

UNIX and C Programming (COMP1000)

Lecture 10: C++

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Department of Computing
Curtin University

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Textbook Reading (Hanly and Koffman)

For more information, see the weekly reading list on Blackboard.

- ▶ **Chapter 15: On to C++**
- ▶ C++ is introduced very briefly by Hanly and Koffman.
- ▶ For more information, look for a dedicated C++ book.
 - ▶ e.g. *Thinking in C++*, by Bruce Eckel (freely available).

Outline

C++ Overview

Scope

Classes

Inheritance

Input and Output

Pointers

Templates

Overloading

C++ Overview

- ▶ This lecture will briefly introduce C++ from a Java(ish) perspective.
- ▶ However, C++ is much older than Java.
- ▶ C and C++ co-evolved.
- ▶ C++ is much more complex than C.

Commonalities with C

- ▶ C++ uses header files in the same way as C.
- ▶ C++ uses the C preprocessor (`#include`, etc.).
- ▶ C++ has the same primitive data types as C (`int`, `float`, etc., but also has a `"bool"` data type).
- ▶ C++ has the same basic control structures as C (`if`, `switch`, `for`, `while` and `do-while`).
- ▶ The `main()` function works the same way in C++ as in C.
- ▶ Like C, C++ lacks garbage collection.

Major Differences with C

- ▶ C++ has classes, with inheritance and polymorphism.
- ▶ C++ uses `"new"` and `"delete"` instead of `"malloc()"` and `"free()"`
- ▶ C++ has namespaces and a different set of libraries.
- ▶ C++ has exception handling (`try-catch`).
- ▶ C++ has operator overloading (which can radically alter the language!)

Filename Extensions

- ▶ The typical filename extensions are:
 - ▶ `".cpp"` for a C++ source file.
 - ▶ `".hpp"` for a C++ header file.
- ▶ The standard C++ header files *don't have extensions*:

```
#include <iostream>
```

Compiling

- ▶ Gcc can compile C++ as well as C:

```
[user@pc]$ gcc -c file1.cpp
```

```
[user@pc]$ gcc -c file2.cpp
```

```
[user@pc]$ gcc file1.o file2.o -o prog -lstdc++
```

- ▶ The `".cpp"` extension tells gcc that it's dealing with C++ code.
- ▶ Other normal gcc options are supported as usual.
- ▶ `"-lstdc++"` tells gcc to link against the C++ library
- ▶ Alternatively, you can use `"g++"`:

```
[user@pc]$ g++ file1.o file2.o -o prog
```

- ▶ Makefiles are used for C++, just as for C.

Namespaces

- ▶ A “namespace” is similar to a “package” in Java.
- ▶ Standard C++ functions and classes are generally in “std”.
- ▶ Thus, you often have this right after your “#include”s:

```
using namespace std;
```

- ▶ Without this, you would have to prepend “std::” to a lot of things.

Scope Resolution Operator — “::”

- ▶ The “::” operator is used to refer to something inside a namespace or class (but not an object!)
- ▶ For instance, to call a **static** method:

```
c = ClassName::methodName(a, b);
```

- ▶ Also (if you don't have “using namespace std;”):

```
std::string str = "Hello world";
```

- ▶ However, to call a **non-static** method:

```
obj.methodName();  
ptr->methodName();
```

- ▶ “.” and “->” mean the same thing as in C.
- ▶ You may (or may not) have a pointer to the object.

Classes

- ▶ Classes in C++ are an extension to structs in C.
- ▶ They have methods (a.k.a. “member functions”).
- ▶ They have public, private and protected fields and member functions.
- ▶ Conventionally:
 - ▶ The class and its members are *declared* in a header file.
 - ▶ Each member function is *defined* in the main source file.

Class Syntax

This would appear in “person.hpp”:

```
class Person {  
    public:  
        Person();           // Constructor  
        Person(string inName, int inAge);  
        ~Person();          // Destructor  
  
        int getAge() const;  // Accessor  
        void setAge(int inAge); // Mutator  
        ... // Other methods  
  
    private:  
        string name; // Private fields  
        int age;  
};
```

Member Function Definitions

This would appear in “person.cpp”:

```
Person::Person(string inName, int inAge) {
    name = inName;
    age = inAge;
}

int Person::getAge() const {
    return age;
}

... // Other methods
```

- ▶ Note the use of “Person::” before each member.
- ▶ Note the “const” after getAge() — this means the method does not modify the object.

Creating and Destroying Objects

- ▶ In C++, the “new” keyword replaces malloc():

```
Person* p;
p = new Person("Ralph", 7);
```

- ▶ Allocates memory for a Person object.
 - ▶ Calls the constructor to initialise it.
- ▶ We can then manipulate the object as follows:

```
int a = p->getAge();
p->setAge(a + 1);
```

- ▶ Also, “delete” replaces free():

```
delete p;
```

- ▶ Calls the *destructor* to clean up.
 - ▶ De-allocates the memory.

Creating and Destroying Arrays

- ▶ The “new” keyword can also allocate arrays:

```
int* array;
array = new int[100];
```

- ▶ Such arrays must eventually be de-allocated with “delete[]” (not “delete”):

```
delete[] array;
```

Stack-Based Objects

We can also allocate objects on the stack:

```
void func() {
    Person p("Ralph", 7); // Constructs p
    ...
    int age = p.getAge();
    p.setAge(age + 1);
    ...
}
```

- ▶ Declares a Person object on the stack (without “new”).
- ▶ The constructor is called immediately.
- ▶ The destructor is called *automatically* at the end of the function.
- ▶ You use “.” to access fields and methods (no dereferencing).
- ▶ You can’t do this in Java!

Destructors

- ▶ A destructor is the inverse of a constructor.
- ▶ With no garbage collection, C++ relies on destructors to clean up.
- ▶ There is only one destructor per class.
- ▶ It takes no parameters and returns nothing.
- ▶ Its role is to free resources (particularly memory) used by the object, before the object itself is removed from memory.

Static Methods

- ▶ C++ supports static fields and methods.
- ▶ A static field/method is shared by all instances of the class.
- ▶ This is same meaning as in Java (*not* C!)
- ▶ For example:

```
class Person {
    public:
        ...
        static void staticFunc(int param);
        ...
};
...
Person::staticFunc(10);
```

Member Access Operators

- ▶ C++ has 3 operators for accessing members of objects, classes and namespaces: “.”, “->” and “::”.
- ▶ You need each one in different circumstances:

Operator	Example	Used when...
.	obj.method()	obj is an object.
->	ptr->method()	ptr is a pointer to an object.
::	cls::method()	cls is a class or namespace.

A Note on Java

- ▶ Java has no equivalent to the “.” operator in C/C++ (because you can’t have an object without a reference).
- ▶ Confusingly, Java uses the symbol “.” to replace “->” and “::”.

The this Pointer

- ▶ As in Java, “this” is a pointer to the current object.
- ▶ Can be used to distinguish between fields and local variables or parameters.
- ▶ We could write our Person constructor as follows:

```
Person::Person(string name, int age) {
    this->name = name;
    this->age = age;
}
```

Inheritance

Classes can inherit/extend other classes, as follows:

```
class Employee : public Person {
public:
    Employee();
    Employee(string name, int age, int salary);
    ~Employee();
    ...
};
```

However:

- ▶ Classes don't have to inherit from anything (unlike in Java).
- ▶ C++ supports multiple inheritance (use sparingly, if at all):

```
class SubClass : public SuperClassA,
                public SuperClassB {
    ...
};
```

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Virtual Methods

In C++, you can't override a method unless it's "virtual":

```
class Person {
    ...
    virtual bool equals(Person* p) const;
    ...
};

class Employee : public Person {
    ...
    virtual bool equals(Employee* e) const;
    ...
};
```

- ▶ `Employee::equals()` overrides `Person::equals()`.
- ▶ In Java, *all* methods are implicitly virtual.

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Calling a Superclass Method

We need to call `Person::equals()` *inside* `Employee::equals()`

- ▶ In Java, we would do this:

```
if(super.equals(var) && ...) {           // Java
    Java keyword
```

- ▶ However, C++ has no "super" keyword.
- ▶ Instead, you refer to the superclass's name:

```
if(Person::equals(var) && ...) {         // C++
    superclass name
```

(This looks like a static method call, but C++ is smart enough to know otherwise.)

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Calling a Superclass Constructor

- ▶ We also need to call `Person`'s constructor from within `Employee`'s constructor.
- ▶ C++ has a different syntax for this:

```
Employee::Employee(string inName, int inAge,
    int inSalary) : Person(inName, inAge)
{
    salary = inSalary;
}
```

- ▶ The super-constructor call is highlighted.
- ▶ `Person`'s constructor is called like a function, but *before* the first brace (and after a colon).

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Pure Virtual (Abstract) Methods

- ▶ A virtual function is “pure” if it has no definition.
- ▶ A “pure” virtual function *must* be overridden.
- ▶ This is equivalent to an abstract method in Java (but there’s no “abstract” keyword).
- ▶ An abstract class is any class containing a pure virtual function.

```
class Person { // Abstract class
    ...
    virtual float calcTax() = 0; // Pure virtual
    ...
};
```

Input and Output

C++ has a radically different syntax for I/O operations:

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

int main() {
    int num1, num2;

    cout << "Enter two integers: ";
    cin >> num1 >> num2;

    cout << "Sum: " << (num1 + num2) << endl;
    return 0;
}
```

- ▶ cin and cout are objects defined in the standard “iostream” library.

Reading and Writing Files

- ▶ The fstream library defines classes for reading and writing files.
 - ▶ ifstream — an input file stream.
 - ▶ ofstream — an output file stream.
- ▶ The constructor of ifstream/ofstream opens a given file.
- ▶ The destructor closes it.
- ▶ Read using the » operator (like cin).
- ▶ Write using the « operator (like cout).

Writing Files — Example

Write the integers 1–100 to file.txt:

```
#include <fstream>

int main() {
    ofstream* file = new ofstream("file.txt");

    for(int i = 0; i < 100; i++) {
        *file << i << endl;
    }

    delete file;
    return 0;
}
```

Writing Files — Alternative Example

Alternatively:

```
#include <fstream>

int main() {
    ofstream file("file.txt"); // Stack-based object

    for(int i = 0; i < 100; i++) {
        file << i << endl;
    }

    return 0;
}
```

- ▶ Now, file is an object on the stack — no pointers.
- ▶ The destructor is called automatically at the function's end.

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References

- ▶ A C++ “reference” is a pointer that is *automatically dereferenced*.
 - ▶ When used, C++ automatically puts a * in front of it.
- ▶ References are set once (when declared). You can't change where they point.

```
int x = 10;
int& y = x; // y is a reference to integer x.

y = 20;     // Sets x to 20.
```

- ▶ Here, y is a reference to x.
- ▶ The & in the declaration means “reference-to”, not “address-of”.
- ▶ But what's the point?

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Reference Parameters

- ▶ Functions (and methods) can take references as parameters:

```
void swap(int& a, int& b) {
    int temp = a;
    a = b;
    b = temp;
}

...
int x = 10, y = 20;
swap(x, y);
```

- ▶ Be careful here — it's not obvious that x and y are being passed by reference!

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Auto Pointers

- ▶ “Auto pointers” are another special type of pointer.
- ▶ *Only one* auto pointer can point to a given object!
 - ▶ If you try to copy the pointer, the original pointer will be wiped.
- ▶ Auto pointers are implemented by the class “auto_ptr”.

```
#include <memory>

...
auto_ptr<Employee> ptr(new Employee());
```

This declares an auto pointer called “ptr”, pointing to a new Employee object.

- ▶ When ptr disappears, the Employee object will be automatically deleted.

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More Smart Pointers

- ▶ Auto pointers are one example of “smart” pointers.
- ▶ Smart pointers are special objects that represent pointers and make them safer or more convenient.
- ▶ The Boost library (not quite part of C++) defines several different types.
- ▶ Some are designed for arrays.
- ▶ Some are designed to allow multiple pointers to a single object.
- ▶ Auto pointers have now been deprecated in standard C++ by “unique pointers”.

Templates

- ▶ Templates in C++ are similar to Java’s generics (but the underlying implementation is very different).
- ▶ Templates let you write generic code that can handle any data type.
- ▶ This is especially useful for containers.
- ▶ Much of the C++ API uses templates (e.g. auto pointers).
- ▶ Both template functions and template classes are possible.

Template Declarations

- ▶ A template (function/class) begins with this line:

```
template <class A, class B, class C>
```

- ▶ This is followed by a normal(ish) function or class definition.
- ▶ The first line provides the “template parameters”: A, B and C.
- ▶ These can be used within the function/class as ordinary data types.

Template Functions

A template function might look like this:

```
template<class T>
T square(T num) {
    return num * num;
}
```

Here, square() is a template function:

- ▶ When called with an `int`, it will return an `int`.
- ▶ When called with a `float`, it will return a `float`.
- ▶ For each data type you use, the compiler generates a separate copy of the function.
- ▶ When called with something that can’t be multiplied, the compiler will output an error.

Template Classes (1)

A template class might look like this:

```
template<class T>
class Secret {
public:
    Secret(T inObj, string inPassword);
    ~Secret();
    T getObj(string inPassword);

private:
    T obj;
    string password;
};
```

- ▶ The “Secret” template class stores an arbitrary piece of data.
- ▶ The class itself doesn’t care what the type is.

Template Classes (2)

We can instantiate the “Secret” template class as follows:

```
Secret<int> *s1 = new Secret<int>(5, "pass");
Secret<string> *s2 =
    new Secret<string>("spaceballs", "12345");

int a    = s1->getObj("pass");
string b = s2->getObj("12345");
```

- ▶ This creates two objects, pointed to by s1 and s2.
- ▶ It also creates two versions of the class — one for ints and one for strings.
- ▶ The getObj() method returns the appropriate type.

Templates vs. Generics

- ▶ C++’s templates and Java’s generics are not quite the same.
- ▶ Templates work by creating different copies for different types.
- ▶ Generics work by automatically inserting safe typecasts.
- ▶ They have similarities:
 - ▶ Both let you re-use code for different data types.
 - ▶ Both let you avoid gratuitous, unsafe typecasting.
- ▶ And differences:
 - ▶ Templates apply to *any* data type; generics apply only to objects.
 - ▶ Templates allow compile-time calculations (“metaprogramming”).

The Standard Template Library (STL)

- ▶ C++ provides a number of standard template classes.
- ▶ These implement most commonly-needed abstract data types: lists, sets, maps, stacks, queues, iterators, etc.
- ▶ For example, vector is a resizable list:

```
vector<int> vec;    // A vectors of ints

for(int i = 0; i < 10; i++) {
    vec.push_back(i);
}

for(int i = 0; i < 10; i++) {
    cout << vec[i] << endl;
}
```

Method/Function Overloading

- ▶ C++ allows for function and method overloading (like Java, but unlike C).
- ▶ Multiple functions/methods can have the same name, but different parameter lists.
- ▶ For example:

```
int readInt() {
    ...
}

int readInt(string prompt) {
    ...
}
```

The compiler will determine which method to call based on the parameters.

Default Arguments

- ▶ C++ lets you set “default” values for function parameters:

```
int readInt(string prompt = "Enter a value: ") {
    ...
}
```

You can call this function with or without a parameter:

```
int x = readInt();
int y = readInt("Enter y: ");
```

When no parameter is given, the default is used.

- ▶ You can do this for several parameters:

```
void func(int w, float x = 1.0, int y = 2) {...}
```

- ▶ Default arguments must come last in the parameter list.

Operator Overloading (1)

- ▶ In C++, it is possible to define different meanings for operators (+, *, ==, &&, ->, [], etc.).
- ▶ Instead of an equals() method for the Person class, we could define the == operator:

```
class Person {
public:
    ...
    bool operator==(const Person& other) const;
    ...
};
```

- ▶ Here, we effectively have a method with the name “operator==”.
- ▶ This will be called when you write “person1 == person2” (if person1 and person2 are both Person objects).

Operator Overloading (2)

- ▶ The applications of operator overloading are endless.
- ▶ It's how the « and » operators work with cin and cout.
- ▶ It's also heavily used by auto pointers and vectors.
- ▶ There are very few limits to what you can do.
- ▶ Use with care! (Gratuitous operator overloading makes your code **extremely unreadable**.)

Wrapping Up

- ▶ This has just been a taste of C++.
- ▶ There are still more features and many more nuances.
- ▶ There are also many other languages that follow in the footsteps of C.
- ▶ Some of these include: Objective C, Java, C#, D and Go.
- ▶ Sadly, this will not be in the exam!

That's all from UCP

- ▶ Hopefully you've understood most of it!
- ▶ Make sure you finish all the pracs.
- ▶ Good luck!