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:**

```cpp
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:

```cpp
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:**

```cpp
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?):

```cpp
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
```

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

```cpp
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:

<table>
<thead>
<tr>
<th>Number</th>
<th>Number Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>7</td>
<td>49</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
</tr>
</tbody>
</table>

5.5 The do-while loop

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

```
<table>
<thead>
<tr>
<th>Statement(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expression</td>
</tr>
<tr>
<td>True</td>
</tr>
<tr>
<td>False</td>
</tr>
</tbody>
</table>
```

do-while syntax and semantics

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

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

• 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:

```cpp
int number = 1;
do {
    cout << "Student" << number << endl;
    number = number + 1;
} while (number <= 3);
cout << "Done" << endl;
```

- Output

```
Student1
Student2
Student3
Done
```

Different ways to control the loop

- **Conditional loop**: body executes as long as a certain condition is true
  - input validation: loops as long as input is invalid
- **Count-controlled loop**: 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.

do-while with menu

```cpp
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');
```

5.6 The for loop

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

```cpp
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
```

expr1

expr2

expr3

expr2

True

False

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:

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

Output

- Student1
- Student2
- Student3
- Done

Counters: redo

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

```cpp
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:

```cpp
cout << "Number  Number Squared" << endl;
cout << "--------  --------------" << endl;
int num;
for (num = 1; num <= 8; num++)
    cout << num << "          " << (num * num) << endl;
```
Define variable in init-exprr

• You may define the loop counter variable inside the for loop’s initialization expression:

```cpp
for (int x = 10; x > 0; x=x-2)  
    cout << x << endl;  
cout << x << endl;  //ERROR, can’t use x here
```

• 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:

```cpp
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

```cpp
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.

Loops in C++ (review)

• **while**

```cpp
while (expression)  
    statement
```

• if expression is true, statement is executed, repeat

• **for**

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

• equivalent to:

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

• **do while**

```cpp
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

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

```cpp
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;
```

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

```cpp
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
```

Keeping a running total

- Output:

```
How many days did you ride you bike? 3
Enter the miles for day 1: 1.4
Enter the miles for day 2: 2.5
Enter the miles for day 3: 1.2
Total miles ridden: 5.1
```

- 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)

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.

<table>
<thead>
<tr>
<th>12:00</th>
<th>1:00</th>
<th>2:00</th>
<th>3:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:01</td>
<td>1:01</td>
<td>2:01</td>
<td></td>
</tr>
<tr>
<td>12:02</td>
<td>1:02</td>
<td>2:02</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>12:59</td>
<td>1:59</td>
<td>2:59</td>
<td></td>
</tr>
</tbody>
</table>
Print a bar graph

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

```c++
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.

```c++
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;
    }
    float avgScore = total/numTests;
    cout << “Average for student “ << student << “ is: “ << avgScore << endl;
}
```

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.

```c++
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 automatically detect end of file

Using >> to detect end of file

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

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

Sum all the values in the file without using a count or sentinel value

- Code:
  ```cpp
  int total = 0;
  while (inputFile >> number) {
    total = total + number;
  }
  cout << "The sum of the numbers in the file: " << total << endl;
  ```

- `numbers.txt:`

```
84
32
99
77
52
```

- Output:
  ```cpp
  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:

```cpp
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:

```cpp
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.