IS 0020
Program Design and Software Tools

Introduction to C++ Programming

Multiple Inheritance

July 26, 2004

22.9 Multiple Inheritance

- Multiple inheritance
  - Derived class has several base classes
  - Powerful, but can cause ambiguity problems
    - If both base classes have functions of the same name
    - Solution: specify exact function using **`::`**
      - **`myObject.BaseClass1::function()`**
  - Format
    - Use comma-separated list

```
class Derived : public Base1, public Base2{
   contents
}
```

base1.h (1 of 1)

```
// Fig. 22.14: base1.h
// Definition of class Base1
#ifndef BASE1_H
#define BASE1_H

// class Base1 definition
class Base1 {
public:
   Base1( int parameterValue ) { value = parameterValue;
   int getData() const { return value; }

protected:      // accessible to derived classes
   int value;   // inherited by derived class

};  // end class Base1

#endif  // BASE1_H
```

There are two base classes in this example, each has its own **`getData`** function.

This base class contains an **`int`**.

```
// Fig. 22.15: base2.h
// Definition of class Base2
#ifndef BASE2_H
#define BASE2_H

// class Base2 definition
class Base2 {
public:
   Base2( char characterData ) { letter = characterData; }
   char getData() const { return letter; }

protected:        // accessible to derived classes
   char letter;   // inherited by derived class

};  // end class Base2

#endif  // BASE2_H
```

base2.h (1 of 1)

derived.h (1 of 1)

```
// Fig. 22.16: derived.h
// Definition of class Derived which inherits
// multiple base classes (Base1 and Base2).
#ifndef DERIVED_H
#define DERIVED_H

#include <iostream>

using std::ostream;

#include "base1.h"
#include "base2.h"

// class Derived definition
class Derived : public Base1, public Base2 {
   friend ostream &operator<<( ostream &, const Derived & );

public:
   Derived( int, char, double );
   double getReal() const;

private:
   double real;   // derived class's private data

};  // end class Derived

#endif  // DERIVED_H
```

Use comma-separated list.

Outline

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```
// Fig. 22.17: derived.cpp
// Member function definitions for class Derived
#include "derived.h"

// constructor for Derived calls constructors for
// class Base1 and class Base2.
// use member initializers to call base-class constructors
Derived::Derived( int integer, char character, double double1 )
   : Base1( integer ), Base2( character ), real( double1 ) { }

// return real
double Derived::getReal() const { return real; }

// display all data members of Derived
ostream &operator<<( ostream &output, const Derived &derived )
{
   output << "    Integer: " << derived.value
          << "\n  Character: " << derived.letter
          << "\nReal number: " << derived.real;

   return output;   // enables cascaded calls

}  // end operator<<
```

Note use of base-class constructors in derived class constructor.

```cpp
// Fig. 22.18: fig22_18.cpp
// Driver for multiple inheritance example.
#include <iostream>

using std::cout;
using std::endl;

#include "base1.h"
#include "base2.h"
#include "derived.h"

int main()
{
   Base1 base1( 10 ), *base1Ptr = 0;  // create Base1 object
   Base2 base2( 'Z' ), *base2Ptr = 0; // create Base2 object
   Derived derived( 7, 'A', 3.5 );    // create Derived object

   // print data members of base-class objects
   cout << "Object base1 contains integer "
        << base1.getData()
        << "\nObject base2 contains character "
        << base2.getData()
        << "\nObject derived contains:\n" << derived << "\n\n";

```

Outline

fig22_18.cpp
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fig22_18.cpp
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```
   // print data members of derived-class object
   // scope resolution operator resolves getData ambiguity
   cout << "Data members of Derived can be"
        << " accessed individually:"
        << "\n    Integer: " << derived.Base1::getData()
        << "\n  Character: " << derived.Base2::getData()
        << "\nReal number: " << derived.getReal() << "\n\n";

   cout << "Derived can be treated as an "
        << "object of either base class:\n";

   // treat Derived as a Base1 object
   base1Ptr = &derived;
   cout << "base1Ptr->getData() yields "
        << base1Ptr->getData() << '\n';

   // treat Derived as a Base2 object
   base2Ptr = &derived;
   cout << "base2Ptr->getData() yields "
        << base2Ptr->getData() << endl;

   return 0;

}  // end main
```

Note calls to specific base class functions.

Can treat derived-class pointer as either base-class pointer.

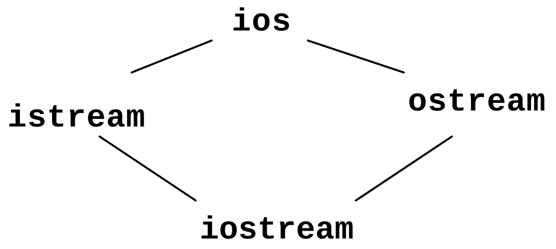
```
Object base1 contains integer 10
Object base2 contains character Z
Object derived contains:
    Integer: 7
  Character: A
Real number: 3.5

Data members of Derived can be accessed individually:
    Integer: 7
  Character: A
Real number: 3.5

Derived can be treated as an object of either base class:
base1Ptr->getData() yields 7
base2Ptr->getData() yields A
```

Outline

fig22_18.cpp
output (1 of 1)

Multiple Inheritance and virtual Base Classes

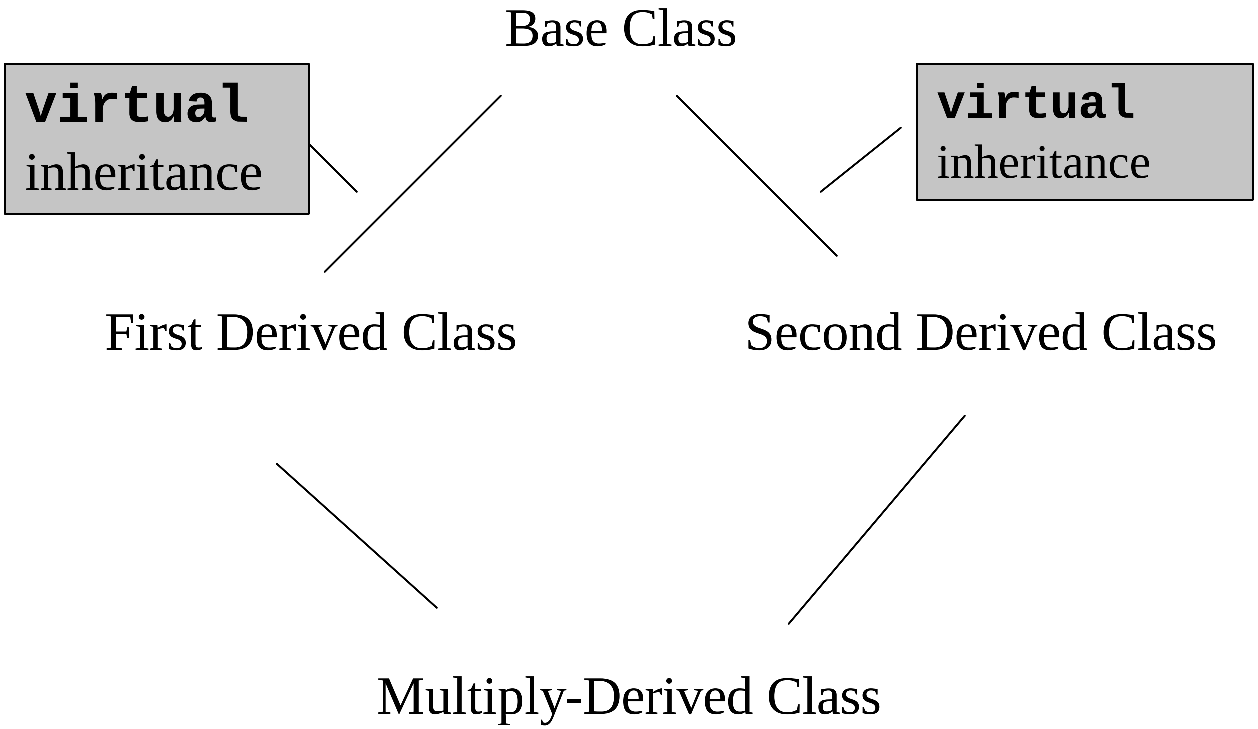
- Ambiguities from multiple inheritance



- **`iostream`** could have duplicate subobjects
  - Data from **`ios`** inherited into **`ostream`** and **`istream`**
  - Upcasting **`iostream`** pointer to **`ios`** object is a problem
    - Two **`ios`** subobjects could exist, which is used?
  - Ambiguous, results in syntax error
    - **`iostream`** does not actually have this problem

Multiple Inheritance and virtual Base Classes

- Solution: use virtual base class inheritance
  - Only one subobject inherited into multiply derived class



Base Class

`virtual` inheritance

`virtual` inheritance

First Derived Class

Second Derived Class

Multiply-Derived Class

fig22_20.cpp
(1 of 3)

```
// Fig. 22.20: fig22_20.cpp
// Attempting to polymorphically call a function that is
// multiply inherited from two base classes.
#include <iostream>

using std::cout;
using std::endl;

// class Base definition
class Base {
public:
   virtual void print() const = 0;  // pure virtual

};  // end class Base

// class DerivedOne definition
class DerivedOne : public Base {
public:

   // override print function
   void print() const { cout << "DerivedOne\n"; }

};  // end class DerivedOne

```

This example will demonstrate the ambiguity of multiple inheritance.

Outline

```
// class DerivedTwo definition
class DerivedTwo : public Base {
public:

   // override print function
   void print() const { cout << "DerivedTwo\n"; }

};  // end class DerivedTwo

// class Multiple definition
class Multiple : public DerivedOne, public DerivedTwo {
public:

   // qualify which version of function print
   void print() const { DerivedTwo::print(); }

};    // end class Multiple

```

fig22_20.cpp
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Outline

fig22_20.cpp
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```
int main()
{
   Multiple both;   // instantiate Multiple object
   DerivedOne one;  // instantiate DerivedOne object
   DerivedTwo two;  // instantiate DerivedTwo object

   // create array of base-class pointe
   Base *array[ 3 ];

   array[ 0 ] = &both;   // ERROR--ambiguous
   array[ 1 ] = &one;
   array[ 2 ] = &two;

   // polymorphically invoke print
   for ( int i = 0; i < 3; i++ )
      array[ i ] -> print();

   return 0;

}  // end main
```

Which base subobject will be used?

fig22_21.cpp
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```cpp
// Fig. 22.21: fig22_21.cpp
// Using virtual base classes.
#include <iostream>

using std::cout;
using std::endl;

// class Base definition
class Base {
public:

   // implicit default constructor

   virtual void print() const = 0; // pure virtual

};  // end Base class

// class DerivedOne definition
class DerivedOne : virtual public Base {
public:

   // implicit default constructor calls
   // Base default constructor

   // override print function
   void print() const { cout << "DerivedOne\n"; }

};  // end DerivedOne class
```

Use virtual inheritance to solve the ambiguity problem.

The compiler generates default constructors, which greatly simplifies the hierarchy.

fig22_21.cpp
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```

// class DerivedTwo definition
class DerivedTwo : virtual public Base {
public:

   // implicit default constructor calls
   // Base default constructor

   // override print function
   void print() const { cout << "DerivedTwo\n"; }

}; // end DerivedTwo class

// class Multiple definition
class Multiple : public DerivedOne, public DerivedTwo {
public:

   // implicit default constructor calls
   // DerivedOne and DerivedTwo default constructors

   // qualify which version of function print
   void print() const { DerivedTwo::print(); }

}; // end Multiple class
```

Use `virtual` inheritance, as before.

```

int main()
{
   Multiple both;   // instantiate Multiple object
   DerivedOne one;  // instantiate DerivedOne object
   DerivedTwo two;  // instantiate DerivedTwo object

   // declare array of base-class pointers and initialize
   // each element to a derived-class type
   Base *array[ 3 ];

   array[ 0 ] = &both;
   array[ 1 ] = &one;
   array[ 2 ] = &two;

   // polymorphically invoke function print
   for ( int i = 0; i < 3; i++ )
      array[ i ]->print();

   return 0;

}  // end main
```

```
DerivedTwo
DerivedOne
DerivedTwo
```

fig22_21.cpp
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