Lecture #16: Inheritance and Interfaces

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), language mechanisms called *inheritance* and *dynamic method selection* accomplish 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

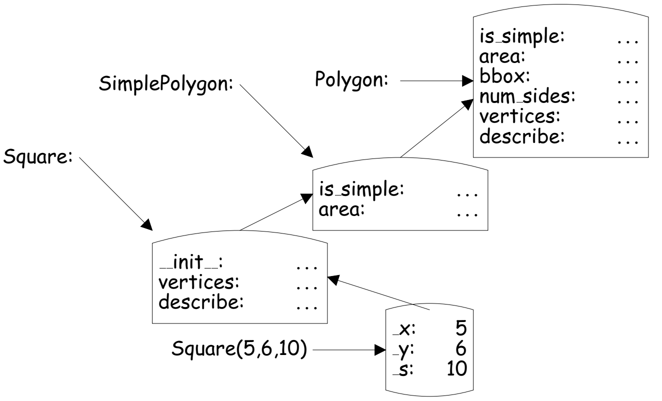
- Finally, a square is a type of simple Polygon:

```
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.



Using Base Types

- Sometimes, we want an overriding method in a subtype to *augment* rather than totally replace an existing method.
- That means that we have to call the original version of the method within the overriding method somehow.
- Can't just do an ordinary method call on self, since that would cause infinite recursion.
- Fortunately, we can explicitly ask for the original version of the method by selecting from the class.

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.

Generic Programming

- Consider the function find:

```
def find(L, x, k):
    """Return the index in L of the kth occurrence of x (k>=0),
    or None if there isn't one."""
    for i in range(len(L)):
        if L[i] == x:
            if k == 0:
                return i
            k -= 1
```

- This same function works on lists, tuples, strings, and (if the keys are consecutive integers) dicts.
- In fact, it works for any list L for which len and indexing work as they do for lists and tuples.
- That is, find is *generic* in the type of L.

The Idea of an Interface

- In Python, this means any type that fits the following *interface*:

```
class SequenceLike:
   def __len__(self):
      """My length, as a non-negative integer."""

   def __getitem__(self, k):
      """My kth element, where 0 <= k < self.__len__()"""
```

  (for which len(L) and L[...] are "*syntactic sugar*.")
- This is one way to describe an *interface*, which in a programming language consists of
  - A *syntactic specification* (operation names, numbers of parameters), and
  - A *semantic specification*—its meaning or behavior (given here by English-language comments.)
- Generic functions are written assuming only that their inputs honor particular interfaces.
- The fewer the assumptions in those interfaces, therefore, the more general (and reusable) the function.

Supertypes as Interfaces

- We call the types that a Python class inherits from its *supertypes* or *base types* (and the defined class, therefore, is a *subtype*).
- Good programming practice requires that we treat our supertypes as interfaces, and adhere to them in the subtypes.
- For example, were we to write

```
class MyQueue(SequenceLike):
   def __len__(self): ...
   def __getitem__(self, k): ...
```

  then good practice says that MyQueue.__len__ should take a single parameter and return a non-negative integer, and that MyQueue.__getitem__ should accept an integer between 0 and the value of self.__len__()
- Python doesn't actually enforce either of these provisions; it's up to programmers to do so.
- Other languages (like C++, Java, or Ada) enforce the syntactic part of the specification.

Duck Typing

- A *statically typed language* (such as Java) requires that you specify a type for each variable or parameter, one that specifies all the operations you intend to use on that variable or parameter.
- To create a generic function, therefore, your parameters' types must be subtypes of some particular interface.
- You can do this in Python, too, but it is not a requirement.
- In fact, our find function will work on any object that responds appropriately to __len__ and __getitem__, regardless of the object's type.
- This property is sometimes called *duck typing:* "This parameter must be a duck, and if it walks like a duck and quacks like a duck, we'll say it *is* a duck."

Consequences of Good Practice

- If we obey the supertype-as-interface guideline, then we can pass any object that has a subtype of SequenceLike to find and expect it to work.
- This fact is an example of what is called the *Liskov Substitution Principle*, after Prof. Barbara Liskov of MIT, who is generally credited with enunciating it.

Interface as Documentation

- The interface (especially its documentation comments) provides a *contract* between clients of the interface and its subtypes—implementations of the interface:

  > "I, the implementor, agree that all the subclasses I define will conform to the signature and comments in this interface, as long as you, the client, obey any restrictions specified in the interface."

- Since Python does not check or enforce the consistency of supertypes and subtypes, use of the guideline is a matter of individual discipline.
- Enforced or not, the interface type provides a convenient place to document the contract.
- But even when using duck typing, good practice requires that we document the assumptions made by the implementor about parameters to methods (what methods they have, in particular).

Example: The __repr__ Method

- When the interpreter prints the value of an expression, it must first convert that value to a (printable) string.
- To do so, it calls the __repr__() method of the value, which is supposed to return a string that suggests how you'd create the value in Python.

```
>>> "Hello"
'Hello'
>>> print(repr("Hello"))
'Hello'
>>> repr("Hello")     # What does the interpreter print?
```

- (As a convenience, the built-in function repr(x) calls x.__repr__.)
- User-defined classes can define their own __repr__ method to control how the interpreter prints them (see HW#6).

Example: The __str__ Method

- When the print function prints a value, it calls the __str__() method to find out what string to print.
- The constructor for the string type, str, does the same thing.
- Again, you can define your own __str__ on a class to control this behavior. (The default is just to call __repr__)

```
>>> class rational:
...     def __init__(num, den): ...
...     def __str__(self):
...         if self.numer() == 0: return "0"
...         elif self.denom() == 1: return str(self.numer())
...         else: return "{0}/{1}".format(self.numer(), self.denom())
...
>>> rational(3,4)
3/4
>>> rational(5, 1)
5
```


Iterators

- In the homework, we introduce the notion of *iterators*, another use of duck typing.
- The **for** statement is actually a generic control construct with the following meaning:

```
for x in C:          tmp_iter = C.__iter__()
    S                try:
                         while True:
                             x = tmp_iter.__next__()
                             S
                     except StopIteration:
                         pass
```

- The __next__ method can use raise StopIteration statement to cause the loop to exit.
- Types that implement __iter__ are called *iterable*, and those that implement __next__ are *iterators*.
- As usual, the builtin functions iter(x) and next(x) are defined to call x.__iter__() and x.__next__().

Problem: Reconstruct the range class

- Want Range(1, 10) to give us something that behaves like a Python range, so that this loop prints 1–9:

```
for x in Range(1, 10):
    print(x)
```

```
class Range:
    def __init__(self, low, high):
        self._low = low
        self._high = high
    def __iter__(self):
        return RangeIter(self)
```

```
class RangeIter:
    def __init__(self, limits):
        self._bound = limits._high
        self._next = limits._low

    def __next__(self):
        if self._next >= self._bound:
            raise StopIteration
        else:
            self._next += 1
            return self._next
```