C++ Constructor Insanity

CSE 333

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Lecture Outline

- **Constructors**
- Copy Constructors
- Assignment
- Destructors
- An extended example

Constructors

- A constructor (ctor) initializes a newly-instantiated object
  - A class can have multiple constructors that differ in parameters
    - Which one is invoked depends on *how* the object is instantiated

- Written with the class name as the method name:

```
Point(const int x, const int y);
```

Default Constructor

- The default constructor does not take any parameters

```
Point();
```

- C++ will automatically synthesize a default constructor if you have *no* user-defined constructors
  - Calls the default ctors on all non-"plain old data" (non-POD) member variables
  - Will fail if you have non-initialized const or reference data members

Synthesized Default Constructor

```
class SimplePoint {
 public:
  // no constructors declared!
  int get_x() const { return x_; }      // inline member function
  int get_y() const { return y_; }      // inline member function
  double Distance(const SimplePoint& p) const;
  void SetLocation(const int x, const int y);

 private:
  int x_;  // data member
  int y_;  // data member
};  // class SimplePoint
```

SimplePoint.h

```
#include "SimplePoint.h"

... // definitions for Distance() and SetLocation()

int main(int argc, char** argv) {
  SimplePoint x;  // invokes synthesized default constructor
  return 0;
}
```

SimplePoint.cc

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 "Point.h"

// defining a constructor with two arguments
Point::Point(const int x, const int y) {
  x_ = x;
  y_ = y;
}

void foo() {
  Point x;          // compiler error:  if you define any
                    // ctors, C++ will NOT synthesize a
                    // default constructor for you.

  Point y(1, 2);    // works:  invokes the 2-int-arguments
                    // constructor
}
```

Multiple Constructors (overloading)

```
#include "Point.h"

// default constructor
Point::Point() {
  x_ = 0;
  y_ = 0;
}

// constructor with two arguments
Point::Point(const int x, const int y) {
  x_ = x;
  y_ = y;
}

void foo() {
  Point x;          // invokes the default constructor
  Point a[3];       // invokes the default ctor 3 times
                    //   (fails if no default ctor)
  Point y(1, 2);    // invokes the 2-int-arguments ctor
}
```

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;
}
```

```
// 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;
}
```

Initialization vs. Construction

```
class Point3D {
 public:
  // constructor with 3 int arguments
  Point3D(const int x, const int y, const int z) : y_(y), x_(x) {
    z_ = z;
  }

 private:
  int x_, y_, z_;  // data members
};  // class Point3D
```

First, initialization list is applied.

Next, constructor body is executed.

Initialization vs. Construction

```
class Point3D {
 public:
  // constructor with 3 int arguments
  Point3D(const int x, const int y, const int z) : y_(y), x_(x) {
    z_ = z;
  }

 private:
  int x_, y_, z_;  // data members
};  // class Point3D
```

- 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 of default initialization (construction) followed by assignment
  - (and no, real code should never mix the two styles this way ☺)

Initialization vs. Construction

- The difference between initialization and assignment start to matter when we have:
  - objects as member variables
  - const member variables
  - reference member variables

Triangle.h

```
class Triangle {
 public:
  Triangle(const Point& p1, const Point& p2, const Point& p3)
    : p1_(p1.get_x(), p1.get_y()) {
    // constructor body
  }

 private:
  Point p1_, p2_, p3_;
  const Point kOrigin;
};  // class Triangle
```

2-parameter constructor called on `p1_`, but default constructor called on `p2_`, `p3_`, and `kOrigin` – is the default constructor's behavior what we want?

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- Constructors
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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)

When Do Copies Happen?

- The copy constructor is invoked if:
  - You *initialize* an object from another object of the same type:

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

  - You pass a non-reference object as a value parameter to a function:

```
void foo(Point x) { ... }

Point y;        // default ctor
foo(y);         // copy ctor
```

  - You return a non-reference object value from a function:

```
Point foo() {
  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?
}

Point x(1, 2);      // two-ints-argument ctor
Point y = x;        // copy ctor
Point z = foo();    // copy ctor? 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

```
#include "SimplePoint.h"

int main(int argc, char** argv) {
  SimplePoint x;
  SimplePoint y(x);  // invokes synthesized copy constructor
  ...
  return 0;
}
```

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Assignment != Construction

- "=" is the assignment operator
  - Assigns values to an *existing, already constructed* object

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

  - How can you tell the difference between assignment `operator=` and a copy constructor that uses =?
    - Answer: are you creating/initializing a new object? If so, it's a copy constructor; if you are just updating an existing object it's assignment

Poll Everywhere

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- How many of each method gets called?
  - Default constructor
  - Two-parameter constructor
  - Copy constructor
  - Assignment operator

Have a great weekend!

```
class Triangle {
 public:
Triangle(const Point& p1, const Point& p2, const Point& p3)
    : p1_(p1.get_x(), p1.get_y()) {
    // constructor body
  }

 private:
  Point p1_, p2_, p3_;
  const Point kOrigin;
};  // class Triangle
```

Having a constant as a member variable is not a good design – better to have only one copy of a constant!

Overloading the "=" Operator

- You can choose to define the "=" operator
  - But there are some rules you should follow:

```
Point& Point::operator=(const Point& rhs) {
  if (this != &rhs) {  // (1) always check against this
    x_ = rhs.x_;
    y_ = rhs.y_;
  }
  return *this;        // (2) always return *this from op=
}

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

Synthesized Assignment Operator

- If you don't define 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

```
#include "SimplePoint.h"

... // definitions for Distance() and SetLocation()

int main(int argc, char** argv) {
  SimplePoint x;
  SimplePoint y(x);
  y = x;              // invokes synthesized assignment operator
  return 0;
}
```

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Destructors

- C++ has the notion of a destructor (dtor)
  - Invoked automatically when a class instance is deleted, goes out of scope, etc. (even via exceptions or other causes!)
  - Place to put your 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)
}
```

Poll Everywhere

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- How many times does the ***destructor*** get invoked?
  - Assume `Point` with everything defined (ctor, cctor, =, dtor)
  - Assume no compiler optimizations

```
Point PrintRad(Point& pt) {
  Point origin(0, 0);
  double r = origin.Distance(pt);
  double theta = atan2(pt.get_y(), pt.get_x());
  cout << "r = " << r << endl;
  cout << "theta = " << theta << " rad" << endl;
  return pt;
}

int main(int argc, char** argv) {
  Point pt(3, 4);
  PrintRad(pt);
  return 0;
}
```

A. 1

B. 2

C. 3

D. 4

E. We're lost…

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Complex Example Walkthrough

See:

`Complex.h`

`Complex.cc`

`testcomplex.cc`

- (Some details like friend functions and namespaces are explained in more detail next lecture, but ideas should make sense from looking at the code and explanations in *C++ Primer*.)

Extra Exercise #1

- Modify your Point3D class from Lec 10 Extra #1
  - Disable the copy constructor and assignment operator
  - Attempt to use copy & assignment in code and see what error the compiler generates
  - Write a `CopyFrom()` member function and try using it instead
    - (See details about `CopyFrom()` in next lecture)

Extra 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