

CSE 333

Lecture 11 - constructor insanity

Hal Perkins

Paul G. Allen School of Computer Science & Engineering

University of Washington

Administrivia

Exercises:

New exercise out today, due Monday morning

Requires a makefile; slight detour now if there are loose ends from yesterday's sections

Yet another exercise (ex11) on 2nd half of this material out Monday, due Wednesday morning (dynamic allocation!)

Calendar updates

HW2 due a week from yesterday. How's it look?

Midterm a week after that. Review in sections that week.

Administrivia (Monday)

attu down this morning but seems to be back. ex10
deadline moved to 2 pm (enough?)

Sample solution posted once cutoff passes

Next exercise out today, due Wednesday morning

This one is a variation on the one due today. Feel free to adapt/
adopt ideas from that sample solution if useful.

HW2: How's it look?

Today's goals

More details on constructors, destructors, operators

Walk through *complex_example/*

pretty hairy and complex

a lesson on why using a **subset of C++** is often better

new / delete / delete[]

str/ example

Constructors

A *constructor* initializes a newly instantiated object

a class can have multiple constructors (overloading)

they differ in the arguments that they accept

which one is invoked depends on how the object is instantiated

You can write constructors for your object

but if you don't write any, C++ might automatically synthesize a *default constructor* for you

the default constructor is one that takes no arguments and that calls default constructors on all non-POD* member variables (*POD = "Plain Old Data")

C++ does this iff your class has no const or reference data members, and no other user-defined constructors

Example of synthesis

see SimplePoint.cc, SimplePoint.h

Constructors, continued

You might choose to define multiple constructors:

```
Point::Point() {
    x_ = 0;
    y_ = 0;
}

Point::Point(const int x, const int y) {
    x_ = x;
    y_ = y;
}

void foo() {
    Point x;      // invokes the default (argument-less) constructor
    Point a[3];  // invokes the default constructor 3 times
    Point y(1,2); // invokes the two-int-arguments constructor
}
```

Constructors, continued

You might choose to define only one:

```
Point::Point(const int x, const int y) {
    x_ = x;
    y_ = y;
}

void foo() {
    // Compiler error; if you define any constructors, C++ will
    // not automatically synthesize a default constructor for you.
    Point x;

    // Works.
    Point y(1,2); // invokes the two-int-arguments constructor
}
```


Initialization lists

Optionally, C++ lets you declare an initialization list as part of your constructor declaration

initializes fields according to parameters in the list

the following two are (nearly) equivalent:

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

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

Initialization vs. construction

```
#ifndef _POINT_H_
#define _POINT_H_

class Point {
public:
    Point(const int x, const int y, const int z)
        : x_(x), y_(y) {
        z_ = z;
    }

private:
    int x_, y_, z_;
}; // class Point

#endif // _POINT_H_
```

Initialization vs. construction

first,
initialization
list is
applied

```
#ifndef _POINT_H_
#define _POINT_H_

class Point {
public:
    Point(const int x, const int y, const int z)
        : x_(x), y_(y) {
        z_ = z;
    }

private:
    int x_, y_, z_;
}; // class Point

#endif // _POINT_H_
```

Initialization vs. construction

```
#ifndef _POINT_H_
#define _POINT_H_

class Point {
public:
    Point(const int x, const int y, const int z)
        : x_(x), y_(y) {
        z_ = z;
    }

private:
    int x_, y_, z_;
}; // class Point

#endif // _POINT_H_
```

next,
constructor
is executed



z_ = z;

Initialization vs. construction

When a new object is created using some constructor:

- first, the initialization list is applied to members

 - in the order that those members appear within the class definition, not the order in the initialization list (!)

 - All other non-POD members are initialized by default constructors

- next, the constructor is invoked, and any statements within it are executed

Prefer initialization to assignment

- An object must already be initialized by a constructor before it can be (re-)assigned - initializer avoids two separate steps

Copy constructors

C++ has the notion of a **copy constructor**

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) { }

Point::Point(const Point &copyme) { // copy constructor
    x_ = copyme.x_;
    y_ = copyme.y_;
}

void foo() {
    // invokes the two-int-arguments constructor
    Point x(1,2);

    // invokes the copy constructor to construct y as a copy of x
    Point y(x); // could also write as "Point y = x;"
}
```

When do copies happen?

The copy constructor is invoked if:

you pass an object as a parameter to a call-by-value function

```
void foo(Point x) { ... }  
  
Point y; // default cons.  
foo(y); // copy cons.
```

you return an object from a function

```
Point foo() {  
    Point y; // default cos.  
    return y; // copy cons.  
}
```

you initialize an object from another object of the same type

```
Point x; // default cons.  
Point y(x); // copy cons.  
Point z = y; // copy cons.
```

But...the compiler is smart...

It 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 constructor.  
    return y; // copy constructor? optimized?  
}  
  
Point x(1,2); // two-ints-argument constructor.  
Point y = x; // copy constructor.  
Point z = foo(); // copy constructor? optimized?
```


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

see SimplePoint.cc, SimplePoint.h

assignment != construction

The “=” operator is the assignment operator

assigns values to an existing, already constructed object

you can overload the “=” operator

```
Point w;           // default constructor.  
Point x(1,2);     // two-ints-argument constructor.  
Point y = w;      // copy constructor.  
y = x;           // assignment operator.
```

Overloading the “=” operator

You can choose to overload the “=” operator

but there are some rules you should follow

```
Point &Point::operator=(const Point& rhs) {
    if (this != &rhs) { // always check against this
        x_ = rhs.x_;
        y_ = rhs.y_;
    }
    return *this; // always return *this from =
}

Point a; // default constructor
a = b = c; // works because "=" returns *this
a = (b = c); // equiv to above, as "=" is right-associative
(a = b) = c; // works because "=" returns a non-const
```

Synthesized assignment oper.

If you don't overload the assignment operator, 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

see SimplePoint.cc, SimplePoint.h

Destructors

C++ has the notion of a **destructor**

invoked automatically when a class instance is deleted / goes out of scope, etc., even via exceptions or other causes

place to put cleanup code - free any dynamic storage or other resources owned by the object

standard C++ idiom for managing dynamic resources

Slogan: “Resource Acquisition Is Initialization” (RAII)

```
Point::~~Point() { // destructor
    // do any cleanup needed when a Point object goes away
    // (nothing to do here since we have no dynamic resources)
}
```

*see complex_example/**

Rule of Three

If you define any of:

Destructor

Copy Constructor

Assignment (operator=)

Then you should normally define all three

Members, friends, or not?

Operators can be implemented in several ways. Advice:

Prefer non-member, non-friend functions for operator overloading in many situations (esp. binary operators)

(Argument symmetry: `operator+(c,d)` instead of `c.operator+(d)`)

Use friend for functions that can't or shouldn't be members of the class (overloaded stream functions, symmetric operators, etc.), if they need to use private object data or functions

Use member functions for things that need to update or access object state (`=`, `+=`, `get_x()`, etc.) or if they naturally are operations on a single object (`matrix.invert()`)

Dealing with the insanity

C++ style guide tip

if possible, disable the copy constr. and assignment operator

not possible if you want to store objects of your class in an STL container, unfortunately

```
class Point {
public:
    Point(int x, int y) : x_(x), y_(y) { }

private:
    // disable copy cons. and "=" by declaring but not defining
    Point(Point &copyme);
    Point &operator=(Point &rhs);
};

Point w;           // compiler error
Point x(1,2);     // OK
Point y = x;      // compiler error
x = w;            // compiler error
```

Disabling copy ctr/= in C++11

C++11 adds new syntax to do this directly

better choice in C++11 code

```
class Point {
public:
    Point(int x, int y) : x_(x), y_(y) { }

    // declare copy cons. and "=" as deleted (C++11)
    Point(Point &copyme) = delete;
    Point &operator=(Point &rhs) = delete;
};

Point w;           // compiler error
Point x(1,2);     // OK
Point y = x;      // compiler error
x = w;            // compiler error
```

Dealing with the insanity

C++ style guide tip

if you disable them, then you should instead probably have an explicit “CopyFrom” function

```
class Point { Point.cc, h
public:
    Point::Point(int x, int y) : x_(x), y_(y) { }
    void CopyFrom(const Point &copy_from_me);

private:
    // disable copy cons. and "=" by declaring but not defining
    Point(const Point &copyme);
    Point &operator=(const Point &rhs);
};
```

```
Point x(1,2);           // OK
Point y(3,4);           // OK
x.CopyFrom(y);         // OK
```

sanepoint.cc

new

To allocate on the heap using C++, you use the “new” keyword instead of the “malloc()” stdlib.h function

you can use new to allocate an object

you can use new to allocate a primitive type

To deallocate a heap-allocated object or primitive, use the “delete” keyword instead of the “free()” stdlib.h function

if you’re using a legacy C code library or module in C++

if C code returns you a malloc()’d pointer, use free() to deallocate it

never free() something allocated with new

never delete something allocated with malloc()

new / delete

see heappoint.cc

C++11 nullptr

C and C++ have long used `NULL` as a pointer value that references nothing

C++11 introduced a new literal for this: `nullptr`

- New reserved word

- Interchangeable with `NULL` for all practical purposes

- But it has type T^* for any/every T , and is not an integer value

- Avoids funny edge cases (see C++ references for details)

- Still can convert to/from integer 0 for tests, assignment, etc.

Advice: use `nullptr` in modern C++ code (but `NULL` will also be around in old code for a long time)

Dynamically allocated arrays

To dynamically allocate an array

```
use "type *name = new type[size];"
```

To dynamically deallocate an array

```
use "delete[] name;"
```

it is an error to use "delete name;" on an array

the compiler probably won't catch this, though!!!

it can't tell if it was allocated with "new type[size];" Or "new type;"

see arrays.cc

malloc vs. new

	malloc()	new
what is it	a function	an operator and keyword
how often used in C	often	never
how often used in C++	rarely	often
allocates memory for	anything	arrays, structs, objects, primitives
returns	a (void *) <i>(needs a cast)</i>	appropriate pointer type <i>(doesn't need a cast)</i>
when out of memory	returns NULL	throws an exception
deallocating	free	delete or delete[]

Overloading the “=” operator

Remember the rules we should follow?

here’s why; hugely subtle bug

```
Foo::Foo(int val) { Init(val); }
Foo::~~Foo() { delete foo_ptr_; }

void Foo::Init(int val) { foo_ptr_ = new int; *foo_ptr_ = val; }

Foo &Foo::operator=(const Foo& rhs) {
    // bug...we forgot our "if (self == &rhs) { ... }" guard
    delete foo_ptr_;
    Init(*(rhs.foo_ptr_)); // might crash here (see below)
    return *this;         // always return *this from =
}

void bar() {
    Foo a(10); // default constructor
    Foo b(20); // default constructor
    a = a;    // crash above; dereference delete'd pointer!!
}
```

Overloading the “=” operator

Remember the rules we should follow?

This is yet another reason for disabling the assignment operator, when possible

*see str/**

Exercise 1

Modify your 3D Point class from lec10 exercise 1

- disable the copy constructor and assignment operator

- attempt to use copy & assign in code, and see what error the compiler generates

- write a CopyFrom() member function, and try using it instead

Exercise 2

Write a C++ class that:

- is given the name of a file as a constructor argument

- has a “GetNextWord()” method that returns the next whitespace or newline-separated word from the file as a copy of a “string” object, or an empty string once you hit EOF.

- has a destructor that cleans up anything that needs cleaning up

Exercise 3

Write a C++ function that:

- uses `new` to dynamically allocate an array of strings

- and uses `delete[]` to free it

- uses `new` to dynamically allocate an array of pointers to strings

- and then iterates through the array to use `new` to allocate a string for each array entry and to assign to each array element a pointer to the associated allocated string

- and then uses `delete` to delete each allocated string

- and then uses `delete[]` to delete the string pointer array

(whew!)

See you on Wednesday!