BMI 826-003

Tools for Reproducible Research

Karl Broman

Biostatistics & Medical Informatics, UW–Madison

kbroman.org
github.com/kbroman
@kwbroman
Course web: kbroman.org/Tools4RR

Karl -- this is very interesting, however you used an old version of the data (n=143 rather than n=226).

I'm really sorry you did all that work on the incomplete dataset.

Bruce

Reproducible

Reproducible

vs.

Replicable

Reproducible

vs.

Correct

Levels of quality

- Are the tables and figures reproducible from the code and data?
- Does the code actually do what you think it does?
- In addition to what was done, is it clear why it was done?

  (e.g., how were parameter settings chosen?)
- Can the code be used for other data?
- Can you extend the code to do other things?

Basic principles

- Everything via code
- Everything automated

  Workflow and dependencies clearly documented

- Get the data in the most-raw form possible
- Get any/all data and meta-data possible
- Keep track of the provenance of all data files
- Be self-sufficient

Why do we care?

- Avoid embarrassment
- More likely correct
- Save time, in the long run
- Greater potential for extensions; higher impact

Your closest collaborator is you six months ago,
but you don't reply to emails.

What could go wrong?

- "The attached is similar to the code we used."
- "Where did this data file come from?!"
- "Can you repeat the analysis, omitting subject X?"
- "This part of your script is now giving an error."

Need to avoid

- Open a file to extract as CSV
- Open a data file to do even a slight edit
- Paste results into the text of a manuscript
- Copy-paste-edit tables
- Copy-paste-adjust figures

Basic tools

- Automation with Make
- Unix command line
- Latex and Markdown
- Knitr
- Version control with git
- R packages
- Python (or Ruby or Perl)

Other topics

- Organizing projects
- Writing clear code
- Don't Repeat Yourself (DRY)
- Testing and debugging
- Handling big jobs
- Licenses; human subjects data

Don't Repeat Yourself

- In code, in documentation, etc.
- Repeated bits of code are harder to maintain

  Write a function
- Use documentation systems like Roxygen2

  Documentation in just one place
- Make use of others' code

This course

- Brief intro to various tools and concepts
- Try everything out as we go along

  Ask questions!
- I don't know everything

  Make suggestions!
- Project
  - Write a bit of R code
  - Use version control
  - Make it an R package
  - Write a vignette

The most important tool is the mindset,
when starting, that the end product
will be reproducible.

– Keith Baggerly

Automation with GNU Make

- `Make` is for more than just compiling software
- The essence of what we're trying to do
- Automates a workflow
- Documents the workflow
- Documents the dependencies among data files, code
- Re-runs only the necessary code, based on what has changed

Example `Makefile`

```
# Example Makefile for a paper
mypaper.pdf: mypaper.bib mypaper.tex Figs/fig1.pdf Figs/fig2.pdf
    pdflatex mypaper
    bibtex mypaper
    pdflatex mypaper
    pdflatex mypaper

# cd R has to be on the same line as R CMD BATCH
Figs/fig1.pdf: R/fig1.R
    cd R;R CMD BATCH fig1.R fig1.Rout

Figs/fig2.pdf: R/fig2.R
    cd R;R CMD BATCH fig2.R fig2.Rout
```

Fancier example

```
FIG_DIR = Figs

mypaper.pdf: mypaper.tex ${FIG_DIR}/fig1.pdf ${FIG_DIR}/fig2.pdf
    pdflatex mypaper

# One line for both figures
${FIG_DIR}/%.pdf: R/%.R
    cd R;R CMD BATCH $(<F)

# Use "make clean" to remove the PDFs
clean:
    rm *.pdf Figs/*.pdf
```

How do you use make?

- If you name your make file `Makefile`, then just go into the directory containing that file and type `make`
- If you name your make file `something.else`, then type `make -f something.else`
- Actually, the commands above will build the first target listed in the make file. So I'll often include something like the following.

  ```
  all: target1 target2 target3
  ```

  Then typing `make all` (or just `make`, if `all` is listed first in the file) will build all of those things.
- To be build a specific target, type `make target`. For example, `make Figs/fig1.pdf`