C++ Classes, Constructors and Copies (oh my!)

CSE 333 Autumn 2025

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Vibe check

- PollEv.com/naomila

- How are you feeling about C++ right about now?

Administrivia

- Naomi's office hours moving to Wednesdays 2:30-3:30p
- No exercise 9 yet (out on Monday)
- A bunch of deadlines coming up in the next few weeks, plan ahead!!!
  - EX9 (it's a big one), EX10, HW2, midterm

Lecture Outline

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

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

- 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
  - These files can also include non-member functions that use the class
  - Common exception: setter and getter methods

- Unlike Java, you can name files anything you want
  - Typically `Name.cc` and `Name.h` for `class Name`

Big ol' example

Point.h

```
#ifndef POINT_H_
#define POINT_H_

class Point {
 public:
  Point(const int x, const int y);
  int get_x() const { return x_; }
  int get_y() const { return y_; }
  double Distance(const Point& p) const;
  void SetLocation(const int x,
                   const int y);

 private:
  int x_;
  int y_;
};

#endif  // POINT_H_
```

Point.cc

```
#include <cmath>
#include "Point.h"

// NOTE: THIS FILE HAS WEIRD AND BAD CODING STYLE!
// We just want to illustrate some language features for you (:

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

double Point::Distance(const Point& p) const {
  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;
}
```

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 if 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 Usage (. cc file)

usepoint.cc

```
#include <iostream>
#include <cstdlib>
#include "Point.h"

using namespace std;

int main(int argc, char** argv) {
  // allocate two Points on the Stack, call the default ctor for each
  Point p1(1, 2);
  Point p2(4, 6);
  cout << "p1 is: (" << p1.get_x() << ", ";
  cout << p1.get_y() << ")" << endl;

  cout << "p2 is: (" << p2.get_x() << ", ";
  cout << p2.get_y() << ")" << endl;

  cout << "dist : " << p1.Distance(p2) << endl;
  return EXIT_SUCCESS;
}
```

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Constructors

- A constructor (ctor) initializes a newly-instantiated object
  - A class can have multiple constructors that differ in parameter count and type
  - Written with the class name as the method name and **no return type** (**!**) :

```
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
  - Calls the default ctors on all non-"plain old data" (non-POD) member variables
  - Leaves the "plain old data" uninitialized (**!**)
  - 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 "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 a[3];      // invokes the default ctor 3 times
                         //   (fails if no default ctor)
  SimplePoint 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.

- 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 ☺)

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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 p1(1, 2);  // invokes the 2-int-arguments constructor

  Point p2(p1);    // invokes the copy constructor
                   // could also be written as "Point p2 = p1;"
}
```

  - 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 p1;       // default ctor
Point p2(p1);    // copy ctor
Point p3 = p2;   // copy ctor
```

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

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

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

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

```
Point foo() {
  Point pt;     // default ctor
  return pt;    // 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 pt;          // default ctor
  return pt;         // copy ctor? optimized?
}

Point pt1(1, 2);     // two-ints-argument ctor
Point pt2 = pt1;     // copy ctor
Point pt3 = 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"

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

int main(int argc, char** argv) {
  SimplePoint pt1;
  SimplePoint pt2(pt1);  // invokes synthesized copy constructor
  ...
  return 0;
}
```

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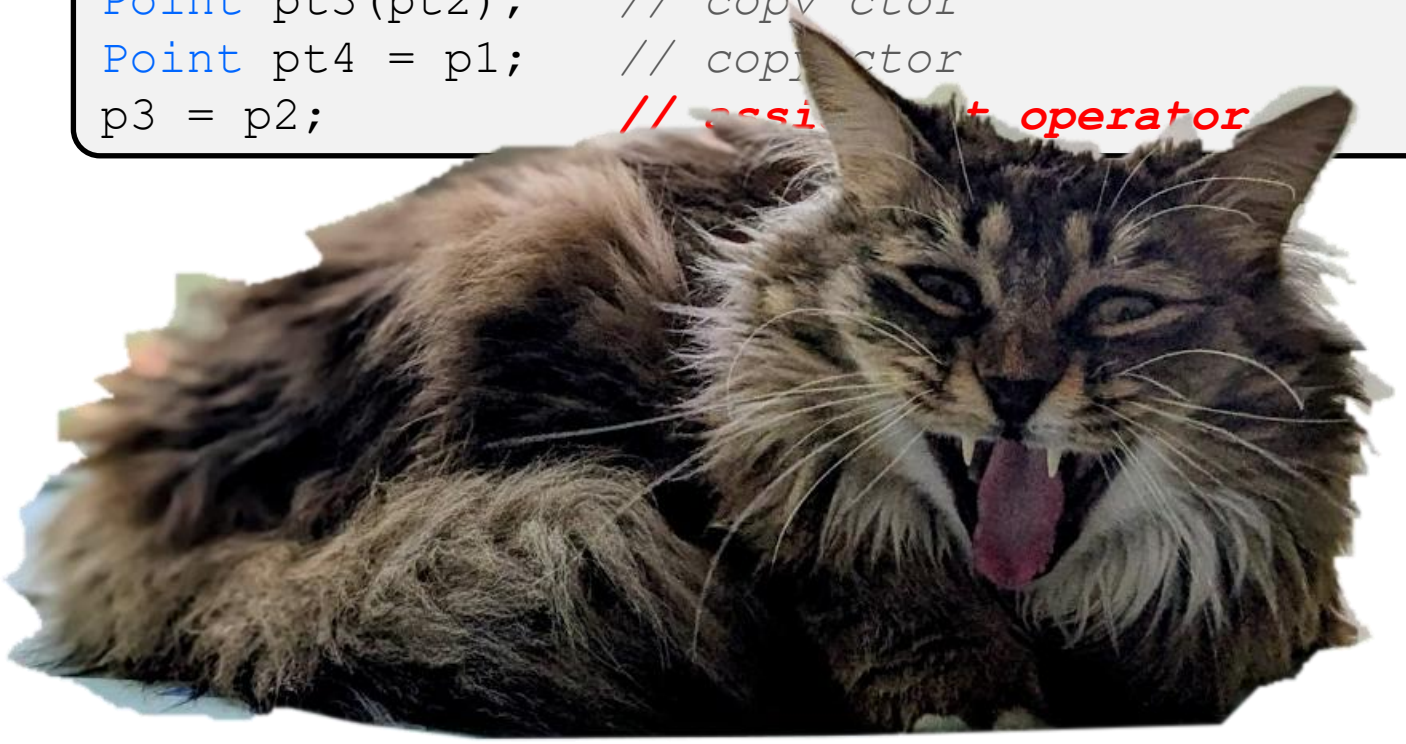
Assignment ain't Construction

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

```
Point pt1;          // default ctor
Point pt2(1, 2);    // two-ints-argument ctor
Point pt3(pt2);     // copy ctor
Point pt4 = p1;     // copy ctor
p3 = p2;            // assignment operator
```



Assignment ain't Construction

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

```
Point pt1;          // default ctor
Point pt2(1, 2);    // two-ints-argument ctor
Point pt3(pt2);     // copy ctor
Point pt4 = p1;     // copy ctor
p3 = p2;            // 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

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 pt1;
  SimplePoint pt2(pt1);
  pt2 = pt1;            // 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)
}
```

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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