Data Visualization with Plotnine

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Introduction

Hi! My name is Julia, and I am a Senior double majoring in Statistical Data Science and Economics. I'm excited to show you the power of data visualization with `Plotnine`, a Python library inspired by R's `ggplot2`. Visualization is a crucial tool to effectively communicate your findings to your audience and `Plotnine` is a useful library to use.

What is `Plotnine`?

`Plotnine` uses grammer of graphics to create layered, customizable visualizations. Grammar of graphics is a framework that provides a systematic approach to creating visual representations of data by breaking down the plot into its fundamental components. To understand this better, think about how sentences have grammer, we can layer our graphics to create complex and detailed visulizations.

Components of the layered grammar of graphics:

- **Layer:** used to create the objects on a plot
- **Data:** defines the source of the information to be visualized
- **Mapping:** defines how the variables are represented in the plot
- **Statistical transformation (stat):** transforms the data, generally by summarizing the information
- **Geometric object (geom):** determines the type of plot type (e.g., points, lines, bars)
- **Position adjustment (position):** adjusts the display of overlapping points to improve clarity
- **Scale:** controls how values are mapped to aesthetic attributes (e.g., color, size)
- **Coordinate system (coord):** maps the position of objects onto the plane of the plot, and controls how the axes and grid lines are drawn
- **Faceting (facet):** used to split the data up into subsets of the entire dataset

You can make a wide array of different graphics with `Plotnine`. Some common examples are:

- Scatterplot `geom_point()`
- Bar Chart `geom_bar()`
- Histogram `geom_histogram()`
- Line Chart `geom_line()`

Installing Plotnine

To use `Plotnine` you must install it into your venv first. The instructions are as follows:

Type this command into either conda, your terminal, gitbash, or whatever you use for package install for your venv.

For **pip:**

```
pip install plotnine
```

For **conda:**

```
conda install -c conda-forge plotnine
```

You can import `Plotnine` without a prefix:

```
from plotnine import *
```

Or with with a prefix to access each component such as:

```
import plotnine as p9
```

This way is generally recommended for larger projects or when collaborating with others for better code maintainability. But for simplicity in this section I will use the first method.

For the examples we will be using NYC open data to visualize motor vehicle crashes from the week of June 30, 2024.

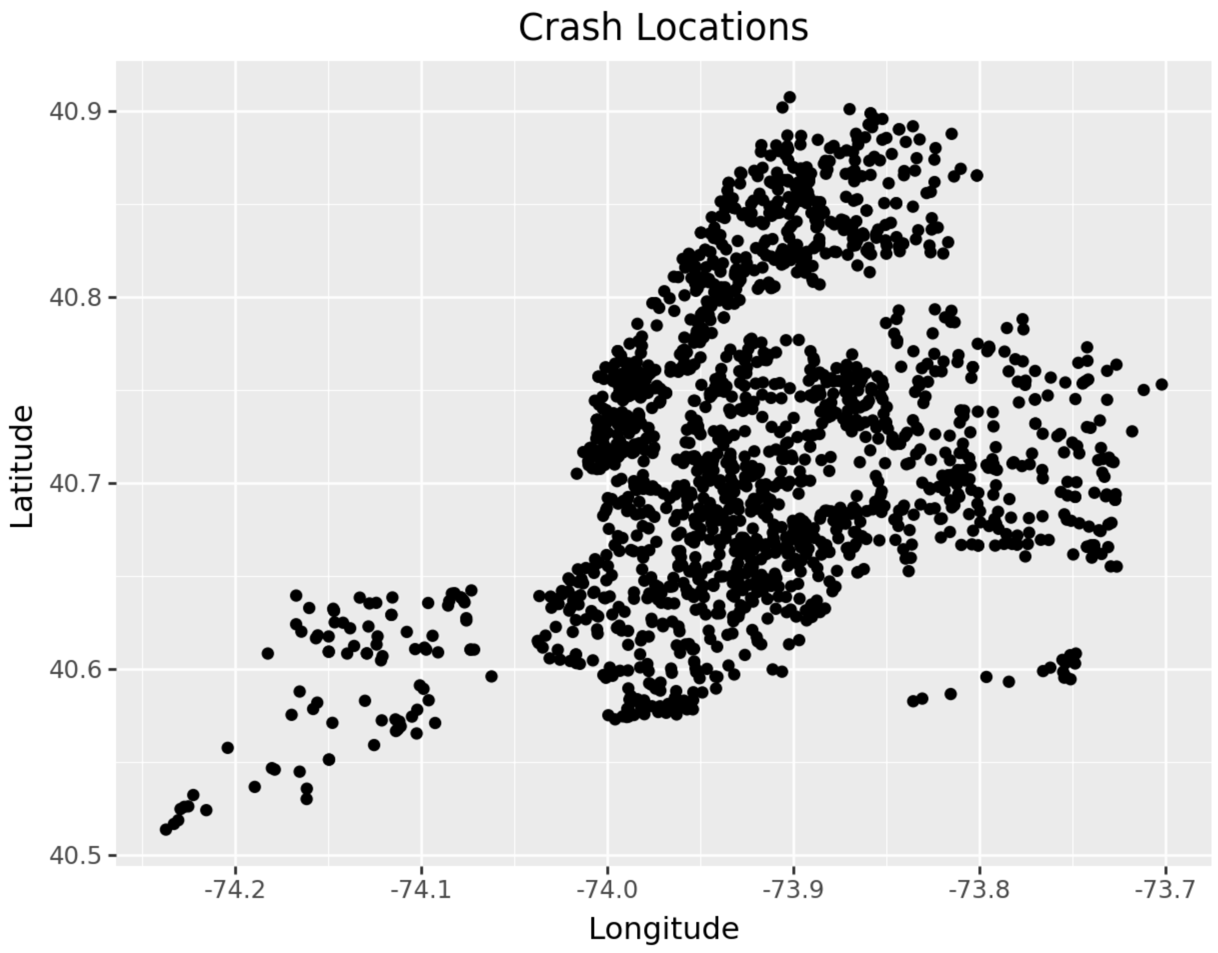
```
import pandas as pd

nyc_crash = pd.read_feather('nyccrashes_cleaned.feather').dropna(subset=['borough'])
```

Scatterplot

Firstly, we will be creating a scatterplot. This can be done with `geom_point()`. Our scatterplot will be displaying Crash Locations based on the longitude and latitude of the crash sites.

Creating a Basic Scatterplot

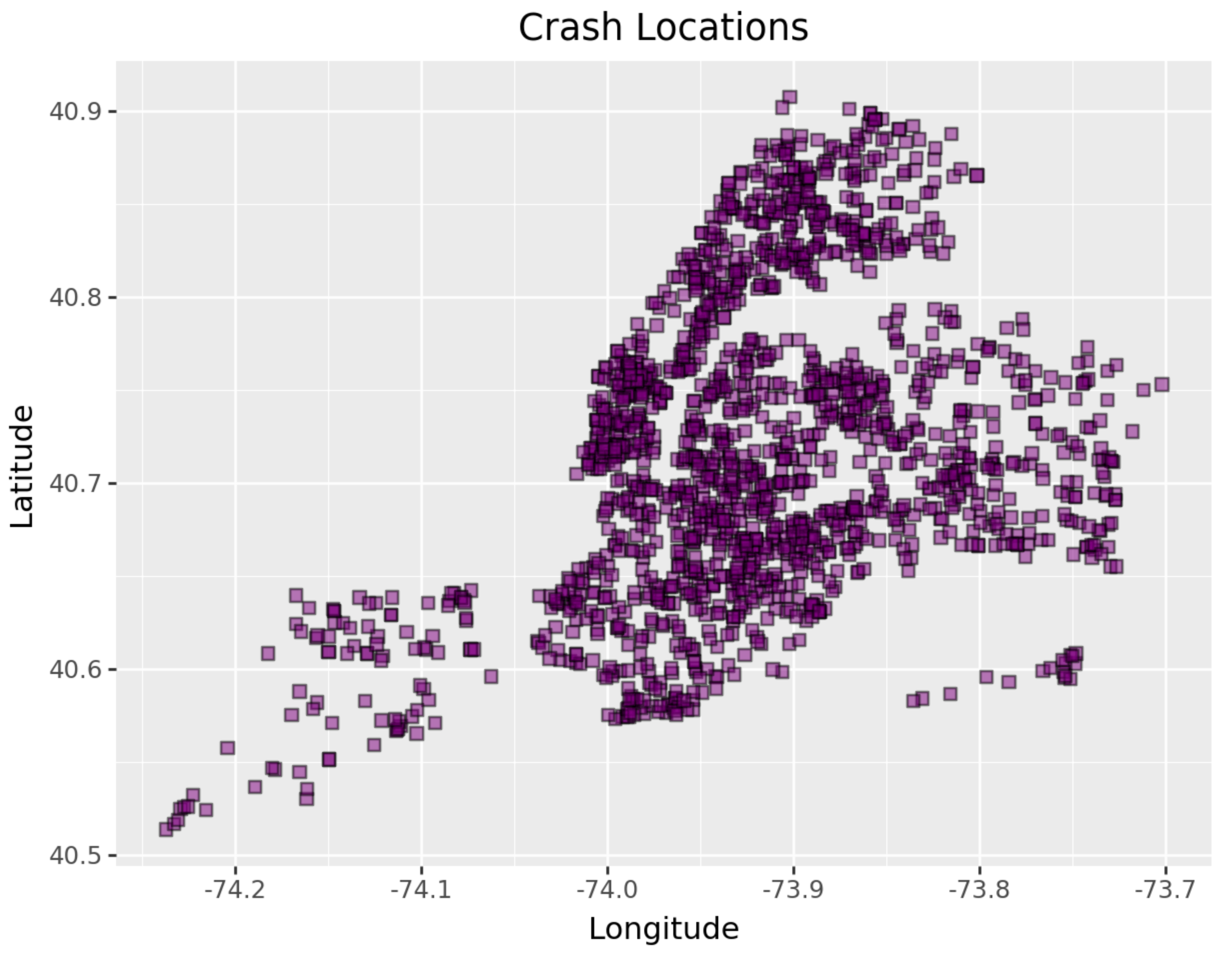
```
import warnings
warnings.filterwarnings("ignore", category=UserWarning)

(ggplot(nyc_crash, aes(x='longitude', y='latitude')) +
# Specifies graph type
    geom_point() +
# Creates labels for graphic
    labs(title='Crash Locations',
         x='Longitude',
         y='Latitude') +
# Because we are plotting maps we want 1:1 ratio
# coord_fixed(): changes the ratio of the x and y axis
    coord_fixed(ratio = 1))
```



Customizing a Scatterplot

You can customize your plot further by changing the color, edge color, transparency, size, or shape of your points. This is done in geom_point().

```python
(ggplot(nyc_crash, aes(x='longitude', y='latitude')) +
# Changes what our points look like
# color= changes the outline color
# fill= changes the fill color
# alpha= changes transparency
# size= changes size
# shape= chanegs shape (s = square)
    geom_point(color = 'black', fill = 'purple',
        alpha = 0.5, size = 2, shape = 's') +
    labs(title='Crash Locations',
         x='Longitude',
         y='Latitude') +
    coord_fixed(ratio = 1))
```



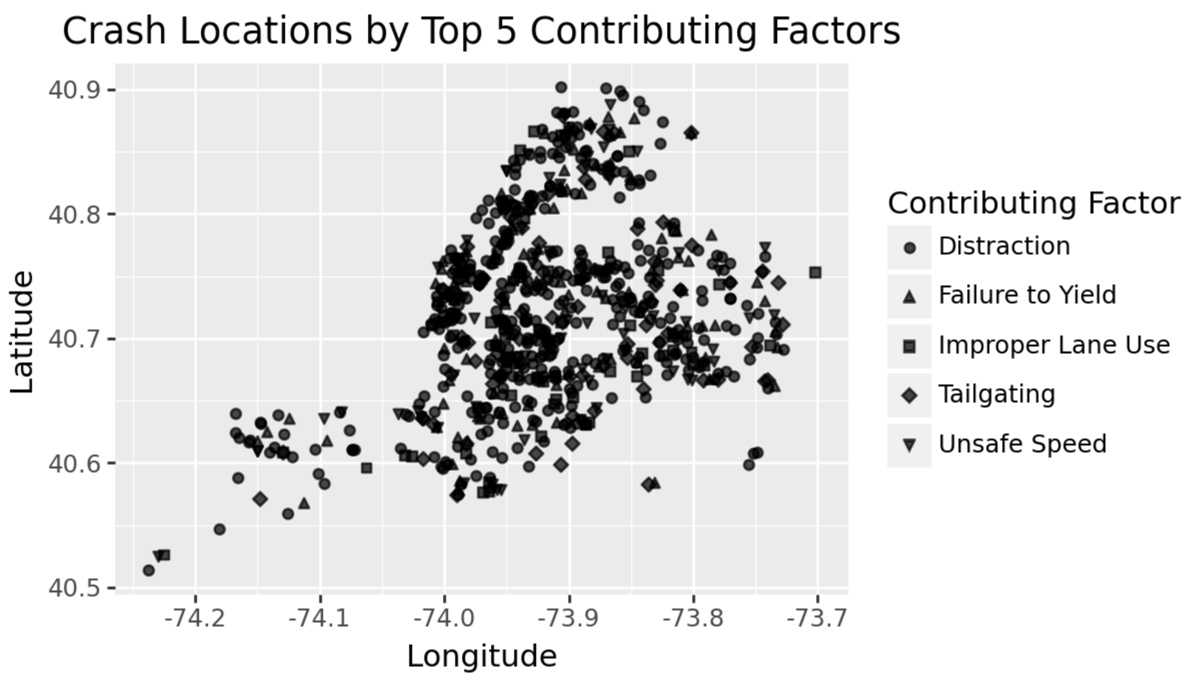
This scatterplot provides a lot of information, yet there are ways we can customize our plot to be more informative for our audience. We can create a scatterplot that differentiates by contributing factor.

Changing Shape by Variables

Changing shape of points by `contributing_factor_vehicle_1`:

```
# List of top 5 reasons for the contributing facor
# Abbreviating names for clairity
factor1 = {"Driver Inattention/Distraction": "Distraction",
           "Failure to Yield Right-of-Way": "Failure to Yield",
           "Following Too Closely": "Tailgating",
           "Unsafe Speed": "Unsafe Speed",
           "Passing or Lane Usage Improper": "Improper Lane Use"}

# Filter the data to only include valid contributing factors
confact = nyc_crash.loc[nyc_crash['contributing_factor_vehicle_1'].isin(factor1)].copy()

# Change to shortened names for better visability
confact.loc[:, 'contributing_factor_vehicle_1'] = confact[
                                                    'contributing_factor_vehicle_1'
                                                    ].replace(factor1)
```

```
# Changes shape of point according to 'contributing_factor_vehicle_1'
(ggplot(confact, aes(x='longitude', y='latitude',
    shape ='contributing_factor_vehicle_1')) +
    geom_point(alpha = 0.7) +
    labs(title='Crash Locations by Top 5 Contributing Factors',
        x='Longitude',
        y='Latitude',
        shape = 'Contributing Factor',
        color= 'Contributing Factor') +
    coord_fixed(ratio = 1) +
    theme(figure_size = (6,5)))
```

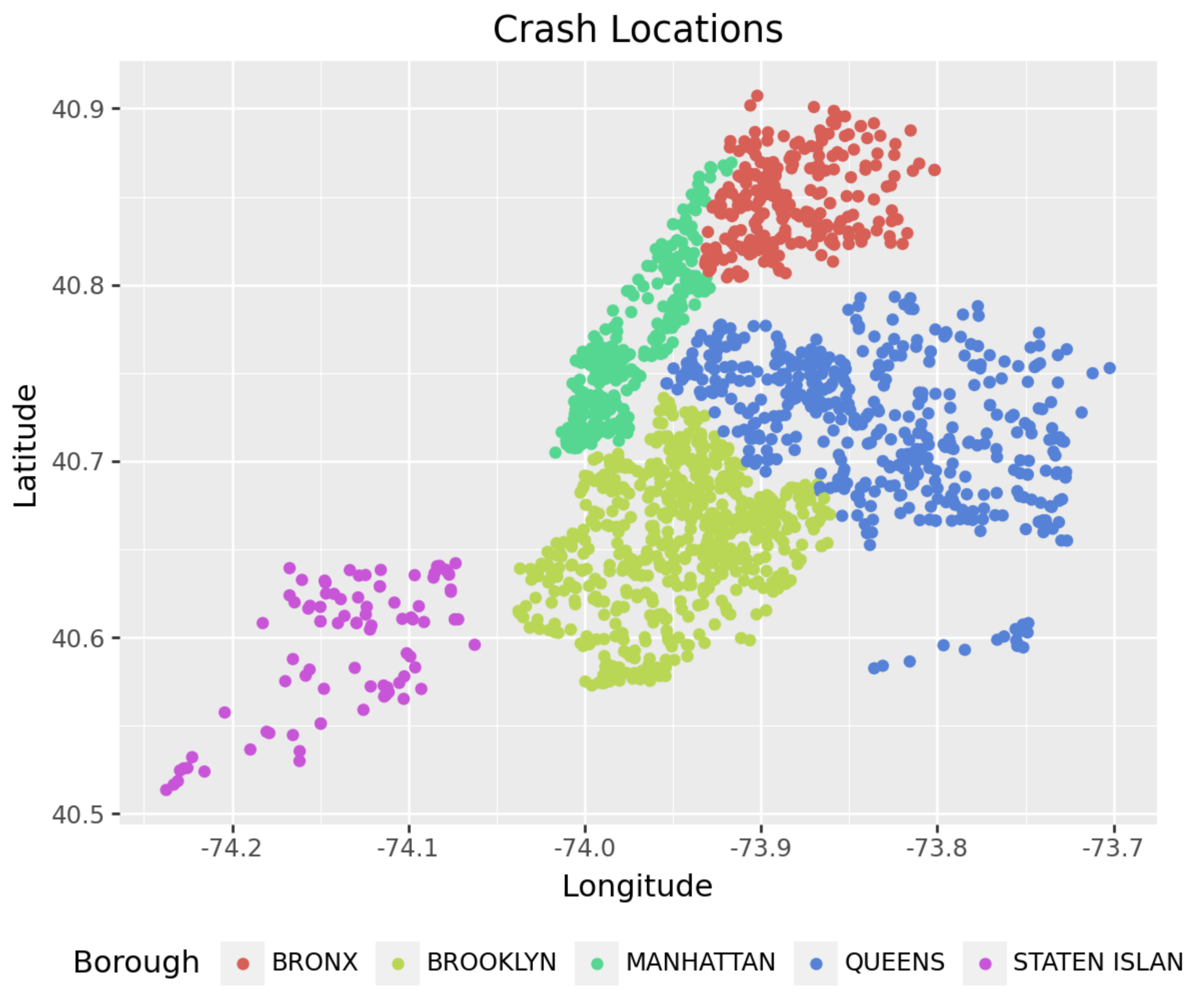


Changing Color by Variables

To add color coordination to your plot in `Plotnine`, specify the variable you want to use for coloring by including `color='variable'` within the `aes()` function. This enables you to visually distinguish different categories in your dataset, enhancing the clarity and interpretability of your plot.

Changing color of point according to borough:

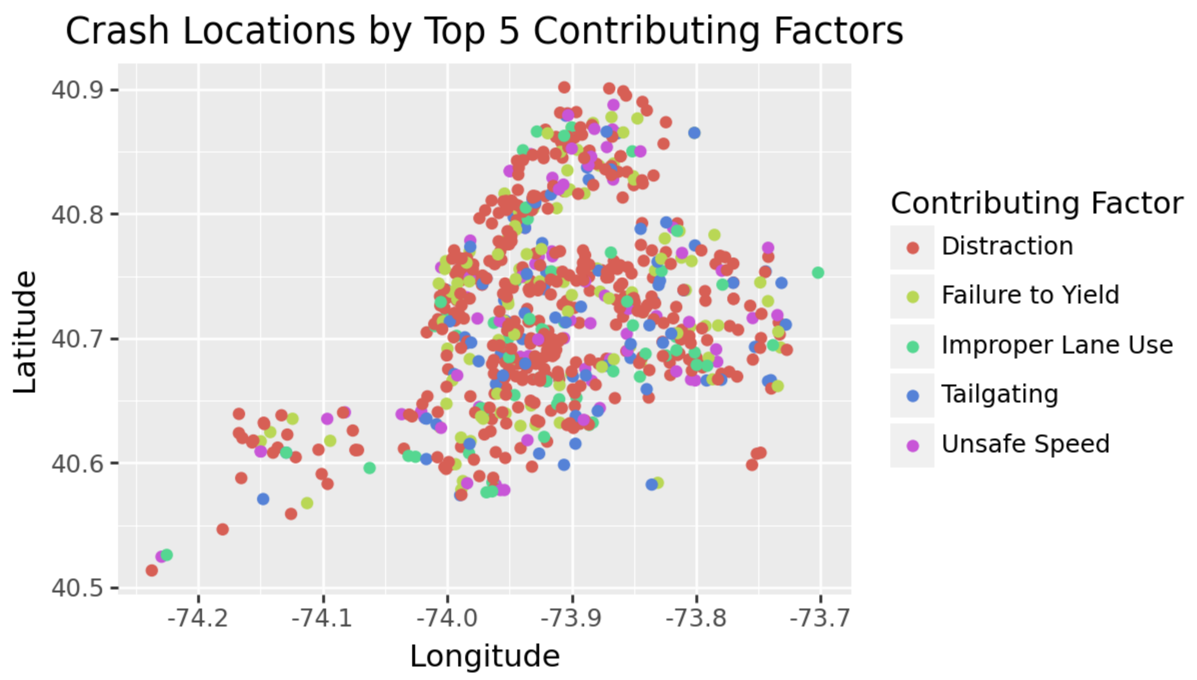
```
# color= changhes color according to 'borough'
(ggplot(nyc_crash, aes(x='longitude', y='latitude', color = 'borough')) +
    geom_point() +
    labs(title='Crash Locations',
        x='Longitude',
        y='Latitude',
# Changes key title to 'Borough'
        color= 'Borough') +
    coord_fixed(ratio = 1) +
# legend_position= changes where the legend is located
    theme(figure_size = (6,5), legend_position='bottom'))
```



As you can see, each borough is represented by its own color, allowing the audience to easily identify which borough the crash occurred in.

Changing color of points by `contributing_factor_vehicle_1`:

```
# color= changes color according to 'contributing_factor_vehicle_1'
(ggplot(confact, aes(x='longitude', y='latitude',
    color ='contributing_factor_vehicle_1')) +
    geom_point() +
    labs(title='Crash Locations by Top 5 Contributing Factors',
        x='Longitude',
        y='Latitude',
        color= 'Contributing Factor') +
        coord_fixed(ratio = 1) +
# Changes plot size to be larger
    theme(figure_size = (6,5)))
```



This graph uses color to distinguish what contributing factor caused the crash.

Adding Linear Regression Line to Plot

If you want to fit a linear regression line, use `geom_smooth()`. Adding this to your plot can be really helpful to visualize trends of your data easier. To add a linear regression line to your scatterplot, you would include the following line of code:

```
geom_smooth(method='lm', se=False, color='red')
```

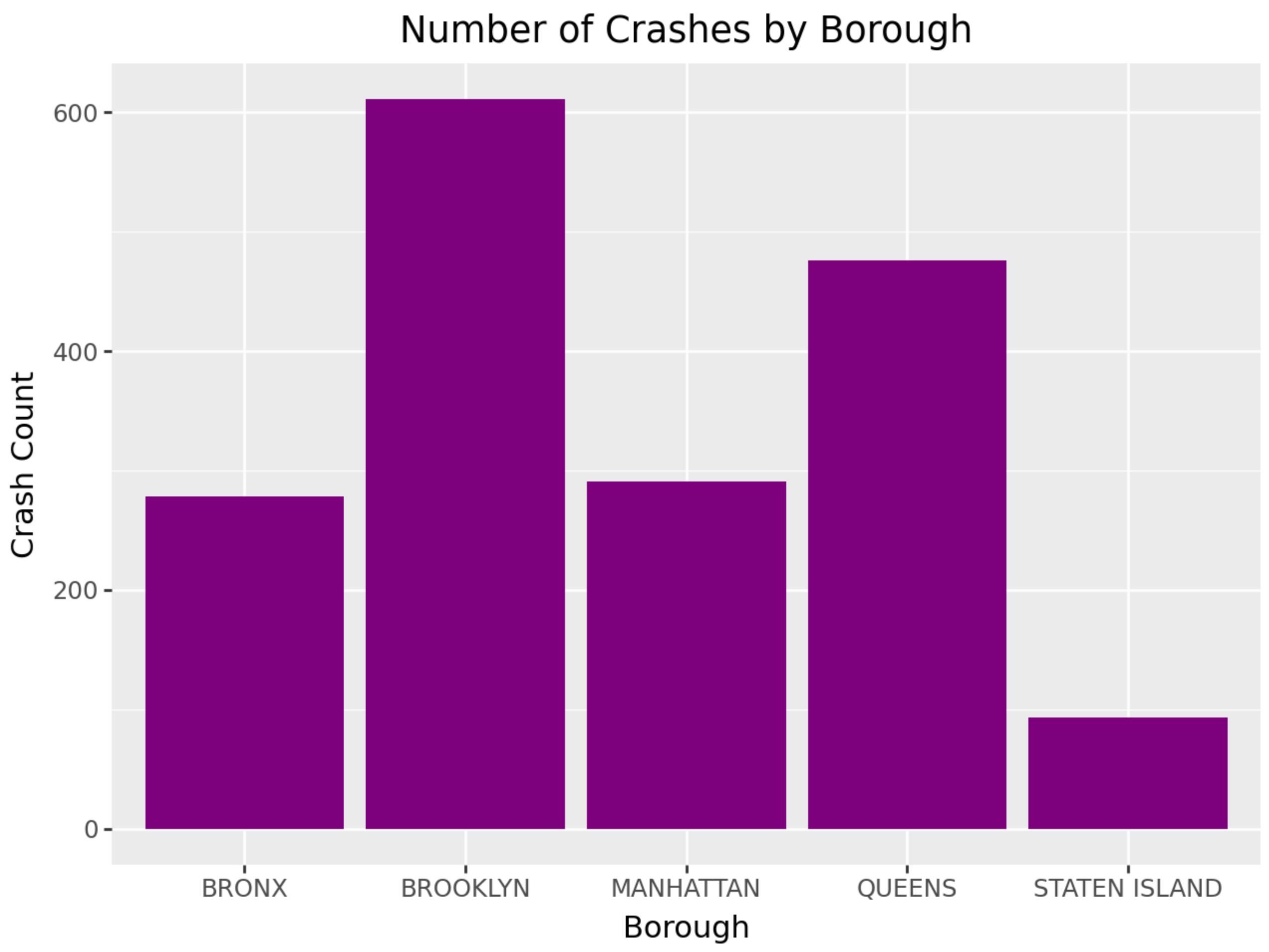
```
<plotnine.geoms.geom_smooth.geom_smooth at 0x2459a743800>
```

Bar Chart

Another common use for displaying data is a bar chart. You can create one with `geom_bar()`. We will start with a simple chart of crashes by borough.

Creating a Basic Bar Chart

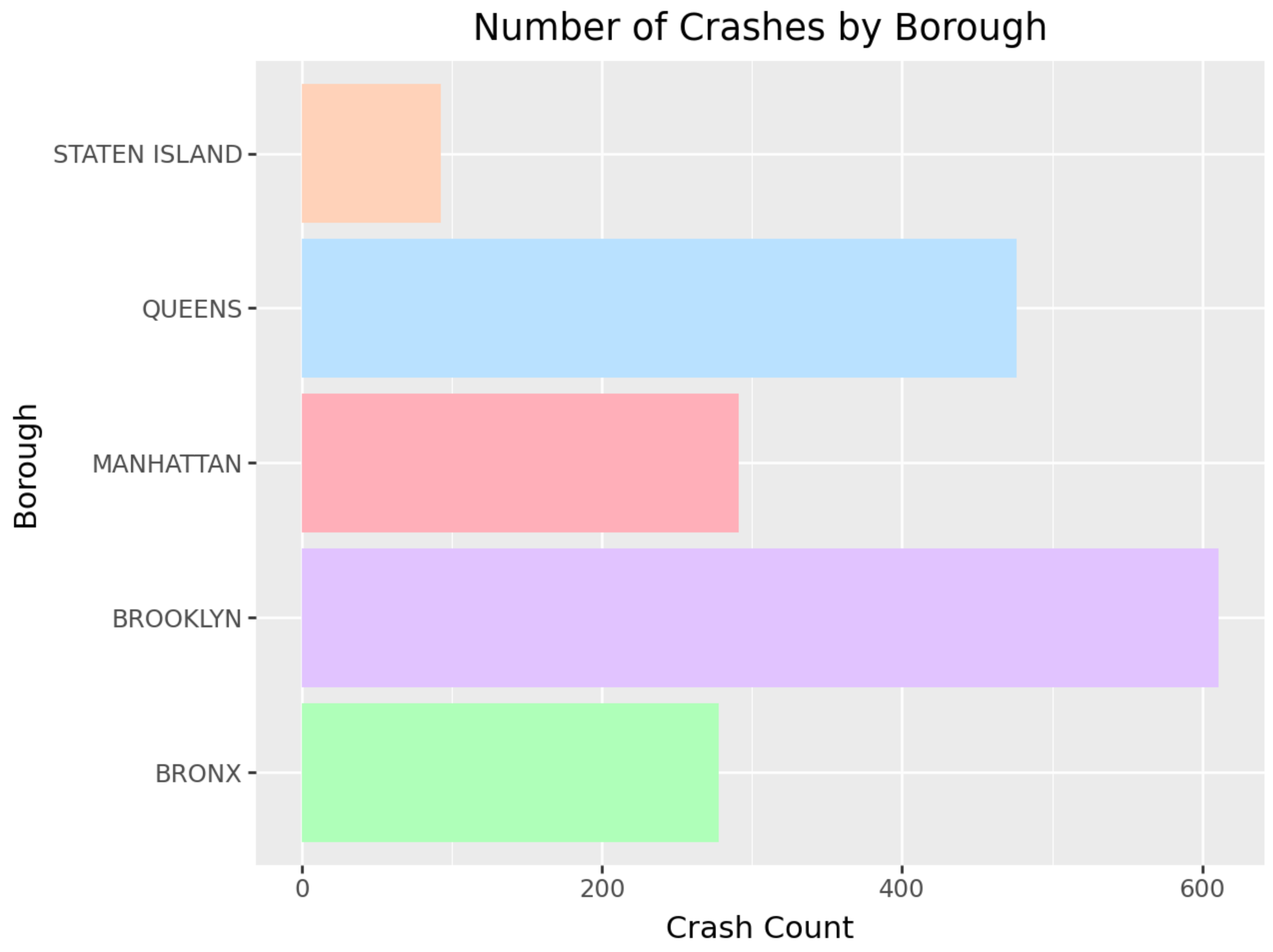
```
(ggplot(nyc_crash, aes(x='borough')) + # Use 'borough' for the x-axis
    geom_bar(fill='purple') +
    labs(title='Number of Crashes by Borough',
        x='Borough',
        y='Crash Count'))
```



Customizing your Bar Chart

You can change up your bar chart a couple of different ways. You can handpick colors you want, designate it to variables, flip orientation, etc:

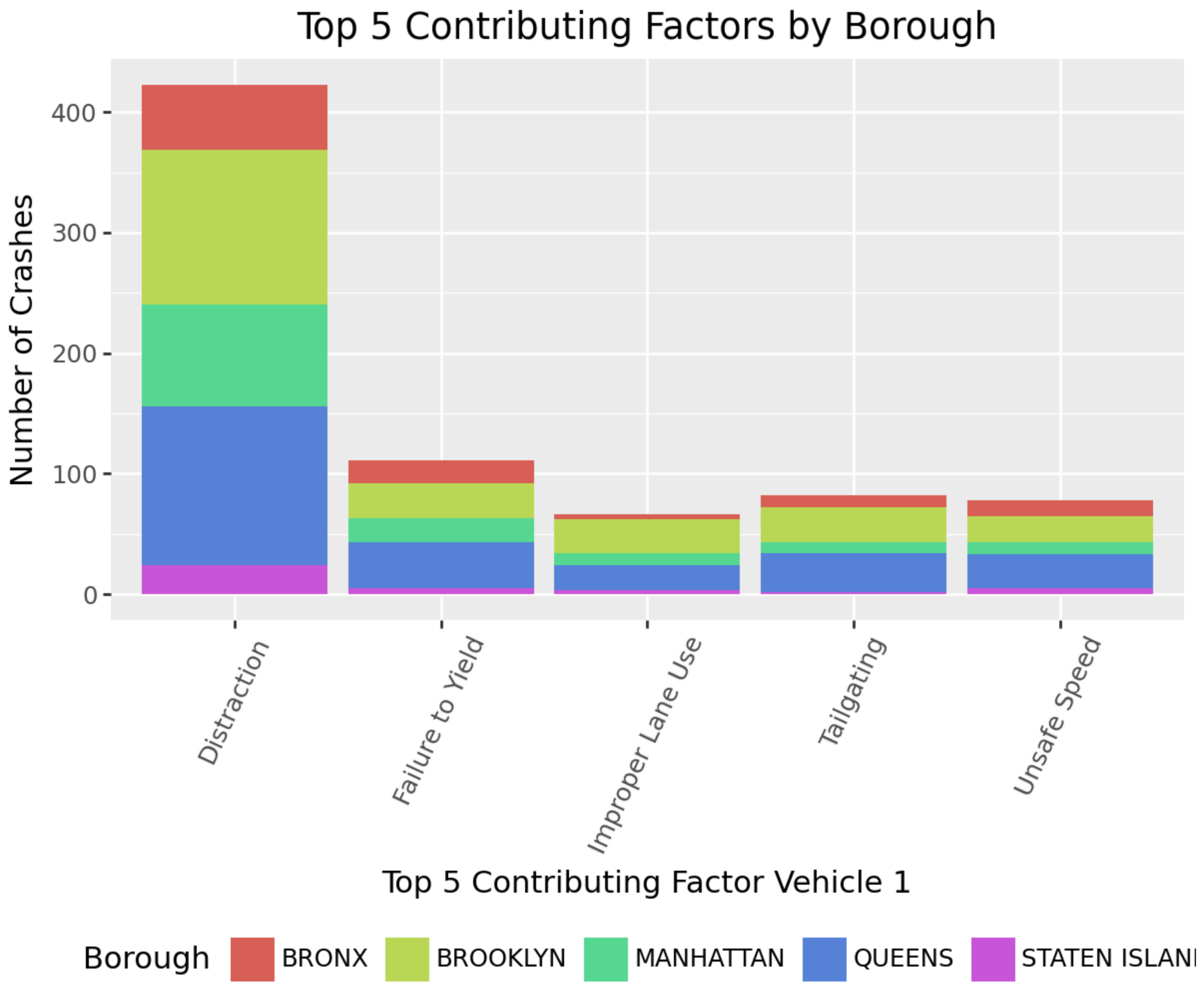
```
# Designate your preffered colors (pastel color codes)
colors = ['#B3FFBA', '#E1C6FF', '#FFB3BA', '#BAE1FF', '#FFD5BA']

# Adding fill= changes the color of bar according to variable
(ggplot(nyc_crash, aes(x='borough', fill = 'borough')) +
# Assigns your preffered colors
   geom_bar(fill = colors) +
# Flips orientation of the chart
   coord_flip() +
   labs(title='Number of Crashes by Borough',
        x='Borough',
        y='Crash Count'))
```



Multivariable Bar Chart

You can also split up a bar chart to make it visually easier to understand.

```
# Using 'confact' dataset again for better visualization
(ggplot(confact, aes(x='contributing_factor_vehicle_1', fill='borough')) +
    geom_bar() +
    labs(title='Top 5 Contributing Factors by Borough',
        x='Top 5 Contributing Factor Vehicle 1',
        y='Number of Crashes',
# Changes key name to "Borough"
        fill ='Borough') +
# size= creates smaller text
# angle= rotates x-axis text for readability
# figure_size= creates a larger image
    theme(axis_text_x=element_text(size=9, angle=65),
            figure_size= (6,5), legend_position='bottom'))
```

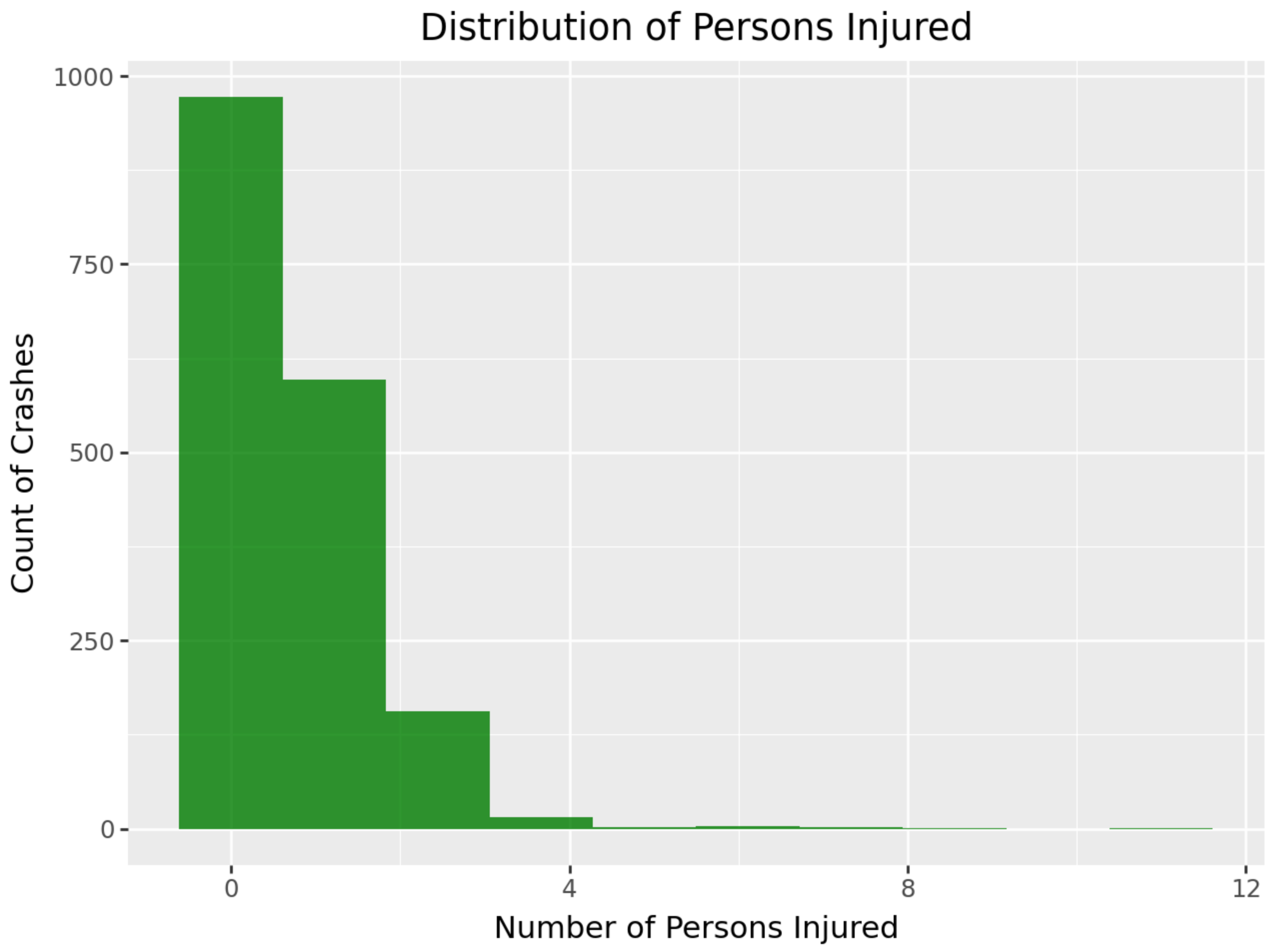


Histogram

Another useful way to display data is a histogram. You can create one with `geom_hisogram()`. Using a histogram is very useful when displaying continuous data.

Basic Histogram

```
(ggplot(nyc_crash, aes(x='number_of_persons_injured')) +
# bins= sets the amount of bars in your histogram
    geom_histogram(bins=10, alpha=0.8, fill='green') +
    labs(title='Distribution of Persons Injured',
        x='Number of Persons Injured',
        y='Count of Crashes'))
```

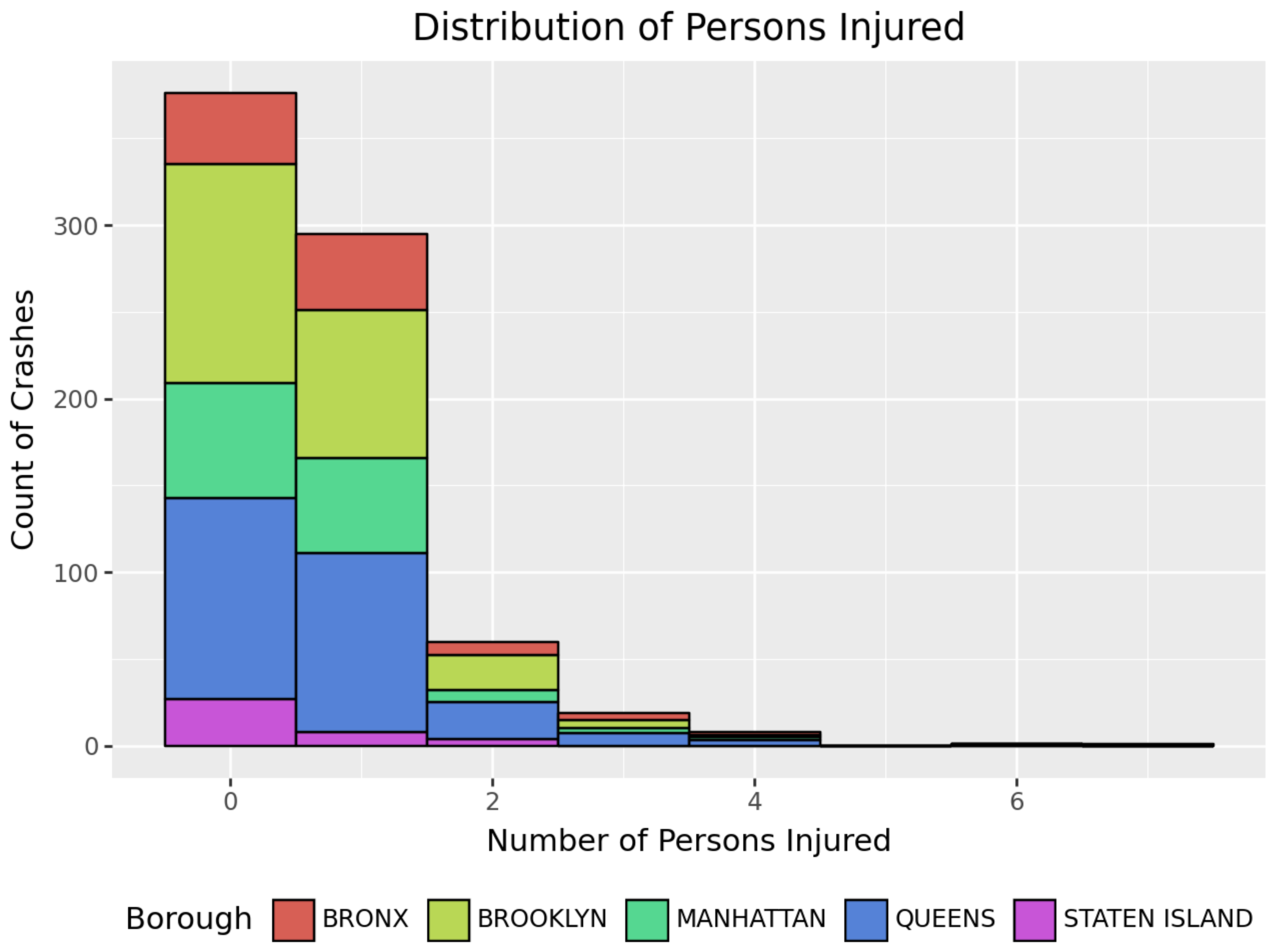


With a histogram it is very easy to understand trends for a dataset and you can see that our NYC crash data is positively skewed.

Multivariable Histogram

Similar to bar charts, you can make Histograms that display more than one variable.

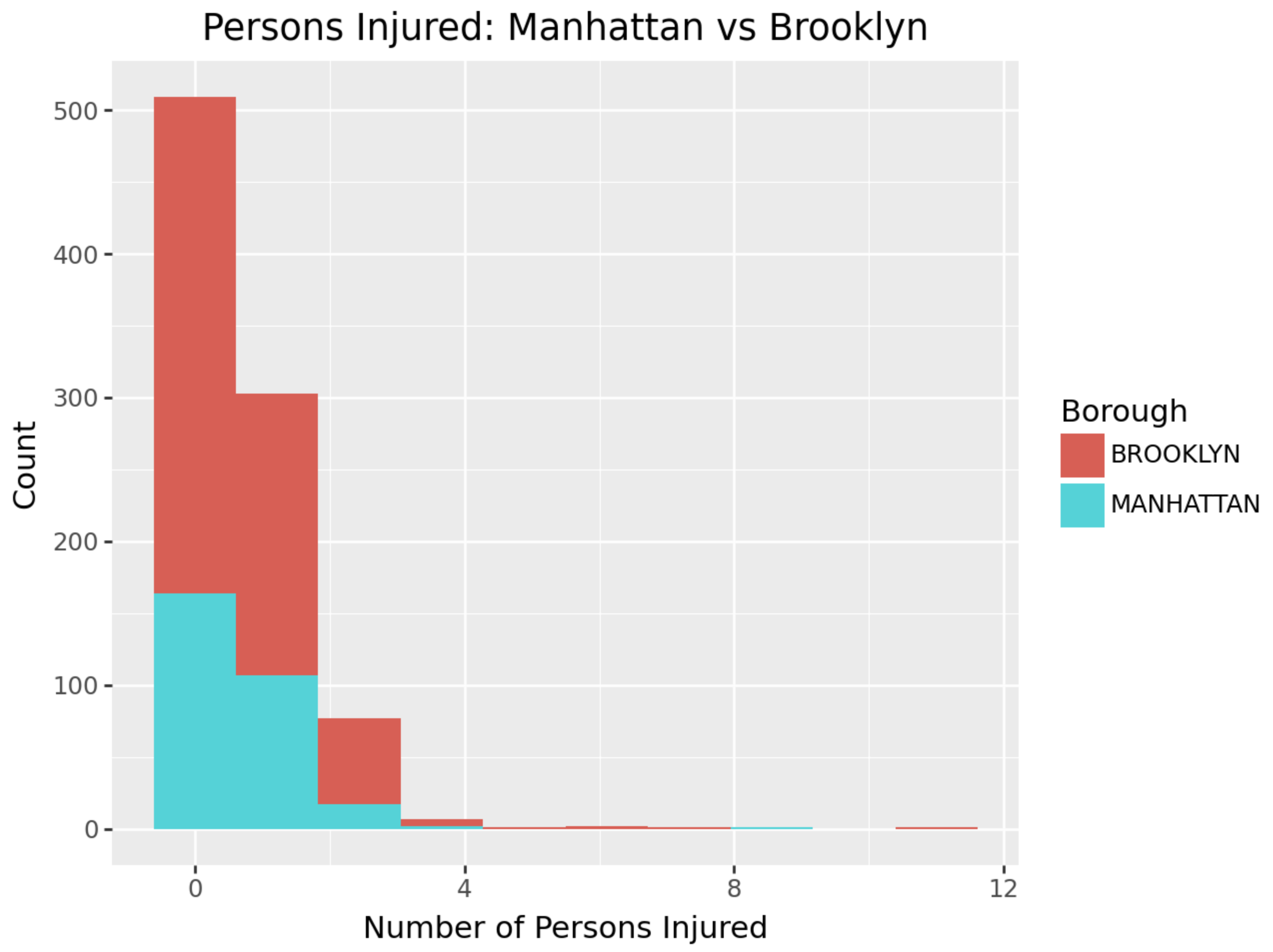
```
(ggplot(confact, aes(x='number_of_persons_injured', fill = 'borough')) +
# binwidth= changes width of your bars
# color= changes outline color for better visability
    geom_histogram(binwidth=1, color = 'black') +
    labs(title='Distribution of Persons Injured',
        x='Number of Persons Injured',
        y='Count of Crashes',
        fill = 'Borough') +
        theme(legend_position='bottom'))
```



Overlapping Histogram

Histograms can also be useful when comparing multiple categories. Here we are comparing Manhattan and Brooklyn’s number of persons injured with an overlapping histogram.

```
# Creating plot if crash is in 'MANHATTAN' or 'BROOKLYN'
(ggplot(nyc_crash[nyc_crash['borough'].isin(['MANHATTAN', 'BROOKLYN'])],
        aes(x='number_of_persons_injured', fill='borough')) +
    geom_histogram(bins=10) +
    labs(title='Persons Injured: Manhattan vs Brooklyn',
        x='Number of Persons Injured',
        y='Count',
        fill='Borough'))
```



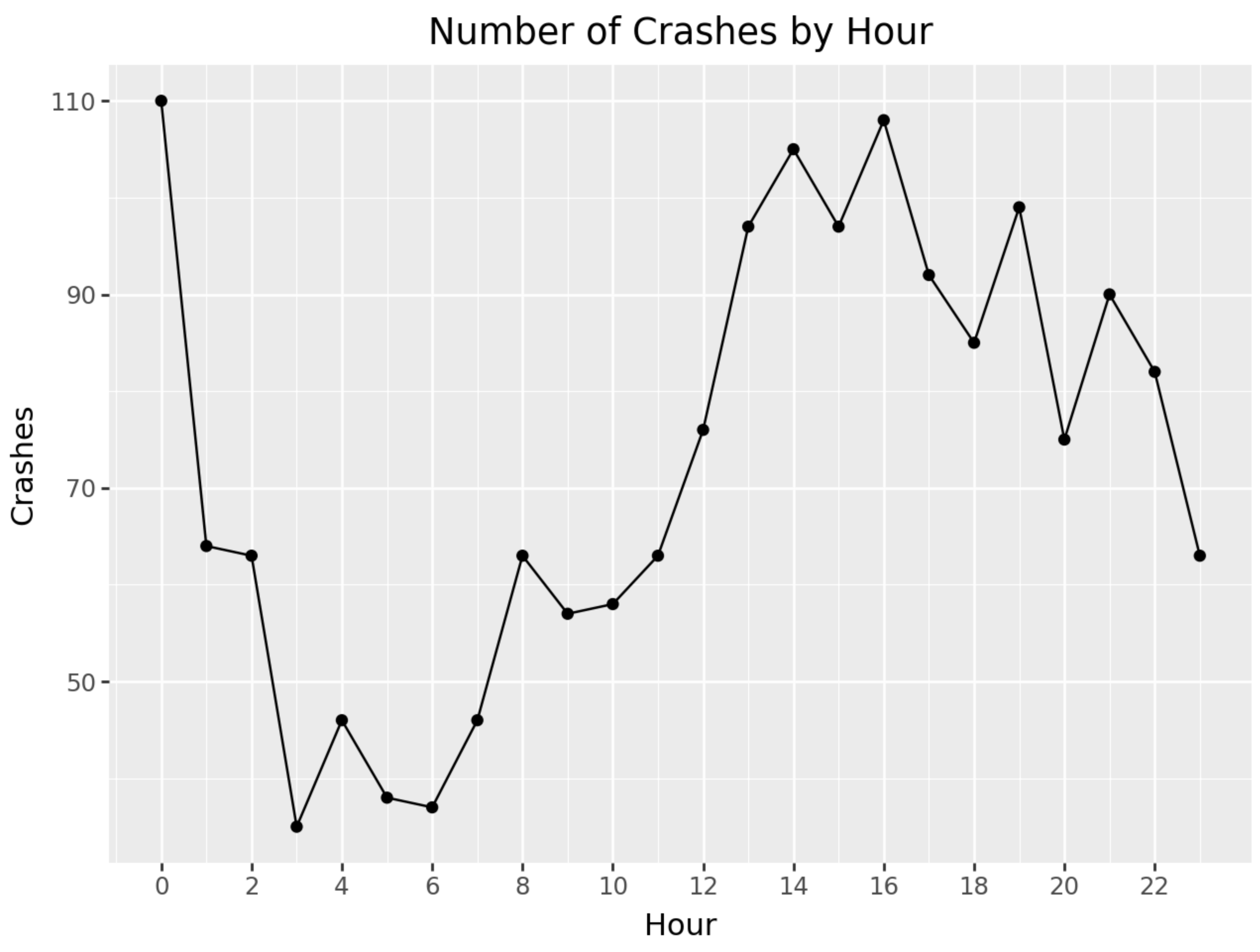
Line Chart

Line charts are great for time-series data and can be created with `geom_line()`. This type of chart is particularly useful for identifying patterns, fluctuations, and trends, making it easier to understand how a variable changes over a specified period. We will create one analyzing Number of Crashes by Hour.

Basic Line Chart

```
# Finding crashes per hour
nyc_crash['crash_datetime'] = pd.to_datetime(nyc_crash['crash_datetime'])

# Extract hour
nyc_crash['crash_hour'] = nyc_crash['crash_datetime'].dt.hour

# Count crashes per hour
crash_counts = (nyc_crash.groupby(['crash_hour'])
                .size().reset_index(name='crash_count'))
```

```
# Plot crashes by hour
(ggplot(crash_counts, aes(x='crash_hour', y='crash_count')) +
# Creates the line chart
    geom_line() +
# Adds points for better visibility
    geom_point() +
    labs(title='Number of Crashes by Hour',
        x='Hour',
        y='Crashes') +
# Formats the x-axis to display ticks by every 2 hours
    scale_x_continuous(breaks=range(0, 24, 2)))
```

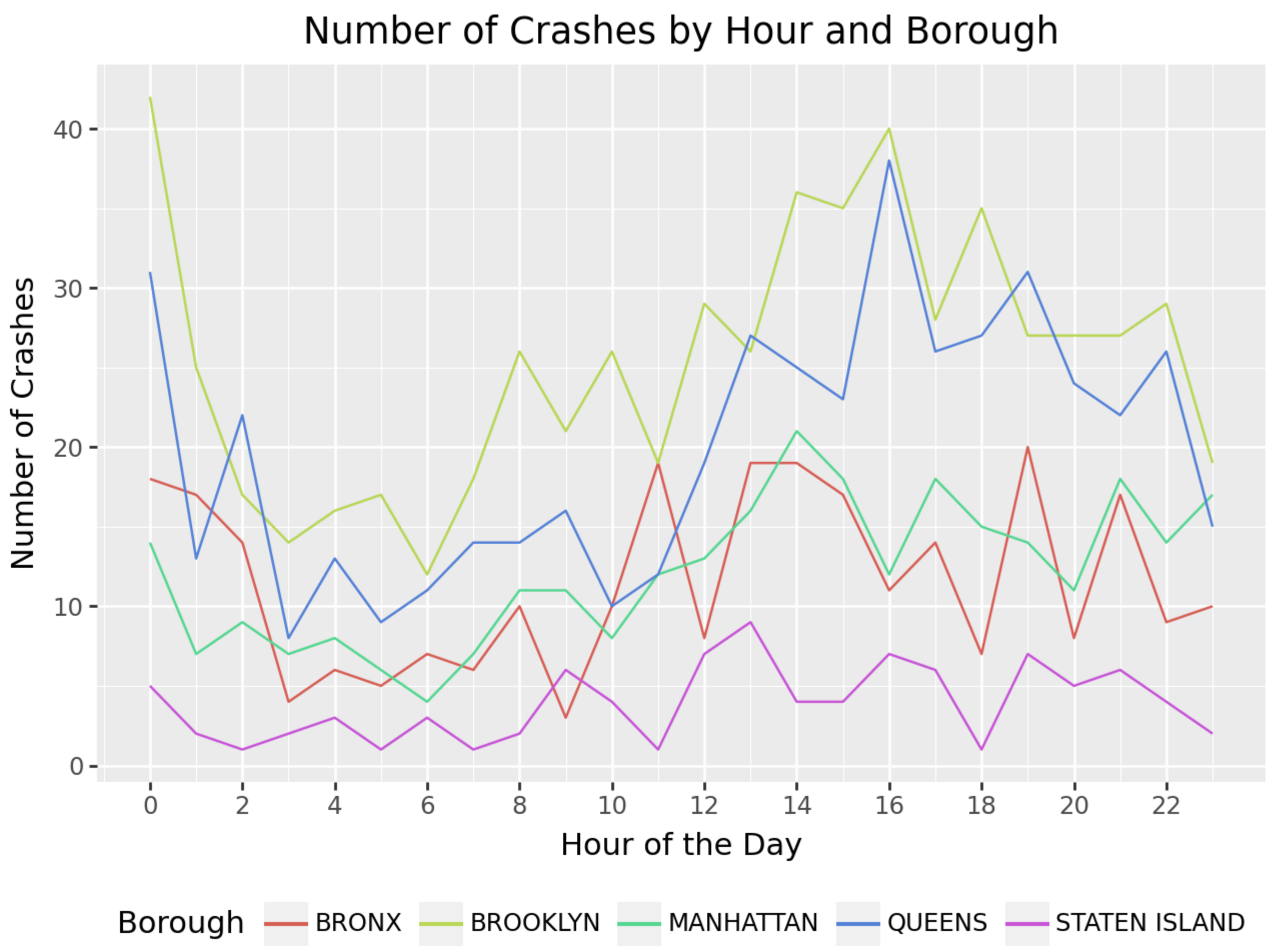


This example is excellent for understanding the grammar of graphics. As you can see, we use `geom_line()` to create the line chart, while also adding `geom_point()`, which is typically used for scatterplots, to make the figure clearer by layering additional details."

Multivariable Line Chart

Similarly to the other figures you can create a line chart with multiple variables. Now we will create a chart with number of crashes by borough.

```
# Setting crash counts to also include borough
crash_counts = nyc_crash.groupby(['crash_hour',
    'borough']).size().reset_index(name='crash_count')

# Plots crashes by hour with different lines for each borough
(ggplot(crash_counts, aes(x='crash_hour', y='crash_count',
    color='borough')) +
# size= changes the thinkness of the lines
    geom_line(size=0.5) +
    labs(title='Number of Crashes by Hour and Borough',
        x='Hour of the Day',
        y='Number of Crashes',
        color = 'Borough') +
    scale_x_continuous(breaks=range(0, 24, 2)) +
    theme(legend_position='bottom'))
```



Faceting Your Plots

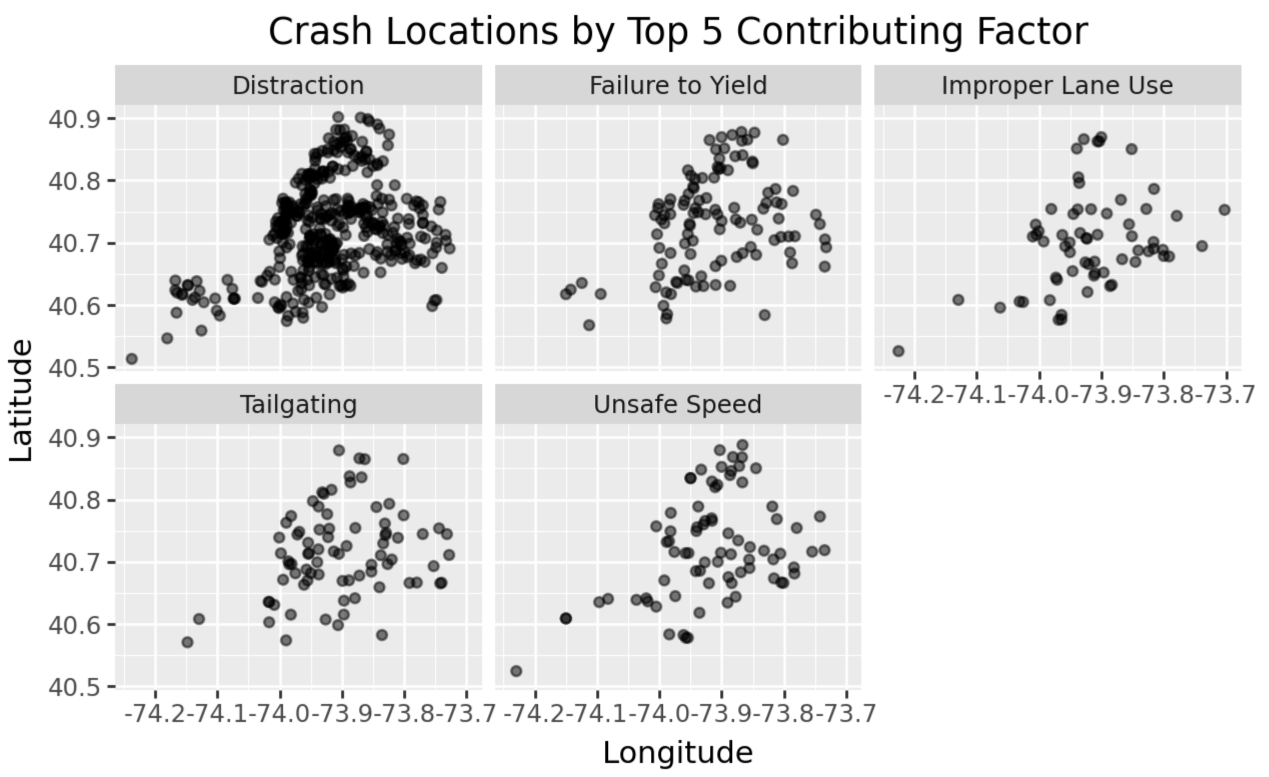
To organize your data in a way that enhances interpretability, you can utilize `facet_grid()` or `facet_wrap()`. This approach allows for the creation of separate plots based on categorical variables, making it easier to identify trends and patterns. You can facet any type of plots, scatterplots, bar charts, histograms, line charts, etc. using one or two variables.

Scatterplots per Facet

Scatterplot of Crash Locations by Contributing Factor with `facet_wrap()`:

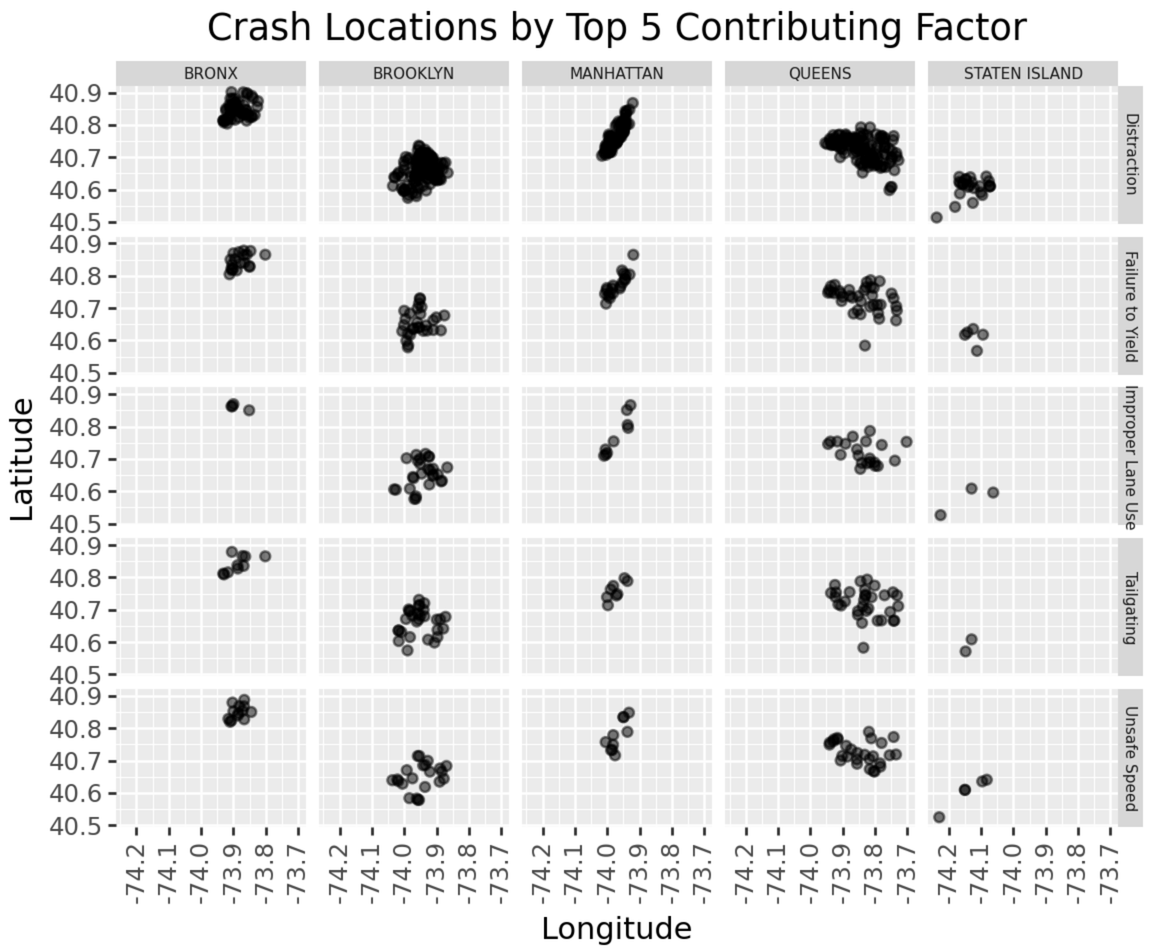
```
(ggplot(confact, aes(x='longitude', y='latitude')) +
    geom_point(alpha=0.5) +
# Creates separate plots for each contributing factor
```

```
    facet_wrap('contributing_factor_vehicle_1') +
    labs(title='Crash Locations by Top 5 Contributing Factor',
        x='Longitude',
        y='Latitude') +
    coord_fixed(ratio = 1))
```



Scatterplot of Two Variables, Crash Locations Contributing Factor and Borough with `facet_grid()`:

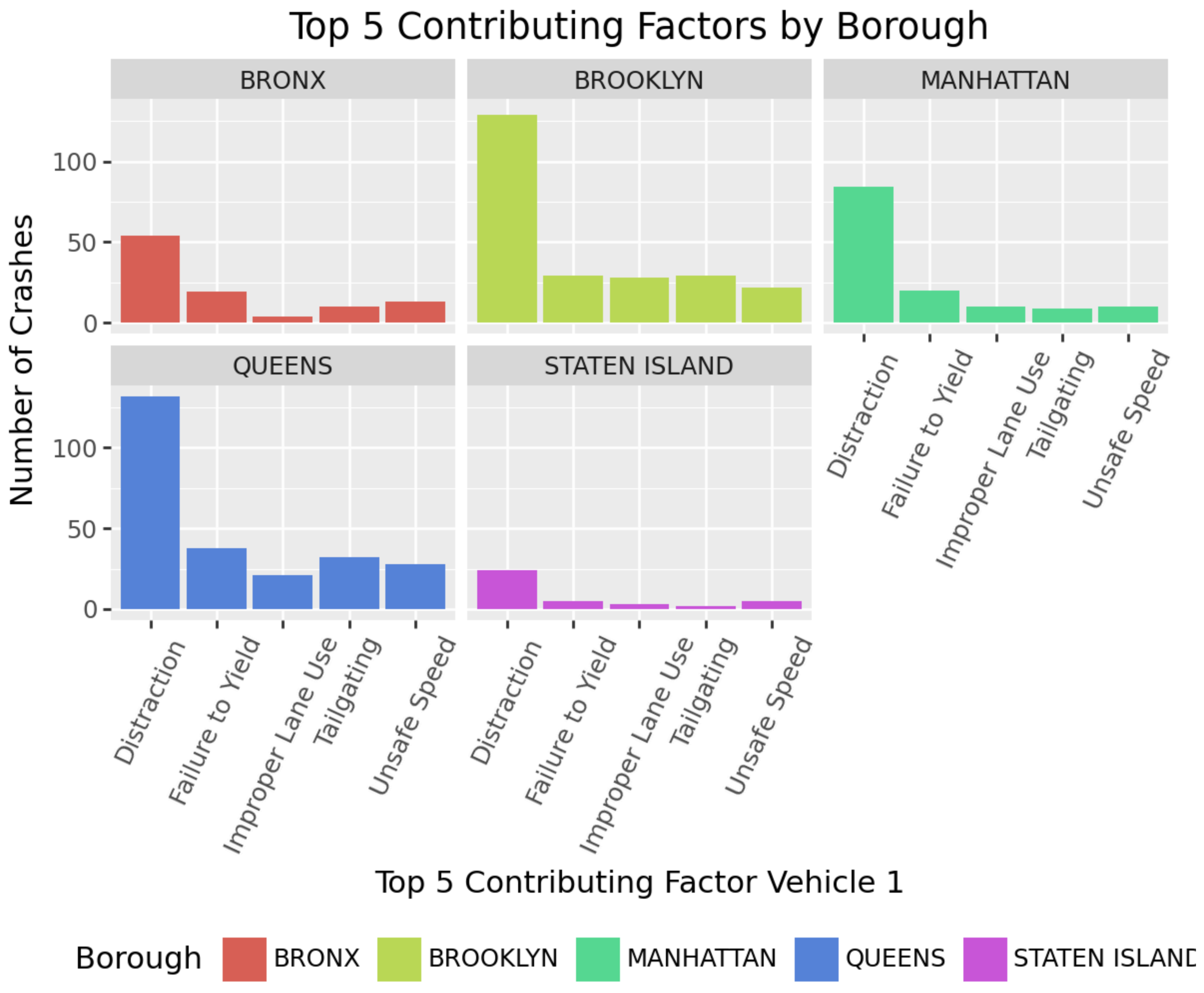
```
(ggplot(confact, aes(x='longitude', y='latitude')) +
    geom_point(alpha = 0.5) +
# Creates a grid of subplots based on the values of two variables
# ~'contributing_factor_vehicle_1' by 'borough'
    facet_grid('contributing_factor_vehicle_1 ~ borough') +
    labs(title='Crash Locations by Top 5 Contributing Factor',
        x='Longitude',
        y='Latitude') +
# Changes angle of text and size of the graphic
    theme(axis_text_x=element_text(angle=90),
# sprip_text=element_text changes text size of the facet titles
        strip_text=element_text(size=5.5)) +
    coord_fixed(ratio = 1))
```



Bar Chart per Facet

Bar chart of Contributing Factors by Borough with `facet_wrap`:

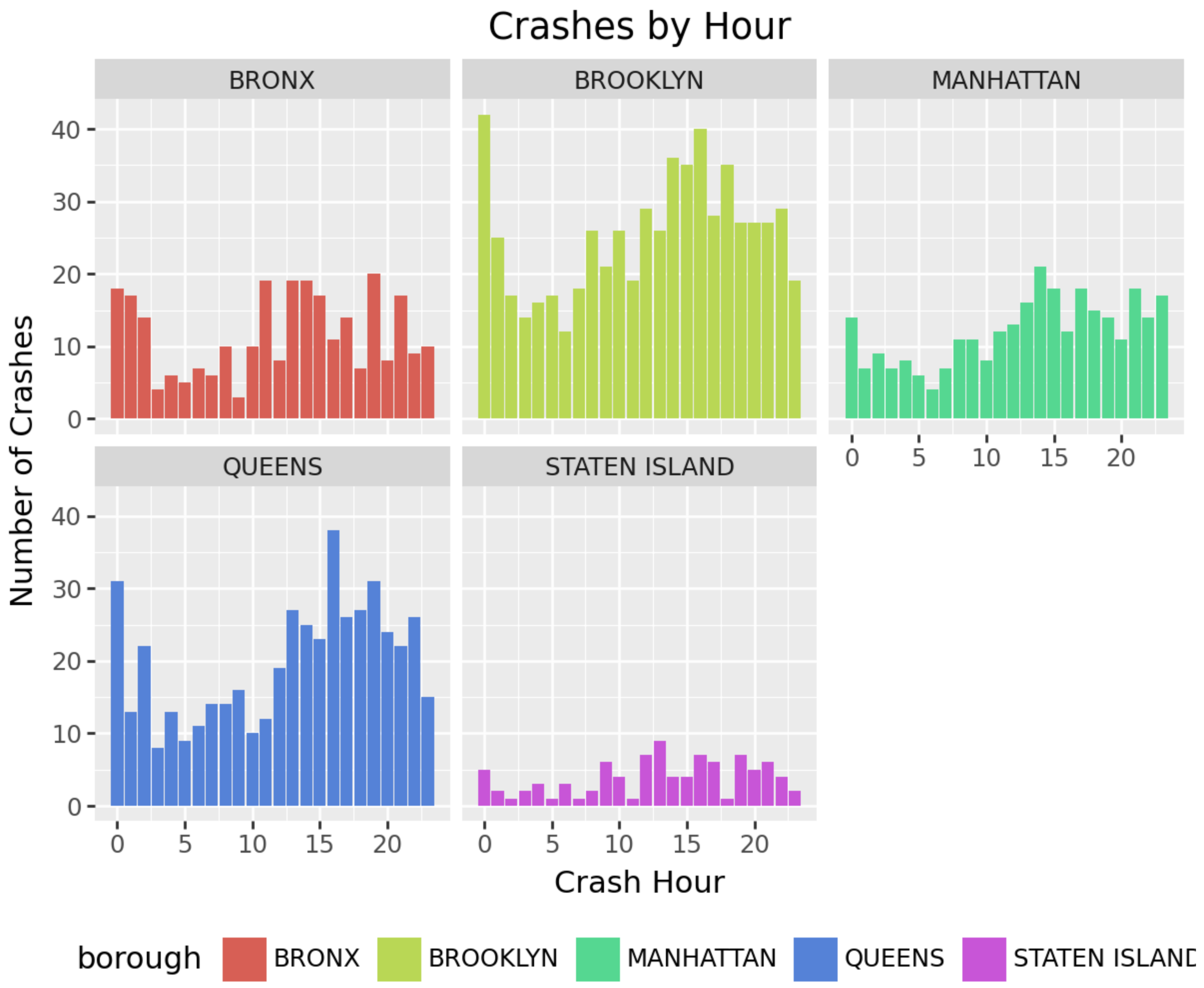
```
(ggplot(confact, aes(x='contributing_factor_vehicle_1', fill='borough')) +
    geom_bar() +
    labs(title='Top 5 Contributing Factors by Borough',
        x='Top 5 Contributing Factor Vehicle 1',
        y='Number of Crashes',
        fill = 'Borough') +
    facet_wrap('~ borough') +
    theme(axis_text_x=element_text(size=9, angle=65),
            figure_size= (6,5), legend_position='bottom'))
```



Histograms per Facet

Histogram of Crashes per Hour by Borough with `facet_wrap`:

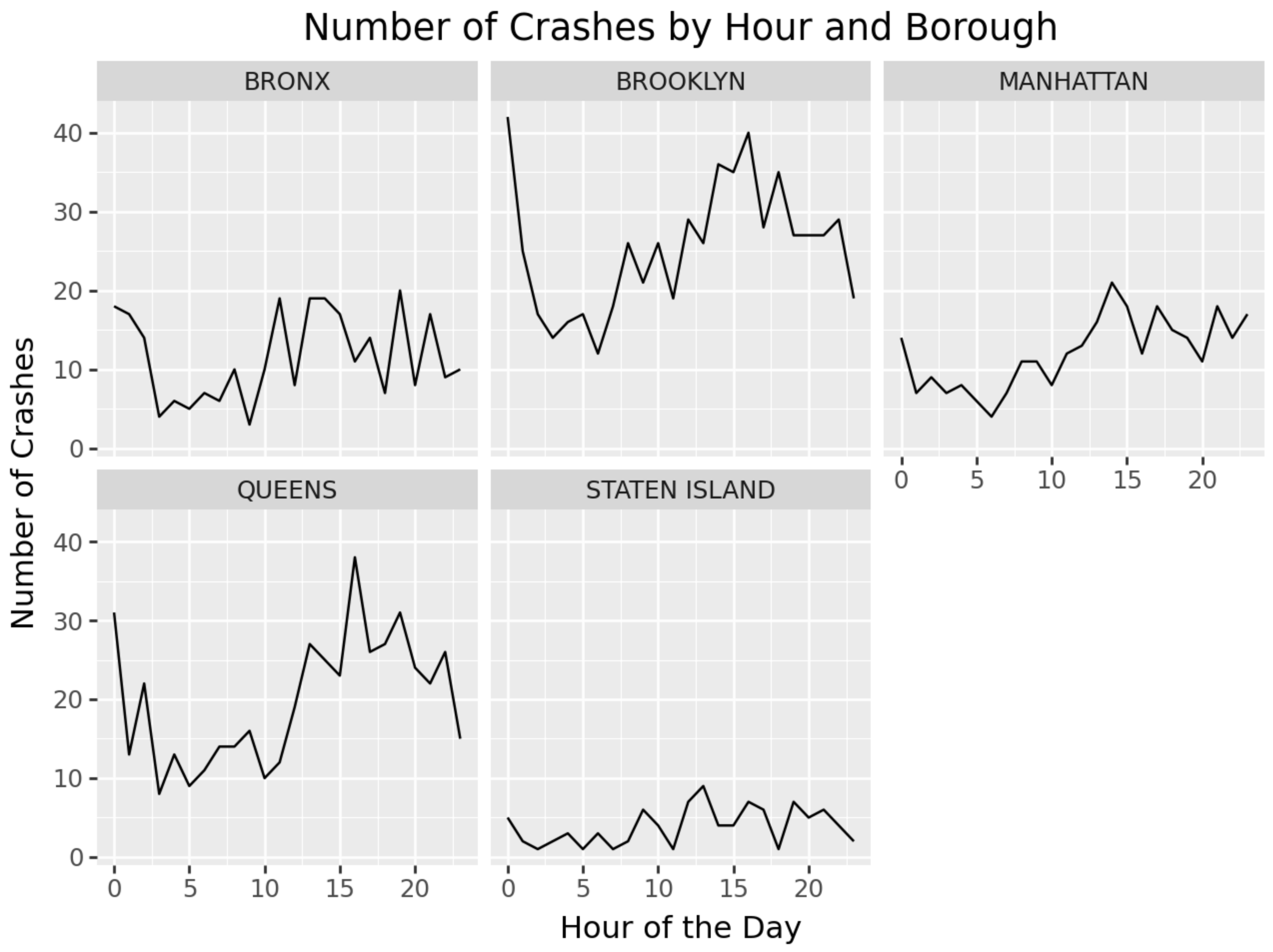
```
(ggplot(crash_counts, aes(x='crash_hour', y='crash_count', fill = 'borough')) +
    geom_bar(stat='identity') +
    labs(x='Crash Hour',
        y='Number of Crashes',
        title = "Crashes by Hour") +
    theme(legend_position='bottom', figure_size= (6,5)) +
    facet_wrap('~ borough'))
```



Line Chart per Facet

You can use plot each variable by on separate panels with `facet_wrap()`.

```
(ggplot(crash_counts, aes(x='crash_hour', y='crash_count')) +
    geom_line() +
    # Breaks the figure up by borough
    facet_wrap("borough") +
    labs(title='Number of Crashes by Hour and Borough',
        x='Hour of the Day',
        y='Number of Crashes'))
```



Conclusion

`Plotnine` is a very powerful tool to make impactful and detailed graphics. The flexibility of its grammar of graphics approach means there are endless ways to modify, enhance, and be creative with your plots. You can layer geoms, adjust aesthetics, and apply scales, facets, and themes.

Creating Specific Plots

- Scatterplot `geom_point()`
- Boxplot `geom_box()`
- Histogram `geom_histogram()`
- Line Chart `geom_line()`
- Bar Chart `geom_bar()`
- Density Plot `geom_denisty()`

Formatting and Customizing Your Figure:

- `fill`: to change the color of the data
- `color`: to change the color of the borders
- `alpha`: to change the transparency
- `bins`: to change the number of bins
- `figure_size`: to change size of graphic

- `geom_smooth`: to add a smoothed line
- `facet`: plot each group on a separate panel
  - `facet_wrap()`: creates a series of plots arranged in a grid, wrapping into new rows or columns as needed
  - `facet_grid()`: allows you to create a grid layout based on two categorical variables, organizing plots in a matrix format
- `theme`: change overall theme

There are many other features and customizations you can do with Plotnine. For more information on how to leverage the full potential of this package for your data visualization needs check out Plotnine's Graph Gallery.

Happy plotting!

Sources

Python Graph Gallery. (2024). Plotnine: ggplot in python. Python Graph Gallery. https://python-graph-gallery.com/plotnine/

Sarker, D. (2018). A comprehensive guide to the grammar of graphics for effective visualization of multi-dimensional data. Towards Data Science. https://towardsdatascience.com/a-comprehensive-guide-to-the-grammar-of-graphics-for-effective-visualization-of-multi-dimensional-1f92b4ed4149

Wilkinson, L. (2012). The grammar of graphics (pp. 375-414). Springer Berlin Heidelberg.