Lecture 19

Using Classes Effectively
Announcements

Reading

- **Tuesday**: Chapter 18
- **Thursday** reading online

Assignments

- A4 due **tonight** at Midnight
  - 10 pts per day late
  - Consultants available tonight
- A5 & A6 posted tomorrow
  - See included *micro*-deadlines

Regrades

- Today is last day to request
  - Show it to me after class
  - I will verify if it is valid
- *Then* request regrade in CMS

**Prelim, Nov 12th 7:30-9:00**
- Material up to November 5
- Recursion + Loops + Classes
- **S/U Students are exempt**
- **Conflict with Prelim time?**
  - Prelim 2 Conflict on CMS
Designing Types

- **Type**: set of values and the operations on them
  - int: (set: integers; ops: +, −, *, /, …)
  - Time (set: times of day; ops: time span, before/after, …)
  - Worker (set: all possible workers; ops: hire, pay, promote, …)
  - Rectangle (set: all axis-aligned rectangles in 2D; ops: contains, intersect, …)

- To define a class, think of a *real type* you want to make
  - Python gives you the tools, but does not do it for you
  - Physically, any object can take on any value
  - Discipline is required to get what you want
Making a Class into a Type

1. Think about what values you want in the set
   - What are the attributes? What values can they have?
2. Think about what operations you want
   - This often influences the previous question
   - To make (1) precise: write a *class invariant*
     - Statement we promise to keep true *after every method call*
   - To make (2) precise: write *method specifications*
     - Statement of what method does/what it expects (preconditions)
   - Write your code to make these statements true!
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 __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"

    def increment(self, hours, mins):
        """Move this time <hours> hours
and <mins> minutes into the future.
        Pre: hours is int >= 0; mins in 0..59"

    def isPM(self):
        """Returns: this time is noon or later."""
Planning out a Class

class Rectangle(object):
    """Instances represent rectangular regions of the plane.
Instance Attributes:
    t: y coordinate of top edge [float]
    l: x coordinate of left edge [float]
    b: y coordinate of bottom edge [float]
    r: x coordinate of right edge [float]
For all Rectangles, l <= r and b <= t."""

def __init__(self, t, l, b, r):
    """The rectangle [l, r] x [t, b]
    Pre: args are floats; l <= r; b <= t"""

def area(self):
    """Return: area of the rectangle."""

def intersection(self, other):
    """Return: new Rectangle describing intersection of self with other."""
class Hand(object):

    """Instances represent a hand in cards. 
Instance Attributes:
    cards: cards in the hand [list of card]
This list is sorted according to the ordering defined by the Card class.""

    def __init__(self, deck, n):
        """Draw a hand of n cards.
        Pre: deck is a list of >= n cards"

    def isFullHouse(self):
        """Return: True if this hand is a full house; False otherwise"

    def discard(self, k):
        """Discard the k-th card."""
Implementing a Class

• All that remains is to fill in the methods. (All?!)  
• When implementing methods:
  1. Assume preconditions are true
  2. Assume class invariant is true to start
  3. Ensure method specification is fulfilled
  4. Ensure class invariant is true when done
• Later, when using the class:
  ▪ When calling methods, ensure preconditions are true
  ▪ If attributes are altered, ensure class invariant is true
Implementing an Initializer

```python
def __init__(self, hour, min):
    """The time hour:min.
    Pre: hour in 0..23; min in 0..59"
    self.hour = hour
    self.min = min
```

Instance variables:
- hour: hour of day [int in 0..23]
- min: minute of hour [int in 0..59]

This is true to start
You put code here
This should be true at the end
Implementing a Method

Instance variables:
hour: hour of day [int in 0..23]
min: minute of hour [int in 0..59]

```python
def increment(self, hours, mins):
    """Move this time <hours> hours
    and <mins> minutes into the future.
    Pre: hours [int] >= 0; mins in 0..59"
    self.min = self.min + mins
    self.hour = self.hour + hours
```

This is true to start
What we are supposed to accomplish
This is also true to start
You put code here

Instance variables:
hour: hour of day [int in 0..23]
min: minute of hour [int in 0..59]
Implementing a Method

Instance variables:

- `hour`: hour of day [int in 0..23]
- `min`: minute of hour [int in 0..59]

```python
def increment(self, hours, mins):
    """Move this time <hours> hours and <mins> minutes into the future.
    Pre: hours [int] >= 0; mins in 0..59"

    self.min = self.min + mins
    self.hour = (self.hour + hours +
                 self.min / 60)
    self.min = self.min % 60
    self.hour = self.hour % 24
```

This is true to start
What we are supposed to accomplish
This is also true to start
You put code here
This should be true at the end
Role of Invariants and Preconditions

• They both serve two purposes
  ▪ Help you think through your plans in a disciplined way
  ▪ Communicate to the user* how they are allowed to use the class

• Provide the *interface* of the class
  ▪ interface btw two programmers
  ▪ interface btw parts of an app

• Important concept for making large software systems
  ▪ Will return to this idea later

* …who might well be you!

**interface** lˈɪntərˌfəs noun
1. a point where two systems, subjects, organizations, etc., meet and interact: the interface between accountancy and the law.
   • *chiefly Physics* a surface forming a common boundary between two portions of matter or space, e.g., between two immiscible liquids: the surface tension of a liquid at its air/liquid interface.

2. *Computing* a device or program enabling a user to communicate with a computer.
   • a device or program for connecting two items of hardware or software so that they can be operated jointly or communicate with each other.

—The Oxford American Dictionary
Implementing a Class

• All that remains is to fill in the methods. (All?!)  
• When implementing methods:
  1. Assume preconditions are true  
  2. Assume class invariant is true to start  
  3. Ensure method specification is fulfilled  
  4. Ensure class invariant is true when done  
• Later, when using the class:
  ▪ When calling methods, ensure preconditions are true  
  ▪ If attributes are altered, ensure class invariant is true

Easy(ish) if we are the user.  
But what if we aren’t?
def anglicize(n):

    """Returns: the anglicization of int n.

    Precondition: n an int, 0 < n < 1,000,000"""

    assert type(n) == int, str(n)+' is not an int'

    assert 0 < n and n < 1000000, str(n)+' is out of range'

    # Implement method here...

Check (part of) the precondition

(Optionalal) Error message when precondition violated
Enforce Method Preconditions with \texttt{assert}

class Time(object):
    """Instances represent times of day."""
    def \_\_init\_\_(self, hour, min):
        """The time hour:min. Pre: hour in 0..23; min in 0..59"""
        assert type(hour) == int
        assert 0 <= hour and hour < 24
        assert type(min) == int
        assert 0 <= min and min < 60

    def increment(self, hours, mins):
        """Move this time <hours> hours and <mins> minutes into the future. Pre: hours is int >= 0; mins in 0..59"""
        assert type(hour) == int
        assert type(min) == int
        assert hour >= 0 and
        assert 0 <= min and min < 60
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

```python
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
```

Helper method
Enforcing Invariants

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

    def getNumerator(self):
        """Returns: numerator"""
        return self.numerator

    def setNumerator(self, value):
        """Sets numerator to value"""
        assert type(value) == int
        self.numerator = value
```

- These are just comments!
  ```python
  >>> p = Fraction(1, 2)
  >>> p.numerator = 'Hello'
  ```
- How do we prevent this?

- **Idea:** Restrict direct access
  - Only access via methods
  - Use asserts to enforce them

- **Examples:**
  ```python
def getNumerator(self):
    """Returns: numerator"""
    return self.numerator
def setNumerator(self, value):
    """Sets numerator to value"""
    assert type(value) == int
    self.numerator = value
```
**Data Encapsulation**

- **Idea**: Force the user to only use methods
- **Do not allow direct access of attributes**

### Setter Method

- Used to change an attribute
- Replaces all assignment statements to the attribute
- **Bad:**
  ```python
  >>> f.numerator = 5
  ```
- **Good:**
  ```python
  >>> f.setNumerator(5)
  ```

### Getter Method

- Used to access an attribute
- Replaces all usage of attribute in an expression
- **Bad:**
  ```python
  >>> x = 3*f.numerator
  ```
- **Good:**
  ```python
  >>> x = 3*f.getNumerator()
  ```
**Data Encapsulation**

```python
class Fraction(object):
    """Instance attributes:
    _numerator: top       [int]
    _denominator: bottom [int > 0]"

def getDenominator(self):
    """Returns: numerator attribute"
    return self._denominator

def setDenominator(self, d):
    """Alters denominator to be d
    Pre: d is an int > 0"
    assert type(d) == int
    assert 0 < d
    self._denominator = d
```

**Getter**

**Setter**

**Naming Convention**

The underscore means “should not access the attribute directly.”

Precondition is same as attribute invariant.
Mutable vs. Immutable Attributes

**Mutable**
- Can change value directly
  - If class invariant met
  - **Example**: t.color
- Has both getters and setters
  - Setters allow you to change
  - Enforce invariants w/ asserts

**Immutable**
- Can’t change value directly
  - May change “behind scenes”
  - **Example**: t.x
- Has only a getter
  - No setter means no change
  - Getter allows limited access

May ask you to differentiate on the exam
**Structure of a Proper Python Class**

```python
class Fraction(object):
    """Instances represent a Fraction
    Attributes:
    _numerator: [int]
    _denominator: [int > 0]"

    def getNumerator(self):
        """Returns: Numerator 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**
- **Getters and Setters.**
- **Initializer for the class. Defaults for parameters.**
- **Python operator overloading**
- **Normal method definitions**
Exercise: Design a (2D) Circle

• What are the attributes?
  ▪ What is the bare minimum we need?
  ▪ What are some extras we might want?
  ▪ What are the invariants?

• What are the methods?
  ▪ With just the one circle?
  ▪ With more than one circle?
Advanced Topic Warning!

The following will not be on the exam

If you ask “Will this be on the Exam”

we will be 😠
**Properties: Invisible Setters and Getters**

```python
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
>>> x = p.numerator()
>>> p.numerator = 2
>>> p.numerator(2)
```

Python converts to

Python converts to
Properties: Invisible Setters and Getters

```python
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

```python
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)