AI-based Audio Analysis of Music and Soundscapes

Fundamentals of Python Programming

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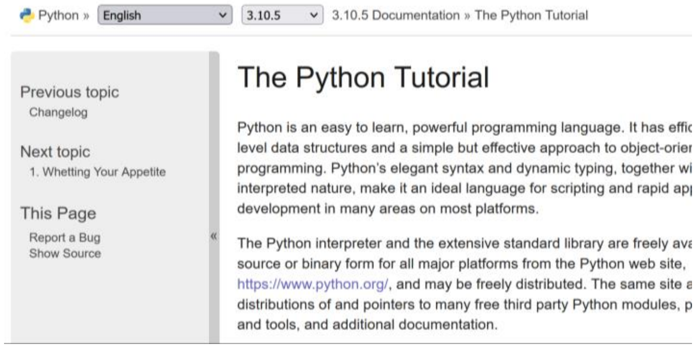
Outline

- Python basics
- Data types
- NumPy (Numeric computing)
- Matplotlib (Data visualization)

Resources

- The Python Tutorial
  - https://docs.python.org/3/tutorial/



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1. Whetting Your Appetite

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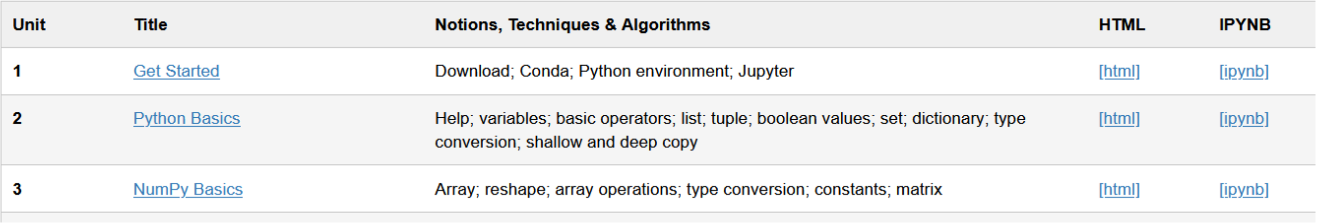
The Python Tutorial

Python is an easy to learn, powerful programming language. It has effic
level data structures and a simple but effective approach to object-orier
programming. Python's elegant syntax and dynamic typing, together wi
interpreted nature, make it an ideal language for scripting and rapid ap
development in many areas on most platforms.

The Python interpreter and the extensive standard library are freely ava
source or binary form for all major platforms from the Python web site,
https://www.python.org/, and may be freely distributed. The same site a
distributions of and pointers to many free third party Python modules, p
and tools, and additional documentation.

Fig. 1 - https://docs.python.org/3/tutorial/

- Preparation Course for Python
  - https://www.audiolabs-erlangen.de/resources/MIR/PCP/PCP.html

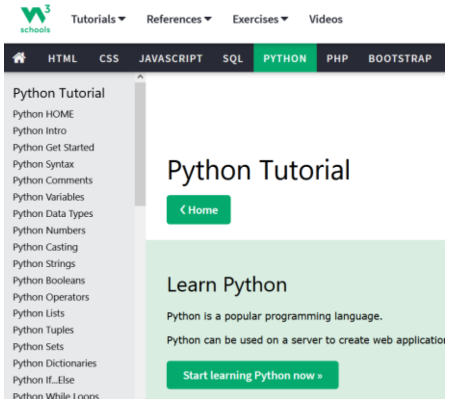


Unit	Title	Notions, Techniques & Algorithms	HTML	IPYNB
1	Get Started	Download; Conda; Python environment; Jupyter	[html]	[ipynb]
2	Python Basics	Help; variables; basic operators; list; tuple; boolean values; set; dictionary; type conversion; shallow and deep copy	[html]	[ipynb]
3	NumPy Basics	Array; reshape; array operations; type conversion; constants; matrix	[html]	[ipynb]

Fig. 2 - https://www.audiolabs-erlangen.de/resources/MIR/PCP/PCP.html

Resources

- W3 Schools – Python Tutorial
  - https://www.w3schools.com/python



Python Tutorial

Learn Python

Python is a popular programming language.

Python can be used on a server to create web applicatio

Fig. 3 - https://www.w3schools.com/python/

- Python Tutorial - Python Full Course for Beginners
  - https://www.youtube.com/watch?v=_uQrJ0TkZlc

Python Basics

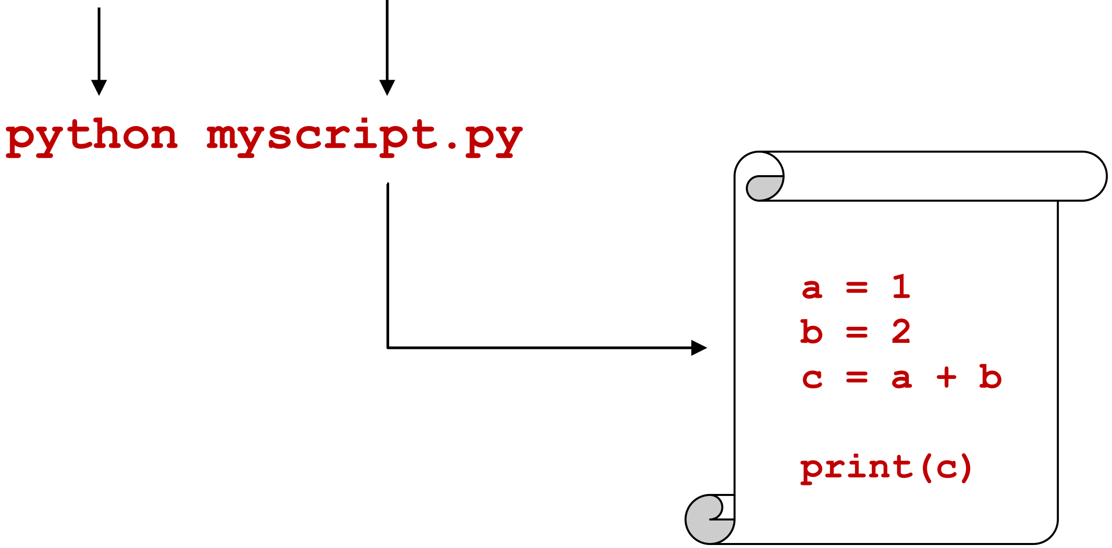
- Free & simple to learn programming language (1989)
- Cross-platform (Windows, MacOS, Linux)
- Great for rapid prototyping
- Interpreted language (not compiled)

- Application Scenarios
  - Science
  - Web Development
  - Data Science / Data Visualization
  - Machine Learning / Artificial Intelligence
  - Desktop GUIs

Python Basics

Workflow

- Common workflow
  - Python Code-Files
  - Python interpreter



```
python myscript.py
```

```
a = 1
b = 2
c = a + b

print(c)
```

Python Basics
Indentations

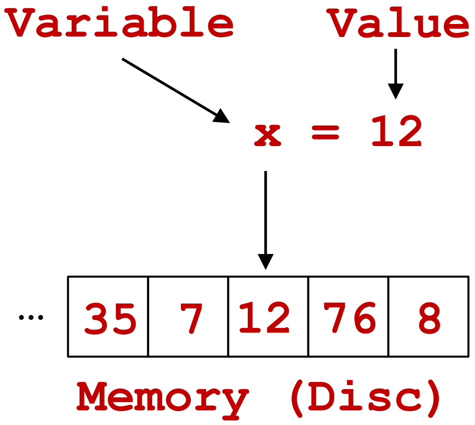
- Often “Tab” is used *(4 spaces are recommended)*
- Used to indicate block / level of code
    - Same number of spaces for the same level of code!

```
x = 12
If x > 24:
    print(x)
    if x > 32:
        print(">32")
```

Python Basics
Variables

- Variables
  - addresses a part of the **memory**
  - has a **name**
  - has a **value**

…



Variable

Value

`x = 12`

… | 35 | 7 | 12 | 76 | 8

Memory (Disc)

Python Basics
Variables

- Variables are not declared
- Variables are created after **value assignment**
- **Data type** is inferred from value

```
x = 12
print(x)   # 12

x = "Hello"
print(x)   # "Hello"
```

Python Basics

Variables

- Variable names can contain
    - Letters (a, b, c, …, A, B, C, …Z)
    - Underscore (_)
    - *(preferably, use small letters and underscore)*

```
first_result = 12.7

print(first_result)  # 12.7
```

Python Basics
Variables

- Access type

```
x = 12
print(x)           # 12
print(type(x))     # int
```

Python Basics
Comments

- One-line comments (#)

```
# this is a short note
```

- Multi-line comments (""")

```
"""
This is a longer comment
to explain more details.
"""
```

Python Basics
if/else & for-loops

- Conditional code execution

```
If a > 4:
    print("larger than four!")
else:
    print("smaller than four!")
```

- Iterate over list:

```
for i in range(4):
    print(i)

# 0, 1, 2, 3

for c in „yahoo":
    print(c)

# y, a, h, o, o
```

Python Basics

Functions

- Block of code (*one functionality*)
    - Name
    - Arguments

Argument(s)

```
def my_print(s):
    print(s)

my_print(123)    # 123
```

```
def my_addition(a, b):
    c = a + b
    return(c)

d = my_addition(1, 2)       # 3
e = my_addition(11, 22)     # 33
```

Return parameter

Python Basics

Functions

- Keyword arguments
    - Optional
    - Default values

Keyword argument(s)

```
def my_spectrogram(signal, db=True):
    # compute spectrogram …
    if db:
        # apply dB scaling
    # return spectrogram
```

Data Types
Strings

- Strings (text)

```
s = "Audio Analysis"
s = 'Audio Analysis`
s = str("Audio Analysis")
```

- Multiline strings

```
s = """Audio analysis
Is often based on signal
processing"""
```

Data Types

Strings

- Strings = Arrays (of bytes)

```
s = "Audio"
print(s[0])          # A
print(s[2])          # d
print(s[-1])         # o
```

- String length

```
s = "Audio"
print(len(s))        # 5
```

- Check for substring

```
s = "Hi Peter"
print("Hello" in s)     # False
print("Hi" in s)        # True
print("Hu" not in s)    # True
```

Data Types
Strings

- Slicing strings

```
s = "Audio"
print(s[0:2])        # Au
print(s[:2])         # Au
print(s[2:])         # dio
print(s[-2:])        # io
```

- Uppercase, Lowercase

```
s = "Audio"
print(s.upper())     # AUDIO
print(s.lower())     # audio
```

- Replace substring

```
s = "birdsong.wav"
s = s.replace(".wav", ".mp3")
print(s)             # birdsong.mp3
```

Data Types

Strings

- Splitting strings

```
s = "car.wav,12,BMW"
parts = s.split(",")
print(parts)
          # ['car.wav', '12', 'BMW']
```

- Joining strings

```
s = ["car","wav"]
filename = ".".join(s)
print(joint)      # car.wav
```

- Formatting strings

```
s1 = "{}.wav".format("car")
s2 = "car" + ".wav"
print(s1)            # car.wav
print(s2)            # car.wav
```

Data Types

Numeric Types

- Integers

```
i1 = 12
i2 = -23
```

- Float (floating point number)

```
f1 = 12.001
f2 = -23.5
```

- Type conversion

```
print(i1)                 # 12
print(type(i1))           # int
i1 = float(i1)
print(i1)                 # 12.0
print(type(i1))           # float
```

Data Types
Numeric Types

- Rounding up/down

```
import math
f = 1.49
print(math.ceil(f))     # 2
print(math.floor(f))    # 1
print(round(f))         # 1
```

Data Types

Lists

- Store data collections
    - Any data type

```
list1 = ["apple", "banana", "cherry"]

list2 = [1, 2, 3]

list3 = [True, False, True]
```

- Zero-based indexing

```
print(list2[0])      # 1
print(list1[2])      # Cherry
```

- Length

```
print(len(list1))    # 3
```

Data Types
Lists

- List comprehension

```
list1 = [2, 4, 6]

list2 = [_ + 1 for _ in list1]

# [3, 5, 7]
```

- Indexing / Slicing like for strings

Data Types

Dictionaries (dicts)

- Key/Value pairs

```
d = {
  "brand": "Ford",
  "model": "Mustang",
  "year": 1964
}

print(d["year"])    # 1964
```

- Keys

```
Print(d.keys())
    # ['brand', 'model', 'year']
```

Data Types
Operators

- Assignment operators

```
i = 12                      # 12
i = i + 2                   # 14
i += 2                      # 16
i -= 2                      # 14
i /= 2                      # 7.0
```

- Comparison operators

```
print(1 == 1)               # True
print(1 <= 2)               # True
print(1 >= 3)               # False
print(1 != 3)               # True
```

Data Types
Operators

- Logical operators

```
i = 1
(i < 3) and (i > 1)     # False
(i < 3) or (i > 1)      # True
not (i > 5)             # True
```

NumPy (Numeric Computing)

- Standard library for working with numerical data in Python
- Core part of various Python libraries
    - Pandas (data analysis)
    - SciPy (scientific computing)
    - Matplotlib (visualization)
    - Scikit-learn (machine learning)

Alias *(for convenience)*

↓

- Needs to be imported first

```
import numpy as np
```

NumPy

Arrays

- Efficient data structure to store multiple values (faster than lists)
- Contains
    - Raw data (values)
    - **dtype** (data type – np.int8 / np.float16 / np.float32)
    - **rank** (number of dimensions)
    - **shape** (size of array along each dimension

NumPy

Arrays

- Example (one-dimensional array)

```
a = np.array([1, 2, 3])
print(a)                   # [1, 2, 3]
print(a.ndim)              # 1
print(a.shape)             # (3,)
print(a.dtype)             # int32
```

1	2	3

- Example (two-dimensional array / matrix):

```
a = np.array([[1.1, 2.2], [3.3, 4.4]])
print(a)                   # [[1.1, 2.2]
                           #  [3.3, 4.4]]
print(a.ndim)              # 2
print(a.shape)             # (2,2)
print(a.dtype)             # float64
```

1.1	2.2
3.3	4.4

NumPy

Arrays

- Create arrays with ones / zeros

```
a = np.zeros([2, 3])
print(a)                   # array([[0., 0., 0.],
                           #         [0., 0., 0.]])

a = np.ones(3)
print(a)                   # array([1., 1., 1.])

a = np.ones(3, dtype=int)
print(a)                   # array([1, 1, 1])
```

NumPy

Arrays

- Create arrays with increasing numbers (**arange**)

```
a = np.arange(4)
print(a)               # array([[0., 1., 2., 3.]])
```

- Indexing / Slicing nparray (like with lists & strings before)

```
a = np.arange(4)
print(a[0])                # 0.
print(a[:2])               # [0., 1.]
print(a[-1])               # 3
```

NumPy

Arrays

- Concatenating two arrays (**concatenate**)

```
a = np.arange(4)
```

0	1	2	3

```
b = np.arange(3)
```

0	1	2

```
print(np.concatenate((a, b)))

                  # array([[0., 1., 2., 3., 0., 1., 2]])
```

0	1	2	3	0	1	2

NumPy

Arrays

- Horizontal stacking (**hstack**) and vertical stacking (**vstack**)

```
a = np.array((1, 2), dtype=int)
```

1	2

```
b = np.array((3, 4), dtype=int)
```

3	4

```
print(np.hstack((a, b)))    # array([1, 2, 3, 4])
```

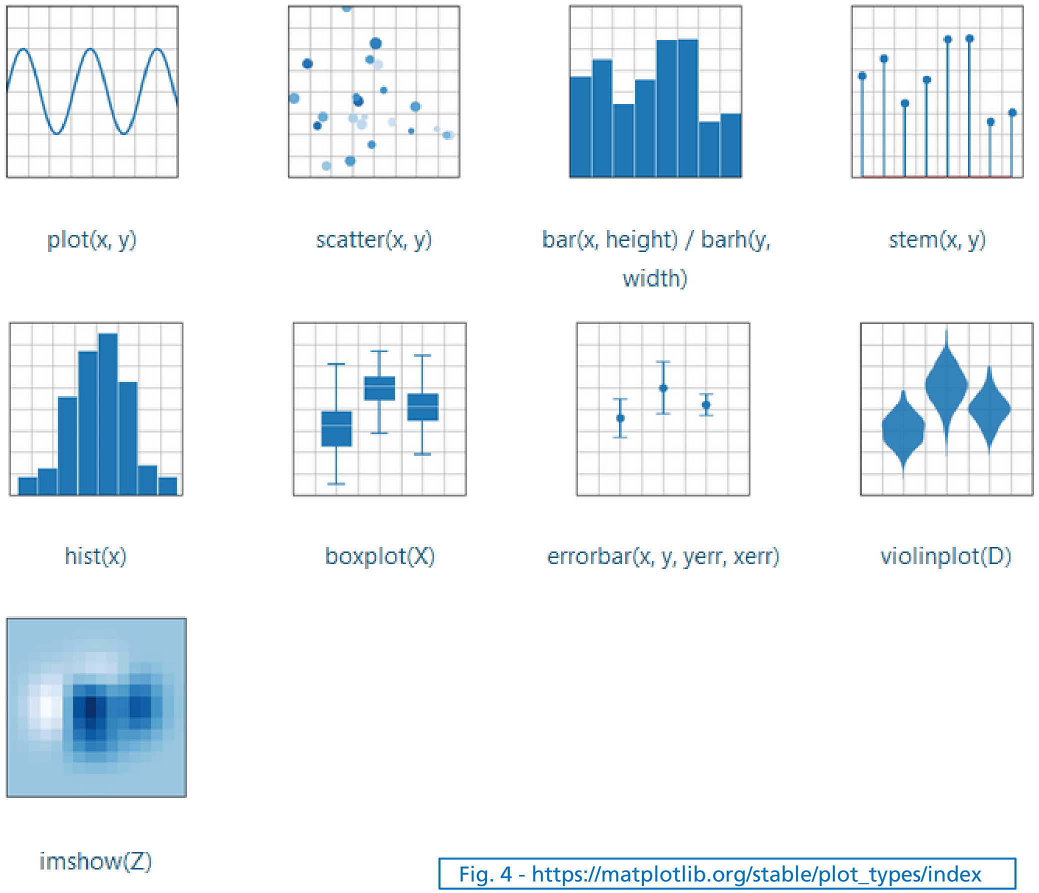
1	2	3	4

```
print(np.vstack((a, b)))    # array([[1, 2],
                                      [3, 4]])
```

1	2
3	4

Matplotlib (Data visualization)

- Plotting types



plot(x, y)

scatter(x, y)

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

stem(x, y)

hist(x)

boxplot(X)

errorbar(x, y, yerr, xerr)

violinplot(D)

imshow(Z)

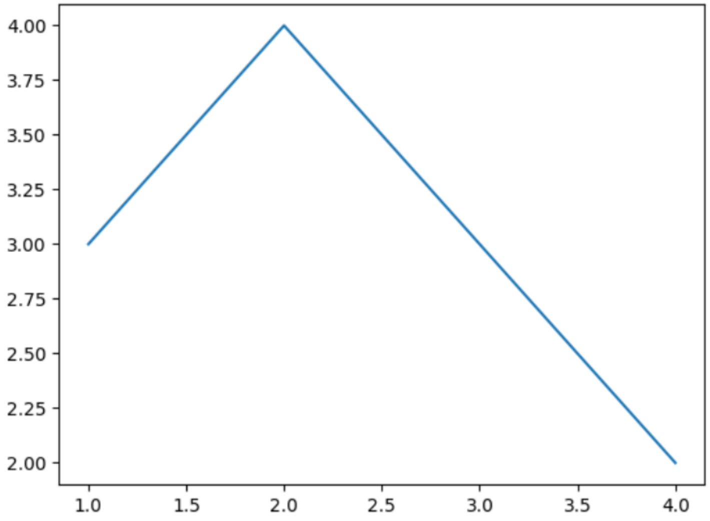
Fig. 4 - https://matplotlib.org/stable/plot_types/index

Matplotlib

First Steps

- Import matplotlib package
- Create figure
- Plot data & show figure

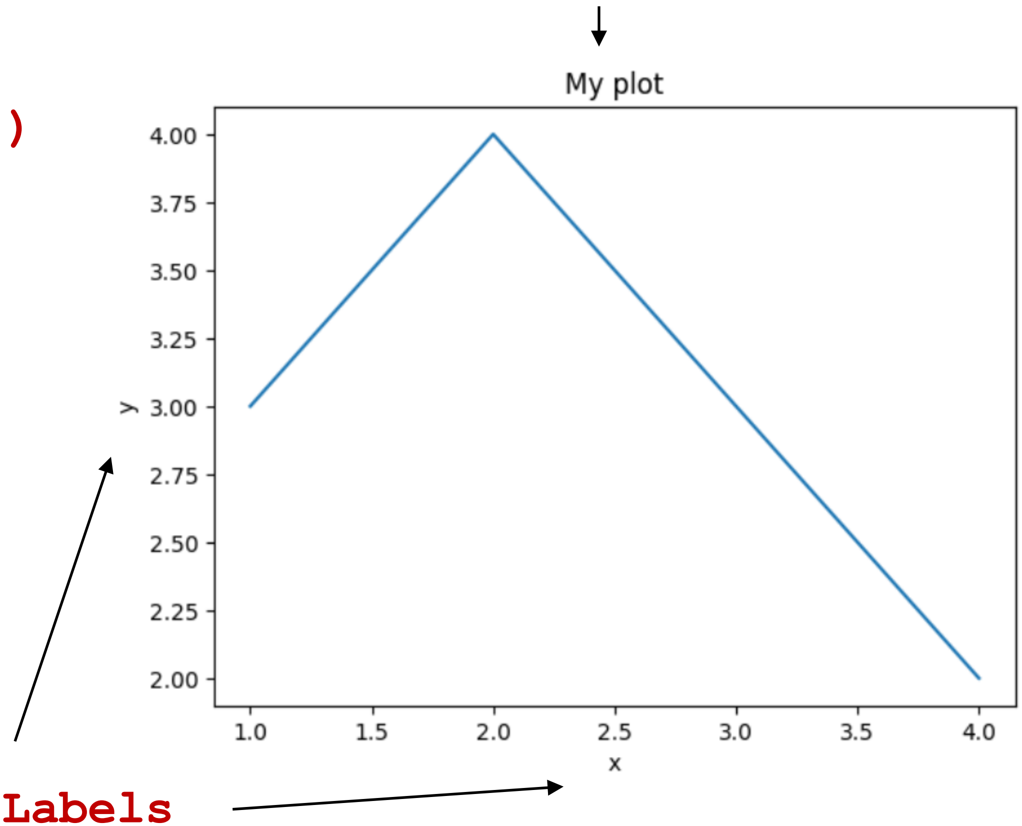
```
import numpy as np
x = np.array((1,2,3,4))
y = np.array((3,4,3,2))

import matplotlib.pyplot as plt

fig, ax = plt.subplots()

ax.plot(x, y)
plt.show()
```



Matplotlib

Axes Labels & Title

```
# ...

fig, ax = plt.subplots()

ax.plot(x, y)
ax.set_xlabel('x')
ax.set_ylabel('y')
ax.set_title('My plot‘)
plt.show()
```



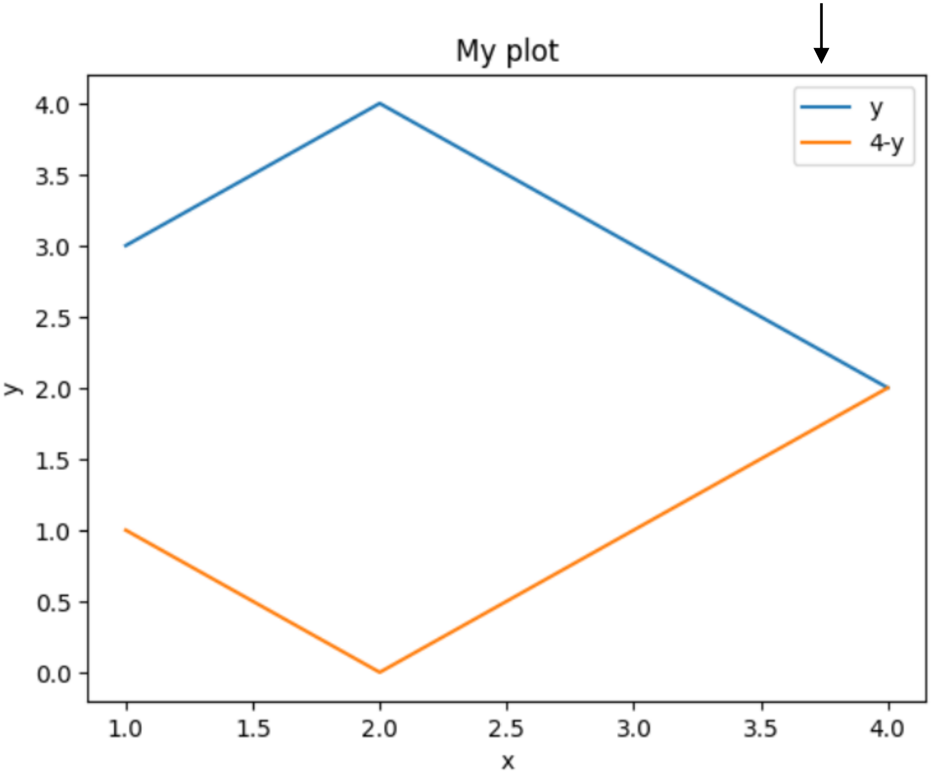
Title

Axes Labels

Matplotlib
Legend

```
# ...

fig, ax = plt.subplots()

ax.plot(x, y, label='y')
ax.plot(x, 4-y, label='4-y‘)

# ...

plt.legend()
plt.show()
```

Legend



Matplotlib

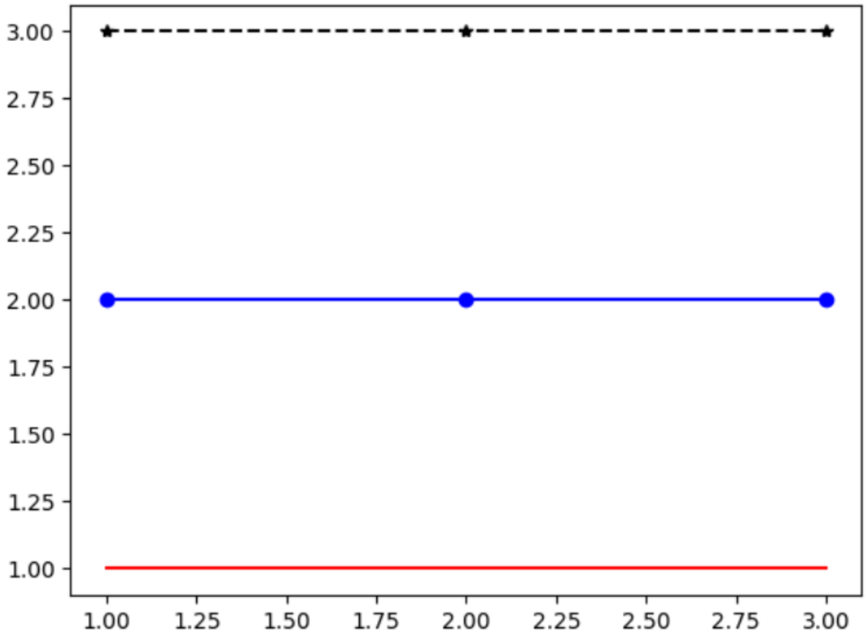
Line-style / marker-style

Color

Marker

Line-Style

```
fig, ax = plt.subplots()
ax.plot([1, 2, 3], [1, 1, 1], 'r-')
ax.plot([1, 2, 3], [2, 2, 2], 'bo-')
ax.plot([1, 2, 3], [3, 3, 3], 'k*--')
plt.show()
```



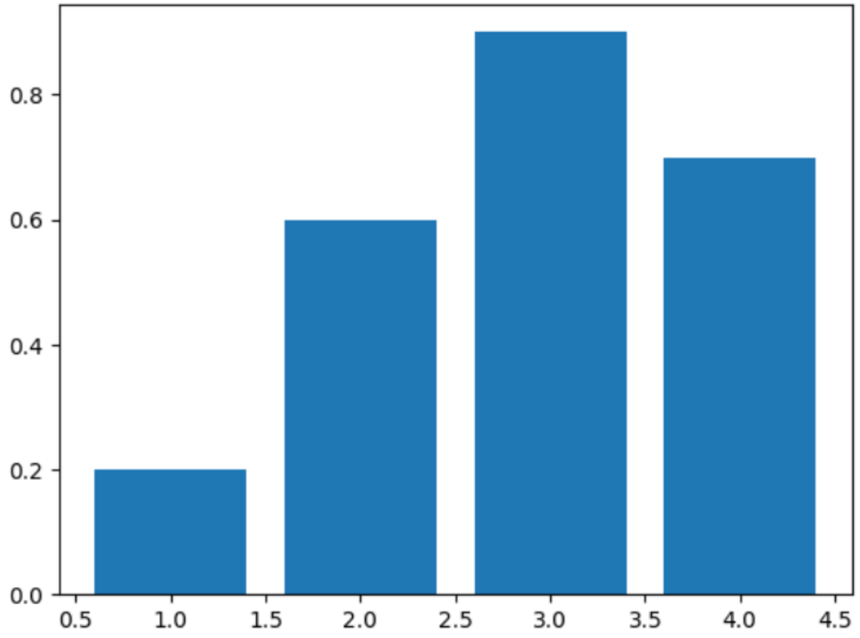
- Short or long form

```
...
..., 'k*--')
..., color='k', marker='*',
linestyle='--')
```

Matplotlib

Bar plot

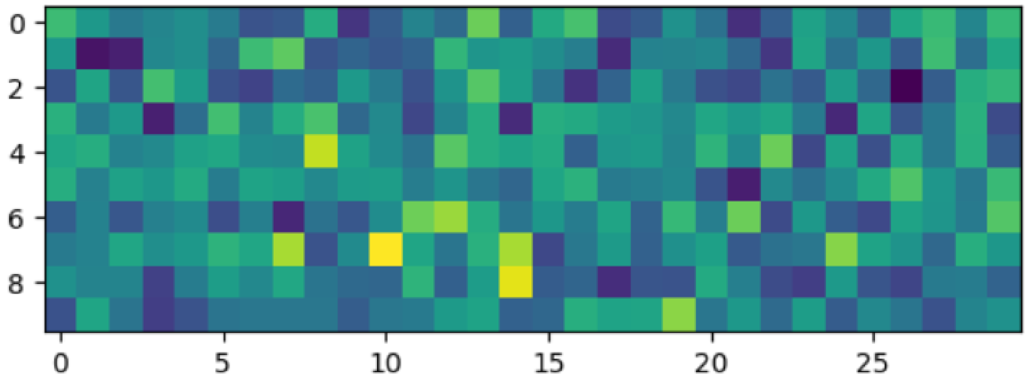
```
fig, ax = plt.subplots()
ax.bar([1, 2, 3, 4], [0.2, 0.6, 0.9, 0.7])
plt.show()
```



Matplotlib

Matrix plots

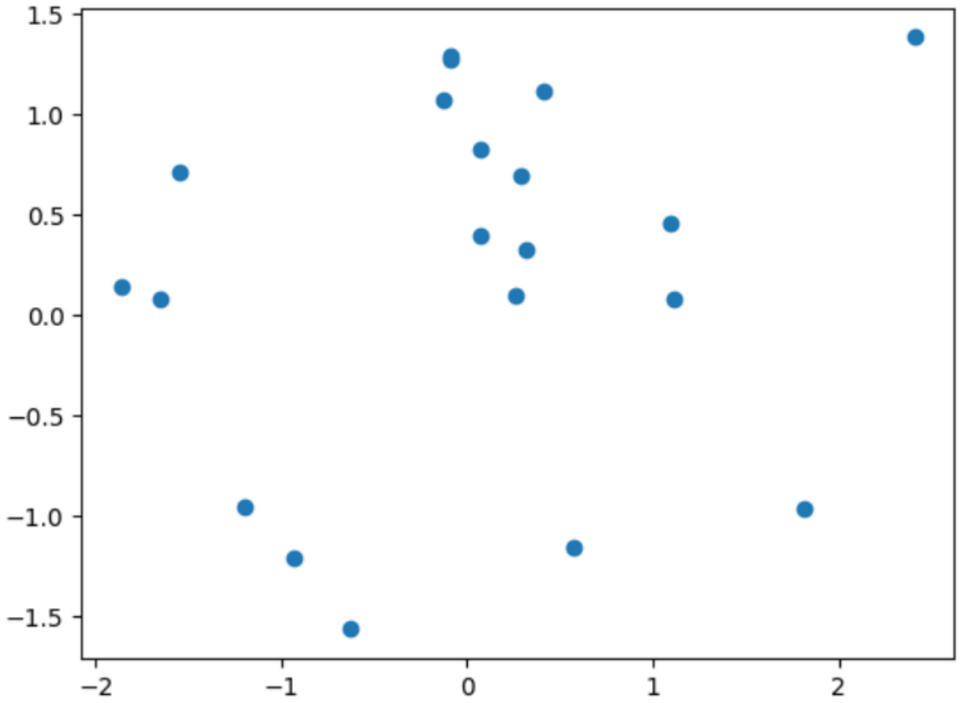
```
mat = np.random.randn(10, 30)
fig, ax = plt.subplots()
ax.imshow(mat)
plt.show()
```



Matplotlib

Scatter plots

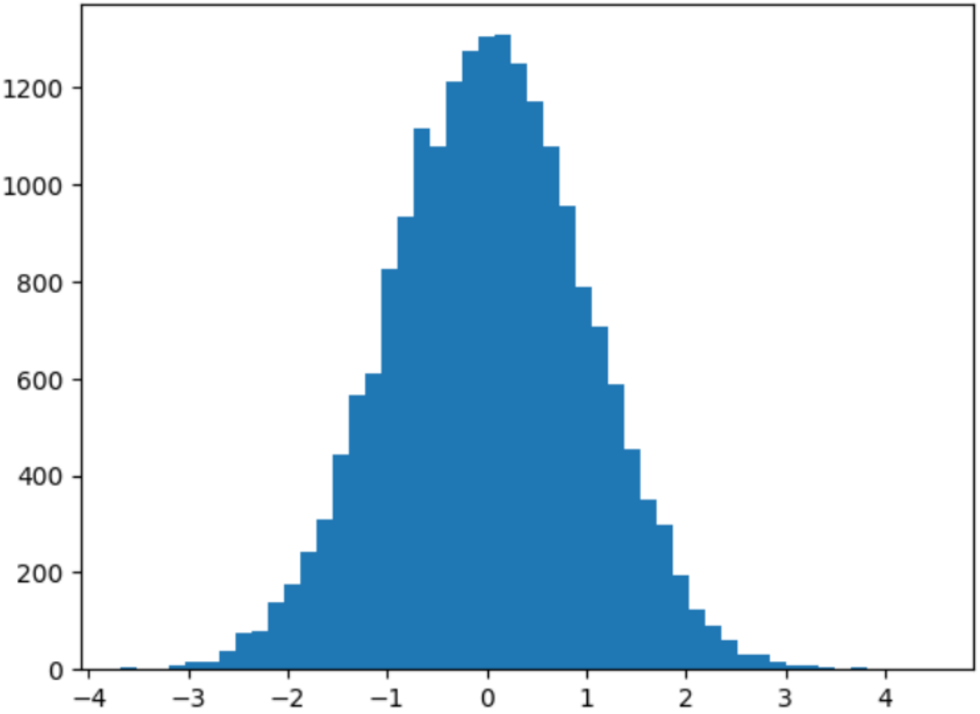
```
x = np.random.randn(20)
y = np.random.randn(20)
fig, ax = plt.subplots()
ax.scatter(x,y)
plt.show()
```



Matplotlib

Histograms

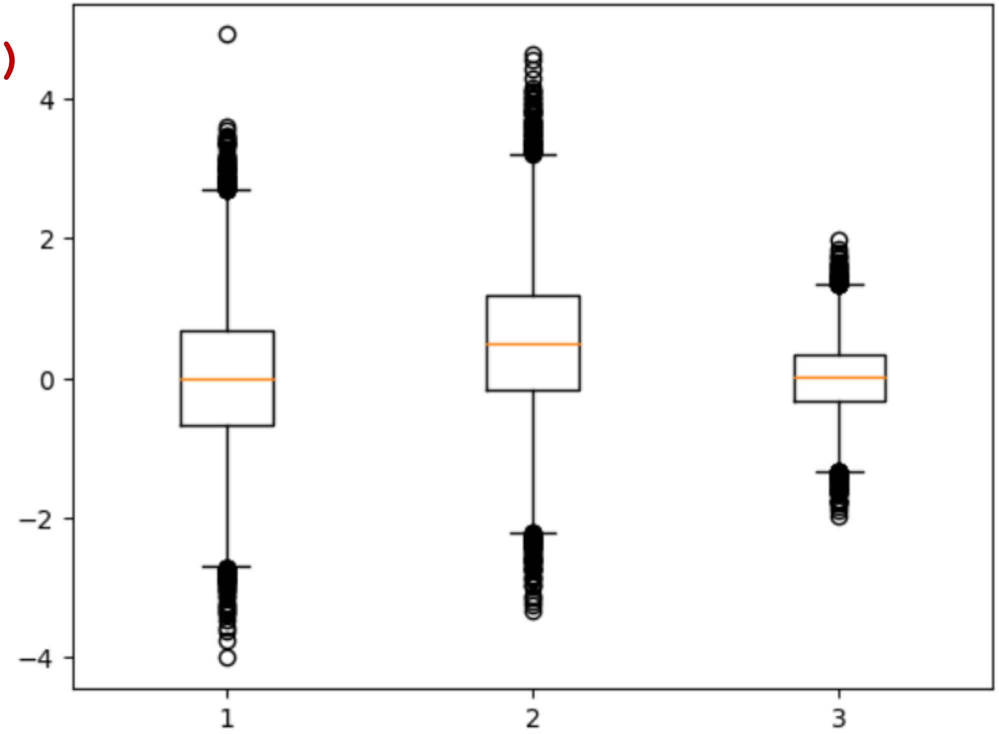
```
x = np.random.randn(20000)
fig, ax = plt.subplots()
ax.hist(x, bins=50)
plt.show()
```



Matplotlib

Boxplots

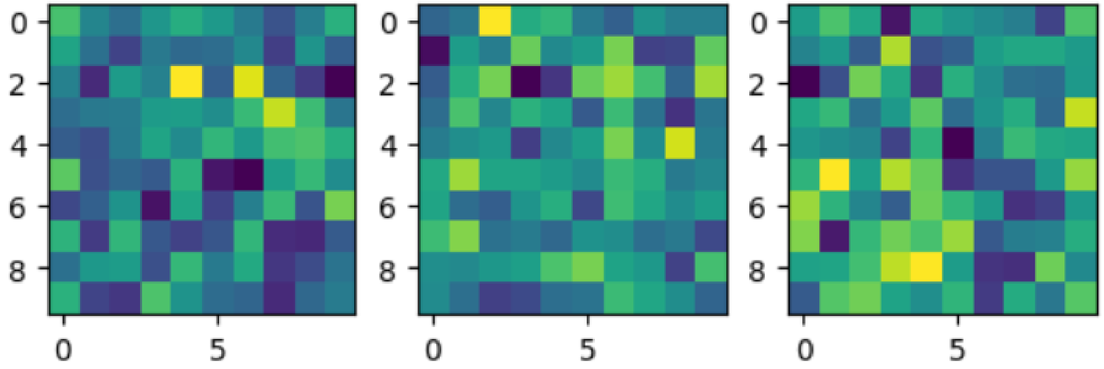
```
x = np.random.randn(20000, 3)
x[:, 1] += 0.5
x[:, 2] /= 2
fig, ax = plt.subplots()
ax.boxplot(x)
plt.show()
```



Matplotlib

Subplots

```
fig, ax = plt.subplots(1, 3)
ax[0].imshow(np.random.randn(10, 10))
ax[1].imshow(np.random.randn(10, 10))
ax[2].imshow(np.random.randn(10, 10))
plt.show()
```


0
2
4
6
8
0
5
0
2
4
6
8
0
5
0
2
4
6
8
0
5