Programming Principles in Python (CSCI 503/490)

Object-Oriented Programming

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Reloading a Module?

- If you re-import a module, what happens?
  - `import my_module`
    `my_module.SECRET_NUMBER # 42`
  - Change the definition of `SECRET_NUMBER` to `14`
  - `import my_module`
    `my_module.SECRET_NUMBER # Still 42!`
- Modules are **cached** so they are not reloaded on each import call
- Can reload a module via `importlib.reload(<module>)`
- Be careful because **dependencies** will persist! (Order matters)

Python Packages

- A package is basically a collection of modules in a directory subtree
- Structures a module namespace by allowing dotted names
- Example:

```
- test_pkg/
      __init__.py
      foo.py
      bar.py
      baz/
          fun.py
```

- For packages that are to be executed as scripts, `__main__.py` can also be added

Finding & Installing Packages

- Python Package Index (PyPI) is the standard repository (https://pypi.org) and pip (pip installs packages) is the official python package installer
- Anaconda is a package index, conda is a package manager
- To install packages:
  - `pip install <package-name>`
  - `conda install <package-name>`
  - Jupyter: Add `% (%pip, %conda)`
- Both pip and conda support environments
  - `venv`
  - `conda env`

Environments

- Both pip and conda support environments
  - venv
  - conda env
- Idea is that you can create different environments for different work
  - environment for cs503
  - environment for research
  - environment for each project

Object-Oriented Programming Concepts

- Abstraction: simplify, hide implementation details, don't repeat yourself
- Encapsulation: represent an entity fully, keep attributes and methods together
- Inheritance: reuse (don't reinvent the wheel), specialization
- Polymorphism: methods are handled by a single interface with different implementations (overriding)

Vehicle Example

- Suppose we are implementing a city simulation, and want to model vehicles driving on the road
- How do we represent a vehicle?
  - Information (attributes): make, model, year, color, num_doors, engine_type, mileage, acceleration, top_speed, braking_speed
  - Methods (actions): compute_estimated_value(), drive(num_seconds, acceleration), turn_left(), turn_right(), change_lane(dir), brake(), check_collision(other_vehicle)

Class vs. Instance

- A **class** is a blueprint for creating instances
  - e.g. Vehicle
- An **instance** is an single object created from a class
  - e.g. 2000 Red Toyota Camry
  - Each object has its own attributes
  - Instance methods produce results unique to each particular instance

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')`

Assignment 4

- Due Today
- Books in Different Languages
- Reading & Writing Files
- Iterators
- Statistics
- String Formatting
- CSCI 503 students compute and output two additional fields

Assignment 5

- Release before Spring Break but due at the end of the week after it
- Revisit the food data but now create a Python package and command-line tool to support our analyses

Creating and Using Instances

- Creating instances:
  - Constructor expressions specify the name of the class to instantiate and specify any arguments to the constructor (not including `self`)
  - Returns new object
  - `car1 = Vehicle('Toyota', 'Camry', 2000, 'red')`
  - `car2 = Vehicle('Dodge', 'Caravan', 2015, 'gray')`
- Calling an instance method
  - `car1.age()`
  - `car1.set_age(20)`
  - Note `self` is not passed explicitly, it's `car1` (instance before the dot)

Used Objects Many Times Before

- Everything in Python is an object!
  - `my_list = list()`
  - `my_list.append(3)`
  - `num = int('64')`
  - `name = "Gerald"`
  - `name.upper()`

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`

Representation methods

- Printing objects:
  - `print(car1) # <__main__.Vehicle object at 0x7efc087c6b20>`
- "Dunder-methods": `__init__`
- Two for representing objects:
  - `__str__`: human-readable
  - `__repr__`: official, machine-readable
-
```
>>> now = datetime.datetime.now()
>>> now.__str__()
'2020-12-27 22:28:00.324317'
>>> now.__repr__()
'datetime.datetime(2020, 12, 27, 22, 28, 0, 324317)'
```

[https://www.journaldev.com/22460/python-str-repr-functions]

Representation methods

- Car example:
  - `class Vehicle:`

```
        …
        def __str__(self):
            return f'{self.year} {self.make} {self.model}'
```

- Don't call `print` in this method! Return a string
- When using, don't call directly, use `str` or `repr`
  - `str(car1)`
- `print` internally calls `__str__`
  - `print(car1)`

Other Dunder Methods

- `__eq__(<other>)`: return `True` if two objects are equal
- `__lt__(<other>)`: return `True` if object < other
- Collections:
  - `__len__()`: return number of items
  - `__contains__(item)`: return `True` if collection contains `item`
  - `__iter__(): returns iterator`
- `__getitem__(index)`: return item at `index` (which could be a key)
- + More

Properties

- Common pattern is getters and setters:

```
- def age(self):
      return 2022 - self.year
- def set_age(self, age):
      self.year = 2022 - age
```

- In some sense, this is no different than year except that we don't want to store `age` separate from `year` (they should be linked)
- Properties allow transformations and checks but are accessed like attributes
-
```
@property
def age(self):
    return 2022 - self.year
```

- `car1.age # 22`

Properties

- Can also define setters
- Syntax is a bit strange, want to link the two: `@<property-name>.setter`
- Method has the same name as the property: How?
- Decorators (`@<decorator-name>`) do some magic
- ```
  @property
  def age(self):
      return 2022 - self.year
  ```
- ```
  @age.setter
  def age(self, age):
      self.year = 2022 - age
  ```
- `car1.age = 20`

Properties

- Add validity checks!
- First car was 1885 so let's not allow ages greater than that (or negative ages)
- ```
  @age.setter
  def age(self, age):
      if age < 0 or age > 2022 - 1885:
          print("Invalid age, will not set")
      else:
          self.year = 2022 - age
  ```
- Better: raise exception (later)
  ```

Class Attributes

- We can add class attributes inside the class indentation:
- Access by prefixing with **class name** or `self`

```
- class Vehicle:
      CURRENT_YEAR = 2022
      …
      @age.setter
      def age(self, age):
          if age < 0 or age > Vehicle.CURRENT_YEAR - 1885:
              print("Invalid age, will not set")
          else:
              self.year = self.CURRENT_YEAR - age
```

- Constants should be CAPITALIZED
- This is not a great constant! (`EARLIEST_YEAR = 1885` would be!)

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`
  ```

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?
  ```

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

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, then initialize its own extra attributes
  - Instance methods can use `super`, too
  ```

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
  ```

- `s = Square(4)`
- `s.set_height(8)`
  - Which method is called?

Overriding Methods

```
class Rectangle:
    def __init__(self, height,
                 width):
        self.h = height
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    def set_height(self, height):
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```

```
class Square(Rectangle):
    def __init__(self, side):
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```

- `s = Square(4)`
- `s.set_height(8)`
  - Which method is called?
  - Polymorphism
  - Resolves according to inheritance hierarchy
- `s.area()`
  - Which method is called?

Overriding Methods

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

- `s = Square(4)`
- `s.set_height(8)`
  - Which method is called?
  - Polymorphism
  - Resolves according to inheritance hierarchy
- `s.area() # 64`
  - Which method is called?
  - If no method defined, goes up the inheritance hierarchy until found