Introduction to R for data analysis

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Aims of workshop

1. Work through a basic data analysis in R.
2. Understand how to import data from a CSV file into an R data frame.
3. Use standard tools to summarize & manipulate data frames.
4. Learn how to install & use R packages.
5. Use ggplot2 to create plots from the processed data.
6. Learn through “live coding”—this includes learning from our mistakes!

Our goal: Analyze Divvy data from 2016 & 2017

- Investigate bike sharing trends in Chicago.
- We will use data made available from Divvy:
  - www.divvybikes.com/system-data
- Much of the effort will be spent importing the data, inspecting the data, and preparing the data for analysis.
- Once we have carefully prepared the data, creating visualizations is (relatively) easy.

It's your choice

Your may choose to...

- Use R on your laptop.
- Use RStudio on your laptop.
- Use R or RStudio (Desktop or Server) on the RCC cluster.
- Pair up with your neighbour.
- Follow what I do on the projector.

Note: If you use the RCC cluster I'm assuming you know how to set up an interactive computing session with appropriate amount of time and memory, load R or RStudio, and display graphics (e.g., using ThinLinc).

Software we will use today

1. **R**
2. R packages **ggplot2** & **cowplot**.
3. **RStudio** (optional).

Note: I'm assuming you have already installed R and/or RStudio on your laptop, or you are using the RCC cluster.

Outline of workshop

1. Initial setup.
2. Load & prepare the Divvy station data.
3. Load & prepare the Divvy trip data.
4. Take a close look at U of C Divvy usage.
5. Create a map of the Divvy stations.
6. Create plots comparing bike sharing in 2016 & 2017.

Initial setup

- WiFi
- Power outlets
- YubiKeys
- Pace, questions (e.g., keyboard shortcuts).

Download or “clone” git repository

Download the workshop packet to your computer.

- Go to: **github.com/rcc-uchicago/R-intro-divvy-2**
- To download, click the green **“Clone or download”** button.

Or, if you have **git**, run this command:

```
git clone https://github.com/rcc-uchicago/
  R-intro-divvy-2.git
```

(Note the URL in the git command should not contain any spaces.)

- *Note:* If you are using the RCC cluster, also download workshop packet on the cluster.

What's in the workshop packet

```
R-intro-divvy-2
  /analysis # Scripts implementing data analyses.
  /code     # Additional code used in analyses.
  /data     # Original ("raw") data.
  /docs     # Additional workshop materials.
  /output   # Processed data & results files.
```

- This setup mimics how I typically organize the code, data and results for my projects.

Open the slides on your computer

- This PDF is useful for copying & pasting code from the slides.
- The PDF is in the “**docs**” folder of the workshop packet.
- You can also view the PDF by clicking the “**docs**” item in the file listing on the GitHub webpage.

Set up your R environment

- Launch R or RStudio.
- *We will run all the code from the "**analysis**" folder*.
- To change your working directory:
  - ▷ In R, use `setwd()` function.
  - ▷ In RStudio, select **Session > Set Working Directory > Choose Directory...**‘

Before continuing, check that you have the right working directory:

```
getwd()   # Should end with "analysis".
```

Run `sessionInfo()`

Check the version of R that you are using:

```
sessionInfo()
```

If you are using an older version of R (version 3.3 or earlier), I strongly recommend upgrading to the latest version. *Some of the examples may not work in older versions of R.*

Check your R environment

The R environment is where all variables and functions are stored and accessed. You should start with an empty environment. Check this:

```
ls()
```

If you see names of objects listed, it means your environment is not empty, and you should restart R with a clean environment.

- Do `rm(list = ls())`.
- Or, in RStudio, go to **Session > Restart R**.

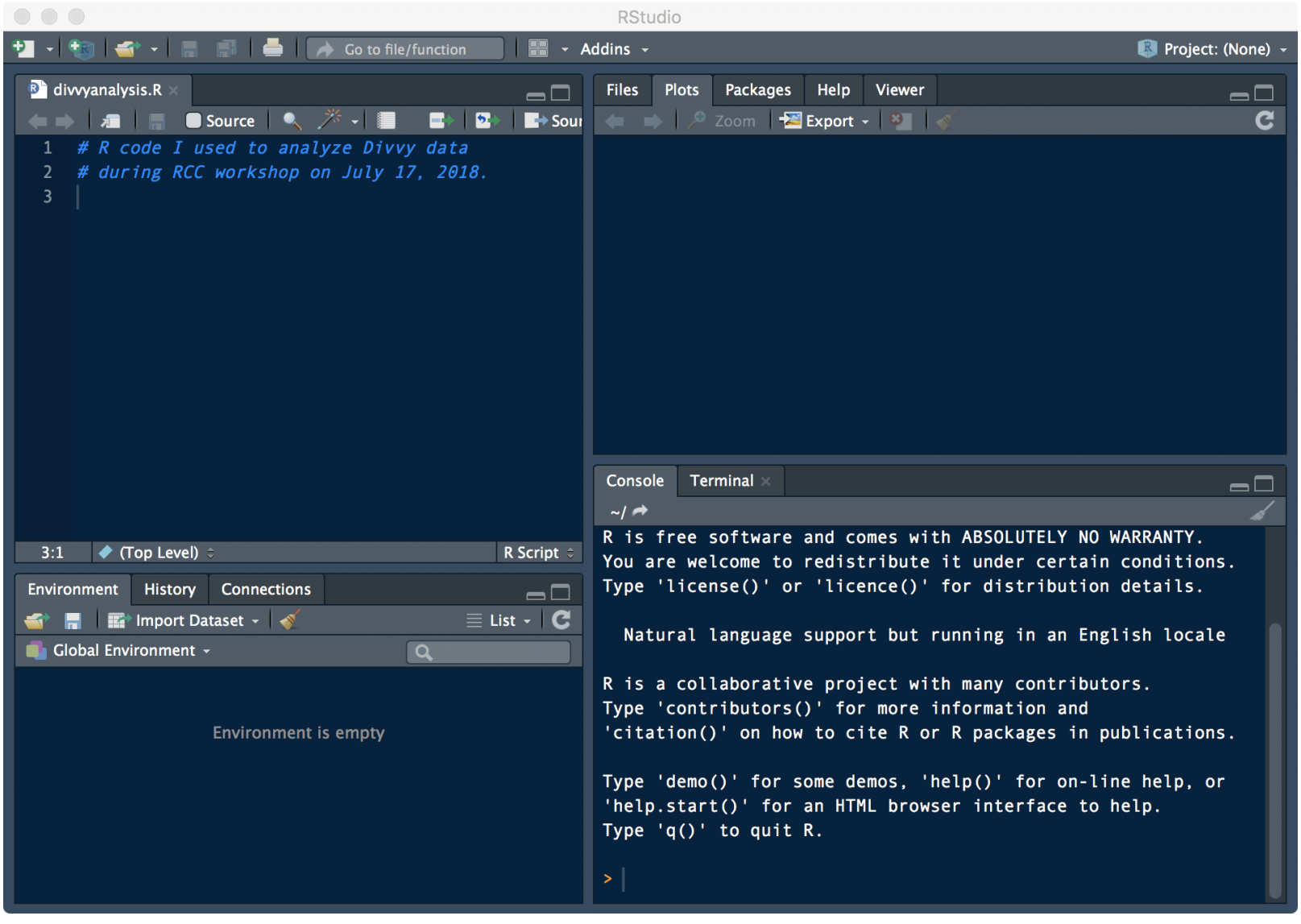
Create a file to keep track of your analysis code

- In RStudio, select **File > R Script**.
- Alternatively, use your favourite editor (nano, emacs, vim, Atom, *etc*).
- Add some comments to the title to remind yourself what this file is for, e.g.,

```
# R code I used to analyze Divvy data
# during RCC workshop on July 17, 2018.
```

- Save the file in the "**analysis**" folder. Name the file whatever you'd like (e.g., `divvyanalysis.R`).
- *We will save all our R code in this file.*

The Console is the “brains” of RStudio



RStudio

Download the Divvy data

- Disk space required: at least **2 GB**.
- Download the 2016 & 2017 data files from here:
  - ▷ **www.divvybikes.com/system-data**
- Download them to the "**data**" folder.
- You should have 4 ZIP files:

```
Divvy_Trips_2016_Q1Q2.zip
Divvy_Trips_2016_Q3Q4.zip
Divvy_Trips_2017_Q1Q2.zip
Divvy_Trips_2017_Q3Q4.zip
```

- Decompress ("unzip") all of these files.
- After unzipping, you should have **15** CSV files.

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Import the station data into R

Load the most recent station data into an R “data frame”:

```
stations <-
  read.csv("../data/Divvy_Stations_2017_Q3Q4.csv",
           stringsAsFactors = FALSE)
```

This creates a new “data frame” object in your environment:

```
ls()
class(stations)
```

What does `read.csv` do, and what is a “data frame”? R has detailed documentation:

```
help(read.csv)
help(data.frame)
```

Inspect the station data

Run these commands to inspect the station data:

```
nrow(stations)
ncol(stations)
head(stations)
tail(stations)
summary(stations)
```

What do we learn about the station data from running these commands? Does this reveal any issues with the data?

Take a closer look at the “dpcapacity” column

Run these commands to take a closer look at the “dpcapacity” column:

```
x <- stations$dpcapacity
class(x)
summary(x)
table(x)
```

What additional insight did we gain from running these commands?

Take an even closer look at dpcapacity data

It is interesting that a few of the Divvy bike stations are much larger than the others, whereas others have no docks. Where are these stations?

```
subset(stations,dpcapacity == 0)
subset(stations,dpcapacity >= 40)
```

Alternatively, we can sort the table rows and inspect the top and bottom rows:

```
rows <- order(stations$dpcapacity,decreasing=TRUE)
stations <- stations[rows,]
head(stations)
tail(stations)
```

Take a closer look at the “city” column

Above we inspected *numeric* data. Here we examine non-numeric data.

```
x <- stations$city
class(x)
summary(x)
```

Unfortunately, the summary is not very useful here. The key is to convert the “city” column to a “factor” (a categorical variable):

```
x <- factor(stations$city)
class(x)
summary(x)
```

Did you discover an issue with the data from running these commands? How could we fix this issue?

Improving the “city” column

Let’s fix this problem. First, select the offending rows of the table:

```
rows <- which(stations$city == "Chicago ")
length(rows)
```

Fix the “city” entry for the selected rows:

```
stations[rows,"city"] <- "Chicago"
```

We also observed that the “city” column is more useful if it is a factor, so let’s convert it to a factor:

```
stations <- transform(stations,
                      city = factor(city))
summary(stations)
```

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Import the Divvy trip data into R

Previously, we used the `read.csv` function to import some of the station data into R. Let's now use the same function to load the most recent trip data:

```
trips <-
  read.csv("../data/Divvy_Trips_2017_Q4.csv",
           stringsAsFactors = FALSE)
```

You may find that this command look longer to run than before. Consider that the trips data is much larger:

```
nrow(trips)
ncol(trips)
```

This gives an opportunity to demonstrate a much faster method for importing large data sets.

Import Divvy trip data using `fread`

Install the **data.table** package from CRAN:

```
install.packages("data.table")
```

Load the functions from the package into your environment:

```
library("data.table")
```

Let's use the `fread` function from this package:

```
trips <- fread("../data/Divvy_Trips_2017_Q4.csv",
               stringsAsFactors = FALSE)
```

One annoying feature of `fread` is that it uses its own "data.table" class, so we need to convert it to a data frame object if we want to use it like other data frames:

```
class(trips) <- "data.frame"
```

More about packages in R

- CRAN is the official package source (cran.r-project.org).
- Other good places to find packages: Bioconductor, GitHub.
- *What packages are already installed?*
  `rownames(installed.packages())`
- *Where are the packages?* `.libPaths()`
- *How to learn more about a package?*
  `help(package=data.table)`
- "Vignettes" are also a great way to learn about a package, e.g., `vignette("datatable-intro")`

A first glance at the trips data

Let's use some of the same commands we used earlier to quickly get an overview of the trip data:

```
nrow(trips)
ncol(trips)
head(trips)
summary(trips)
```

Unfortunately, the summary command isn't particularly informative for many of the columns. We have the same problem as before—we should convert some of the columns to factors.

Convert “gender” to a factor

Let’s start by converting the “gender” column to a factor:

```
trips <- transform(trips,gender = factor(gender))
summary(trips$gender)
```

What problem have we stumbled upon?

Handling “missing” data

In R, “missing data” should always be assigned the special value `NA` (short for “not available” or “not assigned”):

```
i <- which(trips$gender == "")
trips[i,"gender"] <- NA
trips <- transform(trips,
                   gender = factor(gender))
summary(trips$gender)
```

Many functions in R will correctly handle missing data as long as they are encoded as `NA`.

Convert “station” columns to factors

Next, let’s convert the “from station” and “to station” columns to factors:

```
trips <- transform(trips,
  from_station_name = factor(from_station_name),
  to_station_name = factor(to_station_name))
summary(trips)
```

The summary is now more informative. However, this is a better way to convert the “station” columns to factors:

```
x <- stations$name
trips <- transform(trips,
  from_station_name = factor(from_station_name,x),
  to_station_name = factor(to_station_name,x))
```

Why is second approach better?

A note about dates & times

- `summary(trips)` is also not useful for the dates & times.
- Processing dates & times in R is more complicated.
- See `help(strptime)` and the `lubridate` package.

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A closer look at bike trips from U of C

We have put a lot of effort into preparing the Divvy data. Let's examine the trip data departing from the Divvy station at 57th & University. Here we create a new data frame, `uctrips`:

```
ucstation <- "University Ave & 57th St"
uctrips <-
  subset(trips,from_station_name == ucstation)
nrow(uctrips)
```

How do the ages of the riders at U of C compare to citywide riders?

```
summary(uctrips$birthyear)
summary(trips$birthyear)
```

A closer look at bike trips from U of C

What are t he final destinations of trips starting at 57th & University?

```
counts <- table(uctrips$to_station_name)
counts <- counts[counts > 0]
sort(counts,decreasing = TRUE)
```

What is the destination for most riders? How many times did people bike from University & 57th all the way to Millenium Park in Fall 2017?

Save your code & session state

It is important to periodically save:

1. your code,
2. the state of your R environment.

To save your environment, do something like this:

```
save.image("../output/divvyanalysis.RData")
```

Preparing data is tedious

Data preparation is sometimes >90% of the effort!

- *Many analysis mistakes are due to poor data preparation.*

Common issues include:

- Formatting mistakes in CSV file.
- Converting table columns to the appropriate data type.
- Entry inconsistencies (e.g., additional spaces).
- Missing data.
- Many other examples of Poor Practices in recording data.

(And we haven't yet dealt with merging data from multiple files—this usually creates more headaches!)

Moving beyond data preparation

- So far, we have illustrated a few of the challenges of working with large tabular data sets (“data frames”).
- In order to proceed to fun stuff, I’ve “hidden” some of the additional complications—I wrote a function in R to import and merge all the Divvy data into a single data frame.

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Import the 2016 & 2017 Divvy data

I wrote a function “read.divvy.data” that will read all the CSV files, then merge them into two data frames: one for the stations, and one for the trips.

```
source("../code/functions.R")
ls()
```

Choose which station and trip files to import.

```
tripfiles <- Sys.glob("../data/Divvy_Trips*.csv")
stnfile <- "../data/Divvy_Stations_2017_Q3Q4.csv"
```

Import the 2016 & 2017 Divvy data

This may take a few minutes to run.

```
library("data.table")
divvy <- read.divvy.data(stnfile,tripfiles)
```

The output is a "list" containing two data frames:

```
stations <- divvy$stations
trips    <- divvy$trips
rm(divvy)
head(stations)
head(trips)
```

How many more trips were taken in 2017 than in 2016? Try using the `summary` function.

Out first plot: a map of the Divvy stations

We will use the **ggplot2** package. It is a powerful (although not intuitive) set of plotting functions that extend the base plotting fuctions in R.

```
install.packages("ggplot2")
```

Load the ggplot2 functions into your environment:

```
library("ggplot2")
```

The “stations” data frame gives the geographic co-ordinates (latitude & longitude) for each station. With ggplot, we can create a station map in only a few lines of code:

```
p <- ggplot(data     = stations,
            mapping = aes(x = longitude,
                          y = latitude)) +
  geom_point()
print(p)
```

Adjusting the plot

I recommend the **cowplot** package, which extends **ggplot2**.

```
install.packages("cowplot")
```

This code is the same as before, except for a few adjustments to the default settings for plotting points ("**geom_point**"):

```
library(cowplot)
p <- ggplot(data     = stations,
            mapping = aes(x = longitude,
                          y = latitude)) +
  geom_point(shape = 21,fill = "darkblue",
             color = "white",size = 2)
print(p)
```

What geographic features of Chicago are recognizable from this plot?

Scale stations by the number of departures

Next, let's add an additional piece of information to this visualization:

- Number of departures at each station (which should roughly correspond to population density, but maybe not always).

To do this, we need to add a new column to the "stations" data frame containing the total number departures, which is calculated from the "trips" data frame:

```
counts <- table(trips$from_station_id)
class(counts)
length(counts)
head(counts)
```

The counts should be the same order as stations (*why is this?*):

```
all(names(counts) == stations$id)
```

Scale stations by the number of departures

Add these trip counts to the “stations” data frame:

```
counts <- as.vector(counts)
stations <-
  cbind(stations,data.frame(departures = counts))
head(stations)
```

Let’s use this column in our new plot:

```
p <- ggplot(data = stations,
  mapping = aes(x = longitude,y = latitude,
                size = sqrt(departures))) +
  geom_point(shape = 21,fill = "darkblue",
             color = "white")
print(p)
```

Why do we set “size” to `sqrt(departures)`*?*

How to save and share your plot

For exploratory analyses, GIF and PNG are great formats because the files are easy to attach to emails or webpages and they can be viewed nearly universally:

```
ggsave("../output/station_map.png",
       plot = p,dpi = 150)
```

For print or publication, you will want to save in a vector graphics format:

```
ggsave("../output/station_map.pdf",plot = p)
```

Save your code & session state

This is a good time to save your session.

```
save.image("../output/divvyanalysis.RData")
```

Compare 2017 biking activity against 2016

Earlier, we observed an increase in overall trips for 2017. Which stations experienced the greatest increase?

- To examine this, we need to count trips separately for 2016 and 2017.
- Then we add these counts to the "stations" data frame.

We will use the `subset`, `table` and `cbind` functions for this:

```
d <- subset(trips,start.year == 2016)
x <- table(d$from_station_id)
d <- subset(trips,start.year == 2017)
y <- table(d$from_station_id)
stations <-
  cbind(stations,
        data.frame(dep.2016 = as.vector(x),
                   dep.2017 = as.vector(y)))
head(stations)
```

Scatterplot of trips by station (2016 vs. 2017)

Again, now that we have prepared a data frame with the data in the proper format, plotting is relatively straightforward:

```
p <- ggplot(data = stations,
            mapping = aes(x = dep.2016,
                          y = dep.2017)) +
  geom_point(shape = 20,size = 3)
print(p)
```

It is difficult to tell which stations had more trips in 2017—we need to compare against the x = y line.

```
p <- p + geom_abline(slope = 1,color = "skyblue",
             linetype = "dashed") +
       xlim(c(0,6e4)) + ylim(c(0,6e4))
print(p)
```

One station stands out because it has had a much larger increase in trips than other stations. Where is this station?

Save your code & session state

Save your final results for safekeeping.

```
save.image("../output/divvyanalysis.RData")
```

ggplot: Take home points

- Creating sophisticated plots in ggplot requires relatively little effort *provided the data are in the right form.*
- All plots in ggplot2 consist of these 3 elements:
  1. A data frame.
  2. An "aesthetic mapping" that declares how columns are plotted.
  3. A "geom", short for "geometric object," that specifies the type of plot.
- All plots are created by combining "layers" using the + operator.

Parting thoughts

1. Always record your analysis steps in a file so you can reproduce them later.
2. Keep track of which packages (and the versions) you used—`sessionInfo()` is your friend.
3. Use packages—don't reinvent the wheel.
4. Email `help@rcc.uchicago.edu` for advice on using R on the RCC cluster.
5. Use "R Markdown" to document your analyses.
6. See the **workflowr** package for simplifying organizing & sharing of data analyses; e.g., **stephenslab.github.io/wflow-divvy**.