Lecture 8: **Control Statements** (cont)

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EECS 211
Fundamentals of Computer Programming II
April 9th, 2010

4.6 `if...else` Double-Selection Statement

- `if`…`else` double-selection statement
  - specifies an action to perform when the condition is true and a different action to perform when the condition is `false`.
- The following pseudocode prints “Passed” if the student’s grade is greater than or equal to 60, or “Failed” if the student’s grade is less than 60.

```
–If student’s grade is greater than or equal to 60
        Print “Passed”
Else
        Print “Failed”
```

- In either case, after printing occurs, the next pseudocode statement in sequence is “performed.”
- The preceding pseudocode *If…Else* statement can be written in C++ as

```
if ( grade >= 60 )
   cout << "Passed";
else
   cout << "Failed";
```

4.6 if...else Double-Selection Statement (cont.)

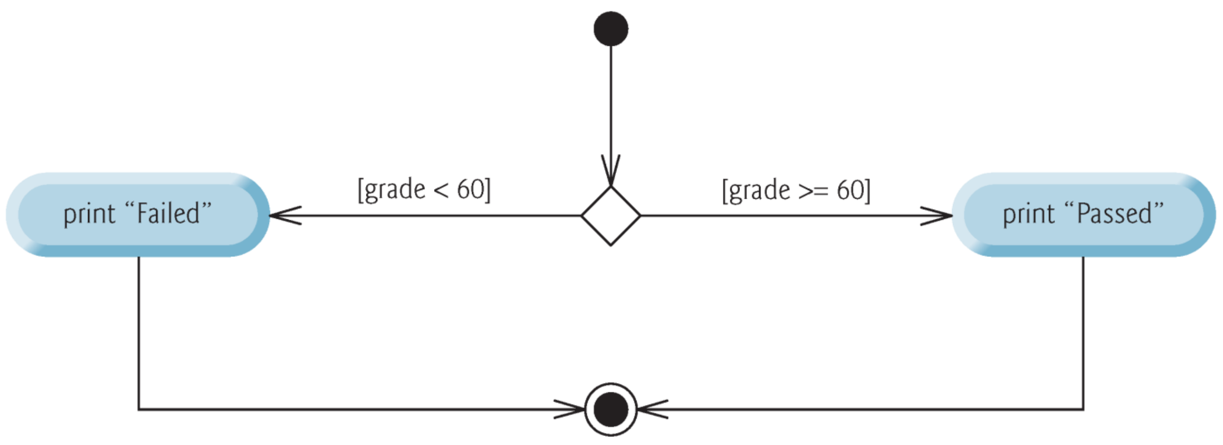


Fig. 4.5 | `if...else` double-selection statement activity diagram.

4.6 `if...else` Double-Selection Statement (cont.)

- Nested if…else statements test for multiple cases by placing `if`…`else` selection statements inside other `if`…`else` selection statements.

```
–If student's grade is greater than or equal to 90
   Print "A"
Else
   If student's grade is greater than or equal to 80
            Print "B"
   Else
            If student's grade is greater than or equal to 70
                     Print "C"
            Else
                     If student's grade is greater than or equal to 60
                              Print "D"
                     Else
                              Print "F"
```

4.6 if...else Double-Selection Statement (cont.)

- This pseudocode can be written in C++ as

```
if ( studentGrade >= 90 ) // 90 and above gets "A"
   cout << "A";
else
   if ( studentGrade >= 80 ) // 80-89 gets "B"
      cout << "B";
   else
      if ( studentGrade >= 70 ) // 70-79 gets "C"
         cout << "C";
      else
         if ( studentGrade >= 60 ) // 60-69 gets "D"
            cout << "D";
         else // less than 60 gets "F"
            cout << "F";
```

- If studentGrade is greater than or equal to 90, the first four conditions are `true`, but only the output statement after the first test executes. Then, the program skips the `else`-part of the "outermost" `if`…`else` statement.

4.6 `if…else` Double-Selection Statement (cont.)

- Most write the preceding `if…else` statement as

  -
    ```
    if ( studentGrade >= 90 ) // 90 and above gets
    "A"
       cout << "A";
    else if ( studentGrade >= 80 ) // 80-89 gets "B"
       cout << "B";
    else if ( studentGrade >= 70 ) // 70-79 gets "C"
       cout << "C";
    else if ( studentGrade >= 60 ) // 60-69 gets "D"
       cout << "D";
    else // less than 60 gets "F"
       cout << "F";
    ```
- The two forms are identical except for the spacing and indentation, which the compiler ignores.
- The latter form is popular because it avoids deep indentation of the code to the right, which can force lines to wrap.

4.6 `if...else` Double-Selection Statement (cont.)

- The C++ compiler always associates an `else` with the immediately preceding `if` unless told to do otherwise by the placement of braces (`{` and `}`).
- This behavior can lead to what's referred to as the dangling-else problem.

```
    • if ( x > 5 )
         if ( y > 5 )
            cout << "x and y are > 5";
      else
         cout << "x is <= 5";
```

appears to indicate that if `x` is greater than `5`, the nested `if` statement determines whether `y` is also greater than `5`.

4.6 `if...else` Double-Selection Statement (cont.)

- The compiler actually interprets the statement as

  -
    ```
    if ( x > 5 )
        if ( y > 5 )
            cout << "x and y are > 5";
        else
            cout << "x is <= 5";
    ```
- To force the nested `if`…`else` statement to execute as intended, use:

  -
    ```
    if ( x > 5 )
    {
        if ( y > 5 )
            cout << "x and y are > 5";
    }
    else
        cout << "x is <= 5";
    ```
- Braces (`{}`) indicate that the second `if` statement is in the body of the first `if` and that the `else` is associated with the first `if`.

4.6 `if...else` Double-Selection Statement (cont.)

- Just as a block can be placed anywhere a single statement can be placed, it's also possible to have no statement at all—called a null statement (or an empty statement).
- The null state-ment is represented by placing a semicolon (`;`) where a statement would normally be.

4.7 while Repetition Statement

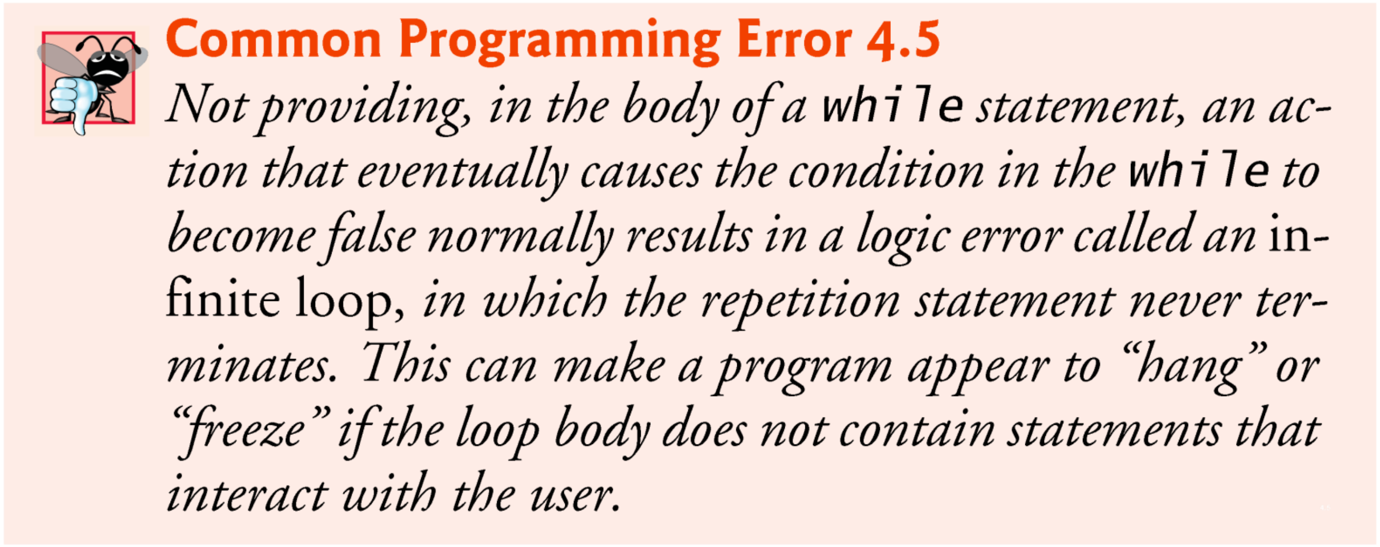
- A repetition statement (also called a looping statement or a loop) allows you to specify that a program should repeat an action while some condition remains true.
    - *While there are more items on my shopping list*
      Purchase next item and cross it off my list
- "There are more items on my shopping list" is true or false.
    - If true, "Purchase next item and cross it off my list" is performed.
        - Performed repeatedly while the condition remains true.
    - The statement contained in the *While* repetition statement constitutes the body of the *While*, which can be a single statement or a block.
    - Eventually, the condition will become false, the repetition will terminate, and the first pseudocode statement after the repetition statement will execute.

4.7 while Repetition Statement (cont.)

- Consider a program segment designed to find the first power of 3 larger than 100. Suppose the integer variable `product` has been initialized to `3`.
- When the following `while` repetition statement finishes executing, `product` contains the result:
  -
    ```
    int product = 3;

    while ( product <= 100 )
       product = 3 * product;
    ```

4.7 `while` Repetition Statement (cont.)



Common Programming Error 4.5

Not providing, in the body of a `while` *statement, an action that eventually causes the condition in the* `while` *to become false normally results in a logic error called an* infinite loop, *in which the repetition statement never terminates. This can make a program appear to "hang" or "freeze" if the loop body does not contain statements that interact with the user.*

4.7 while Repetition Statement (cont.)

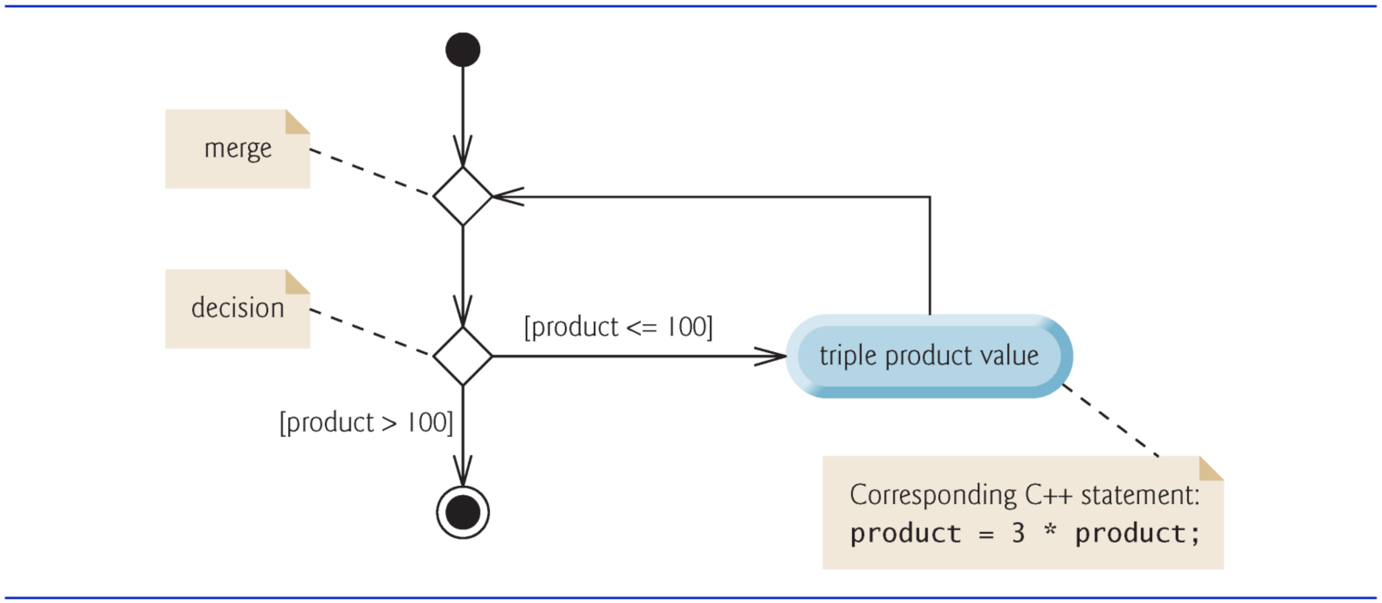


Fig. 4.6 | `while` repetition statement UML activity diagram.

4.8 Formulating Algorithms: Counter-Controlled Repetition

- Consider the following problem statement:
  - A class of ten students took a quiz. The grades (integers in the range 0 to 100) for this quiz are available to you. Calculate and display the total of all student grades and the class average on the quiz.
- The class average is equal to the sum of the grades divided by the number of students.
- The algorithm for solving this problem on a computer must input each of the grades, calculate the average and print the result.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

- We use counter-controlled repetition to input the grades one at a time.
  - This technique uses a variable called a counter to control the number of times a group of statements will execute (also known as the number of iterations of the loop).
  - Often called definite repetition because the number of repetitions is known before the loop begins exe-cut-ing.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

Software Engineering Observation 4.3

Experience has shown that the most difficult part of solving a problem on a computer is developing the algorithm for the solution. The process of producing a working C++ program from the algorithm is typically straightforward.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

```
Set total to zero
Set grade counter to one

While grade counter is less than or equal to ten
    Prompt the user to enter the next grade
    Input the next grade
    Add the grade into the total
    Add one to the grade counter

Set the class average to the total divided by ten
Print the total of the grades for all students in the class
Print the class average
```

Fig. 4.7 | Pseudocode for solving the class average problem with counter-controlled repetition.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

- A total is a variable used to accumulate the sum of several values.
- A counter is a variable used to count—in this case, the grade counter indicates which of the 10 grades is about to be entered by the user.
- Variables used to store totals are normally initialized to zero before being used in a program; otherwise, the sum would in-clude the previous value stored in the total’s memory location.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

```
// display a welcome message to the GradeBook user
void GradeBook::displayMessage()
{
   cout << "Welcome to the grade book for\n" << getCourseName() << "!\n"
      << endl;
} // end function displayMessage

// determine class average based on 10 grades entered by user
void GradeBook::determineClassAverage()
{
   int total; // sum of grades entered by user
   int gradeCounter; // number of the grade to be entered next
   int grade; // grade value entered by user
   int average; // average of grades

   // initialization phase
   total = 0; // initialize total
   gradeCounter = 1; // initialize loop counter

```

Fig. 4.9 | Class average problem using counter-controlled repetition: `GradeBook` source code file. (Part 3 of 4.)

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

```
      // processing phase
      while ( gradeCounter <= 10 ) // loop 10 times
      {
         cout << "Enter grade: "; // prompt for input
         cin >> grade; // input next grade
         total = total + grade; // add grade to total
         gradeCounter = gradeCounter + 1; // increment counter by 1
      } // end while

      // termination phase
      average = total / 10; // integer division yields integer result

      // display total and average of grades
      cout << "\nTotal of all 10 grades is " << total << endl;
      cout << "Class average is " << average << endl;
   } // end function determineClassAverage
```

Fig. 4.9 | Class average problem using counter-controlled repetition: `GradeBook` source code file. (Part 4 of 4.)

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

- Counter variables are normally initialized to zero or one, depending on their use.
- An uninitialized variable contains a "garbage" value (also called an undefined value)—the value last stored in the memory location reserved for that variable.
- The variables `grade` and `average` (for the user input and calculated average, respectively) need not be initialized before they're used—their values will be assigned as they're input or calculated later in the function.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

Common Programming Error 4.6

Not initializing counters and totals can lead to logic errors.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

Error-Prevention Tip 4.2

Initialize each counter and total, either in its declaration or in an assignment statement. Totals are normally initialized to 0. Counters are normally initialized to 0 or 1, depending on how they're used.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

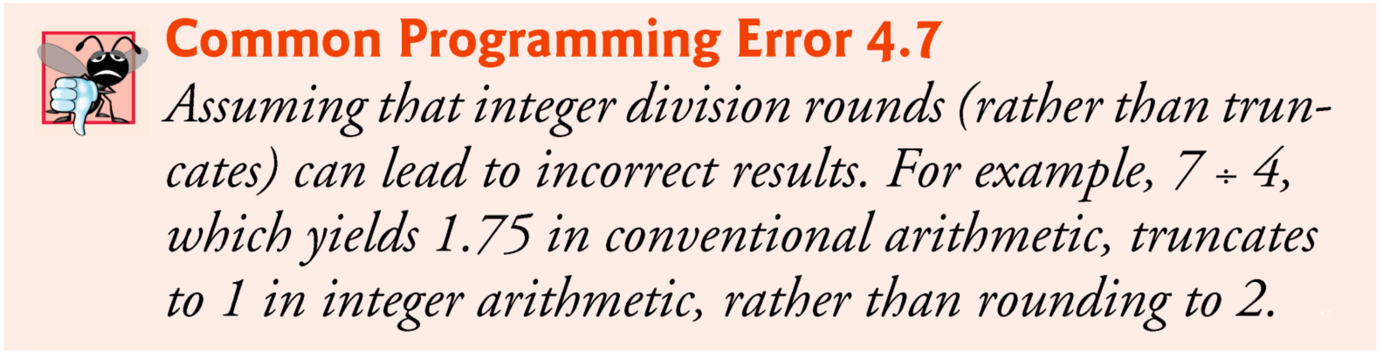
Good Programming Practice 4.7

Declare each variable on a separate line with its own comment for readability.

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)

- The averaging calculation performed in response to the function call in line 12 of Fig. 4.10 produces an integer result.
- Dividing two integers results in integer division—any fractional part of the calculation is lost (i.e., truncated).

4.8 Formulating Algorithms: Counter-Controlled Repetition (cont.)



Common Programming Error 4.7

Assuming that integer division rounds (rather than truncates) can lead to incorrect results. For example, 7 ÷ 4, which yields 1.75 in conventional arithmetic, truncates to 1 in integer arithmetic, rather than rounding to 2.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition

- Let’s generalize the class average problem.
  - Develop a class average program that processes grades for an arbitrary number of students each time it’s run.
- The program must process an arbitrary number of grades.
  - How can the program determine when to stop the input of grades?
- Can use a special value called a sentinel value (also called a signal value, a dummy value or a flag value) to indicate “end of data entry.”
- Sentinel-controlled repetition is often called indefinite repetition
  - the number of repetitions is not known in advance.
- The sentinel value must not be an acceptable input value.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition

Common Programming Error 4.9

Choosing a sentinel value that is also a legitimate data value is a logic error.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition

```
Initialize total to zero
Initialize counter to zero

Prompt the user to enter the first grade
Input the first grade (possibly the sentinel)

While the user has not yet entered the sentinel
    Add this grade into the running total
    Add one to the grade counter
    Prompt the user to enter the next grade
    Input the next grade (possibly the sentinel)

If the counter is not equal to zero
    Set the average to the total divided by the counter
    Print the total of the grades for all students in the class
    Print the class average
else
    Print "No grades were entered"
```

Fig. 4.11 | Class average problem pseudocode algorithm with sentinel-controlled repetition.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

Common Programming Error 4.10

An attempt to divide by zero normally causes a fatal run-time error.

Error-Prevention Tip 4.3

When performing division by an expression whose value could be zero, explicitly test for this possibility and handle it appropriately in your program (such as by printing an error message) rather than allowing the fatal error to occur.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

- An averaging calculation is likely to produce a number with a decimal point—a real number or floating-point number (e.g., 7.33, 0.0975 or 1000.12345).
- Type `int` cannot represent such a number.
- C++ provides several data types for storing floating-point numbers in memory, including float and double.
- Compared to `float` variables, `double` variables can typically store numbers with larger magnitude and finer detail
  - more digits to the right of the decimal point—also known as the number's precision.
- Cast operator can be used to force the averaging calculation to produce a floating-point numeric result.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

```cpp
// Fig. 4.13: GradeBook.cpp
// Member-function definitions for class GradeBook that solves the
// class average program with sentinel-controlled repetition.
#include <iostream>
#include <iomanip> // parameterized stream manipulators
#include "GradeBook.h" // include definition of class GradeBook
using namespace std;

// constructor initializes courseName with string supplied as argument
GradeBook::GradeBook( string name )
{
   setCourseName( name ); // validate and store courseName
} // end GradeBook constructor

// function to set the course name;
// ensures that the course name has at most 25 characters
void GradeBook::setCourseName( string name )
{
   if ( name.length() <= 25 ) // if name has 25 or fewer characters
      courseName = name; // store the course name in the object
   else // if name is longer than 25 characters
   { // set courseName to first 25 characters of parameter name
```

Fig. 4.13 | Class average problem using sentinel-controlled repetition: `GradeBook` source code file. (Part 1 of 5.)

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

```
// determine class average based on 10 grades entered by user
void GradeBook::determineClassAverage()
{
   int total; // sum of grades entered by user
   int gradeCounter; // number of grades entered
   int grade; // grade value
   double average; // number with decimal point for average

   // initialization phase
   total = 0; // initialize total
   gradeCounter = 0; // initialize loop counter

```

Fig. 4.13 | Class average problem using sentinel-controlled repetition: `GradeBook` source code file. (Part 3 of 5.)

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

```
   // processing phase
   // prompt for input and read grade from user
   cout << "Enter grade or -1 to quit: ";
   cin >> grade; // input grade or sentinel value

   // loop until sentinel value read from user
   while ( grade != -1 ) // while grade is not -1
   {
      total = total + grade; // add grade to total
      gradeCounter = gradeCounter + 1; // increment counter

      // prompt for input and read next grade from user
      cout << "Enter grade or -1 to quit: ";
      cin >> grade; // input grade or sentinel value
   } // end while

```

Fig. 4.13 | Class average problem using sentinel-controlled repetition: `GradeBook` source code file. (Part 4 of 5.)

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

```
      // termination phase
      if ( gradeCounter != 0 ) // if user entered at least one grade...
      {
         // calculate average of all grades entered
         average = static_cast< double >( total ) / gradeCounter;

         // display total and average (with two digits of precision)
         cout << "\nTotal of all " << gradeCounter << " grades entered is "
            << total << endl;
         cout << "Class average is " << setprecision( 2 ) << fixed << average
            << endl;
      } // end if
      else // no grades were entered, so output appropriate message
         cout << "No grades were entered" << endl;
   } // end function determineClassAverage
```

Fig. 4.13 | Class average problem using sentinel-controlled repetition: `GradeBook` source code file. (Part 5 of 5.)

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

- The call to setprecision in line 79 (with an argument of `2`) indicates that `double` values should be printed with two digits of precision to the right of the decimal point (e.g., 92.37).
  - Parameterized stream manipulator (argument in parentheses).
  - Programs that use these must include the header `<iomanip>`.
- `endl` is a nonparameterized stream manipulator and does not require the `<iomanip>` header file.
- If the precision is not specified, floating-point values are normally output with six digits of precision.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

- Stream manipulator fixed indicates that floating-point values should be output in fixed-point format, as opposed to scientific notation.
- Fixed-point formatting is used to force a floating-point number to display a specific number of digits.
- Specifying fixed-point formatting also forces the decimal point and trailing zeros to print, even if the value is a whole number amount, such as 88.00.
  - Without the fixed-point formatting option, such a value prints in C++ as 88 without the trailing zeros and decimal point.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

- When the stream manipulators `fixed` and `setprecision` are used in a program, the printed value is rounded to the number of decimal positions indicated by the value passed to `setprecision` (e.g., the value `2` in line 79), although the value in memory re-mains unaltered.
- It's also possible to force a decimal point to appear by using stream manipulator showpoint.
  - If `showpoint` is specified without `fixed`, then trailing zeros will not print.
  - Both can be found in header `<iostream>`.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

```
Welcome to the grade book for
CS101 C++ Programming

Enter grade or -1 to quit: 97
Enter grade or -1 to quit: 88
Enter grade or -1 to quit: 72
Enter grade or -1 to quit: -1

Total of all 3 grades entered is 257
Class average is 85.67
```

Fig. 4.14 | Class average problem using sentinel-controlled repetition: Creating a `GradeBook` object and invoking its `determineClassAverage` member function. (Part 2 of 2.)

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

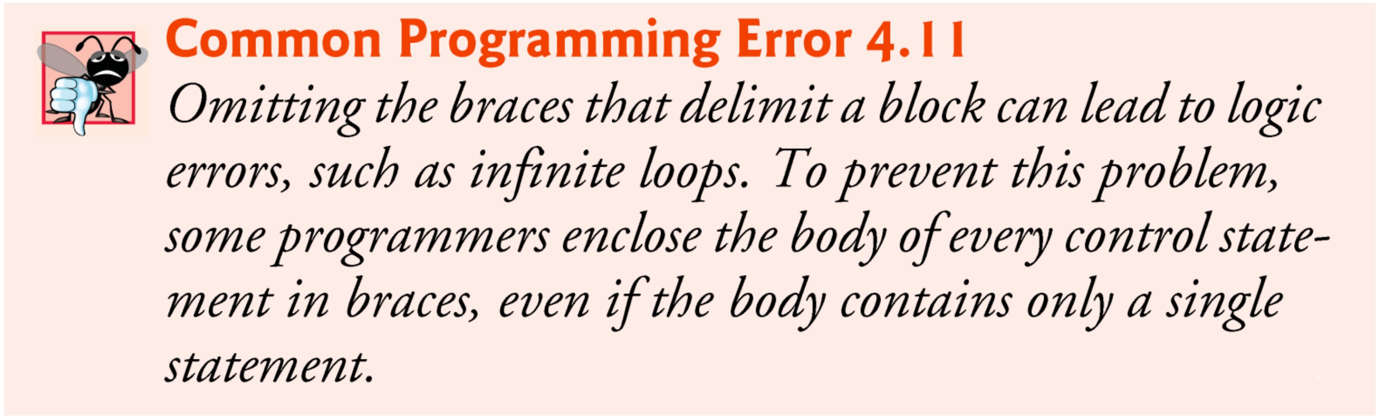
- Notice the block in the `while` loop in Fig. 4.13.
- Without the braces, the last three statements in the body of the loop would fall outside the loop, causing the computer to interpret this code incorrectly, as follows:

```
// loop until sentinel value read from user
while ( grade != -1 )
   total = total + grade; // add grade to total
gradeCounter = gradeCounter + 1; // increment counter

// prompt for input and read next grade from user
cout << "Enter grade or -1 to quit: ";
cin >> grade;
```

- This would cause an infinite loop in the program if the user did not input `–1` for the first grade (in line 57).

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)



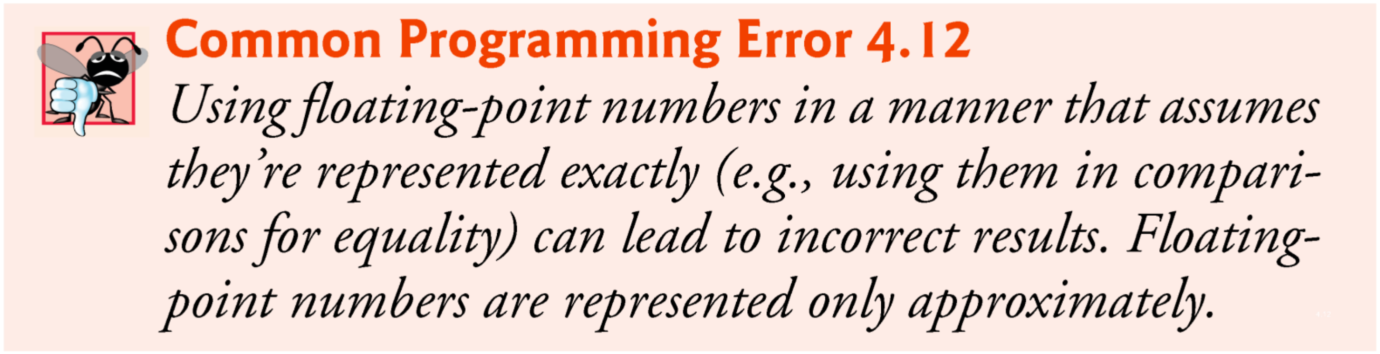
Common Programming Error 4.11

Omitting the braces that delimit a block can lead to logic errors, such as infinite loops. To prevent this problem, some programmers enclose the body of every control statement in braces, even if the body contains only a single statement.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)

- Variables of type `float` represent single-precision floating-point numbers and have seven significant digits on most 32-bit systems.
- Variables of type `double` represent double-precision floating-point numbers.
  - These require twice as much memory as `float` variables and provide 15 significant digits on most 32-bit systems
  - Approximately double the precision of `float` variables
- C++ treats all floating-point numbers in a program's source code as `double` values by default.
  - Known as floating-point constants.
- Floating-point numbers often arise as a result of division.

4.9 Formulating Algorithms: Sentinel-Controlled Repetition (cont.)



Common Programming Error 4.12

Using floating-point numbers in a manner that assumes they're represented exactly (e.g., using them in comparisons for equality) can lead to incorrect results. Floating-point numbers are represented only approximately.

Questions

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