MORE PYTHON CLASS METHODS

(download slides and .py files to follow along)

6.100L Lecture 18

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IMPLEMENTING THE CLASS vs USING THE CLASS

- Write code from two different perspectives

Implementing a new object type with a class

- **Define** the class
- Define **data attributes** (WHAT IS the object)
- Define **methods** (HOW TO use the object)

Class abstractly captures **common** properties and behaviors

Using the new object type in code

- Create **instances** of the object type
- Do **operations** with them

Instances have **specific values** for attributes

RECALL THE COORDINATE CLASS

- Class **definition** tells Python the **blueprint** for a type Coordinate

```
class Coordinate(object):
    """ A coordinate made up of an x and y value """
    def __init__(self, x, y):
        """ Sets the x and y values """
        self.x = x
        self.y = y
    def distance(self, other):
        """ Returns euclidean dist between two Coord obj """
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
```

ADDING METHODS TO THE COORDINATE CLASS

- Methods are functions that **only work with objects of this type**

```
class Coordinate(object):
    """ A coordinate made up of an x and y value """
    def __init__(self, x, y):
        """ Sets the x and y values """
        self.x = x
        self.y = y
    def distance(self, other):
        """ Returns euclidean dist between two Coord obj """
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
    def to_origin(self):
        """ always sets self.x and self.y to 0,0 """
        self.x = 0
        self.y = 0
```

MAKING COORDINATE INSTANCES

- Creating **instances** makes actual Coordinate **objects in memory**
- The objects can be **manipulated**
  - Use **dot notation** to call methods and access data attributes

x data attr has a value of 3
y data attr has a value of 4

```
c = Coordinate(3,4)
origin = Coordinate(0,0)

print(f"c's x is {c.x} and origin's x is {origin.x}")
print(c.distance(origin))

c.to_origin()
print(c.x, c.y)
```

Method didn't return anything,
just set c's x and y to 0.

CLASS DEFINITION OF AN OBJECT TYPE vs INSTANCE OF A CLASS

- Class name is the **type**

  `class Coordinate(object)`

- Class is defined generically
  - Use `self` to refer to some instance while defining the class

  `(self.x – self.y)**2`

  - `self` is a parameter to methods in class definition

- Class defines data and methods **common across all instances**

- Instance is **one specific object**

  `coord = Coordinate(1,2)`

- Data attribute values vary between instances

  `c1 = Coordinate(1,2)`

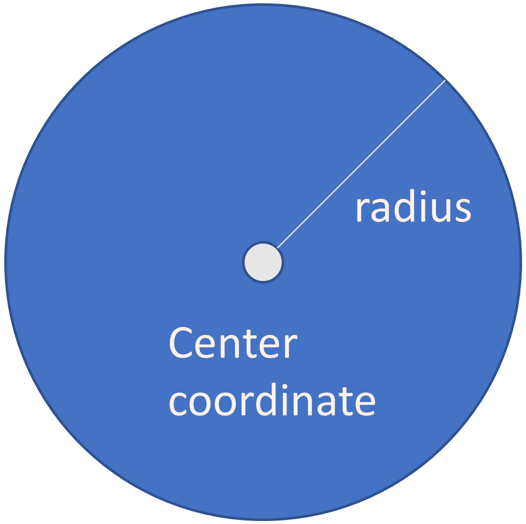
  `c2 = Coordinate(3,4)`

  - `c1` and `c2` have different data attribute values `c1.x` and `c2.x` because they are different objects

- Instance has the **structure of the class**

USING CLASSES TO BUILD OTHER CLASSES

- Example: use Coordinates to build Circles
- Our implementation will use **2 data attributes**
  - Coordinate object representing the center
  - int object representing the radius



CIRCLE CLASS: DEFINITION and INSTANCES

Will be a Coordinate object

Will be an int

```
class Circle(object):
    def __init__(self, center, radius):
        self.center = center
        self.radius = radius
```

Data attributes, do not need to have the same names as params

```
center = Coordinate(2, 2)
my_circle = Circle(center, 2)
```

YOU TRY IT!

- Add code to the init method to check that the type of center is a Coordinate obj and the type of radius is an int. If either are not these types, raise a ValueError.

```
def __init__(self, center, radius):
    self.center = center
    self.radius = radius
```

CIRCLE CLASS: DEFINITION and INSTANCES

```
class Circle(object):
    def __init__(self, center, radius):
        self.center = center
        self.radius = radius
    def is_inside(self, point):
        """ Returns True if point is in self, False otherwise """
        return point.distance(self.center) < self.radius
```

self is a Circle object

point is a Coordinate object

Coordinate object

Method called on a Coordinate obj

Coordinate object

```
center = Coordinate(2, 2)
my_circle = Circle(center, 2)
p = Coordinate(1,1)
print(my_circle.is_inside(p))
```

Method that only works with obj of type Circle

Coordinate object

Circle object

YOU TRY IT!

- Are these two methods in the Circle class functionally equivalent?

```
class Circle(object):
    def __init__(self, center, radius):
        self.center = center
        self.radius = radius

    def is_inside1(self, point):
        return point.distance(self.center) < self.radius

    def is_inside2(self, point):
        return self.center.distance(point) < self.radius
```

EXAMPLE: FRACTIONS

- Create a **new type** to represent a number as a fraction
- **Internal representation** is two integers
  - Numerator
  - Denominator
- **Interface** a.k.a. **methods** a.k.a **how to interact** with `Fraction` objects
  - Add, subtract
  - Invert the fraction
- Let's write it together!

NEED TO CREATE INSTANCES

```
class SimpleFraction(object):
    def __init__(self, n, d):
        self.num = n
        self.denom = d
```

MULTIPLY FRACTIONS

```
class SimpleFraction(object):
    def __init__(self, n, d):
        self.num = n
        self.denom = d
    def times(self, oth):
        top = self.num*oth.num
        bottom = self.denom*oth.denom
        return top/bottom
```

SimpleFraction objects so they each have
* num
* denom

Access num or denom to do the math

ADD FRACTIONS

```
class SimpleFraction(object):
    def __init__(self, n, d):
        self.num = n
        self.denom = d
    .........
    def plus(self, oth):
        top = self.num*oth.denom + self.denom*oth.num
        bottom = self.denom*oth.denom
        return top/bottom
```

LET'S TRY IT OUT

```
f1 = SimpleFraction(3, 4)
f2 = SimpleFraction(1, 4)
print(f1.num)              → 3
print(f1.denom)            → 4
print(f1.plus(f2))         → 1.0
print(f1.times(f2))        → 0.1875
```

YOU TRY IT!

- Add two methods to invert fraction object according to the specs below:

```
class SimpleFraction(object):
    """ A number represented as a fraction """
    def __init__(self, num, denom):
        self.num = num
        self.denom = denom
    def get_inverse(self):
        """ Returns a float representing 1/self """
        pass
    def invert(self):
        """ Sets self's num to denom and vice versa.
            Returns None. """
        pass


# Example:
f1 = SimpleFraction(3,4)
print(f1.get_inverse())   # prints 1.33333333 (note this one returns value)
f1.invert()               # acts on data attributes internally, no return
print(f1.num, f1.denom)   # prints 4 3
```

LET'S TRY IT OUT WITH MORE THINGS

```
f1 = SimpleFraction(3, 4)
f2 = SimpleFraction(1, 4)
print(f1.num)              → 3
print(f1.denom)            → 4
print(f1.plus(f2))         → 1.0
print(f1.times(f2))        → 0.1875
```

What if we want to keep as a fraction?

And what if we want to have print and * work as we would expect?

```
print(f1)         <__main__.SimpleFraction object at 0x00000234A8C41DF0>
print(f1 * f2)    Error!
```

SPECIAL OPERATORS IMPLEMENTED WITH DUNDER METHODS

- +, -, ==, <, >, len(), print, and many others are shorthand notations
- Behind the scenes, these **get replaced by a method**!

https://docs.python.org/3/reference/datamodel.html#basic-customization

- Can **override** these to work with your class

SPECIAL OPERATORS IMPLEMENTED WITH DUNDER METHODS

- Define them with **double underscores** before/after

```
__add__(self, other)       →    self + other
__sub__(self, other)       →    self - other
__mul__(self, other)       →    self * other
__truediv__(self, other)   →    self / other
__eq__(self, other)        →    self == other
__lt__(self, other)        →    self < other
__len__(self)              →    len(self)
__str__(self)              →    print(self)
__float__(self)            →    float(self) i.e cast
__pow__                    →    self**other
```

... and others

PRINTING OUR OWN DATA TYPES

PRINT REPRESENTATION OF AN OBJECT

```
>>> c = Coordinate(3,4)
>>> print(c)
<__main__.Coordinate object at 0x7fa918510488>
```

- **Uninformative** print representation by default
- Define a **`__str__` method** for a class
- Python calls the `__str__` method when used with `print` on your class object
- You choose what it does! Say that when we print a `Coordinate` object, want to show

```
>>> print(c)
<3,4>
```

DEFINING YOUR OWN PRINT METHOD

```
class Coordinate(object):
    def __init__(self, xval, yval):
        self.x = xval
        self.y = yval
    def distance(self, other):
        x_diff_sq = (self.x-other.x)**2
        y_diff_sq = (self.y-other.y)**2
        return (x_diff_sq + y_diff_sq)**0.5
    def __str__(self):
        return "<"+str(self.x)+","+str(self.y)+">"
```

name of special method

must **return a string**

WRAPPING YOUR HEAD AROUND TYPES AND CLASSES

- Can ask for the type of an object instance

```
>>> c = Coordinate(3,4)
>>> print(c)
<3,4>
>>> print(type(c))
<class __main__.Coordinate>
```

Return of the __str__ method

The type of object c is a class Coordinate

- This makes sense since

```
>>> print(Coordinate)
<class __main__.Coordinate>
>>> print(type(Coordinate))
<type 'type'>
```

A Coordinate is a class

A Coordinate class is a type of object

- Use `isinstance()` to check if an object is a `Coordinate`

```
>>> print(isinstance(c, Coordinate))
True
```

EXAMPLE: FRACTIONS WITH DUNDER METHODS

- Create a **new type** to represent a number as a fraction
- **Internal representation** is two integers
  - Numerator
  - Denominator
- **Interface** a.k.a. **methods** a.k.a **how to interact** with `Fraction` objects
  - Add, sub, mult, div to work with +, -, *, /
  - Print representation, convert to a float
  - Invert the fraction
- Let's write it together!

CREATE & PRINT INSTANCES

```
class Fraction(object):
    def __init__(self, n, d):
        self.num = n
        self.denom = d
    def __str__(self):
        return str(self.num) + "/" + str(self.denom)
```

Concatenation means that every piece has to be a str

LET'S TRY IT OUT

```
f1 = Fraction(3, 4)
f2 = Fraction(1, 4)
f3 = Fraction(5, 1)
print(f1)
print(f2)
print(f3)
```

3/4

1/4

5/1

Ok, but looks weird!

YOU TRY IT!

- Modify the str method to represent the Fraction as just the numerator, when the denominator is 1. Otherwise its representation is the numerator then a / then the denominator.

```
class Fraction(object):
    def __init__(self, num, denom):
        self.num = num
        self.denom = denom
    def __str__(self):
        return str(self.num) + "/" + str(self.denom)

# Example:
a = Fraction(1,4)
b = Fraction(3,1)
print(a)      # prints 1/4
print(b)      # prints 3
```

IMPLEMENTING + - * / float()

COMPARING METHOD vs. DUNDER METHOD

```
class SimpleFraction(object):
  def __init__(self, n, d):
    self.num = n
    self.denom = d
    .........
  def times(self, oth):
    top = self.num*oth.num
    bottom = self.denom*oth.denom
    return top/bottom
```

When we use this method, Python evaluates and returns this expression, which creates a float

```
class Fraction(object):
  def __init__(self, n, d):
    self.num = n
    self.denom = d
    .........
  def __mul__(self, other):
    top = self.num*other.num
    bottom = self.denom*other.denom
    return Fraction(top, bottom)
```

Note: we are creating and returning a new **instance of a Fraction**

LETS TRY IT OUT

```
a = Fraction(1,4)
b = Fraction(3,4)
print(a)                1/4
c = a * b
print(c)                3/16
```

Calls the __mul__method behind the scenes. This method returns Fraction(3,16)

Uses __str__ for a Fraction object

CLASSES CAN HIDE DETAILS

- These are all equivalent

```
print(a * b)
```

```
print(a.__mul__(b))
```

```
print(Fraction.__mul__(a, b))
```

Shorthand (nice and clear!)

Call to dunder method, bad style with dunder methods!

Explicit class call, passing in val for self, bad style in general!

- Every operation in Python comes back to a method call
- The first instance makes clear the operation, without worrying about the internal details! **Abstraction at work**

BIG IDEA

Special operations we've been using are just methods behind the scenes.

Things like:
print, len
+, *, -, /, <, >, <=, >=, ==, !=
[]
and many others!

CAN KEEP BOTH OPTIONS BY ADDING A METHOD TO CAST TO A `float`

```
class Fraction(object):
    def __init__(self, n, d):
        self.num = n
        self.denom = d
    .........
    def __float__(self):
        return self.num/self.denom
```

A float since it does the division directly

```
c = a * b
print(c)
print(float(c))
```

→ 3/16

→ 0.1875

Repr for Fraction(3,16)

LETS TRY IT OUT SOME MORE

```
a = Fraction(1,4)
b = Fraction(2,3)
c = a * b
print(c)
```

→ 2/12

- Not quite what we might expect? It's not reduced.
- Can we fix this?

ADD A METHOD

```
class Fraction(object):
   .........
   def reduce(self):
      def gcd(n, d):
         while d != 0:
            (d, n) = (n%d, d)
         return n
      if self.denom == 0:
         return None
      elif self.denom == 1:
         return self.num
      else:
         greatest_common_divisor = gcd(self.num, self.denom)
         top = int(self.num/greatest_common_divisor)
         bottom = int(self.denom/greatest_common_divisor)
         return Fraction(top, bottom)
```

Function to find the greatest common divisor

Call it inside the method

Still want a Fraction object back

```
c = a*b
print(c)
print(c.reduce())
```

→ 2/12

→ 1/6

WE HAVE SOME IMPROVEMENTS TO MAKE

```
class Fraction(object):
   ............
   def reduce(self):
      def gcd(n, d):
         while d != 0:
            (d, n) = (n%d, d)
         return n
      if self.denom == 0:
         return None
      elif self.denom == 1:
         return self.num
      else:
         greatest_common_divisor = gcd(self.num, self.denom)
         top = int(self.num/greatest_common_divisor)
         bottom = int(self.denom/greatest_common_divisor)
         return Fraction(top, bottom)
```

Is this a good idea?
It does not return a Fraction so
can no longer add or multiply
this by other Fractions

CHECK THE TYPES, THEY'RE DIFFERENT

```
a = Fraction(4,1)
b = Fraction(3,9)
ar = a.reduce()
br = b.reduce()
print(ar, type(ar))
print(br, type(br))
c = ar * br
```

ar = a.reduce() → 4

br = b.reduce() → 1/3

print(ar, type(ar)) → 4 <class 'int'>

print(br, type(br)) → 1/3 <class '__main__.Fraction'>

Error! It's trying to multiply an **int** with a **Fraction**.
We never defined how to do this – only a Fraction with another Fraction

YOU TRY IT!

- Modify the code to return a Fraction object when denominator is 1

```
class Fraction(object):
  def reduce(self):
    def gcd(n, d):
      while d != 0:
        (d, n) = (n%d, d)
      return n
    if self.denom == 0:
      return None
    elif self.denom == 1:
      return self.num
    else:
      greatest_common_divisor = gcd(self.num, self.denom)
      top = int(self.num/greatest_common_divisor)
      bottom = int(self.denom/greatest_common_divisor)
      return Fraction(top, bottom)

# Example:
f1 = Fraction(5,1)
print(f1.reduce())    # prints 5/1 not 5
```

WHY OOP and BUNDLING THE DATA IN THIS WAY?

- Code is **organized** and **modular**
- Code is easy to **maintain**
- It's easy to **build upon** objects to make more complex objects

- **Decomposition and abstraction** at work with Python classes
  - Bundling data and behaviors means you can use objects consistently
  - Dunder methods are abstracted by common operations, but they're just methods behind the scenes!