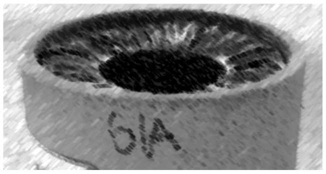

CS61A Lecture 22

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Announcements

- HW7 due tonight
- Ants project due Monday
- HW8 due next Wednesday at 7pm
- Midterm 2 next Thursday at 7pm

Interfaces

Message passing allows **different data types** to respond to the **same message**.

A shared message that elicits similar behavior from different object classes is a powerful method of abstraction.

An *interface* is a **set of shared messages**, along with a specification of **what they mean**.

In languages like Python and Ruby, interfaces are implicitly implemented by providing the right methods with the correct behavior

- *If it quacks like a duck…*

Other languages require interfaces to be explicitly implemented

Example: Rational Numbers

```
class Rational(object):
    def __init__(self, numer, denom):
        g = gcd(numer, denom)
        self.numerator = numer // g
        self.denominator = denom // g
    def __repr__(self):
        return 'Rational({0}, {1})'.format(self.numerator,
                                           self.denominator)
    def __str__(self):
        return '{0}/{1}'.format(self.numerator,
                                self.denominator)
    def __add__(self, num):
        return add_rational(self, num)
    def __mul__(self, num):
        return mul_rational(self, num)
    def __eq__(self, num):
        return eq_rational(self, num)
```

Property Methods

Often, we want the value of instance attributes to be linked.

```
>>> f = Rational(3, 5)
>>> f.float_value
0.6
>>> f.numerator = 4
>>> f.float_value
0.8
>>> f.denominator -= 3
>>> f.float_value
2.0
```

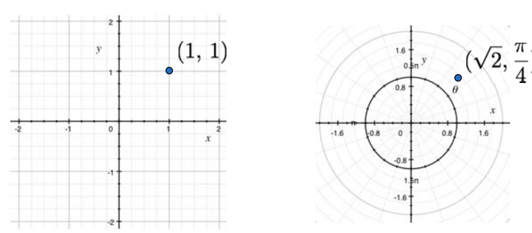
```
@property
def float_value(self):
    return (self.numerator //
            self.denominator)
```

The `@property` decorator on a method designates that it will be called whenever it is *looked up* on an instance.

It allows zero-argument methods to be called without an explicit call expression.

Multiple Representations of Abstract Data

Rectangular and polar representations for complex numbers



Most operations don't care about the representation.

Some mathematical operations are easier on one than the other.

Arithmetic Abstraction Barriers

Complex numbers as whole data values

`add_complex` `mul_complex`

Complex numbers as two-dimensional vectors

`real` `imag` `magnitude` `angle`

Rectangular representation | *Polar representation*

An Interface for Complex Numbers

All complex numbers should have real and imag components.

All complex numbers should have a magnitude and angle.

Using this interface, we can implement complex arithmetic:

```
def add_complex(z1, z2):
    return ComplexRI(z1.real + z2.real,
                     z1.imag + z2.imag)

def mul_complex(z1, z2):
    return ComplexMA(z1.magnitude * z2.magnitude,
                     z1.angle + z2.angle)
```

The Rectangular Representation

```
class ComplexRI(object):

    def __init__(self, real, imag):
        self.real = real
        self.imag = imag

    @property
    def magnitude(self):
        return (self.real ** 2 + self.imag ** 2) ** 0.5

    @property
    def angle(self):
        return atan2(self.imag, self.real)

    def __repr__(self):
        return 'ComplexRI({0}, {1})'.format(self.real,
                                            self.imag)
```

Property decorator: "Call this function on attribute look-up"

`math.atan2(y,x)`: Angle between x-axis and the point (x,y)

The Polar Representation

```
class ComplexMA(object):

    def __init__(self, magnitude, angle):
        self.magnitude = magnitude
        self.angle = angle

    @property
    def real(self):
        return self.magnitude * cos(self.angle)

    @property
    def imag(self):
        return self.magnitude * sin(self.angle)

    def __repr__(self):
        return 'ComplexMA({0}, {1})'.format(self.magnitude,
                                            self.angle)
```

Using Complex Numbers

Either type of complex number can be passed as either argument to **`add_complex`** or **`mul_complex`**:

```
def add_complex(z1, z2):
    return ComplexRI(z1.real + z2.real,
                     z1.imag + z2.imag)

def mul_complex(z1, z2):
    return ComplexMA(z1.magnitude * z2.magnitude,
                     z1.angle + z2.angle)
```

```
>>> from math import pi
>>> add_complex(ComplexRI(1, 2), ComplexMA(2, pi/2))
ComplexRI(1.0000000000000002, 4.0)
>>> mul_complex(ComplexRI(0, 1), ComplexRI(0, 1))
ComplexMA(1.0, 3.141592653589793)
```

We can also define **`__add__`** and **`__mul__`** in both classes.

The Independence of Data Types

Data abstraction and class definitions keep types separate

Some operations need to cross type boundaries

How do we add a complex number and a rational number together?

`add_rational` `mul_rational` | `add_complex` `mul_complex`

Rational numbers as numerators & denominators | *Complex numbers as two-dimensional vectors*

There are many different techniques for doing this!

Type Dispatching

Define a different function for each possible combination of types for which an operation (e.g., addition) is valid

```
def iscomplex(z):
    return type(z) in (ComplexRI, ComplexMA)
def isrational(z):
    return type(z) is Rational
def add_complex_and_rational(z, r):
    return ComplexRI(z.real + r.numerator / r.denominator,
                     z.imag)
def add_by_type_dispatching(z1, z2):
    """Add z1 and z2, which may be complex or rational."""
    if iscomplex(z1) and iscomplex(z2):
        return add_complex(z1, z2)
    elif iscomplex(z1) and isrational(z2):
        return add_complex_and_rational(z1, z2)
    elif isrational(z1) and iscomplex(z2):
        return add_complex_and_rational(z2, z1)
    else:
        add_rational(z1, z2)
```

Converted to a real number (float)

Tag-Based Type Dispatching

Idea: Use dictionaries to dispatch on type (like we did for message passing)

```
def type_tag(x):
    return type_tags[type(x)]

type_tags = {ComplexRI:  'com',
             ComplexMA:  'com',
             Rational:   'rat'}

def add(z1, z2):
    types = (type_tag(z1), type_tag(z2))
    return add_implementations[types](z1, z2)

add_implementations = {}
add_implementations[('com', 'com')] = add_complex
add_implementations[('rat', 'rat')] = add_rational
add_implementations[('com', 'rat')] = add_complex_and_rational
add_implementations[('rat', 'com')] = add_rational_and_complex
```

Declares that **ComplexRI** and **ComplexMA** should be treated uniformly

`lambda r, z: add_complex_and_rational(z, r)`

Type Dispatching Analysis

Minimal violation of abstraction barriers: we define cross-type functions as necessary, but use abstract data types

Extensible: Any new numeric type can "install" itself into the existing system by adding new entries to various dictionaries

```
def add(z1, z2):
    types = (type_tag(z1), type_tag(z2))
    return add_implementations[types](z1, z2)
```

Question: How many cross-type implementations are required to support *m* types and *n* operations?

integer, rational, real, complex

$$m \cdot (m-1) \cdot n$$

add, subtract, multiply, divide

$$4 \cdot (4-1) \cdot 4 = 48$$

Type Dispatching Analysis

Minimal violation of abstraction barriers: we define cross-type functions as necessary, but use abstract data types

Extensible: Any new numeric type can "install" itself into the existing system by adding new entries to various dictionaries

Arg 1	Arg 2	Add	Multiply
Complex	Complex		
Rational	Rational		
Complex	Rational		
Rational	Complex		

Type Dispatching

Message Passing