Programming Principles in Python (CSCI 503/490)

Object-Oriented Programming

Dr. David Koop

Classes and Instances in Python

- Class Definition:
  -
```
class Vehicle:
    def __init__(self, make, model, year, color):
        self.make = make
        self.model = model
        self.year = year
        self.color = color

    def age(self):
        return 2022 - self.year
```
- Instances:
  - `car1 = Vehicle('Toyota', 'Camry', 2000, 'red')`
  - `car2 = Vehicle('Dodge', 'Caravan', 2015, 'gray')`

Visibility

- In some languages, encapsulation allows certain attributes and methods to be hidden from those using an instance
- public (visible/available) vs. private (internal only)
- Python does not have visibility descriptors, but rather conventions (PEP8)
  - Attributes & methods with a leading underscore (_) are intended as private
  - Others are public
  - You can still access private names if you want but generally **shouldn't**:
    - `print(car1._color_hex)`
  - Double underscores leads to **name mangling**:
    `self.__internal_vin` is stored at `self._Vehicle__internal_vin`

Properties

- Properties allow transformations and checks but are accessed like attributes
- getter and setter have same name, but different decorators
- Decorators (`@<decorator-name>`) do some magic
- ```
  @property
  def age(self):
      return 2021 - self.year
  ```
- ```
  @age.setter
  def age(self, age):
      self.year = 2021 - age
  ```
- Using property:

  ```
  - car1.age = 20
  ```

Exercise

- Create Stack and Queue classes
  - Stack: last-in-first-out
  - Queue: first-in-first-out
- Define constructor and push and pop methods for each

Inheritance

- Is-a relationship: Car is a Vehicle, Truck is a Vehicle
- Make sure it isn't composition (has-a) relationship: Vehicle has wheels, Vehicle has a steering wheel
- Subclass is specialization of base class (superclass)
  - Car is a subclass of Vehicle, Truck is a subclass of Vehicle
- Can have an entire hierarchy of classes (e.g. Chevy Bolt is subclass of Car which is a subclass of Vehicle)
- Single inheritance: only one base class
- Multiple inheritance: allows more than base class
  - Many languages don't support, Python does

Instance Attribute Conventions in Python

- Remember, the naming is the convention
- `public`: used anywhere
- `_protected`: used in class and subclasses
- `__private`: used only in the specific class
- Note that double underscores induce name mangling to strongly discourage access in other entities

Subclass

- Just put superclass(-es) in parentheses after the class declaration
-
```
class Car(Vehicle):
    def __init__(self, make, model, year, color, num_doors):
        super().__init__(make, model, year, color)
        self.num_doors = num_doors

    def open_door(self):
        …
```
- `super()` is a special method that locates the base class
  - Constructor should call superclass constructor
  - Extra arguments should be initialized and extra instance methods

Overriding Methods

- ```
  class Rectangle:
      def __init__(self, height,
                   width):
          self.h = height
          self.w = weight

      def set_height(self, height):
          self.h = height
      def area(self):
          return self.h * self.w
  ```
- ```
  class Square(Rectangle):
      def __init__(self, side):
          super().__init__(side, side)

      def set_height(self, height):
          self.h = height
          self.w = height
  ```

Assignment 5

- Due Friday
- Writing a Python Package and Command-Line Tools
- Same Pokémon data
- Analysis and Comparison
- Create package and command-line tool

Quiz Wednesday

- Quiz on Object-Oriented Programming

Class and Static Methods

- Use `@classmethod` and `@staticmethod` decorators
- Difference: class methods receive class as argument, static methods do not
-
```
class Square(Rectangle):
    DEFAULT_SIDE = 10
    …

    @classmethod
    def set_default_side(cls, s):
        cls.DEFAULT_SIDE = s

    @staticmethod
    def set_default_side_static(s):
        Square.DEFAULT_SIDE = s
```

Class and Static Methods

- ```
  class Square(Rectangle):
      DEFAULT_SIDE = 10

      def __init__(self, side=None):
          if side is None:
              side = self.DEFAULT_SIDE
          super().__init__(side, side)
      …
  ```
- ```
  Square.set_default_side(20)
  s2 = Square()
  s2.side # 20
  ```
- ```
  Square.set_default_side_static(30)
  s3 = Square()
  s3.side # 30
  ```
  ```

Class and Static Methods

- ```
  class NewSquare(Square):
      DEFAULT_SIDE = 100
  ```
- ```
  NewSquare.set_default_side(200)
  s5 = NewSquare()
  s5.side # 200
  ```
- ```
  NewSquare.set_default_side_static(300)
  s6 = NewSquare()
  s6.side # !!! 200 !!!
  ```
- Why?
  - The static method sets `Square.DEFAULT_SIDE` not the `NewSquare.DEFAULT_SIDE`
  - `self.DEFAULT_SIDE` resolves to `NewSquare.DEFAULT_SIDE`
  ```

Checking type

- We can check the type of a Python object using the `type` method:
  - `type(6) # int`
  - `type("abc") # str`
  - `s = Square(4)`
  - `type(s) # Square`
- Allows comparisons:
  - ```
    if type(s) == Square:
        # …
    ```
- But this is **False**:
  - ```
    if type(s) == Rectangle:
        # …
    ```

Checking InstanceOf/Inheritance

- How can we see if an object is an **instance** of a particular class or whether a particular class is a **subclass** of another?
- Both check is-a relationship (but differently)
- `issubclass(cls1, cls2)`: checks if `cls1` is-a (subclass of) `cls2`
- `isinstance(obj, cls)`: checks if `obj` is-a(n instance of) `cls`
- Note that `isinstance` is `True` if `obj` is an instance of a class that is a subclass of `cls`

```
- car = Car('Toyota','Camry', 2000, 'red', 4)
  isinstance(car, Vehicle) # True
```

Interfaces

- In some languages, can define an abstract base class
  - The structure is defined but **without implementation**
  - Alternatively, some methods are defined abstract, others are implemented
- Interfaces are important for types
  - Method can specify a particular type that can be abstract
  - This doesn't matter as much in Python
- However, Python does have ABCs (Abstract Base Classes)
  - Solution to be able to check for mappings, sequences via `isinstance`, etc.
  - `abc.Mapping, abc.Sequence, abc.MutableSequence`

Duck Typing

- "If it looks like a duck and quacks like a duck, it must be a duck."
- Python "does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used"
-
```
class Rectangle:
    def area(self):
        …
```
-
```
class Circle:
    def area(self):
        …
```
- It doesn't matter that they don't have a common base class as long as they respond to the methods/attributes we expect: `shape.area()`

[Python Glossary]

Multiple Inheritance

- Can have a class inherit from two different superclasses
- HybridCar inherits from Car and Hybrid
- Python allows this!
  - `class HybridCar(Car, Hybrid): …`
- Problem: how is `super()` is defined?
  - Diamond Problem
  - Python use the **method resolution order** (MRO) to determine order of calls

Method Resolution Order

- The order in which Python checks classes for a method
- `mro()` is a **class** method
- `Square.mro() # [__main__.Square, __main__.Rectangle, object]`
- Order of base classes matters:

```
- class HybridCar(Car, Hybrid):
      pass
  HybridCar.mro() # [__main__.HybridCar, __main__.Car,
                     __main__.Hybrid, __main__.Vehicle, object]
- class HybridCar(Hybrid, Car):
      pass
  HybridCar.mro() # [__main__.HybridCar, __main__.Hybrid,
                     __main__.Car, __main__.Vehicle, object]
```

Operator Overloading

- Dunder methods (`__add__`, `__contains__`, `__len__`)
- Example:
  -
```
class Square(Rectangle):
    …
    @property
    def side(self):
        return self.h
    def __add__(self, right):
        return Square(self.side + right.side)
    def __repr__(self):
        return f'{self.__class__.__name__}({self.side})'
new_square = Square(8) + Square(4)
new_square # Square(12)
```

Operator Overloading Restrictions

- Precedence cannot be changed by overloading. However, parentheses can be used to force evaluation order in an expression.
- The left-to-right or right-to-left grouping of an operator cannot be changed
- The “arity” of an operator—that is, whether it’s a unary or binary operator—cannot be changed.
- You cannot create new operators—only overload existing operators
- The meaning of how an operator works on objects of built-in types cannot be changed. You cannot change + so that it subtracts two integers
- Works only with objects of custom classes or with a mixture of an object of a custom class and an object of a built-in type.

[Deitel & Deitel]

Ternary Operator

- `a = b < 5 ? b + 5 : b - 5`
- Kind of a weird construct, but can be a nice shortcut
- Python does this differently:
- `<value> if <condition> else <value>`
- Example: `absx = x if x >= 0 else -x`
- Reads so that the usual is listed first and the abnormal case is listed last
- "Usually this, else default to this other"

Mixins

- Sometimes, we just want to add a particular method to a bunch of different classes
- For example: `print_as_dict()`
- A mixin class allows us to specify one or more methods and add it as the second
- Caution: Python searches from left to right so a base class should be at the right with mixing

Object-Based Programming

- With Python's libraries, you often don't need to write your own classes. Just
  - Know what libraries are available
  - Know what classes are available
  - Make objects of existing classes
  - Call their methods
- With inheritance and overriding and polymorphism, we have true object-oriented programming (OOP)

[Deitel & Deitel]