CN101

Lecture 4

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

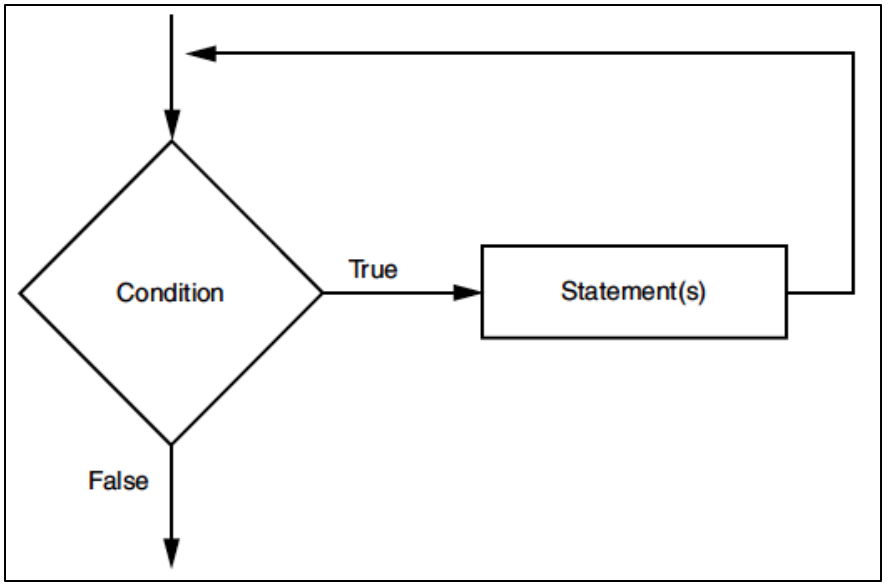
Introduction to Repetition Structures

- 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)

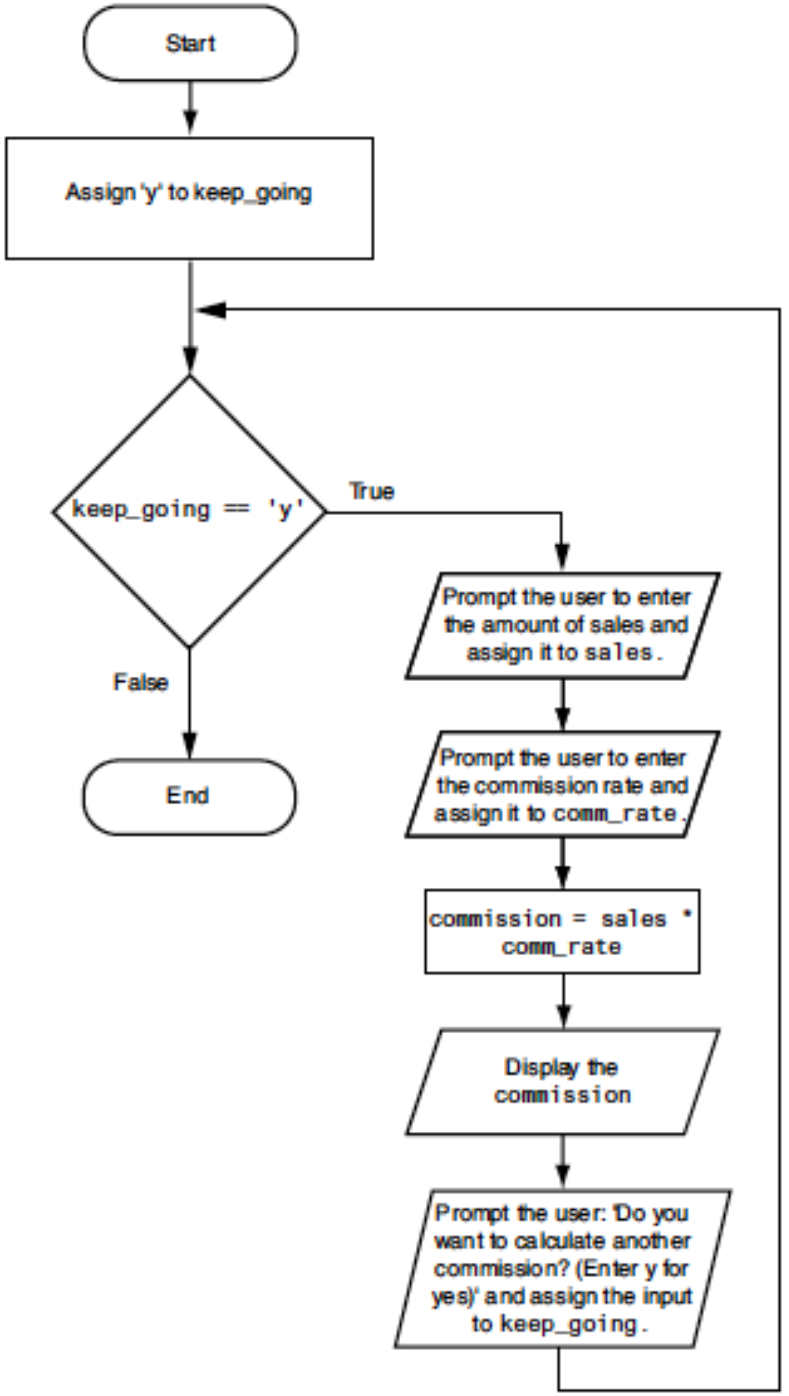
```
Enter the amount of sales: 10000.00 Enter
Enter the commission rate: 0.10 Enter
The commission is $1,000.00
Do you want to calculate another commission (Enter y for yes): y Enter
Enter the amount of sales: 20000.00 Enter
Enter the commission rate: 0.15 Enter
The commission is $3,000.00
Do you want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


Start
Assign 'y' to keep_going
keep_going == 'y'
True
False
End
Prompt the user to enter the amount of sales and assign it to sales.
Prompt the user to enter the commission rate and assign it to comm_rate.
commission = sales * comm_rate
Display the commission
Prompt the user: 'Do you want to calculate another commission? (Enter y for yes)' and assign the input to keep_going.

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
```

1st iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

2nd iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

3rd iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

4th iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

5th iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

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

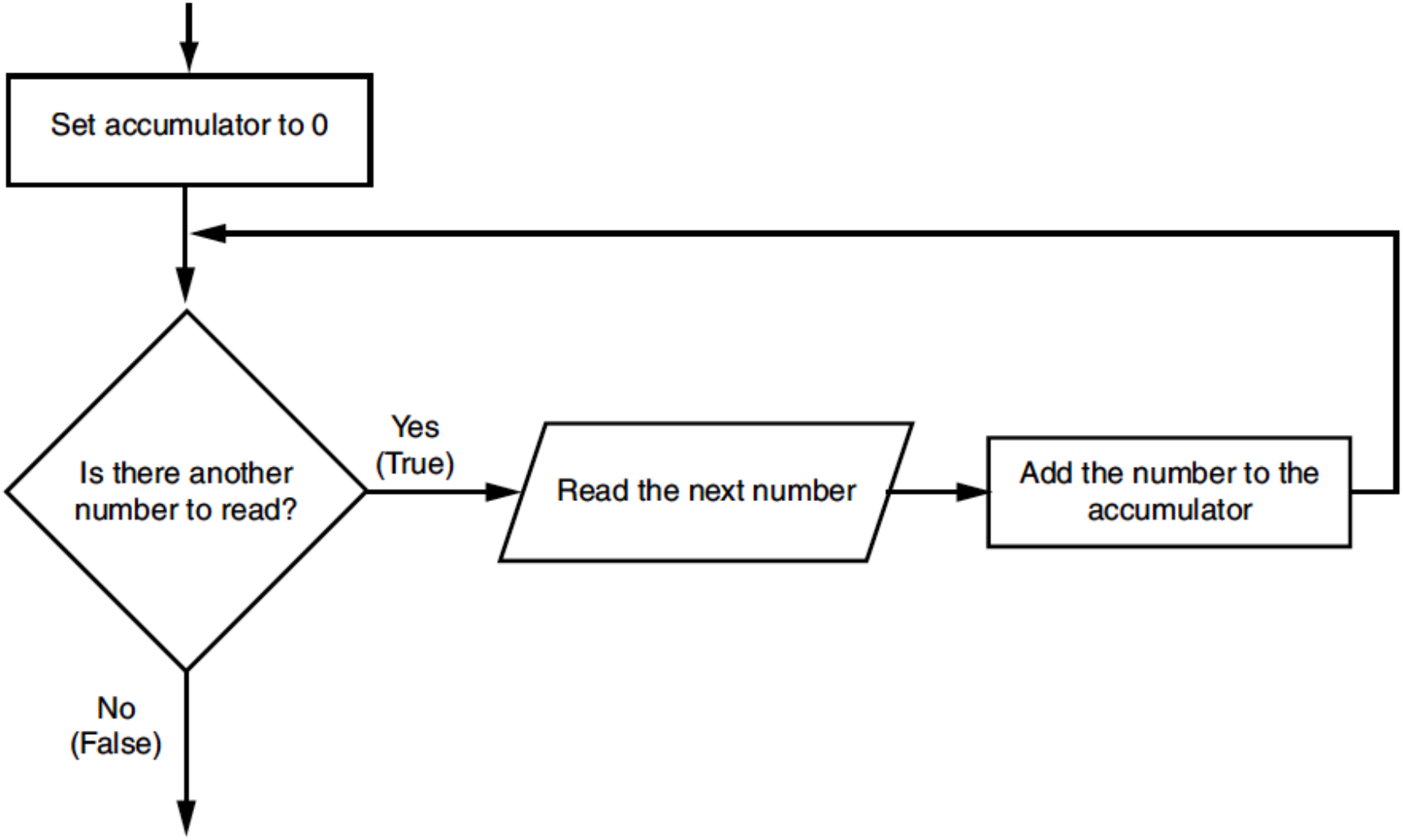
- The `range` function can be used to generate a sequence with numbers in descending order
  - Make sure starting number is larger than end limit, and step value is negative
  - Example: `range (5, 0, -1)`

```
>>> 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
```

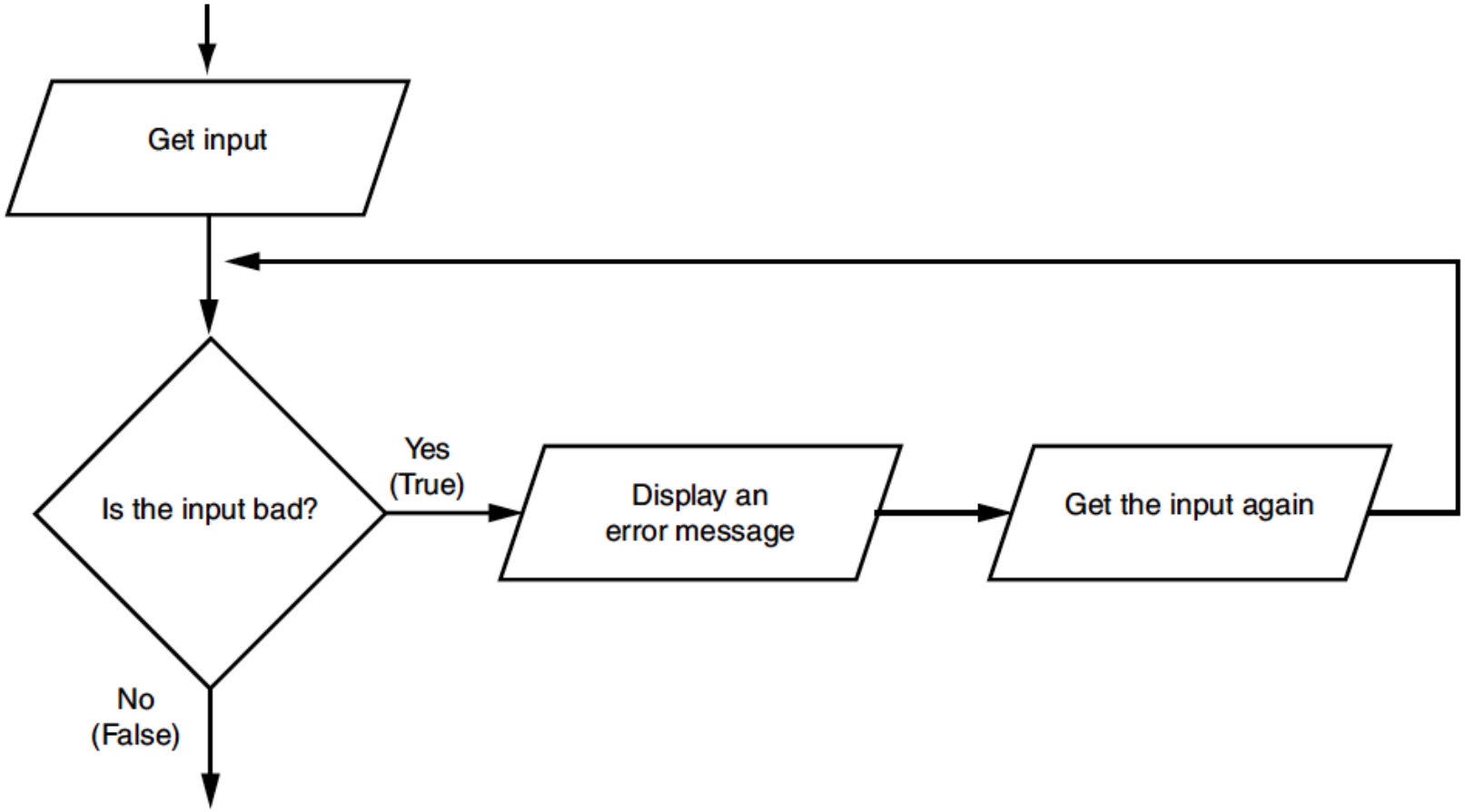
Input Validation Loops

- 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)

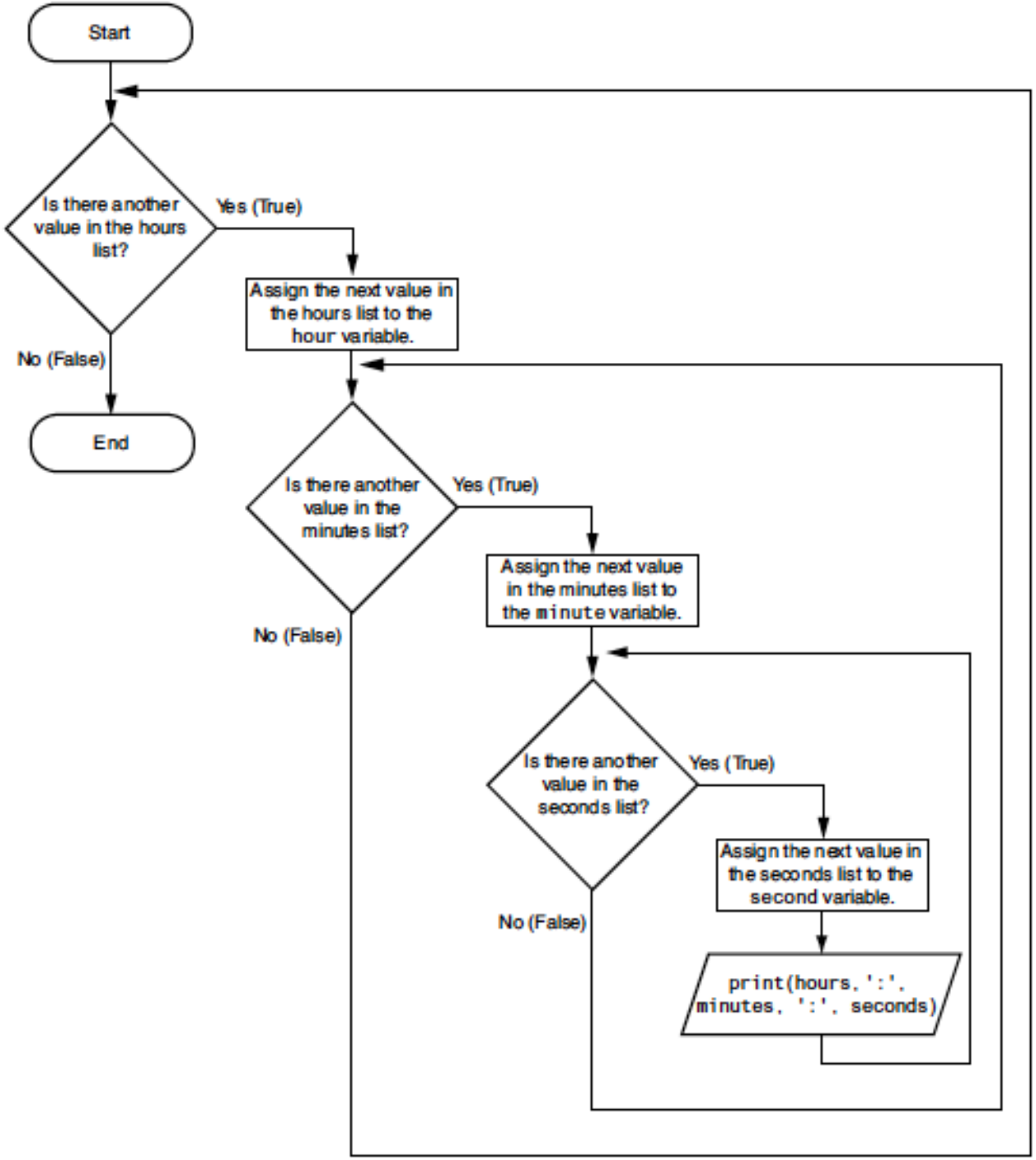
```
1  # This program calculates retail prices.
2
3  MARK_UP = 2.5 # The markup percentage
4  another = 'y' # Variable to control the loop.
5
6  # Process one or more items.
7  while another == 'y' or another == 'Y':
8      # Get the item's wholesale cost.
9      wholesale = float(input("Enter the item's " +
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”


Start
Is there another value in the hours list?
Yes (True)
Assign the next value in the hours list to the hour variable.
No (False)
End
Is there another value in the minutes list?
Yes (True)
Assign the next value in the minutes list to the minute variable.
No (False)
Is there another value in the seconds list?
Yes (True)
Assign the next value in the seconds list to the second variable.
No (False)
print(hours, ':', minutes, ':', 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)

```
1  # This program averages test scores. It asks the user for the
2  # number of students and the number of test scores per student.
3
4  # Get the number of students.
5  num_students = int(input('How many students do you have? '))
6
7  # Get the number of test scores per student.
8  num_test_scores = int(input('How many test scores per student? '))
9
10 # Determine each student's average test score.
11 for student in range(num_students):
12     # Initialize an accumulator for test scores.
13     total = 0.0
14     # Get a student's test scores.
15     print('Student number', student + 1)
16     print('-----------------')
17     for test_num in range(num_test_scores):
18         print('Test number', test_num + 1, end='')
19         score = float(input(': '))
20         # Add the score to the accumulator.
21         total += score
22
23     # Calculate the average test score for this student.
24     average = total / num_test_scores
25
26     # Display the average.
27     print('The average for student number', student + 1,
28           'is:', average)
29     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)

```
1  # This program displays a rectangular pattern
2  # of asterisks.
3  rows = int(input('How many rows? '))
4  cols = int(input('How many columns? '))
5
6  for r in range(rows):
7      for c in range(cols):
8          print('*', end='')
9      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

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

`Break` statement

- The `break` statement is used to exit a loop prematurely
- It can be used in both for loops and while loops
- When `break` is encountered, **the loop is immediately terminated**
- Program execution continues with the next statement after the loop
- `break` is useful for ending loops based on certain conditions

Break examples

```
for i in range(1, 6):
    if i == 4:
        break
    print(i)
```

Program Output:

```
1
2
3
```

```
count = 0
while True:
    count += 1
    if count == 5:
        break
    print(count)
```

Program Output:

```
1
2
3
4
```

Break examples: Input Validation

```
# check Age must be >= 0
while True:
    age = int(input('Enter age: '))
    if age >= 0:
        break
    print('Invalid age')
print(f'Your age is {age}.')
```

Program Output:

```
Enter age: -1
Invalid age
Enter age: 18
Your age is 18.
```

`Continue` statement

- The `continue` command is used inside loops (`for` and `while`)
- It **skips** the rest of the current iteration and **moves to the next one/iteration**
- Useful when you want to skip specific items in a loop
- Helps avoid nested conditional code
- Improves readability and efficiency of your code

Continue examples

```
for num in range(8):
    if num % 2 == 0:
        continue
    print(num)
```

Program Output:

```
1
3
5
7
```

```
count = 0
while count < 5:
    count += 1
    if count == 3:
        continue
    print(count)
```

Program Output:

```
1
2
4
5
```

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
  - `break` and `continue` to control loop