Intro to SYS-6018

Data Mining

SYS 6018 | Spring 2021

intro.pdf

Contents

1 Online Learning

1.1 In case of internet issues

I expect to lose internet access once or twice during the semester. If so, I'll record the remaining lecture and post when internet is restored.

If you lose internet, then watch the recording and ask questions via slack.

1.2 Recording of classroom lectures

I will be recording every lecture in order to accommodate students who will be learning remotely. Because lectures include fellow students, you and they may be personally identifiable on the recordings. These recordings may **only** be used for the purpose of individual or group study with other students enrolled in this class during this semester. You may not distribute them in whole or in part through any other platform or to any persons outside of this class, nor may you make your own recordings of this class unless written permission has been obtained from the Instructor and all participants in the class have been informed that recording will occur. If you want additional details on this, please see Provost Policy 005. If you notice that I have failed to activate the recording feature, please remind me!

1.3 Zoom Etiquette and Expectations

Let's do the best we can with Zoom.

1. Please use a zoom background with your name clearly visible. Darden provides a good option: https://web3.darden.virginia.edu/backgroundgenerator/index.html.
2. Please keep video on as much as possible. If you have to eat, stretch, yawn, or do something that could distract others, please mute your video. But do turn it back on!
3. Please mute your microphone when not speaking.
4. Fight against "screen fatigue". Stand up and stretch, don't work in the bed, get enough sleep!
5. Some of the most helpful moments in class occurs when students ask questions during lecture. Don't be afraid to ask questions! You can raise a virtual hand if I am on a roll, or just unmute and blurt out your question when I go for a breath. But don't let zoom stop you from being an active learner.

2 Technical Requirements

- Working and updated version of R and RStudio
- Install R packages: `tidyverse` and `nycflights13`
- Course Webpage: https://mdporter.github.io/SYS6018

3 About us

3.1 About the Instructor

- Faculty Webpage http://www.faculty.virginia.edu/mdporter

- GitHub https://github.com/mdporter
- Blog https://mdporter.github.io/blog/

3.2 About you

Fill out a notecard with the following information:

1. Your name (with pronunciation hints)
2. Hometown (include country/region if far away)
3. Degrees
4. What type of job to hope to land on graduation (industry, title)
5. 2 things you hope to learn in this course
6. 2 interesting things about you (to help me remember you)

3.3 About our TA

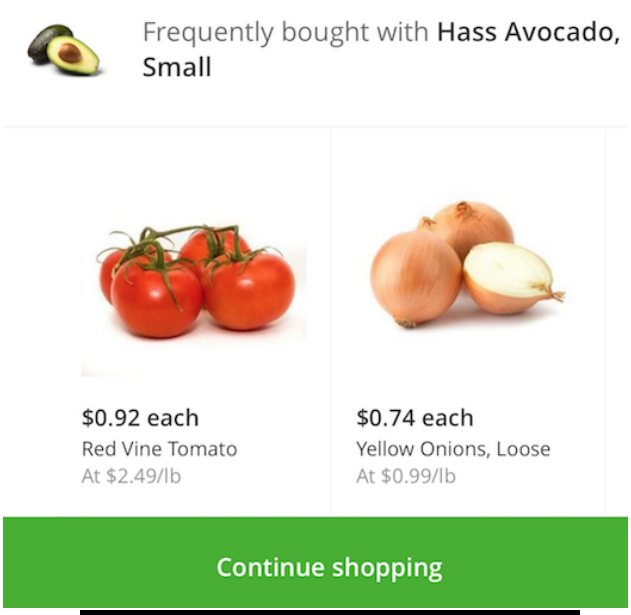
Xiang Guo

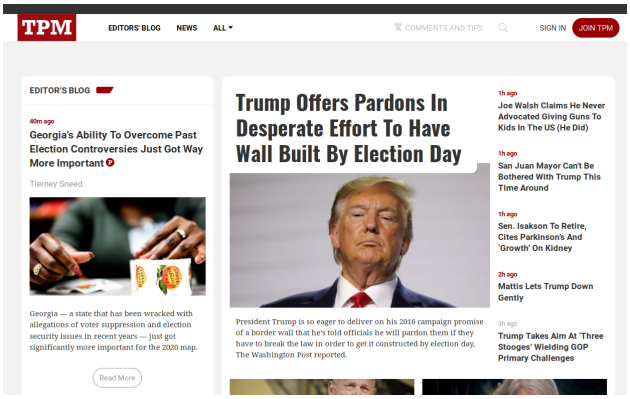
4 The course

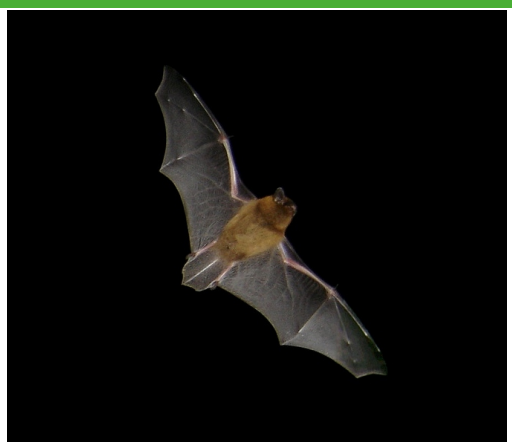
4.1 Topics

- See website: https://mdporter.github.io/SYS6018
- You are expected to be problem solvers
  - doing good on structured homework sets isn't sufficient

4.2 Examples







5 Syllabus

5.1 Course Webpage

- We have a course webpage https://mdporter.github.io/SYS6018/
  - lectures
  - R scripts
  - data sets
- We will use the Collab site for homework submission, solutions, etc.
- We will use the Slack channel: UVA SYS-6018 for other group communication

5.2 Course Prereqs

- Linear Regression
  - Multiple Linear Regression
  - Logistic Regression
  - Categorical Predictors (dummy coding)
  - Implementation in R (lm(), predict(), etc.)
  - Estimation / Model Fitting
  - Cross-validation
- Probability and Statistics
  - Bayes Theorem
  - CDF/PDF/PMF
  - Maximum Likelihood Estimation
  - Distributions: normal, binomial, hypergeometric, etc.
  - Expected value, variance, median, quantiles
  - Mean Square Error
  - Confidence Intervals
  - Hypothesis Testing
- Math
  - Calculus
  - Matrix Calculations
  - PCA, SVD
- Computing
  - data types: vector, matrix, array, list, etc.
  - writing simple functions
  - flow control: loops, if/else, etc.
  - data wrangling
  - generating random variables
  - RMarkdown [*Note: practice HW will cover RMarkdown*]

5.3 Exercise 1

Your Turn #1

Let $X_1, X_2, \ldots, X_n$ be the yearly number of crashes at an intersection (X_i is number of crashes in year i).

- What is an estimate of the probability that there are 100 crashes in year $n + 1$?

5.4 Other Syllabus Material

- Office Hours
- Textbooks
- R, RStudio
- Course Assessment
  - *The exam dates are posted in the Class Schedule (on the course website). Note these now so there are no conflicts.*
  - RMarkdown (See HW0)
  - Class participation. Expect you come prepared with questions. Don't be afraid to ask questions in class. Now is your time to learn.
- Course Management
- **Honor Code**
- Read all syllabus and ask me questions

5.5 Succeding in this course

- Most topics are separated into two lectures
  - First is introduction of new topic
  - Second is more advanced coverage
- Homework is due weekly
  - Before the next topic
  - Due to breaks, this rotates between Mondays and Wednesdays
  - Should start HW after first lecture. Questions in second lecture.
- Assigned Readings *before* every class
  - First listed reading is intro, second is more advanced
  - Start with intro, then re-read the advanced
- Attend office hours!

5.5.1 Coding

- I find that most students struggle with coding. This really hinders your ability to get your mind about the concepts and slows down your learning. The course will use R, but all examples will use the tidyverse dialect. There is no better tool for interactive data analysis and both exploratory and confirmatory modeling.
  - While I encourage tidyverse, you are free to use anything for homework (https://rstudio.github.io/reticulate/).
- Tidyverse is a major improvement over base R, but it can look a bit different and take some time becoming familiar with. The free online book R for Data Science and website provide a good introduction and reference.
- UVA's library offers **personalized help**
  - UVA's Data Literacy in R
  - Dates: Wednesdays, 2/10, 2/17, 2/27, 3/3
  - Time: 2:00 - 4:00 p.m.

    - Place: Virtual Zoom meetings

- UVA's library offers lots of resources
  - Data Science Essentials in R
  - https://data.library.virginia.edu/statlab/
  - https://data.library.virginia.edu/statlab/statlab-articles/
  - https://data.library.virginia.edu/statlab/data-science-resources/
  - https://data.library.virginia.edu/training/
  - https://data.library.virginia.edu/training/past-workshops/
- Rstudio has videos and tutorials
  - https://rstudio.cloud/learn/primers
  - Handy Rstudio cheatsheets

5.5.2 Statistics

- I find students understand the least about statistical concepts. This is so fundamental to all of ML and Data Mining; a strong grasp of statistics will enable the connections between topics to pop out. If you already feel comfortable coding, I suggest you go a quick stat review. Here are two introductory resources:
  - https://moderndive.com/index.html
  - https://www.openintro.org/book/isrs/

5.5.3 Math

- The students who gain the most from the program will embrace mathematical equations. As they say "an equation is worth a thousand words". While we won't do any proofs in this class, we will judiciously use equations to clarify concepts. Spend time to become intimate with math notation – it is worth the investment.

5.5.4 Trustworthy Material

- **Use Trustworthy Material**
  - The assigned readings are trustworthy
  - Blogs and videos you find on the web are not
  - Please don't trust: Toward Data Science, Analytics Vidha, Machine Learning Mastery, Medium

6 Introduction to R

6.1 Getting Help

- A good source of basic data analysis using R is found in the free book R for Data Science.
- Web search, especially *stackoverflow.com* and *stats.stackexchange.com*
- Troubleshooting/Debugging.
  - Check one line of code at a time.
  - Use scripts
  - Make sure it works in plain R before incorporating into Rmd

6.2 RStudio

- Install R and RStudio
- Make use of *Projects* in RStudio

6.3 Using R Packages

It takes two steps to use the functions and data in an R package

1. Install the package
   - i.e., download the package to your computer
   - this only needs to be done one time
   - `install.packages()`
2. Load the package
   - i.e., tell R to look for the package functions and/or data
   - this needs to be done every time R is started (and you want to use the package)
   - `library()`

6.3.1 Note on `tidyverse` package

- The `tidyverse` package https://www.tidyverse.org/packages/ is really just a wrapper to load several related R packages
  - `ggplot2` for graphics
  - `dplyr` for data manipulation
  - `tidyr` for getting data into tidy form
  - `readr` for loading in data
  - `tibble` for improved data frames
  - `purrr` for functional programming
  - `stringr` for string manipulation
  - `forcats` for categorical/factor data
- This provides a nice shortcut to load all of these packages with `library(tidyverse)` instead of each separately:

```
#- the hard way
library(ggplot2)
library(dplyr)
library(tidyr)
```

```
library(readr)
library(tibble)
library(purrr)
library(stringr)
library(forcats)
```

```
#- the easy way
library(tidyverse)
```

6.4 RMarkdown

- Homework will be submitted in Rmd and (html) format
- When you *knit* a Rmd, it:
  1. starts a new instance of R (clean environment)
  2. in the current directory
- Any data or code must first be put into the Rmd file
  - The Rmd won't know about anything in another script or in your R environment
  - Any `source()` or data paths are relative to the current directory of the Rmd
- A homework template will be provided for each homework
  - This will automatically apply a custom format if you have the `R6018` package installed

6.5 Graphics with the `ggplot2` package

The `ggplot2` package is an approach to creating graphics for data analysis.

- See https://ggplot2.tidyverse.org/
- Keep the ggplot2 cheatsheet handy

6.6 Data Transformation with the `dplyr` package

- See https://dplyr.tidyverse.org/
- Keep the dplyr cheatsheet handy

6.6.1 single table verbs

1. `filter()`: find/keep certain rows
   - alternative to `base::subset()`
   - `slice()` to keep by row number
   - helper functions: `between()`: numeric values in a range
2. `arrange()`: reorder rows
   - alternative to `base::order()`
   - helper functions: `desc()` to use descending order
3. `select()`: find/keep certain columns
   - helper functions: `starts_with()`, `ends_with()`, `matches()`, `contains()`, `?select`

4. `mutate()`: add/create new variables
    - alternative to `base::transform()`
    - `transmute()`: only return new variables
5. `summarize()`: produce summary statistics
    - don't confuse with `summary()`
    - most useful when data is *grouped*

6.6.2 Chaining/Pipes

- Multiple operations can be chained together with the *pipe* operator, `%>%`, (pronounced as *then*). Technically, it performs `x %>% f(y) -> f(x, y)`. This lets you focus on the verbs, or actions you are performing.

```
x = c(1:5, NA)
x %>% mean(na.rm=TRUE)
#> [1] 3
mean(x, na.rm=TRUE)
#> [1] 3
```

Your Turn #2

1. Load the `nycflights13` package, which contains airline on-time data for all flights departing NYC in 2013. Also includes useful 'metadata' on airlines, airports, weather, and planes.
2. Load the `tidyverse` package
3. Using the `flights` data,
    - find all flights that were less than 1000 miles (`distance`)
    - Keep only the columns: `dep_delay`, `arr_delay`, `origin`, `dest`, `air_time`, and `distance`
    - Add the Z-score for departure delays
    - Convert the departure and arrival delays into hours
    - Calculate the average flight speed (in mph)
    - order by average flight speed (fastest to slowest)
    - return the first 12 rows

6.6.3 Other useful `dplyr` functions

- `distinct()`: retain unique/distinct rows
- `slice_sample()`: select random rows
- `sample_min/sample_max()`: select rows with smallest/highest values
- `mutate()/add_column()` add new column in particular position
- `add_row()` adds new row(s) to the table
- `na_if(x, y)` converts the `y` valued elements in `x` to `NA`

```
x = c(1, 2, -99, 5, 5, -99)
na_if(x, -99)              # replace -99 with NA
#> [1]  1  2 NA  5  5 NA
```

- `coalesce(x, y)` replaces the `NA` in `x` with `y`

```
x = c(1, 2, NA, 5, 5, NA)
coalesce(x, 0)          # replace NA with 0
#> [1] 1 2 0 5 5 0
```

6.7 Groupwise operations

6.7.1 Split - Apply - Combine

The dplyr operations are more powerful when they can be used with grouping variables. Split - Apply - Combine.

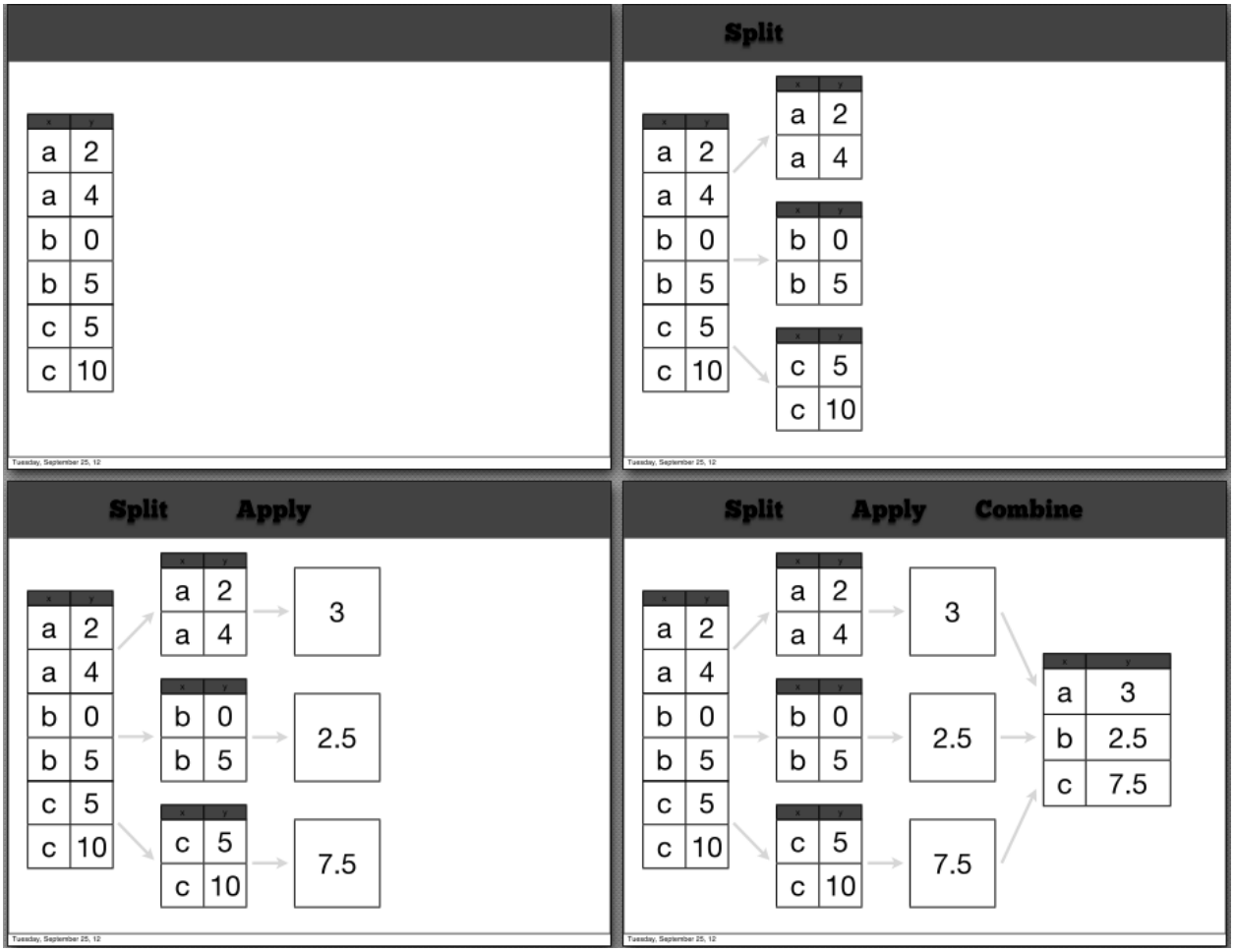


Image from Hadley Wickham UseR tutorial June 2014 http://www.dropbox.com/sh/i8qnluwmuieicxc/AAAgt9tIKoIm7WZKIyK25lh6a

6.7.2 `group_by()`

First use the `group_by()` function to group the data (determines how to split), then apply function(s) to each group using the `summarise()` function. Note: grouping should to be applied on discrete variables (categorical, factor, or maybe integer valued columns).

```
flights %>%
  group_by(origin, dest) %>%   # group by both origin and dest
  summarize(max.delay = max(arr_delay, na.rm=TRUE),
            avg.delay = mean(arr_delay, na.rm=TRUE),
            min.delay = min(arr_delay, na.rm=TRUE),
            count = n() )        # n() gives the group count
#> Warning in max(arr_delay, na.rm = TRUE): no non-missing arguments to max;
#> returning -Inf
#> Warning in min(arr_delay, na.rm = TRUE): no non-missing arguments to min;
```

```
#> returning Inf
#> # A tibble: 224 x 6
#> # Groups:   origin [3]
#>   origin dest  max.delay avg.delay min.delay count
#>   <chr>  <chr>     <dbl>     <dbl>     <dbl> <int>
#> 1 EWR    ALB         328    14.4         -34   439
#> 2 EWR    ANC          39    -2.5         -47     8
#> 3 EWR    ATL         796    13.2         -39  5022
#> 4 EWR    AUS         349    -0.474       -59   968
#> 5 EWR    AVL         228     8.80        -26   265
#> 6 EWR    BDL         266     7.05        -43   443
#> # ... with 218 more rows
```

- `count(...)` is a shortcut for `group_by(...) %>% summarize(n=n())`
- `ungroup()` removes the grouping

6.7.3 Grouped Mutate and Filter

- When data is *grouped*, `mutate()` and `filter()` operate on each group independently

```
#- proportion of carrier at each dest
flights %>%
  count(dest, carrier) %>%
  group_by(dest) %>%                    # group by dest
  mutate(total=sum(n), p=n/sum(n)) %>% # grouped mutate sum(n) is by group
  arrange(desc(total), -p)              # arrange by most freq dest and prop
#> # A tibble: 314 x 5
#> # Groups:   dest [105]
#>   dest  carrier     n total        p
#>   <chr> <chr>   <int> <int>    <dbl>
#> 1 ORD   UA       6984 17283 0.404
#> 2 ORD   AA       6059 17283 0.351
#> 3 ORD   MQ       2276 17283 0.132
#> 4 ORD   9E       1056 17283 0.0611
#> 5 ORD   B6        905 17283 0.0524
#> 6 ORD   EV          2 17283 0.000116
#> # ... with 308 more rows
```

6.8 Relational Data and Joins

Joins are used to combine or merge two datasets. This is a major aspect of SQL.

6.8.1 Mutating Joins

See 13.4 of R4DS

- `inner_join(x, y)` only includes observations that having matching x and y key values. Rows of x can be dropped/filtered.
- `left_join(x, y)` includes all observations in x, regardless of whether they match or not. This is the most commonly used join because it ensures that you don't lose observations from your primary table.
- `right_join(x, y)` includes all observations in y. It's equivalent to `left_join(y, x)`, but the columns will be ordered differently.
- `full_join()` includes all observations from x and y.

- The left, right and full joins are collectively know as **outer joins**. When a row doesn't match in an outer join, the new variables are filled in with missing values.
  - **outer joins** will fill any missing values with `NA`
- If there are duplicate keys, all combinations are returned.
- Missing values are given `NA`.

6.9 Data Importing

6.9.1 `readr` package

- See https://readr.tidyverse.org/
- Keep the data import cheatsheet handy

6.9.2 `readxl` package

- See https://readxl.tidyverse.org/ for importing excel files

6.10 Tidy Data with the `tidyr` package

- https://tidyr.tidyverse.org/
- Keep the data import cheatsheet handy. Page two describes the `tidyr` functionality

6.10.1 Why Tidy Data?

- Tidy data (in form of a data frame) is usually the best form for analysis
  - some exceptions are for modeling (e.g., matrix manipulations and algorithms)
- For presentation of data (e.g., in tables), non-tidy form can often do better
- the functions in `tidyr` usually allow us to covert from non-tidy to tidy for analysis and also from tidy to non-tidy for presentation

6.10.2 Main `tidyr` functions

function	description
`pivot_wider()/spread()`	Spreads a pair of key:value columns into a set of tidy columns
`pivot_longer()/gather()`	Gather takes multiple columns and collapses into key-value pairs, duplicating all other columns as needed. You use `pivot_longer()`/`gather()` when you notice that you have columns that are not variables
`separate()`	turns a single character column into multiple columns
`unite()`	paste together multiple columns into one (reverse of `separate()`)