Advanced Programming with Python

DISCLAIMER: The presented material relies heavily on Python Advance course carried out at CERN. The material is also available freely at the website: https://www.python-course.eu

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In 1999, Guido Van Rossum submitted a funding proposal to DARPA called "Computer Programming for Everybody", in which he further defined his goals for Python:

- An easy and intuitive language just as powerful as major competitors
- Open source, so anyone can contribute to its development
- Code that is as understandable as plain English
- Suitability for everyday tasks, allowing for short development times

0. Hello world

In [1]:
print('Hello world!')
Hello world!

0.1. Zen of Python
1. What is a variable?

Variable in python is always a reference to an object as in python everything, even a function, is an object.

```python
In [3]:
x = 3
y = x
y, x
```

Out[3]:
```
(3, 3)
```

```python
In [4]:
x = 2
```

```python
In [5]:
y, x
```

Out[5]:
```
(3, 2)
```

Conditional statement to assign a value

```python
In [6]:
x = -5
if x > 0:
    label = 'Pos'
else:
    label = 'Neg'
print(label)
```

Neg

The Zen of Python, by Tim Peters

Beautiful is better than ugly.
Explicit is better than implicit.
Simple is better than complex.
Complex is better than complicated.
Flat is better than nested.
Sparse is better than dense.
Readability counts.
Special cases aren't special enough to break the rules.
Although practicality beats purity.
Errors should never pass silently.
Unless explicitly silenced.
In the face of ambiguity, refuse the temptation to guess.
There should be one-- and preferably only one --obvious way to do it.
Although that way may not be obvious at first unless you're Dutch.
Now is better than never.
Although never is often better than *right* now.
If the implementation is hard to explain, it's a bad idea.
If the implementation is easy to explain, it may be a good idea.
Namespaces are one honking great idea -- let's do more of those!
In [7]:
\[
x = -5
\]
\[
label = 'Pos' \textbf{if} \ x > 0 \textbf{ else 'Neg'}
\]
\[
\text{print}(\text{label})
\]

Neg

In [28]:
\[
\text{print('Pos' \textbf{if} \ x > 0 \textbf{ else 'Neg'})}
\]

Neg

2. Basic types

2.1. String

Strings in python are immutable

In [14]:
\[
\text{string} = 'My string'
\text{string}[0] = 'T'
\]

---------------------------------------------------------------------------
TypeError Traceback (most recent call last)
<ipython-input-14-9c1867d9b2ff> in <module>
 1 \text{string} = 'My string'
----> 2 \text{string}[0] = 'T'

TypeError: 'str' object does not support item assignment

In [15]:
\[
\text{string}.\text{replace('M', 'T')}
\]

Out[15]:

'Ty string'

In [16]:
\[
\text{string}
\]

Out[16]:

'My string'

String is iterable

In [17]:
\[
\text{for} \ s \ \text{in} 'My string':
\text{print}(s)
\]

M
y
s
tr
in
g

Formatting of strings
In [18]:
```
from datetime import date
today = date.today()
'Today is ' + str(today) + '.
```
Out[18]:

'Today is 2019-11-28.'

In [23]:
```
'Today is {} and number {}.format(date.today(), [1, 2, 3])
```
Out[23]:

'Today is 2019-11-28 and number [1, 2, 3].'

f-strings have been introduced in Python 3.6

In [21]:
```
print(f'Today is {date.today()}')
```

Today is 2019-11-28

Check if a substring is in a string

In [25]:
```
if 'sub' in 'substring':
    print('True')
```

True

There are already many built-in functions for handling strings in Python

In [29]:
```
dir(list)
```
In [26]:

dir(str)

Out[26]:
['add__', '__class__', '__contains__', '__delattr__', '__delitem__', '__dir__', '__doc__', '__eq__', '__format__', '__ge__', '__getattribute__', '__getitem__', '__gt__', '__hash__', '__init__', '__init_subclass__', '__iter__', '__le__', '__len__', '__lt__', '__mul__', '__ne__', '__new__', '__reduce__', '__reduce_ex__', '__repr__', '__reversed__', '__rmul__', '__setattr__', '__setitem__', '__sizeof__', '__str__', '__subclasshook__', 'append', 'clear', 'copy', 'count', 'extend', 'index', 'insert', 'pop', 'remove', 'reverse', 'sort']
In [32]:

'my first sentence'.upper()

Out[32]:

'MY FIRST SENTENCE'
2.2. Enum

Enum is a data type which links a name to an index. They are useful to represent a closed set of options.

```python
In [33]:
from enum import Enum
class QhBrowserAction(Enum):
    QUERY_BUTTON_CLICKED = 1
    SAVE_BUTTON_CLICKED = 2
    DATE_CHANGED = 3
    QH_NAME_CHANGED = 4
    SLIDER_MOVED = 5

a = QhBrowserAction.DATE_CHANGED
a.name, a.value

Out[33]:
('DATE_CHANGED', 3)
```

```python
In [36]:
a_next = QhBrowserAction(a.value+1)
a_next

Out[36]:
<QhBrowserAction.QH_NAME_CHANGED: 4>
```

```python
In [38]:
if a_next == QhBrowserAction.QH_NAME_CHANGED:
    print('In state {}'.format(a_next.value))

In state 4
```

3. Containers

Container data types in Python are dedicated to store multiple variables of a various type. The basic container types are: lists, tuples, sets, dictionaries.

3.1. Lists

```python
In [39]:
my_list = [1, 'b', True]
my_list

Out[39]:
[1, 'b', True]
```

Lists are 0-indexed and elements are accessed by a square bracket

```python
In [40]:
my_list[0]

Out[40]:
1
```

Lists are mutable
In [42]:
my_list[1] = 0
my_list
Out[42]:
[0, 0, True]

In order to extend a list one can either append...

In [44]:
my_list.append(3)
my_list
Out[44]:
[0, 0, True, 3, 3]

Or simply

In [45]:
my_list + [1, 'b']
Out[45]:
[0, 0, True, 3, 3, 1, 'b']

...or append elements

In [ ]:
my_list += [3]
my_list
In [ ]:
my_list = my_list + [3] # One shall not do that
my_list

Be careful with the last assignment, this creates a new list, so a need to perform a copy - very inefficient for large lists.

How to append a list at the end?

In [47]:
my_list.append([1, 'a'])
my_list
Out[47]:
[0, 0, True, 3, 3, 3, [1, 'a']]

This adds a list as an element, which is not quite what we wanted.

In [58]:
my_list.extend([5])
my_list
Out[58]:
[0, 0, True, 3, 3, 3, [1, 'a'], 1, 'a', 1, 'a', [1, 2], '5', 5]
In [53]:

```python
import itertools
list2d = [[1, 2, 3], [4, 5, 6], [7], [8, 9]]
merged = list(itertools.chain(*list2d))
```

Out[53]:
```
[[1, 2, 3], [4, 5, 6], [7], [8, 9]]
```

Which one to choose in order to add elements efficiently?

https://stackoverflow.com/questions/252703/what-is-the-difference-between-pythons-list-methods-append-and-extend

3.1.1. List comprehension

Old-fashioned way

In [59]:

```python
my_list = []
for i in range(10):
    my_list.append(i)
```

Out[59]:
```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

One-line list comprehension

In [75]:

```python
abs(0.1 - (1.1-1)) < 1e-16
```

Out[75]:
```
True
```

In [65]:

```python
my_list = [1/(i+1) for i in range(10)]
```

Out[65]:
```
[1.0,
  0.5,
  0.3333333333333333,
  0.25,
  0.2,
  0.16666666666666666,
  0.14285714285714285,
  0.125,
  0.11111111111111111,
  0.1]
```

In [66]:

```python
my_list = [i for i in range(10) if i > 4]
```

Out[66]:
```
[5, 6, 7, 8, 9]
```

Generator comprehension
In [76]:

```python
x = {x**2 for x in range(10)}
print(x)
<generator object <genexpr> at 0x7faceb983468>
```

In [87]:

```python
next(x)
```

```
StopIteration
```

```
Traceback (most recent call last)
<ipython-input-87-92de4e9f6b1e> in <module>
----> 1 next(x)
StopIteration:
```

In [93]:

```python
import datetime
str(datetime.datetime.now())
```

```
```

In [103]:

```python
print(datetime.datetime.now())
for x in [(x+1)**2 for x in range(int(1e7))]:
    x**(-1/2)
print(datetime.datetime.now())
```

```
2019-11-28 11:27:55.759043
2019-11-28 11:28:01.770323
```

In [104]:

```python
print(datetime.datetime.now())
lst = [(x+1)**2 for x in range(int(1e7))]
for x in lst:
    x**(-1/2)
print(datetime.datetime.now())
```

```
2019-11-28 11:28:09.839305
2019-11-28 11:28:15.530292
```

Generator returns values on demand - no need to create a table and than iterate over it

In [111]:

```python
x = iter(range(10))
next(x)
```

```
0
```

In [ ]:  

```python
x = {x**2 for x in range(10)}
list(x)
```

3.1.2. Filter, map, reduce
In [105]:
my_list = [-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5]
filter(lambda x: x>0, my_list)

Out[105]:
<filter at 0x7face70b88d0>

Filter returns an iterable generator. Generator is a very important concept in Python!

In [106]:
for el in filter(lambda x: x>0, my_list):
    print(el)

1
2
3
4
5

In [112]:
list(filter(lambda x: x>0, my_list))

Out[112]:
[1, 2, 3, 4, 5]

Map

In [113]:
print(my_list)
list(map(lambda x: abs(x), my_list))

[-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5]

Out[113]:
[5, 4, 3, 2, 1, 0, 1, 2, 3, 4, 5]

Map can be applied to many lists

In [114]:
lst1 = [0,1,2,3,4]
lst2 = [5,6,7,8]
list(map(lambda x, y: x+y, lst1, lst2))

Out[114]:
[5, 7, 9, 11]

Reduce

In [115]:
sum([0,1,2,3,4,5,6,7,8,9,10])

Out[115]:
55
In [116]:
```
from functools import reduce
reduce(lambda x, y: x + y, [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10])
```
Out[116]:
55

$$0+1+\ldots+n = \frac{n(n+1)}{2}$$

### 3.1.3. Iterating over lists

In [119]:
```
i = 0
for el in [-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5]:
    print(i, el)
    i += 1
```
```
0  -5
1  -4
2  -3
3  -2
4  -1
5   0
6   1
7   2
8   3
9   4
10  5
```

**Iterating with index**

In [118]:
```
for index, el in enumerate([-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5]):
    print(index, el)
```
```
0 -5
1 -4
2 -3
3 -2
4 -1
5  0
6  1
7  2
8  3
9  4
10  5
```

**Iterating over two (many) lists**

In [120]:
```
letters = ['a', 'b', 'c', 'd']
numbers = [1, 2, 3, 4, 5]
for l, n in zip(letters, numbers):
    print(l, n)
```
```
a 1
b 2
c 3
d 4
```
3.1.4. Copying lists

In [126]:

```python
x = [1, 2, 3, 4]
y = x
y[0] = 'a'
print(x, y)
['a', 2, 3, 4] ['a', 2, 3, 4]
```

In [128]:

```python
x.copy()
```

Out[128]:

```
[1, 2, 3, 4]
```
In [127]:
x = [1, 2, 3, 4]
y = x.copy()
y[0] = 'a'
print(x, y)

[1, 2, 3, 4] ['a', 2, 3, 4]

In [129]:
x = [[1, 'a'], 2, 3, 4]
y = x.copy() # equivalent to x[:]
y[0][0] = 'a'
print(x, y)

[['b', 'a'], 2, 3, 4] ['a', 2, 3, 4]

In [131]:
x = [[1, 'a'], 2, 3, 4]
y = x.copy()
y[0][0] = 'b'
print(x, y)

[['b', 'a'], 2, 3, 4] [['b', 'a'], 2, 3, 4]

The reason for this behavior is that Python performs a shallow copy.

In [132]:
from copy import deepcopy
x = [[1, 'a'], 2, 3, 4]
y = deepcopy(x)
y[0][0] = 'b'
print(x, y)

[[1, 'a'], 2, 3, 4] [['b', 'a'], 2, 3, 4]

3.1.5. Sorting lists - inplace operations

In [133]:
x = [1, 10, 2, 9, 3, 8, 4, 6, 5]
x = x.sort()
print(x)

None

tlist.sort() is an inplace operation. In general, inplace operations are efficient as they do not create a new copy in memory

In [134]:
x = [1, 10, 2, 9, 3, 8, 4, 6, 5]
x.sort()
print(x)

[1, 2, 3, 4, 5, 6, 8, 9, 10]

list.sorted does create a new variable

In [135]:
x = [1, 10, 2, 9, 3, 8, 4, 6, 5]
sorted(x)
print(x)

[1, 10, 2, 9, 3, 8, 4, 6, 5]
In [136]:
x = [1, 10, 2, 9, 3, 8, 4, 6, 5]
x = sorted(x)
print(x)

[1, 2, 3, 4, 5, 6, 8, 9, 10]

In [137]:
x = [1, 10, 2, 9, 3, 8, 4, 6, 5]
x is sorted(x)

Out[137]:
False

How to sort in a reverted order

In [139]:
x = [1, 10, 2, 9, 3, 8, 4, 6, 5]
x.sort(reverse=True)
print(x)

[10, 9, 8, 6, 5, 4, 3, 2, 1]

Sort nested lists

In [140]:
employees = [(111, 'John'), (123, 'Emily'), (232, 'David'), (100, 'Mark'), (1, 'Andrew')]
employees.sort(key=lambda x: x[0])

Out[140]:
[(1, 'Andrew'), (100, 'Mark'), (111, 'John'), (123, 'Emily'), (232, 'David')]

In [141]:
employees = [(111, 'John'), (123, 'Emily'), (232, 'David'), (100, 'Mark'), (1, 'Andrew')]
employees.sort(key=lambda x: x[1])

Out[141]:
[(1, 'Andrew'), (232, 'David'), (123, 'Emily'), (111, 'John'), (100, 'Mark')]

Also with reversed order

In [142]:
employees = [(111, 'John'), (123, 'Emily'), (232, 'David'), (100, 'Mark'), (1, 'Andrew')]
employees.sort(key=lambda x: x[0], reverse=True)

Out[142]:
[(232, 'David'), (123, 'Emily'), (111, 'John'), (100, 'Mark'), (1, 'Andrew')]

### 3.1.6. List extras
In [143]:
my_list = 5*'a'
my_list
Out[143]:
['a', 'a', 'a', 'a', 'a']

In [144]:
3 in [1,2,3,4,5]
Out[144]:
True

In [149]:
x = ['a']
y = ['a']
x == y
Out[149]:
True

In [150]:
x = ('a')
y = ('a')
x is y
Out[150]:
True

3.2. Tuples

Tuples, similarly to lists can stores elements of different types.

In [152]:
my_tuple = (1,2,3)
my_tuple
Out[152]:
(1, 2, 3)

In [153]:
my_tuple[0]
Out[153]:
1

Unlike the lists, tuples are immutable.

In [154]:
my_tuple[0]=0
---------------------------------------------------------------------------
TypeError                       Traceback (most recent call last)
<ipython-input-154-a0c25be542d6> in <module>
----> 1 my_tuple[0]=0

TypeError: 'tuple' object does not support item assignment
3.3. Sets
Sets are immutable and contain only unique elements

In [155]:
{1, 2, 3, 4}
Out[155]:
{1, 2, 3, 4}

In [156]:
{1, 2, 3, 4}
Out[156]:
{1, 2, 3, 4}

So this is a neat way for obtaining unique elements in a list

In [157]:
my_list = [1, 2, 3, 4, 4, 5, 5, 5]
some(my_list)
Out[157]:
{1, 2, 3, 4, 5}

or a tuple

In [158]:
my_tuple = (1, 2, 3, 4, 4, 5, 5, 5)
some(my_tuple)
Out[158]:
{1, 2, 3, 4, 5}

One can perform set operations on sets ;-)
pm = ['system', 'source', 'I_MEAS', 'I_REF']
signals = pm - ['system', 'source']
signals

Out[165]:
{'I_MEAS', 'I_REF'}

In [174]:
for s in signals:
    print(s)
I_MEAS
I_REF

In [175]:
help(set)
Help on class set in module builtins:
class set(object)
    set() -> new empty set object
    set(iterable) -> new set object

    Build an unordered collection of unique elements.

    Methods defined here:
    __and__(self, value, /)
        Return self&value.
    __contains__(...)  
        x.__contains__(y) <=> y in x.
    __eq__(self, value, /)
        Return self==value.
    __ge__(self, value, /)
        Return self>=value.
    __gt__(self, value, /)
        Return self>value.
    __iand__(self, value, /)
        Return self&=value.
    __init__(self, /, *args, **kwargs)
        Initialize self.  See help(type(self)) for accurate signature.
    __ior__(self, value, /)
        Return self|=value.
    __isub__(self, value, /)
        Return self-=value.
    __iter__(self, /)
        Implement iter(self).
    __ixor__(self, value, /)
        Return self^=value.
    __le__(self, value, /)
    __len__(self, /)
        Return len(self).
```
__lt__ (self, value, /)
    Return self<value.

__ne__ (self, value, /)
    Return self!=value.

__new__ (*args, **kwargs) from builtins.type
    Create and return a new object. See help(type) for accurate signature.

__or__ (self, value, /)
    Return self|value.

__rand__ (self, value, /)
    Return value&self.

__reduce__ (...)
    Return state information for pickling.

__repr__ (self, /)
    Return repr(self).

__ror__ (self, value, /)
    Return value|self.

__rsub__ (self, value, /)
    Return value-self.

__rxor__ (self, value, /)
    Return value^self.

__sizeof__ (...)
    S.__sizeof__() -> size of S in memory, in bytes

__sub__ (self, value, /)
    Return self-value.

__xor__ (self, value, /)
    Return self^value.

add(...)
    Add an element to a set.
    This has no effect if the element is already present.

clear(...)
    Remove all elements from this set.

copy(...)
    Return a shallow copy of a set.

difference(...)
    Return the difference of two or more sets as a new set.
    (i.e. all elements that are in this set but not the others.)
difference_update(...)
    Remove all elements of another set from this set.
discard(...)
    Remove an element from a set if it is a member.
    If the element is not a member, do nothing.
intersection(...)
    Return the intersection of two sets as a new set.
    (i.e. all elements that are in both sets.)
intersection_update(...)
    Update a set with the intersection of itself and another.
```
In [177]:

signals[0]

---------------------------------------------------------------------------
TypeError                       Traceback (most recent call last)
<ipython-input-177-6c9ebb69209b> in <module>
----> 1 signals[0]

TypeError: 'set' object does not support indexing

In [180]:

next(iter(signals))

Out[180]:
'I_MEAS'

In [173]:

list(signals)[0]

Out[173]:
'I_MEAS'

Unpacking variables
In [182]:
first, second = [1, 2]
print(first, second)

ValueError: too many values to unpack (expected 2)

In [183]:
first, second = (1, 2)
print(first, second)
1 2

In [184]:
first, second = {1, 2}
print(first, second)
1 2

In [185]:
employees = [(111, 'John'), (123, 'Emily'), (232, 'David'), (100, 'Mark'), (1, 'Andrew')]
for employee_id, employee_name in employees:
    print(employee_id, employee_name)

111 John
123 Emily
232 David
100 Mark
1 Andrew

3.4. Dictionaries

In [186]:
empty_set = {}
type(empty_set)
Out[186]:
dict

In [187]:
empty_set = set()
type(empty_set)
Out[187]:
set

In [188]:
my_dict = {'a': 1, 'b': 2, 'c': 3, 'd': 4}
my_dict
Out[188]:
{'a': 1, 'b': 2, 'c': 3, 'd': 4}
In [189]:
my_dict['a']

Out[189]:
1

In [190]:
for key in my_dict:
   print(key)

a
b
c
d

In [191]:
for key, value in my_dict.items():
   print(key, value)

a 1
b 2
c 3
d 4

Summary of Python Containers

<table>
<thead>
<tr>
<th>Feature</th>
<th>list</th>
<th>tuple</th>
<th>dict</th>
<th>set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>an ordered collection of variables</td>
<td>an ordered collection of variables</td>
<td>an ordered collection of key,value pairs</td>
<td>a collection of variables</td>
</tr>
<tr>
<td>Duplication of values</td>
<td>yes</td>
<td>yes</td>
<td>unique keys, duplicate values</td>
<td>no</td>
</tr>
<tr>
<td>Mutability</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Creation</td>
<td>[1,2,3]</td>
<td>(1,2,3)</td>
<td>{'a':1}</td>
<td>{1,2,3}</td>
</tr>
<tr>
<td>Empty container</td>
<td>[]</td>
<td>()</td>
<td>{}</td>
<td>set()</td>
</tr>
<tr>
<td>Comprehension</td>
<td>[x for x in range(5)]</td>
<td>tuple((x for x in range(5)))</td>
<td>{k: v for k,v in zip(['a'], [1])}</td>
<td>{x for x in range(5)}</td>
</tr>
<tr>
<td>Accessing element</td>
<td>lst[0]</td>
<td>tpi[0]</td>
<td>ddf['key']</td>
<td>not possible</td>
</tr>
</tbody>
</table>

4. Functions

In [1]:
# lambda functions
f = lambda x: x**2
f(2)

Out[1]:
4

In [31]:

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

Out[31]:
4

4.1. Arguments
In [2]:
```python
def f(a, b, c=3):
    return a+b+c
f(1, 2)
```
Out[2]:
```
6
```
In [3]:
```
f(1, 2, 4)
```
Out[3]:
```
7
```

If the number of arguments matches, one can pass a list

In [5]:
```
lst = [1, 2, 3]
f(*lst)
```
Out[5]:
```
6
```

or a dictionary (provided that key names match the argument names) - very useful for methods with multiple arguments, e.g., plotting, querying databases, etc.

In [6]:
```
dct = {'a': 1, 'b': 2, 'c': 3}
f(**dct)
```
Out[6]:
```
6
```

```
def f(*args):
    print(len(args))
    return args[0]*args[1]*args[2]
f(1, 10, 'a')
```
Out[15]:
```
'aaaaaaaaaa'
```
In [38]:

```python
def f(**kwargs):
    return kwargs['a'] + kwargs['b']
f(a=1, b=2, c=3)
```

Out[38]:

```
3
```

In [17]:

```python
def f(arg, *args, **kwargs):
    return arg + sum(args) + kwargs['f']
f(1, 2, 3, 4, 5, f=6)
```

Out[17]:

```
21
```

In [18]:

```python
def f(a, b, *, c):
    return a+b+c
f(1,2,3)
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-18-ff89bb262ade> in <module>
  1 def f(a, b, *, c):
  2     return a+b+c
----> 3 f(1,2,3)

TypeError: f() takes 2 positional arguments but 3 were given
```

In [19]:

```
f(1,2,scaling=3)
```

Out[19]:

```
6
```

A function passed as an argument

In [20]:

```python
def f(x):
    return x**2
def g(func, x):
    return func(x)
g(f,2)
```

Out[20]:

```
4
```

A function can return multiple values, in fact it returns a tuple

In [23]:

```python
def f():
    return 'a', 'b', 's'
f()
```

Out[23]:

```
('a', 'b', 's')
```
In [32]:
first = list(f())  
# print(first)  
# print(second)

In [33]:
first[1] = 2

In [34]:
first

Out[34]:
['a', 2, 's']

4.2. Recursion

Factorial of an integer $n$ is given as:  
\[
 n! = n \times (n-1) \times (n-2) \times \cdots \times 3 \times 2 \times 1 
\]  
For example:  
\[
 5! = 5 \times 4 \times 3 \times 2 \times 1 = 120 
\]

In [37]:

def factorial(n):
    if n == 1:
        return 1
    else:
        return n*factorial(n-1)

factorial(3)

Out[37]:
6

In [38]:
factorial(5)

Out[38]:
120

In [39]:
factorial(-1)

ERROR:root:Internal Python error in the inspect module.  
Below is the traceback from this internal error.
In [42]:

```python
def factorial(n):
    if not isinstance(n, int) or n <= 0:
        raise ValueError("Argument is not a positive integer")

    if n == 1:
        return 1
    else:
        return n * factorial(n-1)
```

Out[42]:

```
120
```
Flattening a nested list

In [50]:

```python
def flatten_nested_lists(x):
    result = []
    for el in x:
        if isinstance(el, (list, tuple)):
            result.extend(flatten_nested_lists(el))
        else:
            result.append(el)
    return result
```

In [51]:

```python
lst1 = [1]
lst2 = [1, 2]
lst1.append(lst2)
lst1
```

```
--------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-51-d821110e9bc8> in <module>
     1 lst1 = [1]
     2 lst2 = [1, 2]
----> 3 lst1.append(*lst2)
     4 lst1

TypeError: append() takes exactly one argument (2 given)
```

In [51]:

```python
lst = [1, 2, [3,4], [5, [6, 7]]]
flatten_nested_lists(lst)
```

Out[51]:

```
[1, 2, 3, 4, 5, 6, 7]
```

Fibonacci

In [52]:

```python
def fib(n):
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return fib(n-1) + fib(n-2)
[fib(i) for i in range(6)]
```

Out[52]:

```
[0, 1, 1, 2, 3, 5]
```

How many times do we calculate fib(3)?
In [56]:
arguments = []
def fib(n):
    arguments.append(n)
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return fib(n-1) + fib(n-2)
x = [fib(i) for i in range(6)]
print(x)
[0, 1, 1, 2, 3, 5]

In [58]:
counts = {i: arguments.count(i) for i in range(max(arguments)+1)}
counts
Out[58]:
{0: 8, 1: 12, 2: 7, 3: 4, 4: 2, 5: 1}

In [59]:
sum(counts.values())
Out[59]:
34

4.3. Memoization

In computing, memoization or memoisation is an optimization technique used primarily to speed up computer programs by storing the results of expensive function calls and returning the cached result when the same inputs occur again.

source: https://en.wikipedia.org/wiki/Memoization

In [60]:
# Memoization for Fibonacci
# Fibonacci
memo = {0:0, 1:1}
arguments = []
def fib(n):
    arguments.append(n)
    if n not in memo:
        memo[n] = fib(n-1) + fib(n-2)
    return memo[n]
[fib(i) for i in range(6)]
Out[60]:
[0, 1, 1, 2, 3, 5]

In [63]:
counts = {i: arguments.count(i) for i in range(max(arguments)+1)}
counts
Out[63]:
{0: 2, 1: 3, 2: 3, 3: 3, 4: 2, 5: 1}
4.5. Decorators

Decorators are functions dedicated to enhance functionality of a given function, e.g., check parameter inputs, format input

```python
def argument_test_natural_number(f):
    def helper(x):
        if type(x) is int and x > 0:
            return f(x)
        else:
            raise Exception("Argument is not an integer")
    return helper

def factorial(n):
    if n == 1:
        return 1
    else:
        return n*factorial(n-1)

factorial = argument_test_natural_number(factorial)
factorial(3)
```

```
6
```

```
In [60]:
factorial(-1)
---------------------------------------------------------------------------
Exception Traceback (most recent call last)
<ipython-input-60-5aae425d6a8b> in <module>
----> 1 factorial(-1)
<ipython-input-59-74d7cacc5284> in helper(x)
        4 return f(x)
        5 else:
----> 6 raise Exception("Argument is not an integer")
        7 return helper
        8

Exception: Argument is not an integer
```
In [64]:

```python
def argument_test_natural_number(f):
    def helper(x):
        if type(x) is int and x > 0:
            return f(x)
        else:
            raise Exception("Argument is not an integer")
    return helper

@argument_test_natural_number
def factorial(n):
    if n == 1:
        return 1
    else:
        return n*factorial(n-1)

factorial(3)
```

Out[64]:

```
6
```

In [65]:

```python
factorial(-1)
```

Exception Traceback (most recent call last)
<ipython-input-65-5aae425d6a8b> in <module>
----> 1 factorial(-1)

<ipython-input-64-61c7137e6453> in helper(x)
    4     return f(x)
    5     else:
----> 6     raise Exception("Argument is not an integer")
    7     return helper
    8

Exception: Argument is not an integer

In [66]:

```python
def sum_arithmetic_series(n):
    return n*(n+1)/2
sum_arithmetic_series(2)
```

Out[66]:

```
3.0
```

In [67]:

```python
sum_arithmetic_series(1.5)
```

Out[67]:

```
1.875
```

In [68]:

```python
@argument_test_natural_number
def sum_arithmetic_series(n):
    return n*(n-1)/2
sum_arithmetic_series(2)
```

Out[68]:

```
1.0
```
In [69]:
sum_arithmetic_series(1.5)

---------------------------------------------------------------------------
Exception Traceback (most recent call last)
<ipython-input-69-16581ed0c766> in <module>
----> 1 sum_arithmetic_series(1.5)
<ipython-input-64-61c7137e6453> in helper(x)
    4     return f(x)
    5     else:
----> 6     raise Exception("Argument is not an integer")
    7     return helper

Exception: Argument is not an integer

Fixing the Fibonacci series

In [70]:

def memoize(f):
    memo = {}
    def helper(n):
        if n not in memo:
            memo[n] = f(n)
        return memo[n]
    return helper

arguments = []

@memoize
def fib(n):
    arguments.append(n)
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return fib(n-1) + fib(n-2)

[fib(i) for i in range(6)]

Out[70]:
[0, 1, 1, 2, 3, 5]

In [71]:
counts = {i: arguments.count(i) for i in range(max(arguments)+1)}
counts

Out[71]:
{0: 1, 1: 1, 2: 1, 3: 1, 4: 1, 5: 1}

In [72]:
sum(counts.values())

Out[72]:
6

There is a built-in cache decorator
In [ ]:

```
# built-in least-recently used cache decorator
import functools
@functools.lru_cache(maxsize=128, typed=False)
def fib(n):
    if n < 2:
        return
    else:
        return fib(n-1) + fib(n-2)
```

### 4.4. Static variables

In [73]:

```
# Exercise
# - write a decorator counting the number of times a function was called
# - the same but for a varying number of parameters and keyword-arguments

def counter(func):
    # first define function
    def helper(x, *args, **kwargs):
        helper.count += 1
        return func(x, *args, **kwargs) # return function as it is
    # then, define an attribute to be incremented with every call
    # this attribute behaves like a static variable
    # helper exist only after the function definition. Once defined, then we can attach an attribute
    helper.count = 0
    return helper

@counter
def fun(x):
    return x

fun(1)
fun(2)
fun(3)
fun.count
```

Out[73]:

```
3
```

### 4.6. Generators

In [74]:

```
s = "Python"
itero = iter(s)
itero
# what I write is:
# for char in s:
# what python does:
# for char in iter(s)
# in fact it is a while loop until stop is reached
```

Out[74]:

```
<str_iterator at 0x7f4675fb7f28>
```

In [75]:

```
next(itero)
```

Out[75]:

```
'P'
```
In [76]:
next(itero)

Out[76]:
'y'

In [77]:
next(itero)

Out[77]:
't'

In [78]:
next(itero)

Out[78]:
'h'

In [79]:
next(itero)

Out[79]:
'o'

In [80]:
next(itero)

Out[80]:
'n'

In [81]:
next(itero)

---------------------------------------------------------------------------
StopIteration  Traceback (most recent call last)
<ipython-input-81-bc7ed7acd9c9> in <module>
      1 next(itero)

StopIteration:

Own generator

In [87]:

def abc_generator():
   yield "a"
   yield "b"
   yield "c"

x = abc_generator() # we call like a function. A function returns an object

for i in x:
   print(i)

a
b
c
In [86]:
next(x)

---------------------------------------------------------------------------
StopIteration  Traceback (most recent call last)
<ipython-input-86-92de4e9f6b1e> in <module>
----> 1 next(x)

StopIteration:

In [80]:

    # print(next(x))  <-- yield "a"
    # print(next(x))  <-- yield "b"
    # print(next(x))  <-- yield "c"
    # this is a co-process. This function creates a code waiting to be executed, when we assign x = abc_generator()
    # after it reaches a yield, it returns value and stops. Then next is positioned after the yield.x
    x = abc_generator()
    print(next(x))
    print(next(x))
    print(next(x))
    print(next(x))

a
b
c

---------------------------------------------------------------------------
StopIteration  Traceback (most recent call last)
<ipython-input-80-e58ce091c0f7> in <module>
    8 print(next(x))
    9 print(next(x))
   ---> 10 print(next(x))

StopIteration:

A function is also a single-value generator

In [88]:

def abc_generator():
    return "a"

x = abc_generator()
for i in x:
    print(i)
# works, because the returned value is iterable

a

In [82]:
type(abc_generator())

Out[82]:
str

In [83]:

def abc_generator():
    for char in ["a", "b", "c"]:
        yield char
    for i in abc_generator():
        print(i)

a
b
c
In [85]:

type(abc_generator())

Out[85]:
generator

In [ ]:

# Generate a pi value
# pi/4 = 1 - 1/3 + 1/5 - 1/7

def pi_series():
    sum = 0
    i = 1.0
    j = 1
    while True:
        sum = sum + j/i
        yield 4*sum
        i = i + 2
        j = j * -1

    # runs forever
    # we can break with a counter, but it is not a good idea
    for i in pi_series():
        print(i)

In [ ]:

def firstn(g, n):
    for i in range(n):
        yield next(g)

print(list(firstn(pi_series(), 8)))

4.7. Context Manager

Is used to allocate and release some sort of resource when we need it.
Which means that before we start a block we open e.g. a file, and when we are going out, the file is automatically released.
If we don't close, it remains open in a file system. Closing a program, it would close. A good practice is to always close.

With context managers, the benefit is no need to close.
The issue is with the exceptions. With with, the exception is caught and handled.
Context manager is a general concept. The concept is as follows.

    with device():
        before:
        1. check device
        2. start device

        we enter the block:
        1. we do something

        after:
        1. we execute stop block

        in case of exceptions we are sure that the after part will be executed.

In [ ]:

import csv

with open('example.txt', 'w') as out:
    csv_out = csv.writer(out)
    csv_out.writerow(['date', '# events'])
from contextlib import contextmanager

@contextmanager
def device():
    print("Check device")
    device_state = True
    print("Start device")
    yield device_state  # the block after with is executed
    print("Stop device")

with device() as state:
    print("State is ", state)
    print("Device is running!")

5. Exception handling

Exception handling
It is easier to ask for forgiveness than for permission
E.g.

    if fileexists(file_name):
        txt = open(file_name).read()

We first check if the file exists, then in the next step we fetch the file - two operations (asking for permission)
We can try to read, if it is there we are good, otherwise it raises an exception - single operation (asking for forgiveness)

    try:
        txt = open(file_name)
    except Exception as e:
        txt = ""

In [ ]:

while True:
    try:
        x = int(input("Please enter a number: "))
        break
    except ValueError as err:
        print("Error message: ", err)
        print("No valid number. Try again")

try:
    some code
except ZeroDivisionError:
    some code
    there could be a raise here
except FooError:
    some code
except BarError:
    some code
finally:
    some code executed always
In [ ]:
# Finally is executed always
try:
    x = float(input("Your number: "))
    inverse = 10/x
e except ValueError as err:
    print("Error message: ", err)
    print("No valid number. Try again")
finally:
    print("There may or may not have been an exception.")
print("The inverse: ", inverse)

In [ ]:
# assert
x = 5
y = 6
assert x < y, "x has to be smaller than y"