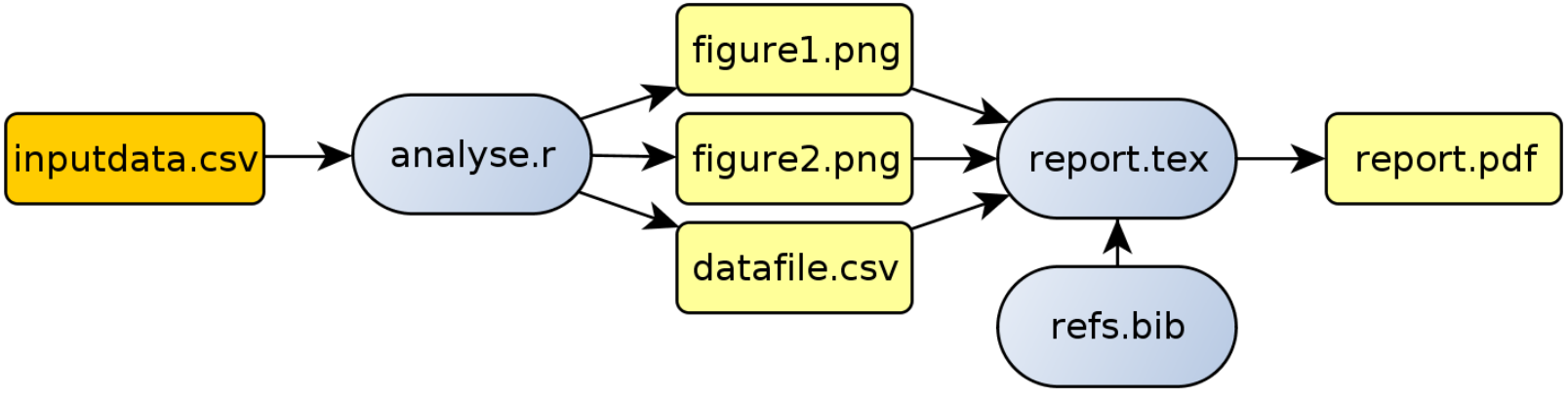
- GNU make
- Centralise jobs to be run
- Jobs are run in order, and only if necessary
- Jobs can be run in parallel in order to use several computer processors
- Can be used to document the whole workflow.

Workflow management

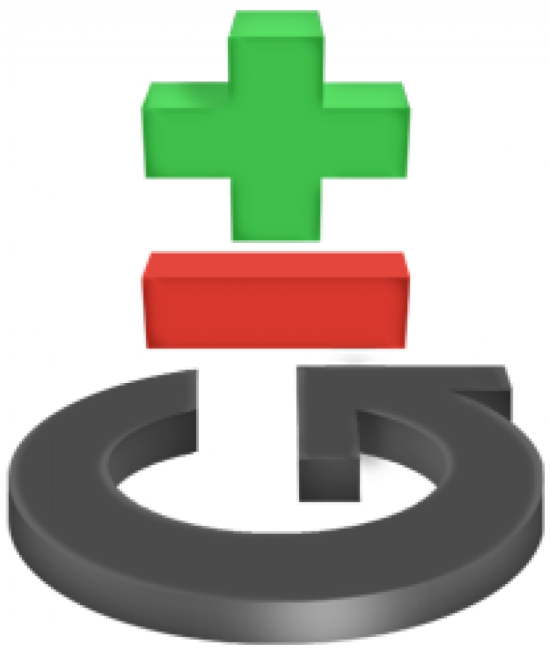
The jobs are written in a text file (makefile):

```
all:  report.pdf

report.pdf:  report.tex datafile.csv refs.bib
    bibtex report
    pdflatex report

datafile.csv:  analyse.r inputdata.csv
    Rscript analyse.r
```

You run the whole process by only typing “make” in a terminal, it’s that easy.



Version control



- GIT
- Saves all gradual changes of files
- Allows to safely keep only one version of each file
- Do not be afraid to delete stuff! You can always come back to previous versions
- Provides an easy outlook of all modifications
- Utilities to compare versions
- Great also for cooperative work

Workflow management

Easy commands:
`git status`: to get list of all modified files
`git add .`: to inform git to save all modifications
`git commit -m "Finished intro of chapter 3"`: to save locally the current state of modifications, with a comment to describe the changes
`git push`: to save the commits to the server

Distribution

github
SOCIAL CODING

- GitHub is a web interface and service to store your git project
- Makes it easy to access your project from anywhere and to share it with others
- Free for open-source projects
- Great for issue tracking (to-do list)

Conclusions

- Great suite of tools for doing proper research, and it's free!
- Risk of mistakes minimised
- Transparent and reproducible
- Fun! Just like playing Lego
- Adopting only one of these tools even is a great improvement over the traditional bad habits
- This workflow allows tackling some large projects comfortably that would be impossible otherwise
- These skills will help you all your life and make your life easier, and are great to get a job
- Open research movement; make research more accessible!

But...

- Scary at first; learning curve significant

But still worth it 100%!