Loops

Unit 4

Sections 5.2-12

CS 1428
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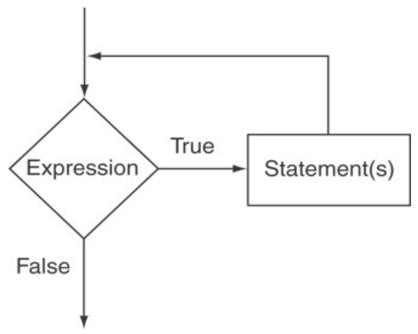
Control Flow (order of execution)

- So far, control flow in our programs has included:
  - sequential processing (1st statement, then 2nd statement…)
  - branching (conditionally skip some statements).
- Chapter 5 introduces loops, which allow us to conditionally repeat execution of some statements.
  - while loop
  - do-while loop
  - for loop

5.2 The `while` loop

- As long as the relational expression is true, repeat the statement



`while` syntax and semantics

- The while statement is used to repeat statements:

```
while (expression)
   statement
```

- How it works:
  - `expression` is evaluated:
  - If it is true, then `statement` is executed, then it starts over (and `expression` is evaluated again).
  - If it is false, then `statement` is skipped (and the loop is done).

`while` example

- Example:

Hand trace!

```
int number = 1;

while (number <= 3)
{
   cout << “Student” << number << endl;
   number = number + 1;
}

cout << “Done” << endl;
```

- Output

```
Student1
Student2
Student3
Done
```

5.3 Using `while` for input validation

- Inspect user input values to make sure they are valid.
- If not valid, ask user to re-enter value:

```
int number;

cout << “Enter a number between 1 and 10: “;
cin >> number;

while (number < 1 || number > 10) {
   cout << “Please enter a number between 1 and 10: “;
   cin >> number;
}

// Do something with number here
```

This expression is true when number is OUT of range.

Explain the valid values in the prompt

Don’t forget to input the next value

Input Validation

- Checking for valid characters:

```
char answer;

cout << “Enter the answer to question 1 (a,b,c or d): “;
cin >> answer;

while (answer != ‘a’ && answer != ‘b’ &&
       answer != ‘c’ && answer != ‘d’)
{
   cout << “Please enter a letter a, b, c or d: “;
   cin >> answer;
}

// Do something with answer here
```

5.4 Counters

- Counter: a variable that is incremented (or decremented) each time a loop repeats.
- Used to keep track of the number of iterations (how many times the loop has repeated).

- Must be initialized before entering loop!!!!

Counters

- Example (how many times does the user enter an invalid number?):

```
int number;
int count = 0;

cout << "Enter a number between 1 and 10: ";
cin >> number;

while (number < 1 || number > 10) {
   count = count + 1;
   cout << "Please enter a number between 1 and 10: ";
   cin >> number;
}
cout << count << " invalid numbers were entered." << endl;

// Do something with number here
```

Counters

- Example, using the counter to control how many times the loop iterates:

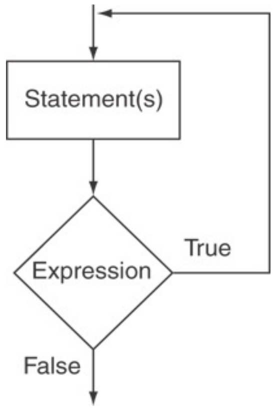
```
cout << "Number  Number Squared" << endl;
cout << "------  --------------" << endl;

int  num = 1;       // counter variable
while (num <= 8) {
   cout << num << "              " << (num * num) << endl;
   num = num + 1;  // increment the counter
}
```

- Output:

```
Number  Number Squared
------  --------------
1             1
2             4
3             9
4             16
5             25
6             36
7             49
8             64
```

5.5 The `do-while` loop

- Execute the statement(s), then repeat as long as the relational expression is true.



`do-while` syntax and semantics

- The `do-while` loop has the test expression at the end:

```
do
   statement
while (expression);
```

Don't forget the semicolon at the end

- How it works:
  - `statement` is executed.
  - `expression` is evaluated:
  - If it is true, then it starts over (and `statement` is executed again).
  - If (when) it is false, the loop is done.
- `statement` always executes at least once.

`do-while` example

- Example:

```
int number = 1;
do
{
   cout << “Student” << number << endl;
   number = number + 1;
} while (number <= 3);

cout << “Done” << endl;
```

- Output

```
Student1
Student2
Student3
Done
```

`do-while` with menu

```
char choice;

do {
   cout << “A: Make a reservation.” << endl;
   cout << “B: View flight status.” << endl;
   cout << “C: Check-in for a flight.” << endl;
   cout << “D: Quit the program.” << endl;
   cout << “Enter your choice: “;

   cin >> choice;

   switch (choice) {
      case ‘A’:  // code to make a reservation
                 break;
      case ‘B’:  // code to view flight status
                 break;
      case ‘C’:  // code to process check-in
                 break;
   }
} while(choice != ‘D’);
```

Different ways to control the loop

- <u>Conditional loop</u>: body executes as long as a certain condition is true
  - input validation: loops as long as input is invalid
- <u>Count-controlled loop</u>: body executes a specific number of times using a counter
  - actual count may be a literal, or stored in a variable.
- Count-controlled loop follows a pattern:
  - initialize counter to zero (or other start value).
  - test counter to make sure it is less than count.
  - update counter during each iteration.

5.6 The `for` loop

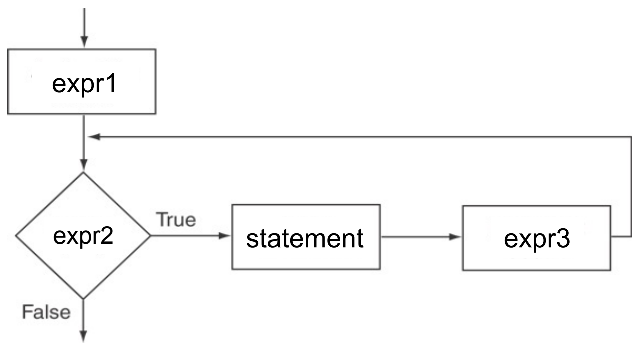
- The for statement is used to easily implement a count-controlled loop.

```
for (expr1; expr2; expr3)
   statement
```

- How it works:
  1. `expr1` is executed (initialization)
  2. `expr2` is evaluated (test)
  3. If it is true, then `statement` is executed, then `expr3` is executed (update), then go to step 2.
  4. If (when) it is false, then `statement` is skipped (and the loop is done).

The `for` loop flow chart

```
for (expr1; expr2; expr3)
   statement
```



The `for` loop and the `while` loop

- The for statement

```
for (expr1; expr2; expr3)
   statement
```

- is equivalent to the following code using a while statement:

```
expr1;               // initialize
while (expr2) {      // test
   statement
   expr3;            // update
}
```

`for` loop example

- Example:

```
int number;
for (number = 1; number <= 3; number++)
{
   cout << "Student" << number << endl;
}

cout << "Done" << endl;
```

Equivalent to
`number = number + 1`

Note: no semicolon

- Output

```
Student1
Student2
Student3
Done
```

Counters: redo

- Example, using the counter to control how many times the loop iterates:

```
cout << "Number  Number Squared" << endl;
cout << "------  --------------" << endl;

int  num = 1;       // counter variable
while (num <= 8) {
   cout << num << "              " << (num * num) << endl;
   num = num + 1;   // increment the counter
}
```

- Rewritten using a for loop:

```
cout << "Number  Number Squared" << endl;
cout << "------  --------------" << endl;

int  num;
for (num = 1; num <= 8; num++)
   cout << num << "              " << (num * num) << endl;
```

Define variable in init-expr

- You may define the loop counter variable inside the for loop's initialization expression:

```
for (int x = 10; x > 0; x=x-2)
   cout << x << endl;

cout << x << endl; //ERROR, can't use x here
```

Hand trace!

- Do NOT try to access x outside the loop (the scope of x is the for loop statement ONLY)
- What is the output of the for loop?

User-controlled count

- You may use a value input by the user to control the number of iterations:

```
int maxCount;
cout << "How many squares do you want?" << endl;
cin >> maxCount;

cout << "Number  Number Squared" << endl;
cout << "------  --------------" << endl;

for (int num = 1; num <= maxCount; num++)
   cout << num << "           " << (num * num) << endl;
```

- How many times does the loop iterate?

The exprs in the for are optional

- You may omit any of the three exprs in the for loop header

```
int value, incr;
cout << "Enter the starting value: ";
cin >> value;

for ( ; value <= 100; )
{
   cout << "Please enter the next increment amount: ";
   cin >> incr;
   value = value + incr;
   cout << value << endl;
}
```

- Style: use a while loop for something like this.
- When expr2 is missing, it is true by default.

Loops in C++
(review)

- **while**

```
while (expression)
   statement
```

statement may be a compound statement (a block: {statements})

  - if expression is true, statement is executed, repeat

- **for**

```
for (expr1; expr2; expr3)
   statement
```

  - equivalent to:

```
expr1;
while (expr2) {
   statement
   expr3;
}
```

- **do while**

```
do
   statement
while (expression);
```

statement is executed.
if expression is true, then repeat

Common tasks solved using loops

- Counting
- Summing
- Calculating an average (the mean value)
- Read input until “sentinel value” is encountered
- Read input from a file until the end of the file is encountered

Counting
(review)

- set a counter variable to 0
- increment it inside the loop (each iteration)
- after each iteration of the loop, it stores the # of loop iterations so far

```
int number;
int count = 0;

cout << “Enter a number between 1 and 10: “;
cin >> number;

while (number < 1 || number > 10) {
   count = count + 1;
   cout << “Please enter a number between 1 and 10: “;
   cin >> number;
}

cout << count << “ invalid numbers entered “ << endl;

// Do something with number here
```

5.7 Keeping a running total
(summing)

- After each iteration of the loop, it stores the sum of the numbers added so far (running total)
- set an accumulator variable to 0
- add the next number to it inside the loop

```
int days;           //Count for count-controlled loop
float total = 0.0;  //Accumulator
float miles;        //daily miles ridden

cout << “How many days did you ride your bike? “;
cin >> days;

for (int i = 1; i <= days; i++)  {
   cout << “Enter the miles for day “ << i << “: ”;
   cin >> miles;
   total = total + miles;
}

cout << “Total miles ridden: “ << total << endl;
```

total is 0 first time through

Keeping a running total

- Output:

```
How many days did you ride you bike? 3
Enter the miles for day 1: 14.2
Enter the miles for day 2: 25.4
Enter the miles for day 3: 12.2
Total miles ridden: 51.8
```

- How would you calculate the average mileage?

5.8 Sentinel controlled loop

- sentinel: special value in a list of values that indicates the end of the data
- sentinel value must **not** be a valid value! -99 for a test score, -1 for miles ridden
- User does not need to count how many values will be entered
- Requires a "priming read" before the loop starts
  - so the sentinel is NOT included in the sum
  - the loop can be skipped (if first value is the sentinel)

Sentinel example

- Example:

```
float total = 0.0;  //Accumulator
float miles;        //daily miles ridden

cout << "Enter the miles you rode on your bike each day, ";
cout << "then enter -1 when finished. " << endl;

cin >> miles;                //priming read
while (miles != -1)  {
   total = total + miles;    //skipped when miles==-1
   cin >> miles;             //get the next one
}

cout << "Total miles ridden: " << total << endl;
```

- Output:

```
Enter the miles you rode on your bike each day,
then enter -1 when finished.
14.2
25.4
12.2
-1
Total miles ridden: 51.8
```

5.9 Which Loop to use?

- Any loop can work for any given problem
- while loop:
  - test at start of loop, good for:
  - validating input, sentinel controlled loops, etc.
- for loop:
  - initialize/test/update, good for:
  - count-controlled loops
- do-while loop
  - always do at least once, good for:
  - repeating on user request, simple menu processing

5.10 Nested loops

- When one loop appears in the body of another
- For every iteration of the outer loop, we do all the iterations of the inner loop
- Example from "real life":
- A clock. For each hour in a day (24), we iterate over 60 minutes.

```
12:00      1:00      2:00      3:00
12:01      1:01      2:01      .
12:02      1:02      2:02      .
...        ...       ...       .
12:59      1:59      2:59      .
```

Print a bar graph

- Input numbers from a file. For each number, output that many asterisks (*) in a row.

```
int number;
ifstream inputFile;
inputFile.open("numbers.txt");
inputFile >> number;  //priming read
while (number!=-1) {
   for (int i = 1; i <= number; i++)
      cout << '*';
   cout << endl;
   inputFile >> number;
}
```

- numbers.txt:

```
8
3
6
10
-1
```

Output:

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

Calculate grades for a class

For each student, input the test scores from the user and output the average.

```
int numStudents, numTests;
cout << "How many students? ";
cin >> numStudents;
cout << "How many test scores? ";
cin >> numTests;
for (int student=1; student <= numStudents; student++) {
   float total = 0, score;
   cout << "Enter the " << numTests
        << " test scores for student " << student << endl;
   for (int test=1; test <= numTests; test++) {
      cin >> score;
      total = total + score;
   }                                              Inner loop
   float avgScore = total/numTests;
   cout << "Average for student" << student        Outer loop
        << " is: " << avgScore << endl;
}
```

Calculate grades for a class

- Output:

```
How many students? 3
How many test scores? 4
Enter the 4 test scores for student 1
88 90.5 92 77.5
Average for student1 is: 87.0
Enter the 4 test scores for student 2
66.5 70.5 80 86
Average for student2 is: 75.8
Enter the 4 test scores for student 3
99 93.5 80 79
Average for student3 is: 87.9
```

5.11 More File I/O

- Can test a file stream variable as if it were a boolean variable to check for various errors.
- After opening a file, if the open operation failed, the value of file stream variable is `false`.

```
ifstream infile;
infile.open("test.txt");

if (!infile) {
    cout << "File open failure!";
    return 1;  //abort program!
}
```

- Note: after ANY input operation, if it fails, the value of file stream variable will then be `false`.

Reading data from a file

- Use `fin>>x;` in a loop
- Problem: when to stop the loop?
- First entry in file could be count of number of items
  - problems: maintenance (must update it whenever data is modified), large files (might be hard to count)
- Could use sentinel value
  - problem: may not be one (every value is valid), maintenance (someone might delete it)
- Want to <u>automatically</u> detect end of file

Using >> to detect end of file

- stream extraction operation (>>) returns `true` when a value was successfully read, `false` otherwise

```
int num;
ifstream inputFile;
inputFile.open(“numbers.txt”);

bool foundValue = (inputFile >> num);
```

- `inputFile >> num`:
  - tries to read a value into `num`
  - if it was successful, result is true (`foundValue` is true)
  - if it failed (non-number char or no more input), result is false (`foundValue` is false, but the value in `num` does not change!)

Using the result of >>

- Example:

```
int number;
ifstream inputFile;
inputFile.open(“numbers.txt”);

bool foundValue = (inputFile >> number);

if (foundValue)
   cout << “The data read in was: “ << number << endl;
else
   cout << “Could not read data from file.” << endl;
```

- Can also use directly as relational expression:

```
if (inputFile >> number)
   ...
```

Sum all the values in the file

without using a count or sentinel value

- Code:

```
int number;
ifstream inputFile;
inputFile.open(“numbers.txt”);

int total = 0;
while (inputFile >> number) {
   total = total + number;
}

cout << “The sum of the numbers in the file: “ << total
     << endl;
```

puts the priming read directly in the test expression

- numbers.txt:

```
84
32
99
77
52
```

Output:

```
The sum of the numbers in the file: 344
```

5.12 Breaking and Continuing

- Sometimes we want to abort (exit) a loop before it has completed.
- The `break` statement can be used to terminate the loop from within:

```
cout << "Guess a number between 1 and 10" << endl;
int number;
while (true) {
   cin >> number;
   if (number == 8)
      break;
}
cout << "You got it." << endl;
```

- Don't do this. It makes your code hard to read and debug.

Stopping a single iteration

- Sometimes we want to abort an iteration (skip to the end of loop body) before it is done.
- The `continue` statement can be used to terminate the current iteration:

```
for (int i=1; i <= 6; i++) {
   if (i == 4)
      continue;
   cout << i << " ";
}
```

- Output:

```
1 2 3 5 6
```

- Don't do this either. It makes your code hard to read and debug.