Department of Computer Science and Engineering
PES University, Bangalore, India

Lecture Notes
Python for Computational Problem Solving
UE23CS151A

Lecture #65
Closures in python

By,
Prof. Sindhu R Pai
Anchor, PCPS - 2023
Prof. Apoorva MS
Assistant Professor
Dept. of CSE, PESU

Verified by,
Prof. Sowmyashree,

Many Thanks to
Dr. Shylaja S S (Director, CCBD and CDSAML Research Centers, Former Chairperson, CSE, PES University)
Prof. Chitra G M (Asst. Prof, Dept. of CSE, PCPS Anchor – 2022)

Introduction

A Closure in Python is a function object that remembers values in enclosing scopes even if they are not present in memory. It can also be defined as a nested function which has access to a free variable from an enclosing function that has finished its execution.

Nested functions are important in closures in Python because they allow you to access variables from the outer function even after the outer function has returned which makes the python code more concise and reusable.

Characteristics of Closures:

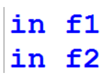
- It is a nested function
- It has access to a free variable in outer scope - A free variable is a variable that is not bound in the local scope. Closures with immutable variables such as numbers and strings - use the nonlocal keyword.
- Nested function is returned by the enclosing function.

Let us understand nested functions i.e one of the characteristics of closure.

Example_code_1: Two function definitions and two calls separately. No nested functions

```
def f1():
   print("in f1")
def f2():
   print("in f2")
f1()
f2()
```

Output:

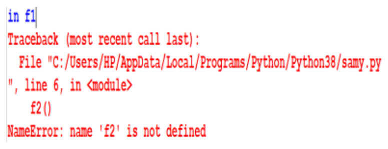


```
in f1
in f2
```

Example_code_2: Function f2 is the Enclosed/Nested function and f1 is the Nesting function/Enclosing function

```
def f1():
   print("in f1")
   def f2():
      print("in f2")
f1()
f2()
```

output:



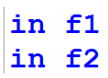
```
in f1
Traceback (most recent call last):
  File "C:/Users/HP/AppData/Local/Programs/Python/Python38/samy.py
", line 6, in <module>
    f2()
NameError: name 'f2' is not defined
```

Note: Function f2 is defined inside the function f1 and after execution of function f1, the f2 function cannot be accessed because it is in the scope of f1 function.

Example_code_3: Function f2 available inside f1.

```
def f1():
    print("in f1")
    def f2():
        print("in f2")
    f2()  #f2 is inside the function f1 so it is accessible
f1()
```

output:

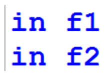


```
in f1
in f2
```

Example_code_4: Function f2 is made as global so it is valid,so f2 can be invoked from outside the f1

```
def f1():
    print("in f1")
    global f2
    def f2():
        print("in f2")
f1()
f2()
```

output:

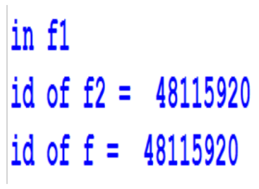


```
in f1
in f2
```

Example_code_5: Enclosing function returns the object of enclosed function. So id of f2 and f must be same

```
def f1():
    print("in f1")
    def f2():
            print("in f2")
    print("id of f2 = ",id(f2))
    return f2
f = f1()
print("id of f = ",id(f))
#f2()
```

output:

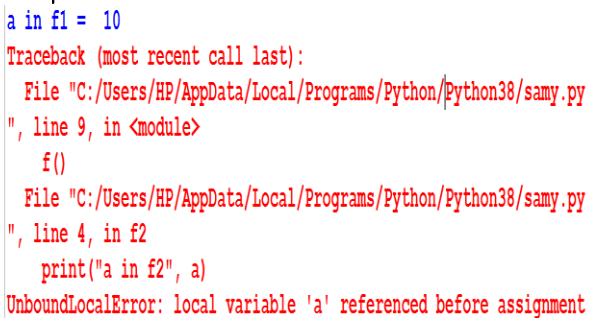


```
in f1
id of f2 =  48115920
id of f =  48115920
```

Example_code_6: The variable created in the enclosing scope cannot be modified in the enclosed function

```
def f1():
    a = 10
    def f2():
        print("a in f2", a)
        a = 11
    print("a in f1 = ", a)    #10
    return f2
f = f1()
f()
#print("a outside ",a) #Error
```

Output:



```
a in f1 =  10
Traceback (most recent call last):
  File "C:/Users/HP/AppData/Local/Programs/Python/Python38/samy.py
", line 9, in <module>
    f()
  File "C:/Users/HP/AppData/Local/Programs/Python/Python38/samy.py
", line 4, in f2
    print("a in f2", a)
UnboundLocalError: local variable 'a' referenced before assignment
```

Function f() is called which executes f2(). Since **'a' value cannot be accessed by the inner function**, it shows Error. **Variable 'a' is a free variable. Not a global variable.** We can make this variable accessible to the inner function by **declaring it as a "nonlocal" in the inner function** so that any modification to that variable in inner function will be reflected even outside the scope of inner function. Modified code is available in Example_code_7.

Example_code_7:

```
def f1():
    a = 10
    def f2():
        nonlocal a
        print("a in f2", a)
        a = 11
    print("a in f1 = ", a)    #10
    return f2
f = f1()
f() # invokes the inner function
```

output:

```
a in f1 =  10
a in f2 10
a in f2 11
```

Is the above example, i.e., Example_code_7 a closure? Yes. See the characteristics of the closures

Example_code_8:

```
def f1():
    a = 10
    def f2():
        a = 11
        print("a in f2:", a)
    print("a in f1:", a)    #10
    return f2
f = f1()
f()
```

Output:

```
a in f1: 10
a in f2: 11
```

Is the above example, i.e., Example_code_8 a closure? Yes. See the characteristics of the closures

Example_code_9:

```
def f1():
    a = 0
    def f2():
        nonlocal a;      a = a + 1;      return a
    return f2
f = f1(); b = f()
print(b)
```

Output:

```
1
```

Is the above example, i.e., Example_code_9 a closure?

Advantages of using Closures:

- We can avoid the use of global values by calling the inner function outside its scope, and accessing the enclosed variable outside its scope
- It provides data hiding.
- It is used while building python micro services

Let us discuss few more examples to know about **nested Functions and closures in detail.**

Example_code_10: Program that shows that, even after deletion of the outer function, the variables of outer function are accessible. Is this closure? Yes.

```
def outerfunc(x):
        def innerfunc():
                print(x)
        return innerfunc
myfunc=outerfunc(7)
myfunc()#refers to innerfunc()
del outerfunc
print("After deletion of outer function")
myfunc()
```

Output:

```
7
After deletion of outer function
7
```

Example_code_11: Is this closure?

```
def make_printer(msg):
   def printer(msg=msg):
      print(msg)
   return printer
printer = make_printer("Hello!")
printer()
```

Output:
```
Hello!
```

Here, the nested function printer() is not a closure because it does not access the free variable variables. The variable msg inside the printer() function is local to printer function and is not accessing the free variable of outer function.

Example_code_12: Is this closure?

```
def make_printer(msg):
   def printer(m):
      print(m, msg)
   return printer
printer = make_printer("Hello!")
printer("world")
#Above code if you change to m = msg in the parameter of printer() and call printer function using printer(), what is the inference?
```

Output:
```
world Hello!
```

Example_code_13: Is this closure?

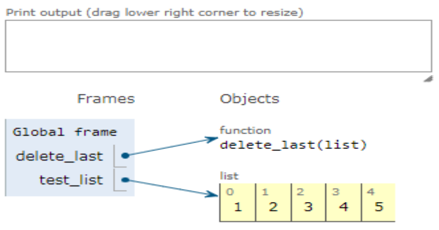
```
def delete_last_item(list):
        def get_last_item():# inner function definition
                list.pop(); print(list)
        return get_last_item #returning inner function
test_list = [1,2,3,4,5]
a=delete_last_item(test_list)#a receives inner function object returned by outer function
a()#function object that invokes inner function only
a()#a can remember the list recieved from delete_last_item function
a()
```

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

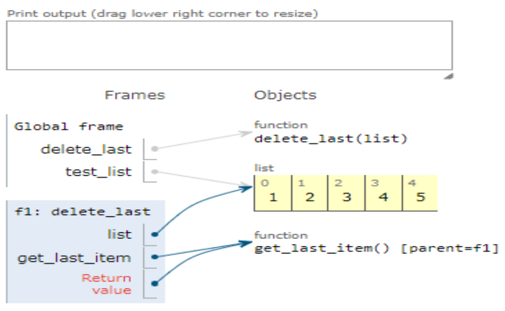
In the above example, list variable is accessed from the outer function delete_last_item to the inner function get_last_item. Variable "a" is able to remember the outer function variable "list" even after execution of outer function completely. Whenever we make a function call like "a()" the inner function get_last_item gets invoked.

Visualization using Python Tutor

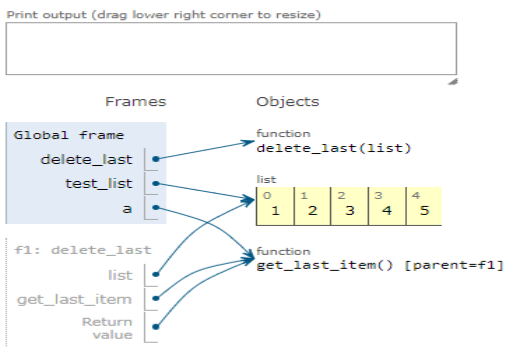
1. Funtion delete_last()is processed as global frame



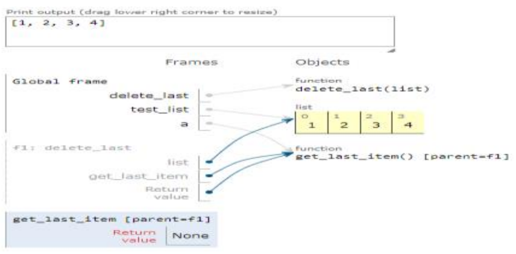
2. Inner function get_last_item is processed and activation record is created as f1



3. Function object a is called which refers to inner function get_last_item and Activation f1 got deleted

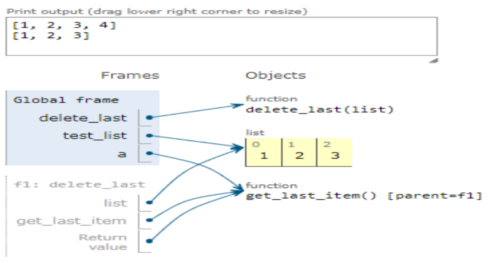


4. Execution of inner function get_last_item and removal of last item 5



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

5.On calling a() again invokes the inner function get_last_item and Removes one more last item 4 from the list .



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

Important points to note:

- **All Nested functions are not closures. But all closures are nested functions.**
- **Use cases are applicable to python decorators.**

-END–