C++11 — What can we already use from the latest standard?

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What is C++11?

Language enhancements

Library enhancements

References



What is C++11?

- There is a C++ standards committee.
- ► The first C++ standard was accepted in 1998: C++98.
- ► An updated standard was accepted in 2003: C++03.
- Proposals for language extensions in 2005: TR1.
- ▶ New standard was finished in 2011: C++11

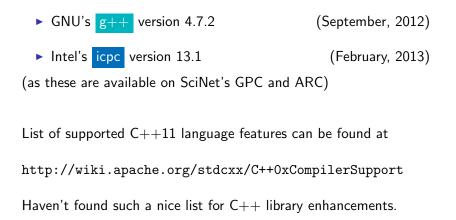
Some C++11 features already existed as compiler-specific extentions, but no compiler is fully C++11 compliant yet.

Aim of this talk:

Show some of the most commonly implemented C++11 features. (will assume reasonable C++03 knowledge)

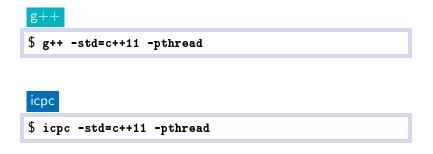


Tested C++11 compilers





How to compile



Not tested here, but for your information, the IBM compilers have a c++11 flags too:

\$ xlc++ -qlanglvl=extended0x

xlc++ not tested much because in aix it lacks many new libraries, and in linux is harder to make work with newer gcc's.



Language enhancements

- ▶ With the C++11 standard, core C++ has changed substantially
- Different pieces of the language fit together better
- Many new features.

We will look at the language extensions first, and consider the library extensions after.



Language enhancements

In particular let's consider:

- Helpful language extensions
- Static asserts
- Range-based for
- Initialization
- Move semantics
- Lambda expressions



Helpful language extensions

auto Placeholder for a type that can be deduced:

```
auto i = 4; //same as "int i = 4"
auto d = 0.4; //same as "double d = 0.4"
auto p = std::make_pair(i,d);
//std::pair<int,double> p = std::make_pair(i,d);
```

decltype Type of a given expression:

```
decltype(std::make_pair(i,d)) p;
p = std::make_pair(i,d);
```

Useful with new function declaration syntax for deduced return types:

```
template <class A, class B>
auto add(const A&a, const B&b) -> decltype(a+b)
{
    return a+b;
}
```



Helpful language extensions

extern template Allows templates to be instantiated in only one translational unit, not in every unit that uses it.

```
template <typename T> class C {
    ...
};
template class C<int>; //explicit instantiation
```

```
elsewhere
```

```
template <typename T> class C {
    ...
};
extern template class C<int>;//no instantiation
```

long long Finally in the standard: at least 64bit.
 standard still ambiguous about the #bits in int s,
 but in <cstdint> there now are int8_t int16_t,
 int32_t, int64_t, uint8_t,
nullptr always a pointer, unlike 0, which is an int first.

Helpful language extensions

Right Angle Brackets So we can just write

std::vector<std::pair<int,double>> p;

OOP stuff: Delegating Constructors, Defaulted And Deleted Functions, override and final



With **assert** we can test for conditions at runtime.

static_assert does the same but at compile time.

```
static_assert(4!=5, "four is not five");
```

If the condition is not fulfilled, the compiler will throw an error and print the message give to **static_assert**



Range-based for loops

For containers, the standard loop is using iterators:

```
std::vector v(10);
for (std::vector::iterator i = v.begin();
    i != v.end();
    i++)
    //something with *i
```

Now we can do:

```
std::vector v(10);
for (auto i: v)
    // something with i
```

This passes a copy by default, so modifying i does not change v. To be able to do that, get a reference:

```
std::vector v(10);
for (auto & i: v)
    // something with i
```

- Not for dynamic arrays.
- Does not cooperate with openmp.



Initialization

- ▶ C++03 has various ways to initialize (arrays of) objects.
- Inherited from C:

```
int i = 7;
float f[3] = {0.1,0.2,0.3};
struct R {
    int i;
    std::string s;
}
R r = {5,"Bill"};
```

Using constructor:

```
struct R {
    int i;
    std::string s;
    R(int ii,const std::string &ss):i(ii),s(ss){}
}
R r(5,"Bill");
```

Explicit assignment, e.g. std::vector and new ed arrays. SciNet

C++11 make this more uniform.

Initialization

- Uniform initialization using curly brackets {}
- Constructor or struct can both use

```
R r {5, "Bill"};
```

Curly brackets call the appropriate constructor if it exists.

Can use with new too:

 $R* r = new R\{5, "Bill"\};$

Can use for arrays too:

R* r = new R[3] {{1,"Bill"},{2,"John"},{3,"Jane"}};

And for containers:

std::vector<R> r {{1,"Bill"},{2,"John"},{3,"Jane"}};

(not supported by icpc)



Initializer lists

```
Consider this last case again:
```

```
std::vector<R> r {{1,"Bill"},{2,"John"},{3,"Jane"}};
```

Which constructor would this call?

In fact, this construction uses a new type of list: initializer list:

- Classes need a constructor that expects an initializer list for this to work. All STL containers should have this.
- If they do, these constructors will be called preferably over others when using curly brackets.
- Need to use the old () constructors if that's not wanted, e.g.

```
std::vector<int > r(9);
```

gives a vector of 9 elements, wheras

```
std::vector<int > r{9};
```

gives a vector with 1 elements, whose value is 9.



▶ In C++03, assigning a temporary object to a named object:

```
class C;
C get_a_C() {
    return C(1,0);
}
C c;
c = get_a_C();
```

means a copy of the temporary has to be made.

- But what we really want is for that temporary to become the named object.
- In other words, we want to move the temporary into the variable c.
- This would be different from copying, because any memory in the object to be moved would not need to be reallocated, moved and freed.



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- Logically can only move things that are temporary, or "rvalues".
- rvalues are expressions that can only occur at the right hand side of an assignment (barring technicalities).
- ► C++11 can handle references to rvalues. The reference to an rvalue of type T is denoted by T&&.
- By defining a constructor and an assignment operator that take an rvalue reference (in addition to the usual ones), a class can implement move semantics.
- These should put the internal state of rhs into the lhs and modify the rhs to become 'deletable' without side effects for the lhs (ie., set all pointers to nullptr).
- Most STL classes should now be doing this.



Example

```
struct X {
  int * x;
  X(): x{nullptr} \}
  "X() { delete x; }
  X(int i): x\{new int \{i\}\} \}
  X(const X&o): x{new int {*o.x}} {}
  X(X\&\&o): x{o.x} \{ o.x = nullptr; \}
   X& operator= (const X&o) {
     if (this != &o)
        x = new int \{*o.x\};
     return *this;
  }
  X& operator= (X&&o) {
     if (this != &o) {
        x = new int \{*o.x\};
        o.x = nullptr;
     }
     return *this;
};
```



Example

```
X get_an_X() {
   return {7};
}
int main() {
   X a(5);
   X b(std::move(a));
   X c;
   c = std::move(b);
   X d;
   d = get_an_x();
}
```



Lambda expressions

- Sometimes you suddenly need a part of your code to become function.
- Example:

```
auto a = new double [5] {2.0,1.1,1.2,1.3,1.4};
double sum {0.0};
for (double * iter=a; iter!=a+5; iter++)
    sum += *iter;
```

To:

```
auto a = new double [5] {2.0,1.1,1.2,1.3,1.4};
double sum {0.0};
std::for_each(a,a+5, ????);
```

(std::for_each is in <algorithm>)

- > ???? should be a function to be called for each.
- Lambda's are functions defined on the spot.



Lambda expressions

```
General strucure:
[capture](arguments) -> return-type
{
    body
}
```

- Like a new style function without a name and without a return type.
- If return type is omited, it is actually deduced from the body's return statement.
- The capture is a list of variables that should be shared with the function's body. These do not have to be global variables!
- So our code can become:

```
auto a = new double [5] {2.0,1.1,1.2,1.3,1.4};
double sum {0.0};
for_each(a,a+5, [&sum](double x){ sum+=x; });
```

Note the ampersand in the capture.



- ► A lot of functionality has been added to C++11 in the form of standard libraries. This includes stuff that was in TR1.
- Many new features as well. Will pick a few.
- Intel compiler depends on underlying g++ for many of these. Need both g++ 4.7.2 and icpc 13.1 for some of this to work.



Library enhancements

In particular let's consider:

- Smart pointers
- Random numbers
- Timing routines
- Threading



Smart pointers

- Smart pointers help avoid memory issues like
 - 1. Not deallocating **new**-ed memory because **delete** is missing.
 - 2. Not deallocating **new**-ed memory because of an exception.
 - 3. Passing a pointer to a class that may use it after its lifetime.
 - 4. Or that may try to delete it.
- Three useful types:
 - 1. std::unique_ptr

A pointer wrapper that will deallocate the memory associated with the pointer when it goes out of scope. Cannot be copied. Can use * and ->.

2. std::shared_ptr

A pointer wrapper that will deallocate the memory associated when there are no more reference to it. Internally increases a reference counter when copied.

3. std::weak_ptr

Like **std::shared_ptr** but without increasing the reference count. Sometimes useful, but rare.

4. std::auto_ptr

Deprecated.

In the header file <memory>.



Random numbers

- The header file <random> has random number generators
- Unlike previous compiler RNGs, these are actually good.
- They're extensible too.
- The random library separates the random number generator from the distribution that numbers are to be drawn from.

```
#include <random>
#include <functional>
int main()
{
   std::uniform_int_distribution<int> distribution(0,99);
   std::mt19937 engine; // Mersenne twister MT19937
   auto generator = std::bind(distribution, engine);
   engine.seed(13);
   int random1 = generator();
   int random2 = distribution(engine);
}
```

Timing routines

- ► The header file <chrono> has standard timing routines.
- Comes with a large number of templates to describe time units, durations, etc.

Example

```
#include <chrono>
int main()
{
  using namespace std::chrono;
   for (int i = 0; i < 10; i++) {</pre>
      auto tick = steady_clock::now();
      // do something
      auto tock =steady_clock::now();
      float time = duration<float>(tock-tick).count();
      std::cout << time << "s" << std::endl:</pre>
   }
```

Multi-threading

- Threads are part of the standard i.e. not an added on library.
- Atomic data type in the standard.
- The header file <thread> implements the thread class.
- The header file <future> implements asynchronous stuff and references to not-yet computed values.
- Very reminiscent of pthreads, but much easier to program for simple cases, while maintaining flexability.
- Too large a subject to properly explain here, let's look at some examples.



Multi-threading example 1

```
#include <iostream>
#include <thread>
void threadfunction() {
   std::cout << "Hello from thread!\n";
}
int main() {
   std::thread th(&threadfunction);
   std::cout << "Hello world!\n";
   th.join();
   return 0;
}</pre>
```



Multi-threading example 2

```
#include <iostream>
#include <vector>
#include <thread>
int main()
{
   std::vector<int> a {1,2,3};
   std::cout << "a.size() = " << a.size() << std::endl;</pre>
   std::thread th1([]() {
      std::cout << "Hello from thread!" << std::endl;</pre>
   });
   std::thread th2(&std::vector<int>::clear,std::ref(a));
   std::cout << "a.size() = " << a.size() << std::endl;</pre>
   std::cout << "Hello world!" << std::endl;</pre>
   th1.join();
  th2.join();
   std::cout << "a.size() = " << a.size() << std::endl;</pre>
  return 0;
}
```

Note: for icpc, this lambda in a thread only works when wrapped in a **std::function<void(void)>**.



References

http://wiki.apache.org/stdcxx/C++0xCompilerSupport
http://www.cplusplus.com/reference
http://en.cppreference.com/w/

