Lecture 18:
Using Classes Effectively
(Chapter 16)

CS 1110

Introduction to Computing Using Python

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Announcements

- Website colors have changed. Don’t be alarmed.
- A3 due Friday at 11:59pm.
- Spring break next week:
  - Currently no office/consulting hours
  - Keep an eye on the calendar
  - Limited piazza
Method Definitions

- Looks like a function `def` but indented inside class
  - 1st parameter always `self`

Example: `p1.greet()`

- Go to class folder for `p1` (i.e., Student) that’s where `greet` is defined
- Now `greet` is called with `p1` as its first argument
- This way, `greet` knows which instance of `Student` it is working with

```python
class Student():
    def __init__(self, name, NetID, is_auditing):
        self.name = name
        self.NetID = NetID
        self.is_auditing = is_auditing
        Student.enrollment = Student.enrollment + 1

    def greet(self):
        """Prints information about the Student to the screen"""
        print("Hi! My name is " + self.name)
        print("My NetID is " + self.NetID)
        if self.is_auditing:
            print("I'm auditing the class")
```

```
Student

enrollment 0

__init__(self, ...) greet(self)

id1

Student

name Jon Li
NetID j1200
is_auditing True
```
We know how to make:

- Class definitions
- Class specifications
- The __init__ function
- Attributes (using self)
- Class attributes
- Class methods
Special Methods in Python

- Start/end with 2 underscores
  - This is standard in Python
  - Used in all special methods
  - Also for special attributes

  - `__init__` for initializer
  - `__str__` for `str()`
  - `__repr__` for `repr()`
  - `__eq__` for `==`, `__lt__` for `<`, ...

- For a complete list, see [https://docs.python.org/3/reference/datamodel.html#basic-customization](https://docs.python.org/3/reference/datamodel.html#basic-customization)

```python
class Point3():
    """Instances are points in 3D space""
    ...

    def __init__(self, x=0, y=0, z=0):
        """Initializer: makes new Point3""
    ...

    def __str__(self):
        """Returns: string with contents""
        return '(' + str(self.x) + ', ' + str(self.y) + ', ' + str(self.z) + ')'

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

See Fractions example at the end of this presentation
Designing Types

• **Type**: set of values and the operations on them
  - int: (set: integers; ops: +, −, *, /, …)
  - Point3 (set: x,y,z coordinates; ops: distanceTo, …)
  - Card (set: suit * rank combinations; ops: ==, !_, <)
  - New ones to think about: Person, Worker, Image, Date, *etc.*

• To define a class, think of a *type* you want to make
Making a Class into a Type

1. What values do you want in the set?
   - What are the attributes? What values can they have?
   - Are these attributes shared between instances (class attributes) or different for each attribute (instance attributes)?
   - What are the class invariants: things you promise to keep true after every method call

2. What operations do you want?
   - This often influences the previous question
   - What are the method specifications: states what the method does & what it expects (preconditions)
   - Are there any special methods that you will need to provide?

Write your code to make it so!
Let’s make the game Hangman

• There is a secret word.
• The user has 10 chances to guess letters until the word has been spelled out.

• Would be great to have a class `SecretWord` that would keep track of both the word we’re guessing and what the user sees / has guessed so far.

Play the game.
import random, hangman
word_list = [ ... words we want user to guess .. ]
N_GUESSES = 10

Set the secret word

for n in list(range(N_GUESSES)):
    print the word so far
    user_guess = input("Guess a letter: ")
    
    Apply guess to the secret word
    if check-if-solved:
        print("YOU WIN!!!")
        break  #jumps out of the for-loop, not allowed for A3!

Reveal the word
What should the SecretWord offer me?

Like a string, but two of them:

• the secret word
• what the user sees

I should be able to:

• Set the secret word
• Print out the word as guessed “so far”
• Determine whether the game is over
• Reveal the secret word
Example: SecretWord

1. What values do you want in the set?
   - What are the attributes? What values can they have?
   - Are these attributes shared between instances (class attributes) or different for each attribute (instance attributes)?
   - What are the *class invariants*: things you promise to keep true *after every method call*

2. What operations do you want?
   - This often influences the previous question
   - What are the *method specifications*: states what the method does & what it expects (preconditions)
   - Are there any special methods that you will need to provide?
Planning out Class: the Attributes

```python
class SecretWord(object):
    """A word to be guessed by a user in a game of hangman."

    Instance Attributes:
    secret_word: word being guessed [str of lower case letters]
    display_word: word as the user sees it: the letters of secret_word show
correctly guessed letters [str of lower case letters and '_']
    secret_word and display_word agree on all letters and have same length
    ""
```

What are the attributes? What values can they have? Are these attributes shared between instances (class attributes) or different for each attribute (instance attributes)? What are the class invariants: things you promise to keep true after every method call
def __init__(self, word):
    """Initializer: creates both secret_word and display_word from word [a str of lower case letters]"

def __str__(self):
    """Returns: both words"

def __len__(self):
    """Returns: the length of the secret word"

Are there any special methods that you will need to provide? What are their preconditions?

You don’t have to do this. But you should consider it.
Careful. Make sure overloading is the right thing to do.
def word_so_far(self):
    """Prints the word being guessed"""

def reveal(self):
    """Prints the word being guessed"""

def apply_guess(self, letter):
    """Updates the display_word to reveal all instances of letter as they appear in the secret_word. (‘_’ is replaced with letter)
letter: the user's guess [1 character string A..Z]
"""

def is_solved(self):
    """Returns True if the entire word has been guessed"""

What are the *method specifications*: states what the method does & what it expects (preconditions)
import random, hangman
word_list = [ ... words we want user to guess .. ]
N_GUESSES = 10
secret = hangman.SecretWord(random.choice(word_list))

for n in list(range(N_GUESSES)):
    secret.word_so_far()
    user_guess = input("Guess a letter: ")
    secret.apply_guess(user_guess):
    if secret.is_solved():
        print("YOU WIN!!!")
        break  #jumps out of the for-loop, not allowed for A3!
    secret.reveal()}
Implementing a Class

• All that remains is to fill in the methods. (All?!)  
• When implementing methods:
  1. Assume preconditions are true (*checking is friendly*)
  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

def __init__(self, word):
    """Initializer: creates both secret_word and display_word
    from word [a str of lower case letters] """
    # JOB OF THIS METHOD

Instance variables:

secret_word: [str of lower case letters]
display_word: the letters of secret_word show correctly guessed letters
    [str of lower case letters and ' _']
secret_word and display_word agree on all letters and have same length
Implementing an Initializer (Q)

```python
def __init__(self, word):
    """Initializer: creates both secret_word and display_word from word [a str of lower case letters] """
    # JOB OF THIS METHOD
    SecretWord.secret_word = word
    SecretWord.display_word = len(word)*'_'

    secret_word = word
    display_word = len(word)*'_'

    self.secret_word = word
    self.display_word = len(word)*'_'
```

Instance variables:  

- `secret_word`: [str of lower case letters]
- `display_word`: the letters of `secret_word` show correctly guessed letters
  - [str of lower case letters and ' _']
- `secret_word` and `display_word` agree on all letters and have same length
Implementing an Initializer (A)

```python
def __init__(self, word):
    """Initializer: creates both secret_word and display_word from word [a str of lower case letters] """
    # JOB OF THIS METHOD
    SecretWord.secret_word = word
    SecretWord.display_word = len(word)*'_'

    secret_word = word
    display_word = len(word)*'_'

    self.secret_word = word
    self.display_word = len(word)*'_'

# CORRECT!

# WHAT BETTER BE TRUE WHEN WE’RE DONE
Instance variables:

secret_word: [str of lower case letters]
display_word: the letters of secret_word show correctly guessed letters
    [str of lower case letters and '_.']
secret_word and display_word agree on all letters and have same length
Implementing guess()

secret_word: [str of lower case letters]  # WHAT YOU CAN COUNT ON
display_word: the letters of secret_word show correctly guessed letters
    [str of lower case letters and '_']
secret_word and display_word agree on all letters and have same length

def apply_guess(self, letter):
    """Updates the display_word to reveal all instances of letter as they
    appear in the secret_word. ('_' is replaced with letter)  # JOB OF METHOD
    letter: the user's guess [1 character string A..Z]"""  # ASSUME TRUE

secret_word: [str of lower case letters]  # WHAT STILL BETTER BE TRUE
display_word: the letters of secret_word show correctly guessed letters
    [str of lower case letters and '_']
secret_word and display_word agree on all letters and have same length
Implementing guess(), v1

secret_word: [str of lower case letters]  # WHAT YOU CAN COUNT ON
display_word: the letters of secret_word show correctly guessed letters
  [str of lower case letters and ' _ ']  # ASSUME TRUE
secret_word and display_word agree on all letters and have same length

def apply_guess(self, letter):
    """Updates the display_word to reveal all instances of letter as they
    appear in the secret_word. ( _ ' is replaced with letter)  # JOB OF METHOD
    letter: the user's guess [1 character string A..Z]"""

    for i in list(range(len(self.secret_word))):
        if self.secret_word[i] == letter:
            self.display_word = self.display_word[:i] + letter + self.display_word[i:]

secret_word: [str of lower case letters]  # WHAT STILL BETTER BE TRUE
display_word: the letters of secret_word show correctly guessed letters
  [str of lower case letters and ' _ ']  # ASSUME TRUE
secret_word and display_word agree on all letters and have same length
Implementing guess(), v2

secret_word: [str of lower case letters]  # WHAT YOU CAN COUNT ON
display_word: the letters of secret_word show correctly guessed letters
   [str of lower case letters and ' _ ']  # JOB OF METHOD
secret_word and display_word agree on all letters and have same length

```
def apply_guess(self, letter):
    """Updates the display_word to reveal all instances of letter as they
    appear in the secret_word. (' _ ' is replaced with letter)
    letter: the user's guess [1 character string A..Z]"
    lower_letter = letter.lower()
    for i in list(range(len(self.secret_word))):
        if self.secret_word[i] == lower_letter:
            self.display_word = self.display_word[:i] + lower_letter + self.display_word[i+1:]
```

secret_word: [str of lower case letters]  # WHAT STILL BETTER BE TRUE
display_word: the letters of secret_word show correctly guessed letters
   [str of lower case letters and ' _ ']
secret_word and display_word agree on all letters and have same length
Planning out a Class: Fraction

- What attributes?
- What invariants?
- What methods?
- What constructor?

class Fraction(object):
    """Instance is a fraction n/d
    Attributes:
        numerator: top [int]
        denominator: bottom [int > 0]
    """

    def __init__(self, n=0, d=1):
        """Init: makes a Fraction"
        self.numerator = n
        self.denominator = d
## Problem: Doing Math is Unwieldy

<table>
<thead>
<tr>
<th>What We Want</th>
<th>What We Get</th>
</tr>
</thead>
</table>
| \( \left( \frac{1}{2} + \frac{1}{3} + \frac{1}{4} \right) \times \frac{5}{4} \) | \[
\begin{align*}
>>> p &= \text{Fraction}(1,2) \\
>>> q &= \text{Fraction}(1,3) \\
>>> r &= \text{Fraction}(1,4) \\
>>> s &= \text{Fraction}(5,4) \\
>>> (p.\text{add}(q.\text{add}(r))).\text{mult}(s)
\end{align*}
\] |
**Operator Overloading: Addition**

```python
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)
```

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

Python converts to operator overloading uses method in object on left.
Operator Overloading: Multiplication

```python
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

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

Operator overloading uses method in object on left.
Operator Overloading: Equality

- By default, `==` compares *folder IDs*
- Can implement `__eq__`

```python
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
        right = self.denominator * q.numerator
        return left == right
```