C and C++

5. C++ — Overloading — Namespaces — Classes

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C++

To quote Bjarne Stroustrup:

"C++ is a general-purpose programming language with a bias towards systems programming that:

- is a better C
- supports data abstraction
- supports object-oriented programming
- supports generic programming."

Alternatively: C++ is "an (almost upwards-compatible) extension of C with support for: classes and objects (including multiple inheritance), operator overloading, exceptions and templates".
[templates are a generalised form of generics]
Much is familiar from Java, but with many subtle differences.

C++ fundamental types

- C++ has all the fundamental types C has
  - character literals (e.g. `'a'`) are now of type `char`
- In addition, C++ defines a new fundamental type, `bool`
- A bool has two values: `true` and `false`
- When cast to an integer, `true`→`1` and `false`→`0`
- When casting from an integer, non-zero values become `true` and `false` otherwise

C++ enumeration

- Unlike C, C++ enumerations define a new type; for example
  `enum flag {is_keyword=1, is_static=2, is_extern=4, ... }`
- When defining storage for an instance of an enumeration, you use its name; for example: `flag f = is_keyword`
- Implicit type conversion is not allowed:
  `f = 5; //wrong` `f = flag(5); //right`
- The maximum valid value of an enumeration is the enumeration's largest value rounded up to the nearest larger binary power minus one
- The minimum valid value of an enumeration with no negative values is zero
- The minimum valid value of an enumeration with negative values is the nearest least negative binary power

References

- C++ supports references, which provide an alternative name for a variable
- Generally used for specifying parameters to functions and return values as well as overloaded operators (more later)
- A reference is declared with the `&` operator; for example:
  `int i[] = {1,2}; int &refi = i[0];`
- A reference must be initialised when it is defined
- A connection between a reference and what it refers to cannot be changed after initialisation; for example:
  `refi++; //increments value referenced`

References in function arguments

- When used as a function parameter, a referenced value is not copied; for example:
  `void inc(int& i) { i++;} //bad style?`
- Declare a reference as `const` when no modification takes place
- It can be noticeably more efficient to pass a large struct by reference
- Implicit type conversion into a temporary takes place for a `const` reference but results in an error otherwise; for example:

```
1 float fun1(float&);
2 float fun2(const float&);
3 void test() {
4   double v=3.141592654;
5   fun1(v); //Wrong
6   fun2(v);
7 }
```

- Cf. Fortran call-by-reference

Overloaded functions

- Functions doing different things should have different names
- It is possible (and sometimes sensible!) to define two functions with the same name
- Functions sharing a name must differ in argument types
- Type conversion is used to find the "best" match
- A best match may not always be possible:

```
1 void f(double);
2 void f(long);
3 void test() {
4   f(1L);  //f(long)
5   f(1.0); //f(double)
6   f(1);   //Wrong: f(long(1)) or f(double(1)) ?
```


Scoping and overloading

- Functions in different scopes are not overloaded; for example:

```
1 void f(int);
2
3 void example() {
4   void f(double);
5   f(1); //calls f(double);
6 }
```

Default function arguments

- A function can have default arguments; for example:
  `double log(double v, double base=10.0);`
- A non-default argument cannot come after a default; for example:
  `double log(double base=10.0, double v); //wrong`
- A declaration does not need to name the variable; for example:
  `double log(double v, double=10.0);`
- Be careful of the lexical interaction between * and =; for example:
  `void f(char*=0); //Wrong '*=' is assignment`

Namespaces

Related data can be grouped together in a namespace:

```
namespace Stack { //header file
void push(char);
char pop();
}
```

```
void f() { //usage
...
Stack::push('c');
...
}
```

```
namespace Stack { //implementation
const int max_size = 100;
char s[max_size];
int top = 0;

void push(char c) { ... }
char pop() { ... }
}
```


Using namespaces

- A namespace is a scope and expresses logical program structure
- It provides a way of collecting together related pieces of code
- A namespace without a name limits the scope of variables, functions and classes within it to the local execution unit
- The same namespace can be declared in several source files
- The global function `main()` cannot be inside a namespace
- The use of a variable or function name from a different namespace must be qualified with the appropriate namespace(s)
  - The keyword `using` allows this qualification to be stated once, thereby shortening names
  - Can also be used to generate a hybrid namespace
  - `typedef` can be used: `typedef Some::Thing thing;`
- A namespace can be defined more than once
  - Allows, for example, internal and external library definitions

Example

```
1  namespace Module1 {int x;}
2
3  namespace Module2 {
4    inline int sqr(const int& i) {return i*i;}
5    inline int halve(const int& i) {return i/2;}
6  }
7
8  using namespace Module1; //"import" everything
9
10 int main() {
11   using Module2::halve;  //"import" the halve function
12   x = halve(x);
13   sqr(x);                //Wrong
14 }
```


Linking C and C++ code

- The directive `extern "C"` specifies that the following declaration or definition should be linked as C, not C++ code:
  `extern "C" int f();`
- Multiple declarations and definitions can be grouped in curly brackets:

```
1 extern "C" {
2   int globalvar; //definition
3   int f();
4   void g(int);
5 }
```

- Why do we need this? E.g. 'Name munging' for overloaded functions.

Linking C and C++ code

- Care must be taken with pointers to functions and linkage:

```
1 extern "C" void qsort(void* p, \
2                 size_t nmemb, size_t size, \
3                 int (*compar)(const void*, const void*));
4
5 int compare(const void*,const void*);
6
7 char s[] = "some chars";
8 qsort(s,9,1,compare); //Wrong
```


User-defined types

- C++ provides a means of defining classes and instantiating objects
- Classes contain both data storage and functions which operate on storage
- Classes have access control:
  `private`, `protected` and `public`
- Classes are created with `class` or `struct` keywords
  - `struct` members default to `public` access; `class` to `private`
- A member function with the same name as a class is called a constructor
- A member function with the same name as the class, prefixed with a tilde (~), is called a destructor
- A constructor can be overloaded to provide multiple instantiation methods
- Can create `static` (i.e. per class) member variables

Example

```
1  class Complex {
2    double re,im;
3   public:
4    Complex(double r=0.0L, double i=0.0L);
5  };
6
7  Complex::Complex(double r,double i) {
8    re=r,im=i;  // deprecated initialisation-by-assignment
9  }
10
11 int main() {
12   Complex c(2.0), d(), e(1,5.0L);
13   return 0;
14 }
```

Constructors and destructors

- A default constructor is a function with no arguments (or only default arguments)
- If no constructor is specified, the compiler will generate one
- The programmer can specify one or more constructors
- Only one constructor is called when an object is created
- There can only be one destructor
  - This is called when a stack-allocated object goes out of scope or when a heap-allocated object is deallocated with `delete`; this also occurs for stack-allocated objects deallocated during exception handling (more later).
  - Stack-allocated objects with destructors are a useful way to release resources on scope exit (similar effect as Java try-finally) – "RAII: Resource Allocation is Initialisation".

Copy constructor

- A new class instance can defined by assignment; for example;
  `Complex c(1,2);`
  `Complex d = c;`
- In this case, the new class is initialised with copies of all the existing class' non-static member variables; no constructor is called
- This behaviour may not always be desirable (e.g. consider a class with a pointer as a member variable)
  - In which case, define an alternative copy constructor:
    `Complex::Complex(const Complex&) { ... }`
- If a copy constructor is not wanted, make the copy constructor a private member function, or in C++11 use `delete`.

Assignment operator

- By default a class is copied on assignment by over-writing all non-static member variables; for example:

```
1 Complex c(), d(1.0,2.3);
2 c = d; //assignment
```

- This behaviour may also not be desirable
- The assignment operator (`operator=`) can be defined explicitly:

```
1 Complex& Complex::operator=(const Complex& c) {
2   ...
3 }
```


Constant member functions

- Member functions can be declared `const`
- Prevents object members being modified by the function:

```
1 double Complex::real() const {
2   return re;
3 }
```

- Logically gives `const Complex *this` instead of `Complex *this`

Arrays and the free store

- An array of class objects can be defined if a class has a default constructor
- C++ has a `new` operator to place items on the heap:
  `Complex* c = new Complex(3.4);`
- Items on the heap exist until they are explicitly deleted:
  `delete c;`
- Since C++ (like C) doesn't distinguish between a pointer to a single object and a pointer to an the first element of an array of objects, array deletion needs different syntax:

```
1 Complex* c = new Complex[5];
2   ...
3 delete[] c; //Cannot use "delete" here
```

- When an object is deleted, the object destructor is invoked
- When an array is deleted, the object destructor is invoked on each element

Exercises

1. Write an implementation of a class `LinkList` which stores zero or more positive integers internally as a linked list on the heap. The class should provide appropriate constructors and destructors and a method `pop()` to remove items from the head of the list. The method `pop()` should return -1 if there are no remaining items. Your implementation should override the copy constructor and assignment operator to copy the linked-list structure between class instances. You might like to test your implementation with the following:

```
1 int main() {
2   int test[] = {1,2,3,4,5};
3   LinkList l1(test+1,4), l2(test,5);
4   LinkList l3=l2, l4;
5   l4=l1;
6   printf("%d %d %d\n",l1.pop(),l3.pop(),l4.pop());
7   return 0;
8 }
```

Hint: heap allocation & deallocation should occur exactly once!