1 OOP

Questions

1.1 What is the relationship between a class and an ADT?

In general, we can think of an abstract data type as defined by some collection of selectors and constructors, together with some behavior conditions. As long as the behavior conditions are met (such as the division property above), these functions constitute a valid representation of the data type.

There are two different layers to the abstract data type:

1) The program layer, which uses the data, and
2) The concrete data representation that is independent of the programs that use the data. The only communication between the two layers is through selectors and constructors that implement the abstract data in terms of the concrete representation.

Classes are a way to implement an Abstract Data Type. But, ADTs can also be created using a collection of functions, as shown by the rational number example. (See Composing Programs 2.2)

1.2 What is the definition of a Class? What is the definition of an Instance?

Class: a template for all objects whose type is that class that defines attributes and methods that an object of this type has.
Instance: A specific object created from a class. Each instance shares class attributes and stores the same methods and attributes. But the values of the attributes are independent of other instances of the class. For example, all humans have two eyes but the color of their eyes may vary from person to person.

1.3 What is a Class Attribute? What is an Instance Attribute?

Class Attribute: A static value that can be accessed by any instance of the class and is shared among all instances of the class.
Instance Attribute: A field or property value associated with that specific instance of the object.

1.4 What Would Python Display?
class Foo():
    x = 'bam'
    def __init__(self, x):
        self.x = x
    def baz(self):
        return self.x

class Bar(Foo):
    x = 'boom'
    def __init__(self, x):
        Foo.__init__(self, 'er' + x)
    def baz(self):
        return Bar.x + Foo.baz(self)

foo = Foo('boo')

Foo.x
|\begin{solution}
'bam'
\end{solution}|
foo.x
|\begin{solution}
'boo'
\end{solution}|
foo.baz()
|\begin{solution}
'boo'
\end{solution}|
Foo.baz()
|\begin{solution}
Error
\end{solution}|
Foo.baz(foo)
|\begin{solution}
'boo'
\end{solution}|
bar = Bar('ang')
Bar.x
|\begin{solution}
'boom'
\end{solution}|
bar.x
|\begin{solution}
'erang'
\end{solution}|
bar.baz()
|\begin{solution}
What Would Python Display?

```python
class Student:
    def __init__(self, subjects):
        self.current_units = 16
        self.subjects_to_take = subjects
        self.subjects_learned = {}
        self.partner = None

    def learn(self, subject, units):
        print("I just learned about " + subject)
        self.subjects_learned[subject] = units
        self.current_units -= units

    def make_friends(self):
        if len(self.subjects_to_take) > 3:
            print("Whoa! I need more help!")
            self.partner = Student(self.subjects_to_take[1:])
        else:
            print("I'm on my own now!")
            self.partner = None

    def take_course(self):
        course = self.subjects_to_take.pop()
        self.learn(course, 4)
        if self.partner:
            print("I need to switch this up!")
            self.partner = self.partner.partner
            if not self.partner:
                print("I have failed to make a friend :(")

tim = Student(['Chem1A', 'Bio1B', 'CS61A', 'CS70', 'CogSci1'])
tim.make_friends()
\begin{solution}
Whoa! I need more help!
\end{solution}
\begin{solution}
print(tim.subjects_to_take)
\end{solution}
\begin{solution}
['Chem1A', 'Bio1B', 'CS61A', 'CS70', 'CogSci1']
\end{solution}
tim.partner.make_friends()
\begin{solution}
Whoa! I need more help!
\end{solution}
tim.take_course()
\begin{solution}[0.25in]
```
Fill in the implementation for the Cat and Kitten classes. When a cat meows, it should say "Meow, (name) is hungry" if it is hungry, and "Meow, my name is (name)" if not. Kittens do the same thing as cats, except they say "i'm baby" instead of "meow", and they say "I want mama (parents name)" after every call to meow().

```python
>>> cat = Cat('Tuna')
>>> kitten = Kitten('Fish', cat)

>>> cat.meow()
meow, Tuna is hungry

>>> kitten.meow()
i'm baby, Fish is hungry

I want mama Tuna

>>> cat.eat()
meow

>>> cat.meow()
meow, my name is Tuna

>>> kitten.eat()
i'm baby

>>> kitten.meow()
meow, my name is Fish

I want mama Tuna

class Cat:
    noise = 'meow'
    def __init__(self, name):
        ...
```
```python
\begin{verbatim}
self.name = name
self.hungry = True
\end{verbatim}
\end{solution}
def meow(self):
|\begin{solution}[lin]
\begin{verbatim}
if self.hungry:
  print(self.noise + ', ' + self.name + ' is hungry!')
else:
  print(self.noise + ', my name is ' + self.name)
\end{verbatim}
\end{solution}
def eat(self):
  print(self.noise)
  self.hungry = False

class Kitten(Cat):
  |\begin{solution}[1.5in]
  \begin{verbatim}
note = "I'm baby"
def __init__(self, name, parent):
  Cat.__init__(self, name)
  self.parent = parent
def meow(self):
  Cat.meow(self)
  print('I want mama' + parent.name)
\end{verbatim}
\end{solution}

Check Your Understanding

1.1 Why do Foo.x and foo.x return different things?

Foo.x is a class attribute, while foo.x is an instance attribute. Foo.x will return
the variable defined under the class Foo, 'bam', while foo.x will return the variable
defined when foo is constructed, 'boo'.

1.2 Can we call the Foo.baz function on bar? How? What will it return?

Yes. We can do this if we call Foo.baz(bar). It runs because Bar objects also have
an attribute x. It will return 'erang'.

1.3 What is tim.subjects_to_take after all the code is run?

['Chem1A', 'Bio1B', 'CS61A']
1.4 What is the difference between a local variable, an instance variable, and a class variable? Give an example of each based on the code given.

A local variable is a variable defined under a method. An instance variable is a variable that persists outside of method calls and retains its value. A class variable is defined outside of a method and is shared by all instances of a class. Class variables will be called on the class name, while instance variables will be called on an instance or self. Local variables only exist during a method call, while instance and class variables persist even after a method is done executing.
2 Object Oriented Trees

Questions

2.1 Define `filter_tree`, which takes in a tree `t` and one argument predicate function `fn`. It should mutate the tree by removing all branches of any node where calling `fn` on its label returns `False`. In addition, if this node is not the root of the tree, it should remove that node from the tree as well.

```python
def filter_tree(t, fn):
    """
    >>> t = Tree(1, [Tree(2), Tree(3, [Tree(4)]), Tree(6, [Tree(7)])])
    >>> filter_tree(t, lambda x: x % 2 != 0)
    >>> t
    tree(1, [Tree(3)])
    >>> t2 = Tree(2, [Tree(3), Tree(4), Tree(5)])
    >>> filter_tree(t2, lambda x: x != 2)
    >>> t2
    Tree(2)
    """

    # Solution
    def helper(t):
        if not fn(t.label):
            t.branches = []
        else:
            for b in t.branches[:]:
                if not fn(b.label):
                    t.branches.remove(b)
                else:
                    helper(b, fn)
        helper(t, fn)
```

2.2 Fill in the definition for `nth_level_tree_map`, which also takes in a function and a tree, but mutates the tree by applying the function to every nth level in the tree, where the root is the 0th level.

```python
def nth_level_tree_map(fn, tree, n):
    """Mutates a tree by mapping a function all the elements of a tree.
    >>> tree = Tree(1, [Tree(7, [Tree(3), Tree(4), Tree(5)]),
    Tree(2, [Tree(6), Tree(4)])])
    >>> nth_level_tree_map(lambda x: x + 1, tree, 2)
    >>> tree
    Tree(2, [Tree(7, [Tree(4), Tree(5), Tree(6)]),
                 Tree(2, [Tree(7), Tree(5)])])
    """

    # Solution
    def helper(tree, level):
```
\begin{verbatim}
if level % n == 0:
    tree.label = fn(tree.label)
    for b in tree.branches:
        helper(b, level + 1)
helper(tree, 0)
\end{verbatim}

Check Your Understanding

2.1 Why can we mutate trees using the Tree class? How does the Tree class differ from the Tree ADT?

The Tree class differs from the Tree ADT in that the Tree class is mutable, while the Tree ADT is not. This means we can change the branches of a tree made with the tree class by using different methods to access them. If we wanted to change the branches of a tree made with the Tree ADT, however, we would have to construct completely new branches.

2.2 How do you guarantee that your code does not recurse forever? Do we need an explicit base case?

The for loop will eventually stop because it iterates through the branches of a tree, and will not be executed if there are none.
3 Linked Lists

Questions

3.1 What is a linked list? Why do we consider it a naturally recursive structure?

A linked list is a data structure with a first and a rest, where the first is some arbitrary element and the rest MUST be another linked list (or Link.empty)

3.2 Draw a box and pointer diagram for the following:

Link('c', Link(Link(6, Link(1, Link('a'))), Link('s')))

3.3 The Link class can represent lists with cycles. That is, a list may contain itself as a sublist. Implement has_cycle that returns whether its argument, a Link instance, contains a cycle. There are two ways to do this: iteratively with two pointers, or keeping track of Link objects we’ve seen already. Try to come up with both!

```python
def has_cycle(link):
    """
    >>> s = Link(1, Link(2, Link(3)))
    >>> s.rest.rest.rest = s
    >>> has_cycle(s)
    True
    """
    # solution 1
    tortoise = link
    hare = link.rest
    while tortoise.rest and hare.rest and hare.rest.rest:
        if tortoise is hare:
            return True
        tortoise = tortoise.rest
        hare = hare.rest.rest
    return False

    # solution 2
    seen = []
    while link.rest:
        if link in seen:
            return True
        seen.append(link)
        link = link.rest
    return False
```

|\begin{solution}

```python
# solution 1
    tortoise = link
    hare = link.rest
    while tortoise.rest and hare.rest and hare.rest.rest:
        if tortoise is hare:
            return True
        tortoise = tortoise.rest
        hare = hare.rest.rest
    return False

# solution 2
    seen = []
    while link.rest:
        if link in seen:
            return True
        seen.append(link)
        link = link.rest
    return False
```

\end{solution}
3.4 Fill in the following function, which checks to see if `sub_link`, a particular sequence of items in one linked list, can be found in another linked list (the items have to be in order, but not necessarily consecutive).

```python
def seq_in_link(link, sub_link):
    """
    >>> lnk1 = Link(1, Link(2, Link(3, Link(4)))))
    >>> lnk2 = Link(1, Link(3))
    >>> lnk3 = Link(4, Link(3, Link(2, Link(1)))))
    >>> seq_in_link(lnk1, lnk2)
    True
    >>> seq_in_link(lnk1, lnk3)
    False
    """
    if sub_link is Link.empty:
        return True
    if link is Link.empty:
        return False
    if link.first == sub_link.first:
        return seq_in_link(link.rest, sub_link.rest)
    else:
        return seq_in_link(link.rest, sub_link)
```

```latex
\begin{verbatim}
def seq_in_link(link, sub_link):
    """
    >>> lnk1 = Link(1, Link(2, Link(3, Link(4)))))
    >>> lnk2 = Link(1, Link(3))
    >>> lnk3 = Link(4, Link(3, Link(2, Link(1)))))
    >>> seq_in_link(lnk1, lnk2)
    True
    >>> seq_in_link(lnk1, lnk3)
    False
    """
    if sub_link is Link.empty:
        return True
    if link is Link.empty:
        return False
    if link.first == sub_link.first:
        return seq_in_link(link.rest, sub_link.rest)
    else:
        return seq_in_link(link.rest, sub_link)
\end{verbatim}
\end{solution}
```
Check Your Understanding

3.1 What can go in the first box of a linked list? What can go in the second?

Any object can go in the box of a linked list, but only linked lists can go in the second box (rest). When a linked list is in the first box, it is a nested linked list.

3.2 For question 2, why do we need to store the linked list first in our code? Why can’t we just iterate through it? Why can we iterate through the linked list without storing it in question 3?

We need to store the linked list so that we still have access to the whole list. If we just iterate through it by moving its pointers, we could lose reference to the nodes at the beginning of the list. In question 3, we don’t need to revisit information at the beginning of the list once we have checked it, so we can iterate through the linked list inputs without storing them to temporary variables.