

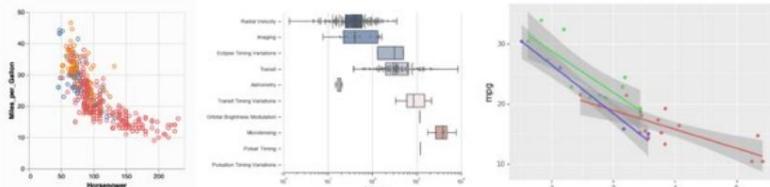
Data Visualization with Python

Veera Muangsin

Plot Types

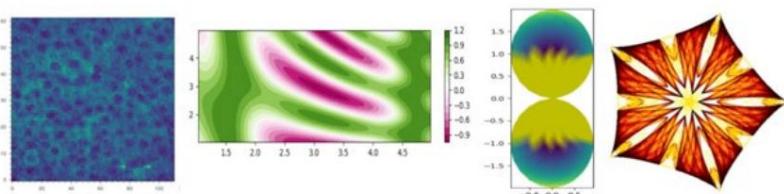
The most basic plot types are shared between multiple libraries, and others are only available in certain libraries.

Given the number of libraries, plot types, and their changes over time, it is very difficult to precisely characterize what's supported in each library. It is usually clear what the focus is if you look at the example galleries for each library.



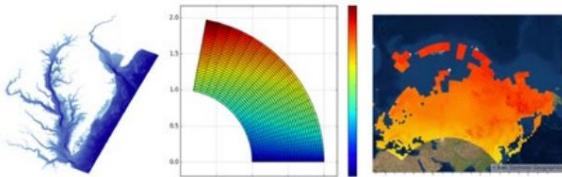
Statistical plots (scatter plots, lines, areas, bars, histograms)

Covered well by nearly all InfoVis libraries, but are the main focus for Seaborn, bqplot, Altair, ggplot2, and plotnine.



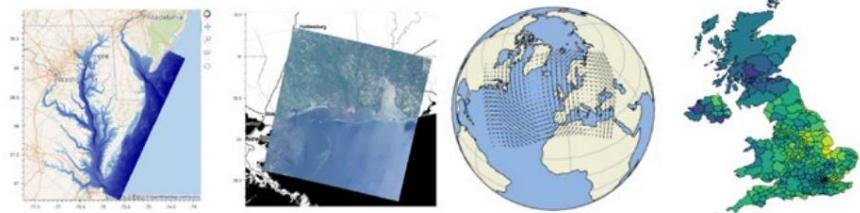
Multidimensional arrays (regular grids, rectangular meshes)

Well supported by Bokeh, Datasader, HoloViews, Matplotlib, Plotly, plus most of the SciVis libraries.



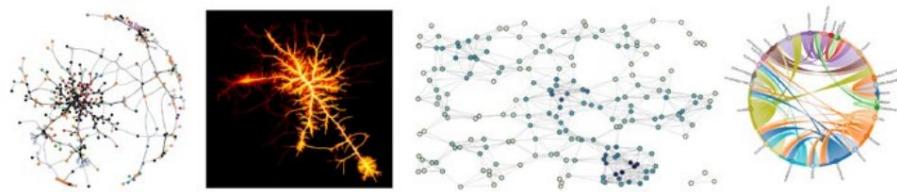
Irregular 2D meshes (triangular grids)

Well supported by the SciVis libraries plus Matplotlib, Bokeh, Datasader, and HoloViews.



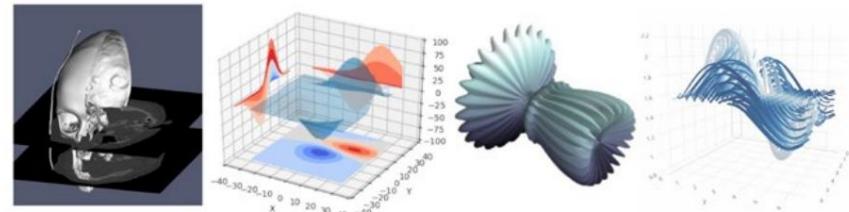
Geographical data

Matplotlib (with Cartopy), GeoViews, ipyleaflet, and Plotly.



Networks/graphs

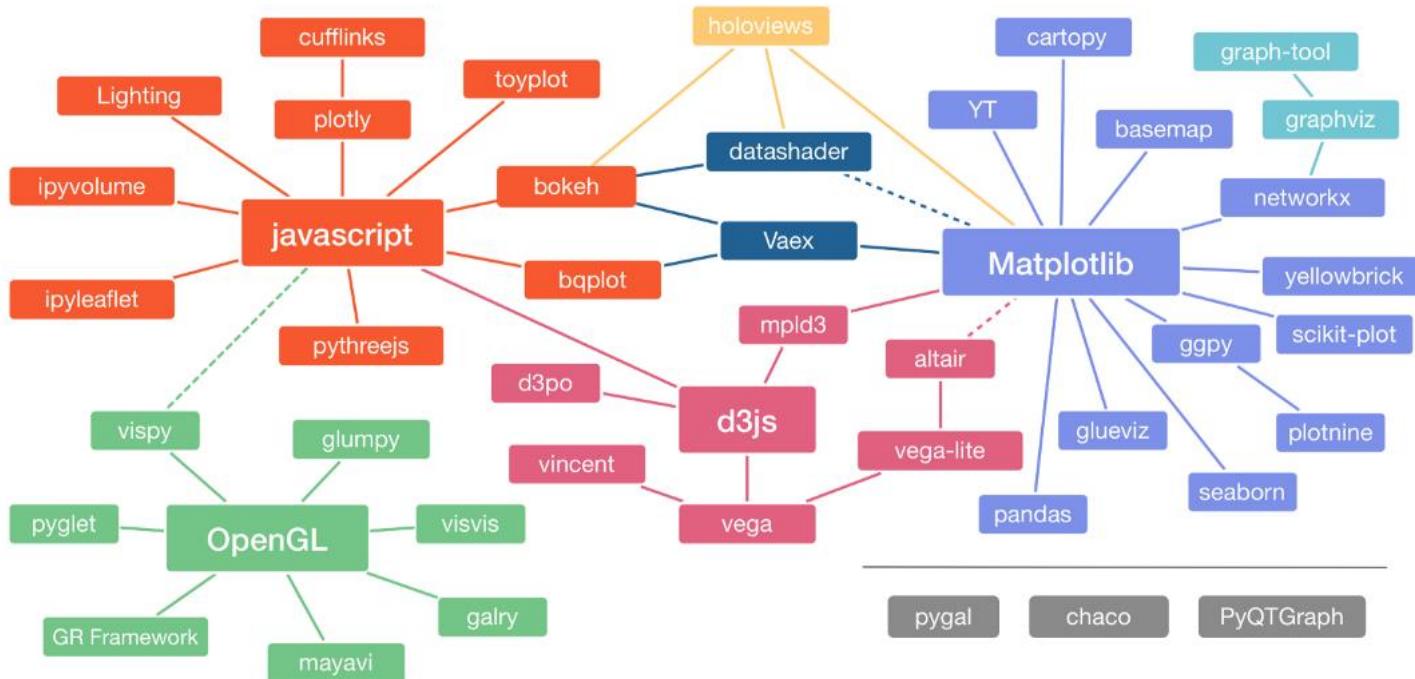
NetworkX, Plotly, Bokeh, HoloViews, and Datasader.



3D (meshes, scatter, etc.)

Fully supported by the SciVis libraries, plus some support in Plotly, Matplotlib, HoloViews, and ipyvolume.

Python Visualization Landscape



- Scientific visualization (green)
 - visualize 3D (+time) physical processes.
 - Based on OpenGL
- Information visualization (all other colors)
- Dashboard and app (not in the diagram)
 - Streamlit
 - Dash
 - Panel
 - Voila
 - PyGWalker

<https://pyviz.org/overviews/index.html>

Python Visualization Packages

- **Matplotlib**
- Matplotlib wrapper
 - **Pandas plot**
 - Seaborn <https://seaborn.pydata.org/>
 - Scikit-plot <https://scikit-plot.readthedocs.io/>
 - Plotnine (ggplot): based on R's ggplot2 <https://plotnine.org/>
- Javascript-based Viz (interactive viz)
 - **Plotly** <https://plot.ly/python/>
 - Bokeh <http://bokeh.org/>
- Dashboard web app
 - **Streamlit** <https://streamlit.io/>
 - Dash (based on Plotly) <https://dash.plotly.com/>

Matplotlib

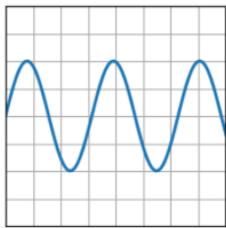
Matplotlib

- <https://matplotlib.org/>
- Mature, widely used
- Emulate MATLAB's plotting capabilities
- Low level
 - Require many steps to adjust the details of a plot
 - Many ways to achieve the same goal
 - plt.title(...), ax.set_title(...), and ax.title.set_text(...), can all set a title for a plot. → confusing
- Wide range of 2D plot types
- Focus on static images
- Export to many file formats (savefig function)
- Limited interactive viz (not enabled by default)

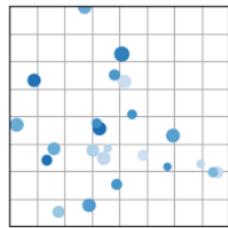
```
import matplotlib.pyplot as plt
```

Plot Types

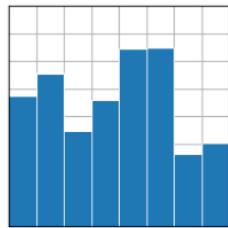
- https://matplotlib.org/stable/plot_types/index.html



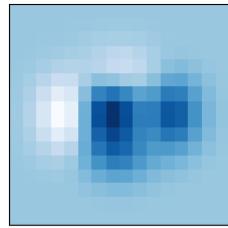
`plot(x, y)`



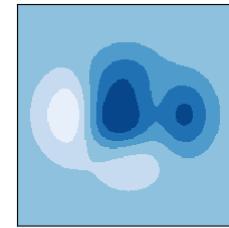
`scatter(x, y)`



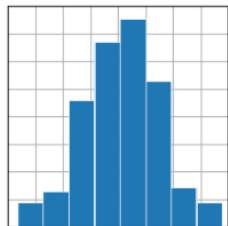
`bar(x, height) / barh(y,
width)`



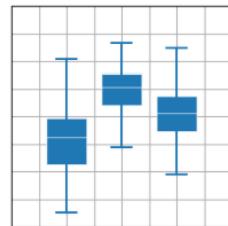
`imshow(Z)`



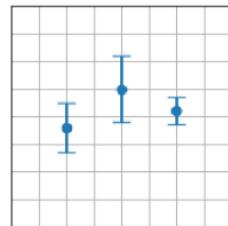
`contourf(X, Y, Z)`



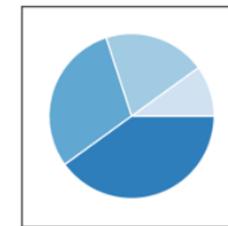
`hist(x)`



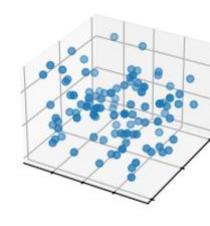
`boxplot(X)`



`errorbar(x, y, yerr, xerr)`



`pie(x)`



`scatter(xs, ys, zs)`

Matplotlib Gallery

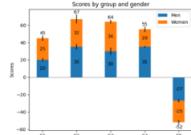
- <https://matplotlib.org/stable/gallery/index.html>

Examples

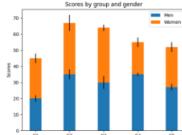
This page contains example plots. Click on any image to see the full image and source code.

For longer tutorials, see our [tutorials page](#). You can also find [external resources](#) and a [FAQ](#) in our [user guide](#).

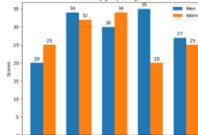
Lines, bars and markers



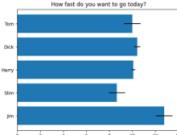
Bar Label Demo



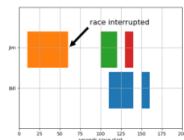
Stacked bar chart



Grouped bar chart with labels



Horizontal bar chart



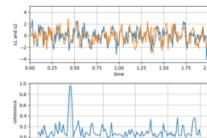
Broken Barh



CapStyle



Plotting categorical variables

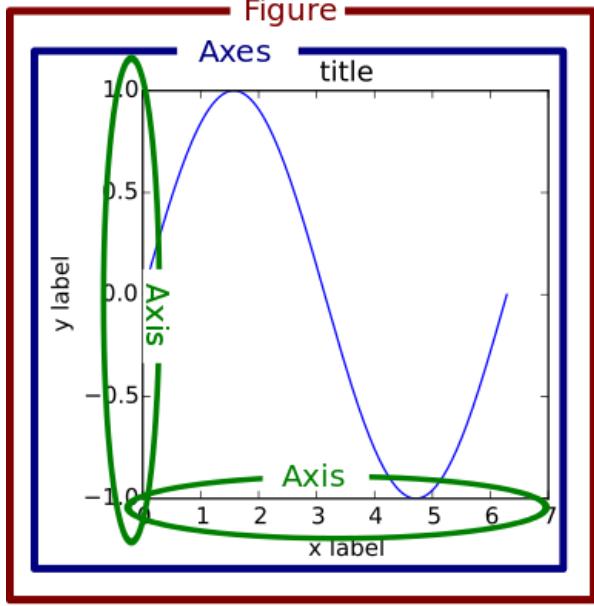


Plotting the coherence of two signals

On this page

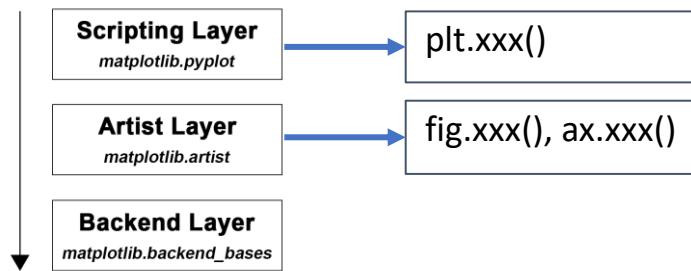
- Lines, bars and markers
- Images, contours and fields
- Subplots, axes and figures
- Statistics
- Pie and polar charts
- Text, labels and annotations
- pyplot
- Color
- Shapes and collections
- Style sheets
- axes_grid1
- axisartist
- Showcase
- Animation
- Event handling
- Front Page
- Miscellaneous
- 3D plotting
- Scales
- Specialty Plots
- Spines
- Ticks
- Units
- Embedding Matplotlib in graphical user interfaces
- Userdemo
- Widgets

Matplotlib components



- Figure: overall space that contain one or more plots
- Axes: individual plots in the figure

Matplotlib APIs



Two styles:

- **Pyplot API**
 - Command style functions that make matplotlib work like MATLAB.
 - `matplotlib.pyplot`
 - Each pyplot function makes some change to a figure: e.g., creates a figure, creates a plotting area in a figure, plots some lines in a plotting area, add labels, etc.
 - More convenient but less flexible than the object-oriented API
- **Object-oriented API**
 - Create `Figure` and `Axes` objects and call their methods to add content and modify the appearance.
 - `matplotlib.figure`: axes creation, figure-level content
 - `matplotlib.axes`: most plotting methods, axis labels, axis styling, etc.
 - More control and customization. Recommended for more complex plots

Stick to one style. Mixing pyplot API with OO API can make your code harder to read and maintain.

Pyplot vs OO

```
import matplotlib.pyplot as plt

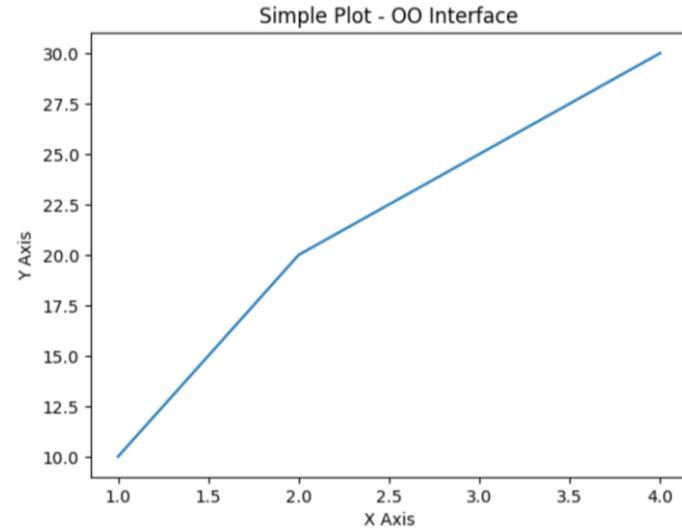
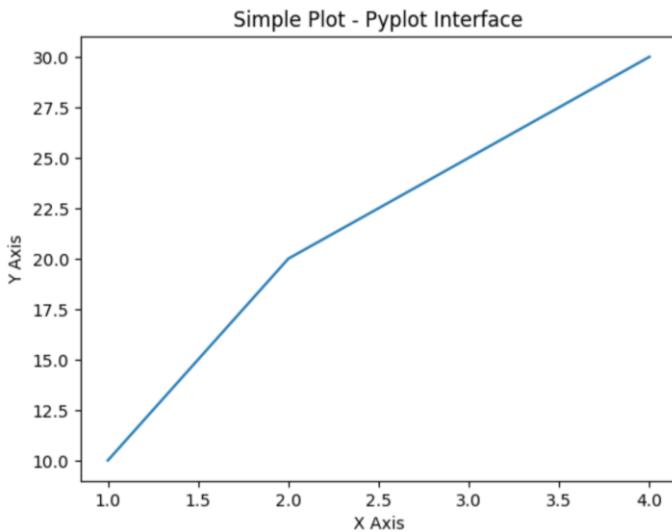
x = [1, 2, 3, 4]
y = [10, 20, 25, 30]

plt.plot(x, y)
plt.title('Simple Plot - Pyplot Interface')
plt.xlabel('X Axis')
plt.ylabel('Y Axis')
plt.show()
```

```
import matplotlib.pyplot as plt

x = [1, 2, 3, 4]
y = [10, 20, 25, 30]

fig, ax = plt.subplots() # Create a figure and an axes.
ax.plot(x, y) # Plot some data on the axes.
ax.set_title('Simple Plot - OO Interface') # Add a title to the axes.
ax.set_xlabel('X Axis') # Add an x-label to the axes.
ax.set_ylabel('Y Axis') # Add a y-label to the axes.
plt.show()
```



same output

Pyplot + OO (possible but not recommended)

Create with pyplot, modify with OO

```
import matplotlib.pyplot as plt

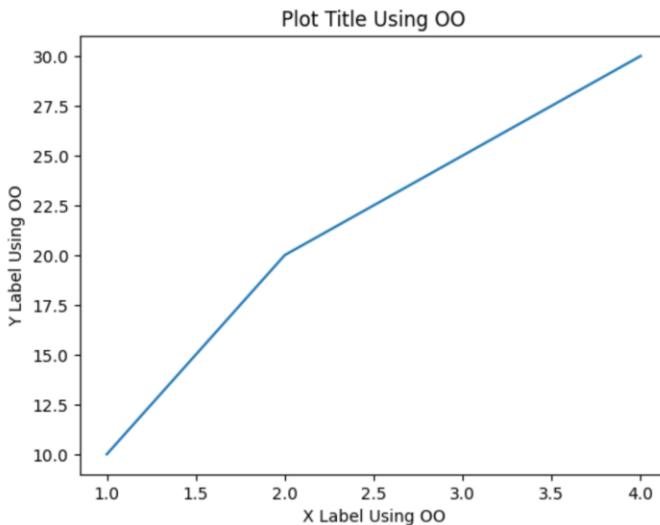
x = [1, 2, 3, 4]
y = [10, 20, 25, 30]

# Create a plot using Pyplot
plt.plot(x, y)

# Grab the current Axes and Figure using Pyplot, then modify using OO
ax = plt.gca() # Get current Axes
fig = plt.gcf() # Get current Figure

# Now, use OO methods
ax.set_title('Plot Title Using OO')
ax.set_xlabel('X Label Using OO')
ax.set_ylabel('Y Label Using OO')

plt.show()
```



Create with OO, modify with pyplot

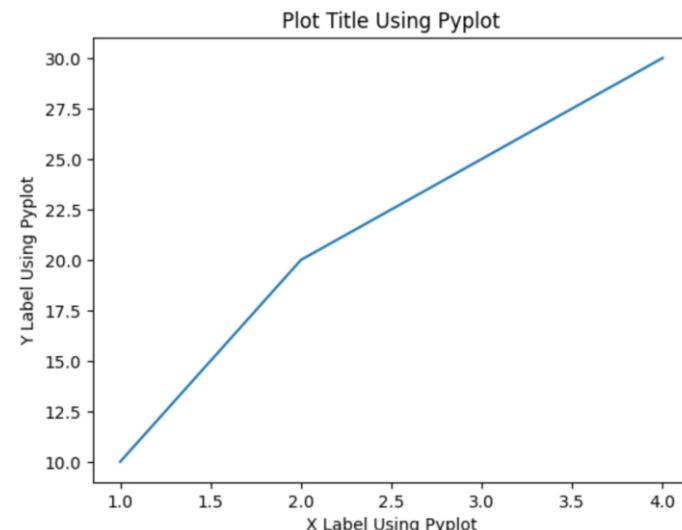
```
import matplotlib.pyplot as plt

x = [1, 2, 3, 4]
y = [10, 20, 25, 30]

# Start with OO
fig, ax = plt.subplots()
ax.plot(x, y)

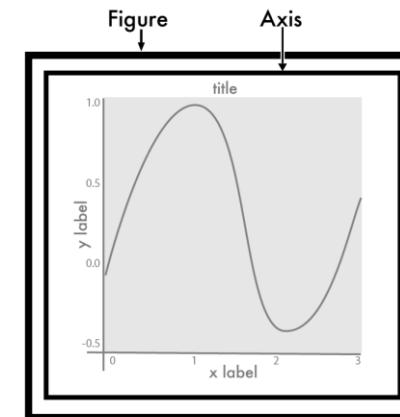
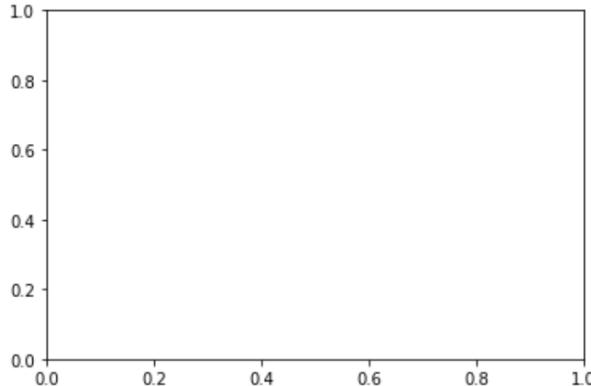
# Use Pyplot to modify, but this affects the current plot
plt.title('Plot Title Using Pyplot')
plt.xlabel('X Label Using Pyplot')
plt.ylabel('Y Label Using Pyplot')

plt.show()
```

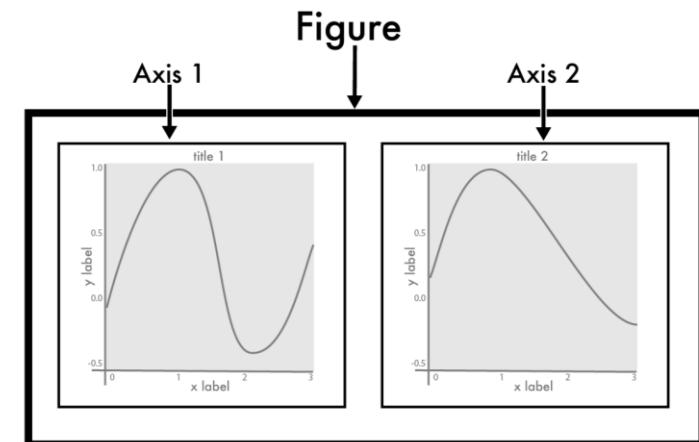
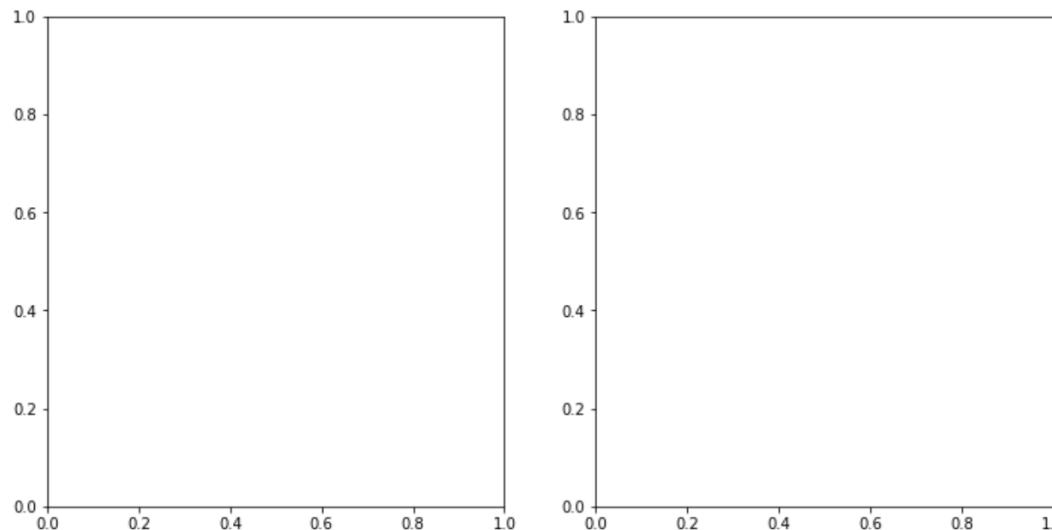


Creating a Figure and one or more Axes using `pyplot.subplots()`

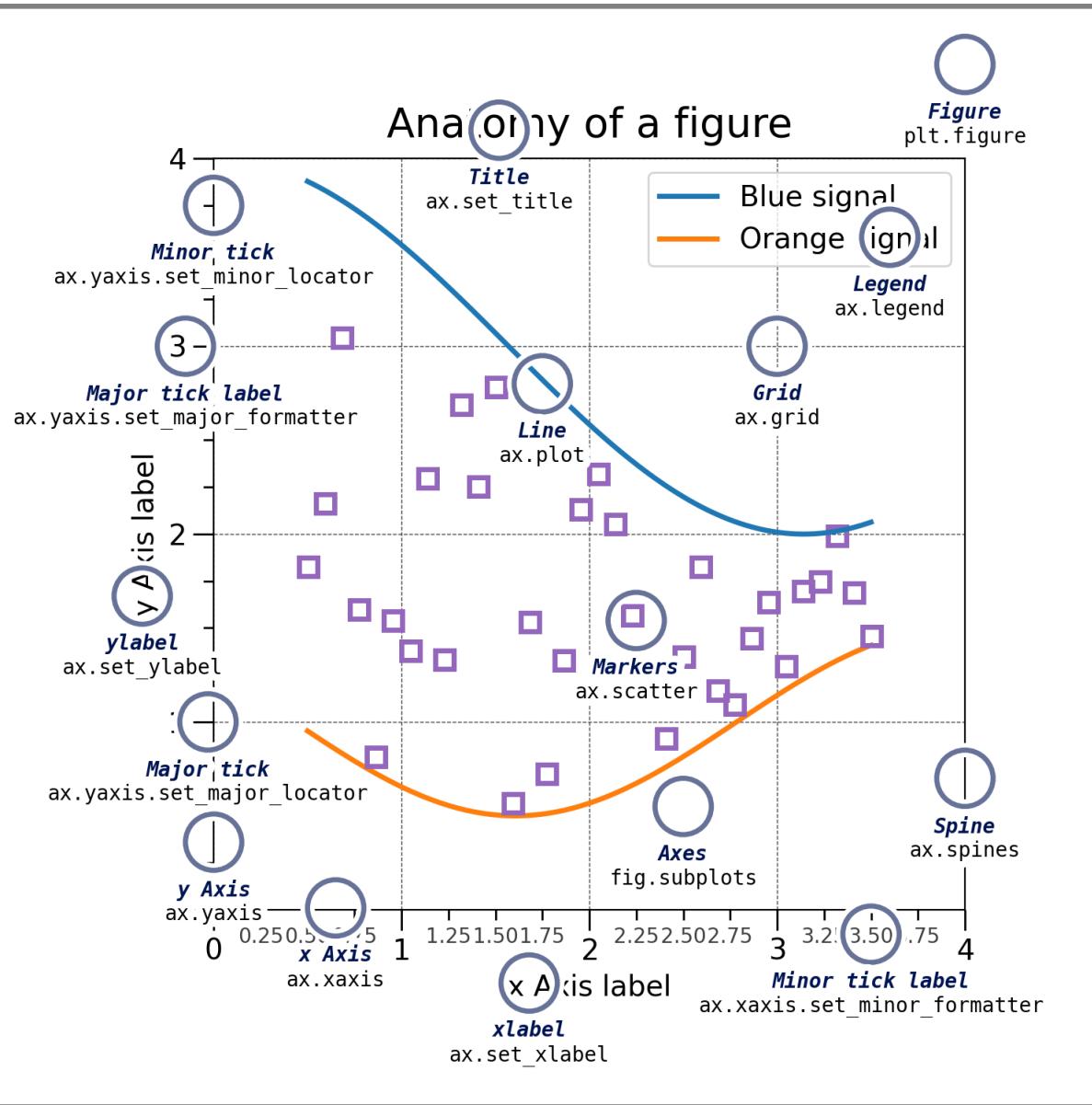
```
# Create a figure containing a single plot (axis)
fig, ax = plt.subplots()
```



```
# Figure with two plots
fig, (ax1, ax2) = plt.subplots(1, 2, figsize = (12, 6))
```



Anatomy of a figure



<https://matplotlib.org/stable/gallery/showcase/anatomy.html>

```

import matplotlib.pyplot as plt
import numpy as np

from matplotlib.patches import Circle
from matplotlib.path_effects import withStroke
from matplotlib.ticker import AutoMinorLocator, MultipleLocator

royal_blue = [0, 20/256, 82/256]

# make the figure
np.random.seed(19680801)

X = np.linspace(0.5, 3.5, 100)
Y1 = 3*np.cos(X)
Y2 = 1+np.cos(1+X/0.75)/2
Y3 = np.random.uniform(Y1, Y2, len(X))

fig = plt.figure(figsize=(7.5, 7.5))
ax = fig.add_axes([0.2, 0.17, 0.68, 0.7], aspect=1)

ax.xaxis.set_major_locator(MultipleLocator(1.000))
ax.xaxis.set_minor_locator(AutoMinorLocator(4))
ax.yaxis.set_major_locator(MultipleLocator(1.000))
ax.yaxis.set_minor_locator(AutoMinorLocator(4))
ax.yaxis.set_minor_formatter("{:.2f}")

ax.set_xlim(0, 4)
ax.set ylim(0, 4)

ax.tick_params(which='major', width=1.0, length=10, labelsize=14)
ax.tick_params(which='minor', width=1.0, length=5, labelsize=10,
               labelcolor='0.25')

ax.grid(linestyle="--", linewidth=0.5, color='0.25', zorder=10)

ax.plot(X, Y1, c='C0', lw=2.5, label="Blue signal", zorder=10)
ax.plot(X, Y2, c='C1', lw=2.5, label="Orange signal")
ax.plot(X[::3], Y3[::3], linewidth=0, markerSize=9,
        marker='s', markerfacecolor='none', markeredgecolor='C4',
        markeredgewidth=2.5)

ax.set_title("Anatomy of a figure", fontsize=20, verticalalignment='bottom')
ax.set_xlabel("x Axis label", fontsize=14)
ax.set_ylabel("y Axis label", fontsize=14)
ax.legend(loc="upper right", fontsize=14)

# Annotate the figure

def annotate(x, y, text, code):
    # Circle marker
    c = Circle((x, y), radius=0.15, clip_on=False, zorder=10, linewidth=2.5,
               edgecolor=royal_blue + [0.6], facecolor='none',
               path_effects=[withStroke(linewidth=7, foreground='white')])
    ax.add_artist(c)

    # use path_effects as a background for the texts
    # draw the path.effects and the colored text separately so that the
    # path.effects cannot clip other texts
    for path_effects in [(withStroke(linewidth=7, foreground='white')), []]:
        color = 'white' if path_effects else royal_blue
        ax.text(x, y-0.2, text, zorder=100,
                ha='center', va='top', weight='bold', color=color,
                style='italic', fontfamily='monospace',
                path_effects=path_effects)

        color = 'white' if path_effects else 'black'
        ax.text(x, y-0.3, code, zorder=100,
                ha='center', va='top', weight='normal', color=color,
                fontfamily='monospace', fontsize='medium',
                path_effects=path_effects)

annotate(3.5, -0.13, "Minor tick label", "ax.xaxis.set_minor_formatter")
annotate(-0.03, 1.0, "Major tick", "ax.xaxis.set_major_locator")
annotate(0.00, 3.75, "Minor tick", "ax.yaxis.set_minor_locator")
annotate(-0.15, 3.00, "Major tick label", "ax.yaxis.set_major_formatter")
annotate(1.68, 4.15, "xlabel", "ax.set_xlabel")
annotate(0.38, 1.67, "ylabel", "ax.set_ylabel")
annotate(1.52, 4.15, "Title", "ax.set_title")
annotate(1.75, 2.00, "Line", "ax.plot")
annotate(2.25, 1.54, "Markers", "ax.scatter")
annotate(3.00, 3.00, "Grid", "ax.grid")
annotate(3.60, 3.58, "Legend", "ax.legend")
annotate(2.5, 0.55, "Axes", "fig.subplots")
annotate(4, 4.5, "Figure", "plt.figure")
annotate(0.65, 0.01, "Axis", "ax.xaxis")
annotate(0.36, 0.13, "y Axis", "ax.yaxis")
annotate(4.0, 0.7, "Spine", "ax.spines")

# frame around figure
fig.patch.set(linewidth=4, edgecolor='0.5')
plt.show()

```

Case study: Iris Flower Dataset

- 50 observations from each of three species of iris flowers
 - Iris Setosa, Iris versicolor, Iris virginica
- 4 features
 - sepal length, sepal width, petal length, petal width
- Task: clustering analysis



Iris setosa

```
iris = pd.read_csv('iris.csv')
iris.head()
```

	Id	SepalLengthCm	SepalWidthCm	PetalLengthCm	PetalWidthCm	Species
0	1	5.1	3.5	1.4	0.2	Iris-setosa
1	2	4.9	3.0	1.4	0.2	Iris-setosa
2	3	4.7	3.2	1.3	0.2	Iris-setosa
3	4	4.6	3.1	1.5	0.2	Iris-setosa
4	5	5.0	3.6	1.4	0.2	Iris-setosa



Iris versicolor



Iris virginica

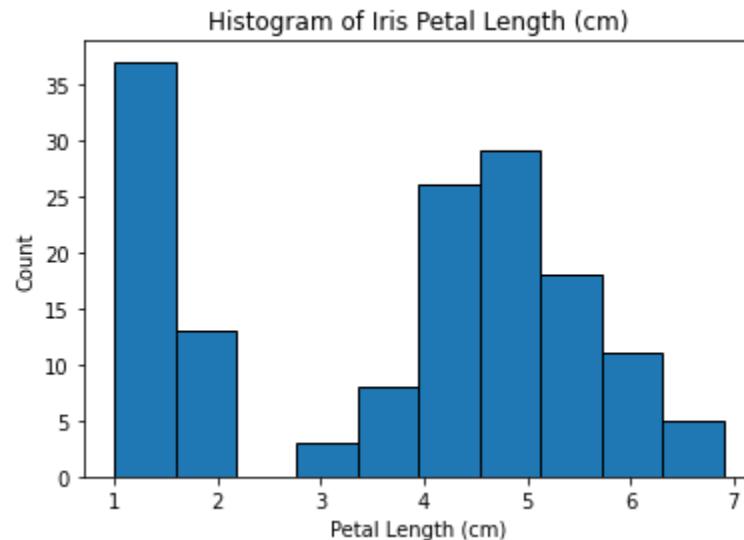
Histogram of one feature

Using pyplot

```
plt.hist(iris['PetalLengthCm'], bins=10, edgecolor='black')
plt.xlabel('Petal Length (cm)')
plt.ylabel('Count')
plt.title('Histogram of Iris Petal Length (cm)')
plt.show()
```

Using OO

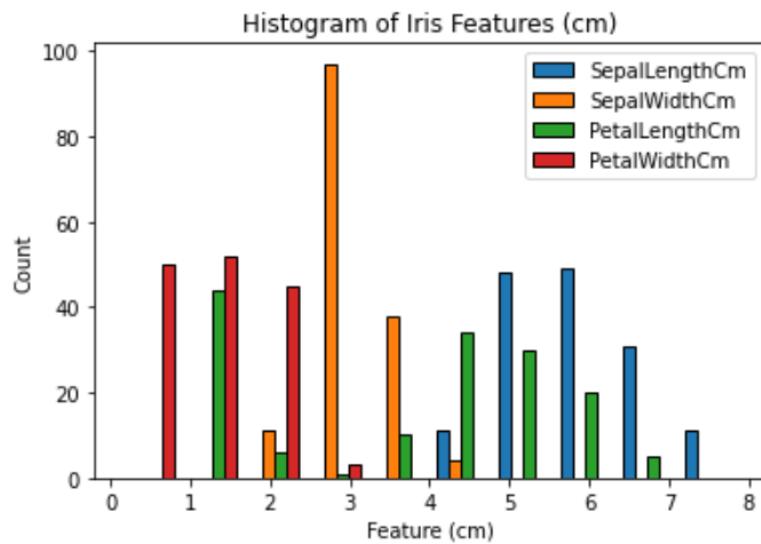
```
fig, axes = plt.subplots()
axes.hist(iris['PetalLengthCm'], bins=10, edgecolor='black')
axes.set_xlabel('Petal Length (cm)')
axes.set_ylabel('Count')
axes.set_title('Histogram of Iris Petal Length (cm)')
plt.show()
```



Note: next examples will show only the pyplot version.

Histogram of all features

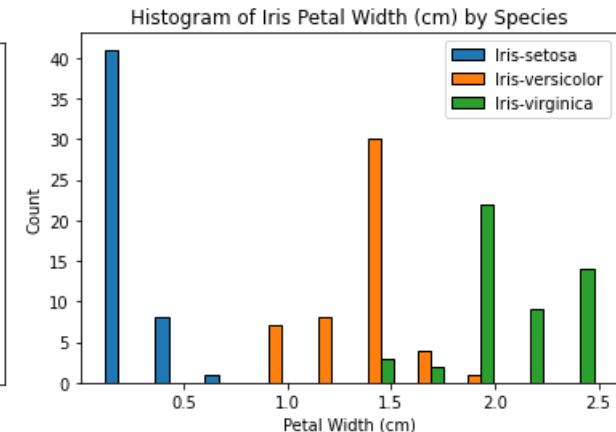
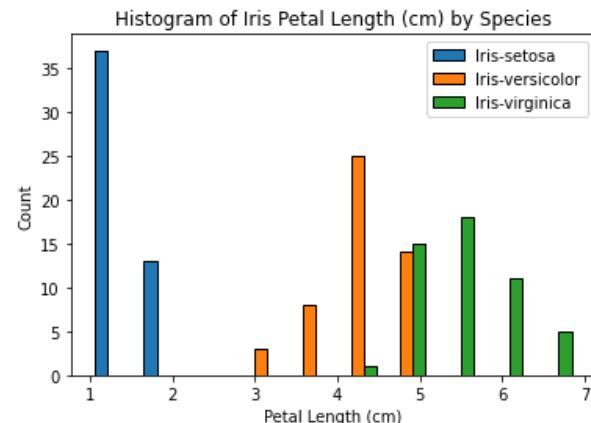
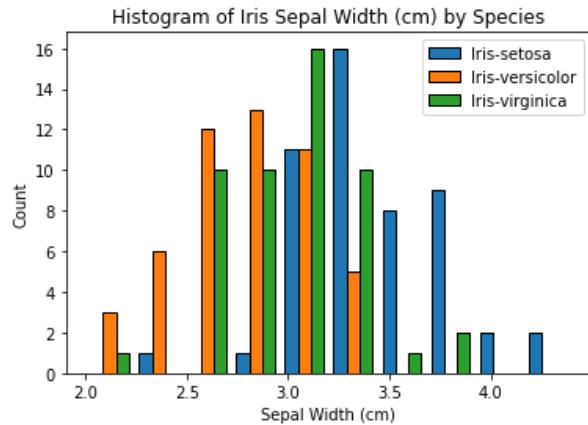
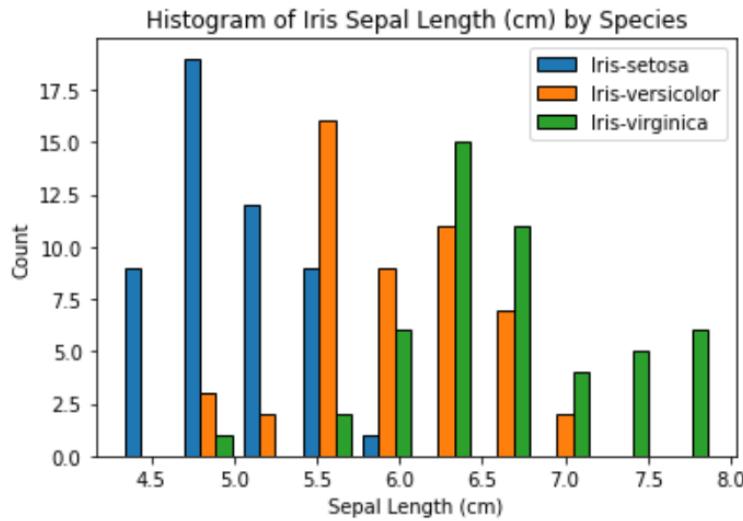
```
plt.hist(iris.loc[:, 'SepalLengthCm':'PetalWidthCm'], bins=10, edgecolor='black', label=iris_features)
plt.legend()
plt.xlabel('Feature (cm)')
plt.ylabel('Count')
plt.title('Histogram of Iris Features (cm)')
plt.show()
```



Histogram of each feature by species

```
SepalLengthCm_groupby_Species = [x['SepalLengthCm'] for _, x in iris[['Species', 'SepalLengthCm']].groupby('Species')]

plt.hist(SepalLengthCm_groupby_Species, bins=10, edgecolor='black', label=iris_species)
plt.legend()
plt.xlabel('Sepal Length (cm)')
plt.ylabel('Count')
plt.title('Histogram of Iris Sepal Length (cm) by Species')
plt.show()
```

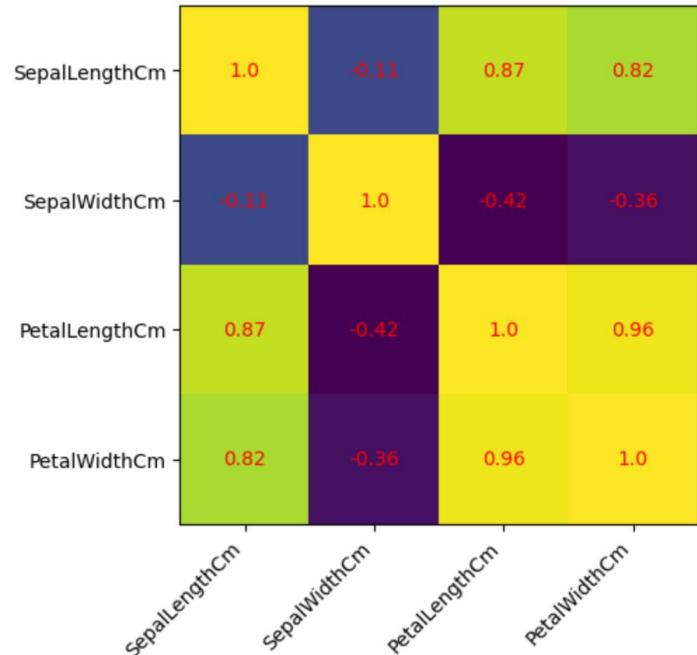


Correlation Heatmap (imshow)

```
correlation = iris.loc[:, 'SepalLengthCm':'PetalWidthCm'].corr()  
correlation
```

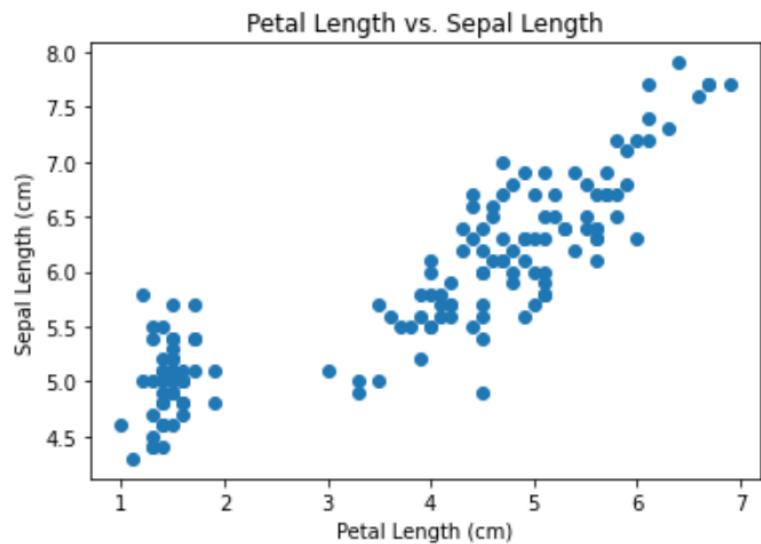
	SepalLengthCm	SepalWidthCm	PetalLengthCm	PetalWidthCm
SepalLengthCm	1.000000	-0.109369	0.871754	0.817954
SepalWidthCm	-0.109369	1.000000	-0.420516	-0.356544
PetalLengthCm	0.871754	-0.420516	1.000000	0.962757
PetalWidthCm	0.817954	-0.356544	0.962757	1.000000

```
plt.imshow(correlation)  
plt.xticks(np.arange(len(correlation)), correlation.index)  
plt.yticks(np.arange(len(correlation)), correlation.index)  
  
# Rotate the tick labels and set their alignment.  
plt.xticks(rotation=45, ha="right")  
  
# Loop over data dimensions and create text annotations.  
for i in range(len(correlation)):  
    for j in range(len(correlation)):  
        text = plt.text(j, i, round(correlation.iloc[i, j], 2),  
                        ha="center", va="center", color="r")  
  
plt.show()
```



Scatter Plot

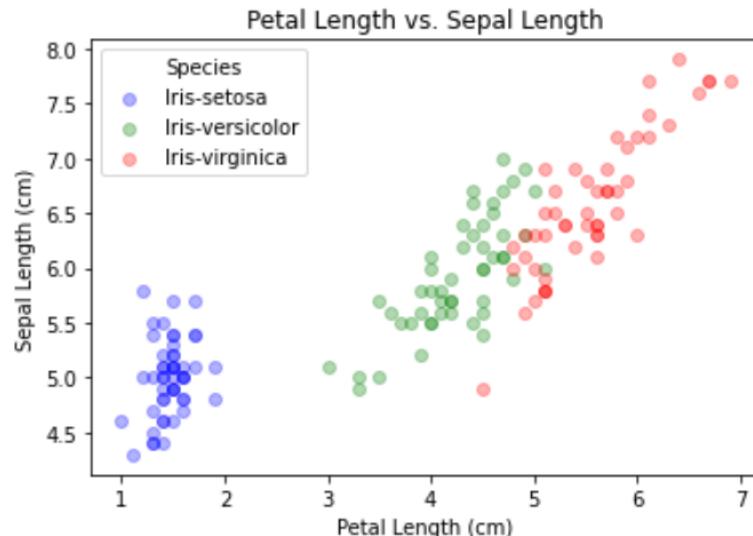
```
plt.scatter(x=iris['PetalLengthCm'], y=iris['SepalLengthCm'])
plt.xlabel('Petal Length (cm)')
plt.ylabel('Sepal Length (cm)')
plt.title('Petal Length vs. Sepal Length')
plt.show()
```



Scatter Plot with colors

```
color_map = dict(zip(iris_species, ['blue', 'green', 'red']))  
color_map  
  
{'Iris-setosa': 'blue', 'Iris-versicolor': 'green', 'Iris-virginica': 'red'}
```

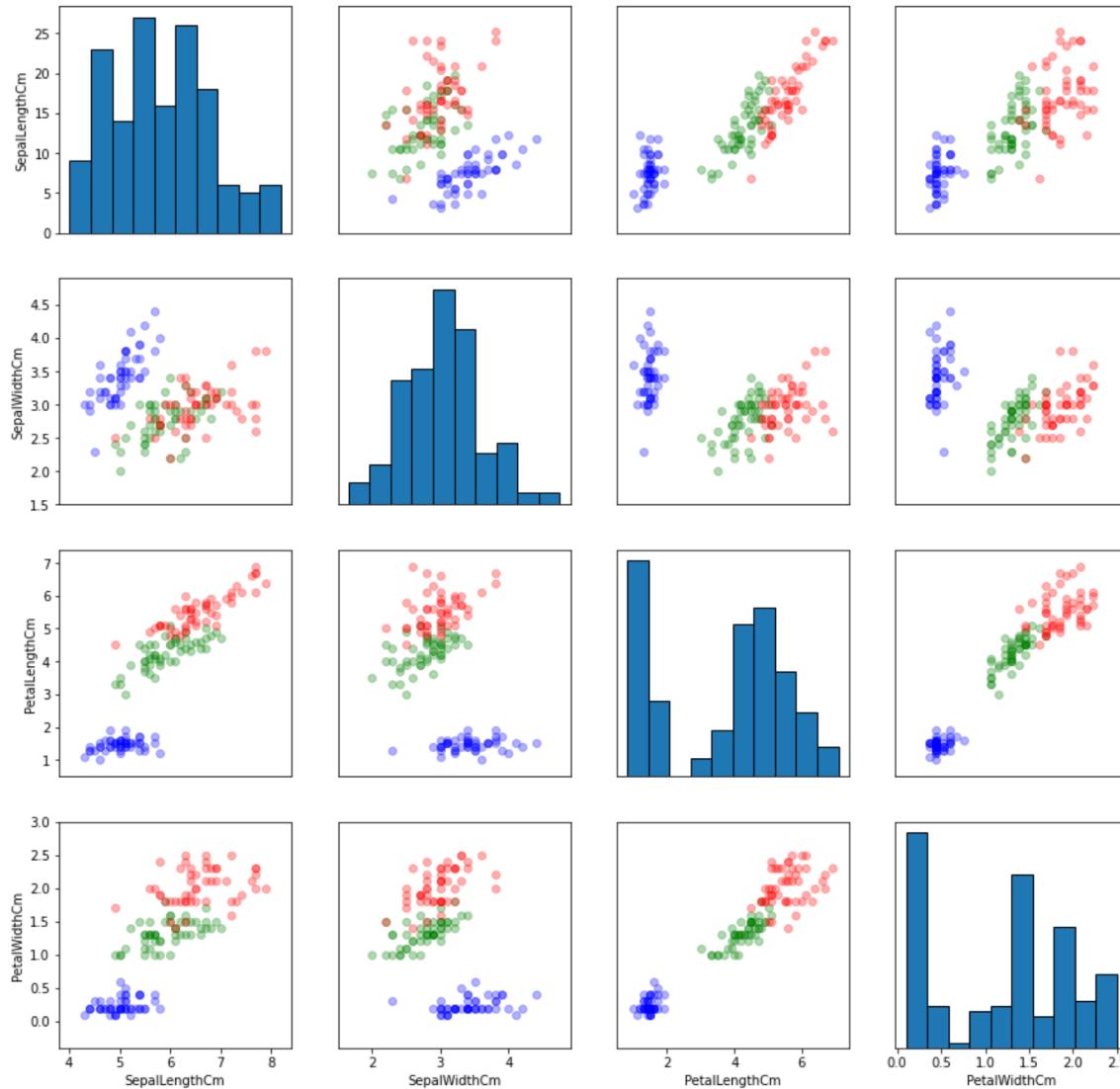
```
for species, group in iris.groupby('Species'):  
    plt.scatter(group['PetalLengthCm'], group['SepalLengthCm'],  
                color=color_map[species],  
                alpha=0.3, edgecolor=None,  
                label=species)  
  
plt.legend(frameon=True, title='Species')  
plt.xlabel('Petal Length (cm)')  
plt.ylabel('Sepal Length (cm)')  
plt.title('Petal Length vs. Sepal Length')  
plt.show()
```



Pair Plot

Pair Plot of the Iris Dataset

Iris-setosa
Iris-versicolor
Iris-virginica



Pair Plot

```
import matplotlib.patches as mpatches

n = len(iris_features)
plt.figure(figsize=(15, 15))

for i in range(n):
    for j in range(n):
        plt.subplot(n, n, i*n + j + 1)

        if i == j:
            plt.hist(iris[iris_features[i]], bins=10, edgecolor='black')
        else:
            for species, group in iris.groupby('Species'):
                plt.scatter(group[iris_features[j]], group[iris_features[i]],
                            color=color_map[species],
                            alpha=0.3, edgecolor=None,
                            label=species)
            plt.xlim([features_min[iris_features[j]]-0.5, features_max[iris_features[j]]+0.5])
            plt.ylim([features_min[iris_features[i]]-0.5, features_max[iris_features[i]]+0.5])

        if i != n-1:
            plt.xticks([])
        else:
            plt.xlabel(iris_features[j])

        if j != 0:
            plt.yticks([])
        else:
            plt.ylabel(iris_features[i])

# Adding the Legend manually
rects = [mpatches.Patch(color=color_map[species], label=species) for species in color_map]
plt.figlegend(rects, color_map.keys(), loc='upper right')

plt.suptitle("Pair Plot of the Iris Dataset")
plt.show()
```

K-Means Clustering

```
from sklearn.cluster import KMeans  
  
kmeans = KMeans(n_clusters=3)  
cluster = kmeans.fit_predict(iris.loc[:, 'SepalLengthCm':'PetalWidthCm'])
```

```
cluster
```

```
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,  
      0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,  
      0, 0, 0, 0, 0, 1, 1, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,  
      1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,  
      1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 1, 2, 2, 2, 2, 1, 2, 2, 2,  
      2, 2, 2, 1, 1, 2, 2, 2, 1, 2, 1, 2, 2, 1, 2, 1, 1, 2, 2, 2, 2,  
      2, 1, 2, 2, 2, 1, 2, 2, 1, 2, 2, 2, 1, 2, 2, 1])
```

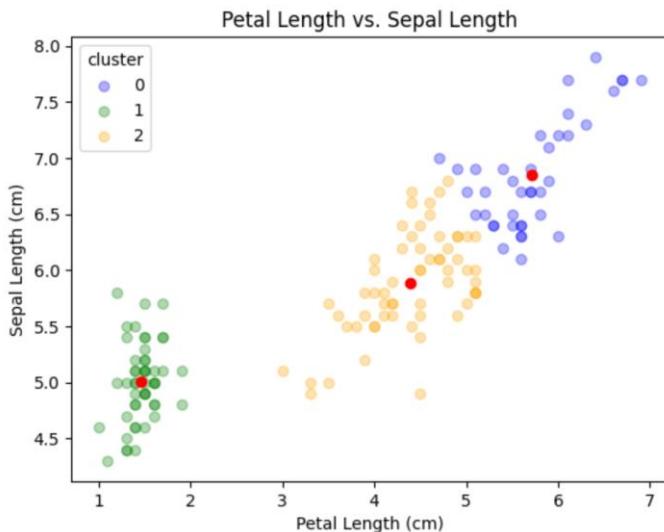
```
iris['cluster'] = cluster
```

```
print(kmeans.cluster_centers_)  
  
[[6.85      3.07368421 5.74210526 2.07105263]  
 [5.006     3.418       1.464       0.244      ]  
 [5.9016129 2.7483871  4.39354839 1.43387097]]
```

K-Means Clustering

```
color_map = ['blue', 'green', 'orange', 'red']

for cluster, group in iris.groupby('cluster'):
    plt.scatter(group['PetalLengthCm'], group['SepalLengthCm'],
                color=color_map[cluster],
                alpha=0.3, edgecolor=None,
                label=cluster)
    plt.scatter(kmeans.cluster_centers_[cluster, 2], kmeans.cluster_centers_[cluster, 0], color=color_map[3])
plt.legend(frameon=True, title='cluster')
plt.xlabel('Petal Length (cm)')
plt.ylabel('Sepal Length (cm)')
plt.title('Petal Length vs. Sepal Length')
plt.show()
```



Compare result

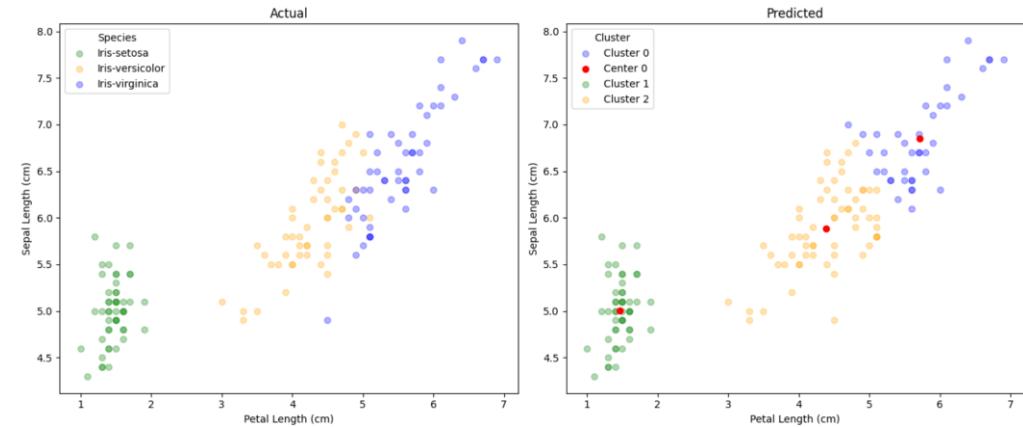
```
# Comparison
plt.figure(figsize=(14, 6))

color_map_species = dict(zip(iris_species, ['green', 'orange', 'blue']))

# Plot actual species distribution
plt.subplot(1, 2, 1)
for species, group in iris.groupby('Species'):
    plt.scatter(group['PetalLengthCm'], group['SepalLengthCm'],
                color=color_map_species[species],
                alpha=0.3, edgecolor=None,
                label=species)
plt.legend(frameon=True, title='Species')
plt.xlabel('Petal Length (cm)')
plt.ylabel('Sepal Length (cm)')
plt.title('Actual')

# Move to the next subplot for predicted clusters
plt.subplot(1, 2, 2)
color_map_cluster = ['blue', 'green', 'orange', 'red']
for cluster, group in iris.groupby('cluster'):
    plt.scatter(group['PetalLengthCm'], group['SepalLengthCm'],
                color=color_map_cluster[cluster],
                alpha=0.3, edgecolor=None,
                label=f"Cluster {cluster}")
    # Plot cluster centers
    plt.scatter(kmeans.cluster_centers_[cluster, 2],
                kmeans.cluster_centers_[cluster, 0],
                color=color_map_cluster[3],
                label=f"Center {cluster}" if cluster == 0 else "")
plt.legend(frameon=True, title='Cluster')
plt.xlabel('Petal Length (cm)')
plt.ylabel('Sepal Length (cm)')
plt.title('Predicted')

plt.show()
```



Pandas Plot

pandas.DataFrame.plot

pandas.DataFrame.plot.area

pandas.DataFrame.plot.bar

pandas.DataFrame.plot.bart

pandas.DataFrame.plot.box

pandas.DataFrame.plot.density

pandas.DataFrame.plot.hexbin

pandas.DataFrame.plot.hist

pandas.DataFrame.plot.kde

pandas.DataFrame.plot.line

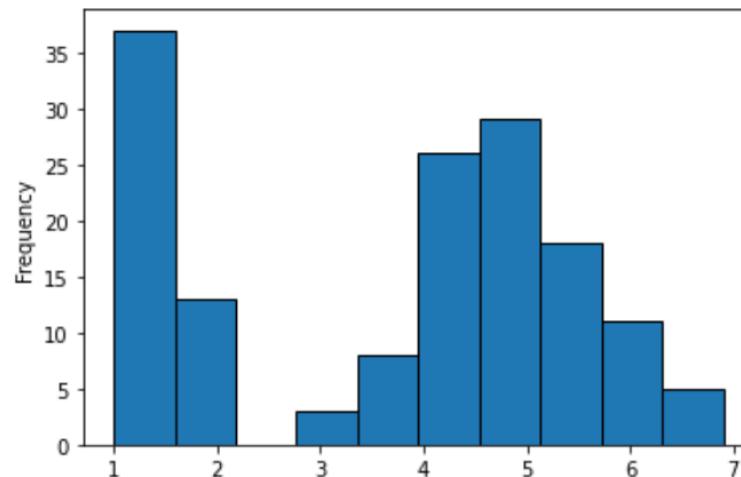
pandas.DataFrame.plot.pie

pandas.DataFrame.plot.scatter

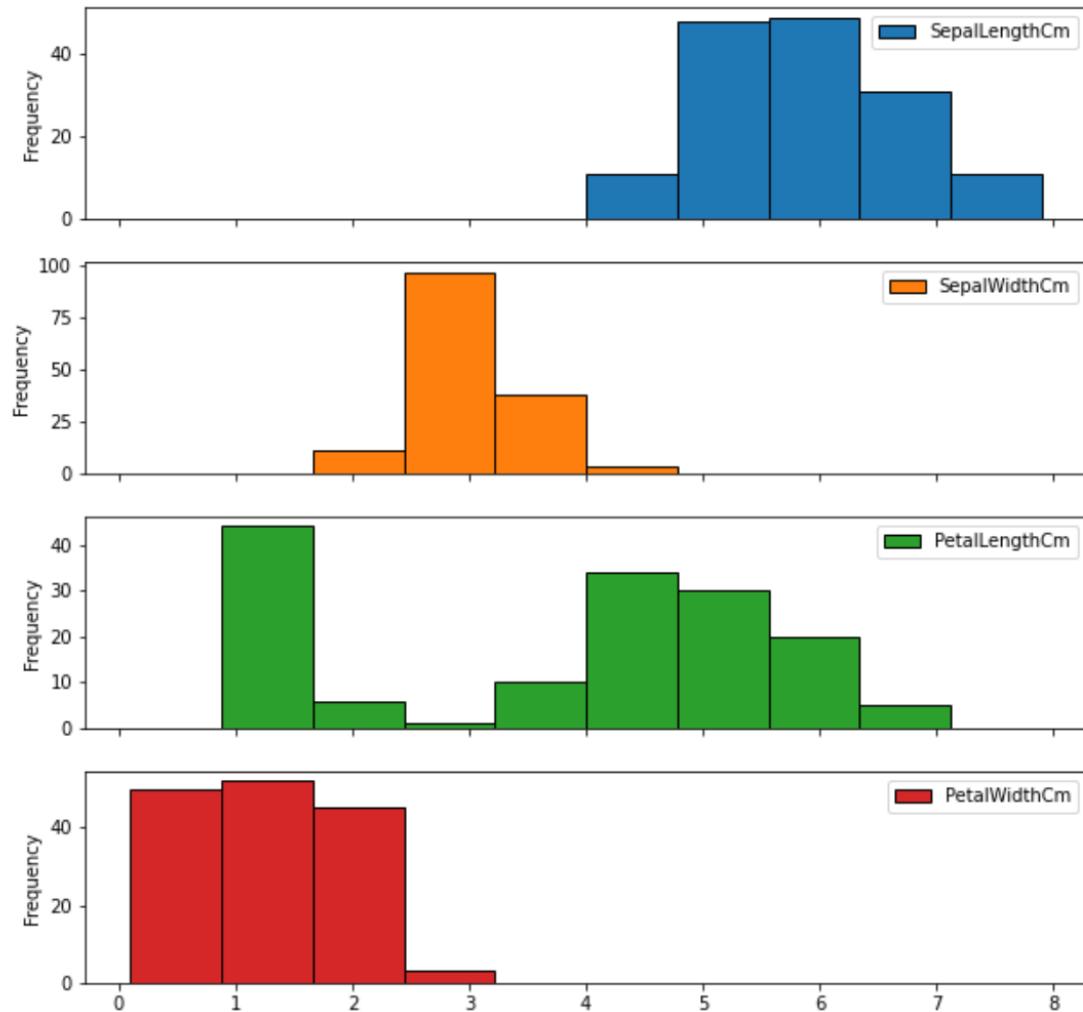
pandas.DataFrame.boxplot

- Pandas provides some basic plot functions.
- Work with Matplotlib
- https://pandas.pydata.org/docs/user_guide/visualization.html

```
iris['PetalLengthCm'].plot.hist(bins=10, edgecolor='black' )  
plt.show()
```



```
iris.loc[:, 'SepalLengthCm':'PetalWidthCm'].plot.hist(bins=10, edgecolor='black', figsize=(10, 10), subplots=True)  
plt.show()
```



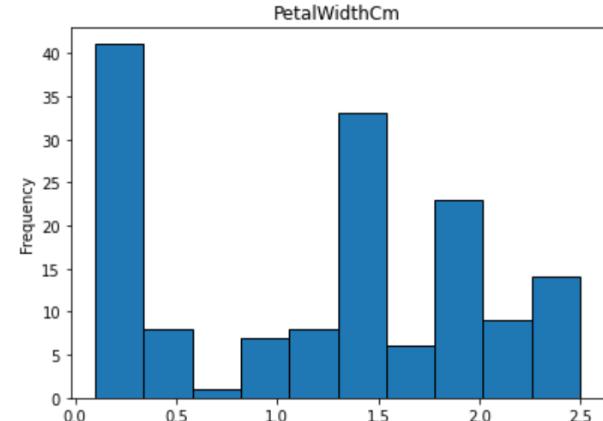
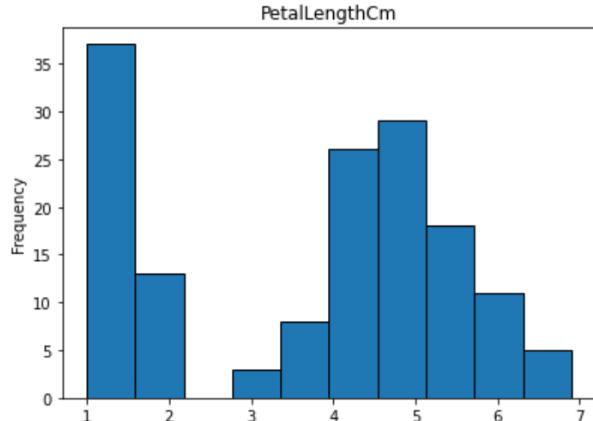
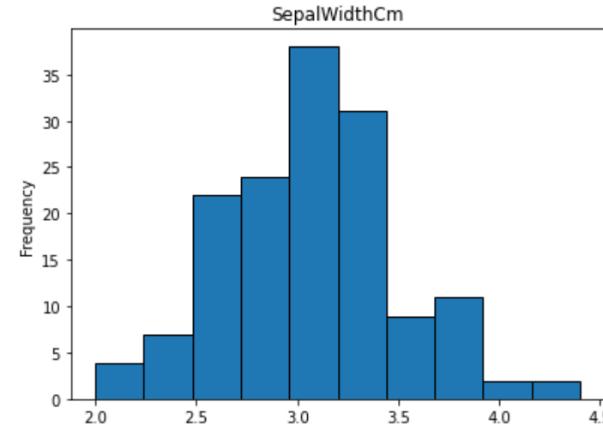
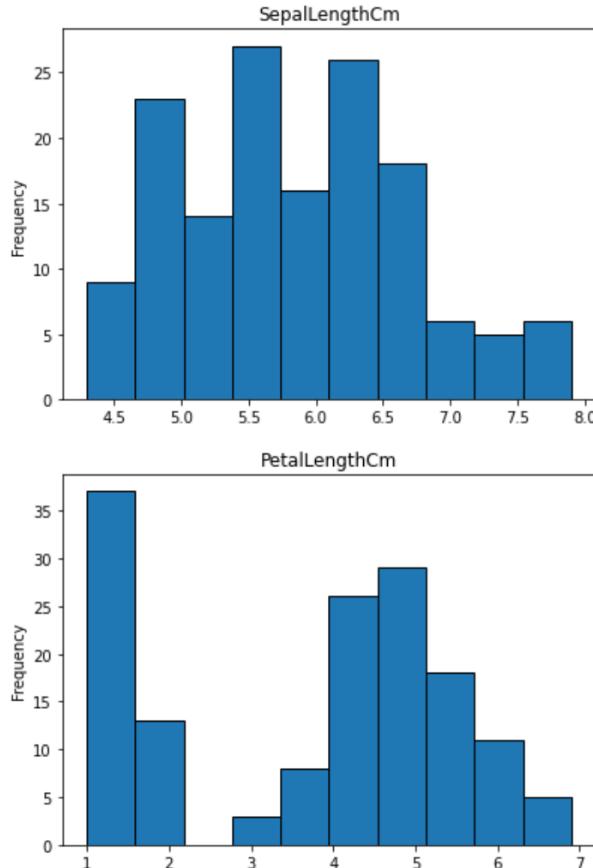
Pandas plot + Matplotlib

```
fig, ax = plt.subplots(2, 2, figsize=(14,10))

iris['SepalLengthCm'].plot.hist(ax=ax[0,0], bins=10, edgecolor='black')
iris['SepalWidthCm'].plot.hist(ax=ax[0,1], bins=10, edgecolor='black')
iris['PetalLengthCm'].plot.hist(ax=ax[1,0], bins=10, edgecolor='black')
iris['PetalWidthCm'].plot.hist(ax=ax[1,1], bins=10, edgecolor='black')

ax[0,0].set_title('SepalLengthCm')
ax[0,1].set_title('SepalWidthCm')
ax[1,0].set_title('PetalLengthCm')
ax[1,1].set_title('PetalWidthCm')

plt.show()
```

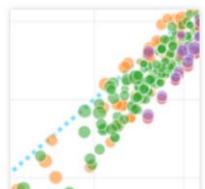


Interactive Visualization with Plotly

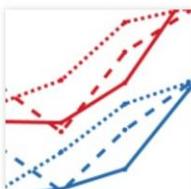
Plotly

- Based on Javascript
- Interactive viz
- Also support
 - 3D viz
 - Animation
 - Geographical viz
- <https://plot.ly/python>
- <https://chart-studio.plotly.com/>

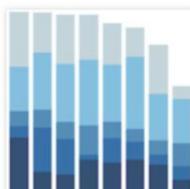
Basic Charts



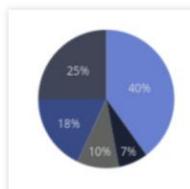
Scatter Plots



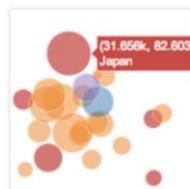
Line Charts



Bar Charts



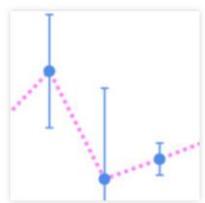
Pie Charts



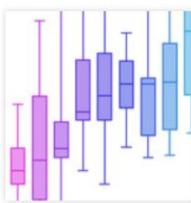
Bubble Charts

[More Basic Charts »](#)

Statistical Charts



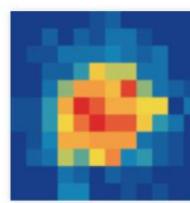
Error Bars



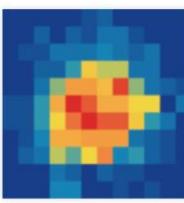
Box Plots



Histograms



Distplots



2D Histograms

[More Statistical Charts »](#)

Maps



MapLibre Migration



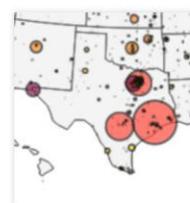
Tile Choropleth Maps



Lines on Tile Maps



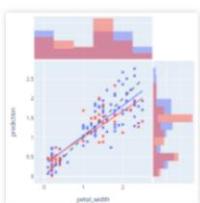
Filled Area on Tile Maps



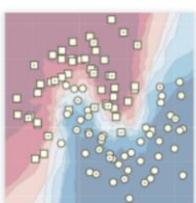
Bubble Maps

[More Maps »](#)

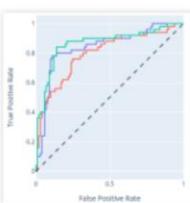
Artificial Intelligence and Machine Learning



ML Regression



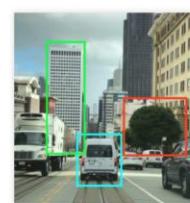
kNN Classification



ROC and PR Curves



PCA Visualization



AI/ML Apps with Dash

[More AI and ML »](#)

Plotly APIs

Two Styles:

- **Graph Objects interface**
 - More control and customization
 - Create a plot using multiple functions to add content and modify the appearance
 - Recommended for more complex plots
- **Plotly Express**
 - High-level wrapper for Plotly
 - Create a plot using one function with a lot of parameters
 - More convenient but less flexible

Stick to one style. Mixing Plotly Express and Graph Objects can make your code harder to read and maintain.

Plotly Graph Objects

- Graph Objects components
 - Figures
 - Traces
 - Layouts

STRUCTURE OF A PLOTLY CHART

```
trace = go.Scatter( x , y ,  
                    mode )
```

```
data = [ trace_1 ,  
         trace_2 ,  
         ... ]
```

```
layout = go.Layout( title ,  
                    x_axis ,  
                    ... )
```

```
fig = go.Figure( data ,  
                  layout )
```

```
trace = go.Scatter(  
    x = df.arr_delay,  
    y = df.dep_delay,  
    mode = 'markers')
```



```
data = [trace]
```



```
layout=go.Layout(title="Departure Delay vs  
                           Arrival Delay",  
                 xaxis={'title':'Arrival Delay'},  
                 yaxis={'title':'Departure Delay'})
```

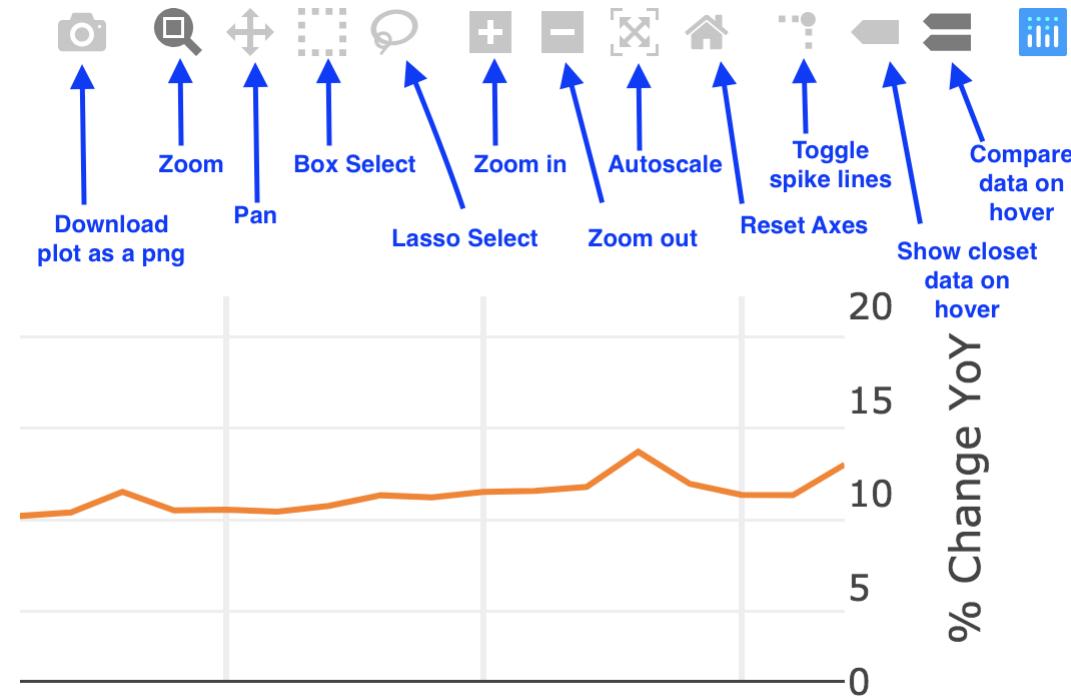


```
fig = go.Figure(data=data, layout=layout)  
iplot(fig)
```



Modebar

- Plotly's modebar is the toolbar that appears when you hover over a Plotly chart.
- It provides interactive features to manipulate the view of the plot.



Histogram with Plotly Graph Objects

```
import plotly.graph_objects as go

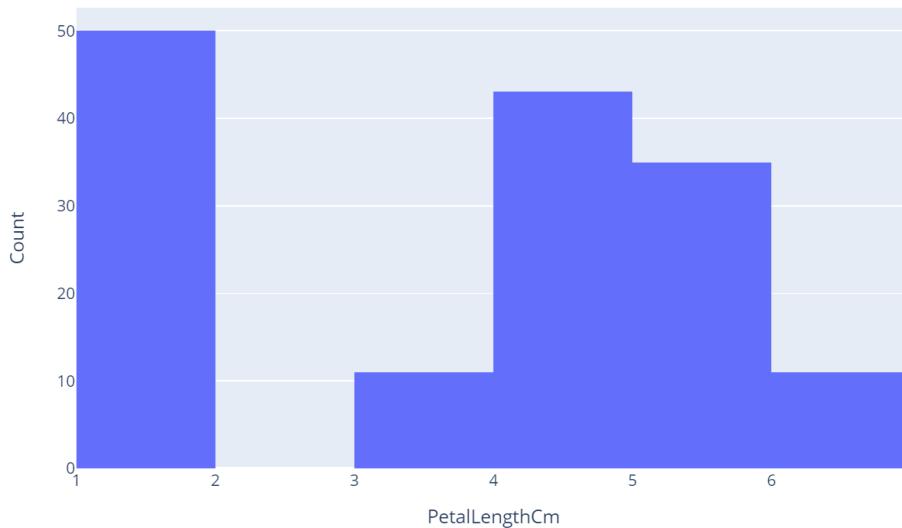
trace = go.Histogram(x= iris['PetalLengthCm'], nbinsx=10)
data = [trace]
layout = go.Layout(xaxis_title="PetalLengthCm", yaxis_title="Count")
fig = go.Figure(data=data, layout=layout)
fig.show()
```

```
import plotly.graph_objects as go

fig = go.Figure()
fig.add_traces(go.Histogram(x= iris['PetalLengthCm'], nbinsx=10))
fig.update_layout(xaxis_title="PetalLengthCm", yaxis_title="Count")
fig.show()
```



Two styles
Same result



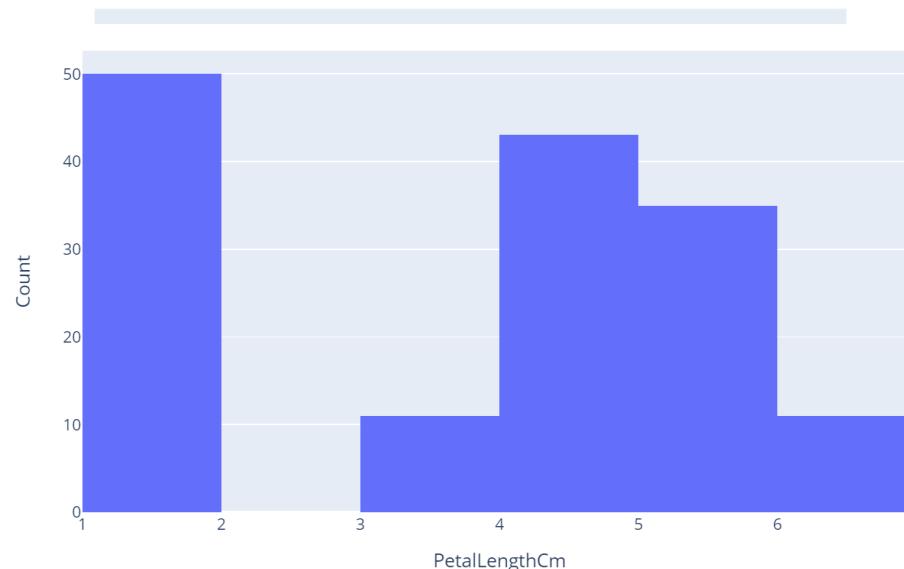
Histogram with Plotly Express

<https://towardsdatascience.com/histograms-with-plotly-express-complete-guide-d483656c5ad7>

plotly.express.histogram

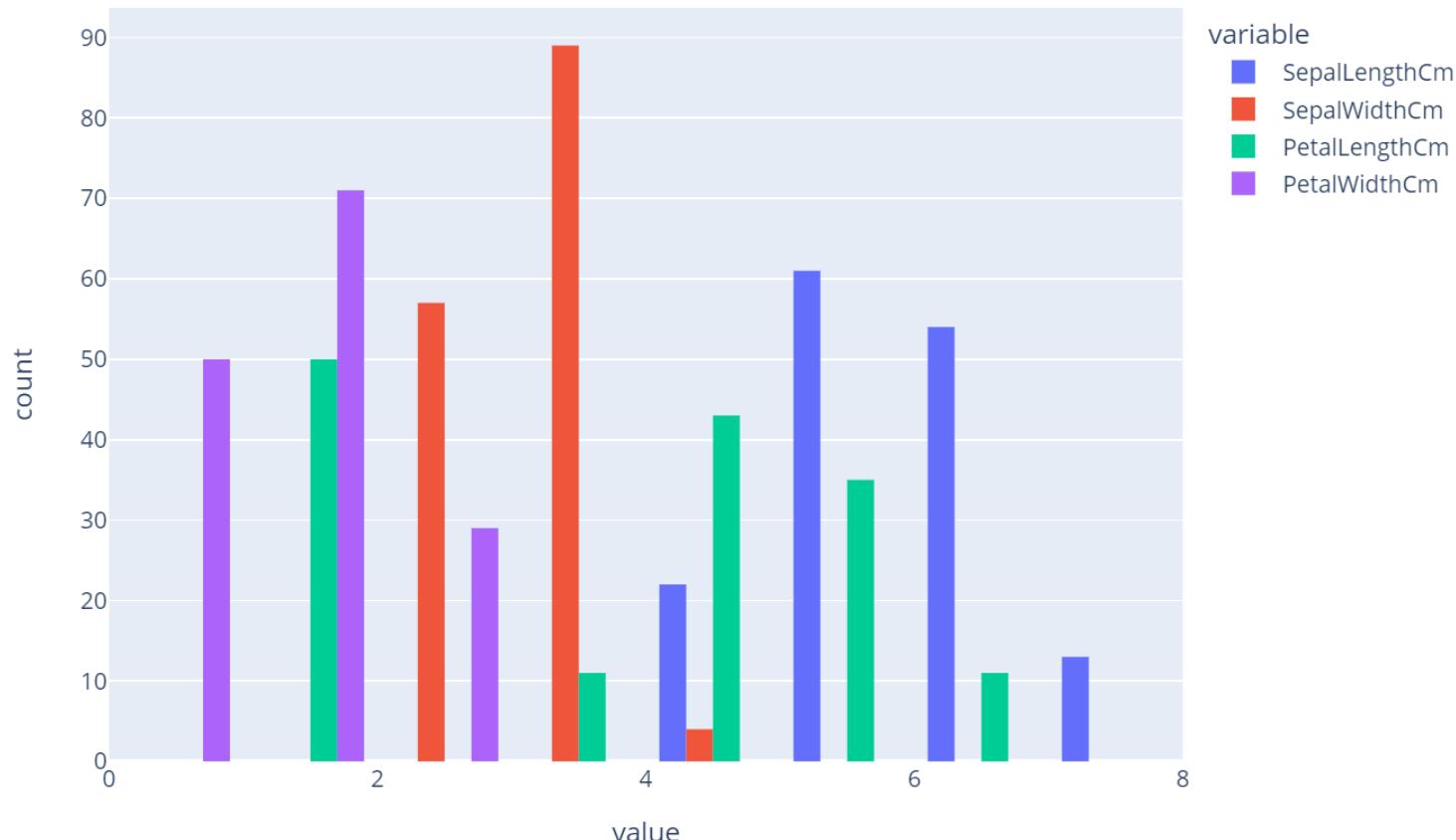
```
plotly.express. histogram (data_frame=None, x=None, y=None, color=None, pattern_shape=None,  
facet_row=None, facet_col=None, facet_col_wrap=0, facet_row_spacing=None, facet_col_spacing=None,  
hover_name=None, hover_data=None, animation_frame=None, animation_group=None,  
category_orders=None, labels=None, color_discrete_sequence=None, color_discrete_map=None,  
pattern_shape_sequence=None, pattern_shape_map=None, marginal=None, opacity=None,  
orientation=None, barmode='relative', barnorm=None, histnorm=None, log_x=False, log_y=False,  
range_x=None, range_y=None, histfunc=None, cumulative=None, nbins=None, text_auto=False, title=None,  
template=None, width=None, height=None)
```

```
import plotly.express as px  
px.histogram(iris, x='PetalLengthCm', nbins=10)
```



Histogram with Plotly Express

```
px.histogram(iris.loc[:, 'SepalLengthCm':'PetalWidthCm'], nbins=10, barmode="group")
```

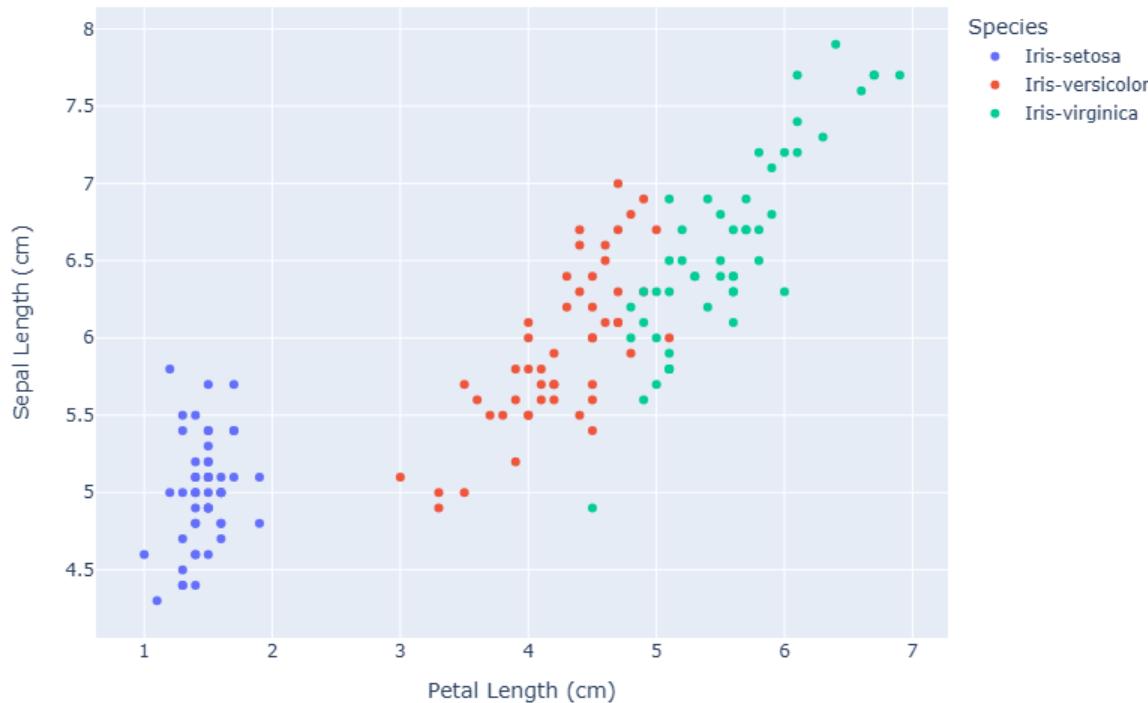


Scatter Plot with Plotly Express

```
fig = px.scatter(iris, x='PetalLengthCm', y='SepalLengthCm',
                  title='Petal Length vs. Sepal Length',
                  color='Species',
                  hover_name='Species',
                  labels=dict(PetalLengthCm='Petal Length (cm)', SepalLengthCm='Sepal Length (cm)'))

fig.update_layout(width=800, height=600)
fig.show()
```

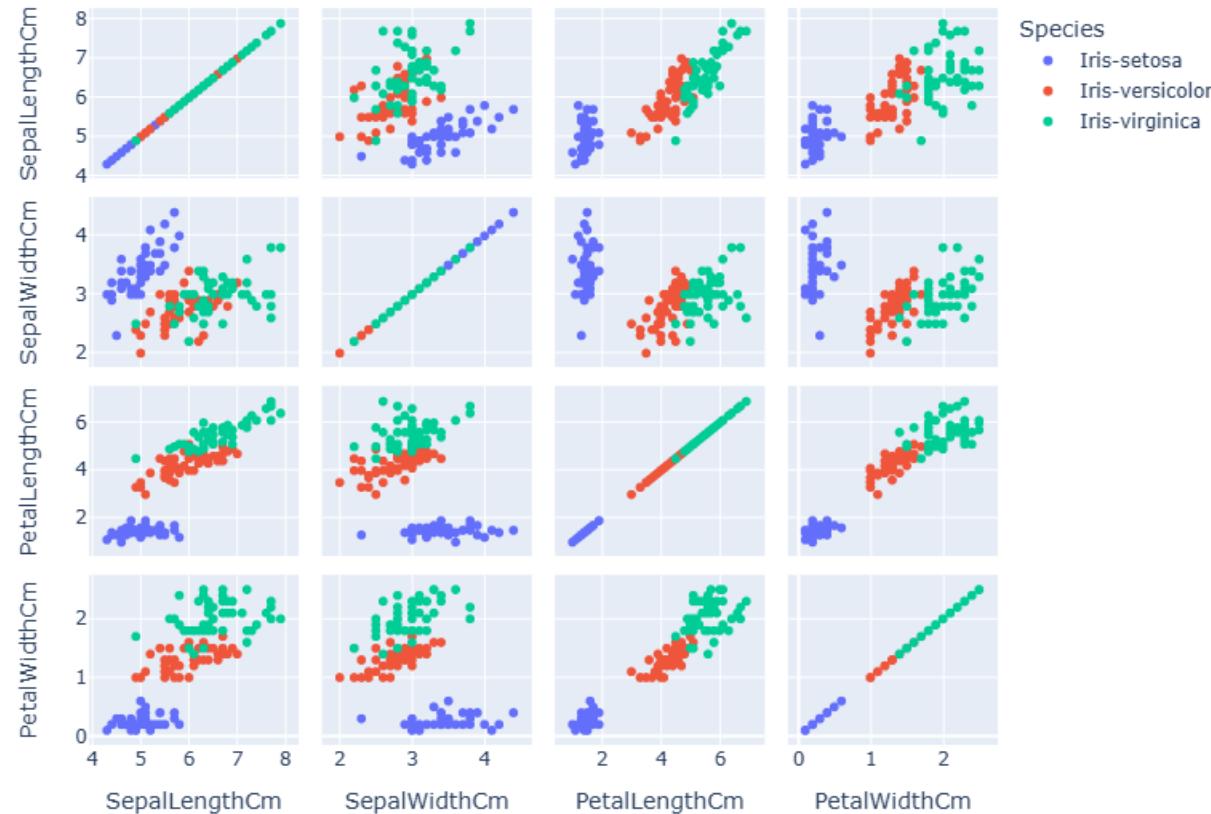
Petal Length vs. Sepal Length



Scatter Matrix (Pair Plot) with Plotly Express

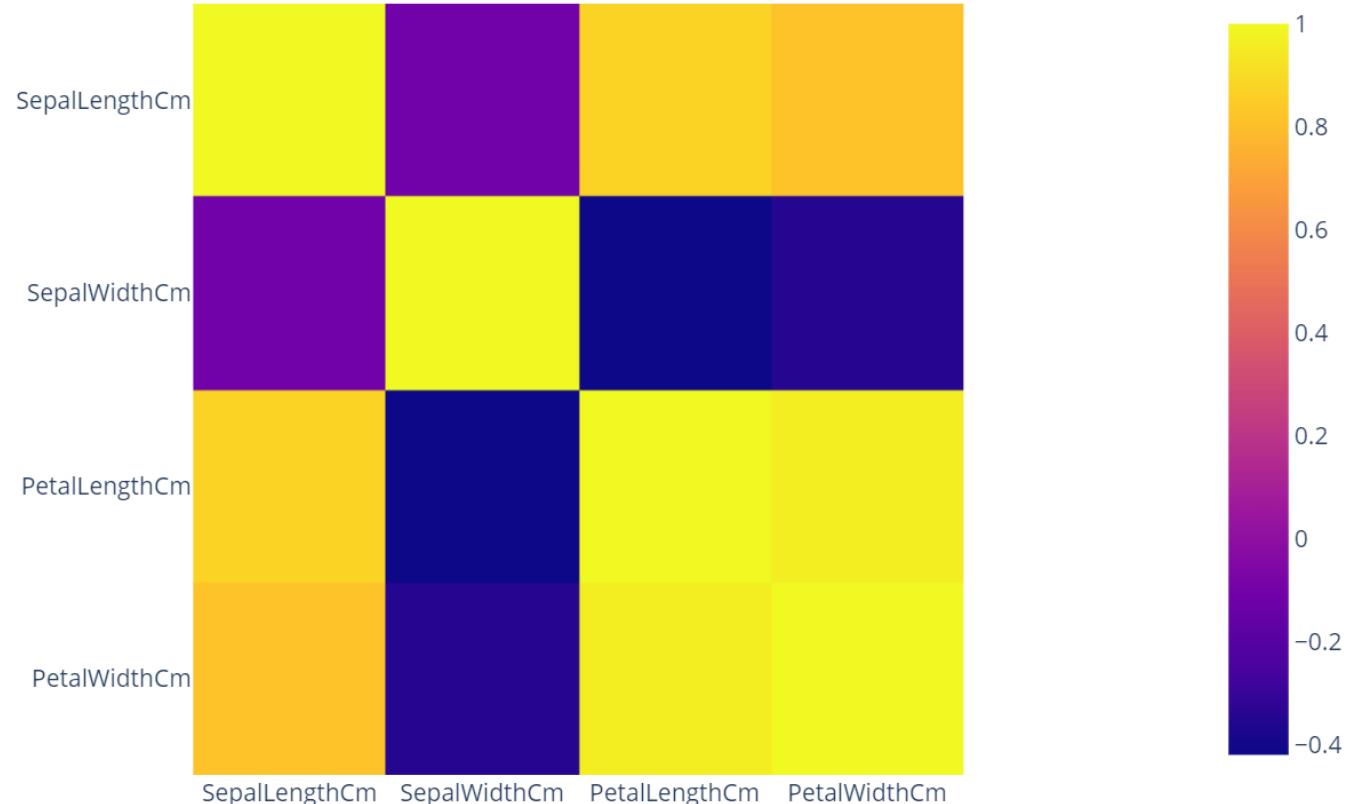
```
fig = px.scatter_matrix(iris,
                        dimensions=['SepalLengthCm', 'SepalWidthCm', 'PetalLengthCm', 'PetalWidthCm'],
                        color='Species')

fig.show()
```



Heatmap with Plotly Express (imshow)

```
fig = px.imshow(correlation)  
fig.show()
```



Data analysis and visualization projects with Plotly

- Spotify
 - <https://www.kaggle.com/code/varunsaikanuri/spotify-data-visualization>
- GapMinder
 - <https://www.kaggle.com/code/ssarkar445/startng-with-plotly-express/notebook>
- Top 100 Universities
 - <https://www.kaggle.com/code/kanncaa1/plotly-tutorial-for-beginners/notebook>
- IMDb movie database
 - <https://www.kaggle.com/code/andrewedward37/visualization-with-plotly-express-a-starter-guide>

Interactive App with **Streamlit**

Streamlit

- Python library for creating web apps for machine learning and data science.
- Built-in support for displaying rich media (charts, maps), data frames, and even machine learning models, making it well-suited for data science and machine learning projects.
- It integrates seamlessly with libraries like Pandas, Matplotlib, Plotly, and others.
- <https://streamlit.io>
- <https://streamlit.io/gallery>
- <https://docs.streamlit.io/get-started>



Snowflake Health

64squaresapexllp

[View source →](#)



WITNESS Explorer

sotrades-pjbarjhoux

[View source →](#)



prettymapp

chriek

[View source →](#)

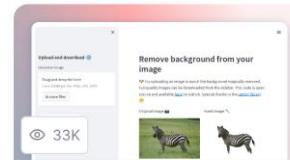
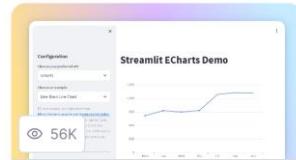


Image Background Remover

tyler-simons

[View source →](#)



Streamlit ECharts Demo

andfanilo

[View source →](#)



Vineyard Site Selection

spencermartel

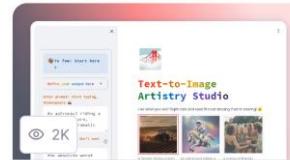
[View source →](#)



friend.tech Dashboard

1cy1c3

[View source →](#)



Replicate Image Generator

tonykipkemboi

[View source →](#)

Streamlit

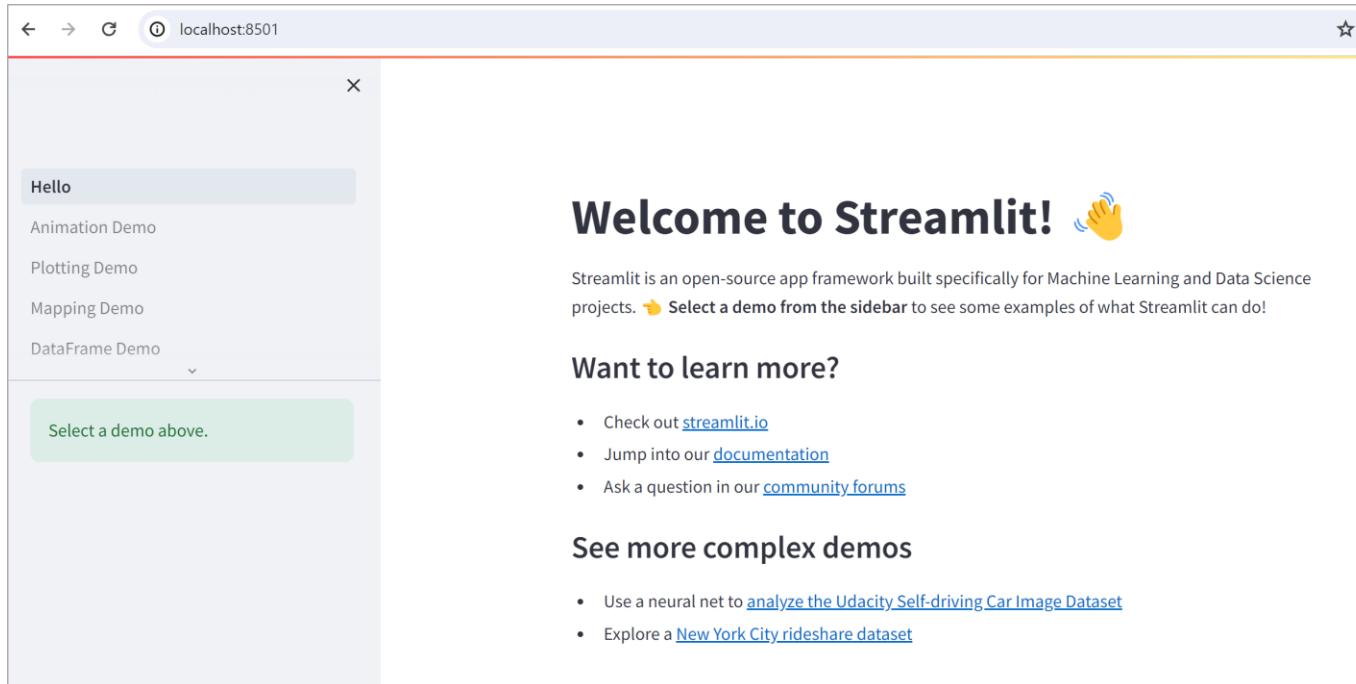
- Install

```
pip install streamlit
```

- Validate the installation by running the built-in ‘hello’ app.

```
streamlit hello
```

The program will run on <http://localhost:8501/>



Streamlit App: Hello World!

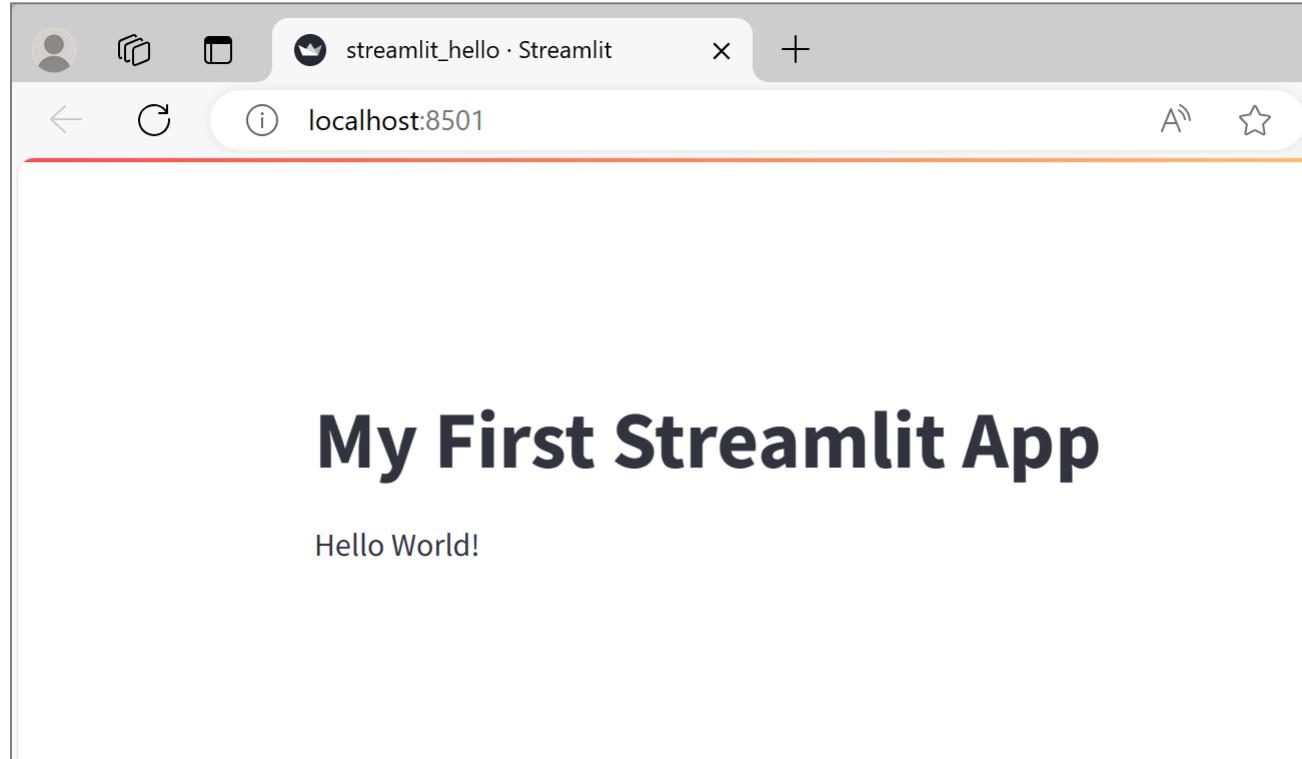
```
import streamlit as st  
  
st.title('My First Streamlit App')  
st.write('Hello World!')
```

streamlit_hello.py

How to run:

Run on command line: `streamlit run .\streamlit_hello.py`

Then open in browser: `http://localhost:8501/`



Streamlit Structure

- Layout
 - `st.container()`, `st.columns()`
 - `st.expander()`
- Sidebar
 - `st.sidebar()`
 - `st.sidebar.number_input()`, `st.sidebar.selectbox()`
- Input
 - `st.number_input()`, `st.selectbox()`, `st.slider()`, `st.button()`,
`st.checkbox()`
- Output
 - `st.write()`, `st.dataframe()`
 - `st.line_chart()`, `st.bar_chart()`, `st.plotly_chart()`
 - `st.map`
- Heading
 - `st.title()`, `st.header()`

Streamlit Structure Demo

Sidebar Controls

Select number of data points
50 - +

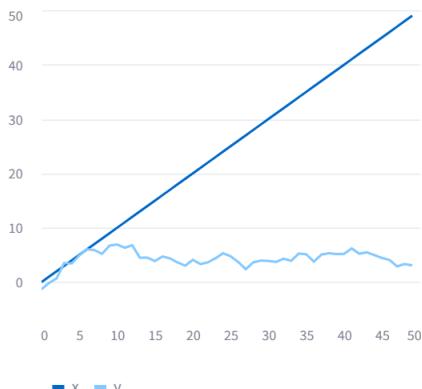
Choose your chart type
Line Chart Bar Chart

Streamlit Demo App

Interactive Data Visualization

The chart in Column 1 and the data in Column 2 change based on sidebar selections.

Column 1: Visualization



Legend: — x — y

Column 2: Data Preview

Preview data

	x	y
0	0	-1.3205
1	1	-0.1507
2	2	0.6985
3	3	3.498
4	4	3.439
5	5	4.9067
6	6	6.0242
7	7	5.8999
8	8	5.2017
9	9	6.7137

See more details ^

This example demonstrates how inputs from the sidebar can dynamically affect the content within the app. Changing the number of data points or the chart type in the sidebar updates the visualization and data preview in real-time.

Streamlit Structure Demo (1)

streamlit_demo.py

```
import streamlit as st
import numpy as np
import pandas as pd

# Sidebar
st.sidebar.header('Sidebar Controls')
# Sidebar Widgets for controlling what's shown in the columns
number = st.sidebar.number_input('Select number of data points', min_value=10, max_value=100,
value=50)
option = st.sidebar.selectbox(
    'Choose your chart type',
    ('Line Chart', 'Bar Chart')
)
st.sidebar.write('You selected:', option)

# Main content
st.title('Streamlit Demo App')

# Using container
with st.container():
    st.header('Interactive Data Visualization')
    st.write('The chart in Column 1 and the data in Column 2 change based on sidebar
selections.')

# Generating sample data based on the number input
data = pd.DataFrame({
    'x': range(number),
    'y': np.random.randn(number).cumsum()
})
```

Streamlit Structure Demo (2)

```
# Columns for displaying charts and data based on sidebar inputs
col1, col2 = st.columns(2)

with col1:
    st.header('Column 1: Visualization')
    if option == 'Line Chart':
        st.line_chart(data)
    elif option == 'Bar Chart':
        st.bar_chart(data['y'])

with col2:
    st.header('Column 2: Data Preview')
    # Checkbox to select whether to preview the data
    if st.checkbox('Preview data', key='preview_data'):
        # Display the DataFrame without the index
        st.dataframe(data.reset_index(drop=True))

# Expander for additional details
with st.expander("See more details"):
    st.write("""
        This example demonstrates how inputs from the sidebar can dynamically affect the content
        within the app. Changing the number of data points or the chart type in the sidebar
        updates the visualization and data preview in real-time.
    """)
```

More Examples

streamlit_examples.py

Welcome to Streamlit!

This is a header

This is a subheader

This is plain text

This is *markdown*

Streamlit's write function can handle multiple data types

```
print('Hello World')
```

Basic Streamlit Charts

Line Chart

Area Chart

Plotly Charts

Sales vs Revenue

Navigation

Choose an example

Data Display

Text Elements

Charts

Input Widgets

Layout

Navigation

Choose an example

Data Display

	name	age	city
0	John	25	New York
1	Mary	30	London
2	Bob	35	Paris

Navigation

Choose an example

Input Widgets

Text Elements

Charts

Input Widgets

Layout

Enter your name

Moo Deng

Enter your age

1

Are you happy?

Choose a color

red

Select a value

9

Submit

Hello Moo Deng, you are 1 years old!

Happiness status: True

Favorite color: red

Slider value: 9

Basic Column Layout

Column 1

This is column 1

Temperature

24 °C

1.2 °C

-2%

Column 2

This is column 2

Humidity

48%

0.5 hPa

-2%

Column 3

This is column 3

Pressure

1013 hPa

0.5 hPa

Nested Layouts

Tab 1 Tab 2 Tab 3

This is content in tab 1

Nested column 1

Nested column 2

Cache

- Each time a user interaction occurs, the entire script is rerun.
- This design choice simplifies the development process but can lead to performance degradation for complex apps.
- To improve performance, Streamlit introduces [caching](#).
- Returned value of a function with the same parameters and the same function code will be cached and reused.
- Use `@st.cache_data` and `@st.cache_resource` decorators.
 - Use `@st.cache_data` for most data objects
 - Use `@st.cache_resource` for database connections, ML models, file handles, threads, etc.

```
@st.cache_data
def load_data(url):
    df = pd.read_csv(url)
    return df

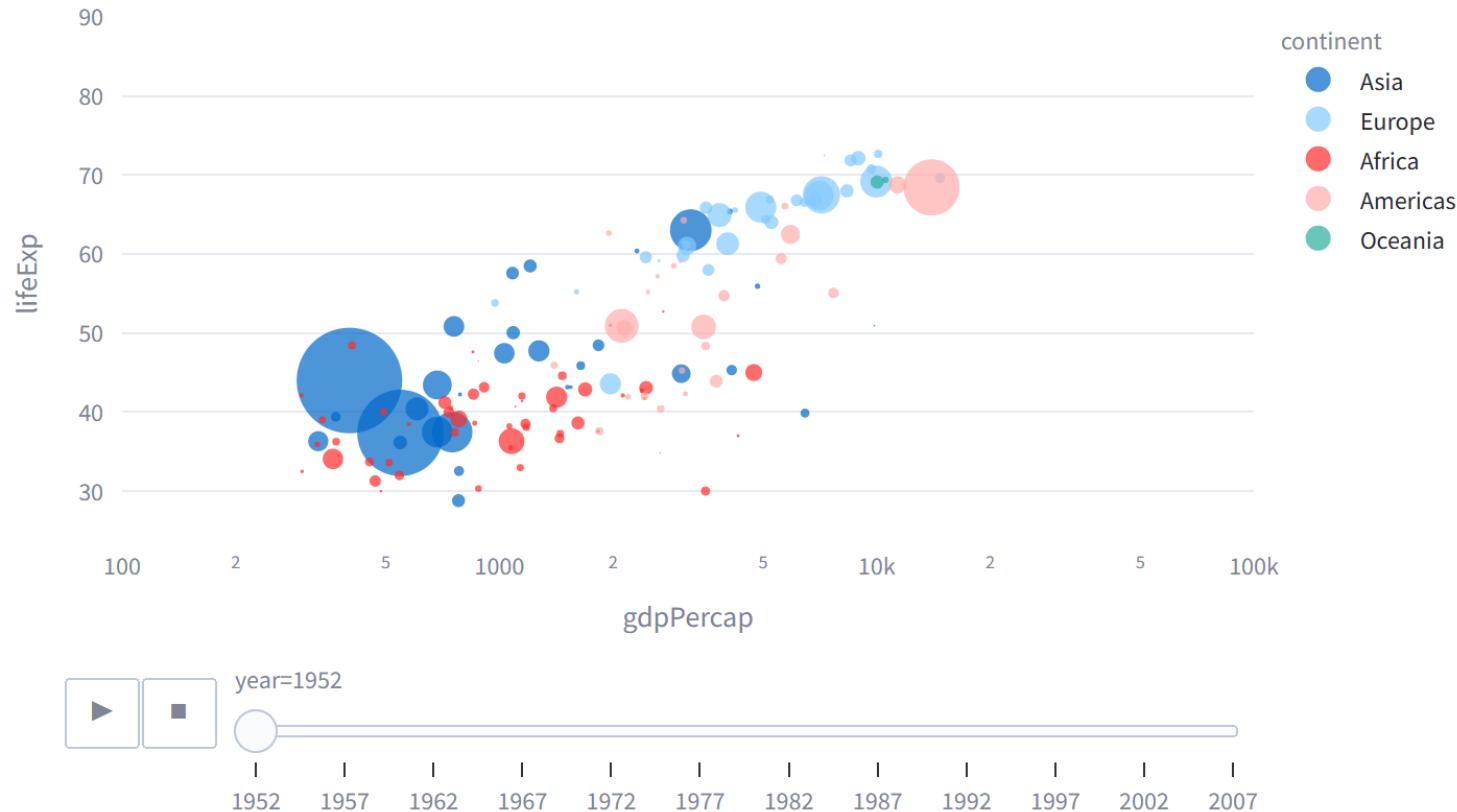
df = load_data("https://github.com/plotly/datasets/raw/master/uber-rides-data1.csv")
```

```
@st.cache_resource
def init_connection():
    host = "hh-pgsql-public.ebi.ac.uk"
    database = "pfmegrnargs"
    user = "reader"
    password = "NWDMCE5xdipIjRrp"
    return psycopg2.connect(host=host, database=database, user=user, password=password)

conn = init_connection()
```

Streamlit + Plotly Animation: Gapminder

Income vs Live Expectancy



Streamlit + Plotly Animation: Gapminder

streamlit_gapminder.py

```
import pandas as pd
import plotly.express as px
import streamlit as st

# Load the dataset
#df = pd.read_csv('https://raw.githubusercontent.com/plotly/datasets/master/gapminderDataFiveYear.csv')
df = pd.read_csv('gapminderData.csv')

def create_animated_figure():
    fig = px.scatter(df,
                      x="gdpPercap",
                      y="lifeExp",
                      animation_frame="year",
                      animation_group="country",
                      size="pop",
                      color="continent",
                      hover_name="country",
                      log_x=True,
                      size_max=55,
                      range_x=[100,100000],
                      range_y=[25,90])

    fig.update_layout(transition={'duration': 100})
    return fig

st.title('Income vs Live Expectancy')

# Display the animated plot
fig = create_animated_figure()
st.plotly_chart(fig)
```

```
country,year,pop,continent,lifeExp,gdpPercap
Afghanistan,1952,8425333,Asia,28.801,779.4453145
Afghanistan,1957,9240934,Asia,30.332,820.8530296
Afghanistan,1962,10267083,Asia,31.997,853.10071
Afghanistan,1967,11537966,Asia,34.02,836.1971382
Afghanistan,1972,13079460,Asia,36.088,739.9811058
Afghanistan,1977,14880372,Asia,38.438,786.11336
Afghanistan,1982,12881816,Asia,39.854,978.0114388
Afghanistan,1987,13867957,Asia,40.822,852.3959448
Afghanistan,1992,16317921,Asia,41.674,649.3413952
Afghanistan,1997,22227415,Asia,41.763,635.341351
Afghanistan,2002,25268405,Asia,42.129,726.7340548
Afghanistan,2007,31889923,Asia,43.828,974.5803384
Albania,1952,1282697,Europe,55.23,1601.056136
Albania,1957,1476505,Europe,59.28,1942.284244
Albania,1962,1728137,Europe,64.82,2312.888958
Albania,1967,1984060,Europe,66.22,2760.196931
Albania,1972,2263554,Europe,67.69,3313.422188
Albania,1977,2509048,Europe,68.93,3533.00391
Albania,1982,2780097,Europe,70.42,3630.880722
Albania,1987,3075321,Europe,72,3738.932735
Albania,1992,3326498,Europe,71.581,2497.437901
Albania,1997,3428038,Europe,72.95,3193.054604
```

streamlit_gapminder_cache.py

```
import pandas as pd
import plotly.express as px
import streamlit as st

# Load the dataset
@st.cache_data
def load_data():
    return pd.read_csv('gapminderData.csv')

# Cache the figure creation, ttl=3600 means the cache will expire after 1 hour
@st.cache_data(ttl=3600)
def create_animated_figure(data):
    fig = px.scatter(data,
                      x="gdpPercap",
                      y="lifeExp",
                      animation_frame="year",
                      animation_group="country",
                      size="pop",
                      color="continent",
                      hover_name="country",
                      log_x=True,
                      size_max=55,
                      range_x=[100,100000],
                      range_y=[25,90])

    fig.update_layout(transition={'duration':100})
    return fig

st.title('Income vs Live Expectancy')

# Load the dataset
df = load_data()

# Display the animated plot
fig = create_animated_figure(df)
st.plotly_chart(fig)
```

Streamlit: Grading App

score
97
95
94
93
83
92
92
91
90
90
89
89
81
88
88
87
87
85
83
82
82
81
81
80
80
80
80
80
79
79
79
79
79
79
79
79
77
78
78
78

Simple Grading App

Enter Scores

Choose input method:

- Manual Entry
- File Upload

Upload CSV file with scores:

Drag and drop file here
Limit 200MB per file • CSV

Browse files

scores.csv 0.5KB

X

Class Statistics

Average

74.9

Median

76.0

Count

139

Detailed Results

	Score	Grade
0	97	A
1	95	A
2	94	A
3	93	A
4	83	B
5	92	A
6	92	A
7	91	A
8	90	A
9	90	A
..

Download Results

Grade Criteria

Minimum score for A: 90 - +

Minimum score for B: 80 - +

Minimum score for C: 70 - +

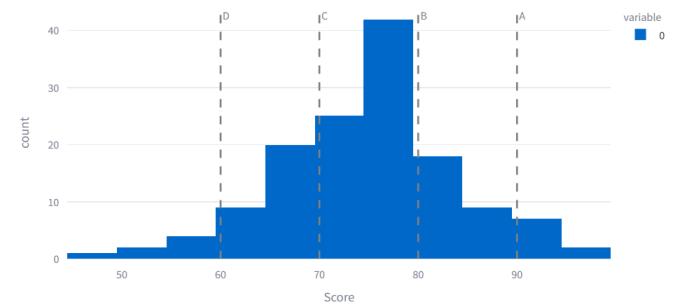
Minimum score for D: 60 - +

Score Distribution

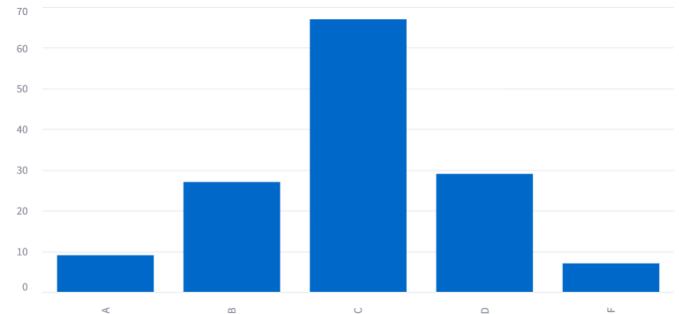
Adjust histogram bin size:

1 5 10

Distribution of Scores



Grade Distribution



Streamlit: Grading App (1)

streamlit_grading.py

```
import streamlit as st
import pandas as pd
import numpy as np
import plotly.express as px

def get_grade(score, grade_min):
    """Convert score to letter grade based on minimum score criteria"""
    if score >= grade_min['A']: return 'A'
    elif score >= grade_min['B']: return 'B'
    elif score >= grade_min['C']: return 'C'
    elif score >= grade_min['D']: return 'D'
    else: return 'F'

def main():
    # Main page title
    st.title('Simple Grading App')

    # Sidebar with grade criteria
    st.sidebar.header('Grade Criteria')
    grade_min = {
        'A': st.sidebar.number_input('Minimum score for A:', value=90),
        'B': st.sidebar.number_input('Minimum score for B:', value=80),
        'C': st.sidebar.number_input('Minimum score for C:', value=70),
        'D': st.sidebar.number_input('Minimum score for D:', value=60)
    }

    # Input section
    st.header('Enter Scores')
    input_method = st.radio('Choose input method:', ['Manual Entry', 'File Upload'])
```

Streamlit: Grading App (2)

```
scores = None

if input_method == 'Manual Entry':
    scores_text = st.text_area(
        "Enter scores (one per line or comma-separated):",
        height=100
    )
    if scores_text:
        if ',' in scores_text:
            scores = [float(x) for x in scores_text.split(',')]
        else:
            scores = [float(x) for x in scores_text.split('\n') if x.strip()]
else:
    uploaded_file = st.file_uploader("Upload CSV file with scores:", type='csv')
    if uploaded_file:
        df = pd.read_csv(uploaded_file)
        scores = df.iloc[:, 0].tolist()

if scores:
    # Convert to numpy array for calculations
    scores = np.array(scores)

    # Display basic statistics
    st.header('Class Statistics')
    col1, col2, col3 = st.columns(3)
    with col1:
        st.metric("Average", f"{np.mean(scores):.1f}")
    with col2:
        st.metric("Median", f"{np.median(scores):.1f}")
    with col3:
        st.metric("Count", len(scores))
```

Streamlit: Grading App (3)

```
# Create histogram with adjustable bins
st.header('Score Distribution')

# Add bin size slider
bin_size = st.slider(
    "Adjust histogram bin size:",
    min_value=1,
    max_value=10,
    value=5,
    help="Smaller values show more detail, larger values show general trends"
)

# Calculate number of bins based on bin size
num_bins = int((np.max(scores) - np.min(scores)) / bin_size) + 1

fig = px.histogram(
    scores,
    nbins=num_bins,
    title='Distribution of Scores',
    labels={'value': 'Score', 'count': 'Number of Students'}
)

# Add grade boundary lines
for grade, min_score in grade_min.items():
    fig.add_vline(
        x=min_score,
        line_dash="dash",
        line_color="gray",
        annotation_text=grade
    )

st.plotly_chart(fig)
```

Streamlit: Grading App (4)

```
# Calculate grades using current criteria
grades = [get_grade(score, grade_min) for score in scores]
grade_counts = pd.Series(grades).value_counts().sort_index()

# Display grade distribution
st.header('Grade Distribution')
st.bar_chart(grade_counts)

# Show detailed results
st.header('Detailed Results')
results_df = pd.DataFrame({
    'Score': scores,
    'Grade': grades
})
st.dataframe(results_df)

# Export option
st.download_button(
    "Download Results",
    results_df.to_csv(index=False),
    "grades.csv",
    "text/csv"
)

if __name__ == '__main__':
    main()
```

Streamlit: Sentiment Analyzer

streamlit_sentiment_analyzer.py

Sentiment Analyzer Based On Text Analysis

adapted from

<https://github.com/patidarparas13/Sentiment-Analyzer-Tool>

View Dataset

Show Raw Dataset

Show Preprocessed Dataset

Show Data Analysis and Model Performance

Analyze Your Text

Enter Text for Analysis

It made me have a liver ache



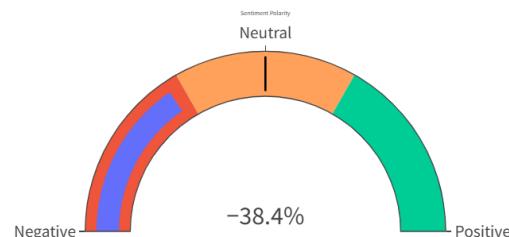
Analyze Sentiment

Sentiment

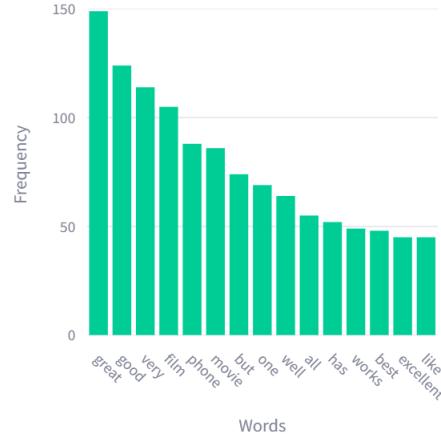
Negative

Confidence

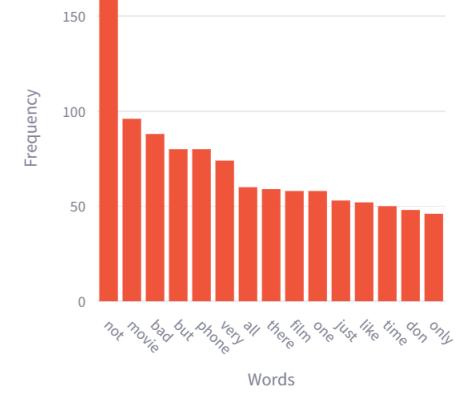
Moderate Confidence



Top Words in Positive Reviews

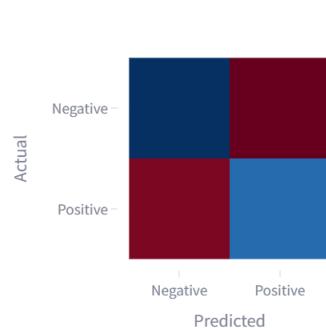


Top Words in Negative Reviews



Model Performance Analysis

Confusion Matrix



Model Confidence Distribution

