COMP(2041|9044) 26T1 — Python Functions

https://www.cse.unsw.edu.au/~cs2041/26T1/

Defining Python Functions

- Python functions can be defined, like C, with a fixed number of parameters

```
def polly(x, a, b, c):
    return a * x ** 2 + b * x + c
```

- functions can be called, like C, with ***positional*** arguments

```
>>> polly(3, 5, -3, 6)
42
```

- or with ***keyword*** arguments

```
>>> polly(a=5, c=6, b=-3, x=3)
42
```

Or with both ***positional*** and ***keyword*** arguments (keyword must follow positional)

```
>>> polly(3, c=6, b=-3, a=5)
42
```

- functions can restrict how they are called using special arguments `/` and `*`

Default Values for Function Arguments

- default values can be specified for function parameters

```
def polly(x, a=1, b=2, c=0):
    return a * x ** 2 + b * x + c
```

- allowing functions to be called without specifying all parameters

```
>>> polly(3)
15
>>> polly(b=1, x=1)
2
```

- convenient consequence - you can add an extra parameter to a function, without changing existing calls, by giving the parameter a default value

Mutable Default Parameter values are Dangerous

- the default value is a single instance
- safe for immutable types: numbers, strings, ...
- unexpected results from mutable types: lists, dicts, ...
  - common bug in Python programs
  - can be used deliberately

```
def append_one(x = []):
  x.append(1)
  return x
```

```
>>> append_one()
[1]
>>> append_one()
[1, 1]
>>> append_one()
[1, 1, 1]
```


Mutable Default values - workaround

```
def append_one(x = None):
    if x is None:
        x = []
    x.append(1)
    return x
```

```
>>> append_one()
[1]
>>> append_one()
[1]
>>> append_one()
[1]
```


Mutable Default values - workaround

```
def append_one(x = None):
    if x is None:
        x = []
    x.append(1)
    return x
```

```
>>> append_one()
[1]
>>> append_one()
[1]
>>> append_one()
[1]
```

Variable Numbers of Function Arguments

- packing/unpacking operators * and ** allow variable number of arguments.
  - Use * to pack positional arguments into tuple
  - Use ** to pack keyword arguments into dict

```
def f(*args, **kwargs):
    print('positional arguments:', args)
    print('keywords arguments:', kwargs)
```

```
>>> f("COMP", 2041, 9044, answer=42, option=False)
positional arguments: ('COMP', 2041, 9044)
keywords arguments: {'answer': 42, 'option': False}
```


Packing Function Arguments

- * and ** can be used in reverse for function calls
  - Use * to unpack iterable (e.g. list or tuple) into positional arguments
  - Use ** to unpack dict into keyword arguments

```
>>> arguments = ['Hello', 'there', 'Andrew']
>>> keyword_argments = {'end' : '!!!\n', 'sep': ' --- '}
>>> print(arguments, keyword_argments)
['Hello', 'there', 'Andrew'] {'end': '!!!\n', 'sep': ' --- '}
>>> print(*arguments, **keyword_argments)
Hello --- there --- Andrew!!!
```


No main function

- Python has no special “main” function called to started execution (unlike e.g C)
- importing a file executes any code in it
- special global variable **__name__** set to module name during import
- if a file is executed rather than imported, **__name__** set to special value **__main__**
- so can call a function when a file is executed like this

```
if __name__ == '__main__':
    initial_function()
```

docstrings

- A Python Docstring is a string specified as first statement of function
- use “”” triple-quotes

```
def polly(x, a, b, c):
    """calculate quadratic polynomial"""
    return a * x ** 2 + b * x + c
```

- provides documentation to human readers but also available for automated tools

```
>>> polly.__doc__
'calculate quadratic polynomial'
```

```
def polly(x, a, b, c):
    """calculate quadratic polynomial
    a -- squared component
    b -- linear component
    c -- offset
    """
    return a * x ** 2 + b * x + c
```


variable scope

- a variable assigned a value in a function is by default **local** to the function
- a variable not assigned a value in a function is by default **global** to entire program
- keyword **`global`** can be used to make variable global

local versus global variables

```
>>> x = 12
>>> def f():
...     x = 34
...     print(x)
>>> def g():
...     global x
...     x = 56
...     print(x)
>>> f()
34
>>> print(x)
12
>>> g()
56
>>> print(x)
56
```

variable scope - more complex example

```
def a():
    x = 1
    print('a', x, y, z)
def b():
    x = 2
    y = 2
    a()
    print('b', x, y, z)
def c():
    x = 3
    y = 3
    global z
    z = 3
    b()
    print('c', x, y, z)
```

source code for scope.py

```
>>> x = 4
>>> y = 4
>>> z = 4
>>> c()
a 1 4 3
b 2 2 3
c 3 3 3
```


List Comprehensions

- List comprehensions can be used to create lists (iterables) concisely.
- In simple cases, they are more readable than for loops or higher-order functions.
- They can be written as: ***expression* `for` *value* `in` *iterable***

```
>>> [x**3 for x in range(10)]
[0, 1, 8, 27, 64, 125, 216, 343, 512, 729]
>>> [str(round(math.pi, digits)) for digits in range(1,7)]
['3.1', '3.14', '3.142', '3.1416', '3.14159', '3.141593']
```

- They can be written as: ***expression* `for` *value* `in` *iterable* `if` *expression2***

```
>>> [x**3 for x in range(10) if x % 2 == 1]
[1, 27, 125, 343, 729]
```

- list comprehensions can be nested but this may less readable than use of loops

lambda - create a small anonymous function

- The keyword **`lambda`** provides creation of small anonymous functions
- **`lambda`** is useful for ***higher-order programming*** - passing functions to other functions.
- **`lambda`** allows the creation of a fucntion within an expression.

```
>>> f = lambda x: x + 42
>>> type(f)
<class 'function'>
>>> f(12)
54
```

- **`lambda`** function body must be a single expression
  - function body can not contain statements such as `while`, `return`
  - better to define a named function if body is complex

lambda - variable binding

Beware variables in the lambda expression are bound when the lamba is evaluated, not when it is created.

```
>>> answer = 42
>>> f = lambda x: x + answer
>>> answer = 15
>>> f(12)
27
>>> answer = 34
>>> f(13)
47
```

Ugly workaround: make the variable the default value of a keyword argument.

```
>>> answer = 42
>>> f = lambda x, y=answer: x + y
>>> answer = 34
>>> f(12)
54
```


enumerate - builtin function

enumerate returns tuples pairing a count with members of an iterable such as a list.

```
>>> languages = ['C', 'Python', 'Shell', 'Rust']
>>> list(enumerate(languages))
[(0, 'C'), (1, 'Python'), (2, 'Shell'), (3, 'Rust')]
>>> list(enumerate(languages, start=42))
[(42, 'C'), (43, 'Python'), (44, 'Shell'), (45, 'Rust')]
```

```
def my_enumerate(sequence, start=0):
    """return a list equivalent to the iterator returned
    by builtin function enumerate
    """
    n = start
    tuples = []
    for element in sequence:
        t = (n, element)
        tuples.append(t)
        n += 1
    return tuples
```

source code for builtin.py

zip - builtin function

zip returns tuples formed from corresponding members of iterables such as lists.

```
>>> languages = ['C', 'Python', 'Shell', 'Rust']
>>> editors = ['vi', 'emacs', 'atom', 'VScode', 'nano']
>>> list(zip(editors, languages))
[('vi', 'C'), ('emacs', 'Python'), ('atom', 'Shell'), ('VScode', 'Rust')]
```

```
def my_zip2(sequence1, sequence2):
    """return a list equivalent to the iterator returned by
    builtin function zip called with 2 sequences.
    Note: zip can be given any number of sequences."""
    tuples = []
    for index in range(min(len(sequence1), len(sequence2))):
        t = (sequence1[index], sequence2[index])
        tuples.append(t)
    return tuples
```

source code for builtin.py

list comprehension + zip example

```
def dot_product0(a, b):
    """return dot product of 2 lists - using for loop + indexing"""
    total = 0
    for i in range(len(a)):
        total += a[i] * b[i]
    return total
```

source code for dot_product.py

```
def dot_product2(a, b):
    """return dot product of 2 lists - using for loop + zip"""
    total = 0
    for x, y in zip(a, b):
        total += x * y
    return total
```

source code for dot_product.py

list comprehension example

```
def is_odd(number):
    return number % 2 == 2
def odd0(numbers):
    """extract odd_numbers from list using for loop"""
    odd_numbers = []
    for n in numbers:
        if is_odd(n):
            odd_numbers.append(n)
    return odd_numbers
def odd1(numbers):
    """extract odd_numbers from list using list comprehension"""
    return [n for n in numbers if is_odd(n)]
```

source code for odd_numbers.py

map - builtin function

map calls a function with argument(s) taken from iterable(s) such as list(s) and returns the functions return values

```
>>> list(map(str, range(10)))
['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']
>>> list(map(lambda x: x**3, range(10)))
[0, 1, 8, 27, 64, 125, 216, 343, 512, 729]
>>> list(map(lambda x, y: x**y, range(10), range(10)))
[1, 1, 4, 27, 256, 3125, 46656, 823543, 16777216, 387420489]
```

```
def my_map1(function, sequence):
    """return a list equivalent to the iterator returned by
    builtin function map called with 1 sequence.
    Note: map can be given more than 1 sequences."""
    results = []
    for value in sequence:
        result = function(value)
        results.append(result)
    return results
```

source code for builtin.py

list comprehension + zip example

```
def multiply(x, y):
    """multipy 2 numbers - operator.mul does this"""
    return x * y
def dot_product4(a, b):
    """return dot product of 2 lists - map"""
    return sum(map(multiply, a, b))
def dot_product5(a, b):
    """return dot product of 2 lists - map + lambda"""
    return sum(map(lambda x, y: x * y, a, b))
def dot_product6(a, b):
    """return dot product of 2 lists - map + operator.mul"""
    return sum(map(operator.mul, a, b))
```

source code for dot_product.py

filter - builtin function

filter returns the elements of am iterable(s) such as list for which the supplied function returns true.

```
>>> list(filter(lambda x: x % 2 == 0, range(10)))
[0, 2, 4, 6, 8]
```

```
def my_filter(function, sequence):
    """return a list equivalent to the iterator returned by
    builtin function filter called with a function.
    Note: filter can be given None instead of a function."""
    filtered = []
    for value in sequence:
        if function(value):
            filtered.append(value)
    return filtered
```

source code for builtin.py

filter + lambda example

```
def is_odd(number):
    return number % 2 == 2
```

source code for odd_numbers.py

```
def odd2(numbers):
    """extract odd_numbers from list using filter"""
    return filter(is_odd, numbers)
def odd3(numbers):
    """extract odd numbers from list using filter + lambda"""
    return filter(lambda n: n % 2 == 2, numbers)
```

source code for odd_numbers.py

sorted + lambda example

```
DAY_LIST = "Sunday Monday Tuesday Wednesday Thursday Friday Saturday".split()
DAY_NUMBER = dict((day, number) for number, day in enumerate(DAY_LIST))
def random_day_of_week():
    return random.choice(DAY_LIST)
def sort_days0(day_list):
    return sorted(day_list, key=lambda day: DAY_NUMBER[day])
def sort_days1(day_list):
    return sorted(day_list, key=DAY_NUMBER.get)
```

source code for sort_days.py

exploring function for combining and contructing futher

The **functools** module provides more functions for higher-order programming, e.g.

```
>>> # sum first 10 positive integers
>>> functools.reduce(operator.add, range(1, 10))
45
>>> # multiply first 10 positive integers
>>> functools.reduce(operator.mul, range(1, 10))
362880
```

The `itertools` module provides functions for combining and constructing **iterators** allowing efficient handling of arbitrarily long sequences.

Type hints

- Python doesn't enforce types even when they are given, thus they are `hints`
- Static type checkers are common that do enforce types as much as possible
- For best results type enforcement should be including in your code
- Type hints help you and others read your code and are highly recommended

```
from typing import Optional, Union

a = 5
b = "Hello World"
# a type hint
c: int = 6
# but not enforced
d: int = "this isn't an int"
# composition of types
e: list[int] = [1, 2, 3, 4, 5]
# more composition of types
f: dict[int, list[tuple[str, str]]] = {1: [('a', 'b'), ('a', 'c')], 3: [('c',
 ↪  's'), ('c', 'g')]}
```

Type hints

```
from typing import Optional, Union

# `Optional` allows for None values
g: Optional[float] = None
# `Union` allows for two or more types
h: Union[int, float] = 4
# type hints can also be used on function arguments and return values
def func(a: int, b: str = 'Hi\n') -> int:
  return len(b * a)
# for variables used in loops, tuple unpacking, or assignment can be
 ↪  pre-hinted
# pre-hinting does not define the variable as it has not assigned a value and
 ↪  python variables must always be initialised
j: int
for j in range(0, 100):
  pass

k: bool
if k := validate(data):
  pass

l: bool
m: int
n: str
l, m, n = (True, 99, "Apple")

# a variables type can be changed by first deleting it then redefining it
o: int = 0
del o
o: str = ""
```