Lecture 21:
More on Classes
(Chapter 17)

CS 1110
Introduction to Computing Using Python

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We know how to make:

- Class definitions
- Class specifications
- The \_init\_ function
- Attributes (using self)
- Class attributes
- Class methods
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

```python
class Student:
    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 presentation
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!
Start next video: design and implement a class for a game
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?
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

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.*
Planning out Class: the Methods

```python
def print_word_so_far(self):
    """Prints the display_word """

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 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?

```python
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
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?)
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
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)

```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)

A

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

B

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

C

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)

```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 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
               [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 in A..Z or 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 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
            [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 in A..Z or a..z]""""  # ASSUME TRUE
lower_letter = letter.lower()
for i in 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
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)
Start next 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

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

Why not use the standard Python math operations?

Pain!
Operator Overloading: Addition

```python
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)

Python converts to
```

```python
>>> r = p + q

Operator overloading uses method in object on left.
```
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`:

\[
\text{Fraction}(2,5)==\text{Fraction}(2,5)
\]

• Can implement `__eq__` to check for equivalence of two *Fractions* instead:

```python
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