

A Short and Incomplete Introduction to Python

Part 9: Object-oriented programming

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Objects

What's an *object*?

A Python object is a bundle of variables and functions.

What variable names and functions comprise an object is defined by the object's *class*.

From one class specification, many objects can be *instanciated*. Different instances can assign different values to the object variables.

Variables and functions in an instance are collectively called *instance attributes*; functions are also termed *instance methods*.

Example: the datetime object, I

```
>>> from datetime import date
```

To instantiate an object,
call the class name like a
function.

```
>>> dt1 = date(2012, 9, 28)
```

```
>>> dt2 = date(2012, 10, 1)
```

Example: the datetime object, II

```
>>> dir(dt1)
['__add__', '__class__', ..., 'ctime', 'day',
'fromordinal', 'fromtimestamp', 'isocalendar',
'isoformat', 'isoweekday', 'max', 'min', 'month',
'replace', 'resolution', 'strftime', 'timetuple',
'today', 'toordinal', 'weekday', 'year']
```

The `dir` function can list all objects attributes.

Note there is no distinction between instance variables and methods!

Example: the datetime object, III

```
>>> dt1.day
28
>>> dt1.month
9
>>> dt1.year
2012
```

Access to object attributes
is done by suffixing the
instance name with the
attribute name, separated
by a dot “.”.

Example: the datetime object, IV

```
>>> dt1 = date(2012, 9, 28)
>>> dt2 = date(2012, 10, 1)
```

```
>>> dt1.day
```

28

```
>>> dt2.day
```

1

The same attribute can
have different values in
different instances!

Instance methods

```
>>> dt1.isoformat()  
'2012-09-28'
```

Invoke an instance method just like any other function.

Objects *vs* modules

Modules are also namespaces of variables and functions.

The dot operator `'.'` is also used to access variables and functions from modules. The `dir()` function is also used to list variables and functions from modules.

But each module has *one and only one* instance in a Python program.

User-defined classes

A 2D vector in Python

This code defines a Python object that implements a 2D vector.

```
class Vector(object):  
    """A 2D Vector."""  
    def __init__(self, x, y):  
        self.x = x  
        self.y = y  
    def add(self, other):  
        return Vector(self.x+other.x,  
                        self.y+other.y)  
    def mul(self, scalar):  
        return Vector(scalar*self.x, scalar*self.y)  
    def show(self):  
        return ("%g,%g" % (self.x, self.y))
```

Source code available at:

<https://raw.githubusercontent.com/gc3-uzh-ch/python-course/master/vector.py>

What does Vector do?

We can create vectors by initializing them with the two coordinates (x, y):

```
>>> u = Vector(1, 0)
>>> v = Vector(0, 1)
```

The `add` method implements vector addition:

```
>>> w = u.add(v)
>>> w.show()
'<1, 1>'
```

The `show` method shows vector coordinates:

```
>>> u.show()
'<1, 0>'
>>> v.show()
'<0, 1>'
```

The `mul` method implements scalar multiplication:

```
>>> v2 = v.mul(2)
>>> v2.show()
'<0, 2>'
```

User-defined classes, I

```
class Vector(object):  
    """A 2D Vector."""  
    def __init__(self, x, y):  
        self.x = x  
        self.y = y  
    def add(self, other):  
        return Vector(self.x+other.x,  
                        self.y+other.y)  
    def mul(self, scalar):  
        return Vector(scalar*self.x, scalar*self.y)  
    def show(self):  
        return ("<%g,%g>" % (self.x, self.y))
```

A class definition starts with the keyword `class`.

The class definition is indented relative to the class statement.

User-defined classes, II

This identifies
user-defined classes.

```
class Vector(object):  
    """A 2D Vector."""  
    def __init__(self, x, y):  
        self.x = x  
        self.y = y  
    def add(self, other):  
        return Vector(self.x+other.x,  
                        self.y+other.y)  
    def mul(self, scalar):  
        return Vector(scalar*self.x, scalar*self.y)  
    def show(self):  
        return ("<%g,%g>" % (self.x, self.y))
```

(Do not leave it out or
you'll get an "old-style"
class, which is deprecated
behavior.)

User-defined classes, II

Classes can have
docstrings.

The content of a class
docstring will be shown as
help text for that class.

```
class Vector(object):  
    """A 2D Vector."""  
    def __init__(self, x, y):  
        self.x = x  
        self.y = y  
    def add(self, other):  
        return Vector(self.x+other.x,  
                        self.y+other.y)  
    def mul(self, scalar):  
        return Vector(scalar*self.x, scalar*self.y)  
    def show(self):  
        return ("<%g,%g>" % (self.x, self.y))
```

User-defined classes, IV

```
class Vector(object):  
    """A 2D Vector."""
```

```
    def __init__(self, x, y):  
        self.x = x  
        self.y = y  
    def add(self, other):  
        return Vector(self.x+other.x,  
                        self.y+other.y)  
    def mul(self, scalar):  
        return Vector(scalar*self.x, scalar*self.y)  
    def show(self):  
        return ("<g,%g>" % (self.x, self.y))
```

The **def** keyword introduces a method definition.

Every method *must* have at least one argument, named **self**.

The self argument

Every method of a Python object always has `self` as first argument.

However, you do not specify it when calling a method: it's automatically inserted by Python:

```
>>> class ShowSelf(object):  
...     def show(self):  
...         print(self)  
...  
>>> x = ShowSelf() # construct instance  
>>> x.show() # 'self' automatically inserted!  
<__main__.ShowSelf object at 0x299e150>
```

The `self` name is a reference to the object instance itself. You *need to* use `self` when accessing methods or attributes of this instance.

Name resolution rules, I

Within a function body, names are resolved according to the **LEGB rule**:

- L** Local scope: any names defined in the current function;
- E** Enclosing function scope: names defined in enclosing functions (outermost last);
- G** global scope: names defined in the toplevel of the enclosing module;
- B** Built-in names (i.e., Python's `__builtins__` module).

Any name that is not in one of the above scopes *must* be qualified.

So you have to write `self.x` to reference an attribute in this instance, `datetime.date` to mean a class defined in module `date`, etc.

Name resolution rules, II

Unqualified name
within a function:
resolves to a local
variable.

```
import datetime as dt

def today():
    td = dt.date.today()
    return "today is " + td.isoformat()

def hey(name):
    print("Hey " + name + "; " + today())

hey("you")
```

Name resolution rules, III

```
import datetime as dt
```

```
def today():
```

```
    td = dt.date.today()
```

```
    return "today is " + td.isoformat()
```

```
def hey(name):
```

```
    print("Hey " + name + "; " + today())
```

```
hey("you")
```

Unqualified name:
since there is no local
variable by that
name, it resolves to a
module-level binding,
i.e., to the `today`
function defined
above.

Name resolution rules, IV

```
import datetime as dt
```

```
def today():
```

```
    td = dt.date.today()
```

```
    return "today is " + td.isoformat()
```

```
def hey(name):
```

```
    print("Hey " + name + "; " + today())
```

```
hey("you")
```

Unqualified name:
resolves to the dt
name created at
global scope by the
import statement.

Name resolution rules, V

Qualified name:
instructs Python to
search the date
attribute within the
dt module.

```
import datetime as dt

def today():
    td = dt.date.today()
    return "today is " + td.isoformat()

def hey(name):
    print("Hey " + name + "; " + today())

hey("you")
```

Name resolution rules, VI

```
import datetime as dt
```

```
def today():
```

```
    td = dt.date.today()
```

```
    return "today is " + td.isoformat()
```

```
def hey(name):
```

```
    print("Hey " + name + "; " + today())
```

```
hey("you")
```

Qualified name:
Python searches the
isoformat attribute
within the td object
instance.

Name resolution rules, VI

```
class Vector(object):  
    def __init__(self, x, y):  
        self.x = x  
        self.y = y  
# ...
```

Unqualified name:
resolves to a local
variable in scope of
function `__init__`.

Name resolution rules, VII

```
class Vector(object):  
    def __init__(self, x, y):  
        self.x = x  
        self.y = y  
    # ...
```

Qualified names:
resolve to attributes
in object **self**.

(Actually,
self.x = ... creates
the attribute **x** on
self if it does not
exist yet.)

Object initialization

The `__init__` method has a special meaning: it is called when an instance is created.

```
class Vector(object):  
    """A 2D Vector."""  
    def __init__(self, x, y):  
        self.x = x  
        self.y = y  
    def add(self, other):  
        return Vector(self.x+other.x, self.y+other.y)  
    def mul(self, scalar):  
        return Vector(scalar*self.x, scalar*self.y)  
    def show(self):  
        return ("<%g,%g>" % (self.x, self.y))
```

Constructors

The `__init__` method is the object constructor. It should *never* return any value.

You never call `__init__` directly, it is invoked by Python when a new object is created from the class:

```
# calls Vector.__init__  
v = Vector(0,1)
```

The arguments to `__init__` are the arguments you should supply when creating a class instance.

(Again, minus the `self` part which is automatically inserted by Python.)

Exercise 9.A: Add a new method `norm` to the `Vector` class: if `v` is an instance of class `Vector`, then calling `v.norm()` returns the norm $\sqrt{v_x^2 + v_y^2}$ of the associated vector. (You will need the `math` standard module for computing square roots.)

Exercise 9.B: Add a new method `unit` to the `Vector` class: if `v` is an instance of class `Vector`, then calling `v.unit()` returns the vector `u` having the same direction as `v` but norm 1.

Appendix

Everything is an object!

The `dir` built-in function is used to list the attributes of an object.

```
>>> dir("hello!")
```

Everything is an object!

The `dir` built-in function is used to list the attributes of an object.

```
>>> dir("hello!")  
['__add__', '__class__', '__contains__',  
 '__delattr__', '__doc__', '__eq__',  
 ...  
 'strip', 'swapcase', 'title',  
 'translate', 'upper', 'zfill']
```

... a string is an object!

Everything is an object!

```
>>> dir([1,2,3])  
['__add__', '__class__', '__contains__',  
...  
'append', 'count', 'extend',  
'index', 'insert', 'pop',  
'remove', 'reverse', 'sort']
```

...a list is an object!

Everything is an object!

Indeed, you can do:

```
>>> "hello world!".split()  
['hello', 'world!']
```

```
>>> [1,1,2,3,5].count(1)  
2
```

Everything is an object!

```
>>> dir(1)
```

Everything is an object!

```
>>> dir(1)
['__abs__', '__add__', '__and__',
...
'conjugate', 'denominator',
'imag', 'numerator', 'real']
```

...an int is an object!

```
>>> (1).numerator
2
>>> (1).denominator
1
```