

# Python: Data Visualization Notes

Klein  
carlj.klein@gmail.com

## 1 Learning Objectives

What good is a data analysis if the answers or findings can't be conveyed properly? Or perhaps even more detrimental, what good is a dataset if the proper questions or hypotheses can't be formed in the first place? How can we properly tell the story the data is providing? Enter in data visualization! Both explaining the data and exploring the data can be significantly helped through the process of data visualization.

Data visualization is two-pronged:

- Exploratory Analysis: Helping to understand the data prior to analysis. Searching for relationships and insights.
- Explanatory Analysis: Helping to present analysis findings, helping to tell a story with the data. After insights were found.

And it's all a part of the entire data analysis process. We can also simplify the data analysis process into 5 steps:

1. Extract
2. Clean: Exploratory
3. Explore: Exploratory
4. Analyze: Exploratory OR Explanatory
5. Share: Explanatory

In this course, we'll be using the matplotlib, seaborn, and Pandas libraries to assist in the data analysis process.

### Concepts

- Design of Visualization
- Exploration of Data

- Univariate Exploration of Data
- Bivariate Exploration of Data
- Multivariate Exploration of Data
- Explanatory Visualizations
- Visualization Case Study

## 2 Design of Visualization

To begin our discussion of visualization, we need to cover some basic vocabulary and distinctions.

Data can be broken into two main categories, each of which can be broken down further:

- Qualitative / Categorical:
  - Nominal: No order
  - Ordinal: Intrinsic Order
- Quantitative / Numerical:
  - Interval: Absolute differences are meaningful (addition and subtraction follows logic)
  - Ratio: relative differences are meaningful (multiplication and division follows logic)

It should be noted that the quantitative data type can be also be broken down into discrete and continuous variables.

What about those 3-dimensions charts or fun backgrounds that we used to add to our science experiment plots as kids? That used to add some fun to our projects, right? While fun for the youth, it turns out there is an empirical rule when figuring out how much the additional "junk" either adds or detracts from conveying the data.

- Data-Ink Ratio = data-ink / total ink used to print the graphic. The higher the Data-Ink Ratio, the better conveyed data is.

Can visualizations be purposefully misleading, even when using the data appropriately? Absolutely!

A great example of this is trying to over-inflate the difference or change between data points during different time periods. Say a presenter is trying to make a claim there was a very large change from one year to the next. We'll say in year

1 the y-value was 100, and in year 2 the y-value was 105. The presenter changes the window of the graph to display from a y-value of 99 to a y-value of 106, and the x-values are only the two years. Obviously, this is going to look like a massive change! In reality, had the reporter shown the data at a true scale, the visual shows in actuality that the change isn't so tremendous.

This concept also has an empirical rule:

- Lie Factor = size of effect shown in graphic / size of effect shown in data  
= (change in visual / visual start) / (change in data / data start)

As was said in the example, this can be used to purposefully distort data. In fact, a Lie Factor  $> 1$  suggests a misleading visual, and even greater than that suggest an even greater disparity from the truth.

Away from the empirical side of visuals, and more into the logical, we come across the common mistake of using too many colors! Colors can be useful when separating categories, however, they it's very easy to cause redundancy with them. Here are some tips when using color:

- Get it right in black and white (and shades of grey)
- Use less intense colors such as natural or pastel, and higher grey colors. The eye can actually concentrate longer under these conditions.
- Color facilitates communication. Use color to separate the data into groups of interest, not just to color a visual.
- Design for Color Blindness. Stay away from red / green pallets, and use blue / orange pallets.

Don't want to overdo it on the color schemes? Don't forget about other visual queues such as shape and size.

Some tips on shape, size & other tools:

- Use different types of encodings, rather than using color (square / dot vs. colors to separate groups of interest).
- Color and shape are good for categorical variables.
- Size of marker can assist in adding additional quantitative data.

## 3 Exploration of Data

We have a dataset on a topic or concept that has been deemed worthy for inspection! Surely, there are some insights to be gained from it. We load up the data, and then we hit a wall... Which columns are important? What questions can be answered? We can find the general statistics of the set, so what?

This section will help with the initial process of data exploration, helping to find what is actually useful and should be examined further in the data. We'll start with single variables from the data and move into visually pairing multiple data points at once.

We'll be using a few different Python libraries in this section:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sb
```

### 3.1 Univariate Exploration of Data

The first tools added into our data exploration toolkit will be for univariate data, or examining the data a single variable at a time. Even though we're going to be using several different libraries, we'll still try to keep track of new and essential commands and terminology:

Commands:

- `df.head`: Retrieves the first few rows of data from a Pandas DataFrame. Able to specify how many rows
- `sb.countplot`: Seaborn's command for generating a bar chart.
- `df[column].value_counts().index`: Will return an immutable sequence sorted number of categorical entries (highest to lowest).
- `df.melt`: Will unpivot a DataFrame from wide to long format (i.e. we can "melt" two entries together).
- `plt.hist`: Matplotlib's command for generating a histogram.
- `sb.distplot`: Seaborn's command for generating a histogram. Default command also includes a density curve estimation.

Terminology:

- bar chart: Useful to show counts across categories.

- relative frequency: Shows proportion of each category in population.
- pie chart: Use these to show how whole of data is broken down into parts, useful when plotting a small number of slices (usually no more than four).
- histogram: Useful to examine quantitative data.

We'll be using a Pokemon dataset for our examples. Let's get an idea of what our data looks like:

```
pokemon = pd.read_csv("pokemon.csv")
pokemon.shape
# pokemon.shape = (807, 14)
pokemon.head(10)
```

## Pokemon.Head(10)

|   | id | species    | generation_id | height | weight | base_experience | type_1 |
|---|----|------------|---------------|--------|--------|-----------------|--------|
| 0 | 1  | bulbasaur  | 1             | 0.7    | 6.9    | 64              | grass  |
| 1 | 2  | ivysaur    | 1             | 1.0    | 13.0   | 142             | grass  |
| 2 | 3  | venusaur   | 1             | 2.0    | 100.0  | 236             | grass  |
| 3 | 4  | charmander | 1             | 0.6    | 8.5    | 62              | fire   |
| 4 | 5  | charmeleon | 1             | 1.1    | 19.0   | 142             | fire   |
| 5 | 6  | charizard  | 1             | 1.7    | 90.5   | 240             | fire   |
| 6 | 7  | squirtle   | 1             | 0.5    | 9.0    | 63              | water  |
| 7 | 8  | wartortle  | 1             | 1.0    | 22.5   | 142             | water  |
| 8 | 9  | blastoise  | 1             | 1.6    | 85.5   | 239             | water  |
| 9 | 10 | caterpie   | 1             | 0.3    | 2.9    | 39              | bug    |

|   | type_2 | hp | attack | defense | speed | special-attack | special-defense |
|---|--------|----|--------|---------|-------|----------------|-----------------|
| 0 | poison | 45 | 49     | 49      | 45    | 65             | 65              |
| 1 | poison | 60 | 62     | 63      | 60    | 80             | 80              |
| 2 | poison | 80 | 82     | 83      | 80    | 100            | 100             |
| 3 | NaN    | 39 | 52     | 43      | 65    | 60             | 50              |
| 4 | NaN    | 58 | 64     | 58      | 80    | 80             | 65              |
| 5 | flying | 78 | 84     | 78      | 100   | 109            | 85              |
| 6 | NaN    | 44 | 48     | 65      | 43    | 50             | 64              |
| 7 | NaN    | 59 | 63     | 80      | 58    | 65             | 80              |
| 8 | NaN    | 79 | 83     | 100     | 78    | 85             | 105             |
| 9 | NaN    | 45 | 30     | 35      | 45    | 20             | 20              |

Now that we've had a peak at the data, let's get into some visualization.

```
# create a bar chart for one of the columns (generation_id)
# this will show counts of each pokemon for each generation
sb.countplot(data = pokemon, x = 'generation_id')
# See Figure 1

# let's use a single neutral color to reduce redundancy and make
# it easier on the eyes
base_color = sb.color_palette()[0]
sb.countplot(data = pokemon, x = 'generation_id', color =
              base_color)
# See Figure 2
```

A simple, yet effective visual trick is adding some order to your plots via sorting.

```
# let's sort the data highest -> lowest
# we can use pandas series function: value_counts()
gen_order = pokemon['generation_id'].value_counts().index
sb.countplot(data = pokemon, x = 'generation_id', color =
              base_color, order = gen_order)
# See Figure 3
```

Let's combine the previous coloring and sorting to look at a new variable. Additionally, since we know the x-axis labels are somewhat long. Two favorable ways

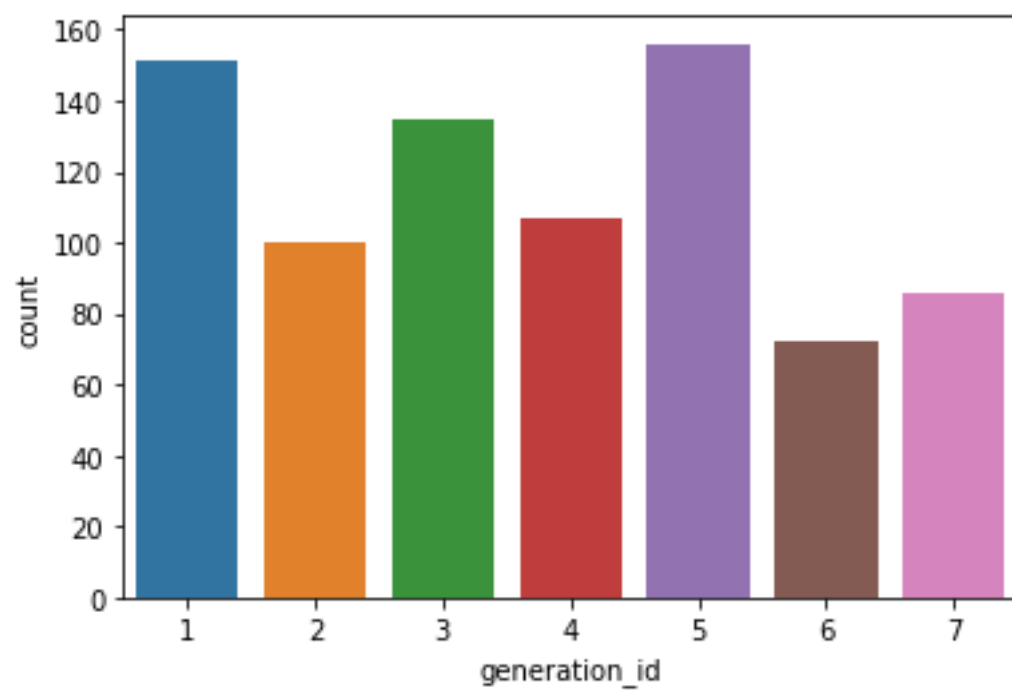


Figure 1: Generic bar chart.

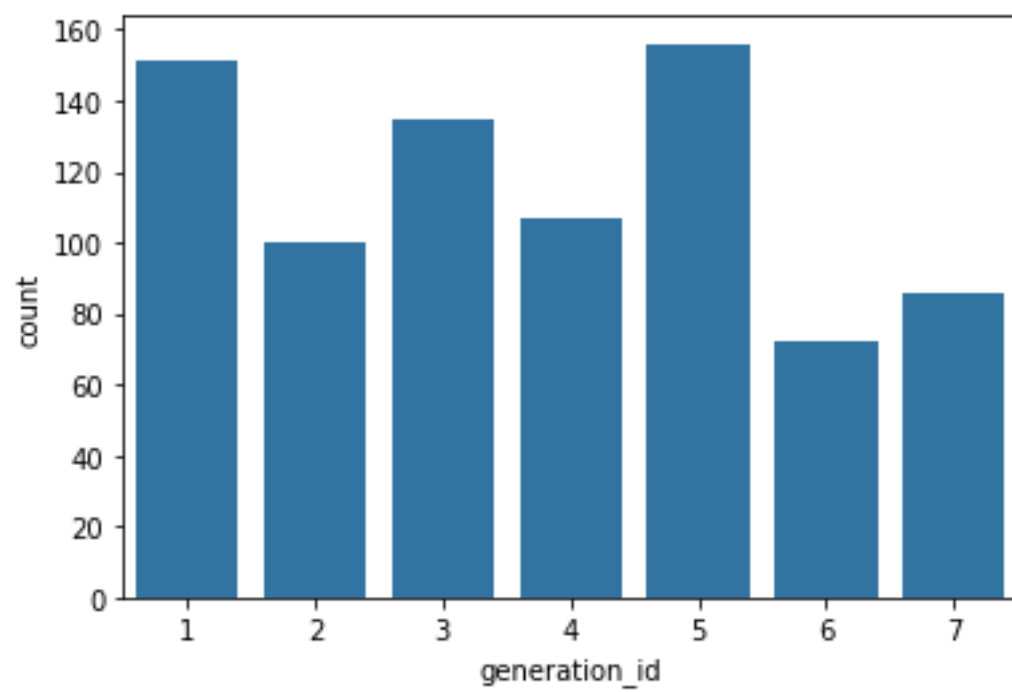


Figure 2: Bar chart with neutral coloring.



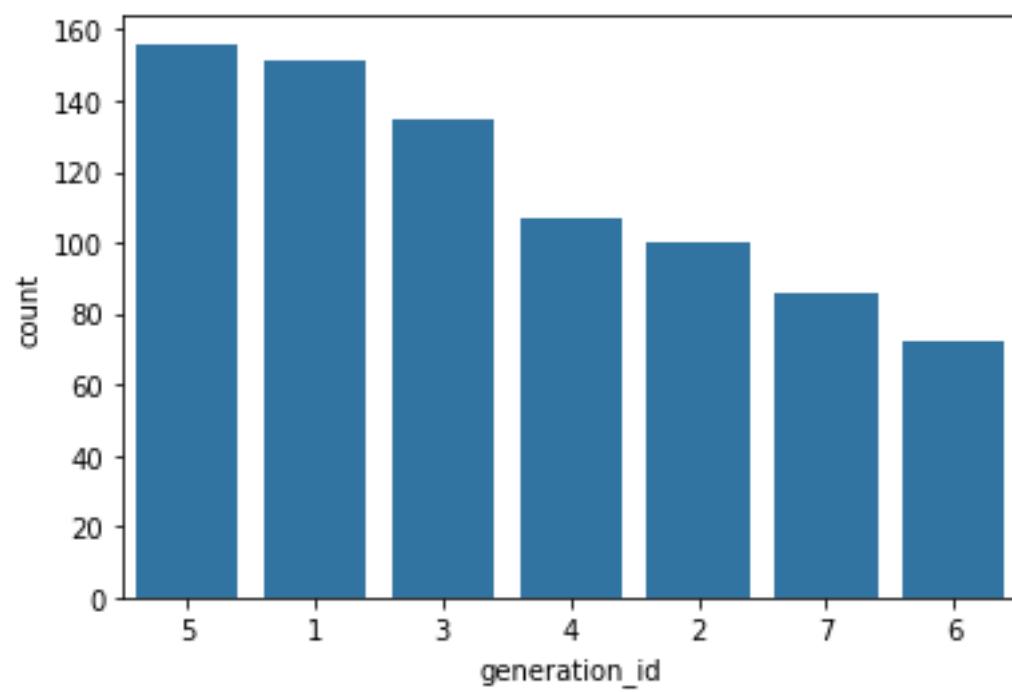


Figure 3: Bar chart with neutral coloring and ordering applied.

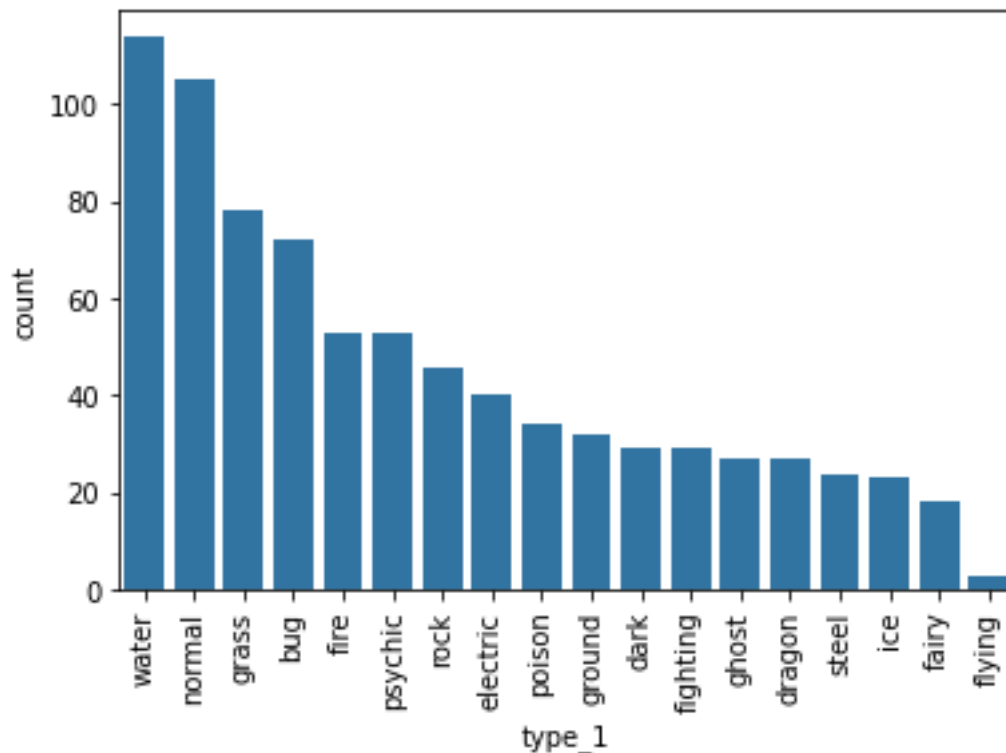


Figure 4: Standard bar chart format with x-axis labels rotated.

of dealing with this is to either rotate the x-axis labels, or create a horizontal bar chart.

```
type_order = pokemon['type_1'].value_counts().index
sb.countplot(data = pokemon, x = 'type_1', color = base_color,
              order = type_order)

plt.xticks(rotation = 90)
# See Figure 4

# Change x to y to change from vertical to horizontal bar chart
sb.countplot(data = pokemon, y = 'type_1', color = base_color,
              order = type_order)
# See Figure 5
```

The previous examples display actual counts in the bar charts, but it can also be useful to display data using relative frequency (proportion of each category in the population). This gives us an opportunity to introduce a few other concepts as well. Most importantly, we'll introduce the melt function, which we'll use to combine two categories (two distinct columns) into a single category.

```
pkmn_types = pokemon.melt(id_vars=['id', 'species'],
```

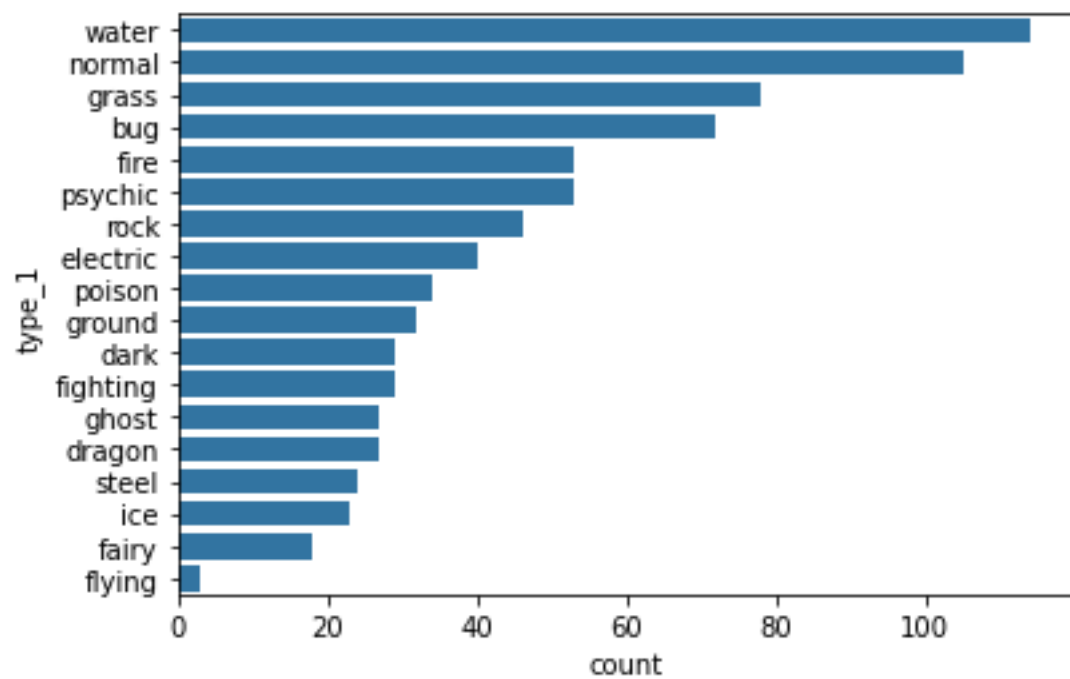


Figure 5: Standard bar chart format in vertical form.

```

        value_vars=['type_1', 'type_2'],
        var_name='type_level',
        value_name='type')

"""
Let's walk through how the melt function is being used here:
- id_vars: columns to utilize as identifier variables
- value_vars: columns to unpivot
- var_name: name of column to describe data being unpivoted
              together
- value_name: name of column to match values from the unpivoted
              labels

Note: the pokemon DataFrame has 807 rows (pokemon entries). This
      use of melt puts two categories
      together into a single category.
      Thus, each pokemon now has two
      entries each, making the
      pkmn_types DataFrame have double
      the rows as the original
      DataFrame or 1614 rows.

"""

base_color = sb.color_palette()[0]
type_counts = pkmn_types['type'].value_counts()
type_order = type_counts.index
sb.countplot(data = pkmn_types, y = 'type', color = base_color,
              order = type_order)

# See Figure 6

# now we'll change the tick counts
n_pokemon = pokemon.shape[0]
max_type_count = type_counts[0]
max_prop = max_type_count / n_pokemon
# note: max_prop = 0.16

tick_props = np.arange(0, max_prop, 0.02)
tick_names = ['{:0.2f}'.format(v) for v in tick_props]
"""
tick_props creates the numbers for an equally spaced axis, while
tick_names takes the numeric
version and returns a list of a
string values.

"""

# The culmination of the above work into a chart:
sb.countplot(data = pkmn_types, y = 'type', color = base_color,
              order = type_order)
plt.xticks(tick_props * n_pokemon, tick_names)
plt.xlabel('proportion')
for j in range(type_counts.shape[0]):
    count = type_counts[j]
    pct_string = '{:0.1f}%'.format(100*count/n_pokemon)
    plt.text(count + j, j, pct_string, va = 'center')
# See Figure 7

```

Whereas bar charts are a great initial step in exploring categorical data, histogram are useful in the exploration of quantitative data. Let's take a look at

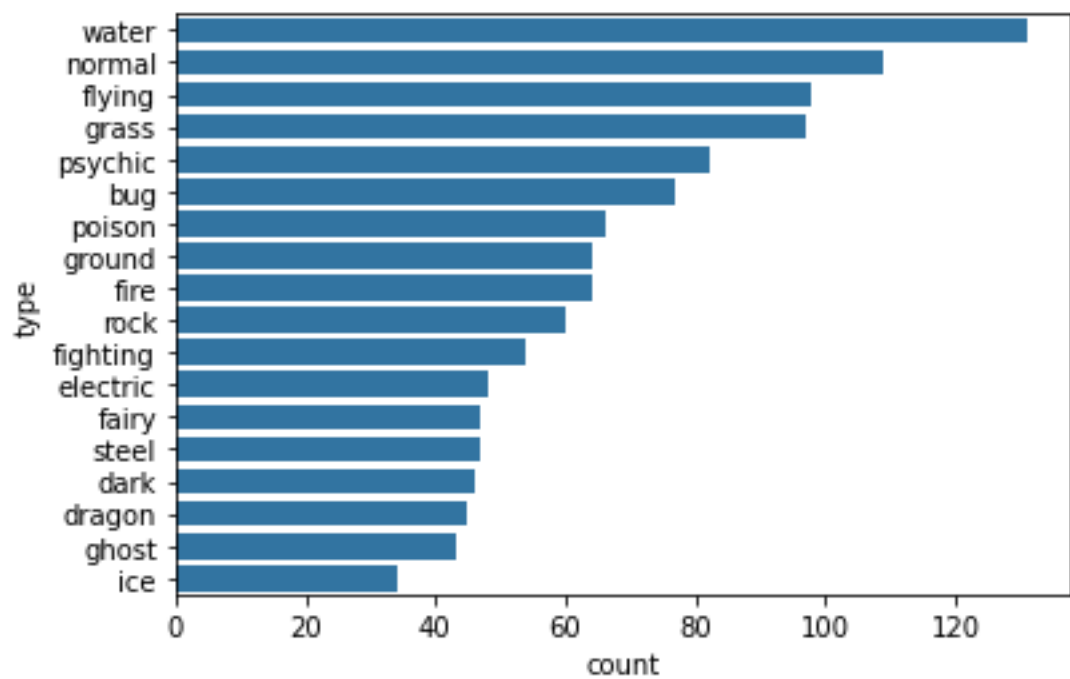


Figure 6: Bar chart of melted pokemon types.

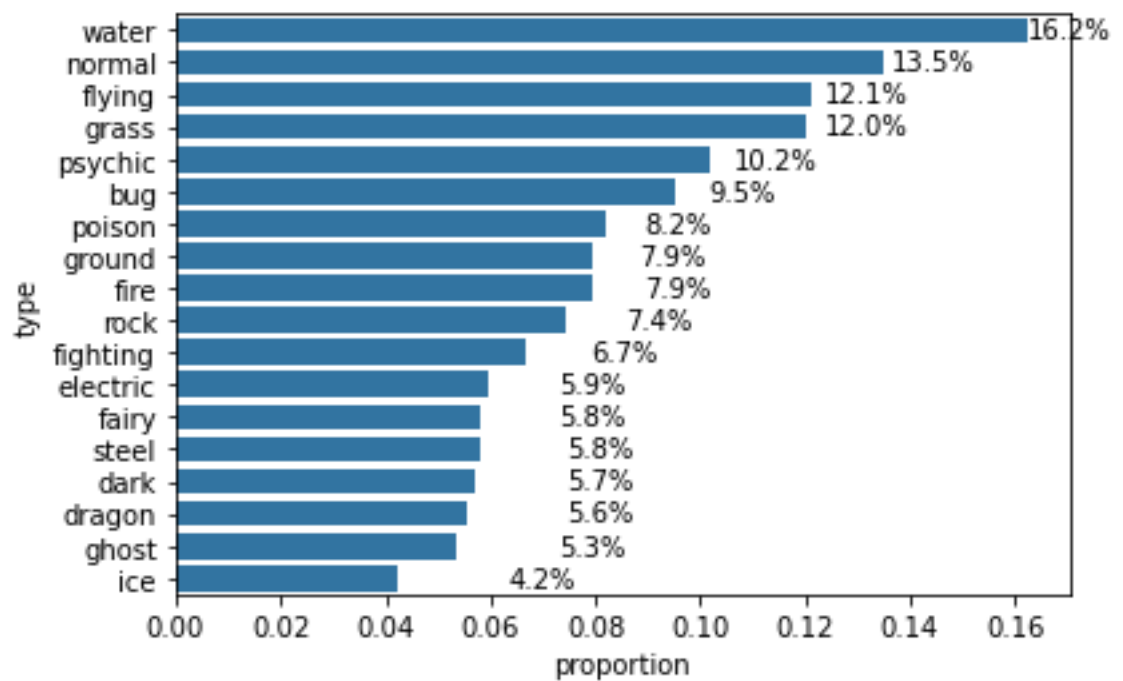


Figure 7: Bar chart of melted pokemon types shown in relative frequency.

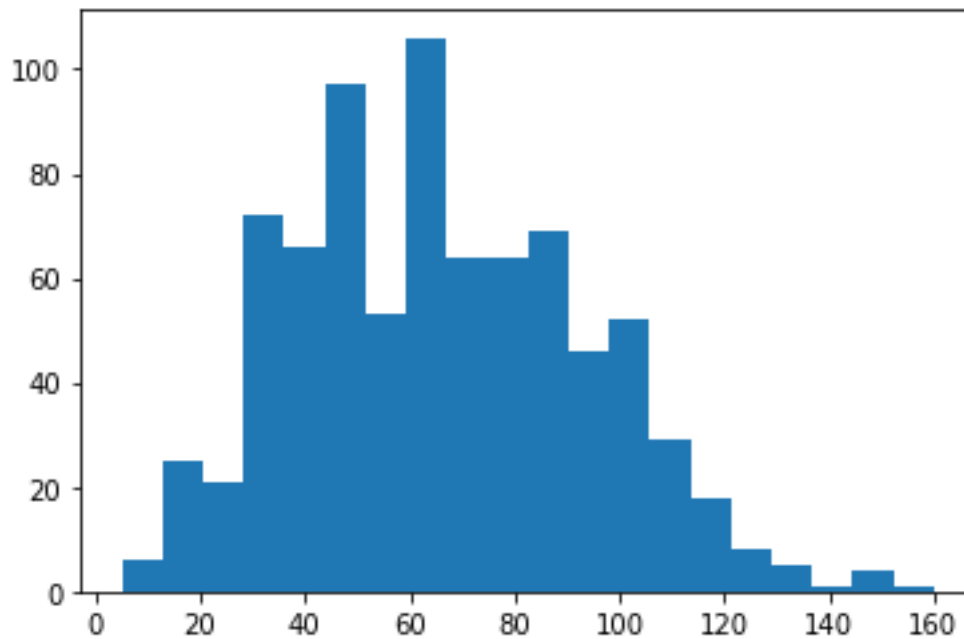


Figure 8: Basic histogram of Pokemon speeds.

our variables in the pokemon DataFrame which contain quantitative data.

```
# basic histogram exploring the speed variable
plt.hist(data = pokemon, x = 'speed', bins = 20)
# See Figure 8

# for histograms, bin specification is paramount in
# visualization

# this is an example
bins = np.arange(0, pokemon['speed'].max() + 5, 5)
# recall that arange will not include last value
plt.hist(data = pokemon, x = 'speed', bins = bins)
# See Figure 9

# Seaborn's histogram command has a default density curve
# estimation
sb.distplot(pokemon['speed'])
# See Figure 10
```

Earlier in the course, we mentioned avoiding a high "lie factor". One case in which it may actually be beneficial to "zoom" in on data is when dealing with outliers, or when a large majority of the data is within certain axis limits.

For example, let's take a look at the height variable of Pokemon.

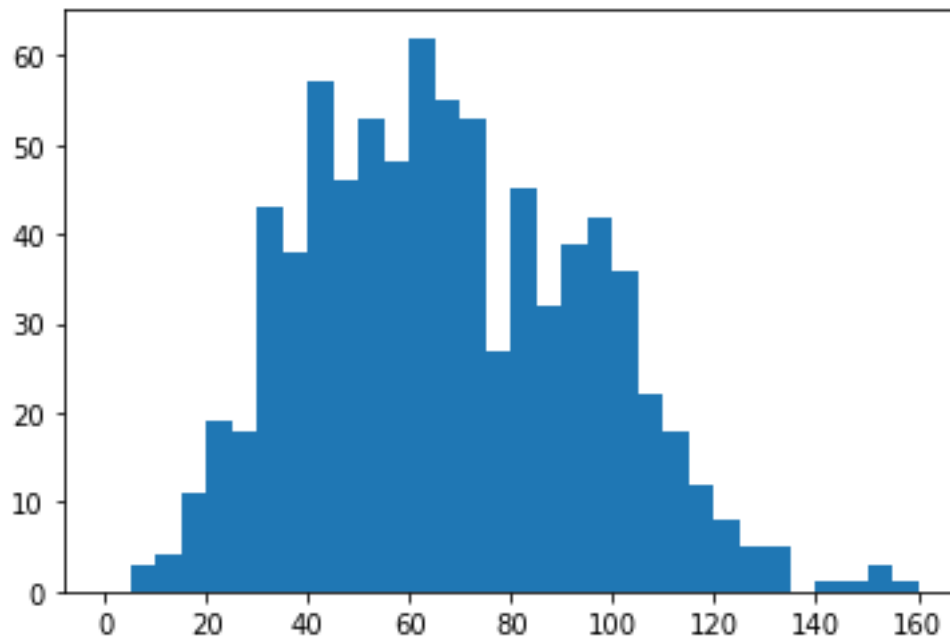


Figure 9: Histogram of Pokemon speeds with altered bins.

```
# even though this is a course on visuals, basic math and
descriptive statistics can still
be beneficial

pokemon['height'].describe()
"""
count      807.000000
mean       1.162454
std        1.081030
min        0.100000
25%        0.600000
50%        1.000000
75%        1.500000
max        14.500000

With the majority of our data between 0 and 1.5, it's acceptable
to change our x-axis limits. The
outlier of 14.5 would make our
histogram and bin choice less
effective from a visual sense.

"""
bins = np.arange(0, pokemon['height'].max() + 0.2, 0.2)
plt.hist(data = pokemon, x = 'height', bins = bins)
plt.xlim((0, 6))
# See Figure 11
```

Another method when dealing with outliers or data points that have very large



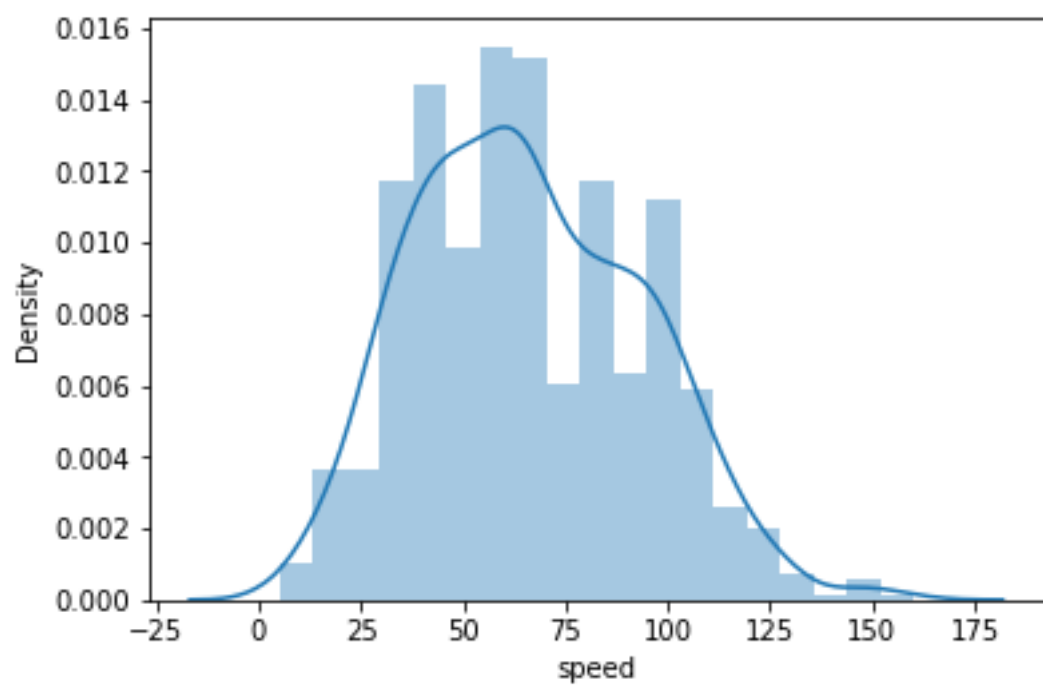


Figure 10: Seaborn's default histogram.

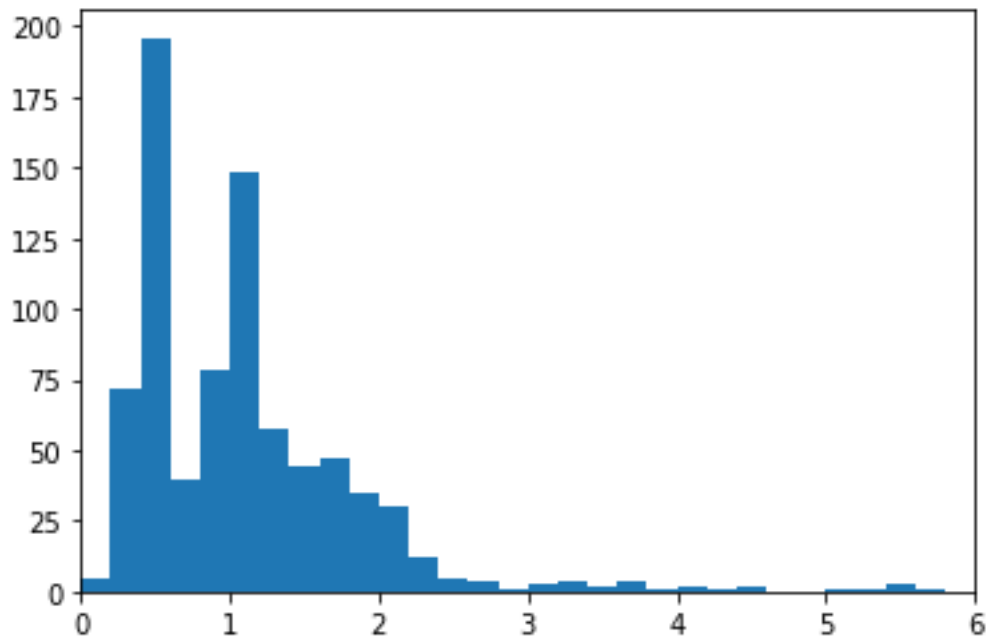


Figure 11: Histogram with altered x-axis limits.

differences between them is with scaling and transformations.

Let's take a look at the weight variable of Pokemon.

```
pokemon['weight'].describe()
"""
count      807.000000
mean       61.771128
std        111.519355
min         0.100000
25%         9.000000
50%        27.000000
75%        63.000000
max       999.900000

Obviously, there exists some outlier(s) here. We should think
about using transformations and
tick-mark manipulation to
visualize the data this time
around.

"""

# Let's see what we're dealing with without any scaling or
transformations
bins = np.arange(0, pokemon['weight'].max() + 40, 40)
plt.hist(data = pokemon, x = 'weight', bins = bins)
```

```

# See Figure 12
"""
Even with specifying the bins, the histogram proves to not be
too insightful. Changing the bins
alone likely won't solve this
issue.
"""

# Let's try applying a transformation of the x-scale, itself
bins = np.arange(0, pokemon['weight'].max() + 40, 40)
plt.hist(data = pokemon, x = 'weight', bins = bins)
plt.xscale('log')
# See Figure 13
"""
It could be argued this is a worse approach, but using a
logarithmic transformation could
steer us in the right direction.
"""

np.log10(pokemon['weight'].describe())
"""
count      2.906874
mean       1.790786
std        2.047350
min        -1.000000
25%         0.954243
50%         1.431364
75%         1.799341
max         2.999957

Applying a logarithmic transformation on the data, itself,
appears to shrink the numbers
into a more manageable scale.
"""

# Get the ticks for bins between [0 - maximum weight]
bins = 10 ** np.arange(-1, 3 + 0.1, 0.1)

# Generate the x-ticks we want to apply
ticks = [0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000]
"""
Important: note here how we are using differently spaced tick
marks in the original scale.
"""

# Convert ticks into string values, to be displayed along the x-
axis
labels = ['{}'.format(v) for v in ticks]

# Plot the histogram
plt.hist(data=pokemon, x='weight', bins=bins);

# The argument in the xscale() represents the axis scale type to
apply.
# The possible values are: {"linear", "log", "symlog", "logit",
...}
plt.xscale('log')

```

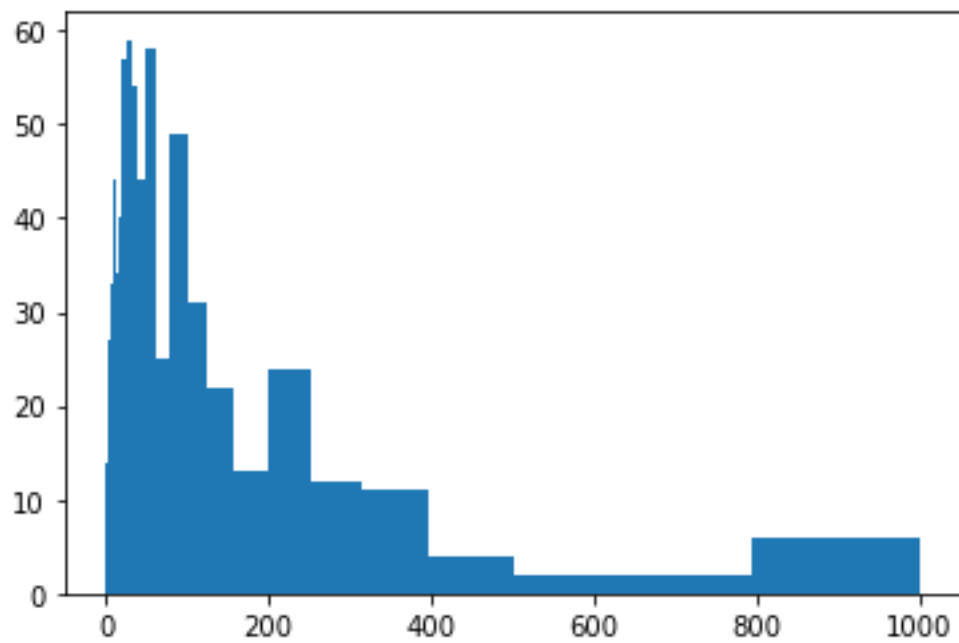


Figure 12: First try histogram of Pokemon's weight.

```
# Apply x-ticks  
plt.xticks(ticks, labels)  
  
# See Figure 14
```

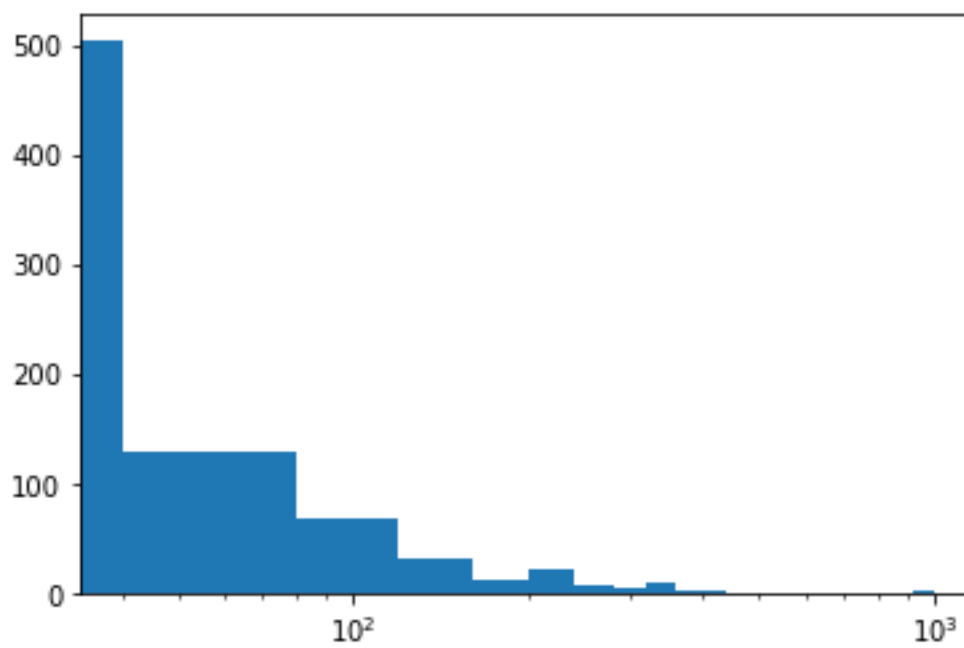


Figure 13: Histogram of Pokemon's weight with a log transformation applied to the x-scale.

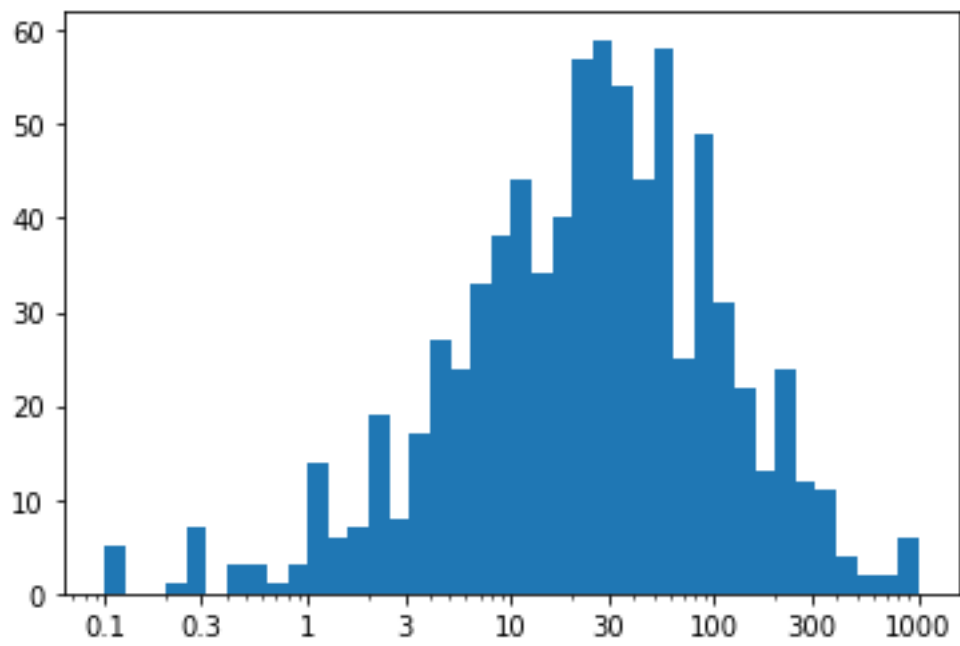


Figure 14: Histogram of Pokemon's weight with transformation and scaling applied.

## 3.2 Bivariate Exploration of Data

Having seen some basic ways to visually examine univariate data, we can move into exploring a data set by comparing two variables at a time with bivariate exploration of data.

Commands:

- `plt.scatter`: Matplotlib's command for a scatter plot.
- `sb.regplot`: Seaborn's command for a scatter plot. Much like `sb`'s histogram default, their plot includes a line of best fit.
- `plt.hist2d`: Matplotlib's command for a heat map.
- `sb.violinplot`: Seaborn's command for a violin plot.
- `sb.boxplot`: Seaborn's command for a box plot.
- Creating Facets:
  - `g = sb.FacetGrid`: Seaborn's initial command for creating facets (creates object to be called in secondary command). Specify category to create facets around.
  - `g.map`: Seaborn's secondary command for creating facets. Specify type of plot and quantitative (usually) data to create facets around.
- `sb.barplot`: Seaborn's bar plot command (not to be confused with `sb.countplot`). For use when pairing categorical values with quantitative values.
- `sb.pointplot`: Seaborn's command for creating a line plot.

Terminology:

- heat maps: Use for discrete vs. discrete variables. Conceptualize as a top down 2-dimensional histogram. Can be an alternative to solving overplotting with a transparency method.
- scatter plots: Use for quantitative vs. quantitative variables.
- violin plots: Use for quantitative vs. qualitative variables. Plots a line from the minimum to maximum of the quantitative values, and features symmetrical smooth curves on both sides of the line which are wider at denser locations.
- box plots: Use for quantitative vs. qualitative variables. Plots a line from the minimum to maximum of the quantitative values, with a box drawn around the interquartile range [Q1:25th percentile, Q3; 75th percentile].
- clustered bar charts: Use for qualitative vs. quantitative variables. Compares variables by plotting aspects of categories side by side.

- faceting: creating a series of plots which share the same set of axes, but each subplot shows a subset of the data.
- line plots: A scatter plot where point estimates are marked for each of the categories with a given confidence interval. Also known as a time series plot.
- overplotting: When data or labels in a data visualization overlap, making it difficult to see individual points.
- sampling: Choose a subset of the data (best if randomized).
- transparency: By making the points partially transparent (increase the opacity), overplotting becomes evident by darker regions.
- jitter: By adding small randomly generated numbers to the values prior to plotting, overplotting becomes event by denser regions.

Although univariate data seems simple by virtue of a single variable, due to practicality, most people are likely more familiar with the first example shown in this section, a scatter plot. This is the classic x vs. y, plot your data using coordinates plot. A very effective tool, and easy to implement when the data consists of a single dependent variable. However, it's not the only tool! Datasets of different complexity and data types require different approaches to understand their stories. Let's dive in with an example.

```
# first things first, let's check out our dataset
fuel_econ = pd.read_csv('fuel-econ.csv')
fuel_econ.shape
# (3929, 20)
fuel_econ.head(10)
```

**fuel\_econ.head(10)**

|   | id    | make       | model          | year | VClass          |
|---|-------|------------|----------------|------|-----------------|
| 0 | 32204 | Nissan     | GT-R           | 2013 | Subcompact Cars |
| 1 | 32205 | Volkswagen | CC             | 2013 | Compact Cars    |
| 2 | 32206 | Volkswagen | CC             | 2013 | Compact Cars    |
| 3 | 32207 | Volkswagen | CC 4motion     | 2013 | Compact Cars    |
| 4 | 32208 | Chevrolet  | Malibu eAssist | 2013 | Midsize Cars    |
| 5 | 32209 | Lexus      | GS 350         | 2013 | Midsize Cars    |
| 6 | 32210 | Lexus      | GS 350 AWD     | 2013 | Midsize Cars    |
| 7 | 32214 | Hyundai    | Genesis Coupe  | 2013 | Subcompact Cars |
| 8 | 32215 | Hyundai    | Genesis Coupe  | 2013 | Subcompact Cars |
| 9 | 32216 | Hyundai    | Genesis Coupe  | 2013 | Subcompact Cars |



|   | drive             | trans             | fuelType         | cylinders | displ    |
|---|-------------------|-------------------|------------------|-----------|----------|
| 0 | All-Wheel Drive   | Automatic (AM6)   | Premium Gasoline | 6         | 3.8      |
| 1 | Front-Wheel Drive | Automatic (AM-S6) | Premium Gasoline | 4         | 2.0      |
| 2 | Front-Wheel Drive | Automatic (S6)    | Premium Gasoline | 6         | 3.6      |
| 3 | All-Wheel Drive   | Automatic (S6)    | Premium Gasoline | 6         | 3.6      |
| 4 | Front-Wheel Drive | Automatic (S6)    | Regular Gasoline | 4         | 2.4      |
| 5 | Rear-Wheel Drive  | Automatic (S6)    | Premium Gasoline | 6         | 3.5      |
| 6 | All-Wheel Drive   | Automatic (S6)    | Premium Gasoline | 6         | 3.5      |
| 7 | Rear-Wheel Drive  | Automatic 8-spd   | Premium Gasoline | 4         | 2.0      |
| 8 | Rear-Wheel Drive  | Manual 6-spd      | Premium Gasoline | 4         | 2.0      |
| 9 | Rear-Wheel Drive  | Automatic 8-spd   | Premium Gasoline | 6         | 3.8      |
|   | pv2               | pv4               | city             | UCity     | highway  |
| 0 | 79                | 0                 | 16.4596          | 20.2988   | 22.5568  |
| 1 | 94                | 0                 | 21.8706          | 26.9770   | 31.0367  |
| 2 | 94                | 0                 | 17.4935          | 21.2000   | 26.5716  |
| 3 | 94                | 0                 | 16.9415          | 20.5000   | 25.2190  |
| 4 | 0                 | 95                | 24.7726          | 31.9796   | 35.5340  |
| 5 | 0                 | 99                | 19.4325          | 24.1499   | 28.2234  |
| 6 | 0                 | 99                | 18.5752          | 23.5261   | 26.3573  |
| 7 | 89                | 0                 | 17.4460          | 21.7946   | 26.6295  |
| 8 | 89                | 0                 | 20.6741          | 26.2000   | 29.2741  |
| 9 | 89                | 0                 | 16.4675          | 20.4839   | 24.5605  |
|   | UHighway          | comb              | co2              | feScore   | ghgScore |
| 0 | 30.1798           | 18.7389           | 471              | 4         | 4        |
| 1 | 42.4936           | 25.2227           | 349              | 6         | 6        |
| 2 | 35.1000           | 20.6716           | 429              | 5         | 5        |
| 3 | 33.5000           | 19.8774           | 446              | 5         | 5        |
| 4 | 51.8816           | 28.6813           | 310              | 8         | 8        |
| 5 | 38.5000           | 22.6002           | 393              | 6         | 6        |
| 6 | 36.2109           | 21.4213           | 412              | 5         | 5        |
| 7 | 37.6731           | 20.6507           | 432              | 5         | 5        |
| 8 | 41.8000           | 23.8235           | 375              | 6         | 6        |
| 9 | 34.4972           | 19.3344           | 461              | 4         | 4        |

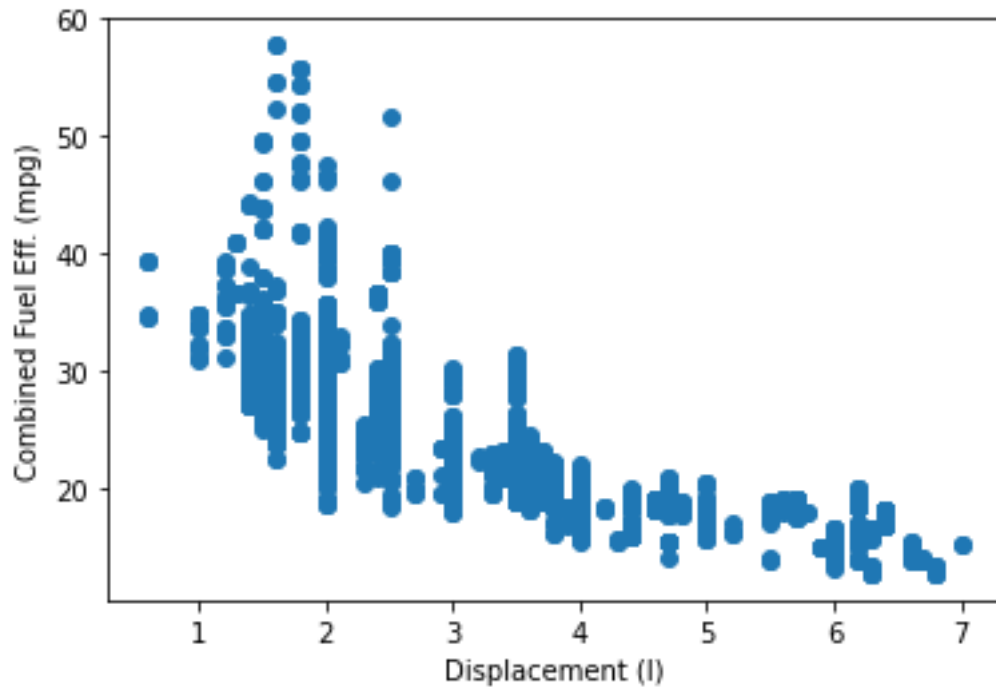


Figure 15: Basic Matplotlib Scatter Plot.

Next, we'll start off with our first bivariate plot, a scatterplot comparing size of the engine, 'displ (L)', to the combined city and highway fuel efficiency, 'comb (mpg)'.

```
plt.scatter(data = fuel_econ, x = 'displ', y = 'comb')
plt.xlabel('Displacement (l)')
plt.ylabel('Combined Fuel Eff. (mpg)')
# See Figure 15

# seaborn's version includes a line
sb.regplot(data = fuel_econ, x = 'displ', y = 'comb', fit_reg =
           True)

plt.xlabel('Displacement (l)')
plt.ylabel('Combined Fuel Eff. (mpg)')
# See Figure 16
```

The dataset we're using has almost 4,000 entries. It will likely be the case that future datasets will have many more elements. Even though we're treating the displacement variable (volume in the engine in Liters) as a quantitative variable, it could almost be expressed as a categorical variable, although it is technically a discrete quantitative variable.

```
fuel_econ['displ'].value_counts().size
# 46 different Liter options in this dataset
```

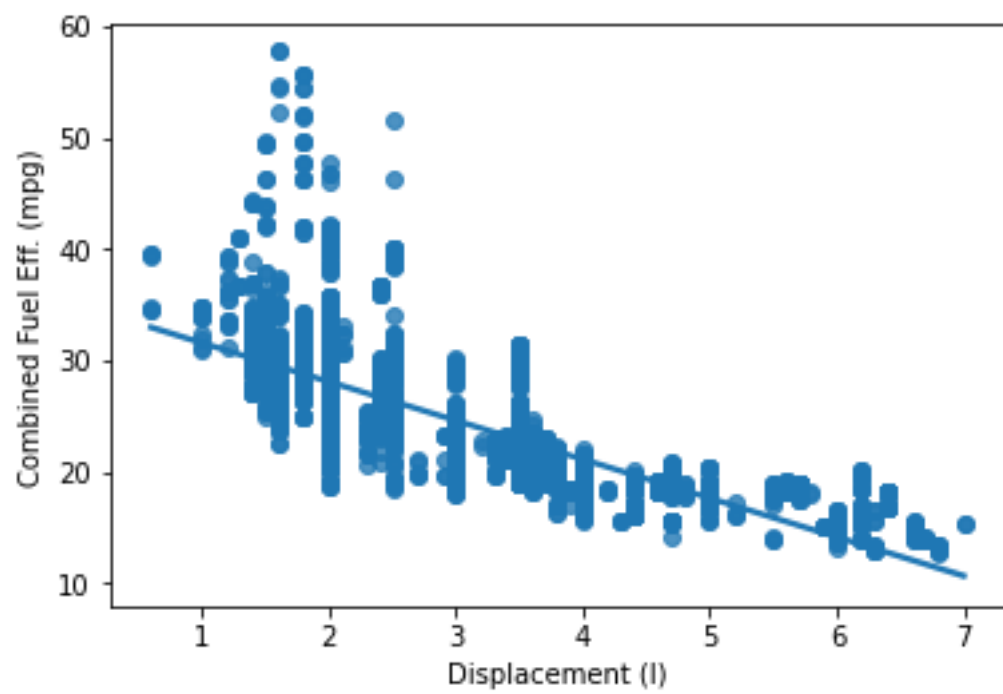


Figure 16: Basic Seaborn Scatter Plot.

```

fuel_econ['displ'].value_counts().head(10)
"""
2.0      907
3.0      515
3.5      245
1.6      243
3.6      208
1.8      189
2.5      169
2.4      142
1.4      136
4.4      130
"""

```

Although there will be different combinations when paired with the fuel efficiency variable, we've still stacked over 900 entries on  $x = 2$ , with much of the data points overlapping each other. This is a prime example of overplotting. How do we fix this?

There are a few main methods to fix overplotting:

- sampling: Choose a subset of the data (best if randomized).
- transparency: By making the points partially transparent (increase the opacity), overplotting becomes evident by the darker regions.
- jitter: By adding small randomly generated numbers to the values prior to plotting, overplotting becomes event by denser regions.
- heat map: think of this as a 2-dimensional histogram where denser regions take on different colors.

In this example, we'll use Seaborn's scatter plot capabilities to add jitter and transparency, where transparency level is denoted with alpha. In a slight change of plot, we're mapping year onto overall fuel efficiency. Year is clearly another true example of discrete data.

```

sb.regplot(data = fuel_econ, x = 'year', y = 'comb', x_jitter = 0
           .3, scatter_kws = {'alpha' : 1/20
                               })
# See Figure 17

```



Figure 17: Seaborn Scatter Plot with jitter and transparency.

Thought we were done with histograms? Let's check them in 2-dimensions with heat maps. Instead of changing the settings on a scatter plot, we could use another type of plot called a heat map. Similar to histograms, we need to be thoughtful with bin selection. So, start with the descriptive statistics.

### Statistics for Heat Map Guidance

|       | displ       | comb        |
|-------|-------------|-------------|
| count | 3929.000000 | 3929.000000 |
| mean  | 2.950573    | 24.791339   |
| std   | 1.305901    | 6.003246    |
| min   | 0.600000    | 12.821700   |
| 25%   | 2.000000    | 20.658100   |
| 50%   | 2.500000    | 24.000000   |
| 75%   | 3.600000    | 28.227100   |
| max   | 7.000000    | 57.782400   |

```
bins_x = np.arange(0.6, 7 + 0.3, 0.3)
bins_y = np.arange(12, 58 + 3, 3)
plt.hist2d(data = fuel_econ, x = 'displ', y = 'comb', cmin = 0.5,
            cmap = 'viridis_r', bins = [
                bins_x, bins_y])

plt.colorbar()
plt.xlabel('Displacement (l)')
plt.ylabel('Combined Fuel Eff. (mpg)')
# See Figure 18
```

Not all inclusive, but to cover a major base, let's use a scatter plot for a continuous quantitative variable vs. a continuous quantitative variable.

```
sb.regplot(data = fuel_econ, x = 'city', y = 'highway',
            scatter_kws = {'alpha' : 1/20})
# See Figure 19
```

Next up is pairing categorical data with quantitative data. There are two useful tools, which seem very similar, but can help tell different stories.

- violin plot
- box plot

One of the main differences between the two is that violin plots are wider where the data is more concentrated, which can be useful to see if data has more than one area of concentration (multimodal). Box plots shouldn't be down played. They are strong in placing emphasis on the interquartile range, and are known to be more simplistic and focused. Let's take a look!

```
# Violin Plots
sb.violinplot(data = fuel_econ, x = 'VClass', y = 'comb', color =
              base_color, inner = None)

plt.xticks(rotation = 15)
# See Figure 20
```

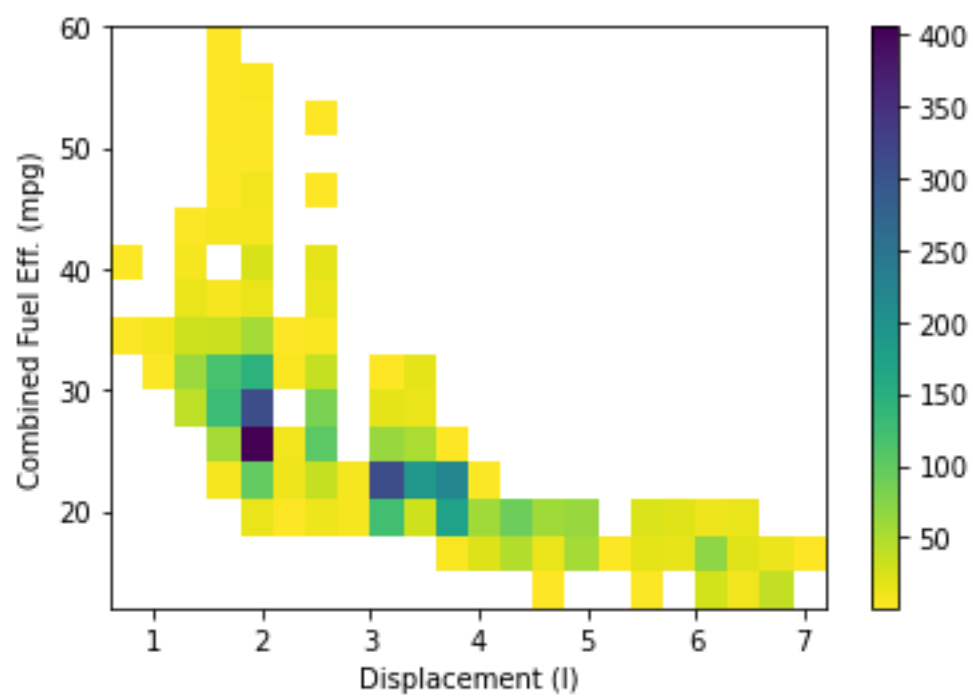


Figure 18: Basic Heat Map.

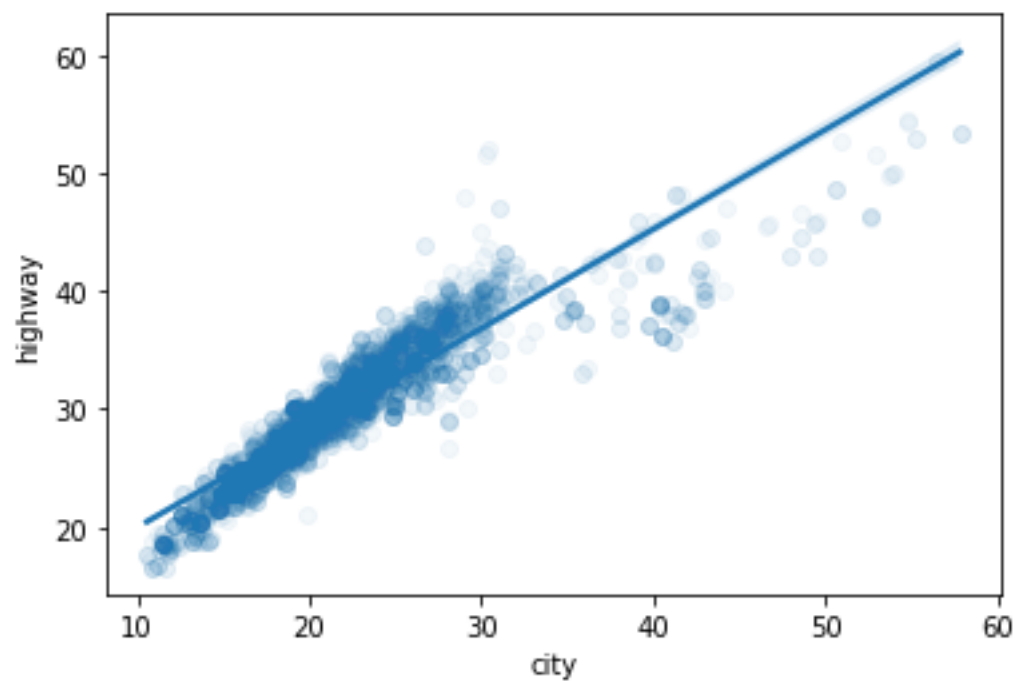


Figure 19: City vs. Highway Scatter Plot.



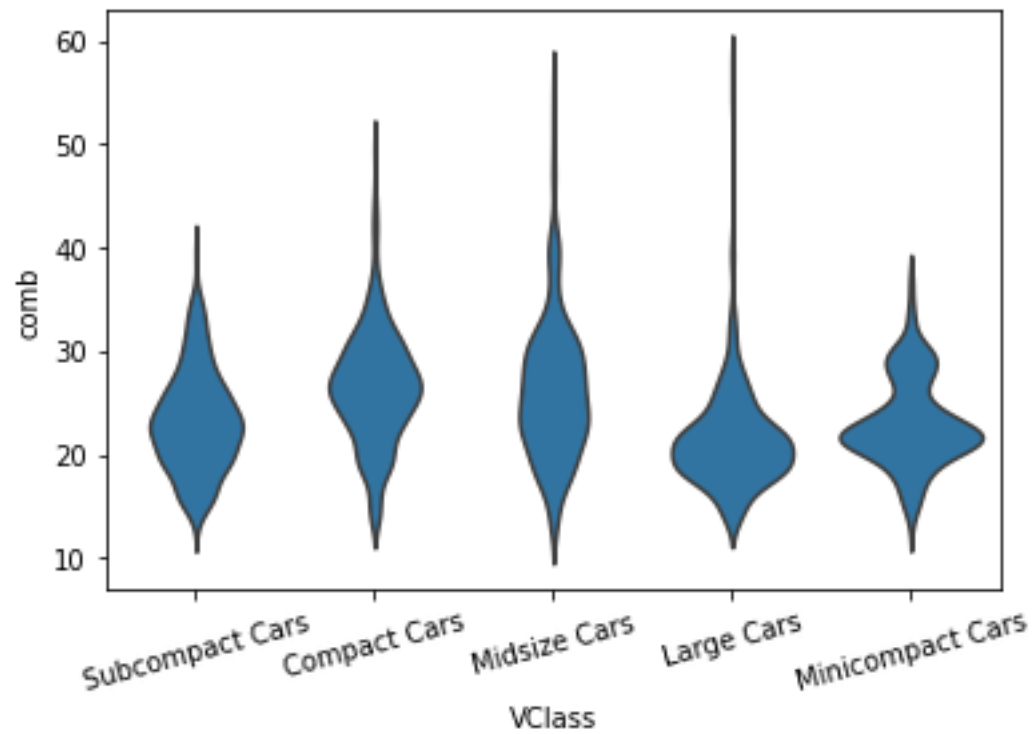


Figure 20: Basic Violin Plot.

```
# Box Plots (simplicity + focus, as compared to the violin plot)
sb.boxplot(data = fuel_econ, x = 'VClass', y = 'comb', color =
            base_color)

plt.xticks(rotation = 15)
# See Figure 21
```

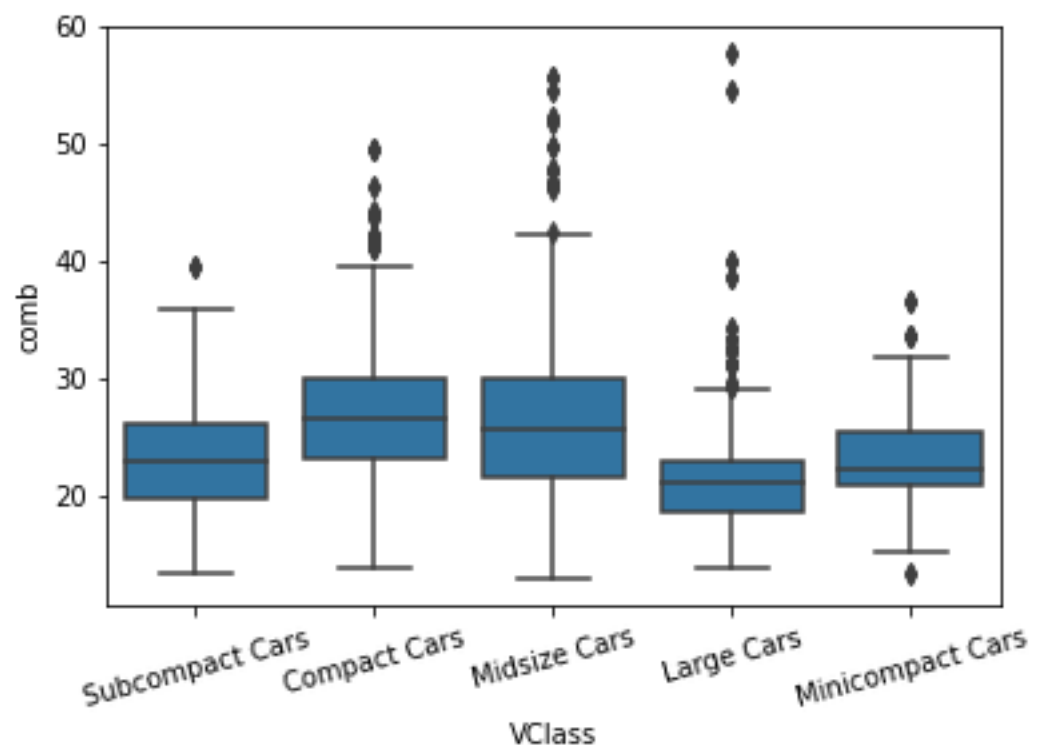


Figure 21: Basic Box Plot.

A quick aside:

It should absolutely be noted that with the prior, current and future plots illustrated, there are a plethora of options with each command. How should we handle the outliers? Can we transpose the IQR onto a violin plot? How can we focus on these specific data points? It's highly recommended to at least scan through at least some of the library and function documentation.

Probably the simplest, yet valuable, plot yet is a clustered bar chart. This takes our bar chart plot from the univariate exploration section, and simply adds more bars. These can be either different categories, or can be aspects of the same category.

For a quick example of a clustered bar chart, we'll continue on with our examination of Vehicle Class ('VClass'). As shown in the violin and box plots, there are 5 different types of vehicles in the dataset. However, we can break down the types of vehicles into subsets based on their transmission types (Automatic vs. Manual).

```
# a bit of data cleaning: just need auto vs. manual from the
                           strings
fuel_econ['trans_type'] = fuel_econ['trans'].apply(lambda x: x.
                                                    split()[0])
sb.countplot(data = fuel_econ, x = 'VClass', hue = 'trans_type')
plt.xticks(rotation = 15)
# See Figure 22
```

Let's do another example of a clustered bar chart that puts together different aspects. In this example, we want to investigate the difference between the two main fuel types (regular and premium) by vehicle class.

```
fuel_econ_subset = fuel_econ.loc[fuel_econ['fuelType'].isin(['
    Premium Gasoline', 'Regular
    Gasoline'])]
sb.countplot(data = fuel_econ_subset, y = 'VClass', hue = '
    fuelType')
# See Figure 23
```

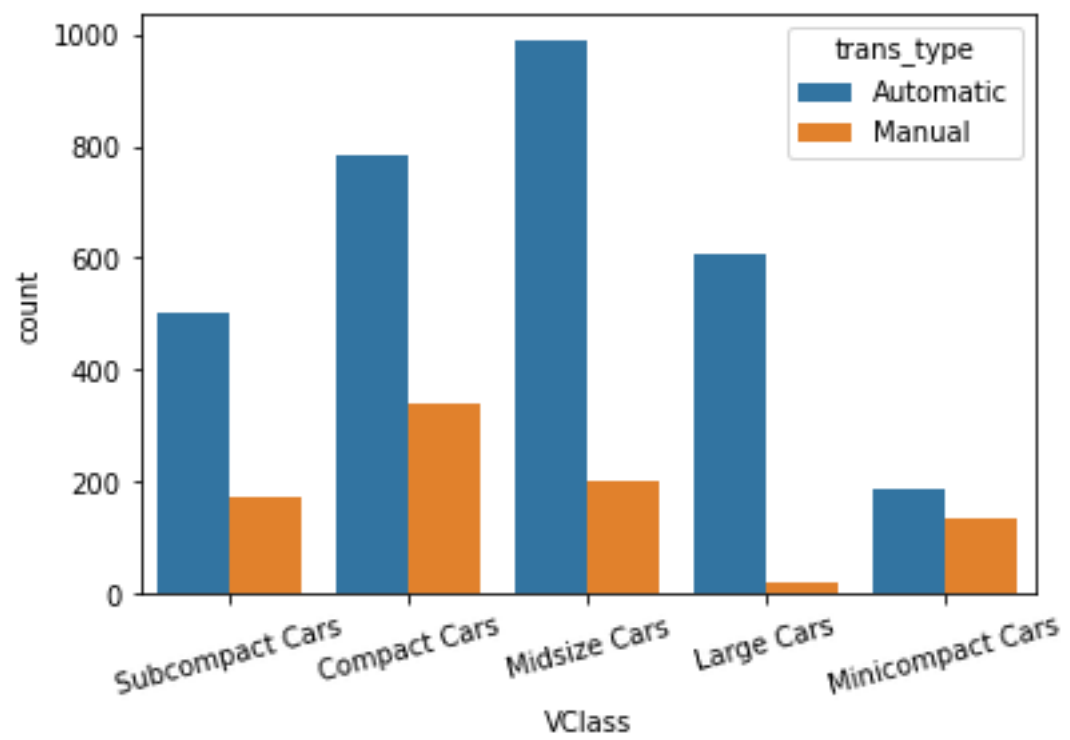


Figure 22: Vertical Clustered Bar Chart.

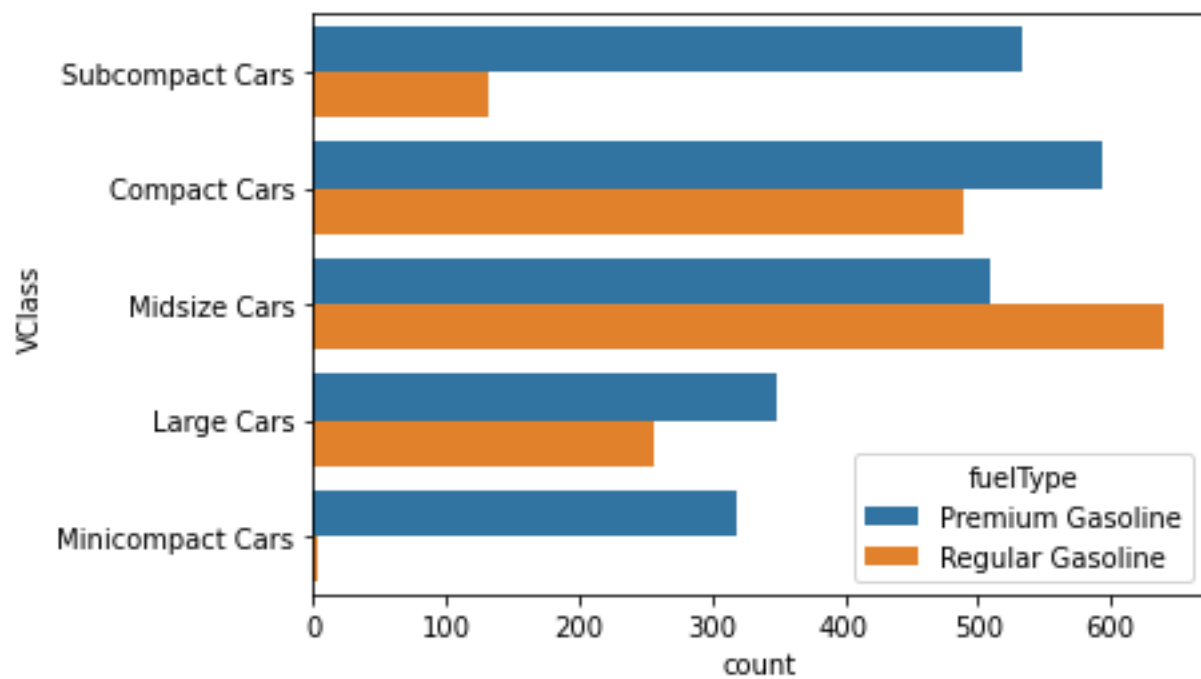


Figure 23: Vertical Clustered Bar Chart.

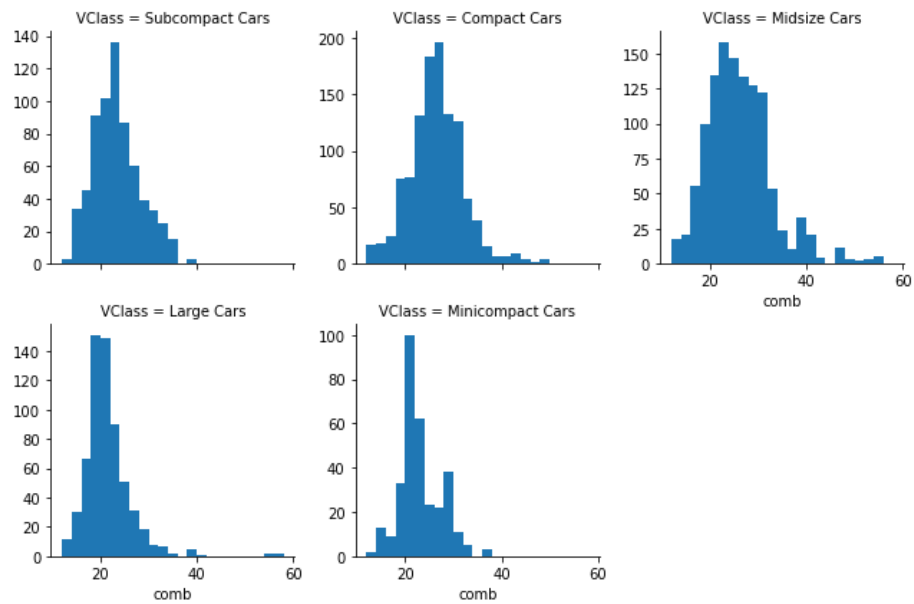


Figure 24: Vehicle Class Fuel Efficiency Facets.

With even more plotting techniques in our visualization toolbox, what happens when it seems sensible to test many different variations of a similar plot against the data, can we avoid creating a single plot at a time? Enter faceting, creating side by side series of plots containing subsets of the data.

For an example, let's create a plot for every type of vehicle paired with combined efficiency.

```
bins = np.arange(12, 58 + 2, 2)
g = sb.FacetGrid(data = fuel_econ, col = 'VClass', col_wrap = 3,
                 sharey = False)
g.map(plt.hist, 'comb', bins = bins)
# See Figure 24
```

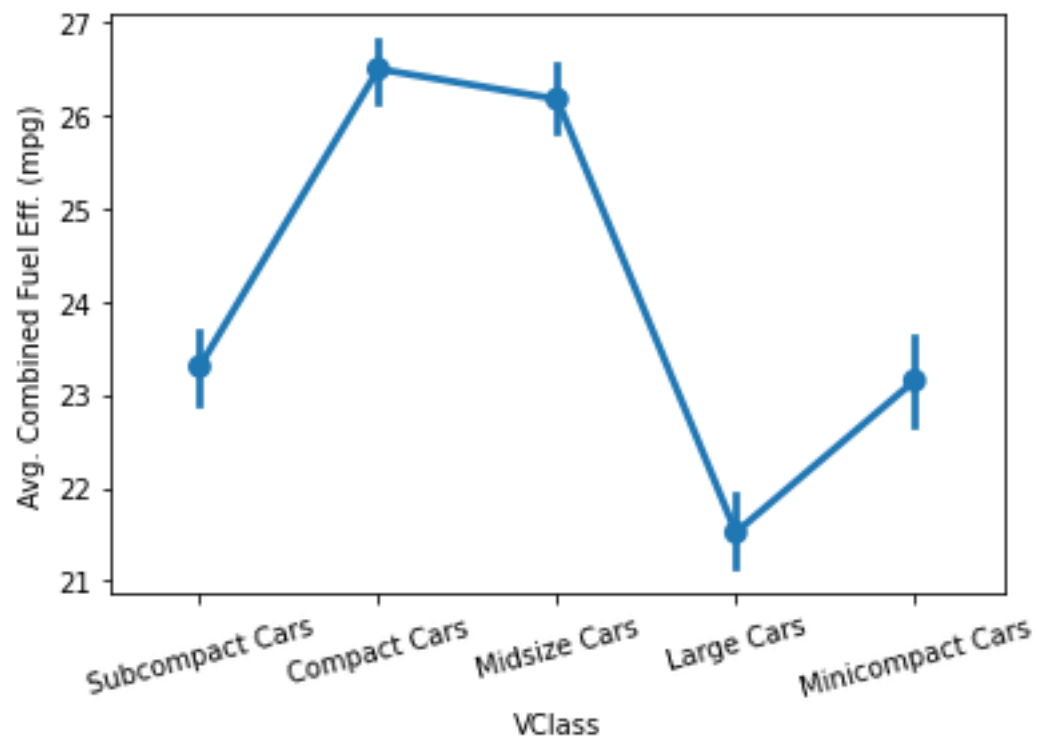


Figure 25: Line Plot.

One last plot to show for this section is a line plot, which shows a point estimate along with a confidence interval while comparing categorical variables with quantitative data.

```
sb.pointplot(data = fuel_econ, x = 'VClass', y = 'comb')
plt.xticks(rotation = 15)
plt.ylabel('Avg. Combined Fuel Eff. (mpg)')
# See Figure 25
```

- 3.3 Multivariate Exploration of Data
- 4 Explanatory Visualizations
- 5 Visualization Case Study