CSE 333
Lecture 11 - constructor insanity

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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.

CSE333 lec 11 C++.3 // 10-20-17 // Perkins
Example of synthesis

see SimplePoint.cc, SimplePoint.h
Constructors, continued

You might choose to define multiple constructors:

```cpp
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:

```cpp
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:

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

```cpp
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

```cpp
#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

```cpp
#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_
```

first, initialization list is applied
Initialization vs. construction

```cpp
#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
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

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

- you return an object from a function
  
  ```cpp
  Point foo() {
    Point y;    // default cons.
    return y;  // copy cons.
  }
  ```

- you initialize an object from another object of the same type
  
  ```cpp
  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

```cpp
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)

```cpp
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
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 {
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
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
<table>
<thead>
<tr>
<th></th>
<th><code>malloc()</code></th>
<th><code>new</code></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>what is it</strong></td>
<td>a function</td>
<td>an operator and keyword</td>
</tr>
<tr>
<td><strong>how often used in C</strong></td>
<td>often</td>
<td>never</td>
</tr>
<tr>
<td><strong>how often used in C++</strong></td>
<td>rarely</td>
<td>often</td>
</tr>
<tr>
<td><strong>allocates memory for</strong></td>
<td>anything</td>
<td>arrays, structs, objects, primitives</td>
</tr>
<tr>
<td><strong>returns</strong></td>
<td>a (void *)</td>
<td>appropriate pointer type</td>
</tr>
<tr>
<td></td>
<td>(needs a cast)</td>
<td>(doesn’t need a cast)</td>
</tr>
<tr>
<td><strong>when out of memory</strong></td>
<td>returns NULL</td>
<td>throws an exception</td>
</tr>
<tr>
<td><strong>deallocating</strong></td>
<td>free</td>
<td>delete or delete[ ]</td>
</tr>
</tbody>
</table>
Overloading the “=” operator

Remember the rules we should follow?

here’s why; hugely subtle bug

```cpp
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’ed 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-separate 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!