

Functions and functional programming

Python is not a functional programming language, but it has a lot of features taken from functional programming languages:

- ▶ closures
- ▶ high order functions and decorators
- ▶ generators
- ▶ coroutines
- ▶ list comprehensions

But First... Let's define a function

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def add(x, y):  
    return x + y
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That's it!!

Not actually... There are a couple of things to notice:

- ▶ python is dynamic
- ▶ parameters don't have a specified type
- ▶ neither do we specify the return type

Evaluation Strategy

- ▶ parameters are just names that point to objects
- ▶ if you pass an immutable object, it looks as if it was passed by value

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```
def increment_value(x):  
    x = x + 1  
    print x  # Outputs: 4
```

```
a = 3  
increment_value(y)  
print a  # Outputs: 3
```

- ▶ Oups... It didn't actually work...

Evaluation Strategy

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```
def increment(values):  
    for i, v in enumerate(values):  
        values[i] = v + 1
```

```
a = [1, 2, 3]  
increment(a)  
print a  # Outputs: [2, 3, 4]
```

Evaluation Strategy

Functions that mutate their input arguments are:

- ▶ said to have **side effects**
- ▶ are best avoided as they might lead to subtle bugs
- ▶ are needed for doing **in-place** changes to large or expensive objects

Evaluation Strategy

- ▶ this is named **call by sharing**
- ▶ it's the same as in languages such as Java or Ruby
- ▶ though Java people name it pass-by-value
- ▶ while Ruby people name it pass-by-reference

Exercises

1. write a function that takes a list of integers and returns the number of even numbers contained in the list
2. write a function that takes a list of integers and returns a new list containing the even numbers from the list
3. write a function that takes a list of integers and **in-place** removes the odd elements

Exercise 3. Take 1

```
def remove_odd(values):  
    for val in values:  
        if val % 2 != 0:  
            values.remove(val)
```

```
a = [1, 1, 1, 2, 4]  
remove_odd(a) # list will be [1, 2, 4]
```

Never add/remove elements while iterating!!

Exercise 3. Take 2

```
import copy

def remove_odd(values):
    for val in copy.copy(values):
        if val % 2 != 0:
            values.remove(val)

a = [1, 1, 1, 2]
remove_odd(a)  # list will correctly be [2, 4]
```

This works, but the algorithm is $O(n^2)$

Exercise 3. Take 3

```
def remove_odd(values):  
    values[:] = [v for v in values if v % 2 == 0]
```

```
a = [1, 1, 1, 2]  
remove_odd(a)  # list will correctly be [2, 4]
```

Default parameter values

```
def increment(x, inc=1):  
    return x + inc
```

```
a = 3  
increment(a)  # returns: 4  
increment(a, 2) # returns: 6
```


Default parameter values

- ▶ you can't have a non-default parameter following a default one. That raises **SyntaxError**
- ▶ default parameter values are assigned at function definition and never change

```
default = 1
def foo(x=default)
    print x
```

```
default = 2
foo() # Outputs: 1
```

Keyword arguments

```
def make_symlink(target , link_name):  
    do_stuff
```

```
make_symlink(target='/foo' , link_name='/bar')
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    do stuff
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```

```
make_symlink(link_name='/bar' , target='/foo')
```

```
make_symlink('/foo' , link_name='/bar')
```

```
make_symlink(target='foo' , '/bar')  # SyntaxError !
```

Varargs functions

```
def make_window(parent , *args , **kwargs):  
    print container  
    print args  
    print kwargs
```

```
make_window(1, 2, 3, 4, 5,  
            color='red',  
            modal=False,  
            visible=True)
```

Varargs functions

```
def make_window(parent , *args , **kwargs):  
    print container    # Outputs: 1  
    print args         # Outputs: (2, 3, 4, 5)  
    print kwargs        # Outputs: {'color ': 'red ',  
                        # 'modal ': False ,  
                        # 'visible ': True}  
  
make_window(1, 2, 3, 4, 5,  
            color='red ',  
            modal=False ,  
            visible=True)
```

Variable scope

Python uses function scope:

- ▶ each time a function executes a new local namespace is created
- ▶ the local namespace contains parameters as well as variables defined inside the function

When resolving variables

- ▶ the local namespace is searched
- ▶ If no match is found, the global namespace is searched

Variable scope

```
var = 10
def foo():
    var = 21
foo()
print var  # Outputs: 10
```

Variable scope

```
var = 10
def foo():
    global var
    var = 21
foo()
print var  # Outputs: 21
```

Nested functions

```
def countdown(initial , msg):  
  
    def show_msg():  
        print '%s_%d' % (msg, n)  
  
    for n in xrange(initial , 0, -1):  
        show_msg()
```

```
countdown(2, 'at:')
```

```
# Output:
```

```
# at:2
```

```
# at:1
```

```
# at:0
```

Functions as first class citizens

What this means:

- ▶ functions can be passed as parameters
- ▶ functions can be return values

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```
def compare(x, y):  
    return cmp(x.lower(), y.lower())
```

```
sorted(['B', 'c', 'a'], compare)  
# Returns ['a', 'B', 'c']
```

Closures

A closure is a function that is packaged together with the surrounding environment

Closure example

Closures can be used for delayed evaluation

```
from urllib import urlopen
```

```
def page(url):  
    def get():  
        return urlopen(url).read()  
    return get
```

```
python = page('http://python.org')  
jython = page('http://jython.org')
```

```
pydata = python()  # Fetches http://python.org  
jydata = jython()  # Fetches http://jython.org
```

High order function example

High order functions are functions that do at least one of

- ▶ take one or more functions as input
- ▶ return a function

High order function example 1

```
def logging_wrapper(func):  
    def wrapped():  
        print 'entering '  
        func()  
        print 'exiting '  
    return wrapped  
  
def foo():  
    print 'fooo '  
  
logged_foo = logging_wrapper(foo)  
logged_foo()  
# entering  
# fooo  
# exiting
```

High order function example 2

```
def logging_wrapper(func):  
    def wrapped():  
        print 'entering '  
        func()  
        print 'exiting '  
    return wrapped
```

```
def foo():  
    print 'fooo '
```

```
foo = logging_wrapper(foo)  
foo()  
# entering  
# fooo  
# exiting
```

Decorators (take 1)

```
def logging_wrapper(func):  
    def wrapped():  
        print 'entering '  
        func()  
        print 'exiting '  
    return wrapped
```

```
@logging_wrapper  
def foo():  
    print 'foo'
```

```
foo()  
# entering  
# foo  
# exiting
```

Decorators (take 2)

```
def logging_wrapper(func):  
    def wrapped(*args, **kwargs):  
        print 'entering '  
        ret_val = func(*args, **kwargs)  
        print 'exiting '  
        return ret_val  
    return wrapped
```

```
@logging_wrapper  
def foo(msg):  
    return 'foo_0%s' % msg
```

```
print foo('bar')  
# entering  
# exiting  
# foo_0 bar
```

Exercise

Write a 'timing' decorator that wraps a function and prints how long the function's execution takes

Hint: use the Timer class from the timeit module:

```
import timeit
t = timeit.Timer()
# do stuff
logging.info(t.timeit())
```

Generators

- ▶ a generator is a function that produces a sequence of values.
- ▶ the sequence can be then consumed with a **for** loop or by explicitly calling **next** on the returned generator object

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```
def my_range( first , last ):  
    i = first  
    while i < last:  
        yield i  
        i += 1
```

```
for x in my_range(0, 3):  
    print x
```

Outputs: 0 1 2

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```
def my_range( first , last ):  
    i = first  
    while i < last:  
        yield i  
        i += 1
```

```
print sum(my_range(0 , 3))  # Outputs: 4
```


Generators

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- ▶ the sequence can be then consumed with a **for** loop or by explicitly calling **next** on the returned generator object

```
def my_range(first , last ):
    i = first
    while i < last:
        yield i
        i += 1
```

```
gen = my_range(0, 3)
print gen.next()  # Outputs 0
print gen.next()  # Outputs 1
print gen.next()  # Outputs 2
print gen.next()  # raised StopIteration !
```

Generators

```
def my_range(first , last ):
    i = first
    while i < last:
        yield i
        i += 1
```

```
gen = my_range(0, 3)
while True:
    try:
        print gen.next()
    except StopIteration:
        break
```

Endless generators

```
import random

def random_generator():
    while True:
        yield random.random()

random_gen = random_generator()
for rand_nr in random_gen:
    print nr
    if rand_nr > 0.5:
        break
random_gen.close()
```

Exercises

1. Write a generator that takes an integer parameter and yields fibonacci numbers smaller than the given argument.
2. Having a binary tree encoded as a tuple (label, left, right) write a generator that yields the labels in pre-order (root, left, right). Write both an iterative and recursive implementation.

Example:

```
tree= ( 'b' ,  
        ( 'a' ,  
          ( 'q' , None , None ) ,  
          None ) ,  
        ( 'z' ,  
          ( 'c' , None , None ) ,  
          ( 'zz' , None , None ) ) )
```

```
for label in iterate(tree):  
    print label
```

Output: b, a, q, z, c, zz

Piping generators

```
def grep(lines , word):  
    for line in lines:  
        if word in line:  
            yield line  
  
f = open('passwd')  
lines = grep(f, 'foo')  
lines = grep(lines, 'bar')  
for line in lines:  
    print line  
f.close()
```

Equivalent: cat some_file | grep foo | grep bar

Piping generators

```
def grep(lines , word):  
    for line in lines:  
        if word in line:  
            yield line  
  
f = open('passwd')  
try:  
    lines = grep(f, 'foo')  
    lines = grep(lines , 'bar')  
    for line in lines:  
        print line  
finally:  
    f.close()
```

Piping generators

```
def grep(lines , word):  
    for line in lines:  
        if word in line:  
            yield line  
  
for ln in grep(grep(open('passwd'), 'foo'), 'bar'):  
    print ln
```

List comprehensions

```
nums = [1, 2, 3, 4, 5]
times_two = [x * 2 for x in nums]
print times_two
# Outputs: [2, 4, 6, 8, 10]
```


List comprehensions

```
nums = [1, 2, 3, 4, 5]
even_times_two = [x * 2 for x in nums if x % 2 == 0]
print even_times_two
# Outputs: [4, 8]
```

List comprehensions

```
sentences = ['mama_are_mere', 'tata_are_pere']  
words = []  
for s in sentences:  
    for w in words:  
        words.append(w.upper())  
  
print words
```