

# A Short and Incomplete Introduction to Python

## Part 9: Object-oriented programming

Riccardo Murri <[riccardo.murri@uzh.ch](mailto:riccardo.murri@uzh.ch)>  
S3IT: Services and Support for Science IT,  
University of Zurich

# 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 ("<fg, %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

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

```
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

```
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
```