15. Polymorphism & Virtual Functions

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15.1 Virtual Functions

CASE 1: Why use virtual function?

```
#include <iostream>
using namespace std;
class Instrument {
public:
        void play( ) const
        {  cout << "Instrument::play()" << endl; }
};
class Wind : public Instrument {
public:
        void play( ) const
        {  cout << "Wind::play()" << endl;    }
};
class Stringed: public Instrument {
public:
        void play( ) const
        {  cout << " Stringed::play()" << endl;  }
};
```

```
void tune(const Instrument& i)
{
    i.play( );
}

void main( )
{
    Wind flute;
    tune(flute);

    Stringed guitar;
    tune(guitar);
}
```

15.1 Virtual Functions(1)

```
#include <iostream>
using namespace std;
class Instrument {
public:
        virtual void play( ) const
        {  cout << "Instrument::play( )" << endl;  }
};
void tune(const Instrument& instru)   {   instru.play( );  }
```

The keyword ***virtual*** indicates that ***play( )*** can act as an interface to the ***play( )*** function defined in this class and the ***play( )*** functions defined in classes derived from it.

15.1 Virtual Functions

CASE 1: Why use virtual function?

```
#include <iostream>
using namespace std;
class Instrument {
public:
        virtual void play( ) const
        {  cout << "Instrument::play()" << endl; }
};
class Wind : public Instrument {
public:
        virtual void play( ) const
        {  cout << "Wind::play()" << endl;    }
};
class Stringed: public Instrument {
public:
        void play( ) const   // virtual can be omitted
        {  cout << " Stringed::play()" << endl;  }
};
```

```
void tune(const Instrument& i)
{
    i.play( );
}

void main( )
{
    Wind flute;
    tune(flute);

    Stringed guitar;
    tune(guitar);
}
```

15.1 Virtual Functions(2)

CASE 2: Why use virtual function?

```
#include <iostream>
using namespace std;

class Instrument {
public:
        void tune()  {  play( );   }
        void play()  const
        {  cout << "Instrument::play()" << endl;  }
};


class Wind : public Instrument
{
public:
        void play() const
        {  cout << "Wind::play()" << endl;    }
};
```

```
class Stringed : public Instrument
{
public:
     void play() const
     {
        cout << " Stringed ::play()";
     }
};

void main() {
     Wind flute;
     flute.tune();

     Stringed guitar;
     guitar.tune();
}
```

15.1 Virtual Functions(3)

[1] There must be the same function definition when overloading the virtual function. It includes *same returning type*, *same function name*, *same arguments number*, *same arguments* sequence and *same arguments type*.

[2] The virtual function must be a member function.

[3] The friend function cannot be defined as a virtual function.

[4] Destructor can be defined as a virtual function, but constructor cannot.

15.1 Virtual Functions(4)

Practice 1

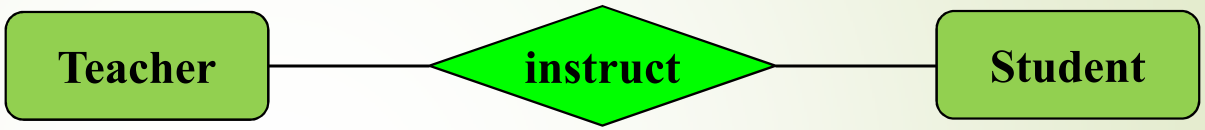
```
class  base
{ public :
     virtual  void  vf1 ( ) ;
     virtual  void  vf2 ( ) ;
     virtual  void  vf3 ( ) ;
     void  f ( ) ;
 } ;
void  main ( )
{
   derived   d ;
   base   * bp = & d ;
   bp -> vf1 ( ) ;          // call derived :: vf1 ( )
   bp -> vf2 ( ) ;          // call base :: vf2 ( )
   bp -> f ( ) ;            // call base :: f ( )
} ;
```

```
class  derived : public  base
{
public :
     void  vf1 ( ) ;       // virtual function
     // overloading, but not a virtual
     void  vf2 ( int ) ;
     char  vf3 ( ) ;       // error
     void f ( ) ;          // Not overload virtual
 } ;
```

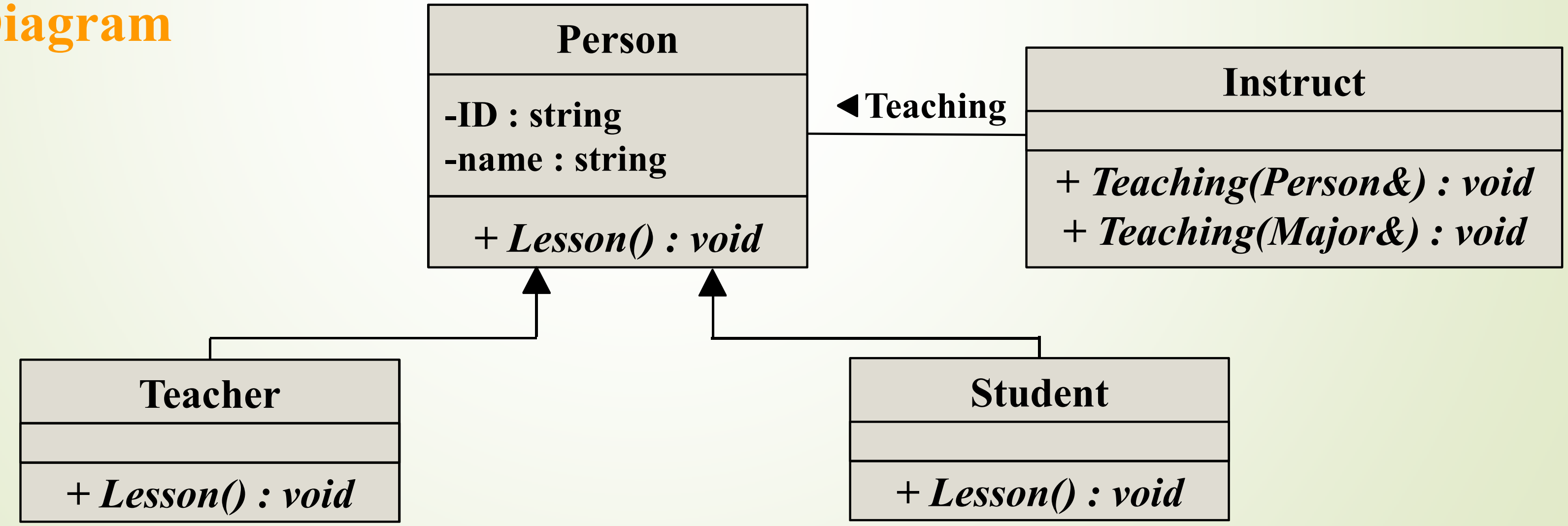
15.2 Use Virtual Functions

Practice 2

ER Model



Class Diagram



15.2 Use Virtual Functions

Practice 2

```cpp
#include <iostream>
using namespace std;
class Person {
private:   string ID, name;
public:
      virtual void Lesson( )  {
            cout << "Person has a lesson ." << endl;
       }
};
class Teacher : public Person  {
public:
      virtual void Lesson( )  {
             cout << "Teacher is teaching." << endl;
       }
};
class Student : public Person  {
public:
      virtual void Lesson( ) {
              cout << "Student is listening. " << endl;
        }
};
```

```cpp
class Instruct
{
public:
     void Teaching(Person& p)   {
              p.Lesson( );
      }
      // instruct graduate to write thesis
      void Teaching(Major& s)   {
              s.Thesis( );
      }
};

void main()
{
        Teacher teacher;
        Student student;

        Instruct instruct;
        instruct.Teaching(teacher);
        instruct.Teaching(student);
}
```

15.3 Virtual Destructors

- Calling the wrong destructor could be disastrous, particularly when it contains a *delete* statement.
- Destructors are not inherited.
- Constructors inherited? No.

15.3 Virtual Destructors(1)

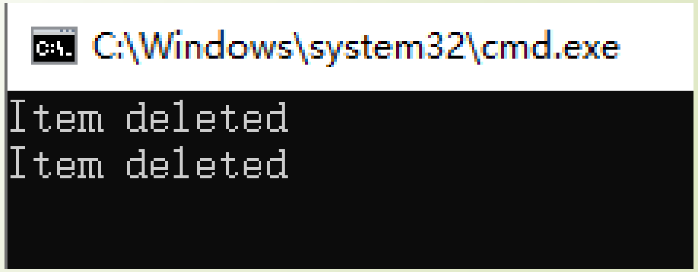
```
#include <iostream>
using namespace std;
class  Item  {
 public:
        Item()    { id = 0;  }
        ~Item()  { cout <<"Item deleted"<<endl;}
 private:  int id;
};

 class BookItem : public Item {
 public:
     BookItem()  {    title = new char [50];    }
    ~BookItem()  {
          cout <<"BookItem deleted"<<endl;
          if (title != nullptr)     delete[ ] title;
      }
 private:      char * title;
};
```

```
int main()
{
        Item * p;
        p = new Item();
        delete p;

        p = new BookItem();
        delete p;

        return 0;
}
```



15.3 Virtual Destructors(2)

```
#include <iostream>
using namespace std;
class  Item
{
 public:
        Item()    { id = 0;  }
        virtual ~Item()  { cout <<"Item deleted"<<endl;}
 private:
        int id;
};
```

15.4 Function Call Binding

Connecting a function call to a function body is called *binding*. When binding is performed before the program is run(by the compiler and linker), it's called *early binding* or *static binding*.

```
#include <iostream>
using namespace std;

class Person {
private:  string ID, name;
public:
      void Lesson( )
       {
            cout << "Person has a lesson ." << endl;
       }
};

class Teacher : public Person  {
public:
      void Lesson( )  {
            cout << "Teacher is teaching." << endl;
       }
};
```

```
class Student : public Person
{
public:
       void Lesson( )
      {
            cout << "Student is listening. ";
       }
};
class Instruct
{
public:
     void Teaching(Person& p)
      {
            p.Lesson( );
      }
};
```

```
void main( )  {
      Teacher teacher;
      Student student;
      Instruct instr;
      instr. Teaching(teacher);
      teach. Teaching(student);
}
```

15.4.1 Function Call Binding

The solution is called *late binding*, which means the binding occurs at runtime, based on the type of the object. Late binding is also called *dynamic binding* or *runtime binding*.

```
#include <iostream>
using namespace std;

class Person {
private:  string ID, name;
public:
      void Lesson( )
       {
            cout << "Person has a lesson ." << endl;
       }
};

class Teacher : public Person  {
public:
      void Lesson( )  {
            cout << "Teacher is teaching." << endl;
       }
};
```

```
class Student : public Person
{
public:
       void Lesson( )
      {
           cout << "Student is listening. ";
       }
};
class Instruct
{
public:
     void Teaching(Person& p)
       {
              p.Lesson( );
       }
};
```

```
void main( )  {
        Teacher teacher;
        Student student;
        Instruct instr;
        instr. Teaching(teacher);
        teach. Teaching(student);
}
```

Polymorphism

15.4.1 Function Call Binding

To simulate printer in Word:

Base Class: PRINTER, Derived Class: MyPrinter

```
class PRINTER
{
public:
      // printer driver
      virtual int print(CObject* pObj);
};

class MyPrinter : public PRINTER
{
public:
     // override printer driver
     virtual int print(CObject* pObj);
     // register my printer in the registry of OS
     bool RegisterMyPrinter();
};
```

```
CHandle API_PRINTER
(PRINTER& p, CObject* pObj)
{
      if (Find_In_Register(p) &&
         Default_Printer(p))
         Call  p.print(pObj);
}
```

15.4.2 How C++ implements late binding

```
#include <iostream>
using namespace std;
class NoVirtual {
    int a;
public:
    void x() const { }
    int i() const { return 1; }
};

class OneVirtual {
    int b;
public:
    virtual void x() const { }
    int i() const { return 1; }
};

class TwoVirtuals {
    int c;
public:
    virtual void x() const { }
    virtual int i() const { return 1; }
};
```

What does compiler do for us (1)?

```
void main() {
    cout << "int: " << sizeof(int);
    cout << "NoVirtual: " << sizeof(NoVirtual);
    cout << "void* : " << sizeof(void*);
    cout << "OneVirtual: " << sizeof(OneVirtual);
    cout << "TwoVirtuals: "<< sizeof(TwoVirtuals);
}
```

C:\Windows\system32\cmd.exe

```
int: 4
NoVirtual: 4
void* : 4
OneVirtual: 8
TwoVirtuals: 8
```

15.4.2 How C++ implements late binding

What does compiler do for us (2)?

```
#include <iostream>
using namespace std;

class NoVirtual {
public:
    int a;
    void x() const {}
    int i() const { return 1; }
};

class OneVirtual {
public:
    int b;
    virtual void x() const {}
    int i() const { return 1; }
};
```

```
void main() {
NoVirtual nov;
OneVirtual onev;


cout << "NoVirtual: " << &nov << endl;
cout << "NoVirtual: a " << &nov.a << endl;


cout << "OneVirtual: " << &onev << endl;
cout << "OneVirtual: b " << &onev.b << endl;
}
```

15.4.2 How C++ implements late binding

What does compiler do for us (3)?

Here is a piece of source code: ***obj.adjust(1);***

```
push  1                  // argument of adjust
push  si                 // this, address of obj
mov   bx, word ptr [si]  // fetches the word that si points to
                         // it's the VPTR(pointer of virtual table)
call  word ptr [bx+4]    // call virtual function adjust
                         // why let bx adds 4? See also P.640 chart
add   sp, 4              // pop argument and release
```

15.5 Variant return type

[1] There must be the same function definition when overloading the virtual function. It includes *same returning type*, *same function name*, *same arguments number*, *same arguments sequence* and *same arguments type*.

[2] The virtual function must be a member function.

[3] The friend function cannot be defined as a virtual function.

If we are *returning* *a pointer or a reference of an object* to a base class, then the overridden version of the function may *returning* *a pointer or a reference of an object* to a class derived from what the base returns.

15.6 Abstract Classes

A ***pure virtual function*** **is a virtual function that contains a pure-specifier, designated by the** ***"=0"*****. It's used to be defined as a interface of derived class.**

```
class  Number        // Abstract class
{
 public :
        Number ( int  i )  { val = i ; }
        virtual   void   Show ( ) = 0 ;    // pure virtual function
protected :
        int   val ;
} ;
```

Number Abstract

```
#include < iostream.h >
class  Number
{ public :
      Number ( int  i )  { val = i ; }
      virtual   void   Show ( ) = 0 ;
  protected :   int   val ;
} ;
class   Hextype  :  public  Number
{ public :
      Hextype ( int  i ) : Number ( i ) { }
      void  Show ( ) {   cout << hex << val;   }
} ;
class  Dectype  :  public  Number
{ public :
      Dectype ( int  i ) : Number ( i ) { }
      void  Show ( ) {   cout << dec << val;  }
} ;
```

```
void   Show ( Number & n )
{
        n. Show ( ) ;
 }

void main ( )
{
      Dectype  d ( 50 ) ;
      Show( d ) ;    // d . Show ( ) ;

      Hextype h ( 16 ) ;
      Show( h ) ;    // h . Show ( ) ;
}
```

15.6 Abstract Classes

- An abstract class is a class that can only be a base class for other classes.
- Abstract classes represent concepts for which objects cannot exist.
- Abstract class couldn't define instances.
- The derived classes of abstract class are used to instantiate objects.

15.6 Pure virtual destructor

In common sense, we don't give the source code for pure virtual function. But in the special, it's possible to provide a definition for a pure virtual function in the base class. *There may be a common piece of code that we want some or all of the derived class definitions to call rather than duplicating that code in every function*.

```
#include <iostream>
using namespace std;
class Pet  {
public:   virtual ~Pet() = 0;
};
// Don't implement in the class
Pet::~Pet( ) {  cout << "~Pet()" << endl; }

class Dog: public Pet {
public:   ~Dog() {   cout << "~Dog()" << endl;   }
};
```

```
void main()
{
        // Upcase
          Pet *p = new Dog();

        // Virtual destructor call
          delete p;
}
```

15.7 Downcasting

C++ provides a special explicit cast called *dynamic_cast* that is a *type-safe* *downcast* operation. When we use *dynamic_cast* to try to cast down to a particular type, the return value will be a *pointer* to the desired type only if the cast is proper and successful, otherwise it will return *zero*.

15.7 Downcasting

```
#include <iostream>
using namespace std;
class Pet  {   public:  virtual ~Pet() { }    };
class Dog : public Pet {   };
class Cat  : public Pet {   };
int main( )
{
        Pet *b = new Cat();  // Upcase
        // Try to cast it to Dog*
        Dog* d1 = dynamic_cast<Dog*>(b);
        // Try to cast it to Cat*
        Cat* d2 = dynamic_cast<Cat*>(b);
        cout << "d1 = " << d1 << endl;
        cout << "d2 = " << d2 << endl;
        delete b;     // call base destructor automatically
        return 0;
}
```

C:\Windows\system32\cmd.exe

```
d1 = 00000000
d2 = 010404D0
```