

Introduction to Programming and Computing for Scientists (2016 HT)

Tutorial-3a: First steps with C++ programming

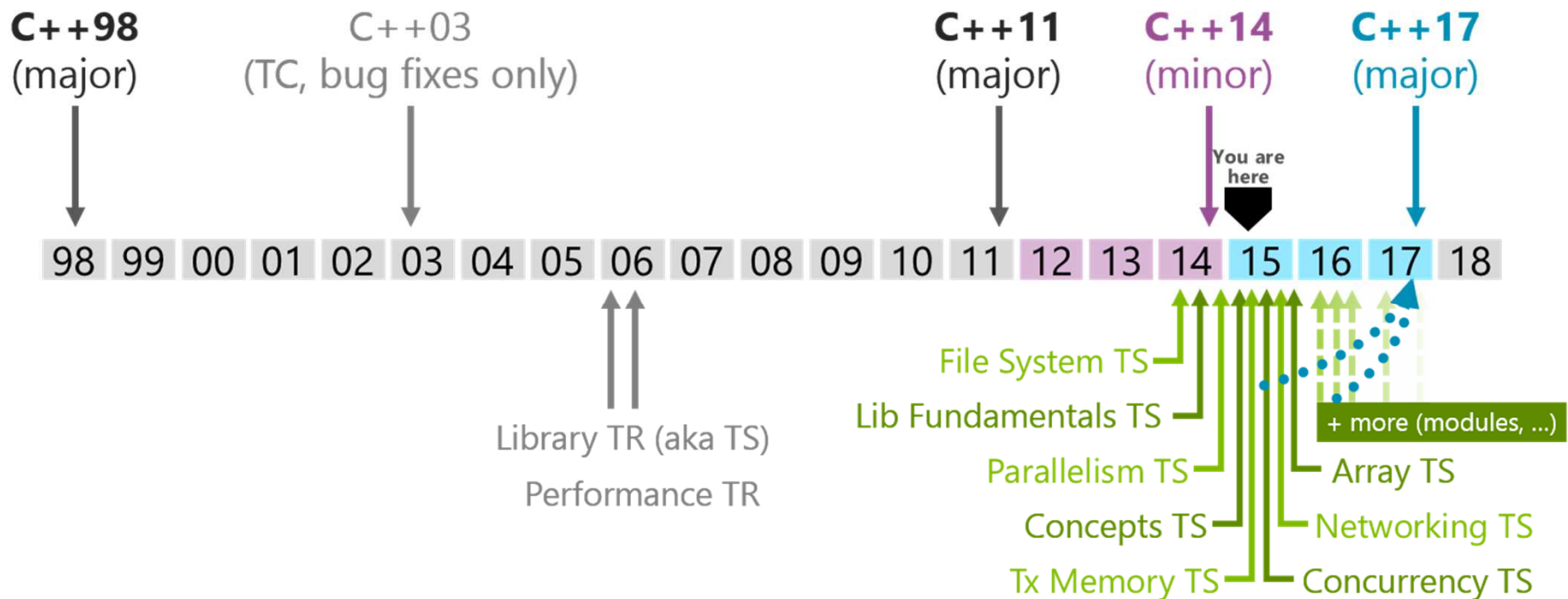
Quick refresher: C++ in a nutshell

- Created by Bjarne Stroustrup at AT&T Bell Laboratories in the early 1980's, later maintenance, governance has been taken over by the Standard C++ Foundation
- General purpose, strongly-typed, high-level programming language based on the C language. C++ is an "incremented" version of C
 - *"the name signifies the evolutionary nature of the changes from C"*
 - ++ is the (post) increment operator in C
 - C++ is much more than that, it is a very powerful & flexible language
- Compiled language
 - Compilers play an important role, standard-compliant and compatible compilers have been a challenge for C++ community for quite a long period
- Multi-paradigm language: **object-oriented**, procedural, functional
- Multi-platform (Windows, Unix, Mac, etc...)



Quick refresher : C++ in a nutshell

- Standardized by an ISO WG
- Promoted, supported by the Standard C++ Foundation, check out their site: <http://isocpp.org>
- Latest version: C++11/14



Before we start...

“C makes it easy to shoot yourself in the foot;
C++ makes it harder, but when you do, it
blows away your whole leg.”

Bjarne Stroustrup, developer of the C++ programming language

“The problem with using C++ ... is
that there’s already a strong
tendency in the language to
require you to know everything
before you can do anything.”

Larry Wall, developer of the Perl language

One of the simplest c++ programs

- Main function
 - No input parameter ()
 - Returns an integer (zero value for success)
 - Main is mandatory
 - C++ programs begin executing at main()
 - What the function does is described within {}
 - // is the way to add single line comments
- The program itself, the body of the main function between the left and right brace {}:
 - Prints a text message to the standard output (screen)
 - Printing is done with the iostream library, therefore the iostream library has to be "included" into the program
 - The library defines several objects & functions to work with I/O streams
 - std::cout is the standard output, printing to the stdout is done via the >> operator
 - std::cout is a c++ way of denoting the namespace of the library
 - The message to be printed is the one in quotes: Hello, world!
 - Note the semicolon (;) at the end of the printout line

```
// simple c++ code

#include <iostream>

int main() {
    std::cout << "Hello, world!";
}
```

From source code to executable

The usual steps for generating a C++ program are:

1. Editing: User writes the source code for a C++ program in the text editor
2. Preprocessing: The C++ preprocessor carries out various source code manipulations before the compiler's translation phase. The manipulations usually include inserting the contents of other source code files, preparing for conditional compilation, and performing various text replacements.
 - e.g. #include statements are taken care by the preprocessor
3. Compilation: The C++ compiler translates the C++ program into machine code (or object code).
4. Linking: The linker links the object codes (user written code and existing libraries) to produce an executable file.

Note: compilers can combine (hide) steps 2-4 from the user.

Exercise 1:

- Type in the simple C++ code from the previous slide (save as hello.cpp)
- Generate an executable: `g++ -o printhello hello.cpp`
- Run the binary file: `./printhello`
- Use the `//` to comment out various lines in the code, compile it and look at the compiler error messages.

basic Input / Output

I/O in C++ is managed via streams of bytes, where a stream is simply a sequence of bytes

- `cout << "some text to be printed out";`
 - `cout` is the output stream object
 - `<<` is the stream insertion operator
 - `cout` and `<<` are used to display text strings on the screen
- `cin >> Variable;`
 - `cin` is the input stream object
 - `>>` is the stream extraction operator
 - `cin` and `>>` are used to take input from the standard input stream (usually the keyboard) and assign it to a variable

Note: more advanced I/O stream operations including character strings and reading/writing to/from files will come later

Exercise 2:

- Write a simple program that asks for two integers and prints out their sum and multiplication!
- Hint: you must declare the variables as e.g. `int A, B`
- Hint: you can chain output strings
- Hint: `\n` is the new line "character" or you can use the `endl` stream object
- Hint: it is possible to use the `+` and `*` operations within the output stream

Variables

- A variable is a “name” that is associated with memory reserved for storing the variable's value.
 - You store data in a program by assigning values to variables
- Every variable has a name, a type, a value and a scope/lifetime:
 - Name: series of characters consisting of letters, digits, and underscores. Case sensitive. No spaces. May not begin with a number.
 - Type: defines what sort of values the variable can store (e.g. int, float or char)
 - Value: a variable gets its value via the assignment operator (=)
 - Scope: a variable can be global or local:
 - Variables declared outside functions, including main(), are global. They exist for the duration of a program and can be accessed from anywhere in the code.
 - Variables declared inside functions are local to those functions. Local variables may be accessed only inside the block in which they are declared. When a function begins, it allocates space on the stack to hold its local variables. This space exists only while the function is active, after the function returns, it deletes the allocated stack space, including all local variables.

Data types

- **Exact ranges and memory sizes** of data types **may differ** depending on compilers, compiler options and operating systems
- Basic types: bool, char, int, float, double
- Modifiers: unsigned, signed (default), short, long

Type (keyword)	Size (byte)	Range
char	1 byte	-128 to 127 or 0 to 255
int	2 bytes	-32,768 to 32,767
unsigned int	2 bytes	0 to 65,535
short int	2 bytes	-32,768 to 32,767
long int	4 bytes	-2,147,483,648 to 2,147,483,647
float	4 bytes	(+/-) 1.17E-38 to 3.4E+38 (6 or 7 significant digits)
double	8 bytes	(+/-) 2.2E-308 to 1.79E+308 (15 significant digits)
long double	16 bytes	(+/-) 3.4E-4932 to 1.1E+4932 (appx. 19 significant digits)

Basic operators

- In C++ the basic operators work the same way as in other languages, including the usual operator precedence (first parentheses, then */%, then +-, then left to right rule)
- division (/) applied to integers will truncate the result (e.g. 5/2 equals to 2 in integer division)
- ++: increment operator adds one to its operand
- --: decrement operator subtracts one from its operand
- =: assignment operator to assign values to variables

Operation	C++ operator
Addition	+
Subtraction	-
Multiplication	*
Division	/
Modulus	%
Decrement	--
Increment	++
Assignment	=

Relational and logical operators

Operation	C++ operator
Equal to	==
Not equal to	!=
Greater than	>
Less than	<
Greater than or equal	>=
Less than or equal	<=
Negation	!
And	&&
OR	
XOR	^
Bitwise AND	&
Bitwise OR	
Bitwise shifts	<< and >>

Variables & basic operations

Exercise 3:

- Determine the actual size of the various data types on your system: g++ compiler of Ubuntu Linux installed on a 32 bit Virtual Machine.
 - Hint: use the sizeof() function: e.g. sizeof(long double) will return the number of bytes your system uses to store a long double variable
 - Check the size of the types listed on the previous slide (char, short int, etc...)

Exercise 4:

- Check what happens when variable values are outside of variable range.
- Write a small code where you assign an initially correct value to a variable (e.g. short int), then you modify the value of the variable by using one of the mathematical operators so that the variable exceeds its range limit.
- try to use various operators
- Hint: the value of overflow will be out of range

```
unsigned short int small, overflow;  
small = 65535; // allowed range 0 to 65535  
overflow = small+100;
```

Functions in C++

- Theoretically all the code could be written inside a single main() function ...
- However, for maintainability and manageability reasons, it is better to break it into smaller procedures. These are called functions.
- Implementing a C++ function involves the following elements:
 - Function definition
 - Consists of header and body
 - Body is the source code that makes up the function
 - Header specifies return value, name and parameter list
 - Function prototype
 - Functions must be declared before they are called
 - Prototypes usually specified in header files that are called via the #include statement
 - Function call
 - The statement that executes a function is called a function call
 - Function calls can be specified any time
 - Can be used in assignments
- later topics: pass by reference or pointers

```
int sumup(int x)
{
    int sum, y = 5;
    sum = x + y;
    return sum;
}
```

```
int sumup(int );
```

```
int bignumber, inputnumber;
inputnumber = 12;
bignumber = sumup ( inputnumber );
```

Functions

Exercise 5: In this exercise, you're required to create a user-defined function to capture the program logic of the main program and call that function from main(). Rewrite the following simple code:

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

int main()
{
    int first, second, larger;
    cout<<"enter the first number:" << endl;
    cin>>first;
    cout<<"enter the second number:" << endl ;
    cin>>second;

    // The program logic that can be turned into a function
    larger = second;

    if (first > second){
        larger= first;
    }
    // Printing the result
    cout << "The larger number is " << larger << endl ;
}
```

Functions and scope of variables

Exercise 6: The program below will not compile because of scope errors. Investigate which variables are used out-of-scope and comment out the corresponding lines.

```
#include <iostream>
using namespace std;
int globalScope = 0; //This is a global variable, visible everywhere.

void foo() {
    int fooScope = 1; //Only visible within foo function
    cout << "fooScope: " << fooScope << endl;
    cout << "localScope: " << localScope << endl;
}
int main() {
    cout << "globalScope: " << globalScope << endl;

    { //Any block declares a scope, even this useless one
        int localScope = 3;
        cout << "localScope: " << localScope << endl;
        foo();
        cout << "fooScope: " << fooScope << endl;
        int globalScope = 100; // variable hiding, very bad practice!
        cout << "globalScope: " << globalScope << endl;
    }
    cout << "localScope: " << localScope << endl;
    cout << "globalScope: " << globalScope << endl;
}
```

Further reading

- In case you quickly need a C++ environment to test some simple code:
 - <http://coliru.stacked-crooked.com/>
 - <http://ideone.com/>
- Standard C++ Foundation:
 - <https://isocpp.org>
- About number representation:
 - http://www.cprogramming.com/tutorial/floating_point/understanding_floating_point_representation.html

Homework

- See the training portal