Python
Functions

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Outline

Outline

Functions

Description

- Functions are the structured or procedural programming way of organizing the logic in your programs.
- Functions: Return a value back to their callers.
- Procedures: Functions that do not return a value.
  (**Python procedures are implied functions because the interpreter implicitly return a default value of** `None`.)

A first procedure

Hello world!

```
In [1]: def hello():
   ...:     print "hello world!"
   ...:

In [2]: result = hello()
hello world!

In [3]: result

In [4]: print result
------> print(result)
None

In [5]: type(result)
Out[5]: <type 'NoneType'>
```

A first function

Double anything

```
In [1]: def double(arg):
   ...:     return arg * 2
   ...:

In [2]: print double(3)
------> print(double(3))
6

In [3]: print double("abc")
------> print(double("abc"))
abcabc

In [4]: print double([1, 2, 3])
------> print(double([1, 2, 3]))
[1, 2, 3, 1, 2, 3]

In [5]:
```

(Creating the illusion of) Returning multiple items

Example

```
In [1]: def returning_multiple_items():
   ...:     return 1, 'a', [1, 2, 3]
   ...:

In [2]: result = returning_multiple_items()

In [3]: print result
------> print(result)
(1, 'a', [1, 2, 3])

In [4]: type(result)
Out[4]: <type 'tuple'>

In [5]: n, c, l = returning_multiple_items()

In [6]: print n, c, l
------> print(n, c, l)
(1, 'a', [1, 2, 3])
```

Arguments

Example

```
In [1]: def connection(host, port):
   ...:     # do something ...
   ...:     print "host: %s, port: %s" % (host, port)
   ...:

In [2]: connection("monge.univ-mlv.fr", 8080)
host: monge.univ-mlv.fr, port: 8080

In [3]: connection(port = 8080, host = "monge.univ-mlv.fr")
host: monge.univ-mlv.fr, port: 8080

In [4]: connection()
---------------------------------------------------------------------------
TypeError   Traceback (most recent call last)

.../func/src/<ipython console> in <module>()

TypeError: connection() takes exactly 2 arguments (0 given)
```

Recursive functions

Example

```
In [1]: def fact(n):
   ...:     if n == 0:
   ...:         return 1
   ...:     else:
   ...:         return n * fact(n-1)
   ...:

In [2]: fact(10)
Out[2]: 3628800

In [3]: fact(100)
Out[3]: 933262154439441526816992388562667004907159682643816214685929
        638952175999932299156089414639761565182862536979208272237582
        511852109168640000000000000000000000L
```

Recursive functions

Example

```
In [1]: def fact(n):
   ...:     def fact_aux(n, acc):
   ...:         if n == 1:
   ...:             return acc
   ...:         else:
   ...:             return fact_aux(n - 1, acc * n)
   ...:     return fact_aux(n, 1)
   ...:

In [2]: fact(10)
Out[2]: 3628800

In [3]: fact(100)
Out[3]: 933262154439441526816992388562667004907159682643816214685929638952175999932299156089414639761565182862536979208272237582511852109168640000000000000000000000L
```

Recursive functions

Example

```
In [1]: def fact(n):
   ...:     def fact_aux(n, acc):
   ...:         if n == 1:
   ...:             return acc
   ...:         else:
   ...:             return fact_aux(n - 1, acc * n)
   ...:     return fact_aux(n, 1)
   ...:

In [2]: fact(-1)

func/<ipython console> in fact(n)
func/<ipython console> in fact(n)
...
func/<ipython console> in fact(n)

RuntimeError: maximum recursion depth exceeded
```

Outline

The simplest function

Example

```
In [1]: def f():
   ...:     pass
   ...:
In [2]: f()
In [3]: print f()
------> print(f())
None
In [4]: type(f)
Out[4]: <type 'function'>
In [5]:
```

Forward references

Example

```
In [1]: def f():
   ...:     g()
   ...:
In [2]: f()
---------------------------------------------------------------------------
NameError Traceback (most recent call last)
.../<ipython console> in <module>()
.../<ipython console> in f()
NameError: global name 'g' is not defined
In [3]: def g():
   ...:     pass
   ...:
In [4]: f()
In [5]: g()
In [6]:
```

Function attributes

Description

- Dotted-attribute notation.
- Closely related to namespaces.

Example

```
In [1]: def f():
   ...:     ' a docstring for function f()'
   ...:     pass
   ...:
In [2]: def g():
   ...:     pass
   ...:
In [3]: f.__doc__
Out[3]: ' a docstring for function f()'
In [4]: g.__doc__
In [5]: g.__doc__ = 'some docstring for function g()'
In [6]: g.__doc__
Out[6]: 'some docstring for function g()'
```

Function attributes

Listing all attributes

```
In [1]: def f():
   ...:     pass
   ...:
In [2]: dir(f)
Out[2]:
['__call__', '__class__', '__closure__', '__code__',
 '__defaults__', '__delattr__', '__dict__', '__doc__',
 '__format__', '__get__', '__getattribute__', '__globals__',
 '__hash__', '__init__', '__module__', '__name__', '__new__',
 '__reduce__', '__reduce_ex__', '__repr__', '__setattr__',
 '__sizeof__', '__str__', '__subclasshook__', 'func_closure',
 'func_code', 'func_defaults', 'func_dict', 'func_doc',
 'func_globals', 'func_name']
```

Passing functions

Description

- In Python, functions are like any other object: they can be referenced (accessed or aliased to other variables), passed as arguments to functions, ...
- Unique characteristic: they are callable.

Example

```
In [1]: def f():
   ...:     print 'in f()'
   ...:
In [2]: f()
in f()
In [3]: g = f
In [4]: g()
in f()
In [5]:
```

Passing functions

Example

```
In [1]: def f():
   ...:     print 'in f()'
   ...:
In [2]: def g(arg_func):
   ...:     arg_func()
   ...:
In [3]: g(f)
in f()
In [4]: g(g)
---------------------------------------------------------------
TypeError Traceback (most recent call last)
.../<ipython console> in <module>()
.../<ipython console> in g(arg_func)
TypeError: g() takes exactly 1 argument (0 given)
In [5]:
```

Passing functions

Example

```
In [1]: def convert(func, x):
   ...:     'conv a number'
   ...:     return func(x)
   ...:
In [2]: convert(int, 12.34)
Out[2]: 12
In [3]: convert(long, 1234)
Out[3]: 1234L
In [4]: convert(float, 1234)
Out[4]: 1234.0
In [5]: convert(str, 1234)
Out[5]: '1234'
In [6]:
```

Passing functions

Example

```
In [1]: def apply_func(func, x):
   ...:     return func(x)
   ...:
In [2]: apply_func(str, 1234)
Out[2]: '1234'
In [3]: apply_func('a string', 1234)
---------------------------------------------------------
TypeError Traceback (most recent call last)
.../<ipython console> in <module>()
.../<ipython console> in apply_func(func, x)
TypeError: 'str' object is not callable
In [5]: callable('a sting')
Out[5]: False
In [6]: def apply_func(func, x):
   ...:     if callable(func):
   ...:         return func(x)
   ...:
In [7]: apply_func('a string', 1234)
In [8]:
```

Outline

Positional arguments

Example

```
In [1]: def f(arg):
   ...:     print 'hello', arg  # defined for only 1 argument
   ...:

In [2]: f()  # 0 argument ...
---------------------------------------------------------
TypeError Traceback (most recent call last)
.../<ipython console> in <module>()
TypeError: f() takes exactly 1 argument (0 given)
In [3]: f('world')  # 1 argument, that's fine
hello world
In [4]: f('cruel', 'world')  # two many arguments ...
---------------------------------------------------------
TypeError Traceback (most recent call last)
.../<ipython console> in <module>()
TypeError: f() takes exactly 1 argument (2 given)
In [5]:
```

Default arguments

```
func(pos_args, def_arg1 = val1, def_arg2 = val2, ...)
```

Example

```
In [1]: def tax_me(cost, rate = .055):
   ...:     return cost + (cost * rate)
   ...:
In [2]: tax_me(100)
Out[2]: 105.5
In [3]: tax_me(100, .195)
Out[3]: 119.5
In [4]: tax_me(rate = .195, cost = 100)
Out[4]: 119.5
In [5]: def tax_me(rate = .055, cost):
   ...:     return cost + (cost * rate)
------------------------------------------------
File "<ipython console>", line 1
SyntaxError: non-default argument follows
             default argument (<ipython console>, line 1)
In [6]:
```

Default arguments

Example

```
In [1]: def conn(host='monge.univ-mlv.fr', database='sqlbase', port=1234):
   ...:     print 'host=%s,database=%s,port=%s' % (host, database, port)
   ...:
In [2]: conn()  # use default arguments
host=monge.univ-mlv.fr,database=sqlbase,port=1234
In [3]: conn('localhost', 'my_sqlbase', 9999) # custom conn
host=localhost,database=my_sqlbase,port=9999
In [4]: conn('localhost', 'my_sqlbase') # use default port
host=localhost,database=my_sqlbase,port=1234
In [5]: conn('localhost') # use default database and default port
host=localhost,database=sqlbase,port=1234
In [6]: conn(port = 9999, database = 'my_sqlbase') # use default host
host=monge.univ-mlv.fr,database=my_sqlbase,port=9999
In [7]:
```

Default arguments

Example

```
n [1]: def conn(host, database='sqlbase', port='1234'):
   ...:     print 'host=%s,database=%s,port=%s' % (host, database, port)
   ...:
In [2]: conn()
---------------------------------------------------------------
TypeError Traceback (most recent call last)

.../<ipython console> in <module>()
TypeError: conn() takes at least 1 argument (0 given)

In [3]: conn('monge.univ-mlv.fr')  # use default arguments
host=monge.univ-mlv.fr,database=sqlbase,port=1234
In [4]: conn('monge.univ-mlv.fr', database='flat')  # use default port
host=monge.univ-mlv.fr,database=flat,port=1234
In [5]: conn('monge.univ-mlv.fr', port=9999)  # use default database
host=monge.univ-mlv.fr,database=sqlbase,port=9999
In [6]: conn('monge.univ-mlv.fr', 9999)  # !!!!!!!!
host=monge.univ-mlv.fr,database=9999,port=1234
In [7]:
```

Modifying arguments

Example

```
In [1]: def f(arg):
    ...:     print 'in f(), arg = ', arg
    ...:     arg[0] = 'x'
    ...:     print 'in f(), arg = ', arg
    ...:

In [2]: l = ['a', 'b', 'c']

In [3]: f(l)
in f(), arg =  ['a', 'b', 'c']
in f(), arg =  ['x', 'b', 'c']

In [4]: l
Out[4]: ['x', 'b', 'c']

In [5]:
```

Modifying arguments

Example

```
In [1]: def f(arg):
...:     print '1: ', arg
...:     arg = arg * 2
...:     print '2: ', arg
...:

In [2]: l = [1, 2, 3]

In [3]: f(l)
1:  [1, 2, 3]
2:  [1, 2, 3, 1, 2, 3]

In [4]: l
Out[4]: [1, 2, 3]
```

Grouped arguments

Description

- Python allows the programmer to execute a function without explicitly specifying individual arguments in the call.
- Group in a tuple (**non-keyword arguments**).
- Group in a dictionnary (**keyword argument**).

```
func(*tuple_grp_nonkw_args, **dict_grp_kw_args)

func(positional_args, kw_args,
     *tuple_grp_nonkw_args, **dict_grp_kw_args)
```

Non-keyword variable arguments

Example

```
[1]: def f(arg1, arg2='default arg2', *the_rest):
   ...:     print 'formal arg 1:', arg1
   ...:     print 'formal arg 2:', arg2
   ...:     for arg in the_rest:
   ...:         print 'another arg:', arg
   ...:
In [2]: f('a')  # use default argument, no non-keyword argument
formal arg 1: a
formal arg 2: default arg2
In [3]: f('a', 'b') # no non-keyword argument
formal arg 1: a
formal arg 2: b
In [4]: f('a', 'b', 'c', 'd')  # some non-keyword argument
formal arg 1: a
formal arg 2: b
another arg: c
another arg: d
In [5]:
```

Keyword variable arguments

Example

```
In [1]: def f(arg1, arg2='default arg2', **the_rest):
   ...:     print 'formal arg 1:', arg1
   ...:     print 'formal arg 2:', arg2
   ...:     for kw_arg in the_rest.keys():
   ...:         print 'another arg %s: %s' % (kw_arg, str(the_rest[kw_arg]))
   ...:
In [2]: f('a')
formal arg 1: a
formal arg 2: default arg2
In [3]: f('a', 'b')
formal arg 1: a
formal arg 2: b
In [4]: f('a', 'b', xtra1='red', xtra2='green')
formal arg 1: a
formal arg 2: b
another arg xtra1: red
another arg xtra2: green
In [5]: f('a', 'b', 'c',  xtra='red', xtra2='green')  # ... TypeError !
```

Non-Keyword and Keyword variable arguments

Example

```
In [1]: def f(arg1, *nkw, **kw):
   ...:     print 'arg1:', arg1
   ...:     for nkw_arg in nkw:
   ...:         print 'xtra nkw arg:', nkw_arg
   ...:     for (kw_arg, kw_val) in kw.items():
   ...:         print 'xtra kw arg %s: %s' % (kw_arg, kw_val)
   ...:
```

Non-Keyword and Keyword variable arguments

Example

```
In [2]: f('a')
arg1: a
In [3]: f('a', 'b', 'c')
arg1: a
xtra nkw arg: b
xtra nkw arg: c
In [4]: f('a', kw_arg1='x', kw_arg2='y')
arg1: a
xtra kw arg kw_arg2: y
xtra kw arg kw_arg1: x
In [5]: f('a', kw_arg1='x', kw_arg2='y', 'b', 'c')
------------------------------------------------
 File "<ipython console>", line 1
SyntaxError: non-keyword arg after keyword arg (<ipython console>, line 1)
In [6]: f('a', 'b', kw_arg1='x')
arg1: a
xtra nkw arg: b
xtra kw arg kw_arg1: x
```

Partial function application

Description

- Functional programming.
- Default and variable arguments.

Example

```
In [1]: from operator import add, mul  # function interfaces to + and *
In [2]: from functools import partial
In [3]: succ = partial(add, 1)
In [4]: double = partial(mul, 2)
In [5]: mul_3 = partial(mul, 3)
In [6]: [(i, succ(i)) for i in range(1, 20, 3)]
Out[6]: [(1, 2), (4, 5), (7, 8), (10, 11), (13, 14), (16, 17), (19, 20)]
In [7]: [(i, double(i)) for i in range(1, 20, 3)]
Out[7]: [(1, 2), (4, 8), (7, 14), (10, 20), (13, 26), (16, 32), (19, 38)]
In [8]: [(i, mul_3(i)) for i in range(1, 20, 3)]
Out[8]: [(1, 3), (4, 12), (7, 21), (10, 30), (13, 39), (16, 48), (19, 57)]
In [9]:
```

Partial function application

Example

```
In [1]: from functools import partial
In [2]: int?
Type:            type
Base Class:      <type 'type'>
String Form:     <type 'int'>
Namespace:       Python builtin
Docstring:
    int(x[, base]) -> integer

    Convert a string or number to an integer, if possible.  A floating point
    argument will be truncated towards zero (this does not include a string
    representation of a floating point number!)  When converting a string, use
    the optional base.  It is an error to supply a base when converting a
    non-string.  If base is zero, the proper base is guessed based on the
    string content.  If the argument is outside the integer range a
    long object will be returned instead.
```

Partial function application

Example

```
In [3]: base2 = partial(int, base=2)
In [4]: base2('0'), base2('1'), base2('101010101'), base2('11111111
Out[4]: (0, 1, 341, 255)
In [5]: base10 = partial(int, base=10)
In [6]: base10('0'), base10('1'), base10('2'), base10('10')
Out[6]: (0, 1, 2, 10)
In [7]:
```

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Global versus local variables

Example

```
In [1]: global_string = "a string" # a global variable
In [2]: def f():
   ...:     local_string = "another string" # a local variable
   ...:     return global_string + " " + local_string
   ...:
In [3]: f()
Out[3]: 'a string another string'
In [4]: print local_string
------> print(local_string)
---------------------------------------------------------------------------
NameError Traceback (most recent call last)
.../<ipython console> in <module>()

NameError: name 'local_string' is not defined
In [5]:
```

The global statement

Example

```
In [1]: def f():
   ...:     print "calling f()"
   ...:     my_variable = 2
   ...:     print "in f(), my_variable =", my_variable
   ...:
In [2]: my_variable = 1
In [3]: my_variable
Out[3]: 1
In [4]: f()
calling f()
in f(), my_variable = 2
In [5]: my_variable
Out[5]: 1
In [6]: my_variable = 3
In [7]: f()
calling f()
in f(), my_variable = 2
In [8]:
```

The global statement

Example

```
In [1]: def f():
   ...:     print "calling f()"
   ...:     global my_variable
   ...:     my_variable = 2
   ...:     print "in f(), my_variable =", my_variable
   ...:
```

The global statement

Example

```
In [2]: my_variable = 1
In [3]: my_variable
Out[3]: 1
In [4]: f()
calling f()
in f(), my_variable = 2
In [5]: my_variable
Out[5]: 2
In [6]: my_variable = 3
In [7]: my_variable
Out[7]: 3
In [8]: f()
calling f()
in f(), my_variable = 2
In [9]: my_variable
Out[9]: 2
```

Number of scopes

Example

```
In [1]: def f():
   ...:     x = 1
   ...:     print "in f(), and before calling g(), x is", x
   ...:     def g():
   ...:         x = 2
   ...:         print "in g(),x is", x
   ...:     g()
   ...:     print "in f() and after calling g(), x is", x
   ...:
In [2]: f()
in f(), and before calling g(), x is 1
in g(),x is 2
in f() and after calling g(), x is 1
In [3]:
```

Closures

Description

- A closure combines an inner function's own code and scope along with the scope of an outer function.
- Closures are usful for setting up calculations, hiding states, letting you move around function objects and scope at will.
- The use of closures draws a strong parallel to partial function application.

Closures: you cannot assign to an outer-scope variable

Example

```
>>> def outer(x):
...     def inner_reads():
...         # Will return outer's 'x'.
...         return x
...     def inner_writes(y):
...         # Will assign to a local 'x', not the outer 'x'
...         x = y
...     def inner_error(y):
...         # Will produce an error: 'x' is local because of the
...         # assignment, but we use it before it is assigned to.
...         tmp = x
...         x = y
...         return tmp
...     return inner_reads, inner_writes, inner_error
...
```

Closures: you cannot assign to an outer-scope variable

Example

```
>>> inner_reads, inner_writes, inner_error = outer(5)
>>> inner_reads()
5
>>> inner_writes(10)
>>> inner_reads()
5
>>> inner_error(10)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 11, in inner_error
UnboundLocalError: local variable 'x' referenced before assignment
```

Closures: work around this limitation by using a mutable container type

Example

```
>>> def outer(x):
...     x = [x]
...     def inner_reads():
...         # Will return outer's x's first (and only) element.
...         return x[0]
...     def inner_writes(y):
...         # Will look up outer's x, then mutate it.
...         x[0] = y
...     def inner_error(y):
...         # Will now work, because 'x' is not assigned to,
...         # just referenced.
...         tmp = x[0]
...         x[0] = y
...         return tmp
...     return inner_reads, inner_writes, inner_error
...
```

Closures: work around this limitation by using a mutable container type

Example

```
>>> inner_reads, inner_writes, inner_error = outer(5)
>>> inner_reads()
5
>>> inner_writes(10)
>>> inner_reads()
10
>>> inner_error(15)
10
>>> inner_reads()
15
```

Closures

Example

```
In [1]: def counter(start_at = 0):
   ...:     count = [start_at]
   ...:     def incr():
   ...:         count[0] += 1
   ...:         return count[0]
   ...:     return incr
   ...:
```

Closures

Example

```
In [2]: count = counter()
In [3]: print count()
------> print(count())
1
In [4]: print count()
------> print(count())
2
In [5]: count = counter(5)
In [6]: print count()
------> print(count())
6
In [7]: print count()
------> print(count())
7
In [8]:
```

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Tracing functions

Example

```
def trace(f):
    def wrap(*args):
        print "before calling " + f.__name__
        f(args)
        print "after calling " + f.__name__
    return wrap

def g(*args):
    print "in g"

g('a', 'b')
h = trace(g)
h('a', 'b')
```

Output

in g before calling g in g after calling g

Composition

Example

```
In [1]: def compose(f, g):
   ...:     "Return a function f(g(x)) given two functions f,g"
   ...:     def h(x):
   ...:         return f(g(x))
   ...:     return h
   ...:
In [2]: def f(x): return x+1
   ...:
In [3]: def g(x): return 2*x
   ...:
```

Composition

Example

```
In [4]: s = compose(f,g)                    # store the composition
In [5]: s
Out[5]: <function h at 0x8374454>           # s is a function !
In [6]: s(3)                                # apply s
Out[6]: 7
In [7]: compose(f, g)(3)                    # do not store the composition
Out[7]: 7
In [8]: r = s                               # alias
In [9]: r(3)
Out[9]: 7
In [10]:
```

Composition

Example

```
def f(x):
    return x+1
def power(f, n):
    "Return a function of f composed with itself n times"
    def identity(x):
        return x
    if n == 0:
        return identity
    f_res = f
    for _ in range(n-1):
        f_res = compose(f_res, f)
    return f_res
print f(f(f(f(1))))          # print 5
power4 = power(f,  4)
print power4(1)              # print 5
print power(f, 0)(1)         # print 1
```

Outline

filter

Example

```
In [1]: def modulo(m):
   ...:     def inner(x):
   ...:         return x % m == 0
   ...:     return inner
   ...:
In [2]: l = range(10)
In [3]: filter(modulo(2), l)
Out[3]: [0, 2, 4, 6, 8]
In [4]: filter(modulo(3), l)
Out[4]: [0, 3, 6, 9]
In [5]: filter(modulo(4), l)
Out[5]: [0, 4, 8]
In [6]: filter(modulo(5), l)
Out[6]: [0, 5]
In [7]:
```

filter

Coding filter

```
In [1]: def my_filter(bool_func, seq):
   ...:     filtered_seq = [] # start with the empty seq
   ...:     for x in seq:
   ...:         if bool_func(x):
   ...:             filtered_seq.append(x)
   ...:     return filtered_seq
   ...:
In [2]: def is_odd(x):
   ...:     return x % 2
   ...:
In [3]: my_filter(is_odd, range(10))
Out[3]: [1, 3, 5, 7, 9]
In [4]:
```

reduce

Example

```
In [1]: def add(x, y):
   ...:     return x + y
   ...:
In [2]: def mult(x, y):
   ...:     return x * y
   ...:
In [3]: reduce(add, range(1, 6))
Out[3]: 15
In [4]: reduce(add, range(1, 6), 10)
Out[4]: 25
In [5]: reduce(mult, range(1, 6))
Out[5]: 120
In [6]: reduce(mult, range(1, 6), .1)
Out[6]: 12.000000000000002
In [7]: reduce(mult, range(1, 6), 2)
Out[7]: 240
In [8]:
```

reduce

Coding reduce

```
In [1]: def my_reduce(bin_func, seq, init = None):
   ...:     list_seq = list(seq) # convert seq to list
   ...:     if init is None:
   ...:         res = list_seq.pop(0)
   ...:     else:
   ...:         res = init
   ...:     for x in list_seq:
   ...:         res = bin_func(res, x)
   ...:     return res
   ...:
In [2]: def add(x, y):
   ...:     return x + y
   ...:
In [3]: my_reduce(add, range(1, 6))
Out[3]: 15
In [4]: my_reduce(add, range(1, 6), 10)
Out[4]: 25
```