Python/R for Data Science

Lecture notes for 2022 Fall at Arkansas Tech University

Xinli Xiao

2022-08-16T01:18:34-05:00

Table of contents

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

1 Preliminaries

1.1 Why Python?

1.1.1 Python is easy to learn and use

1.1.2 Python is easy to read

1.1.3 Python Community is mature and supportive

1.2 Hello world!

We will mainly focus on this code editor mode at the beginning and check our results or do some simple computations in the console.

Notebook is another very popular mode to use Python. We will talk about it later.

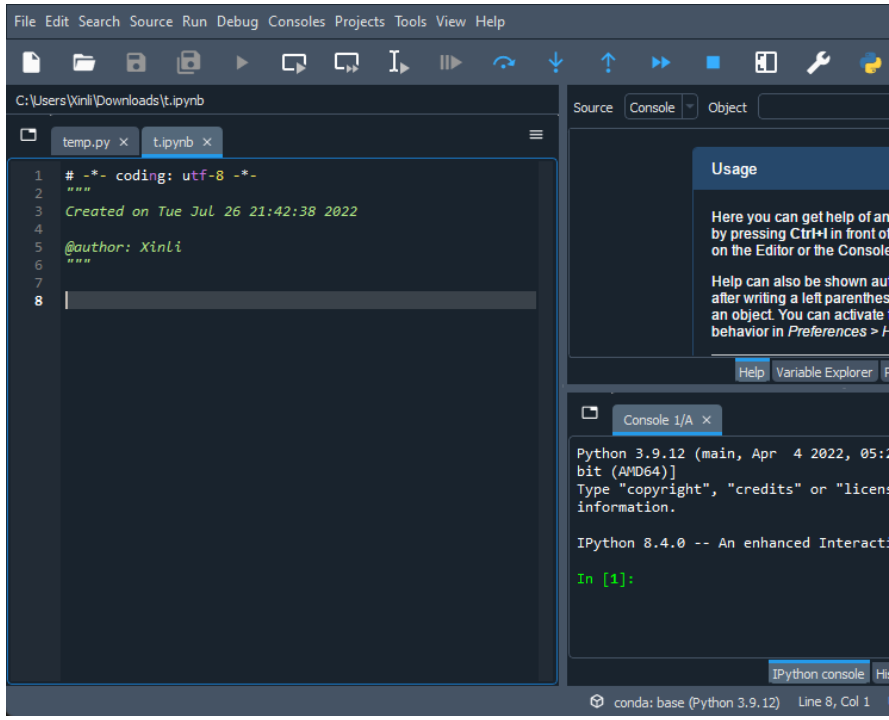
1.2.1 Set up Python environment using IDEs

Please follow the following steps to run your first line of Python codes.

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

1. Go to Anaconda download page. Download and install Anaconda.
2. There are several IDEs for Python bundled with Anaconda. Pick any one you like. I personally use VS Code. Here we use Spyder as an example for now since it doesn't require any configurations.

3. Here is a screenshot of Spyder 5.1.5.



4. The right lower window is the console. Type the following code, and run. If `Hello world!` is displayed, the Python environment is set up successfully. Now you can start to play with Python!

1.2.2 Code editor

The left window is called *Code Editor*. You can write multiple lines of codes in the code editor and run them all together. The output results might appear in the console.

As shown in the screenshot, when press `F5` to run file, the codes in the code editor will be excuted line by line.

The code in the example is

```python
print('Hello world!')
print('Another line')
# Everything after # are comments that won't be excuted.
```

```
Hello world!
Another line
```

1.2.3 IPython and Jupyter

1.2.4 Linters

1.3 Projects

Exercise 1.1 (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 1.2 (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 1.3 (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: FutureWa
  return method()
```

	GRID_TYPE	GAME_ID	GAME_EVENT_ID	PLAYER_ID	PLAYER_NAME	TEAM_II
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: FutureWa
  return method()
```

	GRID_TYPE	GAME_ID	GAME_EVENT_ID	PLAYER_ID	PLAYER_NAME	TEAM_I
2	Shot Chart Detail	0022100002	37	201939	Stephen Curry	16106127
6	Shot Chart Detail	0022100002	176	201939	Stephen Curry	16106127
9	Shot Chart Detail	0022100002	352	201939	Stephen Curry	16106127
16	Shot Chart Detail	0022100002	510	201939	Stephen Curry	16106127
18	Shot Chart Detail	0022100002	642	201939	Stephen Curry	16106127

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.

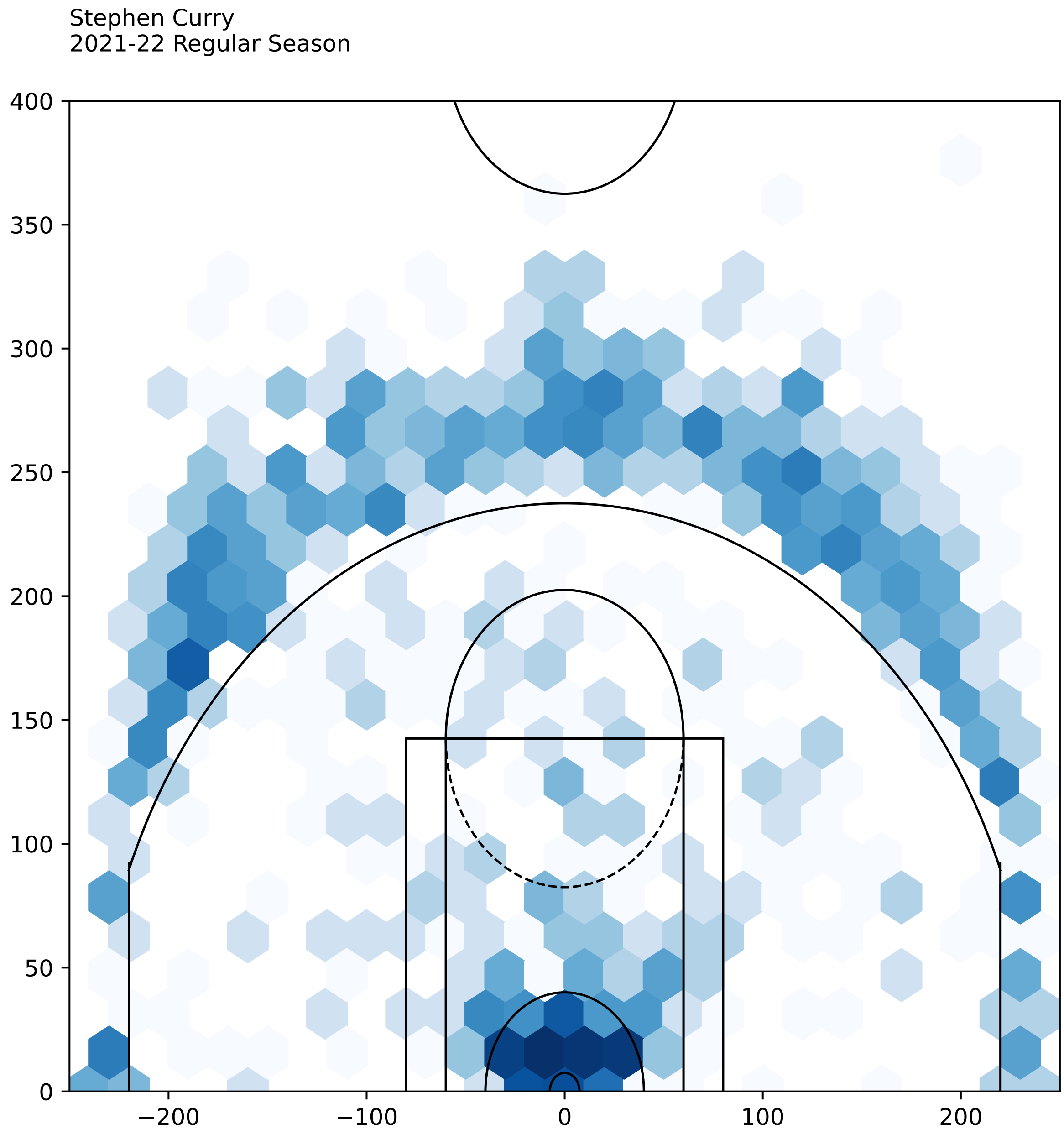
> **Note**
>
> Note that, although `draw_cort` is long, it is not hard to understand. It just draws a court piece by piece.

```python
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)
```

```python
    # 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, widt=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='l
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
400
350
300
250
200
150
100
50
0
−200
−100
0
100
200

2 Python Basics

2.1 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.

2.1.1 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`

2.1.2 `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 loos 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 relations between the variable / constant and the name of the variable / constant. We will talk about these later.

2.2 Fundamentals

This section is mainly based on [2].

2.2.1 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.

```c
/*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 readibility, as follows. However it is not mandatary.

```c
/*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 mandatary.

```python
# 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.

2.2.2 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.

2.2.3 `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 `assests/codes/`. The file is as follows.

```python
# from assests/codes/example.py
display(Markdown(text))
def f(x):
    print(x)

A = 'You get me!'
```

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

```python
from assests.codes import example

example.f(example.A)
```

```
You get me!
```

2.2.4 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+/`.

2.2.5 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.

```python
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`.

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

2.2.6 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.

2.2.7 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 2.1 (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`:  1550113040832
This is the id of the first list of `container`:  1550112987776
This is the new `container`:  ([1, 2], [2])
This is the id of the new `container`:  1550113040832
This is the id of the first list (which is updated) of the new `container`:  1550112987776
```

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

2.3 Flows and Logic

2.3.1 `for` loop

2.3.2 `if` conditional control

2.4 `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`

2.4.1 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]
```

2.5 `dict`

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

2.6 Exercises

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

Exercise 2.1 (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 2.2 (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 2.3 (`==` 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 2.4 (Play with strings)**.** Please excute 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: '. " \
           "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 do
```

Exercise 2.5 (`split` and `join`)**.** Please excute the code below line by line and explain what happens in text cells.

Exercise 2.6 (List reference)**.**

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 2.7 (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 2.8 (More list comprehension)**.** Use list comprehension to find all of the numbers from 1-1000 that are divisible by 7.

Exercise 2.9 (More list comprehension)**.** Count the number of spaces in a string.

Exercise 2.10 (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 2.11 (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]`.

2.7 Projects

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

Exercise 2.12 (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 2.13 (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 2.14 (Color the Gnomic 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')
```

```
redgreenblueyellow
```

Consider an (incomplete) Gnomic 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'\
             'CTGCATGCTTAGTGCACTCACGCAGTATAATTAATAACTAATTACTGTCGTTGACAGGAC'\
             'ACGAGTAACTCGTCTATCTTCTGCAGGCTGCTTACGGTTTCGTCCGTGTTGCAGCCGATC'\
             'ATCAGCACATCTAGGTTTTGTCCGGGTGTGACCGAAAGGTAAGATGGAGAGCCTTGTCCC'\
             'TGGTTTCAACGAGAAAACACACGTCCAACTCAGTTTGCCTGTTTTACAGGTTCGCGACGT'\
             'GCTCGTACGTGGCTTTGGAGACTCCGTGGAGGAGGTCTTATCAGAGGCACGTCAACATCT'\
             'TAAAGATGGCACTTGTGGCTTAGTAGAAGTTGAAAAAGGCGTTTTGCCTCAACTTGAACA'\
             'GCCCTATGTGTTCATCAAACGTTCGGATGCTCGAACTGCACCTCATGGTCATGTTATGGT'\
             'TGAGCTGGTAGCAGAACTCGAAGGCATTCAGTACGGTCGTAGTGGTGAGACACTTGGTGT'\
             'CCTTGTCCCTCATGTGGGCGAAATACCAGTGGCTTACCGCAAGGTTCTTCTTCGTAAGAA'\
             'CGGTAATAAAGGAGCTGGTGGCCATAGTTACGGCGCCGATCTAAAGTCATTTGACTTAGG'\
             'CGACGAGCTTGGCACTGATCCTTATGAAGATTTTCAAGAAAACTGGAACACTAAACATAG'
```

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.