CSCI 104
C++11 Features
Design Patterns

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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.

```
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

```
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

```
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

```
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

```
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

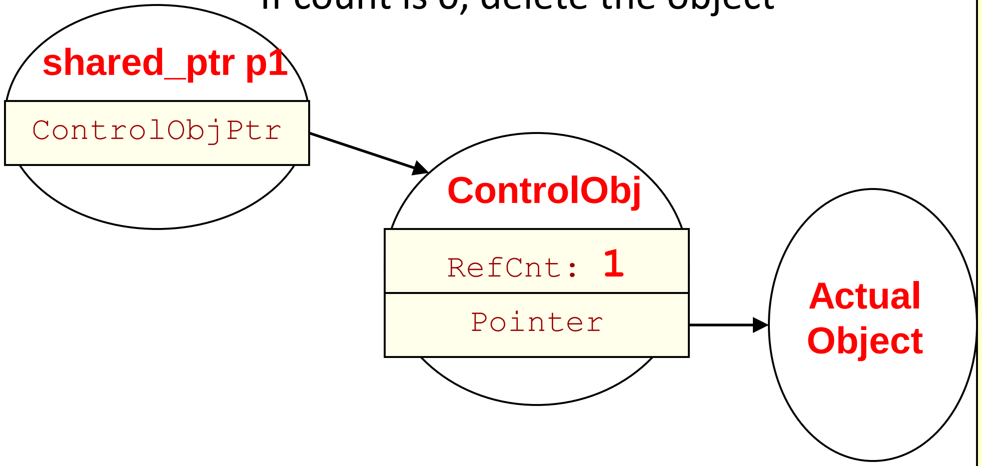
- Could we write a pointer class where we can make copies that somehow "know" to only delete the underlying object when the last copy of the smart pointer dies?
- Basic idea
  - shared_ptr class will keep a count of how many copies are alive
  - shared_ptr destructor simply decrements this count
    - If count is 0, delete the object

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

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



```
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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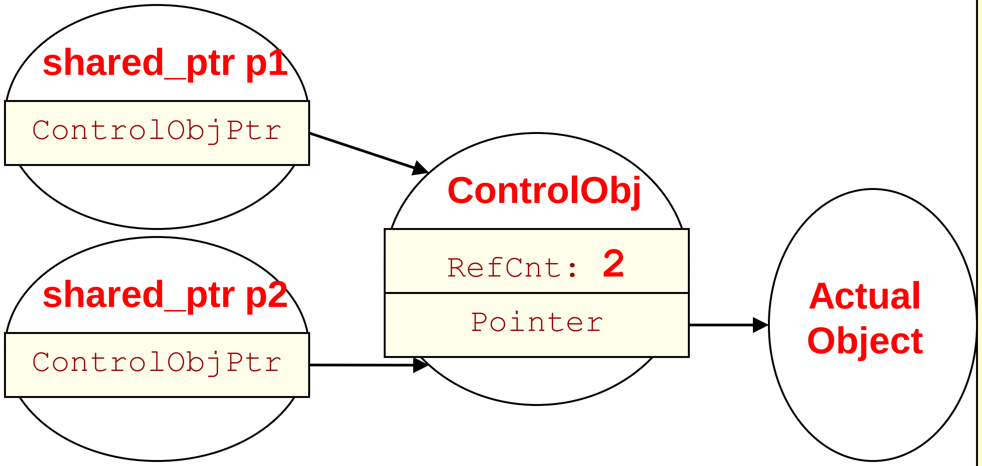

```
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{
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  doit(p1);
  return 0;
}

void doit(shared_ptr<Obj> p2)
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 if(...){
     shared_ptr<Obj> p3 = p2;

 }
}
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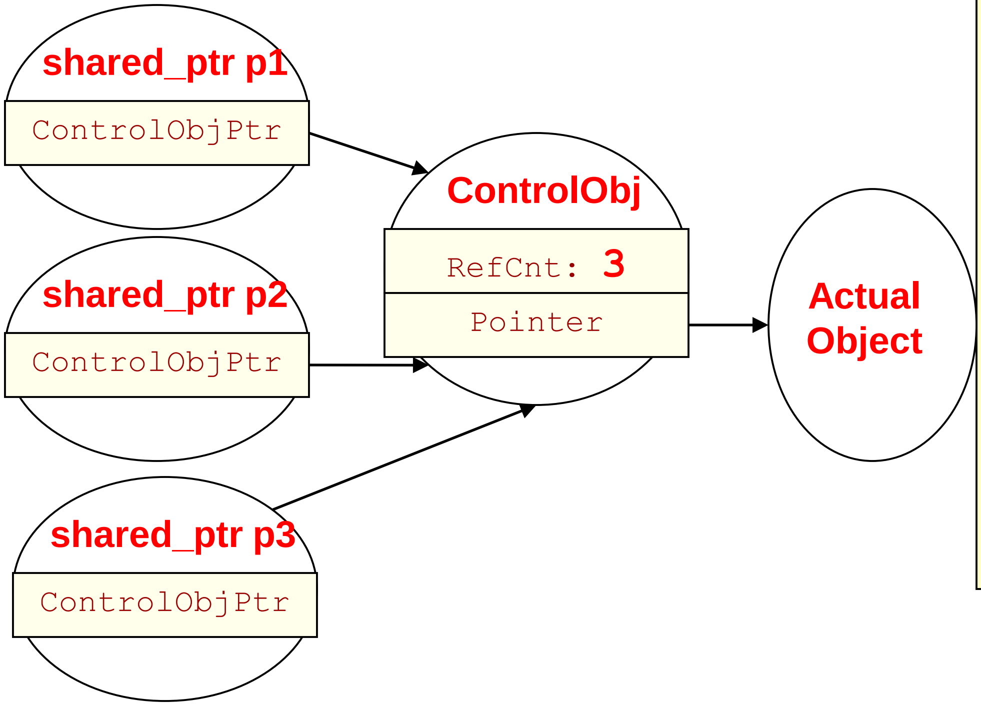

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{
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  return 0;
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{
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  doit(p1);
  return 0;
}

void doit(shared_ptr<Obj> p2)
{
 if(...){
     shared_ptr<Obj> p3 = p2;

 } // p3 dies
}
```

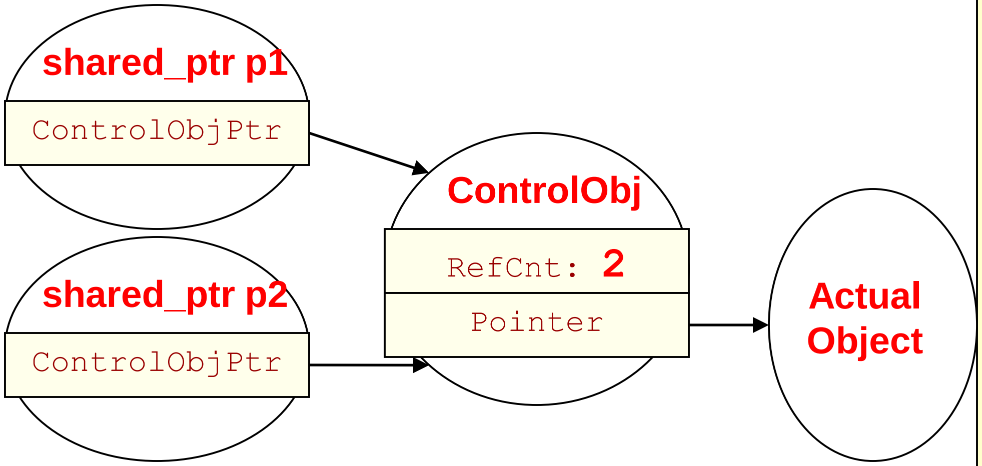

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```
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{
  shared_ptr<Obj> p1(new Obj);
  doit(p1);
  return 0;
}

void doit(shared_ptr<Obj> p2)
{
 if(...){
     shared_ptr<Obj> p3 = p2;

 } // p3 dies
} // p2 dies
```

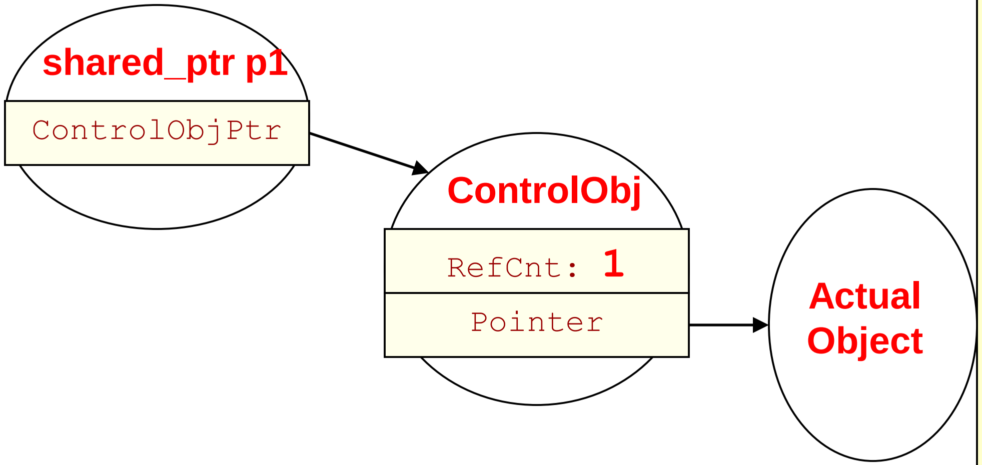

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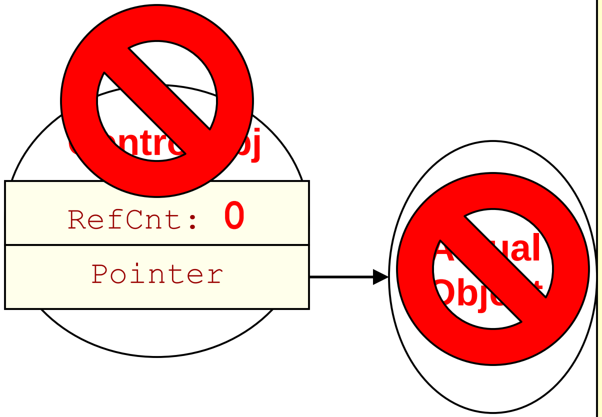


```
int main()
{
  shared_ptr<Obj> p1(new Obj);
  doit(p1);
  return 0;
} // p1 dies

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

```
#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

```
#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");




}
```

One For All

- Can we just make a counter data member of the USCStudent class?
- What's wrong with this?

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

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


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




}
```

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::

```
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

```
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

```
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 **<u>tightly</u>** 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
  - http://sourcemaking.com/

How to design effective class hierarchies with low coupling

SPECIFIC DESIGN PATTERNS

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

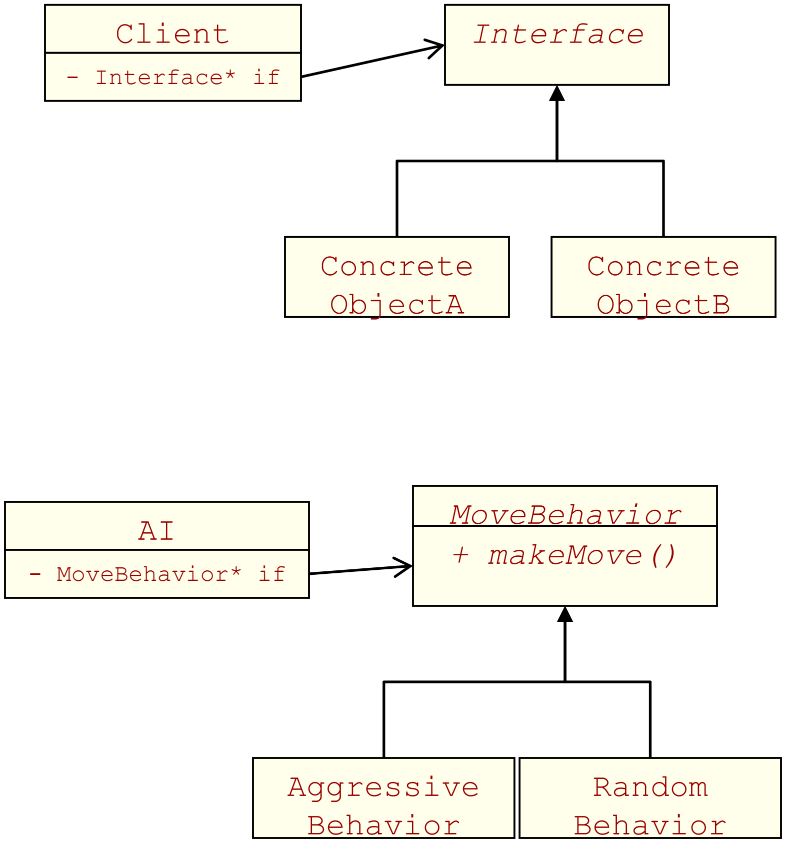
- UML Relationships
  - http://wiki.msvincognito.nl/Study/Bachelor/Year_2/Object_Oriented_Modelling/Summary/Object-Oriented_Design_Process
  - http://www.cs.sjsu.edu/~drobot/cs146/UMLDiagrams.htm
- Design Patterns
  - Strategy
  - Factory Method
  - Template Method
  - Observer

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 = collection.begin()]
    - Dereferences the iterator to access data [*it]
    - Increment/decrement the iterator [++it]

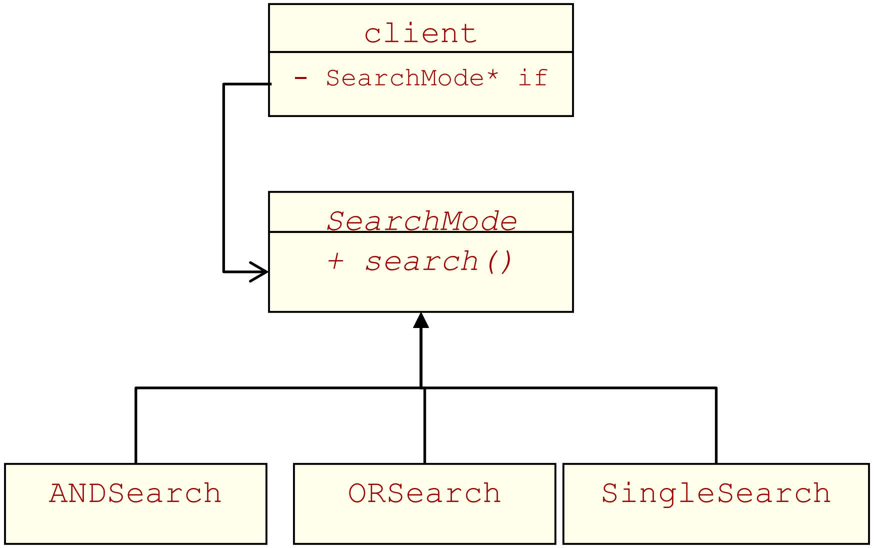
Strategy

- 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

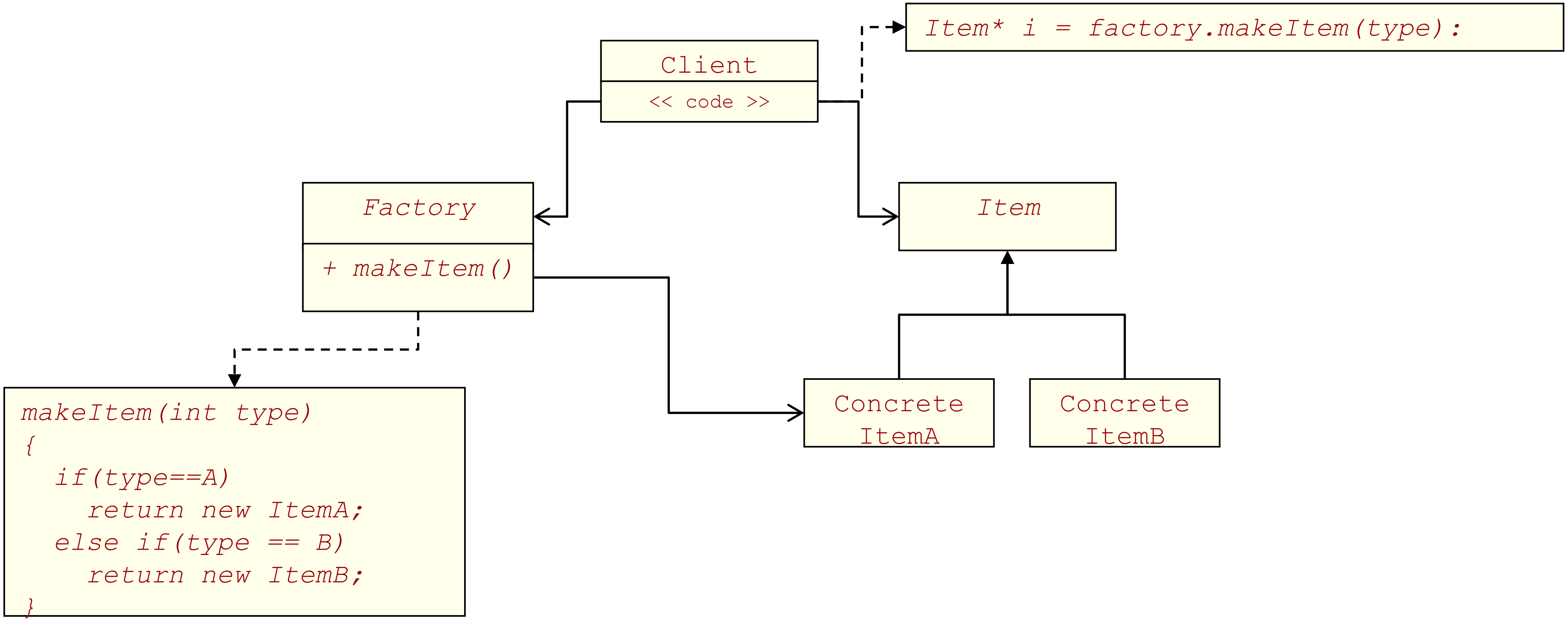


```
string searchType;
string searchWords;

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);
```

Client

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



```
Item* i = factory.makeItem(type):
```

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

Factory Example

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

Factory

```
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;
   }
};
```

Client

```
string searchType;
string searchWords;

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

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

Search Interface

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

Concrete Search

```
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

```
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);
```

```
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

```
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