

The protocol view of python

If you look at the object orientation of python there are three core patterns we have to understand. One of them is protocol view of python.

In [1]:

```
class Polynomial:
    pass

p1 = Polynomial()
p2 = Polynomial()
p1.coeffs = 1, 2, 3 #x**2 + 2x + 3
p2.coeffs = 3, 4, 3 #x**2 + 4x + 3
```

__init__

Why write in 4 lines when we can write it in two lines? Two lines will do.

In [2]:

```
class Polynomial:
    def __init__(self, *coeffs):
        self.coeffs = coeffs

p1 = Polynomial(1, 2, 3)
p2 = Polynomial(3, 4, 3)

print(p1)
print(p2)
```

```
<__main__.Polynomial object at 0x7f2524945da0>
<__main__.Polynomial object at 0x7f2524945e10>
```

__repr__

That looks ugly because we are missing the method that corresponds to what happens when we call top level repr function to figure out the representation of our python object.

In [3]:

```
class Polynomial:
    def __init__(self, *coeffs):
        self.coeffs = coeffs

    def __repr__(self):
        return 'Polynomial(*{!r})'.format(self.coeffs)
```

```
p1 = Polynomial(1, 2, 3)
p2 = Polynomial(3, 4, 3)
```

```
print(p1)
print(p2)
```

```
Polynomial(*(1, 2, 3))
Polynomial(*(3, 4, 3))
```

__add__

What about adding polynomial objects together?

In [4]:

```
class Polynomial:
    def __init__(self, *coeffs):
        self.coeffs = coeffs

    def __repr__(self):
        return 'Polynomial(*{!r})'.format(self.coeffs)

    def __add__(self, other):
        return Polynomial(*(x + y for x, y in zip(self.coeffs, other.coeffs)))
```

```
p1 = Polynomial(1, 2, 3)
p2 = Polynomial(3, 4, 3)
```

```
print(p1)
print(p2)
```

```
print(p1 + p2)
```

```
Polynomial(*(1, 2, 3))
Polynomial(*(3, 4, 3))
Polynomial(*(4, 6, 6))
```

What pattern do we see?

If we have some behaviour we want to implement --> we write some `__function__` to implement it. This functions are called dunder methods.

It has also an abhorrent name *data model methods*. Python documentation contains a whole list of this methods. Whenever we want to implement some behaviour in python we want to tell python "for this arbitrary object do this behaviour, like give the printable representation for this object, perform an addition of this objects."

The pattern is: there is a top-level function or some top-level syntax and there is a corresponding dunder function. The exact arguments that the underscore function takes are determined by python documentation. The default names of the arguments can be picked up by the documentation also.

But there is something more fundamental than this. If we want to implement the summation of two objects $x + y$ --> we implement `__add__`, if we want to define how we instantiate an object --> we implement `__init__`.

`__len__`

What a size of a polynomial might me? The highest degree of the polynomial. We will implement `__len__` function to tell us the size of the polynomial

In [5]:

```
class Polynomial:
    def __init__(self, *coeffs):
        self.coeffs = coeffs

    def __repr__(self):
        return 'Polynomial(*{!r})'.format(self.coeffs)

    def __add__(self, other):
        return Polynomial(*(x + y for x, y in zip(self.coeffs, other.coeffs)))

    def __len__(self):
        return len(self.coeffs)

p1 = Polynomial(1, 2, 3)
p2 = Polynomial(3, 4, 3)

print(len(p1))
```

3

The pattern as we see is as follows:

The python data model is a means by which we can implement protocols. Those protocols have some abstract meaning depending on the object itself. In the case of a polynomial summation means whatever it ment in the math class.

To get its printable representation we use `__repr__`. Printable representation is typically whatever string we have to type in the console to get a new instance of that object.

In each case that protocol exists, there is some underscore method that implements this protocol, and there is some top-level function like `len` or top-level syntax like `+` sign that allows us to invoke that protocol and it all fits together.

When we implement smth like `__len__` we do that by delegating back to the protocol itself. `__len__` is implemented in terms of `len()` being called on a constituent object. `__add__` is implemented by adding up some components.

If we have some top-level syntax like parentheses that come after the object `x()`, we call it the `__call__` protocol.

In [6]:

```

class Polynomial:
    def __init__(self, *coeffs):
        self.coeffs = coeffs

    def __repr__(self):
        return 'Polynomial(*{!r})'.format(self.coeffs)

    def __add__(self, other):
        return Polynomial(*(x + y for x, y in zip(self.coeffs, other.coeffs)))

    def __len__(self):
        return len(self.coeffs)

    def __call__(self):
        #no idea what should polynomial do
        pass

p1 = Polynomial(1, 2, 3)
p2 = Polynomial(3, 4, 3)

```

Metaclasses

If you know what metaclasses are it is very clear and very obvious for why and when you use it and it is something you can kind of shelf away in your mind as "oh, this feature does this, this is why I want to use it, i don't have to use it all the time".

Let's imagine there are two teams on the project and one team writes library code and the other team writes user code. People on the user side can't touch library code.

In [7]:

```

# library.py
class Base:
    def foo(self):
        return 'foo'

# user.py
class Derived(Base):
    def bar(self):
        return self.foo()

# this code can break if there is no foo method in the Base class in the library.

```

What we can do to figure out our code brakes before the runtime? We can write a test for example. We will see that the code fails some time before it hits the runtime production environment.

But maybe there is one thing that we can add to this code so it fails before it hits the runtime production environment?

For example, we can add assert and see if the Base has no foo method before we even came up to derived class.

In [8]:

```
# library.py
class Base:
    def foo(self):
        return 'foo'

#user.py
assert hasattr(Base, 'foo'), "You broke it!"

class Derived(Base):
    def bar(self):
        return self.foo()
```

If we rename the foo method into not_foo method we will get an assertion error.

In [9]:

```
# library.py
class Base:
    def not_foo(self):
        return 'foo'

#user.py
assert hasattr(Base, 'foo'), "You broke it!"

class Derived(Base):
    def bar(self):
        return self.foo()
```

```
-----
AssertionError                                Traceback (most recent call last)
<ipython-input-9-368a1e4322d4> in <module>
      5
      6 #user.py
----> 7 assert hasattr(Base, 'foo'), "You broke it!"
      8
      9 class Derived(Base):
```

AssertionError: You broke it!

So now we have an early warning that this has broken. And what we are trying to do here is enforce a constraint. The user level enforces a constraint on a library level, in other words, **the Derived class is enforcing a constraint on a base class**. The Derived class says "the Base class should have this characteristics in order for me to run and be happy. If it does not foo method implemented i will fail."

Let's say instead, **we are working on a library side and we don't want people to screw code on a user side of the project**. And we can't change anything on the user side of the code. And how do we make sure that the code will be implemented on the user side? There are three answers to this. One is metaclasses. But maybe we can try use `__build_class__` at first.

In [10]:

```
# library3.py
class Base:
    def foo(self):
        return self.bar()

# we write this Base class under the assumption that developer in user department
# will implement bar() method, because if they don't, everything falls apart.

# user.py
class Derived(Base):
    def bar(self):
        return foo()
```

The reason we can call python a protocol oriented language is not just because the python data model is protocol oriented, but the entire python language itself has a notion of hooks and protocols and safety valves within it.

Python code runs from top to bottom linearly and almost every statement except the two of them are actually executable runtime code. In C++ or Java a class statement is not an executable code. In python it is.

In [11]:

```
def _():
    class Base:
        pass

# dis stands for disassemble
from dis import dis
dis(_)
```

```
2          0 LOAD_BUILD_CLASS
          2 LOAD_CONST                    1 (<code object Base at 0x7f2
5240dcd20, file "<ipython-input-11-1203e638e23a>", line 2>)
          4 LOAD_CONST                    2 ('Base')
          6 MAKE_FUNCTION                  0
          8 LOAD_CONST                    2 ('Base')
         10 CALL_FUNCTION                  2
         12 STORE_FAST                    0 (Base)
         14 LOAD_CONST                    0 (None)
         16 RETURN_VALUE
```

LOAD_BUILD_CLASS is an actual executable runtime instruction in the python interpreter for creating a class. There typically in python tends to be a correspondence between some top-level syntax or function and some underscore method that implements that function. There happens to be some top-level mechanism here for building a class (it is not explicitly a function). It turns out in python there is a hook, there is an underscore function that allows us to do things with the process of building classes.

In [12]:

```
#library4.py
class Base:
    def foo(self):
        return 'bar'

# we capture the original build class
old_bc = __build_class__

# we write our own modified build class
def my_bc(*a, **kw):
    print('my buildclass -->', a, kw)
    return old_bc(*a, **kw)

# there is a function __build_class__ in python. It sits on a module builtins
import builtins
# we make import from builtins and swap out our classes
# so we are patching creating classes in python
builtins.__build_class__ = my_bc
# and here we can patch into what python actually does when
# it creates classes

#user.py
class Derived(Base):
    def bar(self):
        return 'bar'

import builtins
```

```
my buildclass --> (<function Derived at 0x7f25240f2598>, 'Derived', <c
lass '__main__.Base'>) {}
```

So we can actually catch the building of the class! We passed a function, the name of the class 'Derived', the bases class 'library4.Base' and function Derived at 0x7f50f86b2ea0.

So we can add our assert into the building class.

This is not typically what we do. It is to show us that idea of python being a protocol-oriented language is actually quite a fundamental piece of python. Almost everything that a python language does in an execution context like building classes, creating functions, importing modules, you can find the hook to get into that and start doing things that we want to do.

`__build_class__` is available for us to use but that is not how we solve the this problem. There are two fundamental features of python that people use to enforce constraints from derived classes to base classes. The first one is the metaclass.

Metaclasses are merely classes that derive from `type` that have some special methods on them (we have to look into the documentation to find out what this methods are) that **allow us to intercept the construction of derived types**.

In [14]:

```
# library.py
class BaseMeta(type):
    def __new__(cls, name, bases, body):
        if not 'bar' in body:
            raise TypeError("bad user class")
        print('BaseMeta.__new__', cls, name, bases, body)
        return super().__new__(cls, name, bases, body)

class Base(metaclass=BaseMeta):
    def bar(self):
        return self.bar()

# user.py
class Derived(Base):
    def bar(self):
        return 'bar'
```

```
my buildclass --> (<function BaseMeta at 0x7f25240f21e0>, 'BaseMeta',
<class 'type'>) {}
my buildclass --> (<function Base at 0x7f25240f21e0>, 'Base') {'metaclasses': <class '__main__.BaseMeta'>}
BaseMeta.__new__ <class '__main__.BaseMeta'> Base () {'__module__': '__main__', '__qualname__': 'Base', 'bar': <function Base.bar at 0x7f25240e32f0>}
my buildclass --> (<function Derived at 0x7f25240f21e0>, 'Derived', <class '__main__.Base'>) {}
BaseMeta.__new__ <class '__main__.BaseMeta'> Derived (<class '__main__.Base'>,) {'__module__': '__main__', '__qualname__': 'Derived', 'bar': <function Derived.bar at 0x7f2524064048>}
```

We can see that it got called with our Derived class. The last argument `{'__module__': 'builtins', '__qualname__': 'Derived', 'bar': function Derived.bar at 0x7f4941758ae8}` is the dictionary with all the methods of that class.

So in order to enforce constraints on the derived class we have to find ways to intercept the construction of the classes. Metaclasses, despite being a "very complicated feature" is a **tool for enforcing constraints down the class hierarchy from a base class to the derived class**.

The third approach is a variation of the metaclass approach. In python 3.6 new feature was introduced called `__init_subclass__` that gives us a method of hooking into creating of a subclass.

In [15]:

```
# library.py
class BaseMeta(type):
    def __new__(cls, name, bases, body):
        if name != 'Base' and not 'bar' in body:
            raise TypeError("bad user class")
        print('BaseMeta.__new__', cls, name, bases, body)
        return super().__new__(cls, name, bases, body)

class Base(metaclass=BaseMeta):
    def foo(self):
        return self.bar()
    def __init_subclass__(self, *a, **kw):
        print('init_subclass', a, kw)
        return super().__init_subclass__(*a, **kw)

# user.py
class Derived(Base):
    def bar(self):
        return 'bar'
```

```
my buildclass --> (<function BaseMeta at 0x7f25240e3d08>, 'BaseMeta',
<class 'type'>) {}
my buildclass --> (<function Base at 0x7f25240e3d08>, 'Base') {'metaclass': <class '__main__.BaseMeta'>}
BaseMeta.__new__ <class '__main__.BaseMeta'> Base () {'__module__': '__main__', '__qualname__': 'Base', 'foo': <function Base.foo at 0x7f25240e3378>, '__init_subclass__': <function Base.__init_subclass__ at 0x7f25240e3268>, '__classcell__': <cell at 0x7f252494f9d8: empty>}
my buildclass --> (<function Derived at 0x7f25240e3d08>, 'Derived', <class '__main__.Base'>) {}
BaseMeta.__new__ <class '__main__.BaseMeta'> Derived (<class '__main__.Base'>,) {'__module__': '__main__', '__qualname__': 'Derived', 'bar': <function Derived.bar at 0x7f2524064598>}
init_subclass () {}
```