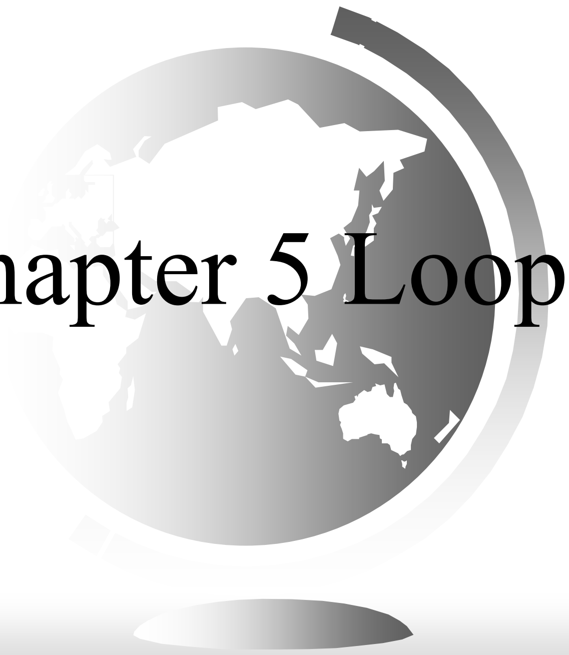


Chapter 5 Loops

Motivations

Suppose that you need to print a string (e.g., "Programming is fun!") a hundred times. It would be tedious to have to write the following statement a hundred times:

```
print("Programming is fun!");
```

So, how do you solve this problem?

Opening Problem

Problem:

100 times

```
print("Programming is fun!");
print("Programming is fun!");
print("Programming is fun!");
print("Programming is fun!");
print("Programming is fun!");
print("Programming is fun!");


...

...

...
print("Programming is fun!");
print("Programming is fun!");
print("Programming is fun!");
```

Introducing while Loops

```
count = 0
while count < 100:
    print("Programming is fun!")
    count = count + 1
```

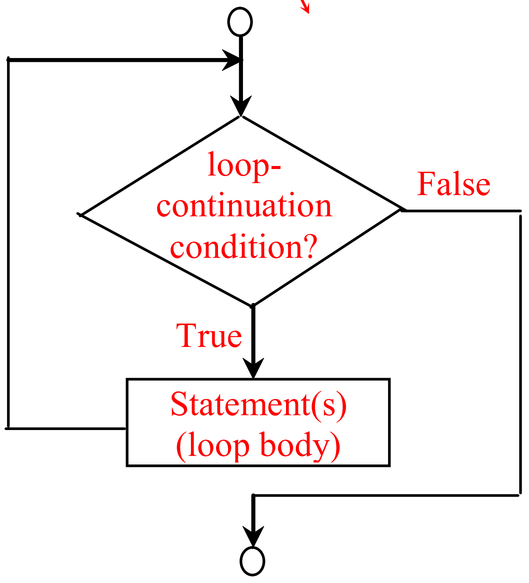
Objectives

- To write programs for executing statements repeatedly by using a **while** loop (§5.2).
- To develop loops following the loop design strategy (§§5.2.1-5.2.3).
- To control a loop with the user’s confirmation (§5.2.4).
- To control a loop with a sentinel value (§5.2.5).
- To obtain a large amount of input from a file by using input redirection instead of typing from the keyboard (§5.2.6).
- To use **for** loops to implement counter-controlled loops (§5.3).
- To write nested loops (§5.4).
- To learn the techniques for minimizing numerical errors (§5.5).
- To learn loops from a variety of examples (**GCD**, **FutureTuition**, **MonteCarloSimulation**, **PrimeNumber**) (§§5.6, 5.8).
- To implement program control with **break** and **continue** (§5.7).

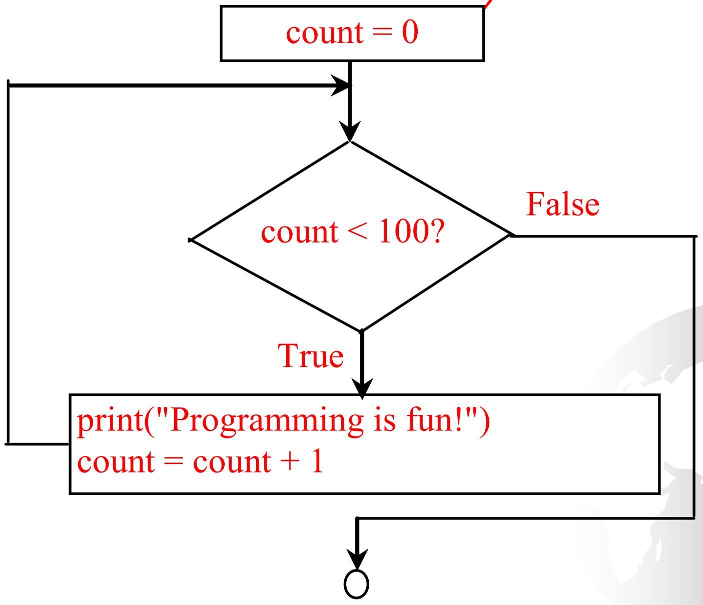
`while` Loop Flow Chart

```
while loop-continuation-condition:
    # Loop body
    Statement(s)
```

```
count = 0
while count < 100:
    print("Programming is fun!")
    count = count + 1
```



(a)



(b)

animation

Trace while Loop

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

Initialize count

Trace while Loop, cont.

(count < 2) is true

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

animation

Trace while Loop, cont.

Print Welcome to Python

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

Trace while Loop, cont.

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

Increase count by 1
count is 1 now

animation

Trace while Loop, cont.

(count < 2) is still true since count is 1

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

animation

Trace while Loop, cont.

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

Print Welcome to Python

animation

Trace while Loop, cont.

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

Increase count by 1
count is 2 now

animation

Trace while Loop, cont.

(count < 2) is false since count is 2 now

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

animation

Trace while Loop

```
count = 0
while count < 2:
    print("Programming is fun!")
    count = count + 1
```

The loop exits. Execute the next statement after the loop.

Problem: An Advanced Math Learning Tool

Recall that Listing 4.4, SubtractionQuiz.py, gives a program that prompts the user to enter an answer for a question on subtraction. Using a loop, you can now rewrite the program to let the user enter a new answer until it is correct.

RepeatSubtractionQuiz

Problem: Guessing Numbers

Write a program that randomly generates an integer between 0 and 100, inclusive. The program prompts the user to enter a number continuously until the number matches the randomly generated number. For each user input, the program tells the user whether the input is too low or too high, so the user can choose the next input intelligently.

GuessNumberOneTime

GuessNumber

Case Study: Multiple Subtraction Quiz

The Math subtraction learning tool program generates just one question for each run. You can use a loop to generate questions repeatedly. This example gives a program that generates five questions and reports the number of the correct answers after a student answers all five questions.

SubtractionQuizLoop

Ending a Loop with a Sentinel Value

Often the number of times a loop is executed is not predetermined. You may use an input value to signify the end of the loop. Such a value is known as a *sentinel value*.

Write a program that reads and calculates the sum of an unspecified number of integers. The input 0 signifies the end of the input.

SentinelValue

Caution

Don’t use floating-point values for equality checking in a loop control. Since floating-point values are approximations for some values, using them could result in imprecise counter values and inaccurate results. Consider the following code for computing 1 + 0.9 + 0.8 + ... + 0.1:

```
item = 1
sum = 0
while item != 0: # No guarantee item will be 0
    sum += item
    item -= 0.1
print(sum)
```

Variable item starts with 1 and is reduced by 0.1 every time the loop body is executed. The loop should terminate when item becomes 0. However, there is no guarantee that item will be exactly 0, because the floating-point arithmetic is approximated. This loop seems OK on the surface, but it is actually an infinite loop.

`for` Loops

```
i = initialValue  # Initialize loop-control variable
while i < endValue:
    # Loop body
    ...
    i++ # Adjust loop-control variable
```

```
for i in range(initialValue, endValue):
    # Loop body
```

range(a, b)

```
>>> for v in range(4, 8):
...     print(v)
...
4
5
6
7
>>>
```

range(b)

```
>>> for i in range(4):
...     print(i)
...
0
1
2
3
>>>
```

range(a, b, step)

```
>>> for v in range(3, 9, 2):
...     print(v)
...
3
5
7
>>>
```

range(a, b, step)

```
>>> for v in range(5, 1, -1):
...     print(v)
...
5
4
3
2
>>>
```

Nested Loops

Problem: Write a program that uses nested for loops to print a multiplication table.

MultiplicationTable

Minimizing Numerical Errors

Numeric errors involving floating-point numbers are inevitable. This section discusses how to minimize such errors through an example.

Here is an example that sums a series that starts with 0.01 and ends with 1.0. The numbers in the series will increment by 0.01, as follows: 0.01 + 0.02 + 0.03 and so on.

TestSum

Problem:
Finding the Greatest Common Divisor

Problem: Write a program that prompts the user to enter two positive integers and finds their greatest common divisor.

Solution: Suppose you enter two integers 4 and 2, their greatest common divisor is 2. Suppose you enter two integers 16 and 24, their greatest common divisor is 8. So, how do you find the greatest common divisor? Let the two input integers be n1 and n2. You know number 1 is a common divisor, but it may not be the greatest common divisor. So you can check whether k (for k = 2, 3, 4, and so on) is a common divisor for n1 and n2, until k is greater than n1 or n2.

GreatestCommonDivisor

Problem: Predicting the Future Tuition

Problem: Suppose that the tuition for a university is $10,000 this year and tuition increases 7% every year. In how many years will the tuition be doubled?

FutureTuition

Problem: Predicating the Future Tuition

```
year = 0  # Year 0
tuition = 10000
year += 1 # Year 1
tuition = tuition * 1.07
year += 1 # Year 2
tuition = tuition * 1.07
year += 1 # Year 3
tuition = tuition * 1.07
```

Case Study: *Converting Decimals to Hexadecimals*

Hexadecimals are often used in computer systems programming (see Appendix F for an introduction to number systems). How do you convert a decimal number to a hexadecimal number? To convert a decimal number *d* to a hexadecimal number is to find the hexadecimal digits h_n, h_{n-1}, h_{n-2}, ... , h_2, h_1, and h_0 such that

$$d = h_n \times 16^n + h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + \ldots + h_2 \times 16^2 + h_1 \times 16^1 + h_0 \times 16^0$$

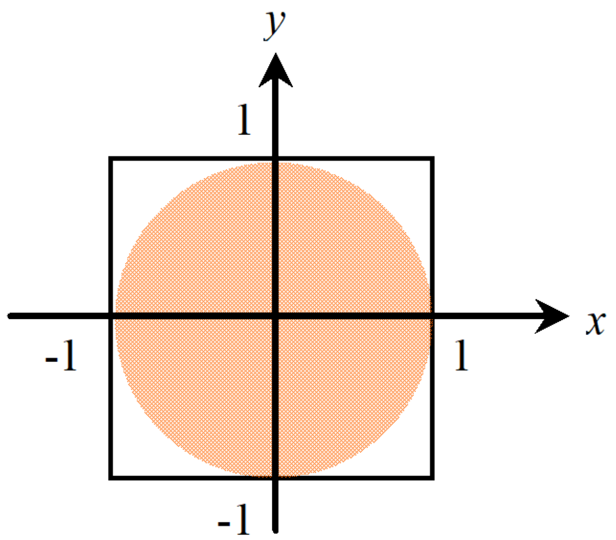
These hexadecimal digits can be found by successively dividing *d* by 16 until the quotient is 0. The remainders are h_0, h_1, h_2, ... , h_{n-2}, h_{n-1}, and h_n.

Dec2Hex

Companion Website

Problem: *Monte Carlo Simulation*

The Monte Carlo simulation refers to a technique that uses random numbers and probability to solve problems. This method has a wide range of applications in computational mathematics, physics, chemistry, and finance. This section gives an example of using the Monto Carlo simulation for estimating π.



circleArea / squareArea = π / 4.

π can be approximated as 4 * numberOfHits / numberOfTrials

MonteCarloSimulation

Using `break` and `continue`

Examples for using the `break` and `continue` keywords:

- TestBreak.py

  TestBreak

- TestContinue.py

  TestContinue

break

```
sum = 0
number = 0

while number < 20:
    number += 1
    sum += number
    if sum >= 100:
        break

print("The number is ", number)
print("The sum is ", sum)
```

Break out of the loop

continue

```
sum = 0
number = 0

while number < 20:
    number += 1
    if number == 10 or number == 11:
        continue
    sum += number

print("The sum is ", sum)
```

Jump to the end of the iteration

Guessing Number Problem Revisited

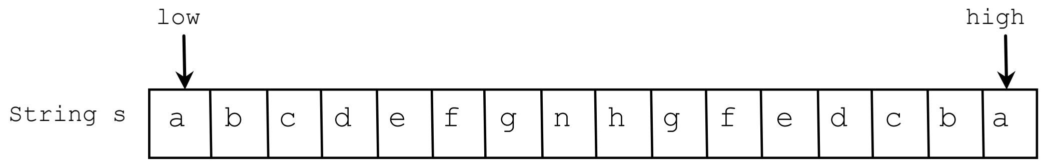
Here is a program for guessing a number. You can rewrite it using a **break** statement.

GuessNumberUsingBreak

Problem: Checking Palindrome

A string is a palindrome if it reads the same forward and backward. The words “mom,” “dad,” and “noon,” for instance, are all palindromes.

The problem is to write a program that prompts the user to enter a string and reports whether the string is a palindrome. One solution is to check whether the first character in the string is the same as the last character. If so, check whether the second character is the same as the second-to-last character. This process continues until a mismatch is found or all the characters in the string are checked, except for the middle character if the string has an odd number of characters.



TestPalindrome

Problem: Displaying Prime Numbers

Problem: Write a program that displays the first 50 prime numbers in five lines, each of which contains 10 numbers. An integer greater than 1 is *prime* if its only positive divisor is 1 or itself. For example, 2, 3, 5, and 7 are prime numbers, but 4, 6, 8, and 9 are not.

Solution: The problem can be broken into the following tasks:

- For number = 2, 3, 4, 5, 6, ..., test whether the number is prime.
- Determine whether a given number is prime.
- Count the prime numbers.
- Print each prime number, and print 10 numbers per line.

PrimeNumber