Functional Programming

olsen software

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Demo folder: 09-FunctionalProgramming

1. Functional Programming in Python

- Overview of functional programming (FP)
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- Lambda example
- Lambdas and parameters

Overview of Functional Programming (FP)

- FP is a style of programming characterised by…
  - Treating computation as the evaluation of functions
  - Use of higher-order functions and/or recursion
  - Immutable (read-only) state
  - Lazy evaluation

- Why use FP?
  - Very amenable to multi-threading
  - Share complex algorithms across multiple threads, to maximise concurrency and increase performance

- Any disadvantages?
  - Quite a steep learning curve
  - Not suitable for every problem

Function Evaluation

- Functions depend only on their inputs, and not on other program state
- For example, consider the following function…

```
def cube(x):
  return x * x * x
```

FunctionEvaluation.py

  - It always gives the same answer for the same input (so it has predictable behaviour - you can reason about its operation)
  - It has no local state, side-effects, or changes to any other program state (so it can be safely executed by multiple threads)

Pure Functions

- A "pure function" is one that has no side effects. This has several useful consequences:
  - If the result of a pure expression is not used, it can be removed without affecting anything else
  - If a pure function is called with the same arguments, you will get the same result (so evaluations can be cached)
  - If there is no data dependency between two pure functions, they can be evaluated in any order, or performed in parallel

Anonymous Functions a.k.a. Lambdas

- A lambda expression is a 1-line inline expression
  - Like an anonymous function

- To define a lambda expression:
  - Use the `lambda` keyword…
  - Followed by the argument list…
  - Followed by a colon…
  - Followed by a 1-line inline expression

```
my_lambda = lambda arg1, arg2, … argn  :  inline_expression
```

- To invoke a lambda expression:
  - Same syntax as a regular function call

```
my_lambda(argvalue1, argvalue2, …, argvaluen)
```

Lambda Example

- A lambda that takes a single parameter and returns the square of that value

```
mylambda = lambda x: x * x

result = mylambda(10)
print(result)
```

Lambda1.py

Lambdas and Parameters

- Lambdas can take multiple parameters
  - List all the parameters after the lambda keyword

```
mylambda = lambda x, y: print("You passed %d, %d" % (x, y))

mylambda(10, 20)
```

LambdaParams.py

- Lambdas can take no parameters
  - Just follow the lambda keyword with a : immediately

```
mylambda = lambda: print("Hello!")

mylambda()
```

LambdaParams.py

2. Higher Order Functions

- Overview of higher-order functions
- Passing a lambda to a function
- Returning a lambda from a function
- Closures

Overview of Higher-Order Functions

- Higher-order functions can use other functions as arguments and return values
  - You can pass a function as a parameter into another function
  - You can return a function from a function

- We'll explore both these techniques in the following slides
  - We'll use lambdas to represent the function parameters/returns

Passing a Lambda to a Function

- You can pass a lambda as a parameter into a function
  - Allows you to write very generic functions

- Example
  - The `apply()` function applies the lambda that you pass in

```
def apply(arg1, arg2, op) :
    return op(arg1, arg2)

result1 = apply(10, 20, lambda x, y: x + y)
print(result1)

result2 = apply(10, 20, lambda x, y: x / y)
print(result2)
```

PassLambdas.py

Returning a Lambda from a Function

- You can return a lambda from a function…

- Consider this simple `concat()` function
  - Concatenates its two parameters in the order specified

```
def concat(str1, str2):
    return str1 + str2
```

ReturnLambdas.py

- Now consider the `flip()` function
  - Takes a binary operation
  - Returns a lambda that performs the operation with args flipped

```
def flip(binaryOp) :
    return lambda x, y: binaryOp(y, x)

# Usage.
flipConcat = flip(concat)
result2 = flipConcat("Hello", "World")
print(result2)
```

ReturnLambdas.py

Closures (1 of 2)

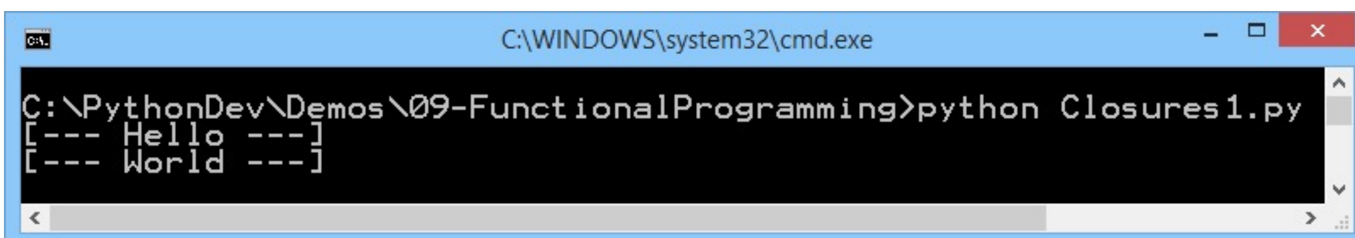
- A closure is a function whose behaviour depends on variables declared outside the scope in which it is then used
  - This is often used when returning functions/lambdas
  - The returned function/lambda remembers the original state in the enclosing function

```
def banner(start, end) :
    return lambda msg: print("%s %s %s" % (start, msg, end))

bannerMsg = banner("[---", "---]")

bannerMsg("Hello")
bannerMsg("World")
```

Closures1.py



Closures (2 of 2)

- Here, `fib` returns a function that calculates Fibonacci numbers, returns the next one each time called

Closures2.py

```
def fib() :

    tup = (1,-1)

    def retfunc():
        nonlocal tup
        tup = (tup[0] + tup[1], tup[0])
        return tup[0]

    return retfunc
```

```
f = fib()

print(f())    # 0
print(f())    # 1
print(f())    # 1
print(f())    # 2
print(f())    # 3
print(f())    # 5
print(f())    # 8
```

- Note 1:
  - `nonlocal` keyword lets you access a variable in external scope

- Note 2:
  - `tup` is a tuple, and you access its members using `[0]` and `[1]`

3. Additonal Techniques

- Recursion
- Tail recursion
- Reduction
- Partial functions

Recursion

- Recursion is commonly used instead of looping
  - It avoids the mutable state associated with loop counters

```
def factorial(n):
    if n == 0:
        return 1
    else:
        return n * factorial(n - 1)
```

```
result = factorial(4)
print("4 factorial is %d\n" % result)
```

Recursion.py

Tail Recursion

- Tail recursion is where the very last thing you do in a function is call yourself
  - The function calls can theoretically be executed in a simple loop

- Here's a tail-recursive implementation of factorial

```
def tailRecursiveFactorial(accumulator, n):
    if n == 0:
        return accumulator
    else:
        return tailRecursiveFactorial(n * accumulator, n - 1)
```

```
result = tailRecursiveFactorial(1, 4)
print("4 factorial is %d\n" % result)
```

TailRecursion.py

Reduction

- The `functools` module has several useful utility functions for functional programming
  - E.g. `reduce()`, which reduces the elements in a collection to a single result

```
from functools import reduce

mylambda = lambda x,y: x+y

result = reduce(mylambda, [3,12,19,1,2,7])
print(result)
```

Reduction.py

Partial Functions

- The `functools` module also allows you to create partial functions, i.e. functions with one or more args already filled in
  - Via `partial()`

```
from functools import partial

multiply = lambda x,y: x * y

times2 = partial(multiply, 2)
times5 = partial(multiply, 5)
times8 = partial(multiply, 8)

print("10 times 2 is %d" % times2(10))
print("10 times 5 is %d" % times5(10))
```

PartialFunctions.py

- Note: If you're interested to learn how this works, see our own version of `partial()` here:
  - `PartialFunctionsHowTheyWork.py`

Any Questions?