C++ Constructor Insanity (part 1) CSE 333 Spring 2023

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Relevant Course Information

- Exercise 6 released today, due next Monday (4/24)
 - Write a substantive class in C++ (uses a lot of what we will talk about in lecture today)
 - Testable material on midterm, but will count as a "bonus" w.r.t. exercise grading
- Homework 2 due next Thursday (4/27)
 - File system crawler, indexer, and search engine
 - Note: libhw1.a (yours or ours) and the .h files from hw1 need to be in right directory (~yourgit/hw1/)
 - Note: use Ctrl-D to exit searchshell
 - Tip: test on directory of small self-made files
 - Partner confirmation by 4/20 @ 11:59 PST; No exceptions!

Lecture Outline (cont'd from last lecture)

Classes

Class definition syntax (in a . h file):

```
class Name {
  public:
    // public member definitions & declarations go here
    private:
    // private member definitions & declarations go here
  }; // class Name
```

- Members can be functions (methods) or data (variables)
- Class member function definition syntax (in a . cc file):

retType Name::MethodName(type1 param1, ..., typeN paramN) {
 // body statements

(1) *define* within the class definition or (2) *declare* within the class definition and then *define* elsewhere

Class Organization

- It's a little more complex than in C when modularizing with struct definition:
 - Class definition is part of interface and should go in . h file
 - Private members still must be included in definition (!)
 - Usually put member function definitions into companion .cc file with implementation details
 - Common exception: setter and getter methods
 - These files can also include non-member functions that use the class
- Unlike Java, you can name files anything you want
 - Typically Name.cc and Name.h for class Name

Const & Classes

Like other data types, objects can be declared as const:

- Once a const object has been constructed, its member variables can't be changed
- Can only invoke member functions that are labeled const
- You can declare a member function of a class as const
 - This means that it cannot modify the object it was called on
 - The compiler will treat member variables as const inside the function at compile time
 - If a member function doesn't modify the object, mark it const!

Class Definition (.h file)



<pre>#ifndef POINT_H_ #define POINT_H_</pre>
<pre>class Point { public: Point(const int x, const int y); // constructor int get_x() const { return x_; } // inline member function int get_y() const { return y_; } // inline member function double Distance(const Point& p) const; // member function void SetLocation(const int x, const int y); // member function</pre>
<pre>private: int x_; // data member int y_; // data member }; // class Point #endif // POINT_H_</pre>

Class Member Definitions (.cc file)

Point.cc

```
#include <cmath>
#include "Point.h"
Point::Point(const int x, const int y) {
 X = X;
 this->y = y; // "this->" is optional unless name conflicts
}
double Point::Distance(const Point& p) const {
  // We can access p's x and y variables either through the
  // get x(), get y() accessor functions or the x , y private
  // member variables directly, since we're in a member
  // function of the same class.
 double distance = (x - p.get_x()) * (x - p.get_x());
  distance += (y - p.y) * (y - p.y);
  return sqrt(distance);
}
void Point::SetLocation(const int x, const int y) {
  X = X;
 y_ = y;
```

Class Usage (.cc file)

usepoint.cc

```
#include <iostream>
#include <cstdlib>
#include "Point.h"
using namespace std;
int main(int argc, char** argv) {
  Point p1(1, 2); // allocate a new Point on the Stack
  Point p2(4, 6); // allocate a new Point on the Stack
  cout << "p1 is: (" << p1.get x() << ", ";</pre>
  cout << pl.get y() << ")" << endl;
  cout << "p2 is: (" << p2.get x() << ", ";
  cout << p2.get y() << ")" << endl;
  cout << "dist : " << pl.Distance(p2) << endl;</pre>
  return EXIT SUCCESS;
```

Reading Assignment

- *Read* the sections in *C++ Primer* covering class constructors, copy constructors, assignment (operator=), and destructors
 - Ignore "move semantics" for now
 - The table of contents and index are your friends...

struct vs. class



- * In C, a struct can only contain data fields
 - No methods and all fields are always accessible
- * In C++, struct and class are (nearly) the same!
 - Both can have methods and member visibility (public/private/protected)
 - Minor difference: members are default public in a struct and default private in a class
- Common style convention:
 - Use struct for simple bundles of data
 - Use class for abstractions with data + functions

Memory Diagrams for Objects

- An **object** is an instance of a class that maintains its *state* independent from other objects
 - This state is the collection of its data members
 - Conceptually, an object acts like a collection of data fields (plus class metadata)
 - Layout is *not* specified or guaranteed, unlike structs in C
- Drawn out as variables within variables:

```
class Point {
    ...
    private:
    int x_; // data member
    int y_; // data member
  }; // class Point
```

Lecture Outline

Constructors

- Copy Constructors
- Assignment (next lecture)
- Destructors (next lecture)

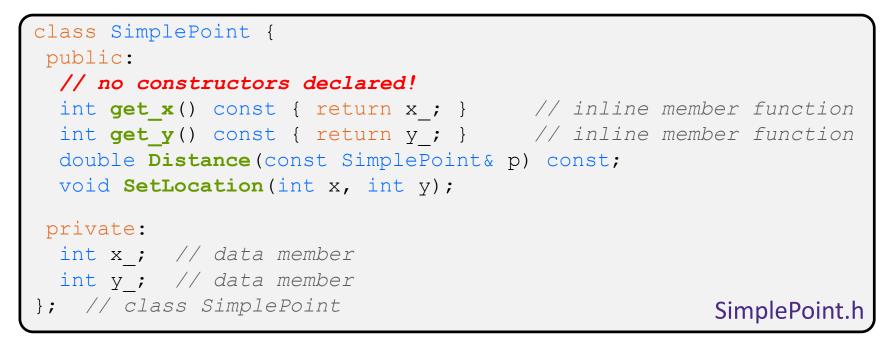
Constructors

- * A constructor (ctor) initializes a newly-instantiated object
 - A class can have multiple constructors that differ in parameters
 - A constructor *must* be invoked when creating a new instance of an object – which one depends on *how* the object is instantiated
- Written with the class name as the method name:

Point(const int x, const int y);

- C++ will automatically create a synthesized default constructor if you have no user-defined constructors
 - Takes no arguments and calls the default ctor on all non-"plain old data" (non-POD) member variables
 - Synthesized default ctor will fail if you have non-initialized const or reference data members

Synthesized Default Constructor Example



#include "SimplePoint.h" SimplePoint.cc ... // definitions for Distance() and SetLocation() int main(int argc, char** argv) { SimplePoint x; // invokes synthesized default constructor return EXIT_SUCCESS; }

Synthesized Default Constructor

 If you define *any* constructors, C++ assumes you have defined all the ones you intend to be available and will *not* add any others

```
#include "SimplePoint.h"
// defining a constructor with two arguments
SimplePoint::SimplePoint(const int x, const int y) {
 X = X;
 y = y;
void Foo() {
  SimplePoint x;
                        // compiler error: if you define any
                        // ctors, C++ will NOT synthesize a
                        // default constructor for you.
  SimplePoint y(1, 2); // works: invokes the 2-int-arguments
                        // constructor
```

Multiple Constructors (overloading)

```
#include "SimplePoint.h"
// default constructor
SimplePoint::SimplePoint() {
 x = 0;
 y = 0;
}
// constructor with two arguments
SimplePoint::SimplePoint(const int x, const int y) {
 X = X;
 y = y;
void Foo() {
  SimplePoint x; // invokes the default constructor
  SimplePoint y(1, 2); // invokes the 2-int-arguments ctor
  SimplePoint a[3]; // invokes the default ctor 3 times
```

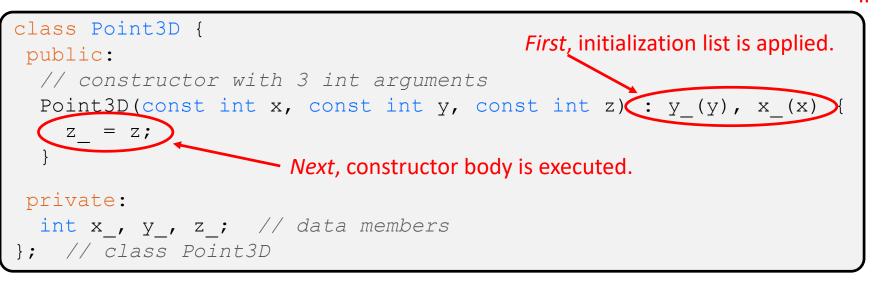
Initialization Lists

- C++ lets you optionally declare an initialization list as part of a constructor definition
 - Initializes fields according to parameters in the list
 - The following two are (nearly) identical:

```
Point::Point(const int x, const int y) {
    x_ = x;
    y_ = y;
    std::cout << "Point constructed: (" << x_ << ",";
    std::cout << y_<< ")" << std::endl;
}</pre>
```

```
// constructor with an initialization list
Point::Point(const int x, const int y) : x_(x), y_(y) {
   std::cout << "Point constructed: (" << x_ << ",";
   std::cout << y_<< ")" << std::endl;
}</pre>
```

Initialization vs. Construction



- Data members in initializer list are initialized in the order they are defined in the class, not by the initialization list ordering (!)
 - Data members that don't appear in the initialization list are *default* initialized/constructed before body is executed
- Initialization preferred to assignment to avoid extra steps
 - Real code should never mix the two styles

Lecture Outline

- Constructors
- * Copy Constructors
- Assignment (next lecture)
- Destructors (next lecture)

Copy Constructors



- C++ has the notion of a copy constructor (cctor)
 - Used to create a new object as a copy of an existing object

```
Point::Point(const int x, const int y) : x_(x), y_(y) { }
// copy constructor
Point::Point(const Point& copyme) {
    x_ = copyme.x_;
    y_ = copyme.y_;
}
void Foo() {
    Point x(1, 2); // invokes the 2-int-arguments constructor
    Point y(x); // invokes the copy constructor
    // could also be written as "Point y = x;"
}
```

Initializer lists can also be used in copy constructors (preferred)

Synthesized Copy Constructor

- If you don't define your own copy constructor, C++ will synthesize one for you
 - It will do a shallow copy of all of the fields (*i.e.*, member variables) of your class
 - Sometimes the right thing; sometimes the wrong thing

```
#include "SimplePoint.h"
... // definitions for Distance() and SetLocation()
int main(int argc, char** argv) {
   SimplePoint x;
   SimplePoint y(x); // invokes synthesized copy constructor
   ...
   return EXIT_SUCCESS;
}
```

When Do Copies Happen?

- The copy constructor is invoked if:
 - You *initialize* an object from another object of the same type:
 - You pass a non-reference object as a value parameter to a function:
 - You return a non-reference object value from a function:

Point	х;	// default ctor
Point	y(x);	// copy ctor
Point	z = y;	// copy ctor

void Foo(Poi	.nt x) { }
Point y; Foo (y);	// default ctor
F.00 (Å) ;	// copy ctor

<pre>Point Foo()</pre>	{	
Point y;		// default ctor
return y;		// copy ctor
}		

Compiler Optimization

- The compiler sometimes uses a "return by value optimization" or "move semantics" to eliminate unnecessary copies
 - Sometimes you might not see a constructor get invoked when you might expect it

```
Point Foo() {
   Point y;   // default ctor
   return y;   // copy ctor? optimized?
}
int main(int argc, char** argv) {
   Point x(1, 2);   // two-ints-argument ctor
   Point y = x;   // copy ctor
   Point z = Foo();  // copy ctor? optimized?
}
```

Extra Exercise #1

- Write a C++ program that:
 - Has a class representing a 3-dimensional point
 - Has the following methods:
 - Return the inner product of two 3D points
 - Return the distance between two 3D points
 - Accessors and mutators for the $x,\,y,$ and z coordinates

Extra Exercise #2

- Write a C++ program that:
 - Has a class representing a 3-dimensional box
 - Use your Extra Exercise #1 class to store the coordinates of the vertices that define the box
 - Assume the box has right-angles only and its faces are parallel to the axes, so you only need 2 vertices to define it
 - Has the following methods:
 - Test if one box is inside another box
 - Return the volume of a box
 - Handles <<, =, and a copy constructor
 - Uses const in all the right places