Lecture #14: OOP

Some Useful Annotations: @staticmethod

- We saw annotations earlier, as examples of higher-order functions.
- For classes, Python defines a few specialized to methods.
- The `@staticmethod` annotation denotes a class method (i.e., ordinary function), which does not apply to any particular object.

```
class Account:
    _total_deposits = 0
    ...
    @staticmethod
    def total_deposits():    # No 'self' needed.
        return Account._total_deposits
```

- Now we can write

```
acct = Account(...)
acct.total_deposits()    # Total deposits in bank.
Account.total_deposits() # Ditto
```

Some Useful Annotations: @property

- I've said that generally, method calls are the preferred way for clients to access an object (rather than direct access to instance variables.)
- This practice allows the class implementor to hide details of implementation.
- Still it's cumbersome to have to say, *e.g.*, `aPoint.getX()` rather than `aPoint.x`, and `aPoint.setX(v)` rather than `aPoint.x = v`.
- To alleviate this, Python introduced the idea of a *property object*.
- When a property object is an attribute of an object, it *calls a function* when it is fetched from its containing object by dot notation.
- The property object can also be defined to call a different function on assignment to the attribute.
- Attributes defined as property objects are called *computed* or *managed* attributes.

Properties (Long Form)

```
class rational:
    def __init__(self, num, den):
        g = gcd(num, den)
        self._num, self._den = num/g, den/g

    def _getNumer(self): return self._num

    def _setNumer(self, val): self._num = val / gcd(val, self._denom)

    numer = property(_getNumer, _setNumer)
    # Alternatively,
    #   numer = property(_getNumer).setter(_setNumer)
```

- As a result,

```
>>> a = rational(3, 4)
>>> a.numer      # Calls a._getNumer()
3
>>> a.numer = 5  # Calls a._setNumer(5)
```

Properties (Short Form)

The built-in `property` function is also a decorator:

```
class rational:
    ...
    @property
    def numer(self): return self._num
    # Equivalent to
    # def TMPNAME(self): return self._num
    # numer = property(TMPNAME)
    # where TMPNAME is some identifier not used anywhere else.

    @numer.setter
    def numer(self, val):
    # Equivalent to
    # def TMPNAME(self, val): self._num = val / gcd(val, self._denom)
    # numer = numer.setter(TMPNAME)
```

This is a bit obscure, but the idea is that every property object has a `setter` method that turns out a new property object that governs both getting and setting of a value.

Recap of Object-Based Features

```
>>> class T:
...     _marked = False
...     def __init__(self, x): self._value = x
...     def value(self):       return self._value
...     def mark(self):        self._marked = True
...     @staticmethod
...     def setMark(x):        T._marked = x
```

Statements	T._marked	T._value	t1._marked	t1._value t1.value()	t2._marked	t2._value t2.value()
	False	<ERROR>				
t1 = T(3) t2 = T(5)						
	False	<ERROR>	False	3	False	5
t1.mark()						
	False	<ERROR>	True	3	False	5
T.setMark(0)						
	0	<ERROR>	True	3	0	5
t1.setMark([])						
	[]	<ERROR>	True	3	[]	5

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()
        X = [ v[0] for v in V ]
        Y = [ v[1] for v in V ]
        return ( min(X), min(Y), max(X), max(Y) )
    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 `SimplePolygon`.
- 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

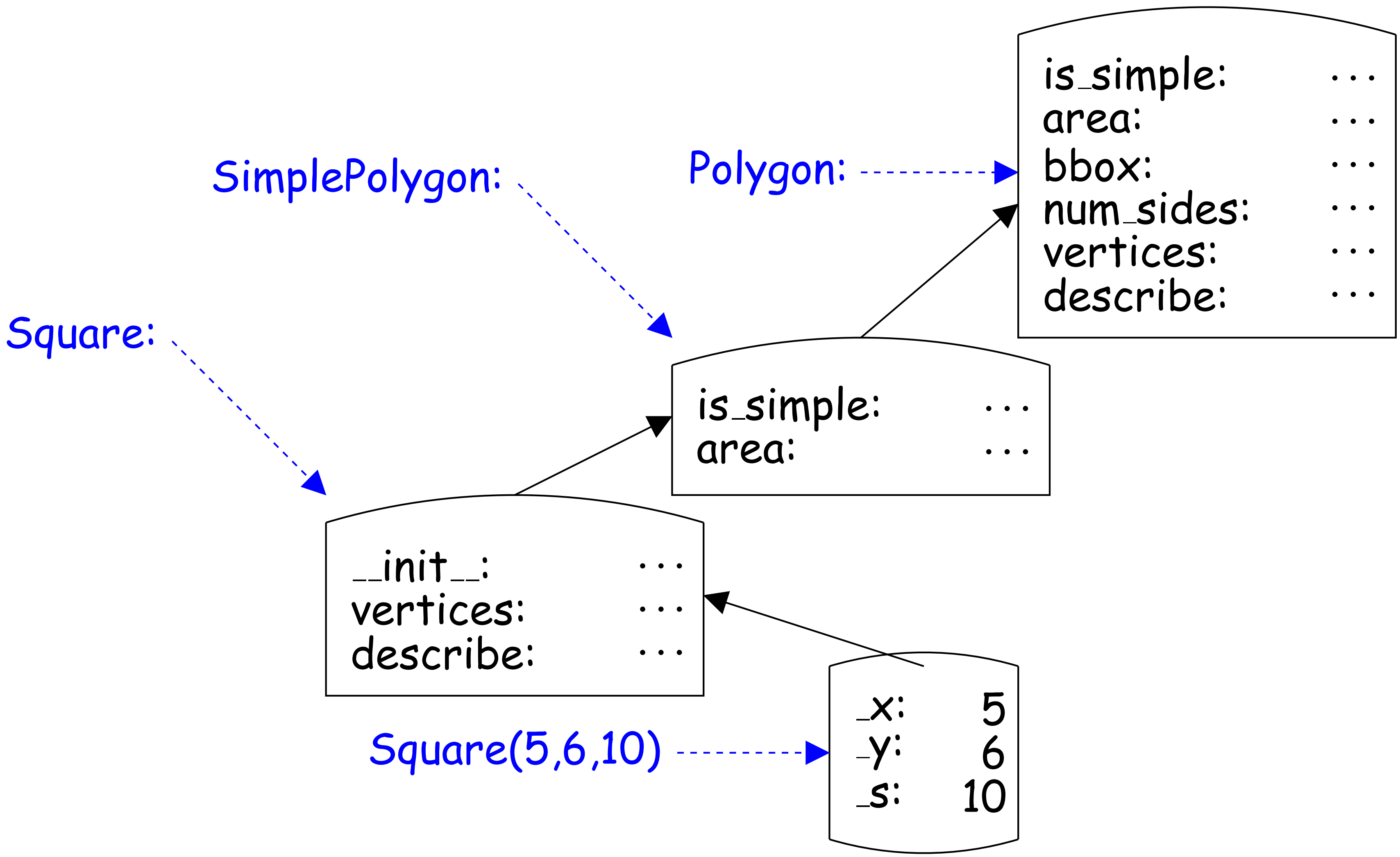
- Finally, a square is a type of simple Polygon:

```
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* the `describe` method to give a more specific description.

(Simple) Inheritance Explained

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



Do You Understand the Machinery?

```
>>> class Parent:
...     def f(s):    # No, you don't have to call it 'self'!
...         print("Parent.f")
...     def g(s):
...         s.f()

>>> class Child(Parent):
...     def f(me):
...         print("Child.f")

>>> aChild = Child()
>>> aChild.g()
# What does Python print?
```

Multiple Inheritance

- A class describes some set attributes.
- One can imagine *assembling* a set of attributes from smaller clusters of related attributes.
- For example, many kinds of object represent some kind of *collection of values* (e.g., lists, tuples, files).
- Built-in kinds of collection have specialized functions representing them as strings (so lists print as `[ ... ]`).
- When we introduce our own notion of collection, we can do this as well, by writing a suitable `__str__(self)` method, which is what `print` calls to print things.
- Many of these methods are similar; perhaps we can consolidate.

Multiple Inheritance Example

```
class Printable:
    """A mixin class for creating a __str__ method that prints
    a sequence object.  Assumes that the type defines __getitem__."""
    def left_bracket(self):
        return type(self).__name__ + "["
    def right_bracket(self):
        return "]"

    def __str__(self):
        result = self.left_bracket()
        for i in range(len(self) - 1):
            result += str(self[i]) + ", "
        if len(self) > 0:
            result += str(self[-1])
        return result + self.right_bracket()
```

Multiple Inheritance Example

- I define a new kind of "sequence with benefits" and would like a distinct way of printing it.

```
class MySeq(list, Printable):
    ...
```

- `MySeqs` will print like

```
MySeq[1, 2, 3]
```

Super

- Sometimes we just want to add to or use the behavior of our parent.
- For example, suppose we have a class that mogrifies:

```
class Transformer:
    def mogrify(self):
        """Do something"""
```

- We want another type that counts how many time `mogrify` is called:

```
class CountedTransformer(Transformer):
    """A Transformer that counts the number of calls to its
    mogrify method."""
    def __init__(self): self._count = 0

    def mogrify(self):
        self._count += 1
        return Transformer.mogrify(self) # Calls Transformer's method
        # Or the "official way": return super().mogrify()

    def count(self):
        return self._count
```

Example: "Memoization"

- Suppose we have

```
class Evaluator:
    def value(self, x):
        some expensive computation that depends only on x

class FastEvaluator(Evaluator):
    def __init__(self):
        self.__memo_table = {}  # Maps arguments to results

    def value(self, x):
        """A memoized value computation"""
        if x not in self.__memo_table:
            self.__memo_table[x] = Evaluator.value(self, x)
        return self.__memo_table[x]
```

- `FastEvaluator.value` must call the `.value` method of its base (super) class, but we can't just say `self.value(x)`, since that gives an infinite recursion.