Introduction to Scientific Python

Lecture 2: Functions and Lists

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Contents

Google Surveys!

- Received input from most of you – please help me help you!
- It seems like a lot of you are interested in Machine Learning...
- How to get the most out of this course

Proposal

- 1-2 paragraph pdf outlining your project ideas
- Email me (lukedeo@stanford.edu) with the subject line:

  `[CME193 PROJECT]LastName-FirstName`.

  I have a filter set up for these.
- Due next Thursday before class (don't stress, this is fun!)

Project

- Content: up to you!
- Some ideas on course website
- Work on your own
- Submit source code and brief write-up (basically updated proposal) via Email
- Due 5pm last day of *this class*, NOT the last day of the quarter.
- See course website
- Ask if things are unclear!

Contents

Simple example

Example: Suppose we want to find the circumference of a circle with radius 2.5. We could write

```
radius = 2.5
circumference = math.pi * radius
```

Functions

Functions are used to abstract components of a program.

Much like a mathematical function, they take some input and then do something to find the result.

Rule of thumb: a functions should do one *obvious* thing!

Functions: def

Start a function definition with the keyword `def`

Then comes the function name, with arguments in braces, and then a colon

```
def func(arg1, arg2):
```

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Functions: body

Then comes, indented, the body of the function

Use `return` to specify the output

```
return result
```

```
def calc_circumference(radius):
    circumference = math.pi * radius
    return circumference
```

Functions: body

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Use `return` to specify the output

`return result`

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def calc_circumference(radius):
    circumference = math.pi * radius
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```

Return

By default, Python returns None

Once Python hits `return`, it will return the output and jump out of the function

```
def loop():
    for x in xrange(10):
        print x
        if x == 3:
            return
```

What does this function do?

Return

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def loop():
    for x in xrange(10):
        print x
        if x == 3:
            return
```

What does this function do?

How to call a function

Calling a function is simple (i.e. run/execute):

```
>> func(2.3, 4)
```

Quick question

What is the difference between `print` and `return`?

Exercise

1. Write a function that prints ‘Hello, world!’
2. Write a function that returns ‘Hello, `name`!’, where `name` is a variable

Exercise solution

```
def hello_world():
    print 'Hello, world!'

def hello_name(name):
    # string formatting: more on this later.
    return 'Hello, {}!'.format(name)
```

Everything is an object

Everything is Python is an object, which means we can pass functions:

```
def twice(f, x):
    ''' apply f twice '''
    return f(f(x))
```

Scope

Variables defined within a function (local), are only accessible within the function.

```
x = 1

def add_one(x):
    x = x + 1  # local x
    return x

y = add_one(x)
# x = 1, y = 2
```

Functions within functions

It is also possible to define functions within functions, just as we can define variables within functions.

```
def function1(x):
    def function2(y):
        print y + 2
        return y + 2

    return 3 * function2(x)

a = function1(2)    # 4
print a             # 12
b = function2(2.5)  # error: undefined name
```

Global keyword

We could (but should not) change global variables within a function

```
x = 0

def incr_x():
    x = x + 1  # does not work

def incr_x2():
    global x
    x = x + 1  # does work
```

Question: What is the difference between the last two functions?

Scope questions

```
def f1():
    global x
    x = x + 1
    return x

def f2():
    return x + 1

def f3():
    x = 5
    return x + 1

x = 0
print f1() # output? x?
print f2() # output? x?
print f3() # output? x?
```

Default arguments

It is sometimes convenient to have default arguments

```
def func(x, a=1):
    return x + a

print func(1)     # 2
print func(1, 2)  # 3
```

The default value is used if the user doesn't supply a value.

More on default arguments

Consider the function prototype: `func(x, a=1, b=2)`

Suppose we want to use the default value for a, but change b:

```
def func(x, a=1, b=3):
    return x + a - b

print func(2)       # 0
print func(5, 2)    # 4
print func(3, b=0)  # 4
```

Docstring

It is important that others, including *you-in-3-months-time* are able to understand what your code does.

This can be easily done using a so called 'docstring', as follows:

```
def nothing():
    """ This function doesn't do anything. """
    pass
```

We can then read the docstring from the interpreter using:

```
>> help(nothing)
This function doesn't do anything.
```

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```
>> help(nothing)
```

This function doesn't do anything.

Question

```
def nothing():
    """ This function doesn't do anything. """
    pass
```

Question: what does `nothing()` return?

Lambda functions

An alternative way to define short functions:

```
cube = lambda x: x*x*x

print cube(3)
```

Pros:

- One line / in line
- No need to name a function

Try to use these for the homework if you can.

Contents

Lists

- Group variables together
- Specific order
- Access items using square brackets: [ ]

However, do not confuse a list with the mathematical notion of a vector.

Accessing elements

- First item: [0]
- Last item: [-1]

```
myList = [5, 2.3, 'hello']

myList[0]     # 5
myList[2]     # 'hello'
myList[3]     # ! IndexError
myList[-1]    # 'hello'
myList[-3]    # ?
```

Note: can mix element types!

Slicing and adding

- Lists can be sliced: [2:5]
- Lists can be multiplied
- Lists can be added

```
myList = [5, 2.3, 'hello']

myList[0:2]     # [5, 2.3]

mySecondList = ['a', '3']

concatList = myList + mySecondList
# [5, 2.3, 'hello', 'a', '3']
```

Multiplication

We can even multiply a list by an integer

```
myList = ['hello', 'world']

myList * 2
# ['hello', 'world', 'hello', 'world']

2 * myList
# ['hello', 'world', 'hello', 'world']
```

Lists are mutable

Lists are mutable, this means that individual elements can be changed.

```
myList = ['a', 43, 1.234]

myList[0] = -3
# [-3, 43, 1.234]

x = 2
myList[1:3] = [x, 2.3]  # or: myList[1:] = [x, 2.3]
# [-3, 2, 2.3]

x = 4
# What is myList now?
```

Copying a list

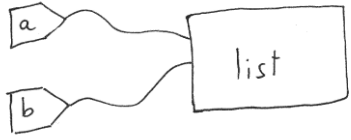
How to copy a list?

```
a = [1, 2, 3]
b = a  # let's copy a
print b

b[1] = 5  # now we want to change an element

print b
# [1, 5, 2]

print a
# [1, 5, 2]
```

.

What just happened?

Variables in Python really are tags:



So `b = a` means: `b` is same tag as `a`.

Image from `http://henry.precheur.org/python/copy_list.html`

Copying a list

Instead: we want:

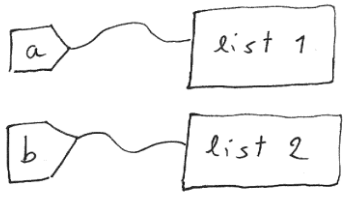


Figure : `b = list(a)` or `b = a[:]`

Image from `http://henry.precheur.org/python/copy_list.html`

Copying a list

```
a = [1, 2, 3]
b = a
c = list(a)
print id(a), id(b), id(c)
```

Functions modify lists

Consider the following function:

```
def set_first_to_zero(xs):
    xs[0] = 0

l = [1, 2, 3]
print l
set_first_to_zero(l)
print l
```

What is printed?

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

Why does the list change, but variables do not?

Functions modify lists

Consider the following function:

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Why does the list change, but variables do not?

We have not changed the tag, only the contents of the list. The variable `l`, that is attached to the list, becomes local. The elements however, do not!

What happens in this case?

```
def list_function(l):
    l = [2, 3, 4]
    return l

l = [1, 2, 3]
print list_function(l)
print l
```

Why does the list change, but variables do not?

We have not changed the tag, only the contents of the list. The variable `l`, that is attached to the list, becomes local. The elements however, do not!

What happens in this case?

```
def list_function(l):
    l = [2, 3, 4]
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l = [1, 2, 3]
print list_function(l)
print l
```

More control over lists

- `len(xs)`
- `xs.append(x)`
- `xs.count(x)`
- `xs.insert(i, x)`
- `xs.sort()` and `sorted(xs)`: what's the difference?
- `xs.remove(x)`
- `xs.pop()` or `xs.pop(i)`
- `x in xs`

All these can be found in the Python documentation, google: 'python list'

Or using `dir(xs)` / `dir([])`

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Or using `dir(xs)` / `dir([])`

Looping over elements

It is very easy to loop over elements of a list using `for`, we have seen this before using `range`.

```
someIntegers = [1, 3, 10]

for integer in someIntegers:
    print integer,
# 1 3 10

# What happens here?
for integer in someIntegers:
    integer = integer*2
```

Looping over elements

Using `enumerate`, we can loop over both element and index at the same time.

```
myList = [1, 2, 4]

for index, elem in enumerate(myList):
    print '{0}) {1}'.format(index, elem)

# 0) 1
# 1) 2
# 2) 4
```

Map

We can apply a function to all elements of a list using `map`

```
l = range(4)
print map(lambda x: x*x*x, l)
# [0, 1, 8, 27]
```

Filter

We can also filter elements of a list using `filter`

```
l = range(8)

print filter(lambda x: x % 2 == 0, l)
# [0, 2, 4, 6]
```

List comprehensions

A very powerful and concise way to create lists is using *list comprehensions*

```
print [i**2 for i in range(5)]
# [0, 1, 4, 9, 16]
```

This is often more readable than using `map` or `filter`

List comprehensions

```
ints = [1, 3, 10]

[i * 2 for i in ints]
# [2, 6, 20]

[[i, j] for i in ints for j in ints if i != j]
# [[1, 3], [1, 10], [3, 1], [3, 10], [10, 1], [10, 3]]

[(x, y) for x in xrange(3) for y in xrange(x+1)]
# ...
```

Note how we can have a lists as elements of a list!

List comprehensions

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[[i, j] for i in ints for j in ints if i != j]
# [[1, 3], [1, 10], [3, 1], [3, 10], [10, 1], [10, 3]]

[(x, y) for x in xrange(3) for y in xrange(x+1)]
# ...
```

Note how we can have a lists as elements of a list!

Implementing map using list comprehensions

Let's implement `map` using list comprehensions

```
def my_map(f, xs):
    return [f(x) for x in xs]
```

Implement filter by yourself in one of the exercises.

Implementing map using list comprehensions

Let's implement `map` using list comprehensions

```
def my_map(f, xs):
    return [f(x) for x in xs]
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Implement filter by yourself in one of the exercises.