Lerntraining Software

Python

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Table of Contents

Overview

Python is ...

- interpreted
- interactive
- object-oriented
- a beginners language!

This tutorial is mostly inspired by
`https://www.tutorialspoint.com/python/index.htm`.
Much of what you learn here you will find there!

This tutorial

- Introduction to basic programming techniques in `python` as well as an outlook to advanced methods
- There are exercises between some sections, where you can try out what you have learned bevor
- The slices are english, as most of the documentation so that you become familiar with the technical terms
- It will be a tight program, so don't worry if you don't understand everything directly! If you are intersted in programming, you can read a lot more in detail. I will present some literature and helpful websites later.
- I will present python2 - what is not the latest standard, but for this tutorial the differences are not relevant.

For you at home, here python is already installed!

- Check if `Python` is already installed: open a terminal and type "python", if not:
- Linux: type `sudo apt-get install python` or `sudo apt-get install python3` for python3
- Windows: `https://www.python.org/downloads/windows/`

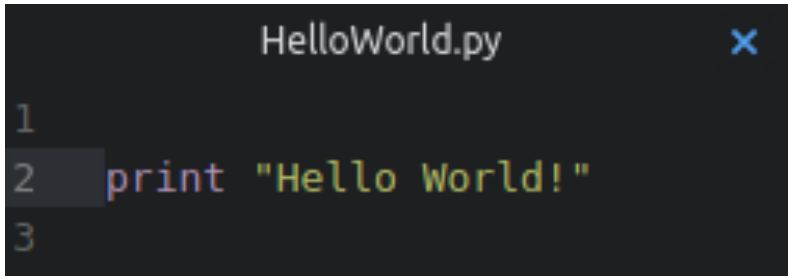
Using *Anaconda* distribution, which makes it easy to install packages:

- `https://www.anaconda.com/download/`

Or use an IDE like *eclipse* or *Visual Studio*

Hello World!

- open an editor
- type: `print "Hello World!"`
- save it as "HelloWorld.py" under ...
- open a terminal and go to your directory with cd ...
- type: `python HelloWorld.py`



Simple Calculations

- now type e.g. `x = 5` and `y = 10` under your print statement
- type `print` and a calculation using +,-,*,/
- save the file, go to your terminal and type `python HelloWorld.py` or press ↑
- What is the result of `x/y`?
- Instead you can try the interactive mode: Open a terminal and type `python`. Now you can type the mathematical expressions directly into the terminal and use it as an calculator.

Variable Types

Python has five basic data types:

- Numbers, like 5 and 10
- Strings, like "Hello World!"
- Lists,
- Dictionary, sometimes very useful but is not presented here
- Tuple

Data types can be stored in variables:

- `x = 10`
- `gravConstant = 9.81`
- `s = "Hello World!"`
- `name = "Sophie"`

Basic numerical types with some examples

Type	Examples	Comment
int	3, -42	signed integer $\leq 2,147,483,647$
long	51924361L	signed integer $> 2,147,483,647$
float	3.14, 3.0+e10, 0.	floating point real values
complex	42.0j, 2.+0.3j	complex numbers, imaginary unit j

Integer Division

The statement `5/10` is interpreted as an integer! Thus, its integer division is 0. Instead type `5./10.` to obtain a float-type value.

Boolean

The result of a comparison which is `True` or `False` is called Boolean. `True` and `False` are special versions of 1 (or any non-zero/null value) and 0, respectively. You can use them in arithmetic contexts.

Arithmetic and Comparison Operators

Operator		Examples
+	Addition	5+10 = 15
-	Subtraction	10-5 = 5
*	Multiplication	10*5 = 50
/	Division	10/5 = 2, 5/10 = 0, 5./10. = 0.5
**	Power	10**5 = 10,000
%	Modulus	10%5 = 0, 5%10 = 5
//	Floor Division	9.//2. = 4.0
==	equal	5==10 is False, 5==5 is True
!=	not equal	5!=10 is True, 5!=5 is False
>	greater than	10 > 5 is True
<	less than	10 < 5 is False
<= or >=		10 >= 5 is True, 5 <= 5 is True

Asignment Operators

Operator	Description	Example
=	Assigns values from the right side to the left side	x = 5+10
+=	Adds right operand to the left one AND assigns the result to the left operand	x += 1 is equivalent to x = x + 1
-=	x -= 1 is equivalent to x = x-1	
*=	x *= 2 is equivalent to x = x*2	
/=	x /= 2 is equivalent to x = x/2	
**=	x **= 2 is equivalent to x = x**2	
%=	x %= 2 is equivalent to x = x%2	
//=	x //= 2 is equivalent to x = x//2	

Other Operators

Bitwise operators

which perform bit by bit operations like: binary AND, OR, shifting

Logical operators

`not` , `or` , `and`

Membership operators

`in` and `not in`

test the membership in a *sequence* such as lists or strings

Identity operators

`is` and `is not`

compare the memory locations of two objects, you can often use them like == and `!=` for example in *if-statements*

Strings and string formatting

- In Python there is no difference between 'chars' and "strings", single and double quotes are treated the same.
- You can create strings simply by putting characters in quotes: str = `"Hello World!"`

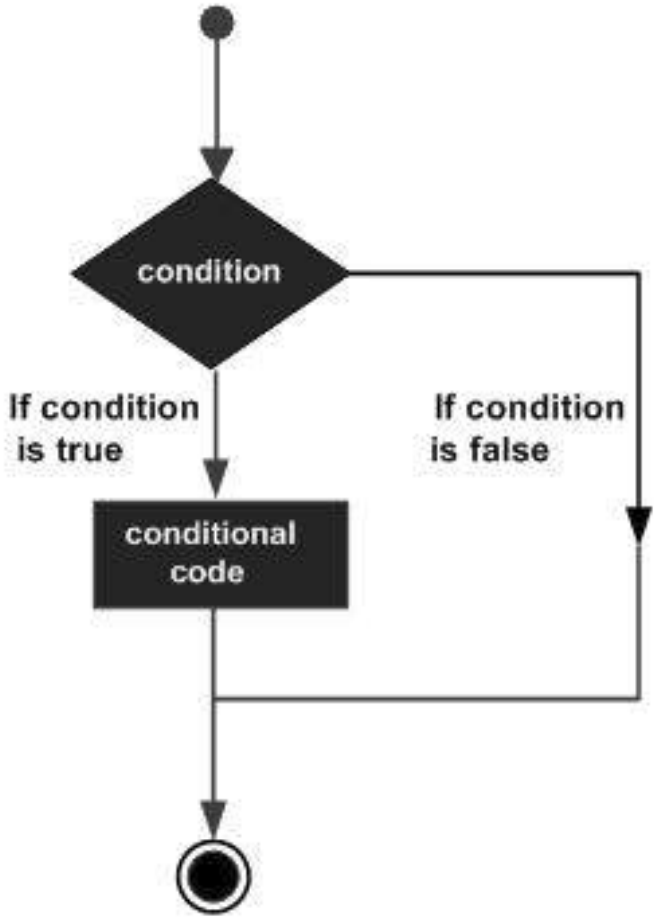
You can format strings using the string formatting operator '%':

```
obj = "Circle"
rad = 2
area = 12.566
print "The area of a %s with radius %i is: %f " %(obj, rad, area)
```

```
sophie@sophie-pc:~/Documents/Uni/SOWAS_Leitung/Le
The area of a Circle with radius 2 is: 12.566000
```

You can find a table with format symbols here: `https://www.tutorialspoint.com/python/python_strings.htm`

If-statements



use `if` and `else` conditions to execute a specific code if a condition is TRUE or to jump to the next (or another conditional) code otherwise

Example

Some `if`, `elif`, `else` statements to compare the values x and y:

```
print "x = %f and y = %f" %(x,y)
if (x > y):
    print "x is greater than y!"
elif(x < y): print "x is smaller than y!"
else:
    print "x is equal y!"
    if x and y >= 5.0:
        print "x and y are greater than 5!"

print "Finish..."
```

Output for different values of x and y:

```
sophie@sophie-pc:~/Documents/Un
x = 2.000000 and y = 3.000000
x is smaller than y!
Finish...
sophie@sophie-pc:~/Documents/Un
x = 6.000000 and y = 6.000000
x is equal y!
x and y are greater than 5!
Finish...
```

Syntax

The conditional code has to be intended or stands in a line (only possible for one statement) with the condition. IDEs and many editors do this automatically.

Exercises

- Write the program `EvenOdd.py` which returns wether a variable is even or odd!
  Use operators and condition statements and print the value as well as the result!
- Write the program `CharInString.py` which returns wether the string `"Hello World!"` contains a specific letter (a so called char)!
  Use membership operators and the program should be case sensitive to keep it simple.
- Bonus: Use a string method (`https://www.tutorialspoint.com/python/python_strings.htm`) to make `CharInString.py` case insensitive

Lists

A list contains several items like strings or numbers, you can easily create a list with [] and ,-separated items:

- `fruits = ["apple", "banana", "strawberry"]`
- `numbers = [1,1,2,3,5,8]`

The items in a list can be of different types:

- `book = ["title", "physics", 1997]`

You can access an item in a list by its index:

- `fruits[1]` is `"banana"`
- `numbers[3]` is 3
- `fruits[0]` is `"apple"`
- `numbers[-1]` is 8

Index

The index of a list starts with 0! You can use negative indices, too!

Manipulating Lists

You can use the index to change an item at the index position:

- `fruits[0] = "mango"` results in `["mango", "banana", "strawberry"]`

You can delete an item at a specific position:

- `del fruits[0]` results in `["banana", "strawberry"]`

List slicing with ':' :

- `numbers[1:4]` results in `[1,2,3]`
- `numbers[2:]` results in `[2,3,5,8]`

Merge lists:

- `numbers` + [13,21,34] results in `[1,1,2,3,5,8,13,21,34]`

List methods

There are some useful methods for lists:

- `len(fruits)` returns the length of the list: 3
- `max(numbers)` returns the maximum value: 8
- `min(numbers)` returns the minimum value: 1
- `list.sort([func])` sorts the list `list`, using an optional sort function
- `list.count(obj)` returns how often `obj` occurs in `list`
- `list.append(obj)` appends `obj` to `list`
- `list.remove(obj)` remove `obj` at any position from `list`

You can find more methods and their decription on `https://www.tutorialspoint.com/python/python_lists.htm` or in the python documentation

Manipulating Strings

Lists and Strings both are sequences, thus accessing substrings and slicing strings works the same way!

Some string methods working on `str = "hello world"`:

- `str.capitalize()` returns: `"Hello world!"`
- `str.count('o')` counts how many times a substring occurs in string: 2
- `str.find('o')` returns the index of the first substring it finds in str: 4 (negative index if substring is not included in str)
- `str.isnumeric()` returns True if all characters in str are decimal: False
- `str.replace('l', 'L')` replaces all 'l' in str with 'L': "heLLo worLd"

for-loops

If you want to repeat a statement while a specific condition is True, you can use loops:

- `while`-loops:
  repeats one or more statements while a condition is true; the condition is tested before executing the conditional code
- `for`-loops:
  iterates over the items of any sequence like strings or lists and executes the conditional code

Examples

for-loop over a list:

```
fruits = ["apple", "banana", "strawberry"]
for fruit in fruits:
    print "I like: %s" %fruit
```

```
sophie@sophie-pc:~/
I like: apple
I like: banana
I like: strawberry
```

while-loop:

```
index = 0;
while index < 4:
    print "Hello World!"
    index += 1
```

```
sophie@sophie
Hello World!
Hello World!
Hello World!
Hello World!
```

Examples

for-loop using `range()`:

```
for x in range(0,10,2):
    print x
```

```
soph
0
2
4
6
8
```

The `range()` method creates a list with the parameters `(begin, end, step)`, where the end-value is not included! Default values are: `begin = 0` and `step = 1`, thus `range(4)` would create the list `[0,1,2,3]`.

Exercises

- Write the program `Faculty.py` that calculates the faculty of a certain number!
- Write the program `FibonacciSeries.py` that returns the Fibonacci Series! Use a list to store your result beginning with `Fibonacci = [0,1]`, the series should not exceed 10,000.
- Calculate the sum of all even numbers in your Fibonacci Series! You can reuse your code from exercise one.

There are many more mathematical problems or "number games" on `https://projecteuler.net/archives` you can solve with the few programming skills (but sometimes a lot of logical thinking) you have achieved here!

Functions

You can organize code, that performs a single action with help of functions. This makes your code more readable and reusable.
You already saw a lot of "build-in" functions, like the `print` statement or the methods to manipulating lists, like `max()`.
You can easily define your own functions using the `def` keyword:

```
def isEven(var):
    if var%2 == 0: return True
    else: return False
```

And calling your function:

```
x = 4
if isEven(4) is True: print "%i is even!"
else: print "%i is odd!"
```

Exercises

- Rewrite your `Faculty.py` program with a function `faculty(n)`!
- Write the function `faculty(n)` *recursive*. This means that the function calls itself! Take care of defining an end condition (like `faculty(0)` returns 1) , otherwise you get stuck in an infinite loop!

```
def isPrim(n):
    if n == 1 or n == 0: return False
    i = 2
    while i**2 <= n:
        if isPrim(i) == True:
            if n%i == 0: return False
        i += 1
    return True
```

Example:
Recursive function to calculate wether n is a prime number!

Modules

For the purpose of organize and reuse your code you can create *Modules* which are basically files containing Python code like functions, variables or *classes*. You can *import* such modules (or single functions) using the `import` statement:

main.py

```
import recursivePrime
from FacultyFunction import faculty

print faculty(4)
print recursivePrime.isPrim(4)
```

Directory path

Your main method and modules must be in the same directory or you have to define a PYTHONPATH.

Namespaces

To avoid typing the module name before each function you imported with the `import` statement or to confuse different functions with similar names, you can use *namespaces*.
Or you can import all items from one module into the current namespace using * (although this is not recommended and should be used wisely)

```
import recursivePrime as prim
import math as m

print prim.isPrim(4)
print m.exp(1)
```

```
from math import *

print exp(1)
print sin(2*pi)
```

Command Line Arguments

For a convenient use of your programs you wouldn't want to open your python file, change the variables, save the file and then run it over the command line. Instead it would be better to run the code and define the variables over the command line:

```
sophie@sophie-pc:~/repositories/SOWAS_Lerntraining$ python CommandLinePrime.py 5
5 is a prime number!
```

This works with the `sys`-module, which you can easily import.
This system module provides the list `sys.argv` which contains command line arguments as strings.
Another way is to read the keyboard input during runtime of your program using the `raw_input` or `input` methods.

sys-module example

```
import sys
from recursivePrime import isPrim

n = int(sys.argv[1]) #sys.argv is a list with strings
#you entered in the command line after 'python', thus
#sys.argv[0] is always the file name! The function int()
#parses the string to an integer

if isPrim(n) is True: print "%i is a prime number!" %n
else: print "%i is not a prime number!" %n
```

Exercises

- Write a new command line based faculty program using the sys module! Import your old `faculty` function to calcuate it!
- Import the math module, and do some random calculation using its member functions. You can find them in the python documentary:
  `https://docs.python.org/2/library/math.html`

Open files

Using the open-function to open files in read (r), write (w) or append (a) modus:

```
print "Writing..."
file = open("example.txt", 'w') #open file in write-modus
file.write("Hello World!")   # writes the string "Hello World!" into example.txt
file.close() # make sure you close your file!

file = open("example.txt", 'r') #opens file in read-only modus
print file.read(5) #reads until a number of 5 bytes is reached
print file.read() # tries to read as much as possible, starting from the last point
file.close()

print "\nAppending..."
file = open("example.txt", 'a') #appends modus
file.write("Hello there!") #appends the string to the file
file.close()
```

Open files

Write-Modus

If you open your file in write modus it overwrites the file if it exists! Otherwise it creates a new one.

- You can use the modus `r+` or `w+` for reading AND writing
- You can set the position in your file using `file.tell()` which returns the position in your file, and `file.seek(offset, from)`. Where `offset` denotes the number of bytes, and `from` specifies from where the bytes are moved
- You can even delete files or make directories using the `os` module: `https://www.tutorialspoint.com/python/python_files_io.htm`

Matplotlib

- Matplotlib is a plotting library. You can import it with the import statement! (Maybe you have to install it first)
- We are going to use the `pyplot` module which provides MATLAB-like interfaces and functions for simple plotting
- We also need the `NumPy` package in particular to get a real-valued `range` function, called `numpy.arange()`, but it's very useful for example for n-dimensional arrays, too!

Simple plot

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

#Create the plot data (lists):
x = np.arange(0.0, 2*np.pi, 0.01)
y = np.sin(x)

#The simplest plot statement without many
#configuration posibilities:
plt.plot(x,y)

plt.xlabel("x")
plt.ylabel("y")
plt.title("A function")

plt.savefig("Plot.png") #if you want to save your plot
plt.show() #to see your plot on screen
```

Matplotlib

- There are many more options you can set for your plots, like the range, colours or point-plots, a legend, some arrows and text boxes,...
- There are many other plots functions like: contour-plots, histograms, 3D-plots, polar plot, scatter plots,...
- You can use TeX statements in your plots using the $-environment
- The best practice is to search for an example which is almost what you need and then to change it so that it fits for your purpose!
- If you want to plot your data with a "lighter" tool, you can use `gnuplot`! `http://www.gnuplot.info/`

Exercises

- Implement an Euler integration for $\partial_t f(t) = f(t)$ with a step size of $\Delta t = 0.1$! Plot your numeric result as well as the analytic one using `np.exp()` in one plot to compare them! In this case, the Euler method is:

$$f_{n+1} = f_n + \Delta t \cdot f_n \tag{1}$$

Where f_n denotes the old solution state and f_{n+1} the new one, after one time step Δt. Thus, you can calculate f_1 using the initial values:

$$f_1 = f_0 + \Delta t \cdot f_0 \tag{2}$$

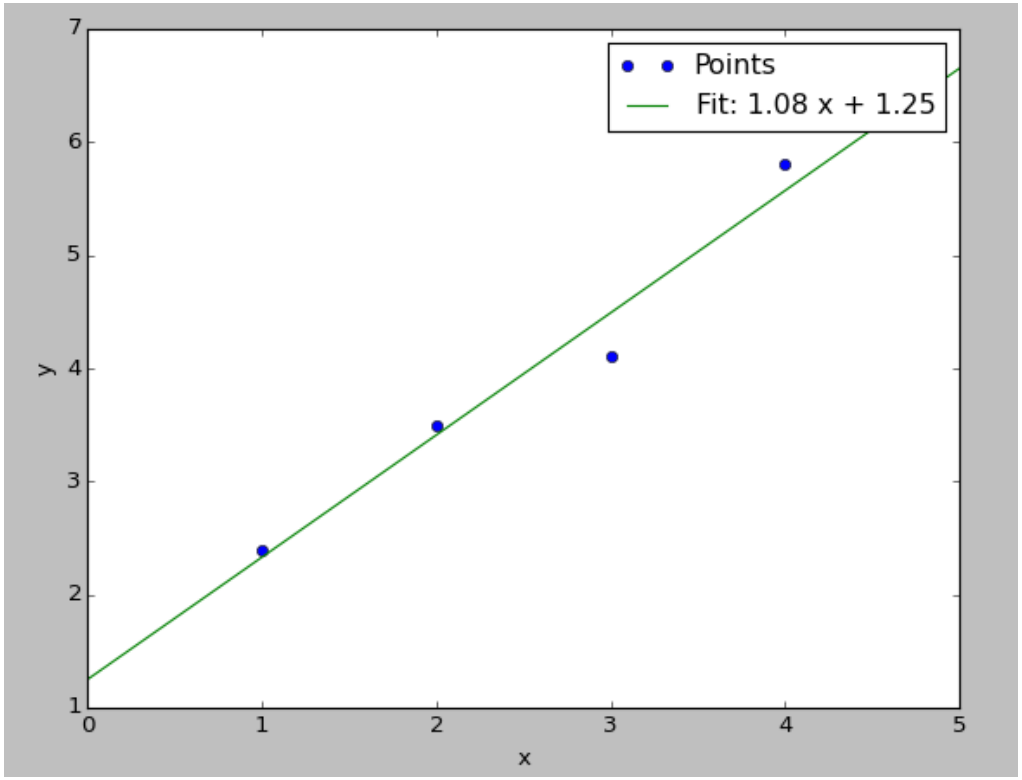
And f_2 can be calculated with f_1 and so on.

Exercises

- Use $f(0) = f_0 = 1$ as initial condition and a final time of $T = 5.0$!
- Store your result of each time step in a list until a final time of $T = 5.0$ is reached. (Hint: use the `append()` method)
- Plot the analytic and numeric result after you reached the final time T in your Euler calculation. You can plot two functions in one plot by simply using the plot statement `plt.plot()` twice.
- Store your results in a file (using a reasonable format) and save your plot! Use `\n` and `\t` to make a newline or a horizontal tab.

Polynomial fit with numpy

Numpy provides a function for polynomial curve fitting based on the minimalization of the squared errors between the polynomial and your points.

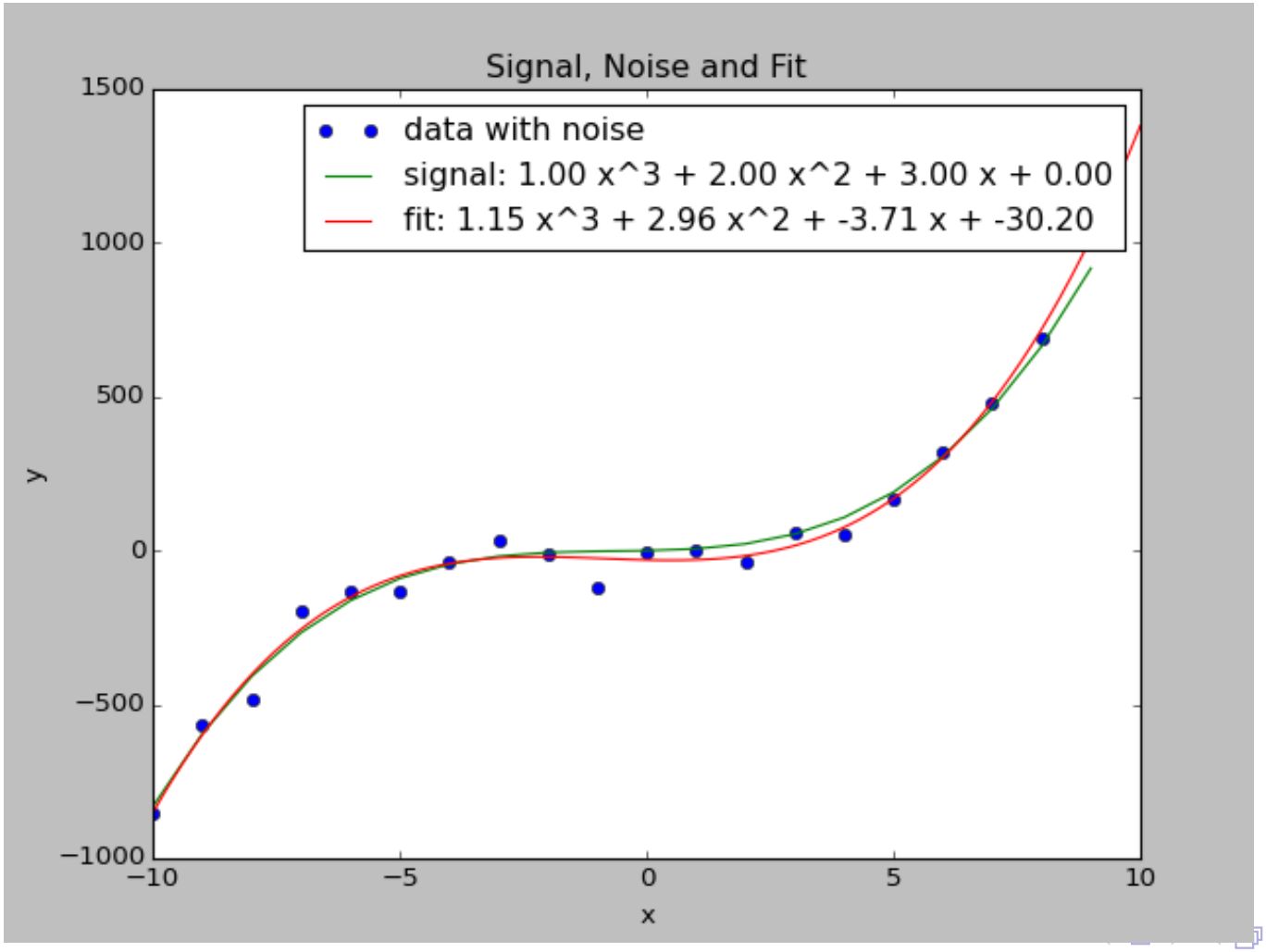


First order polynomial fit by 4 points

Polynomial fit with numpy

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

# 2D numpy array with 4 points:
data = np.array([[1.,2.4], [3.,4.1], [2.,3.5], [4., 5.8]], np.float32)

x = data[:,0]
y = data[:,1]

# fit 1. order polynomial:
z = np.polyfit(x, y, 1)  #returns fit parameter a,b
p = np.poly1d(z) # creates fit fuction with fit parameters

xp = np.linspace(0,5,20) #x coordinates to plot fit

plt.plot(x,y, 'o', label = "Points")
plt.plot(xp,p(xp), label = "Fit: %.2f x + %.2f" %(z[0], z[1]))

plt.xlabel('x')
plt.ylabel('y')
plt.legend()
plt.show()
```

Polynomial fit with numpy



Third-order polynomial fit of random noise on a signal. Comparison between the initial signal and the fit.

Some literature and useful websites

- This tutorial and some advanced methods: `https://www.tutorialspoint.com/python/python_lists.htm`
- Book: *A Primer on Scientific Programming with Python*, Hans Petter Langtangen, you can find it in our library, too!
- No matter what problem you have, someone had it before: `https://stackoverflow.com/`
- Python documentation: `https://www.python.org/` and matplotlib: `https://matplotlib.org/` use the examples and change them according to your wishes!
- If you love mathematical problems: `https://projecteuler.net/`
- My solutions to this exercises and examples: `https://github.com/sophieaerdker/SOWAS_Lerntraining`