Introduction to R for data analysis

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2. Aims of workshop

1. Get hands-on experience with the basic elements of 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 plot data.
6. Learn through “live coding”.

3. Our goal: Analyze Divvy data from 2016 & 2017

- Investigate bike sharing trends in Chicago.
- We will use data made available by Divvy:
  - ▷ www.divvybikes.com/system-data
- We will import and inspect the data, and take steps to prepare the data for analysis and plotting.
- Once we have carefully prepared the data, creating visualizations is (relatively) little effort.

4. The programmatic approach

- Data analysis usually involves *iterative refinement* and *repetition*.
- The *programmatic approach* to data analysis will allow you to...
  - ▷ Automate your analysis.
  - ▷ Quickly create a new analysis from existing code.
  - ▷ Expand capabilities with R packages.

5. It's your choice

Your may choose to...

- Use R on your computer.
- Use RStudio on your computer.
- Use RStudio Cloud.
- Follow what I do on the projector.

6. Software we will use today

1. **R** and/or **RStudio**.
2. R packages **readr**, **ggplot2** & **cowplot**.

7. Outline of workshop

1. Initial setup.
2. Analysis of Divvy station data.
3. Analysis of Divvy trip data.
4. Combining the data.

8. Initial setup

- Set up RStudio Cloud (optional).
- Workshop packet.
- Reading what I type.
- Pace, questions (e.g., keyboard shortcuts).
- Help.

9. Set up RStudio Cloud (optional)

- Go to **https://rstudio.cloud**.
- If necessary, log in or create an account.
- In Your Workspace, select **New Project > New Project From Git Repo**.
- Enter this URL:

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

10. Download or “clone” git repository

If not using RStudio Cloud, download the workshop packet to your computer.

- Go to **http://github.com/rcc-uchicago/R-intro-divvy**
- 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.git
```

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

- If necessary, uncompress the ZIP file.
- If necessary, rename folder to **R-intro-divvy**.

11. What's included in the workshop packet

- **slides.pdf**: These slides.
- **slides.Rmd**: R Markdown source used to generate these slides. *You may open this file in RStudio or your favourite editor.*
- **read_trip_data.R**: Some R code used in the examples.
- **Divvy_Stations_2017_Q3Q4.csv:** Divvy station data.
- **Divvy_Trips_2019_Q4.csv.gz:** 2019 Divvy trip data.

12. Set up your R environment

- Launch R or RStudio.

13. Load code for the hands-on exercises

Open R Markdown source file, **slides.Rmd**.

- In RStudio, select **File > Open File**.
- Alternatively, use your favourite text editor.

14. Run `sessionInfo()`

Check the version of R that you are using:

```
sessionInfo()
```

15. Clear your workspace

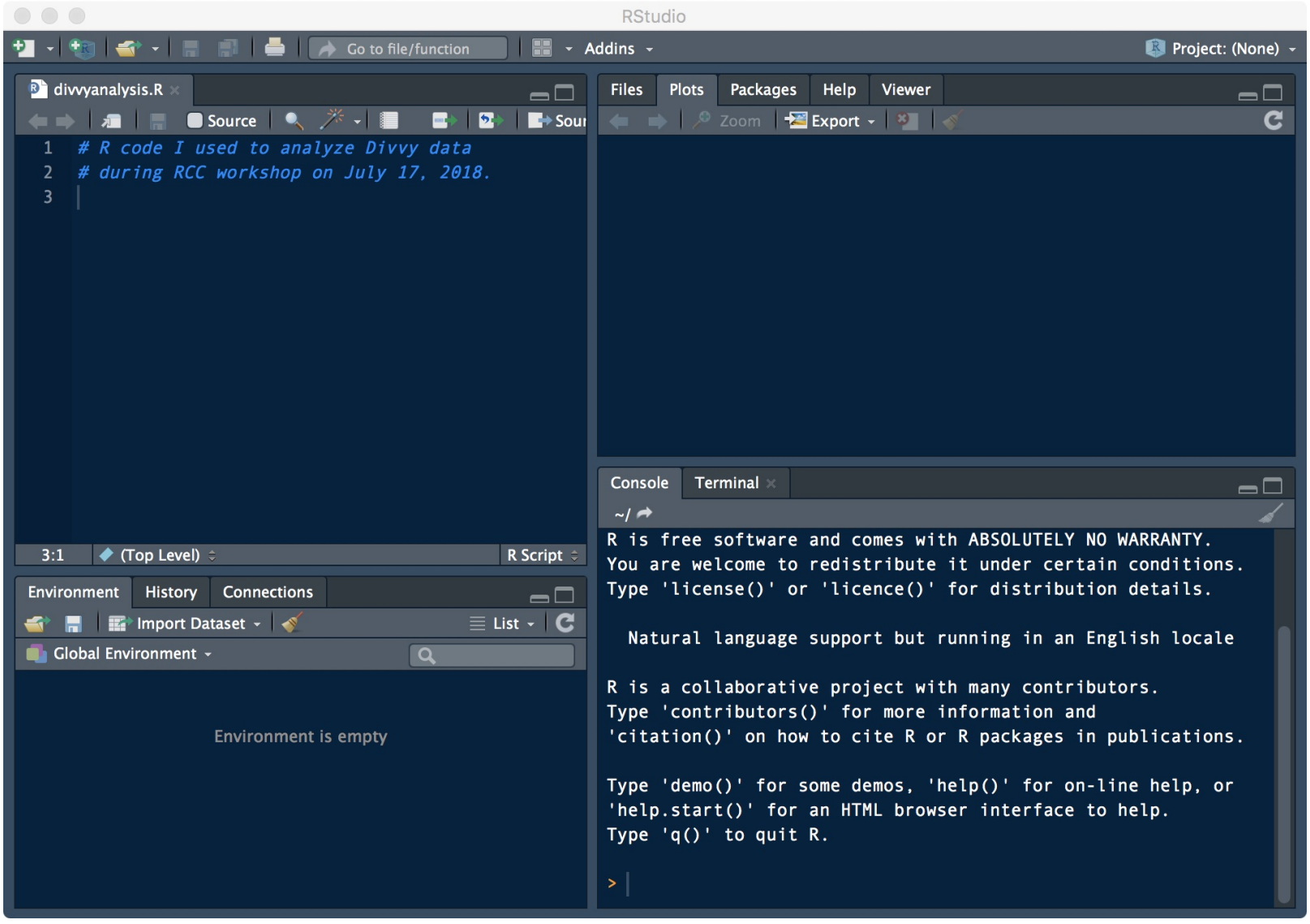
The R environment is where all variables (and functions) are stored and accessed. It is Best Practice to start with an empty environment, or "workspace". Run this:

```
ls()
```

If this outputs names of objects, it means your environment is not empty and you should restart R with a clean environment. Do either:

- `rm(list = ls())`.
- Or, in RStudio, **Session > Clear Workspace**.

16. The Console is where the action is



17. Set your working directory to “R-intro-divvy”

Check that you have the right working directory:

```
list.files()
```

You should see the tutorial files. If you don’t, change your working directory:

- In R, use the `setwd()` function.
- In RStudio, select **Session > Set Working Directory > Choose Directory...‘**

If you have changed your working directory, double-check that you have the right working directory before continuing.

18. Outline of workshop

1. Initial setup.
2. **Analysis of Divvy station data.**
3. Analysis of Divvy trip data.
4. Combining the data.

19. View CSV file

Open the CSV file **Divvy_Stations_2017_Q3Q4.csv** in RStudio or your favourite text editor (e.g., Notepad in Windows, TextEdit on Mac).

20. Import station data into R

Read the station data into a “data frame”:

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

This will create a new object, “stations”, in your environment:

```
ls()
```

It is a “data frame” object:

```
class(stations)
```

21. Inspect the station data

Check that the data were read correctly, and inspect the table:

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

Inspect the data further:

```
sapply(stations,class)
object.size(stations)
```

22. Take a closer look at the “dpcapacity” column

Make a copy of the “dpcapacity” column:

```
x <- stations$dpcapacity
```

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

```
class(x)
length(x)
summary(x)
min(x)
max(x)
mean(x)
median(x)
quantile(x,0.5)
table(x)
```

23. Data subviews

When you are working with large data sets, you need a strategy to inspect manageable subsets of the data. Here are some examples of printing subsets of the data:

```
head(stations,n = 4)
tail(stations,n = 4)
```

More examples:

```
stations[1:4,]
stations$name[1:4]
stations[1:4,2]
stations[1:4,"name"]
```

24. Data subviews

Yet more examples:

```
stations[1:4,c(2,3,6)]
stations[1:4,c("name","city","dpcapacity")]
```

25. Conditional subviews

One powerful way to inspect subsets is by condition. For example, to view all the stations with more than 40 docks, do

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

or, equivalently,

```
stations[stations$dpcapacity > 40,]
```

It is interesting that a couple of the Divvy bike stations have no docks. What are these stations?

```
# Add code here.
```

26. Conditional subviews

Once you have generated a subview that you want to explore further, you can create a new data set from a subview, e.g.,

```
largest_stations<-subset(stations,dpcapacity > 40)
```

This object is also a data frame:

```
class(largest_stations)
```

27. Ordering the stations by number of docks

Here's way to access data on the smallest and largest stations:

```
rows <- order(stations$dpcapacity)
stations2 <- stations[rows,]
head(stations2)
tail(stations2)
```

28. Take a closer look at the “city” column

Above, we examined numeric data. Now let’s take a close look at another type of data.

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

The summary is not very useful here! The key is to convert to a “factor”:

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

29. Fixing the “city” column

Let’s fix the problem of two “Chicago” categories. First, select the offending rows in the table:

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

Fix the “city” column by *overwriting* the selected rows:

```
stations[rows,"city"] <- "Chicago"
x <- factor(stations$city)
summary(x)
```

The “city” column is more useful if it is a factor, so let’s modify this column *inside* the data frame:

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

30. Create a map of the Divvy stations

A scatterplot can be created from two numeric vectors very simply using the "plot" function. Let's see what happens if we plot the geographic co-ordinates (latitude & longitude) of the stations.

```
plot(stations$longitude,stations$latitude,
     pch = 20)
```

The plot function has many, many options. We will not explore these options here. Let's add color to the plot according to the "city" column:

```
plot(stations$longitude,stations$latitude,
     col = stations$city,pch = 20)
```

31. Create stations map using ggplot2

Now let's recreate the stations map using **ggplot2**. It is a powerful (though not immediately intuitive) plotting interface. First, install ggplot2 if you have not already done so. (We will also use cowplot, an extension to ggplot2.)

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

As you can see, the ggplot2 code is a bit more complicated:

```
library(ggplot2)
p1 <- ggplot(stations,
             aes(x = longitude,
                 y = latitude,
                 color = city)) +
  geom_point()
print(p1)
```

What is better about the new plot?

32. More on ggplot2

- All plots in ggplot2 require these three elements:
  1. A data frame.
  2. An "aesthetic mapping" that maps columns to plot features (axes, shapes, colors, *etc.*).
  3. A "geom", short for "geometric object," that specifies the type of plot.
- All plots are created by *adding layers.*
- ggplot2 has an excellent website where you can learn more: `ggplot2.tidyverse.org`

33. A better stations map

Not satisfied with this plot, I experimented with the `geom_point` settings to improve the plot a bit:

```
p2 <- ggplot(stations,
             aes(x = longitude,
                 y = latitude,
                 fill = city)) +
  geom_point(shape = 21,size = 2,color = "white")
print(p2)
```

34. A better stations map

The default colours in ggplot2 are not great; they can be overrided here with the "scale" function `scale_fill_manual`. Also, I'm a big fan of the cowplot theme:

```
library(cowplot)
p2 <- p2 +
  scale_fill_manual(values = c("dodgerblue",
                               "darkorange",
                               "darkblue")) +
  theme_cowplot(font_size = 10)
print(p2)
```

We have only touched the surface of what ggplot2 can do. Observe that adjustments to the plot are made by adding "layers". This is one of the distinctive features of ggplot2.

35. Save & share your plot

Let's save this last plot as a file that can be shared with others.

```
ggsave("stations.png",p2,dpi = 200)
ggsave("stations.pdf",p2)
```

36. Save your results

It is important to periodically save your code and results. (Remember there is no “undo” command in R!) To save your workspace, go to **Session > Save Workspace As...** in RStudio, or run this code:

```
save.image("divvy_analysis.RData")
```

Later, to restore your environment in a new session, select **Session > Load Workspace...** in RStudio, or run this code:

```
load("divvy_analysis.RData")
```

37. Main concepts covered so far

- The R workspace & working directory.
- Read a data frame from a text (CSV) file.
- Tools to inspect a data frame.
- Tools to manipulate a data frame.
- Subviews and conditional subviews.
- Ordering rows of a data frame.
- Factors.
- Creating a plot using “plot”.
- Creating a plot using ggplot2.
- Saving your results.

38. Outline of workshop

1. Initial setup.
2. Analysis of Divvy station data.
3. **Analysis of Divvy trip data.**
4. Combining the data.

39. Automating the data preparation

Now we will analyze the trip data. This is a much larger set of data. Since data preparation can be tedious, I've simplified the preparation of the trip data for you by writing a *script* to do this. Notice that the script loads the **readr** package. So you will need to install this package if you haven't already done so.

```
install.packages("readr")
```

To run the script, simply type:

```
source("read_divvy_data.R")
```

You will find that `read.csv` is horribly slow for large CSV files; for this reason, I used `read_csv` from the **readr** package. I recommend both the **readr** and **data.table** packages for importing large data sets.

36. 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)
```

37. Convert “gender” to a factor

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

```
trips$gender <- factor(trips$gender)
summary(trips$gender)
levels(trips$gender)
```

38. Missing data

- In R, “missing data” should be assigned the special value `NA` (“not available”).
- Many functions in R will correctly handle missing data as long as they are encoded as `NA`.
- The `read_csv` function from the `readr` package was “smart” enough to figure out that blank entries in the CSV file should be converted to `NA`.

39. Convert “station” columns to factors

Likewise, the “from station” column is also more useful as a factor:

```
summary(trips$from_station_name)
trips$from_station_name <-
  factor(trips$from_station_name)
summary(trips$from_station_name)
```

50. Inspect the 2016 & 2017 Divvy data

```
head(stations)
summary(stations)
nrow(trips)
head(trips)
summary(trips)
```

53. Adjusting the plot

ggplot has many options for changing the look of the plot elements:

```
g <- geom_point(shape = 21,fill = "limegreen",
                color = "white",size = 3)
p <- ggplot_add(g,p)
print(p)
```

54. Use color to highlight the largest stations

To do this, map the “dpcapacity” column to colour in the plot:

```
a <- aes(x    = longitude,
         y    = latitude,
         fill = dpcapacity)
p <- ggplot(stations,a)
g <- geom_point(shape = 21,color = "white",
                size = 3)
p <- ggplot_add(g,p)
print(p)
```

55. Use color to highlight the largest stations

The colour scale is not great, so let's improve it:

```
g <- scale_fill_gradient2(low = "dodgerblue",
  mid = "darkblue",high = "red",midpoint = 25)
p <- ggplot_add(g,p)
print(p)
```

56. Scale points by number of departures

We need to add a new column to the “stations” data frame containing the total number departures. It can be calculated from the “trips” data frame:

```
counts <- table(trips$from_station_name)
```

Because we used `read.divvy.data`, station counts should be the same order as the stations. Let’s verify this:

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

57. Scale stations by the number of departures

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

```
stations$departures <- as.vector(counts)
head(stations)
```

Now we can include the “departures” column in a plot:

```
a <- aes(x    = longitude,
         y    = latitude,
         size = sqrt(departures))
p <- ggplot(stations,a)
```

Add points to your plot:

```
# Add code here
```

65. Save your results

Save your final results for safekeeping.

```
save.image("divvy_analysis.RData")
```

67. Why data analysis in R?

- In R, a table or spreadsheet is stored in a “data frame”. A data frame is an *object* that can be explored, manipulated and analyzed with code.
- Developing your R code into a script will allow you to *automate* your data analyses.

68. Parting thoughts

1. Always keep track of your analysis code in a file (ideally, in a script that can be run).
2. Use “R Markdown” to document your analyses.
3. Use packages—don’t reinvent the wheel.
4. Email `help@rcc.uchicago.edu` for advice on using R on the RCC cluster. See also `https://github.com/rcc-uchicago/R-large-scale`.
5. I recommend the **workflowr** package for streamlining your data analyses and making them more reproducible, and easier to share: `https://github.com/jdblischak/workflowr`
6. Thank you!