

Session 1

Introduction to C++

Overview

This module: more programming, in C++

C++ has evolved over three decades, but is still widely used.

Assuming that you are currently a reasonably skillful Java programmer, by the end of this course you should be able to

- read and modify substantial well-written C++ programs
- create classes and small programs in C++ that are correct, robust, clear and reusable
- use the standard libraries effectively

The language is much too large to cover in one term, so we shall focus on the most useful features for writing application code.

This session: Getting started with C++

This session introduces the philosophy of C++, and some simple non-OO programs.

We will touch on the following features of C++:

- Program structure
- Standard libraries: I/O and strings
- Operator overloading
- Class types

All will be explored in greater detail later.

Language history

Language history: Algol 60

Introduced block structure and static typing.

```

procedure Transpose(a) Order:(n);
    value n; array a; integer n;
begin
    real tmp; integer i, j;
    for i := 1 step 1 until n do
        for j := i+1 step 1 until n do
            begin
                tmp := a[i,j];
                a[i,j] := a[j,i];
                a[j,i] := tmp
            end
        end
    end

```

Simula 67

Algol plus classes, inheritance, dynamic allocation (for simulation)

```

class point(x, y); real x, y;
begin
    real r; theta;
    ref(point) procedure rotated(p, n) ..... ;
    boolean procedure equals(p) ..... ;
    real procedure distance(p) ..... ;
    r := sqrt(x^2 + y^2);
    theta := arctan(x, y);
end;

```

```

ref(point) origin, r, s;
origin := new point(0, 0);
r := new point(3, 4);
s := r.rotated(origin, 90);

```

C (1970)

- A small, statically typed language, with low-level features.
- Designed for the Unix operating system.

```

/* return <0 if s<t, 0 if s==t, >0 if s>t */
int strcmp(char *s, char *t) {
    for ( ; *s == *t; s++, t++)
        if (*s == '\0')
            return 0;
    return *s - *t;
}

```

Smalltalk (1972)

Object-orientation (for graphical interfaces), dynamically typed

```
Object subclass: 'Team'  
    instanceVariables: 'members'  
  
members  
    ^members  
  
addMember: aPerson  
    members add: aPerson  
  
removeMember: aPerson  
    members remove: aPerson  
  
init  
    members := OrderedCollection new.
```

C++ and its relatives

1984 Objective-C: C with Smalltalk-style message passing

1985 C++: C plus object-oriented features

1990 *The Annotated C++ Reference Manual*: namespaces, templates, exceptions

1995 Java: C++ greatly simplified (Sun)

1998 C++-98 (ISO standard): standard template library

2000 C#: another simplified C++ (Microsoft)

2011 C++11: many new features (revised in 2014, 2017 and 2020)

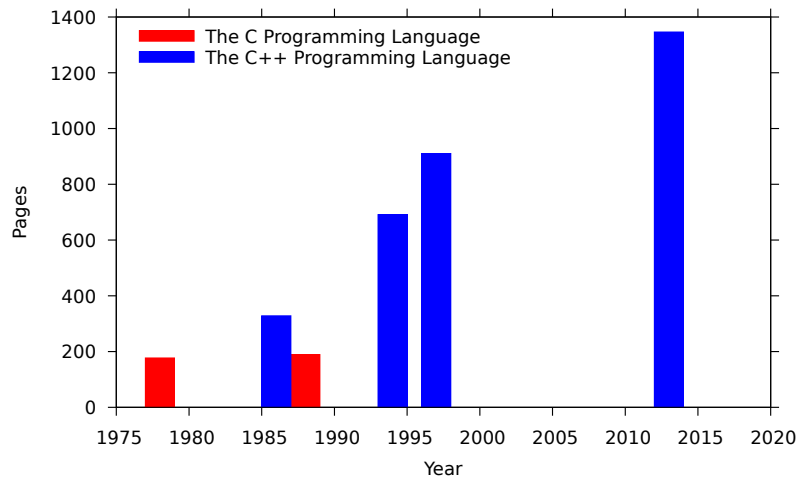
2011 Swift: simplified and safer Objective-C (Apple)

2011 Kotlin: more concise Java

2015 Rust: clever type system combining safety and performance

C++ has grown over the years

Length of descriptive books by language designers:



Philosophy

Java design criteria

- object orientation
- (moderate) simplicity (fewer variant ways of doing things)
- robustness and security (type-safe, automatic memory allocation)
- architecture-neutral (fairly high level)
- precisely specified, e.g. `int` is always 32 bits
- syntax based on C++

C++ design criteria

- support a variety of programming styles, including object oriented (give the programmer more choices)
- favour conciseness over simplicity, e.g. extensive use of overloading and implicit conversions
- powerful (give the programmer more control)
- enable efficient implementation (shift some implementation concerns to the programmer)
- implementation-dependent specification, e.g. `int` is machine word size
- extension of C (machine-level access)

C++ as a composite language

C++ is a very large language, with many layers that have accumulated over time.

In his book *Effective C++*, Scott Meyers suggests thinking of C++ as a “federation of related languages” with different programming styles:

C a low-level language with built-in data types and control structures. Often C features coexist with newer, cleaner versions.

Object-Oriented C++ classes, inheritance, dynamic binding, etc. (But unlike in Java, one can often avoid these.)

Template C++ classes and functions can be parameterized by types.

The Standard Template Library a library of containers, iterators and algorithms using template classes, but not inheritance.

For the first five weeks, we shall focus on the first and last of these, and introduce the second later.

Basic program structure**A small C++ program**

```
#include <iostream>

int main() {
    std::cout << "Hello world!\n";
    return 0;
}
```

- A typical program will begin with several **#include** lines, referencing *system headers* like **<iostream>**, which contain collections of related definitions (in this case for I/O streams).
- This **#include** line brings into scope several names, including **std::cout**, the standard output stream. Here **std** is the standard *namespace*, which is attached to all names defined in the standard libraries, e.g. **std::string**, **std::vector**, etc.

Using the standard namespace

We can avoid putting **std::** in front of every standard name by placing a single **using** declaration at the top, after the **#include** lines:

```
#include <iostream>

using namespace std;

int main() {
    cout << "Hello world!\n";
    return 0;
}
```

(Some style guides prefer to put **std::** everywhere.)

We won't be using any namespaces other than **std**.

Functions

In C++ (as in C but not in Java), one can define functions independent of any class:

```
int square(int n) {  
    return n*n;  
}
```

A function called **main** is used as the entry point of the program:

```
int main() {  
    // whatever you like here  
    return 0;  
}
```

The return value is reported to the system when the program exits: 0 means success; anything else means something went wrong.

Similarities with Java

Many things in the C part of C++ are much the same as in Java:

- primitive types **int**, **double**, etc
- declarations, expressions, comments
- semicolons to end statements and braces for grouping
- **if**, **for**, **while**, **return**.

For example, this means the same in both languages:

```
int factorial(int n) {  
    int prod = 1;  
    for (int i = 1; i <= n; ++i)  
        prod = prod * i;  
    return prod;  
}
```

(but in Java this must be a method inside a class)

Input and output

Text output

This statement writes a string to the standard output (the console):

```
cout << "Hello world!\n";
```

(like `System.out.println("Hello world!");` in Java)

- The `<iostream>` header defines three standard streams:

std::cin standard input (cf. Java's `System.in`)

std::cout standard output (cf. Java's `System.out`)

std::cerr error output (cf. Java's `System.err`)

- The `<<` operator, when applied to an output stream and a string, writes the string to the stream.
- When applied to integers, it performs a left shift (as in Java): the `<<` operator is *overloaded*.

Outputting several things

```
#include <iostream>

using namespace std;

int main() {
    int i = 3;
    cout << "The value is " << i << '\n';
    return 0;
}
```

The `<<` operator associates to the left, and returns the stream, so the above line is equivalent to

```
((cout << "The value is ") << i) << '\n';
```

It is also overloaded for `int` and `char`.

Ending output lines with `endl`

Some authors use `endl` instead of `'\n'`:

```
#include <iostream>

using namespace std;

int main() {
    cout << "Hello world!" << endl;
    return 0;
}
```

but this is slightly different. The `endl` manipulator outputs `'\n'` and then flushes the output, so the output line is equivalent to

```
cout << "Hello world!" << '\n' << flush;
```

But frequent flushing may be costly.

Text input

```
#include <iostream>

using namespace std;

int main() {
    int i;
```

```
    cout << "Type a number: ";
    cin >> i;
    cout << i << " times 3 is " << (i*3) << '\n';
    return 0;
}
```

The >> operator reads from an input stream. It is overloaded in a similar way to the << operator.

Strings

Using strings

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

using namespace std;

int main() {
    cout << "Please enter your first name: ";
    string name;
    cin >> name;

    cout << "Hello, " << name << "!\n";
    cout << "Your name has " << name.size() << " letters.\n";
    return 0;
}
```

Strings details

```
#include <string>
```

includes a standard header defining a type **std::string**.

```
    string name;
```

declares a variable **name** of type **string** and initializes it to an empty string (*different from Java*).

```
    cin >> name;
```

reads one word from standard input into **name**.

```
    cout << name.size();
```

A **string** is an *object*, with a *member function* (method in Java terms) **size()** that returns a number, the length of the string.

Properties of types

- Like Java, C++ has primitive types, like **int** and **double**, and also class types, like **string**.

- In Java, a variable of class type holds a reference to an object, which has to be created with `new`.
- In C++, a variable of class type holds an *object*, which is initialized in some default way if you don't give an initial value.

```
string name; // initialized as empty
string another = "Fred";
string name = another; // copies the string
```

- In contrast, local variables of primitive types are *not* initialized to default values.

Summary

Much of basic C++ is similar to Java, but we've already noticed some differences:

- Different syntax for accessing libraries (`#include` and namespaces)
- Functions can be defined independent of classes.
- More extensive use of overloading
- ***Variables of class type contain objects, not references.*** (We'll explore the consequences of this over the following weeks.)

Next week, we'll look at using sequential containers (**vector**, **list**, **deque**, etc).

Exercises

1. Write a program that requests the user's age, reads the age they provide and then prints out:

X is too young.

if the supplied age is less than 18,

X is too old.

if the supplied age is greater than 30, and

X is the right age.

otherwise, where in each case X is replaced by the supplied age.

2. Write a program that requests the user's name, reads the string they provide and then prints out:

Hello, XXXXXX!
=====

where XXXXXX is replaced by the name provided by the user.

Note: The number of equal signs in the bottom line should adjusted to account for the length of the name provided.

3. The program below is a simple guessing game:

```
#include <iostream>
#include <cstdlib>
#include <ctime>

using namespace std;

int main() {
    srand(time(nullptr));
    int n = 10;
    int secret = rand() % n + 1;
    cout << "Guess a number between 1 and " << n << ": ";
    int guess;
    cin >> guess;
    while (guess != secret) {
        cout << "Wrong! Guess again: ";
        cin >> guess;
    }
    cout << "Correct!\n";
    return 0;
}
```

Some explanations:

- The expression `srand(time(nullptr))` initializes the system's pseudo-random number generator.
- The expression `rand() % n + 1` generates a random number between 1 and `n` (here set to 10).
- The system headers `<cstdlib>` and `<ctime>` make available the functions used in these expressions. (The initial `c` hints that they are borrowed from C.)

Starting with this program:

- (a) Run the program, and make sure you understand it.
- (b) Modify the program so that instead of merely saying that a guess is wrong, it indicates whether the guess was too high or too low.
- (c) Count the number of guesses made, and report them when the user finally succeeds in guessing the secret number.
- (d) Change `n` to something larger, since this version allows the user to guess the secret number more quickly.