

Programming with C++

COMP2011: Program Flow Control

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Introduction



- So far, our C++ program consists of only the `main()` function.
- Inside `main()` is a **sequence** of **statements**, and all statements are executed once and exactly once.
- Such sequential computation can be a big limitation on what can be computed. Therefore, we have
 - **selection**
 - **iteration**

Part I

You Have a Choice: **if**

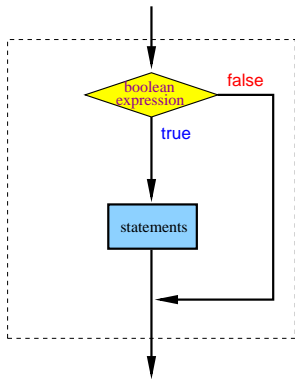


if Statement

Syntax: if Statement

`if (<boolean expression>) <statement>`

`if (<boolean expression>) { <sequence of statements> }`



- Example: Absolute value $|x|$ of x .

```
int x;  
cin >> x;  
  
if (x < 0)  
{  
    x = -x;  
}
```

Example: To Sort 2 Numbers

```
#include <iostream>      /* File: swap.cpp */
using namespace std;

int main() /* To sort 2 numbers so that the 2nd one is larger */
{
    int x, y;             // The input numbers
    int temp;             // A dummy variable for manipulation

    cout << "Enter two integers (separated by whitespaces): ";
    cin >> x >> y;

    if (x > y)
    {
        temp = x;         // Save the original value of x
        x = y;            // Replace x by y
        y = temp;         // Put the original value of x to y
    }

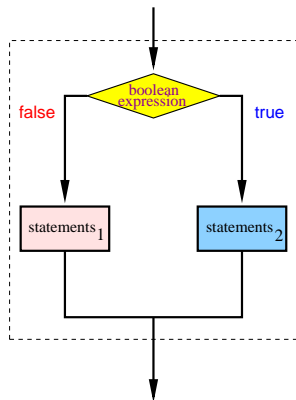
    cout << x << '\t' << y << endl;
    return 0;
}
```

if-else Statement

Syntax: if-else Statement

if (<bool-exp>) <stmt> else <stmt>

if (<bool-exp>) { <stmts> } else { <stmts> }



- Example: To find the larger value.

```
int x, y, larger;  
  
cin >> x >> y;  
  
if (x > y)  
    larger = x;  
else  
    larger = y;
```

Syntax: if-else-if Statement

```
if (<bool-exp>) <stmt>
else if (<bool-exp>) <stmt>
else if (<bool-exp>) <stmt>
:
else < stmt >

if (<bool-exp>) { <stmts> }
else if (<bool-exp>) { <stmts> }
else if (<bool-exp>) { <stmts> }
:
else { <stmts> }
```

Example: Conversion to Letter Grade

```
#include <iostream>          /* File: if-elseif-grade.cpp */
using namespace std;

int main()                   /* To determine your grade (fictitious) */
{
    char grade;              // Letter grade
    int mark; cin >> mark;    // Numerical mark between 0 and 100

    if (mark >= 90)
        grade = 'A';         // mark >= 90
    else if (mark >= 60)
        grade = 'B';         // 90 > mark >= 60
    else if (mark >= 20)
        grade = 'C';         // 60 > mark >= 20
    else if (mark >= 10)
        grade = 'D';         // 20 > mark >= 10
    else
        grade = 'F';         // 10 > mark

    cout << "Your letter grade is " << grade << endl;
    return 0;
}
```


Relational Operators

MATH	C++	Meaning
=	==	equal to
<	<	less than
≤	<=	less than or equal to
>	>	greater than
≥	>=	greater than or equal to
≠	!=	not equal to

- **Relational operators** are used to compare two values.
- The result is **boolean** indicating if the relationship is **true** or **false**.
- Don't mix up the 2 following different expressions:

`x = y` *// This is an assignment*

`x == y` *// This is an equality comparison*

Logical Operators

- **Logical operators** are used to modify or combine **boolean** values.
- C++ has 3 logical operators:
 - **!**: logical NOT
 - **||**: logical OR
 - **&&**: logical AND
- Boolean values
 - **true**: internally represented by **1**; ANY **non-zero** number is also considered **true**
 - **false**: internally represented by **0**

p	q	!p	p && q	p q
T	T	F	T	T
T	F	F	F	T
F	T	T	F	T
F	F	T	F	F

Precedence and Associativity of Boolean Operators

OPERATOR	DESCRIPTION	ASSOCIATIVITY
()	parentheses	—
++ -- ! -	increment, decrement, logical NOT, unary minus	Right-to-Left
* / %	multiply, divide, mod	Left-to-Right
+ -	add, subtract	Left-to-Right
> >= < <=	relational operator	Left-to-Right
== !=	equal, not equal	Left-to-Right
&&	logical AND	Left-to-Right
	logical OR	Left-to-Right
=	assignment	Right-to-Left

- Operators are shown in decreasing order of precedence.
- When you are in doubt of the precedence or associativity, use **extra parentheses** to enforce the order of operations.

What is the value of each of the following boolean expressions:

- `4 == 5`
- `x > 0 && x < 10` `/* if int x = 5 */`
- `5 * 15 + 4 == 13 && 12 < 19 || !false == 5 < 24`
- `true && false || true`
- `x` `/* if int x = 5 */`
- `x ++ == 6` `/* if int x = 5 */`
- `x = 9`
- `x == 3 == 4` `/* assume that x is an int */`

- Both `x = y` and `x == y` are valid C++ expressions
 - `x = y` is an **assignment expression**, assigning the value of `y` to `x`. The expression has a result which is the final value of `x`. (That is why the cascading assignment works.)
 - `x == y` is a **boolean expression**, testing if `x` and `y` are equal, and the result is either true or false.
- But since C++ also interprets integers as boolean, so
 - in `if (x = 3) { <stmts> }`, `<stmts>` are always executed because `(x = 3)` evaluates to 3 — a **non-zero** value — which is interpreted as **true**.
 - in `if (x = 0) { <stmts> }`, `<stmts>` are always **NOT** executed because `(x = 0)` evaluates to 0 which is interpreted as **false**.
- It is not recommended to use an assignment expression as a boolean expression.

if-else Operator: ?:

Syntax: if-else Expression

`(<bool-exp>) ? <then-exp> : <else-exp>;`

- The **ternary** if-else operator: **?:** is used.
- Unlike an **if-else statement**, an **if-else expression** has a value!

Example

```
/* Example: get the larger of two numbers */
larger = (x > y) ? x : y;

/* Example: get the letter grade from the percentile */
grade = (percentile >= 85) ? 'A'
      : ((percentile >= 60) ? 'B'
        : ((percentile >= 15) ? 'C'
          : ((percentile >= 5) ? 'D': 'F')
        )
      )
    );
```

Nested if

- In the **if** or **if-else statement**, the *< stmts >* in the **if**-part or **else**-part can be any statement, including another **if** or **if-else** statement. In the latter case, it is called a **nested if** statement.
- “Nested” means that a complete statement is inside another.

```
if (condition1)
{
    if (condition2)
    {
        if (condition3)
            cout << "conditions 1,2,3 are true." << endl;
        else
            cout << "conditions 1,2 are true." << endl;
    }
    else
        cout << "condition1 true; condition2 false." << endl;
}
```

“Dangling else” Problem

What is the value of x after the following code is executed?

Program code:

```
int x = 15;

if (x > 20)
if (x > 30)
x = 8;
else
x = 9;
```

Interpretation 1:

```
int x = 15;

if (x > 20)
{
    if (x > 30)
        x = 8;
    else
        x = 9;
}
```

Interpretation 2:

```
int x = 15;

if (x > 20)
{
    if (x > 30)
        x = 8;
}
else
    x = 9;
```


“Dangling else” Problem ..

- C++ groups a **dangling else** with the most recent **if**.
- Thus, for the code in the previous page, interpretation 1 is used.
- It is a good programming practice to use extra braces “{ }”
 - to control how your **nested if** statements should be executed.
 - to clarify your intended meaning, together with proper **indentation**.

Part II

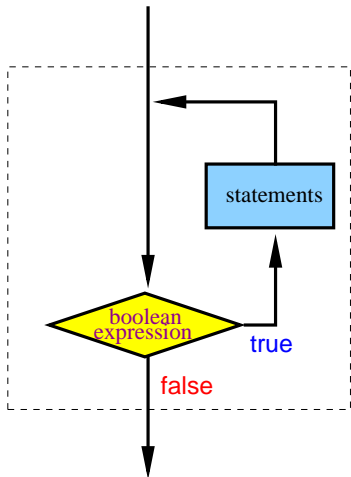
Loops or Iterations



while Loop (Statement)

Syntax: **while** Statement

```
while (<bool-exp>) { <stmts> }
```



- `<stmts>` will be repeated as long as the value of `<bool-exp>` is **true**.
- As usual, `<stmts>` can be a single statement, or a sequence of statements (including another **while** statement), or even no statement!
- What does `while (x > 0) ;` do?
- In general, **while** statement only makes sense if the value of `<bool-exp>` may be changed by `<stmts>` inside the **while** loop.

Example: Factorial using **while** Loop

```
#include <iostream>          /* File: while-factorial.cpp */
using namespace std;

/* To compute  $x! = x(x-1)(x-2)\dots 1$ , where  $x$  is a non -ve integer */
int main()
{
    int factorial = 1;
    int number;

    cout << "Enter a non-negative integer: ";
    cin >> number;

    while (number > 0)
    {
        factorial *= number; // Same as: factorial = factorial*number
        --number;           // Same as: number = number-1
    }

    cout << factorial << endl;
    return 0;
}
```

Example: Factorial using **while** Loop ..

(assume the user enters 4 for the variable *number*)

Iteration	factorial	number	(number > 0)
0	1	4	true
1	4	3	true
2	12	2	true
3	24	1	true
4	24	0	false

Example: Find the Maximum using **while** Loop

```
#include <iostream>      /* File: while-max.cpp */
using namespace std;

// To find the maximum of a list of +ve integers. Stop by inputting a
// character that is not a digit. Assume there is at least one number.
int main()
{
    cout << "Enter a number: ";
    int x; cin >> x;      // Input integers

    int max = x;          // Result initialized with the first number

    cout << "Enter the next number: ";
    while (cin >> x)      // If there is input, cin returns TRUE else FALSE
    {
        if (x > max)
            max = x;
        cout << "Enter the next number: ";
    }

    cout << endl << "The maximum number = " << max << endl;
    return 0;
}
```

A Good Programming Practice on Loops

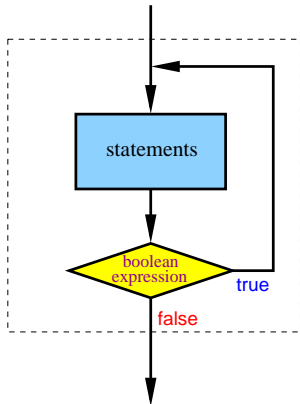
After you have written the codes for a **loop**, try verifying the following cases:

- The **first** iteration.
- The **second** iteration.
- The **last** iteration.
- Do you know exactly how many iterations will be performed?
- How can the loop **terminate**? Otherwise, you have an **infinite** loop! And the program runs forever!

do-while Loop (Statement)

Syntax: do-while Statement

```
do { <stmts> } while (<bool-exp>;
```



- Again, like the **while** statement, `<stmts>` will be repeated as long as the value of `<bool-exp>` is **true**.
- However, unlike the **while** statement, the `<bool-exp>` is evaluated after `<stmts>` at the bottom of **do-while** statement.
- That means, `<stmts>` in **do-while** loop will be executed **at least once**, whereas `<stmts>` in **while** loop may **not** be executed at all.

Example: Factorial using **do-while** Loop

```
#include <iostream> /* File: do-factorial.cpp */
using namespace std; // Compute  $x! = x(x-1)(x-2)\dots 1$ ;  $x$  is non -ve

int main()
{
    int factorial = 1, number;
    cout << "Enter a non-negative integer: ";
    cin >> number;

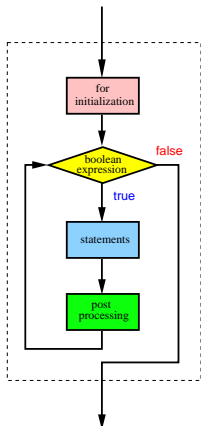
    if (number > 0)
    {
        do
        {
            factorial *= number; // Same as: factorial = factorial*number
            --number;           // Same as: number = number-1
        } while (number > 1);
    }

    cout << factorial << endl;
    return 0;
}
```

for Loop (Statement)

Syntax: for Statement

```
for (<for-initialization> ; <bool-exp> ; <post-processing> )  
{ <stmts> }
```



- **for** statement is a generalization of the **while** statement. The idea is to control the number of iterations, usually by a counter variable.
- **<for-initialization>** sets up the initial values of some variables, usually a **counter**, before executing **<stmts>**.
- **<stmts>** are iterated as long as **<bool-exp>** is **true**.
- At the **end** of **each** iteration, **<post-processing>** will be executed. The idea is to change some values, again usually the counter, so that **<bool-exp>** may become **false**.

Example: Factorial using **for** Loop

```
#include <iostream>          /* File: for-factorial.cpp */
using namespace std;

/* To compute  $x! = x(x-1)(x-2)\dots 1$ , where  $x$  is a non -ve integer */
int main()
{
    int factorial = 1;
    int number;

    cout << "Enter a non-negative integer: ";
    cin >> number;

    for (int j = 1; j <= number; ++j) // Set up a counter to iterate
        factorial *= j;

    cout << number << "! = " << factorial << endl;
    return 0;
}
```

Example: x^n using for Loop

```
#include <iostream>      /* File: for-power.cpp */
using namespace std;

/* To compute  $x^n$ , where x and n are integers, and n >= 0 */
int main()
{
    int x;
    int n;                // Power or exponent
    int result = 1;       // Need to initialize it to 1. Why?

    cout << "Enter a number followed by its +ve power: ";
    cin >> x >> n;

    if (n < 0)
        cerr << "Error: n < 0!" << endl;
    else
    {
        for (int j = 1; j <= n; j++)
            result *= x;

        cout << x << " to the power of " << n << " = " << result << endl;
    }

    return 0;
}
```

Remarks on **for** Statement

- Notice that the variable **j** in the above 2 examples are only defined inside the **for** loop. When the loop is done, **j** disappears, and you cannot use that **j** anymore.
- Don't mis-type a “;” after the first line of the **for** loop. E.g., what is the result of the following code?

```
for (int j = 1; j <= n; j++);  
    result *= x;
```

- **while** statement is a special case of **for** statement. How can you simulate **while** using **for**?
- Sometimes, if the **for**-body is short, you may even further compact the code as follows:

```
for (int j = 1; j <= number; factorial *= j++)  
    ;
```

Which Loop to Use?

- for loop** :
- When you know how to specify the required number of iterations.
 - When the counter variable is also needed for computation inside the loop.
 - e.g. To compute sums, products, and to count.

- while loop** :
- You want to repeat an action but **do not know** exactly how many times it will be repeated.
 - The number of iterations is determined by a **boolean condition**. e.g.

```
while (cin >> x) { ... }
```

- do-while loop** :
- The associated actions have to be executed **at least once**.
 - Otherwise, **do-while** and **while** are used in similar situations.

Part III

Nested Loooooops



Nested Loops Example: Compute Average Score

One may put a **while** loop inside another **while** loop.

```
#include <iostream>                                     /* File: nested-while-avg.cpp */
using namespace std;

int main( )
{
    int NUM_ASSIGNMENTS = 5;                             // Uppercase variable doesn't change
    int j;                                                  // Assignment counter
    int score, sum_of_scores;
    char reply = 'y';                                       // 'y' for yes, 'n' for no; initialized to yes

    cout << "Enter scores for the first student? (y/n) " << endl;

    while ((cin >> reply) && (reply == 'y' || reply == 'Y'))
    {
        sum_of_scores = 0;                                // Reset the accumulator to zero
        j = 1;                                             // Reset the assignment counter to 1

        while (j <= NUM_ASSIGNMENTS)
        {
            cout << "Enter student's score for assignment #" << j << " : ";
            cin >> score;                                  // Remark: one should check input errors here
            sum_of_scores += score;
            j++;
        }

        cout << "The average score = " << sum_of_scores/NUM_ASSIGNMENTS << endl;
        cout << "Enter scores for another student? (y/n) ";

    }

    return 0;
}
```


Nested Loops Example: Multiplication Table

```
#include <iostream>      /* File: multiplication-table.cpp */
#include <iomanip>         // a library that helps control input/output formats
using namespace std;

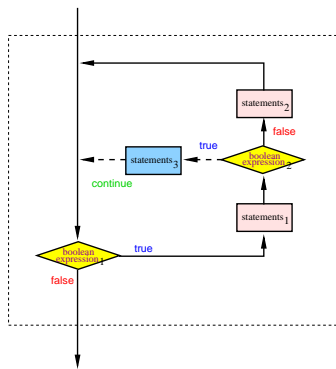
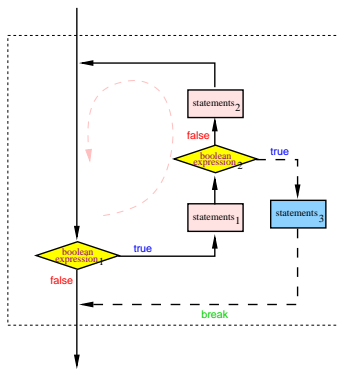
int main()
{
    // To print out products of j*k where j, k = 1,...,10
    for (int j = 1; j <= 10; ++j)
    {
        for (int k = 1; k <= 10; ++k) // Reset k=1 for each j. Why?
            cout << setw(4) << j*k;    // Set the length of output field to 4

        cout << endl;
    }

    return 0;
}
```

break and continue

- A **break** causes the **innermost enclosing loop** to exit **immediately**.
- A **continue** causes the **next iteration** of the enclosing loop to begin.
- That is, in the **while** loop, control passes to test the boolean expression again **immediately**.



Example: Stop Inputs with **break**

```
#include <iostream>          /* File: break-avg.cpp */
using namespace std;

int main()
{
    int NUM_ASSIGNMENTS = 5; // Uppercase variable doesn't change
    int j;                  // Assignment counter
    int score, sum_of_scores;
    char reply = 'y';        // 'y' for yes, 'n' for no; initialized to yes

    cout << "Enter scores for the first student? (y/n) " << endl;
    while ((cin >> reply) && (reply == 'y' || reply == 'Y'))
    {
        sum_of_scores = 0;    // Reset the accumulator to zero
        j = 1;               // Reset the assignment counter to 1

        while (j <= NUM_ASSIGNMENTS)
        {
            cout << "Enter student's score for assignment #" << j << " : ";
            cin >> score;      // Remark: one should check input errors here

            if (score < 0)
            {
                break;
            }

            sum_of_scores += score;
            j++;
        }
        cout << "The average score = " << sum_of_scores/NUM_ASSIGNMENTS << endl;
        cout << "Enter scores for another student? (y/n) " ;
    }
    return 0;
} // Question: What is the output with the input: 4, 5, -6, 7, 8?
```

Example: Ignore Negative Inputs with **continue**

```
#include <iostream>      /* File: continue-avg.cpp */
using namespace std;

int main()
{
    int NUM_ASSIGNMENTS = 5; // Uppercase variable doesn't change
    int j;                  // Assignment counter
    int score, sum_of_scores;
    char reply = 'y';        // 'y' for yes, 'n' for no; initialized to yes

    cout << "Enter scores for the first student? (y/n) " << endl;
    while ((cin >> reply) && (reply == 'y' || reply == 'Y'))
    {
        sum_of_scores = 0;    // Reset the accumulator to zero
        j = 1;                // Reset the assignment counter to 1

        while (j <= NUM_ASSIGNMENTS)
        {
            cout << "Enter student's score for assignment #" << j << " : ";
            cin >> score;      // Remark: one should check input errors here

            if (score < 0)
                continue;

            sum_of_scores += score;
            j++;
        }
        cout << "The average score = " << sum_of_scores/NUM_ASSIGNMENTS << endl;
        cout << "Enter scores for another student? (y/n) " ;
    }
    return 0;
} // Question: What is the output with the input: 4, 5, -6, 7, 8 ?
```

Example: Difference between **break** and **continue**

```
/* File: break-example.cpp */
#include <iostream>
using namespace std;

int main()
{
    int j = 0;

    while (j < 3)
    {
        cout << "Enter iteration "
              << j << endl;

        if (j == 1)
            break;

        cout << "Leave iteration "
              << j << endl;
        j++;
    }

    return 0;
}
```

```
/* File: continue-example.cpp */
#include <iostream>
using namespace std;

int main()
{
    int j = 0;

    while (j < 3)
    {
        cout << "Enter iteration "
              << j << endl;

        if (j == 1)
            continue;

        cout << "Leave iteration "
              << j << endl;
        j++;
    }

    return 0;
}
```

Question: What are the outputs of the 2 programs?

Where Does `continue`; Continue in a `for` Loop?

```
#include <iostream>      /* File: for-continue.cpp */
using namespace std;

int main()
{
    for (int j = 1; j <= 10; j++)
    {
        cout << "j = " << j << endl;

        if (j == 3)
        {
            j = 8;
            continue;      // What if it is replaced by break;
        }
    }

    return 0;
}
```

Common Loop Errors

What is the error in each of the following cases?

- Case 1:

```
int sum;
while (cin >> x)
    sum += x;
```

- Case 2:

```
int j;
while (j < 10)
{
    cout << "hello again!" << endl;
    j++;
}
```

- Case 3:

```
int j = 0;
while (j < 10);
{
    cout << "hello again!" << endl;
    j++;
}
```