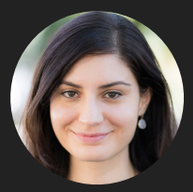
02-08-2023

CS051A

INTRO TO COMPUTER SCIENCE WITH TOPICS IN AI
7: Boolean variables, aliasing, and parameter passing



Alexandra Papoutsaki

she/her/hers

Lectures

Zilong Ye

he/him/his

Labs

Welcome to lecture 7! How did the lab go?

Lecture 7: Boolean variables, aliasing, and parameter passing

- Python function calls
- Booleans
- Sequences
- Aliasing
- Parameter Passing

Today, we will wrap up Lecture 6 by talking about tuples that you saw with Prof Ye in the lab. We will then get into a number of topics that will deepen our understanding of Python and programming languages in general. The first one will tackle the flow of our Python programs when we call functions.

What happens when a function gets called?

- Let's look at this simple file `function-calls.py`
- We can walkthrough what happens when we make a call to `add_then_double`, e.g., `add_then_double(10, 20)`
- 1. The arguments to the function (`10` and `20`) are evaluated.
  - They could have been more complicated expressions, e.g., `add_then_double(5+5, 40/2)`
- 2. The function is then called and the parameters are associated with the arguments that are passed in. Think of it like saying `a = 10` and `b = 20`.
  - We now have two variables in the function that have the values of the arguments.
  - The only tricky thing is that these variables are unique to this function, so even if they're defined globally (outside any function), they will be different than the global variables.

Let's start by looking at the file function-calls.py. We can see that there is a function called `add_then_double`. Let's see what happens when we call add_then_double(10, 20). First, the arguments to the function (10 and 20) are evaluated. Notice that they could have been more complicated expressions that we pass as arguments, e.g., add_then_double(5+5, 40/2).
Second, the function is then called and the parameters are associated with the arguments that are passed in. Think of it like saying a = 10 and b = 20.
We now have two variables in the function that have the values of the arguments.
The only tricky thing is that these variables are unique to this function, so even if they're defined globally (outside any function), they will be different than the global variables.

What happens when a function gets called? (cont'd)

- 3. The function body for `add_then_double` is executed one statement at a time.
  - This will in turn call `add(a, b)`. Like any other function call, we:
    - evaluate the arguments, in this case, we evaluated `a`, which gives us `10`, and `b`, which gives us `20`,
    - we then pass these values to `add` and associate them with parameters `num1` and `num2`.
    - `add` is only one line of code, it adds the number and then returns that value.
      - `num1 + num2` gives us `30` (`10 + 20`)
    - the `return` statement means wherever this function was called, that is the value that call should represent.
      - the call `add(a, b)` will then represent the value `30`
  - We then assign what `add(a,b)` returns to the variable `added`.
  - `double` is called with what was in the variable `added` (`30`) and following the same logic as above gives us back `60`
  - `60` is then associated with the variable `doubled`.
  - Finally, `add_then_double` returns `doubled`, which has the value `60`.

The third step includes the execution of the add_then_double body, one statement at a time.
This will in turn call add(a, b). Like any other function call, we will start by evaluating the arguments (in this case, we evaluated a, which gives us 10, and b, which gives us 20). We then pass these values to add and associate them with parameters num1 and num2. add is only one line of code, it adds the number and then returns that value. num1 + num2 gives us 30 (10 + 20). The return statement means wherever this function was called, that is the value that call should represent. The call add(a, b) will then represent the value 30. We then assign what add(a,b) returns to the variable added. Then function double is called with what was in the variable added (30) and following the same logic as above gives us back 60. 60 is then associated with the variable doubled. Finally, add_then_double returns doubled, which has the value 60.

What happens when a function gets called? (cont'd)

- If we called `add_then_double` from the Python console/shell, we will see the value `60` echoed, not because it was printed out but because that call (`add_then_double(10, 20)`) now represents the value `60`.
- We could just have easily done other things with it, e.g.,

```
>>> add_then_double(10,20)
60
>>> add_then_double(10,20) * 2
120
>>> result = add_then_double(10,20)
>>> result
60
>>> add_then_double(add_then_double(10,20),4)
128
```

If we called add_then_double from the Python console/shell, we will see the value 60 echoed, not because it was printed out but because that call (add_then_double(10, 20)) now represents the value 60. But we could have easily done more complex things with our calls.

Lecture 7: Boolean variables, aliasing, and parameter passing

- Python function calls
- Booleans
- Sequences
- Aliasing
- Parameter Passing

We will switch gears now and talk about booleans which we have seen that are represented with the type bool.

Practice time

- Write a function called `contains` that takes a list and an item and returns `True` if the item is in the list, `False` otherwise, i.e. `def contains(some_list, value):`
- Look at the `contains` function in `contains.py` file
  - Loops through each value in the list.
  - If it finds one that is equal to the item we're looking for, then return `True`
    - Remember that `return` immediately exits the function. This will stop the loop and then give back True from the function.
  - if we make it through the entire list without finding one that's equal, then the loop will finish and we'll return `False`.
    - This is similar to the `isprime` function we saw before in `while.py` code
- The `contains_alternative` function in `contains.py` code is another way of accomplishing this.
  - We use a variable `found` to keep track of whether or not we've found the item and we initialize to `False`.
  - We then loop through all of the values of the list.
  - If we find the item we're looking for, we set the variable `found` to `True`
    - it's fine to set `found` to `True` again if the item exists multiple times in the list.
  - After the loop finishes, we return `found`
    - If we didn't find any, it will still be `False`, otherwise, it will have been set to `True`.

To practice, let’s start by writing a function contains that will take as a parameter a list and an item and will return True if the item is in the list and False otherwise. You can look at the file contains.py to see two versions of contains that use a similar idea (a while loop) to go over the list and compare each of the elements of the list with the provided item. The difference is that in the second version we will use an intermediate bool variable to keep track of whether we have located the item while in the first version, we will return True/False directly.

Built-in contains functionality

- Python has a built-in contains functionality in the form of the `in` keyword that works for lists, strings, and tuples (i.e. sequences).
- Notice that for lists, the item has to be in the list as one of the individual items, we cannot check for a slice.
- But this is not a problem in strings. We can check whether a string contains an entire substring not just a single character.

```
>>> 2 in [1, 2, 3]
True
>>> 5 in [1, 2, 3]
False
>>> "banana" in [1, 2, 3]
False
>>> [1, 2] in [1, 2, 3]
False
>>> [1, 2] in [[1, 2], 2, 3]
True
>>> "a" in "banana"
True
>>> "ana" in "banana"
True
```

Actually, Python has a built-in contains functionality in the form of the in keyword that works for all sorts of sequences. Notice that in behaves slightly differently in lists and strings when it comes to searching for multiple elements.

number-game.py

- Picks a random number between 1 and 20 and keeps prompting the user to guess it until they get it right.
  - It provides hints as to whether they need to guess higher or lower.
- How can we implement this game?
  - We can pick a random guess that the user will have to guess.
  - As long as (`while`) the user hasn't guessed the right answer:
    - Ask the user for their guess.
  - If it's the right answer, print out "Good job!" and somehow indicate that we're done looping.
  - Otherwise, if the guess is too low print out ("A bit higher").
  - Otherwise (i.e. the guess must be too high), print out ("A bit lower").

Time to play a game! If we run at the number-game.py file, we will see that it picks a random number between 1 and 20 and asks us to guess it by giving us hints until we get it :) (what a nice game!).

`number_guessing_game` function in `number-game.py`

- Uses a variable called `correct` and initially sets it to `False`.
- Repeats the same steps while `correct` remains `False` (`while not correct:`).
  - We could have also use a variable like `still_guessing` and set it to `True` and then had `while still_guessing`:
- When the user guesses the right number, we set `correct` to `True` and therefore exit the loop.
- Notice that there are other ways of writing this function, e.g., `number_guessing_game2`

If we look at how the game is actually implemented, we will notice a number_guessing_game function that uses a variable set to False and a while loop that keeps checking whether that variable has been changed to True. If not, it will keep prompting us to keep making guesses and it will give us hints as we provide our guess. Notice that there are other ways of writing this function, e.g., number_guessing_game2

Lecture 7: Boolean variables, aliasing, and parameter passing

- Python function calls
- Booleans
- Sequences
- Aliasing
- Parameter Passing

Let's go back momentarily into sequences, data structures that store data sequentially (e.g., lists, strings, tuples).

A few more sequence operators

- We've seen + for concatenating strings. It also works on other sequences!
- What do you think sequence*x does?
  - Repeats the sequence x times

```
>>> "banana" + " split"
'banana split'
>>> [1, 2, 3] + [4, 5]
[1, 2, 3, 4, 5]
>>> (1, 2, 3) + (4, 5)
(1, 2, 3, 4, 5)
>>> "*" * 10
'**********'
>>> "I'm " + "very " * 4 + "excited"
"I'm very very very very excited"
>>> [0] * 10
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
>>> [1, 2, 3] * 2
[1, 2, 3, 1, 2, 3]
```

We have seen that strings can be concatenated with the + operator. We can apply the same operator for all types of sequences. Another operator that might come handy is the * which repeats the sequence as many times as we tell it. Cool, huh?

Lecture 7: Boolean variables, aliasing, and parameter passing

- Python function calls
- Booleans
- Sequences
- Aliasing
- Parameter Passing

We're pivoting now to a very different topic called aliasing.

Assignment (i.e. =)

- when we say `x = y`, what we're actually saying is let `x` reference the same thing that `y` references.
- `x` and `y` are still separate variables.
- If we say `x = z` that does NOT change the value of `y`.

```
>>> x = 1
>>> y = 2
>>> z = 3
>>> x = y
>>> x
2
>>> y
2
>>> z
3
>>> x = z
>>> x
3
>>> y
2
>>> z
3
```

Let’s start with the basics of assignment which we have seen that is accomplished with the =. When we say x = y, what we’re actually saying is let x reference the same thing that y references. But x and y are still separate variables. If we say now x = z, y will remain unaffected.

References

- Objects reside in memory. Anytime we create an `int`, `float`, `bool`, `str`, `list`, `tuple` it is allocated in memory.
- Variables are references to objects in memory. A variable does NOT hold the value itself, but it is a references to where that value resides.
  - Think of variables like your hands. You can point them at things and then ask questions:
    - what is the name of the thing that my right hand points to?
    - for the thing that my left hand points to, do something?
  - You can point them to new things (i.e. assignment)
  - You can point point them to the same thing (i.e. assignment one to the other) but they are separate things!
  - Similarly, variables are separate things. They can reference the same thing, but they are not the same thing.
- When you ask for the value of a variable, it's actually getting the value of the things it references in memory

In general, all objects we create reside in memory. Variables are actually just references to objects in memory. You can think of variables as your arms (imagine having as many arms as there are variables in your program). When we assign a value to a variable, we point the variable to a memory location that stores that information.

Objects in memory

- If an object is mutable (i.e. it has methods that change the object), then we have to be careful when we have multiple things referencing the same object (this is called aliasing).

```
>>> x = [1, 2, 3, 4, 5]
>>> y = x
>>> x
[1, 2, 3, 4, 5]
>>> y
[1, 2, 3, 4, 5]
```

- what does this look like in memory?
  - There is one list object. Both x and y are references to that same object.

Remember that some objects can be mutable? That is they have methods (special functions called with the dot operator) that change them. In this case, we have to be careful when we have multiple things referencing the same object. This is called aliasing.

Aliasing

- What happens when I call a method that changes/mutates the object?

```
>>> y.reverse()
>>> x
[5, 4, 3, 2, 1]
>>> y
[5, 4, 3, 2, 1]
```

- x and y are references to the same object! Statements that mutate the object that are done on either variable will affect this object.

```
>>> x[0] = 0
>>> x
[0, 4, 3, 2, 1]
>>> y
[0, 4, 3, 2, 1]
>>> y[0] = 15
>>> x
[15, 4, 3, 2, 1]
>>> y
[15, 4, 3, 2, 1]
```

Look at the examples on the right. What x and y will point to might or might not surprise you.

List equality

- == compares whether all corresponding elements of two lists are equal.
- `is` checks whether two references point to the same memory location

```
>>> list1 = [1, 2, 3, 4]
>>> list2 = [1, 2, 3, 4]
>>> list3 = list2
>>> list1 == list2
True
>>> list2 == list3
True
>>> list1 == list3
True
>>> list1 is list2
False
>>> list1 is list3
False
>>> list2 is list3
True
```

Let’s assume we create two lists, list1 and list2 that have the same contents, and make a new reference to list2 with the alias list3. Note the difference between the == operator and the is keyword. == compares whether corresponding elements in two lists are equal; this is why all of our equality checks evaluated to True. If we want to ask whether two identifiers reference the same memory location, we would need to use the is keyword.

ints/floats/bools/strings

- Why hasn't aliasing come up with ints/floats/bools/strings if they are objects?

```
>>> x = 10
>>> y = 10
```

- what does the memory picture look like?
  - We just have one int object!
  - x and y are both references to that one int object
- `int/float/bool/str` types are not mutable!
  - There is no way for us to change the underlying object. Therefore, even though two variables reference the same int, it's as if they referenced separate ints.

Aliasing comes up only with mutable objects (i.e. lists in our case). Any other type we have seen is immutable. If you take an int object, let's say the number 10, there's only one 10 in memory. Both x and y will point to that same 10 and they can't change it but they can point to a different number if we reassign them.

Practice time

- Draw the memory picture for the following:

```
>>> x = 10
>>> y = x
>>> y = 15
>>> x
10
>>> y
15
```

- We now have 2 objects (10 and 15). Just like with lists, changing what y references does not affect x.

This affects what our memory allocation looks like when we run the example above.

Lecture 7: Boolean variables, aliasing, and parameter passing

- Python function calls
- Booleans
- Sequences
- Aliasing
- Parameter Passing

Finally, I want to talk about parameter passing which is central to working with functions.

Parameter passing

- When we define a function's parameters we are defining the "formal parameters".

```
>>> def my_function(a, b):
...     return a + b
```

  - *a* and *b* are formal parameters. Until the function is actually called, they don't represent actual values.
  - When we call a function, the values that we give to the function are called the "actual parameters" or arguments.

```
>>> x = 10
>>> y = 20
>>> my_function(x, y)
30
```

- The values 10 and 20 are the actual parameters (or similarly, x and y become the arguments)

We have already talked about parameters and arguments. Parameters are also called formal parameters and arguments actual parameters.

When a function is called the following happens

- The values of the arguments are determined (we evaluate the expression representing each parameter).
  - The value is just an object (could be an `int`, `float`, `str`, etc).
- These values are then "bound" or assigned to the formal parameters
  - It's very similar to assignment.
    - The formal parameters represent new variables.
    - the formal parameters will then REFERENCE the same objects as those passed in through the arguments/actual parameters.

When a function is called, the values of the arguments are determined and then they are bound to the formal parameters, similar to assignment.

Referencing

- Let's consider the picture for the following code.

```
>>> x = 10
>>> y = 20
>>> my_function(x, y)
30
```

- x and y are both references to `int` objects.
- When we call `my_function`, the formal parameters a and b, will represent two new variables. These variables will reference the same thing as their actual parameters.
  - Think of it like running the statements: `a = x` and `b = y`.
  - a will reference the same thing as x
  - b will reference the same thing as y

In the example above, both x and y are references to int objects. When we call my_function, the formal parameters a and b, will represent two new variables. These variables will reference the same thing as their actual parameters.

(Im)mutability and referencing

- For immutable objects, this whole story doesn't really matter. They could be references to the same thing or copies but if we can't mutate the object, the behavior is the same.
- How does this change for mutable objects, such as lists?
  - x was a variable that references a list object
  - When the function was called, the formal parameter `numbers` will represent a new variable.
  - `numbers` will reference the same thing as x.
  - Think of it like running the statement
    - `numbers = x`
  - Because lists are mutable and since the formal parameter references the same object as what was passed in, changes made to the object referenced by `numbers` will also be seen in `x`.

```
>>> def changer(numbers):
...     numbers[0] = 100
...
...
... def no_changer(numbers):
...     numbers = [0] * 5
...
>>> x = [1, 2, 3, 4, 5]
>>> changer(x)
>>> x
[100, 2, 3, 4, 5]
```

For immutable objects, this whole story doesn't really matter. They could be references to the same thing or copies but if we can't mutate the object, the behavior is the same. The story is different for mutable objects such as lists. Look at the changer function which alters the first element in the list numbers (therefore it alters what x points to).

(Im)mutability and referencing

- Notice, however, that operations that do not change/mutate the object will NOT be seen outside the function
  - In this case, we're assigning `numbers` to some new object (list).
  - We can't change what `x` references!
  - `x` and `numbers` will no longer reference the same object.
    - Any changes to `numbers` after this will not affect `x`.
- Variable assignment and parameter passing is done based on the references (i.e. a shallow copy) rather than a deep copy of the whole object.
  - Performance (it takes work to copy the object).
  - Often, we just want the value and don't need to mutate the underlying object.

```
>>> def changer(numbers):
...     numbers[0] = 100
...
...
... def no_changer(numbers):
...     numbers = [0] * 5
...
>>> x = [1, 2, 3, 4, 5]
>>> changer(x)
>>> x
[100, 2, 3, 4, 5]
>>> no_changer(x)
>>> x
[100, 2, 3, 4, 5]
```

In contrast, the function no_changer, changes the reference of numbers to a new list altogether. Now x and numbers no longer point to the same part of memory! In general, parameter passing is done based on the references (i.e. a shallow copy) rather than a deep copy of the whole object. There are performance and other reasons that we might not want to mutate the underlying object.

Resources

- Textbook: Chapters 6
- function-calls.py
- contains.py
- number-game.py

Homework

- Assignment 3 (in progress)