Developing a Workflow to Maximize Reproducibility and Research Impact: Managing Data, Computer Code, and Projects for Success

Althea A. ArchMiller & John R. Fieberg

7/12/2017

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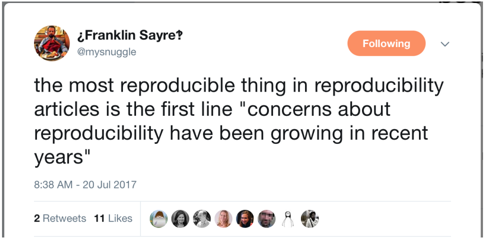


¿Franklin Sayre‽
@mysnuggle

the most reproducible thing in reproducibility articles is the first line "concerns about reproducibility have been growing in recent years"

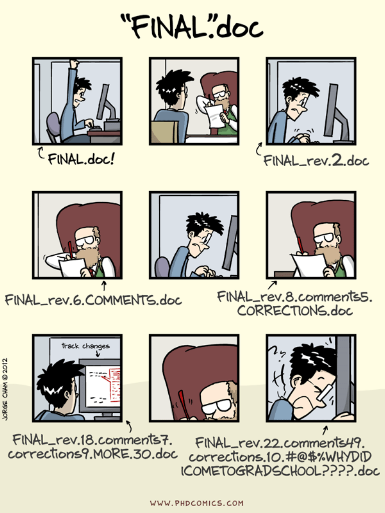
8:38 AM - 20 Jul 2017

2 Retweets 11 Likes

- Program R <www.r-project.org> (required)
- RStudio <www.rstudio.com/products/RStudio> (required)
- Git <git-scm.com> (optional)
- GitHub account <github.com> (optional)
- Microsoft Word (preferable)

Why worry about reproducibility?

Working towards future reproducibility makes my code easier for my collaborators (and me) to read, run, and debug today,
and that's why I think reproducibility is a
win-win for all researchers."
-Althea


"FINAL".doc
FINAL.doc!
FINAL_rev.2.doc
FINAL_rev.6.COMMENTS.doc
FINAL_rev.8.comments5.CORRECTIONS.doc
track changes
FINAL_rev.18.comments7.corrections9.MORE.30.doc
FINAL_rev.22.comments49.corrections.10.#@$%WHYDIDICOMETOGRADSCHOOL????.doc
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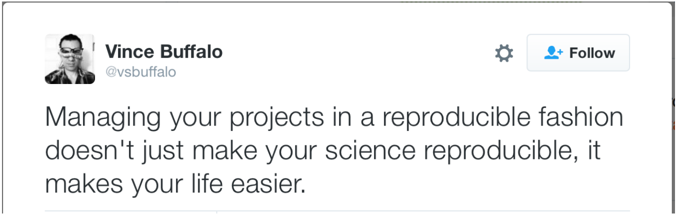
Why worry about reproducibility?



Managing your projects in a reproducible fashion doesn't just make your science reproducible, it makes your life easier.

- make your life easier! Now, and in the future
- collaborations
- broader research impact
- increased citations
- transparency
- grant and journal requirements

"[Reproducibility] provides security, saves time, and forces me to be more thoughtful about my workflow." - Ethan Young

Is my research reproducible?

What formats are your research documents stored in?

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- .txt
- .pdf
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- .R/.Rdata
  - YES - these are considered "reproducible"

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- .doc/.docx
- .sas
- .xls/.xlsx
- any other proprietary file format
  - NO - these are not "reproducible"

Is my research reproducible?

- Is your code linear?
    - Clear environment often and at beginning of script
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    - Don’t rely on manual commenting/uncommenting

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```r
# Here, I want to know what variables are significant?
#       I will try each variable in turn
lm.out <- lm(weight ~ height, data = trial.data)
remove(lm.out) # clear previous lm.out for each
               #   new lm() definition above

# Is the relationship significant?
#     (If not, clear and try a new variable)
summary(lm.out)
```

Is my research reproducible?

- Are your files easily shared with others?
    - Organized directory structure
    - Files relatively linked
    - Well-documented & commented
    - Consistency in coding practices

“The point of having style guidelines is to have a common vocabulary of coding so people can concentrate on *what* you are saying, rather than on *how* you are saying it.” - Google’s R Style Guide

Is my research reproducible?

Do you treat your data as read-only?

- Don't use Excel, etc., to manipulate raw data
- Use an R script for data processing
  - Process data in one script, then save for loading into subsequent scripts
- When archiving, provide raw data and processing code not just final tables

Workshop Outline

The goal for this workshop is to help you develop the tools to develop a workflow to maximize reproducibility, collaborations, and research impact.

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2. R-Markdown and R-Oxygen with knitr for documenting your code and creating reproducible reports

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1. RStudio Projects for organizing data, code, and output
2. R-Markdown and R-Oxygen with knitr for documenting your code and creating reproducible reports
3. GitHub for version-control, collaborating and archiving

1. RStudio Projects for organizing data, code, and output

1: Introduction to RStudio

RStudio is a GUI for R that eases

- programming
- debugging
- data organization
- data processing
- project managment
- program version-controlling and archiving
- plotting
- R library installation and updating

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- Reproduciblity!

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- Processed data
- Analysis scripts
- Paper/Manuscript-related documents
- Sharing documents ("transmittals")
- Metadata
- Maps or other deliverables

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- Sharing documents ("transmittals")
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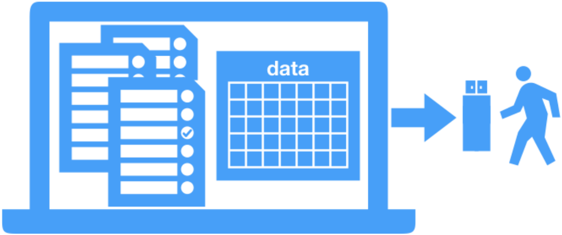
- Maps or other deliverables

RStudio Projects provide an opportunity for you to organize and manage all of these types of folders in **one place** in a way that **relatively links** everything together and **eases sharing**.

1: Introduction to RStudio

C://Documents/Users/arche049/
projects/eco1/raw_data.csv

1: Introduction to RStudio



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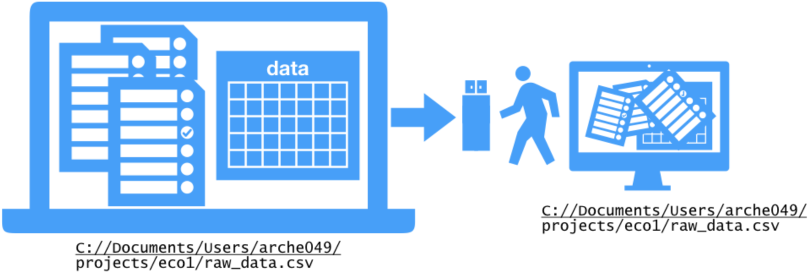

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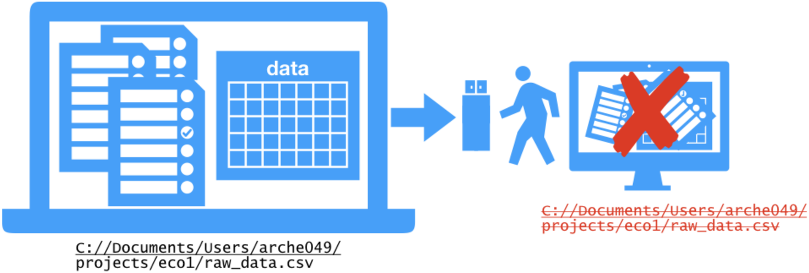
data
C://Documents/Users/arche049/
projects/eco1/raw_data.csv
~~C://Documents/Users/arche049/~~
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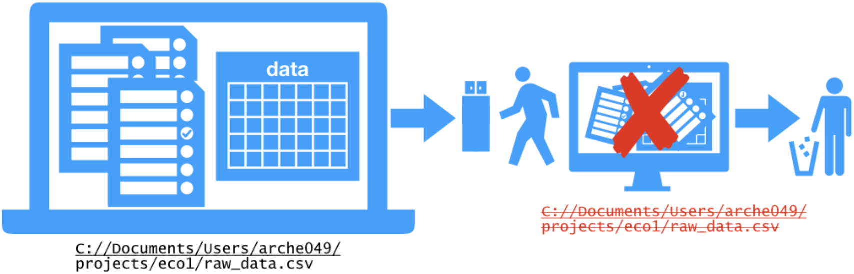
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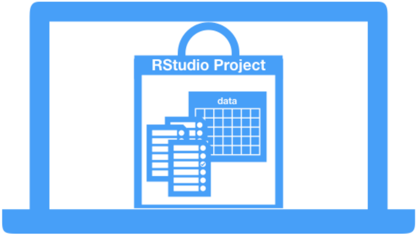

`data/raw_data.csv`

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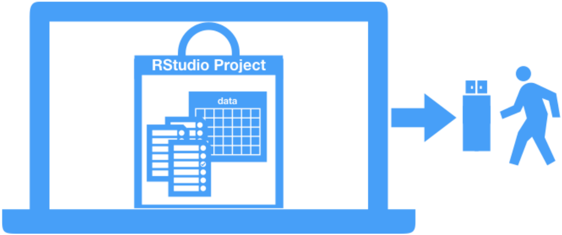

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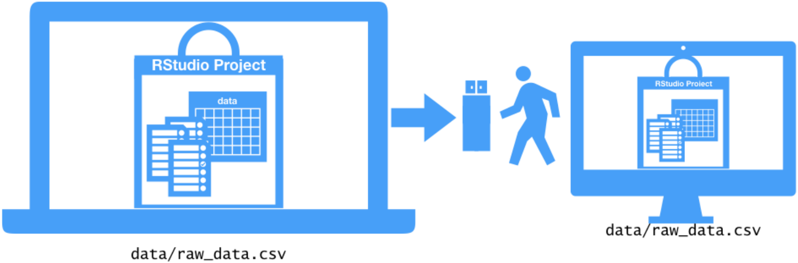

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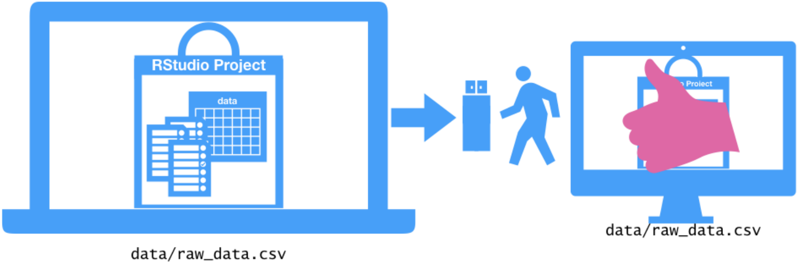

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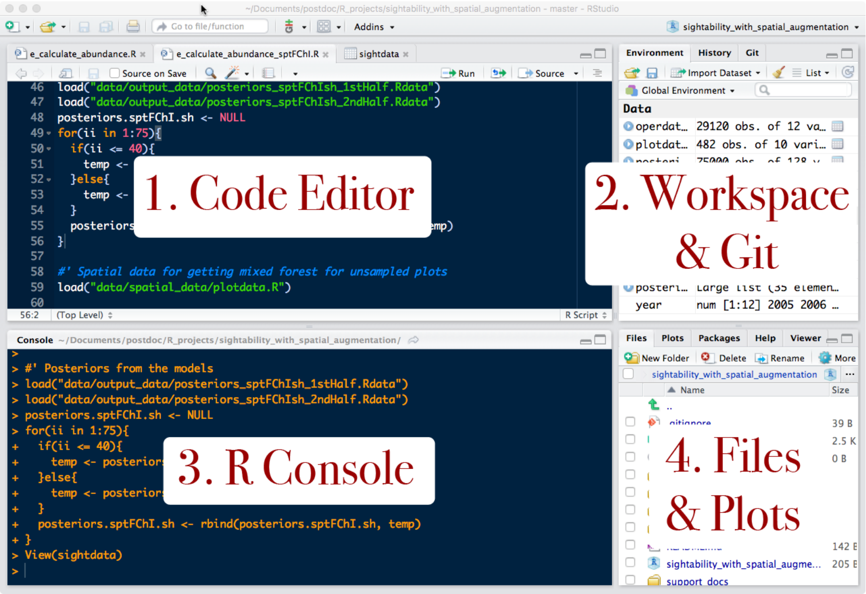


~/Documents/postdoc/R_projects/sightability_with_spatial_augmentation - master - RStudio
Go to file/function
Addins
sightability_with_spatial_augmentation
e_calculate_abundance.R
e_calculate_abundance_sptFChI.R
sightdata
Source on Save
Run
Source
56:2
(Top Level)
R Script
Environment
History
Git
Import Dataset
List
Global Environment
Data
Console ~/Documents/postdoc/R_projects/sightability_with_spatial_augmentation/
Files
Plots
Packages
Help
Viewer
New Folder
Delete
Rename
More
sightability_with_spatial_augmentation
Name
Size

```r
load("data/output_data/posteriors_sptFChIsh_1stHalf.Rdata")
load("data/output_data/posteriors_sptFChIsh_2ndHalf.Rdata")
posteriors.sptFChI.sh <- NULL
for(ii in 1:75){
  if(ii <= 40){
    temp <-
  }else{
    temp <-
  }
  posteriors                                                  mp)
}

#' Spatial data for getting mixed forest for unsampled plots
load("data/spatial_data/plotdata.R")
```

1. Code Editor

operdat…	29120 obs. of 12 va…
plotdat…	482 obs. of 10 vari…
posteri…	75000 obs. of 128 v…
posteri…	Large list (35 elemen…
year	num [1:12] 2005 2006 …

2. Workspace & Git

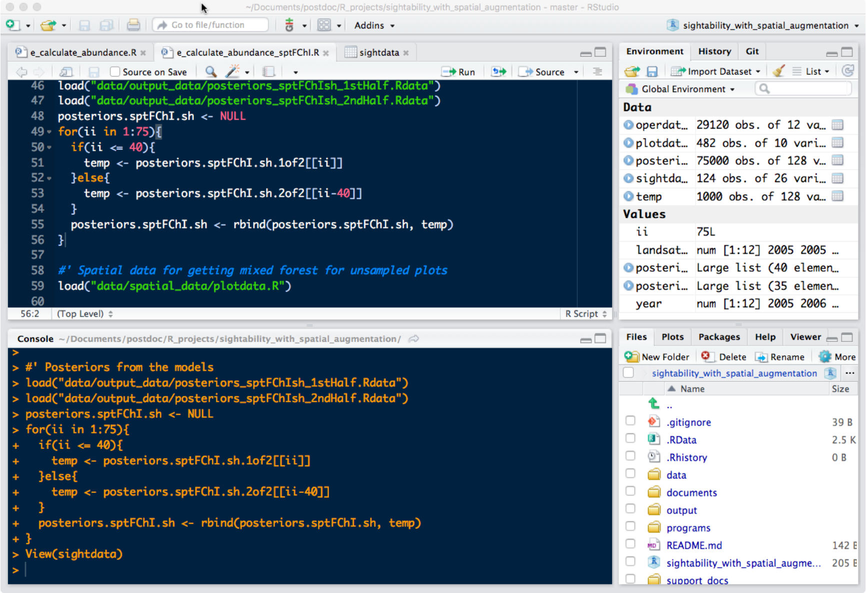
```
>
> #' Posteriors from the models
> load("data/output_data/posteriors_sptFChIsh_1stHalf.Rdata")
> load("data/output_data/posteriors_sptFChIsh_2ndHalf.Rdata")
> posteriors.sptFChI.sh <- NULL
> for(ii in 1:75){
+   if(ii <= 40){
+     temp <- posterior
+   }else{
+     temp <- posterior
+   }
+   posteriors.sptFChI.sh <- rbind(posteriors.sptFChI.sh, temp)
+ }
> View(sightdata)
>
```

3. R Console

Name	Size
..	
.gitignore	39 B
	2.5 K
	0 B
README.md	142 B
sightability_with_spatial_augme…	205 B
support_docs	

4. Files & Plots

1: Introduction to RStudio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56:2
(Top Level)
R Script
Environment
History
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Import Dataset
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Global Environment
Console ~/Documents/postdoc/R_projects/sightability_with_spatial_augmentation/
Files
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Packages
Help
Viewer
New Folder
Delete
Rename
More
sightability_with_spatial_augmentation

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> View(sightdata)
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```

Data

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sightda…	124 obs. of 26 vari…
temp	1000 obs. of 128 va…

Values

ii	75L
landsat…	num [1:12] 2005 2005 …
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year	num [1:12] 2005 2006 …

Name	Size
..	
.gitignore	39 B
.RData	2.5 K
.Rhistory	0 B
data	
documents	
output	
programs	
README.md	142 B
sightability_with_spatial_augme…	205 B
support_docs	

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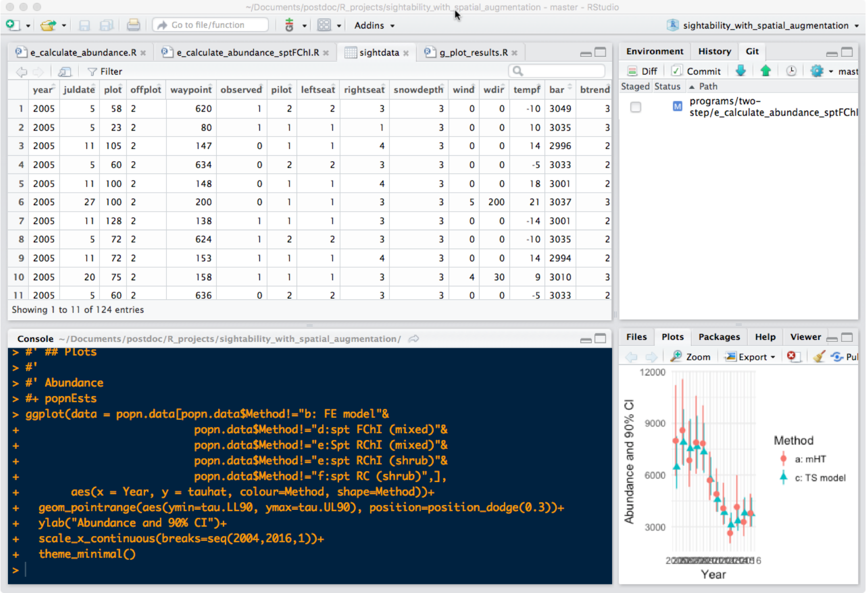

	year	juldate	plot	offplot	waypoint	observed	pilot	leftseat	rightseat	snowdepth	wind	wdir	tempf	bar	btrend
1	2005	5	58	2	620	1	2	2	3	3	0	0	-10	3049	3
2	2005	5	23	2	80	1	1	1	1	3	0	0	10	3035	3
3	2005	11	105	2	147	0	1	1	4	3	0	0	14	2996	2
4	2005	5	60	2	634	0	2	2	3	3	0	0	-5	3033	2
5	2005	11	100	2	148	0	1	1	4	3	0	0	18	3001	2
6	2005	27	100	2	200	0	1	1	3	3	5	200	21	3037	3
7	2005	11	128	2	138	1	1	1	3	3	0	0	-14	3001	2
8	2005	5	72	2	624	1	2	2	3	3	0	0	-10	3035	2
9	2005	11	72	2	153	1	1	1	4	3	0	0	14	2994	2
10	2005	20	75	2	158	1	1	1	3	3	4	30	9	3010	3
11	2005	5	60	2	636	0	2	2	3	3	0	0	-5	3033	2

Showing 1 to 11 of 124 entries

programs/two-step/e_calculate_abundance_sptFChl

Console ~/Documents/postdoc/R_projects/sightability_with_spatial_augmentation/

```
> #' ## Plots
> #'
> #' Abundance
> #+ popnEsts
> ggplot(data = popn.data[popn.data$Method!="b: FE model"&
+                           popn.data$Method!="d:spt FChI (mixed)"&
+                           popn.data$Method!="e:Spt RChI (mixed)"&
+                           popn.data$Method!="e:spt RChI (shrub)"&
+                           popn.data$Method!="f:spt RC (shrub)",],
+        aes(x = Year, y = tauhat, colour=Method, shape=Method))+
+   geom_pointrange(aes(ymin=tau.LL90, ymax=tau.UL90), position=position_dodge(0.3))+
+   ylab("Abundance and 90% CI")+
+   scale_x_continuous(breaks=seq(2004,2016,1))+
+   theme_minimal()
> 
```

Activity 1: Data management and updating

Here, we will read in and process three weeks of experimental data and do some preliminary analysis. Then, we will get a final (4th) week of data, which we will merge with the original data.

The goals are to:

1. Be introduced to RStudio
2. Create a framework for keeping data organized and up-to-date
3. Automatically update our analyses based on the master dataset

Context: Abundance data from ∼75 invertebrate species sampled on various beaches along the Dutch coast.

Zuur, A.F., E.N. Ieno, and G.M. Smith (2007) Analysing Ecological Data. Springer, New York.

Activity 1: Data management and updating

Introduction to RStudio

- Open RStudio

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Introduction to RStudio

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- Set up global options

Remember to not save .Rdata or history! This is important for ensuring that your code is linear and reproducible (i.e., at the beginning of each script, you load all the data you will need for that entire script - no more, no less!)

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- Create a project (using existing, unzipped directory)

Now, your R code pathways will be relatively linked to where that .Rproj file is located. This eases programming and collaboration!

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Now we can do some analysis of invertebrates!

Activity 1: Data management and updating

1. In the File window of RStudio, copy the **student_folders/student_template** folder. Rename the folder after yourself (or an alias).
2. Open a new R Script file and save it to that new folder as **student_folders/ yourname/activity1a_data_processing.R**

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Activity Overview:

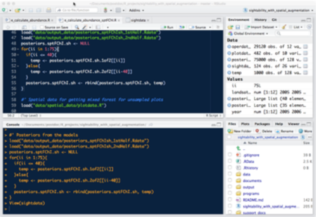
1. We will read in first three weeks of data and combine them, process the data a little bit, and save the merged/processed data for analysis.
2. We will save another new R Script file as **"activity1b_data_analysis.R"** and code/run some preliminary regression analysis.
3. We will pretend to have just gotten the final week's data in and update everything in a "reproducible" way.

2. R-Markdown and R-Oxygen with knitr for documenting your code and creating reproducible reports

Overview of **knitr**

R Code

written with
R-Markdown or
R-Oxygen



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> View(sightdata)
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landsat…   num [1:12] 2005 2005 …
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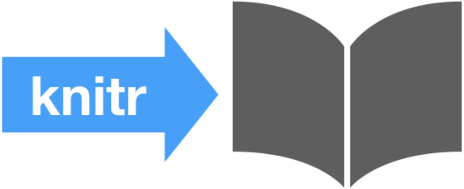
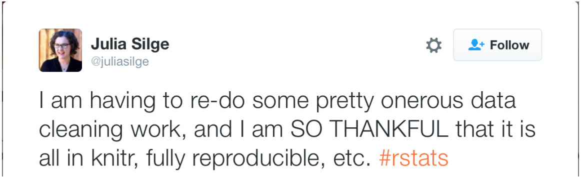
```
sightability_with_spatial_augmentation
Name                                   Size
..
.gitignore                             39 B
.RData                                 2.5 K
.Rhistory                              0 B
data
documents
output
programs
README.md                              142
sightability_with_spatial_augme…       205
support_docs
```

Report

.html
.doc
.pdf



Why **knitr** for manuscripts?



Julia Silge
@juliasilge

I am having to re-do some pretty onerous data cleaning work, and I am SO THANKFUL that it is all in knitr, fully reproducible, etc. #rstats

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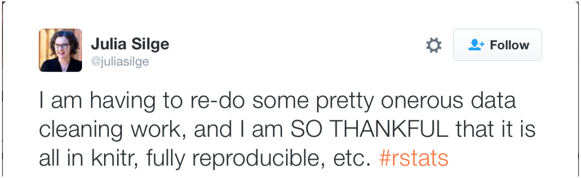

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“I can do reproducible work in R (making me happy) and format the output report in Word (making my collaborators happy)” - Richard Layton `http://rmarkdown.rstudio.com/articles_docx.html`

Why **knitr** for manuscripts?

Native R Scripts (.R extensions) (or any analysis code) are generally not designed for reading, but the **knitr** library has been designed for converting R scripts into readable reports, such as Word, PDF, and/or html documents.

Not only do these types of reports help with collaborating, they provide a great framework for archiving your analyses and results.

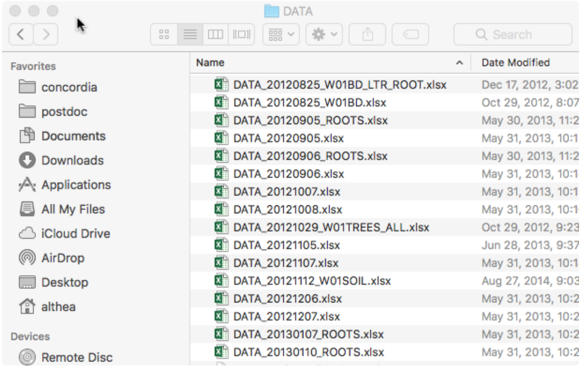
Example:
`https://conservancy.umn.edu/handle/11299/181607`

Documenting Code: General tips

- Consistent and meaningful naming conventions
  - a = b*c
  - weekly.pay = hours.worked*pay.rate (not cross-compatible)
  - weekly_pay = hours_worked*pay_rate
  - weeklyPay = hoursWorked*payRate

Documenting Code: General tips

- Consistent and meaningful naming conventions
  - a = b*c
  - weekly.pay = hours.worked*pay.rate (not cross-compatible)
  - weekly_pay = hours_worked*pay_rate
  - weeklyPay = hoursWorked*payRate
- Use YYYYMMDD or equivalent for dates



Name	Date Modified
DATA_20120825_W01BD_LTR_ROOT.xlsx	Dec 17, 2012, 3:02
DATA_20120825_W01BD.xlsx	Oct 29, 2012, 8:07
DATA_20120905_ROOTS.xlsx	May 30, 2013, 11:2
DATA_20120905.xlsx	May 31, 2013, 10:1
DATA_20120906_ROOTS.xlsx	May 30, 2013, 11:2
DATA_20120906.xlsx	May 31, 2013, 10:1
DATA_20121007.xlsx	May 31, 2013, 10:1
DATA_20121008.xlsx	May 31, 2013, 10:1
DATA_20121029_W01TREES_ALL.xlsx	Oct 29, 2012, 9:23
DATA_20121105.xlsx	Jun 28, 2013, 9:37
DATA_20121107.xlsx	May 31, 2013, 10:1
DATA_20121112_W01SOIL.xlsx	Aug 27, 2014, 9:03
DATA_20121206.xlsx	May 31, 2013, 10:2
DATA_20121207.xlsx	May 31, 2013, 10:2
DATA_20130107_ROOTS.xlsx	May 31, 2013, 10:2
DATA_20130110_ROOTS.xlsx	May 31, 2013, 10:2

Documenting Code: R-Markdown

R-Markdown combines markdown language, which is “an easy-to-write plain text format” and embedded R code chunks that are “run so their output can be included in the final document” [1]

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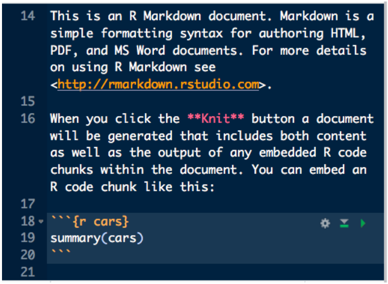
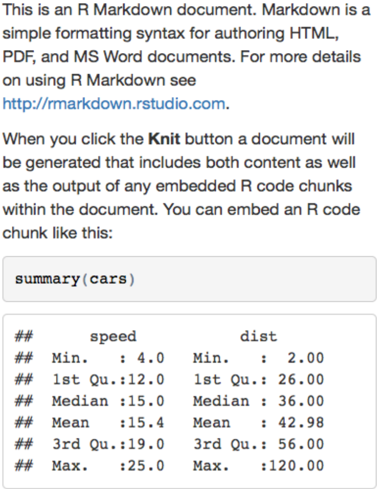


~~~
This is an R Markdown document. Markdown is a
simple formatting syntax for authoring HTML,
PDF, and MS Word documents. For more details
on using R Markdown see
<http://rmarkdown.rstudio.com>.

When you click the **Knit** button a document
will be generated that includes both content
as well as the output of any embedded R code
chunks within the document. You can embed an
R code chunk like this:

```{r cars}
summary(cars)
```

~~~



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```
summary(cars)
```

```
##      speed           dist       
##  Min.   : 4.0   Min.   :  2.00  
##  1st Qu.:12.0   1st Qu.: 26.00  
##  Median :15.0   Median : 36.00  
##  Mean   :15.4   Mean   : 42.98  
##  3rd Qu.:19.0   3rd Qu.: 56.00  
##  Max.   :25.0   Max.   :120.00  
```

[1] www.rmarkdown.rstudio.com

Documenting code: R-Markdown

Exercise 2a: Introduction to R-Markdown

- File > New File > R Markdown...
- Choose "html" - optionally put in a title and press "OK"
- This R-Markdown template is ready to "knit" into an html as-is
  - Click the blue Knit button
  - Save as **"student_folders/yourname/activity2a_intro_rmarkdown.Rmd"**
  - View the resultant html
- Take a few minutes to modify the .Rmd and view how the changes appear in the knit html document.

`https://www.rstudio.com/wp-content/uploads/2015/02/rmarkdown-cheatsheet.pdf`

Documenting code: ezknitr

What folder did the html end up in?

Documenting code: ezknitr

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Now imagine if you wanted to keep the programs/scripts in a folder separate from reports (highly recommended!). You can easily direct the output html file into a different folder using **ezknitr** package.

Documenting code: ezknitr

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Now imagine if you wanted to keep the programs/scripts in a folder separate from reports (highly recommended!). You can easily direct the output html file into a different folder using **ezknitr** package.

```
library(ezknitr)
ezknit("student_folders/yournm/activity2a_intro_rmarkdown.Rmd",
       out_dir = "student_folders/yournm/reports",
       fig_dir = "figures",
       keep_md = F)
```

Note: When using ezknit, must manually save the .Rmd file before knitting!

Documenting Code: R-Oxygen

Instead of using the R-Markdown language, you can also use **pure R scripts** plus **Roxygen comments** (#') to create fully reproducible reports.

Documenting Code: R-Oxygen

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Benefit: The entire program can be written and run in the familiar R Script file, then "spun" into an html/Word/pdf document at any point.

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Documenting Code: R-Oxygen

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- Learning to code with R-Oxygen is arguably more natural since we already use # for commenting

Additionally, use #+ to define and label R chunks like we did with the "'{r ...} code in the R-Markdown language.

Documenting Code: R-Oxygen

Activity 2b: Introduction to R-Oxygen

Here, we'll quickly convert "activity1b_data_analysis.R" into an html document.

1. Open "activity1b_data_analysis.R"
2. Save As...
   "student_folder/yourname/activity2b_intro_roxygen.R"

LaTeX

Another benefit of using knitr/Rmd/Roxygen for creating statistical reports is the nice interface with LaTeX equation syntax.

Activity 3. LaTeX Equations

1. Create a new .Rmd html document
2. Save it as “student_folders/yourname/activity3_latex.Rmd”
3. Create the following in the output html
    - $\alpha + \beta = 2\theta$
    - $\pi^2 = 9.86$
    - $\sum_{i=1}^{n} \sqrt{i} = 42$ (advanced)
4. When you “knit” remember to use ezknitr:

```r
library(ezknitr)
ezknit("student_folders/yourname/activity3_latex.Rmd",
       out_dir = "student_folders/yourname/reports",
       fig_dir = "figures",
       keep_md = F)
```

https://tobi.oetiker.ch/lshort/lshort.pdf (hint: tables on p75)

Putting RStudio & knitr together: Project Workflow

Project Workflow w/ RStudio & knitr

Example project directory

- data/
  - raw_data/
  - processed_data/
  - output_data/
- manuscript/
  - ms_figures/
  - transmissions/
  - submission/
- output/
  - figures/
- programs/
- project_file.Rproj

Project Workflow w/ RStudio & knitr

- **data/**
  - **raw_data/**
    - survey_data20161227.csv
    - survey_data20161230.csv
    - survey_data20170103.csv
  - **processed_data/**
    - survey_data_all.Rdata
  - **output_data/**
    - model_out.Rdata

Project Workflow w/ RStudio & knitr

- **programs/**
  - a_data_processing.R
  - b_data_analysis.R
  - c_plots.R

Project Workflow w/ RStudio & knitr

- **output/**
    - a_data_processing.html
    - b_data_analysis.html
    - c_plots.html
    - **figures/**
        - eda1.jpg
        - scatter1.jpg

Project Workflow w/ RStudio & knitr

- **manuscript/**
  - ms.Rmd
  - ms.pdf
  - ms.docx
  - **ms_figures/**
    - fig1.jpg
    - fig2.jpg

Project Workflow w/ RStudio & knitr

- **manuscript/**
    - ms.Rmd
    - ms.pdf
    - ms.docx
    - **ms_figures/**
        - fig1.jpg
        - fig2.jpg
    - **transmittals/**
        - **from_john/**
        - ms20170523.docx
        - ms20170625.docx
        - **from_bob/**
        - ms20170626.docx

Project Workflow w/ RStudio & knitr

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    - **from_bob/**
    - ms20170626.docx
  - **submission/**
    - ms.pdf
    - fig1.pdf
    - fig2.pdf
    - coverletter.docx

Project Workflow w/ RStudio & knitr

Example of an RStudio project that Althea & John used from conceptualization through publication.

Project Workflow w/ RStudio & knitr

Example of an RStudio project that Althea & John used from conceptualization through publication.

Activity 3: Creating a reproducible report using R-Markdown

Tasks:

1. Knit the rmd as is into a .doc file
2. Add a third week of data and update report
3. Change the formatting using the word-styles-reference-01.docx

3. GitHub for version-control, collaborating and archiving

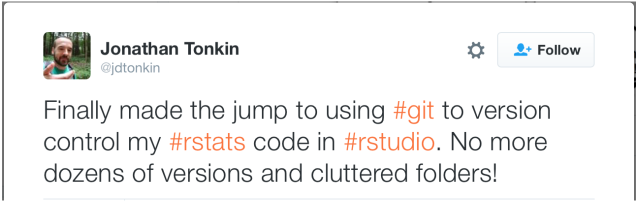
Introduction to GitHub

GitHub provides a place for you to back-up and version-control your R projects.

- Interfaces directly with RStudio
- Free (public repositories or with university email) or cheap (private repositories)
- Facilitates collaboration with other co-authors (or the public)
- Can go back to previous code versions (version-control aspect)

Once you're up and running, it's (usually) simple to use!

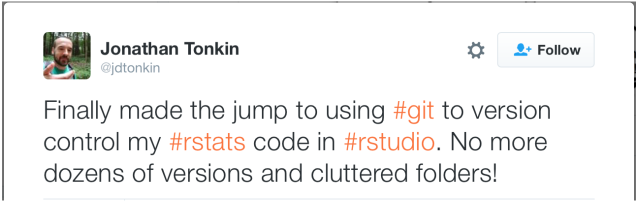
Introduction to GitHub



Jonathan Tonkin
@jdtonkin

Finally made the jump to using #git to version control my #rstats code in #rstudio. No more dozens of versions and cluttered folders!

Introduction to GitHub



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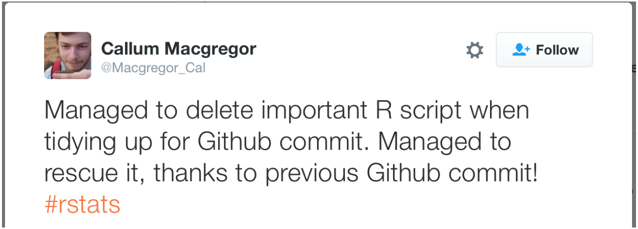
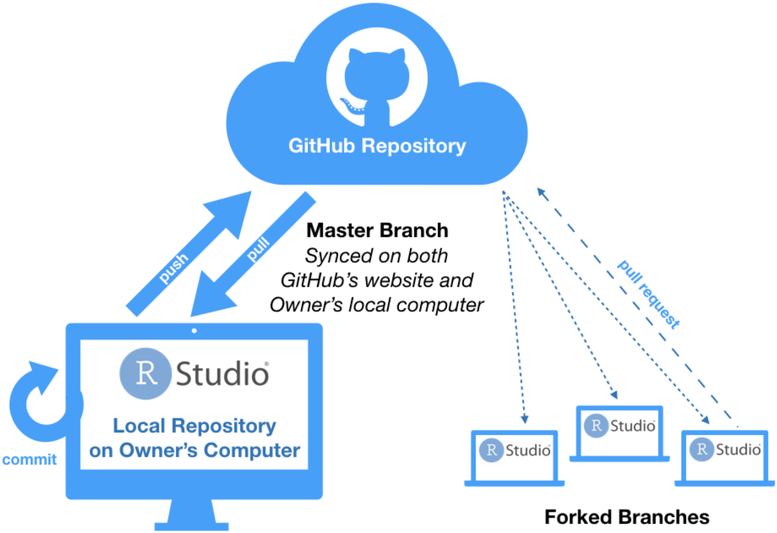


Callum Macgregor
@Macgregor_Cal

Managed to delete important R script when tidying up for Github commit. Managed to rescue it, thanks to previous Github commit! #rstats

GitHub Overview



Master Branch
Synced on both
GitHub's website and
Owner's local computer

Forked Branches
Public repositories only

GitHub Terminology

- **repository**
  - A project (here, an RStudio Project) that contains code, analysis, output, etc that is held by GitHub
  - Repositories may be public or private
  - Most repositories will have one “owner” with direct writing privileges; however,
  - All repositories can be made to include more than one “owner” or “collaborator” with direct write privileges

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  - All repositories can be made to include more than one “owner” or “collaborator” with direct write privileges
- **branch**
  - A particular version of a repository
  - The “master” branch is the original version of the repository, which can be forked (see below) or edited directly by branch owners/collaborators.
  - “Forked” branches are any “clones” that are made by anyone other than the repository owner

GitHub Terminology

- **commit**
  - Verb: to save a change or series of changes to the repository, with an associated “commit message”
  - Noun: the saved changes as an entity, which can be “pushed” back to the associated branch

GitHub Terminology

- **commit**
  - Verb: to save a change or series of changes to the repository, with an associated “commit message”
  - Noun: the saved changes as an entity, which can be “pushed” back to the associated branch
- **push**
  - To merge 1 or more commits back to the associated branch
  - You can only push directly to repositories that you have ownership or collaborator privileges for
  - If you don’t have direct writing privileges, you have to create a “pull request”
  - The direction of a push is from your local version (RStudio) to GitHub server

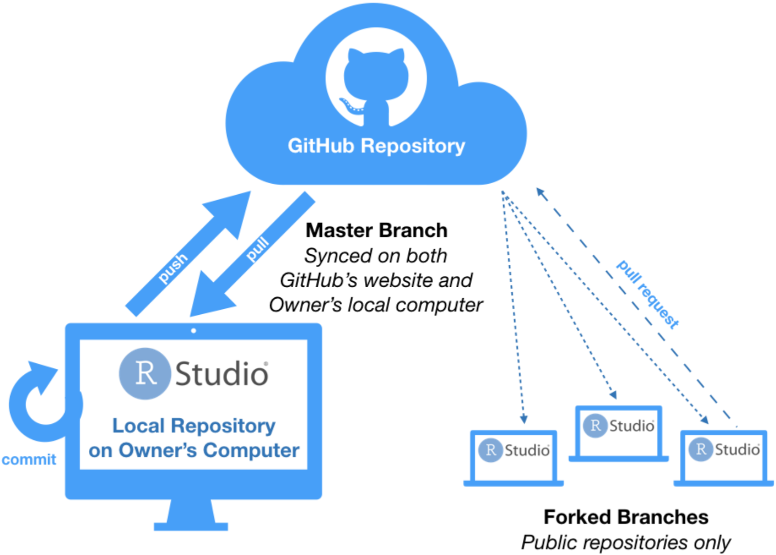
GitHub Terminology

- **pull**
  - To take any changes that have been made to the associated branch and sync them with your local version
  - The direction of a pull is from the GitHub server to your local version (RStudio)

GitHub Terminology

- **pull**
  - To take any changes that have been made to the associated branch and sync them with your local version
  - The direction of a pull is from the GitHub server to your local version (RStudio)
- **pull request**
  - A series of commits that have been made on a forked branch that are being asked to merge with the next upstream branch (i.e., usually the master branch)
  - You will view and accept pull requests through GitHub directly
  - *Side note: Called "pull requests" because you are requesting the branch owner to pull in your changes to their branch.*

GitHub Overview



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Activity 4: Sync today's Rstudio project with GitHub

1. Add git repository to your RStudio project (in RStudio)
2. Commit all of today's work (in RStudio)
3. Push to GitHub (GitHub and RStudio shell)
    - In GitHub, new repository of **same name** as your project (here: "TWS_reproducibility_workshop")
    - Open RStudio shell (In RStudio, Tools > Shell...)

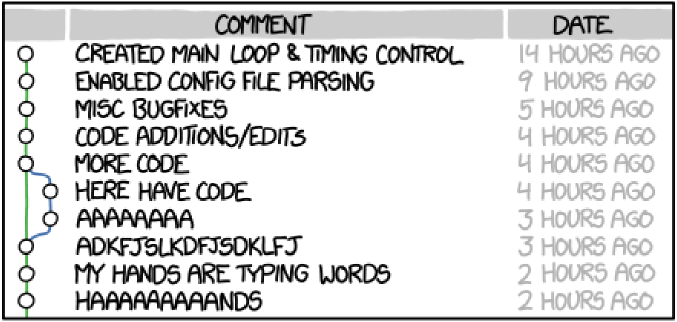
```
git remote add origin https://github.com/
    gitusername/TWS_reproducibility_workshop.git
git config remote.origin.url
    git@github.com:gitusername/TWS_reproducibility_workshop.git
git push -u origin master
git pull -u origin master
```

GitHub

Additional GitHub Tips

- Don't use github with large files (push limit of 100MB, warning >50MB)
  - If necessary, use git-large-file add on (advanced!)
- Create new projects in GitHub first, then sync them with RStudio (File > New Project > Version Control > Git)

Thanks!



COMMENT	DATE
CREATED MAIN LOOP & TIMING CONTROL	14 HOURS AGO
ENABLED CONFIG FILE PARSING	9 HOURS AGO
MISC BUGFIXES	5 HOURS AGO
CODE ADDITIONS/EDITS	4 HOURS AGO
MORE CODE	4 HOURS AGO
HERE HAVE CODE	4 HOURS AGO
AAAAAAAA	3 HOURS AGO
ADKFJSLKDFJSDKLFJ	3 HOURS AGO
MY HANDS ARE TYPING WORDS	2 HOURS AGO
HAAAAAAAANDS	2 HOURS AGO

AS A PROJECT DRAGS ON, MY GIT COMMIT MESSAGES GET LESS AND LESS INFORMATIVE.

Additional resources

- https://swcarpentry.github.io/r-novice-gapminder/02-project-intro/
- knitr documentation and help https://yihui.name/knitr/
- Markdown basics https://daringfireball.net/projects/markdown/basics
- R-Oxygen formatting/tips https://rpubs.com/alobo/spintutorial
- Online Reproducible Research Course http://eriqande.github.io/rep-res-web/
- Excellent GitHub/RStudio tutorial https://www.r-bloggers.com/rstudio-and-github/