Chapter 15: Polymorphism and Virtual Functions

Starting Out with C++
Early Objects
Global Edition

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Topics

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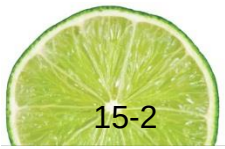
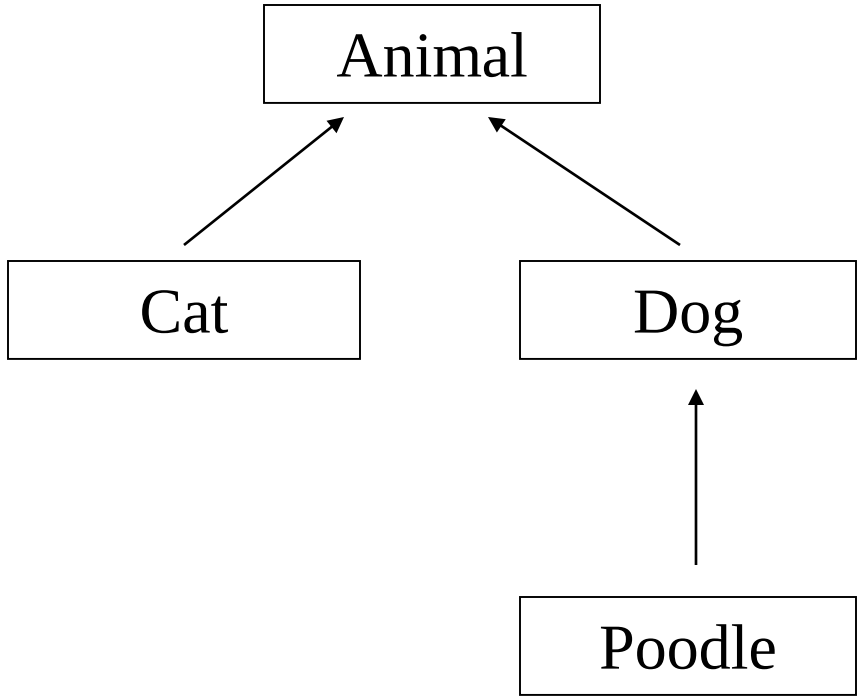


15.1 Type Compatibility in Inheritance Hierarchies

- Classes in a program may be part of an inheritance hierarchy

- Classes lower in the hierarchy are special cases of those above



Type Compatibility in Inheritance

- A pointer to a derived class can be assigned to a pointer to a base class. Another way to say this is:
- A base class pointer can point to derived class objects

```
Animal *pA = new Cat;
```

Type Compatibility in Inheritance

- Assigning a base class pointer to a derived class pointer requires a cast

```
Animal *pA = new Cat;
Cat *pC;
pC = static_cast<Cat *>(pA);
```

- The base class pointer must already point to a derived class object for this to work

P 984 (Figure 15-1) + P985 Inheritance4.h eP934~937

Using Type Casts with Base Class Pointers

- C++ uses the declared type of a pointer to determine access to the members of the pointed-to object

- If an object of a derived class is pointed to by a base class pointer, all members of the derived class may not be accessible

Using Type Casts with Base Class Pointers

- Type cast the base class pointer to the derived class (via **`static_cast`**) in order to access members that are specific to the derived class

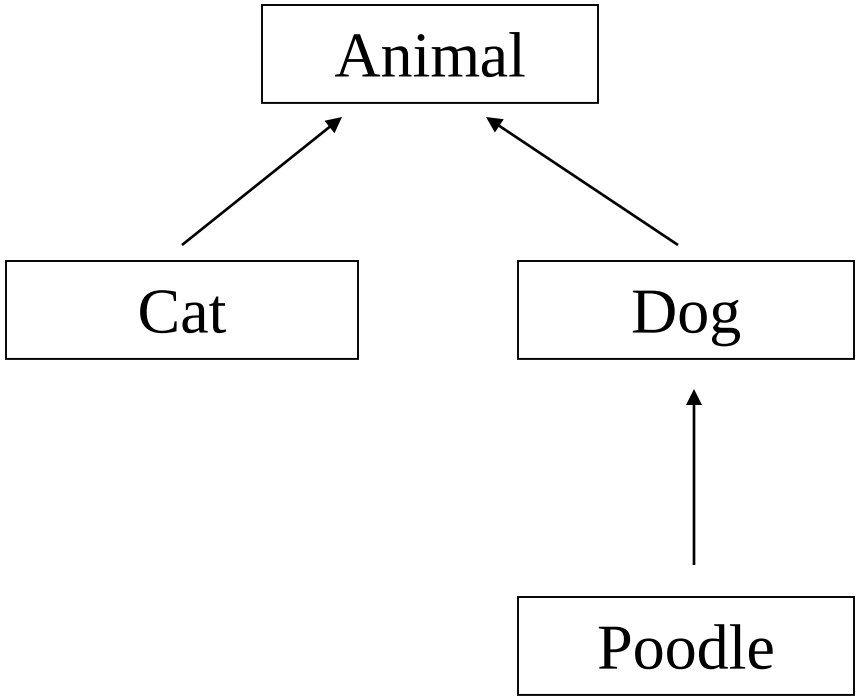
P 988 Program 15-1, eP938~939

15.2 Polymorphism and Virtual Member Functions

- Polymorphic code: Code that behaves differently when it acts on objects of different types
- Virtual Member Function: The C++ mechanism for achieving polymorphism

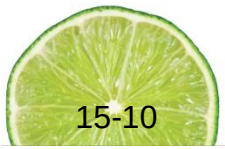
Polymorphism

Consider the Animal, Cat, Dog hierarchy where each class has its own version of the member function id( )



Polymorphism

```
class Animal{
 public: void id(){cout << "animal";}
}
class Cat : public Animal{
 public: void id(){cout << "cat";}
}
class Dog : public Animal{
 public: void id(){cout << "dog";}
}
```



Polymorphism

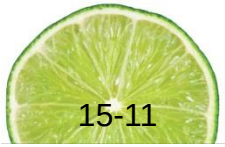
- Consider the collection of different Animal objects

```
Animal *pA[] = {new Animal, new Dog,
                new Cat};
```

and accompanying code

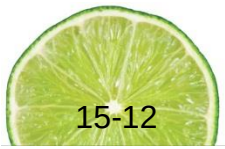
```
for(int k=0; k<3; k++)
    pA[k]->id();
```

- Prints: **`animal animal animal`**, ignoring the more specific versions of **`id()`** in **`Dog`** and **`Cat`**



Polymorphism

- The preceding code is not polymorphic: it behaves the same way even though **`Animal`**, **`Dog`** and **`Cat`** have different types and different **`id()`** member functions
- Polymorphic code would have printed "**`animal dog cat`**" instead of "**`animal animal animal`**"



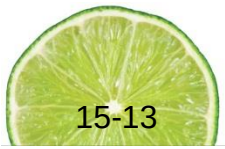
Polymorphism

- The code is not polymorphic because in the expression

  `pA[k]->id()`

  the compiler sees only the type of the pointer **`pA[k]`**, which is pointer to **`Animal`**
- Compiler does not see type of actual object pointed to, which may be **`Animal`**, or **`Dog`**, or **`Cat`**

P989 Program 15-2, eP939~940



Virtual Functions

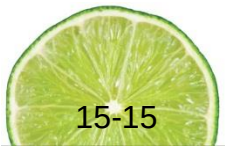
Declaring a function **`virtual`** will make the compiler check the type of each object to see if it defines a more specific version of the virtual function

Virtual Functions

If the member functions **`id()`** are declared virtual, then the code

```
Animal *pA[] = {new Animal,
                new Dog,new Cat};
for(int k=0; k<3; k++)
    pA[k]->id();
```

will print **`animal dog cat`**

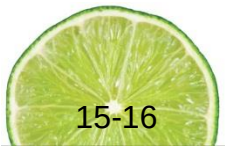


Virtual Functions

How to declare a member function virtual:

```
class Animal{
 public: virtual void id(){cout << "animal";}
}
class Cat : public Animal{
 public: virtual void id(){cout << "cat";}
}
class Dog : public Animal{
 public: virtual void id(){cout << "dog";}
}
```

P992 Program 15-3, eP941~943



Function Binding

- In **`pA[k]->id()`**, Compiler must choose which version of **`id()`** to use: There are different versions in the **`Animal`**, **`Dog`**, and **`Cat`** classes
- Function binding is the process of determining which function definition to use for a particular function call
- The alternatives are *static* and *dynamic* binding

Static Binding

- Static binding chooses the function in the class of the base class pointer, ignoring any versions in the class of the object actually pointed to
- Static binding is done at compile time

Dynamic Binding

- Dynamic Binding determines the function to be invoked at execution time
- Can look at the actual class of the object pointed to and choose the most specific version of the function
- Dynamic binding is used to bind virtual functions

15.3 Abstract Base Classes and Pure Virtual Functions

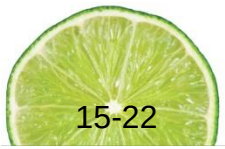
- An abstract class is a class that contains no objects that are not members of subclasses (derived classes)
- For example, in real life, Animal is an abstract class: there are no animals that are not dogs, or cats, or lions…

Abstract Base Classes and Pure Virtual Functions

- Abstract classes are an organizational tool. They are useful in organizing inheritance hierarchies
- Abstract classes can be used to specify an interface that must be implemented by all subclasses

Abstract Functions

- The member functions specified in an abstract class do not have to be implemented
- The implementation is left to the subclasses
- In C++, an abstract class is a class with at least one abstract member function

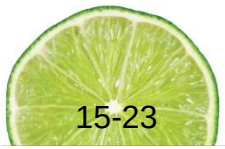


Pure Virtual Functions

- In C++, a member function of a class is declared to be an abstract function by making it virtual and replacing its body with `= 0;`

```
class Animal{
  public:
    virtual void id()=0;
};
```

- A virtual function with its body omitted and replaced with `=0` is called a pure virtual function, or an abstract function



Abstract Classes

- An abstract class can not be instantiated
- An abstract class can only be inherited from; that is, you can derive classes from it
- Classes derived from abstract classes must override all pure virtual functions with a concrete member functions before they can be instantiated.

P998 Program 15-6, eP945~946

15.4 Composition vs. Inheritance

- Inheritance models an 'is a' relation between classes. An object of a derived class 'is a(n)' object of the base class
- Example:
  - an **`UnderGrad`** is a **`Student`**
  - a **`Mammal`** is an **`Animal`**
  - a **`Poodle`** is a **`Dog`**

Composition vs. Inheritance

When defining a new class:

- Composition is appropriate when the new class needs to use an object of an existing class
- Composition models an ‘has a' relation between classes. An object of a composition class ‘has a(n)' object of another class

Composition vs. Inheritance

When defining a new class:

- Inheritance is appropriate when
  - objects of the new class are a subset of the objects of the existing class, or
  - objects of the new class will be used in the same ways as the objects of the existing class

P1005 Program 15-7, eP953~954

15.5 Secure Encryption System, Inc. : A Case Study

- A simple encryption/description framework
- Get char from input file → Encryption → Put the encrypted char into output file
- Class Encryption (P1008, eP956)

P1008 Program 15-8, eP956~958)

Homework 7

TEXT BOOK CH. 15 Programming Challenges

6. Removal of Line Breaks (P1020)

5. File Filter

A file filter reads an input file, transforms it in some way, and writes the results to an output file. Write an abstract file filter class that defines a pure virtual function for transforming a character. Create one subclass of your file filter class that performs encryption, another that transforms a file to all uppercase, and another that creates an unchanged copy of the original file.

The class should have a member function

```
void doFilter(ifstream &in, ofstream &out)
```

that is called to perform the actual filtering. The member function for transforming a single character should have the prototype

```
char transform(char ch)
```

The encryption class should have a constructor that takes an integer as an argument and uses it as the encryption key.

6. Removal of Line Breaks

Create a subclass of the abstract filter class of Programming Challenge 5 that replaces every line break in a file with a single space.