COMP1730/COMP6730

Programming for Scientists

More about lists

Lecture outline

- **Lists**
- Mutable objects & references

Sequence data types (recap)

- A *sequence* contains $n \geq 0$ values (its *length*), each at an *index* from 0 to $n - 1$.
- python's built-in sequence types:
  - strings (`str`) contain only characters;
  - lists (`list`) can contain a mix of value types;
  - tuples (`tuple`) are like lists, but immutable.
- Sequence types provided by other modules:
  - e.g., NumPy arrays (`numpy.ndarray`).

Lists

- python’s `list` is a general sequence type: elements in a `list` can be values of any type.
- List literals are written in square brackets with comma-separated elements:

```
>>> a_list_of_ints = [2, −4, 2, −8 ]
>>> a_date = [12, "August", 2015]
>>> pairs = [ [ 0.4, True ],
              [ "C", False ] ]
>>> type(pairs)
<class ’list’>
```

Creating lists

```
>>> monday = [18, "July"]
>>> friday = [22, "July"]
>>> [monday, friday]
[ [18, "July"], [22, "July"] ]
>>> list("abcd")
[’a’, ’b’, ’c’, ’d’]
>>> list(range(10))
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

List comprehension

- Create a list by evaluating an expression for each element in a sequence:

```
>>> [1/x for x in [1,2,3,4,5]]
[1.0, 0.5, 0.3333333, 0.25, 0.2]
>>> [ord(c) for c in "abcd"]
[97, 98, 99, 100]
```

- Conditional list comprehension selects only elements that satisfy a condition:

```
>>> [i for i in range(2,12) if 12 % i == 0]
[2, 3, 4, 6]
```

Lists of lists

```
>>> A = [ [1, 2], [3, 4, 5],
          [6, 7, 8, 9] ]
>>> A[0]
[1, 2]
>>> A[1][2]
5
>>> [1, 2, 3][2]
3
```

- Indexing and slicing are *operators*
- Indexing and slicing associate to the left. `a_list[i][j] == (a_list[i])[j]`.

Lists of lists

```
>>> A[0]
[1, 2]
>>> A[0:1]
[ [1, 2] ]
>>> A[0:1][1:]
[ ]
>>> A[0:1][1]
IndexError: list index out of range
```

- Indexing a list returns an element, but slicing a list returns a list.

Operations on lists

- `list + list` concatenates lists:

```
>>> [1, 2] + [3, 4]
[1, 2, 3, 4]
```

- `int * list` repeats the list:

```
>>> 2 * [1, 2]
[1, 2, 1, 2]
```

- Equality, `list == list`, and ordering comparisons, `list < list`, `list >= list`, etc, work the same way as for other (standard) sequence types, such as strings.

Lecture outline

- Lists
- **Mutable objects & references**

Values are objects

- In python, every value is an *object*.
- Every object has a unique$^{(\star)}$ identifier.

  ```
  >>> id(1)
  136608064
  ```

  (Essentially, its location in memory.)
- *Immutable* objects never change.
  - For example, numbers (`int` and `float`), strings and tuples.
- *Mutable* objects can change.
  - For example, lists.

Immutable objects

- Operations on immutable objects create new objects, leaving the original unchanged.

```
>>> a_string = "spam"
>>> id(a_string)
3023147264
>>> b_string = a_string.replace(’p’, ’l’)
>>> b_string
’slam’
>>> id(b_string)
3022616448
>>> a_string
’spam’
```

not the same!

Mutable objects

- A mutable object can be modified yet its identity remains the same.
- Lists can be modified through:
  - element and slice assignment; and
  - modifying methods/functions.
- `list` is the only mutable type we have seen so far but there are many other (sets, dictionaries, user-defined classes).

Element & slice assignment

```
>>> a_list = [1, 2, 3]
>>> id(a_list)
3022622348
>>> b_list = a_list
>>> a_list[2] = 0
>>> b_list
[1, 2, 0]
>>> b_list[0:2] = [’A’, ’B’]
>>> a_list
[’A’, ’B’, 0]
>>> id(b_list)
3022622348
```

the same object!

Modifying list methods

- *a_list*.append(*new element*)
- *a_list*.insert(*index*, *new element*)
- *a_list*.pop(*index*)
  - *index* defaults to −1 (last element).
- *a_list*.remove(*a value*)
- *a_list*.extend(*an iterable*)
- *a_list*.sort()
- *a_list*.reverse()
- Note: Most do not return a value.

Passing a mutable data type to a function

- We need to be aware that function argument passing follows the same rules as assignment.
- The form of argument-passing and object assignment described above is called “pass-by-object-reference” in the python community.
- Thus mutable data types such as list use pass by reference semantics in function calling, and so we need to be careful that a function does not inadvertently modify an argument.

Passing a mutable data type to a function

```
# return list with 0 at end
def f(input_list):
     input_list.append(0)
     return input_list

ll = [1,2,3]
b = f(ll)
print(b)
print(ll) # ll unexpectedly modified
```

Copying a mutable data structure

- A copy can be made of a mutable data structure such as list by its *copy* method, or the *copy* function in module *copy*.
- `a_list = [1,2,3]`
- `b_list = a_list.copy()`
- `import copy`
- `b_list = copy.copy(a_list)`

Passing an immutable data type to a function

- The form of argument-passing and object assignment described above is called “pass-by-object-reference” in the python community.
- Note that, strictly, the same “pass-by-object-reference” mechanism is used for all types including immutable data types such as floating point numbers.
- However, as such types are immutable the effect is essentially the same as pass-by-value in practice.

Lists contain references

- Assignment associates a (variable) name with a *reference* to a value (object).
  - The variable still references the same object (unless reassigned) even if the object is modified.
- *A list contains references to its elements.*
- Slicing a list creates a new list, but containing references to the same objects (“shallow copy”).
- Slice assignment *does not copy*.

```
>>> a_list = [1,2,3]
>>> b_list = a_list
>>> a_list.append(4)
>>> print(b_list)
```

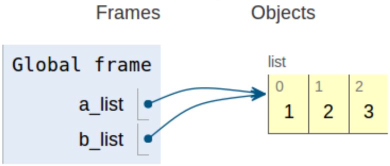
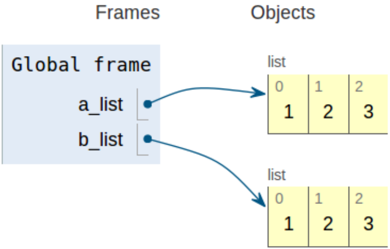


Image from `pythontutor.com`

```
>>> a_list = [1,2,3]
>>> b_list = a_list[:]
>>> a_list.append(4)
>>> print(b_list)
```



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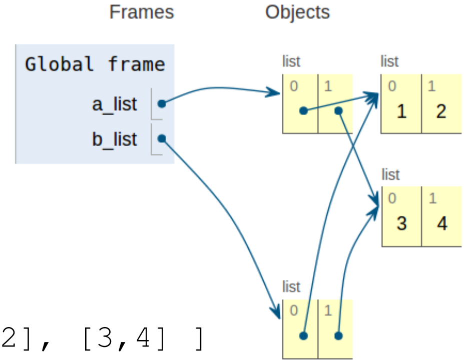

```
>>> a_list = [ [1,2], [3,4] ]
>>> b_list = a_list[:]
>>> a_list[0].reverse()
>>> b_list.reverse()
>>> print(b_list)
```

Image from `pythontutor.com`

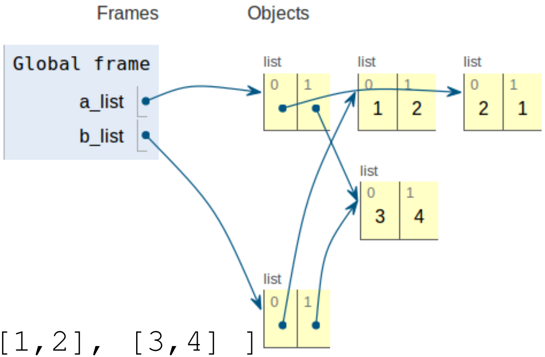

Image from `pythontutor.com`

```
>>> a_list = [ [1,2], [3,4] ]
>>> b_list = a_list[:]
>>> a_list[0] = a_list[0][::-1]
>>> b_list.reverse()
>>> print(b_list)
```

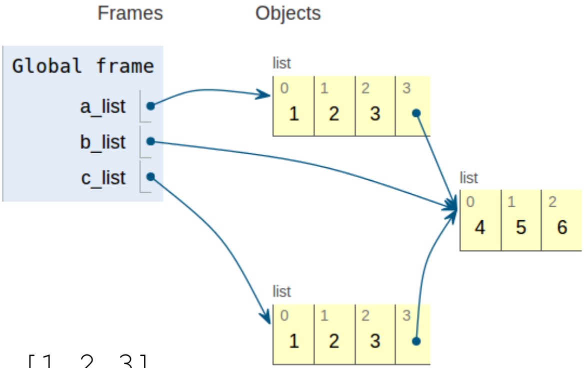

Image from `pythontutor.com`

```
>>> a_list = [1,2,3]
>>> b_list = [4,5,6]
>>> a_list.append(b_list)
>>> c_list = a_list[:]
>>> b_list[0] = 'A'
```

Shallow vs. deep copy

```
>>> import copy
>>> a_list = [[1,2], [3,4]]
>>> id(a_list)
3054870700
>>> id(a_list[0]), id(a_list[1])
(3054874028,3073291596)
>>> b_list = a_list[:]
>>> id(b_list)
3072077420
>>> id(b_list[0]), id(b_list[1])
(3054874028,3073291596)
>>> c_list = copy.deepcopy(a_list)
>>> id(c_list[0]), id(c_list[1])
(3057394764,3057585932)
```

equal!

not equal!

Use `deepcopy` judiciously

- Creating 10,000 copies of a list of 1,000 lists of 10 integers.

	Time	Memory
Shallow copy	0.4s	39.3 MB
Deep copy	305 s	1071 MB

Common mistakes

```
>>> a_list = [3,1,2]
>>> a_list = a_list.sort()

>>> a_list = [1,2,3]
>>> b_list = a_list
>>> a_list.append(b_list)

>>> a_list = [[]] * 3
>>> a_list[0].append(1)
```