POLYMORPHISM

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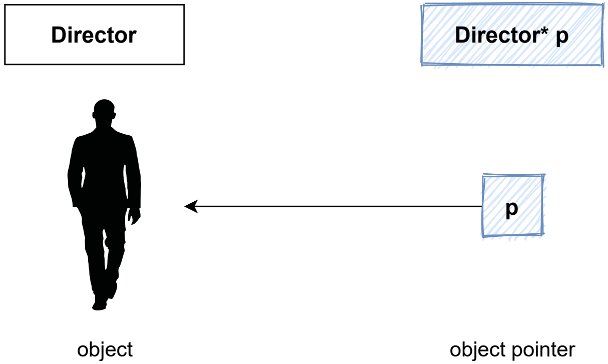
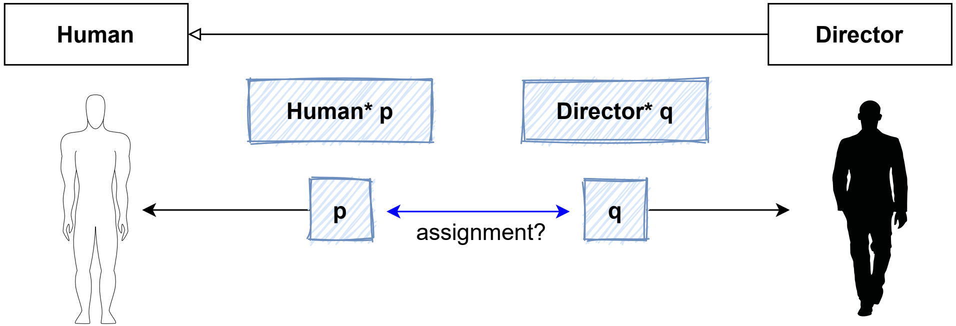
Contents

Basics of Polymorphism

Object Reference and Object Pointer



Object Pointer and Assignment



Polymorphism

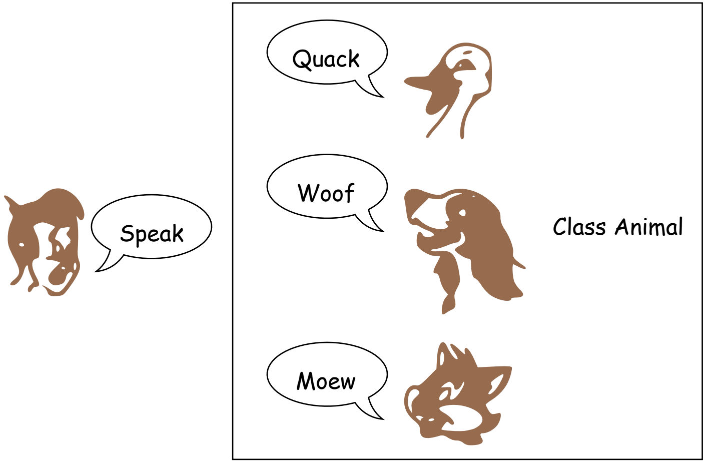
Concept 1 (General)

“Poly” is Greek for *many*, and “morph” means *form*. **Polymorphism** is that feature of object-oriented languages that allows objects of different types to be treated similarly.

Concept 2 (C++)

Polymorphism allows *an object reference variable* or *an object pointer* to reference objects of different types and to call the correct member functions, depending upon the type of object being referenced.

Polymorphism (cont.)



Need for Polymorphic Behavior

- It is possible that both `Tuna` and `Carp` provide their own `Tuna::Swim()` and `Carp::Swim()` methods to make `Tuna` and `Carp` different swimmers.
- If a user with an instance of `Tuna` uses the base class type to invoke `Fish::Swim()`, he ends up executing only the generic part `Fish::Swim()` and not `Tuna::Swim()`, even though that base class instance `Fish` is a part of a `Tuna`.

Listing 1

```cpp
#include <iostream>
using namespace std;
class Fish {
public:
   void Swim() {
      cout << "Fish swims!" << endl;
   }
};
class Tuna:public Fish {
public:
   // override Fish::Swim
   void Swim() {
      cout << "Tuna swims!" << endl;
   }
};
```

```cpp
void MakeFishSwim(Fish& InputFish) {
   // calling Fish::Swim
   InputFish.Swim();
}
int main() {
   Tuna myDinner;
   // calling Tuna::Swim
   myDinner.Swim();
   // sending Tuna as Fish
   MakeFishSwim(myDinner);
   return 0;
}
```

Polymorphic Behavior Implemented Using Virtual Functions

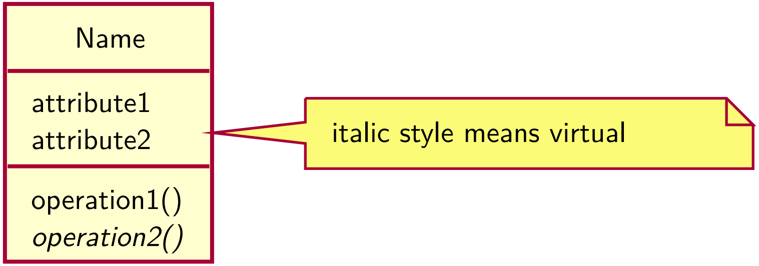
Concept 3

The **virtual function** provides the ability to define a function in a base class and have a function of the same name and type in a derived class called when a user calls the base class function.

Syntax

```
class Base {
   virtual ReturnType FunctionName (Parameter List);
};
class Derived : public Base {
   ReturnType FunctionName (Parameter List);
};
```

UML


Name
attribute1
attribute2
operation1()
operation2()
italic style means virtual

Listing 2

```cpp
#include <iostream>
using namespace std;
class Fish {
public:
   virtual void Swim() {
      cout << "Fish swims!" << endl;
   }
};
class Tuna:public Fish {
public:
   // override Fish::Swim
   void Swim() {
      cout << "Tuna swims!" << endl;
   }
};
```

```cpp
class Carp:public Fish {
public:
   // override Fish::Swim
   void Swim() {
      cout << "Carp swims!" << endl;
   }
};
void MakeFishSwim(Fish& InputFish) {
   // calling virtual method Swim()
   InputFish.Swim();
}
int main() {
   Tuna myDinner;
   Carp myLunch;
   // sending Tuna as Fish
   MakeFishSwim(myDinner);
   // sending Carp as Fish
   MakeFishSwim(myLunch);
   return 0;
}
```

Need for Virtual Destructors

- What happens when a function calls operator `delete` using a pointer of type `Base*` that actually points to an instance of type `Derived`?

```
#include <iostream>
using namespace std;
class Fish {
public:
   Fish() {
      cout << "Constructed Fish" << endl;
   }
   ~Fish() {
      cout << "Destroyed Fish" << endl;
   }
};
class Tuna:public Fish {
public:
   Tuna() {
      cout << "Constructed Tuna" << endl;
   }
   ~Tuna() {
      cout << "Destroyed Tuna" << endl;
   }
};
```

```
void DeleteFishMemory(Fish* pFish) {
   delete pFish;
}
int main() {
   cout << "Allocating a Tuna on the free store:"
         << endl;
   Tuna* pTuna = new Tuna;
   cout << "Deleting the Tuna: " << endl;
   DeleteFishMemory(pTuna);
   cout << "Instantiating a Tuna on the stack:" <<
          endl;
   Tuna myDinner;
   cout << "Automatic destruction as it goes out
         of scope: " << endl;
   return 0;
}
```

Need for Virtual Destructors (cont.)

- To avoid this problem, we use virtual destructors

```
class Fish {
public:
    Fish() {
        cout << "Constructed Fish" << endl;
    }
    virtual ~Fish() { // virtual destructor!
        cout << "Destroyed Fish" << endl;
    }
};
```

Static binding vs Dynamic binding

Binding

- The determination of which method in the class hierarchy is to be used for a particular object.

Static (Early) Binding

- When the compiler can determine which method in the class hierarchy to use for a particular object.

Dynamic (Late) Binding

- When the determination of which method in the class hierarchy to use for a particular object occurs during program execution.

How Do virtual Functions Work

- Consider a `class Base` that declared N virtual functions:

```
class Base {
public:
    virtual void Func1() {
        // Func1 implementation
    }
    virtual void Func2() {
        // Func2 implementation
    }
    // .. so on and so forth
    virtual void FuncN() {
        // FuncN implementation
    }
};
```

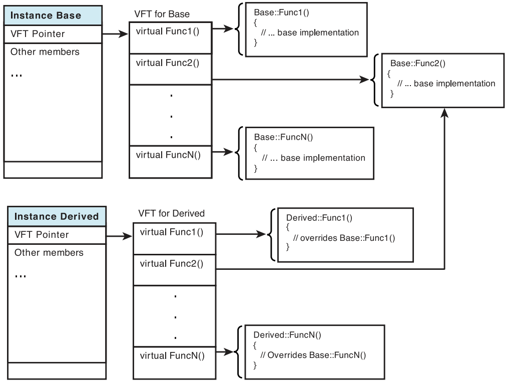
How Do virtual Functions Work (cont.)

- `class Derived` that inherits from `Base` overrides `Base::Func2()`, exposing the other virtual functions directly from `class Base`:

```
class Derived: public Base {
public:
    virtual void Func1() {
        // Func2 overrides Base::Func2()
    }
    // no implementation for Func2()
    virtual void FuncN() {
        // FuncN implementation
    }
};
```

How Do virtual Functions Work (cont.)

- The compiler sees an inheritance hierarchy and understands that the `Base` defines certain virtual functions that have been overridden in `Derived`. What the compiler now does is to create a table called the **Virtual Function Table** (VFT) for every class that implements a virtual function or derived class that overrides it.


Instance Base
VFT Pointer
Other members
...
VFT for Base
virtual Func1()
virtual Func2()
virtual FuncN()
Base::Func1() { // ... base implementation }
Base::Func2() { // ... base implementation }
Base::FuncN() { // ... base implementation }
Instance Derived
VFT Pointer
Other members
...
VFT for Derived
virtual Func1()
virtual Func2()
virtual FuncN()
Derived::Func1() { // overrides Base::Func1() }
Derived::FuncN() { // Overrides Base::FuncN() }

How Do virtual Functions Work (cont.)

- Each table is comprised of function pointers, each pointing to the available implementation of a virtual function

```
void DoSomething(Base& objBase) {
    objBase.Func1();    // invoke Derived::Func1
}
int main()
{
    Derived objDerived;
    objDerived.Func2();
    DoSomething(objDerived);
};
```

Abstract Base Classes and Pure Virtual Functions

Concept 4

- **A pure virtual function** is a virtual member function of a base class that must be overridden.
- When a class contains a pure virtual function as a member, that class becomes an **abstract base class**.
- An abstract base class cannot be instantiated.

Syntax

```
class AbstractBase {
public:
    virtual void DoSomething() = 0;  // pure virtual method
};
```

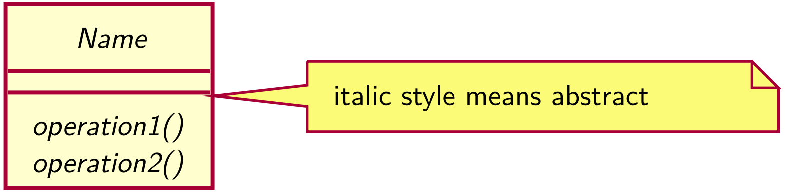
Object-Oriented Design

- Sometimes it is helpful to begin a class hierarchy with *an abstract base class*. The abstract base class represents the generic, or abstract, form of all the classes that are derived from it.

Principle

“High-level modules should not depend upon low-level modules. Both should depend upon abstractions.”
“Abstractions should not depend on details. Details should depend on abstractions.”

UML



Listing 3

```
#include <iostream>
using namespace std;
class Fish {
public:
   // a pure virtual function Swim
   virtual void Swim() = 0;
};
class Tuna:public Fish {
public:
   void Swim() {
      cout << "Tuna swims" << endl;
   }
};
```

```
class Carp:public Fish {
   void Swim() {
      cout << "Carp swims" << endl;
   }
};
void MakeFishSwim(Fish& inputFish) {
   inputFish.Swim();
}
int main() {
   // Fish myFish;   // Fails
   Carp myLunch;
   Tuna myDinner;
   MakeFishSwim(myLunch);
   MakeFishSwim(myDinner);
   return 0;
}
```

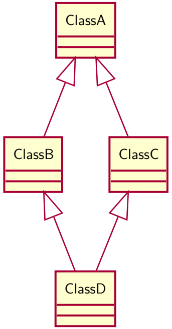
Diamond Problem

Diamond Problem

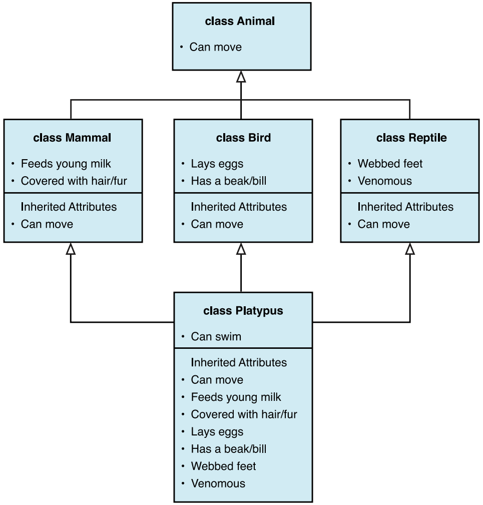
Replicated based class

- With the ability of specifying more than one base class, there may be a chance of having the same base class more than once.

Diamond problem

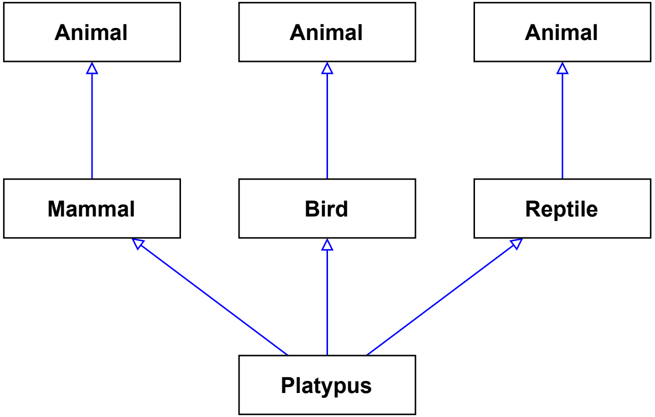


Diamond Problem (cont.)



- What happens when we instantiate a `Platypus`? How many instances of class `Animal` are instantiated for one instance of `Platypus`?

Diamond Problem (cont.)



Lisiting 4

```
#include <iostream>
using namespace std;
class Animal {
public:
   Animal() {
      cout << "Animal constructor" <<
           endl;
   }
   int Age;
};
class Mammal:public Animal {
};
class Bird:public Animal {
};
class Reptile:public Animal {
};
```

```
class Platypus:public Mammal, public
    Bird, public Reptile {
public:
   Platypus() {
      cout << "Platypus constructor"
          << endl;
   }
};
int main() {
   Platypus duckBilledP;
   // Age is ambiguous as there are
   // three instances of base Animal
   duckBilledP.Age = 25;
   return 0;
}
```

Using virtual Inheritance to Solve the Diamond Problem

- The solution is in virtual inheritance

Syntax

```
class Derived1: public virtual Base {
   // ... members and functions
};
class Derived2: public virtual Base {
   // ... members and functions
};
```

Lisiting 5

```
#include <iostream>
using namespace std;
class Animal {
public:
   Animal() {
      cout << "Animal constructor" <<
           endl;
   }
   int Age;
};
class Mammal:public virtual Animal {
};
class Bird:public virtual Animal {
};
class Reptile:public virtual Animal {
};
```

```
class Platypus:public Mammal, public
    Bird, public Reptile {
public:
   Platypus() {
      cout << "Platypus constructor"
          << endl;
   }
};
int main() {
   Platypus duckBilledP;
   // no compile error
   duckBilledP.Age = 25;
   return 0;
}
```

Virtual Copy Constructors?

Virtual Copy Constructors?

- It is technically impossible in C++ to have virtual copy constructors
- Virtual copy constructors are not possible because the `virtual` keyword in context of base class methods being overridden by implementations available in the derived class are about polymorphic behavior generated at runtime.
- Constructors, on the other hand, are not polymorphic in nature as they can construct only a fixed type, and hence C++ does not allow usage of the virtual copy constructors.
- **Design pattern**: Propotype Pattern

Virtual Clone Method

```
class Fish {
public:
   virtual Fish* Clone() const = 0; // pure virtual function
};

class Tuna:public Fish {
// ... other members
public:
   Fish* Clone() const {      // virtual clone function
      return new Tuna(*this); // return new Tuna that is
                              // a copy of this
   }
};
```

Workshop

Quiz

1. What is a virtual method?

   . . . .

   . . . .

   . . . .

2. When does static binding take place? When does dynamic binding take place?

   . . . .

   . . . .

   . . . .

3. What is an abstract base class?

   . . . .

   . . . .

   . . . .

Exercises

- Programming Challenges of chapter 15 [Gaddis, 2014]
  9. File Filter
  12. Ship , CruiseShip , and CargoShip Classes

References

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Gaddis, T. (2014).
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Jones, B. (2014).
Sams teach yourself C++ in one hour a day.
Sams.