CS 61A Fall 2022

Mutability, Iterators, Generators

Discussion 6: October 5, 2022

##Walkthrough Videos

Feel free to try these problems on the worksheet in discussion or on your own, and then come back to reference these walkthrough videos as you study.

To see these videos, you should be logged into your berkeley.edu email.

Mutability

Some objects in Python, such as lists and dictionaries, are **mutable**, meaning that their contents or state can be changed. Other objects, such as numeric types, tuples, and strings, are **immutable**, meaning they cannot be changed once they are created.

Let's imagine you order a mushroom and cheese pizza from La Val's, and they represent your order as a list:

```
>>> pizza = ['cheese', 'mushrooms']
```

With list mutation, they can update your order by mutate `pizza` directly rather than having to create a new list:

```
>>> pizza.append('onions')
>>> pizza
['cheese', 'mushrooms', 'onions']
```

Aside from `append`, there are various other list mutation methods:

- `append(el)`: Add `el` to the end of the list. Return `None`.
- `extend(lst)`: Extend the list by concatenating it with `lst`. Return `None`.
- `insert(i, el)`: Insert `el` at index `i`. This does not replace any existing elements, but only adds the new element `el`. Return `None`.
- `remove(el)`: Remove the first occurrence of `el` in list. Errors if `el` is not in the list. Return `None` otherwise.
- `pop(i)`: Remove and return the element at index `i`.

We can also use list indexing with an assignment statement to change an existing element in a list. For example:

```
>>> pizza[1] = 'tomatoes'
>>> pizza
['cheese', 'tomatoes', 'onions']
```

Q1: WWPD: Mutability

What would Python display? In addition to giving the output, draw the box and pointer diagrams for each list to the right.

```
>>> x = [1, 2, 3]
>>> y = x
>>> x += [4]
>>> x
```

[1, 2, 3, 4]

```
>>> y # y is pointing to the same list as x, which got mutated
```

[1, 2, 3, 4]

```
>>> x = [1, 2, 3]
>>> y = x
>>> x = x + [4] # creates NEW list, assigns it to x
>>> x
```

[1, 2, 3, 4]

```
>>> y   # y still points to OLD list, which was not mutated
```

[1, 2, 3]

```
>>> s1 = [1, 2, 3]
>>> s2 = s1
>>> s1 is s2
```

True

```
>>> s2.extend([5, 6])
>>> s1[4]
```

6

```
>>> s1.append([-1, 0, 1])
>>> s2[5]
```

[-1, 0, 1]

```
>>> s3 = s2[:]
>>> s3.insert(3, s2.pop(3))
>>> len(s1)
```

5

```
>>> s1[4] is s3[6]
```

True

```
>>> s3[s2[4][1]]
```

1

```
>>> s1[:3] is s2[:3]
```

False

```
>>> s1[:3] == s2[:3]
```

True

```
>>> s1[4].append(2)
>>> s3[6][3]
```

2

Q2: Add This Many

Write a function that takes in a value `x`, a value `el`, and a list `s`, and adds `el` to the end of `s` the same number of times that `x` occurs in `s`. **Make sure to modify the original list using list mutation techniques.**

```
def add_this_many(x, el, s):
    """ Adds el to the end of s the number of times x occurs in s.
    >>> s = [1, 2, 4, 2, 1]
    >>> add_this_many(1, 5, s)
    >>> s
    [1, 2, 4, 2, 1, 5, 5]
    >>> add_this_many(2, 2, s)
    >>> s
    [1, 2, 4, 2, 1, 5, 5, 2, 2]
    """
    count = 0
    for element in s:
        if element == x:
            count += 1
    while count > 0:
        s.append(el)
        count -= 1
```

Two alternate solutions involve iterating over the list indices and iterating over a copy of the list:

```
def add_this_many_alt1(x, el, s):
    for i in range(len(s)):
        if s[i] == x:
        s.append(el)
```

```
def add_this_many_alt2(x, el, s):
    for element in list(s):
        if element == x:
        s.append(el)
```

Iterators

An iterable is an object where we can go through its elements one at a time. Specifically, we define an **iterable** as any object where calling the built-in `iter` function on it returns an *iterator*. An **iterator** is another type of object which can iterate over an iterable by keeping track of which element is next in the iterable.

For example, a sequence of numbers is an iterable, since `iter` gives us an iterator over the given sequence:

```
>>> lst = [1, 2, 3]
>>> lst_iter = iter(lst)
>>> lst_iter
<list_iterator object ...>
```

With an iterator, we can call `next` on it to get the next element in the iterator. If calling `next` on an iterator raises a `StopIteration` exception, this signals to us that the iterator has no more elements to go through. This will be explored in the example below.

Calling `iter` on an iterable multiple times returns a new iterator each time with distinct states (otherwise, you'd never be able to iterate through a iterable more than once). You can also call `iter` on the iterator itself, which will just return the same iterator without changing its state. However, note that you cannot call `next` directly on an iterable.

For example, we can see what happens when we use `iter` and `next` with a list:

```
>>> lst = [1, 2, 3]
>>> next(lst)             # Calling next on an iterable
TypeError: 'list' object is not an iterator
>>> list_iter = iter(lst) # Creates an iterator for the list
>>> next(list_iter)       # Calling next on an iterator
1
>>> next(iter(list_iter)) # Calling iter on an iterator returns itself
2
>>> for e in list_iter:   # Exhausts remainder of list_iter
...     print(e)
3
>>> next(list_iter)       # No elements left!
StopIteration
>>> lst                   # Original iterable is unaffected
[1, 2, 3]
```

Q3: WWPD: Iterators

What would Python display?

```
>>> s = "cs61a"
>>> s_iter = iter(s)
>>> next(s_iter)
```

'c'

```
>>> next(s_iter)
```

's'

```
>>> list(s_iter)
```

['6', '1', 'a']

```
>>> s = [[1, 2, 3, 4]]
>>> i = iter(s)
>>> j = iter(next(i))
>>> next(j)
```

1

```
>>> s.append(5)
>>> next(i)
```

5

```
>>> next(j)
```

2

```
>>> list(j)
```

[3, 4]

```
>>> next(i)
```

StopIteration

Generators

We can define custom iterators by writing a *generator function*, which returns a special type of iterator called a **generator**.

A generator function has at least one `yield` statement and returns a ***generator*** *object* when we call it, without evaluating the body of the generator function itself.

When we first call `next` on the returned generator, then we will begin evaluating the body of the generator function until an element is yielded or the function otherwise stops (such as if we `return`). The generator remembers where we stopped, and will continue evaluating from that stopping point on the next time we call `next`.

As with other iterators, if there are no more elements to be generated, then calling `next` on the generator will give us a `StopIteration`.

For example, here's a generator function:

```
def countdown(n):
    print("Beginning countdown!")
    while n >= 0:
        yield n
        n -= 1
    print("Blastoff!")
```

To create a new generator object, we can call the generator function. Each returned generator object from a function call will separately keep track of where it is in terms of evaluating the body of the function. Notice that calling `iter` on a generator object doesn't create a new bookmark, but simply returns the existing generator object!

```
>>> c1, c2 = countdown(2), countdown(2)
>>> c1 is iter(c1)  # a generator is an iterator
True
>>> c1 is c2
False
>>> next(c1)
Beginning countdown!
2
>>> next(c2)
Beginning countdown!
2
```

In a generator function, we can also have a `yield from` statement, which will **yield** each element **from** an iterator or iterable.

```
>>> def gen_list(lst):
...     yield from lst
...
>>> g = gen_list([1, 2])
>>> next(g)
1
>>> next(g)
2
>>> next(g)
StopIteration
```

Q4: WWPD: Generators

What would Python display? If the command errors, input the specific error.

```
>>> def infinite_generator(n):
...     yield n
...     while True:
...         n += 1
...         yield n
>>> next(infinite_generator)
```

TypeError

```
>>> gen_obj = infinite_generator(1)
>>> next(gen_obj)
```

1

```
>>> next(gen_obj)
```

2

```
>>> list(gen_obj)
```

Infinite Loop

Q5: Filter-Iter

Implement a generator function called `filter_iter(iterable, f)` that only yields elements of `iterable` for which `f` returns True.

```
def filter_iter(iterable, f):
    """
    >>> is_even = lambda x: x % 2 == 0
    >>> list(filter_iter(range(5), is_even)) # a list of the values yielded from the call
     to filter_iter
    [0, 2, 4]
    >>> all_odd = (2*y-1 for y in range(5))
    >>> list(filter_iter(all_odd, is_even))
    []
    >>> naturals = (n for n in range(1, 100))
    >>> s = filter_iter(naturals, is_even)
    >>> next(s)
    2
    >>> next(s)
    4
    """
    for elem in iterable:
        if f(elem):
            yield elem

# Alternate solution (only works if iterable is not an infinite iterator)
def filter_iter(iterable, f):
    yield from [elem for elem in iterable if f(elem)]
```

Q6: Primes Generator

Write a function `primes_gen` that takes a single argument `n` and yields all prime numbers less than or equal to `n` in decreasing order. Assume `n >= 1`. You may use the `is_prime` function included below, which we implemented in Discussion 3.

Optional Challenge: Now rewrite the generator so that it also prints the primes in *ascending order*.

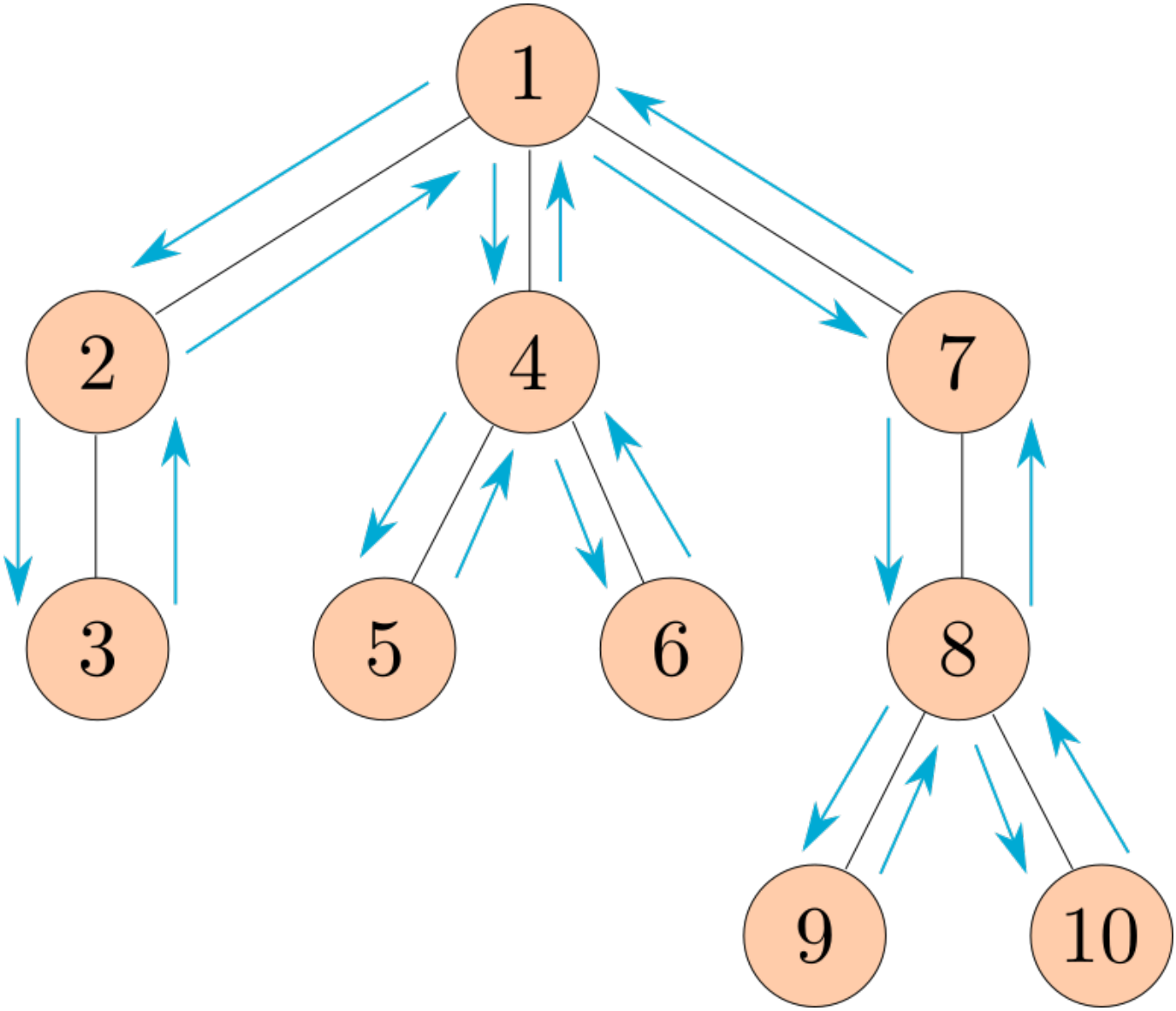
```
def is_prime(n):
    """Returns True if n is a prime number and False otherwise.
    >>> is_prime(2)
    True
    >>> is_prime(16)
    False
    >>> is_prime(521)
    True
    """
    def helper(i):
        if i > (n ** 0.5): # Could replace with i == n
            return True
        elif n % i == 0:
            return False
        return helper(i + 1)
    return helper(2)

def primes_gen(n):
    """Generates primes in decreasing order.
    >>> pg = primes_gen(7)
    >>> list(pg)
    [7, 5, 3, 2]
    """
    if n == 1:
        return
    if is_prime(n):
        yield n
    yield from primes_gen(n-1)
```

Q7: Generate Preorder

Part 1:

First define the function `preorder`, which takes in a tree as an argument and returns a list of all the entries in the tree in the order that `print_tree` would print them.

The following diagram shows the order that the nodes would get printed, with the arrows representing function calls.



preorder

Note: This ordering of the nodes in a tree is called a preorder traversal.

```
def preorder(t):
    """Return a list of the entries in this tree in the order that they
    would be visited by a preorder traversal (see problem description).

    >>> numbers = tree(1, [tree(2), tree(3, [tree(4), tree(5)]), tree(6, [tree(7)])])
    >>> preorder(numbers)
    [1, 2, 3, 4, 5, 6, 7]
    >>> preorder(tree(2, [tree(4, [tree(6)])]))
    [2, 4, 6]
    """
    if branches(t) == []:
        return [label(t)]
    flattened_branches = []
    for child in branches(t):
        flattened_branches += preorder(child)
    return [label(t)] + flattened_branches

# Alternate solution
from functools import reduce

def preorder_alt(t):
    return reduce(add, [preorder_alt(child) for child in branches(t)], [label(t)])
```

Part 2:

Similarly to `preorder` defined above, define the function `generate_preorder`, which takes in a tree as an argument and now instead `yield`s the entries in the tree in the order that `print_tree` would print them.

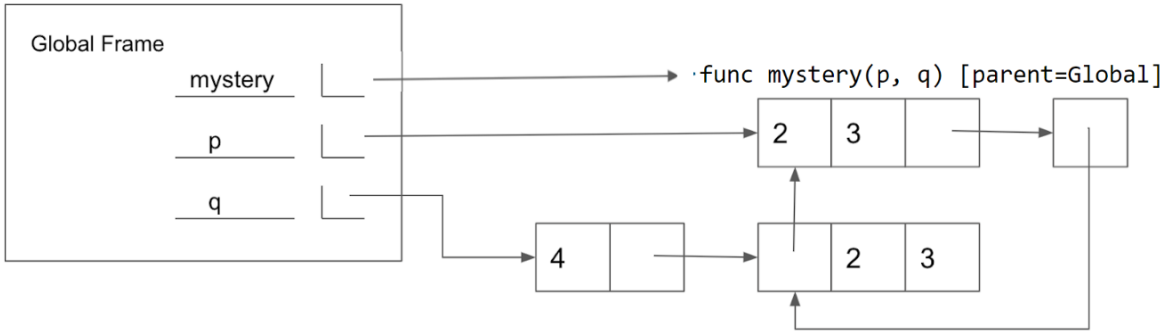
> **Hint:** How can you modify your implementation of `preorder` to `yield from` your recursive calls instead of returning them?

```
def generate_preorder(t):
    """Yield the entries in this tree in the order that they
    would be visited by a preorder traversal (see problem description).

    >>> numbers = tree(1, [tree(2), tree(3, [tree(4), tree(5)]), tree(6, [tree(7)])])
    >>> gen = generate_preorder(numbers)
    >>> next(gen)
    1
    >>> list(gen)
    [2, 3, 4, 5, 6, 7]
    """
    yield label(t)
    for b in branches(t):
        yield from generate_preorder(b)
```

Q8: (Optional) Mystery Reverse Environment Diagram

Fill in the lines below so that the variables in the **global frame** are bound to the values below. Note that the image does not contain a full environment diagram. **You may only use brackets, colons, `p` and `q` in your answer.**

Hint: If you get stuck, feel free to try out different combinations in PythonTutor!



envdiagram

```
def mystery(p, q):
    p[1].extend(q)
    q.append(p[1:])

p = [2, 3]
q = [4, [p]]
mystery(q, p)
```