Introduction to R for data analysis

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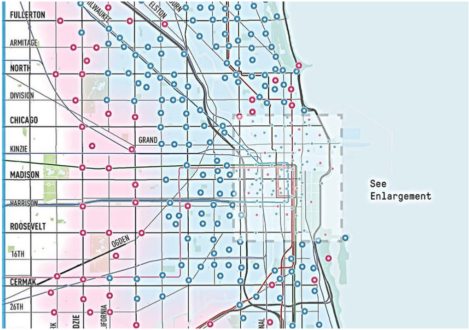


2. Aims of workshop

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

- 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.
- Arranging Zoom and RStudio on the screen.
- 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

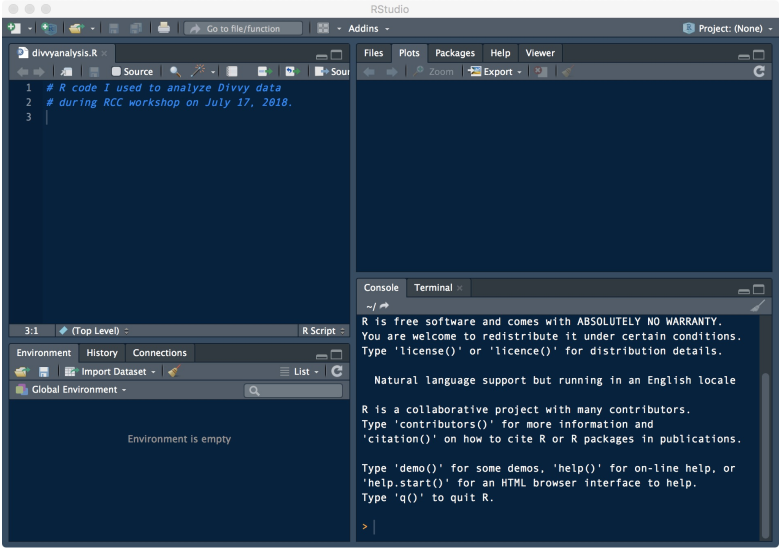
The R environment is where all variables (and functions) are stored and accessed. It is Best Practice to start with an empty environment, or "workspace". Run this:

```
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. RStudio: a workspace for data analysis



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

```
R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

>
```

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.

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

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:

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

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

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

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_trip_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.

40. 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)
```

What types of data are stored in this table?

41. Missing data

- In R, “missing data” has a special value, `NA` (short for “not available” or “not assigned”). Most data types allow NAs.
- 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`.

42. Plot number of trips by day

The days of the year are numbered:

```
summary(trips$dayofyear)
```

Let’s count the number of trips by day. This is easily done if we first convert the “dayofyear” column to a factor:

```
trips$dayofyear <- factor(trips$dayofyear)
counts <- table(trips$dayofyear)
```

Do you see a trend in the number of trips by day? This trend may be more obvious if we plot the counts:

```
counts <- as.numeric(counts)
plot(274:365,counts,pch = 20)
```

One “trick” I used here was to first convert the output from `table` to a (numeric) vector, since `plot` expects numeric vectors as input.

43. Plot number of trips by day using ggplot2

To recreate the same plot using ggplot2, we first need to construct a data frame for plotting:

```
pdat <- data.frame(day = 274:365,counts = counts)
```

Now that we have a data frame for plotting, the ggplot2 code is rather straightforward:

```
p <- ggplot(pdat,aes(x = day,y = counts)) +
  geom_point() +
  theme_cowplot()
```

44. Where are the most frequently used Divvy stations?

Here we will create a plot that uses both the stations and trip data: a map of the stations, in which the area of each station is proportional to the number of trips from that station. To create this plot, we will have to *combine* the stations data and trip data. The number of trips by station is easily counted because we have converted the “from_station_name” to a factor:

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

The problem is that the stations in the trips table are not quite the same as the stations in the stations table:

```
length(stations$name)
length(names(counts))
length(intersect(stations$name,names(counts)))
```

The key is to select the elements of `counts` by name:

```
stations$trips <- as.numeric(counts[stations$name])
```

45. Where are the most frequently used Divvy stations?

With this new “trips” column in the stations data frame, creating the plot using ggplot2 is now mostly straightforward:

```
p <- ggplot(stations,
            aes(x = longitude,
                y = latitude,
                size = sqrt(trips))) +
  geom_point(shape = 21,color = "white",
             fill = "black") +
  theme_cowplot()
print(p)
```

Notice that I scaled the size of the points by the *square root* of the number of trips so that the *area* of the points proportional to the number of trips.

46. Save your results

Save the results of your analysis.

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

47. 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!