Programming in Modern C++

Module M27: Polymorphism: Part 2: Static and Dynamic Binding

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All url's in this module have been accessed in September, 2021 and found to be functional

Module Recap

- Introduced type casting
- Understood the difference between implicit and explicit type casting
- Introduced the notions of type casting in a class hierarchy – upcast and downcast

Module Objectives

- Understand Static and Dynamic Binding
- Understand Polymorphic Type

Module Outline

Type Binding

Type of an Object

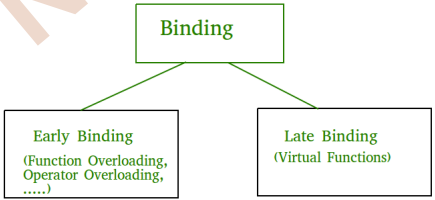
- The *static type* of the object is the type declared for the object while writing the code
- Compiler *sees static type*
- The *dynamic type* of the object is determined by the type of the object to which it *refers at run-time*
- Compiler *does not see dynamic type*

```
class A { };
class B : public A { };

int main() {
    A *p;
    p = new B; // Static type of p is A*
               // Dynamic type of p is B*
}
```

Static and Dynamic Binding

- **Static binding** (early binding): When a function invocation binds to the function definition based on the static type of objects
  - This is done at *compile-time*
  - Normal *function calls*, *overloaded function calls*, and *overloaded operators* are examples of *static binding*
- **Dynamic binding** (late binding): When a function invocation binds to the function definition based on the dynamic type of objects
  - This is done at *run-time*
  - *Function pointers*, *Virtual functions* are examples of *late binding*



Comparison of Static and Dynamic Binding

Basis	Static Binding	Dynamic Binding
• Event Occurrence • Information	• Events occur at *compile time* – *Static Binding* • All information needed to call a function is known at *compile time*	• Events occur at *run time* – *Dynamic Binding* • All information needed to call a function is known only at *run time*
• Advantage • Time	• *Efficiency* • *Fast execution*	• *Flexibility* • *Slow execution*
• Actual Object	• Actual object is *not used for binding*	• Actual object is *used for binding*
• Alternate name	• *Early Binding*	• *Late Binding*
• Example	• *Method Overloading* Normal function call, Overloaded function call, Overloaded operators	• *Method Overriding* Virtual functions

Static Binding

Inherited Method

```
#include<iostream>
using namespace std;
class B { public:
    void f() { }
};
class D : public B { public:
    void g() { } // new function
};
int main() { B b; D d;

    b.f(); // B::f()
    d.f(); // B::f() ----- Inherited
    d.g(); // D::g() ----- Added
}
```

- Object `d` of derived class inherits the base class function `f()` and has its own function `g()`
- Function calls are resolved at compile time based on static type

Overridden Method

```
#include<iostream>
using namespace std;
class B { public:
    void f() { }
};
class D : public B { public:
    void f() { }
};
int main() { B b; D d;

    b.f(); // B::f()
    d.f(); // D::f() ----- Overridden
           // masks the base class function
}
```

- If a member function of a base class is redefined in a derived class with the same signature then it masks the base class method
- The derived class method `f()` is linked to the object `d`. As `f()` is redefined in the derived class, the base class version cannot be called with the object of a derived class

Member Functions: Overrides and Overloads: RECAP (Module 22)

Inheritance

```
class B { public: // Base Class
    void f(int i);
    void g(int i);
};
class D: public B { public: // Derived Class
    // Inherits B::f(int)


    // Inherits B::g(int)

};
B b;
D d;

b.f(1); // Calls B::f(int)
b.g(2); // Calls B::g(int)

d.f(3); // Calls B::f(int)
d.g(4); // Calls B::g(int)
```

- D::f(int) overrides B::f(int)
- D::f(string&) overloads B::f(int)

Override & Overload

```
class B { public: // Base Class
    void f(int);
    void g(int i);
};
class D: public B { public: // Derived Class
    // Inherits B::f(int)
    void f(int);      // Overrides B::f(int)
    void f(string&); // Overloads B::f(int)
    // Inherits B::g(int)
    void h(int i);    // Adds D::h(int)
};
B b;
D d;

b.f(1);      // Calls B::f(int)
b.g(2);      // Calls B::g(int)

d.f(3);      // Calls D::f(int)
d.g(4);      // Calls B::g(int)

d.f("red"); // Calls D::f(string&)
d.h(5);      // Calls D::h(int)
```

using Construct – Avoid Method Hiding


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

class A { public:
    void f() { }
};

class B : public A { public:
     // To overload, rather than hide the base class function f(),
     // it is introduced into the scope of B with a using declaration
    using A::f;
    void f(int) { } // Overloads f()
};
int main() {
    B b; // function calls resolved at compile time

    b.f(3); // B::f(int)
    b.f();  // A::f()
}
```


- Object `b` of derived class linked to with inherited base class function `f()` and the overloaded version defined by the derived class `f(int)`, based on the input parameters – function calls resolved at compile time

Dynamic Binding

Non-Virtual Method

```
#include<iostream>
using namespace std;
class B { public:
    void f() { }
};
class D : public B { public:
    void f() { }
};
int main() {
    B b;
    D d;

    B *p;

    p = &b; p->f(); // B::f()
    p = &d; p->f(); // B::f()
}
```

- `p->f()` always binds to `B::f()`
- Binding is decided by the *type of pointer*
- **Static Binding**

Virtual Method

```
#include<iostream>
using namespace std;
class B { public:
    virtual void f() { }
};
class D : public B { public:
    virtual void f() { }
};
int main() {
    B b;
    D d;

    B *p;

    p = &b; p->f(); // B::f()
    p = &d; p->f(); // D::f()
}
```

- `p->f()` binds to `B::f()` for a `B` object, and to `D::f()` for a `D` object
- Binding is decided by the *type of object*
- **Dynamic Binding**

Static and Dynamic Binding

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

class B { public:
    void f() { cout << "B::f()" << endl; }
    virtual void g() { cout << "B::g()" << endl; }
};
class D: public B { public:
    void f() { cout << "D::f()" << endl; }
    virtual void g() { cout << "D::g()" << endl; }
};
 int main() { B b; D d;

     B *pb = &b;
     B *pd = &d; // UPCAST

     B &rb = b;
     B &rd = d;  // UPCAST

     b.f(); // B::f()
     b.g(); // B::g()
     d.f(); // D::f()
     d.g(); // D::g()

     pb->f(); // B::f() -- Static Binding
     pb->g(); // B::g() -- Dynamic Binding
     pd->f(); // B::f() -- Static Binding
     pd->g(); // D::g() -- Dynamic Binding

     rb.f();  // B::f() -- Static Binding
     rb.g();  // B::g() -- Dynamic Binding
     rd.f();  // B::f() -- Static Binding
     rd.g();  // D::g() -- Dynamic Binding

     return 0;
}
```

Polymorphic Type

Polymorphic Type: Virtual Functions

- *Dynamic binding* is possible only for pointer and reference data types and for member functions that are declared as `virtual` in the base class
- These are called Virtual Functions
- If a member function is declared as virtual, it can be overridden in the derived class
- If a member function is not virtual and it is re-defined in the derived class then the latter definition hides the former one
- Any class containing a virtual member function – by definition or by inheritance – is called a Polymorphic Type
- A hierarchy may be *polymorphic* or *non-polymorphic*
- A non-polymorphic hierarchy has little value

Polymorphism Rule


```
#include <iostream>
using namespace std;
class A { public:
    void f()         { cout << "A::f()" << endl; } // Non-Virtual
    virtual void g() { cout << "A::g()" << endl; } // Virtual
    void h()         { cout << "A::h()" << endl; } // Non-Virtual
};
class B : public A { public:
    void f()         { cout << "B::f()" << endl; } // Non-Virtual
    void g()         { cout << "B::g()" << endl; } // Virtual
    virtual void h() { cout << "B::h()" << endl; } // Virtual
};
class C : public B { public:
    void f()         { cout << "C::f()" << endl; } // Non-Virtual
    void g()         { cout << "C::g()" << endl; } // Virtual
    void h()         { cout << "C::h()" << endl; } // Virtual
};
```

```
int main() {
    B *q = new C; A *p = q;

    p->f();
    p->g();
    p->h();

    q->f();
    q->g();
    q->h();
}
```

```
A::f()
C::g()
A::h()
B::f()
C::g()
C::h()
```

Module Summary

- Discussed Static and Dynamic Binding
- Polymorphic type introduced