

1 Representation - A Note on Str and Repr

There are two main ways to produce the "string" of an object in Python: `str()` and `repr()`. While the two are similar, they are used for different purposes. `str()` is used to describe the object to the end user in a "Human-readable" form, while `repr()` can be thought of as a "Computer-readable" form mainly used for debugging and development.

When we define a class in Python, `str()` and `repr()` are both built-in functions for the class. We can call an object's `str()` and `repr()` by using their respective functions. These functions can be invoked by calling `repr(obj)` or `str(obj)` rather than the dot notation format `obj.__repr__()` or `obj.__str__()`. In addition, the `print()` function calls the `str()` function of the object, while simply calling the object in interactive mode calls the `repr()` function.

Here's an example:

```
class Test:
    def __str__(self):
        return "str"
    def __repr__(self):
        return "repr"

>>> a = Test()
>>> str(a)
'str'
>>> repr(a)
'repr'
>>> print(a)
str
>>> a
repr
```

print(): str()
interactive mode: repr()

Questions

- 1.1 What would Python display? Feel free to use the environment diagram template below to help with visualization.

```
class A():
    def __init__(self, x):
        self.x = x
    def __repr__(self):
        return self.x
    def __str__(self):
        return self.x * 2
```

```
class B():
    def __init__(self):
        print("boo!")
        self.a = []
    def add_a(self, a):
        self.a.append(a)
    def __repr__(self):
        print(len(self.a))
        ret = ""
        for a in self.a:
            ret += str(a)
        return ret
```

```
>>> A("one")
```

```
one
```

```
>>> print(A("one"))
```

```
oneone
```

```
>>> repr(A("two"))
```

```
'two'
```

```
>>> b = B()
```

```
boo!
```

```
>>> b.add_a(A("a"))
```

```
>>> b.add_a(A("b"))
```

```
>>> b
```

```
2
aabb
```

Global frame	
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

f1: _____ [parent=_____]	
_____	_____
_____	_____
_____	_____
Return Value	_____

f2: _____ [parent=_____]	
_____	_____
_____	_____
_____	_____
Return Value	_____

f3: _____ [parent=_____]	
_____	_____
_____	_____
_____	_____
Return Value	_____

2 Linked Lists

There are many different implementations of sequences in Python. Today, we'll explore the linked list implementation.

A linked list is either an empty linked list, or a `Link` object containing a `first` value and the `rest` of the linked list.

To check if a linked list is an empty linked list, compare it against the class attribute `Link.empty`:

```
if link is Link.empty:
    print('This linked list is empty!')
else:
    print('This linked list is not empty!')
```

Implementation

```
class Link:
    empty = ()
    def __init__(self, first, rest=empty):
        assert rest is Link.empty or isinstance(rest, Link)
        self.first = first
        self.rest = rest

    def __repr__(self):
        if self.rest:
            rest_str = ', ' + repr(self.rest)
        else:
            rest_str = ''
        return 'Link({0}{1})'.format(repr(self.first), rest_str)

    def __str__(self):
        string = '<'
        while self.rest is not Link.empty:
            string += str(self.first) + ' '
            self = self.rest
        return string + str(self.first) + '>'
```

Questions

- 2.1 Write a function that takes in a linked list and returns the sum of all its elements. You may assume all elements in `lnk` are integers.

```
def sum_nums(lnk):
    """
    >>> a = Link(1, Link(6, Link(7)))
    >>> sum_nums(a)
    14
    """
```

```
    sum = 0
    while lnk is not Link.empty:
        sum += lnk.first
        lnk = lnk.rest
    return sum
```

recursive solution:

```
def sum_nums(lnk):
    if lnk is Link.empty:
        return 0
    return lnk.first + sum_nums(lnk.rest)
```

- 2.2 Write a function that takes in a Python list of linked lists and multiplies them element-wise. It should return a new linked list.

If not all of the `Link` objects are of equal length, return a linked list whose length is that of the shortest linked list given. You may assume the `Link` objects are shallow linked lists, and that `lst_of_lns` contains at least one linked list.

```
def multiply_lns(lst_of_lns):
    """
    >>> a = Link(2, Link(3, Link(5)))
    >>> b = Link(6, Link(4, Link(2)))
    >>> c = Link(4, Link(1, Link(0, Link(2))))
    >>> p = multiply_lns([a, b, c])
    >>> p.first
    48
    >>> p.rest.first
    12
    >>> p.rest.rest.rest is Link.empty
    True
    """

    # Note: you might not need all lines in this skeleton code
    _____ = _____
    for _____:
        if _____:
            _____
            _____
    _____
    _____
```

recursive solution:

```
product = 1
for lnk in lst_of_lns:
    if lnk is Link.empty:
        return Link.empty
    product *= lnk.first
lst_of_lns_rest = [lnk.rest for lnk in lst_of_lns]
return Link(product, multiply_lns(lst_of_lns_rest))
```

iterative solution:

```
import operator
from functools import reduce

def prod(factors):
    return reduce(operator.mul, factors, 1)

head = Link.empty
tail = head
while Link.empty not in lst_of_lns:
    all_prod = prod([l.first for l in lst_of_lns])
    if head is Link.empty:
        head = Link(all_prod)
        tail = head
    else:
        tail.rest = Link(all_prod)
        tail = tail.rest
    lst_of_lns = [l.rest for l in lst_of_lns]
return head
```

- 2.3 **Tutorial:** Write a recursive function `flip_two` that takes as input a linked list `lnk` and mutates `lnk` so that every pair is flipped.

```
def flip_two(lnk):
    """
    >>> one_lnk = Link(1)
    >>> flip_two(one_lnk)
    >>> one_lnk
    Link(1)
    >>> lnk = Link(1, Link(2, Link(3, Link(4, Link(5)))))
    >>> flip_two(lnk)
    >>> lnk
    Link(2, Link(1, Link(4, Link(3, Link(5)))))
    """

    if lnk is Link.empty or lnk.rest is Link.empty:
        return
    lnk.first, lnk.rest.first = lnk.rest.first, lnk.first
    flip_two(lnk.rest.rest)
```


- 2.4 **Tutorial:** Implement `filter_link`, which takes in a linked list `link` and a function `f` and returns a generator which yields the values of `link` for which `f` returns `True`.

Try to implement this both using a while loop and without using any form of iteration.

```
def filter_link(link, f):
    """
    >>> link = Link(1, Link(2, Link(3)))
    >>> g = filter_link(link, lambda x: x % 2 == 0)
    >>> next(g)
    2
    >>> next(g)
    StopIteration
    >>> list(filter_link(link, lambda x: x % 2 != 0))
    [1, 3]
    """

    while _____:
        if _____:
            _____
            _____

    while link is not Link.empty:
        if f(link.first):
            yield link.first
            link = link.rest
```

3 Trees

Recall the tree abstract data type: a tree is defined as having a label and some branches. Previously, we implemented the tree abstraction using Python lists. Let's look at another implementation using objects instead:

```
class Tree:
    def __init__(self, label, branches=[]):
        for b in branches:
            assert isinstance(b, Tree)
        self.label = label
        self.branches = branches

    def is_leaf(self):
        return not self.branches
```

Notice that with this implementation we can mutate a tree using attribute assignment, which wasn't possible in the previous implementation using lists.

```
>>> t = Tree(3, [Tree(4), Tree(5)])
>>> t.label = 5
>>> t.label
5
```

Questions

- 3.1 Define a function `make_even` which takes in a tree `t` whose values are integers, and mutates the tree such that all the odd integers are increased by 1 and all the even integers remain the same.

```
def make_even(t):
    """
    >>> t = Tree(1, [Tree(2, [Tree(3)]), Tree(4), Tree(5)])
    >>> make_even(t)
    >>> t.label
    2
    >>> t.branches[0].branches[0].label
    4
    """
    if t.label % 2 != 0:
        t.label += 1
    for b in t.branches:
        make_even(b)
```

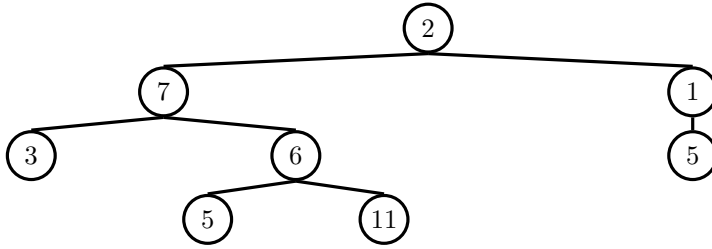
- 3.2 Define a function `square_tree(t)` that squares every value in the non-empty tree `t`. You can assume that every value is a number.

```
def square_tree(t):
    """Mutates a Tree t by squaring all its elements."""

    t.label = t.label ** 2
    for b in t.branches:
        square_tree(b)
```

3.3 **Tutorial:** Define the procedure `find_paths` that, given a Tree `t` and an `entry`, returns a list of lists containing the nodes along each path from the root of `t` to `entry`. You may return the paths in any order.

For instance, for the following tree `tree_ex`, `find_paths` should return:



```
def find_paths(t, entry):
    >>> tree_ex = Tree(2, [Tree(7, [Tree(3), Tree(6, [Tree(5), Tree(11)])]), Tree(1, [Tree(5)])])
    >>> find_paths(tree_ex, 5)
    [[2, 7, 6, 5], [2, 1, 5]]
    >>> find_paths(tree_ex, 12)
    []
```

```
paths = []
if _____:
    _____
    for _____:
        _____
    return _____
```

```
paths = []
if t.label == entry:
    paths.append([t.label])
for b in t.branches:
    for path in find_paths(b, entry):
        paths.append([t.label] + path)
return paths
```

alternate solution using list comprehension:

```
paths = []
if t.label == entry:
    paths.append([t.label])
for b in t.branches:
    branch_paths = [[t.label] + path for path in find_paths(b, entry)]
    paths.extend(branch_paths)
return paths
```

- 3.4 Write a function that combines the values of two trees `t1` and `t2` together with the `combiner` function. Assume that `t1` and `t2` have identical structure. This function should return a new tree.

Hint: consider using the `zip()` function, which returns an iterator of tuples where the first items of each iterable object passed in form the first tuple, the second items are paired together and form the second tuple, and so on and so forth.

```
def combine_tree(t1, t2, combiner):
    """
    >>> a = Tree(1, [Tree(2, [Tree(3)])])
    >>> b = Tree(4, [Tree(5, [Tree(6)])])
    >>> combined = combine_tree(a, b, mul)
    >>> combined.label
    4
    >>> combined.branches[0].label
    10
    """

    combined = [combine_tree(b1, b2, combiner) for b1, b2 in zip(t1.branches, t2.branches)]
    return Tree(combiner(t1.label, t2.label), combined)
```

- 3.5 Implement the `alt_tree_map` function that, given a function and a `Tree`, applies the function to all of the data at every other level of the tree, starting at the root.

```
def alt_tree_map(t, map_fn):
    """
    >>> t = Tree(1, [Tree(2, [Tree(3)]), Tree(4)])
    >>> negate = lambda x: -x
    >>> alt_tree_map(t, negate)
    Tree(-1, [Tree(2, [Tree(-3)]), Tree(4)])
    """

    def helper(t, depth):
        if depth % 2 == 0:
            label = map_fn(t.label)
        else:
            label = t.label
        branches = [helper(b, depth+1) for b in t.branches]
        return Tree(label, branches)

    return helper(t, 0)
```