

CS11 – Introduction to C++

Winter 2011-2012
Lecture 2

Our Point Class – Point.hh

```
// A 2D point class!
class Point {
    double x_coord, y_coord;      // Data-members

public:
    Point();                      // Constructors
    Point(double x, double y);

    ~Point();                     // Destructor

    double getX();                // Accessors
    double getY();
    void setX(double x);
    void setY(double y);
};
```

Copying Classes

- Now you want to make a copy of a Point

```
Point p1(3.5, 2.1);  
Point p2(p1);           // Copy p1.
```

- This works, because of the copy-constructor
- Copy-constructors make a copy of another instance
 - Any time an object needs to be copied, this guy does it.
- Copy-constructor signature is:

```
MyClass(MyClass &other); //Copy-constructor
```
- Note that the argument is a reference.
 - Why doesn't `MyClass(MyClass other)` make sense?
 - Hint: default C++ argument-passing is pass-by-value
 - Because `other` would need to be copied with the copy ctor

Required Class Operations

- No copy-constructor in our `Point` declaration!
- C++ requires that all classes must provide certain operations
 - If you don't provide them, the compiler will make them up (following some simple rules)
 - This can lead to problems
- Required operations:
 - At least one non-copy constructor
 - A copy constructor
 - An assignment operator (covered next week)
 - A destructor

More C++ Weirdness

- This calls the copy-constructor:

```
Point p1(19.6, -3.5);  
Point p2(p1); // Copy p1
```

- So does this:

```
Point p1(19.6, -3.5);  
Point p2 = p1; // Identical to p2(p1).
```

- Syntactic sugar for calling the copy-constructor.

- This is different:

```
Point p1(19.6, -3.5);  
Point p2;  
p2 = p1;
```

- Calls the default constructor on `p2`, then does assignment

Local Variables

- Functions can have local variables

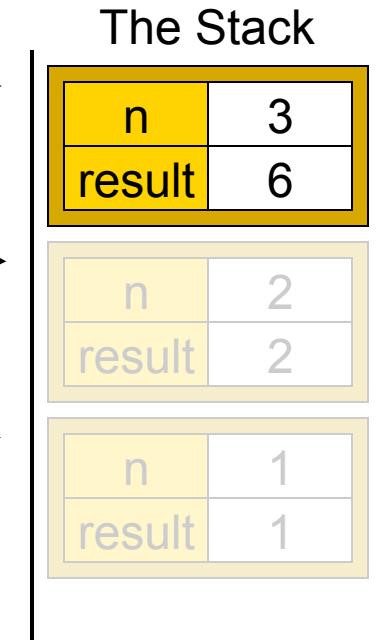
- Variables that exist only within the function

```
int factorial(int n) {  
    int result;  
  
    if (n > 1)  
        result = n * factorial(n - 1);  
    else  
        result = 1;  
  
    return result;  
}
```

- **result** is a local variable
 - Its scope is the **factorial** function
 - Each invocation of **factorial** has its own **result** value

Local Variables and The Stack

- Local variables are stored on “the stack”
 - Each function invocation creates a new “frame” on the stack, with that function’s local variables
 - `factorial(3)`
 - `n = 3, result = 3 * factorial(2)`
 - `factorial(2)`
 - `n = 2, result = 2 * factorial(1)`
 - `factorial(1)`
 - `n = 1, result = 1`
 - When a function returns to the caller, its stack frame is reclaimed



The Stack and The Heap

- Stack space is managed automatically
 - Space for a variable is allocated when it comes into scope
 - Space is reclaimed when it goes out of scope
- Stack space is limited to a (smallish) fixed size!

```
int compute() {  
    // Ten million integers for computation  
    int array[10 * 1024 * 1024];  
    ...  
}
```

- **array** is a local variable... stack overflow!!
- Can allocate much larger chunks of memory from “the heap”
- Must manually allocate and release heap memory

Heap Allocation in C++

- In C we use `malloc()` to allocate memory, and `free()` to release it
- In C++ we use `new` to allocate memory, and `delete` to release it
 - Result is a typed pointer, unlike `malloc()`
 - `new` and `delete` are operators in C++, not functions like `malloc()` / `free()`
- Example:

```
Point *p = new Point(3.5, 2.1);  
p->setX(3.8); // Use the point  
....  
delete p; // Free the point!
```

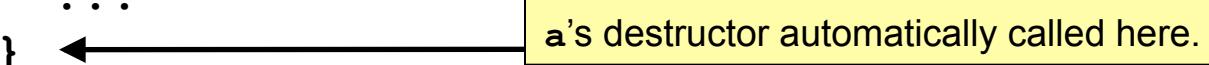
p is a pointer to the Point instance

“member access” operator – use with object pointers

Freeing Memory in C++

■ Local variables: destructor is called *automatically*

```
void doStuff() {  
    Point a(-4.75, 2.3);      // Make a Point  
    ...  
}
```

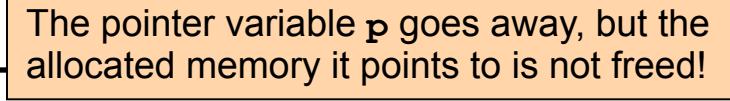


a's destructor automatically called here.

■ With heap-allocated objects, you clean them up!

- The compiler doesn't know when the memory can be reclaimed
- Example:

```
void leakMemory() {  
    Point *p = new Point(-4.75, 2.3);  
    ...  
}
```



The pointer variable p goes away, but the allocated memory it points to is not freed!

- If you don't call **delete p**; then this function will leak!

Allocating Arrays in C++

- Arrays of objects can be created in C++

```
Point tenPoints[10];           // Index 0..9
tenPoints[3].setX(21.78); // Fourth element
```

- Default constructor is called on each element

- The **new** operator can also allocate arrays

```
Point *somePoints = new Point[8]; // Index 0..7
somePoints[5].setY(-14.4); // 6th element
```

- Dynamically allocated arrays must be freed with **delete []** operator!

```
delete[] somePoints; // Clean up my Points
```

- Compiler won't stop you from using **delete**

💣 Funky problems will occur if you don't use **delete []**

More Dynamic Arrays

- Can dynamically allocate arrays of primitive types using **new** as well

```
int numValues = 35;
```

```
int *valArray = new int[numValues];
```

- With primitives, the values are uninitialized!
 - Use a loop to initialize the values.

```
for (int i = 0; i < numValues; i++)
```

```
    valArray[i] = 0;
```

- Free the array using the **delete []** operator

Managing Memory in Classes

- When a class dynamically allocates memory:
 - Do the allocation in the constructor(s)
 - Release memory in the destructor
- Example: Vector of **float** values

```
class FloatVector {  
    // Size of the vector  
    int numElems;  
  
    // Dynamically allocated array of vector's elements  
    float *elems;  
  
public:  
    FloatVector(int n);  
    ~FloatVector();  
};
```

Float-Vectors

■ Definitions – `FloatVector.cc`

```
// Initialize a vector of n floats.
FloatVector::FloatVector(int n) {
    numElems = n;
    elems = new float[numElems];
    for (int i = 0; i < numElems; i++)
        elems[i] = 0;
}

// Clean up the float-vector.
FloatVector::~FloatVector() {
    delete[] elems; // Release the memory for the array.
}
```

Well-Behaved Classes

- Now, **FloatVector** cleans up after itself.

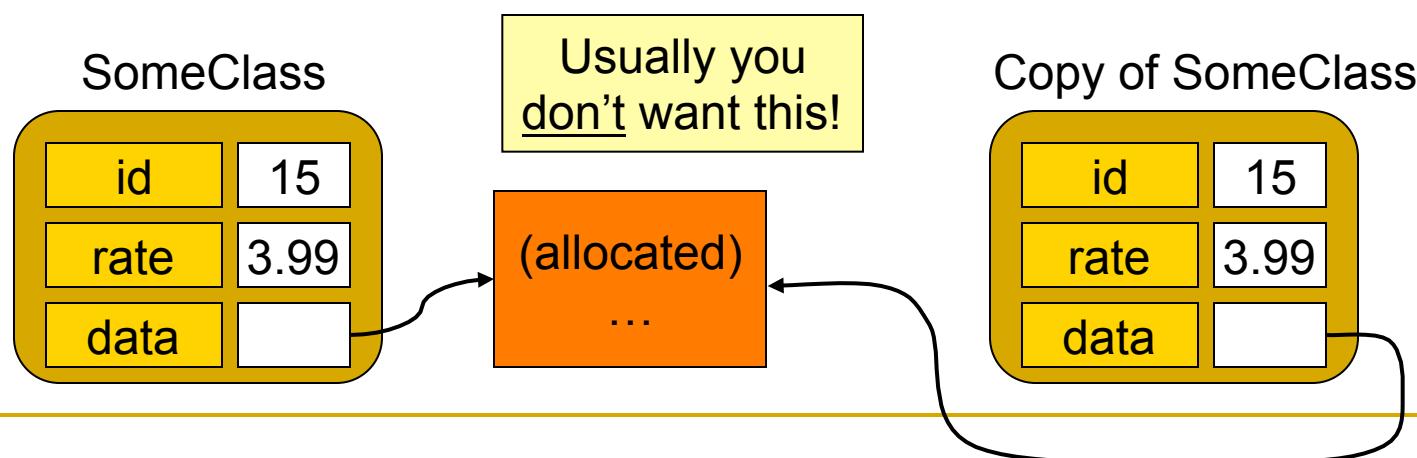
```
float calculate() {  
    FloatVector fvect(100);    // Use our vector  
    ...  
}
```

fvect's destructor automatically called here.

- **fvect** is a local variable
 - Its destructor is automatically called at end of function
- The destructor frees the memory it allocated
- We clearly don't want the default destructor
 - The allocated memory wouldn't get released.

Default Copy-Constructor

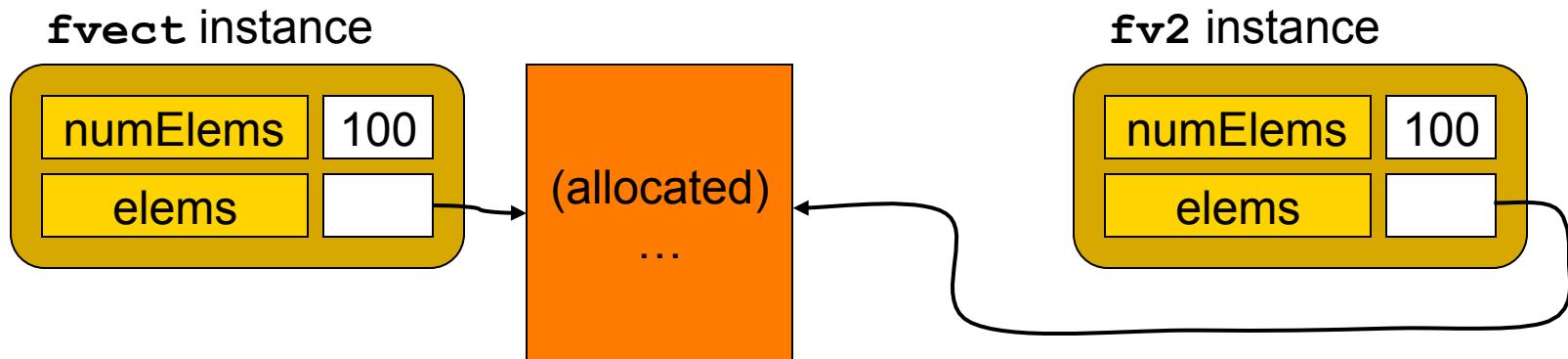
- Compiler will provide a copy-constructor
 - Simply copies values of all internal data-members
 - This is a shallow copy
 - If the data-member is a pointer, only the pointer is duplicated!
 - Now the original and the copy share the same memory



Naughty Copy-Constructors

- Default `FloatVector` copy-constructor is also unacceptable – it performs a shallow copy

```
FloatVector fv2 = fvect; // Same as fv2(fvect)  
fvect.setelem(3, 5.2); // Also changes fv2!
```

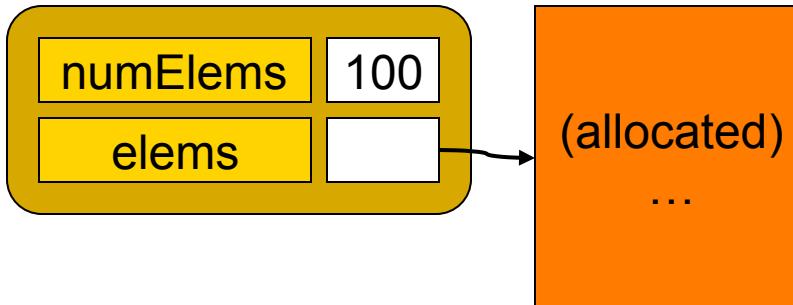


Well-Behaved Copy Constructors

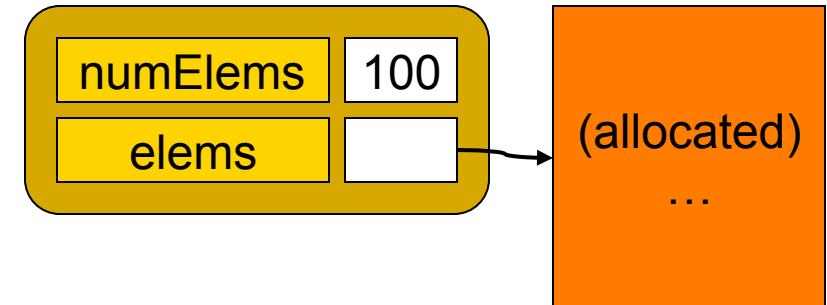
- Create our own copy-constructor; do a deep copy

```
FloatVector::FloatVector(FloatVector &fv) {  
    numElems = fv.numElems;  
    // DON'T just copy the pointer value  
    elems = new float[numElems]; // Allocate space  
    for (int i = 0; i < numElems; i++)  
        elems[i] = fv.elems[i]; // Copy the data over  
}
```

`fvect` instance



`fv2` instance



Assertions!

- Extremely valuable tool in software development

```
#include <cassert> // assert.h in C
```

```
...
```

```
assert(condition);
```

- If *condition* is false, the program will halt.
- Error is displayed, with line number of failure.
- Assertions are debug-only, so you can compile them out!
 - `g++ -DNDEBUG myprog.cc -o myprog`

- Use assertions to catch bugs

- Actual data errors, or logical/flow-control errors

- Get in the habit of using them early and often!

Assertion Tips

- Don't check separate conditions in one `assert` call
 - ❑ `assert(index >= 0 && isValid(value)) ;`
 - ❑ If this fails, which problem happened??

- Use `assert(false)` to check flow-control issues

```
switch (mode) {    // One case for each mode value
    case MODE_ONESHOT:
        ...
    case MODE_REPEAT:
        ...
    default:
        assert(false); // Should never get here!
}
```

- Don't use assertions to check valid scenarios
 - ❑ A user entering bad data is perfectly reasonable to expect

More Assertion Patterns

- Assert that function-arguments satisfy necessary constraints
 - e.g. index-values are in the proper range
 - e.g. input to binary-search function is actually sorted
- Assert that complicated return-values actually match expected results
 - e.g. check that result of a sort is actually in sorted order!
- These two points are called “Design by Contract”
 - Functions have a contract that if the inputs satisfy certain constraints, the outputs will satisfy expected results
- This is built into some languages (e.g. Eiffel)
- For the rest of us, we can use assertions instead

Even More Assertions!

- Use assertions to test loop invariants
- Use assertions to explicitly state and test any other assumptions in your code
 - If your code assumes certain conditions hold, explicitly state and verify them with assertions
 - Assertions also help document these assumptions
- Of course, don't get carried away...

```
int i = 50;  
assert(i == 50);
```

The C++ **bool** Data Type

- C++ adds a new Boolean type
- New keywords: **true** and **false**
- Use this data-type instead of **int** for flags or other Boolean variables
- Comparisons (**> < == != ...**) produce **bool** values

Converting **bools**

- **bool** expressions can be converted to **int**
 - **true** → 1, and **false** → 0
- **ints** and pointers can be converted to **bool**
 - nonzero → **true**, and zero → **false**
- Example:

```
FILE *pFile = fopen("data.txt", "r");  
if (!pFile) { /* Complain */ }
```

- **pFile** is converted to **bool** type
- Best style is to write (**pFile == 0**)
- (This is C-style IO too; use C++ IO if possible.)

The Importance of Good Style

- Complicated problems expose the importance of good coding style
 - It's about understanding things easily
 - Make peripheral issues easy to spot and fix
 - Concentrate on the important issues!
- Most time in software development is spent debugging and maintaining existing code!
 - ...maybe by you, after you've forgotten the details
 - ...*most often* by your coworkers
 - Don't give them reasons to hate you. ☺

Commenting Tips

- Don't repeat the code – explain its purpose.

BAD: `i++;` *// Increment i.*

GOOD: `i++;` *// Skip past this shape.*

- Don't overcomment; don't undercomment.

 - Comments should be clear and concise

 - Focus on commenting subtle or complex code

- Comment every function's purpose, at least briefly.

 - Note any arguments that are invalid for the function

 - Describe the return-value, if it isn't completely obvious

- Also comment every class' purpose, and note any relevant implementation details.

Good Style Tips

- Don't want to spend time on syntax issues
 - Mismatched or missing curly-braces { }
 - Where a function or block begins or ends
 - "What's the scope of this variable??"
- Good naming also facilitates understanding
 - Choose variable / function names that convey the *semantic* meaning
 - A few exceptions to this rule:
 - `i`, `j`, `k` are common loop-variable names
 - Names should be only as long as necessary

Indentation and Brace-Placement

One common style:

```
int someFunc(int x, bool flag) {  
    if (flag) {  
        return x * 2;  
    }  
    else {  
        return x * x;  
    }  
}
```

Another common style:

```
int someFunc(int x, bool flag)  
{  
    if (flag)  
    {  
        return x * 2;  
    }  
    else  
    {  
        return x * x;  
    }  
}
```

- Consistent indentation scheme
- Indentation should be 2, 3, or 4 spaces

Using Spaces

- Put spaces around binary operators

```
// Calculate discriminant of quadratic equation.  
double discriminant = b * b - 4 * a * c;
```

- Put spaces after **if**, **else**, **for**, **while**, **do** keywords

```
if (x < 6) {  
    for (j = 0; j < 23; j++) {  
        a[j] = x * j;  
    }  
}
```

- Put spaces after commas

```
result = someFunction(x, y, r, theta, value);
```

Coding Style

- Bad coding style *will* impact your productivity.
 - It will take you more time to find syntax issues.
- Bad coding style *will* impact your peers.
- Best to get in the habit now!

This Week's Lab

- You will create a Matrix class from scratch
 - Two-dimensional integer matrix
 - The dimensions can be specified in the constructor
- You will need to allocate an array of integers using **new []**, and free it using **delete []**
 - Do these things in the constructors and destructor
- Provide a copy-constructor that makes a completely separate copy of the Matrix
 - No shallow-copy. Allocate the right amount of space in the new Matrix, and copy the values from the original.

Hints For The Lab

- Don't try to allocate a multidimensional array
 - These are complicated, and usually not worth the hassle.
 - You *will* have bugs.
- Allocate a single array with the total number of elements you need (`numRows × numCols`)
 - Use the (row, col) coordinates to calculate the proper array-index (e.g. `index = row × numCols + col`)
- Make sure your calculated index values are in the proper range with assertions
 - `0 ≤ index < numRows × numCols`
- Default constructor creates a 0×0 matrix
 - Remember to initialize the array pointer
 - Initializing to 0 is fine; deleting a 0 pointer is a no-op in C++

Some More Hints

- A few matrix-math operations
 - Make sure the arguments have the appropriate dimensions

```
Matrix m1(5,5);  
Matrix m2(2,2);  
...  
m1.add(m2);      // Trip an assertion
```
- Reuse your work
 - Should only do index-calculation in a very few places (`getelem` and `setelem`, at most)

Next Week!

- Making operators meaningful for your classes
- Getting the performance of references,
without the pain of references