Module 06

Topics:
• Iterative structure in Python

Readings: ThinkP 7
In Python, repetition can be recursive

def count_down_rec(x):
    ''' Produces the list
        [x, x-1, x-2, ..., 1,0]
    count_down: Nat -> (list of Nat)'''
    if x == 0:
        return [0]
    else:
        return [x] + count_down_rec(x-1)
But it can be different → Iteration

def count_down(x):
    answer = []
    while x >= 0:
        answer.append(x)
        x = x - 1
    return answer

What happens when we call \texttt{count\_down(3)}?
Calling `count_down(3)`

- **L1, L2:** \( x \leftarrow 3, \) \( \text{answer} \leftarrow [] \)
- **L3:** Since \( x \geq 0 \), execute **L4, L5**:
  - \( \text{answer} \leftarrow [3], \ x \leftarrow 2 \)
- Now, return to **L3:** since \( x \geq 0 \), execute **L4, L5**:
  - \( \text{answer} \leftarrow [3,2], \ x \leftarrow 1 \)
- Now, return to **L3:** since \( x \geq 0 \), execute **L4, L5**:
  - \( \text{answer} \leftarrow [3,2,1], \ x \leftarrow 0 \)
- Now, return to **L3:** since \( x \geq 0 \), execute **L4, L5**:
  - \( \text{answer} \leftarrow [3,2,1,0], \ x \leftarrow -1 \)
- Now, return to **L3:** since \( x < 0 \), do not execute **L4, L5**
- **L6:** return \([3,2,1,0]\)
**while loop basics**

- If the continuation test is **True**, execute the loop body
- If the continuation test is **False**, do not execute the loop body
- After completing the loop body:
  - Evaluate the continuation test again
- The body usually includes an update of variables used in the continuation test
while loop template

## initialize loop variables
while test:
    ## body, including statements to:
    ## - update variables used in test
    ## - update value being calculated
    ## additional processing
Steps for writing a `while` loop

You must determine

– how to initialize variables outside the loop
– when the loop body should be executed, or, when it should stop
– what variables must be updated in the loop body so the loop will eventually stop
– what other actions are needed within the loop body

Note: these can be determined in any order – just fill in the template!
Example: Checking Primality

A number $n \geq 2$ is prime if it has no factors other than 1 and itself.

To test if a number $n$ is prime:

• Check every number from 2 to $n-1$
• If you find a factor of $n$, stop and return $\text{False}$
• If none of them are, stop and return $\text{True}$
Implementation of \texttt{prime}

def is_prime (n):
    '''is\_prime: \text{Nat} \rightarrow \text{Bool}
    Requires: n \geq 2'''
    test\_factor = 2
    while test\_factor < n:
        if n \% test\_factor == 0:
            return False
        else:
            test\_factor = test\_factor + 1
    ## tried all the numbers from 2 to n-1
    return True
Testing a *while* loop

Include tests, when possible, for which the body executes

- zero times
- exactly one time
- a "typical" number of times
- the maximum number of times

Also, if the continuation test involves multiple conditions, test each way that the loop may terminate
Testing `is_prime`

Consider the following test cases:

- **n=2** (loop body does not execute)
- **n=3** (loop body executes once, terminates because `test_factor` equals `n`)
- **n=4** (loop body executes once, terminates because 2 is a factor)
- **n=5** (maximum iterations, no factors found)
- **n=77** (larger composite number)
- **n=127** (larger prime number)
Beware of “infinite loops”

```python
while True:
    print( 'runs forever' )

x = -5
total = 0
while x < 0:
    total = 2.0 ** x
    x = x-1
print( total )
```

Notes:

- it is impossible to write a program that identifies if a loop will run indefinitely (more in CS360)
- The code will eventually be terminated in WingIDE with an error – it isn’t really “infinite”
Exercise: \textit{factorial}

Write a Python function to calculate $n!$

- Use a \texttt{while} loop that counts from 1 to $n$
- Use a \texttt{while} loop that counts down from $n$ to 1
Why use loops instead of recursion?

• Iteration, like accumulative recursion, may allow for a more “natural” solution
• Python won’t let us recurse thousands of times
• Iteration is more memory efficient
  – for each recursive call, we need memory for parameters
  – for an iterative call, we may just need to update an existing variable
• Iteration will generally run faster
Another type of loop: 

- While loops are called *guarded* iteration:
  - If the test evaluates to **True**, execute the body

- Another approach:
  - Iterate over all members in a collection
  - Called *bounded* iteration

```python
for item in collection:
    loop_body
```
for loop examples

for food in ['avocado', 'banana', 'cabbage']:
    print(food.upper())

for base in 'ACGGGGTTCG' :
    print(base)

CS116 Winter 2019
06: Iteration
for loop examples using `range`

```python
sum_all = 0
for i in range(2, 5):
    sq = i*i
    sum_all = sum_all + sq
print(sum_all)
```

```python
for j in range(10, 2, 2):
    print(j)
```

- `range` is an iterator, it can generate a collection
  - the next value in the `range` is computed automatically with each pass through the `for` loop
**for and while**

**while**
- Loop counter should be initialized outside loop
- Includes continuation test before body
- Should update loop variables in body of loop
- Body contains steps to repeat

**for**
- Loop counter initialized automatically
- Continues while more elements in collection, or more values in iterator
- Loop variable updated automatically – do not update in loop
- Body contains steps to repeat
Revisiting `multiply_by` example

The function `multiply_by` consumes a list of integers (called `values`) and an integer (called `factor`) and mutates `values` by multiplying each entry in `values` by `factor`. The function returns `None`.

Implement `multiply_by` using a loop.
What does this function do?

def smaller(L, x):
    p = 0
    while p < len(L):
        if L[p] < x:
            return p
        else:
            p = p+1
    return False

How many iterations would \( \text{smaller}([10,8,6],3) \) involve? \( \text{smaller}([7,10,2], 8) \)? \( \text{smaller}(L,x) \) for any \( L \) and \( x \)?
Nested Lists and Loops

In Module 04, we considered nested lists like:

\[ L = [[[1,2]], [], [7,8,9,10]] \]

What is printed by the following?

```python
for m in L:
    print(sum(m))
```

What if we want to access all values in a list like \( L \)?
def nested_max(alol):
    '''produces the largest value in alol
    nested_max: (listof (listof Int)) -> Int
    requires: alol is nonempty
                Lists in alol are nonempty
    Example:
    nested_max([[1,5,3], [3],[35,1,2]]) => 35
    '''
    cur_max = alol[0][0]
    for L in alol:  # each list in alol
        for elem in L:  # each value in L
            if elem > cur_max:
                cur_max = elem
    return cur_max
What does this function do?

def mult_table(n):
    table = []
    for r in range(n):
        row = []
        for c in range(n):
            row.append(r*c)
        table.append(row)
    return table

How many total iterations would mult_table(5) involve? mult_table(n) for any Nat n?
Question: What is the value of \( L \) after the following `for` loop terminates?

\[
L = [2,4,6,8,10]
\]

```
for x in L:
    if x%2==0:
        L.remove(x)
```

**Warning**: Do not add/remove entries in a list that you are looping over using a `for` loop.
Goals of Module 06

• Understand that iteration is central to Python
• Understand the difference between `while` and `for` loops
• Be able to use a loop to solve a problem