Advanced Programming Concepts with C++ CSI2372 – Fall 2017

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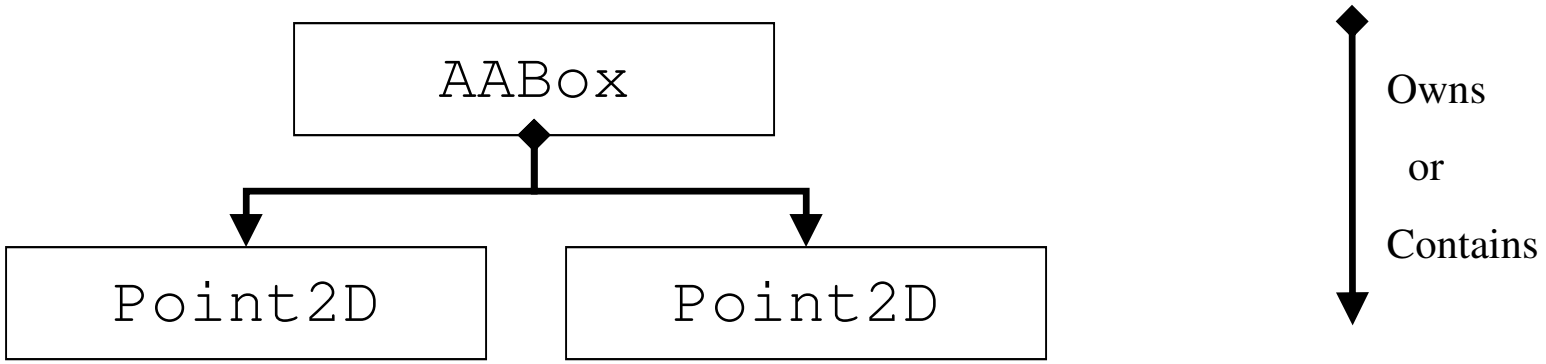
This Lectures

OO

- **Object-oriented design**
  - Class relationships: aggregation, generalization and inheritance, Ch. 15.1, 15.2, 15.5
  - Pointer attributes and this pointer, 13.5
  - Copy construction and assignment, Ch. 13.1

Class Relationships – Aggregation

- **The "has a" relationship**
  - Containment relation, e.g., AABox contains two Point2D




```
class AABox {
  Point2D d_lowerLeft;
  Point2D d_upperRight;
public:
  AABox( Point2D _lowerLeft, Point2D _upperRight ); …
};
```

Example

- Make sure all necessary constructors exist
- Make use of initializer lists

```
class AABox {
  AABox( Point2D _lowerLeft, Point2D _upperRight ) :
    d_lowerLeft(_lowerLeft), d_upperRight(_upperRight)
{} …
  bool inside( const Point2D& _pt ) const;
};
```

- What if an object is to be default initialized but has no default argument constructor?

Example Continued

– Assume AABox has no default constructor and no reasonable dummy argument

```
class Triangle {
  Point2D d_vA, d_vB, d_vC;
  AABox d_bbox;
public:
  Triangle( const Point2D& _vA, const Point2D& _vB,
            const Point2D& _vC );
};

Triangle::Triangle( const Point2D& _vA, const Point2D& _vB,
                    const Point2D& _vC )
: d_vA( _vA ), d_vB( _vB ), d_vC( _vC ), d_bbox( ? ) {
}
```

Aside: Syntax Pointer to Object

- **Special syntax for accessing attributes and methods through pointer to objects**

```
class Triangle { …
public:
  AABox* d_bbox;
  Triangle( const Point2D& _vA, const Point2D& _vB,
            const Point2D& _vC )
  : d_vA( _vA ), d_vB( _vB ), d_vC( _vC ), d_bbox(0) {}
};

Point2D p2D;
d_bbox.inside( p2D );
(*d_bbox).inside( p2D );
d_bbox->inside( p2D );
```

Aggregation Summary

  - Contained objects must be initialized in a initializer list or must have a default constructor
    - Pointers must be initialized but not the object pointed to
    - C++11 allows the use of in-class initializers which is preferable to initializer lists for each constructor
- **Internal aggregation**
  - Objects constructs (and destructs) the objects which it owns
- **External aggregation**
  - Contained objects are constructed elsewhere and a reference or pointer is passed in

Aggregation with Pointers

- **Internal aggregation means an object constructs the object which it owns during a constructor**
- **It needs to destruct the owned object in destructor**

```
class Triangle { …
  AABox* d_bbox;
public:
  …
  ~Triangle( );   // clean up our objects
};

Triangle::~Triangle() {
  delete d_bbox;
}
```

Defining our own Copy Constructor

- **Default copy constructor makes a shallow copy**

```
class Triangle { …
  AABox* d_bbox;
public:
  …
  Triangle( const Triangle& oTri );
};
// shallow copy ctor - same as default
Triangle::Triangle( const Triangle& oTri )
    : d_bbox( oTri.d_bbox ) {}
```

- **Shallow copy with pointer types is nearly always wrong**
  - Change the copy constructor to make a deep copy

Deep Copy

```
// deep copy ctor - internal aggregation
Triangle::Triangle( const Triangle& oTri )
    : d_bbox( 0 ) {
  d_bbox = new AABox( oTri.d_bbox );
}
```

- **Leads to rule of 3:**
  - if a class needs a non-default copy constructor, it also needs a non-default destructor and assignment operator (to be discussed later)
  - Rule of 3 has become rule of 5 in some cases with C++11 for move ctor and move assignment

Class Relationships – Generalization and Inheritance

- **Generalization and Inheritance**
  - The “is a” relationship
  - Inheritance from a general class to a more specific one
- **Same concept than in Java**
  - Child (or derived) class inherits methods and attributes from the parent (or base) class
- **Example:**
  - Class `Vector2D` is an extension of class `Point2D`

```
class Vector2D : public Point2D;
```

- **Difference to Java**
  - Multiple base classes (inheritance)
  - Use of access modifiers

Full Syntax

- **Specification of a base class:**

```
base-spec :
: base-list
base-list :
base-specifier
base-list , base-specifier
base-specifier :
complete-class-name
virtual access-specifier_opt complete-class-name
access-specifier virtual_opt complete-class-name
access-specifier :
private
protected
public
```

Effect of Access Modifiers

- **Default access modifier for inheritance of classes is private**
- **Default access modifier for inheritance of structures is public**

Access in a base class	Access in a derived class		
	Public Inheritance	**Protected Inheritance**	**Private Inheritance**
`private`	*Not accessible*	*Not accessible*	*Not accessible*
`protected`	`protected`	`protected`	`private`
`public`	`public`	`protected`	`private`

Inheritance Example
Initializer List Problem

```
class Point2D {
protected:
  double d_x;
  double d_y;
public:
  Point2D(double _x=0.0, double _y=0.0) : d_x(_x), d_y(_y) {}
  Point2D Point2D::min( const Point2D& _oPoint ) const {
      return Point2D((d_x < _oPoint.d_x)?d_x:_oPoint.d_x,
                     (d_y < _oPoint.d_y)?d_y:_oPoint.d_y); }
};
class Vector2D : public Point2D {
  double d_length;
public:
  Vector2D(double _x=0.0, double _y=0.0) : d_x(_x), d_y(_y)
    { d_length = std::sqrt(dot(*this));}
  double dot( const Vector2D& _oVect ) const;
};
```

Protected Inheritance Example Access Problem

```
class Vector2D : protected Point2D {
  double d_length;
public:
  Vector2D(double _x=0.0, double _y=0.0) : d_x(_x), d_y(_y)
    { d_length = std::sqrt(dot(*this));}
  void dot( const Vector2D& _oVec ) const;
};

…
Vector2D v2DA( 3, 2 );
Vector2D v2DB( 1, 1 );
v2DB.min( p2D );
…
```

Aside: Preventing Class Derivation

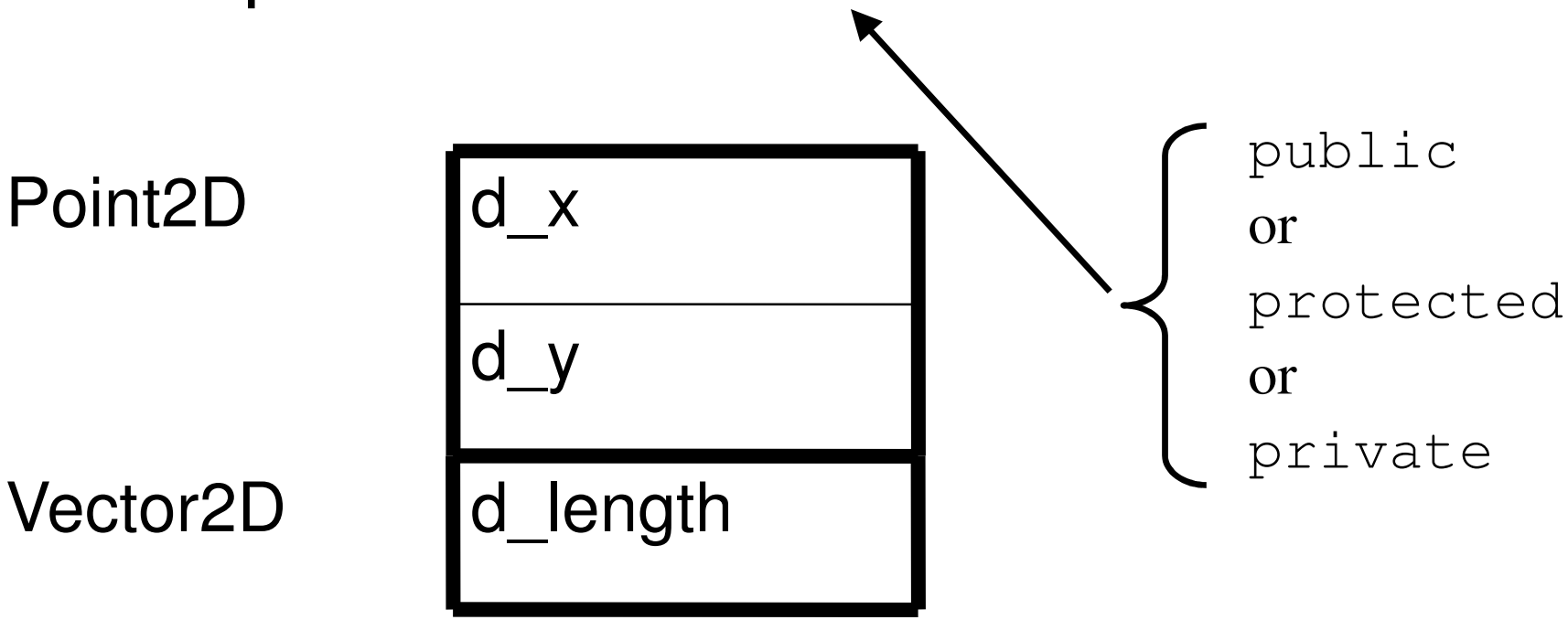
- **Classes can be declared final in order to prevent the class from being used as a base class**

```
class NoBase final {
  …
};

class DerivedA : NoBase {
  …
};

class DerivedB : public NoBase {
  …
};
```

Layout of a Derived Class

- Object of derived class contains a base class object
- Methods of both classes can be applied (as long as access modifiers are respected)

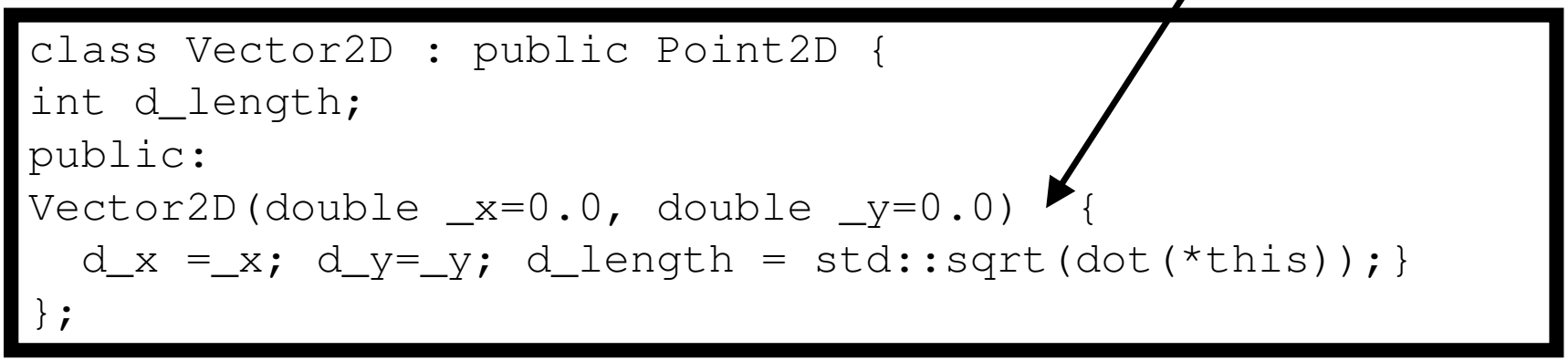
- **Example:** `class Vector2D : Point2D`



Constructor and Destructor of Derived Class

- **Constructor**
  - Calls the default constructor of the base class
    - Before attributes of the derived class are initialized
  - Use intializer list for use of non-default constructor
    - Base class constructor is always called first independent of order of initializer list
- **Example**

`Point2D()` is called!



```
class Vector2D : public Point2D {
int d_length;
public:
Vector2D(double _x=0.0, double _y=0.0) {
  d_x =_x; d_y=_y; d_length = std::sqrt(dot(*this));}
};
```

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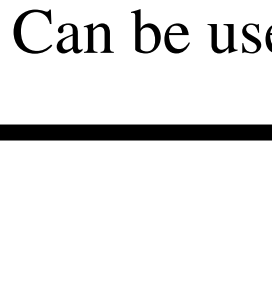
- **Example**




```
class Vector2D : public Point2D {
int d_length;
public:
Vector2D(double _x=0.0, double _y=0.0) : Point2D(_x,_y)
    { d_length = std::sqrt(dot(*this));}
};
```

Copy Constructor

- **Default Copy Constructor**
  - Calls copy constructor of base class first
- **Defined copy constructor**
  - Must explicitly call copy constructor of base class

```
class Vector2D : public Point2D {
int d_length;
public:
  Vector2D(const Vector2D& _oVec ) : Point2D( _oVec ) { … }
};
```

Destructor

- **Base class destructor is always executed after the derived class has been destructed**
  - Overriding the destructor has no effect on the execution of the base class destructor
  - Different then copy constructor and assignment operator
    - Aside: In general can also use default in C++11

```
class Vector2D : public Point2D {
…
public:
  ~Vector2D() {}
    // Point2D part of Vector2D is destructed after Vector2D
 // automatic – no explicit call
};
```

Next Lecture

OO

- **Object-oriented design**
  - Polymorphism: Virtual functions, abstract classes and dynamic cast
  - Exceptions Basics
  - Inline functions, static members