Advanced Programming Concepts with C++ CSI2372 – Fall 2017

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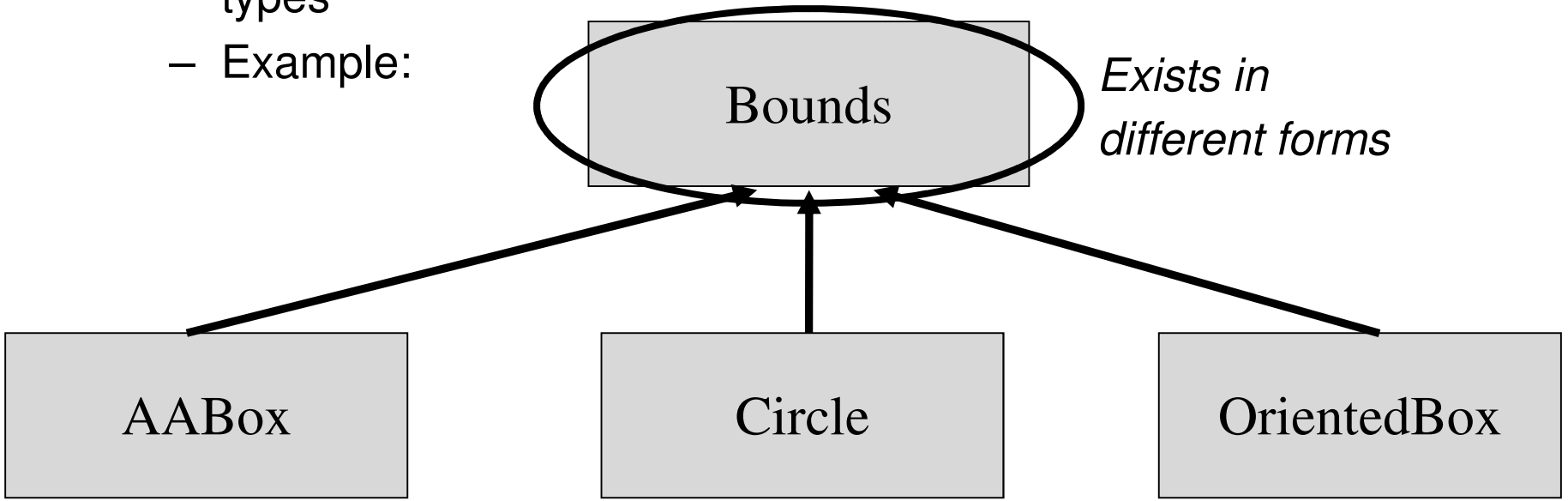
This lecture

OO

- **Object-oriented design**
  - Polymorphism
    - Virtual Functions, Ch. 15.3, 15.7
    - Abstract classes, Ch. 15.4
    - Dynamic cast, Ch. 19.2.1

Polymorphism and Inheritance

- **Goal: Abstraction**
  - Base class summarizes the behavior of all derived classes.
- **Concept: Polymorphism**
  - A base class handle may give access to different derived types
  - Example:

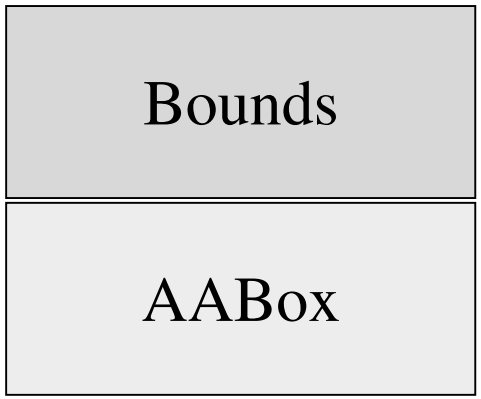


Example: Polymorphism

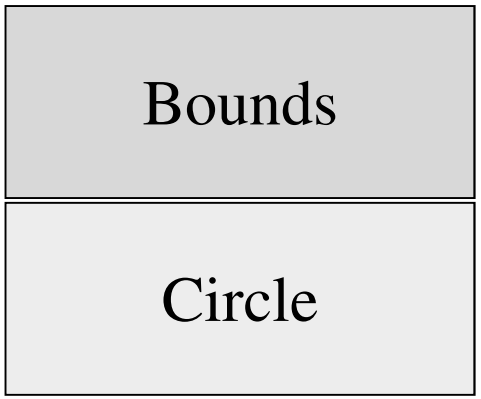
- Call function defined for all bounding primitives
- Execute different code depending on derived class type of `Bounds`

- **Example: Enclose boundary samples**

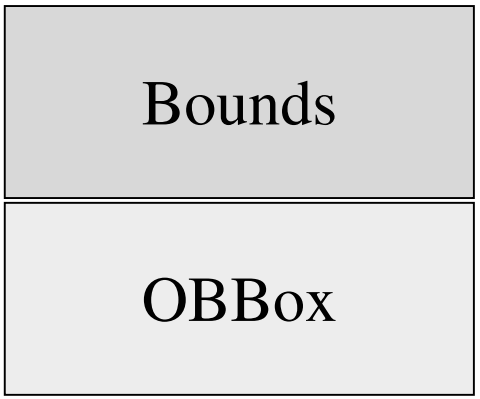
enclose with AAB



enclose with circle



enclose with OBB



Example in C++: AABox, Circle and OBBox are Bounds with different properties

```
// Define class hierarchy
class Bounds { … };
class AABox: public Bounds { … };
class Circle : public Bounds { … };
class OBBox : public Bounds { … };

// Handles to different bounds
Bounds *boundsA = new AABox();
Bounds *boundsB = new Circle();
OBBox objOBB; Bounds& boundsC = objOBB;

// Each bounds should behave differently
Point2D pts[4];
boundsA->enclose( pts, 4 ); // use algorithm for AABox
boundsB->enclose( pts, 4 ); // use algorithm for Circle
boundsC.enclose( pts, 4 ); // use algorithm for OBBox
```

Dynamic Binding and Virtual Methods

- **In Java all methods are virtual**
  - Virtual machine decides at run-time what method to execute
- **In C++ only methods declared virtual are virtual**
  - Dynamic binding is only invoked when pointer or reference to an object is used
  - Type of object is not known until run time but base object is guaranteed to be part of object

Definition of a Virtual Function

```
class Bounds {   …
public:
  virtual bool isInside( const Point2D& _qPt ) const;
  virtual bool enclose( Points2D _extrema[], int _size ) {
     return false; }
};
class AABox : public Bounds { …
public:
  virtual bool isInside( const Point2D& _pt ) const {
     if ( _pt.isSmaller( d_upperRight ) &&
           _pt.isGreater( d_lowerLeft ))
     return true; else return false;
  }
};
```

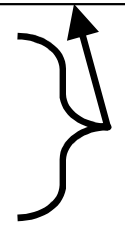
- **Keyword virtual in derived class optional; once a base class defined function virtual**

Override

- **As soon as we define a function with the same signature than a virtual function in the base class, we override the function: In C++11, we can use `override`**

```
class Bounds {   …
public:
  virtual bool isInside( const Point2D& _qPt ) const;
  virtual bool enclose( Points2D _extrema[], int _size );
  virtual double area();
};
class AABox : public Bounds { …
public:
  virtual bool isInside( const Point2D& _pt ) const;
  bool enclose( Points2D _extrema[], int _size );
  double area() override;
};
```

All virtual functions over-riding functions in Bounds



Call of a Virtual Function

```
// use a reference to base class (could change for pointer)
int isInside( const Bounds& _bounds, const Point2D& pt ) {
  int res = _bounds.isInside( pt );
  return res;
}

int main() {
  AABox aab;
  Circle circ;
  Point2D pts[4];
  aab.enclose( pts, 4 ); circ.enclose( pts, 4 );
  Point2D pt( 2.0, 3.0 );
  cout << "Inside AA_Box? " << isInside( aab, pt );
  cout << "Inside Circle? " << isInside( circ, pt );
}
```

Example: Virtual Destructors

- **Base class Bounds**
  - No need for a dtor by itself; built-in is just fine
  - But we don't know about derived classes.
- **Derived class**
  - Virtual dtor provides a hook for dtor of derived class

```
class Bounds {
public: …
  virtual ~Bounds() {};
};
class AABox : public Bounds { …
  ~AABox();
};
```

Virtual Destructors (Dtors)

- **Base classes require a virtual destructor**
  - Consider what destructor needs to be called:

```
int main() {
  Bounds* boundShape = new Bounds();
  Bounds* boxShape = new AABox();
  delete boundShape; // delete a Bounds
  delete boxShape; // delete a AABox by deleting a Bounds
}
```

  - A virtual destructor is needed in the base class, even if it does not need a destructor itself. Because an object of a derived class may be destructed through a pointer to the base class!

Abstract Classes

- **Familiar Concept from Java**
  - No objects of an abstract class
  - Abstract classes serve purely as a base class
- **Differences to Java**
  - No keyword abstract
  - Methods are non-virtual by default
  - No interfaces; can use abstract classes with only pure virtual methods instead

Pure Virtual Functions and Abstract Classes

- One pure virtual functions make a class abstract
- Abstract classes similar to Java
- Objects of abstract classes can not be generated
- Abstract classes with only pure virtual functions serve similar role than Java interfaces

```
class myAbstractBase {
public:
virtual float myVirtualFunc() = 0;
}
```

Improvements for Implementing Class Hierarchies in C++11

- **Inheritance of constructors**
  - Inherent parent constructors for the derived class
  - Constructors “change” their name
  - Default and copy constructor are not inherited but synthesized in the usual way
  - Access level remains the same

```
class GoalPoint2D : public Point2D {
public:
  using Point2D::Point2D; // All constructors from Point2D
};
…
GoalPoint2D( 2.0, 4.0 );
```

Dynamic Cast

- **Run-time cast**
  - Not a compile-time cast than other named casts
  - No old-style cast equivalent
  - Works with handles: object pointers or object references
- **Uses**
  - Down-casts
    - turning a base-class into a sub-class
  - Cross-casts
    - multiple inheritance, casting between different parent hierarchies

“Down-Casts”

- Abstraction often implies using a base class to represent a sub-class in interfaces
- However: Would like to interact with sub-class

- **Solution: Cast the object down the hierarchy**

```
Bounds *getBounds() {
  Bounds *res = new AABox();
  return res;
}
Bounds *myBounds = getBounds();
AABox *myAABox = dynamic_cast<AABox *>( getBounds() );
```

Errors using Dynamic Casts

- **Dynamic casts can produce run-time errors**
  - Pointers returned by cast is 0
  - Reference cast will throw exception bad_cast

```
Bounds *getBounds() {
  return new Circle();
}
Bounds& getBoundsAsRef() {
  AABox *res = new AABox();
  return *res;
}
// myObb will be 0
OBBox *myObb = dynamic_cast<OBBox *>( getBounds() );
// Line below will throw
OBBox &myObbRef = dynamic_cast<OBBox &>( getBoundsAsRef() );
```

Next

Text is beautiful

- **Input and output streams**
  - Relevant classes for STL Stream I/O
  - File handling
  - Overloading the insertion and extraction operators
  - String streams