

Python/R for Data Science

Lecture notes for 2022 Fall at Arkansas Tech University

Xinli Xiao

2022-10-07T00:08:49-05:00

Table of contents

Preface	4
I Part I: Python	5
II Preliminaries	6
1 Why Python?	7
1.1 Python is easy to learn and use	7
1.2 Python is easy to read	7
1.3 Python Community is mature and supportive	7
2 Hello world!	8
2.1 Setup the Python environment	8
2.1.1 VS Code + Anaconda	8
2.1.2 Google Colab	8
2.2 Hello World!	8
2.3 Python code cells and Notebooks	10
2.4 Linters	10
2.5 IPython and Jupyter	10
3 Projects	11
III Python Basics	18
4 Built-in Types: numeric types and str	19
4.1 Numeric types and math expressions	19
4.2 str	19
5 Fundamentals	22
5.1 Indentation	22
5.2 Binary operators and comparisons	23
5.3 import	23
5.4 Comments	24

5.5	Dynamic references, strong types	24
5.6	Everything is an object	25
5.7	Mutable and immutable objects	25
6	Flows and Logic	27
6.1	for loop	27
6.2	if conditional control	27
7	list	28
7.1	List Comprehension	28
8	dict	29
9	Exercises	30
10	Projects	34
IV	Package: numpy	37
11	Basics	39
12	Create np.ndarray	40
13	Mathematical and Statistical Methods	41
14	Common attributes and methods	42
15	Basic indexing and slicing	43
16	Boolean Indexing	45
17	Fancy indexing	46
18	Copies and views	48
19	More commands	50
20	More advanced commands	51
21	Examples	53
22	Exercises	57
23	Projects	61

V	Package: pandas	63
24	Basic pandas	65
24.1	Series and DataFrame	65
24.2	Accessing data	67
24.3	Updating data	67
24.4	Indexing, Selection, and Filtering	68
24.5	Essential functions	70
24.6	Function Application and Mapping	70
24.7	Sorting and Ranking	71
24.8	Summarizing and Computing Descriptive Statistics	72
24.9	Unique Values, Value Counts, and Membership	72
24.10	Reading and Writing Data in Text Format	72
24.11	Copies and views	72
25	Data cleaning	73
25.1	Handling Missing Data	73
25.2	Data Transformation	76
25.3	Example: Movies	77
25.4	String Manipulation	78
25.5	Regular expression	79
26	Data Wrangling	82
26.1	Hierarchical indexing	82
26.2	Combining and Merging Datasets	86
26.2.1	merge()	86
26.2.2	concat()	91
27	Data Aggregation and Group Operations	93
27.1	split-apply-combine model	93
27.2	More aggregation functions	96
27.3	Some examples	96
28	Exercises	98
29	Projects	105
VI	Visualization	107
30	matplotlib.pyplot	109
30.1	matplotlib interface	109
30.2	Downstream packages	116

30.3	plotting	118
30.3.1	plt.plot()	118
30.3.2	plt.bar() and plt.barh()	119
30.3.3	plt.scatter()	123
30.3.4	plt.hist()	124
30.4	plt.boxplot()	125
30.5	Titles, labels and legends	126
30.6	Annotations	127
30.7	Example	129
31	seaborn	132
31.1	Scatter plots with relplot()	133
31.2	regplot()	137
31.3	pairplot()	138
31.4	barplot	139
31.5	Histogram	141
32	Examples	143
32.1	Example 1: USA.gov Data From Bitly	143
32.2	Example 2: US Baby Names 1880–2010	147
32.3	Example 3: USDA Food Database	147
32.4	Example 4: 2012 Federal Election Commission Database	147
33	Exercises	148
34	Projects	150
	References	152
	Appendices	152
VII	Setup	153
A	VS Code + Anaconda	154
B	Google Colab	160
B.1	Install packages	160
B.2	Upload files	160
B.3	Mount Google Drive	160

VIII	PATH	162
IX	Virtual environments	165

Preface

This is the lecture notes for STAT 2304 Programming languages for Data Science 2022 Fall at ATU. If you have any comments/suggetions/concers about the notes please contact me at my email xxiao@atu.edu.

Part I

Part I: Python

Part II

Preliminaries

1 Why Python?

1.1 Python is easy to learn and use

1.2 Python is easy to read

1.3 Python Community is mature and supportive

2 Hello world!

2.1 Setup the Python environment

In this section we are going to setup the Python developing environment.

2.1.1 VS Code + Anaconda

Click [Appendix A](#) to see the detailed steps for VS Code and Anaconda. You may also check out [the official document](#). It contains more features but less details.

We will talk about the relation between Python and Anaconda and more about packages sometime later.

2.1.2 Google Colab

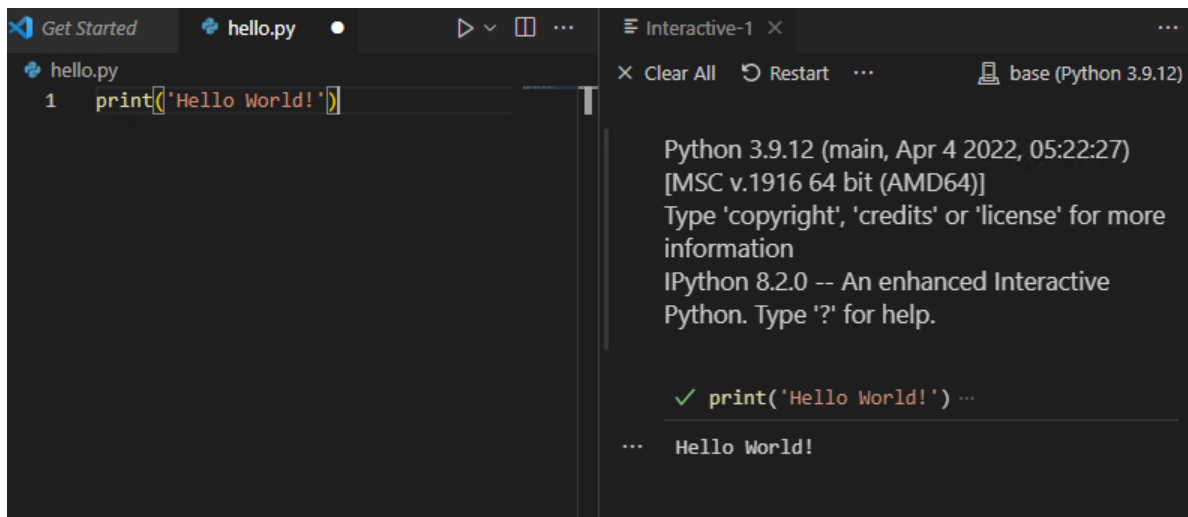
Click [Appendix B](#) for more details.

2.2 Hello World!

Take VS Code as an example. In the editor window, type in the code, and run the file in the interactive window.

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

If you see a small green check mark in the interactive window and also the output **Hello World!**, you are good to go!



The screenshot shows a Jupyter Notebook window with a single cell. The cell contains the code `print('Hello World!')`. The output of the cell is `Hello World!`. The interface includes a toolbar with icons for running, saving, and other actions. The top bar shows the file name `hello.py` and the Python version `base (Python 3.9.12)`.

```
Get Started | hello.py | [Run] | [Save] | [Close] | [More]
```

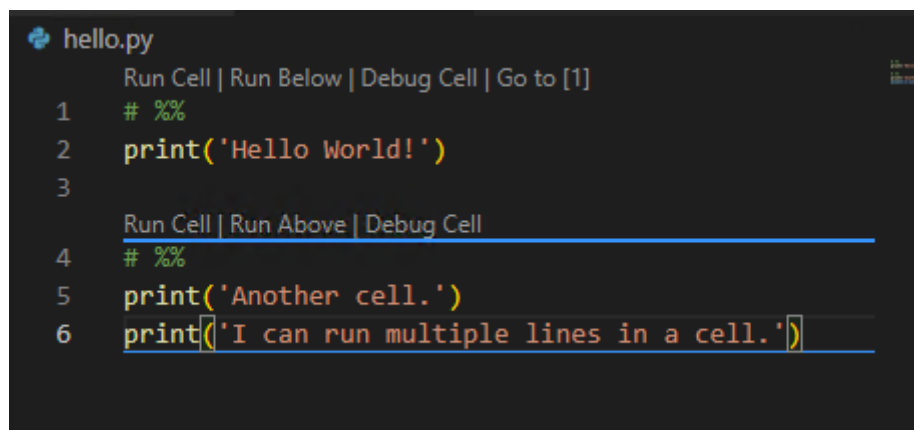
```
hello.py
```

```
1 print('Hello World!')
```

```
Python 3.9.12 (main, Apr 4 2022, 05:22:27)
[MSC v.1916 64 bit (AMD64)]
Type 'copyright', 'credits' or 'license' for more
information
IPython 8.2.0 -- An enhanced Interactive
Python. Type '?' for help.
```

```
✓ print('Hello World!') ...
```

```
... Hello World!
```



The screenshot shows a Jupyter Notebook window with a single cell. The cell contains the following code:

```
Run Cell | Run Below | Debug Cell | Go to [1]
```

```
1 # %%
```

```
2 print('Hello World!')
```

```
3
```

```
Run Cell | Run Above | Debug Cell
```

```
4 # %%
```

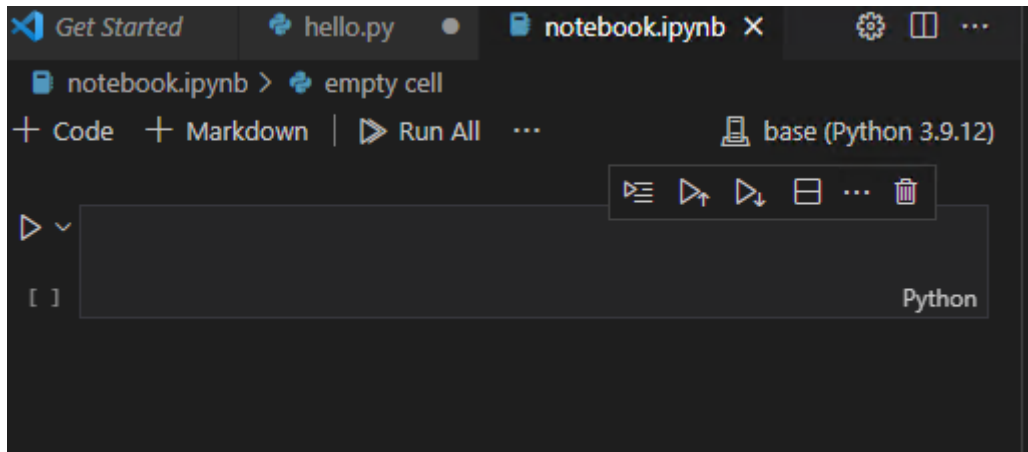
```
5 print('Another cell.')
```

```
6 print('I can run multiple lines in a cell.')
```

2.3 Python code cells and Notebooks

In VS Code you can run codes cell by cell. Each cell is separated by the symbol `# %%`. Each cell may contain multiple lines. You may click the small button on top of the cell or use keybindings.

This feature actually mimic the notebook. We may start a real Python Notebook file by directly creating a file with extension `.ipynb`.



The layout is straightforward.

2.4 Linters

2.5 IPython and Jupyter

3 Projects

Exercise 3.1 (Hello world!). Please set up a Python developing environment, including for .py file and for notebook, that will be used across the semester. Then print **Hello World!**.

Exercise 3.2 (Define a function and play with `time`). Please play with the following codes in a Jupyter notebook. We haven't talked about any of them right now. Try to guess what they do and write your guess in markdown cells.

```
import time

def multistr(x, n=2):
    return x * n

t0 = time.time()
x = 'Python'
print(multistr(x, n=10))
t1 = time.time()
print("Time used: ", t1-t0)
```

Exercise 3.3 (Fancy Basketball plot). Here is an example of the data analysis. We pull data from a dataset, filter the data according to our needs and plot it to visualize the data. This is just a show case. You are encouraged to play the code, make tweaks and see what would happen. You don't have to turn in anything.

The data we choose is Stephen Curry's shots data in 2021-2022 regular season. First we need to load the data. The data is obtained from `nba.com` using `nba_api`.

```
from nba_api.stats.static import players
from nba_api.stats.endpoints import shotchartdetail
```

```
player_dict = players.get_players()
```

The shots data we need is in `shotchartdetail`. However to use it we need to know the id of Stephen Curry using the dataset `player_dict`.

```
for player in player_dict:
    if player['full_name'] == 'Stephen Curry':
        print(player['id'])
```

201939

So the id of Stephen Curry is 201939. Let's pull out his shots data in 2021-2022 season.

```
results = shotchartdetail.ShotChartDetail(
    team_id = 0,
    player_id = 201939,
    context_measure_simple = 'FGA',
    season_nullable = '2021-22',
    season_type_all_star = 'Regular Season')
df = results.get_data_frames()[0]
df.head()
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	GRID_TYPE	GAME_ID	GAME_EVENT_ID	PLAYER_ID	PLAYER_NAME	TEAM_ID
0	Shot Chart Detail	0022100002	26	201939	Stephen Curry	161061274
1	Shot Chart Detail	0022100002	34	201939	Stephen Curry	161061274
2	Shot Chart Detail	0022100002	37	201939	Stephen Curry	161061274
3	Shot Chart Detail	0022100002	75	201939	Stephen Curry	161061274
4	Shot Chart Detail	0022100002	130	201939	Stephen Curry	161061274

`df` is the results we get in terms of a `DataFrame`, and we show the first 5 records as an example.

These are all attempts. We are interested in all made. By looking at all the columns, we find a column called `SHOT_MADE_FLAG` which shows what we want. Therefore we will use it to filter the records.

```
df_made = df[df['SHOT_MADE_FLAG']==1]
df_made.head()
```



```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	GRID_TYPE	GAME_ID	GAME_EVENT_ID	PLAYER_ID	PLAYER_NAME	TEAM_ID
2	Shot Chart Detail	0022100002	37	201939	Stephen Curry	161061274
6	Shot Chart Detail	0022100002	176	201939	Stephen Curry	161061274
9	Shot Chart Detail	0022100002	352	201939	Stephen Curry	161061274
16	Shot Chart Detail	0022100002	510	201939	Stephen Curry	161061274
18	Shot Chart Detail	0022100002	642	201939	Stephen Curry	161061274

We also notice that there are two columns `LOC_X` and `LOC_Y` shows the coordinates of the attempts. We will use it to draw the heatmap. The full code for drawing out the court `draw_court` is folded below. It is from [Bradley Fay GitHub](#).

i Note

Note that, although `draw_court` is long, it is not hard to understand. It just draws a court piece by piece.

```
from matplotlib.patches import Circle, Rectangle, Arc
import matplotlib.pyplot as plt

def draw_court(ax=None, color='gray', lw=1, outer_lines=False):
    """
    Returns an axes with a basketball court drawn onto to it.

    This function draws a court based on the x and y-axis values that the NBA
    stats API provides for the shot chart data. For example, the NBA stat API
    represents the center of the hoop at the (0,0) coordinate. Twenty-two feet
    from the left of the center of the hoop in is represented by the (-220,0)
    coordinates. So one foot equals +/-10 units on the x and y-axis.
    """
    if ax is None:
        ax = plt.gca()

    # Create the various parts of an NBA basketball court

    # Create the basketball hoop
    hoop = Circle((0, 0), radius=7.5, linewidth=lw, color=color, fill=False)

    # Create backboard
```

```

backboard = Rectangle((-30, -7.5), 60, -1, linewidth=lw, color=color)

# The paint
# Create the outer box Of the paint, width=16ft, height=19ft
outer_box = Rectangle((-80, -47.5), 160, 190, linewidth=lw, color=color,
                      fill=False)
# Create the inner box of the paint, width=12ft, height=19ft
inner_box = Rectangle((-60, -47.5), 120, 190, linewidth=lw, color=color,
                      fill=False)

# Create free throw top arc
top_free_throw = Arc((0, 142.5), 120, 120, theta1=0, theta2=180,
                    linewidth=lw, color=color, fill=False)
# Create free throw bottom arc
bottom_free_throw = Arc((0, 142.5), 120, 120, theta1=180, theta2=0,
                       linewidth=lw, color=color, linestyle='dashed')
# Restricted Zone, it is an arc with 4ft radius from center of the hoop
restricted = Arc((0, 0), 80, 80, theta1=0, theta2=180, linewidth=lw,
                color=color)

# Three point line
# Create the right side 3pt lines, it's 14ft long before it arcs
corner_three_a = Rectangle((-220, -47.5), 0, 140, linewidth=lw,
                          color=color)
# Create the right side 3pt lines, it's 14ft long before it arcs
corner_three_b = Rectangle((220, -47.5), 0, 140, linewidth=lw, color=color)
# 3pt arc - center of arc will be the hoop, arc is 23'9" away from hoop
three_arc = Arc((0, 0), 475, 475, theta1=22, theta2=158, linewidth=lw,
                color=color)

# Center Court
center_outer_arc = Arc((0, 422.5), 120, 120, theta1=180, theta2=0,
                      linewidth=lw, color=color)
center_inner_arc = Arc((0, 422.5), 40, 40, theta1=180, theta2=0,
                      linewidth=lw, color=color)

# List of the court elements to be plotted onto the axes
court_elements = [hoop, backboard, outer_box, inner_box, top_free_throw,
                  bottom_free_throw, restricted, corner_three_a,
                  corner_three_b, three_arc, center_outer_arc,
                  center_inner_arc]

```

```

    if outer_lines:
        # Draw the half court line, baseline and side out bound lines
        outer_lines = Rectangle((-250, -47.5), 500, 470, linewidth=lw,
                                color=color, fill=False)
        court_elements.append(outer_lines)

    # Add the court elements onto the axes
    for element in court_elements:
        ax.add_patch(element)

    return ax

# Create figure and axes
fig = plt.figure(figsize=(6, 6))
ax = fig.add_axes([0, 0, 1, 1])

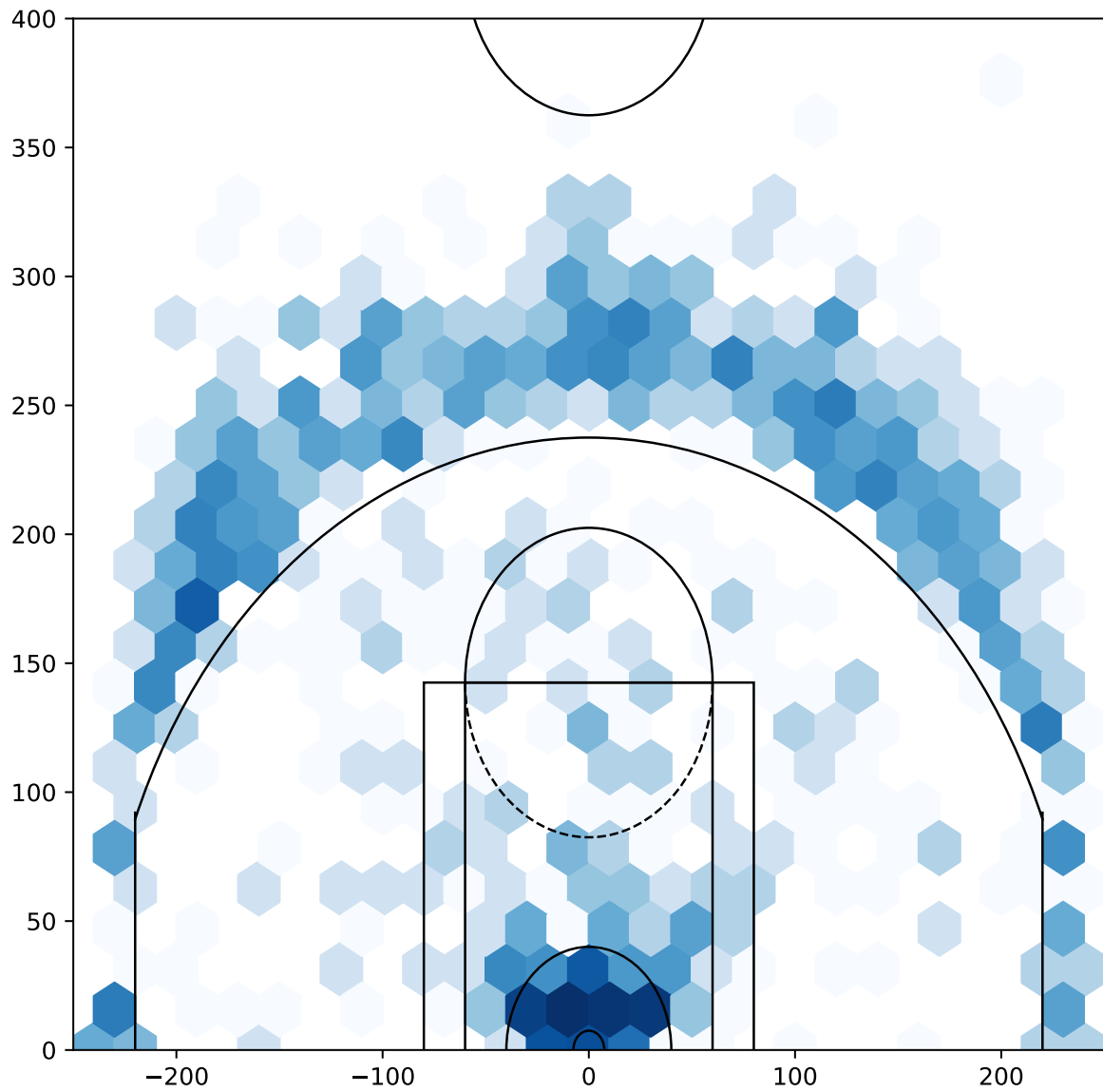
# Plot hexbin of shots
ax.hexbin(df['LOC_X'], df['LOC_Y'], gridsize=(30, 30), extent=(-300, 300, 0, 940), bins='1
ax = draw_court(ax, 'black')

# Annotate player name and season
ax.text(0, 1.05, 'Stephen Curry\n2021-22 Regular Season', transform=ax.transAxes, ha='left

# Set axis limits
_ = ax.set_xlim(-250, 250)
_ = ax.set_ylim(0, 400)

```

Stephen Curry
2021-22 Regular Season



Click for Hint.

```
from nba_api.stats.static import players
from nba_api.stats.endpoints import shotchartdetail
player_dict = players.get_players()
```

These lines import some packages and get player information and save them into `player_dict`.

```
for player in player_dict:
    if player['full_name'] == 'Stephen Curry':
        print(player['id'])
```

Go through all records in `player_dict`. If the name of a player is `Stephen Curry`, get his `id`. Then we will know the `id` of `Stephen Curry`.

To be omitted.

Part III

Python Basics

4 Built-in Types: numeric types and str

This section is based on [1].

There are several built-in data structures in Python. Here is an (incomplete) list:

- `None`
- Boolean — `True`, `False`
- Numeric Types — `int`, `float`, `complex`
- Text Sequence Type — `str`
- Sequence Types — `list`
- Map type — `dict`

We will cover numeric types and strings in this section. The rests are either simple that are self-explained, or not simple that will be discussed later.

4.1 Numeric types and math expressions

Numeric types are represented by numbers. If there are no confusions, Python will automatically detect the type.

```
x = 1 # x is an int.  
y = 2.0 # y is a float.
```

Python can do math just like other programming languages. The basic math operations are listed as follows.

- `+`, `-`, `*`, `/`, `>`, `<`, `>=`, `<=` works as normal.
- `**` is the power operation.
- `%` is the mod operation.
- `!=` is not equal

4.2 str

Scalars are represented by numbers and strings are represented by quotes. Example:

```
x = 1          # x is a scalar.
y = 's'        # y is a string with one letter.
z = '0'        # z looks like a number, but it is a string.
w = "Hello"    # w is a string with double quotes.
```

Here are some facts.

1. For strings, you can use either single quotes ' or double quotes ".
2. \ is used to denote escaped words. You may find the list [Here](#).
3. There are several types of scalars, like `int`, `float`, etc.. Usually Python will automatically determine the type of the data, but sometimes you may still want to declare them manually.
4. You can use `int()`, `str()`, etc. to change types.

Although `str` is a built-in type, there are tons of tricks with `str`, and there are tons of packages related to strings. Generally speaking, to play with strings, we are interested in two types of questions.

- Put information together to form a string.
- Extract information from a string. We briefly talk about these two tasks.

Note

There is a very subtle relation between the variable / constant and the name of the variable / constant. We will talk about these later.

Example 4.1. Here is an example of playing with strings. Please play with these codes and try to understand what they do.

```
import re

def clean_strings(strings):
    result = []
    for value in strings:
        value = value.strip()
        value = re.sub('[!#?]', '', value)
        value = value.title()
        result.append(value)
    return result

states = [' Alabama ', 'Georgia!', 'Georgia', 'georgia', 'Fl0rIda',
```



```
        'south carolina##', 'West virginia?']  
print(clean_strings(states))
```

```
['Alabama', 'Georgia', 'Georgia', 'Georgia', 'Florida', 'South Carolina', 'West Virginia']
```

5 Fundamentals

This section is mainly based on [2].

5.1 Indentation

One key feature about Python is that its structures (blocks) is determined by **Indentation**.

Let's compare with other languages. Let's take C as an example.

```
/*This is a C function.*/  
int f(int x){return x;}
```

The block is defined by {} and lines are separated by ;. **space** and **newline** are not important when C runs the code. It is recommended to write codes in a “beautiful, stylish” format for readability, as follows. However it is not mandatory.

```
/*This is a C function.*/  
int f(int x) {  
    return x;  
}
```

In Python, blocks starts from : and then are determined by indents. Therefore you won't see a lot of {} in Python, and the “beautiful, stylish” format is mandatory.

```
# This is a Python function.  
def f(x):  
    return x
```

The default value for indentation is 4 spaces, which can be changed by users. We will just use the default value in this course.

i Note

It is usually recommended that one line of code should not be very long. If you do have one, and it cannot be shortened, you may break it into multiline codes directly in Python.

However, since indentation is super important in Python, when break one line code into multilines, please make sure that everything is aligned perfectly. Please see the following example.

```
results = shotchartdetail.ShotChartDetail(  
    team_id = 0,  
    player_id = 201939,  
    context_measure_simple = 'FGA',  
    season_nullable = '2021-22',  
    season_type_all_star = 'Regular Season')
```

5.2 Binary operators and comparisons

Most binary operators behaves as you expected. Here I just want to mention `==` and `is`.

- `==` is testing whehter these two objects have the same value.
- `is` is testing whether these two objects are exactly the same.

Note

You may use `id(x)` to check the id of the object `x`. Two objects are identical if they have the same id.

5.3 import

In Python a module is simply a file with the `.py` extension containing Python code. Assume that we have a Python file `example.py` stored in the folder `asests/codes/`. The file is as follows.

```
# from asests/codes/example.py  
  
def f(x):  
    print(x)  
  
A = 'You get me!'
```

You may get access to this function and this string in the following way.

```
from assests.codes import example

example.f(example.A)
```

You get me!

5.4 Comments

Any text preceded by the hash mark (pound sign) `#` is ignored by the Python interpreter. In many IDEs you may use hotkeys to directly toggle multilines as comments. For example, in VS Code the default setting for toggling comments is `ctrl+/*`.

5.5 Dynamic references, strong types

In some programming languages, you have to declare the variable's name and what type of data it will hold. If a variable is declared to be a number, it can never hold a different type of value, like a string. This is called *static typing* because the type of the variable can never change.

Python is a *dynamically typed* language, which means you do not have to declare a variable or what kind of data the variable will hold. You can change the value and type of data at any time. This could be either great or terrible news.

On the other side, “dynamic typed” doesn't mean that types are not important in Python. You still have to make sure that the types of all variables meet the requirements of the operations used.

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

`TypeError: unsupported operand type(s) for +: 'int' and 'str'`

In this example, `b` was first assigned by a number, and then it was reassigned by a `str`. This is totally fine since Python is dynamically types. However later when adding `a` and `b`, the type error occurs since you cannot add a number and a `str`.

i Note

You may always use `type(x)` to detect the type of the object `x`.

5.6 Everything is an object

Every number, string, data structure, function, class, module, and so on exists in the Python interpreter in its own “box”, which is referred to as a *Python object*.

Each object has an associated type (e.g., string or function) and internal data. In practice this makes the language very flexible, as even functions can be treated like any other object.

Each object might have attributes and/or methods attached.

5.7 Mutable and immutable objects

An object whose internal state can be changed is *mutable*. On the other hand, *immutable* doesn't allow any change in the object once it has been created.

Some objects of built-in type that are mutable are:

- Lists
- Dictionaries
- Sets

Some objects of built-in type that are immutable are:

- Numbers (Integer, Rational, Float, Decimal, Complex & Booleans)
- Strings
- Tuples

Example 5.1 (Tuples are not really “immutable”). You can treat a tuple as a container, which contains some objects. The relations between the container and its contents are immutable, but the objects it holds might be mutable. Please check the following example.

```
container = ([1], [2])
print('This is `container`: ', container)
print('This is the id of `container`: ', id(container))
print('This is the id of the first list of `container`: ', id(container[0]))
```

```
container[0].append(2)
print('This is the new `container`: ', container)
print('This is the id of the new `container`: ', id(container))
print('This is the id of the first list (which is updated) of the new `container`: ', id(c
```

This is `container`: ([1], [2])

This is the id of `container`: 2320714296640

This is the id of the first list of `container`: 2320714258176

This is the new `container`: ([1, 2], [2])

This is the id of the new `container`: 2320714296640

This is the id of the first list (which is updated) of the new `container`: 2320714258176

You can see that the tuple `container` and its first object stay the same, although we add one element to the first object.

6 Flows and Logic

6.1 for loop

- `range(10)`
- `list`

6.2 if conditional control

7 list

Note

In Python, a list is an ordered sequence of object types and a string is an ordered sequence of characters.

- Access to the data
- Slicing
- Methods
 - `append` and `+`
 - `extend`
 - `pop`
 - `remove`
- `in`
- `for`
- `list()`
- `sorted`
- `str.split`
- `str.join`

7.1 List Comprehension

List Comprehension is a convenient way to create lists based on the values of an existing list. It cannot provide any real improvement to the performance of the codes, but it can make the codes shorter and easier to read.

The format of list Comprehension is

```
newlist = [expression for item in iterable if condition == True]
```


8 dict

- Access to the data
- Methods
 - directly add items
 - `update`
 - `get`
 - `keys`
 - `values`
 - `items`
- `dict()`
- dictionary comprehension

9 Exercises

Most problems are based on [3], [1] and [4].

Exercise 9.1 (Indentation). Please tell the differences between the following codes. If you don't understand `for` don't worry about it. Just focus on the indentation and try to understand how the codes work.

```
for i in range(5):  
    print('Hello world!')  
print('Hello world!')
```

```
for i in range(5):  
    print('Hello world!')  
    print('Hello world!')
```

```
for i in range(5):  
print('Hello world!')  
print('Hello world!')
```

```
for i in range(5):  
    pass  
print('Hello world!')  
print('Hello world!')
```

Exercise 9.2 (Play with built-in data types). Please first guess the results of all expressions below, and then run them to check your answers.

```
print(True and True)  
print(True or True)  
print(False and True)
```

```
print((1+1>2) or (1-1<1))
```

Exercise 9.3 (`==` vs `is`). Please explain what happens below.

```
a = 1
b = 1.0
print(type(a))
print(type(b))

print(a == b)
print(a is b)
```

```
<class 'int'>
<class 'float'>
True
False
```

Exercise 9.4 (Play with strings). Please execute the code below line by line and explain what happens in text cells.

```
# 1
answer = 10
wronganswer = 11
text1 = "The answer to this question is {}. If you got {}, you are wrong.".format(answer,
print(text1)

# 2
var = True
text2 = "This is {}".format(var)
print(text2)

# 3
word1 = 'Good '
word2 = 'buy. '
text3 = (word1 + word2) * 3
print(text3)
```

```
# 4
sentence = "This is\ngood enough\nfor a exercise to\nhave so many parts. " \
           "We would also want to try this symbol: '. ' '\n" \
           "Do you know how to type \" in double quotes?"
print(sentence)
```

The answer to this question is 10. If you got 11, you are wrong.

This is True.

Good buy. Good buy. Good buy.

This is

good enough

for a exercise to

have so many parts. We would also want to try this symbol: '. Do you know how to type " in d

Exercise 9.5 (split and join). Please excute the code below line by line and explain what happens in text cells.

```
sentence = 'This is an example of a sentence that I expect you to split.'

wordlist = sentence.split(' ')

newsentence = '\n'.join(wordlist)
print(newsentence)
```

Exercise 9.6 (List reference). Please finish the following tasks.

1. Given the list **a**, make a new reference **b** to **a**. Update the first entry in **b** to be 0. What happened to the first entry in **a**? Explain your answer in a text block.
2. Given the list **a**, make a new copy **b** of the list **a** using the function **list**. Update the first entry in **b** to be 0. What happened to the first entry in **a**? Explain your answer in a text block.

Exercise 9.7 (List comprehension). Given a list of numbers, use list comprehension to remove all odd numbers from the list:

```
numbers = [3,5,45,97,32,22,10,19,39,43]
```

Exercise 9.8 (More list comprehension). Use list comprehension to find all of the numbers from 1-1000 that are divisible by 7.

Exercise 9.9 (More list comprehension). Count the number of spaces in a string.

Exercise 9.10 (More list comprehension). Use list comprehension to get the index and the value as a tuple for items in the list ['hi', 4, 8.99, 'apple', ('t,b', 'n')]. Result would look like [(index, value), (index, value), ...].

Exercise 9.11 (More list comprehension). Use list comprehension to find the common numbers in two lists (without using a tuple or set) `list_a = [1, 2, 3, 4]`, `list_b = [2, 3, 4, 5]`.

Exercise 9.12 (Probability). Compute the probability that two people out of 23 share the same birthday. The math formula for this is

$$1 - \frac{365!/(365-23)!}{365^{23}} = 1 - \frac{365}{365} \cdot \frac{365-1}{365} \cdot \frac{365-2}{365} \cdot \dots \cdot \frac{365-22}{365}.$$

1. To directly use the formula we have to use a high performance math package, e.g. `math`. Please use `math.factorial` to compute the above formula.
2. Please use the right hand side of the above formula to compute the probability using the following steps.
 - a. Please use the list comprehension to create a list $[\frac{365}{365}, \frac{365-1}{365}, \frac{365-2}{365}, \dots, \frac{365-22}{365}]$.
 - b. Use `numpy.prod` to compute the product of elements of the above list.
 - c. Compute the probability by finishing the formula.
3. Please use `time` to test which method mentioned above is faster.

10 Projects

Most projects are based on [2], [5].

Exercise 10.1 (Determine the indefinite article). Please finish the following tasks.

1. Please construct a list `aeiou` that contains all vowels.
2. Given a word `word`, we would like to find the indefinite article `article` before `word`. (Hint: the article should be `an` if the first character of `word` is a vowel, and `a` if not.)

Click for Hint.

Solution. Consider `in`, `.lower()` and `if` structure.

Exercise 10.2 (Datetime and files names). We would like to write a program to quickly generate `N` files. Every time we run the code, `N` files will be generated. We hope to store all files generated and organize them in a neat way. To achieve this, one way is to create a subfolder for each run and store all files generated during that run in the particular subfolder. Since we would like to make it fast, the real point of this task is to find a way to automatically generate the file names for the files generated and the folder names for the subfolders generated. You don't need to worry about the contents of the files and empty files are totally fine for this problem.

Click for Hint.

Solution. One way to automatically generate file names and folder names is to use the date and the time when the code is run. Please check `datetime` package for getting and formatting date/time, and `os` packages for playing with files and folders.

Exercise 10.3 (Color the Gnomonic data). We can use ASCII color codes in the string to change the color of strings, as an example `\033[91m` for red and `\033[94m` for blue. See the following example.

```
print('\033[91m'+ 'red' + '\033[92m'+ 'green' + '\033[94m'+ 'blue' + '\033[93m'+ 'yellow')
```

Consider an (incomplete) Gnomonic data given below which is represented by a long sequence of A, C, T and G. Please color it using ASCII color codes.

```
Gnomicdata = 'TCGATCTCTTGTAGATCTGTTCTCTAAACGAACTTTAAAATCTGTGTGGCTGTCACTCGG'\
              'CTGCATGCTTAGTGCACTCACGCAGTATAATTAATACTAATTACTGTCGTTGACAGGAC'\
              'ACGAGTAACTCGTCTATCTTCTGCAGGCTGCTTACGGTTTCGTCCGTGTTGCAGCCGATC'\
              'ATCAGCACATCTAGGTTTTGTCCGGGTGTGACCGAAAGGTAAGATGGAGAGCCTTGTCCC'\
              'TGTTTTCAACGAGAAAAACACACGTCCAACCTCAGTTTGCCTGTTTTACAGGTTTCGCGACGT'\
              'GCTCGTACGTGGCTTTGGAGACTCCGTGGAGGAGGTCTTATCAGAGGCACGTCAACATCT'\
              'TAAAGATGGCACTTGTGGCTTAGTAGAAGTTGAAAAAGGCGTTTTGCCTCAACTTGAACA'\
              'GCCCTATGTGTTTCATCAAACGTTCCGATGCTCGAACTGCACCTCATGGTCATGTTATGGT'\
              'TGAGCTGGTAGCAGAACTCGAAGGCATTAGTACGGTCGTAGTGGTGAGACACTTGGTGT'\
              'CCTTGTCCTCATGTGGGCGAAATACCAAGTGGCTTACCGCAAGGTTCTTCTTCGTAAGAA'\
              'CGGTAATAAAGGAGCTGGTGGCCATAGTTACGGCGCCGATCTAAAGTCATTTGACTTAGG'\
              'CGACGAGCTTGGCACTGATCCTTATGAAGATTTTCAAGAAAACCTGGAACACTAAACATAG'
```

Click for Hint.

Solution (Hint). You may use `if` to do the conversion. Or you may use `dict` to do the conversion.

Exercise 10.4 (sorted). Please read through the [Key funtions](#) in this article, and sort the following two lists.

1. Sort `list1 = [[11,2,3], [2, 3, 1], [5,-1, 2], [2, 3,-8]]` according to the sum of each list.
2. Sort `list2 = [{'a': 1, 'b': 2}, {'a': 3, 'b': 4},{'a': 5, 'b': 2}]` according to the `b` value of each dictionary.

Exercise 10.5 (Fantasy Game Inventory). You are creating a fantasy video game. The data structure to model the player's inventory will be a dictionary where the keys are string values describing the item in the inventory and the value is an integer value detailing how many of that item the player has. For example, the dictionary value `{'rope': 1, 'torch': 6, 'gold coin': 42, 'dagger': 1, 'arrow': 12}` means the player has 1 rope, 6 torches, 42 gold coins, and so on.

Write a program to take any possible `inventory` and display it like the following:

Inventory:

12 arrow

42 gold coin

1 rope

6 torch

1 dagger

Total number of items: 62

Part IV

Package: numpy

The main reference for this chapter is [2].

11 Basics

The basic data structure for **numpy** is **numpy.ndarray**. You may treat it as a generalized version of lists. However it can do so much more than the build-in **list**.

To use **numpy**, we just import it. In most cases you would like to use the alias **np**.

```
import numpy as np
```

Note

In many cases, **numpy.ndarray** is a huge object since it stores tons of data. Therefore many of the operations related to **numpy.ndarray** are “in-place” by default. This means that if you don’t explicitly ask for a copy, there will be only one copy of the array and all later operations make changes to the original one.

However there are many cases that

12 Create np.ndarray

- convert a list into a numpy array.
- `np.zeros`, `np.zeros_like`
- `np.ones`, `np.ones_like`
- `np.eye`
- `np.random.rand`
- `np.arange`
- `np.linspace`

Note

Please be very careful about the format of the input. For example, when you want to specify the dimension of the array, using `np.zeros`, you need to input a **tuple**. On the other hand, when using `np.random.rand`, you just directly input the dimensions one by one.

```
import numpy as np

np.zeros((3, 2))
np.random.rand(3, 2)
```

In this case, the official documents are always your friend.

13 Mathematical and Statistical Methods

- `+`, `-`, `*`, `/`, `**`, etc..
- `np.sin`, `np.exp`, `np.sqrt`, etc..
- `mean`, `sum`, `std`, `var`, `cumsum`
- `max` and `min`
- `maximum` and `minimum`
- `argmin` and `argmax`
- `np.sort`
- `np.unique`, `np.any`
- `np.dot`: Matrix multiplication
- `np.concatenate`
- Broadcast

Example 13.1 (Axis). Given `A = np.array([[1,2],[3,4]])` and `B = np.array([[5,6],[7,8]])`, please use `np.concatenate` to concatenate these two matrices to get a new matrix, in the order:

- A left, B right
- A right, B left
- A up, B down
- A down, B up

14 Common attributes and methods

- `shape`
- `dtype`
- `ndim`
- Any arithmetic operations between equal-size arrays applies the operation element-wise.

Example 14.1. MNIST is a very famous dataset of hand written images. Here is how to load it. Note that in this instance of the dataset the data are stored as **numpy** arrays.

```
import tensorflow as tf

(X_train, y_train), (X_test, y_test) = tf.keras.datasets.mnist.load_data()
X_train.shape
```

15 Basic indexing and slicing

First see the following example.

```
Example 15.1 as np
arr = np.arange(10)

print(arr[5])
print(arr[5:8])

arr[5:8] = 12
print(arr)

print(arr[5:8:2])
print(arr[8:5:-1])
print(arr[::-1])
```

```
5
[5 6 7]
[ 0  1  2  3  4 12 12 12  8  9]
[12 12]
[ 8 12 12]
[ 9  8 12 12 12  4  3  2  1  0]
```

To do slicing in higher dimensional case, you may either treat a **numpy** array as a nested list, or you may directly work with it with multiindexes.

```
Example 15.2 as np
arr3d = np.arange(12).reshape(2, 2, 3)

print('case 1:\n {}'.format(arr3d))
```

```
print('case 2:\n {}'.format(arr3d[0, 1, 2]))
print('case 3:\n {}'.format(arr3d[:, 0: 2, 1]))
print('case 4:\n {}'.format(arr3d[:, 0: 2, 1:2]))
```

```
case 1:
[[[ 0  1  2]
  [ 3  4  5]]

 [[ 6  7  8]
  [ 9 10 11]]]
case 2:
5
case 3:
[[ 1  4]
 [ 7 10]]
case 4:
[[[ 1]
  [ 4]]

 [[ 7]
  [10]]]
```


16 Boolean Indexing

numpy array can accept index in terms of numpy arrays with boolean indexing.

```
Example 16.1
import numpy as np
a = np.arange(4)
b = np.array([True, True, False, True])
print(a)
print(b)
print(a[b])
```

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

We could combine this way with the logic computation to filter out the elements we don't want.

Example 16.2. Please replace the odd number in the array by its negative.

```
import numpy as np
arr = np.arange(10)
odd = arr % 2 == 1
arr[odd] = arr[odd] * (-1)

print(arr)
```

```
[ 0 -1  2 -3  4 -5  6 -7  8 -9]
```

17 Fancy indexing

Fancy indexing is a term adopted by NumPy to describe indexing using integer arrays.

Example 17.1 as np

```
arr = np.zeros((8, 4))
for i in range(8):
    arr[i] = i

arr[[4, 3, 0, 6]]
```

```
array([[4., 4., 4., 4.],
       [3., 3., 3., 3.],
       [0., 0., 0., 0.],
       [6., 6., 6., 6.]])
```

Example 17.2 as np

```
arr = np.arange(32).reshape((8, 4))
print(arr)
print(arr[[1, 5, 7, 2], [0, 3, 1, 2]])
print(arr[[1, 5, 7, 2]][:, [0, 3, 1, 2]])
```

```
[[ 0  1  2  3]
 [ 4  5  6  7]
 [ 8  9 10 11]
 [12 13 14 15]
 [16 17 18 19]
 [20 21 22 23]]
```

```
[24 25 26 27]
[28 29 30 31]]
[ 4 23 29 10]
[[ 4  7  5  6]
 [20 23 21 22]
 [28 31 29 30]
 [ 8 11  9 10]]
```

18 Copies and views

The view of an numpy array is a way to get access to the array without copying internal data. When operating with a view, the original data as well as all other views of the original data will be modified simultaneously.

The default setting for copies and views is that, basic indexing and slicing will make views, and advanced indexing and slicing (e.g. boolean indexing, fancy indexing, etc.) will make copies. For other operations, you need to check the documents to know how they work. For example, `np.reshape` creates a view where possible, and `np.flatten` always creates a copy.

You may use `np.view()` or `np.copy()` to make views or copies explicitly. ::: {#exm-}

```
import numpy as np
arr = np.arange(10)
b = arr[5:8]
print('arr is {}'.format(arr))
print('b is {}'.format(b))

b[0] = -1
print('arr is {}'.format(arr))
print('b is {}'.format(b))

arr[6] = -2
print('arr is {}'.format(arr))
print('b is {}'.format(b))

print('The base of b is {}'.format(b.base))
```

```
arr is [0 1 2 3 4 5 6 7 8 9]
b is [5 6 7]
arr is [ 0  1  2  3  4 -1  6  7  8  9]
b is [-1  6  7]
arr is [ 0  1  2  3  4 -1 -2  7  8  9]
b is [-1 -2  7]
The base of b is [ 0  1  2  3  4 -1 -2  7  8  9]
```

:::

The way to make explicit copy is `.copy()`.

```
Example 18.1
import numpy as np
arr = np.arange(10)
b = arr[5:8].copy()
print('arr is {}'.format(arr))
print('b is {}'.format(b))

b[0] = -1
print('arr is {}'.format(arr))
print('b is {}'.format(b))

arr[6] = -2
print('arr is {}'.format(arr))
print('b is {}'.format(b))

print('The base of b is {}'.format(b.base))
```

```
arr is [0 1 2 3 4 5 6 7 8 9]
b is [5 6 7]
arr is [0 1 2 3 4 5 6 7 8 9]
b is [-1  6  7]
arr is [ 0  1  2  3  4  5 -2  7  8  9]
b is [-1  6  7]
The base of b is None
```

19 More commands

- `.T`
- `axis=n` is very important.
- `np.reshape()`
- `np.tile()`
- `np.repeat()`

20 More advanced commands

- `np.where()`
- `np.any()`
- `np.all()`
- `np.argsort()`

Example 20.1. Get the position where elements of `a` and `b` match.

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

np.where(a == b)
```

```
(array([1, 3, 5, 7], dtype=int64),)
```

```
Example 20.2. a = np.array([1,2,3,2,3,4,3,4,5,6])
b = np.array([7,2,10,2,7,4,9,4,9,8])

np.where(a == b, a*2, b+1)
```

```
array([ 8,  4, 11,  4,  8,  8, 10,  8, 10,  9])
```

```
Example 20.3 (Playing with axis).
a = np.array([[1,2],[3,4]],[[5,6],[7,8]])

np.any(a==1, axis=0)
```

```
np.any(a==1, axis=1)
np.any(a==1, axis=2)
```

```
np.any(a==2, axis=0)
np.any(a==2, axis=1)
np.any(a==2, axis=2)
```

```
np.any(a==5, axis=0)
np.any(a==5, axis=1)
np.any(a==5, axis=2)
```

```
array([[False, False],
       [ True, False]])
```


21 Examples

Example 21.1 (Random walks). Adam walks randomly along the axis. He starts from 0. Every step he has equal possibility to go left or right. Please simulate this process.

Use `choices` to record the choice of Adam at each step. We may generate a random array where 0 represents left and 1 represents right.

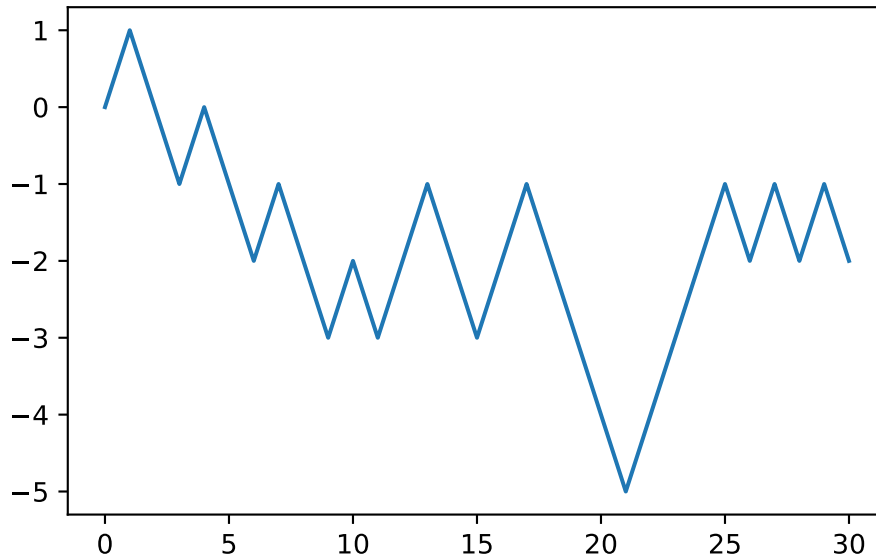
Use `positions` to record the position of Adam at each step. Using `choices`, the position is +1 if we see a 1 and the position is -1 if we see a 0. So the most elegant way to perform this is to

1. Convert `choices` from `{0, 1}` to `{-1, 1}`.
2. To record the starting position, we attach 0 to the beginning of the new `choices`.
3. Apply `cumsum` to `choices` to get `positions`.

```
import numpy as np

step = 30
choices = np.random.randint(2, size=step)
choices = choices * 2 - 1
choices = np.concatenate(([0], choices))
positions = choices.cumsum()

import matplotlib.pyplot as plt
plt.plot(positions)
```



Example 21.2 (Many random walks). We mainly use `numpy.ndarray` to write the code in the previous example. The best part here is that it can be easily generalized to many random walks.

Still keep `choices` and `positions` in mind. Now we would like to deal with multiple people simultaneously. Each row represents one person's random walk. All the formulas stay the same. We only need to update the dimension setting in the previous code.

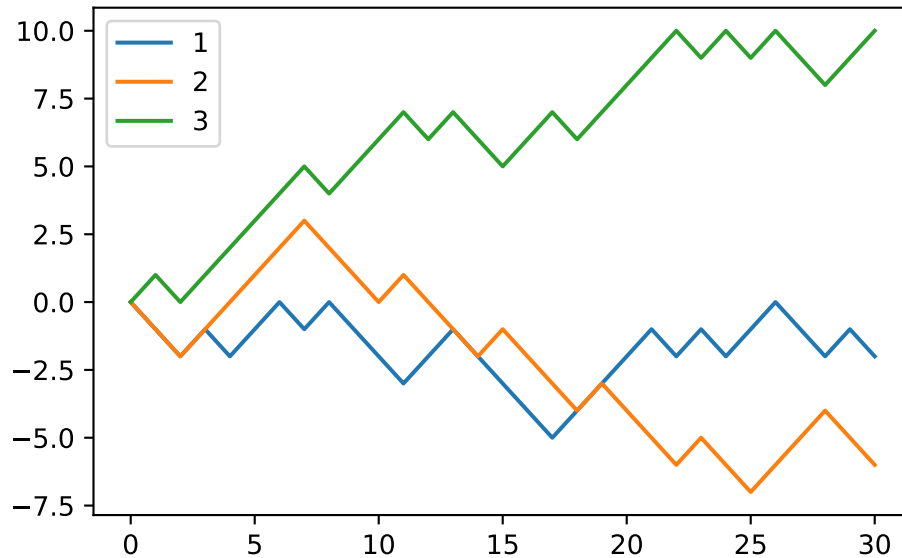
- Update `size` in `np.random.randint`.
- Update `[0]` to `np.zeros((N, 1))` in `concatenate`.
- For `cumsum` and `concatenate`, add `axis=1` to indicate that we perform the operations along `axis 1`.
- We plot each row in the same figure. `plt.legend` is used to show the label for each line.

```
import numpy as np

step = 30
N = 3
choices = np.random.randint(2, size=(N, step))
choices = choices * 2 - 1
choices = np.concatenate((np.zeros((N, 1)), choices), axis=1)
positions = choices.cumsum(axis=1)
```

```
import matplotlib.pyplot as plt
for row in positions:
    plt.plot(row)
plt.legend([1, 2, 3])
```

<matplotlib.legend.Legend at 0x19ab2ec1310>



Example 21.3 (Analyze positions). We play with the numpy array `positions` to get some information about the random walks of three generated in the previous example.

- The maximal position:

```
positions.max()
```

10.0

- The maximal position for each one:

```
positions.max(axis=1)
```

```
array([ 0.,  3., 10.])
```

- The maximal position across all three for each step:

```
positions.max(axis=0)
```

```
array([ 0.,  1.,  0.,  1.,  2.,  3.,  4.,  5.,  4.,  5.,  6.,  7.,  6.,  
        7.,  6.,  5.,  6.,  7.,  6.,  7.,  8.,  9., 10.,  9., 10.,  9.,  
        10.,  9.,  8.,  9., 10.])
```

- Check whether anyone once got to the position 3:

```
(positions>=3).any(axis=1)
```

```
array([False,  True,  True])
```

- The number of people who once got to the position 3:

```
(positions>=3).any(axis=1).sum()
```

```
2
```

- Which step for each one gets to the right most position:

```
positions.argmax(axis=1)
```

```
array([ 0,  7, 22], dtype=int64)
```

22 Exercises

Many exercises are from [6].

Exercise 22.1 (array). Write a NumPy program to create a 3×3 matrix with values ranging from 2 to 10.

Exercise 22.2 (array). Write a NumPy program to create a null vector of size 10 and update sixth value to 11.

Exercise 22.3 (array). Write a NumPy program to reverse an array (first element becomes last).

Exercise 22.4 (array). Write a NumPy program to create a 10×10 2D-array with 1 on the border and 0 inside.

Exercise 22.5 (repeat and tile). Given `a = np.array([1,2,3])`, please get the desired output `array([1, 1, 1, 2, 2, 2, 3, 3, 3, 1, 2, 3, 1, 2, 3, 1, 2, 3])`.

Exercise 22.6 (Compare two numpy arraies). Consider two `numpy` arraies `x` and `y`. Compare them entry by entry. We would like to know how many are the same.

Click to expand.

Solution. Note that `bool` values `True` and `False` can be treated as numbers 1 and 0.

```
import numpy as np

x = np.array([1, 2, 3, 4, 5])
y = np.array([2, 1, 4, 4, 5])

numofsame = np.sum(x == y)
print(numofsame)
```

2

Exercise 22.7. Get all items between 5 and 10 from an array `a = np.array([2, 6, 1, 9, 10, 3, 27])`.

Exercise 22.8. Swap rows 1 and 2 in the array `arr = np.arange(9).reshape(3,3)`.

Exercise 22.9. Please finish the following tasks.

1. Reverse the rows of a 2D array `arr = np.arange(9).reshape(3,3)`.
2. Reverse the columns of a 2D array `arr = np.arange(9).reshape(3,3)`.

Exercise 22.10. Create a 2D array of shape 5x3 to contain random decimal numbers between 5 and 10.

Exercise 22.11. Use the following code to get the dataset `iris`.

```
import numpy as np

url = 'https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data'
iris_1d = np.genfromtxt(url, delimiter=',', dtype=None, encoding=None)
```

1. `iris_1d` is a 1D numpy array that each item is a tuple. Please construct a new 1D numpy array that each item is the last component of each tuple in `iris_1d`.
2. Convert `iris_1d` into a 2D array `iris_2d` by omitting the last field of each item.

Exercise 22.12 (Normalization). Use the following code to get an 1D array `sepalength`.

```
import numpy as np

url = 'https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data'
sepalength = np.genfromtxt(url, delimiter=',', dtype='float', usecols=[0],
                           encoding=None)
```

Please normalize it such that the values of each item is between 0 and 1.

Exercise 22.13. `np.isnan()` is a function to check whether each entry of a numpy array is `nan` or not. Please use this as well as `np.where` to find all `nan` entries in an array.

You may use the following array `iris_2d` to test your code.

```
import numpy as np
url = 'https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data'
iris_2d = np.genfromtxt(url, delimiter=',', dtype='float', encoding=None)
iris_2d[np.random.randint(150, size=20), np.random.randint(4, size=20)] = np.nan
```

Exercise 22.14. Select the rows of `iris_2d` that does not have any `nan` value.

```
import numpy as np
url = 'https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data'
iris_2d = np.genfromtxt(url, delimiter=',', dtype='float', usecols=[0,1,2,3],
                        encoding=None)
iris_2d[np.random.randint(150, size=20), np.random.randint(4, size=20)] = np.nan
```

Exercise 22.15. Replace all `nan` with 0 in numpy array `iris_2d`.

```
import numpy as np
url = 'https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data'
iris_2d = np.genfromtxt(url, delimiter=',', dtype='float', usecols=[0,1,2,3],
                        encoding=None)
iris_2d[np.random.randint(150, size=20), np.random.randint(4, size=20)] = np.nan
```

Exercise 22.16. Consider `x = np.array([1, 2, 1, 1, 3, 4, 3, 1, 1, 2, 1, 1, 2])`. Please find the index of 5th repetition of number 1 in `x`.

23 Projects

Exercise 23.1 (Adding one axis). Please download [this file](#).

1. Please use `matplotlib.pyplot.imread()` to read the file as a 3D numpy array.
2. Check the shape of the array.
3. Add one additional axis to it as axis 0 to make it into a 4D array.

Exercise 23.2 (Random). Please finish the following tasks.

1. Use the package `np.random` to flip a coin 100 times and record the result in a list `coin`.
2. Assume that the coin is not fair, and the probability to get H is `p`. Write a code to flip the coin 100 times and record the result in a list `coin`, with a given parameter `p`. You may use `p=.4` as the first choice.
3. For each list `coin` created above, write a code to find the longest H streak. We only need the biggest number of consecutive H we get during this 100 tosses. It is NOT necessary to know when we start the streak.

Click for Hint.

Solution. The following ideas can be used to solve the problem.

- `np.where`
- string, `split` and `join`

Exercise 23.3 (Bins). Please read the [document of `np.digitize`](#), and use it to do the following task.

Set the following bins:

- Less than 3: `small`
- 3-5: `medium`

- Bigger than 5: `large`

Please transform the following data `iris_2c` into texts using the given bins.

```
import numpy as np
url = 'https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data'
iris_2c = np.genfromtxt(url, delimiter=',', dtype='object')[:, 2].astype('float')
```

Exercise 23.4. Consider a 2D numpy array `a`.

```
import numpy as np
a = np.random.rand(5, 5)
```

1. Please sort it along the 3rd column.
2. Please sort it along the 2nd row.

Click for Hint.

Solution. Please use `np.argsort` for the problem.

Exercise 23.5 (One-hot vector). Compute the one-hot encodings of a given array. You may use the following array as a test example. In this example, there are 3 labels. So the one-hot vectors are 3 dimensional vectors.

For more information about one-hot encodings, you may check the [Wiki page](#). You are not allowed to use packages that can directly compute the one-hot encodings for this problem.

```
import numpy as np
arr = np.random.randint(1,4, size=6)
```

Exercise 23.6. From the given 1d array `arr = np.arange(15)`, generate a 2d matrix using strides, with a window length of 4 and strides of 2, like `[[0,1,2,3], [2,3,4,5], [4,5,6,7]...]`.

Part V

Package: pandas

The basic data structure for `pandas` is `pandas.DataFrame`. You may treat it as a generalized version of tables.

To use `pandas`, we just import it. In most cases you would like to use the alias `pd`.

```
import pandas as pd
```

Since `DataFrame` is more like a table, the biggest questions here is not to do computations (which is still very important), but to retrieve, search, sort, merge, etc.. those data.

24 Basic pandas

24.1 Series and DataFrame

A *Series* is a 1-d array-like object which has index. The default index is starting from 0. You may change the index to be something assigned by you. Thus it can be treated as a generalization of a dict.

```
obj = pd.Series([3, 1, 2, 4])
print(obj)
```

```
0    3
1    1
2    2
3    4
dtype: int64
```

```
obj2 = pd.Series([3, 1, 2, 4], index=['a', 'b', 'c', 'd'])
print(obj2)
```

```
a    3
b    1
c    2
d    4
dtype: int64
```

```
data3 = {'a': 3, 'b': 1, 'c': 2, 'd': 4}
obj3 = pd.Series(data3)
print(obj3)
```

```
a    3
b    1
```

```
c    2
d    4
dtype: int64
```

A *DataFrame* represents a rectangular table of data and contains an ordered collection of columns, each of which can be a different value type. The *DataFrame* has both a row and column index; it can be thought of as a dict of *Series* all sharing the same index. When displaying a *DataFrame*, we may use `.head()` to just display the first few rows for efficiency.

```
import pandas as pd

data = {'a': [1, 2, 3, 4, 5, 6, 7],
        'b': [1.1, 2.1, 3.1, 4.1, 5.1, 6.1, 7.1],
        'c': ['a', 'b', 'c', 'd', 'e', 'f', 'g']}
df = pd.DataFrame(data)
df.head()
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()
```

	a	b	c
0	1	1.1	a
1	2	2.1	b
2	3	3.1	c
3	4	4.1	d
4	5	5.1	e

i Note

We may use the setting `columns=` or `index=` as well as the methods `.rename(columns=, index=)` to change the column names and the index names. See the following example.

```
import numpy as np
import pandas as pd
data = pd.DataFrame(np.arange(16).reshape((4, 4)),
                    index=['Ohio', 'Colorado', 'Utah', 'New York'],
                    columns=['one', 'two', 'three', 'four'])
```

24.2 Accessing data

- A column in a DataFrame can be retrieved as a Series either by dict-like notation or by attribute. What one gets from this is a Series object.
 - dict-like notation: `df['a']`
 - by attribute: `df.a`. Note that if the name of the column is not suitable for attribute names, this method doesn't work.
- Rows are retrieved by `.loc` if using the row index, and by `.iloc` if using the row number.

24.3 Updating data

- Assign values to a column of a DataFrame will update that column. If the column doesn't exist, new column will be created.
- When assign values with non-existent row index, that part of the data will be discarded.
- Any time if there are no values with a specific column and row, it will show as `NaN`.

Example 24.1. as pd

```
data = {'a': [1, 2, 3, 4],
        'b': [1.1, 2.1, 3.1, 4.1],
        'c': ['a', 'b', 'c', 'd']}
df = pd.DataFrame(data)

newcol = {1: 'good', 3: 'better', 5: 'best'}
df['d'] = pd.Series(newcol)
df
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	a	b	c	d
0	1	1.1	a	NaN
1	2	2.1	b	good
2	3	3.1	c	NaN
3	4	4.1	d	better

24.4 Indexing, Selection, and Filtering

- Series indexing (`obj[...]`) works analogously to NumPy array indexing, except you can use the Series's index values instead of only integers.
- We can use logical expression to filter DataFrame.

```
import pandas as pd

data = pd.DataFrame(np.arange(16).reshape((4, 4)),
                    index=['Ohio', 'Colorado', 'Utah', 'New York'],
                    columns=['one', 'two', 'three', 'four'])
data[data['one']>5]
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning: return method()

	one	two	three	four
Utah	8	9	10	11
New York	12	13	14	15

- `.loc`, `.iloc`

```
import pandas as pd
data = pd.DataFrame(np.arange(16).reshape((4, 4)),
                    index=['Ohio', 'Colorado', 'Utah', 'New York'],
                    columns=['one', 'two', 'three', 'four'])
print(data.loc['Colorado', ['two', 'three']])
print(data.iloc[2, [3, 0, 1]])
```

```
two      5
three    6
Name: Colorado, dtype: int32
four     11
one      8
two      9
Name: Utah, dtype: int32
```

- Slicing with labels behaves differently than normal Python slicing in that the endpoint is inclusive.


```
import pandas as pd

obj = pd.Series(np.arange(4.), index=['a', 'b', 'c', 'd'])
obj['b':'c']
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	0
b	1.0
c	2.0

- Reindex `.reindex()`:

```
import pandas as pd
data = pd.DataFrame(np.arange(16).reshape((4, 4)),
                    index=['Ohio', 'Colorado', 'Utah', 'New York'],
                    columns=['one', 'two', 'three', 'four'])

data.reindex(index = ['Colorado', 'Arkansas', 'New York'],
             columns = ['three', 'five', 'one'])
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	three	five	one
Colorado	6.0	NaN	4.0
Arkansas	NaN	NaN	NaN
New York	14.0	NaN	12.0

i Note

`.loc` and `.reindex` are very similar to each other. The main difference between these two is that `.loc` will return a view and `.reindex` will return a copy in most cases.

i Note

When locate data using indexes, duplicate labels will return all results.

24.5 Essential functions

- Arithmetic and Data Alignment Elements of the same index and columns will be computed. By default, if any entry is `nan`, the answer will be `nan`. You may use `fill_value` argument to fill the empty slots.

```
Example 24.2. as pd  
import numpy as np  
df1 = pd.DataFrame(np.arange(12.).reshape((3, 4)), columns=list('abcd'))  
df2 = pd.DataFrame(np.arange(20.).reshape((4, 5)), columns=list('abcde'))  
df2.loc[1, 'b'] = np.nan  
  
df1.add(df2, fill_value=0)
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	a	b	c	d	e
0	0.0	2.0	4.0	6.0	4.0
1	9.0	5.0	13.0	15.0	9.0
2	18.0	20.0	22.0	24.0	14.0
3	15.0	16.0	17.0	18.0	19.0

Relatedly, when reindexing a Series or DataFrame, you can also specify a `fill_value`.

24.6 Function Application and Mapping

We may apply functions to each row/column of a DataFrame. If the function is built-in function that is compatible with DataFrame, you can directly call the function that it will be applied automatically to each row/column. If it is not, we can call `apply` to get the desired result.

```
Example 24.3. as pd  
data = pd.DataFrame(np.random.rand(4, 4),  
                     index=['Ohio', 'Colorado', 'Utah', 'New York'],
```

```

        columns=['one', 'two', 'three', 'four'])

f = lambda x: x.max() - x.min()

print(data.apply(f))
print(data.apply(f, axis='columns'))

```

```

one      0.760203
two      0.194292
three    0.798163
four     0.532792
dtype: float64
Ohio     0.749393
Colorado 0.632478
Utah     0.750407
New York 0.473706
dtype: float64

```

We can use more complicated function to get more complicated result.

```

Example 24-4. as pd
data = pd.DataFrame(np.random.rand(4, 4),
                    index=['Ohio', 'Colorado', 'Utah', 'New York'],
                    columns=['one', 'two', 'three', 'four'])

f = lambda x: pd.Series([x.max(), x.min()], index=['max', 'min'])

print(data.apply(f))

```

```

      one      two      three      four
max  0.652675  0.986649  0.781956  0.891398
min  0.552298  0.169863  0.090304  0.063122

```

24.7 Sorting and Ranking

- `.sort_values(by=)`
- `.rank(ascending=, method=)`

24.8 Summarizing and Computing Descriptive Statistics

- `sum, cumsum`
- `mean, median`
- `.describe()`
- `.cov, .corr`

24.9 Unique Values, Value Counts, and Membership

- `unique`
- `value_counts`

24.10 Reading and Writing Data in Text Format

- `read_csv`
- `read_excel`
- `df.to_csv`

24.11 Copies and views

- `inplace`

25 Data cleaning

25.1 Handling Missing Data

- np.nan, pd.NA
- pd.isnull(), np.isnan()
- dropna, fillna

```
Example 25.1. In [25]: import pandas as pd
import numpy as np

data = pd.DataFrame([[1., 6.5, 3.], [1., np.nan, np.nan],
                    [np.nan, np.nan, np.nan], [np.nan, 6.5, 3.]])
cleaned = data.dropna()
cleanedrow = data.dropna(how='all')
data
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning:
return method()
```

	0	1	2
0	1.0	6.5	3.0
1	1.0	NaN	NaN
2	NaN	NaN	NaN
3	NaN	6.5	3.0

```
cleaned
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning:
return method()
```

	0	1	2
0	1.0	6.5	3.0

```
cleanedrow
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()
```

	0	1	2
0	1.0	6.5	3.0
1	1.0	NaN	NaN
3	NaN	6.5	3.0

```
data[4] = np.nan
cleaned1 = data.dropna(axis=1, how='all')
cleanedthresh = data.dropna(thresh=2)
data
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()
```

	0	1	2	4
0	1.0	6.5	3.0	NaN
1	1.0	NaN	NaN	NaN
2	NaN	NaN	NaN	NaN
3	NaN	6.5	3.0	NaN

```
cleaned1
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()
```

	0	1	2
0	1.0	6.5	3.0
1	1.0	NaN	NaN
2	NaN	NaN	NaN
3	NaN	6.5	3.0

cleanedthresh

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	0	1	2	4
0	1.0	6.5	3.0	NaN
3	NaN	6.5	3.0	NaN

```
fill0 = data.fillna(0)
filldict = data.fillna({1: 0.5, 2: -0.1})
data
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	0	1	2	4
0	1.0	6.5	3.0	NaN
1	1.0	NaN	NaN	NaN
2	NaN	NaN	NaN	NaN
3	NaN	6.5	3.0	NaN

fill0

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	0	1	2	4
0	1.0	6.5	3.0	0.0
1	1.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.0	6.5	3.0	0.0

filldict

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	0	1	2	4
0	1.0	6.5	3.0	NaN
1	1.0	0.5	-0.1	NaN
2	NaN	0.5	-0.1	NaN
3	NaN	6.5	3.0	NaN

25.2 Data Transformation

- `.duplicated()`, `drop_duplicates()`

```

Example 25.2 as np
import pandas as pd

data = pd.DataFrame({'k1': ['one', 'two'] * 3 + ['two'],
                        'k2': [1, 1, 2, 3, 3, 4, 4]})
data.drop_duplicates(['k1'], keep='last')

```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning:
return method()

	k1	k2
4	one	3
6	two	4

- `pd.Series.map()`, `pd.DataFrame.apply()`

```

Example 25.3 as pd
import numpy as np

data = pd.DataFrame({'food': ['bacon', 'pulled pork', 'bacon',
                             'Pastrami', 'corned beef', 'Bacon',
                             'pastrami', 'honey ham', 'nova lox'],
                     'ounces': [4, 3, 12, 6, 7.5, 8, 3, 5, 6]})

```



```

meat_to_animal = {
    'bacon': 'pig',
    'pulled pork': 'pig',
    'pastrami': 'cow',
    'corned beef': 'cow',
    'honey ham': 'pig',
    'nova lox': 'salmon'
}

data['animal'] = data['food'].str.lower().map(meat_to_animal)

data['food'].map(lambda x: meat_to_animal[x.lower()])

```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
 return method()

	food
0	pig
1	pig
2	pig
3	cow
4	cow
5	pig
6	cow
7	pig
8	salmon

- replace
- rename
- describe
- permutation
- sample
- dummy variables

25.3 Example: Movies

Below we explore the MovieLens 1M datasets. You may download it from this [link](#).

```

import pandas as pd
import numpy as np
mnames = ['movie_id', 'title', 'genres']
movies = pd.read_table('assets/datasets/movies.dat', sep='::',
                      header=None, names=mnames, engine="python",
                      encoding='ISO-8859-1')

all_genres = list()
movies['genres'].map(lambda x: all_genres.extend(x.split('|')))

genres = pd.unique(all_genres)

dummies = pd.DataFrame(np.zeros((len(movies), len(genres))), columns=genres)

for i, gen in enumerate(movies.genres):
    indices = dummies.columns.get_indexer(gen.split('|'))
    dummies.iloc[i, indices] = 1

movies_windic = movies.join(dummies.add_prefix('Genre_'))

```

25.4 String Manipulation

The key idea in this section is that, all methods in `pd.Series.str` will be applied to each entry of the Series.

Example 25.4.

```

import pandas as pd
import numpy as np
s = pd.Series(["A ", " B ", "C", "Aaba", " Baca ", np.nan, "CABA", "dog", "cat"])

s.str.lower()
s.str.split('a')
s.str.len()
s.str.strip()
s.str.replace("A", '1')

```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning: return method()

	0
0	1
1	B
2	C
3	1aba
4	Baca
5	NaN
6	C1B1
7	dog
8	cat

Example 25.5. We could also use `.str` to play with column names and row indexes.

```
import pandas as pd
import numpy as np
df = pd.DataFrame(np.random.randn(3, 2),
                  columns=[" Column A ", " Column B "], index=range(3))

df.columns = df.columns.str.strip().str.lower().str.replace(' ', '_')
df
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
 return method()

	column_a	column_b
0	0.722271	0.563629
1	-0.603209	0.806060
2	0.361664	-0.605431

25.5 Regular expression

Regular expressions provide a flexible way to search or match string patterns in text. A single expression, commonly called a *regex*, is a string formed according to the regular expression language. Python's built-in `re` module is responsible for applying regular expressions to strings.

For details of the regular expression language in Python, please read the official documents from [here](#). There are also many great websites for learning regex. [This](#) is one example.

We will briefly mentioned a few rules here.

- `.`: matches any character except a newline.
- `\d`: matches any digit. It is the same as `[0-9]`.
- `\w`: matches any alphabetic or numeric character. It is the same as `[a-zA-Z0-9_]`.
- `\s`: matches any whitespaces. It is the same as `[\t\n\r\f\v]`.
- `*`: Causes the resulting RE to match 0 or more repetitions of the preceding RE, as many repetitions as are possible.
- `+`: Causes the resulting RE to match 1 or more repetitions of the preceding RE, as many repetitions as are possible.
- `?`: Causes the resulting RE to match 0 or 1 repetitions of the preceding RE.
- `*?`, `+`?, `??`: The `*`, `+`, and `?` qualifiers are all greedy; they match as much text as possible. Adding `?` after the qualifier makes it perform the match in non-greedy or minimal fashion; as few characters as possible will be matched.
- `{m}`: Specifies that exactly `m` copies of the previous RE should be matched.
- `{m,n}`: Causes the resulting RE to match from `m` to `n` repetitions of the preceding RE, attempting to match as many repetitions as possible.
- `{m,n}?`: Causes the resulting RE to match from `m` to `n` repetitions of the preceding RE, attempting to match as few repetitions as possible.
- `[]`: Used to indicate a set of characters.
- `()`: set groups.

Example 25.6.

```
text = "foo bar\t baz \tqux"
pattern = '\s+'
regex = re.compile(pattern)
regex.split(text)
```

```
['foo', 'bar', 'baz', 'qux']
```

- `.match()`
- `.search()`
- `.findall()`
- `.split()`
- `.sub()`

We can use `()` to specify groups, and use `.groups()` to get access to the results.

Example 25.7.

```
pattern = r'([A-Z0-9._%+-]+)@([A-Z0-9.-]+)\.([A-Z]{2,4})'
regex = re.compile(pattern, flags=re.IGNORECASE)
m = regex.match('wesm@bright.net')
m.groups()
```

```
('wesm', 'bright', 'net')
```

To use regex to DataFrame and Series, you may directly apply `.match`, `.findall`, `.replace` after `.str`, with the regex pattern as one of the arguments.

`.extract` is a method that is not from `re`. It is used to extract the matched groups and make them as a DataFrame.

Example 25.8.

```
import pandas as pd
import numpy as np
mnames = ['movie_id', 'title', 'genres']
movies = pd.read_table('assests/datasets/movies.dat', sep='::',
                      header=None, names=mnames, engine="python",
                      encoding='ISO-8859-1')

pattern = r'([a-zA-Z0-9_\s,.\?;:\']+)\((\d{4})\)'
movies = movies.join(movies.title.str.extract(pattern).rename(columns={0: 'movie title', 1: 'year'})
```

26 Data Wrangling

26.1 Hierarchical indexing

Pandas support a more complex indexing system, that the index may have multiple levels. See the following example.

```
import pandas as pd
import numpy as np

data = pd.Series(np.random.randn(9),
                  index = [['a', 'a', 'a', 'b', 'b', 'c', 'c', 'd', 'd'],
                           [1, 2, 3, 1, 2, 3, 1, 2, 3]])

data
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

			0
a	1		-0.121189
	2		1.059276
	3		2.027761
b	1		0.339491
	2		-0.349993
c	3		0.618772
	1		0.701095
d	2		-0.298742
	3		-0.887485

You may look at the Series using different levels of indexes.

```
data['a']
```

	0
1	-0.121189
2	1.059276
3	2.027761

```
data.loc[:, 2]
```

	0
a	1.059276
b	-0.349993
d	-0.298742

You may use `groupby` to group by levels and do calculations related to levels. More `.groupby()` will be discussed in the next section.

```
data.groupby(level=1).sum()
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	0
1	0.919396
2	0.410541
3	1.759048

From the example above, you may notice that the 2-level hierarchical indexing for a Series works very similar to a DataFrame. In fact, you may translate it back and forth between a 2-level indexing Series and a DataFrame.

```
df = data.unstack()
df
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	1	2	3
a	-0.121189	1.059276	2.027761
b	0.339491	-0.349993	NaN
c	0.701095	NaN	0.618772
d	NaN	-0.298742	-0.887485

```
df.stack()
```

		0
a	1	-0.121189
	2	1.059276
	3	2.027761
b	1	0.339491
	2	-0.349993
c	1	0.701095
	3	0.618772
d	2	-0.298742
	3	-0.887485

For DataFrame the index for both axes can be multiindex. The usual indexing way can be used if you want to start from the first level of the index. The more specific method to extract data is `.xs`.

Example 26-1. `as pd`

```
df1 = pd.DataFrame(  
    {  
        "A": ["A0", "A1", "A2", "A3"],  
        "B": ["B0", "B1", "B2", "B3"],  
        "C": ["C0", "C1", "C2", "C3"],  
        "D": ["D0", "D1", "D2", "D3"],  
    },  
    index=[0, 1, 2, 3],  
)  
  
df2 = pd.DataFrame(  
    {  
        "A": ["A4", "A5", "A6", "A7"],  
        "B": ["B4", "B5", "B6", "B7"],  
        "C": ["C4", "C5", "C6", "C7"],  
        "D": ["D4", "D5", "D6", "D7"],  
    },  
    index=[4, 5, 6, 7],  
)
```



```
df = pd.concat([df1, df2], keys=['x', 'y'])
```

```
df
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

		A	B	C	D
x	0	A0	B0	C0	D0
	1	A1	B1	C1	D1
	2	A2	B2	C2	D2
	3	A3	B3	C3	D3
y	4	A4	B4	C4	D4
	5	A5	B5	C5	D5
	6	A6	B6	C6	D6
	7	A7	B7	C7	D7

```
df['A']
```

		A
x	0	A0
	1	A1
	2	A2
	3	A3
y	4	A4
	5	A5
	6	A6
	7	A7

```
df.loc['x']
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	A	B	C	D
0	A0	B0	C0	D0
1	A1	B1	C1	D1
2	A2	B2	C2	D2
3	A3	B3	C3	D3

```
df.loc['x',3]
```

	x
	3
A	A3
B	B3
C	C3
D	D3

```
df.xs(3, level=1, drop_level=False)
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

		A	B	C	D
x	3	A3	B3	C3	D3

26.2 Combining and Merging Datasets

26.2.1 merge()

Merge combines datasets by linking rows using one or more keys. This is from relational databases (e.g., SQL-based).

Here are some examples.

Example 26-2. as pd

```
df1 = pd.DataFrame({'key': ['b', 'b', 'a', 'c', 'a', 'a', 'b'],
                    'data1': range(7)})
df2 = pd.DataFrame({'key': ['a', 'b', 'd'], 'data2': range(3)})
```

The two DataFrames are displayed as follows.

```
df1
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	key	data1
0	b	0
1	b	1
2	a	2
3	c	3
4	a	4
5	a	5
6	b	6

```
df2
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	key	data2
0	a	0
1	b	1
2	d	2

```
pd.merge(df1, df2, on='key')
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	key	data1	data2
0	b	0	1
1	b	1	1
2	b	6	1
3	a	2	0
4	a	4	0
5	a	5	0

If the column names are different in each object, you can specify them separately.

```
df3 = pd.DataFrame({'lkey': ['b', 'b', 'a', 'c', 'a', 'a', 'b'],
                    'data1': range(7)})
df4 = pd.DataFrame({'rkey': ['a', 'b', 'd'],
                    'data2': range(3)})
pd.merge(df3, df4, left_on='lkey', right_on='rkey')
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	lkey	data1	rkey	data2
0	b	0	b	1
1	b	1	b	1
2	b	6	b	1
3	a	2	a	0
4	a	4	a	0
5	a	5	a	0

By default `merge` does an inner join, that the keys in the result are the interesection found in both tables. Below are different types of `merge`. To specify the method for merge, the option is `how`.

- `inner`
- `left`
- `right`
- `outer`

Let's see the following examples.

```
df1 = pd.DataFrame({'Key': [1, 2], 'A': [0, 2], 'B': [1, 3]})
df1
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	Key	A	B
0	1	0	1
1	2	2	3

```
df2 = pd.DataFrame({'Key': [1, 3], 'C': [0, 2], 'D': [1, 3]})
df2
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	Key	C	D
0	1	0	1
1	3	2	3

```
pd.merge(df1, df2, on='Key', how='inner')
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	Key	A	B	C	D
0	1	0	1	0	1

```
pd.merge(df1, df2, on='Key', how='outer')
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	Key	A	B	C	D
0	1	0.0	1.0	0.0	1.0
1	2	2.0	3.0	NaN	NaN
2	3	NaN	NaN	2.0	3.0

```
pd.merge(df1, df2, on='Key', how='left')
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	Key	A	B	C	D
0	1	0	1	0.0	1.0
1	2	2	3	NaN	NaN

```
pd.merge(df1, df2, on='Key', how='right')
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	Key	A	B	C	D
0	1	0.0	1.0	0	1
1	3	NaN	NaN	2	3

i Note

If a key combination appears more than once in both tables, the resulting table will have the Cartesian product of the associated data. Here is a very basic example with one unique key combination

```
df1 = pd.DataFrame({'key': ['b', 'b', 'a', 'c', 'a', 'b'],
                    'data1': range(6)})
df2 = pd.DataFrame({'key': ['a', 'b', 'a', 'b', 'd'],
                    'data2': range(5)})
pd.merge(df1, df2, on='key', how='left')
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning: merge() is deprecated. Use merge() instead.
return method()

	key	data1	data2
0	b	0	1.0
1	b	0	3.0
2	b	1	1.0
3	b	1	3.0
4	a	2	0.0
5	a	2	2.0
6	c	3	NaN
7	a	4	0.0
8	a	4	2.0
9	b	5	1.0
10	b	5	3.0

i Note

If the merge keys in a DataFrame is in its index instead of column(s), we could pass `left_index=True` or `right_index=True` or both instead of setting `left_on/right_on/on`.

26.2.2 concat()

The `concat()` function (in the main pandas namespace) performs concatenation operations along an axis while performing optional set logic (union or intersection) of the indexes (if any) on the other axes.

```
import pandas as pd

df1 = pd.DataFrame(
    {
        "A": ["A0", "A1", "A2", "A3"],
        "B": ["B0", "B1", "B2", "B3"],
        "C": ["C0", "C1", "C2", "C3"],
        "D": ["D0", "D1", "D2", "D3"],
    },
    index=[0, 1, 2, 3],
)

df2 = pd.DataFrame(
    {
        "A": ["A4", "A5", "A6", "A7"],
        "B": ["B4", "B5", "B6", "B7"],
        "C": ["C4", "C5", "C6", "C7"],
        "D": ["D4", "D5", "D6", "D7"],
    },
    index=[4, 5, 6, 7],
)

df3 = pd.DataFrame(
    {
        "A": ["A8", "A9", "A10", "A11"],
        "B": ["B8", "B9", "B10", "B11"],
        "C": ["C8", "C9", "C10", "C11"],
        "D": ["D8", "D9", "D10", "D11"],
    },
    index=[8, 9, 10, 11],
)

pd.concat([df1, df2, df3], keys=['x', 'y', 'z'])
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()
```

		A	B	C	D
x	0	A0	B0	C0	D0
	1	A1	B1	C1	D1
	2	A2	B2	C2	D2
	3	A3	B3	C3	D3
y	4	A4	B4	C4	D4
	5	A5	B5	C5	D5
	6	A6	B6	C6	D6
	7	A7	B7	C7	D7
z	8	A8	B8	C8	D8
	9	A9	B9	C9	D9
	10	A10	B10	C10	D10
	11	A11	B11	C11	D11

```
pd.concat([df1, df2, df3], axis=1)
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	A	B	C	D	A	B	C	D	A	B	C	D
0	A0	B0	C0	D0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
1	A1	B1	C1	D1	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	A2	B2	C2	D2	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
3	A3	B3	C3	D3	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
4	NaN	NaN	NaN	NaN	A4	B4	C4	D4	NaN	NaN	NaN	NaN
5	NaN	NaN	NaN	NaN	A5	B5	C5	D5	NaN	NaN	NaN	NaN
6	NaN	NaN	NaN	NaN	A6	B6	C6	D6	NaN	NaN	NaN	NaN
7	NaN	NaN	NaN	NaN	A7	B7	C7	D7	NaN	NaN	NaN	NaN
8	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	A8	B8	C8	D8
9	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	A9	B9	C9	D9
10	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	A10	B10	C10	D10
11	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	A11	B11	C11	D11

- `pd.concat`

27 Data Aggregation and Group Operations

27.1 split-apply-combine model

We would like to apply group operations based on the split-apply-combine model.

- In the first stage of the process, data contained in a pandas object is *split* into groups based on one or more keys that you provide. We then use `.groupby(keys)` to perform the split step. The result is a grouped `groupby` object.
- Once this is done, a function is *applied* to each group, producing a new value.
- Finally the results of all those function applications are combined into a result object. We may apply groupby functions directly as methods to groupby objects. The result is the combined result object.

Example 27.1. as pd

```
df = pd.DataFrame({'key1' : ['a', 'a', 'b', 'b', 'a'],
                   'key2' : ['one', 'two', 'one', 'two', 'one'],
                   'data1' : np.random.randn(5),
                   'data2' : np.random.randn(5)})

df
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	key1	key2	data1	data2
0	a	one	0.708399	-0.938759
1	a	two	-0.710759	-1.552390
2	b	one	0.878501	-0.169334
3	b	two	-0.902860	-1.427753
4	a	one	-0.011656	0.919464

Now we want to group data1 in df by key1.

```
grouped = df['data1'].groupby(df['key1'])
grouped
```

```
<pandas.core.groupby.generic.SeriesGroupBy object at 0x000001DC4EC82E50>
```

What we get is a groupby object and we could apply group functions to it.

The method to look at each group is `.get_group`.

```
grouped.get_group('a')
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning:
    return method()
```

	data1
0	0.708399
1	-0.710759
4	-0.011656

We may directly apply some group functions to the groupby object.

```
grouped.mean()
```

	data1
key1	
a	-0.004672
b	-0.012179

```
grouped.size()
```

	data1
key1	
a	3
b	2

We could iterate over groups.

```

for name, group in grouped:
    print('name', name)
    print('group', group)

```

```

name a
group 0    0.708399
1   -0.710759
4   -0.011656
Name: data1, dtype: float64
name b
group 2    0.878501
3   -0.902860
Name: data1, dtype: float64

```

We could convert the group object into list and dictionary.

```
list(grouped)
```

```

[('a',
  0    0.708399
  1   -0.710759
  4   -0.011656
  Name: data1, dtype: float64),
 ('b',
  2    0.878501
  3   -0.902860
  Name: data1, dtype: float64)]

```

```
dict(list(grouped))
```

```

{'a': 0    0.708399
      1   -0.710759
      4   -0.011656
      Name: data1, dtype: float64,
 'b': 2    0.878501
      3   -0.902860
      Name: data1, dtype: float64}

```

27.2 More aggregation functions

- `.describe()`
- `.count()`
- `.sum()`
- `.mean()`
- `.median`
- `.std(), .var()`
- `.min(), .max()`
- `.prod()`
- `.first(), .last()`
- `.agg()`

27.3 Some examples

Example 27.2. Consider the following DataFrame.

```
import pandas as pd
df = pd.DataFrame({'location': ['East', 'East', 'East', 'East',
                                'West', 'West', 'West', 'West'],
                   'data': np.random.randn(8)},
                  index=['Ohio', 'New York', 'Vermont', 'Florida',
                          'Oregon', 'Nevada', 'California', 'Idaho'])
df.loc[['Vermont', 'Nevada', 'Idaho'], 'data'] = np.nan
```

We would like to fill in NA values with the mean from each group.

```
df.groupby('location').apply(lambda x: x.fillna(x.mean()))
```

```
C:\Users\Xinli\AppData\Local\Temp\ipykernel_20292\2040193686.py:1: FutureWarning: Dropping o
df.groupby('location').apply(lambda x: x.fillna(x.mean()))
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureW
return method()
```

	location	data
Ohio	East	1.786523
New York	East	-0.473073
Vermont	East	0.978115
Florida	East	1.620895
Oregon	West	1.116834
Nevada	West	0.346468
California	West	-0.423897
Idaho	West	0.346468

We could also fill in NA values with predefined values, similar to the non-groupby case.

```
df.groupby('location').apply(lambda x: x.fillna({'East': 0.1,
                                                'West': -0.5}[x.name]))
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning:
return method()

	location	data
Ohio	East	1.786523
New York	East	-0.473073
Vermont	East	0.100000
Florida	East	1.620895
Oregon	West	1.116834
Nevada	West	-0.500000
California	West	-0.423897
Idaho	West	-0.500000

28 Exercises

Most problems are based on [7].

Exercise 28.1. Please use the following code to generate a series `ser`, and then finish the following tasks.

```
import pandas as pd
import numpy as np

mylist = list('abcedfghijklmnopqrstuvwxyz')
myarr = np.arange(26)
mydict = dict(zip(mylist, myarr))
ser = pd.Series(mydict)
```

1. Convert the series `ser` into a dataframe `df` with its index as another column on the dataframe.
2. Pick the two columns of `df` and set them into two serieses `ser1` and `ser2`.
3. Combine two series `ser1` and `ser2` to form a new dataframe `newdf`, and name their columns `ser1` and `ser2`.

Exercise 28.2. Consider two serieses `ser1` and `ser2`. You may use the following `ser1` and `ser2` as an example. The output of each questions below should be a series. You may want to learn the following commands:

- `np.union1d()`
- `np.intersect1d()`
- `np.isin()`

```
import pandas as pd

ser1 = pd.Series([1, 2, 3, 4, 5])
```

```
ser2 = pd.Series([4, 5, 6, 7, 8])
```

1. Find all the elements from `ser1` that are also in `ser2`.
2. Find all the elements from `ser2` that are also in `ser1`.
3. From `ser1` remove items present in `ser2`.
4. Find the union of `ser1` and `ser2`.
5. Find the intersection of `ser1` and `ser2`.
6. Find all the elements that are in either `ser1` or `ser2`, but not both.

Exercise 28.3 (Some statistics). Please check the following commands and answer the following questions.

- `np.percentile()`

How to get the minimum, 25th percentile, median, 75th, and max of a numeric series? You may use the following Series as an example.

```
import pandas as pd
ser = pd.Series(np.random.normal(10, 5, 25))
```

Exercise 28.4. Please use `pd.Series.value_counts()` to calculate the frequency counts of each unique value of the following Series.

```
import pandas as pd
import numpy as np
ser = pd.Series(np.take(list('abcdefgh'), np.random.randint(8, size=30)))
```

Exercise 28.5. Please keep the top 2 most frequent items of `ser` as it is and replace everything else as `Other`.

```
import pandas as pd
import numpy as np
ser = pd.Series(np.take(list('abcdefgh'), np.random.randint(8, size=30)))
```

Exercise 28.6. Please use `pd.cut` or `pd.qcut` to bin the Series `ser` into 10 equal deciles. You may use the following `ser` as an example.

```
import pandas as pd
ser = pd.Series(np.random.random(20))
```

Exercise 28.7. Consider the Series `ser`:

```
import pandas as pd
import numpy as np
ser = pd.Series(np.random.randint(1, 10, 7))
```

Find the positions of numbers that are multiples of 3 from `ser`.

Exercise 28.8. Compute the mean of `weights` of each `fruit`.

```
import pandas as pd
fruit = pd.Series(np.random.choice(['apple', 'banana', 'carrot'], 10))
weights = pd.Series(np.linspace(1, 10, 10))
df = pd.DataFrame({'fruit': fruit, 'weights': weights})
```

Exercise 28.9. Consider the following DataFrame.

```
import pandas as pd
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/Cars93_miss.csv')
```

1. Check if `df` has any missing values.
2. Please count the number of missing values in each column.
3. Please replace all missing values in `Min.Price` and `Max.Price` with their mean respectively.

Exercise 28.10. Replace the spaces in `my_str = 'dbc deb abed gade'` with the least frequent character.

Exercise 28.11. Suppress scientific notations like `e-03` in `df` and print up to 4 numbers after decimal.

```
import pandas as pd
import numpy as np
df = pd.DataFrame(np.random.random(4)**10, columns=['random'])
df
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	random
0	2.528745e-01
1	1.549450e-09
2	3.170207e-04
3	5.502305e-03

Exercise 28.12. Format the values in column `random` of `df` as percentages.

```
import pandas as pd
import numpy as np
df = pd.DataFrame(np.random.random(4), columns=['random'])
df
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	random
0	0.798735
1	0.352947
2	0.827024
3	0.218454

Exercise 28.13 (Regular expressions). Please use regular expressions to finish the following tasks.

1. Match a string that has an **a** followed by zero or more **b**'s.
2. Match a string that has an **a** followed by one or more **b**'s.
3. Match a string that has an **a** followed by zero or one **b**.
4. Match a string that has an **a** followed by three **b**'s.

Exercise 28.14 (More regex). Find all words starting with **a** or **e** in a given string:

```
text = "The following example creates an ArrayList with a capacity of 50 elements. Four el
```

Exercise 28.15 (More regex). Write a Python code to extract year, month and date from a url1:

```
url1= "https://www.washingtonpost.com/news/football-insider/wp/2016/09/02/odell-beckhams-f
```

Exercise 28.16 (More regex). Please use regex to parse the following str to create a dictionary.

```
text = r'''
{
    name: Firstname Lastname;
    age: 100;
    salary: 10000
}
'''
```

Exercise 28.17. Consider the following DataFrame.

```
data = [['Evert van Dijk', 'Carmine-pink, salmon-pink streaks, stripes, flecks. Warm pink
['Every Good Gift', 'Red. Flowers velvety red. Moderate fragrance. Average diam
['Evghenya', 'Orange-pink. 75 petals. Large, very double bloom form. Blooms in
['Evita', 'White or white blend. None to mild fragrance. 35 petals. Large, full
['Evrathin', 'Light pink. [Deep pink.] Outer petals white. Expand rarely. Mild f
['Evita 2', 'White, blush shading. Mild, wild rose fragrance. 20 to 25 petals.
```

```
df = pd.DataFrame(data, columns = ['NAME', 'BLOOM'])
df
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning:
return method()

	NAME	BLOOM
0	Evert van Dijk	Carmine-pink, salmon-pink streaks, stripes, fl...
1	Every Good Gift	Red. Flowers velvety red. Moderate fragrance...
2	Evghenya	Orange-pink. 75 petals. Large, very double b...
3	Evita	White or white blend. None to mild fragrance....
4	Evrathin	Light pink. [Deep pink.] Outer petals white. ...
5	Evita 2	White, blush shading. Mild, wild rose fragran...

Please use regex methods to find all the () in each columns.

Exercise 28.18. Get the last two rows of `df` whose row sum is greater than 100.

```
import pandas as pd
df = pd.DataFrame(np.random.randint(10, 40, 60).reshape(-1, 4))
```

Exercise 28.19. The groupby object `df_grouped` is given below.

```
import pandas as pd
import numpy as np
df = pd.DataFrame({'fruit': ['apple', 'banana', 'orange'] * 3,
                   'price': np.random.rand(9),
                   'taste': np.random.randint(0, 11, 9)})

df_grouped = df.groupby(['fruit'])
```

1. Get the group belonging to `apple` as a DataFrame.
2. Find the second largest value of `taste` for `banana`.
3. Compute the mean `price` for every `fruit`.

Exercise 28.20. Join df1 and df2 by fruit/pazham and weight/kilo.

```
df1 = pd.DataFrame({'fruit': ['apple', 'banana', 'orange'] * 3,  
                    'weight': ['high', 'medium', 'low'] * 3,  
                    'price': np.random.randint(0, 15, 9)})  
  
df2 = pd.DataFrame({'pazham': ['apple', 'orange', 'pine'] * 2,  
                    'kilo': ['high', 'low'] * 3,  
                    'price': np.random.randint(0, 15, 6)})
```

29 Projects

Exercise 29.1. Extract the valid emails from the series `emails`. The regex `pattern` for valid emails is provided as reference.

```
import pandas as pd
emails = pd.Series(['buying books at amazom.com',
                    'rameses@egypt.com',
                    'matt@t.co',
                    'narendra@modi.com'])
pattern = '[A-Za-z0-9._%+-]+@[A-Za-z0-9.-]+\.[A-Za-z]{2,4}'
```

Exercise 29.2. Consider the following DataFrame.

```
import pandas as pd
import numpy as np
df = pd.read_csv('https://raw.githubusercontent.com/selva86/datasets/master/Cars93_miss.csv')
```

1. Replace NaN with string missing in columns `Manufacturer`, `Model` and `Type`.
2. Create an index as a combination of these three columns.

Exercise 29.3. Given the following DataFrame.

```
import pandas as pd
df = pd.DataFrame({
    'name': ['James', 'Jane', 'Melissa', 'Ed', 'Neil'],
    'age': [30, 40, 32, 67, 43],
    'score': ['90%', '95%', '100%', '82%', '87%'],
    'age_missing_data': [30, 40, 32, 67, None],
    'income': [100000, 80000, 55000, 62000, 120000]
})
```

```
}))
```

- Please use `.map` to create a new column `numeric_score` whose value is the number version of `score`.
- Please use `.apply` to create a new column `numeric_score` whose value is the number version of `score`.

Exercise 29.4. From `ser = pd.Series(['Apple', 'Orange', 'Plan', 'Python', 'Money'])`, find the words that contain at least 2 vowels.

Exercise 29.5. Please download the [given file](#) with sample emails, and use the following code to load the file and save it to a string `content`.

```
with open('asests/datasets/test_emails.txt', 'r') as f:
    content = f.read()
```

Please use regex to play with `content`.

1. Get all valid email address in `content`, from both the header part or the body part.
2. There are two emails in `content`. Please get the sender's email and the receiver's email from `content`.
3. Please get the sender's name.
4. Please get the subject of each email.

Exercise 29.6. The following DataFrame is given.

```
import pandas as pd
df = pd.DataFrame(["STD, City      State",
                   "33, Kolkata    West Bengal",
                   "44, Chennai    Tamil Nadu",
                   "40, Hyderabad  Telengana",
                   "80, Bangalore  Karnataka"],
                  columns=['row'])
```

1. Split the columns into a list with 3 entries.
2. Make the first row (row 0) into a header.
3. Create a new DataFrame out of the data.

Part VI

Visualization

The main reference for this Chapter is [2].

30 matplotlib.pyplot

matplotlib is a modern and classic plot library. Its main features are inspired by MATLAB. In this book we mostly use pyplot package from matplotlib. We use the following import convention:

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

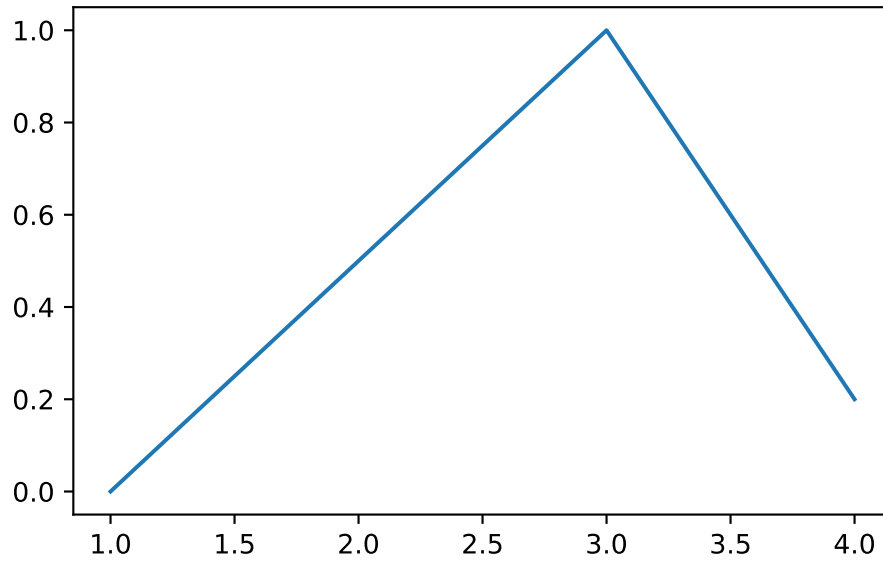
30.1 matplotlib interface

matplotlib has two major application interfaces, or styles of using the library:

- An explicit **Axes** interface that uses methods on a **Figure** or **Axes** object to create other Artists, and build a visualization step by step. You may treat this **Figure** object as a canvas, and **Axes** as plots on a canvas. There might be one or more plots on one canvas. This has also been called an *object-oriented* interface.
- An implicit **pyplot** interface that keeps track of the last **Figure** and **Axes** created, and adds Artists to the object it thinks the user wants.

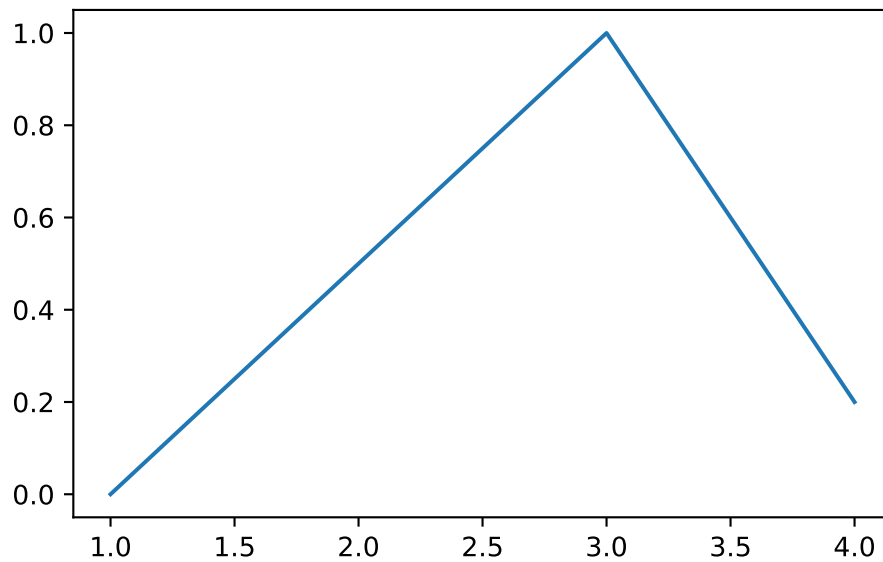
Here is an example of an explicit interface.

```
fig = plt.figure()
ax = fig.subplots()
ax.plot([1, 2, 3, 4], [0, 0.5, 1, 0.2])
```



Here is an example of an implicit interface.

```
plt.plot([1, 2, 3, 4], [0, 0.5, 1, 0.2])
```



i Note

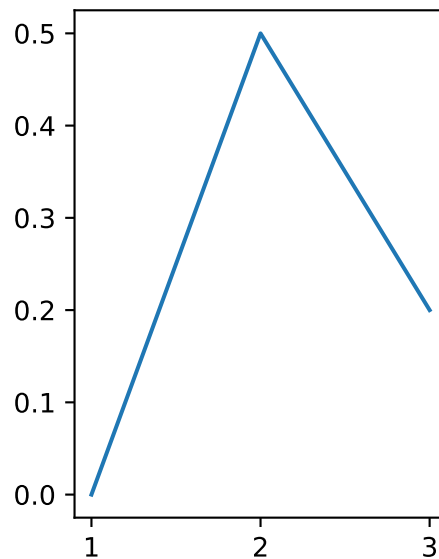
If the plot is not shown, you may want to type `plt.show()` to force the plot being rendered. However, to make `plt.show()` work is related to switching `matplotlib` backends, and is sometimes very complicated.

The purpose to explicitly use `fig` and `ax` is to have more control over the configurations. The first important configuration is subplots.

- `.subplot()`
- `.subplots()`
- `.add_subplot()`

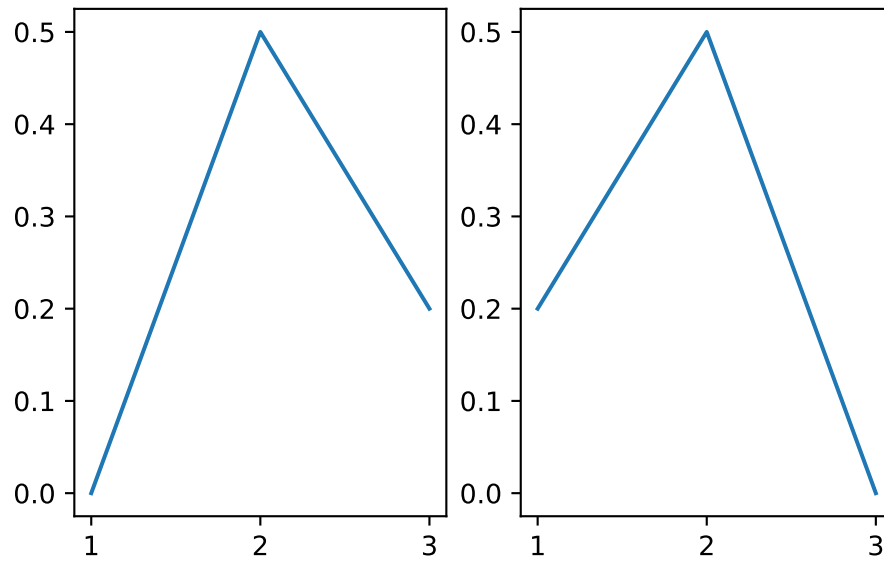
Please see the following examples.

```
Example 30  
plt.plot([1, 2, 3], [0, 0.5, 0.2])
```



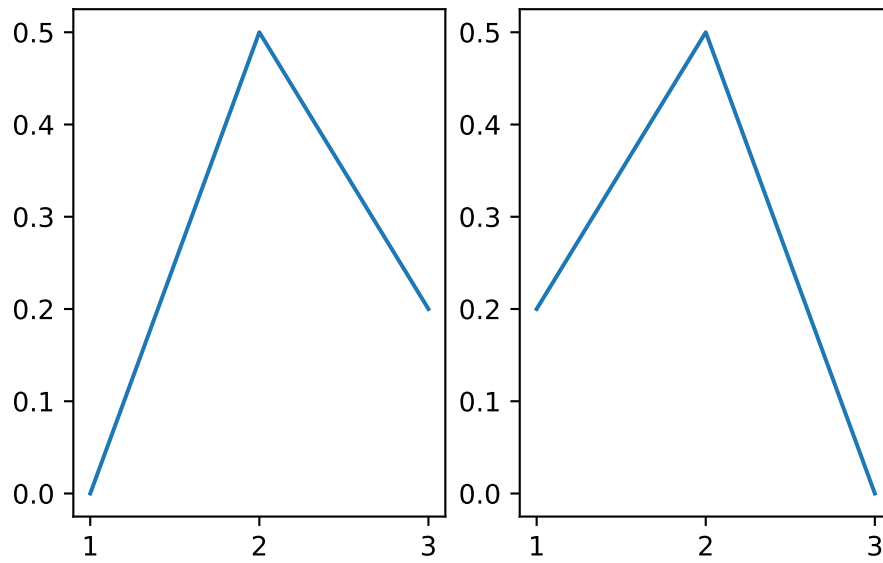
```
Example 30  
plt.plot([1, 2, 3], [0, 0.5, 0.2])
```

```
plt.subplot(1, 2, 2)
plt.plot([3, 2, 1], [0, 0.5, 0.2])
```



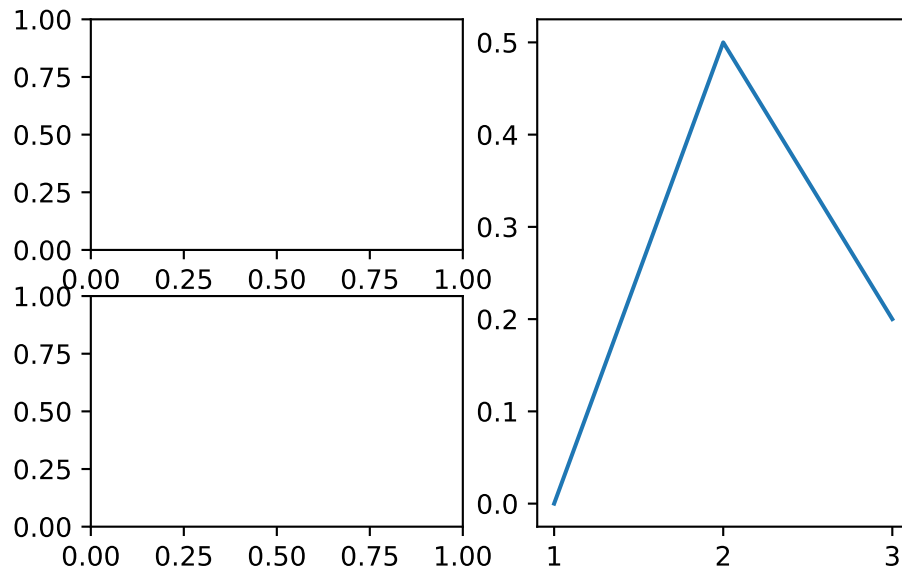
Example 30.3

```
plt.subplots(1, 2)
axs[0].plot([1, 2, 3], [0, 0.5, 0.2])
axs[1].plot([3, 2, 1], [0, 0.5, 0.2])
```



Example 304 `as np`
`fig = plt.figure()`
`ax1 = fig.add_subplot(2, 2, 1)`
`ax2 = fig.add_subplot(2, 2, 3)`
`ax3 = fig.add_subplot(1, 2, 2)`

`ax3.plot([1, 2, 3], [0, 0.5, 0.2])`

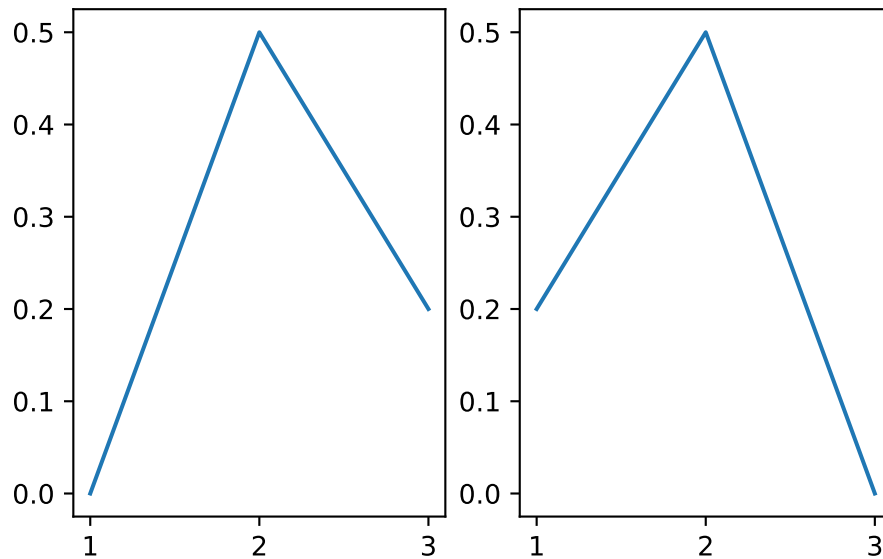


The arguments 2, 2, 1 means that we split the figure into a 2x2 grid and the axis `ax1` is in the 1st position. The rest is understood in the same way.

Example 30.5. If you don't explicitly initialize `fig` and `ax`, you may use `plt.gcf()` and `plt.gca()` to get the handles for further operations.

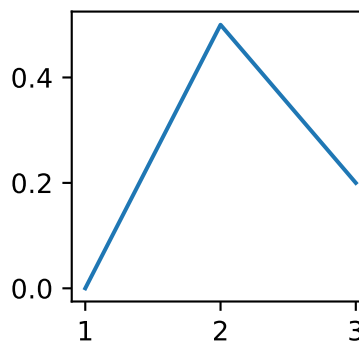
```
plt.subplot(1, 2, 1)
ax = plt.gca()
ax.plot([1, 2, 3], [0, 0.5, 0.2])

plt.subplot(1, 2, 2)
ax = plt.gca()
ax.plot([3, 2, 1], [0, 0.5, 0.2])
```



The purpose to explicitly use `fig` and `ax` is to have more control over the configurations. For example, when generate a `figure` object, we may use `figsize=(3, 3)` as an option to set the figure size to be 3x3. `dpi` is another commonly modified option.

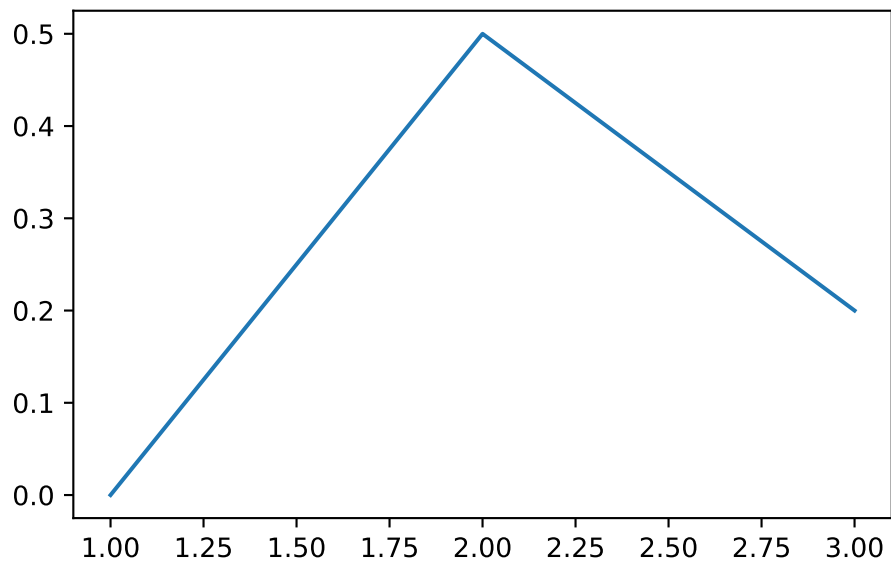
```
fig = plt.figure(figsize=(2, 2), dpi=50)
plt.plot([1, 2, 3], [0, 0.5, 0.2])
```



If you would like to change this setting later, you may use the following command before plotting.

```
fig.set_size_inches(10, 10)
fig.set_dpi(300)
```

```
plt.plot([1, 2, 3], [0, 0.5, 0.2])
```



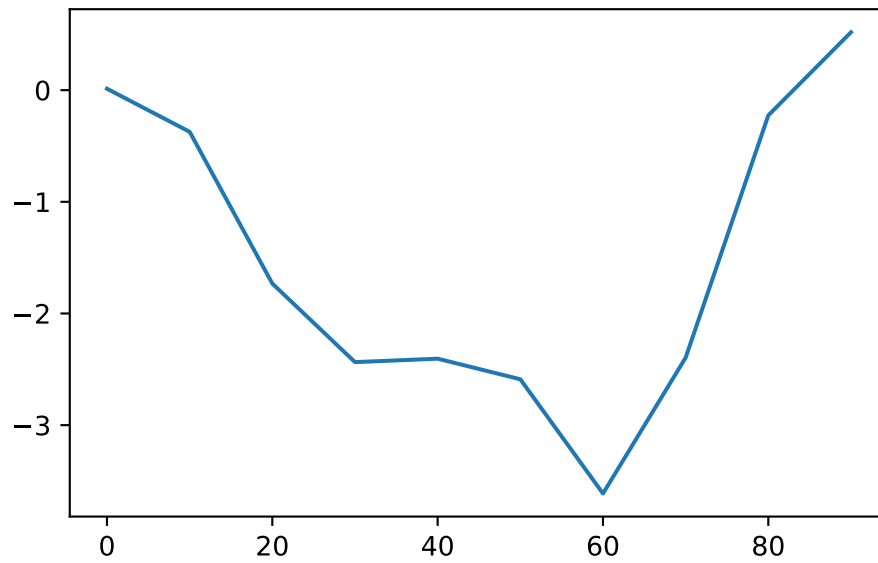
You may use `fig.savefig('filename.png')` to save the image into a file.

30.2 Downstream packages

There are multiple packages depending on `matplotlib` to provide plotting. For example, you may directly plot from a Pandas DataFrame or a Pandas Series.

```
Example 30-6. as pd
import numpy as np
s = pd.Series(np.random.randn(10).cumsum(), index=np.arange(0, 100, 10))
s.plot()
```

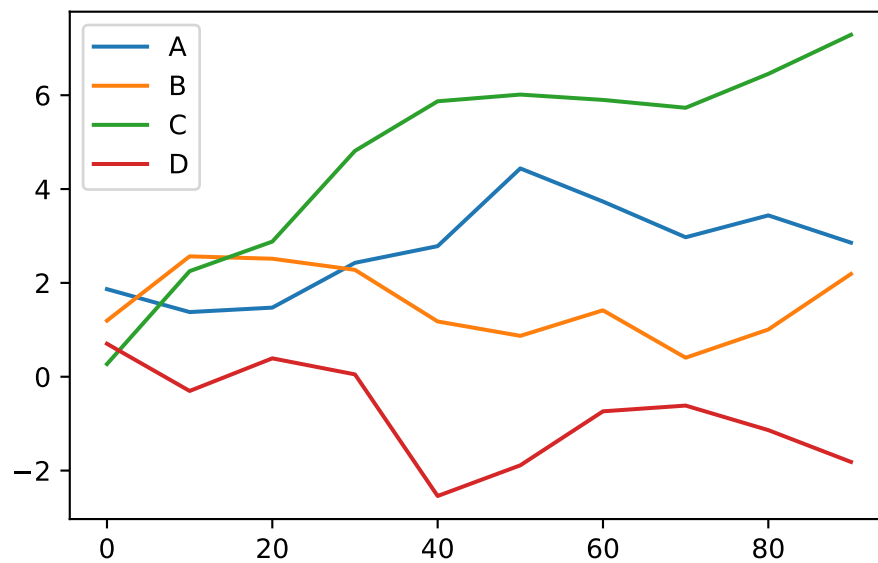
<AxesSubplot:>



```
df = pd.DataFrame(np.random.randn(10, 4).cumsum(0),
                  columns=['A', 'B', 'C', 'D'],
                  index=np.arange(0, 100, 10))

df.plot()
```

<AxesSubplot:>



30.3 plotting

30.3.1 `plt.plot()`

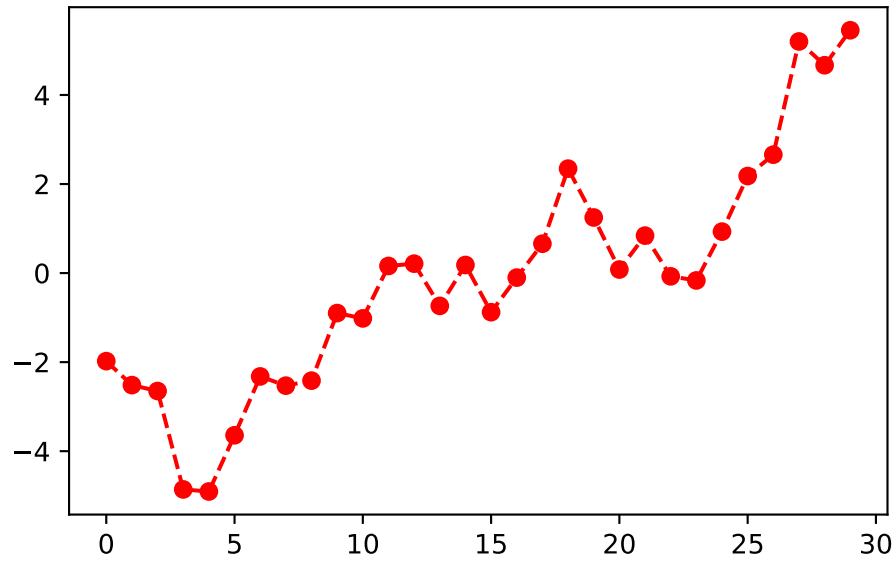
This is the command for line plotting. You may use `linestyle='--'` and `color='g'` to control the line style and color. The style can be shortened as `g--`.

Here is a list of commonly used linestyles and colors.

- line styles
 - `solid` or `-`
 - `dashed` or `--`
 - `dashdot` or `-.`
 - `dotted` or `:`
- marker styles
 - `o` as circle markers
 - `+` as plusses
 - `^` as triangles
 - `s` as squares
- colors
 - `b` as blue
 - `g` as green
 - `r` as red
 - `k` as black
 - `w` as white

The input of `plt.plot()` is two lists `x` and `y`. If there is only one list inputed, that one will be recognized as `y` and the index of elements of `y` will be used as the default `x`.

```
plt.plot(np.random.randn(30).cumsum(), color='r', linestyle='--', marker='o')
```



You may compare it with this [Example](#) for the purpose of `seaborn` from next Section.

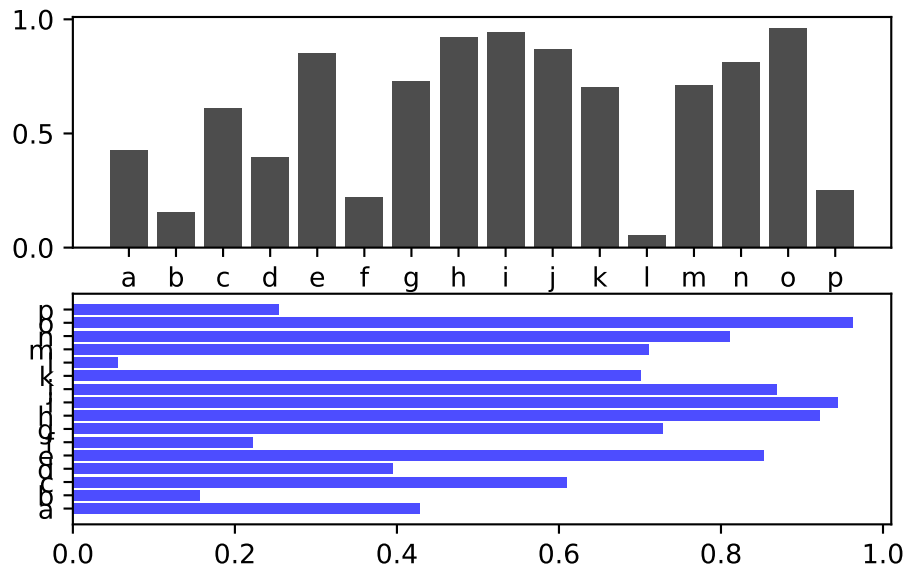
30.3.2 `plt.bar()` and `plt.barh()`

The two commands make vertical and horizontal bar plots, respectively. ::: {#exm-}

```
import pandas as pd
data = pd.Series(np.random.rand(16), index=list('abcdefghijklmnop'))

fig, axes = plt.subplots(2, 1)
axes[0].bar(x=data.index, height=data, color='k', alpha=0.7)
axes[1].barh(y=data.index, width=data, color='b', alpha=0.7)
```

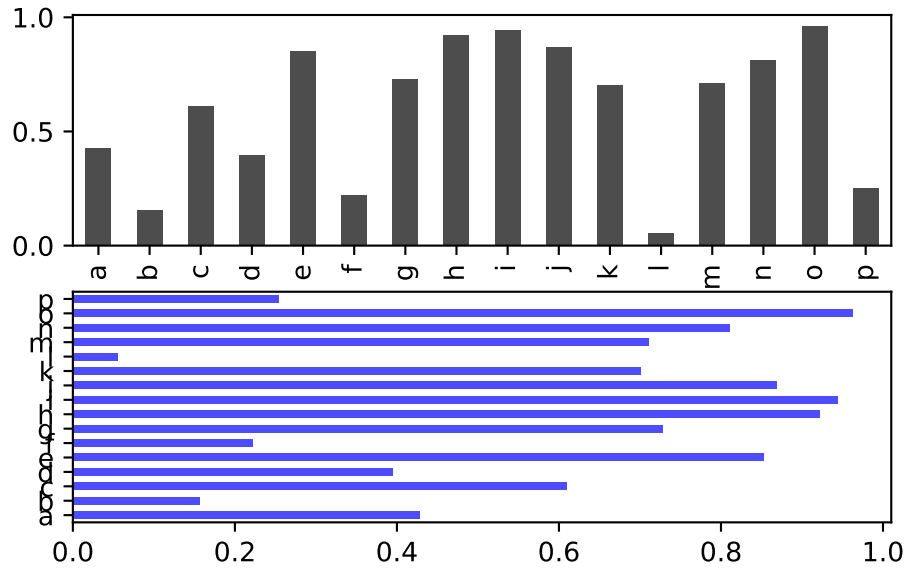
<BarContainer object of 16 artists>



We may also directly plot the bar plot from the Series.

```
fig, axes = plt.subplots(2, 1)
data.plot.bar(ax=axes[0], color='k', alpha=0.7)
data.plot.barh(ax=axes[1], color='b', alpha=0.7)
```

<AxesSubplot:>



...

With a DataFrame, bar plots group the values in each row together in a group in bars. This is easier if we directly plot from the DataFrame.

```

Example 30.8
df = DataFrame(np.random.rand(6, 4),
               index=['one', 'two', 'three', 'four', 'five', 'six'],
               columns=pd.Index(['A', 'B', 'C', 'D'], name='Genus'))
df

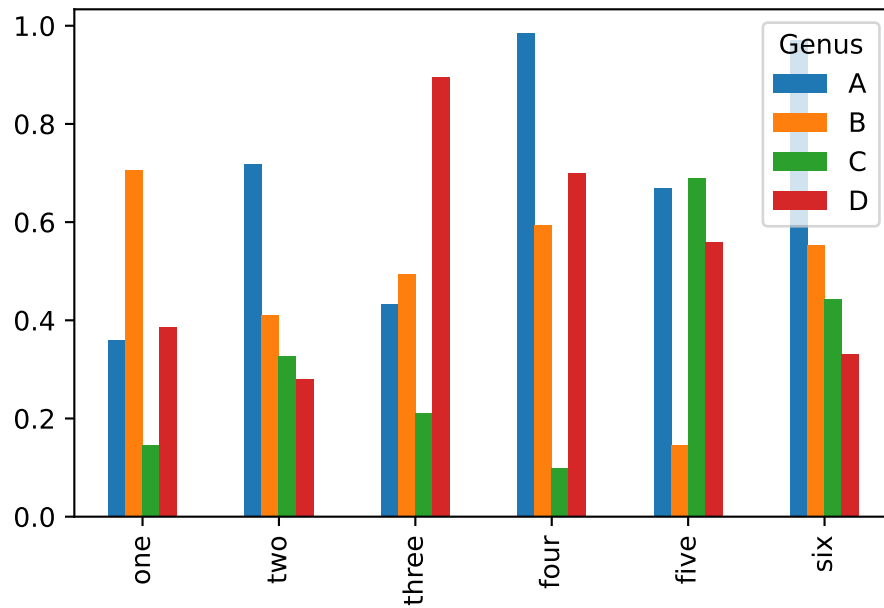
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning: return method()

Genus	A	B	C	D
one	0.360519	0.706304	0.145623	0.386449
two	0.717516	0.410948	0.327674	0.279105
three	0.432509	0.494889	0.210798	0.895215
four	0.984264	0.593068	0.098620	0.700498
five	0.668920	0.144951	0.690305	0.558761
six	0.970854	0.553347	0.443436	0.331605

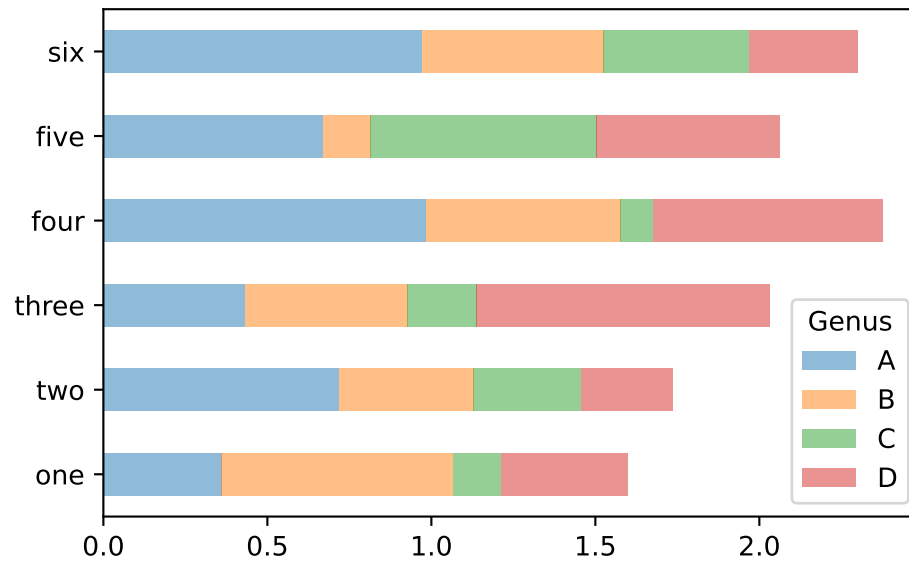
```
df.plot.bar()
```

<AxesSubplot:>



```
df.plot.barh(stacked=True, alpha=0.5)
```

<AxesSubplot:>



30.3.3 plt.scatter()

Example 30.9 `Example 30.9`

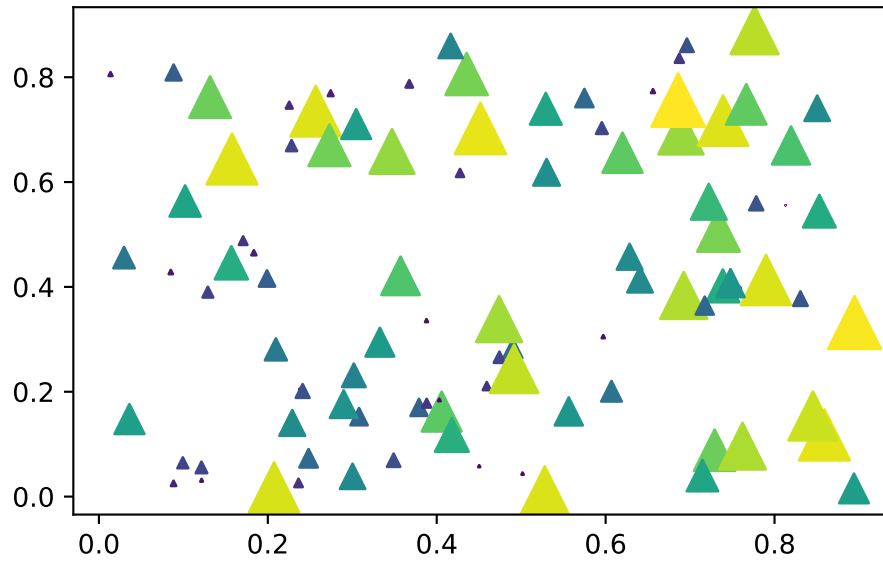
```

import numpy as np

N = 100
data = 0.9 * np.random.rand(N, 2)
area = (20 * np.random.rand(N))**2
c = np.sqrt(area)
plt.scatter(data[:, 0], data[:, 1], s=area, marker='^', c=c)

```

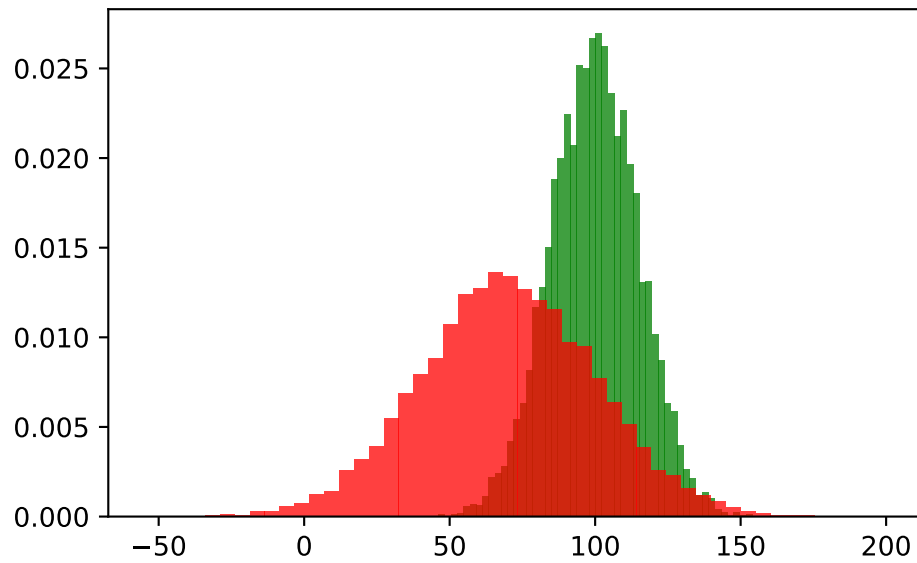
<matplotlib.collections.PathCollection at 0x1f3785ee7f0>



30.3.4 plt.hist()

Here are two plots with build-in statistics. The plot command will have statistics as outputs. To disable it we could send the outputs to a temporary variable `_`. ::: {#exm-histogram1}

```
mu, sigma = 100, 15
x = mu + sigma * np.random.randn(10000)
y = mu-30 + sigma*2 * np.random.randn(10000)
_ = plt.hist(x, 50, density=True, facecolor='g', alpha=0.75)
_ = plt.hist(y, 50, density=True, facecolor='r', alpha=0.75)
```

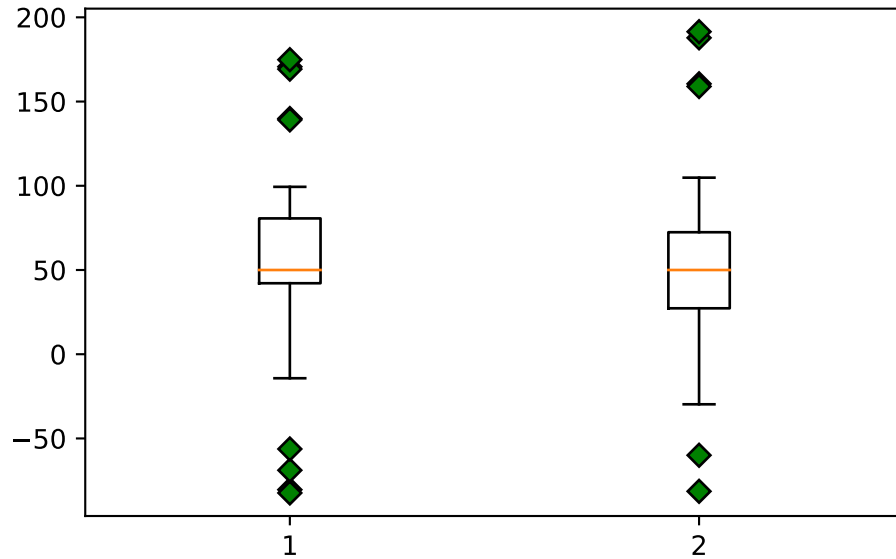



...

30.4 plt.boxplot()

```
Example 30.10
spread = np.random.rand(50) * 100
center = np.ones(30) * 50
flier_high = np.random.rand(10) * 100 + 100
flier_low = np.random.rand(10) * -100
data = np.concatenate((spread, center, flier_high, flier_low)).reshape(50, 2)

_ = plt.boxplot(data, flierprops={'markerfacecolor': 'g', 'marker': 'D'})
```



30.5 Titles, labels and legends

- Titles
 - `plt.title(label)`, `plt.xlabel(label)`, `plt.ylabel(label)` will set the title/xlabel/ylabel.
 - `ax.set_title(label)`, `ax.set_xlabel(label)`, `ax.set_ylabel(label)` will do the same thing.
- Labels
 - `plt` methods
 - * `xlim()`, `ylim()`, `xticks()`, `yticks()`, `xticklabels()`, `yticklabels()`
 - * all the above with arguments
 - `ax` methods
 - * `get_xlim()`, `get_ylim()`, etc..
 - * `set_xlim()`, `set_ylim()`, etc..
- Legends
 - First add `label` option to each piece when plotting, and then add `ax.legend()` or `plt.legend()` at the end to display the legends.
 - You may use `handles, labels = ax.get_legend_handles_labels()` to get the handles and labels of the legends, and modify them if necessary.

```

Example 30.11
import numpy as np
fig, ax = plt.subplots(1, 1)
ax.plot(np.random.randn(1000).cumsum(), 'k', label='one')
ax.plot(np.random.randn(1000).cumsum(), 'r--', label='two')
ax.plot(np.random.randn(1000).cumsum(), 'b.', label='three')

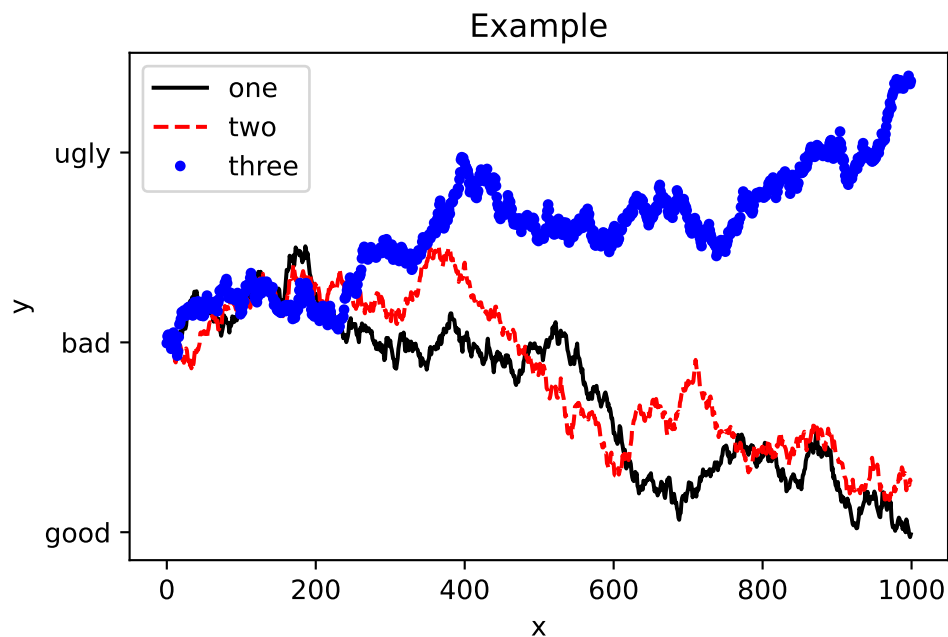
ax.set_title('Example')
ax.set_xlabel('x')
ax.set_ylabel('y')

ax.set_yticks([-40, 0, 40])
ax.set_yticklabels(['good', 'bad', 'ugly'])

ax.legend(loc='best')

```

<matplotlib.legend.Legend at 0x1f3787df670>



30.6 Annotations

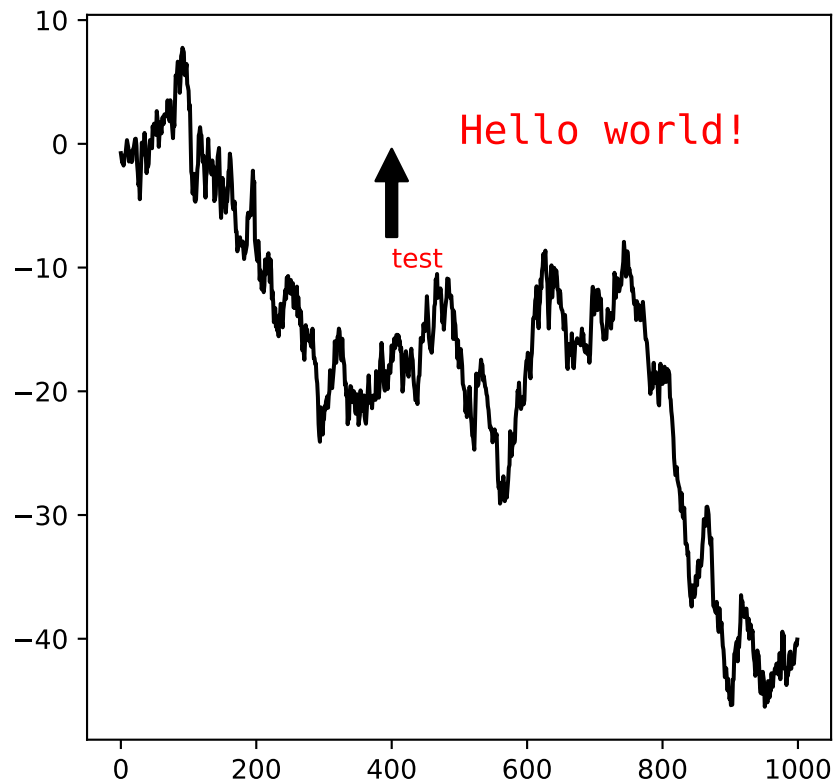
- The command to add simple annotations is `ax.text()`. The required arguments are the coordinates of the text and the text itself. You may add several options to modify the

style.

- If arrows are needed, we may use `ax.annotate()`. Here an arrow will be shown from `xytext` to `xy`. The style of the arrow is controlled by the option `arrowprops`.

```
Figure 30.12: subplots(figsize=(5, 5))  
ax.plot(np.random.randn(1000).cumsum(), 'k', label='one')  
ax.text(500, 0, 'Hello world!', family='monospace', fontsize=15, c='r')  
ax.annotate('test', xy=(400, 0), xytext=(400, -10), c='r',  
            arrowprops={'facecolor': 'black',  
                        'shrink': 0.05})
```

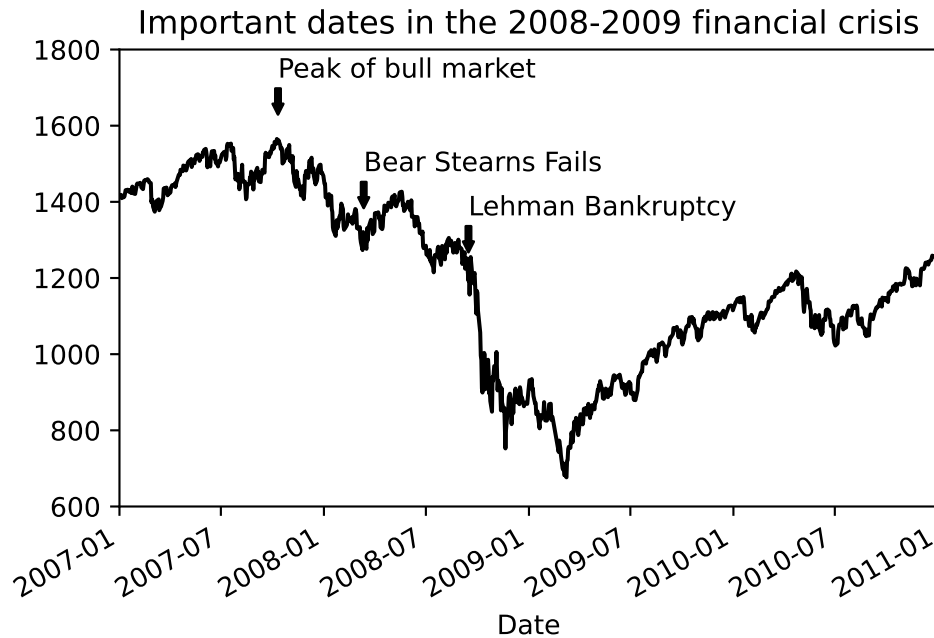
`Text(400, -10, 'test')`



30.7 Example

Example 30.13. The stock data can be downloaded from [here](#).

```
from datetime import datetime
fig, ax = plt.subplots()
data = pd.read_csv('assests/datasets/spx.csv', index_col=0, parse_dates=True)
spx = data['SPX']
spx.plot(ax=ax, style='k-')
crisis_data = [(datetime(2007, 10, 11), 'Peak of bull market'),
               (datetime(2008, 3, 12), 'Bear Stearns Fails'),
               (datetime(2008, 9, 15), 'Lehman Bankruptcy')]
for date, label in crisis_data:
    ax.annotate(label, xy=(date, spx.asof(date) + 75),
               xytext=(date, spx.asof(date) + 225),
               arrowprops=dict(facecolor='black', headwidth=4, width=2,
                               headlength=4),
               horizontalalignment='left', verticalalignment='top')
ax.set_xlim(['1/1/2007', '1/1/2011'])
ax.set_ylim([600, 1800])
_ = ax.set_title('Important dates in the 2008-2009 financial crisis')
```



Example 30.14. Here is an example of arrows with different shapes. For more details please read the official [document](#).

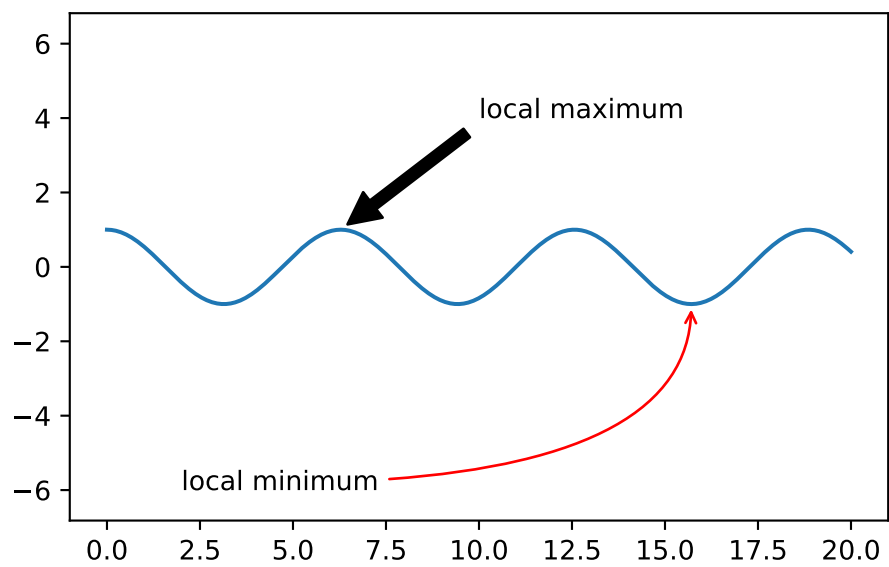
```
fig, ax = plt.subplots()

x = np.linspace(0, 20, 1000)
ax.plot(x, np.cos(x))
ax.axis('equal')

ax.annotate('local maximum', xy=(6.28, 1), xytext=(10, 4),
            arrowprops=dict(facecolor='black', shrink=0.05))

ax.annotate('local minimum', xy=(5 * np.pi, -1), xytext=(2, -6),
            arrowprops=dict(arrowstyle="->",
                            connectionstyle="angle3,angleA=0,angleB=-90",
                            color='r'))
```

```
Text(2, -6, 'local minimum')
```



31 seaborn

There are some new libraries built upon `matplotlib`, and `seaborn` is one of them. `seaborn` is for statistical graphics.

`seaborn` is used imported in the following way.

```
import seaborn as sns
```

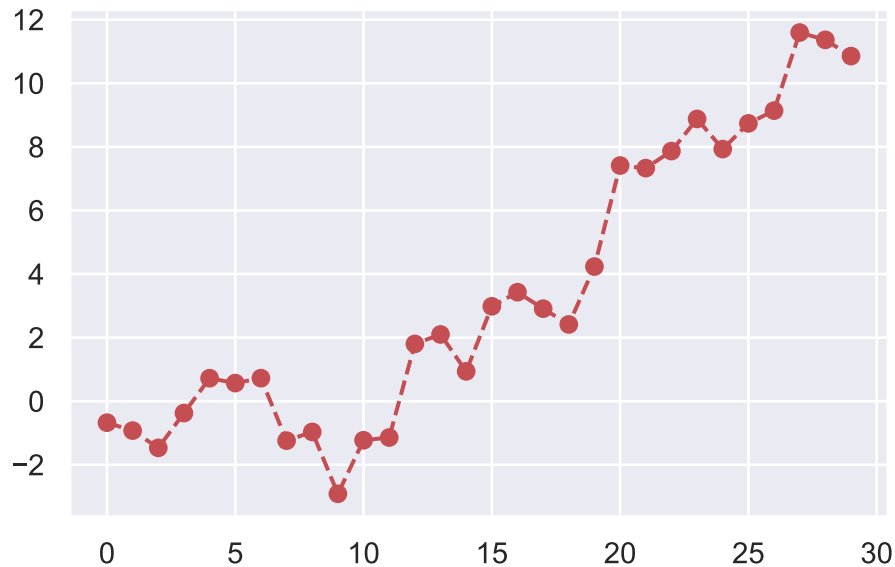
`seaborn` also modifies the default `matplotlib` color schemes and plot styles to improve readability and aesthetics. Even if you do not use the `seaborn` API, you may prefer to import `seaborn` as a simple way to improve the visual aesthetics of general `matplotlib` plots.

To apply `sns` theme, run the following code.

```
sns.set_theme()
```

Let us directly run a few codes from the last section and compare the differences between them.

```
plt.plot(np.random.randn(30).cumsum(), color='r', linestyle='--', marker='o')
```

Please compare the output of the same code with [the previous example](#)

31.1 Scatter plots with `relplot()`

The basic scatter plot method is `scatterplot()`. It is wrapped in `relplot()` as the default plotting method. So here we will mainly talk about `relplot()`. It is named that way because it is designed to visualize many different statistical relationships.

The idea of `relplot()` is to display points based on the variables `x` and `y` you choose, and assign different properties to alter the appearance of the points.

- `col` will create multiple plots based on the column you choose.
- `hue` is for color encoding, based on the column you choose.
- `size` will change the marker area, based on the column you choose.
- `style` will change the marker symbol, based on the column you choose.

Example 31.2. Consider the following example. `tips` is a DataFrame, which is shown below.

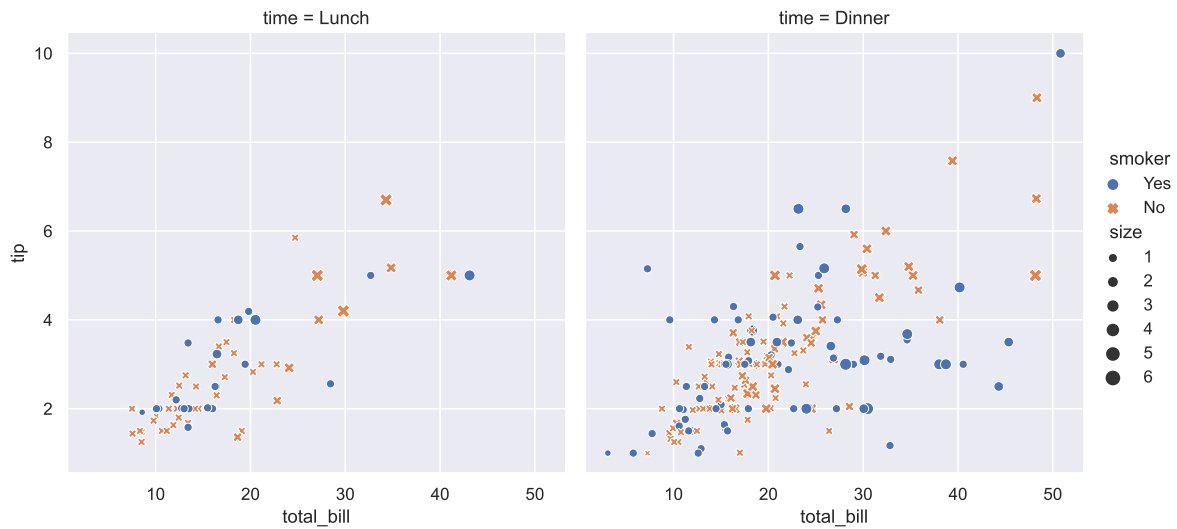
```
import seaborn as sns
tips = sns.load_dataset("tips")
tips
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
    return method()
```

	total_bill	tip	sex	smoker	day	time	size
0	16.99	1.01	Female	No	Sun	Dinner	2
1	10.34	1.66	Male	No	Sun	Dinner	3
2	21.01	3.50	Male	No	Sun	Dinner	3
3	23.68	3.31	Male	No	Sun	Dinner	2
4	24.59	3.61	Female	No	Sun	Dinner	4
5	25.29	4.71	Male	No	Sun	Dinner	4
6	8.77	2.00	Male	No	Sun	Dinner	2
7	26.88	3.12	Male	No	Sun	Dinner	4
8	15.04	1.96	Male	No	Sun	Dinner	2
9	14.78	3.23	Male	No	Sun	Dinner	2
10	10.27	1.71	Male	No	Sun	Dinner	2
11	35.26	5.00	Female	No	Sun	Dinner	4
12	15.42	1.57	Male	No	Sun	Dinner	2
13	18.43	3.00	Male	No	Sun	Dinner	4
14	14.83	3.02	Female	No	Sun	Dinner	2
15	21.58	3.92	Male	No	Sun	Dinner	2
16	10.33	1.67	Female	No	Sun	Dinner	3
17	16.29	3.71	Male	No	Sun	Dinner	3
18	16.97	3.50	Female	No	Sun	Dinner	3
19	20.65	3.35	Male	No	Sat	Dinner	3
20	17.92	4.08	Male	No	Sat	Dinner	2
21	20.29	2.75	Female	No	Sat	Dinner	2
22	15.77	2.23	Female	No	Sat	Dinner	2
23	39.42	7.58	Male	No	Sat	Dinner	4
24	19.82	3.18	Male	No	Sat	Dinner	2
25	17.81	2.34	Male	No	Sat	Dinner	4
26	13.37	2.00	Male	No	Sat	Dinner	2
27	12.69	2.00	Male	No	Sat	Dinner	2
28	21.70	4.30	Male	No	Sat	Dinner	2
29	19.65	3.00	Female	No	Sat	Dinner	2
30	9.55	1.45	Male	No	Sat	Dinner	2
31	18.35	2.50	Male	No	Sat	Dinner	4
32	15.06	3.00	Female	No	Sat	Dinner	2
33	20.69	2.45	Female	No	Sat	Dinner	4
34	17.78	3.27	Male	No	Sat	Dinner	2
35	24.06	3.60	Male	No	Sat	Dinner	3
36	16.31	2.00	Male	No	Sat	Dinner	3
37	16.93	3.07	Female	No	Sat	Dinner	3
38	18.69	2.31	Male	No	Sat	Dinner	3
39	31.27	5.00	Male	No	Sat	Dinner	3
40	16.04	2.24	Male	No	Sat	Dinner	3
41	17.46	2.54	Male	No	Sun	Dinner	2
42	13.94	3.06	Male	No	Sun	Dinner	2
43	9.68	1.32	Male	No	Sun	Dinner	2
44	30.40	5.60	Male	No	Sun	Dinner	4
45	18.29	3.00	Male	No	Sun	Dinner	2
46	22.23	5.00	Male	No	Sun	Dinner	2
47	32.40	6.00	Male	No	Sun	Dinner	4
48	28.55	2.05	Male	No	Sun	Dinner	3
49	18.04	3.00	Male	No	Sun	Dinner	2
50	12.54	2.50	Male	No	Sun	Dinner	2
51	10.29	2.60	Female	No	Sun	Dinner	2

```
sns.relplot(data=tips,
            x="total_bill", y="tip", col="time",
            hue="smoker", style="smoker", size="size")
```

<seaborn.axisgrid.FacetGrid at 0x1f37ac37be0>



The default type of plots for `relplot()` is scatter plots. However you may change it to line plot by setting `kind='line'`.

```
Example 8113 sns.relplot(data=dots, kind="line",
                        x="time", y="firing_rate", col="align",
                        hue="choice", size="coherence", style="choice",
                        facet_kws=dict(sharex=False))
```

<seaborn.axisgrid.FacetGrid at 0x1f37879a880>



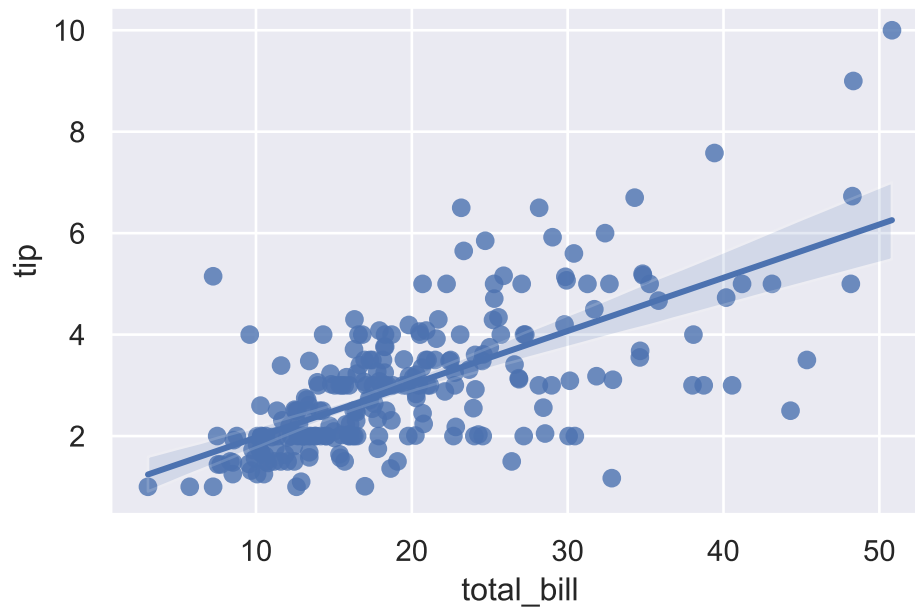
31.2 regplot()

This method is a combination between scatter plots and linear regression.

Example 31.4. We still use `tips` as an example.

```
sns.regplot(x='total_bill', y='tip', data=tips)
```

```
<AxesSubplot:xlabel='total_bill', ylabel='tip'>
```



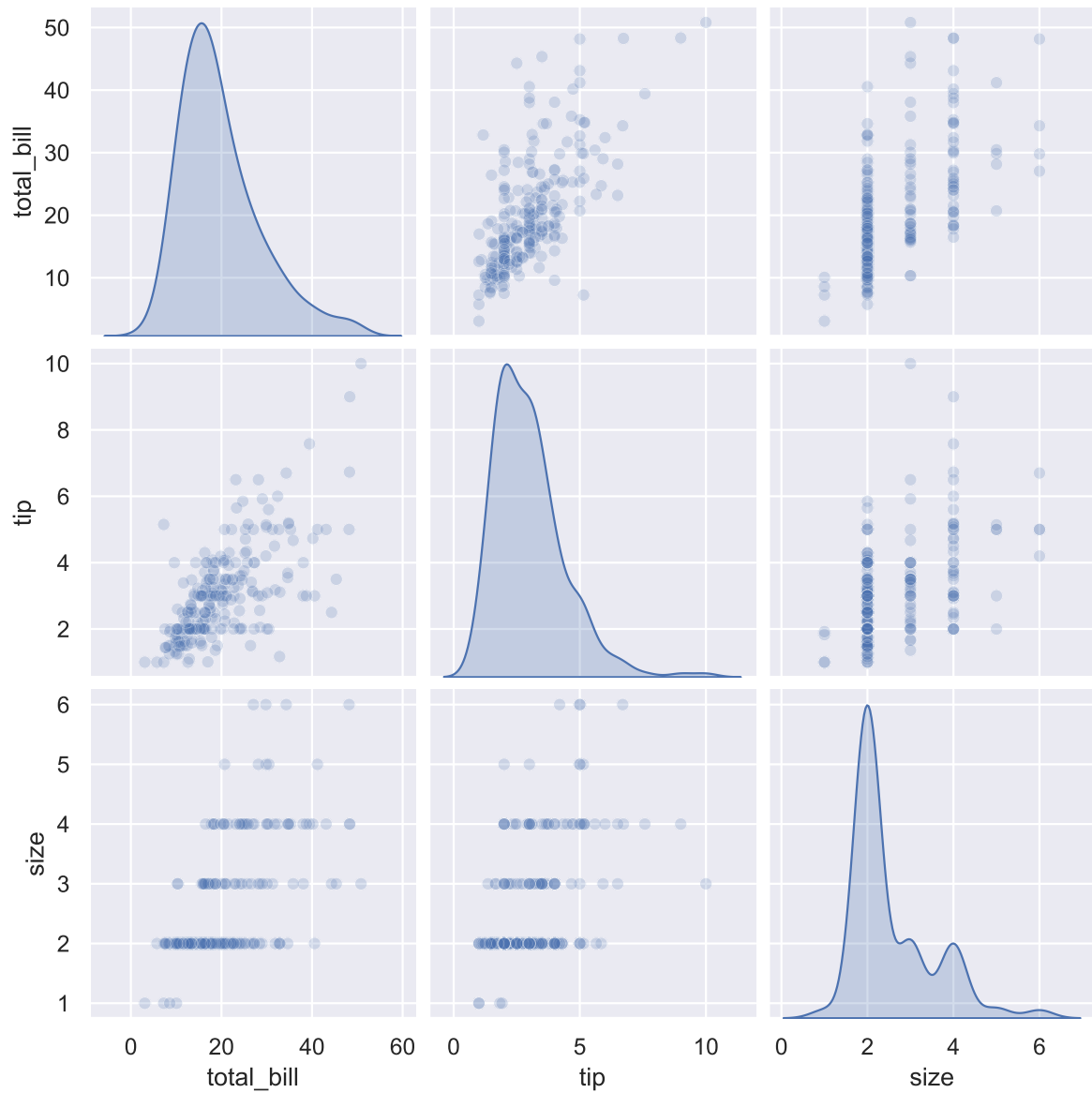
31.3 pairplot()

This is a way to display the pairwise relations among several variables.

Example 31.5. The following code shows the pairplots among all numeric data in `tips`.

```
sns.pairplot(tips, diag_kind='kde', plot_kws={'alpha': 0.2})
```

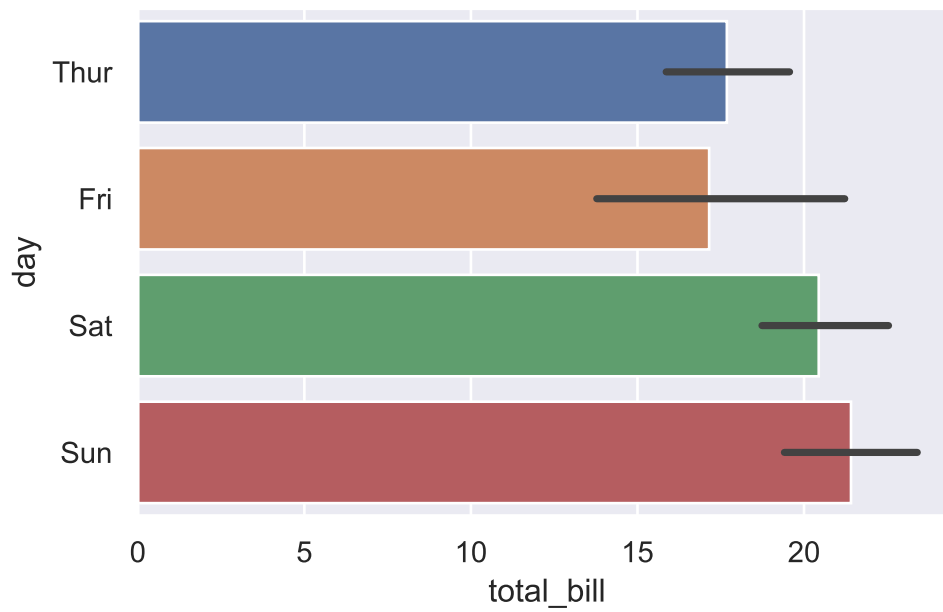
```
<seaborn.axisgrid.PairGrid at 0x1f37f69c8b0>
```



31.4 barplot

Example 31.6 `barplot(x='total_bill', y='day', data=tips, orient='h')`

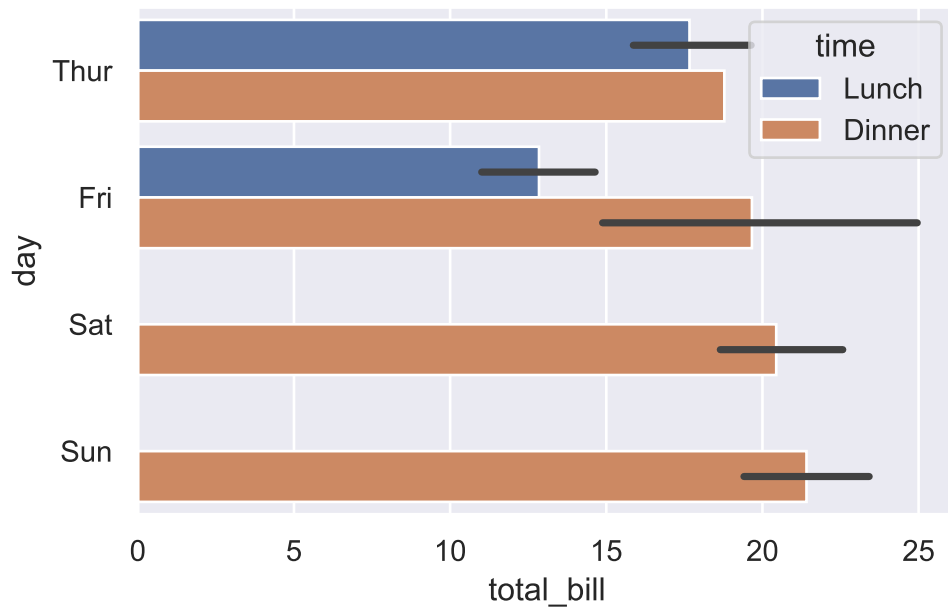
```
<AxesSubplot:xlabel='total_bill', ylabel='day'>
```



In the plot, there are several `total_bill` during each day. The value in the plot is the average of `total_bill` in each day, and the black line stands for the 95% confidence interval.

```
sns.barplot(x='total_bill', y='day', hue='time', data=tips, orient='h')
```

```
<AxesSubplot:xlabel='total_bill', ylabel='day'>
```

In this plot, lunch and dinner are distinguished by colors.

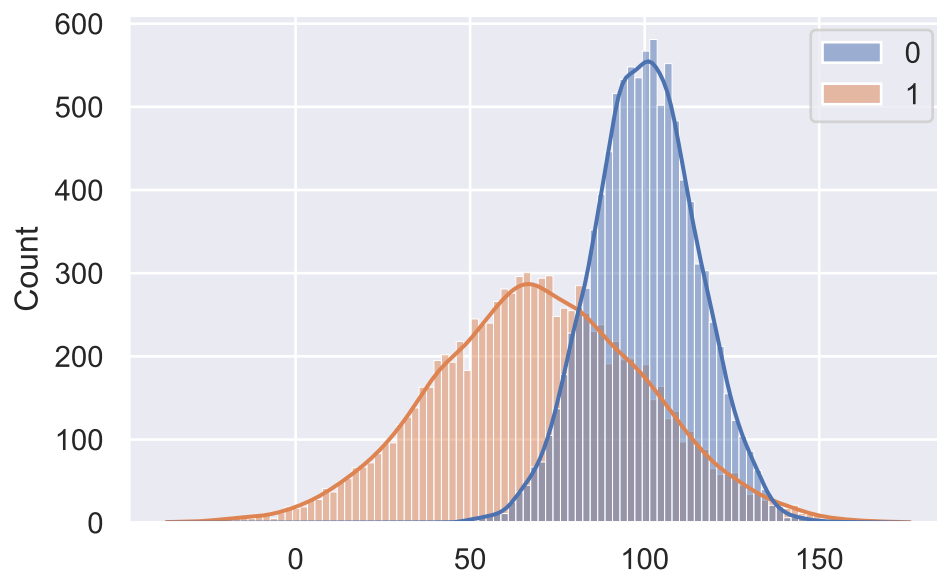
31.5 Histogram

```

Example 31.700, 15
mu = 31.700, sigma = 15
x = mu + sigma * np.random.randn(10000)
y = mu - 30 + sigma * 2 * np.random.randn(10000)
df = pd.DataFrame(np.array([x,y]).T)
sns.histplot(df, bins=100, kde=True)

```

<AxesSubplot:ylabel='Count'>



Please compare this plot with [this Example](#)

32 Examples

32.1 Example 1: USA.gov Data From Bitly

In 2011, URL shortening service Bitly partnered with the US government website `USA.gov` to provide a feed of anonymous data gathered from users who shorten links ending with `.gov` or `.mil`. The data is gotten from [2].

The data file can be downloaded from [here](#). The file is mostly in JSON. It can be converted into a DataFrame by the following code.

```
import pandas as pd
import numpy as np
import json
path = 'assests/datasets/example.txt'
df = pd.DataFrame([json.loads(line) for line in open(path)])
```

We mainly use `tz` and `a` columns. So let us clean it.

```
df['tz'] = df['tz'].fillna('Missing')
df['tz'][df['tz'] == ''] = 'Unknown'
df['a'] = df['a'].fillna('Missing')
df['a'][df['a'] == ''] = 'Unknown'
```

We first want to extract the timezone information from it. The timezone info is in the column `tz`.

```
tzzone = df['tz']
tvc = tzzone.value_counts()
tvc
```

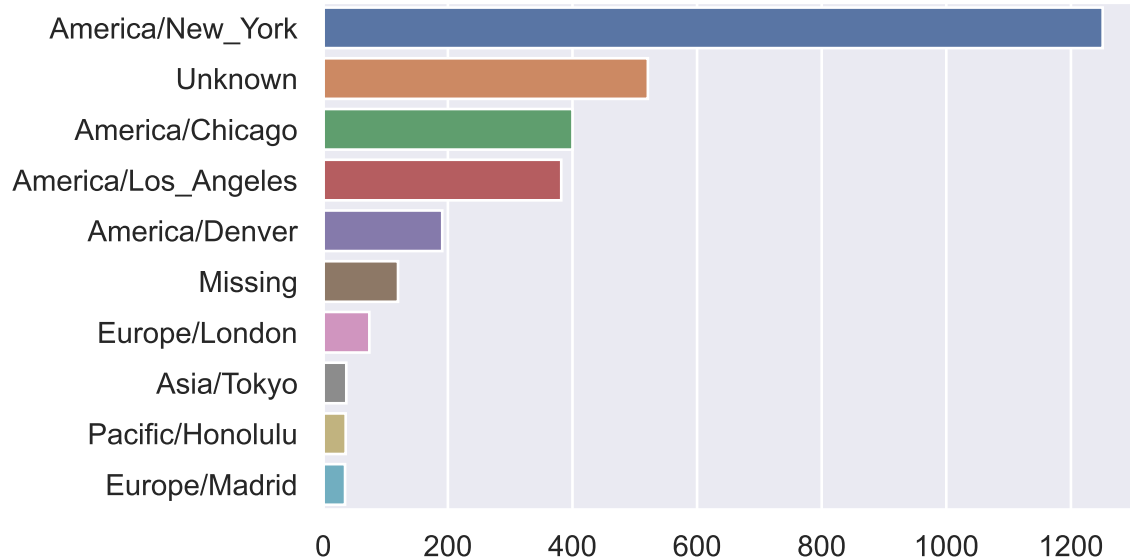
```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning:
return method()
```

	tz
America/New_York	1251
Unknown	521
America/Chicago	400
America/Los_Angeles	382
America/Denver	191
Missing	120
Europe/London	74
Asia/Tokyo	37
Pacific/Honolulu	36
Europe/Madrid	35
America/Sao_Paulo	33
Europe/Berlin	28
Europe/Rome	27
America/Rainy_River	25
Europe/Amsterdam	22
America/Indianapolis	20
America/Phoenix	20
Europe/Warsaw	16
America/Mexico_City	15
Europe/Stockholm	14
Europe/Paris	14
America/Vancouver	12
Pacific/Auckland	11
Europe/Moscow	10
Europe/Helsinki	10
Europe/Oslo	10
Europe/Prague	10
Asia/Hong_Kong	10
America/Puerto_Rico	10
Asia/Calcutta	9
America/Montreal	9
Asia/Istanbul	9
Europe/Lisbon	8
America/Edmonton	6
Chile/Continental	6
Australia/NSW	6
Europe/Vienna	6
Asia/Bangkok	6
Europe/Athens	6
Asia/Seoul	5
Europe/Budapest	5
America/Anchorage	5
Europe/Copenhagen	5
Asia/Dubai	4
Asia/Beirut	4 148
America/Halifax	4
Europe/Zurich	4
Europe/Bucharest	4
Europe/Brussels	4
America/Winnipeg	4
Asia/Jakarta	3
Asia/Harbin	3

After cleaning data, we would like to visualize the value counts.

```
import seaborn as sns
sns.set_theme()
sns.barplot(x=tvcs[:10].values, y=tvcs[:10].index)
```

<AxesSubplot:>



We then would like to extract information from the column `a`. This column is about the agent of the connection. The important info is the part before the space ' '.

```
agent = df['a']
agent = agent.str.split(' ').str[0]
avc = agent.value_counts()
avc[:10]
```

C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()

	a
Mozilla/5.0	2594
Mozilla/4.0	601
GoogleMaps/RochesterNY	121
Missing	120
Opera/9.80	34
TEST_INTERNET_AGENT	24
GoogleProducer	21
Mozilla/6.0	5
BlackBerry8520/5.0.0.681	4
BlackBerry8520/5.0.0.592	3

Now let us assume that, if `Windows` appears in column `a` the user is using `Windows` os, if not then not. In this case, the os can be detected by the following code.

```
df['os'] = np.where(df['a'].str.contains('Windows'), 'Windows', 'Not Windows')
```

Now we can make a bar plot about the counts based on `os` and `timezone`.

```
tz_os_counts = df.groupby(['tz', 'os']).size().unstack().fillna(0)
tz_os_counts.head()
```

```
C:\Users\Xinli\anaconda3\envs\ml22\lib\site-packages\IPython\core\formatters.py:343: FutureWarning
return method()
```

os	Not Windows	Windows
tz		
Africa/Cairo	0.0	3.0
Africa/Casablanca	0.0	1.0
Africa/Ceuta	0.0	2.0
Africa/Johannesburg	0.0	1.0
Africa/Lusaka	0.0	1.0

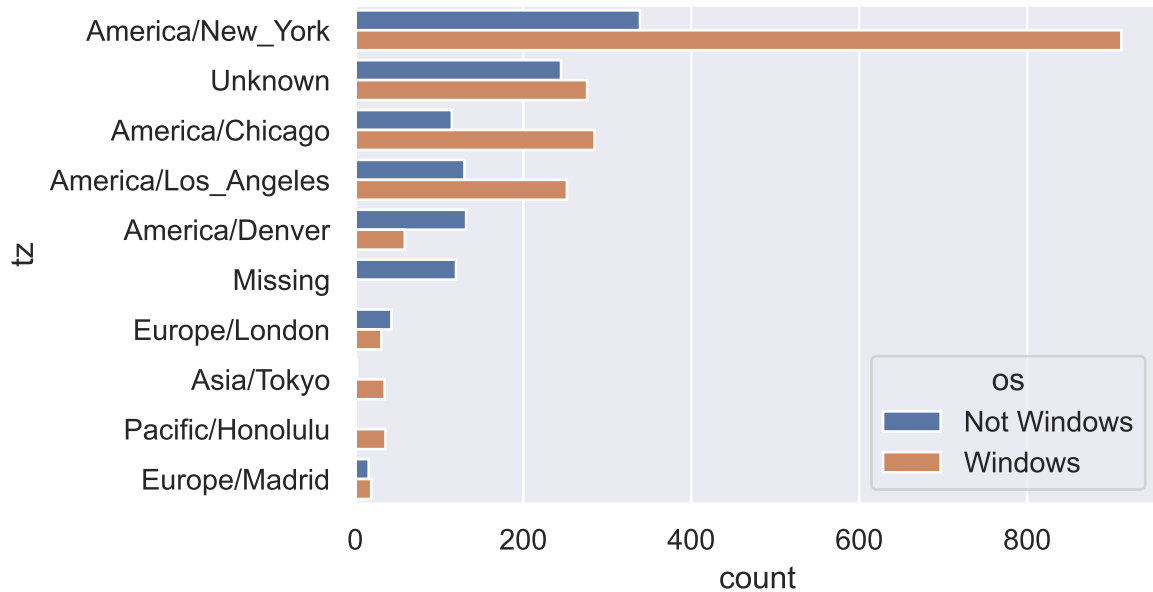
We then turn it into a `DataFrame` using the `.stack()`, `.unstack()` tricks.

```
tovc = tz_os_counts.stack()[tz_os_counts.sum(axis=1).nlargest(10).index]
tovc.name = 'count'
dftovc = pd.DataFrame(tovc).reset_index()
```

Finally we may draw the bar plot.

```
sns.barplot(x='count', y='tz', hue='os', data=dftovc)
```

```
<AxesSubplot:xlabel='count', ylabel='tz'>
```



32.2 Example 2: US Baby Names 1880–2010

32.3 Example 3: USDA Food Database

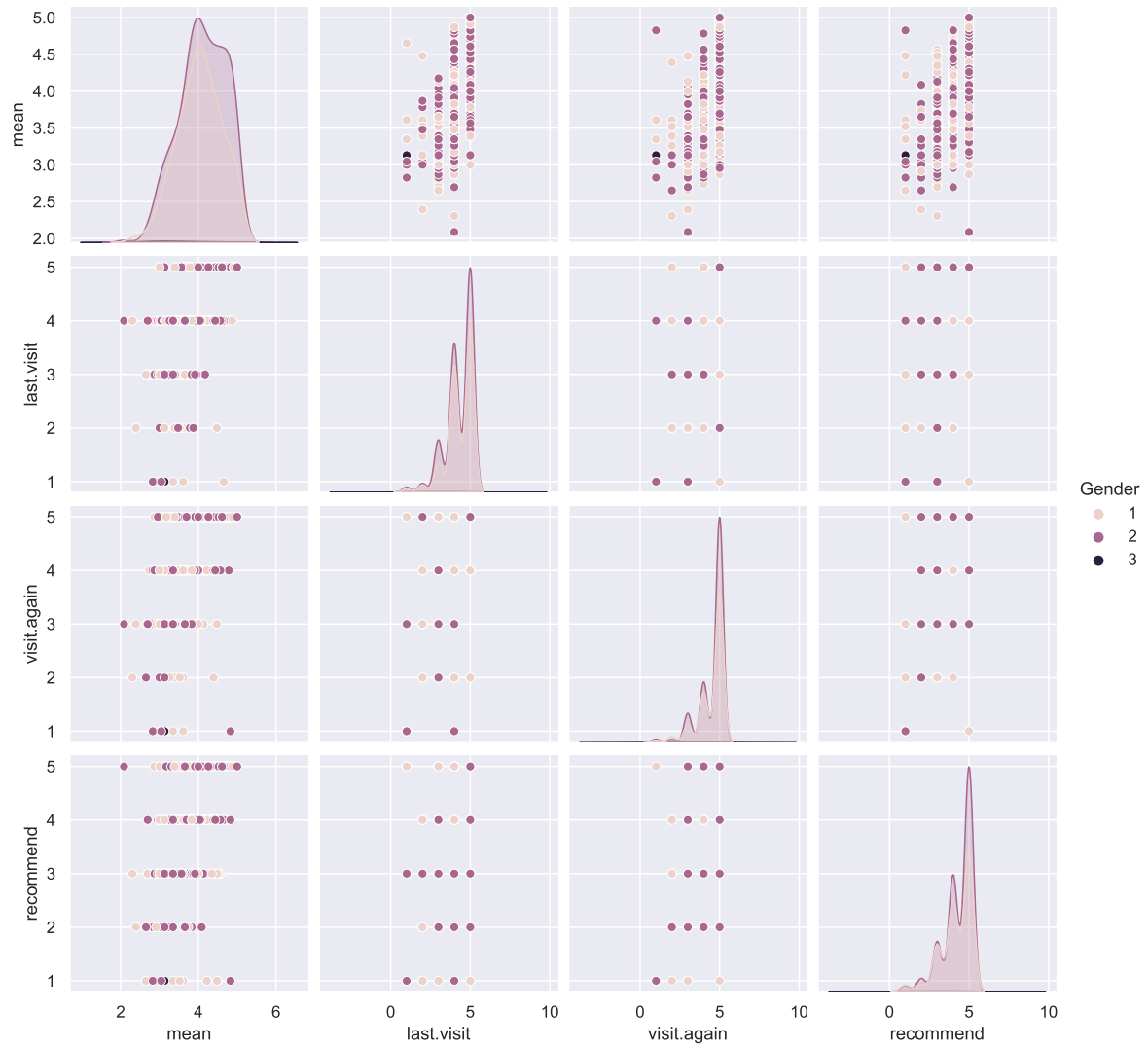
32.4 Example 4: 2012 Federal Election Commission Database

33 Exercises

Exercise 33.1. Please download the `mtcars` file from [here](#) and read it as a DataFrame. Then create a scatter plot of the `drat` and `wt` variables from `mtcars` and color the dots by the `carb` variable.

```
df = pd.read_csv('assests/datasets/QSR.csv')
df['mean']=df.loc[:, 'appealing': 'menu'].mean(axis=1)
sns.pairplot(data=df[['mean', 'last.visit', 'visit.again', 'recommend', 'Gender']], hue='G
```

```
<seaborn.axisgrid.PairGrid at 0x1f302873220>
```

34 Projects

References

- [1] YOUENS-CLARK, K. (2020). *Tiny python projects*. Manning Publications.
- [2] MCKINNEY, W. (2017). *Python for data analysis: Data wrangling with pandas, NumPy, and IPython*. O'Reilly Media.
- [3] SHAW, Z. A. (2017). *Learn python 3 the hard way*. Addison Wesley.
- [4] SWEIGART, A. (2020). *Automate the boring stuff with python, 2nd edition practical programming for total beginners: Practical programming for total beginners*. No Starch Press.
- [5] KLOSTERMAN, S. (2021). *Data science projects with python: A case study approach to gaining valuable insights from real data with machine learning*. Packt Publishing, Limited.
- [6] PRABHAKARAN, S. (2018). [101 NumPy exercises for data analysis \(python\)](#).
- [7] PRABHAKARAN, S. (2018). [101 pandas exercises for data analysis](#).

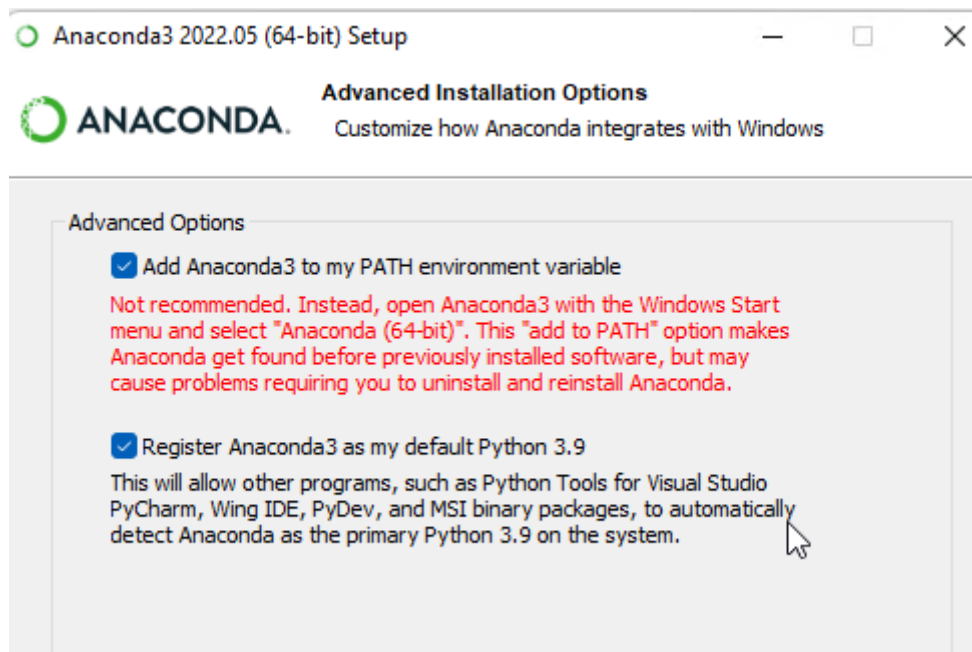
Part VII

Setup

A VS Code + Anaconda

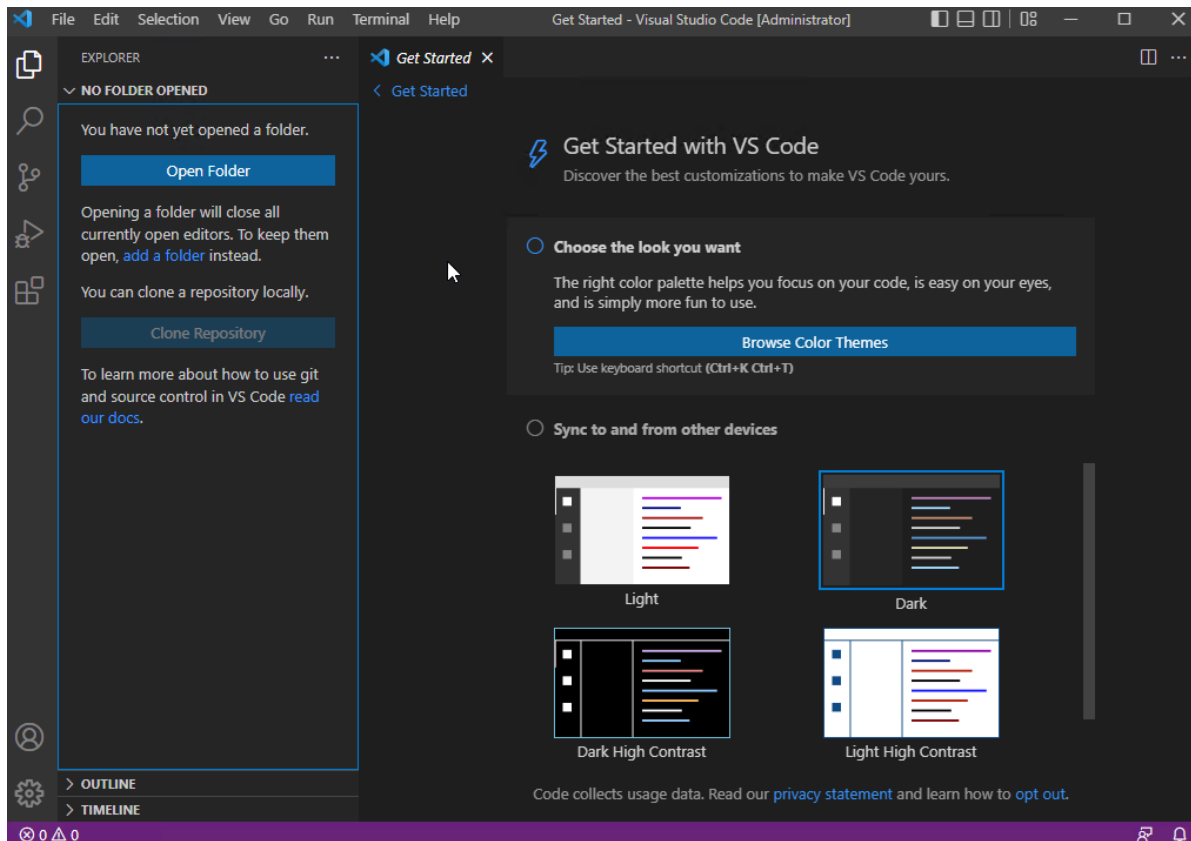
Note that all the following steps are tested in Windows 10/11. If you use other operation systems please contact me.

1. Go to [Anaconda download page](#). Download and install Anaconda.
2. Go to [VS Code download page](#). Download and install VS Code. Actually Anaconda contains one copy of VS Code. Here I just assume that some of you intall VS Code before Anaconda.
3. When installing VS Code, you may accept all default settings. When installing Anaconda, please pay attention to the PATH setting.

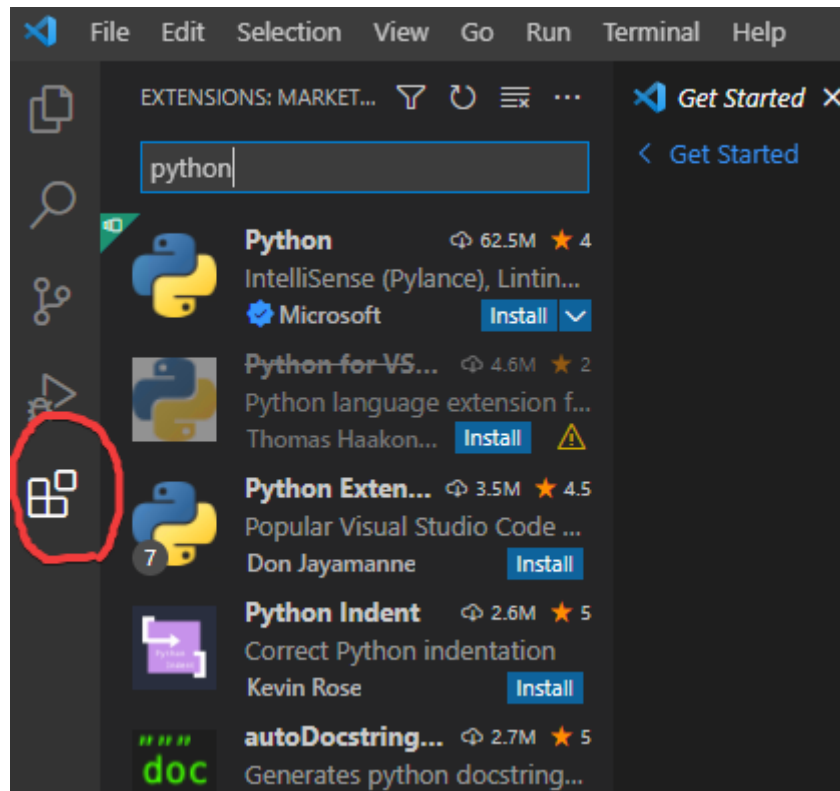


The first box is unchecked by default. This setting is related to the ability to easily run Python code in Terminals. I recommend you to check it. If you don't check it during this step, you may add it to the system environment variable PATH manually later.

4. The UI of VS Code looks as follows.



Please look at the fifth tab from the left sidebar. It is the Extension tab.



Please search for `python` and install the first Python extension from Microsoft. It will actually install five extensions. These are all we need for now.

5. After all are installed, go to the first Explorer tab on the left side bar, and **Open Folder**. This is the working directory for your project.

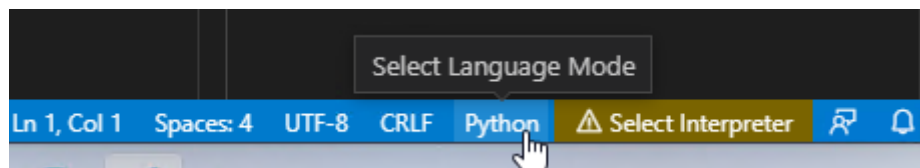
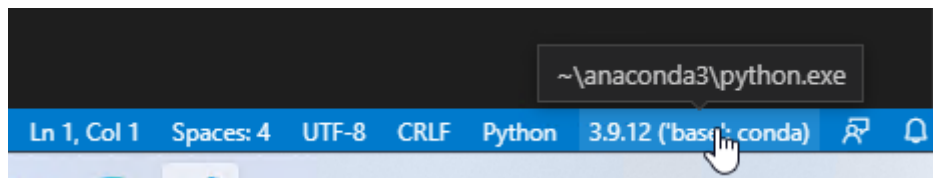
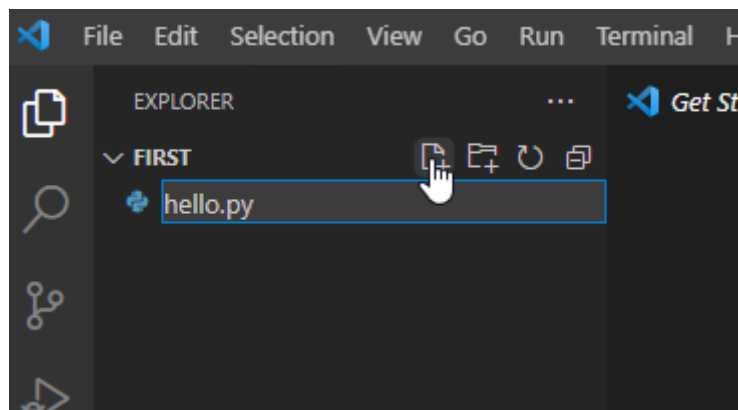
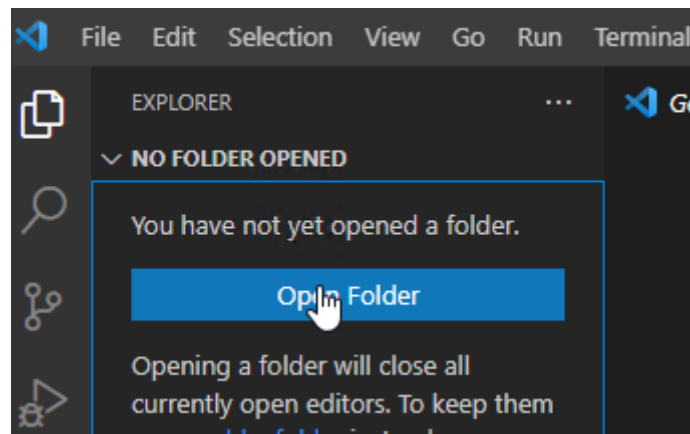
Choose one folder and start a new `.py` file.

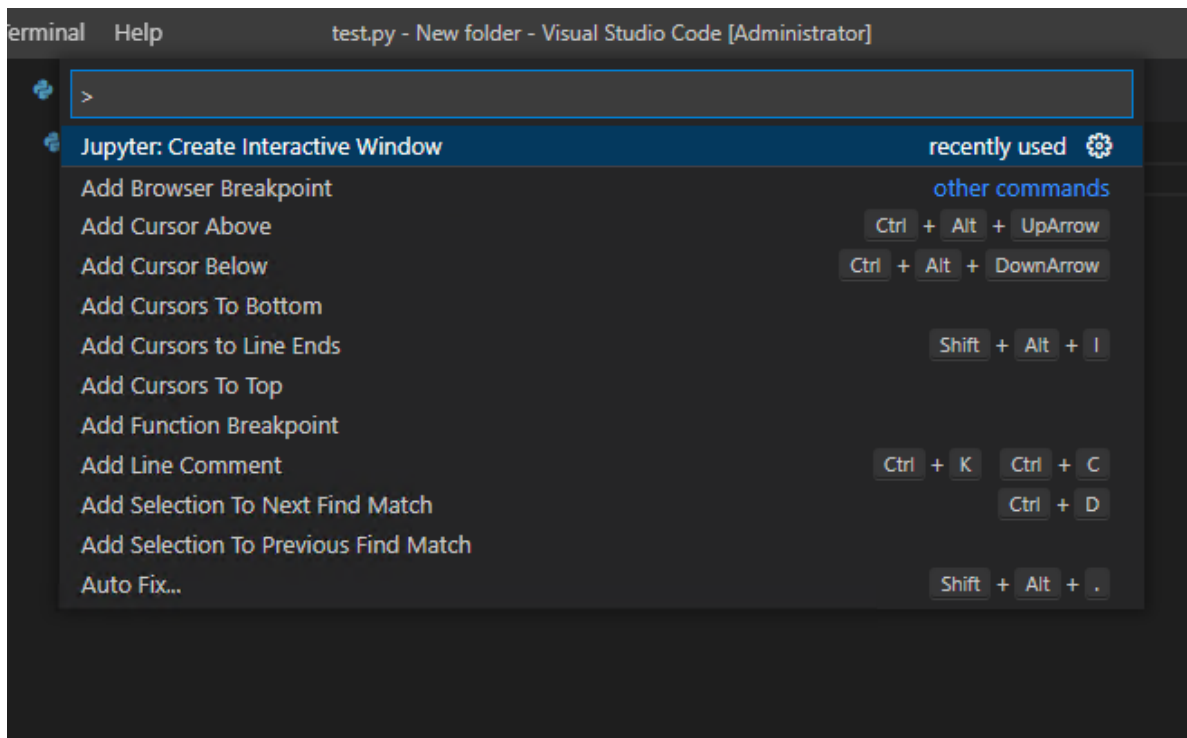
6. If everything is setup correctly, you may see the Python version and environment name at the right lower corner. In our case the environment name is `base`. We will need it in the future.

Note that we are not looking at the **Python** for Language Mode. If you see **Select Interpreter** there, it means that VS Code doesn't find your Python interpreter. Please restart VS Code or select it manually, or check whether Anaconda is installed correctly.

To check whether everything is setup correctly, please run the following tests.

1. Use `ctrl+shift+p` to open the Command Palette, type "Jupyter: Create Interactive Window" and press `enter` to open the Jupyter interactive window.





If the interactive window starts and you see the loading information of your kernel as follows, especially you see the environment name on the right upper corner, then you get everything correctly. However we will still do more tests.

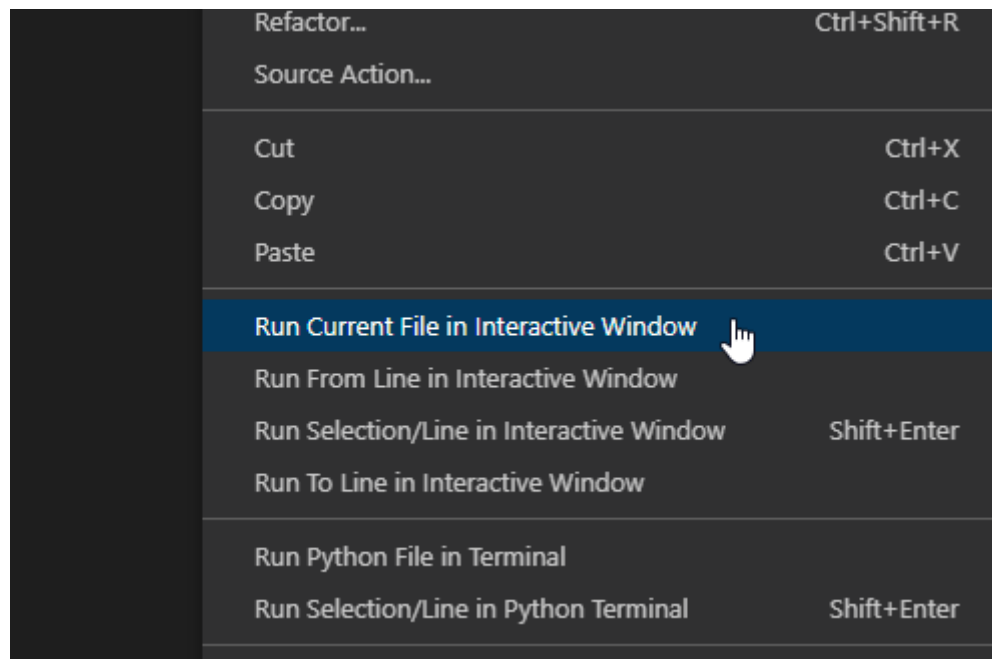
2. In the window type `import numpy as np` to test whether you are able to import packages. If you don't see any error messages then it means good.
3. In the editor window, type `import numpy as np` and right click the body to choose **Run Current File in Interactive Window**, and see whether it runs in interactive window.
4. Open the terminal. Please use **Command Prompt** instead of **Powershell**. Activate the conda environment by type the command `conda activate base` in the example above. Please change the name to match your own environment. If `conda` cannot be recognized, please register Python and Anaconda to the system environment path. Please see the next Appendix for details.

Interactive-1 X

X Clear All ↺ Restart ... base (Python 3.9.12)

```
Python 3.9.12 (main, Apr 4 2022,
05:22:27) [MSC v.1916 64 bit (AMD64)]
Type 'copyright', 'credits' or 'license' for
more information
IPython 8.2.0 -- An enhanced Interactive
Python. Type '?' for help.
```

```
[1] import numpy as np
✓ 0.2s
```



B Google Colab

Google Colab is a product from Google Research, that allows anybody to write and execute arbitrary Python code through the browser, and is especially well suited to machine learning, data analysis and education.

Here is the link to [Google Colab](#). To use it you should have a Google account. Otherwise it is very simple to start, since a lot of packages for our course are already installed.

B.1 Install packages

If you would like to install more packages, you can type `%pip install + package name` in a code cell and execute it.

The drawback here is that Google Colab can only stay for 24 hours. After that, all additionally installed packages will be earsed. However you can put `%pip install + package name` at the beginning of your notebook and these packages will be installed every time you run the notebook.

B.2 Upload files

You may directly upload files to the working directory of Google Colab. This has to be done in the browser. When working with these files, you may just use relative paths.

The drawback here is that Google Colab can only stay for 24 hours. After that, although your `.ipynb` files will be stores, all other files will be earsed.

B.3 Mount Google Drive

One way to let the uploaded files stay in cloud is to upload them to Google Drive, and then load your Google Drive contents from Google Colab.

Goole Drive is a cloud storage service provided by Google. When you register a Google account you will be automatically assigned a Google Drive account. You may get access to it from [this link](#).

Here are the steps to mount Google Drive:

1. Upload your files to your Google Drive.
2. Run the following codes in Colab code cells before you are loading the uploaded files:

```
from google.colab import drive
drive.mount('/content/gdrive')
```

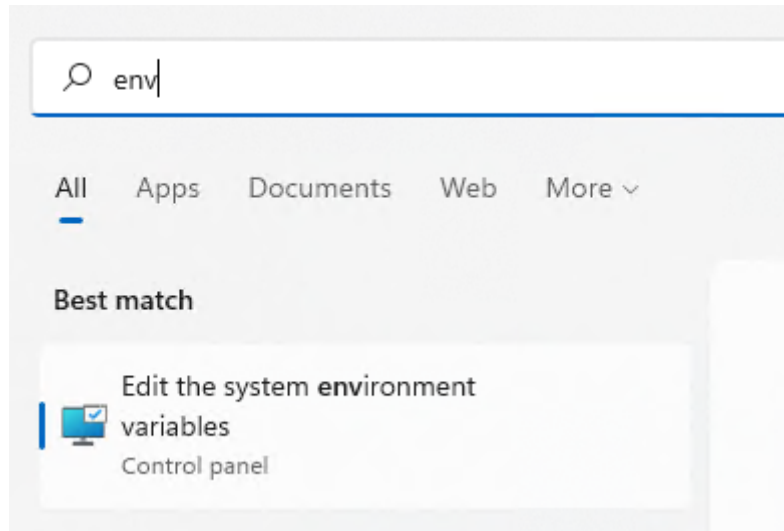
3. A window pop up asking you about the permission. Authorize and the drive is mounted.
4. To work in directories, the most popular commands are
 - `%ls`: list all files and folders in the working directory.
 - `%cd + folder name`: Get into a specific folder.
 - `%cd ..`: Get into the parent folder. Then use these commands to find the files your just uploaded.
5. Finally you may directly get access to those files just like they are in the working directory.

Part VIII

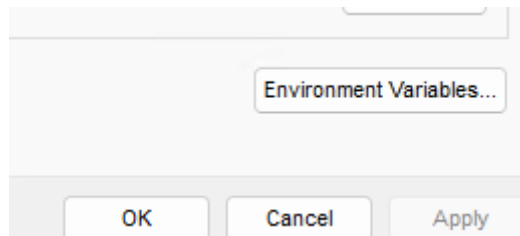
PATH

Here are the steps to edit the system environment variables in Windows 10/11.

1. First in the start menu search for `Edit the system environment variables`.



2. Then click the `Environment Variables...` button at the right lower corner.



3. Find the `Path` variable in either the upper window or the lower window. Use which one depends on whether you want to register the variable for the user or for the machine. In this example I add for the user.
4. Finally double click the variable and add the following path to it. You need to make changes according to your installation. I recommend you to locate your Anaconda installation first to get the path.

User variables for WDAGUtilityAccount

Variable	Value
Path	C:\Users\WDAGUtilityAccount\anaconda3;C:\Users\WDAGUtilityAc...
TEMP	C:\Users\WDAGUtilityAccount\AppData\Local\Temp
TMP	C:\Users\WDAGUtilityAccount\AppData\Local\Temp

New... Edit... Delete

System variables

Variable	Value
ComSpec	C:\Windows\system32\cmd.exe
DriverData	C:\Windows\System32\Drivers\DriverData
NUMBER_OF_PROCESSORS	8
OS	Windows_NT
Path	C:\Windows\system32;C:\Windows;C:\Windows\System32\Wbem;...
PATHEXT	.COM;.EXE;.BAT;.CMD;.VBS;.VBE;.JS;.JSE;.WSF;.WSH;.MSC
PROCESSOR_ARCHITECTURE	AMD64

New... Edit... Delete

C:\Users\WDAGUtilityAccount\anaconda3
C:\Users\WDAGUtilityAccount\anaconda3\Library\mingw-w64\bin
C:\Users\WDAGUtilityAccount\anaconda3\Library\usr\bin
C:\Users\WDAGUtilityAccount\anaconda3\Library\bin
C:\Users\WDAGUtilityAccount\anaconda3\Scripts

Part IX

Virtual environments