CPT106

C++ Programming and Software Engineering II

Lecture 9 Polymorphism

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Outline

- Pointers to objects
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  - Pointers to derived classes
- Polymorphism
  - Methods Overlapping
  - Introduction to Polymorphism
    - Static Binding
    - Dynamic Binding
  - Virtual Methods
  - Pure Virtual Methods
  - Virtual destructor

1.1 Pointers to objects

- A pointer can point to an object created by a class.
  - Example:

```
complexClass cNum1;
complexClass *ptr1;
ptr1 = &cNum1;
```

  - Call methods in two ways:
    - dot operator (object):

```
cNum1.show();
cNum1.set(5,10);
```

    - arrow operator (object pointer):

```
ptr1-> show();
ptr1-> set(5,10);
```

1.1 Pointers to objects

- Dynamic memory allocation for object
  - Example:

```
complexClass *ptr1 = new complexClass;
ptr1-> show();
ptr1-> set(5,10);
delete ptr1;
```

- Dynamic memory allocation for objects array
  - Example:

```
int N=5;
complexClass *ptr2 = new complexClass[N];
ptr2[0].show();
*(ptr2+1)->set(5,10);
delete [] ptr2;
```

1.2 Pointers to derived classes (I)

- Pointers can be used to point not only base class objects but also objects of derived classes.
  - Pointers to objects of a base class are type-compatible with pointers to objects of a derived class.
  - Therefore, a single pointer variable can be made to point to objects belonging to different classes.

```
class clA
{public:
        int a;
        void show() {cout<<a;}
};

class clB: public clA
{public:
        int b;
        void show() {cout<<a<<b;}
};
```

```
clA *ptr1, obA;
clB obB;
ptr1 = &obA;
ptr1 = &obB;
```

```
clA *ptr2 = new clA;
clA *ptr3 = new clB;
clB *ptr4 = new clA;     X
```

1.2 Pointers to derived classes (II)

- Problems:
  - 1. Pointer declared from derived class cannot point to object of base class;

```
clA p1;
clB *ptr2 = &p1;   X
```

```
clB p2;
clA *ptr1 = &p2;   √
```

  - 2. Using **`ptr1`**, we can access only the members which are inherited from base class, but not the members originally defined in derived class.

```
clB p2;
clA *ptr1 = &p2;
```

```
ptr1-> a = 1;   √
ptr1-> b = 1;   ×
```

1.2 Pointers to derived classes (III)

- Problems:
  - 3. In case a method of derived class has the same name as the method of base class, then any reference to that member by **`ptr1`** will always access the base class member.

```
class clA
{public:
        int a;
        void show() {cout<<a;}
};

class clB: public clA
{public:
        int b;
        void show() {cout<<a<<b;}
};
```

```
int main()
{       clB p2;
        clA *ptr1 = &p2;
        ptr1-> show();
        return 0;
};
```

2.1 Methods Overlapping

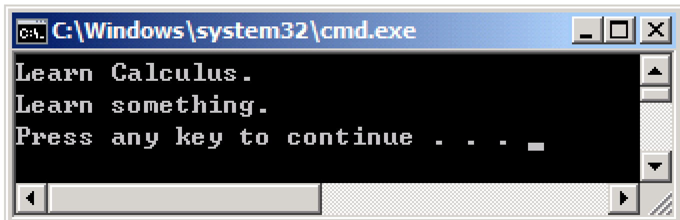
- Function member in base class and subclass can have same name, same parameter list.

Not overloading !!!

```
class student
{public:         ......
        void study()
        {cout<<"Learn something."<<endl;}
 protected: ......
};

class undergraduate: public student
{public:         ......
        void study()
        {cout<<"Learn Calculus."<<endl;}
 protected: ......
};
```

```
int main()
{       undergraduate s1;
        s1.study();
        student s2;
        s2.study();
        return 0;
}
```



2.2 Introduction to Polymorphism

- Polymorphism is one of the crucial features of OOP
  - Polymorphism means a function in the derived class can have the same name as in the base class but does different things.
  - “One name, multiple forms”

- Types of polymorphism:
  - Compile time polymorphism
  - Run time polymorphism

2.2.1 Static Binding

- Overloaded functions and operators
  - Appropriate overloaded function are selected for invoking by matching arguments list;
  - Known to compiler at the compilation stage;
  - Called "early binding" "static binding" "compile time polymorphism"

```
class clA
{       int x;
public:
        void show ();
        void show (int a);
};
```

```
int main()
{       clA ob1;
        clA *ptr = &ob1;
        ptr->show();
        ptr->show(5);
        return 0;
};
```

The "methods overlap" is one kind of polymorphism.

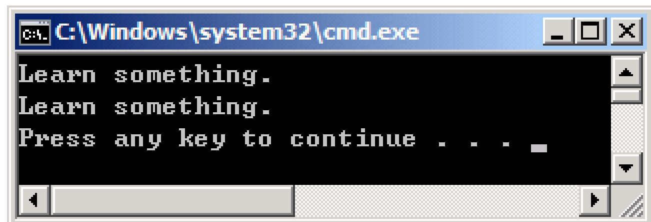
- Static binding:
  - to call the function of the base class from an object of the derived class
  - determined in compile time

```
class student
{public:        ......
        void study()
        {cout<<"Learn something."<<endl;}
 protected: ......
};

class undergraduate: public student
{public:        ......
        void study()
        {cout<<"Learn Calculus."<<endl;}
 protected: ......
};
```

Static Binding

```
int main()
{       undergraduate s1;
        s1.student::study();
        student s2;
        s2.study();
        return 0;
}
```

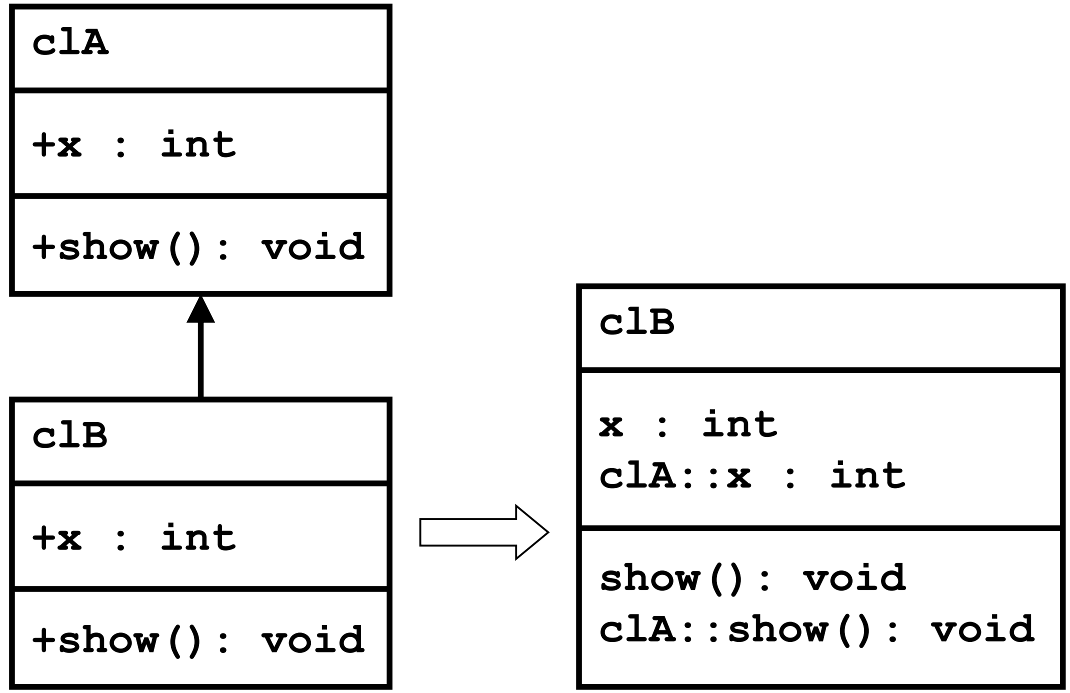


2.2.2 Dynamic Binding

- Dynamic Binding
  - Which function should be called will be decided during the execution of a programme.
  - Called "late binding" "run time polymorphism"

```
class clA
{       int x;
public:
        void show ();
};

class clB: public clA
{       int x;
public:
        void show ();
};
```



2.2.2 Dynamic Binding

```
clA ob1, *ptr;
// ptr is a pointer pointing to the object of class clA

clB ob2;

//A pointer of a base class type can be used to point to a derived class
if (……)
        ptr = &ob1;    // pointing to an object of the base class
else
        ptr = &ob2;.   // pointing to an object of the derived class

ptr->show();
```

Actually, since **`ptr`** *is declared as a pointer for* **`clA`** *class, the method* **`show()`** *of* **`clA`** *is always called. Not* ***dynamic*** *!*

Which function will be called ?

Dynamic binding ---- which function should be called will be decided during the execution of a programme.

2.3 Virtual Methods

- Solution: Using "virtual methods"
  - add keyword "**`virtual`**" in front of the methods declaration.
  - Then the program will find out which methods should be called according to what object the pointer is pointing to.

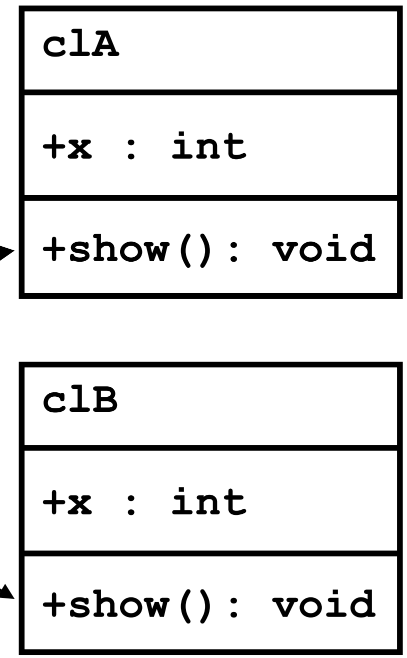
In the base class

```
clA ob1, *ptr;

clB ob2;

if (......)
        ptr = &ob1;
else
        ptr = &ob2;

ptr->show();
```



2.3.1 Example

```
class student
{public: ……
     virtual void study()
     {cout<< "Learn something."<<endl;}
 protected: ……
};

class undergraduate: public student
{public: ……
     void study()
     {cout<< "Learn Calculus."<<endl;}
 protected: ……
};
```

```
int main()
{     cout<<“Choose: \n”;
      cout<<“1 for student; \n”;
      cout<<“2 for undergraduate: \n";
      cin>>choice;
      student st1, *pst;
      undergraduate ust2;
      if (choice==1)
          pst=&st1;
      else
          pst=&ust2;
      pst->study();
      return 0;
}
```

```
C:\Windows\system32\cmd.exe
Choose:
1 for student;
2 for undergraduate:
1
Learn something.
Press any key to continue . . .
```

```
C:\Windows\system32\cmd.exe
Choose:
1 for student;
2 for undergraduate:
2
Learn Calculus.
Press any key to continue . . .
```

2.3.2 Rules for Virtual Methods

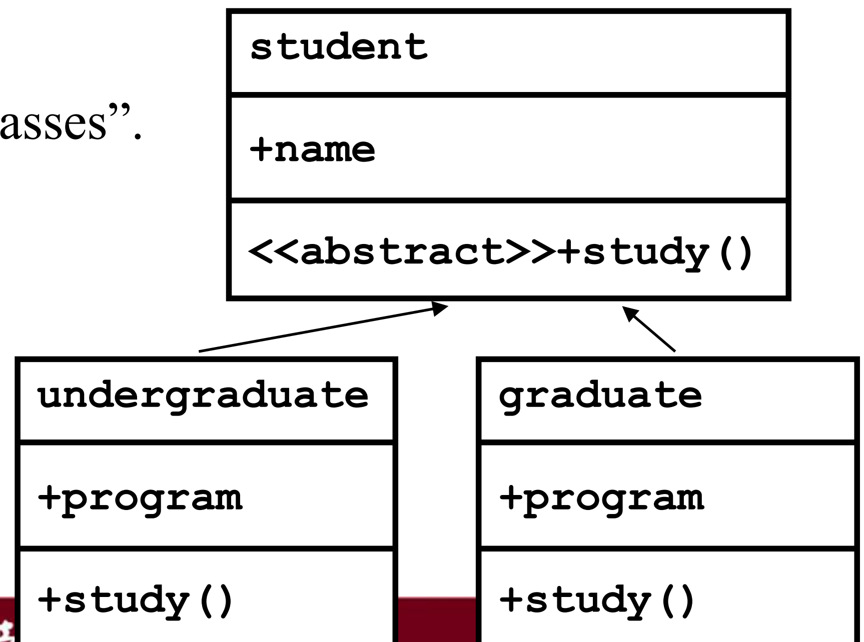
- Basic rules for “virtual methods”
  - The virtual functions must be members of some class;
  - They are accessed by using object pointers;
  - A virtual function can be a friend of another class;
  - A virtual function in a base class must be defined, even though it may not be used;
    - If a virtual function is defined in the base class, it need not be necessarily redefined in the derived class.
  - The prototypes of the base class version of a virtual function and all the derived class versions must be identical;
    - meaning “same name, same parameter list”
    - If different, they will be considered as “function overloading”

2.4 Pure Virtual Methods

- If the virtual function defined in base class doesn't perform any task, but only serves as a *placeholder*, it is a "do-nothing" function.
  - Such functions are called "pure virtual functions".
  - Syntax:

```
virtual void study()=0;
```

- A class containing pure virtual functions cannot be used to declare any objects of its own.
  - Such classes are called "abstract base classes".
  - The main objective of an abstract base class is
    - to provide some traits to the derived classes
    - to create a base pointer required for achieving run time polymorphism.



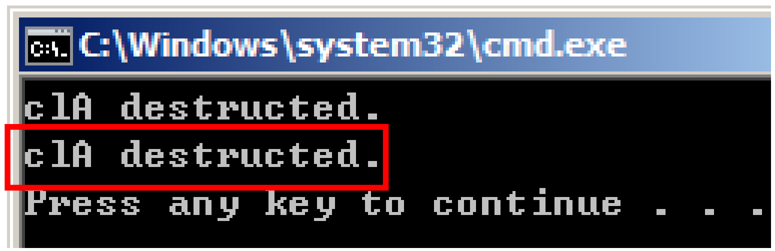
2.5 Virtual destructor

- It is a good policy to always make destructors virtual.
  - Why?
  - Example:

```
class clA
{public:
      ~clA()
      {cout<<"clA destructed.\n";}
};

class clB: public clA
{public:
      ~clB()
      {cout<<"clB destructed.\n";}
};
```

```
int main()
{
      clA *ptr1 = new clA;
      delete ptr1;
      clA *ptr2 = new clB;
      delete ptr2;
      return 0;
};
```



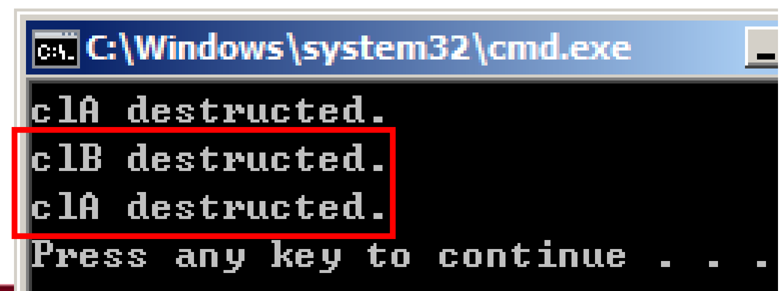
2.5 Virtual destructor

- It is a good policy to always make destructors virtual.
  - Why?
  - Example:

```
class clA
{public:
     virtual ~clA()
     {cout<<"clA destructed.\n";}
};

class clB: public clA
{public:
     ~clB()
     {cout<<"clB destructed.\n";}
};
```

```
int main()
{
     clA *ptr1 = new clA;
     delete ptr1;
     clA *ptr2 = new clB;
     delete ptr2;
     return 0;
};
```



3. Example of Polymorphism

- Attack()

Swordsman

Archer

Magician

3. Example of Polymorphism

- A character is try to perform attack action, but the attack for all 3 jobs are different:
  - swordsman :: chop, damage should be determined by player's AP and enemy's DP
  - Archer :: shoot, damage should be determined by player's speed and enemy's DP
  - Magician :: fire ball, damage should be determined by player's intelligence
- Since which job the user is using will be determined according to user's choice, in execution stage. Therefore, the run-time polymorphism is needed here.

3. Example of Polymorphism

```
class player
{
public:
    virtual void attack();
};
```

```
class swordsman : public player
{
public:
    void attack();   // chop
};
```

```
class magician: public player
{
public:
    void attack();   // fireBall
};
```

```
class archer: public player
{
public:
    void attack();   // shoot
};
```

Summary

- Modern object-oriented programming (OOP) technqiue provide 3 capabilities:
  - ***Encapsulation***: is the process of combining data and functions into a single unit called class.
  - ***Inheritance***: a means of specifying hierarchical relationships between classes.
  - ***Polymorphism*** :is the ability to use an operator or function in different ways.