Introduction to:
Computers & Programming:
Loops in Python

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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
    • The loop uses one member of the sequence at a time, until there are no more members
An Endless Loop

• 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 boolean expression is never False.
  – Any program can be stopped using Control-C
What is a *while* Loop? 2

• A loop that iterates a limited number of times

```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?
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
New Material Introduced in the `one_minute_timer` function

- The `range` function
  - `range` takes one or two integers `m` and `n` as an arguments
  - when `m` is left out, it is (by default) set to 0
  - creates a sequence of numbers from `m` to `n-1`

- A `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
Looping Through a String

• Using a **for** loop
  
  ```python
  def for_string_loop (string):
    for letter in string:
      print(letter)
  
  – for-string-loop('Downward')
  ```

• Using a **while** loop
  
  ```python
  def while_string_loop (string):
    position = 0
    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 range 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
Example: Drawing an asterisk triangle

• def draw_n_asterisks(n):
    
    for current_length in range(n):
        print('*', end='')
    
    – print can take a named argument
    • End='' indicates what to print at the end of the string
      – the character in between the single quotes
    • In this case, nothing
    • The default is a 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
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?
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
One Way to Describe a Checkerboard

- A Checkerboard is an 8 X 8 square with alternating colors, e.g., red and black.
- A Checkerboard can be broken down into 4 bars, each a 2 X 8 bar of alternating colors.
- A 2 X 8 bar of alternating colors can be broken down into 4 composite squares, each consisting of 2 X 2 small squares.
A Pictoral Description

\[ X_4 = \begin{array}{cccc} & & & \text{X} \\ & \text{X} & & \text{X} \\ & & & \text{X} \end{array} \quad X_4 = \begin{array}{cccccccc} & & & & & & & \text{X} \\ & \text{X} & & & & & & \text{X} \\ & & & & & & & \text{X} \end{array} \]

\[ X_4 = \begin{array}{cccccccccccc} & & & & & & & & & \text{X} & & & & \text{X} \\ & & & & & & & & & \text{X} & & & & \text{X} \\ & & & & & & & & & \text{X} & & & & \text{X} \end{array} \]
One Way A Turtle Can Draw a Checkerboard?

• The turtle can draw one square and it could fill in with a color of our choice.
• The turtle can make four such squares next to each other, forming a composite square.
• It can make four composite squares next to each other, to form a bar.
• It can make four such bars, one under the other to form a checkerboard.
for_loop_checkerboard.py

• Basic setup
  – import turtle
  – my_screen = turtle.Screen()
  – my_screen.setup(0.5, 0.75, 0, 0)
    • width, height, startx, starty
  – my_turtle = turtle.Turtle(shape='turtle')

• draw_colored_turtle_square
• draw_4_black_and_red
• draw_4_black_and_red_4_times
• make_checkerboard
for_loop_checkerboard.py  2

• Setup and then do something 4 times
  – Building block
  – Move in between blocks

• draw_colored_turtle_square
  – Setup: set colors and begin to fill
  – Repeated Steps:
    • put the pen down, move forward, turn left
  – Pick pen up and fill in color

• draw_4_black_and_red
  – Setup: initialize fill color and pen color
  – Repeated Steps: change fill color,
    draw_colored_turtle_square, turn right, move forward
for_loop_checkerboard.py  3

• draw_4_black_and_red_4_times
  – repeated steps:
    • draw_4_black_and_red
    • move forward

• make_checkerboard
  – Setup: set turtle speed
  – Repeated Steps:
    • draw_4_black_and_red_4_times
    • Turn 180 degrees, move forward, turn 270 degrees, move forward turn 270 degrees
Woops

• While writing the checkerboard program, several mistakes led me to realize some interesting artistic possibilities
  – make_mistake1 – is the result of drawing bars with different angles

• This led me to experiment with different colors, more bars, etc., to make interesting patterns (wacky_bars, wacky_bars2)
About wacky_bars and wacky_bars2

• `random.random()` – chooses number between 0 and 1
• Colors in the turtle library consist of combinations of red, green and blue
  – Red has a value from 0 to 255
  – Green has a value from 0 to 255
  – Blue has a value from 0 to 255
  – 0,0,0 is black and 255,255,255 is white
• `math.ceil(random.random() * 255)` – choose a number between 1 and 255
• 3 such random numbers identifies a random color
More about wacky_bars

• Let red, green, blue be 3 numbers between 1 and 255

• Applying the following should produce contrasting colors:
  – red == (red - 128) % 255
  – green = (green - 128) % 255
  – blue = (blue - 128) % 255

• I am unaware of any scientific/artistic significance to this relation, e.g., these pairs of colors are not complementary
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 true, 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

• Finish Reading Chapter 4
• Write function that will make a rectangle consisting of any character:
  – Make_character_rectangle(height, width, char)
    • Should make **height** rows of **width** instances of **char**
• Write a function that makes a parallelogram of characters:
  – Make_character_parallelogram(height, width, char)
    • The loop should add height-N spaces to the beginning of each line, where N starts out at 1 (the first line) and ends with height (the last line). Thus the parallelogram leans right, but touches the left margin.
• Write a timer that prints out every one tenth of a second
  – It should use the format:   Hours:Minutes:Seconds.fraction
  – For example,  00:00:00.0,   00:00:00.1,   00:00:00.2, etc.