

## Lecture #16: Inheritance and Interfaces

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## 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.

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## 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.

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## Partial Implementations

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

```
class Polygon:
    def is_simple(self): raise NotImplemented # (see next slide)
    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 {}".format(self.vertices())
```

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## Quick Aside: raise

- The statement `raise NotImplemented` is said to *raise an exception*.
- Usually used to signal an error ("*exceptional condition*").
- But sometimes used for regular programming (iterators later in this lecture).
- In place of `NotImplemented`, can use any subtype of the built-in class `BaseException`.
- And now, back to Polygons.

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## 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*.

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## A Concrete Type

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

```
class Square(SimplePolygon):
    def __init__(self, x11, y11, side):
        """A square with lower-left corner at (x11,y11) and
        given length on a side."""
        self._x = x11
        self._y = y11
        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)
```

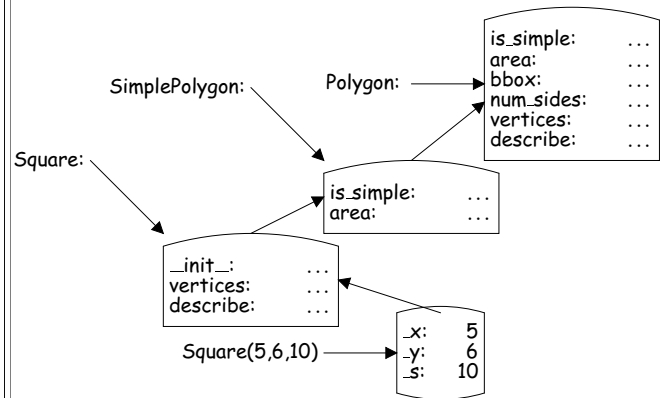
- Don't have to define `area`, etc., since the defaults work.
- We chose to *override* `describe` to give a more specific description.

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## Inheritance Explained

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



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## 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.

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## 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.
- So we search for `.value` starting in `Evaluator`, as plain function.

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## super()

- Usually, when (as in `FastEvaluator`) we want to call a method we are overriding, we want to clearly mark this fact.
- So, the usual way to write `FastEvaluator` is like this:

```
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] = super().value(x)
        return self.__memo_table[x]
```

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## 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`.

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## 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.

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## 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.

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## 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.”
- In sum, an explicit supertype is not required in Python to get the benefits of generic programming, but it can help document what we're doing.

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## 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.

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## 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).

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## 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).

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## 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.number() == 0: return "0"
...         elif self.denom() == 1: return str(self.number())
...         else: return "{0}/{1}".format(self.number(), self.denom())
...
>>> rational(3,4)
3/4
>>> rational(5, 1)
5
```