

Lecture 4: Exploratory Data Analysis and Base R Graphics

STAT GR4206/5206 *Statistical Computing & Introduction to Data Science*

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Last Time

- Multiple linear regression
- Least squares estimation and least squares equation
- Linear algebra related to linear regression
- Basic introduction to the projection approach of regression

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 ~ 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 Analysis¹

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

↳ **subjective**

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.

¹EDA 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 **Fundamental Questions :**

1. What type of **variation** occurs **within** my variables? (**1 variable**)
2. What type of **covariation** occurs **between** my variables? (**multiple variable**)

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).

difference between
bargraph and
histogram

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.

Bargraphs in R

16.88 mwh

Plotting a Bargraph of Diamond Cut

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

Cut	Count
Fair	1610
Good	4906
Ideal	21551
Premium	13791
Very Good	12082

= sample size

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

name of data frame → col
list → table → levels

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

Bargraphs in R

Plotting a Bargraph of Diamond Cut

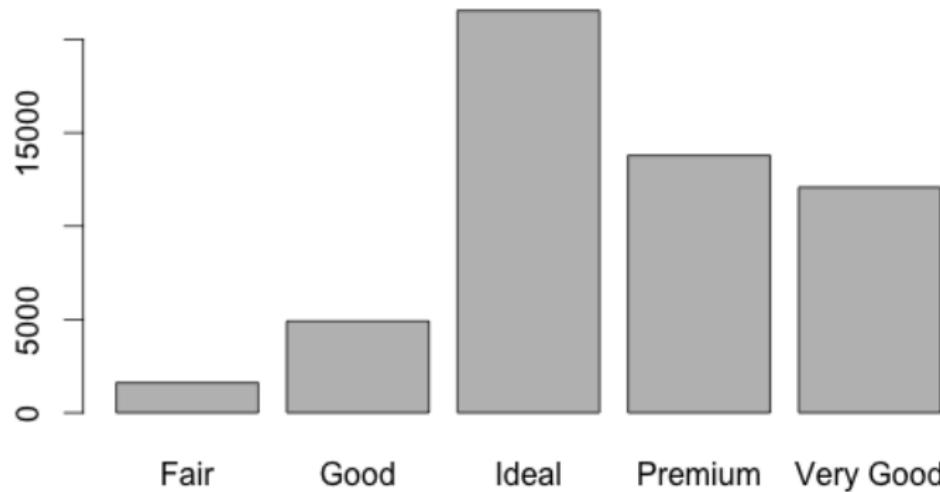
```
> barplot(height = table(diamonds$cut),  
+           names.arg = names(table(diamonds$cut)))
```



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.

Bargraphs in R

Plotting a Bargraph of Diamond Cut

```
> levels(diamonds$cut) → always outputs vector of character strings
```

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

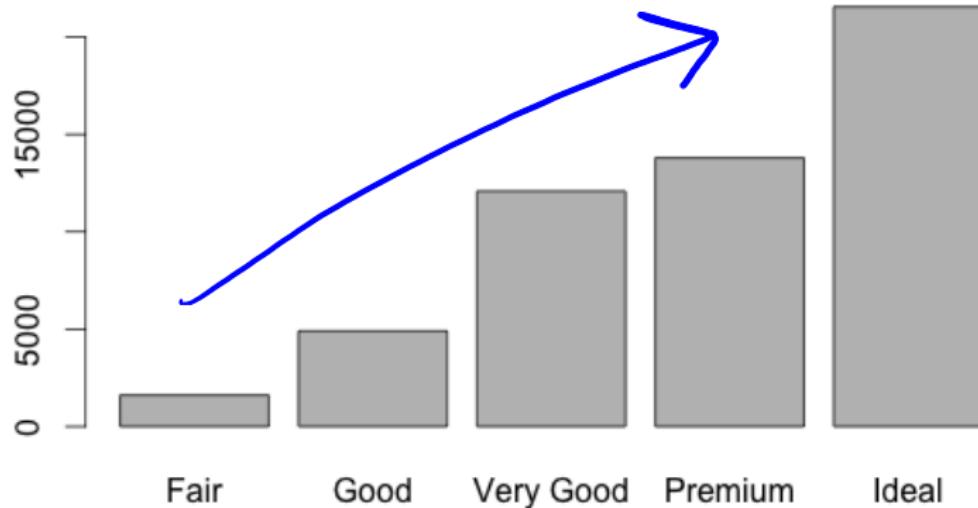
```
> diamonds$cut <- factor(diamonds$cut, level = c("Fair",  
+                               "Good", "Very Good", "Premium",  
+                               "Ideal")) → reallocating levels  
+  
> levels(diamonds$cut)
```

```
[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.

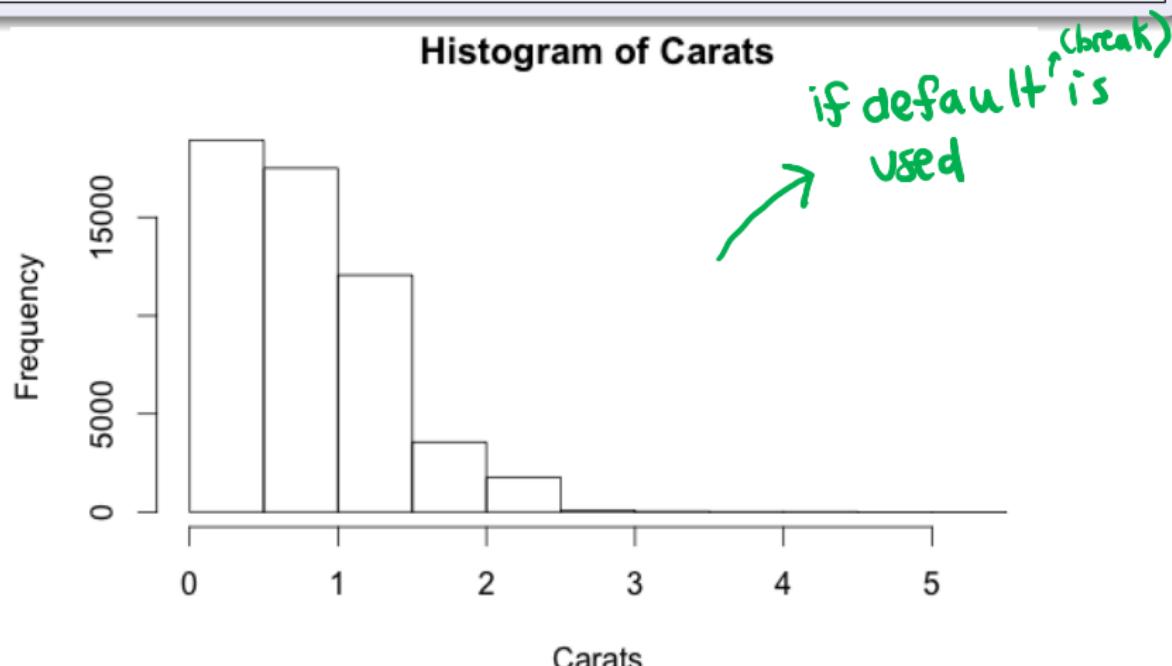
subjectivity in how
↑ big bin is.

- 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.
(number)
- 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

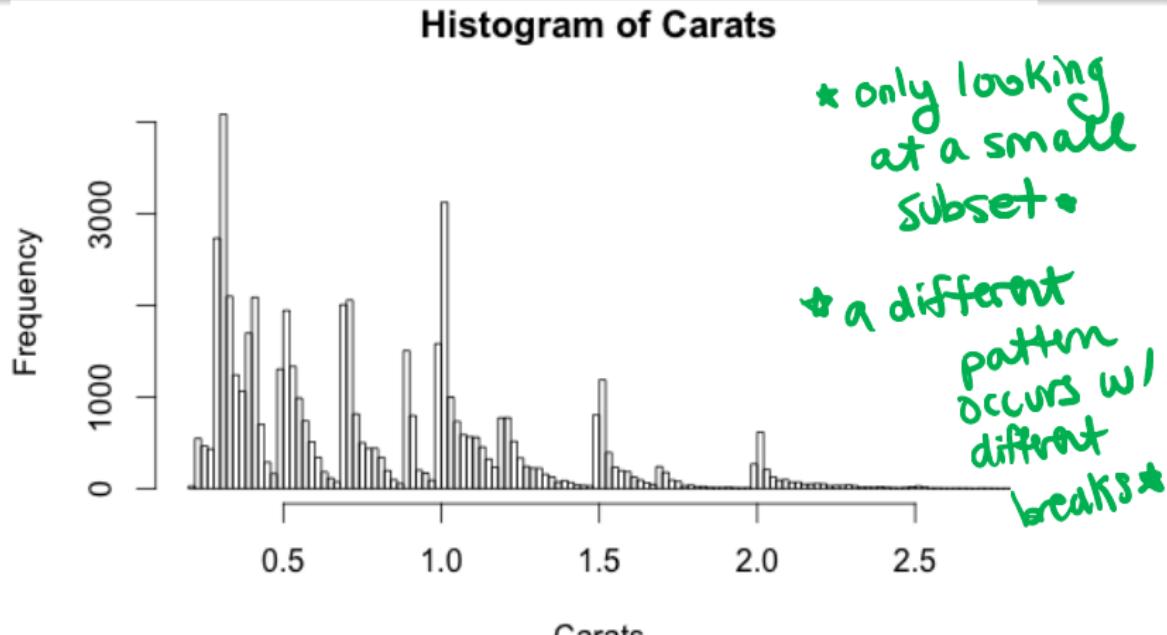
```
> hist(diamonds$carat, main = "Histogram of Carats",  
+       xlab = "Carats")
```



Histograms in R

Plotting a Bargraph of Diamond Cut

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



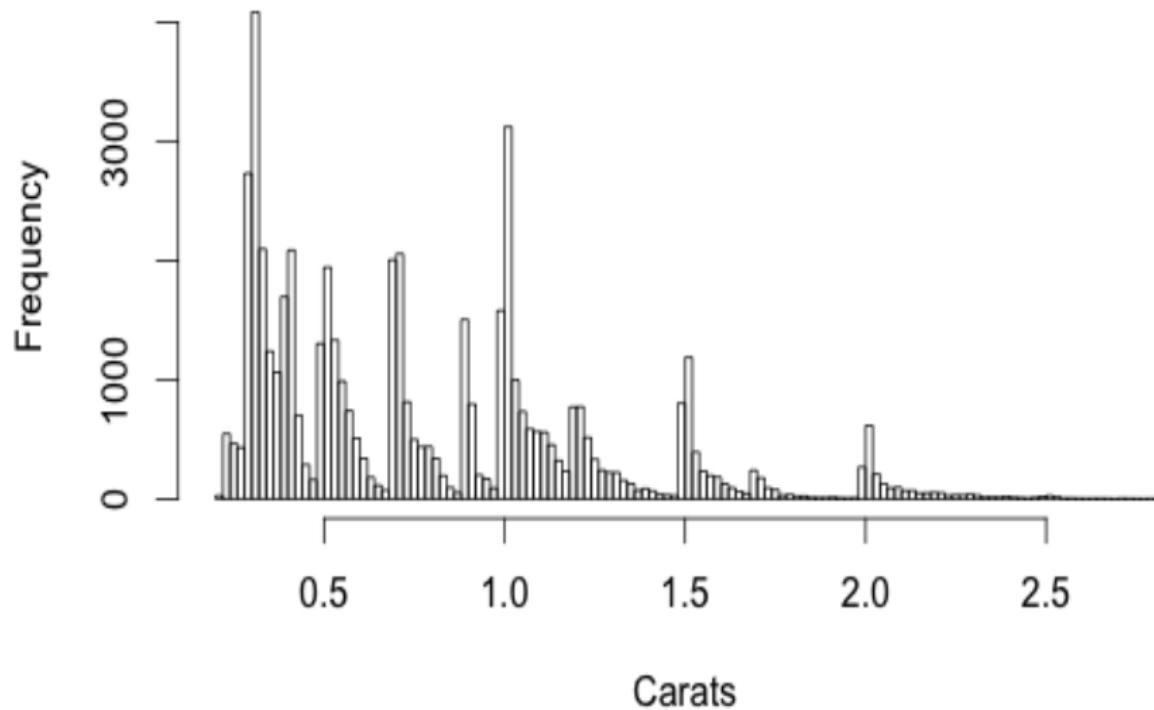
Visualizing Variation

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

Histogram of Carats



Covariation

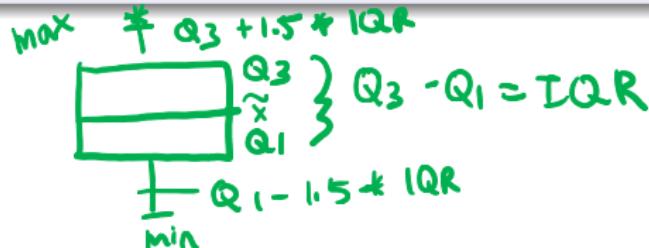
Covariation is the tendency for the values of **two or more variables** to vary together in a related way.

- 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~~ **multiple box plot**.
- 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 25th percentile of the distribution to the 75th percentile (the IQR).
- The line in the middle is the median. → inner quartile range
- 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")
```

↳ if you reference database
you didn't have to do
by cut



main = maintitle

Scatterplot in R

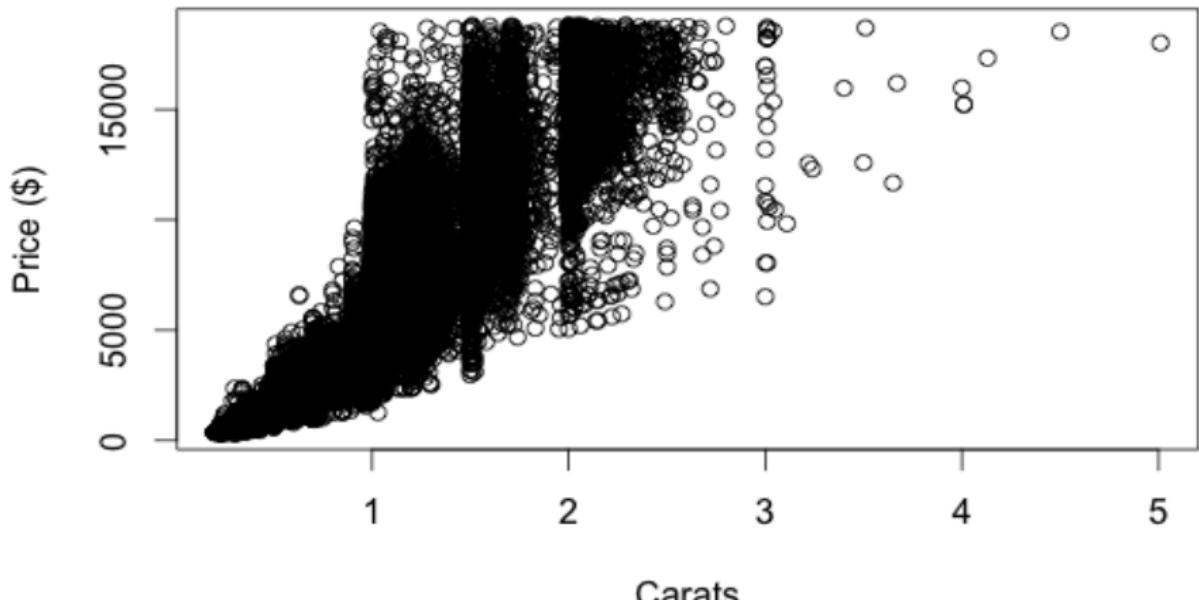
Produce a scatterplot using `plot(x, y)` where `x` is a vector of x-values and `y` a vector of y-values.

Scatterplot in R

Plotting a Scatterplot of Diamond Price vs. Carat

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

↑ not hemostatic b/c so many
#s.



Visualizing Covariation

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

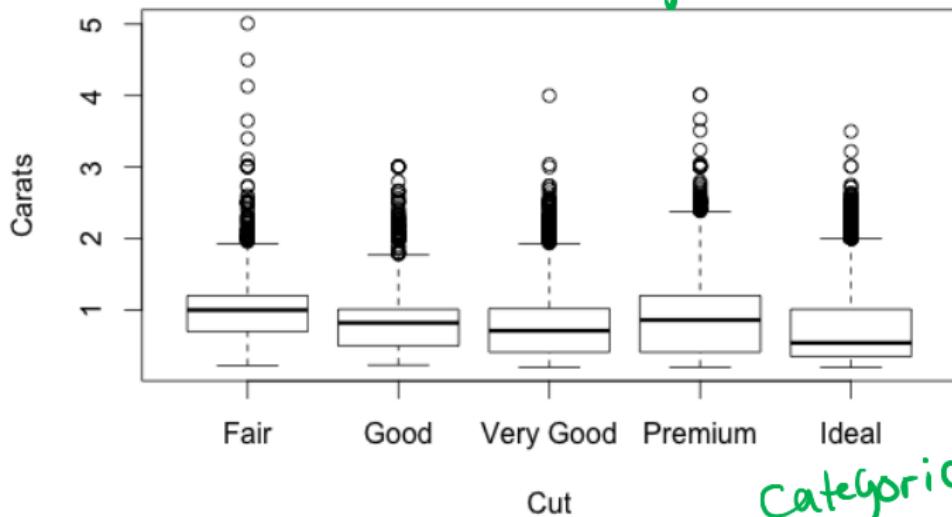
Ask yourself the following questions.

- 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")
```

covariation b/w categorical & numerical



Categorical data
will typically bring up box plot.

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.

You want more dimensions on one dimension plot
var

Not →  3D plot for 1 dimension var

Basics of Plotting

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), ]
```

if replace = false
cannot pull
some data set
if replace = true
can pull from
some data set?

Sampling 1: max rows but only
takes 1000 samples.

To make plot more tangible to
look at.

Building a Visualization: An Example

Run 1st

```
> plot(log(small_diam$carat), log(small_diam$price),  
+       col = small_diam$cut) gives out names in legend  
needs to be vector of character strings  
> legend("bottomright", legend = levels(small_diam$cut),  
+        fill = 1:length(levels(small_diam$cut)), cex = .5)
```

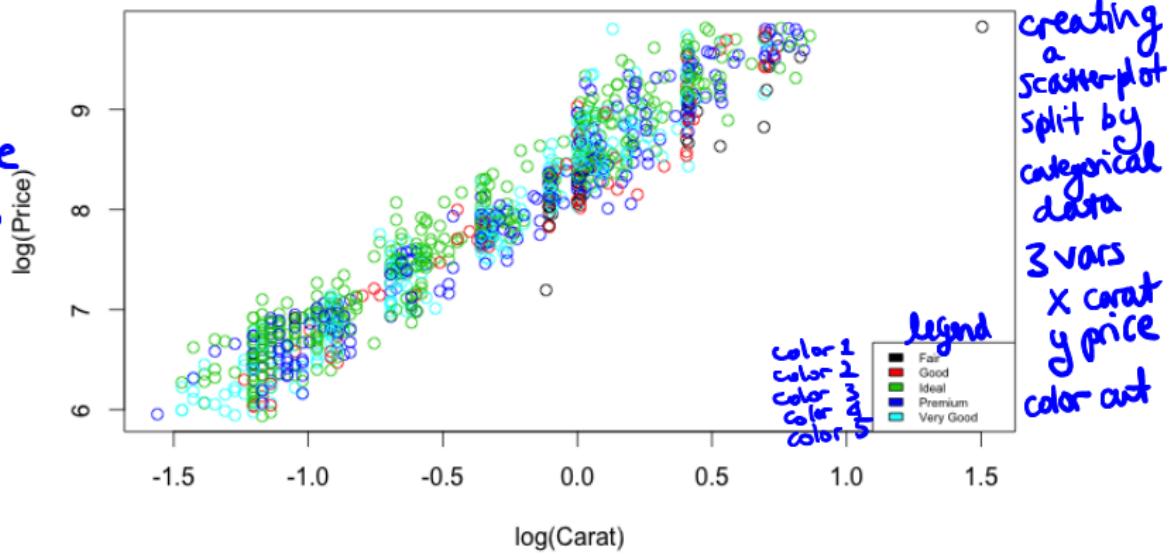
↳ fills boxes out w/ colors (colors 1-5)

↳ size of legend

creating a scatter-plot split by categorical data

3 vars
x carat
y price
color cut

factor variable
R stores it as numeric



Building a Visualization: An Example

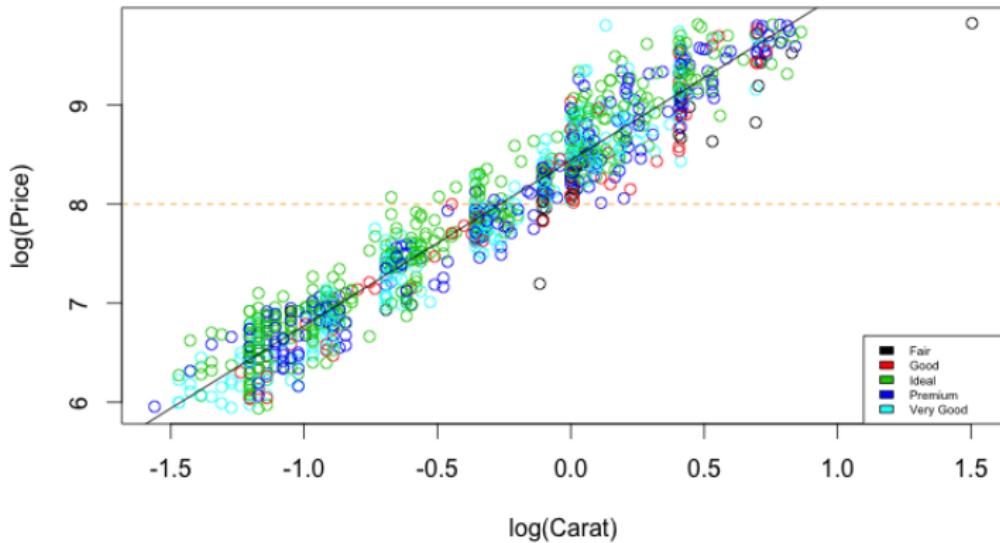
Adding Lines to a Scatterplot

- 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.

can use h & v
↓ ↓
horizontal vertical

Building a Visualization: An Example

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

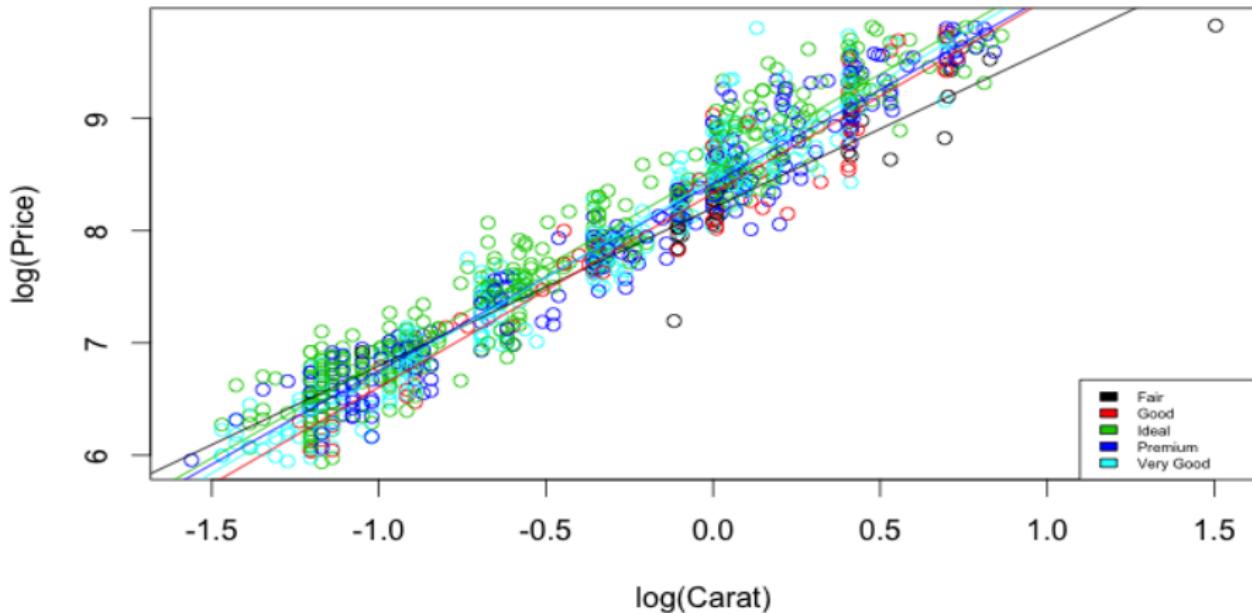
Let's instead plot a regression line for each cut separately.

You still have to run the plot!

```
> cuts      <- levels(small_diam$cut) vector of different cuts
> col_counter <- 1
> for (i in cuts) { creates logical vector
+   this_cut    <- small_diam$cut == i
+   this_data   <- small_diam[this_cut, ] → subsetting to extract only that cut
+   this_lm     <- lm(log(this_data$price) → use lm using subset
+                     ~ log(this_data$carat)) subset
+   abline(this_lm, col = col_counter) → adds the color to line
+   col_counter <- col_counter + 1 → use this to change colors per line
+ }
```

Building a Visualization: An Example

Slight Interaction (Slight change between slope of lines)



Building a Visualization: An Example

Adding Points to a Scatterplot

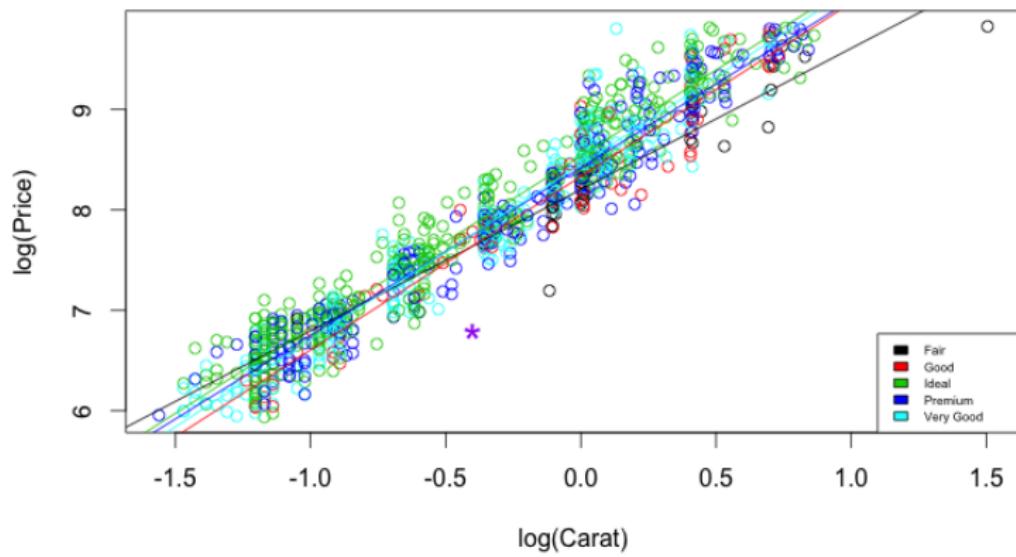
- Most easily done with `points(x,y)`.
- (x,y) is the location of the point to be added.
- `example(points)` could be helpful.

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")
```

↳ shape



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 text to be added at the specified location.
- The `locator()` function we saw in Lecture 1 can be useful here.

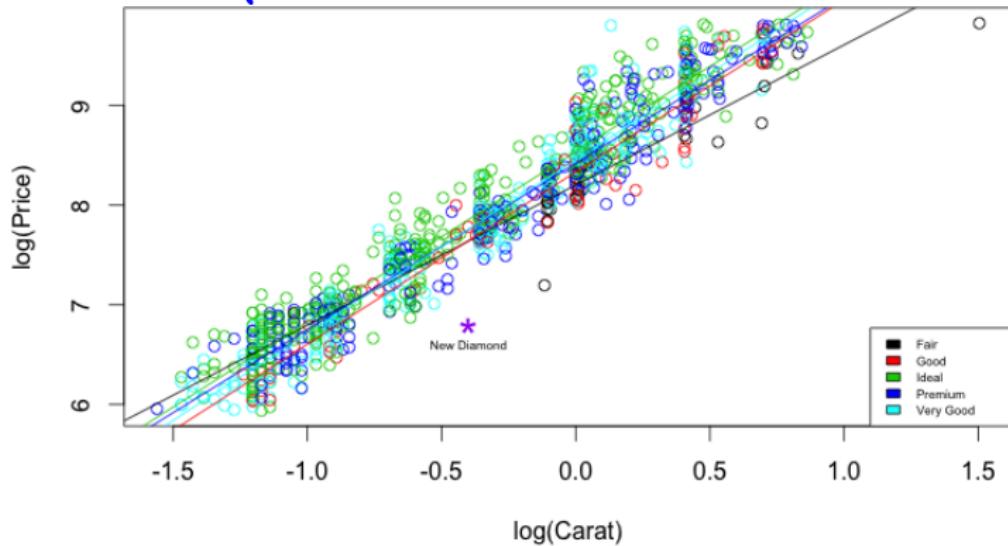
Building a Visualization: An Example

We add text to the new point we just added.

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

*↑
pushes text down*

↳ size of letters



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	<i>Point Character.</i> Character of the points in the plot.
main	Title of the plot.
xlab, ylab	Axes labels.
lty	<i>Line Type.</i> E.g. 'dashed', 'dotted', etc. <i>could also use 1,2,3</i>
lwd	<i>Line Width.</i> Line width relative to default = 1.
cex	<i>Character Expand.</i> 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.