Lecture #13: Objects and Classes

Data Abstraction vs. Function Abstraction

- Functions perform *computations*; their specifications abstract from possible implementations of a particular computation.
- In the old days, programs tended to be organized around functions or modules comprising related functions. The data were just the operands.
- Now we tend to organize instead around the data—around *objects* or types (*classes*) of objects.
- Objects have *state*, which is accessed and manipulated by means of *attributes*.
- The set of attributes and their behavior is analogous to the syntactic and semantic specification of a function.
- In previous lectures, we've seen standard Python objects and ways to get (in effect) new kinds of objects using functions and non-local variables. We've defined data types using them by defining a set of functions to be used to construct, query, and modify them.
- Python also provides a standard way to gather together state and attributes of new types of date: *classes*.

Extending the Mutable Objects: Classes

- In languages such as Python, Java, and C++, an *object* is an *instance* of a class; the class is called the object's *type*.
- The Python `class` statement defines new classes or types, creating new, vaguely dictionary-like varieties of object.

Simple Classes: Bank Account

```
      # type name
class Account:
    # constructor method
    def __init__(self, initial_balance):
        self._balance = initial_balance

    def balance(self):  # instance method
        # instance variable:
        return self._balance

    def deposit(self, amount):
        if amount < 0:
            raise ValueError("negative deposit")
        self._balance += amount

    def withdraw(self, amount):
        if 0 <= amount <= self._balance:
            self._balance -= amount
        else: raise ValueError("bad withdrawal")
```

```
>>> mine = Account(1000)
>>> mine.deposit(100)
>>> mine.balance()
1100
>>> mine.withdraw(200)
>>> mine.balance()
900
```

Class Concepts

- 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 *operations* specific to these objects.
    - In particular, an operation for *initializing* the state of an object.
  - A means of *creating* new objects.

Class Machinery

- 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.
```

Attribute Access

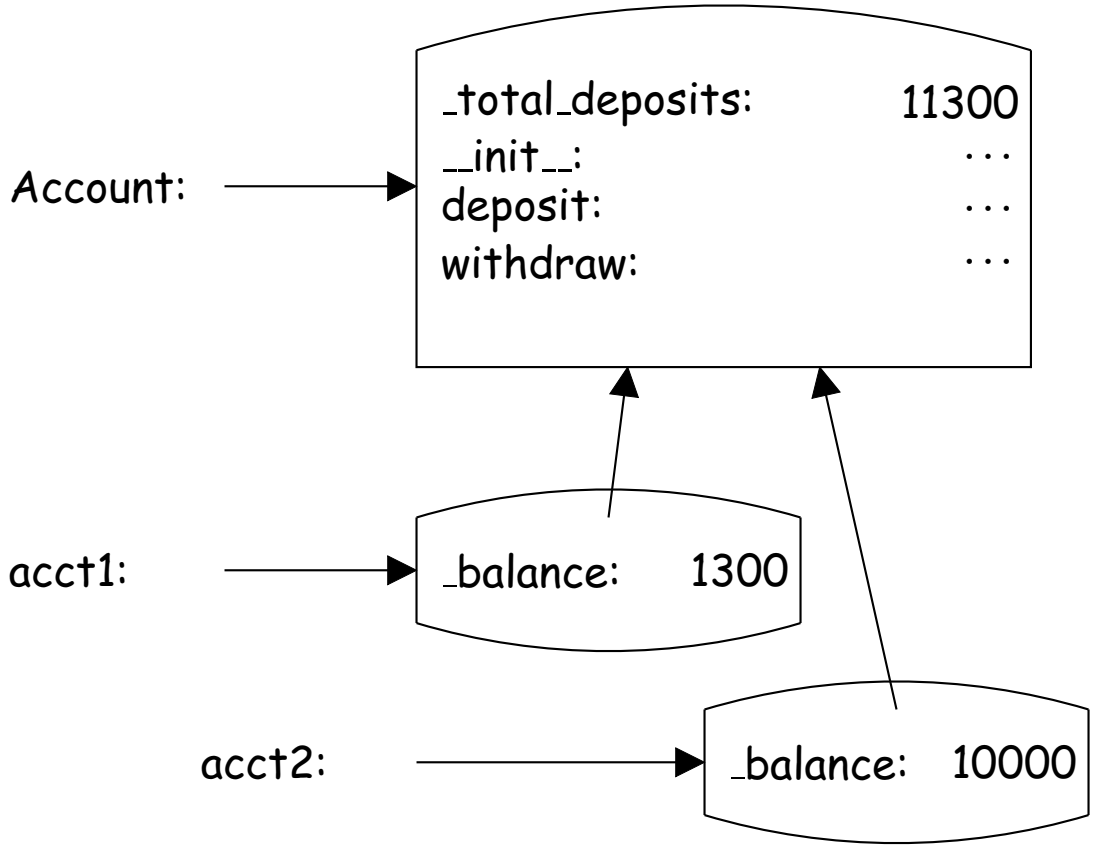
- In general, the notation *X.Y* means "The value named *Y* in the object pointed to by *X*."
- Unlike C++ or Java, Python takes a very dynamic approach.
- Classes and class instances behave rather like environment frames.
- Given a pointer to some object, `obj`,
  - `obj.x = value` looks for a definition of `x` in the object referenced by `obj`, creating one if it doesn't exist, and assigning `value` to it.
  - When not being assigned to, `obj.x` returns the definition of `x` in the object referenced by `obj`, if any,
  - ...and if there is no such definition, it returns the value defined for `x` in the class itself, if any.

Modeling Attributes in Python

```
class Account:
    _total_deposits = 0

    def __init__(...):
        self._balance = ...
        Account._total_deposits = ...


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

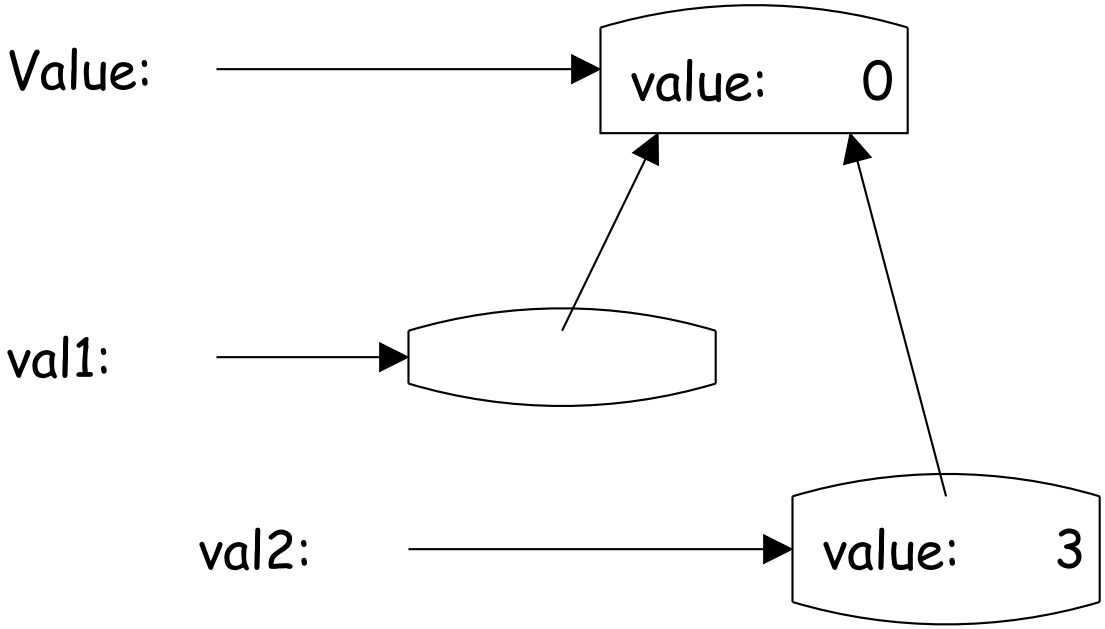


- Curved boxes are objects.
- Flat-bottomed boxes are class objects.
- 'x.y': look for 'y' starting at 'x'

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).

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



Attributes of Classes

- In Python *classes themselves are objects*.
- (You might well ask "What is the type of a class?" **Answer:** a builtin class called *type*, whose type is itself.)
- Therefore, classes themselves have attributes.
- Assignments and **defs** immediately inside a class define *class attributes*.
- Since `obj.x` looks for `x` in the class of `obj` if it doesn't find it in `obj` itself, the attributes defined in a class provide default values for attributes of the object that are instances of the class.

Methods

- Consider

```
>>> class Foo:
...     def set(self, x):
...         self.value = x
>>> aFoo = Foo(10)
```

- The access `aFoo.set` returns the `set` method defined in `Foo` (since we haven't set it in `aFoo`.
- However, in this particular case (function retrieved from the class of an object), what gets returned is a little different.

```
>>> aFoo.set
<bound method Foo.set of ...>
```

- A *bound method* is an ordinary function that has its first parameter "pre-bound" to a particular value—in this case to `aFoo`.

```
>>> aFoo.set(13)  # First parameter (self) of set is aFoo, x is 13.
>>> aFoo.value
13
```

- The effect is (almost) the same as

```
>>> Foo.set(aFoo, 13)
```

Class Attributes in Python

- 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 something confusing called a *class attribute*.

Class Attribute Example

```
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

    def total_deposits():     # Define a class method.
        return Account._total_deposits
```

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

Classes and Operators

- Many standard operators defined in Python are essentially "syntactic sugar" for method calls.
- Examples:
  - `x+y` becomes `x.__add__(y)` if `__add__` is defined for `x`.
  - `x[k]` becomes `x.__getitem__(k)`.
  - `x[k] = 3` becomes `x.__setitem__(k, 3)`.
  - `len(x)` calls `x.__len__()`.
  - `repr(x)` calls `x.__repr__()`, which is what the interpreter uses to print the value of expressions you type.

Class Machinery: Summary

- Classes have *attributes*, created by assignment statements and `defs` in the class body.
- Function-values attributes of classes are called *methods*.
- Classes beget objects called *instances*, created by "calling" the class: `Account(1000)`.
- Each such `Account` object initially shares the attributes of its class.
- Attributes can be accessed using `object.attribute` notation.
- A method call `mine.deposit(100)` is essentially the same as `Account.deposit(mine, 100)`.
- By convention, we call the first argument of a method `self` to indicate that it is the object from which we got the method.
- When an object is created, the special `__init__` method is called on it first.
- Assigning to an attribute of an object (`a.b = v`) gives that object its own attribute (not shared with the class), if it doesn't have it already.