http://www.cs.cornell.edu/courses/cs1110/2021sp

Lecture 18: **More on Classes** (Chapter 17)

CS 1110

Introduction to Computing Using Python

[E. Andersen, A. Bracy, D. Fan, D. Gries, L. Lee,
S. Marschner, C. Van Loan, W. White]

Announcements

- *Take care of yourself and one another at this difficult time*
- A4 and Lab 14 deadline postponed to Fri Apr 16
- Lab 15 deadline postponed to Mon Apr 19
- *In addition to your enrolled lab section, you can join other online sections to get help on the lab exercises!*
- A5 release postponed to a after Wellness Days
- Prelim 2 on Apr 22 (Thurs)
- Prelim 2 seat or online session assigned last Friday. You have until *Wedn Apr 14* to make a "regrade request" in CMS *with justification*

We know how to make:

- Class definitions
- Class specifications
- The __init__ function
- Attributes (using self)
- Class attributes
- Class methods

Review… from last lecture

Rules to live by:

1. Refer to Class Attributes using the Class Name

```
s1 = Student("xy1234", [ ], "History")

print("max credits = " + str(Student.max_credit))
```

2. Don’t forget **self**
   - in parameter list of method (method header)
   - when defining method (method body)

Don’t forget self, Part 1

```
s1 = Student(“xy1234”, [ ], "History")
s2 = Student(“ab132”, [ ], “Math”)
s1.enroll("AEM 2400", 4)
```

<var>.<method_name> **always** passes <var> as first argument

TypeError: enroll() takes 2 positional arguments but 3 were given

```
class Student:
    def __init__(self, netID, courses, major):
        self.netID = netID
        self.courses = courses
        self.major = major
        # < rest of constructor goes here >

    def enroll(~~self,~~ name, n):  # if you forget self
        if self.n_credit + n > Student.max_credit:
            print("Sorry your schedule is full!")
        else:
            self.courses.append((name, n))
            self.n_credit = self.n_credit + n
            print("Welcome to "+ name)
```

Don't forget self, Part 2 (Q)

```
s1 = Student("xy1234", [ ], "History")
s2 = Student("ab132", [ ], "Math")
s1.enroll("AEM 2400", 4)
```

What happens?

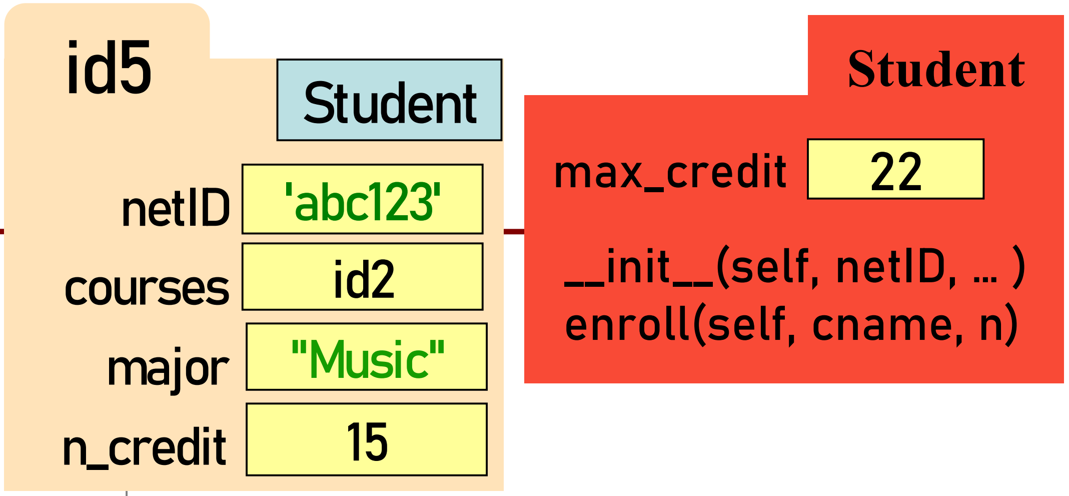
A) Error
B) Nothing, self is not needed
C) creates new local variable n_credit
D) creates new instance variable n_credit
E) creates new Class attribute n_credit

if you forget self

```
class Student:
    def __init__(self, netID, courses, major):
        self.netID = netID
        self.courses = courses
        self.major = major
        # < rest of constructor goes here >

    def enroll(self, name, n):
→       if ~~self~~.n_credit + n > Student.max_credit:
            print("Sorry your schedule is full!")
        else:
            self.courses.append((name, n))
            self.n_credit = self.n_credit + n
            print("Welcome to "+ name)
```

Method Definitions



Looks like a function def

- But indented *inside* class
- 1st parameter always **self**

Example:

s1.enroll("AEM 2400", 4)

- Go to class folder for **s1** (*i.e.*, **Student**) that's where **enroll** is defined
- Now **enroll** is called with **s1** as its first argument
- Now **enroll** knows which instance of **Student** it is working with

```
def __init__(self, netID, courses=[ ], major=None):
    self.netID = netID
    self.courses = courses
    self.major = major
    # < rest of init fn goes here >


def enroll( self, cname, n):
    if self.n_credit + n > Student.max_credit:
        print("Sorry your schedule is full!")
    else:
        self.courses.append([cname, n])
        self.n_credit = self.n_credit + n
        print("Welcome to "+ cname)
```

init is just one of many **Special Methods**

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()

__eq__ for ==

__lt__ for <, ...

Optional: for a complete list, see https://docs.python.org/3/reference/datamodel.html#basic-customization

```
class Point2:
    """Instances are points in 2D space"""
    ...

    def __init__(self,x=0,y=0):
        """Initializer: makes new Point2"""
        ...

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

    def __eq__(self, other):
        """Returns: True if both coordinates equal"""
        return self.x == other.x and self.y == other.y
```

See Fractions example at the end of this lecture

Designing Types

- **Type**: set of values and the operations on them
  - int: (**set**: integers; **ops**: +, –, *, /, …)
  - Point2 (**set**: x,y coordinates; **ops**: distanceTo, …)
  - Card (**set**: suit * rank combinations; **ops**: ==, !=, <)
  - Others to think about: Person, Student, 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 instance (instance attributes)?
   - What are the *class invariants:* things you promise to keep true **after every method call** *(see* n_credit *invariant)*
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 a word guessing game

- 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 does the game go?

```
word_list = [ ... candidate
              words for user
              to guess ... ]
N_GUESSES = 10
Set the secret word

User guesses
  until no more guesses
  or secret is solved

Reveal the word
```

What should the SecretWord offer me?

Like a string, but **two** of them:

1. the secret word
2. 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:
  """A word to be guessed by a user in a word guessing game.

  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
  """
```

How about a list of letters and '_' ?

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 Attributes

```
class SecretWord:
  """A word to be guessed by a user in a word guessing game.

  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 [list of single 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 reveal(self):
    """Prints the word being guessed"""
def print_word_so_far(self):
    """Prints the display_word """

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 in A..Z or 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 SecretWord to be used?

```
import random, wordGuess
word_list = [ ... candidate
              words for user
              to guess ... ]
N_GUESSES = 10
Set the secret word

User guesses
  until no more guesses
  or secret is solved

Reveal the word
```

How is SecretWord to be used?

```
import random, wordGuess
word_list = [ ... candidate
              words for user
              to guess ... ]
N_GUESSES = 10
Set the secret word


guess_the_word(
  secret word,
  N_GUESSES)


Reveal the word
```

```
if secret is solved or out of guesses
    print appropriate message and stop game
otherwise
    print the word-in-progress
    user guesses a letter
    apply guess to the secret word
    potentially guess again (is secret solved?
                             #guesses left?)
```

How is SecretWord to be used?

```
import random, wordGuess
word_list = [ ... candidate
              words for user
              to guess ... ]
N_GUESSES = 10
Set the secret word

guess_the_word(
  secret word,
  N_GUESSES)

Reveal secret word
```

```
def guess_the_word(secret, n_guesses_left):
    if secret is solved:
        print("YOU WIN!!!")
    elif n_more_guesses==0:
        print("Sorry you're out of guesses")
    else:
        print the word-in-progress
        user_guess= input("Guess a letter: ")
        apply guess to the secret word
        guess_the_word(secret, n_guesses_left-1)
```

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 (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 HAS 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
          [list of single lower case letters and '_']
  secret_word and display_word agree on all letters and have same length

Implementing apply_guess()

```
secret_word: [str of lower case letters]      # WHAT YOU CAN COUNT ON
display_word: the letters of secret_word show correctly guessed letters
                  [list of single 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 in A..Z or a..z]""" # ASSUME TRUE
```

```
secret_word: [str of lower case letters]      # WHAT STILL HAD 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
```

Watch video:

operator overloading

Planning out a Class: Fraction

- What *attributes*?
- What *invariants*?
- What *methods*?
- What *initializer* and other *special methods*?

```
class Fraction:
    """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"""
       assert type(n)==int
       assert type(d)==int and d>0
       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:
    """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
```

$\Downarrow$ Python converts to

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

Operator overloading uses method in object on left.

Operator Overloading: Multiplication

```
class Fraction:
    """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***, e.g., the following expression evaluates to False:

  Fraction(2,5)==Fraction(2,5)

- Can implement __eq__ to check for equivalence of two Fractions instead

```
class Fraction:
    """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
```

Optional:
for a complete list, see https://docs.python.org/3/reference/datamodel.html#basic-customization