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):
    diff = new - old
    return (diff / old) * 100
```

(4 spaces) · 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

$$\overbrace{\text{(old, new)}}^{\text{parameters}}$$

```
def change_in_percent(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(483, 530)
-8.867924528301886
```

* The arguments are expressions.
* Their number should match the parameters.
  - Some exceptions; more about this later.
* A function call is an expression: it's 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, evalutes 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)
```
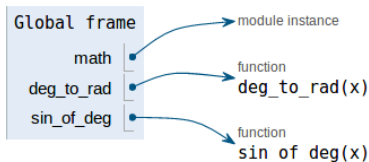
```
9  ans = 0.3907
10 print(ans
```

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)
```
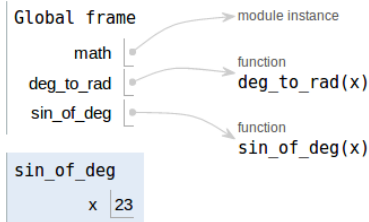


```
Global frame                    → module instance
          math                     function
   deg_to_rad                      deg_to_rad(x)
   sin_of_deg                      function
                                   sin_of_deg(x)

sin_of_deg
          x  23
```

(Image from `pythontutor.com`)

```python
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)
```
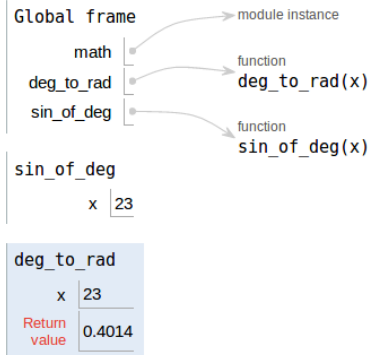
(Image from `pythontutor.com`)

```python
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)
```
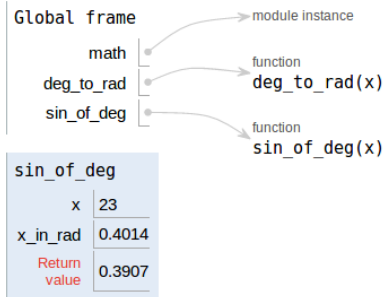
(Image from `pythontutor.com`)

```
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)
```
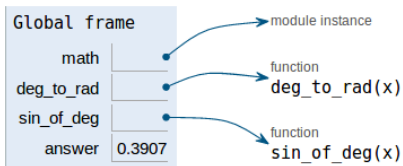

Global frame		
math		→ module instance
deg_to_rad		→ function deg_to_rad(x)
sin_of_deg		→ function sin_of_deg(x)
answer	0.3907	

(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 <u>interactive mode</u>, 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.

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

Testing and Documentation

Function testing

* A function is a logical unit of testing.
  - Specify 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*.