Assorted Topics

ITP 435 – Spring 2016
Week 1, Lecture 2

Lecturer: Sanjay Madhav

Lab 1: RLE Compressor

- In class demonstration.

Unit Test

- Used to validate whether or not specific functionality works
- In theory, every feature should have a unit test that proves it functions correctly
- Many tools for this in C++…
  - Google Test
  - Boost Test Library
  - MiniCppUnit (Simple one to use)

Unit Testing Example

- WebKit HTML renderer

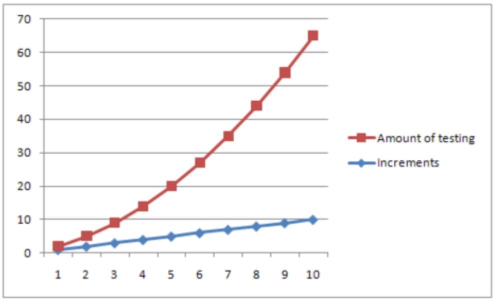
Safari

- The testing framework prints out the DOM (Document Object Model) and compares the actual output to the expected

- Thousands of unit tests (that take a few hours to run)

Regression

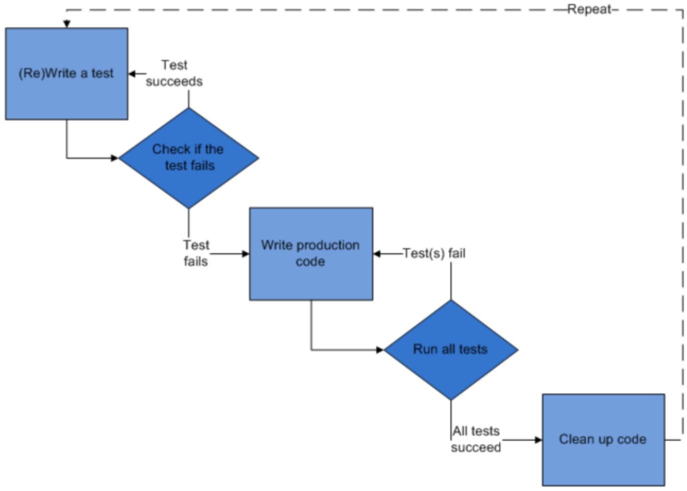
- A test that previously worked no longer works
- In a strict environment, unexpected regressions means the code cannot be committed



- Imperative that tests are automated for this to be efficient

Test-Driven Development

- Essentially means "write unit tests before writing the code"



Pointers (Review)

- A ***pointer*** is a type of variable that stores a memory address. Hopefully you remember this!
- Since memory addresses are binary numbers, from the perspective of the computer there really isn't much of a difference between an integer and a pointer
- However, when we use a pointer, we are telling C++ that we're using this number as a memory address

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More simply, sometimes people will say "pointers are integers" which is an accurate, though somewhat simplistic, way to look at it

Declaring a Pointer Example

```
int x = 0;
double y = 5.0;

int* z = &x;
```

	Memory	
Variable	**Address**	**Value**
x	0x04	0
y	0x08	5.0
z	0x10	??

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If we declare this pointer, what's "value" should be stored in it?

Declaring a Pointer Example

```
int x = 0;
double y = 5.0;

int* z = &x;
```

	Memory	
Variable	Address	Value
x	0x04	0
y	0x08	5.0
z	0x10	0x04

It’s 0x04, because we initialized it to the address of x, which is at 0x04.

Null Pointers

- Previously, null pointers were represented with 0 (or `NULL`, which is just a define as 0).
- This is not strongly typed...

```
void f1(int);
void f1(char *);

// 0 could mean int or it could mean a NULL pointer...
// Compiler always choose the “int” version.
f1(0);
```

- In C++11, there is a now a `nullptr` keyword, which is strongly typed

```
// nullptr is strongly-typed, so it calls the char* version
f1(nullptr);
```

Arrays and Pointers

```
int fib[] = {
   1,
   1,
   2,
   3,
   5,
};

int* ptr1 = &(fib[0]);
int* ptr2 = &(fib[4]);
```

	Memory	
Variable	Address	Value
fib[0]	0x10	1
fib[1]	0x14	1
fib[2]	0x18	2
fib[3]	0x1C	3
fib[4]	0x20	5
ptr1	0x24	0x10
ptr2	0x28	0x20

Pointer to a Pointer

```
double a = 10.0;

double* ptr1 = &a;
double* ptr2 = &a;

// ** because pointer to pointer!
double** ptrToPtr = &ptr1;

// Dereferencing...
// *ptrToPtr = ??
// **ptrToPtr = ??

// Address of...
// &ptrToPtr == ??
```

	Memory	
Variable	**Address**	**Value**
a	0x10	10.0
ptr1	0x18	0x10
ptr2	0x1C	0x10
ptrToPtr	0x20	0x18

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So ptrToPtr is 0x18 because that’s the memory address of ptr1

Pointer to a Pointer

```
double a = 10.0;

double* ptr1 = &a;
double* ptr2 = &a;

// ** because pointer to pointer!
double** ptrToPtr = &ptr1;

// Dereferencing...
// *ptrToPtr = 0x10
// **ptrToPtr = 10.0

// Address of...
// &ptrToPtr == 0x20
```

	Memory	
Variable	**Address**	**Value**
a	0x10	10.0
ptr1	0x18	0x10
ptr2	0x1C	0x10
ptrToPtr	0x20	0x18

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The many uses of const

- Global variables that never change:

```
const int ScreenWidth = 1024;
```

- You should use the above as opposed to a define:

```
#define SCREEN_WIDTH 1024
```

- If you have a pointer, it can either be constant itself, or point to a constant value:

```
// Name is pointer to a const char
const char* Name = "Sanjay";
// pWidth is a const pointer to an int
int* const pWidth = &ScreenWidth;
// Name is a const pointer to a const char
const char* const Name = "Sanjay";
```

Passing by Value

- Basic types are okay to pass by value:

```
// Declares add, which passes lhs and rhs by value
int Add(int lhs, int rhs);
```

- You should almost never pass classes by value:

```
// BAD!!! Makes unnecessary copies of lhs/rhs
Vector3 Add(Vector3 lhs, Vector3 rhs);
```

Passing with Pointers

- You could pass with pointers (you have to in plain old C). This guarantees that you don't copy over the class data.

```
// lhs and rhs are passed as pointers
Vector3 Add(Vector3* lhs, Vector3* rhs);
```

- But pointers do not have to have a valid address:

```
// This is a valid call, and probably will crash
Add(nullptr, nullptr);
```

Pass by Reference

- Like with pointers, you don't copy over class data when passing by reference:

```
// lhs and rhs are passed by reference
Vector3 Add(Vector3& lhs, Vector3& rhs);
```

- However, if you pass by regular reference, Add could change the values of lhs and rhs.

- Instead, you can pass by const reference:

```
// Add is disallowed from changing lhs or rhs
Vector3 Add(const Vector3& lhs, const Vector3& rhs);
```

Const Correctness

- Suppose Vector3 has a function Clear that sets x, y, and z to 0:

```
class Vector3
  {
public:
      void Clear(); // Resets to 0
};
```

- The compiler has to prevent you from running Clear on a const reference to a Vector3:

```
// This won't compile
void Calculate(const Vector3& v)
{
     v.Clear();
}
```

Const Member Functions

- If you have a function that does not change member data, you need to mark it as a const function:

```
class Vector3
{
public:
	float GetX() const; // GetX() can’t change member data
};
```

- You can then run GetX() on const references:

```
// Works
void Calculate(const Vector3& v)
{
	std::cout << v.GetX();
}
```

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Note that functions declared outside a class cannot be const.

Const Best Practices

- Any member functions which do not change member data in your class should be declared as const member functions.

  (If you don't do this, other programmers might get mad)

- Pass classes by const reference when you want to guarantee your function does not modify said class.

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C-style Casts

- In C, to cast from one type to another you typically do:

```
int i;
float f = (float) i;
```

- Problem 1: Searching for all casts in a file is impossible.

- Problem 2: C-style casts allow you to do crazy (unsafe) stuff like:

```
int random_address = 0x123456;
char* garbage = (char*)random_address;
(*garbage) = 'a'; // probably will crash
```

C++ Style Casts

- static_cast – Allows you to do implicit conversions (eg. int -> float), as well as within a class hierarchy (without any runtime checks)

```
int i;
float f = static_cast<float> (i);
```

- reinterpret_cast – Allows you to do any cast you can do in C.

```
int random_address = 0x123456;
char* garbage = reinterpret_cast<char*> (random_address);
```

- const_cast – Allows you to strip the "const" away from const references (you should stay away from this in most cases)

- dynamic_cast – Does a "down cast" from parent class to child class, while checking whether or not it is valid at runtime.

dynamic_cast

- A down cast allows you to take a parent class pointer, and at runtime try to cast it to a child class.
- Eg. If you have a “Shape” pointer, and want to find out if it’s a “Triangle” at runtime, you can do:

```
Shape* myShape;
Triangle* myTriangle = dynamic_cast<Triangle*> (myShape);
if (myTriangle) // dynamic_cast returns 0 if not a triangle
{
      // do something
}
```

- In most cases, dynamic_cast shouldn’t be necessary if we correctly used polymorphism.
- This requires runtime-type information to be enabled in the compiler.

Note, you can also do a down cast with `static_cast`, but it will do no check to ensure the cast is valid.

(A Little More) Complex Pointer Stuff

- A pointer that points to a struct/class often points to the first member:

```
struct MyStruct
{
   int m_Int;
};
MyStruct* s;
(void*) s == (void*) &(s->m_Int) // TRUE
```

- void* pointers can be cast to any other type:

```
void* v;
MyStruct* s = reinterpret_cast<MyStruct*> (v);
```

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Exception: If the class/struct has virtual functions, the pointer may not necessarily point to the first element.

Pointer Arithmetic

- Results of pointer arithmetic depend on the type, and don't work on void*:

```
int* i;
i++; // Increments memory address by 4 bytes (sizeof(int))
char* c;
c++; // Increments memory address by 1 byte (sizeof(char))
void* v;
v++; // Compile error
```

An Issue with Const

- In some instances, you may have a member variable which needs to be modifiable even in a const member function.
- Consider a multi-threaded file system:

```
class FileSystem
{
private:
    std::mutex Lock;
public:
    unsigned int GetBytesFree() const;
};
```

- We want `GetBytesFree` to be const, since it's not changing anything in the actual file system.
- However, if we are going to use our mutex to guarantee it's thread safe, we need `GetBytesFree` to be able to modify `Lock`.

Mutable to the rescue

- If you mark a variable as mutable, then it can be changed even in a const member function:

```
class FileSystem
{
private:
    mutable std::mutex Lock; // Lock can now be changed
public:
    unsigned int GetBytesFree() const;
};
```

- With great power comes great responsibility… you should only use mutable in very specific and unique cases such as the above.

Static

- A class can have a static variable, which means it's shared between all instances of the class.

```
// StaticTest.h
class StaticTest
{
private:
     static int num_instances;
}

// StaticTest.cpp
int StaticTest::num_instances = 0;
```

- In the above, I could make the constructor increment num_instances and the destructor decrement it. Then I know how many instances of my class are in use at any one time.

Static, Continued

- A static variable declared within a function retains state between subsequent calls to the function.

```
void MyFunction()
{
    // Track the number of times the function is called
    // num_calls is initialized on load of the program
    static int num_calls = 0;
    num_calls++;
}
```

Empty Class

- If you have this:

```
class Empty { };
```

- What code gets run when you do this?

```
Empty* test = new Empty();
delete test;
```

Compiler Generated Functions (in C++ 98)

- That empty class effectively is:

```
class Empty
{
public:
     Empty() { /*...*/ }
     Empty(const Empty& rhs) { /*...*/ }
     ~Empty() {}
     Empty& operator=(const Empty& rhs) { /*...*/ }
};
```

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Constructor, copy constructor, destructor, and assignment operator

In C++11, there are two more functions (which we'll talk about later)

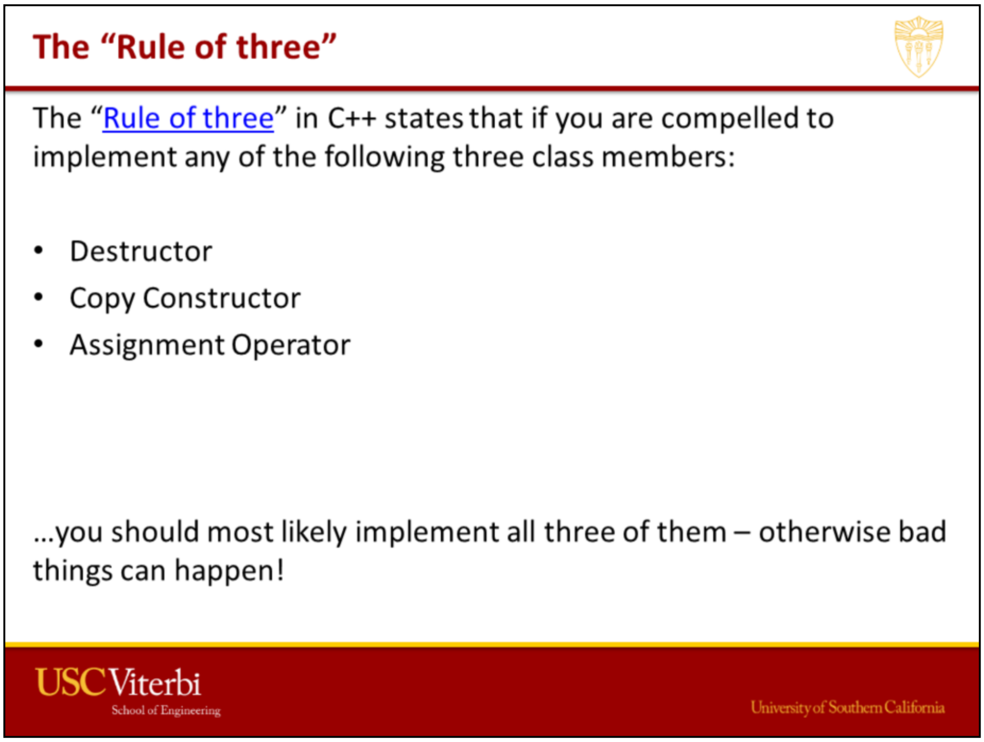
Default copy/assignment

- Default copy constructor and assignment operators are ***shallow*** copies
- So something like this:

```
template <class T>
class List<T>
{
/*...*/
private:
    Node<T>* pHead;
};
```

- Would not copy properly if you did this:

```
List<int> L1;
L1.Add(123);
List<int> L2(L1); // shallow copy bad :(
```



So for instance, if you are dynamically allocating stuff, that tells you that you need a destructor to prevent memory leaks. By the rule of three, this means you probably need copy constructor and assignment to ensure you are doing deep copies.

Disallowing Functions

- If you declare a normally auto-generated function as private, it's not usable by anyone:

```
class Test
{
private:
    // Prevent anyone from using these functions!!
    Test(const Test& rhs){ }
    Test& operator=(const Test& rhs) { }
};
```

Implicit Construction

- If you have this:

```
class A
{
public:
      A(int value);
};
void my_func(const A& my_A);
```

- The following is legal code:

```
my_func(12345); // Will construct an A with provided integer
```

Explicit Keyword

- To disallow previous scenario, use `explicit`:

```
class A
{
public:
    explicit A(int value);
};
```

- Then only this would be allowed:

```
my_func(A(1234));
```

Override Keyword

- Suppose there is a Class A:

```
class A
{
public:
   virtual void TakeDamage(int amount);
};
```

- Class B inherits from A, and overrides TakeDamage:

```
class B : public A
{
public:
   void TakeDamage();
};
```

- What’s wrong with this picture (yes, it compiles!)?

Class B intends to override TakeDamage, but it in fact implements a new take damage that does not override A’s, because the parameters are different.

Override Keyword, Cont'd

- The keyword `override` after the function name/parameters says "I guarantee this overrides a function from a parent class"

- So if we wrote the code as:

```
class B : public A
{
public:
   void TakeDamage() override;
};
```

- Error C3668: 'B::TakeDamage' : method with override specifier 'override' did not override any base class methods

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So using override can be a good way to prevent such errors.