Programming with C++

COMP2011: Program Flow Control I

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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

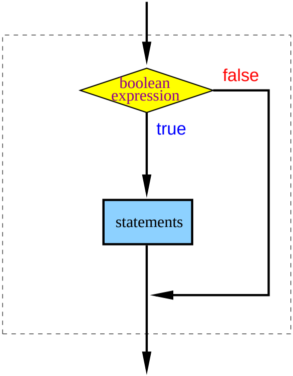
You Have a Choice: **if**

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

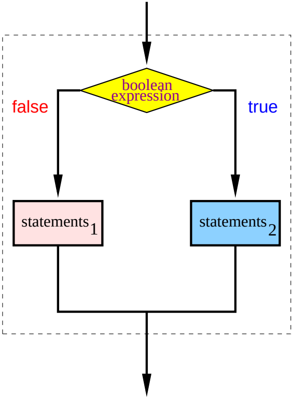
```cpp
#include <iostream>     /* File: swap.cpp */
using namespace std;

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;
```

if-else-if Statement

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;           // Numerical mark between 0 and 100
    cin >> mark;

    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
$\leq$	<=	less than or equal to
$>$	>	greater than
$\geq$	>=	greater than or equal to
$\neq$	! =	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.

= != ==

- 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.

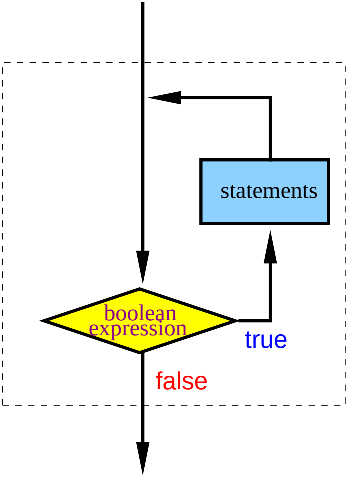
Part II

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)...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	$(\text{number} > 0)$
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

```cpp
#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;
}
```

Example: Continuously Halving a float Number

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

int main()
{
    int count = 0;      // Count how many times that x can be halved
    float x;            // Number to halve

    cout << "Enter a positive number: ";
    cin >> x;

    while (x > 0.1)
    {
        cout << "Halving " << count++ << " time(s); "
             << "x = " << x << endl;
        x /= 2;
    }

    return 0;
}
```

Example: Continuously Halving a float Number ..

```
Enter a positive number: 7
Halving 0 time(s); x = 7
Halving 1 time(s); x = 3.5
Halving 2 time(s); x = 1.75
Halving 3 time(s); x = 0.875
Halving 4 time(s); x = 0.4375
Halving 5 time(s); x = 0.21875
Halving 6 time(s); x = 0.109375
```

Example: Continuously Halving an int Number

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

int main()
{
    int count = 0;      // Count how many times that x can be halved
    int x;              // Number to halve

    cout << "Enter a positive number: ";
    cin >> x;

    while (x > 0.1)
    {
        cout << "Halving " << count++ << " time(s); "
             << "x = " << x << endl;
        x /= 2;
    }

    return 0;
}
```

Example: Continuously Halving an int Number ..

```
Enter a positive number: 7
Halving 0 time(s); x = 7
Halving 1 time(s); x = 3
Halving 2 time(s); x = 1
```

A Good Programming Practice on Loops

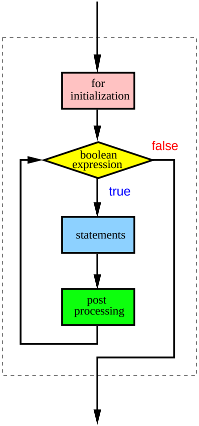
After you have written the codes for a loop, try verifying the following cases:

- 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!

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)...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++)
    ;
```