Lecture 22

Miscellaneous Topics 4
+ Memory Allocation

Declarations in Classes: Enumerations

- Since the class definition also provides a sense of "scope", we can perform declarations and definitions within the class definition.
- Indeed, we do just that with member functions and member variables.
- But there are other types that can be declared and defined as well.
- We'll look at enumerations first.

```
class Example
{
public:
  void setCounter(int argCounter=kInitialValue);
private:
  enum CounterValues {
    kInitialValue=0,  kLastValue
  };
  int counter;
}
```

Declarations in Classes: Enumerations

- The constants defined in the enumeration may be used anywhere in the class, and in other classes by the following rules:
- If the enumerations are declared protected, they may be used only in derived classes.
- If the enumerations are declared public, they may be accessed from anywhere provided their fully qualified names are used:

```
int main()
{
  Example anExample;

  // In order to use the enumeration defined in Example
  // we must qualify it with the class name (Example::)
  anExample.setCounter(Example::kLastValue);
}
```

Declarations in Classes: Static Members

- A static member variable is a variable declared in the class definition but is treated like a global variable:
  - There is only one copy of it no matter how many instances of its class exist
  - If its value is changed by any one instance, the value is changed for all the instances
- In effect, it is a global variable but only visible outside the class if declared in the `public` section.

```
class Example
{
public:
  Example() { currentTotal = 0; }
  void addToTotal(int aValue);
private:
  static int currentTotal;
};
```

Static Members

- There's only one problem…
- Since the static member doesn't really exist in the class, separate storage must be allocated for it outside the class.
- This is done in the form of a global variable using the fully qualified name of the static member...

```
class Example
{
public:
  Example() { currentTotal = 0; }
  void addToTotal(int aValue);
private:
  static int currentTotal;
};

int Example::currentTotal = 0;  // Define the static member
```

Static Members

- If you don't define space for the static member in this manner, you will get a linker error!
- The static member may be accessed outside of the class only if it is declared in one of the class' `public` sections.
- If so, the static member may be accessed anywhere by using its fully qualified name:

```
int main()
{
  Example e1;

  Example::currentTotal = 5;        // There are two ways to
  cout << e1.currentTotal << endl;  // access the same var!

  return 0;
}
```

Static Members

- A static member function is a little different since there is already only one copy of the code used to implement a member function.
- A static member function has no `this` pointer and cannot access individual non-static member fields.
- However a static member function may be called without creating an instance of the class in which it is defined...

```
class Example
{
public:
  static void printBanner() { cout << "Hello World" << endl; }
};
int main()
{
  Example::printBanner();
  return 0;
}
```

Demonstration #1

Declarations in Classes

Nested Classes

- In addition to declaring enumerations and static member variables/functions within classes you can also define other *classes* within classes.
- These are called "Nested Class Definitions"
- Consider the following:

```
class X {           // X is an arbitrary class
public:
  class Y           // Y is defined in X's public section
  {};
private:            // Z is defined in X's private section
  class Z
  {};
};
```

Nested Classes

- The fact that class `Y` is defined in the public section of class `X` means the following:
  - Objects of class `Y` may be created outside the scope of `X` only if fully qualified name is used (`X::Y`)
- The fact that class `Z` is defined in the private section of class `X` means the following:
  - Objects of class `Z` may only be created within the scope of `X`.
- If Y had been defined within a protected section of class `X`'s definition, objects of type `Y` could be created anywhere in the scope of `X` as well as in the scope of any class derived from `X`.
- Any member variables/functions of Y are accessible according to the normal public, private and protected used in classes.
- Having said all of this, CodeWarrior does not appear to honor the restrictions on `Z` and will let me declare a class of type `X::Z` outside of the scope of `X`.

Nested Classes

- An example of nested class definitions might involve list management.
- Consider the following:

```
class List {
public:
  List():the_head(NULL){}   // standard constructor
  ~List();                  // standard destructor
private:
  class Node {              // Nested definition of Node
  public:
    string the_value;       // the "value" of an element
    Node *next;             // pointer to next element
  };
  Node *the_head;           // the first element
};
```

Demonstration #2

Nested Class Definitions

Memory Allocation

- No matter what system or platform you are programming for, there is one constant…
- Memory allocation is slow!
- The general problem is that no matter how good the generic memory management algorithm is behind the `new` operator, it is burdened by the fact that it must be prepared to allocate and manage blocks of memory which are of varying sizes.
- Now, please keep in mind that *slow* is a *relative term*. When looked at individually, even the slowest memory allocation is still fairly fast under a modern OS and/or modern hardware.
- Under MacOS, memory management is particularly slow due to there being an extra layer of indirection present (handles).
- So, what a perfect platform to talk about memory management on!

Demonstration #3

Lots of Dynamic Allocation

Memory Allocation

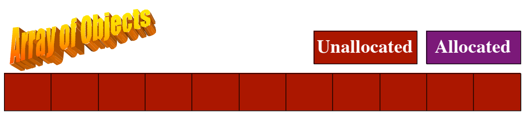
- As you can see, even though memory allocation is slow, it still takes *a lot* of memory allocations to slow us down.
- But, in the "real world", you'd be surprised at how quickly repeated memory allocation can slow down your program.
- Acknowledging this, C++ lets you do something truly bizarre…
- You can overload the `new` operator and define your own memory management routines.
- Just *try* doing that in Java!!!!
- Of course, if you can overload `new` you must be able to overload delete as well.
- Overloading the `new` and `delete` operators is done just like any other operator overload, except there is a slightly special syntax:
  - `void *operator new(size_t);`
  - `void operator delete(void *);`

Memory Allocation

- OK, but that means I actually have to *implement* some memory management routines!
- *WHY* would I want to do that?
- Because the generic memory management routines are slow!
- They're slow because they have to be able to deal with any size object.
- If you know you will need to dynamically allocate a lot of the same objects during the course of your program you can define your own memory management routines for allocations of that object type.
- A typical memory management routine to handle repeated allocations of the same type can be implemented in a way that will be more efficient than the generic routine.
- Let's do it!

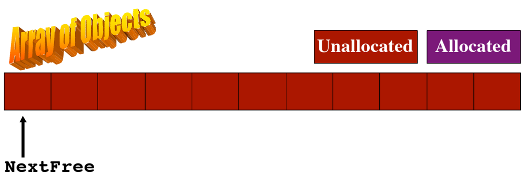
Memory Management

- The idea is somewhat simple, when you think about it.
- You allocate a block of memory (using the generic routine) to form an "array" of the objects in question.
- When `YourObject::operator new` is called, you "give out" one of your previously allocated objects.
- That means you need to keep track of what's allocated and what is not!
- When you start out, you'll have something like this:



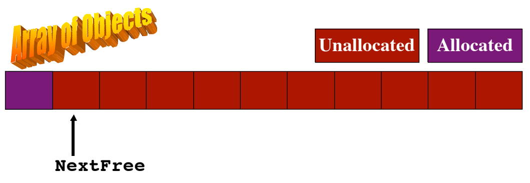
Memory Management

- But how do you "dole out" pre-allocated objects in an orderly fashion?
- First, you'll need a pointer variable which will be used to point to consecutive items in your array. We'll call it `NextFree`.
- It will, of course, start at the beginning of the array.



Memory Management

- When one object is allocated via a call to `YourObject::operator new`, we'll return the object that `NextFree` is pointing at and then increment `NextFree` to the next item in the array.
- That would look like this:



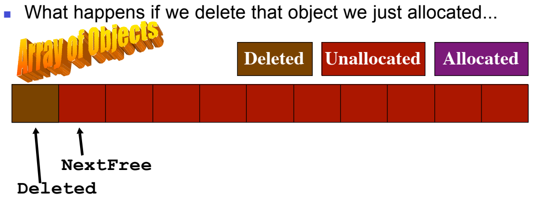
Memory Management

- But what happens when `YourObject::operator delete` is called?
- We need to keep track of deleted objects as well.
- We do this in the form of a "pseudo" linked list.
- I say pseudo because in a regular linked list, the implication is that each element is allocated only when necessary.
- What we're going to do is make each object in our pre-allocated array similar to a linked list `Node` with two fields, the first is an instance of `YourObject`, the second is a "next" pointer.
- It might look like this:

```
class Element {
public:
  YourObject  theObject;
  Element     *nextElement;
};
```

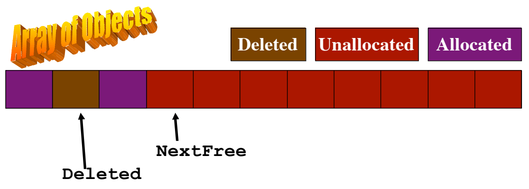
Memory Management

- Now, when we delete an object, we'll put it at the beginning of a linked list of "deleted" objects.
- Whenever `YourObject::operator new` is called, we'll first check to see if there are any objects on the "deleted objects" list.
- If there are, we'll return the first object from that list instead of the object pointed at by `NextFree`.
- What happens if we delete that object we just allocated...



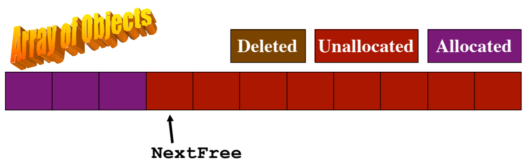
Memory Management

- OK, now let's say that we allocated three more objects and then delete the second object we allocated in that run.



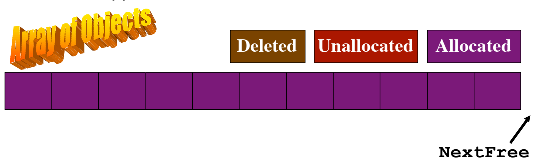
Memory Management

- Now, let's allocate another object.
- We'll use the first one on our list of deleted objects...



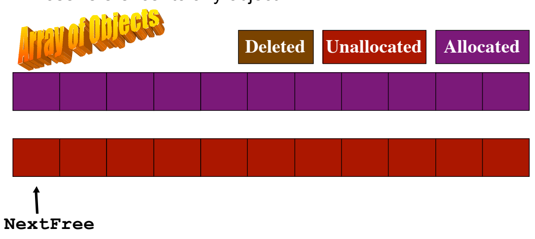
Memory Management

- But what happens if we allocate all the elements in our array?
- You can always fall back on the default operator new in your YourObject::operator new code.
- As a matter of fact, in YourOperator::operator new, you should always check that the size requested matches the size of the object you've defined the memory handler for, and default to ::operator new if it doesn't.
- But what happens in this situation:



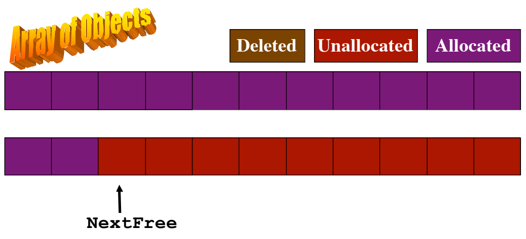
Memory Management

- It's actually pretty simple.
- We just allocate another array.
- It doesn't matter if it's not contiguous with the previous array, our linked list of deleted objects will mean we'll never "lose reference" to any object:



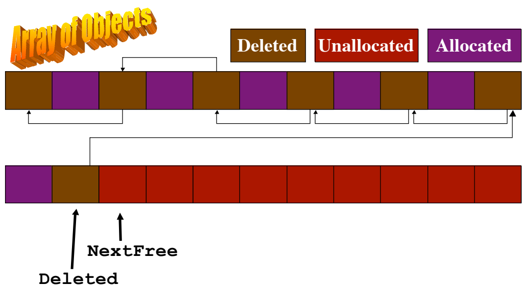
Memory Management

- Now, let's allocate two more objects:



Memory Management

- And now delete every other object:



Memory Management

- Any questions on the memory management algorithm?
- Let's look at some code:

Demonstration #4

Better Dynamic Allocation ?

Lecture 22

Final Thoughts