Week 8: Basic Introduction to `tidyverse` and `ggplot`

STAT GR5206 *Statistical Computing & Introduction to Data Science*

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Today

"The tidyverse is an opinionated collection of R packages designed for data science. All packages share an underlying philosophy and common APIs".

`tidyverse`

- `dplyr`: data manipulation
- `ggplot2`: creating advanced graphics
- `readr`: reading in rectangular data.
- `tibble`: A `tibble`, or `tbl_df`, is a modern reimagining of the `data.frame`.
- `tidyr`: creating tidy data.
- `purrr`: enhancing R's functional programming (FP).

The above statement was taken directly from the `tidyverse` website: https://www.tidyverse.org

Today

We focus on a few packages:

tidyverse and a few other topics

- tibble: A tibble, or tbl_df, is a modern reimagining of the data.frame
- Review of the Split/Apply/Combine model and the plyr package
- purrr: enhancing R's functional programming (FP)
- Reshaping data and the reshape2 package
- tidyr: creating tidy data
- ggplot2: creating advanced graphics

tibble

tibble package

tibble

- Tibbles are data frames, but they tweak some older behaviours to make life a little easier. (according to tidyverse)
- Convert a traditional dataframe to a tibble using as_tibble()

```
> library(tibble)
> as_tibble(head(iris,3))
```

```
# A tibble: 3 x 5
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
*        <dbl>       <dbl>        <dbl>       <dbl> <fct>
1         5.10        3.50         1.40       0.200 setosa
2         4.90        3.00         1.40       0.200 setosa
3         4.70        3.20         1.30       0.200 setosa
```

tibble package

tibble

- Create a tibble dataframe from scratch using tibble()

```
> df <- tibble(
+               x = 1:3,
+               y = sample(seq(1,5,by=2),3),
+               z = rnorm(3)
+               )
```

tibble package

tibble

- Tibbles are data frames, but they tweak some older behaviours to make life a little easier. (according to tidyverse)
- `tibble()` does much less
- `tibble()` never changes the type of the inputs (e.g. it never converts strings to factors!)
- `tibble()` never changes the names of variables
- `tibble()` never creates row names
- It's possible for a tibble to have column names that are not valid R variable names (e.g., ":)" or " ")
- `tribble()` is a transposed tibble

Subsetting a `tibble`

```
> df$x
```

```
[1] 1 2 3
```

```
> df[["x"]]
```

```
[1] 1 2 3
```

```
> df[,1]
```

```
# A tibble: 3 x 1
      x
  <int>
1     1
2     2
3     3
```

Subsetting a tibble

```
> df[df$x>1,]
```

```
# A tibble: 2 x 3
      x     y      z
  <int> <dbl>  <dbl>
1     2    1. -0.200
2     3    3. -0.821
```

To use these in a pipe (see purrr section), you will need to use the special placeholder . (period)

```
> library(purrr)
> df %>% .$x
```

```
[1] 1 2 3
```

Review of Split/Apply/Combine

Example: Strikes dataset

Dataset on 18 countries over 35 years (compiled by Bruce Western, in the Sociology Department at Harvard University). The measured variables:

- `country`, `year`: country and year of data collection
- `strike.volume`: days on strike per 1000 workers
- `unemployment`: unemployment rate
- `inflation`: inflation rate
- `left.parliament`: leftwing share of the government
- `centralization`: centralization of unions
- `density`: density of unions

Example: Strikes dataset

Our Research Question

Is there a relationship between a country's ruling party alignment (left versus right) and the volume of strikes?

How could we approach this?

- Worst way: by hand, write 18 separate code blocks
- Bad way: explicit `for()` loop, where we loop over countries
- Best way: split appropriately, then use an apply-type function.

Example: Strikes dataset

Since $18 \times 35 = 630$, some years missing from some countries

```
> strikes <- read.csv("strikes.csv", as.is = TRUE)
> dim(strikes)
```

```
[1] 625   8
```

```
> head(strikes, 3)
```

```
    country year strike.volume unemployment inflation
1 Australia 1951           296          1.3      19.8
2 Australia 1952           397          2.2      17.2
3 Australia 1953           360          2.5       4.3
  left.parliament centralization density
1              43      0.3748588      NA
2              43      0.3751829      NA
3              43      0.3745076      NA
```

Strikes Data Set, Revisited

Recall, data set on political economy of strikes:

```
> # Function to compute coefficients from regressing number
> # of strikes (per 1000 workers) on leftwing share of the
> # government
>
> my.strike.lm <- function(country.df) {
+   return(coef(lm(strike.volume ~ left.parliament,
+                  data=country.df)))
+ }
```

Strikes Data Set, Revisited

```
> # Getting regression coefficients separately
> # for each country, old way:
>
> strikes.list  <- split(strikes, f = strikes$country)
> strikes.coefs <- sapply(strikes.list, my.strike.lm)
> strikes.coefs[, 1:12]
```

```
                  Australia    Austria    Belgium    Canada
(Intercept)     414.7712254 423.077279 -56.926780 -227.8218
left.parliament  -0.8638052  -8.210886   8.447463   17.6766
                    Denmark  Finland      France   Germany
(Intercept)     -1399.35735 108.2245 202.4261408 95.657134
left.parliament    34.34477  12.8422  -0.4255319 -1.312305
                  Ireland      Italy     Japan Netherlands
(Intercept)     -94.78661 -738.74531 964.73750  -32.627678
left.parliament  55.46721   40.29109 -24.07595    1.694387
```

Strikes Data Set, Revisited

```
> # Getting regression coefficient separately for each
> # country, new way, in three formats:
> library(plyr)
> strike.coef.a <- daply(strikes, .(country), my.strike.lm)
> # Get back an array, note the difference to sapply()
>
> head(strike.coef.a)
```

```
country     (Intercept) left.parliament
  Australia   414.77123      -0.8638052
  Austria     423.07728      -8.2108864
  Belgium     -56.92678       8.4474627
  Canada     -227.82177      17.6766029
  Denmark   -1399.35735      34.3447662
  Finland     108.22451      12.8422018
```

Strikes Data Set, Revisited

```
> strike.coef.d <- ddply(strikes, .(country), my.strike.lm)
> head(strike.coef.d) # Get back a data frame
```

```
    country (Intercept) left.parliament
1 Australia   414.77123      -0.8638052
2   Austria   423.07728      -8.2108864
3   Belgium   -56.92678       8.4474627
4    Canada  -227.82177      17.6766029
5   Denmark -1399.35735      34.3447662
6   Finland   108.22451      12.8422018
```

Strikes Data Set, Revisited

```
> strike.coef.l <- dlply(strikes, .(country), my.strike.lm)
> head(strike.coef.l, 3) # Get back a list
```

```
$Australia
    (Intercept) left.parliament
    414.7712254      -0.8638052

$Austria
    (Intercept) left.parliament
     423.077279       -8.210886

$Belgium
    (Intercept) left.parliament
     -56.926780        8.447463
```

Section III

`purrr`

purrr

Pipeline

- The first argument is always the data, so `purrr` works naturally with the pipe.
- The symbol %>% is used to construct the pipeline.
- All purrr functions are type-stable. They always return the advertised output type (`map()` returns lists; `map_dbl()` returns double vectors), or they throw an errror.
- `All map()` functions either accept function, formulas, a character vector, or a numeric vector.

The above bullets were taken directly from the `tidyverse` website: https://www.tidyverse.org

Strikes Data Set, Revisited

Basic purrr pipeline

Write a purrr pipeline that produces equivalent output to the function `my.strike.lm`

```
> # Function to compute coefficients from regressing number
> # of strikes (per 1000 workers) on leftwing share of the
> # government
>
> my.strike.lm <- function(country.df) {
+   return(coef(lm(strike.volume ~ left.parliament,
+                  data=country.df)))
+ }
> # Define Italy dataframe
> Italy.df <-strikes[strikes$country=="Italy",]
```

Strikes Data Set, Revisited

Basic purrr pipeline

```
> # Old way
> my.strike.lm(Italy.df)
```

```
    (Intercept) left.parliament
     -738.74531        40.29109
```

```
> # purrr pipeline
> library(purrr)
> Italy.df%>%
+   lm(strike.volume ~ left.parliament,data=.)%>%
+   coef
```

```
    (Intercept) left.parliament
     -738.74531        40.29109
```

More about map()

What is map()?

- The map function transform the input, returning a vector the same length as the input.
- map() returns a list or a data frame.
- map_lgl(), map_int(), map_dbl() and map_chr() return vectors of the corresponding type; map_dfr() and map_dfc() return data frames created by row-binding and column-binding respectively.
- They require dplyr to be installed.

The above bullets were taken directly from the tidyverse website: https://www.tidyverse.org

More about map()

Basic Example

```
> # map() will output a list.
> map(c(1,exp(1),1000),log)
```

```
[[1]]
[1] 0

[[2]]
[1] 1

[[3]]
[1] 6.907755
```

More about map()

Basic Example

```
> # map_dbl() outputs a double precision vector.
> map_dbl(1:3,log)
```

```
[1] 0.0000000 0.6931472 1.0986123
```

```
> # map() is often used in a pipeline.
> 1:3%>%map_dbl(log)
```

```
[1] 0.0000000 0.6931472 1.0986123
```

More about map(): Basic Example

```
> # Write a R funciton
> f <- function(x) {return(log(x)+sin(x))}
> f(c(1,exp(1),1000))
```

```
[1] 0.841471 1.410781 7.734635
```

```
> # Or use vectorized R operations
```

Create a function on the fly with a pipeline

~ log(.) + sin(.)

function (x) {log(x)+sin(x)}

```
> # Use a purrr pipeline
> c(1,exp(1),1000)%>%map_dbl(~ log(.)+sin(.))
```

```
[1] 0.841471 1.410781 7.734635
```

Example: Strikes dataset

Our Research Question

- Is there a relationship between a country's ruling party alignment (left versus right) and the volume of strikes?
- Use a `purrr` pipeline to accomplish this task.

Recall using `dlply()`

```
> strike.coef <- daply(strikes, .(country), my.strike.lm)
> head(strike.coef, 3) # returns an array
```

```
country      (Intercept) left.parliament
  Australia    414.77123      -0.8638052
  Austria      423.07728      -8.2108864
  Belgium      -56.92678       8.4474627
```

Example: Strikes dataset

Our Research Question

- Is there a relationship between a country's ruling party alignment (left versus right) and the volume of strikes?
- Use a `purrr` pipeline to accomplish this

`purrr` pipeline

```
> strike.coef <-
+   strikes%>%
+     split(.$country)%>%
+     map(~ lm(strike.volume ~ left.parliament,data=.))%>%
+     map(coef)
```

Example: Strikes dataset

Output as a list

```
> head(strike.coef,3) # returns a list
```

```
$Australia
    (Intercept) left.parliament
    414.7712254      -0.8638052

$Austria
    (Intercept) left.parliament
     423.077279       -8.210886

$Belgium
    (Intercept) left.parliament
     -56.926780        8.447463
```

Example: Strikes dataset

Our Research Question

- Is there a relationship between a country's ruling party alignment (left versus right) and the volume of strikes?
- Use a `purrr` pipeline to accomplish this

purrr pipeline

```
> library(dplyr)
> # the map_dfr() depends on the dplyr package
> strike.coef <-
+   strikes%>%
+     split(.$country)%>%
+       map(~ lm(strike.volume ~ left.parliament,data=.))%>%
+       map_dfc(coef)
```

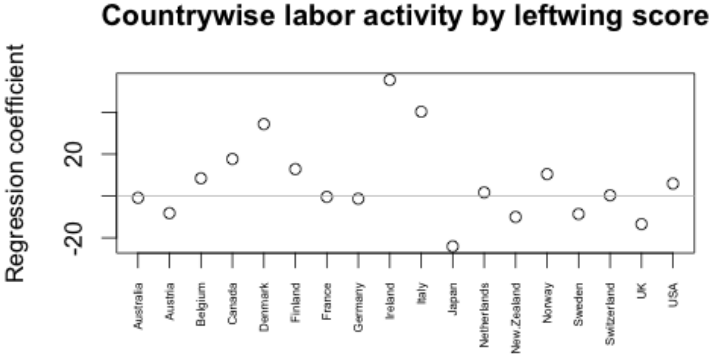
Example: Strikes dataset

Output as a dataframe (tibble class dataframe)

```
> strike.coef[,1:5] # returns a dataframe (tibble)
```

```
# A tibble: 2 x 5
  Australia Austria Belgium Canada Denmark
      <dbl>   <dbl>   <dbl>  <dbl>   <dbl>
1   415.     423.    -56.9  -228.  -1399.
2    -0.864   -8.21    8.45   17.7    34.3
```

Example: Strikes dataset



Example: Strikes dataset

Our Research Question

- Consider the following example taken directly from the `tidyverse` website: https://www.tidyverse.org
- The following example uses`purrr` to solve a fairly realistic problem: split a data frame into pieces, fit a model to each piece, compute the summary, then extract the R^2.

```
> mtcars %>%
+   split(.$cyl) %>% # from base R
+   map(~ lm(mpg ~ wt, data = .)) %>%
+   map(summary) %>%
+   map_dbl("r.squared")
```

```
        4         6         8
0.5086326 0.4645102 0.4229655
```

Reshaping Dataframes

Reshaping

Common to have data where some variables identify units, and others are measurements.

- **Wide** form: columns for ID variables plus 1 column per measurement.
    - Good for things like correlating measurements, or running regressions.
- **Narrow** form: columns for ID variables, plus 1 column identifying measurement, plus 1 column giving value.
    - Good for summarizing, subsetting.

Reshaping

Common to have data where some variables identify units, and others are measurements.

- **Wide** form: columns for ID variables plus 1 column per measurement.
  - Good for things like correlating measurements, or running regressions.
- **Narrow** form: columns for ID variables, plus 1 column identifying measurement, plus 1 column giving value.
  - Good for summarizing, subsetting.

Often want to convert between wide and narrow format, or change what's ID and what's measure

Reshaping

- reshape package introduced data-reshaping tools.
- reshape2 package simplifies lots of common uses.
- melt() turns a wide dataframe into a narrow one.
- dcast() turns a narrow dataframe into a wide one.
- acast() turns a narrow dataframe into a wide array.

Reshaping

Example [1]

snoqualmie.csv has precipitation every day in Snoqualmie, WA for 36 years (1948–1983). One row per year, one column per day, units of 1/100 inch.

```
> snoq <- read.csv("snoqualmie.csv", header = FALSE,
+                  as.is = TRUE)
> colnames(snoq) <- 1:366
> snoq$year      <- 1948:1983
> snoq[1:3, 360:367]
```

```
  360 361 362 363 364 365 366 year
1   0   0   0   0  49 114  17 1948
2  47 245 121  72  27  41  NA 1949
3   4  40  10   5  93  23  NA 1950
```

[a] From P. Guttorp, Stochastic Modeling of Scientific Data

Reshaping

Example

```
> #install.packages("reshape2")
> require(reshape2)
> snoq.melt <- melt(snoq, id.vars = "year",
+                   variable.name = "day",
+                   value.name = "precip")
> head(snoq.melt)
```

```
  year day precip
1 1948   1    136
2 1949   1     17
3 1950   1      1
4 1951   1     34
5 1952   1      0
6 1953   1      2
```

Reshaping

Example

```
> tail(snoq.melt)
```

```
      year day precip
13171 1978 366     NA
13172 1979 366     NA
13173 1980 366     80
13174 1981 366     NA
13175 1982 366     NA
13176 1983 366     NA
```

```
> dim(snoq.melt) # 36*366
```

```
[1] 13176     3
```

Reshaping

Example

Being sorted by day of the year and then by year is a bit odd

```
>  snoq.melt.chron <- snoq.melt[order(snoq.melt$year), ]
>  head(snoq.melt.chron)
```

```
    year day precip
1   1948   1    136
37  1948   2    100
73  1948   3     16
109 1948   4     80
145 1948   5     10
181 1948   6     66
```

Reshaping

Example

Most years have 365 days so some missing values:

```
> leap.days <- snoq.melt.chron$day == 366
> sum(is.na(snoq.melt.chron$precip[leap.days]))
```

```
[1] 27
```

Reshaping

Example

Most years have 365 days so some missing values:

```
> leap.days <- snoq.melt.chron$day == 366
> sum(is.na(snoq.melt.chron$precip[leap.days]))
```

```
[1] 27
```

Tidy with `na.omit()`:

```
> snoq.melt.chron <- na.omit(snoq.melt.chron)
```

Reshaping

Example

Today's precipitation vs. next day's:

```
> short.chron <- snoq.melt.chron[-nrow(snoq.melt.chron), ]
> precip.next <- snoq.melt.chron$precip[-1]
> snoq.pairs  <- data.frame(short.chron, precip.next)
> head(snoq.pairs)
```

```
    year day precip precip.next
1   1948   1    136         100
37  1948   2    100          16
73  1948   3     16          80
109 1948   4     80          10
145 1948   5     10          66
181 1948   6     66          88
```

Reshaping

Example

```
> snoq[1:3, 360:367]
```

```
  360 361 362 363 364 365 366 year
1   0   0   0   0  49 114  17 1948
2  47 245 121  72  27  41  NA 1949
3   4  40  10   5  93  23  NA 1950
```

acast() casts into an array rather than a dataframe.

Reshaping

Example

- The formula could also specify multiple ID variables (including original measure variables), different measure variables (including original ID variables)...
- Also possible to apply functions to aggregates which all have the same IDs, select subsets of the data, etc.
- Recommended reading:
  - Hadley Wickham, "Reshaping Data with the reshape Package", *Journal of Statistical* Software 21 (2007): 12, `http://www.jstatsoft.org/v21/i12`

tidyr

Reshaping

The tidyr package

tidyr is the latest package related to reshaping data.

tidyr and related packages

tidyr	gather	spread
reshape(2)	melt	cast
spreadsheets	unpivot	pivot
databases	fold	unfold

Section V

ggplot

BaseR Graphics

We study advanced visualization techniques using the `mpg` dataset. Let's try to answer the question: do cars with bigger engines use more fuel than cars with small engines?

BaseR Graphics

We study advanced visualization techniques using the `mpg` dataset. Let's try to answer the question: do cars with bigger engines use more fuel than cars with small engines?

Read about the data using ?mpg.

```
> dim(mpg)
```

```
[1] 234  11
```

```
> head(mpg,3)
```

```
# A tibble: 3 x 11
  manufacturer model displ  year   cyl trans    drv     cty
  <chr>        <chr> <dbl> <int> <int> <chr>    <chr> <int>
1 audi         a4     1.80  1999     4 auto(l5) f          18
2 audi         a4     1.80  1999     4 manual(âĂę f        21
3 audi         a4     2.00  2008     4 manual(âĂę f        20
```

Basics of Plotting

Recall,

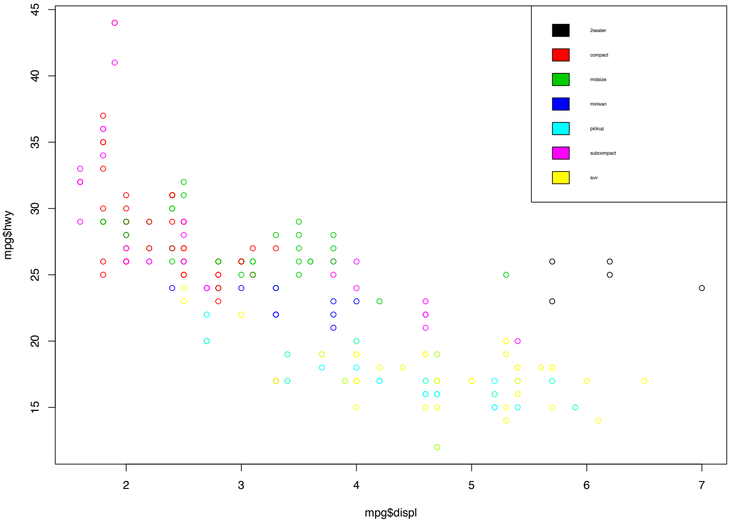
- Visualization variation (of a single variable):
  - `hist()` – Histograms.
  - `barplot()` – Bargraphs.
- Visualizing covariation (of multiple variables):
  - `plot()` – Scatterplots.
  - `boxplot()` – Boxplots (box-and-whisker plots).

Building a Visualization: An Example

Base R Code

```
> plot(mpg$displ,mpg$hwy,col = factor(mpg$class))
> legend("topright",
+        legend = levels(factor(mpg$class)),
+        fill = 1:length(levels(factor(mpg$class))),
+        cex = 1)
```

Building a Visualization: An Example



ggplot2

- R has several systems for making graphs (we've looked at the base R functions).
- ggplot2 is one of the most elegant and flexible.
- ggplot2 uses a coherent system (or 'grammar') for describing and building graphs.

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- R has several systems for making graphs (we've looked at the base R functions).
- ggplot2 is one of the most elegant and flexible.
- ggplot2 uses a coherent system (or 'grammar') for describing and building graphs.

Need to run `install.packages("ggplot2")` now and `library("ggplot2")` every time you want to use it!

ggplot2

Let's try to answer the question: do cars with bigger engines use more fuel than cars with small engines?

Read about the data using ?mpg.

```
> dim(mpg)
```

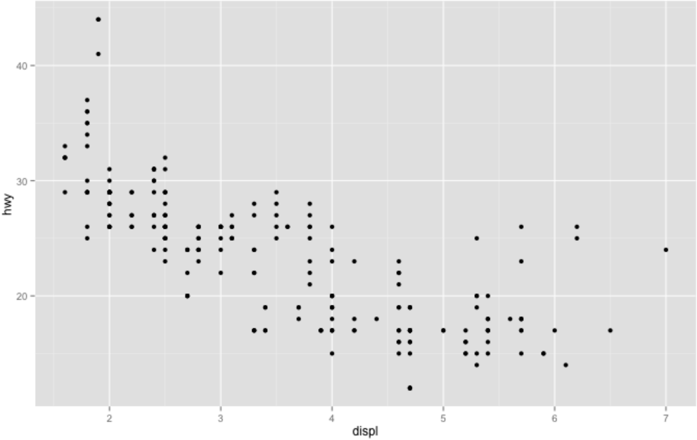
```
[1] 234  11
```

```
> head(mpg, 3)
```

```
# A tibble: 3 x 11
  manufacturer model displ  year   cyl trans      drv     cty
  <chr>        <chr> <dbl> <int> <int> <chr>      <chr> <int>
1 audi         a4     1.80  1999     4 auto(l5)   f        18
2 audi         a4     1.80  1999     4 manual(âĂę f          21
3 audi         a4     2.00  2008     4 manual(âĂę f          20
# ... with 3 more variables: hwy <int>, fl <chr>,
```

A First Plot

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy))
```



A First Plot

Let's break apart the code:

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy))
```

A First Plot

Let's break apart the code:

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy))
```

- Begin a plot with ggplot().
    - It creates the coordinate axis that you add to.
    - The first argument is the dataset

A First Plot

Let's break apart the code:

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy))
```

- Begin a plot with `ggplot()`.
  - It creates the coordinate axis that you add to.
  - The first argument is the dataset
- Next you want to add layers to the plot.
  - In our example: `geom_point()` adds a layer of points.
  - Lots of different `geom` functions doing different things.

A First Plot

Let's break apart the code:

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy))
```

- Begin a plot with `ggplot()`.
  - It creates the coordinate axis that you add to.
  - The first argument is the dataset
- Next you want to add layers to the plot.
  - In our example: `geom_point()` adds a layer of points.
  - Lots of different `geom` functions doing different things.
- `geom` functions take `mapping` arguments.
  - Defines how variables in your dataset are mapped to visual properties.
  - Always paired with `aes()`.
  - The `x` and `y` arguments specify which variables to map to the axes.

A First Plot

General structure:

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>))
```

To create a plot, replace the bracketed sections in the code above with a datatset, a geom function, and a set of mappings.

From this template, we can make many different kinds of graphs using `ggplot`.

Check Yourself

Tasks

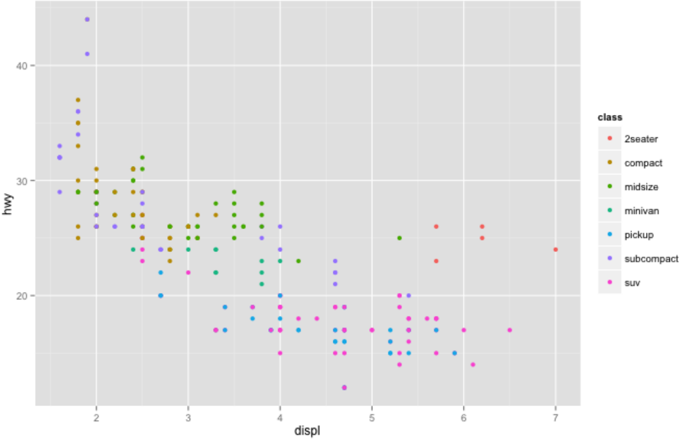
- Plot just `ggplot(data = mpg)`. What do you get?
- Make a scatterplot of `hwy` vs. `cyl`.
- Make a scatterplot of `class` vs. `drv`. Why is this plot not useful?

Aesthetic Mappings

- We can add a third variable to a scatterplot by mapping it to an **aesthetic**.
- An **aesthetic** is a visual property of the objects in the plot.
- Things like size, color, shape of points.

Mapping Aesthetics

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x=displ, y=hwy, color=class))
```



Check Yourself

Tasks

- Instead of mapping class to the color aesthetic, map it to the alpha aesthetic or the size aesthetic.
- Instead of mapping class to the color aesthetic, map it to the shape aesthetic. Note that ggplot() will only use 6 shapes at a time. What does this mean for our plot?
- What does the following code do?

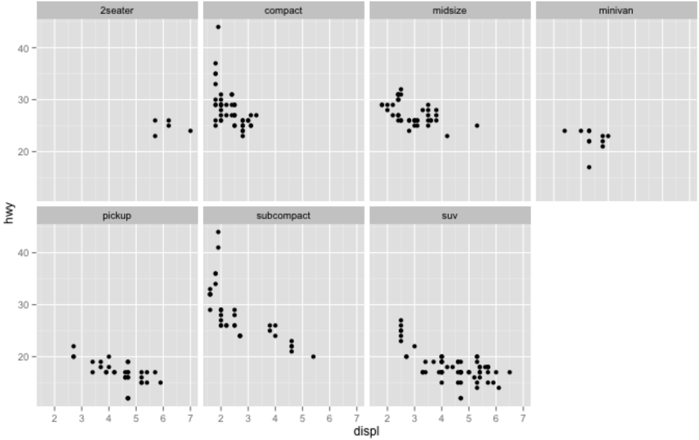
  ```
  ggplot(data = mpg) +
    geom_point(mapping = aes(x=displ, y=hwy), color="blue")
  ```
- Map a continuous variable in the mpg dataset, like cty, to the alpha, shape, and size aesthetics. What does this do?

Facets

- We saw we could add categorical variables to plots using aesthetics.
- Can also do this by splitting the plot into **facets**, which are subplots that each display one subset of the data.
- Use the `fact_wrap()` command to facet a plot by a single variable.
- The argument is a formula created with ˜ followed by a variable name.

Facets

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy)) +
  facet_wrap(~ class, nrow = 2)
```



Check Yourself

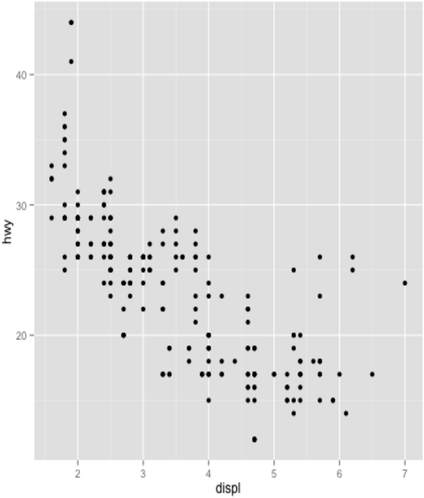
Tasks

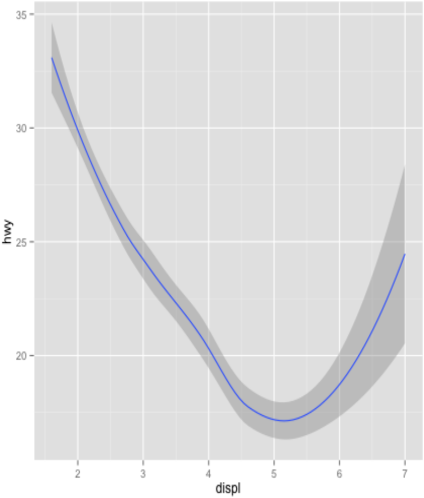
- Facet on two variables use the `facet_grid()` command. An example is the following:

  ```
  ggplot(data = mpg) +
    geom_point(mapping = aes(x = displ, y = hwy)) +
    facet_grid(drv ~ class)
  ```

  What do the empty cells mean?
- Look at `?facet_wrap`. What do `nrow` and `ncol` do? Why doesn't `facet_grid()` have `nrow` and `ncol` arguments?
- What happens if you facet on a continuous variable?

Geometric Objects



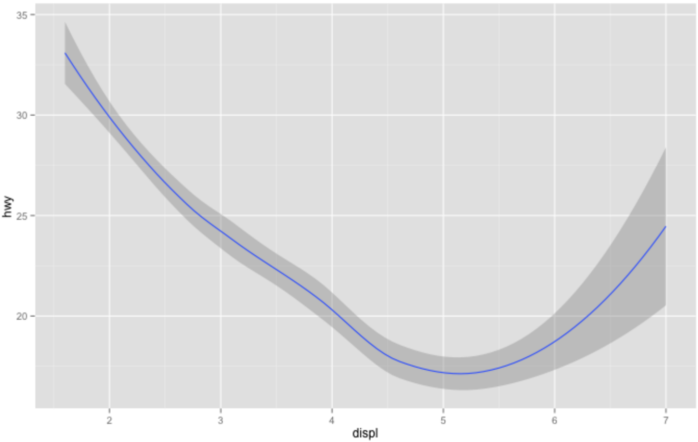


Geometric Objects

- In the previous slide, each plot used a different **visual object** to represent the data.
- Produce this by using different `geoms`.
- A `geom` is a geometrical object used to represent data in a plot.
- Often describe plots by the type of `geom` they use. For example, bar graphs use bar `geoms`.

Geometric Objects

```
ggplot(data = mpg) +
  geom_smooth(mapping = aes(x = displ, y = hwy))
```



Geometric Objects

- Every geom takes a mapping argument but not every aesthetic works with every geom.
    - E.g., you can set the shape of a point, but not a line. You can set the linetype of a line.
- ggplot2 has around 30 different geoms.
- Can get help with ?geom_smooth, for example.

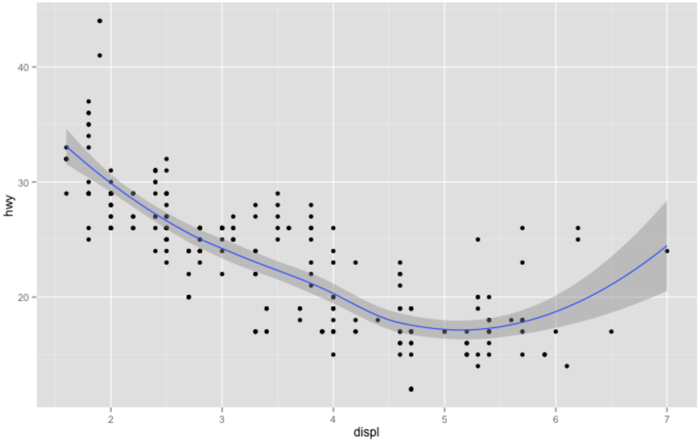
Geometric Objects

Some Commonly-used geoms

geom Name	Used to...	Aesthetics
geom_histogram	Visualize a Continuous Variable	x .
geom_bar	Visualize a Discrete Variable	x.
geom_point	Visualize a Two Continuous Variables	x, y.
geom_text	Add Labels to a Plot	x, y, label.
geom_boxplot	Visualize Continuous and Discrete Variables	x, y.
geom_jitter	Visualize a Two Variables	x, y.
many more ...		

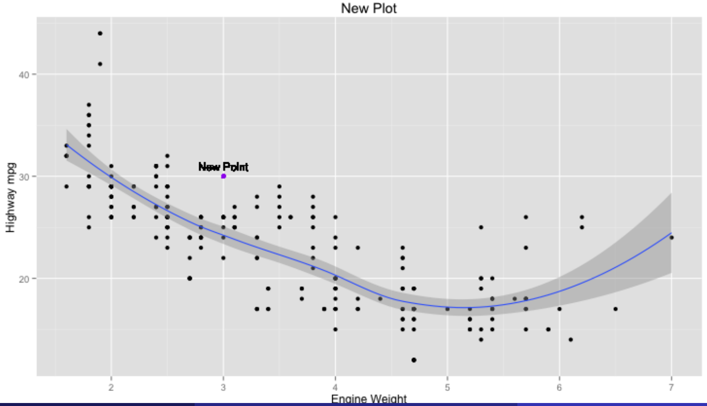
Layering geoms

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy)) +
  geom_smooth(mapping = aes(x = displ, y = hwy))
```



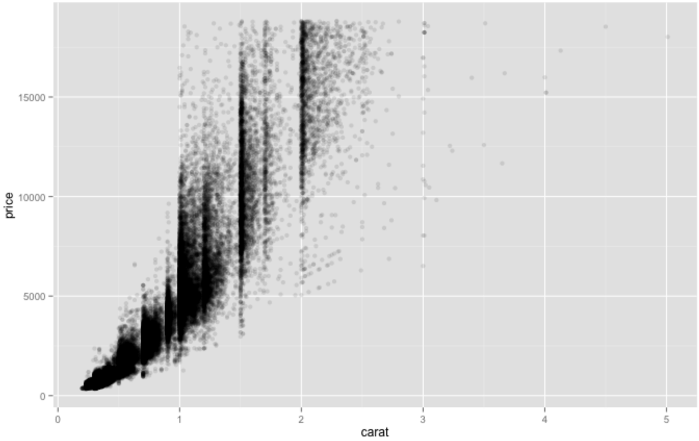
Adding Axis Labels

```
ggplot(data = mpg) +
  geom_point(mapping = aes(x = displ, y = hwy)) +
  geom_smooth(mapping = aes(x = displ, y = hwy)) +
  geom_point(mapping = aes(x=3, y=30), color = "purple") +
  geom_text(mapping = aes(x=3, y=31, label = "New Point"), size=4) +
  labs(title = "New Plot", x = "Engine Weight", y = "Highway mpg")
```



Layering geoms

```
> ggplot(data = diamonds) +
+   geom_point(mapping = aes(x = carat, y = price),
+              alpha = 1/10)
```



Check Yourself

Exercise:

Use the built-in `iris` dataset.

- Plot iris `Sepal.Width` on the x-axis and `Sepal.Length` on the y-axis. Color the points according to whether the iris is a setosa or not.
- Plot two regression lines on the plot, one for the setosa iris and one for non-setosa iris. Hint: Use `geom_abline(intercept, slope)`.