

COMP1730/COMP6730

Programming for Scientists

Functions



Lecture outline

- * Function definition.
- * Function calls & order of evaluation.
- * Assignments in functions; local variables.
- * Function testing & documentation.

Functions

- * In programming, a *function* is a piece of the program that is given a name, and can be *called* by that name.
- * Functions definitions promote *abstraction* (“what, not how”) and help break a complex problem into smaller parts.
- * To encapsulate computations on data, functions have *parameters* and a *return value*.

Function definition (reminder)

```
      name
      ───────────
def change_in_percent (old, new) :
|← 4 spaces | diff = new - old
|           | return (diff / old) * 100 } suite
```

- ★ A function definition consists of a name and suite.
- ★ The extent of the suite is defined by indentation, which must be the same for all statements in the suite (standard is 4 spaces).

Function definition

```
def change_in_percent (parameters old, new) :  
    diff = new - old  
    return (diff / old) * 100
```

- * Function *parameters* are (variable) names; they can be used (only) in the function suite.
- * Parameters' values will be set only when the function is called.
- * `return` is a statement: when executed, it causes the function call to end, and return the value of the expression.

Function call

- * To call a function, write its name followed by its *arguments* in parentheses:

```
>>> change_in_percent(431, 482)
11.832946635730858
```

- * The arguments are expressions.
- * Their number should match the parameters.
 - Some exceptions; more about this later.
- * A function call is an expression: its value is the value returned by the function.



Function Call Execution

Order of evaluation

- * The python interpreter always executes instructions one at a time in sequence; this includes expression evaluation.
- * To evaluate a function call, the interpreter:
 - First, evaluates the argument expressions, one at a time, from left to right.
 - Then, executes the function suite with its parameters assigned the values returned by the argument expressions.
- * Same with operators: first arguments (left to right), then the operation.

The call stack

- ★ When evaluation of a function call begins, the current instruction sequence is put “on hold” while the expression is evaluated.
- ★ When execution of the function suite ends, the interpreter returns to the next instruction after where the function was called.
- ★ The “to-do list” of where to come back to after each current function call is called the *stack*.



```
import math

# Convert degrees to radians.
def deg_to_rad(x):
    return x * math.pi / 180

# Take sin of an angle in degrees.
def sin_of_deg(x):
    x_in_rad = deg_to_rad(x)
    return math.sin(x_in_rad)

ans = sin_of_deg(23)
print(ans)
```



```
1 import math
2 def deg_to_rad(x):
    ...
3 def sin_of_deg(x):
    ...
4 ans=sin_of_deg(23)
5 x_in_rad=deg_to_rad(23)
6 return 23*math.pi/180
7 x_in_rad=0.4014
8 return math.sin(0.4014)
9 ans = 0.3907
10 print(ans)
```

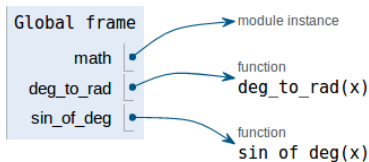
stack depth

```
import math

def deg_to_rad(x):
    return x * math.pi / 180

def sin_of_deg(x):
    x_in_rad = deg_to_rad(x)
    return math.sin(x_in_rad)

answer = sin_of_deg(23)
```



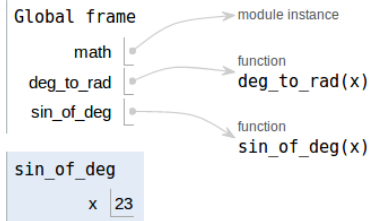
(Image from pythontutor.com)

```
import math

def deg_to_rad(x):
    return x * math.pi / 180

def sin_of_deg(x):
    x_in_rad = deg_to_rad(x)
    return math.sin(x_in_rad)

answer = sin_of_deg(23)
```



(Image from pythontutor.com)

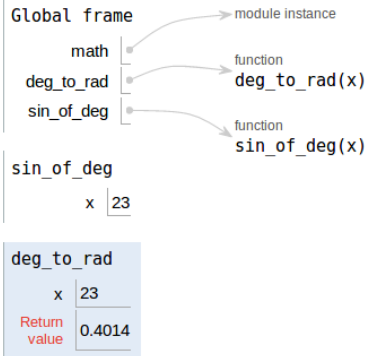


```
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def deg_to_rad(x):
    return x * math.pi / 180

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    x_in_rad = deg_to_rad(x)
    return math.sin(x_in_rad)

answer = sin_of_deg(23)
```



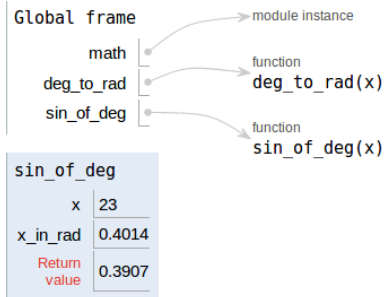
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```
import math

def deg_to_rad(x):
    return x * math.pi / 180

def sin_of_deg(x):
    x_in_rad = deg_to_rad(x)
    return math.sin(x_in_rad)

answer = sin_of_deg(23)
```



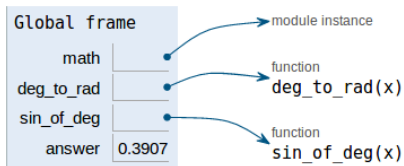
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import math

def deg_to_rad(x):
    return x * math.pi / 180

def sin_of_deg(x):
    x_in_rad = deg_to_rad(x)
    return math.sin(x_in_rad)

answer = sin_of_deg(23)
```



(Image from pythontutor.com)

Assignments in functions

- * Variables assigned in a function (including parameters) are *local* to the function.
 - Local variables are “separate” – the interpreter uses a new namespace for each function call.
 - Local variables that are not parameters are undefined before the first assignment in the function suite.
 - Variables with the same name used outside the function are unchanged after the call.
- * The full story is a little more complicated – we’ll return to it later in the course.

Functions with no `return`

- * If execution of a function suite reaches the end of the suite without encountering a `return` statement, the function call returns the special value `None`.
 - `None` is used to indicate “no value”.
 - The type of `None` is `NoneType` (different from any other value).
- * In interactive mode, the interpreter does *not* print the return value of an expression when the value is `None`.

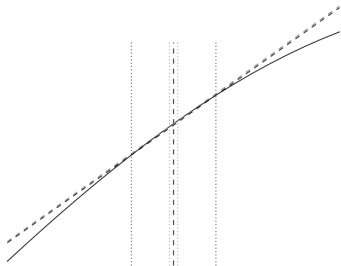
Side effects and return values

- * An expression *evaluates to* a value.
- * A statement does not return a value, but executing it causes something to happen, e.g.,
 - `a_number = 2 + 3` : variable `a_number` becomes associated with the value 5;
 - `print(2 + 3)` : the value 5 is printed.This is called a *side effect*.
- * We can write functions with or without side effects, and functions that do or don't return a value (other than `None`).

- * Functions with side effects and `None` return:
 - `robot.drive_right()`
 - `print(...)`
- * Functions with return value and no side effect:
 - `math.sin(x)`
 - `change_in_percent(old, new)`
- * Functions with side effects and return value?
 - Possible.
- * Functions with no side effect and `None` return value?

Functions of functions

- * In python, functions are also values: a function can be passed as argument to another function.
- * Example: Compute an approximation of the derivative of any function at a point.



```
def derivative(f, x, d):  
    return (f(x + d) - f(x - d)) / (2*d)  
  
ans = derivative(math.sin, math.pi/4, 0.1)
```



Testing and Documentation



Function testing

- ★ A function is a logical unit of testing.
 - Document the assumptions (for example, type and range of argument values);
 - Test a variety of cases under the assumptions.
- ★ What are “edge cases”?
 - Typical (numeric) examples: values equal to/less than/greater than zero; very large and very small values; values of equal and opposite signs; etc.
- ★ Remember that floating-point numbers have limited precision; `==` can fail.

```
>>> change_in_percent (1, 2)
100.0
>>> change_in_percent (2, 1)
-50.0
>>> change_in_percent (1, 1)
0.0
>>> change_in_percent (1, -1)
-200.0
>>> change_in_percent (0, 1)
ZeroDivisionError
```


The function docstring

```
def change_in_percent(old, new):  
    '''Return change from old to new, as  
    a percentage of the old value.  
    old value must be non-zero.'''  
    return ((new - old) / old) * 100
```

- * A *docstring* is a string literal written as the first statement inside a function's suite.
- * Acts like a comment, but accessible through the built-in help system.
- * Describe *what* the function does (if not obvious from its name), and its *limits* and *assumptions*.