CSCI 104
C++11 Features
Design Patterns
Mark Redekopp
Plugging the leaks

SMART POINTERS
C++11, 14, 17

• Most of what we have taught you in this class are language features that were part of C++ since the C++98 standard

• New, helpful features have been added in C++11, 14, and now 17 standards
  – Beware: compilers are often a bit slow to implement the standards so check the documentation and compiler version
  – You often must turn on special compile flags to tell the compiler to look for C++11 features, etc.
    • For g++ you would need to add: `-std=c++11` or `-std=c++0x`

• Many of the features in the these revisions to C++ are originally part of 3rd party libraries such as the Boost library
Pointers or Objects? Both!

• In C++, the dereference operator (*) should appear before...
  – A pointer to an object
  – An actual object

• "Good" answer is
  – A Pointer to an object

• "Technically correct" answer...
  – EITHER!!!!

• Due to operator overloading we can make an object behave as a pointer
  – Overload operator *, &, ->, ++, etc.

```cpp
class Thing
{
}

int main()
{
    Thing t1;
    Thing *ptr = &t1
    // Which is legal?
    *t1;
    *ptr;
}
```
A "Dumb" Pointer Class

• We can make a class operate like a pointer
• Use template parameter as the type of data the pointer will point to
• Keep an actual pointer as private data
• Overload operators
• This particular class doesn't really do anything useful
  – It just does what a normal pointer would do

```cpp
template <typename T>
class dumb_ptr
{
  private:
    T* p_;  
  public:
    dumb_ptr(T* p) : p_(p) { } 
    T& operator*() { return *p_; } 
    T* operator->() { return p_; } 
    dumb_ptr& operator++() // pre-inc
    { ++p_; return *this; }
};

int main()
{
  int data[10];
  dumb_ptr<int> ptr(data);

  for(int i=0; i < 10; i++){
    cout << *ptr;  ++ptr;
  }
}
```
A "Useful" Pointer Class

- I can add automatic memory deallocation so that when my local "unique_ptr" goes out of scope, it will automatically delete what it is pointing at.

```cpp
template <typename T>
class unique_ptr
{
private:
    T* p_;  
public:
    unique_ptr(T* p) : p_(p) { }  
    ~unique_ptr() { delete p_; }
    T& operator*() { return *p_; }
    T* operator->() { return p_; }
    unique_ptr& operator++() // pre-inc  
    { ++p_; return *this; }
};

int main()
{
    unique_ptr<Obj> ptr(new Obj);
    // ...
    ptr->all_words();
    // Do I need to delete Obj?
}
```
A "Useful" Pointer Class

• What happens when I make a copy?
• Can we make it impossible for anyone to make a copy of an object?
  – Remember C++ provides a default "shallow" copy constructor and assignment operator

```cpp
template <typename T>
class unique_ptr
{
private:
    T* p_;  

public:
    unique_ptr(T* p) : p_(p) {}  
    ~unique_ptr() { delete p_; }  
    T& operator*() { return *p_; }  
    T* operator->() { return p_; }  
    unique_ptr& operator++() // pre-inc
    { ++p_; return *this; }  
};

int main()
{
    unique_ptr<Obj> ptr(new Obj);
    unique_ptr<Obj> ptr2 = ptr;
    // ...
    ptr2->all_words();
    // Does anything bad happen here?
}
```
Hiding Functions

- Can we make it impossible for anyone to make a copy of an object?
  - Remember C++ provides a default "shallow" copy constructor and assignment operator
- Yes!!
  - Put the copy constructor and operator= declaration in the private section...now the implementations that the compiler provides will be private (not accessible)
- You can use this technique to hide "default constructors" or other functions

```cpp
template <typename T>
class unique_ptr{
    private:
        T* p_
    public:
        unique_ptr(T* p) : p_(p) { }
        ~unique_ptr() { delete p_; }
        T& operator*() { return *p_; }
        T* operator->() { return p_; }
        unique_ptr& operator++() // pre-inc
        { ++p_; return *this; }
    private:
        unique_ptr(const UsefultPtr& n);
        unique_ptr& operator=(const UsefultPtr& n);
};

int main()
{
    unique_ptr<Obj> ptr(new Obj);
    unique_ptr<Obj> ptr2 = ptr;
    // Try to compile this?
}
A "shared" Pointer Class

• Could we write a pointer class where we can make copies that somehow "know" to only delete the underlying object when the last copy of the smart pointer dies?

• Basic idea
  – shared_ptr class will keep a count of how many copies are alive
  – shared_ptr destructor simply decrements this count
    • If count is 0, delete the object

```cpp
#include <iostream>

template <typename T>
class shared_ptr
{
public:
    shared_ptr(T* p);
    ~shared_ptr();
    T& operator*();
    shared_ptr& operator++();

private:
    T* p;
    int ref_count;

    void increment()
    {
        ref_count++;
    }

    void decrement()
    {
        ref_count--;
    }

    void check()
    {
        if (ref_count == 0)
            delete p;
    }

    shared_ptr(T* p) : p(p), ref_count(1) {}
    ~shared_ptr()
    {
        decrement();
        check();
    }
    T& operator*()
    {
        check();
        return *p;
    }
    shared_ptr& operator++()
    {
        check();
        return *this;
    }

private:

    static void* get_pointer(T* p)
    {
        return p;
    }
};

void f1()
{
    shared_ptr<Obj> ptr(new Obj);
    cout << "In F1\n" << *ptr << endl;
    return ptr;
}

int main()
{
    shared_ptr<Obj> p2 = f1();
    cout << "Back in main\n" << *p2;
    cout << endl;
    return 0;
}
```
A "shared" Pointer Class

• Basic idea
  – shared_ptr class will keep a count of how many copies are alive
  – Constructors/copies increment this count
  – shared_ptr destructor simply decrements this count
    • If count is 0, delete the object

```cpp
int main()
{
    shared_ptr<Obj> p1(new Obj);
    doit(p1);
    return 0;
}

void doit(shared_ptr<Obj> p2)
{
    if(...){
        shared_ptr<Obj> p3 = p2;
    }
}
```
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    doit(p1);
    return 0;
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    if(...){
        shared_ptr<Obj> p3 = p2;
    }
}
```
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    return 0;
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        shared_ptr<Obj> p3 = p2;
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{
    shared_ptr<Obj> p1(new Obj);
    doit(p1);
    return 0;
}

void doit(shared_ptr<Obj> p2)
{
    if(...)
    {
        shared_ptr<Obj> p3 = p2;
    }
    // p3 dies
}
```
A "shared" Pointer Class

• Basic idea
  – shared_ptr class will keep a count of how many copies are alive
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    • If count is 0, delete the object

```cpp
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{
    shared_ptr<Obj> p1(new Obj);
    doit(p1);
    return 0;
}

void doit(shared_ptr<Obj> p2)
{
    if(...){
        shared_ptr<Obj> p3 = p2;
    } // p3 dies
} // p2 dies
```
A "shared" Pointer Class

• Basic idea
  – shared_ptr class will keep a count of how many copies are alive
  – shared_ptr destructor simply decrements this count
    • If count is 0, delete the object

```cpp
int main()
{
    shared_ptr<Obj> p1(new Obj);
    doit(p1);
    return 0;
} // p1 dies

void doit(shared_ptr<Obj> p2)
{
    if(...){
        shared_ptr<Obj> p3 = p2;
    } // p3 dies
} // p2 dies
```
C++ shared_ptr

- C++ std::shared_ptr / boost::shared_ptr
  - Boost is a best-in-class C++ library of code you can download and use with all kinds of useful classes
- Can only be used to point at dynamically allocated data (since it is going to call delete on the pointer when the reference count reaches 0)
- Compile in g++ using '-std=c++11' since this class is part of the new standard library version

```cpp
#include <memory>
#include "obj.h"
using namespace std;

shared_ptr<Obj> f1()
{
    shared_ptr<Obj> ptr(new Obj);
    // ...
    cout << "In F1\n" << *ptr << endl;
    return ptr;
}

int main()
{
    shared_ptr<Obj> p2 = f1();
    cout << "Back in main\n" << *p2;
    cout << endl;
    return 0;
}
```

$ g++ -std=c++11 shared_ptr1.cpp obj.cpp
C++ shared_ptr

• Using shared_ptr's you can put pointers into container objects (vectors, maps, etc) and not have to worry about iterating through and deleting them

• When myvec goes out of scope, it deallocates what it is storing (shared_ptr's), but that causes the shared_ptr destructor to automatically delete the Objs

• Think about your project homeworks...this might be (have been) nice

```cpp
#include <memory>
#include <vector>
#include "obj.h"
using namespace std;

int main()
{
    vector<shared_ptr<Obj>> myvec;

    shared_ptr<Obj> p1(new Obj);
    myvec.push_back(p1);

    shared_ptr<Obj> p2(new Obj);
    myvec.push_back(p2);

    return 0;
    // myvec goes out of scope...
}
```

$ g++ -std=c++11 shared_ptr1.cpp obj.cpp
shared_ptr vs. unique_ptr

- Both will perform automatic deallocation
- Unique_ptr only allows one pointer to the object at a time
  - Copy constructor and assignment operator are hidden as private functions
  - Object is deleted when pointer goes out of scope
  - Does allow "move" operation
    - If interested read more about this on your own
    - C++11 defines "move" constructors (not just copy constructors) and "rvalue references" etc.
- Shared_ptr allow any number of copies of the pointer
  - Object is deleted when last pointer copy goes out of scope
- Note: Many languages like python, Java, C#, etc. all use this idea of reference counting and automatic deallocation (aka garbage collection) to remove the burden of memory management from the programmer
RAII

Class Obj{
    int val;
public:
    ...
    void f1()
    {
        val++;
        if( ) {
            return;
        } else {
        }
        val--; 
    };
}
STATIC MEMBERS
One For All

• As students are created we want them to have unique IDs

• How can we accomplish this?

class USCStudent {
    public:
        USCStudent(string n) : name(n)
        { id = __________ ; // ????
        }

    private:
        string name;
        int id;
    }

int main()
{
    // should each have unique IDs
    USCStudent s1("Tommy");
    USCStudent s2("Jill");
}
• Can we just make a counter data member of the USCStudent class?

• What's wrong with this?
One For All

• It's not something that we can do from w/in an instance
  – A student doesn't assign themselves an ID, they are told their ID

• Sometimes there are functions or data members that make sense to be part of a class but are shared amongst all instances
  – The variable or function doesn't depend on the instance of the object, but just the object in general
  – We can make these 'static' members which means one definition shared by all instances

class USCStudent {
public:
    USCStudent(string n) : name(n) {
        id = id_cntr++; }

private:
    static int id_cntr;
    string name;
    int id;
}

// initialization of static member
int USCStudent::id_cntr = 1;

int main()
{
    USCStudent s1("Tommy"); // id = 1
    USCStudent s2("Jill");  // id = 2
}

### Static Data Members

- A 'static' data member is a single variable that all instances of the class share.
- Can think of it as belonging to the class and not each instance.
- Declare with keyword 'static'.
- Initialize outside the class in a .cpp (can't be in a header).
  - Precede name with className::

```cpp
class USCStudent {
public:
    static int id_cntr;
    USCStudent(string n) : name(n)
    { id = id_cntr++; }

private:
    static int id_cntr;
    string name;
    int id;
}

// initialization of static member
int USCStudent::id_cntr = 1;

int main()
{
    USCStudent s1("Tommy");  // id = 1
    USCStudent s2("Jill");  // id = 2
}
```
Another Example

- All US Citizens share the same president, though it changes over time.
- Rather than wasting memory for each citizen to store a pointer to the president, we can make it static.
- However, private static members can't be accessed from outside functions.
- For this we can use a static member functions.

```cpp
class USCitizen{
    public:
        USCitizen();
    
    private:
        static President* pres;
        string name;
        int ssn;
    }

int main()
{
    USCitizen c1;
    USCitizen c2;
    President* curr = new President;

    // won't compile..pres is private
    USCitizen::pres = curr;
}
```
Static Member Functions

- Static member functions do tasks at a class level and can't access data members (since they don't belong to an instance)
- Call them by preceding with 'className::'
- Use them to do common tasks for the class that don't require access to an instance's data members
  - Static functions could really just be globally scoped functions but if they are really serving a class' needs it makes sense to group them with the class

```cpp
class USCitizen{
public:
    USCitizen();
    static void setPresident(President* p)
    { pres = p; }

private:
    static President* pres;
    string name;
    int ssn;
}

int main()
{
    USCitizen c1;
    USCitizen c2;
    President* curr = new President;
    USCitizen::setPresident(curr);
    ...
    President* next = new President;
    USCitizen::setPresident(next);
}
```
It's an object, it's a function...it's both rolled into one!

DESIGN PATTERNS AND PRINCIPLES
Coupling

• Coupling refers to how much components depend on each other's implementation details (i.e. how much work it is to remove one component and drop in a new implementation of it)
  – Placing a new battery in your car vs. a new engine
  – Adding a USB device vs. a new processor to your laptop

• OO Design seeks to reduce coupling (i.e. **loose** coupling) as much as possible
  – If you need to know or depend on the specific implementation of another class to write your current code, you are **tightly** coupled...BAD!!!!
  – Code should be designed so modification of one component/class does not require modification and unit-testing of other components
    • Just unit-test the new code and test the overall system
Design Principles

• Let the design dictate the details as much as possible rather than the details dictate the design
  – Top-down design
  – A car designer shouldn't say, "It would be a lot easier to make anti-lock brakes if the driver would just pulse the brake pedal 30 times a second"

• Open-Close Principle
  – Classes should be open to extension but closed to modification (After initial design and testing that is)
    • To alter behavior and functionality, inheritance should be used
    • Base classes should be designed with that in mind (i.e. extensible)
  – Extend and change behavior by allocating different (derived) objects at creation and passing them in (via the abstract base class pointer) to an object
    • Did you use this idea during the semester?
  – The client has programmed to an interface and thus doesn't need to change (is decoupled)
Re-Factoring

• $f(x) = axy + bxy + cy$
  – How would you factor this?
  – $f(x) = y(x(a+b)+c)$
  – We pull or **lift** the common term out leaving just what is unique to each term

• During design implementation we often need to refactor our code which may include
  – Extracting a common sequence of code into a function
  – Extracting a base class when you see many classes with a common interface
  – Replacing if..else statements based on the "type" of thing with polymorphic classes
  – ...and many more
SPECIFIC DESIGN PATTERNS

How to design effective class hierarchies with low coupling
Design Patterns

• Common software practices to create modular code
  – Often using inheritance and polymorphism
• Researches studied software development processes and actual code to see if there were common patterns that were often used
  – Most well-known study resulted in a book by four authors affectionately known as the "Gang of Four" (or GoF)
    • Design Patterns: Elements of Reusable Object-Oriented Software by Erich Gamma, Richard Helm, Ralph Johnson and John Vlissides

• Creational Patterns
  – Singleton, Factory Method, Abstract Factory, Builder, Prototype
• Structural Patterns
  – Adapter, Façade, Decorator, Bridge, Composite, Flyweight, Proxy
• Behavioral Patterns
  – Iterator, Mediator, Chain of Responsibility, Command, State, Memento, Observer, Template Method, Strategy, Visitor, Interpreter
Understanding UML Relationships

• UML Relationships
  – http://wiki.msvincognito.nl/Study/Bachelor/Year_2/Object_Oriented_Modelling/Summary/Object-Oriented_Design_Process

• Design Patterns
  – Strategy
  – Factory Method
  – Template Method
  – Observer
Iterator

- Decouples organization of data in a collection from the client who wants to iterate over the data
  - Data could be in a BST, linked list, or array
  - Client just needs to...
    - Allocate an iterator \([it = \text{collection}.\text{begin}()]\)
    - Dereferences the iterator to access data \([*it]\)
    - Increment/decrement the iterator \([++it]\)
Strategy

- Abstracting interface to allow alternative approaches
- Fairly classic polymorphism idea
- In a video game the AI may take different strategies
  - Decouples AI logic from how moves are chosen and provides for alternative approaches to determine what move to make
- Recall "Shapes" exercise in class
  - Program that dealt with abstract shape class rather than concrete rectangles, circles, etc.
  - The program could now deal with any new shape provided it fit the interface
Your Search Engine

- Think about your class project and where you might be able to use the strategy pattern
- AND, OR, Normal Search

```cpp
string searchType;
string searchWords;

cin >> sType;
SearchMode* s;
if(sType == "AND") {
  s = new ANDSearch;
}
else if(sType == "OR") {
  s = new ORSearch;
}
else {
  s = new SingleSearch;
}
getline(cin, searchWords);
s->search(searchWords);
```
Factory Pattern

- A function, class, or static function of a class used to abstract creation
- Rather than making your client construct objects (via 'new', etc.), abstract that functionality so that it can be easily extended without affecting the client

```java
makeItem(int type)
{
    if(type==A)
        return new ItemA;
    else if(type == B)
        return new ItemB;
}
```

```java
Item* i = factory.makeItem(type);
```
Factory Example

- We can pair up our search strategy objects with a factory to allow for easy creation of new approaches

```cpp
class SearchFactory{
public:
    static SearchMode* create(string type) {
        if(type == "AND")
            return new ANDSearch;
        else if(searchType == "OR")
            return new ORSearch;
        else
            return new SingleSearch;
    }
};
```

```cpp
string searchType;
string searchWords;

cin >> sType;
SearchMode* s = SearchFactory::create(sType);
getline(cin, searchWords);
s->search(searchWords);
```

**Search Interface**

```cpp
class SearchMode {
public:
    virtual search(set<string> searchWords) = 0;
...}
```

**Concrete Search**

```cpp
class AndSearchMode : public SearchMode {
public:
    search(set<string> searchWords){
        // perform AND search approach
    }
    ...
};
```
Factory Example

- The benefit is now I can add new search modes without the client changing or even recompiling

```cpp
class SearchFactory{
public:
    static SearchMode* create(string type)
    {
        if(type == "AND")
            return new ANDSearch;
        else if(searchType == "OR")
            return new ORSearch;
        else if(searchType == "XOR")
            return new XORSearch;
        else
            return new SingleSearch;
    }
};

string searchType;
string searchWords;

cin >> sType;
SearchMode* s = SearchFactory::create(sType);

getline(cin, searchWords);
s->search(searchWords);
```

```cpp
class XORSearchMode : public SearchMode
{
    public:
        search(set<string> searchWords);
        ...
};
```
On Your Own

• Design Patterns
  – Observer
  – Proxy
  – Template Method
  – Adapter

• Questions to try to answer
  – How does it make the design more modular (loosely coupled)
  – When/why would you use the pattern

• Resources
  – http://sourcemaking.com/
  – http://www.vincehuston.org/dp/
  – http://www.oodesign.com/
Templates vs. Inheritance

- Inheritance and dynamic-binding provide run-time polymorphism
  - Example:
    - Strategy *s; ...; s->search(words);
- C++ templates provide compile-time inheritance

```cpp
class ANDSearch {
    public:
        set<WebPage*> search(vector<string>& words);
};
class ORSearch {
    ...
};

template <typename S>
set<WebPage*> doSearch(S* search_mode,
    vector<string>& words)
{
    return search_mode->search(words);
}
...
ANDSearch mode;
Set<WebPage*> results = doSearch(mode, ...);
```
Templates vs. Inheritance

• Benefit of inheritance and dynamic-binding is its ability to store different-type but related objects in a single container
  – Example:
    • `foreach` shape `s` in Shapes { `s`->getArea(); }`
  – Benefit: Different objects in one collection

• Benefit of templates is less run-time overhead (faster) due to compiler ability to optimize since it knows the specific type of object used