21. Designing & Using Classes

Topics:
- Methods
- getters and setters
- class invariants
- More on assert and isinstance
- Sorting w.r.t. an Attribute
- Class Variables

Methods

Methods are functions that are defined inside a class definition.

We have experience using them with strings

```
s.upper(),s.find(s1),s.count(s2),
s.append(s2), s.split(c), etc
```

and lists

```
L.append(x),L.extend(x),L.sort(),etc
```

Methods

Now we show how to implement them.

We will revisit the `Point` class that we used earlier, and define methods for computing distance and midpoints.

Anticipate this:

```
delta = P.Dist(Q)
C = A.Midpoint(B)
```

The dot notation syntax for method calls

The Point Class

```
class Point:
    """
    Attributes:
        x: float, the x-coordinate of a point
        y: float, the y-coordinate of a point
        d: float, distance to origin
    """
    def __init__(self,x,y):
        self.x = x
        self.y = y
        self.d = sqrt(x**2+y**2)
```

The constructor

Assume proper importing from math class

A Simple Method: `Dist`

```
class Point:
    def __init__(self,x,y):
        self.x = x
        self.y = y
        self.d = sqrt(x**2+y**2)

    def Dist(self,other):
        """ Returns the distance from
        self to P
        PreC: other is a point
        """
        dx = self.x - other.x
        dy = self.y - other.y
        return sqrt(dx**2+dy**2)
```

Using the `Dist` Method

Let's create two point objects and compute the distance between them. This can be done two ways…

```
>>> P = Point(3,4)
>>> Q = Point(6,8)
>>> deltaPQ = P.Dist(Q)
>>> deltaQP = Q.Dist(P)
>>> print deltaPQ,deltaQP
5.0 5.0
```

The usual "dot" notation for invoking a method

A Simple Method: Midpoint

```
class Point:
    def __init__(self,x,y):
        self.x = x
        self.y = y
        self.d = sqrt(x**2+y**2)
    def Midpoint(self,0ther) :
        """ Returns the midpoint of the
        line segment that connects self
        to other
        PreC: other is a point
        """
        xm = (self.x + other.x)/2.0
        ym = (self.y + other.y)/2.0
        return Point(xm,ym)
```

A class method can call the class constructor

Using the `Midpoint` Method

Let's create two point objects and compute the midpoint. This can be done two ways…

```
>>> P = Point(1,2)
>>> Q = Point(3,4)
>>> MPQ = P.Midpoint(Q)
>>> MQP = Q.Midpoint(P)
>>> print MPQ
( 2.000, 3.000)      distance =   3.606
>>> print MQP
( 2.000, 3.000)      distance =   3.606
```

Recall: `__str__(self)`

```
def __str__(self):
    s = '(%6.3f,%6.3f)   distance = %6.3f'
                 %(self.x,self.y,self.d)
```

With this method in place, we have a handy way of "printing out" an object:

```
>>> P = Point(3,4)
>>> print P
( 3.000, 4.000)      distance =   5.000
```

Method Implementation: Syntax Concerns

```
class Point:
          :
    def Dist(self,other):
        """ Returns the distance from
        self to other
        PreC: other is a point
        """
        dx = self.x - other.x
        dy = self.y - other.y
        return sqrt(dx**2+dy**2)
```

Note indentation.
A class method is part of the class definition.

Method Implementation: Syntax Concerns

```
class Point:
          :
    def Dist(self,other):
        """ Returns the distance from
        self to P
        PreC: P is a point
        """
        dx = self.x - other.x
        dy = self.y - other.y
        return sqrt(dx**2+dy**2)
```

Note the use of "self".
It is always the first argument of a method.

Method Implementation: Syntax Concerns

```
class Point:
          :
    def Dist(self,other):
        """ Returns the distance from
        self to P
        PreC: P is a point
        """
        dx = self.x - other.x
        dy = self.y - other.y
        return sqrt(dx**2+dy**2)
```

Think like this: "We are going to apply the method `dist` to a pair of Point objects, `self` and `other`."

Methods and (Regular) Functions

```
def Dist(self,other):
  dx = self.x - other.x
  dy = self.y - other.y
  D = sqrt(dx**2+dy**2)
  return D
```

```
>>> P = Point(3,4)
>>> Q = Point(6,8)
>>> P.Dist(Q)
5.0
```

```
def Dist(P,Q):
  dx = P.x - Q.x
  dy = P.y - Q.y
  D = sqrt(dx**2+dy**2)
  return D
```

```
>>> P = Point(3,4)
>>> Q = Point(6,8)
>>> Dist(Q,P)
5.0
```

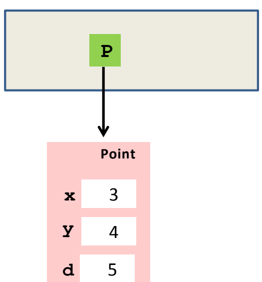
Visualizing a Method Call Using State Diagrams

Let's see what happens when we execute the following:

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

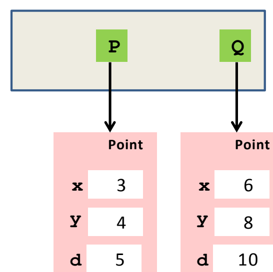
Visualizing a Method Call

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```



Visualizing a Method Call

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

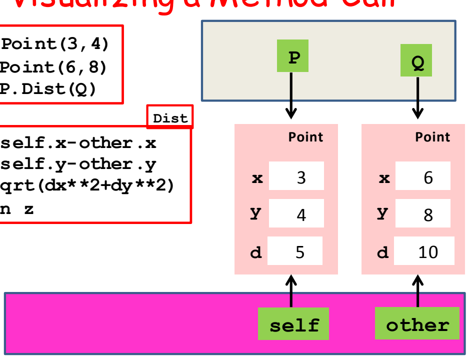


Visualizing a Method Call

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

Dist

```
dx = self.x-other.x
dy = self.y-other.y
z = sqrt(dx**2+dy**2)
return z
```



Method: `Dist`

```
class Point:
      :
    def Dist(self,other):
        """ Returns the distance from
        self to P
        PreC: other is a point
        """
        dx = self.x - other.x
        dy = self.y - other.y
        return sqrt(dx**2+dy**2)
```

Think of self and other as input parameters

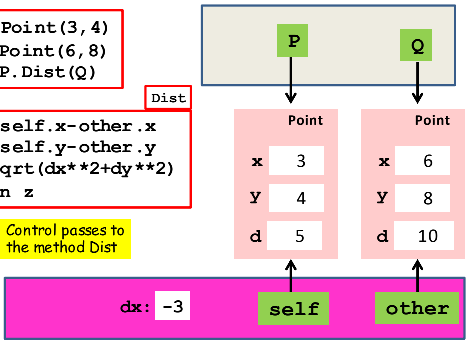
Visualizing a Method Call

```
  P = Point(3,4)
  Q = Point(6,8)
● D = P.Dist(Q)
```

Dist

```
● dx = self.x-other.x
  dy = self.y-other.y
  z = sqrt(dx**2+dy**2)
  return z
```

Control passes to the method Dist

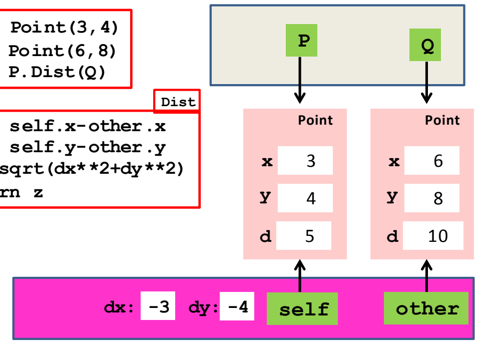


Visualizing a Method Call

```
  P = Point(3,4)
  Q = Point(6,8)
● D = P.Dist(Q)
```

Dist

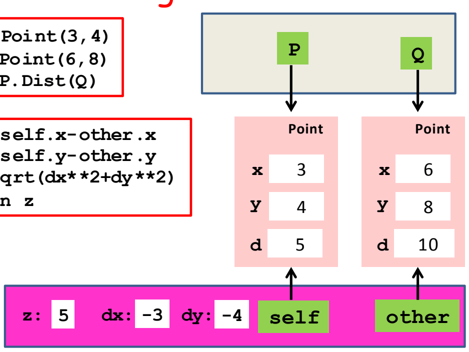
```
  dx = self.x-other.x
● dy = self.y-other.y
  z = sqrt(dx**2+dy**2)
  return z
```



Visualizing a Method Call

```
  P = Point(3,4)
  Q = Point(6,8)
● D = P.Dist(Q)
```

```
  dx = self.x-other.x
  dy = self.y-other.y
● z = sqrt(dx**2+dy**2)
  return z
```

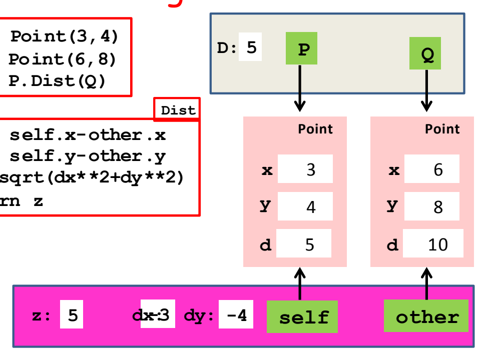


Visualizing a Method Call

```
  P = Point(3,4)
  Q = Point(6,8)
● D = P.Dist(Q)
```

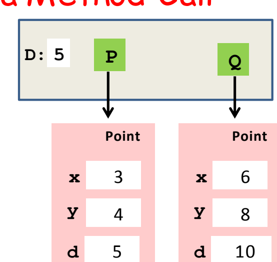
Dist

```
  dx = self.x-other.x
  dy = self.y-other.y
  z = sqrt(dx**2+dy**2)
● return z
```



Visualizing a Method Call

```
  P = Point(3,4)
  Q = Point(6,8)
● D = P.Dist(Q)
```



Let's Turn Our Attention to Some Software Engineering Issues that Relate to Classes

Motivation

This becomes increasingly important as the problems get bigger and multiple software developers are on the scene.

At the CS 1110 level, we begin to practice these habits and motivate their relevance.

Setter and Getter Methods

Motivation:

Changing the attributes of an object by "freely'' using the dot-notation is dangerous and short sighted.

```
>>> P = Point(3,4)
>>> P.x = 0
>>> print P
( 0.000, 4.000)       distance =    5.000
```

The "class invatiant" that sqrt(P.x**2 + P.y**2) == P.d is broken

Getter Methods

Access attributes through getter methods.

```
def get_x(self):
    return self.x

def get_y(self):
    return self.y

def get_d(self):
    return self.d
```

```
>>> P = Point(3,4)
>>> a = P.get_x()
>>> b = P.get_y()
>>> c = P.get_d()
>>> print a,b,c
3.0 4.0 5.0
```

Typically name these simple methods in this style.

Getter Methods—Why?

Access attributes through getter methods.

```
def get_x(self):
    return self.x

def get_y(self):
    return self.y

def get_d(self):
    return self.d
```

```
>>> P = Point(3,4)
>>> a = P.get_x()
>>> b = P.get_y()
>>> c = P.get_d()
>>> print a,b,c
3.0 4.0 5.0
```

You don't want the user to "see" and work with attributes.

Setter Methods

```
def set_x(self,x):
    self.x = x
    self.d = sqrt(self.x**2+self.y**2)

def set_y(self,y):
    self.y = y
    self.d = sqrt(self.x**2+self.y**2)
```

```
>>> P = Point(3,4)
>>> P.set_x(0)
>>> print P
( 0.000, 4.000)       distance =    4.000
```

Setter Methods—Why?

Good:

```
>>> P = Point(3,4)
>>> P.set_x(0)
>>> print P
( 0.000, 4.000)       distance =    4.000
```

Automatically maintains the required connection among the x, y, and d attributes

Bad:

```
>>> P = Point(3,4)
>>> P.x = 0
>>> P.d = sqrt(P.x**2+P.y**2)
>>> print P
( 0.000, 4.000)       distance =    4.000
```

Requires programmer attentiveness. Don't forget to update P.d

Setter Methods Justification- A Tale of Two Software Engineers

Bob and Sue each develop a Point class with this constructor:

```
def __init__(self,x,y):
    self.x = x
    self.y = y
    self.d = sqrt(x**2+y**2)
```

Sue uses setter methods. Bob does not.

Setter Methods Justification- A Tale of Two Software Engineers

Bob is very successful. Tons of python code is written that uses his stuff. Millions of references like this are out there:

```
P.x = blahblah
P.d = sqrt(P.x**2+P.y**2)
```

But then…

Setter Methods Justification- A Tale of Two Software Engineers

One day Bob's boss says "we have a new definition of distance. Instead of

`sqrt(x**2+y**2)`

we now have to use

`abs(x)  + abs(y)`

Bob must direct customers to change those millions of P.d updates to reflect the new definition of distance.

Setter Methods Justification- A Tale of Two Software Engineers

One the other hand, to maintain Sue's software, the customers just have change one line of code in the constructor:

```
def __init__(self,x,y):
    self.x = x
    self.y = y
    self.d = abs(x)+abs(y)
```

Sue's Setter Is Modified

Before…

```
def set_x(self,x):
    self.x = x
    self.d = sqrt(self.x**2+self.y**2)

def set_y(self,y):
    self.y = y
    self.d = sqrt(self.x**2+self.y**2)
```

Sue's Setter Is Modified

After…

```
def set_x(self,x):
    self.x = x
    self.d = abs(self.x)+abs(self.y)

def set_y(self,y):
    self.y = y
    self.d = abs(self.x)+abs(self.y
```

Moral:

Bob is moved to an interior cubical
with no window!

Reminder about `assert` and `isinstance`

Using Assert in the Class Setting

```
def __init__(self,x,y):

   Bx = type(x)==float or type(x)==int
   assert Bx, 'x must be a number'

   By = type(y)==float or type(y)==int
   assert By,'y must be a number'

   self.x = x
   self.y = y
   self.d = sqrt(x**2+y**2)
```

The usual check-the-preconditions business

Using `isinstance` in a Class Setting

```
def Midpoint(self,P):
   B = isinstance(P,Point)
   assert B,'P must be a Point'

   xm = (self.x+P.x)/2.0
   ym = (self.y+P.y)/2.0
   return Point(xm,ym)
```

The function isinstance can be use to check for user-defined types

Sorting Lists of Objects

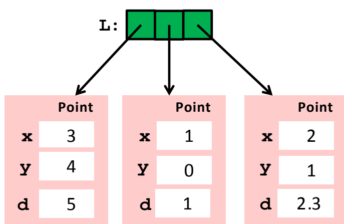
A Sorting Problem

Suppose we have a list of Points, i.e., a list of references to Point objects.

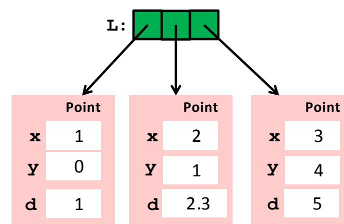
Let's sort the list based on distance from origin.

It involves writing a getter function.

Before



After



How to Do It

Write a "getter" function that takes a point and returns the value of its d attribute:

```
def getD(P):
      return P.d
```

Now use the sort method as follows

```
L.sort(key = getD)
```

This will permute the references in L so that they refer to point objects in the required order, i.e., in order of distance from origin.

A New Example to Illustrate the Notion of a Class Variable

Class Variables

Class variables are shared among all instances of the class.

We illustrate with an example.

Then we will formally distinguish between class variables and instance variables

The Class `SimpleDate`

We define a class that can be used to carry out certain computations with dates. For example:

1. Cornell was founded on 4/27/1865. Today is 4/14/2015. How many days has Cornell been around?

2. What's the date 1000 days from now?

Before We Begin

1. A "date string" looks like this: '4/14/2015'.

2. Assume the availability of

```
def isLeapYear(y):
    """ Returns True if y is a leap year.
    Otherwise returns False
    """
```

y is not a century year and is divisible by 4
or
y is a century year and is divisible by 400.

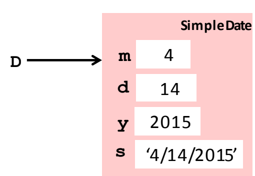
Four Attributes

```
m: int, index of month
d: int, the day
y: int, the year
s: str, a date string
```

Creating a SimpleDate Object:

```
D = SimpleDate('4/14/2015')
```

Visualizing a SimpleDate

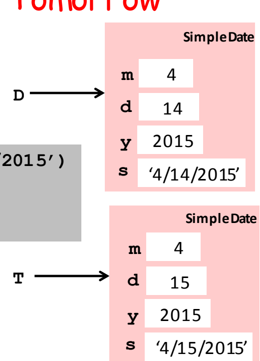



```
>>> D = SimpleDate('4/14/2015')
```

Methods in SimpleDate

```
__str__(self)
    pretty prints the date encoded
    in self
Tomorrow(self)
    returns a SimpleDate object that
    encodes the day after self
dateIndex(self)
    returns number of days from 1/1/1600
    to the date encoded in self
FutureDate(self,n)
    returns the SimpleDate encoding of
    the date that is n days after self
```

The Method Tomorrow




```
>>> D = SimpleDate('4/14/2015')
>>> T = D.Tomorrow()
>>> print T
April 15, 2014
```

Pretty printing via __str__

Useful Class Variables

These variables house handy data:

```
TheMonths =['','January','February','March',
            'April','May','June','July',
            'August','September','October',
            'November','December']

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

Methods can access this data via self and the dot notation, e.g.,

`self.TheMonths[self.m]`

Visualizing the Overall Class

```
class SimpleDate:

    TheMonths =  blah
    nDays =  blah
      def blah blah

      def blah blah

      def blah blah
```

Class Variables

Methods

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]
```

Creating and Printing a SimpleDate Object

```
>>> Today = SimpleDate('4/14/2015')
>>> print Today
April 14, 2015
>>> T = Today.Tomorrow()
>>> print T
April 15, 2015
```

The `isequal` Method

```
def isequal(self,other):
    B1 = self.m == other.m
    B2 = self.d == other.d
    B3 = self.y == other.y
    return B1 and B2 and B3
```

Can be used to check if two `SimpleDate` objects represent the same date.

Method `dateIndex`

```
def dateIndex(self):
    idx = 1
    Day = SimpleDate('1/1/1600')
    while not Day.isequal(self):
       idx+=1
       Day = Day.Tomorrow()
    return idx
```

1 = Jan 1 ,1600. Count forward from this baseline

How Old is Cornell in Days?

```
>>> Today = SimpleDate('4/14/2015')
>>> nToday = Today.dateIndex()
>>> Founding = SimpleDate('4/27/1865')
>>> nFounding = Founding.dateIndex()
>>> CornellDays = nToday-nFounding
>>> print CornellDays
54773
```