1 Object Oriented Programming

In a previous lecture, you were introduced to the programming paradigm known as Object-Oriented Programming (OOP). OOP allows us to treat data as objects - like we do in real life.

For example, consider the class Student. Each of you as individuals are an instance of this class. So, a student Angela would be an instance of the class Student.

Details that all CS 61A students have, such as name, year, and major, are called instance attributes. Every student has these attributes, but their values differ from student to student. An attribute that is shared among all instances of Student is known as a class attribute. An example would be the instructors attribute; the instructors for CS 61A, DeNero and Hilfinger, are the same for every student in CS 61A.

All students are able to do homework, attend lecture, and go to office hours. When functions belong to a specific object, they are said to be methods. In this case, these actions would be bound methods of Student objects.

Here is a recap of what we discussed above:

- **class**: a template for creating objects
- **instance**: a single object created from a class
- **instance attribute**: a property of an object, specific to an instance
- **class attribute**: a property of an object, shared by all instances of a class
- **method**: an action (function) that all instances of a class may perform
Questions

1.1 Below we have defined the classes Instructor, Student, and TeachingAssistant, implementing some of what was described above. Remember that we pass the self argument implicitly to instance methods when using dot-notation.

class Instructor:
    degree = "PhD (Magic)" # this is a class attribute
    def __init__(self, name):
        self.name = name # this is an instance attribute

    def lecture(self, topic):
        print("Today we're learning about " + topic)

dumbledore = Instructor("Dumbledore")
class Student:
    instructor = dumbledore

    def __init__(self, name, ta):
        self.name = name
        self.understanding = 0
        ta.add_student(self)

    def attend_lecture(self, topic):
        Student.instructor.lecture(topic)
        if Student.instructor == dumbledore:
            print(Student.instructor.name + " is awesome!")
        else:
            print("I miss Dumbledore.")
        self.understanding += 1

    def visit_office_hours(self, staff):
        staff.assist(self)
        print("Thanks, " + staff.name)

class TeachingAssistant:
    def __init__(self, name):
        self.name = name
        self.students = {}

    def add_student(self, student, student):
        self.students[student.name] = student

    def assist(self, student):
        student.understanding += 1
What will the following lines output?

```python
>>> snape = TeachingAssistant("Snape")
>>> harry = Student("Harry", snape)
>>> harry.attend_lecture("potions")

Today we're learning about potions
Dumbledore is awesome!

>>> hermione = Student("Hermione", snape)
>>> hermione.attend_lecture("herbology")

Today we're learning about herbology
Dumbledore is awesome!

>>> hermione.visit_office_hours(TeachingAssistant("Hagrid"))

Thanks, Hagrid

>>> harry.understanding

1

>>> snape.students["Hermione"].understanding

2

>>> Student.instructor = Instructor("Umbridge")
>>> Student.attend_lecture(harry, "transfiguration")   # Equivalent to harry.attend_lecture("transfiguration")

Today we're learning about transfiguration
I miss Dumbledore.
We now want to write three different classes, Mailman, Client, and Email to simulate email. Fill in the definitions below to finish the implementation!

```python
class Email:
    """Every email object has 3 instance attributes: the message, the sender name, and the recipient name.  """
    def __init__(self, msg, sender_name, recipient_name):
        self.msg = msg
        self.sender_name = sender_name
        self.recipient_name = recipient_name

class Mailman:
    """Each Mailman has an instance attribute clients, which is a dictionary that associates client names with client objects.  """
    def __init__(self):
        self.clients = {}

    def send(self, email):
        """Take an email and put it in the inbox of the client it is addressed to.  """
        client = self.clients[email.recipient_name]
        client.receive(email)

    def register_client(self, client, client_name):
        """Takes a client object and client_name and adds it to the clients instance attribute.  """
        self.clients[client_name] = client
```
class Client:
    """Every Client has instance attributes name (which is used for addressing emails to the client), mailman (which is used to send emails out to other clients), and inbox (a list of all emails the client has received). """

    def __init__(self, mailman, name):
        self.inbox = []
        self.mailman = mailman
        self.name = name
        self.mailman.register_client(self, self.name)

    def compose(self, msg, recipient_name):
        """Send an email with the given message msg to the given recipient client. """
        email = Email(msg, self.name, recipient_name)
        self.mailman.send(email)

    def receive(self, email):
        """Take an email and add it to the inbox of this client. """
        self.inbox.append(email)
2 Inheritance

Let’s explore another tool: inheritance. Suppose we want the Dog and Cat classes.

```python
class Dog(object):
    def __init__(self, name, owner):
        self.name = name
        self.owner = owner
    def eat(self, thing):
        print(self.name + " ate a " + str(thing) + "!")
    def talk(self):
        print(self.name + " says woof!")

class Cat(object):
    def __init__(self, name, owner, lives=9):
        self.name = name
        self.owner = owner
        self.lives = lives
    def eat(self, thing):
        print(self.name + " ate a " + str(thing) + "!")
    def talk(self):
        print(self.name + " says meow!")

class Pet(object):
    def __init__(self, name, owner):
        self.is_alive = True  # It's alive!!!
        self.name = name
        self.owner = owner
    def eat(self, thing):
        print(self.name + " ate a " + str(thing) + "!")
    def talk(self):
        print(self.name)

class Dog(Pet):
    def __init__(self, name, owner):
        Pet.__init__(self, name, owner)
    def talk(self):
        print(self.name + ' says woof!')
```

Notice that there’s a lot of repeated code! This is where inheritance comes in. In Python, a class can inherit the instance variables and methods of another class.

```python
class Pet(object):
    def __init__(self, name, owner):
        self.is_alive = True  # It's alive!!!
        self.name = name
        self.owner = owner
    def eat(self, thing):
        print(self.name + " ate a " + str(thing) + "!")
    def talk(self):
        print(self.name)

class Dog(Pet):
    def __init__(self, name, owner):
        Pet.__init__(self, name, owner)
    def talk(self):
        print(self.name + ' says woof!')
```

Inheritance often represents a hierarchical relationship between two or more classes where one class is a more specific version of the other. For example, a dog is a pet. By making `Dog` a subclass of `Pet`, we did not have to redefine `self.name`, `self.owner`, or `eat`. However, since we want `Dog` to `talk` differently, we did redefine, or override, the `talk` method.
Questions

2.1 Implement the Cat class by inheriting from the Pet class. Make sure to use superclass methods wherever possible. In addition, add a lose_life method to the Cat class.

class Cat(Pet):
    def __init__(self, name, owner, lives=9):
        Pet.__init__(self, name, owner)
        self.lives = lives

    def talk(self):
        """A cat says meow! when asked to talk."""

        print('meow!')

    def lose_life(self):
        """A cat can only lose a life if they have at least one life. When lives reaches zero, 'is_alive' becomes False."
        if self.lives > 0:
            self.lives -= 1
            if self.lives == 0:
                self.is_alive = False
        else:
            print("This cat has no more lives to lose :(")

2.2 More cats! Fill in the methods for NoisyCat, which is just like a normal Cat. However, NoisyCat talks a lot, printing twice whatever a Cat says.

class NoisyCat(Cat):
    """A Cat that repeats things twice."""
    def __init__(self, name, owner, lives=9):
        # Is this method necessary? Why or why not?
No, this method is not necessary because NoisyCat already inherits Cat's `__init__` method

```python
def talk(self):
    """Repeat what a Cat says twice."""

Cat.talk(self)
Cat.talk(self)
```

2.3 (Summer 2013 Final) What would Python display?

```python
class A:
    def f(self):
        return 2
    def g(self, obj, x):
        if x == 0:
            return A.f(obj)
        return obj.f() + self.g(self, x - 1)

class B(A):
    def f(self):
        return 4

>>> x, y = A(), B()
>>> x.f()
2
>>> B.f()
Error (missing self argument)
>>> x.g(x, 1)
4
>>> y.g(x, 2)
8
```

2.4 Implement the Yolo class so that the following interpreter session works as expected.

(Summer 2013 Final)

```python
>>> x = Yolo(1)
>>> x.g(3)
4
```
>>> x.g(5)
6
>>> x.motto = 5
>>> x.g(5)
10

class Yolo:
    def __init__(self, motto):
        self.motto = motto
    def g(self, n):
        return self.motto + n
The TAs are building a social networking website called CS61A+. The TAs plan to represent the network in a class called `Network` that supports the following method:

- `add_friend(user1, user2)` adds `user1` and `user2` to each other’s friends lists. If `user1` or `user2` are not in the `Network`, add them to the dictionary of friends.

Help the TAs implement these two methods to make their social networking website popular!

```python
class Network:
    
    def __init__(self):
        self.friends = {}  # Maps users to a list of their friends

    def add_friend(self, user1, user2):
        if user1 not in self.friends:
            self.friends[user1] = []
        if user2 not in self.friends:
            self.friends[user2] = []
```

```python
>>> cs61a_plus = Network()
>>> cs61a_plus.add_friend('Robert', 'Jeffrey')
>>> cs61a_plus.friends['Robert']['Jeffrey']
['Jeffrey']
>>> cs61a_plus.friends['Jeffrey']['Robert']
['Robert']
>>> cs61a_plus.add_friend('Jessica', 'Robert')
>>> cs61a_plus.friends['Robert']['Jeffrey', 'Jessica']
'''
```
self.friends[user2] = []
self.friends[user1].append(user2)
self.friends[user2].append(user1)
CS61A+ turns out to be unpopular. To attract more users, the TAs want to implement a feature that checks if two users have at most \( n \) degrees of separation. Consider the following CS61A+ Network:

```python
self.friends = {
    'Robert': ['Jeffrey', 'Jessica'],
    'Jeffrey': ['Robert', 'Jessica', 'Yulin'],
    'Jessica': ['Robert', 'Jeffrey', 'Yulin'],
    'Yulin': ['Jeffrey', 'Jessica'],
    'Albert': []
}
```

- There is 1 degree of separation between Robert and Jeffrey, because they are direct friends.
- There are 2 degrees of separation between Robert and Yulin (Robert \( \rightarrow \) Jessica \( \rightarrow \) Yulin)
- The degree of separation between Albert and anyone else is undefined, since Albert has no friends.

```python
class Network:
    # Code from previous question

def degrees(self, user1, user2, n):
    """In these doctests, assume cs61a_plus is a Network with the dictionary of friends described in the example.

    >>> cs61a_plus.degrees('Robert', 'Yulin', 2)  # Exactly 2 degrees
    True
    >>> cs61a_plus.degrees('Robert', 'Jessica', 2)  # Less than 2 degrees
    True
    >>> cs61a_plus.degrees('Yulin', 'Robert', 1)  # More than 1 degree
    False
    >>> cs61a_plus.degrees('Albert', 'Jessica', 10)  # No friends!
    False
    """

    if ________________________________:
        return True

    elif ________________________________:
        return False

    for friend in ________________________________:
        if ________________________________:
            return True

    return ________________________________
```
class Network:
    # Code from previous question

def degrees(self, user1, user2, n):
    '''
    >>> cs61a_plus = Network()
    >>> cs61a_plus.friends = {
        ...     'Robert': ['Jeffrey', 'Jessica'],
        ...     'Jeffrey': ['Robert', 'Jessica', 'Yulin'],
        ...     'Jessica': ['Robert', 'Jeffrey', 'Yulin'],
        ...     'Yulin': ['Jeffrey', 'Jessica'],
        ...     'Albert': []
        ...
    }
    >>> cs61a_plus.degrees('Robert', 'Yulin', 2)  # Exactly 2 degrees
    True
    >>> cs61a_plus.degrees('Robert', 'Jessica', 2)  # Less than 2 degrees
    True
    >>> cs61a_plus.degrees('Yulin', 'Robert', 1)  # More than 1 degree
    False
    >>> cs61a_plus.degrees('Albert', 'Jessica', 10)  # No friends!
    False
    '''

    if user1 == user2:
        return True

    elif n <= 0:
        return False

    for friend in self.friends[user1]:
        if self.degrees(friend, user2, n - 1):
            return True

    return False