MUTABLE DATA AND NONLOCAL 5

COMPUTER SCIENCE 61A

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1 Mutating Lists

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

```
>>> pizza1 = ['cheese', 'mushrooms']
```

Five minutes later, you realize that you really want onions on the pizza. Based on what we know so far, Domino's would have to build an entirely new list to add onions:

```
>>> pizza2 = pizza1 + ['onions']
>>> pizza2
['cheese', mushrooms', 'onions']
>>> pizza1 # the original list is unmodified
['cheese', 'mushrooms']
```

But this is silly, considering that all Domino's had to do was add onions on top of `pizza1` instead of making an entirely new `pizza2`.

Python actually allows you to *mutate* some objects, includings lists and dictionaries. Mutability means that the object's contents can be changed. So instead of building a new `pizza2`, we can use `pizza1.append('onions')`. Now `pizza1` would be

```
>>> pizza1.append('onions')
>>> pizza1
['cheese', 'mushrooms', 'onions']
```

Although lists and dictionaries are mutable, many other objects, such as numeric types, tuples, and strings, are *immutable*, meaning they cannot be changed once they are created.

1.1 What Would Python Output?

Consider the following definitions and assignments and determine what Python would output for each of the calls below *if they were evaluated in order*. Draw the box and pointers diagrams to the right in order to keep track of the state.

1.
```
>>> lst1 = [1, 2, 3]
>>> lst2 = lst1
>>> lst2 is lst1
```

Solution: `True`

2.
```
>>> lst1.append(4)
>>> lst1
```

Solution: `[1, 2, 3, 4]`

3.
```
>>> lst2
```

Solution: `[1, 2, 3, 4]`

4.
```
>>> lst2[1] = 42
>>> lst2
```

Solution: `[1, 42, 3, 4]`

5.
```
>>> lst1
```

Solution: `[1, 42, 3, 4]`

6.
```
>>> lst1 = lst1 + [5]
>>> lst1
```

Solution: `[1, 42, 3, 4, 5]`

7.
```
>>> lst2
```

Solution: `[1, 42, 3, 4]`

8. `>>> lst2 is lst1`

Solution: `False`

2 List Methods

List *methods* are functions that are bound to a specific list. They're called using *dot notation*, in the form `lst.method()`. Some common list methods:

- `lst.append(el)` mutates `lst` to add `el` to the end
- `lst.insert(i, el)` mutates `lst` to add `el` at index `i`
- `lst.sort()` mutates `lst` to sort elements in place
- `lst.remove(el)` mutates `lst` to remove the first occurrence of `el` in `lst`. If `el` is not in `lst`, an error will be thrown.
- `lst.index(el)` returns the index of the first occurence of `el` in `lst`. If `el` is not in `lst`, an error will be thrown. This method does not mutate `lst`.

None of the mutating list methods *return* a new list — they simply modify the original list and return `None`.

2.1 List Mutation Questions

1. Write a function `square_elements` which takes a `lst` and replaces each element with the square of that element. *Mutate* `lst` *rather than returning a new list*.

```
def square_elements(lst):
    """Squares every element in lst.
    >>> lst = [1, 2, 3]
    >>> square_elements(lst)
    >>> lst
    [1, 4, 9]
    """
```

Solution:

```
    for i in range(len(lst)):
        lst[i] = lst[i]**2
```

2. Write a function which reverses a list using mutation. Don't use the `reverse` list method.

```
def reverse_list(lst):
    """Reverses lst in-place (mutating the original list).
    >>> lst = [1, 2, 3, 4]
    >>> reverse_list(lst)
    >>> lst
    [4, 3, 2, 1]
    >>> pi = [3, 1, 4, 1, 5]
    >>> reverse_list(pi)
    >>> pi
    [5, 1, 4, 1, 3]
    """
```

Solution:

```
    for i in range(len(lst)//2):
        lst[i], lst[len(lst) - i - 1] = \
            lst[len(lst) - i - 1], lst[i]
```

2.2 Extra Practice

1. Write a function which takes in a list `lst`, and two values `x` and `y`, and adds as many `y`s to the end of `lst` as there are `x`s. Do not use the `count` list method.

```
def add_this_many(x, y, lst):
    """Adds y to the end of lst the number of times x occurs.
    >>> lst = [1, 2, 4, 2, 1]
    >>> add_this_many(1, 5, lst)
    >>> lst
    [1, 2, 4, 2, 1, 5, 5]
    """
```

Solution:

```
    count = 0
    for el in lst:
        if el == x:
            count += 1
    while count > 0:
```

```
        lst.append(y)
        count -= 1
```

2. Write a function that removes all instances of `el` from `lst`.

```
def remove_all(el, lst):
    """Removes all instances of el from lst.
    >>> x = [3, 1, 2, 1, 5, 1, 1, 7]
    >>> remove_all(1, x)
    >>> x
    [3, 2, 5, 7]
    """
```

Solution:

```
    while el in lst:
        lst.remove(el)
```

3 Dictionaries

Dictionaries are data structures which map keys to values. Dictionaries in Python are unordered, unlike real-world dictionaries — in other words, key-value pairs are not arranged in the dictionary in any particular order. Let's look at an example:

```
>>> pokemon = {'pikachu': 25, 'dragonair': 148, 'mew': 151}
>>> pokemon['pikachu']
25
>>> pokemon['jolteon'] = 135
>>> pokemon
{'jolteon': 135, 'pikachu': 25, 'dragonair': 148, 'mew': 151}
>>> pokemon['ditto'] = 25
>>> pokemon
{'jolteon': 135, 'pikachu': 25, 'dragonair': 148,
'ditto': 25, 'mew': 151}
```

The *keys* of a dictionary can be any *immutable* value, such as numbers, strings, and tuples. Dictionaries themselves are mutable; we can add, remove, and change entries after creation. There is only one value per key, however — if we assign a new value to the same key, it overrides any previous value which might have existed.

To access the value of `dictionary` at `key`, use the syntax

```
dictionary[key]
```

Element selection and reassignment work similarly to sequences, except the square brackets contain the key, not an index.

3.1 What Would Python Output?

Assume these commands are entered in order after the above code has been executed in the interpreter.

1. `>>> 'mewtwo' in pokemon`

   Solution: `False`

2. `>>> len(pokemon)`

   Solution: `5`

3. ```
   >>> pokemon['ditto'] = pokemon['jolteon']
   >>> pokemon[('diglett', 'diglett', 'diglett')] = 51
   >>> pokemon[25] = 'pikachu'
   >>> pokemon
   ```

   Solution:

   ```
   {'mew': 151, 'ditto': 135, 'jolteon': 135, 25: 'pikachu',
   'pikachu': 25, ('diglett', 'diglett', 'diglett'): 51,
   'dragonair': 148}
   ```

4. ```
   >>> pokemon['mewtwo'] = pokemon['mew'] * 2
   >>> pokemon
   ```

   Solution:

   ```
   {'mew': 151, 'ditto': 135, 'jolteon': 135, 25: 'pikachu',
   'pikachu': 25, ('diglett', 'diglett', 'diglett'): 51,
   'mewtwo': 302, 'dragonair': 148}
   ```

5. `>>> pokemon[['firetype', 'flying']] = 146`

Solution: `Error: unhashable type`

Note that the last example demonstrates that dictionaries cannot use other mutable data structures as keys. However, dictionaries can be arbitrarily deep, meaning the *values* of a dictionary can be themselves dictionaries.

3.2 Using Dictionaries

- To add `val` corresponding to `key` *or* to replace the current value of `key` with `val`:

```
dictionary[key] = val
```

- To iterate over a dictionary's keys:

```
for key in dictionary: # OR for key in dictionary.keys()
    do_stuff()
```

- To iterate over a dictionary's values:

```
for value in dictionary.values():
    do_stuff()
```

- To iterate over a dictionary's keys and values:

```
for key, value in dictionary.items():
    do_stuff()
```

- To remove an entry in a dictionary:

```
del dictionary[key]
```

- To get the value corresponding to `key` and remove the entry:

```
dictionary.pop(key)
```

3.3 Dictionary Questions

1. Given a dictionary `d`, replace all occurences of `x` *as a value (not a key)* with `y`.

```
def replace_all(d, x, y):
    """
    >>> d = {'foo': 2, 'bar': 3, 'garply': 3, 'xyzzy': 99}
    >>> replace_all(d, 3, 'poof')
    >>> d
    {'foo': 2, 'bar': 'poof', 'garply': 'poof', 'xyzzy': 99}
    """
```

Solution:

```
    for key in d:
        if d[key] == x:
            d[key] = y
```

3.4 Extra Practice

1. Given an arbitrarily deep dictionary `d`, replace all occurences of `x` *as a value (not a key)* with `y`. Hint: You will need to combine iteration and recursion.

```
def replace_all_deep(d, x, y):
    """
    >>> d = {1: {2: 3, 3: 4}, 2: {4: 4, 5: 3}}
    >>> replace_all_deep(d, 3, 1)
    >>> d
    {1: {2: 1, 3: 4}, 2: {4: 4, 5: 1}}
    """
```

Solution:

```
    for key in d:
        if d[key] == x:
            d[key] = y
        elif type(d[key]) == dict:
            replace_all_deep(d[key], x, y)
```

2. Given a (non-nested) dictionary `d`, write a function which deletes all occurrences of `x` as a value. You cannot delete items in a dictionary as you are iterating through it.

```
def remove_all(d, x):
    """
    >>> d = {1:2, 2:3, 3:2, 4:3}
    >>> remove_all(d, 2)
    >>> d
    {2: 3, 4: 3}
    """
```

Solution:

```
    keys_to_delete = [key for key in d if d[key] == x]
    for key in keys_to_delete:
        del d[key]
```

4 Nonlocal

The `nonlocal` keyword can be used to modify a variable in the parent frame outside the current frame (as long as it's not the global frame). For example, consider `make_step`, which uses `nonlocal` to modify `num`:

```
def make_step(num):
    def step():
        nonlocal num
        num = num + 1
        return num
    return step
```

4.1 Nonlocal Environment Diagrams

1. Draw the environment diagram for the following series of calls after `make_step` has been defined:

```
>>> s = make_step(3)
>>> s()
>>> s()
```

Solution: See Python Tutor.

4.2 Nonlocal Misconceptions

For each of the following pieces of code, explain what's wrong with the use of nonlocal.

1.
```
a = 5
def add_one(x):
    nonlocal x
    x += 1

>>> add_one(a)
```

Solution: Nonlocal cannot be used if there is no variable x defined in a parent frame. Here x is already a local variable.

2.
```
a = 5
def another_add_one():
    nonlocal a
    a += 1

>>> another_add_one(a)
```

Solution: Nonlocal cannot be used to modify variables in the global frame.

4.3 Extra Practice

1. Given the definition of `make_shopkeeper` below, draw the environment diagram.

```
def make_shopkeeper(total_gold):
    def buy(cost):
        nonlocal total_gold
        if total_gold < cost:
            return 'Go farm some more champions'
        total_gold = total_gold - cost
        return total_gold
    return buy

infinity_edge, zeal, gold = 3800, 1100, 3800
shopkeeper = make_shopkeeper(gold - 1000)
shopkeeper(zeal)
shopkeeper(infinity_edge)
```

Solution: See Python Tutor.