C++: A Crash Introduction

C++: A Crash introduction

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C++: A Crash introduction

Typographical conventions

- Text in `Courier new` font indicates Linux commands that should be typed literally by the user in the terminal.
- Text in **`Courier new bold`** font indicates directories.
- Text in *`Courier new italic`* font indicates human readable files or ascii files.
- Text in **Arial bold font** indicates program elements such as variables, function names, classes, statements and so on. It also indicate environment variables, and keywords. They also highlight important information.
- Text in Arial underline in blue font indicates URLs and email addresses.
- This icon indicates a warning or a caution ⚠
- This icon indicates a tip, suggestion, or a general note 👆
- This symbol indicates that a Linux command should be typed literally by the user in the terminal $>
- This symbol indicates that you must press the enter key ↵

C++: A Crash introduction

Typographical conventions

- Large code listing, ascii files listing, and screen outputs can be written in a square box, as follows:

```
1       #include <iostream>
2       using namespace std;
3
4       // main() is where program execution begins.  It is the main function.
5       // Every program in c++ must have this main function declared
6
7       int main ()
8       {
9               cout << "Hello world";                          //prints Hello world
10              return 0;                                       //returns nothing
11      }
```

- To improve readability, the text might be colored.
- The font can be `Courier new` or **Arial bold**.
- And when required, the line number will be shown.

C++: A Crash introduction

On the training material

- In the directory **`101CPP`** of the training material, you will find the source code of all the examples we will illustrate in the following slides.

- To compile the source code, type in the terminal:
  - `$> g++ file_name.C -o executable_name`
  - `$> ./executable_name`

- Take your time, and try to understand the concepts implemented in these examples.

- Also, try to get familiar with the syntax.

C++: A Crash introduction

- Before continuing, we want to remind you that this is an introductory C++ course.
- Our goal is to help you familiarize with the basic concepts of C++.
- So keep calm, try to follow all the examples, and ask questions.

C++ Program Structure: The Hello World Program

- Let us study the basic structure of a C++ program by looking at a simple code that prints on the screen the words **Hello world.**

```
#include <iostream>
using namespace std;

// main() is where program execution begins.  It is the main function.
// Every program in c++ must have this main function declared
int main ()
{
    cout << "Hello world";          //prints Hello world
    return 0;                       //returns nothing
}
```

C++ Comments

- In C++ you can comment a single line, up to the end of a line, or a whole block as follow:

```
#include <iostream>
using namespace std;

int main ()   //This is a comment up to the end of the line
{
    //This is a single line comment

    //The next block is commented using
    /*
        cout << "Hello world";
        return 0;
    */
}
```

- Do not nest block comments (/*   */). ⚠

Revisiting a C++ Program: The Hello World Program

- **Line 1**: lines beginning with the hash symbol (#) are directives read and interpreted by the preprocessor. In this case the directive **#include <iostream>** instructs the preprocessor to include the C++ standard library **iostream**, that allows to perform standard input and output operations. In this case, we use the object **cout** (which belongs to **iostream**) to write to the screen the message “Hello world”.

```
 1     #include <iostream>
 2     using namespace std;
 3
 4     // main() is where program execution begins.  It is the main function.
 5     // Every program in c++ must have this main function declared
 6     int main ()
 7     {
 8         cout << "Hello world";        //prints Hello world
 9         return 0;                     //returns nothing
10     }
```

Revisiting a C++ Program: The Hello World Program

- **Line 2**: in this line we introduce the namespace **std**, which has global scope. All the entities (variables, types, constant, and functions) of the standard C++ library (in this case **iostream**) are declared within the **std** namespace. If we do not use line 2, we will need to replace line 8 with:

```
std::cout << "Hello world";
```

```
 1     #include <iostream>
 2     using namespace std;
 3
 4     // main() is where program execution begins.  It is the main function.
 5     // Every program in c++ must have this main function declared
 6     int main ()
 7     {
 8         cout << "Hello world";       //prints Hello world
 9         return 0;                    //returns nothing
10     }
```

Revisiting a C++ Program: The Hello World Program

- **Line 3**: this is a blank line. Blank lines have no effect on a program, they simply improve readability of the code.
- **Line 4:** this line is commented. Commented lines have no effect on the behavior of the program.
- **Line 5:** this line is commented. Commented lines have no effect on the behavior of the program.

```
 1    #include <iostream>
 2    using namespace std;
 3
 4    // main() is where program execution begins.  It is the main function.
 5    // Every program in c++ must have this main function declared
 6    int main ()
 7    {
 8        cout << "Hello world";      //prints Hello world
 9        return 0;                   //returns nothing
10    }
```

Revisiting a C++ Program: The Hello World Program

- **Line 6**: this line declares the **main** function. A function is a group of statements which a given name, in this case **main**. The function **main** is a special function in all C++ programs; it is the function called when the program is run. The execution of all C++ programs begin with the **main** function, regardless of where the function is actually located within the code. Every program in C++ must have this function declared.

```
 1    #include <iostream>
 2    using namespace std;
 3
 4    // main() is where program execution begins.  It is the main function.
 5    // Every program in c++ must have this main function declared
 6    int main ()
 7    {
 8        cout << "Hello world";      //prints Hello world
 9        return 0;                   //returns nothing
10    }
```

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Revisiting a C++ Program: The Hello World Program

- **Lines 7 and 10**: the open brace **{** at line 7 indicates the beginning of the function **main**, and the closing brace **}** at line 10, indicates its end. Everything between the braces is the function's body that defines what happens when **main** is called. All functions use braces to indicate the beginning and end of their definitions.

```
 1     #include <iostream>
 2     using namespace std;
 3
 4     // main() is where program execution begins.  It is the main function.
 5     // Every program in c++ must have this main function declared
 6     int main ()
 7     {
 8          cout << "Hello world";        //prints Hello world
 9          return 0;                     //returns nothing
10     }
```

Revisiting a C++ Program: The Hello World Program

- **Lines 8**: this line is a C++ statement. A statement is an expression that can actually produce some effect. They are executed in the same order as they appear within the function's body. This statement has three parts. First, **cout**, which identifies the output device (usually the screen). Then the insertion operator **<<**, which indicates that what follows is inserted into **cout**. Finally, a sentence within quotes **"Hello world"**, is the content inserted into the standard output. Remember, every statement ends with semicolon (;).

```
 1    #include <iostream>
 2    using namespace std;
 3
 4    // main() is where program execution begins.  It is the main function.
 5    // Every program in c++ must have this main function declared
 6    int main ()
 7    {
 8        cout << "Hello world";      //prints Hello world
 9        return 0;                   //returns nothing
10    }
```

Revisiting a C++ Program: The Hello World Program

- **Lines 9**: this statement defines the exit status, that is, after executing all the statements, the function **main** returns the value 0. As the **main** function is of type **int**, it returns an **int** (0 in this case). In this case, if the main function does not return 0, it means that something went wrong during execution. To know the exit status of the last executed program, type in terminal **echo $?**. In this case, if you get 0 everything is ok and if you get something else, something went wrong during execution.

```
 1    #include <iostream>
 2    using namespace std;
 3
 4    // main() is where program execution begins.  It is the main function.
 5    // Every program in c++ must have this main function declared
 6    int main ()
 7    {
 8        cout << "Hello world";        //prints Hello world
 9        return 0;                     //returns nothing
10    }
```

C++ Program Structure
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`hello_world.C`*
    - *`hello_world_arg.C`*
- To compile the program *`hello_world.C`*, type in the terminal
    - `$> g++ ./hello_world.C -o run`
- To run this program, type in the terminal
    - `$> ./run`
- To get the exit status, type in the terminal
    - `$> echo $?`
- A few more compiling instructions alternatives,
    - `$> g++ -Wall -Wno-comment ./hello_world.C -o run`
    - `$> g++ -O3 ./hello_world.C -o run`

Basic Input and Output

- The C++ standard libraries provide an extensive set of input/output capabilities.
- C++ uses streams to perform input and output operations in sequential media such as the screen, the keyboard, or a file.
- The C++ standard library defines a handful of stream objects that can be used to do I/O operations. These are the stream objects that we will use most of the times:
    - **cin** standard input stream
    - **cout** standard output stream
- When using **cin** we use the insertion operator **>>**, and when using **cout** we use the insertion operator **<<**, as follows
    - **cin >> someString_in**
    - **cout << “Some message out”**
- To access the stream objects, we need to use the I/O library header file **<iostream>**.
- Additionally, you can use the I/O library header file **<iomanip>** to format the I/O, and the I/O library header file **<fstream>** to do I/O operations from/to a file.

C++: A Crash introduction

Basic Input and Output

- Let us use **cout** to print a message on the screen, **cin** to read in a string, and **cout** to print a message on the screen using the string information read using **cin**.

```
#include <iostream>
#include <string>

using namespace std;

int main ()
{
    string name1;                                //declare string variable
    cout << "Please enter your name:";               //prints message
    cin  >> name1;                              //get string from keyboard
    cout << “Hi “<< name2;          //prints message and string name1

    return 0;
}
```

C++: A Crash introduction

Basic Input and Output
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`hello_world_IO.C`*

C++: A Crash introduction

C++ Data Types

- Main data types in C++:

Type	**Keyword**
Boolean	**bool**
Character	**char**
Integer	**int**
Floating point	**float**
Double floating point	**double**
Valueless	**void**
Wide character	**wchar_t**

C++ Data Types Modifiers

- C++ allows the **char**, **int**, and **double** data types to have modifiers preceding them. A modifier is used to alter the meaning of the base type so that it better fits the actual needs. The data type modifiers are listed here:
    - **signed**
    - **unsigned**
    - **long**
    - **short**

- The modifiers **signed**, **unsigned**, **long**, and **short** can be applied to integer base types. In addition, **signed** and **unsigned** can be applied to **char**, and **long** can be applied to **double**. For example
    - **unsigned int y;** **//4 bytes. Range from 0 to 4294967295**
    - **signed int y;** **//4 bytes. Range from -2147483648 to -2147483647**

Variable Declaration & Initialization

- You declare the variables by using the C++ data types.
- You initialize a variable by assigning it a value.
- To initialize a variable you need to first declare it.
- All variables that we plan to use must have been declared (and initialized) before we use them.
- Take a look a the following examples:

```
int a, b, c;              //Declaration
int aa = 5.12;            //Declaration and initialization, it will only read the integer part
int b (2);                //Declaration and initialization, this is equivalent to b = 2
float pi;                 //Declaration
pi = 3.14159;             //Initialization
```

Scope of Variables

- All the variables that we intend to use in a program must have been declared with its type specifier in an earlier point in the code.
- A variable can be either of global or local scope. A global variable is a variable declared in the main body of the source code, outside all functions, while a local variable is one declared within the body of a function or a block.

```cpp
#include <iostream>
using namespace std;

int a = 4;                           //global scope variable

// main() is where program execution begins.
int main ()
{
    int b = 4;                       //local scope variable
    int result;

    result = a*b;
    cout << result << endl;           //prints result
    return 0;
}
```

Constants Variables

- Constants are expressions with a fixed value.
- Constants variable can be declared by using the **#define** preprocessor directive or by using the **const** prefix with a specific data type. For example,

```
#include <iostream>
using namespace std;

#define PI 3.14159                //global scope constant
#define NEWLINE '\n'              //global scope constant

int main ()
{
    const float pi = 3.14159;     //local scope constant
    float r = 1.0;
    double area_circle, area_circle2;
    area_circle  = 2*PI*r;
    area_circle2     = 2*pi*r;
    cout << area_circle  << endl;  //prints result
    cout << NEWLINE;               //insert new line
    cout << area_circle2 << endl;  //prints result
    return 0;
}
```

C++ Operators

- An operator is a symbol that tells the compiler to perform specific mathematical or logical manipulations.
- C++ is rich in built-in operators. Hereafter, we introduce a few of the operators available:

• Assignment Operator:	**=**
• Arithmetic Operators:	**+, -, \, *, %**
• Increase/decrease:	**++, --**
• Relational Operators:	**==, !=, >, <, >=, <=**
• Logical Operators:	**&&, ||, !**
• Bitwise Operators:	**&, |, ^, ~, <<, >>**
• Assignment Operators:	**+=, -=, *=, /=, %=, <<=, >>=, &=, ^=, |=**
• Miscellaneous Operators:	**?** , comma (**,**), arrow (**->**), **sizeof(),** and so on.

- **And by the way, the list is not complete.**

Data types, variables, and operators
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`cons_var.C`*
    - *`math_operations.C`*
    - *`operators1.C`*
    - *`operators2.C`*
    - *`var_declaration.C`*
    - *`var_scope.C`*

C++ Control Structures

- Control structures are portions of program code that contain statements within them and, depending on the circumstances, execute these statements in a certain way. There are typically two kinds: **conditionals** and **loops.**

- **Conditional structure: if and else**

The **if** keyword is used to execute a statement or block only if a condition is fulfilled. Its form is:

```
if (condition) statement
```

For example:

```
if (x == 7)
cout << “x is 7";
```

will print the “x is 7” only if the value stored in the x variable is indeed 7.

C++ Control Structures

- If we want more than a single statement to be executed in case that the condition is true we can specify a block using **braces { }**:

```
if (condition) statement
{


}
```

- For example:

```
if (x == 7)

{

    cout << “x is ”;

    cout << x;

}
```

C++ Control Structures

- **Conditional structure: if and else**
- We can additionally specify what we want to do if the condition is not fulfilled by using the keyword **else**. It is used in conjunction with **if**, as follows:

```
if (condition)
        statement1
else
        statement2
```

- For example:

```
if (x == 7)
        cout << “x is 7”;
else
        cout << “x is not 7”;
```

prints on the screen “x is 7” if indeed x has a value of 7, but if it does not, it prints out “x is not 7”.

C++ Control Structures

- **Conditional structure: if, else if and if**
- The **if - else** structures can be concatenated with the intention of verifying a range of values. The following example shows us its use:

```
if (x > 0)
    cout << “x is positive";
else if (x < 0)
    cout << “x is negative";
else
    cout << “x is 0";
```

- Remember that in case that we want more than a single statement to be executed, we must group them in a block by enclosing them in **braces { }**
- The conditional structures can be nested.
- It is always a good programming practice to use a single and clear indentation style.

C++ Control Structures

- **Loops:** loops have as purpose to repeat a statement a certain number of times or while a condition is fulfilled.

- **The while loop**

The format is:

```
while (expression) statement
```

and it simply repeats the statement while the condition set in expression is true. For example:

```
while (n>0)
{
        cout << "n is a positive number";
        n = n – 1;          //We can also use --n
}
```

C++ Control Structures

- **The do-while loop**

The format is:

do statement while (condition)

It does the same as the **while** loop, except that the condition in the **do-while** loop is evaluated after the execution of the statement instead of before. For example:

```
do
{
        cout << “n is not equal to zero”;
        n = n + 1;          //We can also use n++
}
while (n != 0) ;
```

C++ Control Structures

- **The for loop**

The format is:

```
for (initialization; condition; increase)  statement;
```

It repeat the statement while the condition remains true, like the **while** loop. The **for** loop is designed to allow a counter variable that is initialized at the beginning of the loop and incremented (or decremented) on each iteration of the loop. For example:

```
for (int x = 0; x < 10; x++)
{
      cout << x << endl;
}
return 0;
```

This program will print out the values 0 through 9, each on its own line.

C++ Control Structures

- In the **for** loop, the initialization and increase fields are optional. They can remain empty, but in all cases the semicolon signs between them must be written. For example, we could write:

```
for (;n<10;)
{
    // whatever here...
}
```

if we want to specify no initialization and no increase.

We also could write

```
for (;n<10;n++)
{
    // whatever here...
}
```

if we want to include an increase field but no initialization (maybe because the variable was already initialized somewhere else).

C++ Control Structures

- Optionally, using the comma operator (**,**) we can specify more than one expression in any of the fields included in a **for** loop.

- The comma operator (**,**) is an expression separator, it serves to separate more than one expression where only one is generally expected. For example, suppose that we want to initialize more than one variable in our loop:

```
for ( n=0, i=100 ; n!=i ; n++, i-- )
{
        // whatever here...
}
```

- This loop will execute for 50 times if neither n or i are modified within the loop. n starts with a value of 0, and i with a value of 100, the condition is n! = i (that is to say, n is not equal to i). Because n is increased by one and i decreased by one, the loop's condition will become false after the 50th loop, when both n and i will be equal to 50.

C++ Control Structures

- Remember, in case that we want more than a single statement to be executed, we must group them in a block by enclosing them in **braces { }**
- You will also need to declare somewhere the initialization and increase (or decrease) variables.
- The loops structures can be nested.
- It is always a good programming practice to use a single and clear indentation style.

C++ Control Structures
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`dowhile_loop.C`*
    - *`for_loop.C`*
    - *`if_else.C`*
    - *`if_else_if.C`*
    - *`random_numbers.C`*
    - *`while_loop.C`*

Functions

- A function is a group of statements that together perform a task. Every C++ program has at least one function which is the **main ( )** function.

- You can divide your code into separate functions. How you divide your code among different functions is up to you.

- A function **declaration** tells the compiler about a function's name, return type, and parameters. A function **definition** provides the actual body of the function.

- The C++ standard library provides numerous built-in functions that your program can call. For example, function **strcat ( )** concatenate two strings, function **memcpy ( )** copy one memory location to another location.

- A function is also knows as a method, sub-routine, procedure, etc.

Functions

- To use a function, we use the following format:

type name (parameter1, parameter2, ...) { statements }

where:

- **type** is the data type specifier of the data returned by the function.
- **name** is the identifier by which it will be possible to call the function.
- **parameters** (as many as needed): they allow to pass arguments to the function when it is called. The different parameters are separated by commas. Each parameter consists of a data type specifier followed by an identifier, like any regular variable declaration (for example: **int x**).
- **statements** is the function's body. It is a block of statements surrounded by **braces { }**

Functions

- For example:

```
#include <iostream>
using namespace std;

int addition (int a, int b)                         //function declaration
{
    int c;                                          //function definition
    c=a+b;                                          //function definition
    return (c);                                     //function definition
}

int main ()
{
    int answer;
    answer = addition (5,3);                        //call to function addition
    cout << "The result is " << answer;
    return 0;
}
```

C++: A Crash introduction

Functions

- Defining functions (both formats are equivalent):

Function definition in one single block

```
#include <iostream>
using namespace std;

//function definition
int addition (int a, int b)
{
     int c;          //function definition
     c=a+b;          //function definition
     return (c);     //function definition
}

int main ()
{
     int answer;

     //call to function addition
     answer = addition (5,3);
     cout << "The result is " << answer;
     return 0;
}
```

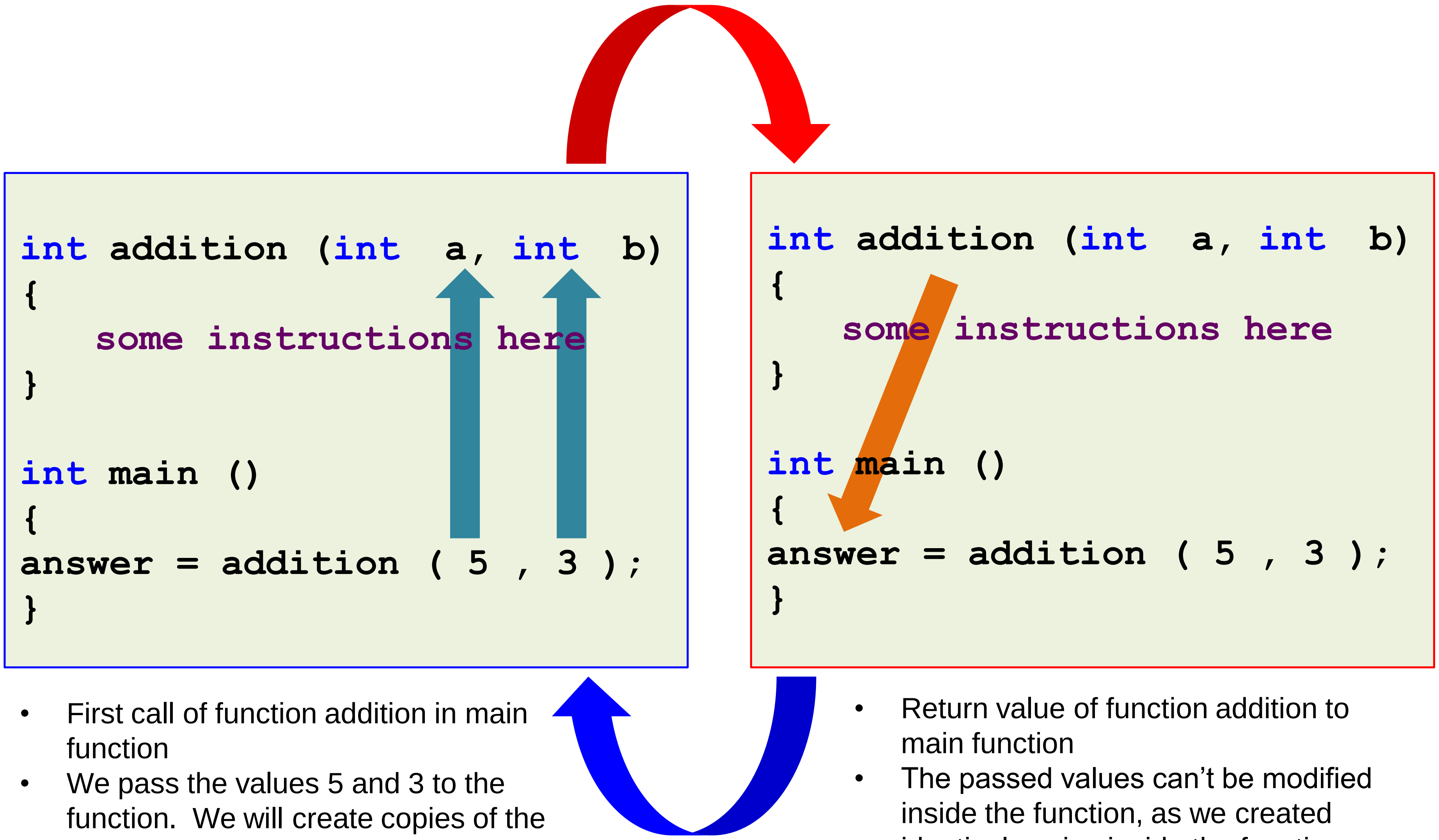
Definition of the function in two blocks:
Function prototype + body of the function

```
#include <iostream>
using namespace std;

//function prototype
int addition (int , int );

int main ()
{
     int answer;
     //call to function addition
     answer = addition (5,3);
     cout << "The result is " << answer;
     return 0;
}

//function definition
int addition (int a, int b)
{
     int c;          //function statements
     c=a+b;          //function statements
     return (c);     //function statements
}
```

Functions

- We can pass the variables or arguments to a function by value or by reference.
- When calling a function and passing the variables by value, what we pass to the function are copies of their values but never the variables themselves.
- When passing the variables by value, any modification to the passed variables within the function will not have any effect in the values of the variables outside it.
- When a variable is passed by reference we are not passing a copy of its value, but we are somehow passing the variable itself to the function and any modification that we do to the local variables will have an effect in their counterpart variables passed as arguments in the call to the function.
- Passing by reference is also an effective way to allow a function to return more than one value.

Functions. Arguments passed by value.



```
int addition (int  a, int  b)
{
    some instructions here
}

int main ()
{
answer = addition ( 5 , 3 );
}
```

```
int addition (int  a, int  b)
{
    some instructions here
}

int main ()
{
answer = addition ( 5 , 3 );
}
```

- First call of function addition in main function
- We pass the values 5 and 3 to the function. We will create copies of the values inside the function.

- Return value of function addition to main function
- The passed values can't be modified inside the function, as we created identical copies inside the function.

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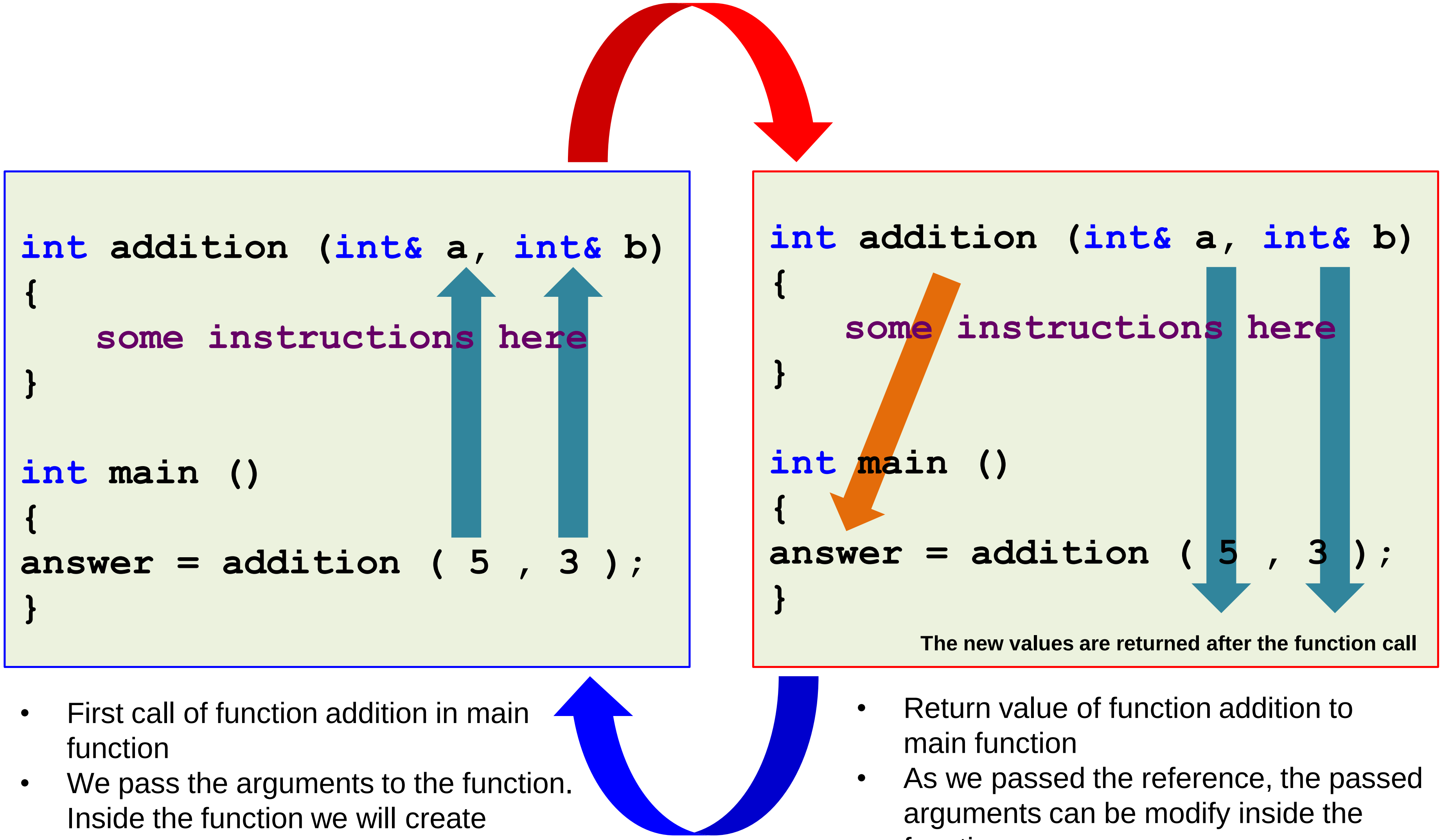
Functions. Arguments passed by reference.



```
int addition (int& a, int& b)
{
    some instructions here
}

int main ()
{
answer = addition ( 5 , 3 );
}
```

```
int addition (int& a, int& b)
{
    some instructions here
}

int main ()
{
answer = addition ( 5 , 3 );
}
```

The new values are returned after the function call

- First call of function addition in main function
- We pass the arguments to the function. Inside the function we will create aliases to the arguments.

- Return value of function addition to main function
- As we passed the reference, the passed arguments can be modify inside the function.

Functions

- The scope of variables declared within a function or any other inner block is only their own function or their own block and cannot be used outside of them. Therefore, the scope of local variables is limited to the same block level in which they are declared.

- Nevertheless, we also have the possibility to declare global variables; these are visible from any point of the code, inside and outside all functions.

- If a function does not returns a value, it should be declared as a **void** function.

- Two different functions can have the same name only if their parameter types or number of parameters are different, this practice is called **overloading functions**.

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Overloading Functions

- Function overloading:

```
#include <iostream>
using namespace std;

int addition (int a, int b)
{
    return (a+b);
}

double addition (double a, double b)
{
    return (a+b);
}

int main ()
{
    int x=5, y=5;
    double xx=5.1, yy=4.9;
    cout << operate(x,y) << endl;
    cout << operate(xx,yy) << endl;
    return 0;
}
```

C++: A Crash introduction

Functions
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`function_addition.C`*
    - *`function_by_reference0.C`*
    - *`function_by_reference1.C`*
    - *`function_by_value0.C`*
    - *`function_by_value1.C`*
    - *`function_overloading.C`*
    - *`function_swap.C`*
    - *`function_void.C`*

Arrays

- An array is a fixed number of elements of the same type stored sequentially in memory. Therefore, an integer array holds some number of integers, a character array holds some number of characters, and so on. The size of the array is referred to as its dimension. To declare an array in C++, we write the following:

```
type arrayName [dimension];
```

where **type** is a valid data type (**int**, **float**, **double**,etc), **arrayName** is a valid identifier. and **dimension** (which is always enclosed in **square brackets [ ]**) specifies the number of elements contained in the array.

- To declare an integer array named coor, which is made up of four elements, we write

```
int coor [4];
```

Arrays

- Like normal variables, the elements of an array must be initialized before they can be used; otherwise we will almost certainly get unexpected results in our program. There are several ways to initialize the array. One way is to declare the array and then initialize some or all of the elements:

```
int  coor [4];
coor [0] = 1;
coor [1] = 0;
coor [2] = 3;
coor [3] = 7;
```

- Another way is to initialize some or all of the values at the time of declaration:

```
int coor [4] = { 1, 0, 3, 7 };
```

- Sometimes it is more convenient to leave out the size of the array and let the compiler determine the array's size for us, based on how many elements we give it:

```
int coor [ ] = { 1, 0, 3, 7, 2, 5, 2, 11 };
```

In this case, the compiler will create an integer array of dimension 8.

Arrays

- C++ also supports the creation of multidimensional arrays through the addition of more than one set of brackets. Thus, a two-dimensional array can be created as follows:

```
type arrayName [dimension1][dimension2];
```

- The array will have **dimension1 x dimension2** elements of the same type. The first index indicates which of **dimension1** sub-arrays to access, and then the second index accesses one of **dimension2** elements within that sub-array. Initialization and access thus work similarly to the one-dimensional case:

```
int  coor [2][4];
coor [0][0] = 1;
coor [0][1] = 0;
coor [0][2] = 3;
coor [0][3] = 7;
coor [1][0] = 2;
coor [1][1] = 5;
coor [1][2] = 2;
coor [1][3] = 11;
```

C++: A Crash introduction

Arrays

- The array can also be initialized at declaration in the following ways:

```
int coor [2][4] = { 1, 0, 3, 7, 2, 5, 2, 11 };
int coor [2][4] = { { 1, 0, 3, 7 } , { 2, 5, 2, 11 } };
```

Note that dimensions must always be provided when initializing multidimensional arrays, as it is otherwise impossible for the compiler to determine what the intended element partitioning is.

- Multidimensional arrays are merely an abstraction for programmers, as all of the elements in the array are sequential in memory. Declaring **int coor[2][4];** is the same thing as declaring **int coor[8];**.

C++: A Crash introduction

Arrays

- To initialize all elements of a multidimensional array to 0 (or any other value), we do as follows:

```
int coor [2][20] = { 0 };
```

- Similar for a normal array:

```
int coor [4] = { 0 };
```

- Arrays can be also initialized (and accessed) by using **for** loops, as follows:

```
int   coor [2][20];
for (int i = 0; i < 2; i++)
{
        for (int j = 0; j < 20; j++)
        {
                coor[i][j] = 0;
        }
}
```

C++: A Crash introduction

Arrays

- **Accessing the values of an array.** In any point of a program in which an array is visible, we can access the value of any of its elements individually as if it was a normal variable, thus being able to both read and modify its value. The format is as simple as:

  ```
  array_name[index]
  ```

- Following the previous examples in which coor has 4 elements and each of those elements was of type **int**,

  ```
  int coor[4] = { 1, 0, 3, 7 };
  ```

- For example, to store the value 30 in the third element of coor, we write the following statement:

  ```
  coor[2] = 30;
  ```

- To pass the value of the third element of coor to a variable named a, we write:

  ```
  a = coor[2];
  ```

Therefore, the expression **coor[2]** is for all purposes like a variable of type **int**.

Arrays

- **Arrays as parameters.** If we want to pass a single-dimension array as an argument in a function, the only thing we need to do when declaring the function is to specify in its parameters the element type of the array, an identifier and a pair of void **square brackets [ ]**. For example, the function:

```
void myFunction(int param[ ])
{
      //some instructions here
}
```

accepts a parameter of type array of **int**, named param. In order to pass to this function an array declared as

```
int coor [100];
```

- It would be enough to write a call like this:

```
myFunction (coor);
```

C++: A Crash introduction

Arrays

- For example:

```
#include <iostream>
using namespace std;

void printArray (int arg [ ], int length)

{
      for (int n=0; n < length; n++)
      {
            cout << arg [n] << endl;
      }
      cout << endl;
}

int main ()
{
      int firstArray [ ] = {1, 2, 3, 4};
      int secondArray [ ] = {2, 6, 12, 10, 0};
      printArray (firstArray, 4);
      printArray (secondArray, 5);
      return 0;
}
```

- In this program, the first parameter (**int arg [ ]**) in the function **printArray**, accepts any array whose elements are of type **int**, whatever its length. For this reason we have included a second parameter that tells the function the length of each array that we pass. This allows the **for** loop to know the range to iterate.

Arrays

- In a function declaration it is also possible to include multidimensional arrays. For a two dimensions array, the format is: **type name [ ] [dimension2]**
- For example, a function with a multidimensional array as argument could be:

```
void myFunction (int param [ ][4])
```

Notice that the first brackets are left blank while the following ones are not. This is because the compiler must be able to determine within the function which is the size of each additional dimension.

- Alternatively, you could also define the dimension of the array when passing it to the function as a parameter, as follows:

```
void myFunction (int param [2][4])
void myFunction (int param [4])
```

- When passing an array to a function, we pass the starting address of the array. As a consequence of this we have direct access to the array. This means that any change we do to the array passed to the function is a change to the original array.

C++: A Crash introduction

Arrays
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
  - *`arrays1.C`*
  - *`arrays2.C`*
  - *`arrays3.C`*
  - *`arrays4.C`*
  - *`arrays5.C`*

Pointers

- Pointers are one of the most powerful and confusing aspects of the C++ language. Some C++ tasks are performed more easily with pointers, and other C++ tasks, such as dynamic memory allocation, can not be performed without them.

- A pointer is a variable that holds the address of another variable. Like any variable, we must declare a pointer before we can use it. The general form of a pointer variable declaration is:

```
type *var-name;
```

Here, **type** is the pointer's base type; it must be a valid C++ type and **var-name** is the name of the pointer variable. The asterisk is being used to designate a variable as a pointer. Some examples of pointers are:

```
int *ip;           // pointer to an integer double
double *dp;        // pointer to a double float
float* fp;         // pointer to a float char
char * ch          // pointer to character
```

Pointers

- Since pointers only hold addresses, when we assign a value to a pointer, the value has to be an address. To get the address of a variable, we use the ampersand (**&**) operator which denotes an address in memory.

```
int nValue = 5;
int *pnPtr = &nValue;       // assign address of nValue to pnPtr
cout << &nValue << endl;    // print the address of variable nValue
cout << pnPtr << endl;      // print the address that pnPtr is holding
```

- When the above code is compiled and executed, its output is (on my computer):

```
0012FF7C
0012FF7C
```

Pointers

- **Using Pointers (Dereferencing pointers):** The other operator that is commonly used with pointers is the dereference operator (*). A dereferenced pointer evaluates the contents of the address it is pointing to.

```
int nValue = 5;
cout << &nValue;          // prints address of nValue
cout << nValue;           // prints contents of nValue
int *pnPtr = &nValue;     // pnPtr points to nValue
cout << pnPtr;            // prints address held in pnPtr, which is &nValue
cout << *pnPtr;           // prints contents pointed to by pnPtr, which is contents of nValue
```

- The above program prints (on my computer)

```
0012FF7C
5
0012FF7C
5
```

In other words, when **pnPtr** is assigned to **&nValue: pnPtr** is the same as **&nValue** and ***pnPtr** is the same as **nValue**

Pointers

- Finally, we also can do the following with pointers::

    - Pass pointers to functions.
    - Return pointers from functions.
    - Use pointers to pointers.
    - Use an array of pointer.
    - Perform arithmetic operations on a pointer (**++**, **--**, **+**, and **-**) and pointer comparisons (**==**, **<**, and **>**).

Pointers
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`pointer1.C`*
    - *`pointer2.C`*
    - *`pointer3.C`*
    - *`pointer_dynmem.C`*
    - *`references.C`*

C++: A Crash introduction

Namespaces

- Namespaces address the problem of naming conflicts between different pieces of code.

- For example, we might be writing some code that has a function named **myFunction ( )**. If we decide to use a third-party library, which also has a **myFunction ( )** function. The compiler has no way of knowing which version of **myFunction ( )** we are referring to within our code. We can not change the library’s function name, and it would be a big pain to change your own.

- A namespace is designed to overcome this difficulty and is used to differentiate similar functions, classes, variables etc., that have the same name available in different libraries. Using namespace, we can define the context in which names are defined. In essence, a namespace defines a scope.

C++: A Crash introduction

Namespaces

```
#include <iostream>
using namespace std;

namespace first_space    // first name space
{
  void func()
    {
       cout << "Inside first_space" << endl;
    }
}
namespace second_space   // second name space
{
  void func()
    {
       cout << "Inside second_space" << endl;
    }
}

int main ()
{
   // Calls function from first name space.
   first_space::func();

   // Calls function from second name space.
   second_space::func();

   return 0;
}
```

- A namespace definition begins with the keyword namespace followed by the namespace name as follows:

  namespace namespace_name
  {
  // code declarations
  }

- To call the namespace-enabled version of either function or variable, prepend the namespace name as follows:

  namespace_name::code;

C++: A Crash introduction

Namespaces
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`namespaces.C`*

Defined Data Types (typedef)

- C++ allows the definition of our own types based on other existing data types. We can do this using the keyword **typedef**, whose format is:

```
typedef existing_type new_type_name ;
```

where **existing_type** is a C++ fundamental or compound type and **new_type_name** is the name for the new type.

- For example:

```
typedef vector<double> doubleVector;
```

In this way:

```
vector<double> a(8);
```

is equivalent to:

```
doubleVector a(8);
```

- **typedef** does not create different types. It only creates synonyms of existing types.

Defined Data Types (typedef)
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`typedef.C`*
    - *`typedef_vector.C`*

Classes

- A class is nothing else but an user defined data type, you can see them as user defined data types on steroids.

- A class is used to specify the form of an object and it combines data representation and methods for manipulating that data into one neat package. That is, in one class we can declare the variables type and what we want to do with those variables (functions).

- The data and functions within a class are called members of the class.

- The members of the class can have private, protected, or public access. These access specifier determine how the members are accessed.

- By default, all members of a class have private access for all its members.

Classes

- Classes are generally declared using the keyword **class**, with the following format:

```
class class_name {
    access_specifier_1:
        member1;
    access_specifier_2:
        member2;
    ...
} object_names;
```

where **class_name** is a valid identifier for the class, **object_names** is an optional list of names for objects of this class. The body of the declaration can contain members, that can be either data or function declarations, and optionally **access specifiers**.

Classes

- An access specifier is one of the following three keywords: **private**, **public** or **protected**. These specifiers modify the access rights that the members following them acquire:

  - **private** members of a class are accessible only from within other members of the same class or from their friends.
  - **protected** members are accessible from members of their same class and from their friends, but also from members of their derived classes.
  - **public** members are accessible from anywhere where the object is visible.

By default, all members of a class declared with the **class** keyword have private access for all its members.

Classes

- For example:

```
class CRectangle
{
        int x, y;
    public:
        void set_values ( int , int );
        int area (void);
} rect;
```

Declares a **class** (i.e., a data type) called **CRectangle** and a object (i.e., a variable) of this class called **rect**. This **class** contains four members: two data members of type **int** (member x and member y) with **private** access, and two member functions with **public** access: **set_value ( )** and **area ( )**, of which for now we have only included their declaration, not their definition.

C++: A Crash introduction

Classes

- In the previous declaration of the **CRectangle** **class** and **rect** object; we can access any public member of the object **rect** as if they were normal functions or normal variables. This is done by using the dot (**.**) operator in combination with the name of the object and the name of the member. For example:

```
rect.set_values (3,4);
myarea = rect.area();
```

- In the next slide we show a complete program for the class **CRectangle**, where we declare the class with all its members, then the functions definition and then we access the class within the main function.

C++: A Crash introduction

Classes

```
#include <iostream>
using namespace std;

class CRectangle
{
     int x,y;

public:
     //Prototype function
     void set_values ( int , int );

     int area ()     //Member function
     {
          return (x*y);
     }
};

//Definition of the member function
void CRectangle::set_values ( int a , int b )
{
     x = a;
     y = b;
}

int main ( )
{
     CRectangle rect;
     rect.set_values (3,4);
     cout<<"area: "<< rect.area ( );
     return 0;
}
```

- The most important new feature in this program is the scope operator (**::**), included in the definition of **set_values ( )**. It is used to define a member of a class from outside the **class** definition itself.
- You may notice that the definition of the member function **area ( )** has been included directly within the definition of the **class**.
- The only difference between defining a **class** member function within its **class** or to include only the prototype and later its definition, is that in the first case the function is considered an inline member function, while in the second case it is a normal member function (not-inline). This supposes no difference in behavior.

C++: A Crash introduction

Class Constructor

```
#include <iostream>
using namespace std;

class CRectangle
{
     int x,y;
public:
     CRectangle ( int , int );  //Constructor
     int area ()                //Member function
     {
          return (x*y);
     }
};

//Definition of the constructor function
CRectangle::CRectangle ( int a , int b )
{
     x = a;
     y = b;
}

int main ( )
{
   CRectangle recta   (3,4);
   CRectangle rectb   (5,12);
   cout<<"recta area: "<< recta.area ( ) << endl;
   cout<<"rectb area: "<< rectb.area ( ) << endl;
   return 0;
}
```

- Objects generally need to initialize variables or assign dynamic memory during their creation to become operative and to avoid returning unexpected values during their execution.
- In order to initialize classes, a special function called constructor is used. It is automatically called whenever a new object of the class is created.
- This constructor function must have the same name as the **class** and can not have any return type, not even **void**.
- Constructor can not be called explicitly as if they were regular member functions. They are only executed when a new object of that class is created.

C++: A Crash introduction

Class Destructors

```
class CRectangle
{
     int x, y;
public:
     CRectangle ( int , int );//Constructor
     ~CRectangle ( );         //Destructor
     int area ()              //Member function
     {
          return (x*y);
     }
};
//Definition of the constructor function
CRectangle::CRectangle ( int a , int b )
{
     x = a;
     y = b;
}
//Definition of the constructor function
CRectangle::~CRectangle ( )
{
     //delete x;    //for dynamic memory
     //delete y;    //for dynamic memory
}
```

- We can also use a special function called destructor. A destructor does the opposite of a constructor. It is automatically called when an object is destroyed, either because its scope of existence has finished or because it is an object dynamically assigned and it is released using the operator **delete**.
- As for constructors, the destructors must have the same name as the class, but preceded with a tilde sign (**~**) and it must also return no value.
- The use of destructors is especially suitable when an object assigns dynamic memory during its lifetime and at the moment of being destroyed we want to release the memory that the object was allocated.

Classes

- If we do not declare any constructor and destructor in a class definition, the compiler assumes the **class** to have a default constructor and destructor with no arguments.
- It is perfectly valid to create pointers that point to classes. We simply have to consider that once declared, a class becomes a valid data type, so we can use the class name as the type for the pointer. For example:

```
CRectangle * prect;
```

is a pointer to an object of **class** **CRectangle**.

- In order to refer directly to a member of an object pointed by a pointer we can use the arrow operator (**->**) of indirection.

```
prect -> set_values (2,4)
```

C++: A Crash introduction

Classes
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`class1.C`*
    - *`class2.C`*
    - *`class3.C`*
    - *`class4.C`*
    - *`class5.C`*
    - *`class6.C`*
    - *`class7.C`*
    - *`class8.C`*
    - *`class9.C`*
    - *`class10.C`*

Templates

- Templates are the foundation of generic programming which involves writing code in a way that is independent of any particular type.

- A template is a blueprint or formula for creating a generic class or a function.

  - **Function templates:** functions templates are special functions that can operate with generic types. This allows us to create a function template whose functionality can be adapted to more than one type or class without repeating the entire code for each type.

  - **Class templates:** we can also write class templates, so that a class can have members that use template parameters as types.

Function Templates

- The general form of a **template** function definition is as follows:

```
template <class identifier> identifier function_name (parameter list)
{
    // body of function
    // declare variables using identifier
}
```

- For example, to create a **template** function that adds two numbers:

```
template <class T>  T addval(T a, T b)
{
    return (a + b);
}
```

Here, we have created a **template** function with **T** as its identifier. The **template** identifier represents a type that has not yet been specified. The function **addval**, returns the addition of the two parameter of this still undefined type.

Function Templates

- To use this function **template**, we use the following format for the function call:

  function_name <type> (parameter list);

- For example, to call the function **addval** to add two variables of type **int**

  int x, y;

  addval <int> (x,y);

When the compiler encounters this call to a **template** function, it uses the **template** to automatically generate a function replacing each appearance of **T** by the type passed as the actual **template** parameter (**int** in this case) and then calls it. This process is automatically performed by the compiler and is invisible to the programmer.

- In the next slide we show the whole program

Function Templates

```
#include <iostream>
using namespace std;

template <class T>
T addval(T a, T b)
{
     T result;
     result = a + b;
     return (result);
}

int main ( )
{
     int k = 6, m = 4, p;
     double n = 3.14, r = 13.01, u;
     p = addval <int> (k,m);
     u = addval <double> (n,r);
     cout << "The result is " << p << endl;
     cout << "The result is " << u << endl;
     return 0;
}
```

- In this case, we have used **T** as the **template** identifier, but you can use any name identifier you like.
- In this example, we used the function **template** **addval** twice. The first time with arguments of type **int** and the second one with arguments of type **double**. The compiler has instantiated and then called each time the appropriate version of the function.
- As you can see, the type **T** is used within the **addval** template function even to declare new objects of that type:

  T result;

Function Templates

- We can also define function templates that accept more than one type parameter, simply by specifying more template identifiers between the **angle brackets < >**. For example

```
template <class T, class U>  T addval(T a, U b)
{
    T result;
    result = a + b;
    return (result);
}
```

In this case, our function template **addval ( )**, accepts two identifiers of different types and returns an object of the same type as the first identifier that is passed. After this declaration, we can call **addval( )**:

```
int  x;
double y;
addval <int, double> (x,y);
```

Class Templates

- The general form of a **template** class definition is as follows:

```
template <class identifier> class class_name
{
    // body of the class
}
```

- For example, to create the **template** class twovals:

```
template <class T>
class twovals
{
            T values [2];
    public:
            twovals (T first, T second)
            {
                values [0] = first;
                values [1] = second;
            }
} ;
```

Class Templates

- The **class template** that we have just defined, stores two elements of any valid type. For example, if we want to declare an object of this **class** to store two integer values with the values 100 and 25:

  twovals<int> my_object (100,25);

- This same **class template** can be used to create an object to store any other type

  twovals<int> my_object (3.14159, 343.3);

- The only member function in the previous **class template** has been defined inline within the **class** declaration itself. In case that we want to define a function member outside the declaration of the **class template**, we must always precede that definition with the **template < >** prefix.
- In the next slide we show a sample program.

Class Templates

```
#include <iostream>
using namespace std;

template <class T>
class twovals
{
          T a, b;
     public:
          twovals (T first, T second)
          {
               a = first;
               b = second;
          }
          T getmax ();
} ;
template <class T>
T twovals <T>::getmax ()
{
     T retval;
     retval = a>b ? a : b;
     return retval;
}

int main ( )
{
     twovals <int> myobject (100,75);
     cout << myobject.getmax ( ) << endl;
     return 0;
}
```

- In this case, we have used **T** as the **template** identifier, but you can use any name identifier you like.

- Notice the syntax of the definition of member function **getmax ( )**

  template <class T>
  T twovals <T>::getmax ()

- Confused by so many **T**?. There are three **T** in this declaration. The first one is the **template** identifier. The second **T** refers to the type returned by the function. And the third **T** (the one between **angle brackets < >**) is also a requirement, it specifies that this function's **template** identifier is also the **class template** identifier.

Class and Function Templates

- If you look for the definition of template in a dictionary, you will find a definition that is similar to the following:

  “a template is a model that serves as a pattern for creating similar objects”.

- One type of template that is very easy to understand is that of a stencil. A stencil is an object (e.g. a piece of cardboard) with a shape cut out of it (e.g. the letter J). By placing the stencil on top of another object, then spraying paint through the hole, you can very quickly produce stenciled patterns in many different colors.

- Note that you only need to create a given stencil once, you can then use it as many times as you like to create stenciled patterns in whatever colors you like.

- Even better, you don’t have to decide the color of the stenciled pattern you want to create until you decide to actually use the stencil.

Class and Function Templates

- At a first glance class and functions templates are difficult to understand, you just need to get use with the syntax.

- In C++, templates serve as a pattern for creating other similar functions or classes.

- The basic idea behind templates in C++ is to create functions and classes without having to specify the exact type of some or all of the variables.

- Instead, we define the function or class using placeholder types, called template type parameters (identifiers). Once we have created a function using these placeholder types, we have effectively created a function stencil or class stencil.

Class and Function Templates
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`templates1.C`*
    - *`templates2.C`*

C++ Standard Template Library (STL)

- The C++ STL library is a powerful set of C++ template classes that provide general purpose templated classes and functions that implement many popular and commonly used algorithms and data structures like vectors, lists, queues, and stacks.
- The core of the C++ STL library is made up of three well-structured components:
    - **Containers:** they are used to manage collections of objects of a certain kind. There are several different types of containers like deque, list, vector, etc.
    - **Algorithms:** they act on containers. They provide the means by which you will perform initialization, sorting, searching, and transforming of the contents of containers.
    - **Iterators:** are used to step through the elements of collections of objects.
- A full discussion about all the three C++ STL components is outside of the scope of this lecture. From now on, keep in mind that all the three components have a rich set of pre-defined functions which help us in doing complicated tasks in a very efficient way.
- Let us take a look at the following program to demonstrates the vector container (a C++ Standard Template) which is similar to an array with an exception that it automatically handles its own storage requirements in case it grows.

C++ Standard Template Library (STL)

```
#include <iostream>
#include <vector>          //STL vector library

using namespace std;

int main()
{
    // create a templated vector object to store int
    vector<int> vec;
    int i;

    // display the original size of vec
    cout << "vector size = " <<
    vec.size() << endl;

    // push 5 values into the vector
    for(i = 0; i < 5; i++)
    {
        vec.push_back(i);
    }
```

First part of the code

```
    // display extended size of vec
    cout << "extended vector size = "
    << vec.size()    << endl;

    // access 5 values from the vector
    for(i = 0; i < 5; i++)
    {
    cout << "value of vec [" << i << "]
    = " << vec[i]      << endl;
    }

    // use iterator to access the values
    vector<int>::iterator v = vec.begin();

    while( v != vec.end())
    {
    cout << "value of v = " << *v << endl;
    v++;
    }

    return 0;
}
```

Second part of the code

C++ Standard Template Library (STL)
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/src`**.
- The files related to the concepts introduced in the previous sections are:
    - *`stl1.C`*
    - *`stl2.C`*
    - *`stl3.C`*
    - *`stl4.C`*
    - *`stl5.C`*

Creating and using static and shared C++ libraries

- Most large software projects contains several components (e.g., PETSC, trilinos, LAPACK, boost, BLAS, OpenFOAM®, SU2), some of which you may use later on in some other project.
- By separating the software into many components we improve code organization, usability, readability, and maintainability.
- When you have a reusable set of functions, it is helpful to build a library (static or dynamic) so you do not have to copy the source code over and over in your project. You only have one set of well tested functions, well documented, organized in a library that you can use with any program.
- By using libraries, we keep different modules of the program disjoint and we can change them without affecting others.
- Hereafter we are going to study how to create, compile, link, and use static and shared C++ libraries.

Creating and using static and shared C++ libraries

- Let’s take a look at this piece of code which contains one function (**addition**).
- Imagine that we would like to use the function **addition** over and over among different projects or files. To do so we will need to copy and paste the function in every single piece of code, and this can be a cumbersome and error prone task.
- Now imagine that you found an error in the function, you will need to modify every single file where you use this function. This can be a very time consuming.
- By adding modularity, you can create one single file with the function, and then call this function.

```
#include <iostream>
using namespace std;

int addition (int a, int b)                         //function declaration
{
     int c;                                         //function definition
     c=a+b;                                         //function definition
     return (c);                                    //function definition
}

int main ()
{
     int answer;
     answer = addition (5,3);                       //call to function addition
     cout << “The result is “ << answer;
     return 0;
}
```

Creating and using static and shared C++ libraries

- One way to add modularity to our project, is to first erase the function definition in the file `addition.C` and add it into a separate header file with the name `myfunction.H`. This header file contains the function definition.
- In the file containing the main function, we add the directive **#include "myfunction.H"**. Basically we are telling the preprocessor we would like to use whatever is inside the file `myfunction.H`.
- At compiling time, the preprocessor will process the information of the header files.
- At this point, we can reuse the file `myfunction.H`.

addition.C

```
#include <iostream>
#include "myfunction.h"

using namespace std;

int main ()
{
     int answer;
     answer = addition (5,3);
     cout << "The result is " << answer;
     return 0;
}
```

myfunction.H

```
int addition (int a, int b)
{
     int c;
     c=a+b;
     return (c);
}
```

Creating and using static and shared C++ libraries

- So far the code is easier to maintain, but we haven't created a library. To create the library we need to take an additional step.
- Let's split the previous header file into two parts. The file `myfunction.h` containing the function prototype and the file `fadd.C` containing the function definition.
- Now we use the file `fadd.C` to create the library (dynamic or static).
- After creating the library, we can compile the program by linking it with the library containing the function **addition**.

addition.C

```
#include <iostream>
#include "myfunction.h"

using namespace std;

int main ()
{
      int answer;
      answer = addition (5,3);
      cout << "The result is " << answer;
      return 0;
}
```

fadd.C

```
int addition (int a, int b)
{
      int c;
      c=a+b;
      return (c);
}
```

myfunction.h

```
int addition (int , int )
```

Creating and using static and shared C++ libraries

- Let's assume that the files *addition.C*, *fadd.C*, and *myfunction.h*, are all located in the same directory, namely, **/home/user/project**

- To create a dynamic library using the file *fadd.C*, you can proceed as follows:
  - `$> g++ –fPIC –c ./fadd.C –o ./fadd.o`
  - `$> g++ -shared –fPIC –o ./libfadd.so ./fadd.o`

- To compile the program using the dynamic library you just created:
  - `$> g++ –fPIC ./addition.C –o myprogram -I. -L. -lfadd`

- To run the program you first need to add the location of the dynamic library to the environment variables:
  - `$> LD_LIBRARY_PATH=$LD_LIBRARY_PATH:/home/user/project/`
  - `$> export LD_LIBRARY_PATH`

- To run the program:
  - `$> ./myprogram`

Creating and using static and shared C++ libraries Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/library`**.
- The files related to the concepts introduced in the previous sections are:
    - *`include/function_addition1.H`*
    - *`include/function_addition2.H`*
    - *`src/fadd.C`*
    - *`src/function_addition0.C`*
    - *`src/function_addition1.C`*
    - *`src/function_addition2.C`*
    - *`src/function_addition3.C`*

- In the *`README.FIRST`* file you will find the compilation instructions for different cases.

Debugging C++ Applications

- In a few words, a debugger is a program that runs another program one line at a time, and prints out the values of each variable after executing each line.
- Hereafter we will use the GNU debugger or **gdb**, which is text based. Have in mind that there are many other options (text and GUI based).
- To debug a program with **gdb** (or any other debugger), the program must be compiled with debug support. This means that we need to recompile the program.
- Also, the compilation using debug support takes longer and use more computational resources.
- The final executable is slower and the file's dimension is bigger.
- Do not use a program compiled with debug support to do production runs.

Debugging C++ Applications

- Let's introduce **gdb** using a simple program.
- The source code of the sample program is located in the directory **`101CPP/debugging`**.
- To compile the program with debug support, you can proceed as follows:
    - `$> g++ -g ./src/function_addition0.C -o run -I./include`
- The –g flag enables debug support with the gnu compilers.
- To start debugging our program, type in terminal:
    - `$> gdb ./run`
- At this point, you should be inside the debugger prompt,
    - `(gdb)`
- Let's play with the debugger, we are going to show you the basic commands, the rest is on you.

Debugging C++ Applications

- To get some basic help, type in the prompt,
  - `(gdb)  help`
- If you need help on aliases, type in the prompt,
  - `(gdb)  help aliases`
- If you want to exit the debugger, type in the prompt,
  - `(gdb)  quit`
- To run the program, type in the prompt,
  - `(gdb)  run`
- If you want to see the listing of the main function (10 lines), type in the prompt,
  - `(gdb)  list`
- Let’s insert a breakpoint in line 25 (the main function), type in the prompt,
  - `(gdb)  break 25`
- Let’s run again the program, the execution will stop in the next function after the breakpoint, and we will be able to run line by line and monitor all the variables, type in the prompt,
  - `(gdb)  run`

Debugging C++ Applications

- To know where we are in the source code, type in the terminal,
    - `(gdb)  where`
- To step in into the code, type in the terminal,
    - `(gdb)  step`
- To list the code around line 14 (10 lines), type in the prompt,
    - `(gdb)  list 14`
- At this point we are inside the function addition, let's advance one more line,
    - `(gdb)  step`
- We just evaluated c, to know the value stored in this variable, type in the terminal
    - `(gdb)  print c`
- To change the value of c, type in the terminal
    - `(gdb)  set var c=5`
- To step into the next line without evaluating functions, type in the terminal,
    - `(gdb)  next`
- To execute the program until the end, type in the terminal,
    - `(gdb)  continue`

Debugging C++ Applications
Hands on tutorials

- The source code of the sample files is located in the directory **`101CPP/debugging`**.
- The files related to the concepts introduced in the previous sections are:
    - *`include/function_addition0.H`*
    - *`src/function_addition0.C`*

- In the *`README.FIRST`* file you will find the compilation instructions.

C++: A Crash introduction

C++ and OpenFOAM®

- OpenFOAM® is entirely written in C++ and is fully object oriented.
- In OpenFOAM® there is a wide number of classes defined. They are used to define, discretize, and solve PDE systems.
- To assemble the linear system, OpenFOAM® uses arrays, pointers, and dynamic memory allocation.
- OpenFOAM® uses namespaces.
- OpenFOAM® uses typedefs a lot, they make the code easy to read.
- OpenFOAM® is heavily templated. It uses class and function templates a lot!
- OpenFOAM® uses its own template library, which is STL conforming. In principle it works similar to the STL library.
- Unfortunately, OpenFOAM® API is not well documented.

C++: A Crash introduction

C++ and OpenFOAM®

C++ is a complex programming language, rich in features. OpenFOAM® use all C++ features.

Unknown OpenFOAM® programmer

OpenFOAM® is an excellent piece of C++ and software engineering. Decent piece of CFD code.

H. Jasak

A few good C++ references

- **The C++ Programming Language.**
  B. Stroustrup. 2013, Addison-Wesley.
- **The C++ Standard Library**.
  N. Josuttis. 2012, Addison-Wesley.
- **C++ for Engineers and Scientists.**
  G. J. Bronson. 2012, Cengage Learning.
- **Sams Teach Yourself C++ in One Hour a Day.**
  J. Liberty, B. Jones. 2004, Sams Publishing.
- **C++ Primer.**
  S. Lippman, J. Lajoie, B. Moo. 2012, Addison-Wesley.
- http://www.cplusplus.com/
- http://stackoverflow.com/