Lec 10 - matplotlib

Statistical Computing and Computation

Sta 663 | Spring 2022

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matplotlib

matplotlib vs. pyplot

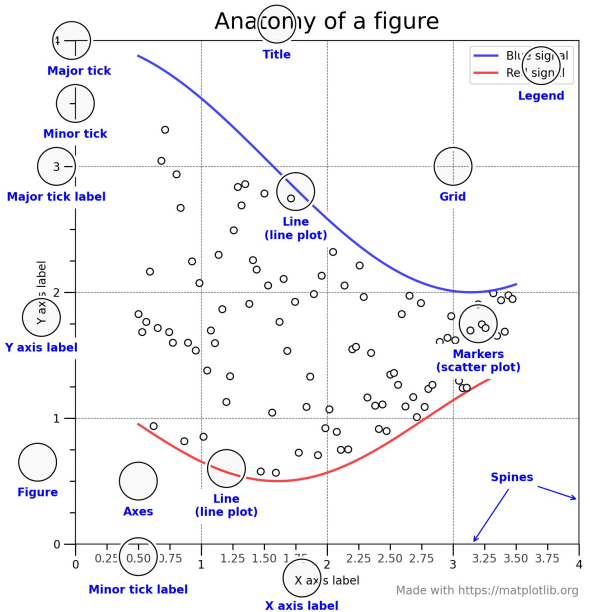
> matplotlib is a comprehensive library for creating static, animated, and interactive visualizations in Python.

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

Why do we usually import only pyplot then?

> Matplotlib is the whole package; matplotlib.pyplot is a module in matplotlib; and pylab is a module that gets installed alongside matplotlib.
>
> Pyplot provides the state-machine interface to the underlying object-oriented plotting library. The state-machine implicitly and automatically creates figures and axes to achieve the desired plot.

Plot anatomy



Other important terminology:

- **Figure** - The entire plot (including subplots)
- **Axes** - Subplot attached to a figure, contains the region for plotting data and axis'
- **Axis** - Set the scale and limits, generate ticks and ticklabels
- **Artist** - Everything visible on a figure: text, lines, axis, axes, etc.

Basic plot - OO style

```
x = np.linspace(0, 2*np.pi, 100)
y1 = np.sin(x)
y2 = np.cos(x)

fig, ax = plt.subplots(figsize=(6, 3))
ax.plot(x, y1, label="sin(x)")
ax.plot(x, y2, label="cos(x)")
ax.set_title("Simple Plot")
ax.legend()
```

Basic plot - pyplot style

```
x = np.linspace(0, 2*np.pi, 100)
y1 = np.sin(x)
y2 = np.cos(x)

plt.figure(figsize=(6, 3))
plt.plot(x, y1, label="sin(x)")
plt.plot(x, y2, label="cos(x)")
plt.title("Simple Plot")
plt.legend()
```

Subplots

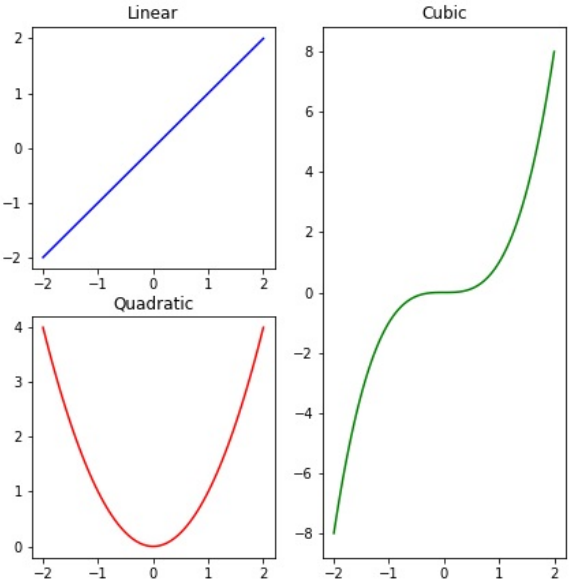
```
x = np.linspace(0, 2*np.pi, 30)
y1 = np.sin(x)
y2 = np.cos(x)

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(9, 3))
ax1.plot(x, y1, "--b", label="sin(x)")
ax2.plot(x, y2, ".-r", label="cos(x)")
fig.suptitle("Subplot")
ax1.set_title("subplot 1")
ax2.set_title("subplot 2")
ax1.legend()
ax2.legend()
```

More subplots

```
x = np.linspace(-2, 2, 101)

fig, axs = plt.subplots(2, 2, figsize=(4, 4))
axs[0,0].plot(x, x, "b", label="linear")
axs[0,1].plot(x, x**2, "r", label="quadratic")
axs[1,0].plot(x, x**3, "g", label="cubic")
axs[1,1].plot(x, x**4, "c", label="quartic")
[ax.legend() for row in axs for ax in row]
fig.suptitle("More subplots")
```

Fancy subplots (moscaic)

```
x = np.linspace(-2, 2, 101)

fig, axd = plt.subplot_mosaic([['upleft', 'right'
                               ['lowleft', 'right

axd['upleft'].plot(x, x, "b", label="linear")
axd['lowleft'].plot(x, x**2, "r", label="quadrati
axd['right'].plot(x, x**3, "g", label="cubic")

axd['upleft'].set_title("Linear")
axd['lowleft'].set_title("Quadratic")
axd['right'].set_title("Cubic")
```



Format strings

For quick formating of plots (scatter and line) format strings are a useful shorthand, generally they use the format `'[marker][line][color]'`,

character	shape
.	point
,	pixel
o	circle
v	triangle down
^	triangle up
<	triangle left
	triangle

character	line style
-	solid
--	dashed
-.	dash-dot
:	dotted

character	color
b	blue
g	green
r	red
c	cyan
m	magenta
y	yellow
k	black

See Notes section of pyplot.plot docs

Plotting data

Beyond creating plots for arrays (and lists), addressable objects like dicts and DataFrames can be used via `data`,

```
np.random.seed(19680801)  # seed the random number generator.
d = {'x': np.arange(50),
     'color': np.random.randint(0, 50, 50),
     'size': np.abs(np.random.randn(50)) * 100}
d['y'] = d['x'] + 10 * np.random.randn(50)


plt.figure(figsize=(6, 3))
plt.scatter('x', 'y', c='color', s='size', data=d)
plt.xlabel("x-axis")
plt.ylabel("y-axis")
```

Example from Basic Usage guide

Constrained layout

To fix the legend clipping we can use the "contrained" layout to adjust automatically,

```
np.random.seed(19680801)  # seed the random number generator.
d = {'x': np.arange(50),
     'color': np.random.randint(0, 50, 50),
     'size': np.abs(np.random.randn(50)) * 100}
d['y'] = d['x'] + 10 * np.random.randn(50)


plt.figure(figsize=(6, 3), layout="constrained")
plt.scatter('x', 'y', c='color', s='size', data=d)
plt.xlabel("x-axis")
plt.ylabel("y-axis")
```

pyplot w/ pandas data

Data can also come from DataFrame objects or series,

```
df = pd.DataFrame({
  "x": np.random.normal(size=10000)
}).assign(
  y = lambda d: np.random.normal(0.75*d.x, np.sqr
)

fig, ax = plt.subplots(figsize=(5,5))
ax.scatter('x', 'y', c='k', data=df, alpha=0.1, s
ax.set_xlabel('x')
ax.set_ylabel('y')
ax.set_title("Bivariate normal ($\\rho=0.75$)")
```

pyplot w/ pandas series

Series objects can also be plotted directly, the index is used as the x axis values,

```
s = pd.Series(
  np.cumsum( np.random.normal(size=100) ),
  index = pd.date_range("2022-01-01", periods=100
)

plt.figure(figsize=(3, 3), layout="constrained")

plt.plot(s)

plt.show()
```

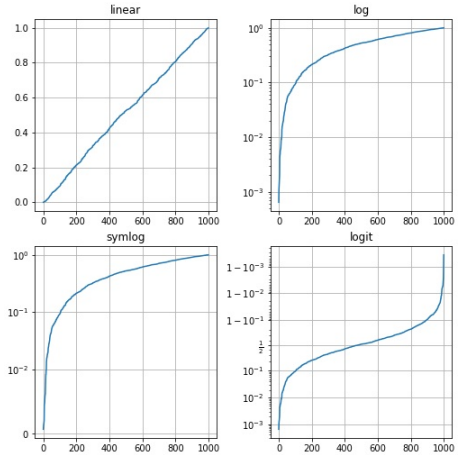
```
plt.figure(figsize=(3, 3), layout="constrained")

plt.plot(s.index, s.values)
plt.xticks(rotation=45)
```

```
plt.show()
```

Scales

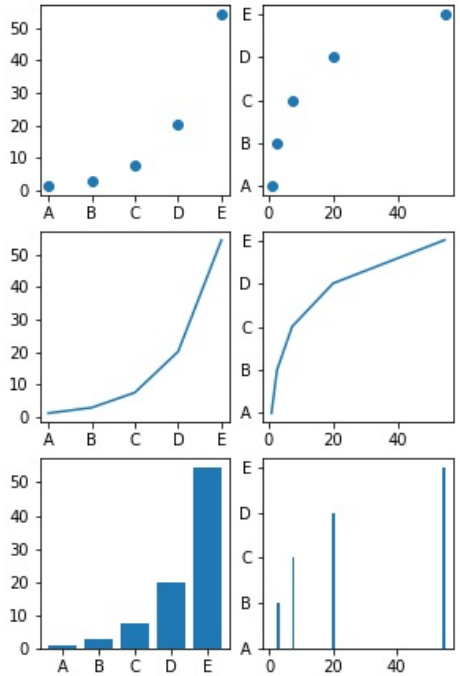
Axis scales can be changed via `plt.xscale()`, `plt.yscale()`, `ax.set_xscale()`, or `ax.set_yscale()`, supported values are "linear", "log", "symlog", and "logit".

```
y = np.sort( np.random.sample(size=1000) )
x = np.arange(len(y))

plt.figure(layout="constrained")

scales = ['linear', 'log', 'symlog', 'logit']
for i, scale in zip(range(4), scales):
  plt.subplot(221+i)
  plt.plot(x, y)
  plt.grid(True)
  if scale == 'symlog':
    plt.yscale(scale, linthresh=0.01)
  else:
    plt.yscale(scale)
  plt.title(scale)


plt.show()
```



Categorical data

```
df = pd.DataFrame({
  "cat": ["A", "B", "C", "D", "E"],
  "value": np.exp(range(5))
})

plt.figure(figsize=(4, 6), layout="constrained")

plt.subplot(321)
plt.scatter("cat", "value", data=df)
plt.subplot(322)
plt.scatter("value", "cat", data=df)

plt.subplot(323)
plt.plot("cat", "value", data=df)
plt.subplot(324)
plt.plot("value", "cat", data=df)

plt.subplot(325)
plt.bar("cat", "value", data=df)
plt.subplot(326)
plt.bar("value", "cat", data=df)

plt.show()
```



Histograms

```
df = pd.DataFrame({
  "x1": np.random.normal(size=100),
  "x2": np.random.normal(1,2, size=100)
})

plt.figure(figsize=(4, 6), layout="constrained")

plt.subplot(311)
plt.hist("x1", bins=10, data=df, alpha=0.5)
plt.hist("x2", bins=10, data=df, alpha=0.5)

plt.subplot(312)
plt.hist(df, alpha=0.5)

plt.subplot(313)
plt.hist(df, stacked=True, alpha=0.5)

plt.show()
```

Boxplots

```
df = pd.DataFrame({
  "x1": np.random.normal(size=100),
  "x2": np.random.normal(1,2, size=100),
  "x3": np.random.normal(-1,3, size=100)
}).melt()

plt.figure(figsize=(4, 4), layout="constrained")

plt.boxplot("value", positions="variable", data=df)
```

```
## ValueError: List of boxplot statistics and `positions` values must have same the length
```

```
plt.boxplot(df.value, positions=df.variable)
```

```
## ValueError: List of boxplot statistics and `positions` values must have same the length
```

Boxplots (cont.)

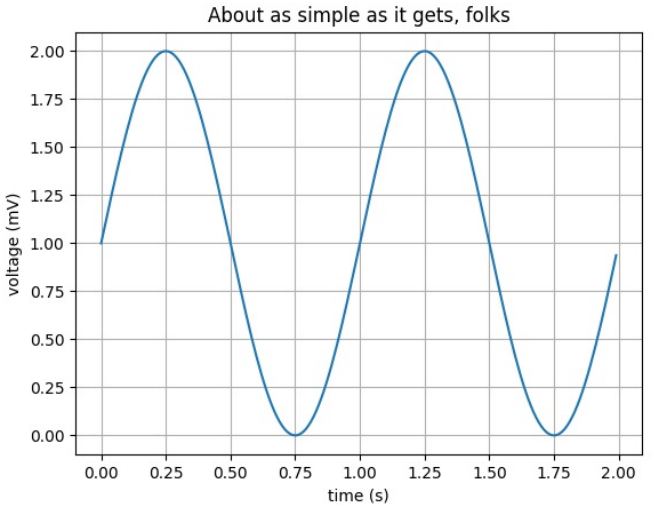
```
df = pd.DataFrame({
  "x1": np.random.normal(size=100),
  "x2": np.random.normal(1,2, size=100),
  "x3": np.random.normal(-1,3, size=100)
})

plt.figure(figsize=(4, 6), layout="constrained")

plt.subplot(211)
plt.boxplot(df)

plt.subplot(212)
plt.violinplot(df)


plt.show()
```

Other Plot Types

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

Exercise 1

To the bets of your ability recreate the following plot,



From matplotlib examples

Plotting with pandas

plot methods

Both Series and DataFrame objects have a plot method which can be used to create visualizations - dtypes determine the type of plot produced. Note these are just pyplot plots and can be formated as such.

```
s = pd.Series(
  np.cumsum( np.random.normal(size=100) ),
  index = pd.date_range("2022-01-01", periods=100, freq="D")
)

plt.figure(figsize=(3,3), layout="constrained")
s.plot()
plt.show()
```

DataFrame plot

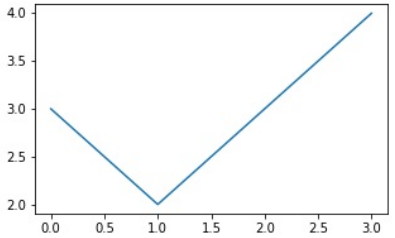
```
df = pd.DataFrame(
  np.cumsum( np.random.normal(size=(100,4)), axis=0),
  index = pd.date_range("2022-01-01", periods=100, freq="D"),
  columns = list("ABCD")
)

plt.figure(layout="constrained")
df.plot(figsize=(5,3))
plt.show()
```

DataFrame line styles

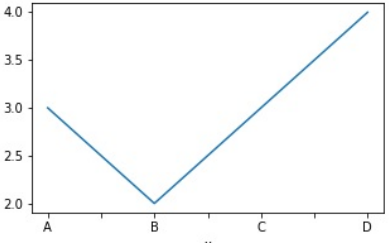
```
df.plot(
  figsize=(5,3),
  style = {
    "A": "-b",
    "B": "--y",
    "C": "-.g",
    "D": ":r"
  }
)
```

DataFrame plot - categorical

```
df = pd.DataFrame({
 "x": list("ABCD"),
 "y": np.random.poisson(lam=2, size=4)
})

df.plot(figsize=(5,3), legend=False)
```




```
df.set_index("x").plot(figsize=(5,3),legend=False
```

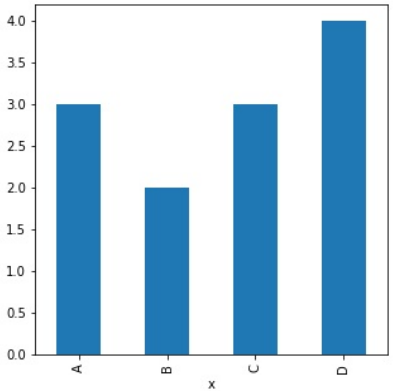



```
df.set_index("x").plot(
  figsize=(5,3), kind="bar", legend=False
)
```

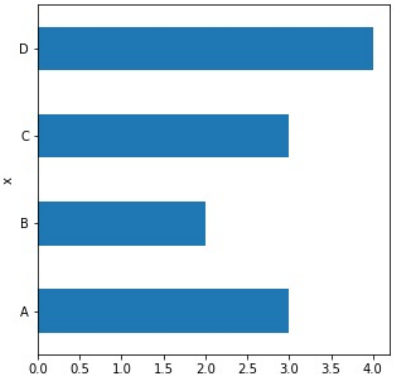
Other plot types

Plot types can be changed via the `kind` argument or using one of the `DataFrame.plot.<kind>` method,

```
df.set_index("x").plot.bar(
  legend=False, figsize=(5,5)
)
```

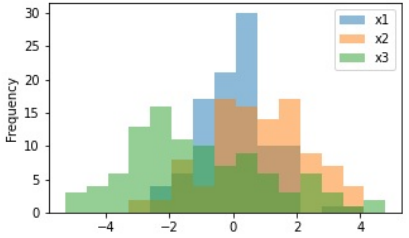



```
df.set_index("x").plot.barh(
  legend=False, figsize=(5,5)
)
```

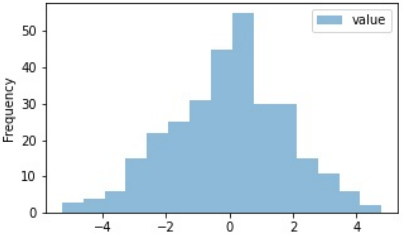


Wide vs long - histograms

```
df = pd.DataFrame({
  "x1": np.random.normal(size=100),
  "x2": np.random.normal(1,1.5, size=100),
  "x3": np.random.normal(-1,2, size=100)
})

df.plot.hist(figsize=(5,3), alpha=0.5, bins=15)
```




```
df_wide = df.melt()
df_wide.plot.hist(figsize=(5,3), alpha=0.5, bins=
```




```
df_wide.set_index("variable").plot.hist(
  figsize=(5,3), alpha=0.5, bins=15
)
```

plot and groupby

```
df_wide
```

```
##     variable     value
## 0         x1  1.471225
## 1         x1 -0.178315
## 2         x1  0.156732
## 3         x1  0.291983
## 4         x1  1.593502
## ..       ...       ...
## 295       x3 -3.202525
## 296       x3 -4.066616
## 297       x3  0.095091
## 298       x3 -2.446253
## 299       x3 -1.810505
##
## [300 rows x 2 columns]
```

```
plt.figure(figsize=(5,5))

_ = ( df_wide
      .groupby("variable")["value"]
      .plot.hist(
        alpha=0.5, legend=True, bins=15
      )
    )

plt.show()
```

Here we are plotting Series objects hence the need to use `plt.figure()` and `plt.show()`.

pandas and subplots

```
plt.figure(figsize=(5,3))
```

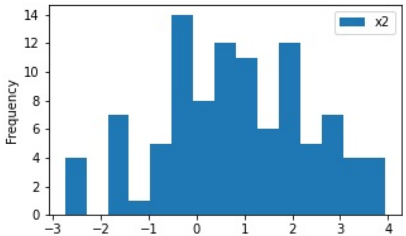
```
plt.subplot(211)
```

```
df[["x1"]].plot.hist(bins=15, figsize=(5,3))
```

```
plt.subplot(212)
```

```
df[["x2"]].plot.hist(bins=15, figsize=(5,3))
```

```
plt.show()
```




```
fig, (ax1, ax2) = plt.subplots(2,1, figsize=(5,5)

df[["x1"]].plot.hist(ax = ax1, bins=15)
```

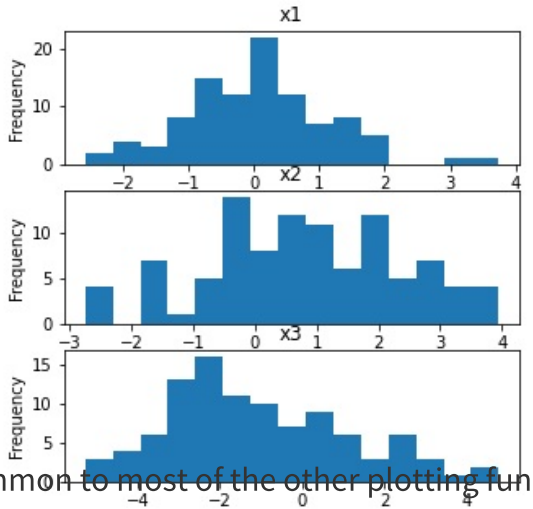
```
df[["x2"]].plot.hist(ax = ax2, bins=15)
```

```
plt.show()
```

Using by

```
df_wide.plot.hist(bins=15, by="variable", legend=False, figsize=(5,5))
```

```
plt.show()
```



Note the by argument is not common to most of the other plotting functions - only box also has it.

Higher level plots - pair plot

The pandas library also provides the `plotting` submodule with several useful higher level plots,

```
cov = np.identity(5)
cov[1,2] = cov[2,1] = 0.5
cov[3,0] = cov[0,3] = -0.8

df = pd.DataFrame(
  np.random.multivariate_normal(mean=[0]*5, cov=c
  columns = ["x1","x2","x3","x4","x5"]
)

df
```

```
##            x1        x2        x3        x4
## 0   -0.675512 -0.072846  0.536075 -0.480851  0.
## 1    0.867784 -0.099565  0.014922 -1.403662  0.
## 2    0.028221 -1.572683 -2.679542 -1.030949 -0.
## 3    0.434528 -0.570881  0.446828 -0.424219 -1.
## 4    0.320779  0.294548  0.834556 -0.261610 -0.
## ..        ...       ...       ...       ...
## 995 -0.642675  1.500878  0.244987  0.472639  0.
## 996  1.481997  0.902982  1.271029 -1.003460 -0.
## 997  0.001276  1.001031 -0.196185 -0.430334 -0.
```

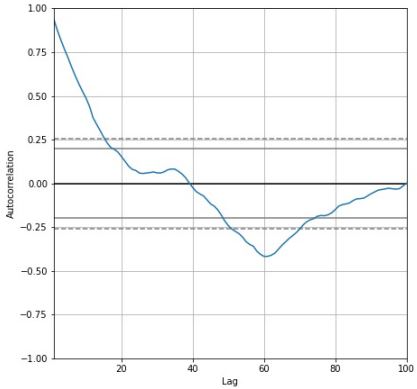
```
pd.plotting.scatter_matrix(df, alpha=0.2, diagona
```

```
plt.show()
```

Autocorrelation plots

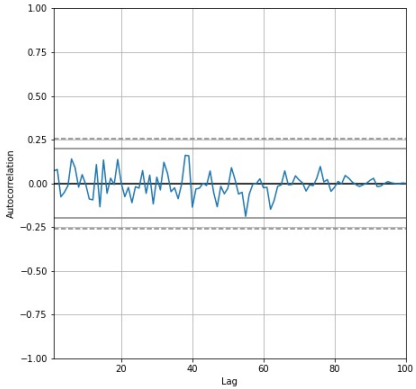
```
rw = pd.Series(
  np.cumsum( np.random.normal(size=100) ),
)

pd.plotting.autocorrelation_plot(rw)
```

```
plt.show()
```




```
wn = pd.Series(
  np.random.normal(size=100),
)

pd.plotting.autocorrelation_plot(wn)
```

```
plt.show()
```



Other plots

```
dir(pd.plotting)
```

```
## ['PlotAccessor', '__all__', '__builtins__', '__cached__', '__doc__', '__file__', '__loader__', '__name__', '
```