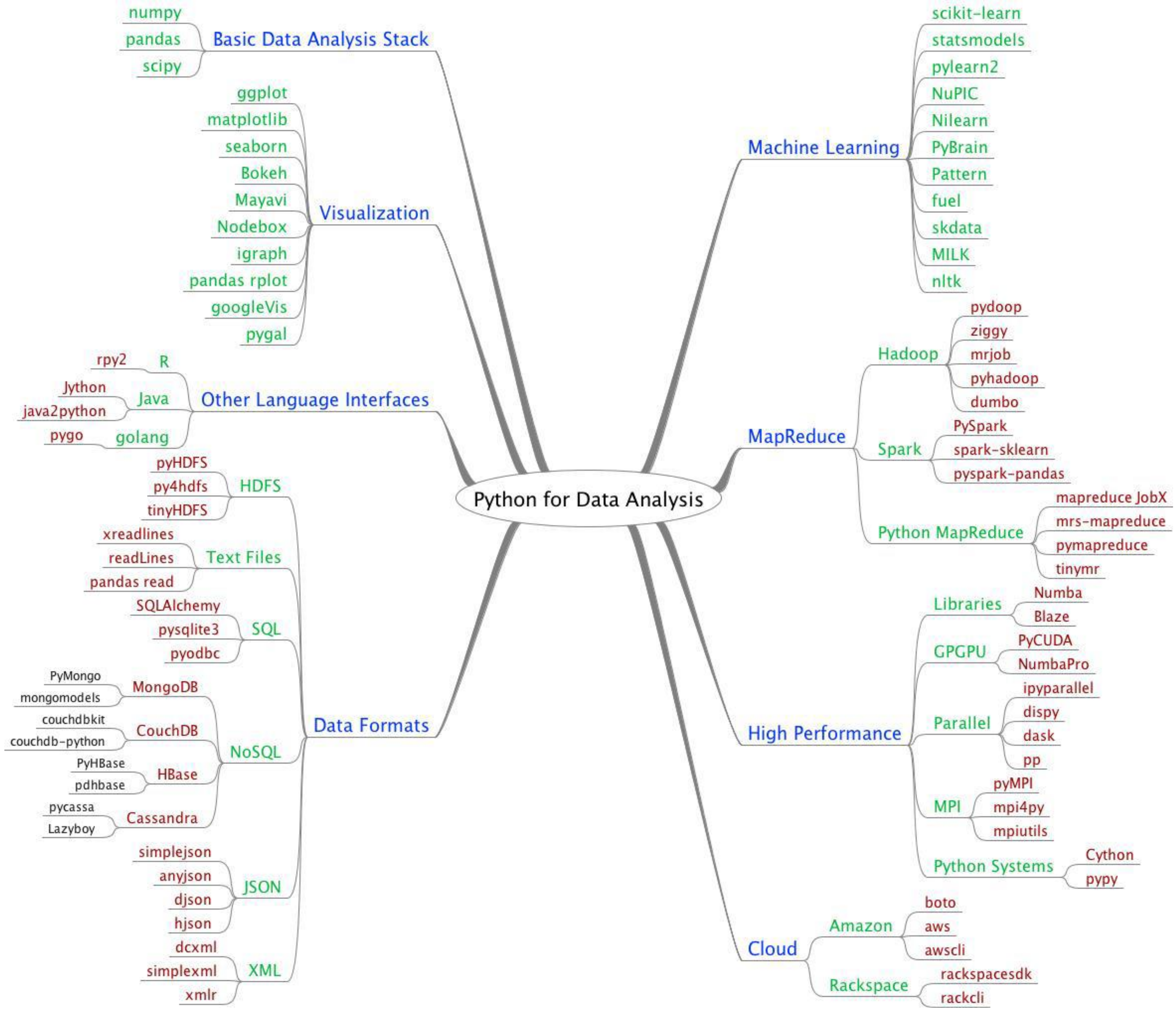
CS100 Python Introduction to Programming

Lecture 28. Data analysis and Visualization

Fu Song

School of Information Science and Technology

ShanghaiTech University



Python for Data Analysis
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Learning Objectives

- Understand and use
  - NumPy
  - Pandas
  - Matplotlib

NumPy, Pandas and Matplotlib

- NumPy: a general-purpose library that provides numerical arrays, and functions to manipulate the arrays efficiently
- Pandas: a data-manipulation library that provides data structures and operations for manipulating tables and time series data
- Matplotlib: a 2D plotting library that provides support for producing plots, graphs, and figures

NumPy

- NumPy is the fundamental package for scientific computing with Python
- It contains among other things:
  1. a powerful N-dimensional array object and related functions for manipulating arrays
  2. useful linear algebra, Fourier transform, and random number capabilities
  3. reading data from and writing data to files
  4. vectorized computation
- How to install NumPy

  pip3 install numpy

The NumPy array object

- NumPy provides a multidimensional array object called ndarray
- NumPy arrays are typed arrays of a fixed size.
- NumPy arrays are homogenous and can contain objects of only one type

同质的，纯系的

- An ndarray consists of two parts:
  1. The actual data that is stored in a contiguous block of memory
  2. The metadata describing the actual data

元数据，中介数据

Advantages of NumPy arrays

- NumPy arrays
  - homogeneous
  - easy to ascertain the storage
    查明
  - execute vectorized operations for a complete array
  - utilizes an optimized C API to make the array operations particularly quick
  - hence good at large data analysis
- Lists
  各种各样的
  - heterogeneous
  - have to loop through the list

Create an ndarray object

```
>>> import numpy as np
>>> data = [[1, 2, 3, 4], [5, 6, 7, 8]]
>>> a = np.array(data) #create an array from a list
>>> a
array([[1, 2, 3, 4],
[5, 6, 7, 8]])
  # create an 0-array with shape given by a tuple
>>> np.zeros((3,6))
array([[0., 0., 0., 0., 0., 0.],
[0., 0., 0., 0., 0., 0.],
[0., 0., 0., 0., 0., 0.]])
>>> np.array([np.arange(2,5),np.arange(4,7)])
array([[2, 3, 4],                    # from arrange ~range
[4, 5, 6]])
```

Some metadata

```
>>> import numpy as np
>>> data = [[1, 2, 3, 4], [5, 6, 7, 8]]
>>> a = np.array(data) # create an array from list
>>> a
array([[1, 2, 3, 4],
[5, 6, 7, 8]])
>>> a.ndim                 # metadata ndim = dimension
2
>>> a.shape               # metadata shape
(2, 4)
>>> a.dtype
dtype('int32')
```

NumPy array vs list

```
import numpy as np
import time

a = np.arange(1000000)
l = list(range(1000000))

start = time.time()
for _ in range(10):
    a2 = a * 2
print(time.time() - start)

start = time.time()
for _ in range(10):
    l2 = [x * 2 for x in l]
print(time.time() - start)
```

Output:

0.05100297927856445
1.9661142826080322

Data Types for ndarrays

- Python has an integer type, a float type, and complex type; nonetheless, this is not sufficient for scientific calculations

- In practice, we still demand more data types with varying precisions and, consequently, different storage sizes of the type

NumPy numerical types:

Type	Description
bool	Boolean (True or False) stored as a bit
inti	Platform integer (normally either int32 or int64)
int*n* (n=8,16,32,64)	Integer (-2^{n-1} to $2^{n-1}-1$)
uint*n* (n=8,16,32,64)	Unsigned integer (0 to $2^{n}-1$)
float*n* (n=16,32,64)	Half/single/double precision
complex*n* (n=64,128)	Complex number, represented by two n/2 bit floats (real and imaginary components)

PS: float = float64

Create ndarray with specific type

```
>>> import numpy as np
>>> data = [[1, 2, 3, 4], [5, 6, 7, 8]]
>>> a = np.array(data) # create an array from list
>>> a
array([[1, 2, 3, 4],
[5, 6, 7, 8]])
>>> a.dtype
dtype('int32')
>>> b = np.array(data, dtype=np.int8)
>>> b
array([[1, 2, 3, 4],
[5, 6, 7, 8]], dtype=int8)
>>> b.dtype
dtype('int8')
```

ndarray Type casting

```
>>> import numpy as np
>>> data = [[1, 2, 3, 4], [5, 6, 7, 8]]
>>> a = np.array(data) # create an array from list
>>> a
array([[1, 2, 3, 4],
[5, 6, 7, 8]])
>>> a.dtype
dtype('int32')
>>> b = a.astype(np.float32) #astype: type casting
>>> b
array([[1., 2., 3., 4.],
[5., 6., 7., 8.]], dtype=float32)
>>> b.dtype
dtype('float32')
```

Indexing

- indexing is similar to list
  - indexing: $a[i_1]\ldots[i_k]$
  - assignment via indexing:
    $a[i_1]\ldots[i_k]$ =same shape of (n-k) sub-dimen
- Efficient indexing for array (not work for list),
  - Tuple indexing: $a[i_1,\ldots,i_k]$, or $a[(i_1,\ldots,i_k)]$
  - assignment via tuple indexing: $a[i_1,\ldots,i_k]$ or $a[(i_1,\ldots,i_k)]$= same shape of (n-k) sub-dimen
- All of these indexing return a new view of original data, it does not copy items in array

```
>>> l = [[[1, 2, 3], [4, 5, 6]], [[7, 8, 9], [10, 11,
12]]]
>>> a = np.array(l)
>>> l[0][1]
[4, 5, 6]
>>> a[0][1]
array([4, 5, 6])
>>> a[0,1]     # [0,1] => [(0,1)] (0,1) is a tuple
array([4, 5, 6])
>>> l[0,1]
Traceback (most recent call last):…TypeError: list
indices must be integers or slices, not tuple
>>> a[0][1] = [1,2,3]
>>> a
array([[[ 1, 2, 3],
[ 1, 2, 3]],
[[ 7, 8, 9],
[10, 11, 12]]])
```

Array Indexing

- Array indexing (or any sequence-like object that can be converted to an array, with the exception of tuples)

$$a[\ [i_1,\ldots,i_k]\ ]$$

  - i_j indicates which value in array to use in place of the index
  - what is returned is a copy of the original data, not a view as one gets for other indexing

?

- Multi-array indexing

$$a[l_1,\ldots,l_k]$$

  - $l_1,\ldots,l_k$ are sequence-like objects exception of tuples

```
>>> l = [[[1, 2, 3], [4, 5, 6]], [[7, 8, 9], [10, 11,
12]]]
>>> a = np.array(l)
>>> a
array([[[ 1, 2, 3],
[ 4, 5, 6]],
[[ 7, 8, 9],
[10, 11, 12]]])

>>> a[ [1,1] ]
array([[[ 7, 8, 9],
[10, 11, 12]],
[[ 7, 8, 9],
[10, 11, 12]]])

>>> a[[0,1],[1,0]] # indexing Multi-dim arrays
array([[4, 5, 6],
[7, 8, 9]])
```

Slicing

- 1-dimensional array: same as sequence-like object
  - slicing: a[start=0[:stop=-1[:step=1]]]
  - slicing: a[start=0[:stop=-1[:step=1]]] = newsubarray

- multi-dimensional array: dimensional-wise slicing

  a[
  $start_1$=0[:$stop_1$=-1[:$step_1$=1]]], # first dim
  ……,
  $start_k$=0[:$stop_1$=-1[:$step_k$=1]]], #k^{th} dim
  ]
- Only return a new view of original data

```
>>> a = np.array([[[1, 2, 3], [4, 5, 6]],
           [[7, 8, 9], [10, 11, 12]]])
>>> a[0:2,1:2]
array([[[ 4, 5, 6]],
[[10, 11, 12]]])

>>> a[0:2][1:2]
array([[[ 7, 8, 9],
[10, 11, 12]]])
>>> a[0:2,1:2,1:2]
array([[[ 5]],
[[11]]])
>>>
```

Fancy indexing

- Fancy indexing is indexing that does not involve integers or slices, which is conventional indexing
- Fancy indexing is done based on an internal NumPy iterator object.
- The following three steps are performed:
  1. The iterator object is created
  2. The iterator object gets bound to the array
  3. Array elements are accessed via the iterator

```python
import numpy as np
arr = np.zeros((5,5))
print(arr)

for i in range(5):
    arr[i] = i
print(arr)

print(arr[[4, 3, 0]])

xmax = arr.shape[0]
ymax = arr.shape[1]

arr[range(xmax),range(ymax)]=-1
print(arr)
```

```
[[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. 1. 1. 1.]
 [2. 2. 2. 2. 2.]
 [3. 3. 3. 3. 3.]
 [4. 4. 4. 4. 4.]]
[[4. 4. 4. 4. 4.]
 [3. 3. 3. 3. 3.]
 [0. 0. 0. 0. 0.]]
[[-1.  0.  0.  0.  0.]
 [ 1. -1.  1.  1.  1.]
 [ 2.  2. -1.  2.  2.]
 [ 3.  3.  3. -1.  3.]
 [ 4.  4.  4.  4. -1.]]
```

Boolean indexing

- It returns a 1-D array containing all the elements in the indexed array corresponding to all the true elements in the boolean array

a[b]

- Boolean indexing is indexing based on a Boolean array and falls in the family of fancy indexing
- Since Boolean indexing is a kind of fancy indexing, the way it works is essentially the same

```python
import numpy as np
arr = np.zeros((5,5))

for i in range(5):
    arr[i] = i
print(arr)

b1 = arr >=1
b2 = arr <=3
b = b1 & b2

print(b1)
print(b)
print(arr[b])
```

```
[[0. 0. 0. 0. 0.]
 [1. 1. 1. 1. 1.]
 [2. 2. 2. 2. 2.]
 [3. 3. 3. 3. 3.]
 [4. 4. 4. 4. 4.]]
[[False False False False False]
 [ True  True  True  True  True]
 [ True  True  True  True  True]
 [ True  True  True  True  True]
 [ True  True  True  True  True]]
[[False False False False False]
 [ True  True  True  True  True]
 [ True  True  True  True  True]
 [ True  True  True  True  True]
 [False False False False False]]
[1. 1. 1. 1. 1. 2. 2. 2. 2. 2. 3. 3. 3. 3. 3.]
```

Broadcasting

- NumPy attempts to execute a procedure even though the operands do not have the same shape
- For an operation op on an array object a and a scalar s

  s op a or a op s

  - the scalar s is broadened to the shape of the array a
  - then the operation is executed on two array objects in an element-by-element fashion

```
>>> a = np.array([[1,2],[3,4]])
>>> a + 2
array([[3, 4],
[5, 6]])
>>> a + np.array([[2,2],[2,2]])
array([[3, 4],
[5, 6]])
>>> a * 2
array([[2, 4],
[6, 8]])
>>> a ** 2
array([[ 1, 4],
[ 9, 16]], dtype=int32)
>>> a * a
array([[ 1, 4],
[ 9, 16]])
```

Universal Functions

- A universal function (ufunc) is a function that operates on ndarrays in an element-by-element fashion, supporting
  - array broadcasting,
  - type casting,
  - and several other standard features.
- A ufunc is a "vectorized" wrapper for a function that takes a fixed number of scalar inputs and produces a fixed number of scalar outputs
- ufuncs are instances of the numpy.ufunc class
- Many of the built-in functions are implemented in compiled C code

```
>>> a = np.array([[1,2],[3,4]])
>>> a
array([[1, 2],
[3, 4]])
>>> b = a**2
>>> b
array([[ 1, 4],
[ 9, 16]], dtype=int32)
>>> np.sqrt(b)
array([[1., 2.],
[3., 4.]])
>>> c = np.array([[-1,4],[-3,5]])
>>> np.maximum(a,c)
array([[1, 4],
[3, 5]])
```

Conditional Logic as Array Operations

- np.where(condition, [x, y]), returns
  - ndarray or tuple of ndarrays, if both `x` and `y` are specified, the output array contains elements of `x` where `condition` is True, and elements from `y` elsewhere.
  - If only `condition` is given, return the tuple ``condition.nonzero()``, the indices where `condition` is True.

Conditional Logic as Array Operations

如果再加一行会怎样

```
>>>np.where([[True, False], [True, False]],
            [[1, 2], [3, 4]],
            [[9, 8], [7, 6]])
array([[1, 8],[3, 6]])
>>> x = np.arange(9.).reshape(3, 3)
>>> x
array([[0., 1., 2.],
[3., 4., 5.],
[6., 7., 8.]])
>>> np.where( x > 4 )
(array([1, 2, 2, 2], dtype=int32),
array([2, 0, 1, 2], dtype=int32))
            # return pair of index
```

File Input and Output with Arrays

- Save and load one array

save(file, arr) and load(file)

  - save an array to a binary file in ``.npy`` format
  - load an array from a binary file in ``.npy`` format
  - file : file, str, or pathlib.Path
  - arr : array data to be saved

```
>>> x = np.array([[0,1,2],[3,4,5],[6,7,8]])
>>> np.save("x.npy",x)
>>> np.load("x.npy")
array([[0, 1, 2],
[3, 4, 5],
[6, 7, 8]])
>>>
```

File Input and Output with Arrays

- Save and load arrays

  savez(file, *args, **kwds) and load(file)

  - save arrays to a binary file in ``.npz`` format
  - load arrays from a binary file in ``.npz`` format
  - file : file, str, or pathlib.Path
  - args (optional): arrays to save to the file. The arrays will be saved with names "arr_0", "arr_1", and so on.
  - kwds (optional) : arrays to save to the file. Arrays will be saved in the file with the keyword names
  - At least one argument is given

File Input and Output with Arrays

```
>>> x = np.array([[0,1,2],[3,4,5],[6,7,8]])
>>> x = np.array([[0,1,2],[3,4,5],[6,7,8]])
>>> np.savez("file.npz",x,y)
>>> xy = np.load("file.npz")
>>> xy['arr_0']
array([[0, 1, 2],
[3, 4, 5],
[6, 7, 8]])
>>> xy['arr_1']
array([[1, 2],
[3, 4]])
```

Pandas

- pandas is an open source library providing high-performance, easy-to-use data structures and data analysis tools for the Python
- The two primary data structures of pandas,
  - Series (1-dimensional)
  - DataFrame (2-dimensional)
- Handle the vast majority of typical use cases in finance, statistics, social science, and many areas of engineering
- How to install pandas

pip3 install pandas

Series

- The Pandas Series data structure is a one-dimensional, heterogeneous array with labels
- Ordered dict
- A Series data structure can be created via:
  - Using a Python dict: the sorted dict keys will become the index unless supply the index
  - Using a NumPy array: index values starting from 0
  - Using a single scalar value: supply the index
- Index and values can be obtained via

  s.index and s.values

- Access values of specific index: $s[[i_1,\ldots,i_k]] = v$

Series from array

```
>>> import pandas as pd
>>> s1 = pd.Series([4,7,-5,3])
>>> s1
0 4            # first column is index
1 7            # 2nd column is value
2 -5
3 3
dtype: int64
>>> s1.index
RangeIndex(start=0, stop=4, step=1)
>>> s1.values
array([ 4, 7, -5, 3], dtype=int64)
>>> s1[2]
-5
```

Series from array

```
>>> import pandas as pd
>>> s2 = pd.Series([4,7,-5,3],
                    index = ['a','b','c','d'])
>>> s2                # specify index
a 4
b 7
c -5
d 3
dtype: int64
>>> s2.index
Index(['a', 'b', 'c', 'd'], dtype='object')
>>> s2.values
array([ 4, 7, -5, 3], dtype=int64)
>>> >>> s2['b']
7
```

Series from dict

```
>>> d = {'Ohio': 35000, 'Texas': 71000,
'Oregon':16000, 'Utah': 5000}
>>> s3 = pd.Series(d)
>>> s3
Ohio 35000
Texas 71000
Oregon 16000
Utah 5000
dtype: int64
>>> s3 [["Utah","Ohio"]] # select view of some
Utah 5000
Ohio 35000
dtype: int64
```

Series from dict

- **Create a Series from dict with choosing order index**
- **The 2nd argument determines the order**
- **Miss data is denoted by NaN, pd.isnull and pd.notnull**

```
>>> d = {'Ohio': 35000, 'Texas': 71000,
'Oregon':16000, 'Utah': 5000}
>>> o = ['Oregon','Utah','Texas','Shanghai']
>>> s4 = pd.Series(d,o)
>>> s4
Oregon 16000.0
Utah 5000.0
Texas 71000.0
Shanghai NaN
dtype: float64
```

Index can be renamed

- **Index of a series can be renamed via**
  s.index = newindex
- Note: no s.values = newvalues

```
>>> d = {'Ohio': 35000, 'Texas': 71000,
'Oregon':16000, 'Utah': 5000}
>>> s = pd.Series(d)
>>> s.index = [1,2,3,4]
>>> s
1 35000
2 71000
3 16000
4 5000
dtype: int64
```

Operations on Series

- **Index-label by index-label computation**
- **NaN op v= NaN = v op NaN** ?
- **Slicing via index s[start=0:end=-1:stop=1]**
- **NumPy functions can operate on Series**

```
>>> s3
Ohio 35000
Texas 71000
Oregon 16000
Utah 5000
dtype: int64
```

```
>>> s4
Oregon 16000.0
Utah 5000.0
Texas 71000.0
Shanghai NaN
dtype: float64
```

```
>>> s3 + s4
Ohio NaN
Oregon 32000.0
Shanghai NaN
Texas 142000.0
Utah 10000.0
dtype: float64
```

DataFrames

- DataFrame is a labeled two-dimensional data structure similar to Microsoft Excel
- The columns in Pandas DataFrame can be of different types
- DataFrame can be created via:
  - Using another DataFrame or Series
  - Using 1-D NumPy array, list, dict
  - Composition of arrays that has a 2-D shape
  - Reading from a file, such as a CSV file

Create a DataFrame from Dict

```
>>> data = {'state': ['Ohio', 'Ohio', 'Ohio',
'Nevada', 'Nevada', 'Nevada'],
'year': [2000, 2001, 2002, 2001, 2002, 2003],
'pop': [1.5, 1.7, 3.6, 2.4, 2.9, 3.2]}
>>> frame = pd.DataFrame(data)
>>> frame
state year pop
0 Ohio 2000 1.5
1 Ohio 2001 1.7
2 Ohio 2002 3.6
3 Nevada 2001 2.4
4 Nevada 2002 2.9
5 Nevada 2003 3.2
>>>
```

	pop	state	year
0	1.5	Ohio	2000
1	1.7	Ohio	2001
2	3.6	Ohio	2002
3	2.4	Nevada	2001
4	2.9	Nevada	2002
5	3.2	Nevada	2003

Get Header (first five rows)

```
>>> data = {'state': ['Ohio', 'Ohio', 'Ohio',
'Nevada', 'Nevada', 'Nevada'],
'year': [2000, 2001, 2002, 2001, 2002, 2003],
'pop': [1.5, 1.7, 3.6, 2.4, 2.9, 3.2]}
>>> frame = pd.DataFrame(data)
>>> frame.head()
state year pop
0 Ohio 2000 1.5
1 Ohio 2001 1.7
2 Ohio 2002 3.6
3 Nevada 2001 2.4
4 Nevada 2002 2.9
>>>
```

	pop	state	year
0	1.5	Ohio	2000
1	1.7	Ohio	2001
2	3.6	Ohio	2002
3	2.4	Nevada	2001
4	2.9	Nevada	2002
5	3.2	Nevada	2003

Create a DataFrame from Dict

- Create a DataFrom from dict with choosing order
- The 2nd argument determines the order
- Miss column is denoted by NaN

```
>>> data = {‘state’: [‘Ohio’, ‘Ohio’, ‘Ohio‘],
'year': [2000, 2001, 2002],
'pop': [1.5, 1.7, 3.6]}
>>> frame = pd.DataFrame(data,
columns=['year','state','pop','nocol'])
>>> frame
year state pop nocol
0 2000 Ohio 1.5 NaN
1 2001 Ohio 1.7 NaN
2 2002 Ohio 3.6 NaN
```

Indexing on DataFrame

- Get row index: frame.index
- Row index renaming: frame.index = newIndex
- Get column index: frame.columns
- Column index renaming: frame.columns = newColumns
- Get a specific column: frame[columnName]
- Set/add a column: frame[columnName]=Column
- Row/column reindex:
  - frame.reindex([a list of row reindex])
  - frame.reindex(columns=[a list of columns reindex])
- Drop row/columns: ?
  - frame.drop([a list of row index])
  - frame.drop([a list of columns reindex], axis='columns')

Indexing of DataFrame

```
>>> data = {'state': ['Ohio', 'Ohio', 'Ohio'],
'year': [2000, 2001, 2002],
'pop': [1.5, 1.7, 3.6]}
>>> frame = pd.DataFrame(data)
>>> frame.index
RangeIndex(start=0, stop=3, step=1)
>>> frame.columns
Index(['state', 'year', 'pop'], dtype='object')
>>> frame['year']
0 2000
1 2001
2 2002
Name: year, dtype: int64
```

Selection with loc and iloc

- Selects specific rows and columns
  - frame.loc([rownames],[columnnames])
  - frame.iloc([rowindex],[columnIndex])

- Set values of specific rows and columns
  - frame.loc([rownames],[columnnames]) = values
  - frame.iloc([rowindex],[columnIndex]) = values

Selection with loc and iloc

```
>>> import numpy as np
>>> import pandas as pd
>>> frame = pd.DataFrame(np.arange(16).reshape((4,
4)),
index=['Ohio', 'Colorado', 'Utah', 'New York'],
columns=['one', 'two', 'three', 'four'])
>>> frame.loc['Colorado', ['two', 'three']]
two 5
three 6
Name: Colorado, dtype: int32
>>> frame.iloc[1, [1, 2]]
two 5
three 6
Name: Colorado, dtype: int32
```

Selection with loc and iloc

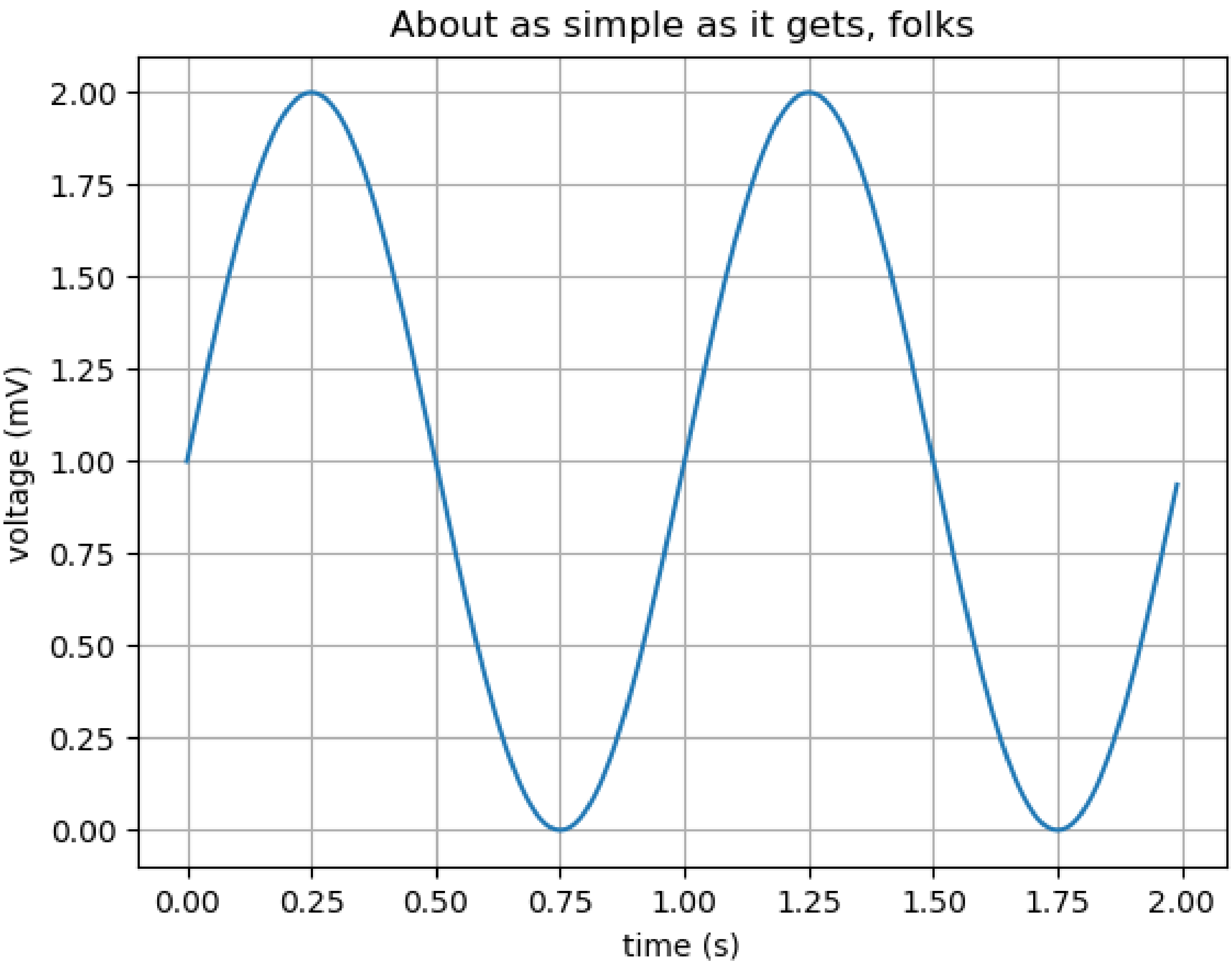
```
>>> import numpy as np
>>> import pandas as pd
>>> frame = pd.DataFrame(np.arange(16).reshape((4,
4)),
index=['Ohio', 'Colorado', 'Utah', 'New York'],
columns=['one', 'two', 'three', 'four'])
>>> frame.loc['Colorado', ['two', 'three']]
two 5
three 6
Name: Colorado, dtype: int32
>>> frame.iloc[1, [1, 2]]
two 5
three 6
Name: Colorado, dtype: int32
```

matplotlib

- Matplotlib is a 2D plotting library which produces publication quality
- Matplotlib tries to make easy things easy and hard things possible.
- Generate plots, histograms, power spectra, bar charts, errorcharts, scatterplots, etc., with just a few lines of code
- How to install matplotlib

  pip3 install matplotlib

Line Plot

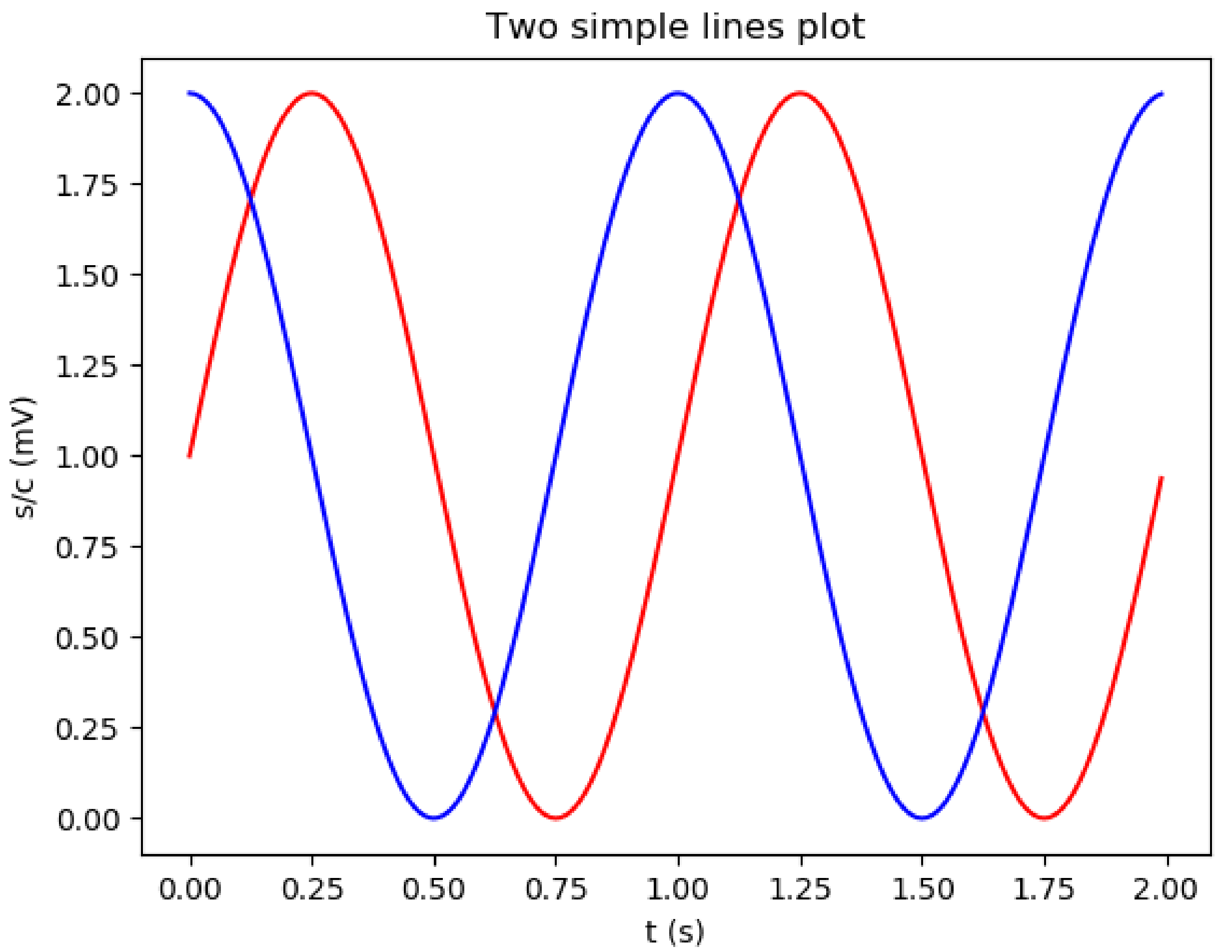

About as simple as it gets, folks
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
voltage (mV)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
time (s)

Line Plot

```
import matplotlib.pyplot as plt
import numpy as np
# Data for plotting
t = np.arange(0.0, 2.0, 0.01)  # sample points
s = 1 + np.sin(2 * np.pi * t)  # line function
fig, ax = plt.subplots() # create a fig and a plot
ax.plot(t, s)                  # x-axis and y-axis
ax.set(xlabel='time (s)', ylabel='voltage (mV)',
title='A simple line plot')
ax.grid()                   # draw grid in figure

fig.savefig("test.png")  # save figure to a file
plt.show()                   # show figure
```

Two Lines Plot



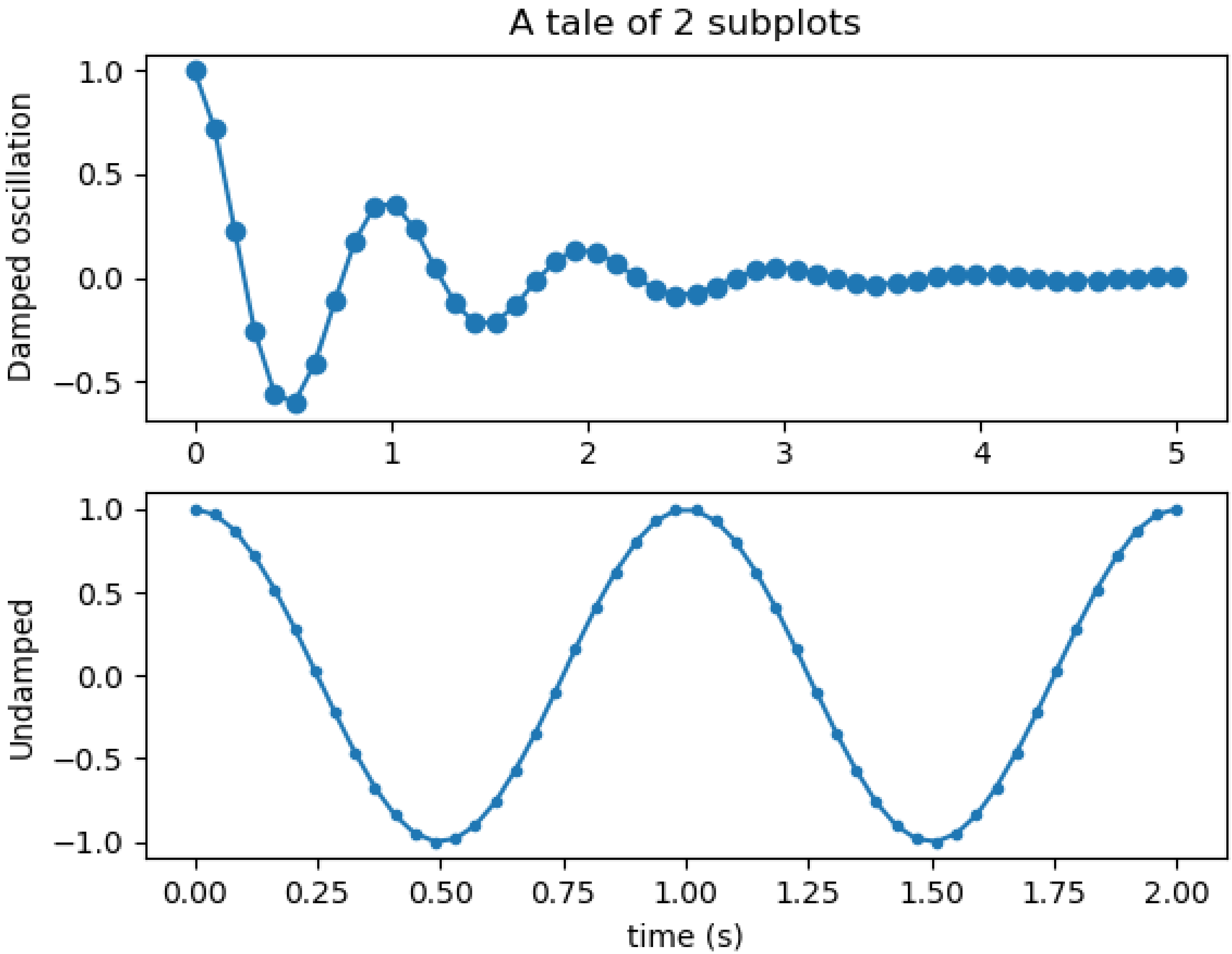
Line Plot

```
import matplotlib.pyplot as plt
import numpy as np
# Data for plotting
t = np.arange(0.0, 2.0, 0.01) # data range
s = 1 + np.sin(2 * np.pi * t) # sin function
c = 1 + np.cos(2 * np.pi * t) # cos function

fig, ax = plt.subplots() # create a fig and a plot
ax.plot(t, s,'r', t,c,'b') # x-axis and y-axis
ax.set(xlabel='time (s)', ylabel='voltage (mV)',
ax.set(xlabel='t (s)', ylabel='s/c
(mV)',title='Two simple lines plot')

plt.show()                           # show figure
```

Multiple subplots

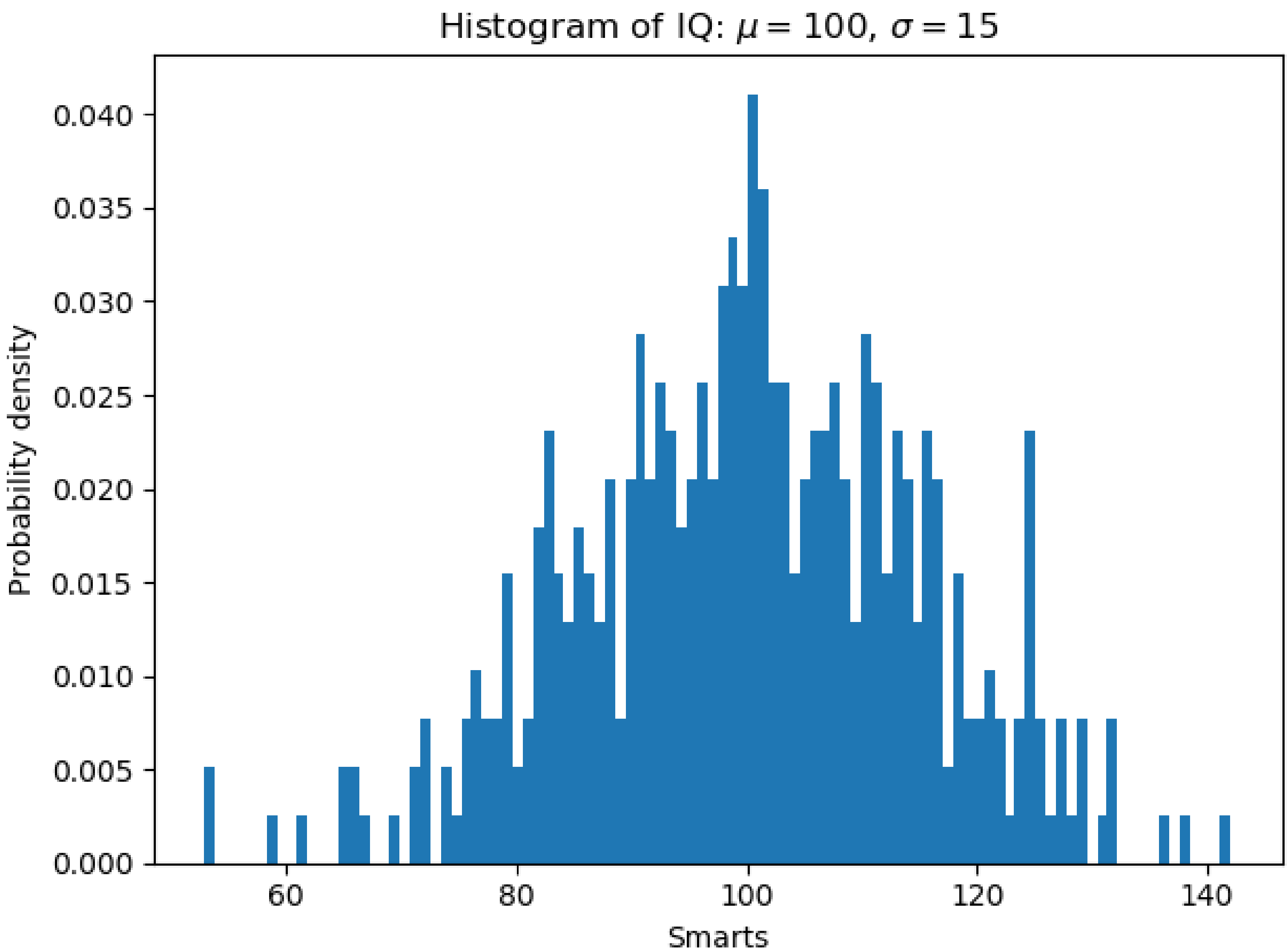


Multiple subplots

```
import numpy as np
import matplotlib.pyplot as plt
x1 = np.linspace(0.0, 5.0)                    # sample points
x2 = np.linspace(0.0, 2.0)
y1 = np.cos(2 * np.pi * x1) * np.exp(-x1)
y2 = np.cos(2 * np.pi * x2)                   # line function
plt.subplot(2, 1, 1) #first row in 2 row & 1 columns
plt.plot(x1, y1, 'o-')  # o- : type of line
plt.title('A tale of 2 subplots')
plt.ylabel('Damped oscillation')

plt.subplot(2, 1, 2)  #2nd row in 2 row & 1 columns
plt.plot(x2, y2, '.-')
plt.xlabel('time (s)')
plt.ylabel('Undamped')
plt.show()
```

histogram

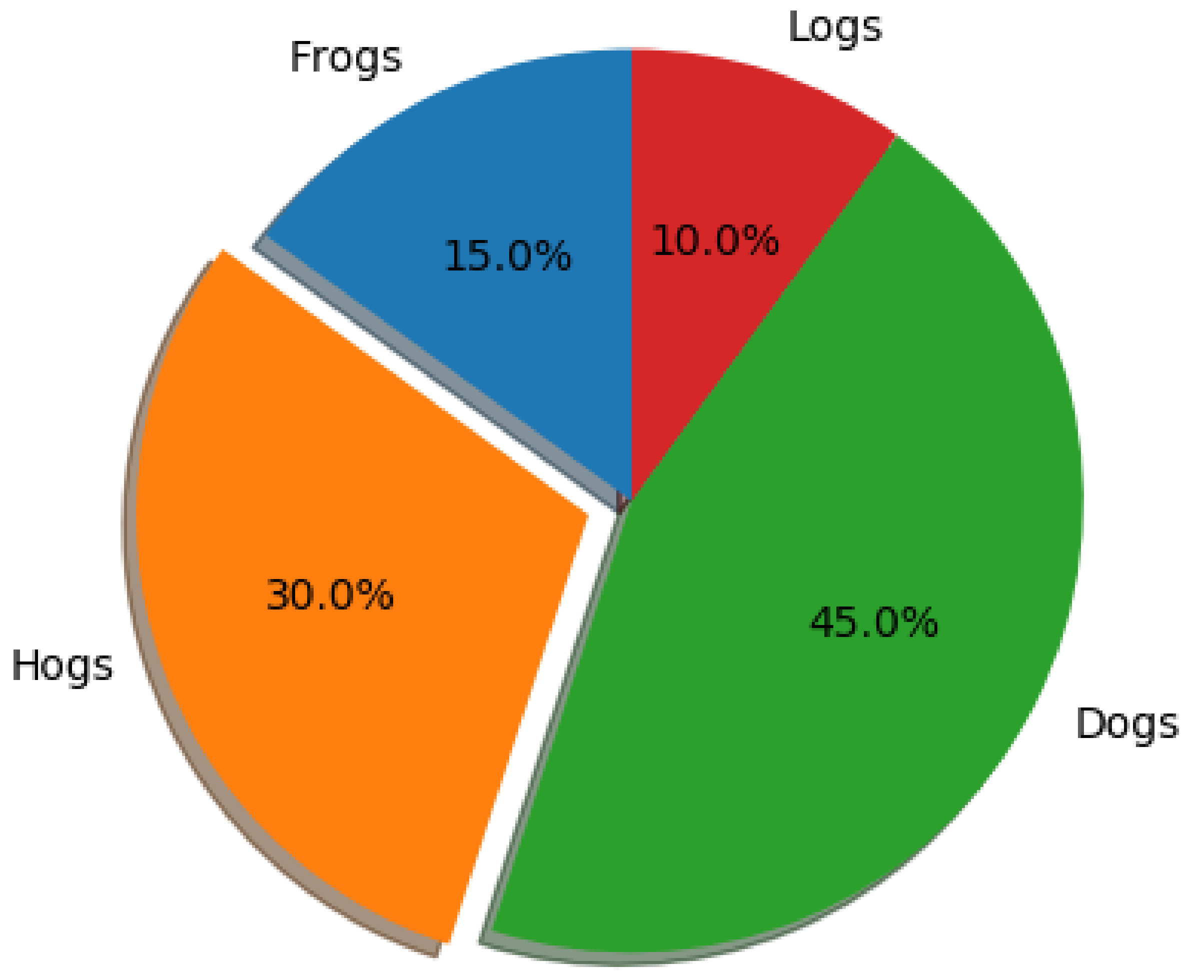


Histogram of IQ: $\mu = 100$, $\sigma = 15$
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Probability density
60
80
100
120
140
Smarts

histogram

```
import numpy as np
import matplotlib.pyplot as plt
np.random.seed(19680801)
# example data
mu = 100 # mean
sigma = 15 # standard deviation
x = mu + sigma * np.random.randn(437)
 # Normal distribution
num_bins = 100 # numer of bins
fig, ax = plt.subplots()
# the histogram of the data
ax.hist(x, num_bins, density=1)
ax.set_xlabel('Smarts')
ax.set_ylabel('Probability density')
ax.set_title(r'Histogram of IQ: $\mu=100$,$\sigma=15$')
plt.show()
```

Basic pie chart



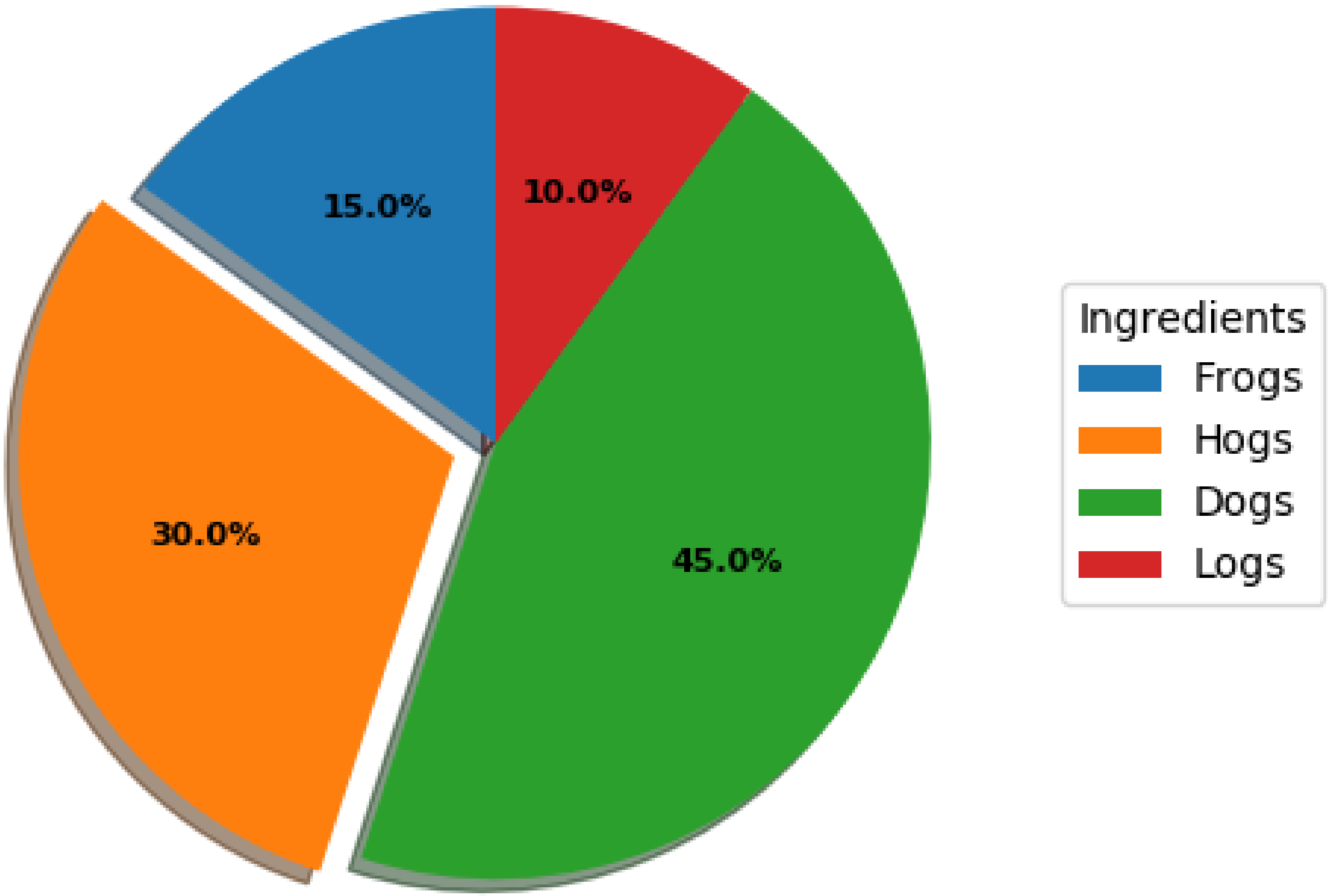
Basic pie chart

```
import matplotlib.pyplot as plt
# Pie chart, where the slices will be ordered and
plotted counter-clockwise:
labels = 'Frogs', 'Hogs', 'Dogs', 'Logs'
sizes = [15, 30, 45, 10]
explode = (0, 0.1, 0, 0) # only "explode" the 2nd
slice (i.e. 'Hogs')

fig1, ax = plt.subplots()
ax.pie(sizes, explode=explode, labels=labels,
autopct='%1.1f%%',
shadow=True, startangle=90)

plt.show()
```

Labeling a pie



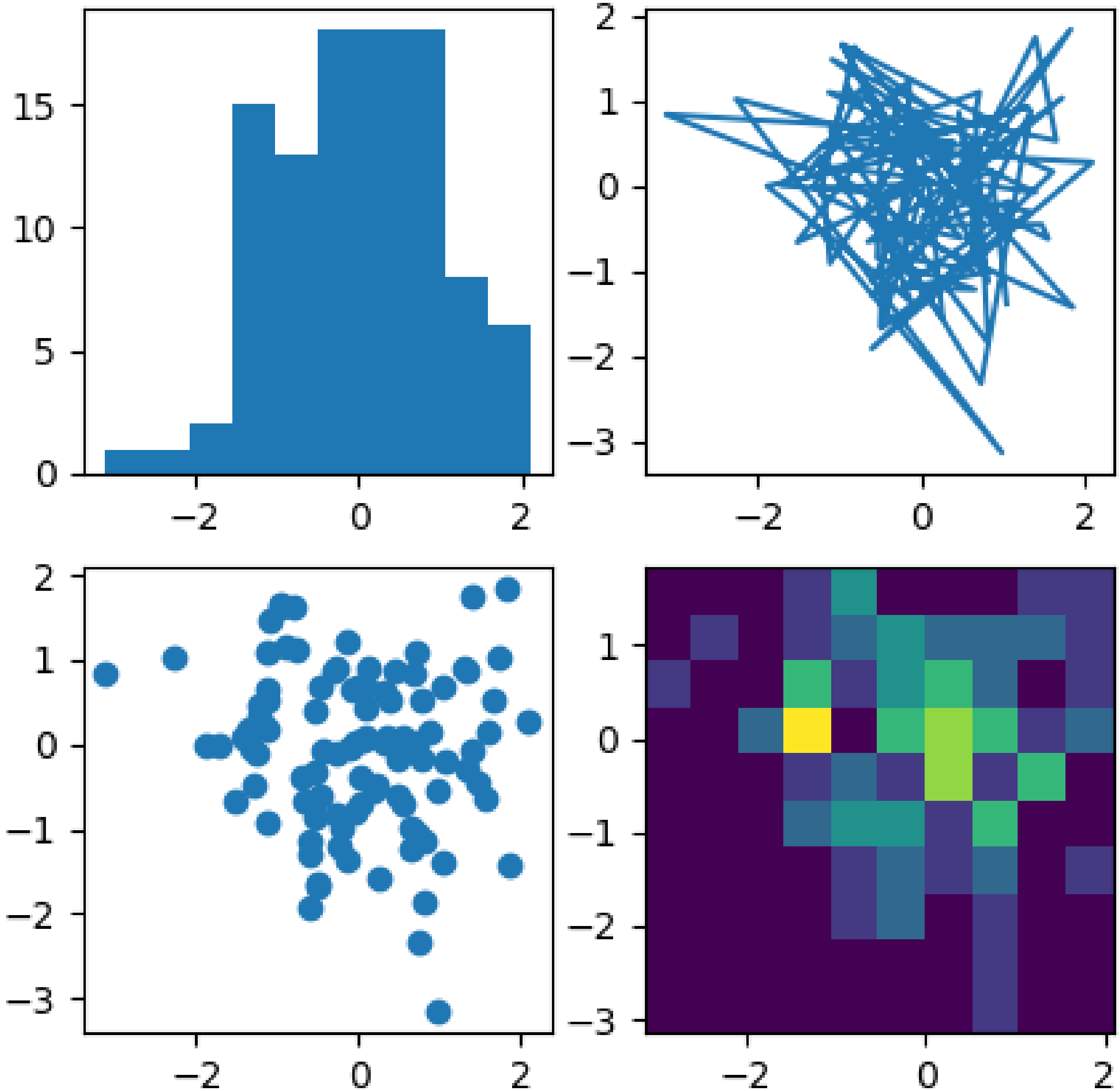
Labeling a pie

```
import matplotlib.pyplot as plt
# Pie chart, where the slices will be ordered and plotted counter-clockwise:
labels = 'Frogs', 'Hogs', 'Dogs', 'Logs'
sizes = [15, 30, 45, 10]
explode = (0, 0.1, 0, 0)
fig, ax = plt.subplots()
wedges,texts,autotexts=ax.pie(sizes,explode=explode, autopct='%1.1f%%',shadow=True, startangle=90)

ax.legend(wedges,labels,title="Ingredients",loc="center left",bbox_to_anchor=(1, 0, 0.5, 1))

plt.setp(autotexts, size=8, weight="bold")
plt.show()
```

Many plot types



Many plot types

```python
import matplotlib.pyplot as plt
import numpy as np

np.random.seed(19680801)
data = np.random.randn(2, 100)

fig, axs = plt.subplots(2, 2, figsize=(5, 5))
axs[0, 0].hist(data[0])
axs[1, 0].scatter(data[0], data[1])
axs[0, 1].plot(data[0], data[1])
axs[1, 1].hist2d(data[0], data[1])

plt.show()
```

An example

- 2018 Type-II vaccine data of Shanghai

```
      name src    create_company    report_company prov  year  price
0  重组乙型肝炎疫苗  国产  华北制药金坦生物技术股份有限公司  华北制药金坦生物技术股份有限公司  上海市  2018   93.5
1  重组乙型肝炎疫苗  国产     大连汉信生物制药有限公司      大连汉信生物制药有限公司  上海市  2018   89.5
2  重组乙型肝炎疫苗  国产   上海葛兰素史克生物制品有限公司    上海葛兰素史克生物制品有限公司  上海市  2018   83.5
3  重组乙型肝炎疫苗  国产     北京北生研生物制品有限公司      北京北生研生物制品有限公司  上海市  2018   41.5
4  重组乙型肝炎疫苗  国产   上海葛兰素史克生物制品有限公司    上海葛兰素史克生物制品有限公司  上海市  2018   93.5
```

[61 rows x 7 columns]

```
>>> import matplotlib.pyplot as plt
>>> import pandas as pd
>>> data = pd.read_csv("shanghai.csv")
 # read data from csv file
```

```
…
>>> data.head()
name src create_company report_company prov year
price
0 重组乙型肝炎疫苗 国产 华北制药金坦生物技术股份有限
公司 华北制药金坦生物技术股份有限公司 上海市 2018
93.5
1 重组乙型肝炎疫苗 国产 大连汉信生物制药有限公司 大连
汉信生物制药有限公司 上海市 2018 89.5
2 重组乙型肝炎疫苗 国产 上海葛兰素史克生物制品有限公
司 上海葛兰素史克生物制品有限公司 上海市 2018 83.5
3 重组乙型肝炎疫苗 国产 北京北生研生物制品有限公司 北
京北生研生物制品有限公司 上海市 2018 41.5
4 重组乙型肝炎疫苗 国产 上海葛兰素史克生物制品有限公
司 上海葛兰素史克生物制品有限公司 上海市 2018 93.5
```

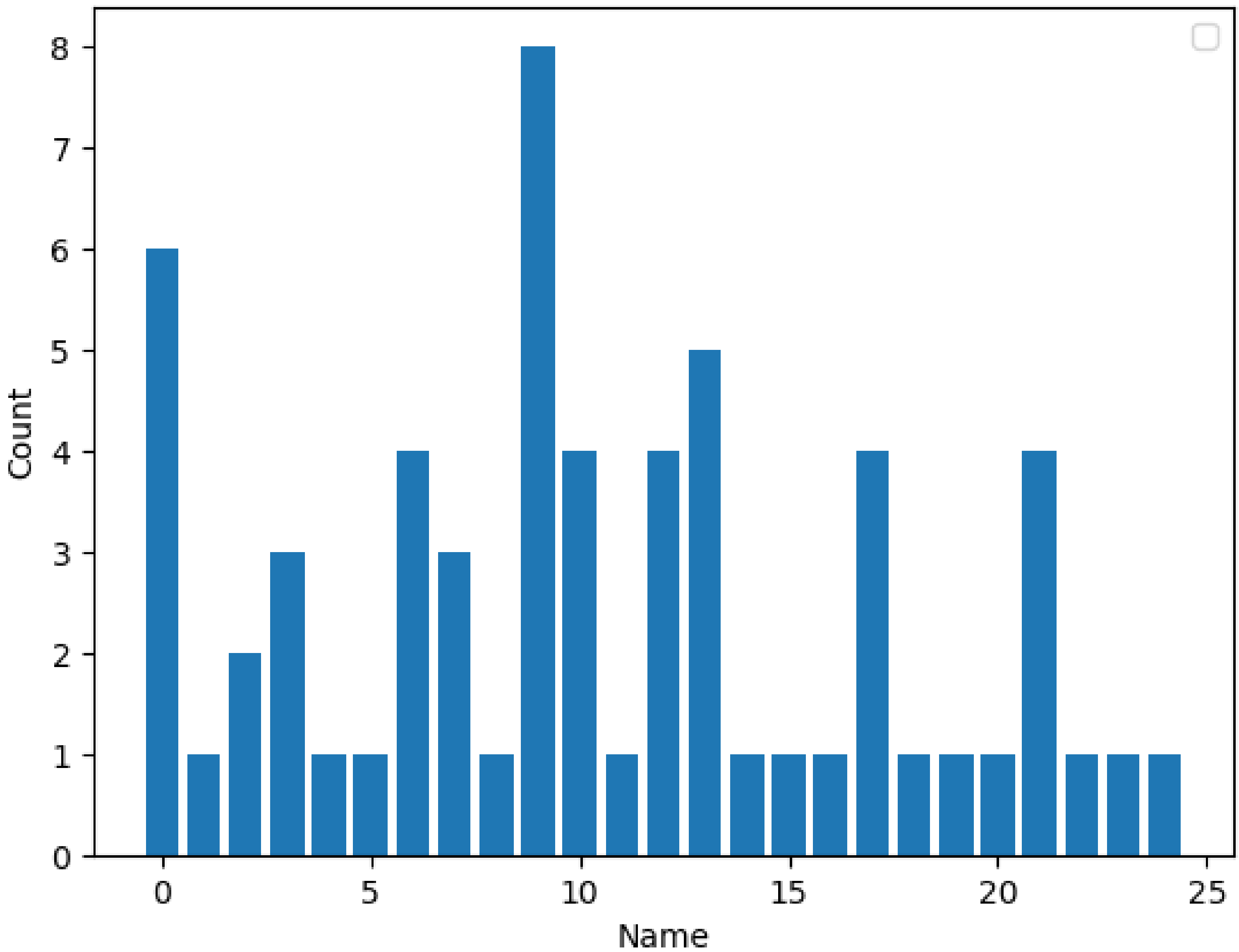
```
…
>>> s = data['name']
>>> names = s.drop_duplicates()
```

```
0                  重组乙型肝炎疫苗
6                  乙型脑炎灭活疫苗
7           ACYW135群脑膜炎球菌多糖疫苗
9              A群C群脑膜炎球菌多糖结合疫苗
12               麻疹风疹联合减毒活疫苗
13               麻腮风联合减毒活疫苗
14                 水痘减毒活疫苗
18               23价肺炎球菌多糖疫苗
21             13价肺炎球菌多糖结合疫苗
22                 流感病毒裂解疫苗
30                 甲型肝炎灭活疫苗
34                 腮腺炎减毒活疫苗
35              b型流感嗜血杆菌结合疫苗
39                   人用狂犬病疫苗
44                 口服轮状病毒活疫苗
45        重组B亚单位/菌体霍乱疫苗（肠溶胶囊）儿童用
46                 重组戊型肝炎疫苗
47               肠道病毒71型灭活疫苗
51          无细胞百白破b型流感嗜血杆菌联合疫苗
52     AC群脑膜炎球菌（结合）b型流感嗜血杆菌（结合）联合疫苗
53  吸附无细胞百白破灭活脊髓灰质炎和b型流感嗜血杆菌（结合）联合疫苗
54                 狂犬病人免疫球蛋白
58                   吸附破伤风疫苗
59              双价人乳头瘤病毒吸附疫苗
60               四价人乳头瘤病毒疫苗
Name: name, dtype: object
```

```
…
>>> s = data['name']
>>> names = s.drop_duplicates()
>>> counts = [sum(data['name']==n) for n in names]
>>> counts
[6, 1, 2, 3, 1, 1, 4, 3, 1, 8, 4, 1, 4, 5, 1, 1,
1, 4, 1, 1, 1, 4, 1, 1, 1]
```

```python
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np

data = pd.read_csv("shanghai.csv")
data.head()
s = data['name']
names = s.drop_duplicates()
counts = [sum(data['name']==n) for n in names]
fig, ax = plt.subplots()
x = np.linspace(0, len(names)-1, len(names))
ax.bar(x,counts)
ax.set_xlabel('Name')
ax.set_ylabel('Count')
plt.show()
```


Count
Name
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25

Recap

- Understand and use
  - NumPy
  - Pandas
  - Matplotlib