CN101

Lecture 6-7

Repetition Structures

Topics

- Introduction to Repetition Structures
- The `while` Loop: a Condition-Controlled Loop
- The `for` Loop: a Count-Controlled Loop
- Calculating a Running Total
- Sentinels
- Input Validation Loops
- Nested Loops

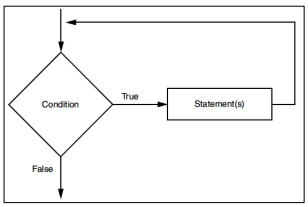
Introduction to Repetition Structures

- Often have to write code that performs the same task multiple times
  - Disadvantages to duplicating code
    - Makes program large
    - Time consuming
    - May need to be corrected in many places
- Repetition structure: makes computer repeat included code as necessary
  - Includes condition-controlled loops and count-controlled loops

The `while` Loop: a Condition-Controlled Loop

- `while` loop: while condition is true, do something
  - Two parts:
    - Condition tested for true or false value
    - Statements repeated as long as condition is true
  - In flow chart, line goes back to previous part
  - General format:

```
while condition:
      statement
      statement
      etc.
```



The `while` Loop: a Condition-Controlled Loop (cont'd.)

- In order for a loop to stop executing, something has to happen inside the loop to make the condition false
- Iteration: one execution of the body of a loop
- `while` loop is known as a *pretest* loop
  - Tests condition before performing an iteration
    - Will never execute if condition is false to start with
    - Requires performing some steps prior to the loop

Program 4-1 (commission.py)

```
1  # This program calculates sales commissions.
2
3  # Create a variable to control the loop.
4  keep_going = 'y'
5
6  # Calculate a series of commissions.
7  while keep_going == 'y':
8      # Get a salesperson's sales and commission rate.
9      sales = float(input('Enter the amount of sales: '))
10     comm_rate = float(input('Enter the commission rate: '))
11
12     # Calculate the commission.
13     commission = sales * comm_rate
14
15     # Display the commission.
16     print('The commission is $',
17           format(commission, ',.2f'), sep='')
18
19     # See if the user wants to do another one.
20     keep_going = input('Do you want to calculate another ' +
21                        'commission (Enter y for yes): ')
```

Program Output (with input shown in bold)

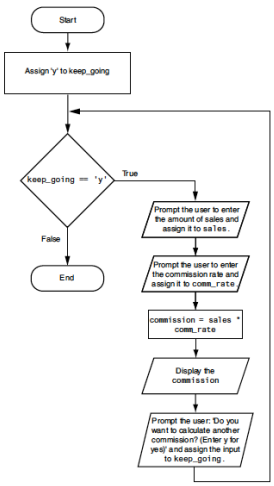
```
Enter the amount of sales: 10000.00 Enter
Enter the commission rate: 0.10 Enter
The commission is $1,000.00
Do you want to calculate another commission (Enter y for yes): y Enter
Enter the amount of sales: 20000.00 Enter
Enter the commission rate: 0.15 Enter
The commission is $3,000.00
Do you want to calculate another commission (Enter y for yes): y Enter
Enter the amount of sales: 12000.00 Enter
Enter the commission rate: 0.10 Enter
The commission is $1,200.00
Do you want to calculate another commission (Enter y for yes): n Enter
```


This condition is tested.

```
while keep_going == 'y':
    # Get a salesperson's sales and commission rate.
    sales = float(input('Enter the amount of sales: '))
    comm_rate = float(input('Enter the commission rate: '))

    # Calculate the commission.
    commission = sales * comm_rate

    # Display the commission.
    print('The commission is $',
          format(commission, ',.2f'), sep='')

    # See if the user wants to do another one.
    keep_going = input('Do you want to calculate another ' +
                       'commission (Enter y for yes): ')
```

If the condition is true, these statements are executed, and then the loop starts over.

If the condition is false, these statements are skipped, and the program exits the loop.



Program 4-2 (temperature.py)

```
1  # This program assists a technician in the process
2  # of checking a substance's temperature.
3
4  # Named constant to represent the maximum
5  # temperature.
6  MAX_TEMP = 102.5
7
8  # Get the substance's temperature.
9  temperature = float(input("Enter the substance's Celsius temperature: "))
10
11 # As long as necessary, instruct the user to
12 # adjust the thermostat.
13 while temperature > MAX_TEMP:
14     print('The temperature is too high.')
15     print('Turn the thermostat down and wait')
16     print('5 minutes. Then take the temperature')
17     print('again and enter it.')
18     temperature = float(input('Enter the new Celsius temperature: '))
19
20 # Remind the user to check the temperature again
21 # in 15 minutes.
22 print('The temperature is acceptable.')
23 print('Check it again in 15 minutes.')
```


Program Output (with input shown in bold)

```
Enter the substance's Celsius temperature: 104.7 Enter
The temperature is too high.
Turn the thermostat down and wait
5 minutes. Take the temperature
again and enter it.
Enter the new Celsius temperature: 103.2 Enter
The temperature is too high.
Turn the thermostat down and wait
5 minutes. Take the temperature
again and enter it.
Enter the new Celsius temperature: 102.1 Enter
The temperature is acceptable.
Check it again in 15 minutes.
```


Infinite Loops

- Loops must contain within themselves a way to terminate
  - Something inside a `while` loop must eventually make the condition false
- Infinite loop: loop that does not have a way of stopping
  - Repeats until program is interrupted
  - Occurs when programmer forgets to include stopping code in the loop

The `for` Loop: a Count-Controlled Loop

- Count-Controlled loop: iterates a specific number of times
  - Use a `for` statement to write count-controlled loop
    - Designed to work with sequence of data items
      - Iterates once for each item in the sequence
    - General format:

```
for variable in [val1, val2, etc]:
    statements
```

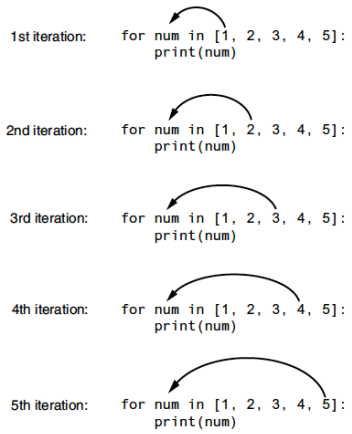
    - Target variable: the variable which is the target of the assignment at the beginning of each iteration

Program 4-4 (simple_loop1.py)

```
1  # This program demonstrates a simple for loop
2  # that uses a list of numbers.
3
4  print('I will display the numbers 1 through 5.')
5  for num in [1, 2, 3, 4, 5]:
6      print(num)
```

Program Output

```
I will display the numbers 1 through 5.
1
2
3
4
5
```

Program 4-5 (simple_loop2.py)

```
1  # This program also demonstrates a simple for
2  # loop that uses a list of numbers.
3
4  print('I will display the odd numbers 1 through 9.')
5  for num in [1, 3, 5, 7, 9]:
6      print(num)
```

Program Output

```
I will display the odd numbers 1 through 9.
1
3
5
7
9
```


Program 4-6 (simple_loop3.py)

```
1  # This program also demonstrates a simple for
2  # loop that uses a list of strings.
3
4  for name in ['Winken', 'Blinken', 'Nod']:
5      print(name)
```

Program Output

```
Winken
Blinken
Nod
```


Using the `range` Function with the `for` Loop

- The `range` function simplifies the process of writing a `for` loop
  - `range` returns an iterable object
    - Iterable: contains a sequence of values that can be iterated over
- `range` characteristics:
  - One argument: used as ending limit
  - Two arguments: starting value and ending limit
  - Three arguments: third argument is step value

```
>>> for num in range(5):
        print(num)


0
1
2
3
4
```

```
>>> for num in range(1, 5):
        print(num)


1
2
3
4
```

```
>>> for num in range(1, 10, 2):
        print(num)


1
3
5
7
9
```


Program 4-7 (simple_loop4.py)

```
1  # This program demonstrates how the range
2  # function can be used with a for loop.
3
4  # Print a message five times.
5  for x in range(5):
6      print('Hello world')
```

Program Output

```
Hello world
Hello world
Hello world
Hello world
Hello world
```


Using the Target Variable Inside the Loop

- Purpose of target variable is to reference each item in a sequence as the loop iterates
- Target variable can be used in calculations or tasks in the body of the loop
  - Example: calculate square of each number in a range

Number	Square
1	1
2	4
3	9
4	16
5	25
6	36
7	49
8	64
9	81
10	100

Program 4-8 (squares.py)

```
1  # This program uses a loop to display a
2  # table showing the numbers 1 through 10
3  # and their squares.
4
5  # Print the table headings.
6  print('Number\tSquare')
7  print('--------------')
8
9  # Print the numbers 1 through 10
10 # and their squares.
11 for number in range(1, 11):
12     square = number**2
13     print(number, '\t', square)
```

Program Output

```
Number  Square
--------------
1       1
2       4
3       9
4       16
5       25
6       36
7       49
8       64
9       81
10      100
```


Letting the User Control the Loop Iterations

- Sometimes the programmer does not know exactly how many times the loop will execute
- Can receive range inputs from the user, place them in variables, and call the `range` function in the for clause using these variables
  - Be sure to consider the end cases: `range` does not include the ending limit

Program 4-10 (user_squares1.py)

```
1  # This program uses a loop to display a
2  # table of numbers and their squares.
3
4  # Get the ending limit.
5  print('This program displays a list of numbers')
6  print('(starting at 1) and their squares.')
7  end = int(input('How high should I go? '))
8
9  # Print the table headings.
10 print()
11 print('Number\tSquare')
12 print('--------------')
13
14 # Print the numbers and their squares.
15 for number in range(1, end + 1):
16     square = number**2
17     print(number, '\t', square)
```

Program Output (with input shown in bold)

```
This program displays a list of numbers
(starting at 1) and their squares.
How high should I go? 5 Enter

Number    Square
-----------------
1         1
2         4
3         9
4         16
5         25
```


Program 4-11 (user_squares2.py)

```
1  # This program uses a loop to display a
2  # table of numbers and their squares.
3
4  # Get the starting value.
5  print('This program displays a list of numbers')
6  print('and their squares.')
7  start = int(input('Enter the starting number: '))
8
9  # Get the ending limit.
10 end = int(input('How high should I go? '))
11
12 # Print the table headings.
13 print()
14 print('Number\tSquare')
15 print('--------------')
16
17 # Print the numbers and their squares.
18 for number in range(start, end + 1):
19     square = number**2
20     print(number, '\t', square)
```


Program Output (with input shown in bold)

```
This program displays a list of numbers and their squares.
Enter the starting number: 5 Enter
How high should I go? 10 Enter

Number  Square
---------------
5         25
6         36
7         49
8         64
9         81
10        100
```


Generating an Iterable Sequence that Ranges from Highest to Lowest

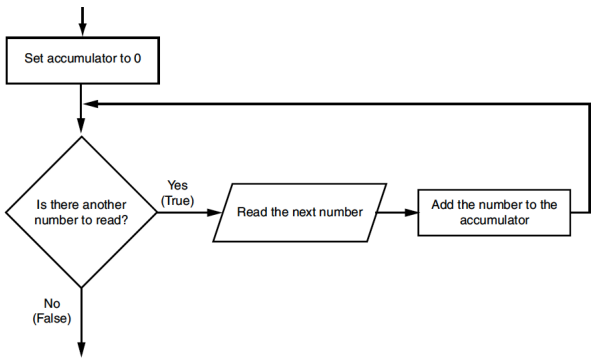
- The `range` function can be used to generate a sequence with numbers in descending order
  - Make sure starting number is larger than end limit, and step value is negative
  - Example: `range (5, 0, -1)`

```
>>> for num in range(5, 0, -1):
        print(num)


5
4
3
2
1
```


Calculating a Running Total

- Programs often need to calculate a total of a series of numbers
  - Typically include two elements:
    - A loop that reads each number in series
    - An *accumulator* variable
  - Known as program that keeps a running total: accumulates total and reads in series
  - At end of loop, accumulator will reference the total

Calculating a Running Total (cont'd.)



Program 4-12 (sum_numbers.py)

```
1  # This program calculates the sum of a series
2  # of numbers entered by the user.
3
4  MAX = 5 # The maximum number
5
6  # Initialize an accumulator variable.
7  total = 0.0
8
9  # Explain what we are doing.
10 print('This program calculates the sum of')
11 print(MAX, 'numbers you will enter.')
12
13 # Get the numbers and accumulate them.
14 for counter in range(MAX):
15     number = int(input('Enter a number: '))
16     total = total + number
17
18 # Display the total of the numbers.
19 print('The total is', total)
```


Program Output (with input shown in bold)

```
This program calculates the sum of
5 numbers you will enter.
Enter a number: 1 Enter
Enter a number: 2 Enter
Enter a number: 3 Enter
Enter a number: 4 Enter
Enter a number: 5 Enter
The total is 15.0
```


The Augmented Assignment Operators

- In many assignment statements, the variable on the left side of the = operator also appears on the right side of the = operator
- Augmented assignment operators: special set of operators designed for this type of job
  - Shorthand operators

The Augmented Assignment Operators (cont'd.)

Statement	What It Does	Value of x after the Statement
`x = x + 4`	Add 4 to x	10
`x = x - 3`	Subtracts 3 from x	3
`x = x * 10`	Multiplies x by 10	60
`x = x / 2`	Divides x by 2	3
`x = x % 4`	Assigns the remainder of x / 4 to x	2

Operator	Example Usage	Equivalent To
`+=`	`x += 5`	`x = x + 5`
`-=`	`y -= 2`	`y = y - 2`
`*=`	`z *= 10`	`z = z * 10`
`/=`	`a /= b`	`a = a / b`
`%=`	`c %= 3`	`c = c % 3`

Sentinels

- Sentinel: special value that marks the end of a sequence of items
  - When program reaches a sentinel, it knows that the end of the sequence of items was reached, and the loop terminates
  - Must be distinctive enough so as not to be mistaken for a regular value in the sequence
  - Example: when reading an input file, empty line can be used as a sentinel

Program 4-13 (property_tax.py)

```
1  # This program displays property taxes.
2
3  TAX_FACTOR = 0.0065 # Represents the tax factor.
4
5  # Get the first lot number.
6  print('Enter the property lot number')
7  print('or enter 0 to end.')
8  lot = int(input('Lot number: '))
9
10 # Continue processing as long as the user
11 # does not enter lot number 0.
12 while lot ! = 0:
13     # Get the property value.
14     value = float(input('Enter the property value: '))
15
16     # Calculate the property's tax.
17     tax = value * TAX_FACTOR
18
19     # Display the tax.
20     print('Property tax: $', format(tax, ',.2f'), sep='')
21
22     # Get the next lot number.
23     print('Enter the next lot number or')
24     print('enter 0 to end.')
25     lot = int(input('Lot number: '))
```

Program Output (with input shown in bold)

```
Enter the property lot number
or enter 0 to end.
Lot number: 100 Enter
Enter the property value: 100000.00 Enter
Property tax: $650.00.
Enter the next lot number or
enter 0 to end.
Lot number: 200 Enter
Enter the property value: 5000.00 Enter
Property tax: $32.50.
Enter the next lot number or
enter 0 to end.
Lot number: 0 Enter
```

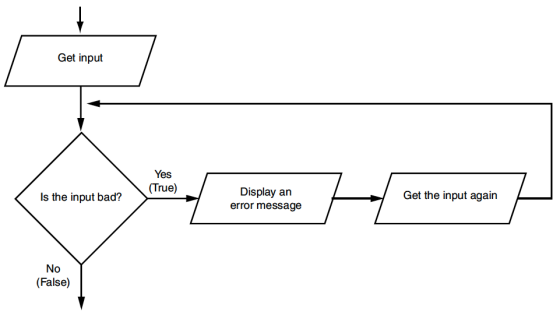

Input Validation Loops

- Computer cannot tell the difference between good data and bad data
  - If user provides bad input, program will produce bad output
  - GIGO: garbage in, garbage out
  - It is important to design program such that bad input is never accepted

Input Validation Loops (cont'd.)

- Input validation: inspecting input before it is processed by the program
  - If input is invalid, prompt user to enter correct data
  - Commonly accomplished using a `while` loop which repeats as long as the input is bad
    - If input is bad, display error message and receive another set of data
    - If input is good, continue to process the input

Input Validation Loops (cont'd.)



Program 4-16 (retail_with_validation.py)

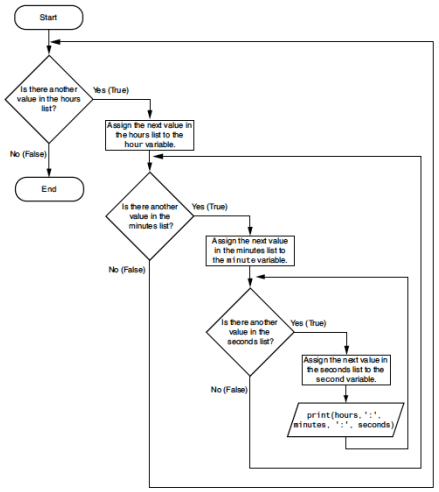
```
1  # This program calculates retail prices.
2
3  MARK_UP = 2.5 # The markup percentage
4  another = 'y' # Variable to control the loop.
5
6  # Process one or more items.
7  while another == 'y' or another == 'Y':
8      # Get the item's wholesale cost.
9      wholesale = float(input("Enter the item's " +
10                             "wholesale cost: "))
11
12     # Validate the wholesale cost.
13     while wholesale < 0:
14         print('ERROR: the cost cannot be negative.')
15         wholesale = float(input('Enter the correct' +
16                                 'wholesale cost: '))
17
18     # Calculate the retail price.
19     retail = wholesale * MARK_UP
20
21     # Display the retail price.
22     print('Retail price: $', format(retail, ',.2f'), sep='')
23
24
25     # Do this again?
26     another = input('Do you have another item? ' +
27                     '(Enter y for yes): ')
```


Program Output (with input shown in bold)

```
Enter the item's wholesale cost: -.50 Enter
ERROR: the cost cannot be negative.
Enter the correct wholesale cost: 0.50 Enter
Retail price: $1.25.
Do you have another item? (Enter y for yes): n Enter
```

Nested Loops

- Nested loop: loop that is contained inside another loop
  - Example: analog clock works like a nested loop
    - Hours hand moves once for every twelve movements of the minutes hand: for each iteration of the "hours," do twelve iterations of "minutes"
    - Seconds hand moves 60 times for each movement of the minutes hand: for each iteration of "minutes," do 60 iterations of "seconds"



Nested Loops (cont'd.)

- Key points about nested loops:
  - Inner loop goes through all of its iterations for each iteration of outer loop
  - Inner loops complete their iterations faster than outer loops
  - Total number of iterations in nested loop:

```
number_iterations_inner  x
number_iterations_outer
```


Program 4-17 (test_score_averages.py)

```
# This program averages test scores. It asks the user for the
# number of students and the number of test scores per student.

# Get the number of students.
num_students = int(input('How many students do you have? '))

# Get the number of test scores per student.
num_test_scores = int(input('How many test scores per student? '))

# Determine each student's average test score.
for student in range(num_students):
    # Initialize an accumulator for test scores.
    total = 0.0
    # Get a student's test scores.
    print('Student number', student + 1)
    print('-----------------')
    for test_num in range(num_test_scores):
        print('Test number', test_num + 1, end='')
        score = float(input(': '))
        # Add the score to the accumulator.
        total += score

    # Calculate the average test score for this student.
    average = total / num_test_scores

    # Display the average.
    print('The average for student number', student + 1,
          'is:', average)
    print()
```


Program Output (with input shown in bold)

```
How many students do you have? 3 Enter
How many test scores per student? 3 Enter
Student number 1
-----------------
Test number 1: 100 Enter
Test number 2: 95 Enter
Test number 3: 90 Enter
The average for student number 1 is: 95.0

Student number 2
-----------------
Test number 1: 80 Enter
Test number 2: 81 Enter
Test number 3: 82 Enter
The average for student number 2 is: 81.0

Student number 3
-----------------
Test number 1: 75 Enter
Test number 2: 85 Enter
Test number 3: 80 Enter
The average for student number 3 is: 80.0
```


Program 4-18 (rectangluar_pattern.py)

```
# This program displays a rectangular pattern
# of asterisks.
rows = int(input('How many rows? '))
cols = int(input('How many columns? '))

for r in range(rows):
    for c in range(cols):
        print('*', end='')
    print()
```

Program Output (with input shown in bold)

```
How many rows? 5 Enter
How many columns? 10 Enter
**********
**********
**********
**********
**********
```

Program 4-19 (triangle_pattern.py)


```
1  # This program displays a triangle pattern.
2  BASE_SIZE = 8
3
4  for r in range(BASE_SIZE):
5      for c in range(r + 1):
6          print('*', end='')
7      print()
```

Program Output

```
*
**
***
****
*****
******
*******
********
```

Program 4-20 (stair_step_pattern.py)


```
1  # This program displays a stair-step pattern.
2  NUM_STEPS = 6
3
4  for r in range(NUM_STEPS):
5     for c in range(r):
6        print(' ', end='')
7     print('#')
```

Program Output

```
#
 #
  #
   #
    #
     #
```


Summary

- This chapter covered:
  - Repetition structures, including:
    - Condition-controlled loops
    - Count-controlled loops
    - Nested loops
  - Infinite loops and how they can be avoided
  - `range` function as used in `for` loops
  - Calculating a running total and augmented assignment operators
  - Use of sentinels to terminate loops