20. More Complicated Classes

Topics:
- Example: The class **Fraction**
- Operator Overloading
- Class Invariants
- Example: The class **SimpleDate**
- Class Variables
- **deepcopy**

A Class For Manipulating Fractions

You in Grade School:

```
2/3 + 13/6 = (2*6+13*3)/(3*6)
           = 51/18
           = 17/6
```

Python in College:

```
>>> x = Fraction(2,3)
>>> y = Fraction(13,6)
>>> z = x+y
>>> print z
17/6
```

A Class For Manipulating Fractions

You in Grade School:

```
2/3 * 3/4 = (2*3)/(3*4)
          = 6/12
          = 1/2
```

Python in College:

```
>>> x = Fraction(2,3)
>>> y = Fraction(3,4)
>>> z = x+y
>>> print z
1/2
```

Let's Define a Class to Do This Stuff

```
class Fraction(object):
    """
    Attributes:
        num: the numerator [int]
        den: the denominator [int]
    """
```

Not good enough. Do not want zero denominators!

Let's Define a Class to Do This Stuff

```
class Fraction(object):
    """
    Attributes:
        num: the numerator [int]
        den: the denominator [nonzero int]
    """
```

Still not good enough. Fractions should be reduced to lowest terms, e.g., -3/2 not -24/16

A Note About Greatest Common Divisors

p	q	gcd(p,q)	p/q
16	24	8	2/3
19	47	1	19/47
15	25	5	3/5

Reducing a fraction to lowest terms involves finding the gcd of the numerator and denominator and dividing.

Computing the Greatest Common Divisor

```
def gcd(a,b):
      a = abs(a)
      b = abs(b)
      r = a%b
      while r>0:
            a = b
            b = r
            r = a%b
      return b
```

Euclid's Algorithm

300BC

We will assume this is given and won't worry why it works

Back to the Class Definition

```
class Fraction(object):
    """
    Attributes:
         num: the numerator [int]
         den: the denominator [nonzero int]
         num/den is reduced to lowest terms
    """
```

These "rules" define a class invariant. Properties that all **Fraction** objects obey.

The Constructor

```
def __init__(self,p,q=1):
      d = gcd(p,q)
      self.num = p/d
      self.den = q/d
```

```
>>> x = Fraction(10,4)
>>> print x
5/2
```

```
>>> x = Fraction(10)
>>> print x
10/1
```

Whole numbers are fractions too. Handy to use the optional argument feature.

Let's Look at the Methods Defined in the Class **Fraction**

Informal synopsis:

	in	out
negate	2/3	-2/3
Invert	2/3	3/2
__add__	2/3 + 1/6	5/6
__mul__	2/3 * 1/6	1/9

The double underscore methods make a nice notation possible. Instead of `f1.add(f2)` we can just write `f1+f2`.

The **negate** Method

```
def negate(self):
    """ Returns the negative of self
    """
    F = Fraction(-self.num,self.den)
    return P
```

```
>>> x = Fraction(6,-5)
>>> print x
-6/5
>>> y = x.negate()
>>> print y
6/5
```

The **invert** Method

```
def invert(self):
    """ Returns the reciprocal of self
    PreC: self is not zero
    """
    F = Fraction(self.den,self.num)
    return F
```

```
>>> x = Fraction(100,95)
>>> print x
20/19
>>> y = x.invert()
>>> print y
19/20
```

Consider Addition

```
s = 'dogs' + 'and' + 'cats'

x = 100 + 200 + 300

y = 1.2 + 3.4 + 5.6
```

What "+" signals depends on the operands.
Python figures it out.
We say that the "+" operation is overloaded.

Let's Define "+" For Fractions

```
def __add__(self,f):
    N = self.num*f.den + self.den*f.num
    D = self.den*f.den
    return Fraction(N,D)
```

```
>>> A = Fraction(2,3)
>>> B = Fraction(1,4)
>>> C = A + B
>>> print C
11/12
```

By defining __add__ this way we can say A+B instead of A.__add__(B)

Underlying math: a/b + c/d = (ad+bc)/bd

Likewise for Multiplication

```
def __mul__(self,f):
    N = self.num*f.num
    D = self.den*f.den
    return Fraction(N,D)
```

```
>>> A = Fraction(2,3)
>>> B = Fraction(1,4)
>>> C = A*B
>>> print C
1/6
```

By defining __mul__ this way we can say A*B instead of A.__mul__(B)

Would Like Some Flexibility

Sometimes we would like to add an integer to a fraction:

2/3 + 5 = 17/3

To make this happen Python needs to know the type of the operands, i.e., "who is to the right of the "+" and who is to the left of the "+"?

Using the Built-In Boolean-Valued Function `isinstance`

```
>>> x = 3/2
>>> isinstance(x,Fraction)
False
>>> y = Fraction(3,2)
>>> isinstance(y,Fraction)
True
```

Feed **isinstance** it the "mystery" object and a class and it will tell you if the object is an instance of the class.

A More Flexible `__add__`

```
def __add__(self,f):
  if isinstance(f,Fraction):
    N = self.num*f.den + self.den*f.num
    D = self.den*f.den
  else:
    N = self.num + self.den*f
    D = self.den
  return Fraction(N,D)
```

If f is a Fraction, use (a/b + c/d) = (ad+bc)/(bd)

A More Flexible __add__

```
def __add__(self,f):
  if isinstance(f,Fraction):
    N = self.num*f.den + self.den*f.num
    D = self.den*f.den
  else:
    N = self.num + self.den*f
    D = self.den
  return Fraction(N,D)
```

If f is an integer, use (a/b + f) = (a+bf)/b

A More Flexible __mul__

```
def __mul__(self,f):
   if isinstance(f,Fraction):
       N = self.num*f.num
       D = self.den*f.den
   else:
       N = self.num*f
       D = self.den
   return Fraction(N,D)
```

If f is a Fraction, use (a/b)(c/d) = (ac)/(bd)

A More Flexible __mul__

```
def __mul__(self,f):
   if isinstance(f,Fraction):
       N = self.num*f.num
       D = self.den*f.den
   else:
       N = self.num*f
       D = self.den
   return Fraction(N,D)
```

If f is an int, use (a/b)(f) = (af)/b

Be Careful!

```
>>> F = Fraction(2,3)
>>> G = F + 1
>>> print G
5/3
>>> H = 1 + F
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s)
for +: 'int' and 'instance'
```

When you add an int to a Fraction, the int must be on the right side of the +

An Example

Let's compute 1 + 1/2 + 1/3 + ... + 1/15

```
n = 15
s = Fraction(0)
for k in range(1,n+1):
    s = s + Fraction(1,k)
print s
```

This "+" invokes __add__.

```
1195757/360360
```

Next, a Class that Supports Computations with Dates

If Today is July 4, 1776, then What is Tomorrow's Date?

```
>>> D = SimpleDate('7/4/1776')
>>> print D
July 4, 1776
>>> E = D.Tomorrow()
>>> print E
July 5, 1776
```

The Check is in the Mail and will Arrive in 1000 Days

```
>>> D = SimpleDate('1/1/2016')
>>> A = D+1000
>>> print A
September 27, 2018
```

How Many Days from Pearl Harbor to 9/11?

```
>>> D1 = SimpleDate('9/11/2001')
>>> D2 = SimpleDate('12/7/1941')
>>> NumDays = D1-D2
>>> print NumDays
21828
```

Class Variables

To pull this off, it will be handy to have a "class variable" that houses information that figures in date-related computations…

```
nDays =[0,31,28,31,30,31,30,31,31,30,31,30,31]
```

The Attributes

```
class SimpleDate(object):
   """
   Attributes:
         m: index of month [int]
         d: the day [int]
         y: the year [int]
         m, d, and y identify a
         valid date.
   """
```

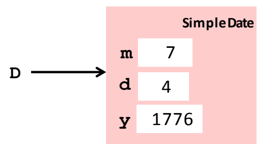
The Leap Year Problem

An integer y is a leap year if it is not a century year and is divisible by 4 or if is a century year and is divisible by 400.

```
def isLeapYear(self):
    """ Returns True if and only if
     self encodes a date that part of
     a leap year.
    """
    thisWay = ((y%100>0) and y%4==0)
    thatWay = ((y%100==0) and (y%400==0))
    return thisWay or thatWay
```

Visualizing a `SimpleDate` Object

```
>>> D = SimpleDate('7/4/1776')
```



The `SimpleDate` Constructor

```
def __init__(self,s):
    """ Returns a reference to a SimpleDate
    representation of the date encoded in s.

    PreC: s is a date string of the form
    'M/D/Y' where M, D and Y encode the month
    index, the day, and the year.
    """
    v = s.split('/')
    m = int(v[0]),d = int(v[1]),y = int(v[2])
    self.m = m, self.d = d, self.y  = y
```

If s = '7/4/1776' then v = ['7','4','1776']

The `SimpleDate` Constructor

Note that

`D = SimpleDate('7/32/1776')`

and

`D = SimpleDate('2/29/2015')`

produce `SimpleDate` objects that encode invalid dates.

The `SimpleDate` Constructor

```
def __init__(self,s):
    """ Returns a reference to a SimpleDate
    representation of the date encoded in s.

    PreC: s is a date string of the form
    'M/D/Y' where M, D and Y encode the month
    index, the day, and the year.
    """
    v = s.split('/')
    m = int(v[0]);d = int(v[1]);y = int(v[2])
    self.m = m; self.d = d; self.y  = y
```

A good place to guard against "bad" input using `assert`.

Use Class Variable `nDays`

```
nDays =[0,31,28,31,30,31,30,31,31,30,31,30,31]
```

```
v = s.split('/')
m = int(v[0]);d = int(v[1]);y = int(v[2])
assert 1<=m<=12, 'Invalid Month'
assert 1<=d<=self.nDays[m], 'Invalid  Day'
```

Needs more work. Does not handle leap year situations.
Nothing wrong with `SimpleDate('2/29/2016')`

Some `SimpleDate` Methods

Informally…

`Tomorrow`	the next day's date
`__eq__`	when are two dates the same?
`__add__`	'7/4/1776' + 364 is '7/3/1777'
`__sub__`	'3/2/2016' - '2/28/2016' is 3

Visualizing the Overall Class

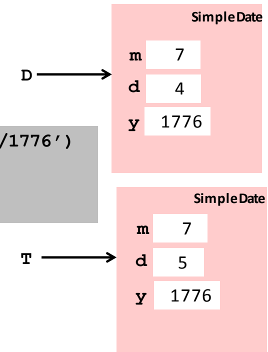
```
class SimpleDate(object):
    nDays = [ blah ]
    def __init__(self,s):
    def __str__(self):
    def __eq__(self,other):
    def __add__(self,other)
    def __sub__(self,other):
    def Tomorrow(self):
    def isLeapYear(self):
```

Class Variables

Constructor

Methods

The Method **Tomorrow**




```
>>> D = SimpleDate('7/4/1776')
>>> T = D.Tomorrow()
>>> print T
July 5, 1776
```

Pretty printing via __str__

The Method **Tomorrow**

Need a bunch of if constructions to handle end-of-month and end-of-year situations with possible leap year issues:

```
'7/4/1776'   --->  '7/5/1776'
'2/28/1776'  --->  '2/29/1776'
'2/28/1777'  --->  '3/1/1777'
'7/31/1776'  --->  '8/1/1776'
'12/31/1776' --->  '1/1/1777'
```

The __eq__ Method

```
def __eq__(self,other):
  """ Returns True if and only if other
    encodes the same date as self
  """
   B1 = self.m == other.m
   B2 = self.d == other.d
   B3 = self.y == other.y
   return B1 and B2 and B3
```

```
>>> D1 = SimpleDate('7/4/1776')
>>> D2 = SimpleDate('4/1/1066')
>>> D1==D2
False
```

The __add__ Method

```
def __add__(self,n):
   """ Returns a date that is n days
   later than self.
   PreC: n is a nonegative integer.
   """
   Day = self
   for k in range(n):
       Day = Day.Tomorrow()
   return Day
```

```
>>> D = SimpleDate('1/1/2016')
>>> E = D + 365
>>> print E
December 31, 2016
```

The __sub__ Method

```
def __sub__(self,other):
   """ D2-D1 returns the number of days from
    D1 to D2. D2 must be the later date.
   """
   k = 0
   Day = other
   while not (Day==self):
       k+=1
       Day = Day.Tomorrow()
   return k
```

```
>>> D1 = SimpleDate('9/11/2001')
>>> D2 = SimpleDate('12/7/1941')
>>> D1-D2
21828
```

Referencing a Class Variable

```
def Tomorrow(self):
   m = self.m
   d = self.d
   y = self.y
   Last = self.nDays[m]
   if isLeapYear(y) and m==2:
        Last+=1
             :
```

`nDays =[0,31,28,31,30,31,30,31,31,30,31,30,31]`

More on Copying Objects

A subtle issue is involved if you try to copy objects that have attributes that are objects themselves.

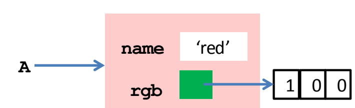
More on Copying Objects

To illustrate consider this class

```
class MyColor:
    """
    Attributes:
        rgb: length-3 float list
        name: str
    """
    def __init__(self,rgb,name):
        self.rgb = rgb
        self.name = name
```

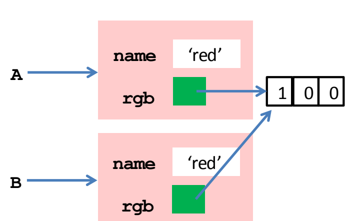
More on Copying Objects

```
>>> A = MyColor([1,0,0],'red')
```



More on Copying Objects

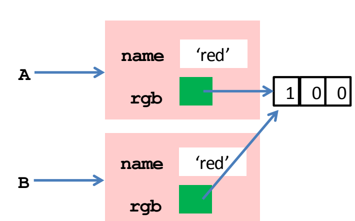
```
>>> B = copy(A)
```



More on Copying Objects

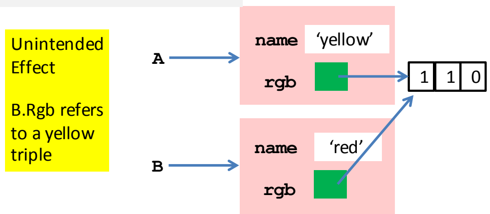
```
>>> B = copy(A)
```

Now let's make a yellow



More on Copying Objects

```
>>> A.rgb[1]=1
>>> A.name = 'yellow'
```



More on Copying Objects

```
>>> B = deepcopy(A)
```