Introduction to: Computers & Programming: Loops in Python

Adam Meyers
New York University
Outline

• What is a Loop?
• While Loops
• For Loops
• Examples
• Nested Loops
What is a Loop?

- Loops are control structures
  - A block of code repeats
  - The extent of the repetition is usually limited in some way

- Two kinds of Loops in Python
  - **while** loops
    - The evaluation of a boolean expression determines when the repetition stops
    - Changes in values of variables lead to different evaluations of the boolean expression on each repetition
    - When the expression is evaluated as *False*, the loop halts
    - If the expression can never evaluate as *False*, the loop is endless
  
  - **for** loops
    - The length of a “sequence” determines how many times the body executes
      - A sequence is an object that is made up of other objects (arranged in an order), e.g., a string is a sequence of characters: “duck” = “d”, “u”, “c”, “k”.
    - The loop uses one member of the sequence at a time, ending with the last one
An Endless Loop: keeping time

• Example

```python
def endless_timer():
    import time
    now = 0
    while True:
        time.sleep(1)
        now = now + 1
        print(now)
```

• This loop will keep counting seconds until stopped with a Control-C
What is a **while** Loop?

- A while loop consists of:
  - The word *while*
  - A boolean expression (**True** on the last slide)
  - A colon :
  - The body: an indented block of instructions

- The body of the loop repeats
  - until the boolean expression is False

- The loop on the previous slide is endless
  - because **True** does not change in value
  - And **True** does not equal **False**.

- Any program can be stopped using Control-C
A “normal” `while` Loop

• Normal loops iterate until some condition is True (endless loops are unusual)
  
  ```python
def seconds_stop_watch (total_seconds):
    import time
    now = 0
    while (now < total_seconds):
        time.sleep(1)
        now = now + 1
        print(now)
  ```

• If we call `seconds_stop_watch` with 5 as an argument
  – The variable `now` is initialized to 0
  – The loop iterates 5 times
  – Each time: a second passes, 1 is added to `now` and `now` is printed
  – In this way, 1 to 5 is printed over 5 seconds

• How many times would a loop beginning `while False: repeat?`
Loops for Guiding User Input

- `def get_yes_or_no_answer()::`
  ```python
  ## User must respond “yes” or “no”
  output = 'initial_input' # initialize the variable output
  while(not ((output == 'yes') or (output == 'no'))):
    if output != 'initial_input':
      print('Invalid Input!')
    output=(input("Please respond: 'yes' or 'no')
  
  if output=='yes':
    return(True)
  elif output=='no':
    return(False)
  ```

- `def get_integer_from_user()::`
  ```python
  ## User must respond with a single digit
  output = 'initial_input' # initialize variable output
  while (not (output in '0123456789')):
    if output != 'initial_input':
      print('Invalid Input!')
    output=(input("choose an integer. ')
  
  return(output)
  ```
A sample *for* loop

- This function simulates a 60 second timer
  ```python
def one_minute_timer ():
    print(0)
    for second in range(60):
        time.sleep(1)
        print(second + 1)
  ```
- The function prints 0, then enters a *for* loop
  - The loop iterates through a list of numbers from 0 to 59
    - The variable *second* is assigned that number as a value
    - The system waits one second
    - The system prints *second* + 1
The range function

- `range` takes three arguments:
  - `START`: An optional 1st argument (starts at START)
  - `MAXIMUM`: A required 2nd argument (ends before MAXIMUM)
  - `INCREMENT`: An optional 3rd argument
- When left out, START defaults to 0
- When left out, INCREMENT defaults to 1
- creates a sequence of numbers from `START` to `MAXIMUM-1` such that consecutive items in the sequence differ by `INCREMENT`
- Examples:
  - `range(5) → [0,1,2,3,4]`
  - `range(2,5) → [2,3,4]`
  - `range(0,10,2) --> [0,2,4,6,8]`
  - `range(10,2,-2) → [10,8,6,4]`
Looping Through a Range

• def factorial(number):

    total = 1  ## example of accumulator variable
    for num in range(1,number+1):
        total=total*num
    return(total)
Looping through String

- def accum_spaces_and_add_stars(word):
  output = '* ' ## also an accumulator variable
  for letter in string:
    output = output+letter+' '
  output = output+'*'
  return(output)
The *for* loop

- The first line – *for variable in sequence*:
  - *for* and *in* are keywords
  - *variable* can be any legal variable name
  - *sequence* is an ordered set of items
    - Python sequences includes data types like: *range, list, string*, …
- The body of the loop repeats once for each item in the sequence
- On each iteration, the variable is bound to the next item in the sequence
- Examples:
  - *for character in 'multi-character'*:
    ```python
    print(character)
    ```
  - *for number in range(5)*:
    ```python
    print(number)
    ```
Looping Through a String

• Using a `for` loop
  
  ```python
  def for_string_loop (string):
      for letter in string:
          print(letter)
  
  # Example
  for_string_loop('Downward')
  ```

• Using a `while` loop
  
  ```python
  def while_string_loop (string):
      position = 0  # counter
      while(position < len(string)):
          print(string[position])
          position = 1 + position
  ```
Lengths and elements of Sequences

• The function `len` returns a sequence's length
  – The number of characters – `len('Downward')`
  – The number of integers in a range – `len(range(60))`
  – Etc.

• Elements in a sequence can be identified by their position, beginning with 0 and ending in one less than the length.
  – 'Downward'[0], range(5,10)[0]
  – 'Downward'[7], range(5,10)[4]
  – 'Downward'[8], range(5,10)[5] --- these are errors
for loops vs. while loops

• With some code modification, it is always possible to replace a for loop with a while loop, but not the other way around

• for loops are used for situations where you know the number of iterations ahead of time
  – e.g., looping through sequences

• There is no significant efficiency difference

• The difference relates to ease in which humans can read/write code
Simple Examples of Nested Loops

• What do you expect to be returned from the following loop within a loop?
  – def print_1_to_4_by_a_to_d():
    for number in [1,2,3,4]:
      for letter in 'abcd':
        print(number,letter)

• Function based on above example
  – def print_two_item_combinations(seq1,seq2):
    for item1 in seq1:
      for item2 in seq2:
        print(item1,item2)

• Notice that embedded loops are indented under higher loops
Example: Printing a Multiplication table

• def multiplication_table (high_num):
    for num1 in range(1, 1+high_num):
        for num2 in range(1, 1+high_num):
            print(num1,'X',num2, '=' , num1*num2)

• How does this work?
A Few More Details About “print”

- `print` takes 2 optional arguments:
  - `sep='*'` – prints asterisk between arguments
    - Default: prints spaces between arguments
  - `end='$'` – prints dollar sign at the end of line
    - Default – prints newline character at end of line
- `def test1()`:
  ```python
  print('New','York','University',sep='*',end='$')
  print('Blah','Blah','Blah',sep='*',end='$')
  ```
- `def test2()`:
  ```python
  print('New','York','University')
  print('Blah','Blah','Blah')
  ```
Example: Drawing an asterisk triangle

- def draw_n_asterisks(n):
  for current_length in range(n):
    print('*', end='')
    - Printing nothing (the empty string) at the end of each line, instead of the newline character

- def asterisk_triangle(base_size):
  for current_length in range(1, base_size + 1):
    draw_n_asterisks(current_length)
  print()
Drawing an asterisk triangle 2

• Nested Loops – a single function

```python
def asterisk_triangle2(base_size):
    for current_length in range(1, base_size + 1):
        for n in range(current_length):
            print('*', end='')
        print()
```

• Python indicates depth of nesting via indentation
  – Suppose the last line was indented once
Sample Problem for Class

- Write a function that:
  - Takes three arguments:
    - base_size
    - repetitions
    - hour_glass_or_diamond
  - This function makes a pattern of asterisks that repeats the number of times indicated by repetitions
  - Each cycle consists of two triangles, one the upside down version of each other, both of which have a base of size base_size
  - If hour_glass_or_diamond is in the 'hour glass' setting, the function draws an upside down triangle and then a right side up triangle
  - If hour_glass_or_diamond is in the 'diamond' setting, the function draws the right side up triangle first and the upside down one second
Summary

• Loops provide a way to repeat blocks of instructions
• While loops are the most general
  – They require a condition for exiting the loop
    • If the condition is never false, the loop is endless
• For loops provide a simple way of repeating a block
  – once for each element in a sequence
  – or a fixed number of times
• A For loop can always be replaced by an equivalent While loop
• It is often useful to have nested loops (loops within loops)
Homework

• Go to HW part of website
  – 004: 
    http://cs.nyu.edu/courses/spring17/CSCI-UA.0002-004/index.html#HomeworkSchedule
  – 009: 
    http://cs.nyu.edu/courses/spring17/CSCI-UA.0002-009/index.html#HomeworkSchedule

• See HW due February 22