CS202: Programming Systems

Week 5

Virtual functions and polymorphism

11/2016

CS202 – What will be discussed?

- **IS-A** and **HAS-A** relationship
- Virtual functions and polymorphism
- Pure virtual functions
- Abstract class

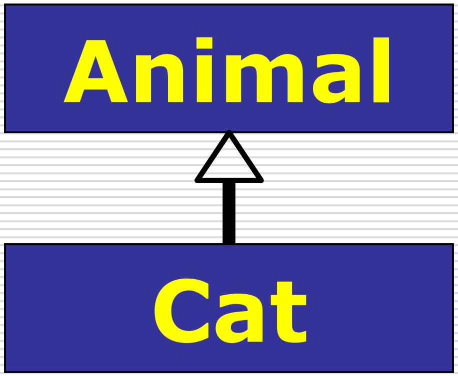
IS-A and **HAS-A** relationship

- The inheritance is only applied when there is a "**IS-A**" relationship between classes
  - E.g. Dog **is an** animal.
    Or, employer **is an** employee.

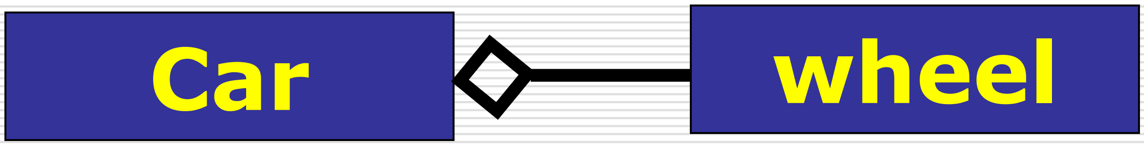
- When two classes have a "**HAS-A**" relationship, we declare one class as a member of the other.

An example

- Cat “is an” animal.



- Car “has a” wheel.



An example (cont.)

```
class Animal
{
    ...
};

class Cat: public Animal
{
    ...
};
```

```
class Wheel
{
    ...
};

class Car
{
private:
    Wheel wh;
};
```

A pointer to Base class

- A pointer to base class can be assigned with the address of an object of the derived class.
- For example:

```
Animal *pAni;
Cat c;
pAni = &c; //OK
```

Implicit type conversion in inheritance

- It is normal to pass a derived class variable to a function with an argument of base class data type. The compiler will do an implicit conversion.

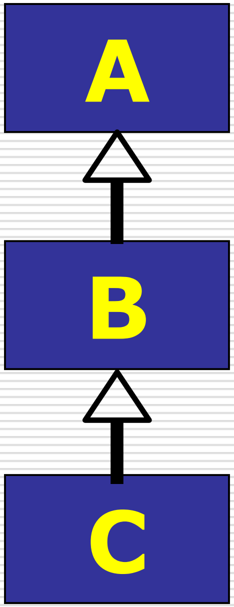
```
Animal::process(const Animal &a);

int main(){
   Cat c;
   Animal::process(c); //OK
}
```

Static binding

Consider the following situation:

- **`class A`** has **`void print()`**
- **`class B`** also has **`void print()`**
- **`class C`** has **`void print()`** too



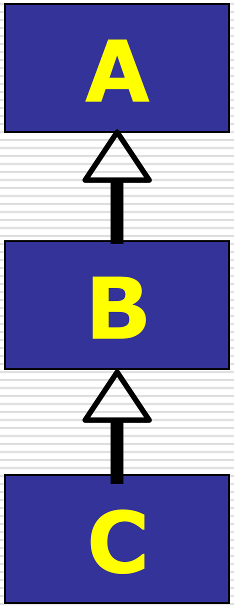

```
int main() {
    C varC;
    B varB;
    varB.print();    // print() of B
    varC.print();    // print() of C
    varC.B::print(); // print() of B
}
```

Static binding

- Another example:

```
int main() {
    A varA;
    B varB;
    C varC;
    A* var1, *var2

    var1 = &varC;
    var2 = &varB;
    var1->print();// print() of A
    var2->print();// print() of A
}
```



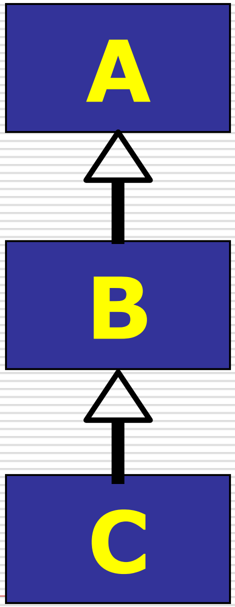
Virtual function

- Virtual function: in the base class, member functions will become virtual functions if we add the **`virtual`** keyword in front of their declarations.
- For example: **`virtual void print();`**
- In the derived class, the definition of virtual member function can be re-define according to the requirement of that class.
- Note: it is allowed to have or not have the **`virtual`** keyword in front of the virtual functions of the derived class.

Dynamic binding

- When using virtual functions, compiler will make sure which member function will be invoked according to which object is calling. For example `print()` is a virtual function

```
int main() {
    A varA;
    B varB;
    C varC;
    A* var1, *var2;
    var1 = &varC;
    var2 = &varB;
    var1->print(); // print() of C
    var2->print(); // print() of B
}
```



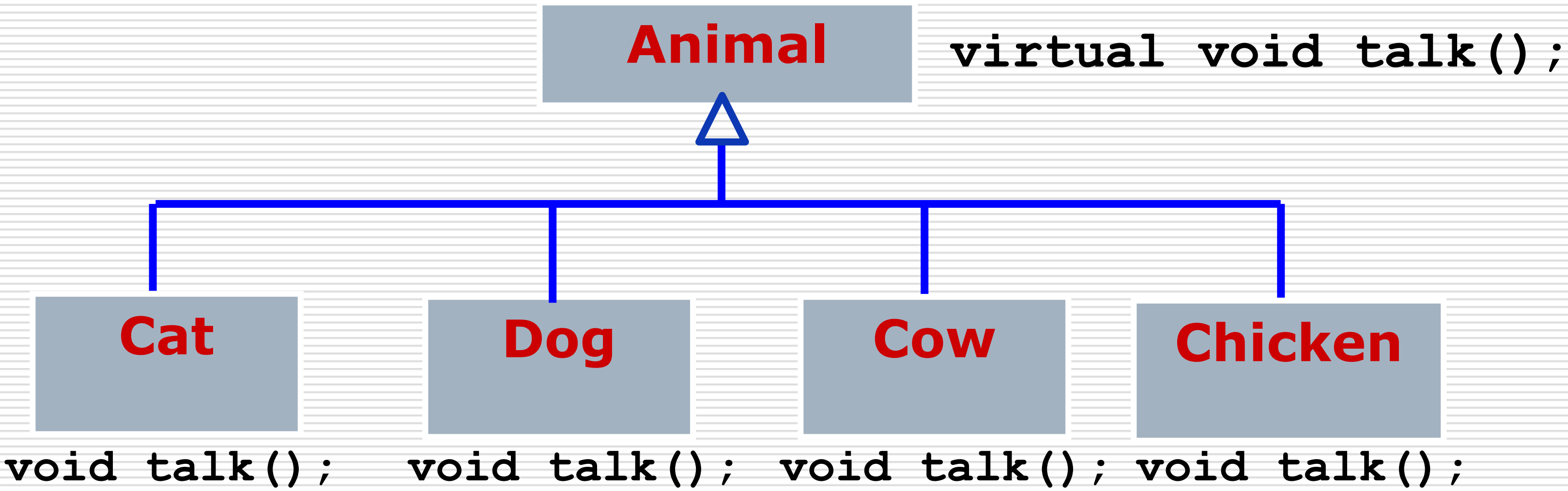
Polymorphism: Virtual function & Dynamic binding

- Beside the **`virtual`** keyword, the compiler will use dynamic binding only when the calling object is manipulated via a pointer or a reference.
- Calling a function using the scope resolution operator :: ensures that the virtual mechanism is not used.
- In the derived class, if the virtual function is not re-defined, compiler will look for the latest definition of this function in the inheritance hierachical structure.

Polymorphism

- Clearly, to implement polymorphism, the compiler must store some kind of type information in each object of class A and use it to call the right version of the virtual function **`print()`**. In a typical implementation, the space taken is just enough to hold a pointer.
- Typical implementation of virtual functions is to add to every object of a class with at least one virtual function a pointer to the virtual function table
- This table contains pointers to all the virtual functions of the classes the object belongs to

An example




```
int main() {
    Animal *pAni;
    Cat c;
    Dog d;
    pAni = &c; pAni->talk(); // talk() of Cat
    pAni = &d; pAni->talk(); // talk() of Dog
}
```

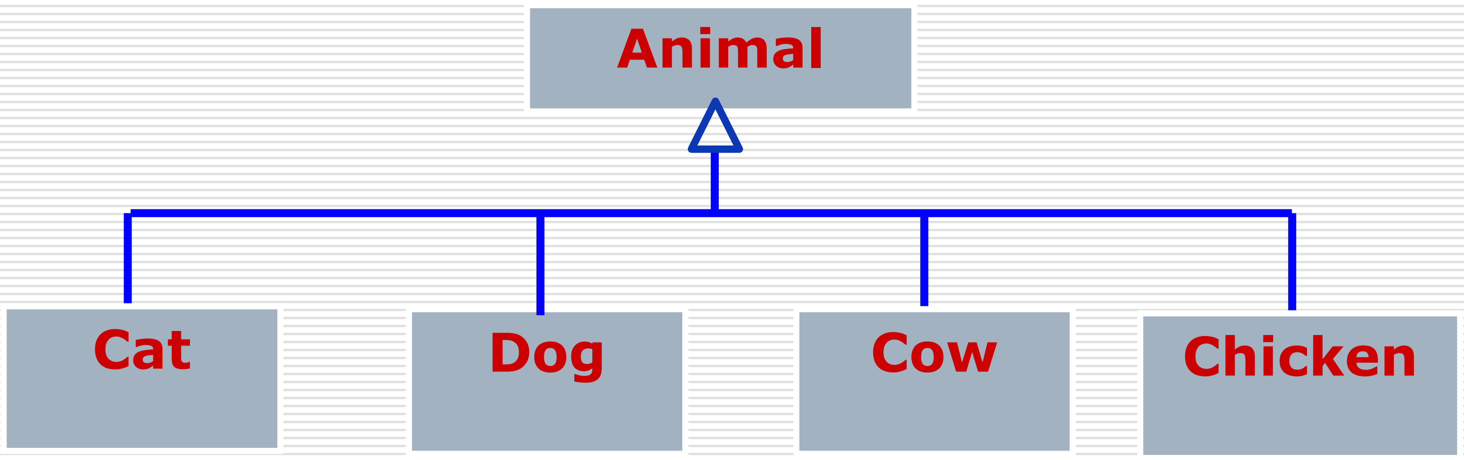
Virtual Constructor? **NO!!!**
Virtual Destructor? YES!

- **NO** virtual constructor!
  - Each constructor is used to initialize the class itself.
  - Constructors are designed to run from Base to Derived classes.
- Virtual destructor: YES!
  - The destructor should be virtual in order to free the memory/resource of the correct object.

Pure virtual function

- Consider the **`class Animal`** again

```
virtual void talk();
```



Pure virtual function

- Then

```
int main()
{
    Animal a; //What animal?
    a.talk(); //non-sense: how can it talk()
}
```

- **`talk()`** can be changed to pure virtual:

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

Abstract class

- A class which has one or more virtual functions becomes abstract class.
- No objects of the abstract class can be created.

```
Animal a; //Error!
```

Abstract class

- A pure virtual function that is not overriden in a derived class remains a pure virtual function, so the derived class is also an abstract class.
- An important use of abstract classes is to provide an interface without exposing any implementation details.
- Every class having at least one virtual function should have the virtual destructor.