IIT Madras
BSc Degree

Lesson-5.2

Lists

Mutability

Consider the following problem:

> Assume that you work at a company that analyzes cricket matches. As a part of the data collection process in the IPL, the data-processing team is tasked with recording the runs scored in every ball in every match. It is your colleague's turn to do the bookkeeping for the final match between CSK and MI. Just before the start, the "0" key on his keyboard stops functioning. As a workaround, you cleverly suggest that he use the letter "O" instead of 0. Once the match is over, you collect the list of runs scored. Write a program that replaces all appearances of the letter "O" with the number 0. I leave it to your imagination to decide who won the finals!

Solution

```python
runs = [1, 4, 2, 'O', 4, 'O'] # the data for one over is given here
print(runs)
for i in range(len(runs)):
    if runs[i] == 'O':
        runs[i] = 0
print(runs)
```

The most interesting line is the fifth one: `runs[i] = 0`. We are updating a list **in-place**. Python permits this operation because lists are **mutable**. Contrast this with strings that are immutable, which means that they cannot be updated in-place. Mutability makes lists powerful; but reckless exercise of power always results in instability as is demonstrated by this notorious example:

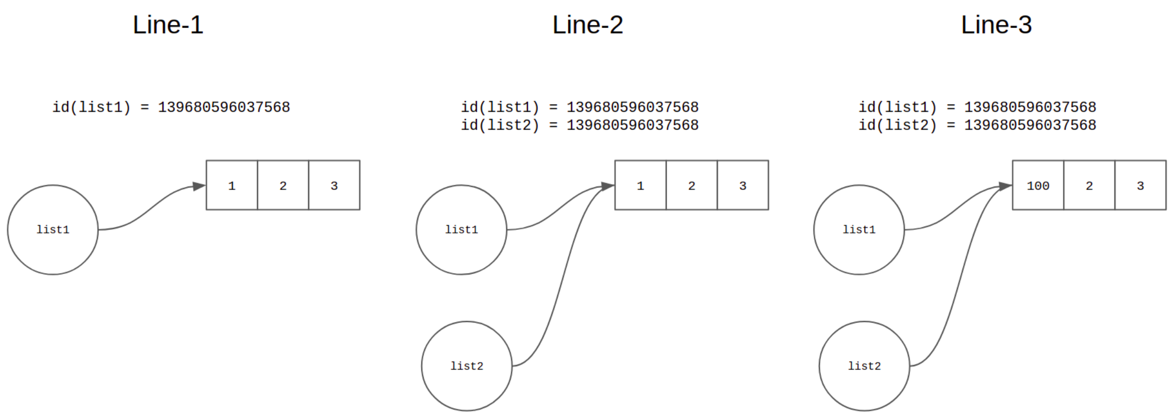
```python
list1 = [1, 2, 3]
list2 = list1
list2[0] = 100
print(list1)
print(list2)
```

Both give the same output even though we are only modifying `list2` in-place!

```
[100, 2, 3]
[100, 2, 3]
```

What is happening here? To understand this, we will take the help of a built-in function called `id`. Every object in Python has a unique identity: if `x` is an object, then `id(x)` returns this object's identity. From the Python documentation, "this is guaranteed to be unique among simultaneously existing objects". In the implementation of the Python that we use, this unique `id` is nothing but the object's memory address.

```python
1   list1 = [1, 2, 3]
2   list2 = list1
3   list2[0] = 100
```



Line-1
id(list1) = 139680596037568
list1
1 2 3
Line-2
id(list1) = 139680596037568
id(list2) = 139680596037568
list1
list2
1 2 3
Line-3
id(list1) = 139680596037568
id(list2) = 139680596037568
list1
list2
100 2 3

In line-2, we are *not* creating a new object. We are merely creating another name, also called an alias, for the same object. Think of this like having a nickname. Your name and nickname are two different words, but both of them refer to you. To see if two Python names point to the same object, we can use the `is` keyword:

```python
list1 = [1, 2, 3]
list2 = list1
list2[0] = 100
print(list1 is list2)
```

This prints `True`. Now consider another scenario:

```python
list1 = [1, 2, 3]
list2 = [1, 2, 3]
print(list1 == list2)
print(list1 is list2)
```

This gives the following output:

```
True
False
```

This because equality and identity are two different things. In the code, line-3 checks for equality of two lists, line-4 checks if the two lists point to the same object. `list1` and `list2` point to two different objects and consequently have different identities. But, they store the same sequence of items and are hence equal.

How do we create a copy of a list so that updating one doesn't end up changing both? Python provides three ways to do this:

```
 1  list1 = [1, 2,  3]
 2  list2 = list(list1)
 3  list3 = list1[:]
 4  list4 = list1.copy()
 5
 6  list2[0] = 100
 7  list3[0] = 200
 8  list4[0] = 300
 9
10  print(list1, list2, list3, list4)
11  print(list1 is not list2, list1 is not list3, list1 is not list4)
```

This results in the following output:

```
[1, 2, 3] [100, 2, 3] [200, 2, 3] [300, 2, 3]
True True True
```

- In line-2, we pass `list1` as an argument to the `list` function which returns a new list object with the same sequence of elements as `list1`.
- In line-3, we are slicing the list. Slicing a list results in a new list object. As no `start` or `stop` values are mentioned, they are going to default to `0` and `len(list1)` respectively. So, the entire list is returned. However, it is a brand new object.
- In line-4, we use a method call `copy` that is defined for the `list` object.

Lines 10 and 11 verify that the methods used to copy lists in lines 2, 3 and 4 actually work.

Call by reference

Mutability impacts the way lists are handled in functions. Consider these two snippets:

```
# Snippet-1
def foo():
    L.append(1)

L = [0]
print(f'L before: {L}')
foo()
print(f'L after: {L}')
```

`Snippet-1` doesn't have any parameters. Since `L` is not being assigned a new value inside `foo`, the scope of `L` remains global.

```
1  # Snippet-2
2  def foo(L_foo):
3      L_foo.append(1)
4      print(L is L_foo)
5  
6  L = [0]
7  print(f'L before: {L}')
8  foo(L)
9  print(f'L after: {L}')
```

`Snippet-2` has `L_foo` as a parameter whose scope is local to `foo`. But note that modifying `L_foo` within the function changes `L` outside the function. This is because, `L_foo` and `L` point to the same object. How did this aliasing happen? The function call at line-8 works something like an assignment statement: `L_foo = L`, so `L_foo` is just another name that refers to the object that `L` is bound to. This type of function call where a reference to an object is passed is termed call by reference. Whenever a mutable variable is passed as an argument to a function, the references to the corresponding object are passed.

If all this seems too complicated, just remember that modifying mutable objects within a function produces side effects outside the function. What if we don't want these side effects? We have to create a new list object like we did before:

```
1  def foo(L_foo):
2      L_foo.append(1)
3      print(L is L_foo)
4  
5  L = [0]
6  print(f'L before: {L}')
7  foo(list(L))
8  print(f'L after: {L}')
```

`foo` doesn't produce any side effects. Line-7 could be replaced with `foo(L[:])` or `foo(L.copy())`.