A-Lab Tutorial
Data Wrangling and Visualization in R

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Overview

1. Teaching Learning Objectives (TLOs)
2. Boring Stuff
3. Concepts
4. R and Tidyverse Crashcourse
5. Q & A

Workshop Outline

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Teaching Learning Objectives (TLOs)

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- Q&A.

Before We Begin..

Please take a few minutes to think about the data for your own project (alternatively, do this once you have access to it):

- Which questions do you have to answer? Which can you answer? Which do you want to answer? Why are they important? List a few.

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- What are your hypotheses?
- What method do you need to apply?
- Is there prior work (i.e. literature, news, . . .) that attempts to answer it that you can leverage?

Example

Want to understand the value of different skills. Long history in Economics on estimating the 'Returns to "Skill"'.

- How valuable is learning to code? What's the $-value associated with R?
- My Research: What skills do employers demand and how much are they willing to pay.
- Ideal data: Panel data of job postings annotated with skills demanded and employer. Each row is a bundle of skills and a $-value (wage).
- Hypothesis: Value of coding is high and has increased over time.
- Method: OLS Regression (for interpretability) with employer fixed effects

- Conversely, if I wanted to predict the future value of R, I'd instead need a time series of $-values for R and might use ARIMA.

Data Wrangling

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Methods to transform raw data into usable a format to answer a specific research question.

- Different research questions require different data formats.

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Installation of R

- R: https://cloud.r-project.org/
- RStudio Desktop IDE: https://www.rstudio.com/products/rstudio/download/
- Install packages via 'Tools' or via `install.packages(<package_name>)`:
  - tidyverse
    - ★ includes several extremely useful packages: tidyr, dplyr, purrr, stringr, forcats, lubridate, ggplot2
  - ...
  - mice, tidytext, philentropy, lfe, rpart, causaltree, glmnet, fuzzywuzzy, shinyr, nnet, neuralnet, tensorflow, sf, ...

Project Environment Tips

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  →hrefhttps://dplyr.tidyverse.org/articles/programming.htmlquosures)

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  →hrefhttps://dplyr.tidyverse.org/articles/programming.htmlquosures)
- Use (Jupyter) Notebooks to explore data. Later, move to automating stuff via command line and `screen` (or batch files, i.e. on Sloan's Engaging Server).

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Tidy Data

- **Every column is a variable.**

NOT

brand_model	year	mileage
Audi_A4	1999	18
Audi_A4	2008	20
VW_GTI	1999	19
VW_GTI	2008	22
...	...	...

- Can be fixed with `separate()`.

Tidy Data

- **Every column is a variable.**
- **Every row is an observation.**

NOT

brand	model	mileage_1999	mileage_2008
Audi	A4	18	20
VW	GTI	19	22
...	...	...	

- Can be fixed with `pivot_longer()`, `pivot_wider()` (formerly `gather()`, `spread()`).

Tidy Data

- **Every column is a variable.**
- **Every row is an observation.**
- **Every cell is a single value.**

brand	model	mileages_1999_2008
Audi	A4	(18, 20)
VW	GTI	(19 , 22)
...	...	...

- Can be fixed with `separate()` and `pivot_longer()`.

Tidy Data

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- **Every row is an observation.**
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brand	**model**	**year**	mileage	...
Audi	A4	1999	18	...
Audi	A4	2008	20	...
VW	GTI	1999	19	...
VW	GTI	2008	22	...
VW	GTI	2012	24	...
Mazda	CX-5	2017	23	...
...	...	...	...	...

- Tidy data: Each row has a **unique key (or index)** and **values**.
- Here, the key/index is **brand x model x year**, values are mileage.

Tidy Data - Easier Said than Done

- Example I: Which car has the lowest fuel consumption?

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- Definition of clean data depends on the question(s). $\rightarrow$ Need to know how to transform one data format into another.

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Chaining with Pipes

- Pipes let you read code from left to right by chaining commands together. $\rightarrow$ More legible code.

Without Chaining	With Chaining
f(x)	$x \rightarrow f$
f(x, y)	$x \rightarrow f(y)$
f(g(x))	$x \rightarrow f \rightarrow g$

Basic Operations

- `filter`: filter data based on logical condition.
- `mutate`: create new (and change old) variables.
- `group_by`, `ungroup()`: define (temporary) keys.
- `summarize`: Used with `group_by` to aggregate columns. `arrange`: reorder rows (i.e. sort). `select`: subset (and reorder) columns.

Quick Example

Common Operations

- Log: $log(x + 1)$
- %-Change over time: $group\_by(Group)\% > \%arrange(-T)\% > \%mutate(Change = last(X)/first(X) - 1$
-

More Advanced Words

- `across` (supersedes `mutate_at` and `mutate_if`).
- `pivot_longer`, `pivot_wider`: Make dataset longer or wider (i.e. from time series to panel or vice versa).

Types of Data

- Cross-Sectional Data: Many subjects, one point in time.
- Time Series: One subject, many points in time.
- Panel Data: Many subjects, many points in time. May be unbalanced, i.e. some (subject, time) combinations are missing.
- Multidimensional Panel Data: More than 2 dimensions, i.e. (subject, time, group)

Long versus Wide Data

wide

id	x	y	z
1	a	c	e
2	b	d	f

long

id	key	val
1	x	a
2	x	b
1	y	c
2	y	d
1	z	e
2	z	f

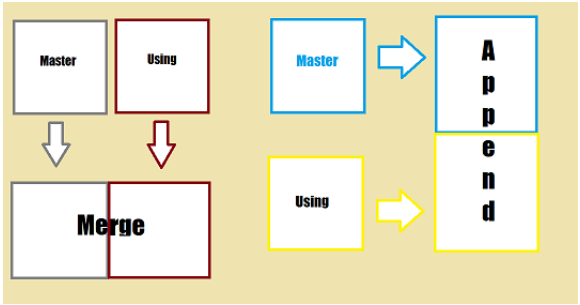
- The first allows analyses at the id (1, 2) level, the second at the id, key level.

Aggregation

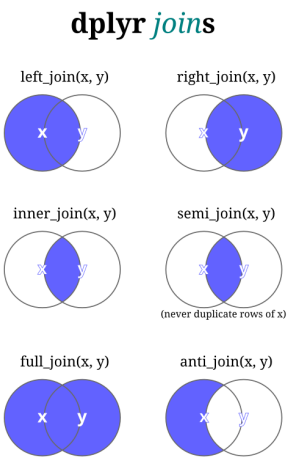
- Groups/Reduces multiple rows into one:
- `df <- cars %>% group_by(brand, year) %>% summarize(num_models = n(), mean_mpg = mean(mpg, na.rm = TRUE)`
- Common Aggregation functions: `mean()`, `sd()`, `first()`, `last()`, `sum()`, `min()`, `max()`, `n()`

Joins/Merges and Appends

- Append: Requires same column names (`bind_rows()`, `bind_cols()`
- Join/Merge: Requires key to identify matching rows.
  - Left Outer Join: Keep all (including unmatched) rows from left. (`left_join`).
  - Inner Join: Only keep matching rows (`inner_join()`).
  - Anti Join: Only keep unmatched rows from left (`anti_join()`).
  - Full Join: Keep all rows from both left and right (`full_join()`).



Join Types Visualized



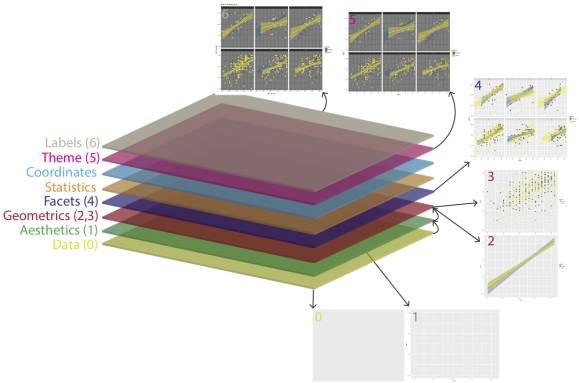
Package Overview

Type	R	Python
Missing Values	`mice`	`fancyimpute, statsmodels`
Data Wrangling	`dplyr`	`pandas`
Strings	`stringr`	built-in, `pandas`
(Fuzzy) String Matching	`fuzzywuzzyR`	`fuzzywuzzy`
Dates	`lubridate`	built-in, `pandas`
Geographical	`ggmap, maps, maptools`	`geopandas`
Visualization	`ggplot2, bokeh`	`plotnine, bokeh, matplotlib`
Regressions (with p-values)	`lm, lfe`	`statsmodels`
Machine Learning	`caret, glmnet, rpart`	`scikit-learn`
Deep Learning	`ttensorflow, keras`	`tensorflow, keras, pytorch`

- All Python packages can also be accessed in R with the R package `reticulate` (may be slower than built-ins though).

Visualizations with ggplot2

- Plots are built layer-by-layer.
- Most important layer: the `geom layer`



Visualization Advice

- No double Y-axes $\rightarrow$ Very misleading.
- Maximize the 'Data-Ink-Ratio' $\rightarrow$ Keep it simple.
- use themes like `theme_bw()` to make figures consistent.
- thick/horizontal lines to highlight, no or muted tick lines
- Think about aspect ratio of your presentation (on Zoom it's usually 16:9, while in-person it's often 4:3) versus write-up. Often need to make axes titles larger than defaults.

Tips & Tricks I

- Start early!!!

- Don't oversell your data.
- Communicate well with your team, your mentor, your company.
- Robustness checks, Validity tests, Simplicity (start with a baseline).
- Clean, consistent figures and formatting.
- Practice for your final presentation.

Tips & Tricks II

- Use flags in the header of your script to set constant variables, i.e. path/file names, etc.
- Keep a diary of what you've tried. Spending < 2 Minutes per day on this is already enough and really helps.
- Read the documentation.
- Use github for version control (especially good with team mates).
- Proper motivation and embedding in existing literature or context for final write-up.
- Cite references (use citation management like Zotero or Mendeley).

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Q & A

- These were just very general points, vocab, and code snippets to get you started.
- While there's a lot to learn and do, don't feel overwhelmed. A lot of the material here may not apply to your specific project.
- There are incredible online resources - use them!
- You can always talk to you mentors!

Thank You!

For feedback, questions, or comments,
please email me: ssteffen@mit.edu
sebastiansteffen.com