Lecture #15: OOP

- Just as def defines functions and allows us to extend Python with new operations, class defines types and allows us to extend Python with new kinds of data.
- What do we want out of a class?
  - A way of defining named *new types* of data.
  - A means of defining and accessing *state* for these objects.
  - A means of defining and using *operations* specific to these objects.
  - In particular, an operation for *initializing* the state of an object.
  - A means of *creating* new objects.

From Last Time

- The Account type illustrated how we do each of these

```
class Account:                    Define named new type

    def __init__(self, initial_balance):  How to initialize
        self.__balance = initial_balance  Create/modify state

    def balance(self):            Define new operation on Accounts
        return self.__balance     Access state of an Account

    ...

myAccount = Account(1000)         Create a new Account object,
print(myAccount.balance())        Operate on an Account object.
```


Class Attributes

- Sometimes, a quantity applies to a type as a whole, not a specific instance.
- For example, with Accounts, you might want to keep track of the total amount deposited from all Accounts.
- This is an example of a *class attribute.*

Class Attributes in Python

```
class Account:
    __total_deposits = 0      Define/initialize a class attribute
    def __init__(self, initial_balance):
        self.__balance = initial_balance
        Account.__total_deposits += initial_balance
    def deposit(self, amount):
        self.__balance += amount
        Account.__total_deposits += amount

    @staticmethod
    def total_deposits():     Define a class method.
        return Account.__total_deposits
```

```
>>> acct1 = Account(1000)
>>> acct2 = Account(10000)
>>> acct1.deposit(300)
>>> Account.total_deposits()
11300
>>> acct1.total_deposits()
11300
```

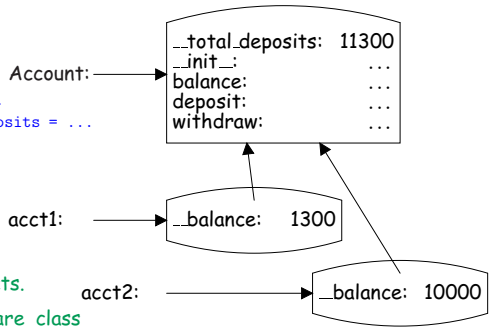

Modeling Attributes in Python

- Unlike C++ or Java, Python takes a very dynamic approach.
- Classes and class instances behave rather like environment frames.

```
def Account:
    __total_deposits = 0

    def __init(...):
        self.__balance = ...
        Account.__total_deposits = ...

acct1 = Account(1000)
acct2 = Account(10000)
acct1.deposit(300)
```

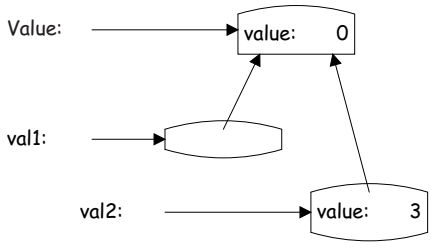


- Curved boxes are objects.
- Flat-bottomed boxes are class objects.
- 'x.y': look for 'y' starting at 'x'

Assigning to Attributes

- Assigning to an attribute of an object (including a class) is like assigning to a local variable: it creates a new binding for that attribute in the object selected from (i.e., referenced by the expression on the left of the dot).

```
>>> def Value:
...     value = 0
...
>>> val1 = Value()
>>> val2 = Value()
>>> val2.value = 3
>>> val1.value
0
>>> Value.value
0
>>> val2.value
3
```



Methods

- Consider

```
>>> def Foo:
...     def set(self, x):
...         self.value = x
>>> aFoo = Foo()
>>> aFoo.set(13)  # The first parameter of set is aFoo.
>>> aFoo.value
13
>>> aFoo.set
<bound method Foo.set of ...>
```

- Selection of attributes from objects (other than classes) that were defined as functions in the class does something to those attributes so that they take one fewer parameters: first parameter is *bound to* the selected-from object.
- Effect of selecting aFoo.set is like calling partial_bind(aFoo, Foo.set), where

```
def partial_bind(obj, func): return lambda x: func(obj, x)
```


Inheritance

- Classes are often conceptually related, sharing operations and behavior.
- One important relation is the *subtype* or *"is-a"* relation.
- Examples: A car is a vehicle. A square is a plane geometric figure.
- When multiple types of object are related like this, one can often define operations that will work on all of them, with each type adjusting the operation appropriately.
- In Python (like C++ and Java), a language mechanism called *inheritance* accomplishes this.

Example: Geometric Plane Figures

- Want to define a collection of types that represent polygons (squares, trapezoids, etc.).
- First, what are the common characteristics that make sense for all polygons?

```
class Polygon:
    def is_simple(self):
        """True iff I am simple (non-intersecting)."""
    def area(self): ...
    def bbox(self):
        """(xlow, ylow, xhigh, yhigh) of bounding rectangle."""
    def num_sides(self): ...
    def vertices(self):
        """My vertices, ordered clockwise, as a sequence
        of (x, y) pairs."""
    def describe(self):
        """A string describing me."""
```

- The point here is mostly to document our concept of Polygon, since we don't know how to implement any of these in general.

Partial Implementations

- Even though we don't know anything about Polygons, we can give default implementations.

```
class Polygon:
    def is_simple(self): raise NotImplemented
    def area(self): raise NotImplemented
    def vertices(self): raise NotImplemented
    def bbox(self):
        V = self.vertices()
        xlow, ylow =  xhigh, yhigh = V[0]
        for x, y in V[1:]:
            xlow, ylow = min(x, xlow), min(y, ylow),
            xhigh, yhigh = max(x, xhigh), max(y, yhigh),
        return xlow, ylow, xhigh, yhigh
    def num_sides(self): return len(self.vertices())
    def describe(self):
        return "A polygon with vertices {0}".format(self.vertices())
```


Specializing Polygons

- At this point, we can introduce simple (non-intersecting) polygons, for which there is a simple area formula.

```
class SimplePolygon(Polygon):
    def is_simple(self): return True
    def area(self):
        a = 0.0
        V = self.vertices()
        for i in range(len(V)-1):
            a += V[i][0] * V[i+1][1] - V[i+1][0]*V[i][1]
        return -0.5 * a
```

- This says that a SimplePolygon is a kind of Polygon, and that the attributes of Polygon are to be *inherited* by simple Polygon.
- So far, none of these Polygons are much good, since they have no defined vertices.
- We say that Polygon and SimplePolygon are *abstract types*.

A Concrete Type

- Finally, a square is a type of simple Polygon:

```
class Square(SimplePolygon):
    def __init__(self, xll, yll, side):
        """A square with lower-left corner at (xll,yll) and
        given length on a side."""
        self.__x = xll
        self.__y = yll
        self.__s = side
    def vertices(self):
        x0, y0, s = self.__x, self.__y, self.__s
        return ((x0, y0), (x0, y0+s), (x0+s, y0+s),
                (x0+s, y0), (x0, y0))
    def describe(self):
        return "A {0}x{0} square with lower-left corner ({1},{2})" \
               .format(self.__s, self.__x, self.__y)
```

- Don't have to define area,, etc., since the defaults work.
- We chose to *override* describe to give a more specific description.

Inheritance Explained

- Inheritance (in Python) works like nested environment frames.