Tutorial 1: Basic Python Programming

You need to know some basic Python programming to complete the project. This tutorial will teach you these basics. If you are already familiar with Python, you can skip this tutorial and proceed to Tutorial 2.

If you are looking for some additional resources to learn Python, QuantEcon is a great resource for learning programming, with a focus on economics and finance. You can find their Python programming lectures here.

Introduction

Python is a general purpose programming language, which is free and open source. Open source means that the code is available for anyone to use, modify, and distribute.

Python, when installed, comes with a standard library that includes many modules and functions to perform common tasks. However, we often need to use additional *packages* to perform more specialized tasks. Some of the most commonly used packages for data analysis and scientific computing include:

- **NumPy**: provides support for large, multi-dimensional arrays and matrices, along with a collection of mathematical functions to operate on these arrays.
- **Pandas**: provides data structures and data analysis tools for working with structured data.
- **Matplotlib**: provides enhanced functionality for creating plots.
- **SciPy**: provides a collection of numerical algorithms and toolboxes to perform scientific computing tasks such as differentiation, intergration, optimization, etc.

Getting Started

For this project, you will use Google Colab, which is a free cloud service that allows you to write and execute Python code in your browser.

You will write and execute your code in Colab notebooks, which are interactive documents that can contain both code and rich text elements (such as paragraphs, equations, figures, links, etc.). Colab notebooks have the file extension `.ipynb`. If you have used Jupyter notebooks before, note that Colab notebooks are just Jupyter notebooks that are hosted by Colab.

To get started, follow these steps:

1. Open your web browser and go to Google Colab.
2. Sign in with your Google account.
3. Create a new notebook by clicking on `File` -> `New notebook in drive`.
4. You can now start writing and executing Python code in the notebook. To test it out, type `print('Hello!')` in a code cell and run it by clicking the play button or pressing `Shift + Enter`.
5. Once you are done, you can save the notebook to your Google Drive or download it to your computer.

Aside: If you want to do some serious programming, you should install Python on your computer, which takes a bit more work. But since the focus of this class is not programming, Google Colab is sufficient for our purposes.

Navigating this Tutorial

This tutorial is meant to be interactive, so you need to use the `Run` button to execute the code snippets to see the output. You can also modify the code and run it to see how the output changes. Remember that once you refresh the page, the code will go back to its original state. Try it with the code snippet below by first running it and then replacing `World` with your name and running it again.

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

You can also copy the code to a Google Colab notebook and play around with it there.

Python Basics

Importing libraries

In Python, you can import libraries using the `import` statement. For example, to import the `numpy` library and then use `sqrt` function from it, you can do the following:

```
import numpy
numpy.sqrt(25)
```

However, it is common to import libraries with an alias to make the code more readable. For example, you can import `numpy` as `np`, which is a common convention, and then use the `sqrt` function as follows:

```
import numpy as np
np.sqrt(25)
```

Data types and variables

Python has several built-in data types, including integers, floats, booleans, strings, and lists.

- Integers: whole numbers, e.g., 1, 2, 3, etc.
- Floats: numbers with decimal points, e.g., 1.0, 2.5, 3.14, etc.
- Booleans: True or False.
- Strings: sequences of characters enclosed in single or double quotes, e.g., ‘Hello’, “World”, etc.
- Lists: ordered collections of elements enclosed in square brackets, e.g., [1, 2, 3], [‘a’, ‘b’, ‘c’], etc.

You can assign values to variables using the `=` operator. Python will automatically infer the data type based on the value assigned to the variable.

For instance, you can assign the integer value of 1 to a variable `x` as follows:

```
x = 1
x
```

Note that in the above code, we added `x` at the end, so that when we run the code, Python will print the value of `x`.

To create a list, we can enclose the elements in square brackets as follows:

```
x = [1, 1.1, 'Hello', True]
x
```

Lists can contain elements of different data types. You can access elements of a list using their index. Python uses zero-based indexing, meaning the first element of the list has an index of 0.

```
print('1st element:', x[0])
print('3rd element:', x[2])
```

Functions

Python has a number of built-in functions that are available without import. For example, the `print` function is used to display output. Some other built-in functions include `len`, `max`, `min`, `sum`, etc. You can try these out in the code cell below:

```
x = [0, 1, 2, 3, 4]
sum(x)
```

We also saw that if built-in functions are not sufficient, we can import libraries and use functions from them (e.g., `numpy.sqrt`).

However, sometimes we need to define our own functions. We can define a function using the `def` keyword followed by the function name and the arguments in parentheses. The function body is indented and can contain multiple lines of code. Here is an example of a simple function that returns the square of a number:

```
def square(x):
    return x**2

square(5)
```

Note that in Python, `**` is used for exponentiation.

Exercise: Define a function `add` that takes two arguments `x` and `y` and returns their sum. Test the function by calling it with `x=3` and `y=4`.

Now say we defined the function `f` as follows:

```
def f(x, a, b):
    return a*x + b
```

We can call the function `f` with the arguments `x=2`, `a=3`, and `b=4` either as `f(2, 3, 4)` or as `f(x=2, a=3, b=4)`. Both will give the same result. Try it out.

NumPy Arrays

NumPy is a popular Python library for numerical computing. The most important data structure in NumPy is the `ndarray`, which is a multi-dimensional array. You can create a NumPy array from a Python list using the `np.array` function. For example:

```
import numpy as np
x = np.array([0, 1, 2, 3, 4])
x
```

NumPy arrays are similar to lists but must contain elements that are either all numeric or all boolean. You can perform element-wise operations on NumPy arrays, which is not possible with Python lists. For example, you can square all elements of the NumPy array defined above as follows:

```
x**2
```

Sometimes it can be useful to create a grid of evenly spaced numbers. You can do this using the `np.linspace` function, which takes the start, end, and number of points as arguments. For example, to create an array of 5 numbers between 0 and 1:

```
np.linspace(0, 1, 5)
```

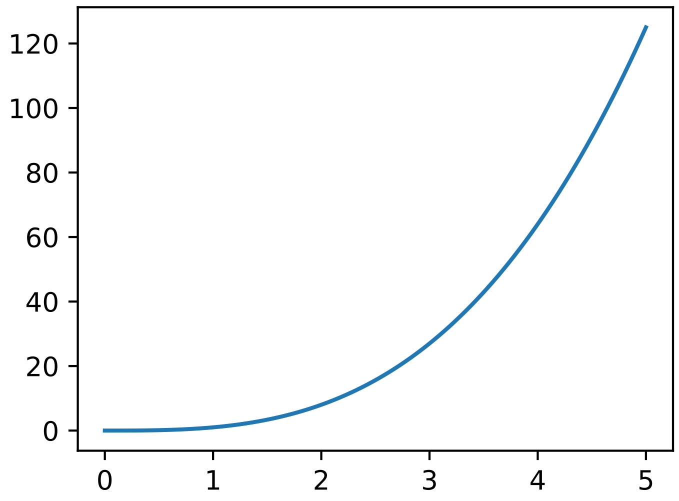
Plots

We will use the `matplotlib` library to create plots. To do so, we first need to import the `pyplot` module from `matplotlib`. Then we can use the `plot` function to create a simple line plot.

Here is an example of creating a plot of $y = x^3$ for x between 0 and 5:

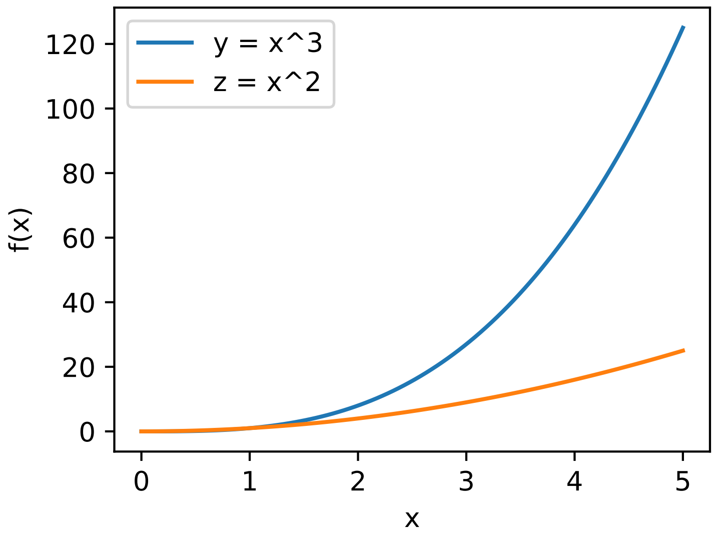
```
import matplotlib.pyplot as plt
import numpy as np

x = np.linspace(0, 5, 100)
y = x**3
plt.plot(x, y)
```



Now what if we wanted to add another line for $z = x^3$ to the same plot? We can do this by calling the `plot` function again. The code below implements this and also adds a legend and labels to the plot.

```
plt.plot(x, y, label='y = x^3')
plt.plot(x, x**2, label='z = x^2')
plt.xlabel('x')
plt.ylabel('f(x)')
plt.legend()
```



Loops

Loops are used to execute a block of code multiple times. Python has two types of loops: `for` loops and `while` loops.

A `for` loop is used to iterate over a sequence (e.g., a list, tuple, string, or range). Here is an example of a `for` loop that prints the elements of a list:

```
for i in [1, 2, 3]:
    print(i)
```

A `while` loop is used to execute a block of code as long as a condition is true. Here is an example of a `while` loop that prints the numbers from 1 to 3:

```
i = 1
while i <= 3:
    print(i)
    i += 1
```

List comprehensions utilize a `for` loop to create a new list by applying an operation to each element of an existing list. Here is an example of a list comprehension that squares each element of a list:

```
x = [1, 2, 3]
squared = [i**2 for i in x]
squared
```

Conditional Statements

Conditional statements are used to perform different actions based on different conditions. Python has `if`, `elif`, and `else` statements for this purpose. Here is an example of an `if` statement that prints whether a number is positive, negative, or zero:

```
x = 5
if x > 0:
    print('Positive')
elif x < 0:
    print('Negative')
else:
    print('Zero')
```

Optimization in Python

We can also use Python to solve optimization problems. To do this, we will use the `scipy.optimize` module from the `SciPy` library.

Here is an example of solving a simple optimization problem using the `minimize` function from `scipy.optimize`. The code below minimizes the function $f(x) = (x - 2)^2$:

```python
from scipy.optimize import minimize

def f(x):
    return (x - 2)**2

result = minimize(f, x0=0)
result
```

The `minimize` function takes the function to minimize and an initial guess `x0` as arguments. It returns an object that contains information about the optimization result. The optimal value of x is contained in the `x` attribute of the result object, which can also be accessed directly by calling `result.x`. What is the optimal value of x in this case?

Tutorial 2 will show you how to solve a slightly more complex optimization problem using Python.