Reproducible Research

Class #13 | GEOG 215

Intro To Spatial Data Science

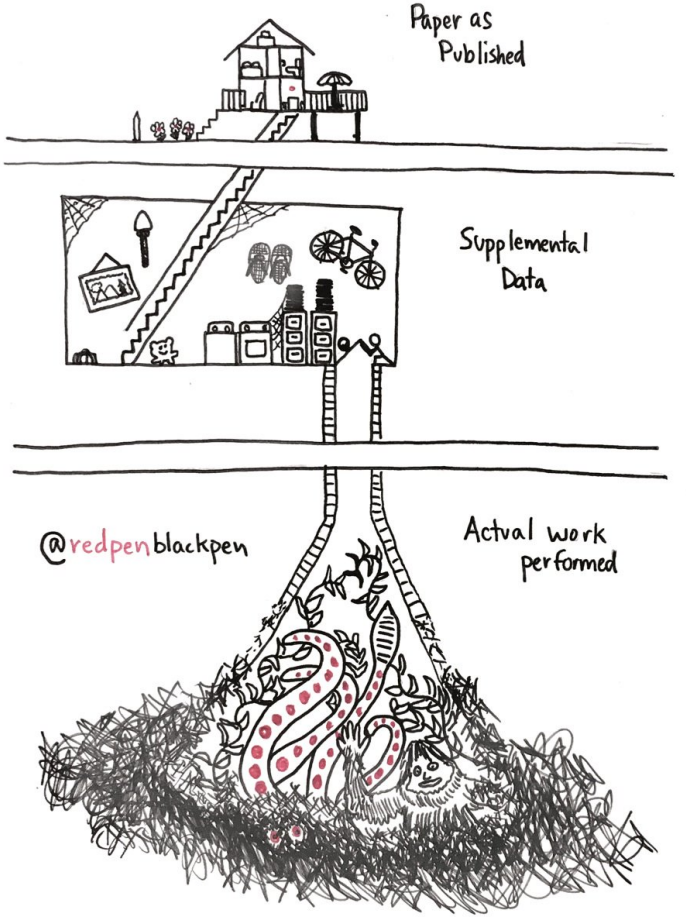
Today's Class

Reproducible Research

- Motivation
- What is it?
- Why is it important?
- How to do it?

Midterm logistics

Reality of Scholarly Communication



Scholarly communication

Traditional modes of communication of analytical results are:

- Manuscripts
- Reports
- Presentations
- Posters
- Websites
- Dashboards

Purpose of scholarly communication

- To report what you've actually discovered, clearly enough that someone else can discover it for themselves.
    - To make it easier for readers to understand what you did
    - *To make it easier for readers to replicate/reproduce what you did*

However....

Modern statistical software = ”blackbox”

Readers are supposed to focus on the final results

- *and not the code that derived it*

Should I even care about the code?

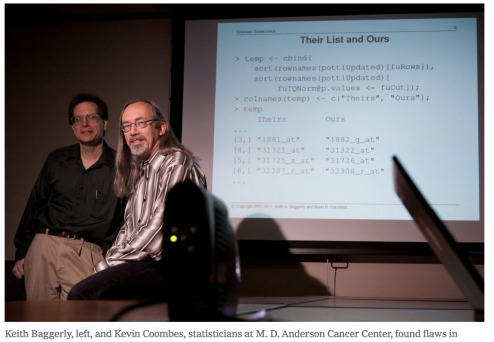
YESSSSSSSSS!!! YOU SHOULD

I AM SERIOUS!!! YOU SHOULD

Reproducibility crisis in science

Intentional mistakes

How Bright Promise in Cancer Testing Fell Apart



Keith Baggerly, left, and Kevin Coombes, statisticians at M. D. Anderson Cancer Center, found flaws in research on tumors. Michael Stravato for The New York Times

Reproducibility crisis in science

Unintentional mistakes

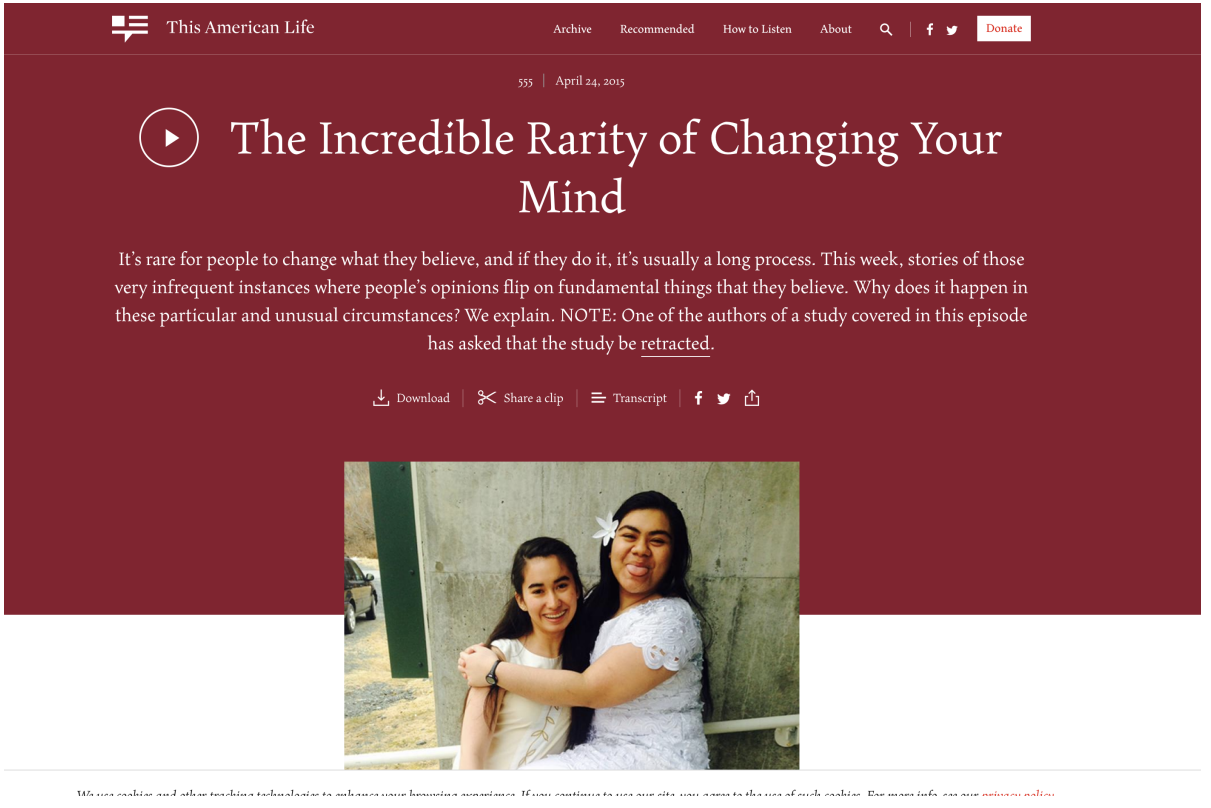
Bad spreadsheet merge kills depression paper, quick fix resurrects it

The authors of a paper showing a link between immune response and depression requested a retraction after they realized they'd merged two spreadsheets with mismatching ID codes.

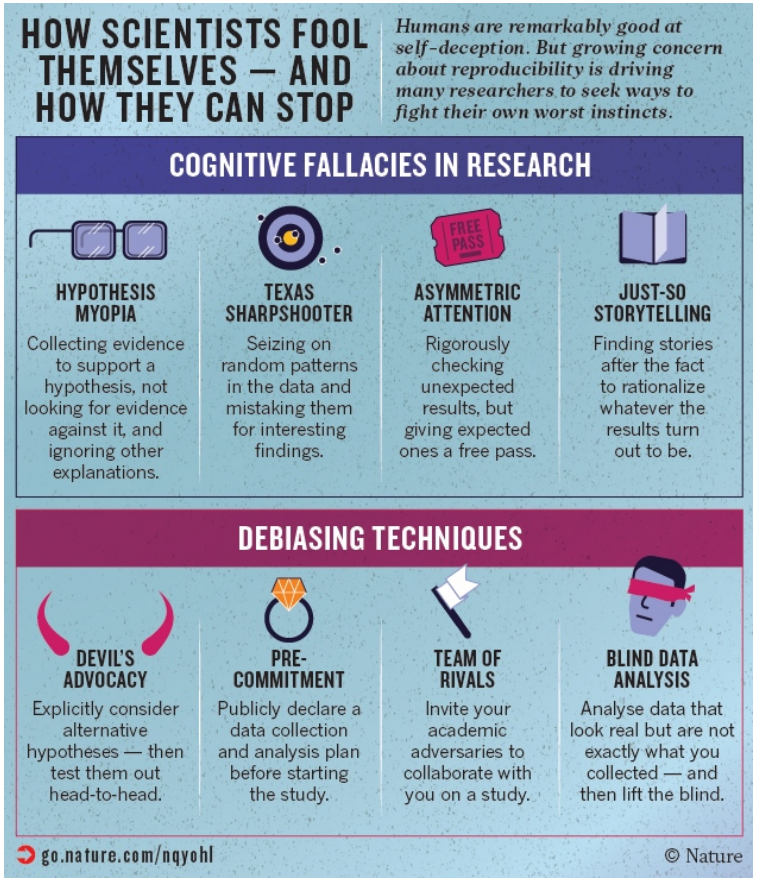
Here's the notice for "Lower CSF interleukin-6 predicts future depression in a population-based sample of older women followed for 17 years," retracted in February 2014:

> *This article has been retracted: please see Elsevier Policy on Article Withdrawal (http://www.elsevier.com/locate/withdrawalpolicy).*

Influence on the public



Researchers (including you and me) are fallible too



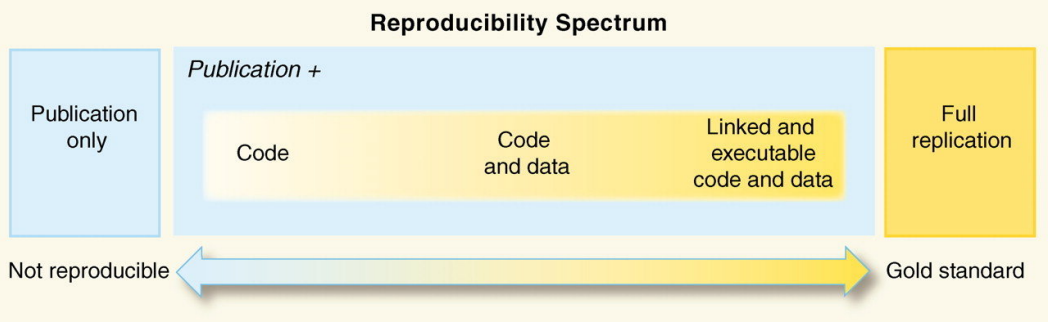
Reproducible Research

- Original data and (computer code) can be re-analyzed by an independent investigator to obtain the same results
    - The analysis can be successfully repeated
    - Highly important in studies where computational analysis plays a large role

Reproducible Research

- **Expose more of the research workfow to our audience**
    - Easier for them to make a more informed assessment of our methods and results
    - Easier for them to adapt our methods to their own research

Reproducible Research



Reproducible Research

- Science moves forward when discoveries are **replicated** and **reproduced**
    - Many important scientific advancements have been incremental
    - Verifiability and reproducibility are among the cornerstones of the scientific process.
    - They allow scientists to **"stand on the shoulder of giants".**
    - incremental + incremental + incremental .... + incremental = *"Nobel Prize"*

Replicable vs Reproducible

Replicable Research

- If you *collected new data* and *performed the experiment again* or *answered the same question*, would you receive consistent results?
- independent investigators use methods, protocols, data, and equipment to confirm scientific claims.
- Often expensive, and tough to do as new settings can induce errors or differences
- Replicable research is reproducible

Replicable vs Reproducible Vs Correct Research

Reproducible Research

- when data sets and computer code are made available for researchers to verify results
- If you ran analysis on the same data using the same set of methods that the researcher specified, would you receive same results?
- A study is reproducible if there is a specific set of computational functions/analyses (usually specified in terms of code) that exactly reproduce all of the numbers in a *published* paper from *raw* data
- *Reproducible* is not necessarily *replicable*
- *Reproducible/replicable* is not necessarily *correct*
    - The study could be poorly designed or executed but still be reproducible or replicable

Why should I care?

- Avoid embarrassment
- Save time, in the long run
- Improves your mental health ! ! ! (ask me)
- Show evidence of correctness
    - Allows for independent evaluation
- Greater potential for extension impact for your work
    - Others can build on your work/methods
    - You can build on your prior work

> 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.”

How to perform do reproducible research?

Good News!

You already doing some of it

Bad News

- Importance is widely recognized, but not widely practiced
- More start up time

--

- Not sent up for instant gratificiation
- Takes a different mindset (Challenges our biases and in some cases, EGO!)

However

- Will be outweighed by time saved later
- You can go back in time and fix errors with confidence
- Becomes easier with practice

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

Four facets of reproducibility

- *Documentation*
    - Use markdown to document your workflow so that anyone can pick up your data and follow what you are doing
    - Use *literate programming* so that your analysis and your results are tightly connected, or better yet, unseperable
- *Organization*
    - tools to organize your projects so that you don't have a single folder with hundreds of files
- *Automation*
    - the power of scripting to create automated data analyses
- *Dissemination*
    - publishing is not the end of your analysis, but paves way for future research.

YOU ARE ALREADY DOING ALL OF THIS

Is this reproducible ?

- Open a an excile file to extract as CSV
- Open a csv file in word and delete first blank row
- Save your graph from R on your desktop and paste it in your markdown file
- Manually type in numbers/results in your Rmarkdown Document
- Submit your final project in word, and Paste results into the text

In future labs/assignments

- We will practice and assess how reproducible our analysis is

MID-TERMS LOGISTICS

Midterm Exam Structure

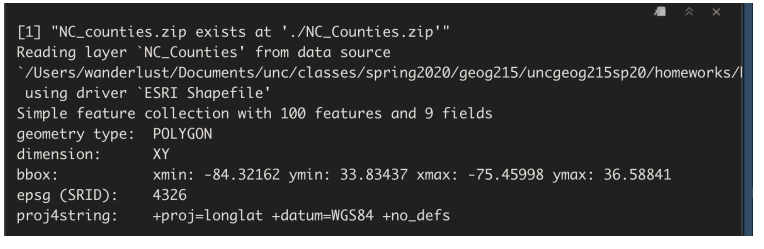
- 15% of your grade
- Timed exam on Sakai
- Multiple choice, True and False, fill in the blanks, short answers
- Focus on both theory and programming skills
- Covers all material till (including) today.
- Lectures, labs, readings, data camp
- Distributed Thursday morning
- Take exam by March 4, 11:59 pm.
- You can study together, but no collaboration while taking exam
- Piazza will be paused during exam time

Your resources

- Class materials (lectures, labs, readings, piazza, data camp)
- Your TA, me (for clarifying questions)
- Practice Questions (w answers)
    - We will go through some in class on Wednesday and some for you to practice on your own
- Wednesday's class
    - Send me any doubts you have about course material that you would like to be discussed by tomorrow night

Examples

Answer Qs based on screenshots:



- How many attributes, and features are there?
- Is this a projected system ? True of False
- What does each observation represent?

Answer Qs based on code:

```
colnames(nc_wide)
```

```
[1] "geoid"           "name"            "white"           "black"
[5] "native_americans" "hispanic"        "poc"             "white_majority"
[9] "total_population" "med_hh_income"
```

```
newdat <- nc_wide %>% select(geoid:black, ends_with("n"))
```

Based on this code: what will be the dimensions of newdat ?

Output type 1

```
x <- c(1:6,5,NA,NA,10,5)
which(x >=5)
```

What will be the output?

a. An error

b. logical vector with 7 elements

c. logical vector with 11 elements

d. NA

e. numerical vector with 7 elements

f.numerical vector with 5 elements

Output type 2

```
x <- c(1:6,5,NA,NA,10,5)
which(x >=5)
```

What will be the output?

a. An error

b. FALSE TRUE NA NA TRUE TRUE

c. 5 6 7 10 11

d. 5 6 7 NA NA 10 11

e. 2 3 NA NA 6 7

f. 2 3 6 7

Fill in the blanks: Type 1

```
colnames(nc_wide)
```

```
[1] "geoid"           "name"            "white"           "black"
[5] "native_americans" "hispanic"        "poc"             "white_majority"
[9] "total_population" "med_hh_income"
```

```
dat <- nc_wide %>% ______(med_hh_income > 10000) %>%
  _______(name, people_of_color = poc) %>%
  ________(name)
```

fill in the blanks to get the data with poc greater 10000, with 2 columns sorted by poc in ascending order.

Fill in the blanks: Type 2

```
dat <- nc_wide %>% ______(poc > 1000) %>%
  _______(name, poc) %>%
  ________(poc)
```

```
# A tibble: 99 x 2
   name      people_of_color
   <chr>               <dbl>
 1 Graham               1129
 2 Mitchell             1143
 3 Madison              1265
 4 Yancey               1307
 5 Alleghany            1425
 6 Tyrrell              1922
 7 Ashe                 1986
 8 Camden               2047
 9 Avery                2203
10 Hyde                 2215
# … with 89 more rows
```

fill in the blanks to get the following dataset