HIGHER ORDER FUNCTIONS 3

COMPUTER SCIENCE 88

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1 Higher Order Functions

A **higher order function** (HOF) is a function that manipulates other functions by taking in functions as arguments, returning a function, or both.

1.1 Functions as Arguments

One way a higher order function can exploit other functions is by taking functions as input. Consider this higher order function called `negate`.

```
def negate(f, x):
    return -f(x)
```

`negate` takes in a function `f` and a number `x`. It doesn't care what exactly `f` does, as long as `f` takes in a number and returns a number. Its job is simple: call `f` on `x` and return the negation of that value.

1.2 Questions

1. Here are some possible functions that can be passed through as `f`.

   ```
   def square(n):
       return n * n

   def double(n):
       return 2 * n
   ```

   What will the following Python statements output?

   ```
   >>> negate(square, 5)
   ```

Solution:
-25

```
>>> negate(double, -19)
```

Solution:
38

```
>>> negate(double, negate(square, -4))
```

Solution:
32

2. Implement a function `keep_ints`, which takes in a function `cond` and a number `n`, and only prints a number from `1` to `n` if calling `cond` on that number returns `True`:

```
def keep_ints(cond, n):
    """Print out all integers 1..i..n where cond(i) is true

    >>> def is_even(x):
    ...     # Even numbers have remainder 0 when divided by 2.
    ...     return x % 2 == 0
    >>> keep_ints(is_even, 5)
    2
    4
    """
```

Solution:

```
    i = 1
    while i <= n:
        if cond(i):
            print(i)
        i += 1
```

1.3 Functions as Return Values

Often, we will need to write a function that returns another function. One way to do this is to define a function inside of a function:

```
def outer(x):
    def inner(y):
        ...
    return inner
```

The return value of `outer` is the function `inner`. This is a case of a function returning a function. In this example, `inner` is defined inside of `outer`. Although this is a common pattern, we can also define `inner` outside of `outer` and still use the same `return` statement.

```
def inner(y):
    ...
def outer(x):
    return inner
```

1.4 Questions

1. Use this definition of `outer` to fill in what Python would print when the following lines are evaluated.

```
def outer(n):
    def inner(m):
        return n - m
    return inner
>>> outer(61)
```

Solution:
`<function outer.inner ...>`

```
>>> f = outer(10)
>>> f(4)
```

Solution:
`6`

```
>>> outer(5)(4)
```

Solution:
`1`

2. Implement a function `keep_ints` like before, but now it takes in a number `n` and returns a function that has one parameter `cond`. The returned function prints out all numbers from 1..i..n where calling `cond(i)` returns True.

```
def keep_ints(n):
    """Returns a function which takes one parameter cond and
    prints out all integers 1..i..n where calling cond(i)
    returns True.

    >>> def is_even(x):
    ...     # Even numbers have remainder 0 when divided by 2.
    ...     return x % 2 == 0
    >>> keep_ints(5)(is_even)
    2
    4
    """
```

Solution:

```
    def do_keep(cond):
        i = 1
        while i <= n:
            if cond(i):
                print(i)
            i += 1
    return do_keep
```

2 Environment Diagrams

1. Draw the environment diagram for evaluating the following code

```
def f(x):
    return y + x
y = 10
f(8)
```

> **Solution:** Solution: https://goo.gl/rZnzaM

2. Draw the environment diagram for evaluating the following code

```
def dessef(a, b):
        c = a + b
        b = b + 1

b = 6
dessef(b, 4)
```

> **Solution:** Solution: https://goo.gl/4m3NRD

3. Draw the environment diagram for evaluating the following code

```
def foo(x, y):
        foo = bar
        return foo(bar(x, x), y)

def bar(z, x):
        return z + y

y = 5
foo(1, 2)
```

> **Solution:** Solution: https://goo.gl/7Kcx6n