The Zen of C++

2nd Edition

Adnan Zejnilovic

Chapter 4

Loops

Introduction

- What is a loop?
  - A repetitive statement that executes as long as certain condition is true
  - Similar to conditional statement, except that it repeats
  - Depending on where the condition is evaluated loops could be classified as
    - Pre-test loops
    - Post-test loops

Loop Classifications

- Depending on where the condition (test) takes place, loops could be
  - Pre-test loop
    - Evaluate the expression (condition) first and determine whether to execute the body of the loop
    - No guarantees that will execute at all
      - May execute or may not execute depending on how the expression (condition) evaluates
  - Post-test loops
    - Executes the body of the loop at least once
    - Tests the expression (condition) to determine whether it needs to execute more than once
    - Guaranteed to execute at least once

The While Loop

Pre-test loop

Syntax:

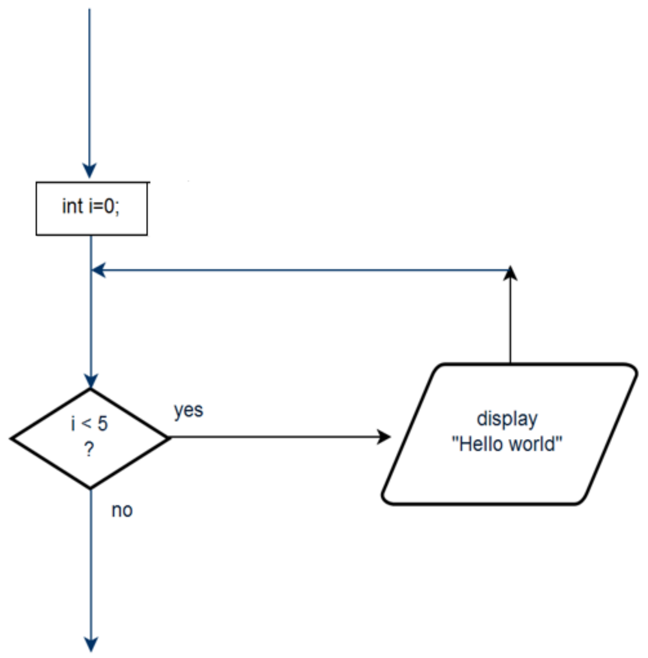
- Keyword “**while**” (expression/condition) followed by
- The body of the loop

Example:

Notice: no “;” at the end of the expression

```
int i=0;
while (i < 5)
     cout << “Hello world”;
```

The While Loop contd.



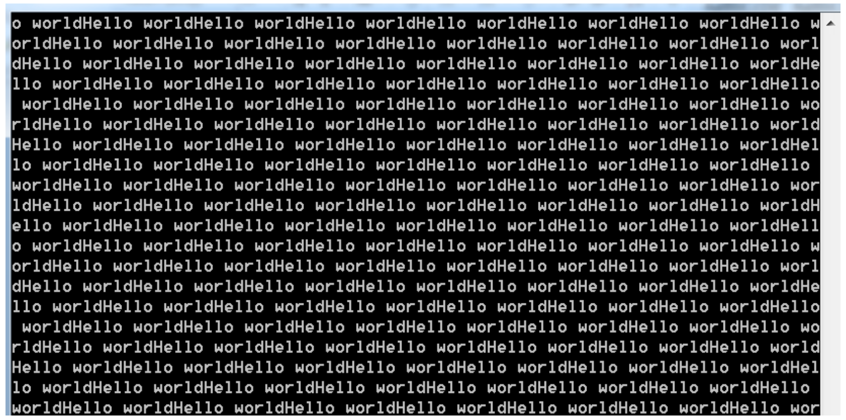
```
int i=0;
while (i < 5)
     cout << “Hello world”;
```

```
Step1: Evaluate the expression (i< 5)
Step2: if true,execute the body of the loop
Step3: go to Step1.
```

Infinite Loop

```
int i=0;
while (i < 5)
     cout << "Hello world";
```

- This code would result in an infinite loop
- The reason?
- i is always zero
- Every time the test is performed (i<5) the answer is YES
- Question: How do we correct this?



```
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```

Infinite Loop Corrected

```
int i=0;
while (i < 5)
{
      cout << "Hello world";
      i++;
}
```

1. Need to find a way to stop the loop from executing!

   How?

2. **increment i !**
   With each iteration, i will get incremented (updated):
   i=0……is 0 < 5? Yes. Display "Hello World". Increment i.
   i=1….. Is 1 < 5? Yes. Display "Hello world". Increment i.
   i=2……is 2 < 5? Yes. Display "Hello world". Increment i.
   i=3……is 3 < 5? Yes. Display "Hello world". Increment i.
   i=4……is 4 < 5? Yes. Display "Hello world". Increment i.
   i=5……is 5 < 5? No. Skip the body of th e loop

Counters

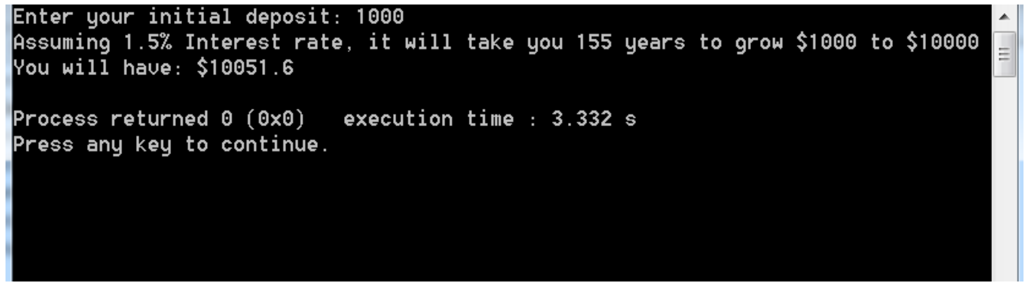
- Sometimes you will need to count how many times your loop executes.
- Examples:
  - Count how many customers enter your store during business hours
  - Count how many cars enter the toll booth
  - Count how many years (days/months/hours/minutes) some process takes until it completes
- A counter needs to have a starting (“initial”) value
- Usually the initial value is set to zero
- The initial value is incremented by one with each iteration of the loop

Counters

- Example:
  - Determine how many years will it take for a certain amount of money (principal) to reach maturity
  - Assume the bank gives you 1.5% interest
  - Assume maturity is $10,000

```cpp
int main()
{
    const double TEN_K = 10000.00;
    const double INTEREST = 0.015;     // 1.5% intestest
    int numYears = 0;
    double principalAmt, initialAmt,interest;

    cout << "Enter your initial deposit: ";
    cin >> initialAmt;
    principalAmt = initialAmt;  // copy initialAmt to principalAmt for the purpose of reporti
    while (principalAmt < TEN_K)
    {
        interest = principalAmt * INTEREST;
        principalAmt = principalAmt + interest;
        numYears = numYears + 1;
    }

    cout << "Assuming " << INTEREST * 100
         << "% Interest rate, it will take you " << numYears
         << " years to grow $" << initialAmt
         << " to $" << TEN_K << endl;

    cout << "You will have: $" << principalAmt << endl;
    return 0;
}
```

Output:



```
Enter your initial deposit: 1000
Assuming 1.5% Interest rate, it will take you 155 years to grow $1000 to $10000
You will have: $10051.6

Process returned 0 (0x0)   execution time : 3.332 s
Press any key to continue.
```

Accumulators

- Accumulators are identical to counters with one difference
- Both counters and accumulators must have initial value which is then incremented or decremented in the loop depending on programming logic.
- The difference is that accumulators are used to keep a running total
- When their value is incremented/decremented, it is incremented/decremented by the value of the variable being accumulated

Sentinels

- A Sentinel is a special value that is used to mark the end of user input.
- Usually this is a value that is not typical for the data being collected.
- Example:
    - Keeping track of goals scored by a soccer player.
    - A Sentinel value could be set to -99 because nobody scores negative goals, and even worse, 99 of them!

Sentinels – Example Program

This program tracks number of customers that enter the store ---------- (counter)
It also “accumulates” each customer deposit --------------------------------(accumulator)
Lastly, it terminates when -99 is entered as billAmt -------------------------(sentinel)

```
#include <iostream>

using namespace std;
const int MY_SENTINEL = -99;
int main()
{
    double billAmt,
           totalProfit = 0.0;              // accumulator
    int    numCustomers = 0;               // counter
    cout << "Enter the bill amount: ";
    cin >> billAmt;                        // priming read

    while (billAmt != MY_SENTINEL)
    {
        totalProfit += billAmt;
        numCustomers++;
        cout << "Enter the bill amount: ";
        cin >> billAmt;
    }

    cout << numCustomers << " customer visits. Total profit: " << totalProfit << endl;
    return 0;
}
```

Priming Read

- "priming read" (prime read) is a read (data capture) ahead of the loop.
- Priming read is used to determine whether to enter the loop or not
- Used with "pre-test" loops

```
cout << "Enter the bill amount: ";
cin >> billAmt;                           // priming read

while (billAmt != MY_SENTINEL)
{
    totalProfit += billAmt;
    numCustomers++;
    cout << "Enter the bill amount: ";
    cin >> billAmt;
}
```

For Loop

- When you know ahead of time how many iterations your program is going to need to accomplish a certain task you can use a so-called ***count*** controlled loop.

```
SYNTAX:
    [1]initialization
    [2]test
    [3]body of the loop
    [4]update

    for ([1]initialization; [2]test; [4]update )
    {
        [3] body of the loop

    }
```

The numbers represent the order of execution of statements in the for loop”

For Loop

```
SYNTAX:
    [1]initialization
    [2]test
    [3]body of the loop
    [4]update

    for ([1]initialization; [2]test; [4]update )
    {
        [3] body of the loop

    }
```

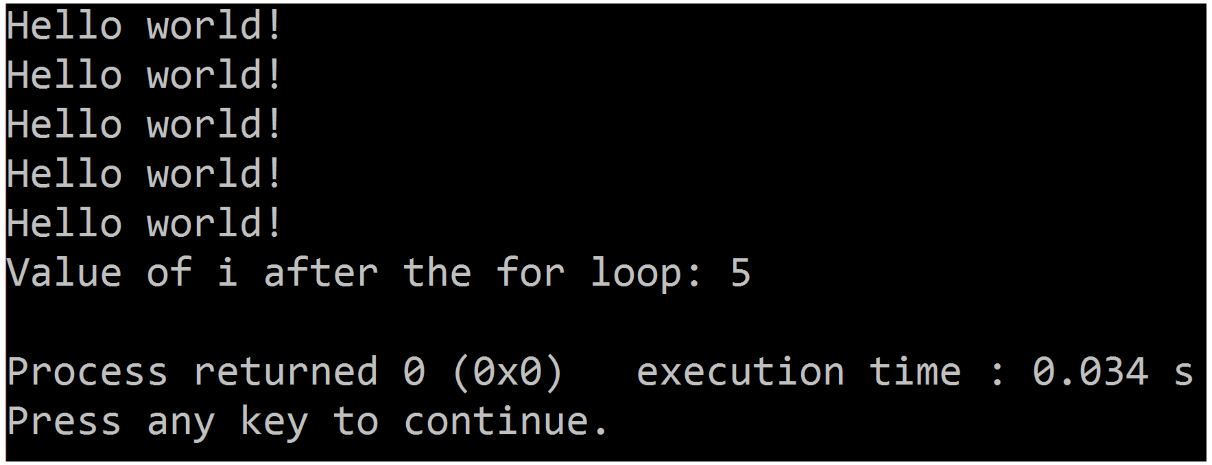
```
for (int i=0; i<5; i++)
{
    cout << "Hello world!" << endl;
}
```

Section	Statement
[1] initialization	int i=0;
[2] test/condition	i<5;
[3] body	cout << “Hello world” << endl;
[4] update	i++

For Loop

```
int i;   // declare i
for (i=0; i<5; i++)
{
    cout << "Hello world!" << endl;
}
cout << "Value of i after the for loop: " << i << endl;
```

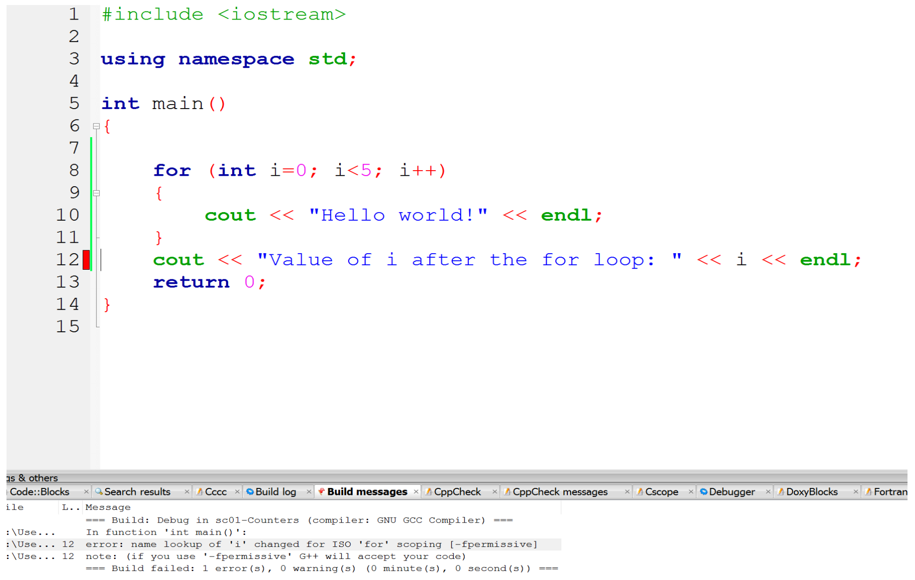
- Variable “i” is in scope even after the loop terminates.
- The program compiles and displays value of “i”:



```
Hello world!
Hello world!
Hello world!
Hello world!
Hello world!
Value of i after the for loop: 5

Process returned 0 (0x0)   execution time : 0.034 s
Press any key to continue.
```

```
for (int i=0; i<5; i++)
{
    cout << "Hello world!" << endl;
}
cout << "Value of i after the for loop: " << i << endl;
```

- Variable “i” is local to the loop.
- We get a syntax error if we try to display it afte
  the loop



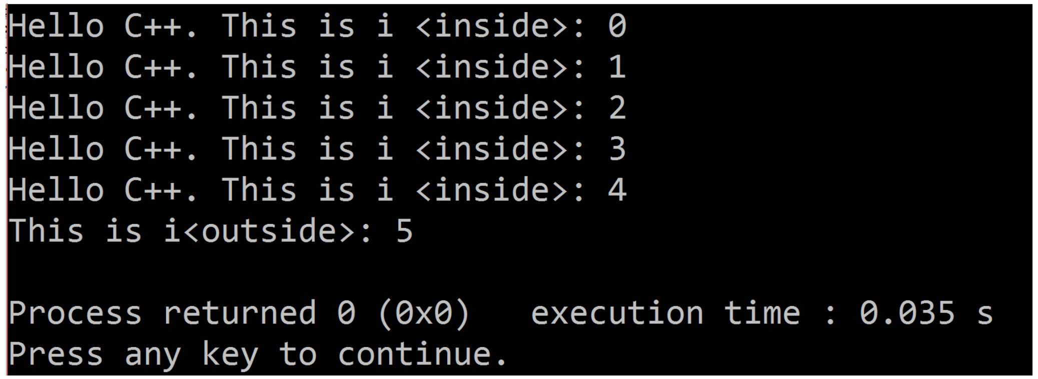
```
 1  #include <iostream>
 2
 3  using namespace std;
 4
 5  int main()
 6  {
 7
 8      for (int i=0; i<5; i++)
 9      {
10          cout << "Hello world!" << endl;
11      }
12      cout << "Value of i after the for loop: " << i << endl;
13      return 0;
14  }
15
```

```
ile        L..  Message
                === Build: Debug in sc01-Counters (compiler: GNU GCC Compiler) ===
:\Use...        In function 'int main()':
:\Use... 12     error: name lookup of 'i' changed for ISO 'for' scoping [-fpermissive]
:\Use... 12     note: (if you use '-fpermissive' G++ will accept your code)
                === Build failed: 1 error(s), 0 warning(s) (0 minute(s), 0 second(s)) ===
```

For Loop – Omitting Sections

- You could omit sections (initialization, test, or update) and still have your loop execute.

```
int i=0;   // initialization done outside of the for loop
for ( ; i<5; i++)     // ommited initialization section
{
    cout << "Hello C++. ";
    cout << "This is i <inside>: " << i << endl;
}

cout << "This is i<outside>: " << i << endl;
```

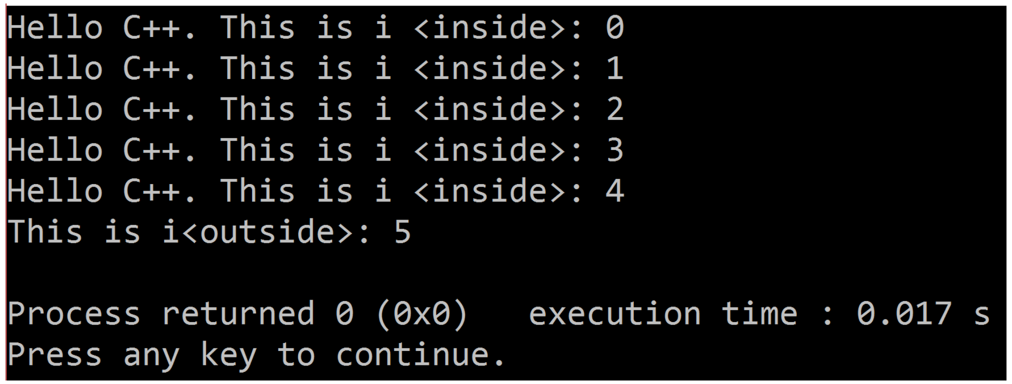


```
Hello C++. This is i <inside>: 0
Hello C++. This is i <inside>: 1
Hello C++. This is i <inside>: 2
Hello C++. This is i <inside>: 3
Hello C++. This is i <inside>: 4
This is i<outside>: 5

Process returned 0 (0x0)   execution time : 0.035 s
Press any key to continue.
```

For Loop – Omitting Sections

```
int i=0;  // initialization done outside of the for loop
for ( ; ; i++)     // omitted initialization and test section
{
     if (i<5)
     {
          cout << "Hello C++. ";
          cout << "This is i <inside>: " << i << endl;
     }
     else
          break;
}
```

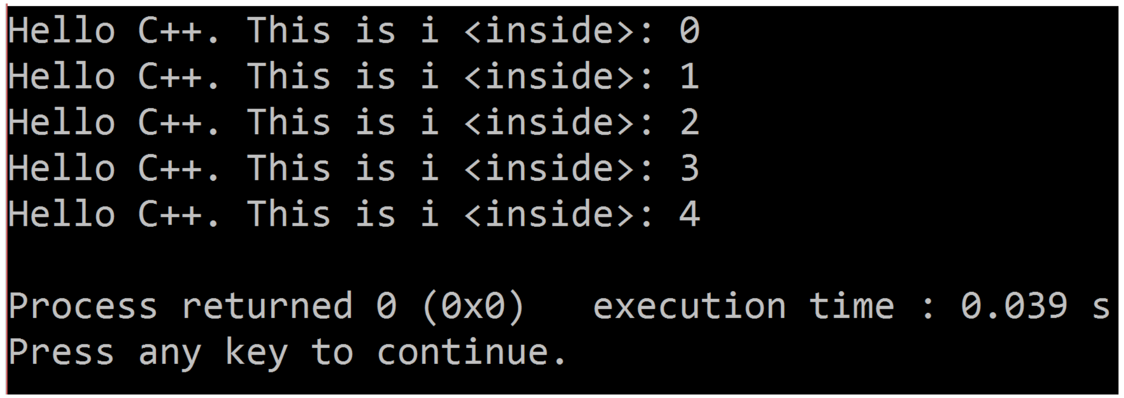
Use the break statement to terminate the loop



```
Hello C++. This is i <inside>: 0
Hello C++. This is i <inside>: 1
Hello C++. This is i <inside>: 2
Hello C++. This is i <inside>: 3
Hello C++. This is i <inside>: 4
This is i<outside>: 5

Process returned 0 (0x0)   execution time : 0.017 s
Press any key to continue.
```

For Loop – Omitting Sections

```cpp
for (int i=0; i<5; )      // omitted update section
{
    cout << "Hello C++. ";
    cout << "This is i <inside>: " << i << endl;
    i++;        // performing update here
}
```

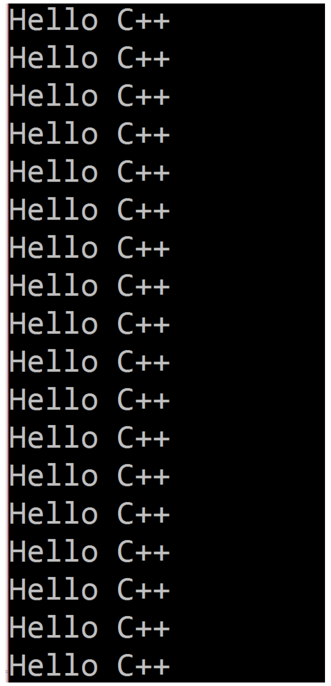


```
Hello C++. This is i <inside>: 0
Hello C++. This is i <inside>: 1
Hello C++. This is i <inside>: 2
Hello C++. This is i <inside>: 3
Hello C++. This is i <inside>: 4

Process returned 0 (0x0)   execution time : 0.039 s
Press any key to continue.
```

For Loop – Omitting Sections

```
for ( ; ; )     // ommited all sections
{
    cout << "Hello C++" << endl;
}
```

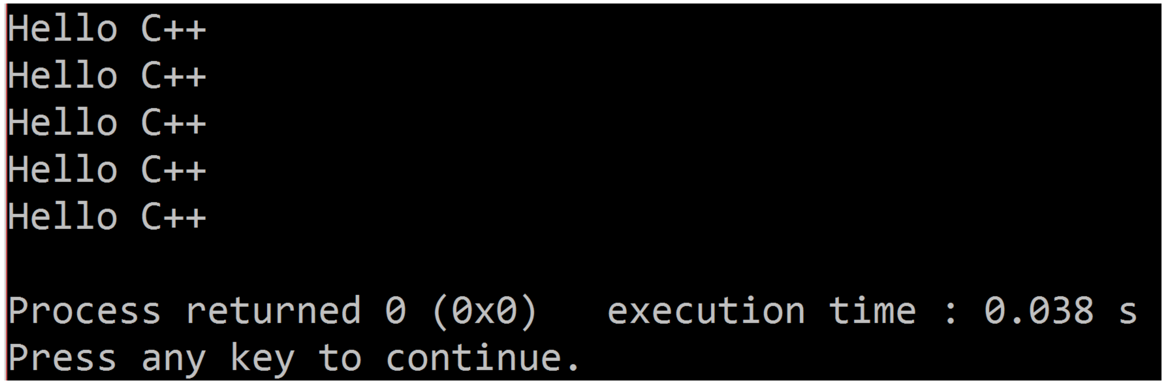
Results in an infinite loop:



```
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++
```

- Use the break statement to terminate the loop

```
int i=0;
for ( ; ; )     // ommited all sections
{
    cout << "Hello C++" << endl;
    if (i==4)
        break;   // break out of the loop
    i++;         // increment i;
}
```



```
Hello C++
Hello C++
Hello C++
Hello C++
Hello C++

Process returned 0 (0x0)   execution time : 0.038 s
Press any key to continue.
```

What Not to Do

Do not put a “;” at the end of the loop header

```
for (int i=0; i<5;i++ );
```

- While it is syntactically correct, the body of the loop will not execute

Do not update loop control variable in the body of the loop:

```
for (int i=0; i<5;i++)
{
    cout << "Hello C++. ";
    cout << "This is i <inside>: " << i << endl;
    i+=2;      // another update here
}
```

- As a programmer you want to control your code

Rewriting a for Loop as a while Loop

- Both are pretest loops so it is possible to rewrite for as a while:

```
int numGames;         // number of games played
int totalPoints = 0; // accumulator
int points;           // points scored in a game
double avg;           // average points per game


cout << "How many games: ";
cin >> numGames;
      [1] Initialization        [2] Test          [4] Update
for (int game=0; game < numGames; game++)
{
   cout << "Game #" << game+1 << " points: ";     [3] Body
   cin >> points;
   totalPoints = totalPoints + points; // add points to the accumulator
}

// calculate the average
avg = static_cast<double>(totalPoints)/numGames;

// display the result
cout << "The player averaged: " << avg << " points in "
     << numGames << " games" << endl;
```

Rewritten as a while loop:

```
//[1] initialization
int game=0;

//[2] condition
while (game < numGames)
{
    //[3] statement(s)
    cout << "Game #" << game+1 << " points: ";
    cin >> points;

    totalPoints = totalPoints + points;

    // [4] update
    game++;
}


// calculate the average
avg = static_cast<double>(totalPoints)/numGames;

// display the result
// display the result
cout << "The player averaged: " << avg << " points in "
     << numGames << " games" << endl;
```

Rewriting a while Loop as a for Loop

while loop

[1] initialization

[2] Test

[3] Body

[4] Update

```
int j=0;
while (j<10)
{
    cout << "This is j: " << j << endl;
    j++;
}
```

for loop

[1] initialization

[2] Test

[4] Update

[3] Body

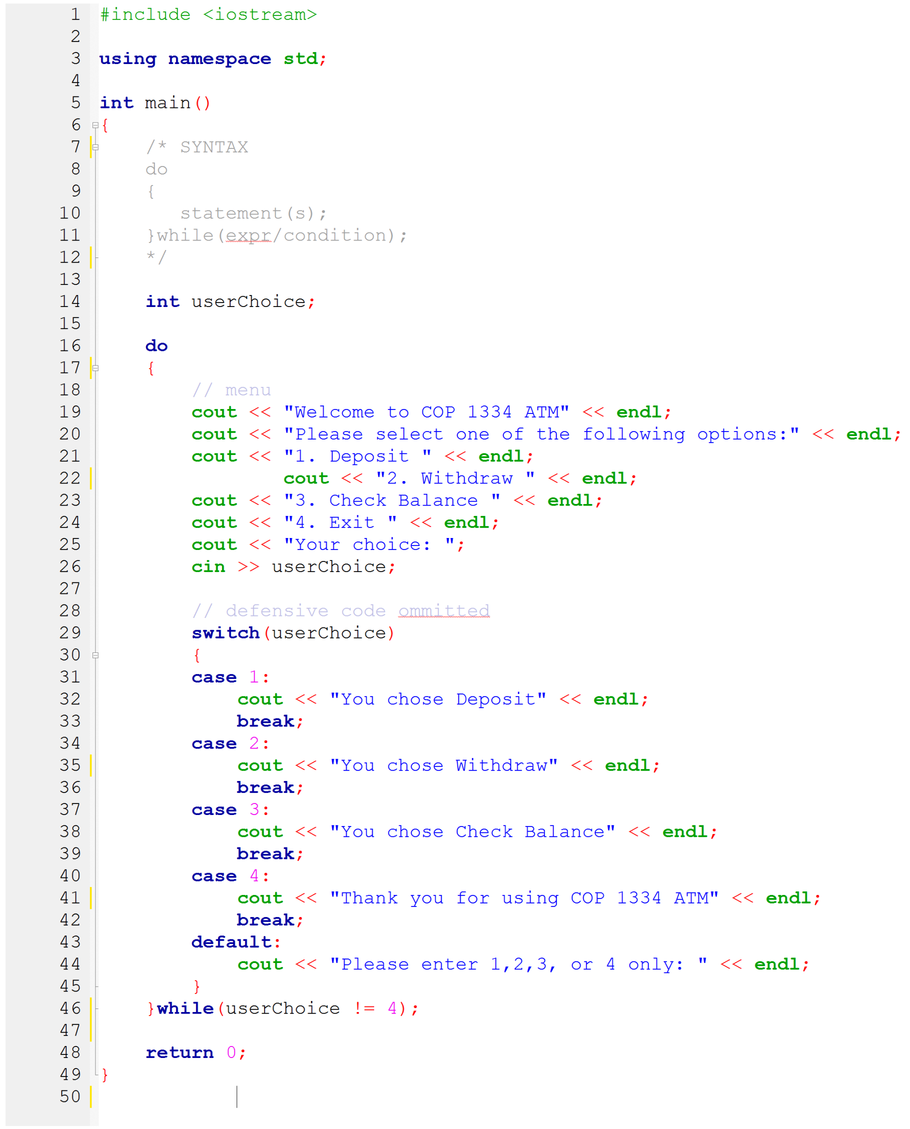
```
j=0;
for (; j<10; j++)
{
    cout << "This is j: " << j << endl;
}
```

The do-while Loop

The general format of the do while loop is:

```
do
{
    statement(s);
} while (expression);
```

- This is a post-test loop
- Guaranteed to execute at least once

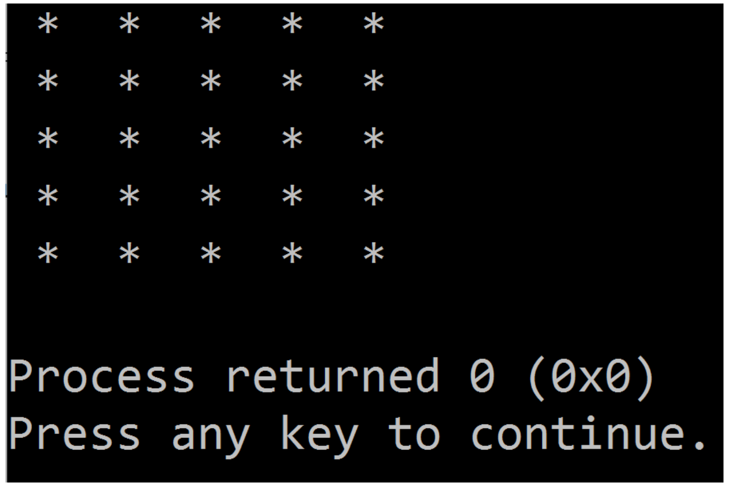


```cpp
#include <iostream>

using namespace std;

int main()
{
    /* SYNTAX
    do
    {
       statement(s);
    }while(expr/condition);
    */

    int userChoice;

    do
    {
        // menu
        cout << "Welcome to COP 1334 ATM" << endl;
        cout << "Please select one of the following options:" << endl;
        cout << "1. Deposit " << endl;
                cout << "2. Withdraw " << endl;
        cout << "3. Check Balance " << endl;
        cout << "4. Exit " << endl;
        cout << "Your choice: ";
        cin >> userChoice;

        // defensive code ommitted
        switch(userChoice)
        {
        case 1:
            cout << "You chose Deposit" << endl;
            break;
        case 2:
            cout << "You chose Withdraw" << endl;
            break;
        case 3:
            cout << "You chose Check Balance" << endl;
            break;
        case 4:
            cout << "Thank you for using COP 1334 ATM" << endl;
            break;
        default:
            cout << "Please enter 1,2,3, or 4 only: " << endl;
        }
    }while(userChoice != 4);

    return 0;
}
```

Nested Loops

- Could be used to print data in a table
- Print a pattern

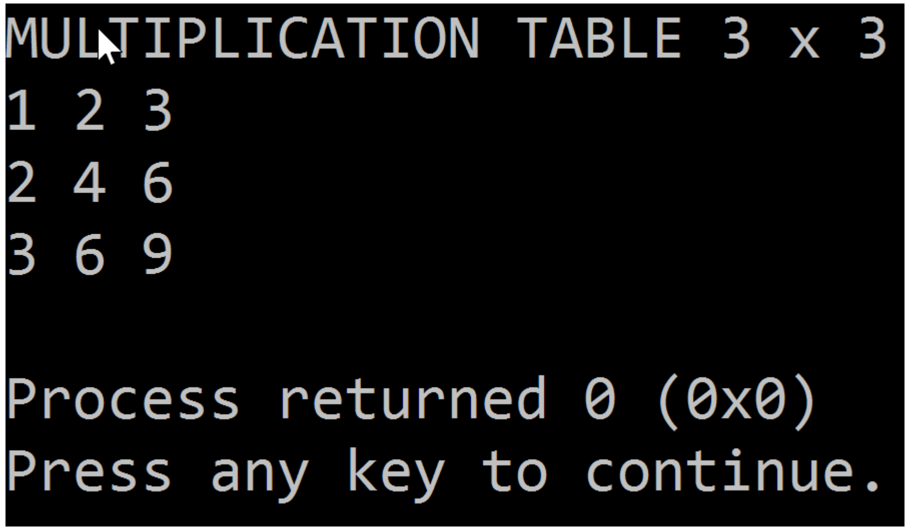
```
for (int row=0; row < 5; row++)        // OUTTER LOOP
{
    for (int col=0; col<5; col++) // INNER LOOP
    {
        cout << " * " ;
    }
    cout << endl;
}
```



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


Process returned 0 (0x0)
Press any key to continue.
```

Nested Loops

```
cout << "MULTIPLICATION TABLE 3 x 3" << endl;

for (int row=0; row < 3; row++)       // OUTTER LOOP
{
    for (int col=0; col<3; col++) // INNER LOOP
    {
        cout << (row+1) * (col + 1) << " ";
    }
    cout << endl;
}
```



```
MULTIPLICATION TABLE 3 x 3
1 2 3
2 4 6
3 6 9

Process returned 0 (0x0)
Press any key to continue.
```