Lecture 4: Exploratory Data Analysis and Base R Graphics

STAT GR5206 *Statistical Computing & Introduction to Data Science*

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Last Time

- **Filtering**. Accessing elements of a structure based on some criteria. `v[v>5]`, `m[ m[,1]!=0, ]`.
- **Lists**. Elements can all be different types. Access like `l[[3]]`, `l$name`. Create with `list()`.
- `NA` **and** `NULL` **values**. `NA` is missing data and `NULL` doesn't exist.
- **Factors and Tables**. Factors is how `R` classifies categorical variables.
- **Dataframes**. Used for data that is organized with rows indicating cases and columns indicating variables.
- **Importing and Exporting Data in** `R`. Use `read.csv()` and `read.table()` depending on dataset type. The working directory.
- **Control Statements**. We studied iteration, `for` loops and `while` loops, and `if, else` statements.
- **Vectorized Operations**. To be used instead of iterations.

Exploratory Data Analysis and R Graphics

Diamonds Dataset

- Download `diamonds.csv` from the Canvas page.
- Save to your computer and set your working directory to match that location.
- Run `diamonds <- read.csv("diamonds.csv", as.is = TRUE)`.

- Note that we could have just ran the line of code:
- `diamonds <- read.csv("diamonds.csv", as.is = FALSE)`.
- `as.is = FALSE` converts all character variables to factors.

Diamonds Dataset

Info on $\sim$ 54000 diamonds from `www.diamondse.info`.

Variables

- **Carat** – Weight of the diamond (0.2 - 5.01).
- **Color** – Diamond color from J (worst) to D (best).
- **Clarity** – A measurement of how clear the diamond is (I1 (worst), SI1, SI2, VS1, VS2, VVS1, VVS2, IF (best)).
- **Cut** – Quality of the cut (Fair, Good, Very Good, Premium, Ideal).
- **Price** – Price in US dollars.

Diamonds Dataset

Code example.

Diamonds Dataset

Think by yourself for a few minutes: what are some interesting questions we could answer using this dataset?

Diamonds Dataset

Think by yourself for a few minutes: what are some interesting questions we could answer using this dataset?

Some ideas:

- What does the distribution of diamond prices look like? Symmetric? Skewed?
- How does a diamond's price relate to its weight?
- Does the relationship between the price and the weight change depending on the quality of the diamond's cut?

Exploratory Data Analysis [1]

Exploratory Data Analysis, or EDA for short, is exploring data in a systematic way.

It's an iterative process:

1. Generate questions about your data.
2. Search for answers by visualizing, transforming, and modelling your data.
3. Use what you learn to refine your questions and or generate new questions.

[1] EDA slides developed from G. Grolemund and H. Wickham.

Exploratory Data Analysis

EDA is a way for you to learn about and better understand your data.

Asking Questions

1. What type of **variation** occurs **within** my variables?
2. What type of **covariation** occurs **between** my variables?

We focus on each of these questions separately.

Variation

Variation is the tendency of measured values of a variable to change measurement-to-measurement.

- Visualizing the distribution of a variable is the best way to understand the patterns of a variable's variance.
- Visualize the distribution of a **categorical** variable using a bargraph.
- Visualize the distribution of a **continuous** variable using a histogram (or boxplot).

Bargraphs in R

Produce a bargraph using `barplot(heights, labels)` where `heights` is a vector of values for the heights of each bar and `labels` is an optional vector of labels for each bar.

- Can use `table()` as input for the bar heights.
- The order that `table()` uses is the order of the factor levels of its input.

Plotting a Bargraph of Diamond Cut

```
> table(diamonds$cut)
```

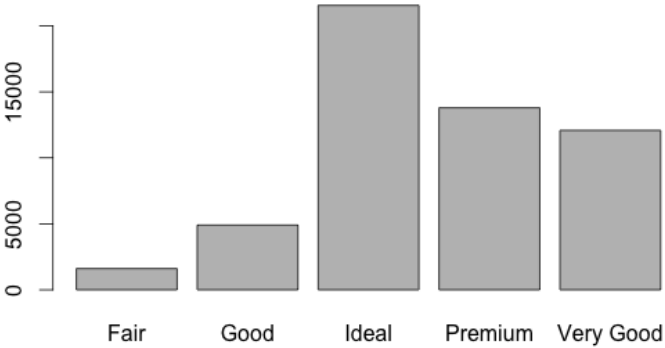
```
     Fair      Good     Ideal   Premium Very Good
     1610      4906     21551     13791     12082
```

```
> names(table(diamonds$cut))
```

```
[1] "Fair"      "Good"      "Ideal"     "Premium"
[5] "Very Good"
```

Plotting a Bargraph of Diamond Cut

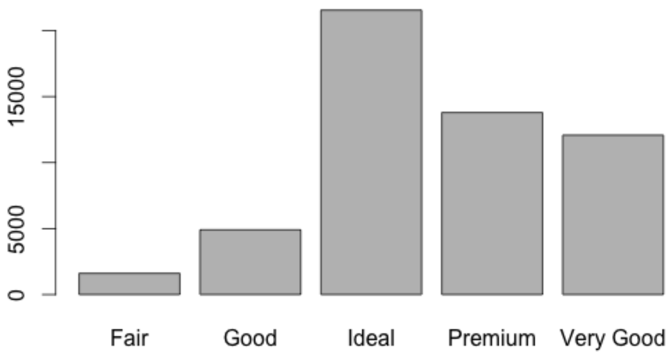
```
> barplot(height = table(diamonds$cut),
+         names.arg = names(table(diamonds$cut)))
```



Bargraphs in R

Plotting a Bargraph of Diamond Cut

```
> barplot(height = table(diamonds$cut),
+         names.arg = names(table(diamonds$cut)))
```



Oops! The order should be `Fair`, `Good`, `Very Good`, `Premium`, `Ideal`.

Plotting a Bargraph of Diamond Cut

```
> levels(diamonds$cut)
```

```
[1] "Fair"      "Good"      "Ideal"     "Premium"
[5] "Very Good"
```

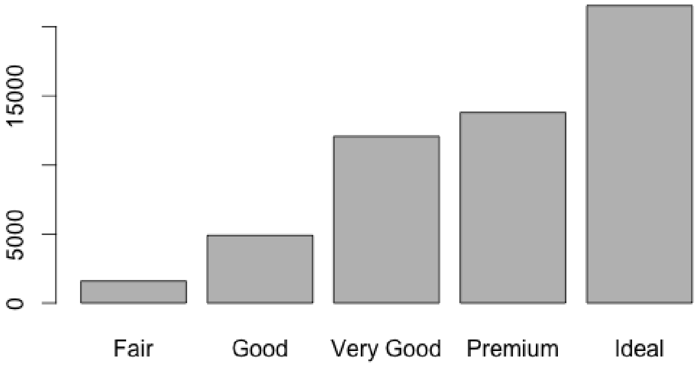
```
> diamonds$cut <- factor(diamonds$cut, level = c("Fair",
+                        "Good", "Very Good", "Premium",
+                        "Ideal"))
> levels(diamonds$cut)
```

```
[1] "Fair"      "Good"      "Very Good" "Premium"
[5] "Ideal"
```

Bargraphs in R

Plotting a Bargraph of Diamond Cut

```
> barplot(height = table(diamonds$cut),
+         names.arg = names(table(diamonds$cut)))
```



Histograms in R

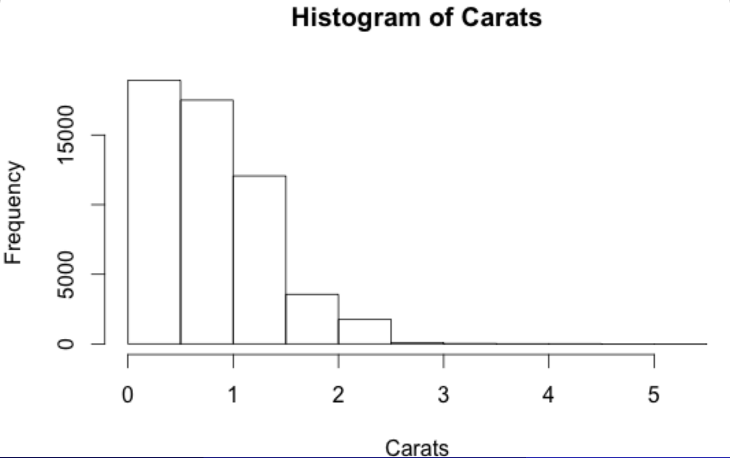
Produce a histogram using `hist(values)` where `values` is a vector of values.

- A histogram divides the x-axis into equally-spaced bins with the height of the bars used to indicate the number of observations falling within the bin.
- Change the width of the histogram's bins using `break =` argument. This specifies the number of bins.
- Make sure to explore different binwidths as different widths will display different patterns in the data.

Histograms in R

Plotting a Bargraph of Diamond Cut

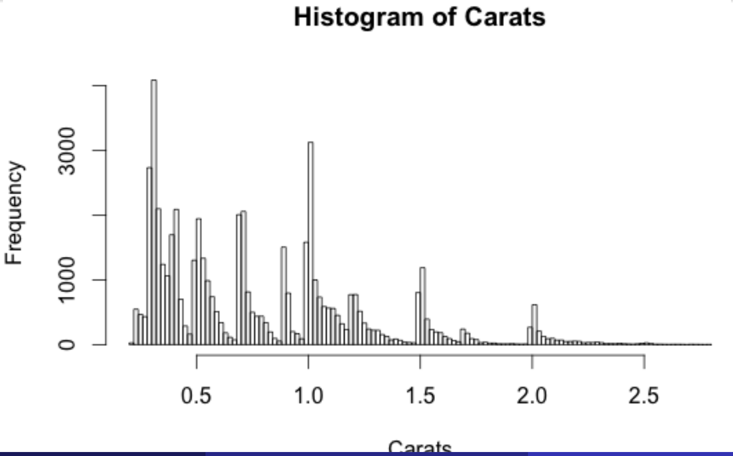
```
> hist(diamonds$carat, main = "Histogram of Carats",
+       xlab = "Carats")
```



Histograms in R

Plotting a Bargraph of Diamond Cut

```
> hist(diamonds$carat[diamonds$carat < 3], breaks = 100,
+       main = "Histogram of Carats", xlab = "Carats")
```

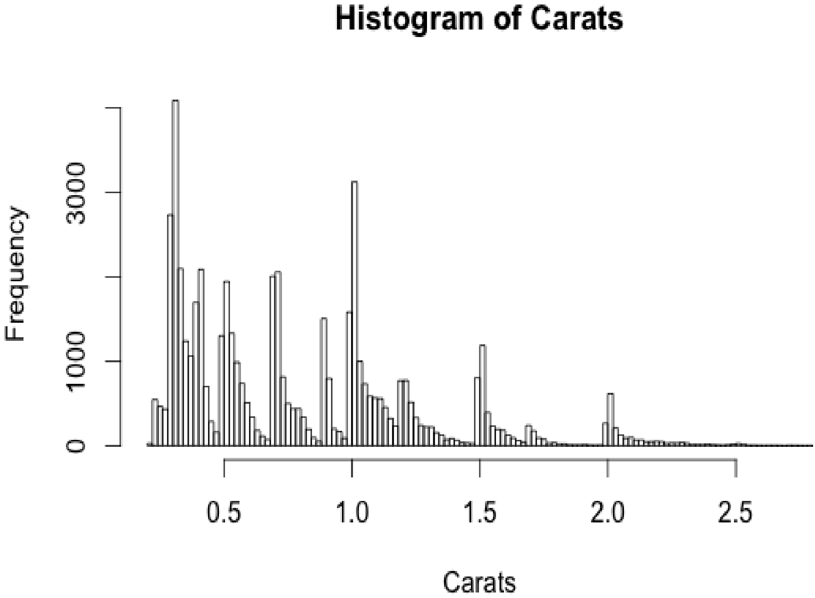


Visualizing Variation

What should we be looking for in these plots?

- Use the plots to create new questions.
  - What do you want to learn more about?
  - Are there any interesting patterns I want to explore.
- Use the plots to better understand the data.
  - Do these plots match my expectations? Why or why not?
  - Do the data cluster in interesting ways?
  - What are the typical values? Outliers? Why?
  - How could this be misleading?

Visualizing Variation



Covariation

Covariation is the tendency for the values of two or more variables to vary together in a related way.

- Visualizing the relationship between variables is the best way to spot covariation.
- Visualize the distribution of a **categorical** variable and a **continuous** variable using a boxplot.
- Visualize the distribution of two **continuous** variables using a scatterplot.

Boxplots in R

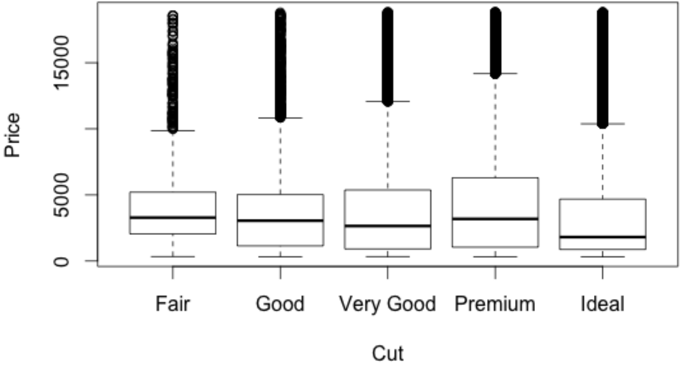
Produce a boxplot (box-and-whisker plot) using `boxplot(values ~ group)` where `values` is a vector of data to be split according to `group`.

- The box stretches from the 25^{th} percentile of the distribution to the 75^{th} percentile (the IQR).
- The line in the middle is the median.
- The 'whiskers' extend to 1.5 times the IQR on either end.

Boxplots in R

Plotting a Boxplot of Diamond Price by Cut

```
> boxplot(price ~ cut, data = diamonds, ylab = "Price",
+         xlab = "Cut")
```



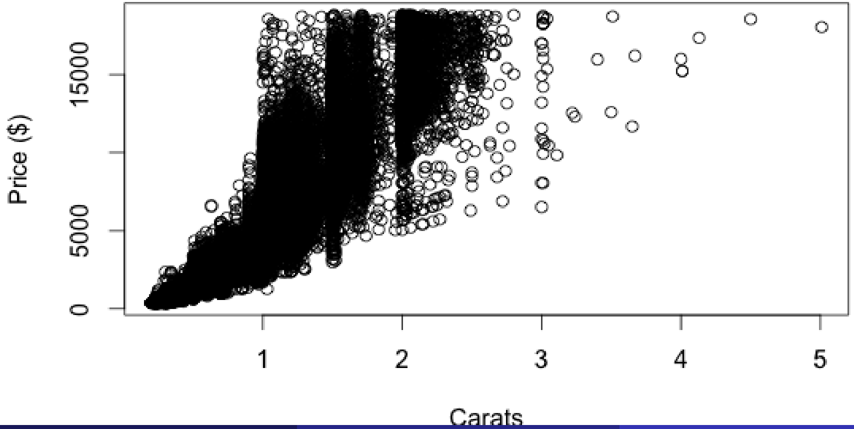
Scatterplot in R

Produce a scatterplot using `plot(x,y)` where `x` is a vector of x-values and `y` a vector of y-values.

Scatterplot in R

Plotting a Scatterplot of Diamond Price vs. Carat

```
> plot(diamonds$carat, diamonds$price, xlab = "Carats",
+       ylab = "Price ($)")
```



Visualizing Covariation

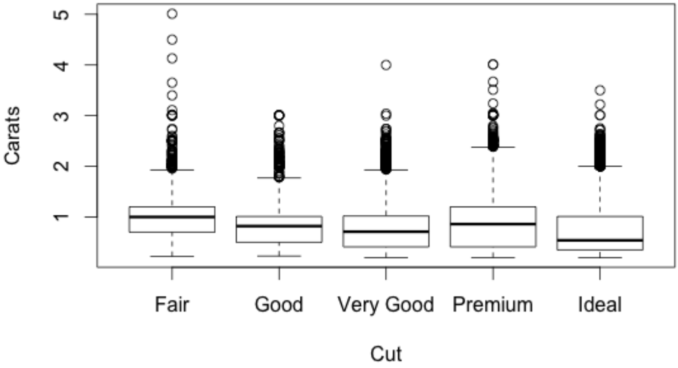
If a relationship exists between two variables it will show up as patterns in your plots.

Ask yourself the following questions.

- Is that pattern random (due to chance)?
- What relationship does the pattern imply?
- Is the relationship strong, weak, linear, non-linear, etc.?
- What other variables might affect the relationship?
- Does the relationship change if you look at individual subgroups of the data?

Boxplots in R

```
> boxplot(carat ~ cut, data = diamonds, ylab = "Carats",
+         xlab = "Cut")
```



Often Visualization Isn't Enough

- Difficult to understand the relationship between `price` and `cut` because `price` and `carat` and `carat` and `cut` are also related.
- Here we would need to use a model (last class, linear models) to consider all these relationships simultaneously.

The `plot()` function.

- The foundation of many of `R`'s graphics functions.
- Often one builds up the graph in stages with `plot()` as a base.
- Each call to `plot()` begins a new graph window.
- Takes arguments, called *graphical parameters*, to change various aspects of the plot. (`?par`)

Building a Visualization: An Example

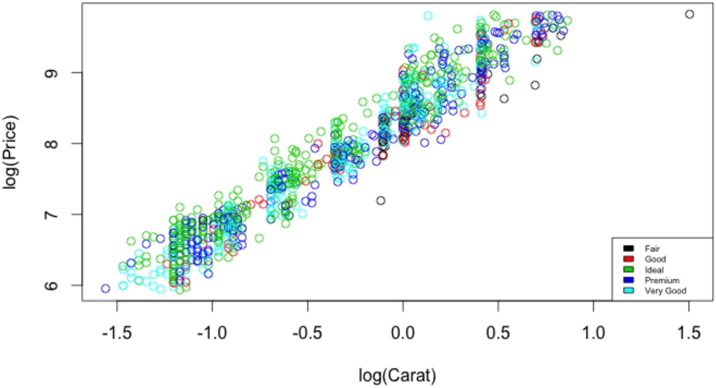
Back to the diamonds.

First, we create a smaller dataset from `diamonds` by randomly selecting 1000 rows.

```
> rows       <- dim(diamonds)[1]
> small_diam <- diamonds[sample(1:rows, 1000), ]
```

Building a Visualization: An Example

```
> plot(log(small_diam$carat), log(small_diam$price),
+       col = small_diam$cut)
> legend("bottomright", legend = levels(small_diam$cut),
+         fill = 1:length(levels(small_diam$cut)), cex = .5)
```



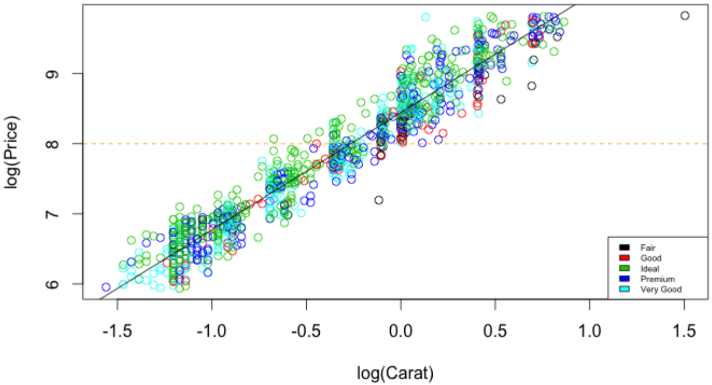
Building a Visualization: An Example

Adding Lines to a Scatterplot

- Add a straight line with `abline(int, slope)`.
  - `int` is the intercept of the line.
  - `slope` is the slope of the line.
- `lines()` can also be used.
  - Most simply, pass `lines()` `x` and `y` vectors and it connects the points.

Building a Visualization: An Example

```
> abline(8, 0, col = "orange", lty = 2)
> lm1 <- lm(log(small_diam$price) ~ log(small_diam$carat))
> abline(lm1)
```



Building a Visualization: An Example

Let's instead plot a regression line for each cut separately.

How do we do this?

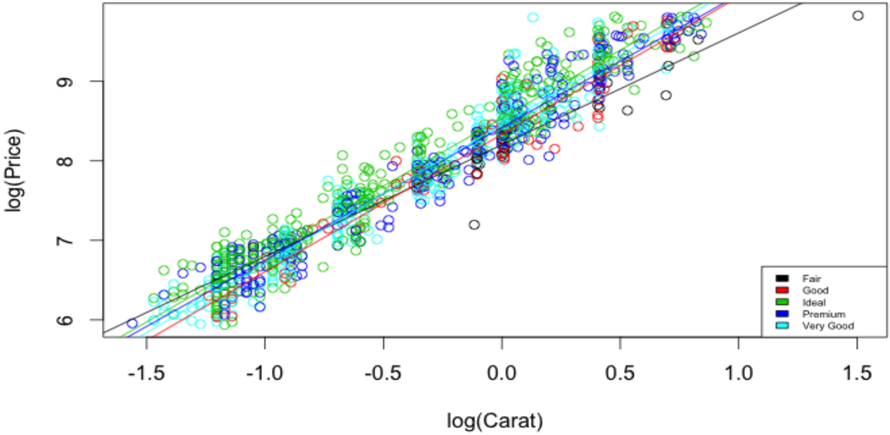
- Think about this task for a moment.

Building a Visualization: An Example

Let's instead plot a regression line for each cut separately.

```
> cuts        <- levels(small_diam$cut)
> col_counter <- 1
> for (i in cuts) {
+   this_cut    <- small_diam$cut == i
+   this_data   <- small_diam[this_cut, ]
+   this_lm     <- lm(log(this_data$price)
+                      ~ log(this_data$carat))
+   abline(this_lm, col = col_counter)
+   col_counter <- col_counter + 1
+ }
```

Building a Visualization: An Example



Building a Visualization: An Example

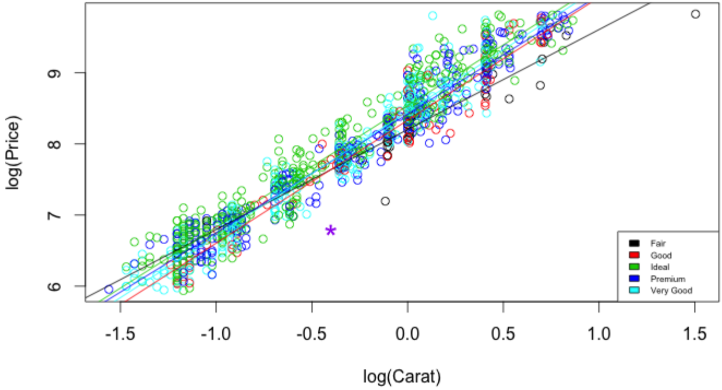
Adding Points to a Scatterplot

- Most easily done with `points(x,y)`.
- `(x,y)` is the location of the point to be added.
- `example(points)` could be helpful.

Building a Visualization: An Example

We add a new point for a diamond that is $898 and 0.67 carats.

```
> points(-0.4, 6.8,  pch = "*", col = "purple")
```



Building a Visualization: An Example

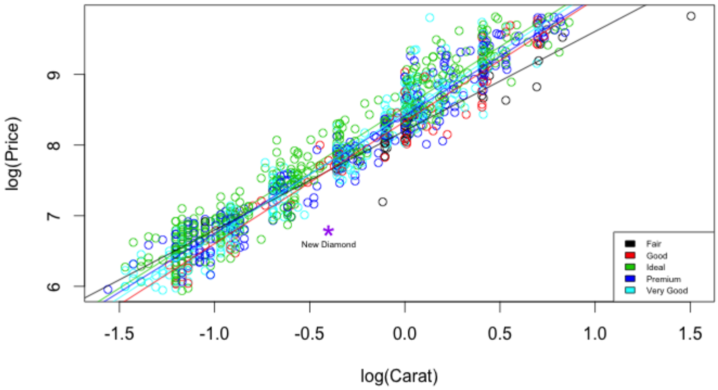
Adding Text to a Scatterplot

- Most easily done with `text(x,y, label)`.
  - `(x,y)` is the location of the text to be added.
  - `label` is the the text to be added at the specified location.
- The `locator()` function we saw in Lecture 1 can be useful here.

Building a Visualization: An Example

We add text to the new point we just added.

```
> text(-0.4, 6.8 - .2, "New Diamond", cex = .5)
```



Useful Graphical Parameters

The table below lists a selection of `R`'s graphical parameters. More info at `http://www.statmethods.net/advgraphs/parameters.html` or using `?par`.

Parameter	Description
`pch`	*Point Character*. Character of the points in the plot.
`main`	Title of the plot.
`xlab, ylab`	Axes labels.
`lty`	*Line Type*. E.g. 'dashed', 'dotted', etc.
`lwd`	*Line Width*. Line width relative to default = 1.
`cex`	*Character Expand*. Character size relative to default = 1.
`xlim, ylim`	The limits of the axes.
`mfrow`	Plot figures in an array (e.g. next to each other).
`col`	Plotting color.

Saving graphs to Files

Coding Example.

Optional Reading

- Chapter 2 (2.3.2, 2.3.5) An Introduction to Statistical Learning.
- Chapter 7 (Exploratory Data Analysis) in R for Data Science.

Moving on from Base R Graphics

- We will learn about more advanced plotting tools using the `ggplot2` package soon.
- Base `R` graphics are good when you want to produce something quick, like for EDA.
- `ggplot2` provides more sophisticated graphing tools for communicating your results.