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Lecture 18: Using Classes Effectively (Chapter 17)

CS 1110

Introduction to Computing Using Python

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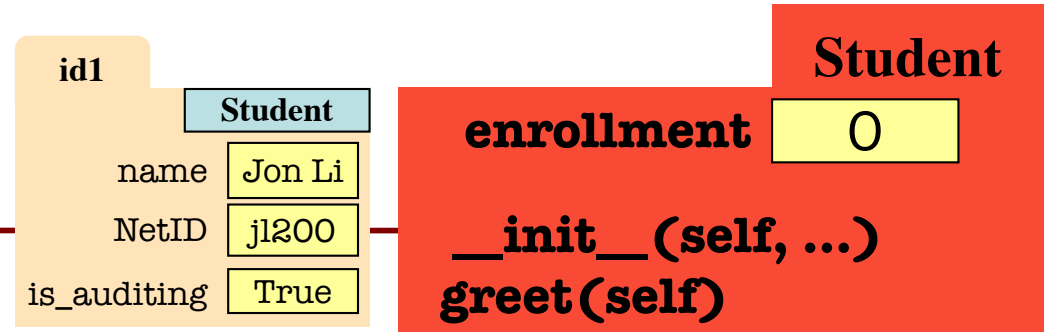
Announcements

- 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

```
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")
```

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

```
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.

How is this going to be used?

```
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

```
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

Planning out Class: the Methods

```
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.

Planning out Class: the Methods

```
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)

How is this going to be used?

```
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: **# WHAT BETTER BE TRUE WHEN WE'RE DONE**

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)

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

 # JOB OF THIS METHOD

A

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

B

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

C

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

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

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)

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

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

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

C
```
self.secret_word = word                    # CORRECT!
self.display_word = len(word)*'_'
```

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

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 '_']
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

    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 '_']
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 '_']
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
    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

What We Want

$$\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{4}\right)*\frac{5}{4}$$

Why not use the standard Python math operations?

What We Get

```
>>> p = Fraction(1,2)
>>> q = Fraction(1,3)
>>> r = Fraction(1,4)
>>> s = Fraction(5,4)
>>> (p.add(q.add(r))).mult(s)
```

Pain!

Operator Overloading: Addition

```
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)
```

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

Python converts to

```
>>> r = p.__add__(q)
```

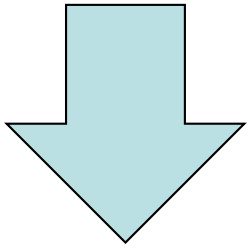
Operator overloading uses method in object on left.

Operator Overloading: Multiplication

```
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

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

Operator overloading uses method in object on left.

Operator Overloading: Equality

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

```
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 == rght
```