Chapter 6: Looping

Objectives

- Learn about the loop structure
- Create `while` loops
- Use shortcut arithmetic operators
- Create `for` loops
- Create `do…while` loops
- Nest loops
- Improve loop performance

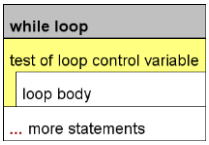
Learning About the Loop Structure

- **Loop**
  - A structure that allows repeated execution of a block of statements
- **Loop body**
  - A block of statements
  - Executed repeatedly
- **Iteration**
  - One execution of any loop

Learning About the Loop Structure (cont'd.)

- Three types of loops
  - `while`
    - The loop-controlling Boolean expression is the first statement
  - `for`
    - A concise format in which to execute loops
  - `do…while`
    - The loop-controlling Boolean expression is the last statement

Learning About the Loop Structure (cont'd.)



A `while` loop structure (is general to most looping structures)

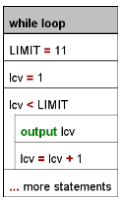
Creating `while` Loops

- **`while` loop**
  - Executes a body of statements continually
    - As long as the Boolean expression that controls entry into the loop continues to be `true`
  - Consists of:
    - The keyword `while`
    - Followed by a Boolean expression within parentheses
    - Followed by the body of the loop; can be a single statement or a block of statements surrounded by curly braces

Writing a Definite `while` Loop

- **Definite loop**
  - Performs a task a predetermined number of times
  - Also called a counted loop
- Write a definite loop
  - Initialize the loop control variable
    - The variable whose value determines whether loop execution continues
  - While the loop control variable does not pass a limiting value, the program continues to execute the body of the `while` loop

Writing a Definite `while` Loop (cont'd.)



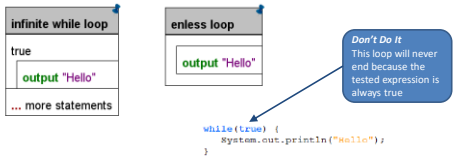

```
int lcv;
final int LIMIT = 11;

lcv = 1;
while(lcv < LIMIT) {
   System.out.println(lcv);
   lcv = lcv + 1;
}
```

A `while` loop that displays the integers 1 through 10

Writing a Definite `while` Loop (cont'd.)

- Write a definite loop (cont'd.)
  - The body of the loop must include a statement that alters the loop control variable
- **Infinite loop**
  - A loop that never ends
  - Can result from a mistake in the `while` loop
  - Do not write intentionally

Writing a Definite `while` Loop (cont'd.)



A `while` loop that displays "Hello" infinitely

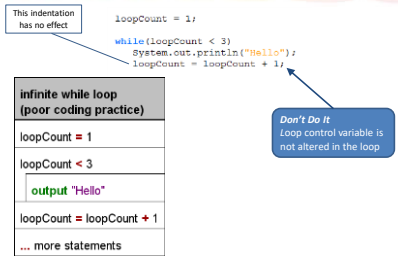
Writing a Definite `while` Loop (cont'd.)

- Suspect an infinite loop when:
  - The same output is displayed repeatedly
  - The screen remains idle for an extended period of time
- To exit an infinite loop, press and hold Ctrl, then press C or Break

Pitfall: Failing to Alter the Loop Control Variable Within the Loop Body

- Prevent the `while` loop from executing infinitely
  - The named loop control variable is initialized to a starting value
  - The loop control variable is tested in the `while` statement
  - If the test expression is `true`, the body of the `while` statement takes action
    - Alters the value of the loop control variable
  - The test of the `while` statement must eventually evaluate to `false`

Pitfall: Failing to Alter the Loop Control Variable Within the Loop Body (cont'd.)



A `while` loop that displays "Hello" infinitely because `loopCount` is not altered in the loop body

Pitfall: Unintentionally Creating a Loop with an Empty Body

- Loop control variable
  - A variable that is altered and stored with a new value
    `loopCount = loopCount + 1`
    - The equal sign assigns a value to the variable on the left
  - The variable should be altered within the body of the loop
- **Empty body**
  - A body with no statements
  - Caused by misplaced semicolons

Altering a Definite Loop's Control Variable

- **Incrementing** the variable
  - Alter the value of the loop control variable by adding 1
- **Decrementing** the variable
  - Subtract 1 from the loop control variable
- Clearest and best method
  - Start the loop control variable at 0 or 1
  - Increment by 1 each time through the loop
  - Stop when the loop control variable reaches the limit

Altering a Definite Loop's Control Variable (cont'd.)

```
loopCount = 3;
while(loopCount > 1)
{
   System.out.println("Hello");
   loopCount = loopCount - 1;
}
```

Figure 6-7 A `while` loop that displays "Hello" twice, decrementing the `loopCount` variable in the loop body

Writing an Indefinite `while` Loop

- Indefinite loop
  - Altered by user input
    - Controlled by the user
    - Executed any number of times
- Validating data
  - Ensure a value falls within a specified range
  - Use indefinite loops to validate input data
  - If a user enters incorrect data, the loop repeats

Writing an Indefinite `while` Loop (cont'd.)

```
import java.util.Scanner;
public class BankBalance
{
   public static void main(String[] args){
      double balance;
      int response;
      int year = 1;
      final double INT_RATE = 0.03;
      Scanner keyboard = new Scanner(System.in);
      System.out.print("Enter initial bank balance > ");
      balance = keyboard.nextDouble();
      System.out.println("Do you want to see next year's balance?");
      System.out.print("Enter 1 for yes");
      System.out.print(" or any other number for no >> ");
      response = keyboard.nextInt();
      while(response == 1){
         balance = balance + balance * INT_RATE;
         System.out.println("After year " + year + " at " +  INT_RATE +
            " interest rate, balance is $" + balance);
         year = year + 1;
         System.out.println("\nDo you want to see the balance " +
            "at the end of another year?");
         System.out.print("Enter 1 for yes");
         System.out.print(" or any other number for no >> ");
         response = keyboard.nextInt();
      }
   }
```

Figure 6-8 The `BankBalance` application

Validating Data

- Ensuring data falls within a specific range
- **Priming read**
  - Input retrieved before the loop is entered
  - Within a loop, the last statement retrieves the next input value and checks the value before the next entrance of the loop

Validating Data (cont'd.)

```
import java.util.Scanner;
public class EnterSmallValue{
   public static void main(String[] args){
      int userEntry;
      final int LIMIT = 3;
      Scanner input = new Scanner(System.in);
      System.out.print("Please enter an integer no higher than " +
         LIMIT + " > ");
      userEntry = input.nextInt();
      while(userEntry > LIMIT){
         System.out.println("The number you entered was too high");
         System.out.print("Please enter an integer no higher than " +
            LIMIT + " > ");
         userEntry = input.nextInt();
      }
      System.out.println("You correctly entered " + userEntry);
   }
}
```

Figure 6-8 The `EnterSmallValue` application

Using Shortcut Arithmetic Operators

- **Accumulating**
  - Repeatedly increasing a value by some amount
- Java provides shortcuts for incrementing and accumulating
  - `+=` **add and assign operator**
  - `-=` **subtract and assign operator**
  - `*=` **multiply and assign operator**
  - `/=` **divide and assign operator**
  - `%=` **remainder and assign operator**

Using Shortcut Arithmetic Operators (cont'd.)

- **Prefix increment operator** and **postfix increment operator**
  `++someValue, someValue++`
  - Use only with variables
  - Unary operators
    - Use with one value
  - Increase a variable's value by 1
    - No difference between operators (unless other operations are in the same expression)

Using Shortcut Arithmetic Operators (cont'd.)

```
int value;

value = 24;
++value; // Result: value is 25
   // (incremented and then used)

value = 24;
value++; // Result: value is 25
   // (value is used then incremented)

value = 24;
value = value + 1; // Result: value is 25

value = 24;
value += 1; // Result: value is 25
```

Figure 6-13 Four ways to add 1 to a value

Using Shortcut Arithmetic Operators (cont'd.)

- **Prefix increment operator** and **postfix increment operator** (cont'd.)
  - **Prefix ++**
    - The result is calculated and stored
    - Then the variable is used
  - **Postfix ++**
    - The variable is used
    - Then the result is calculated and stored
- Prefix and postfix decrement operators
  `--someValue`
  `someValue--`
  - Similar logic to increment operators

Using Shortcut Arithmetic Operators (cont'd.)

```
public class PrefixPostfixDemo{
   public static void main(String[] args){
      int myNumber, answer;
      myNumber = 17;
      System.out.println("Before incrementing, myNumber is " +
         myNumber);
      answer = ++myNumber;
      System.out.print("After prefix increment, myNumber is " +
         myNumber);
      System.out.println(" and answer is " + answer);
      myNumber = 17;
      System.out.println("Before incrementing, myNumber is " +
         myNumber);
      answer = myNumber++;
      System.out.print("After postfix increment, myNumber is " +
         myNumber);
      System.out.println(" and answer is " + answer);
   }
}
```

```
Before incrementing, myNumber is 17
After prefix increment, myNumber is 18 and answer is 18
Before incrementing, myNumber is 17
After postfix increment, myNumber is 18 and answer is 17
```

Figure 6-14 The `PrefixPostfixDemo` application

Creating a `for` Loop

- **`for` loop**
  - Used when a definite number of loop iterations is required
  - One convenient statement indicates:
    - The starting value for the loop control variable
    - The test condition that controls loop entry
    - The expression that alters the loop control variable

Creating a `for` Loop (cont'd.)

```
int val;

for(val = 1; val < 11; val++){
   System.out.println(val);
}

val = 1;
while(val < 11){
   System.out.println(val);
   val++;
}
```

Figure 6-18 A `for` loop and a `while` loop that displays the integers 1 through 10

Creating a `for` Loop (cont'd.)

- Other uses for the three sections of a `for` loop
  - Initialization of more than one variable
    - Place commas between separate statements
  - Performance of more than one test using AND or OR operators
  - Decrementing or performance of some other task
  - Altering more than one value
- You can leave one or more portions of a `for` loop empty
    - Two semicolons are still required as placeholders

Creating a `for` Loop (cont'd.)

- Use the same loop control variable in all three parts of a `for` statement
- To pause a program:
  - Use the `for` loop that contains no body (**do-nothing** loop)

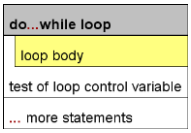
```
for(x = 0; x < 100000; x++);
```

  - Or use the built-in `sleep()` method

Learning How and When to Use a `do…while` Loop

- **`do…while` loop**
  - A **posttest loop**
  - Checks the value of the loop control variable
    - At the bottom of the loop
    - After one repetition has occurred
  - Performs a task at least one time
  - You are never required to use this type of loop
  - Use curly braces to block the statement
    - Even with a single statement

Learning How and When to Use a do…while Loop (cont'd.)



General structure of a do...while loop

Learning How and When to Use a do…while Loop (cont'd.)

```
import java.util.Scanner;
public class BankBalance2{
   public static void main(String[] args){
      double balance;
      int response;
      int year = 1;
      final double INT_RATE = 0.03;
      Scanner keyboard = new Scanner(System.in);
      System.out.print("Enter initial bank balance >> ");
      balance = keyboard.nextDouble();
      do{
         balance = balance + balance * INT_RATE;
         System.out.println("After year " + year + " at " +  INT_RATE +
            " interest rate, balance is $" + balance);
         year = year + 1;
         System.out.println("\nDo you want to see the balance " +
            "at the end of another year?");
         System.out.print("Enter 1 for yes");
         System.out.print(" or any other number for no >> ");
         response = keyboard.nextInt();
      } while(response == 1);
   }
}
```

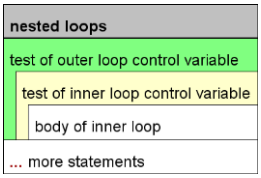
Figure 6-23 A do...while loop for the BankBalance2 application

Learning About Nested Loops

- **Inner loop** and **outer loop**
  - An inner loop must be entirely contained in an outer loop
  - Loops can never overlap
- To print three mailing labels for each of 20 customers:

```
for(customer = 1; customer <= 20; customer++)
   for(color = 1; color <= 3; color++)
      outputLabel ();
```

Learning About Nested Loops (cont'd.)



Nested loops

Improving Loop Performance

- Make sure a loop does not include unnecessary operations or statements
- Consider the order of evaluation for short-circuit operators
- Make comparisons to zero (0)
- Employ loop fusion to combine loops

Avoiding Unnecessary Operations

- Do not use unnecessary operations or statements:
  - Within a loop's tested expression
  - Within the loop body
- Avoid:

```
while (x < a + b)
// loop body
```

- Instead use:

```
int sum = a + b;
while(x < sum)
// loop body
```

Considering the Order of Evaluation of Short-Circuit Operators

- Short-circuit evaluation
  - Each part of an AND or an OR expression is evaluated only as much as necessary to determine the value of the expression
- Important to consider the number of evaluations that take place
  - When a loop might execute many times

Comparing to Zero

- Making a comparison to zero (0) is faster than making a comparison to any other value
- To improve loop performance, compare the loop control variable to zero (0)
- Do-nothing loop
  - Performs no actions other than looping

Comparing to Zero (cont'd.)

```
import java.time.*;
public class CompareLoopTimes{
   public static void main(String[] args){
      int startTime, endTime;
      final int REPEAT = 100_000;
      final int FACTOR = 1_000_000;
      LocalDateTime now;
      now = LocalDateTime.now();
      startTime = now.getNano();
      for(int x = 0; x <= REPEAT; x++)
         {for(int y = 0; y <= REPEAT; y++);}
      now = LocalDateTime.now();
      endTime = now.getNano();
      System.out.println("Time for loops starting from 0: " +
          ((endTime - startTime) / FACTOR) + " milliseconds");
      now = LocalDateTime.now();
      startTime = now.getNano();
      for(int x = REPEAT; x >= 0; x--)
         {for(int y = REPEAT; y >= 0; y--);}
      now = LocalDateTime.now();
      endTime = now.getNano();
      System.out.println("Time for loops ending with 0: " +
          ((endTime - startTime) / FACTOR) + " milliseconds");
   }
}
```

```
----jGRASP wedge2: pid for process is 12588.
Time for loops starting from 0: 47 milliseconds
Time for loops ending with 0: 8 milliseconds
```

Figure 6-29 The `CompareLoopTimes` application

Employing Loop Fusion

- **Loop fusion**
  - A technique of combining two loops into one
  - Will not work in every situation

Don't Do It

- Don't insert a semicolon at the end of a `while` clause
- Don't forget to block multiple statements that should execute in a loop
- Don't make the mistake of checking for invalid data using a decision instead of a loop
- Don't ignore subtleties in the boundaries used to stop loop performance
- Don't repeat steps within a loop that could just as well be placed outside the loop

Summary

- The loop structure allows repeated execution of a block of statements
  - Infinite loop
  - Definite loop
  - Nest loop
- You must change the loop control variable within the looping structure
- Use the `while` loop to execute statements while some condition is `true`

Summary (cont'd.)

- Execute the `while` loop
  - Initialize the loop control variable, test in the `while` statement, and alter the loop control variable
- Prefix ++ and postfix ++
  - Increase a variable's value by 1
  - The variable is used
    - The result is calculated and stored
- Unary operators
  - Use with one value

Summary (cont'd.)

- Binary operators
  - Operate on two values
- Shortcut operators `+=`, `-=`, `*=`, and `/=`
  - Perform operations and assign the result in one step
- `for` loop
  - Initializes, tests, and increments in one statement
- `do…while` loop
  - Tests a Boolean expression after one repetition
- Improve loop performance
  - Do not include unnecessary operations or statements