Lecture 18

Advanced Class Design

Announcements for This Lecture

This Week

- Assignment 4 due tonight
  - Consultants 4:30-9:30
  - TAs and I have office hours
  - Late penalty is -10pts/day
- Survey due by next class
  - Do as individuals!
  - Same format as before
- **Reading**: Chapter 18

Assignment 5

- Brand new assignment
  - We are still beta testing it
  - There will probably be bugs
  - Expect regular fixes/updates
  - But we will be lenient…
- Will be longer!
  - Start the assignment earlier
  - Finish Part I before prelim
- Will go online tomorrow

Converting Values to Strings

str() Function

- **Usage**: str(<expression>)
  - Evaluates the expression
  - Converts it into a string
- How does it convert?
  - str(1) → '1'
  - str(True) → 'True'
  - str('abc') → 'abc'
  - str(Point()) → '(0.0,0.0,0.0)'

Backquotes

- **Usage**: `<expression>`
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  - `1` → '1'
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  - `Point()` → "<class 'Point'> (0.0,0.0,0.0)"

Converting Values to Strings

str() Function

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  - str('abc') → 'abc
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What type is this value?

Backquotes

- **Us**
  -
  -
- Ho
  - \`1\` → '1'
  - \`True\`
  - \`'abc'\`
  - \`Point()\`

"<class 'Point'> (0.0,0.0,0.0)"

Backquotes are for *unambigious* representation

The value's type is clear

What Does str() Do On Objects?

- Does **NOT** display contents

  `>>> p = Point(1,2,3)`

  `>>> str(p)`

  `'<Point object at 0x1007a90>'`

- Must add a special method
  - `__str__` for str()
  - `__repr__` for backquotes
- Could get away with just one
  - Backquotes require `__repr__`
  - str() can use `__repr__` (if `__str__` is not there)

```
class Point(object):
    """Instances are points in 3d space"""
    …
    def __str__(self):
        """Returns: string with contents"""
        return '('+self.x + ',' +
                    self.y + ',' +
                    self.z + ')'

    def __repr__(self):
        """Returns: unambiguous string"""
        return str(self.__class__)+
                str(self)
```

What Does str() Do On Objects?

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```

Special Methods in Python

- Have seen three so far
  - __init__ for initializer
  - __str__ for str()
  - __repr__ for backquotes
- Start/end w/ two underscores
  - This is standard in Python
  - Used in all special methods
  - Also for special attributes
- For a complete list, see

  http://docs.python.org/reference/datamodel.html

```
class Point(object):
    """Instances are points in 3D space"""
    …

    def __init__(self,x=0,y=0,z=0):
        """Initializer: makes new Point"""
        …

    def __str__(self,q):
        """Returns: string with contents"""
        …

    def __repr__(self,q):
        """Returns: unambiguous string"""
        …
```

Challenge: Implementing Fractions

- Python has many built-in math types, but not all
  - Want to add a new type
  - Want to be able to add, multiply, divide etc.
  - Example: ½*¾ = ⅜
- Can do this with a class
  - Objects are fractions
  - Have built-in methods to implement +, *, /, etc…
  - **Operator overloading**

```
class Fraction(object):
    """Instance attributes:
        numerator:   top      [int]
        denominator: bottom [int > 0]"""

    def __init__(self,n=0,d=1):
        """Initializer: makes a Frac"""
        self.numerator = n
        self.denominator = d

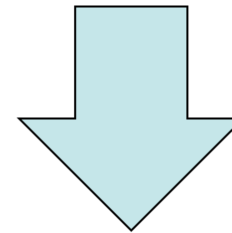
    def __str__(self):
        """Returns: Fraction as string"""
        return (str(self.numerator)
                +'/'+str(self.denominator))
```

Operator Overloading: Multiplication

```
class Fraction(object):
    """Instance attributes:
        numerator:    top        [int]
        denominator: bottom [int > 0]"""

    def __mul__(self,q):
        """Returns: Product of self, q
        Makes a new Fraction; does not
        modify contents of self or q
        Precondition: q a Fraction"""
        assert type(q) == Fraction
        top = self.numerator*q.numerator
        bot = self.denominator*q.denominator
        return Fraction(top,bot)
```

```
>>> p = Fraction(1,2)
>>> q = Fraction(3,4)
>>> r = p*q
```



Python converts to

```
>>> r = p.__mul__(q)
```

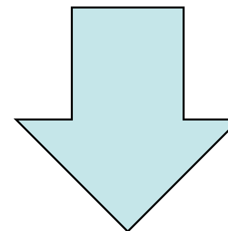
Operator overloading uses method in object on left.

Operator Overloading: Addition

```
class Fraction(object):
    """Instance attributes:
        numerator:   top      [int]
        denominator: bottom [int > 0]"""

    def __add__(self,q):
        """Returns: Sum of self, q
        Makes a new Fraction
        Precondition: q a Fraction"""
        assert type(q) == Fraction
        bot = self.denominator*q.denominator
        top = (self.numerator*q.denominator+
               self.denominator*q.numerator)
        return Fraction(top,bot)
```

```
>>> p = Fraction(1,2)
>>> q = Fraction(3,4)
>>> r = p+q
```



Python converts to

```
>>> r = p.__add__(q)
```

Operator overloading uses method in object on left.

Comparing Objects for Equality

- Earlier in course, we saw == compare object contents
  - This is not the default
  - **Default**: folder names
- Must implement `__eq__`
  - Operator overloading!
  - Not limited to simple attribute comparison
  - **Ex**: cross multiplying

$$\frac{1}{2} \quad \frac{2}{4}$$

4 4

```
class Fraction(object):
    """Instance attributes:
        numerator:   top       [int]
        denominator: bottom [int > 0]"""

    def __eq__(self,q):
        """Returns: True if self, q equal,
        False if not, or q not a Fraction"""
        if type(q) != Fraction:
            return False
        left = self.numerator*q.denominator
        rght = self.denominator*q.numerator
        return left == rght
```

Issues With Overloading ==

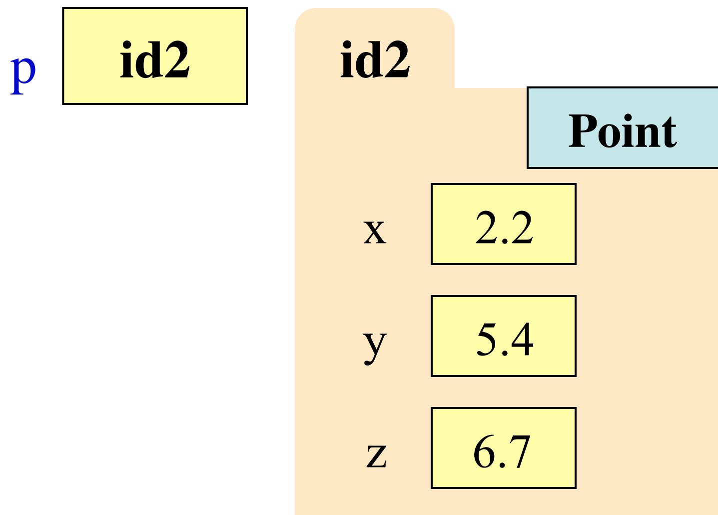
- Overloading == **does not** also overload comparison !=
  - Must implement `__ne__`
  - Why? Will see later
  - But (not x == y) is okay!
- What if you still want to compare Folder names?
  - Use is operator on variables
  - (x is y) True if x, y contain the same folder name
  - Check if variable is empty: `x is None` (x == None is bad)

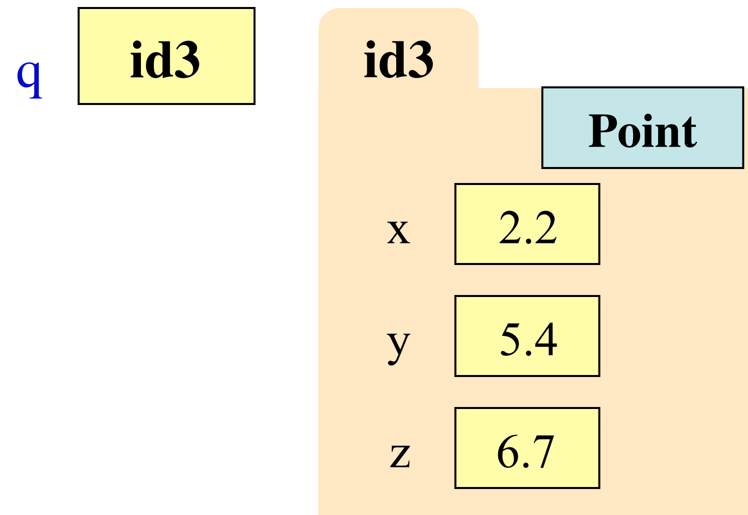
```
class Fraction(object):
    …
    def __eq__(self,q):
        """Returns: True if self, q equal,
        False if not, or q not a Fraction"""
        if type(q) != Fraction:
            return False
        left = self.numerator*q.denominator
        rght = self.denominator*q.numerator
        return left == rght

    def __ne__(self,q):
        """Returns: False if self, q equal,
        True if not, or q not a Fraction"""
        return not self == q
```

is Versus ==

- `p is q` evaluates to `False`
  - Compares folder names
  - Cannot change this
- `p == q` evaluates to `True`
  - But only because method `__eq__` compares contents





Always use `(x is None)` **not** `(x == None)`

Getting Information About a Class

- Recall the help() function shows module contents
  - Works on classes too
  - **Example**: help(Point)
- Can even use on object
  - In that case, runs help on the class of that object
  - Example: help(p)
- Shows all methods
  - And **class** attributes

```
class Fraction(__builtin__.object)
 | Instance is a fraction n/d
 | Instance Attributes:
 |     numerator:   top part    [int]
 |     denominator: bottom part [int > 0]
 |
 | Methods defined here:
 |
 | __add__(self, other)
 |     Returns: Sum of self and other as a
 |     new Fraction. Does not modify
 |     contents of self or other.
 |
 |    Precondition: other is a Fraction
…
```

Hiding Methods From Access

- Put underscore in front of a method will make it **hidden**
  - Will not show up in help()
  - But it is still there…
- Hidden methods
  - Can be used as **helpers** inside of the same class
  - But it is bad style to use them outside of this class
- Can do same for attributes
  - Underscore makes it hidden
  - Do not use outside of class

```
class Fraction(object):
    """Instance attributes:
        numerator:   top       [int]
        denominator: bottom [int > 0]"""

    def _is_denominator(self,d):
        """Return: True if d valid denom"""
        return type(d) == int and d > 0

    def __init__(self,n=0,d=1):
        assert self._is_denominator(d)
        self.numerator = n
        self.denominator = d
```

HIDDEN

Helper method

From Last Time: Data Encapsulation

```
class Time(object):
    """Instances represent times of day.
    Instance Attributes:
        _hour: hour of day [int in 0..23]
        _min: minute of hour [int in 0..59]"""

    def getMin(self):
        """Returns: min attribute"""
        return self._min

    def setMin(self, mins):
        """Alters min attribute to be mins
        Pre: mins is in 0..59"""
        assert type(mins) == int
        assert 0 <= mins and mins < 60
        self._min = mins
```

Do this for all of your attributes

Getter

Setter

Naming Convention

The underscore means "should not access the attribute directly."

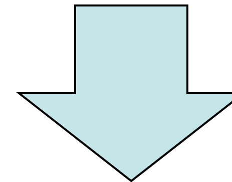
Precondition is same as attribute invariant.

Properties: Invisible Setters and Getters

```
class Fraction(object):
    """Instance attributes:
        _numerator:    [int]
        _denominator: [int > 0]"""
    @property
    def numerator(self):
        """Numerator value of Fraction
        Invariant: must be an int"""
        return self._numerator

    @numerator.setter
    def numerator(self,value):
        assert type(value) == int
        self._numerator = value
```

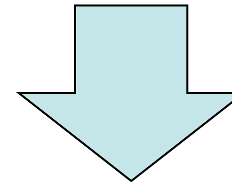
```
>>> p = Fraction(1,2)
>>> x = p.numerator
```



Python converts to

```
>>> x = p.numerator()
```

```
>>> p.numerator = 2
```



Python converts to

```
>>> p.numerator(2)
```

Properties: Invisible Setters and Getters

```
class Fraction(object):
    """Instance attributes:
        _numerator:    [int]
        _denominator: [int > 0]"""
    @property
    def numerator(self):
        """Numerator value of Fraction
        Invariant: must be an int"""
        return self._numerator
    @numerator.setter
    def numerator(self,value):
        assert type(value) == int
        self._numerator = value
```

Specifies that next method is the **getter** for property of the same name as the method

Docstring describing property

Property uses **hidden** attribute.

Specifies that next method is the **setter** for property whose name is numerator.

Properties: Invisible Setters and Getters

```
class Fraction(object):
    """Instance attributes:
        _numerator:    [int]
        _denominator: [int > 0]"""
    @property
    def numerator(self):
        """Numerator value of Fraction
        Invariant: must be an int"""
        return self._numerator

    @numerator.setter
    def numerator(self,value):
        assert type(value) == int
        self._numerator = value
```

Goal: Data Encapsulation
Protecting your data from other, "clumsy" users.

Only the **getter** is required!

If no **setter**, then the attribute is "immutable".

Replace **Attributes** w/ **Properties**
(Users cannot tell difference)

Structure of a Proper Python Class

```
class Fraction(object):
    """Instances represent a Fraction
      Attributes:
         _numerator: [int]
        _denominator: [int > 0]"""
    @property
    def numerator(self):
        """Numerator value of Fraction"""
    ...
    def __init__(self,n=0,d=1):
        """Initializer: makes a Fraction"""
     ...
    def __add__(self,q):
        """Returns: Sum of self, q"""
    ...
    def normalize(self):
        """Puts Fraction in reduced form"""
    ...
```

Docstring describing class
Attributes are all **hidden**

Properties for *each* attribute.
Put invariants in **getter**.

Initializer for the class.
Defaults for parameters.

Python operator overloading

Normal method definitions

Summary + Files

- Methods with double underscores are special
  - Used to implement **operators** (e.g. +, ==, <)
  - Great for implementing mathematical objects
  - **Example**: `fraction.py`
- Attributes cannot enforce invariants
  - Want to wrap them in getters, setters
  - Setters use asserts to enforce invariants
  - **Example**: `betterfraction.py`
- **Properties** provide invisible getters, setters
  - Make attributes hidden, and use properties instead
  - **Example**: `bestfraction.py`