Module 25: Programming in C++

Inheritance: Part 5 (`private` & `protected` Inheritance)

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Slides taken from NPTEL course on Programming in C++

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Module Objectives

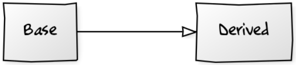
- Explore restricted forms of inheritance (`private` and `protected`) in C++ and their semantic implications

Module Outline

- `ISA` Relationship
- Inheritance in C++
  - Semantics
  - Data Members and Object Layout
  - Member Functions
    - Overriding
    - Overloading
  - `protected` Access
  - Constructor & Destructor
  - Object Lifetime
- Example – Phone Hierarchy
- Inheritance in C++ (`private`)
  - Implemented-As Semantics

Inheritance in C++: Semantics

- Derived **ISA** Base



```
class Base;                        // Base Class = Base
class Derived: public Base; // Derived Class = Derived
```

- Use keyword `public` after class name to denote inheritance
- Name of the Base class follow the keyword

Inheritance Exercise: What is the output?

```
class B {
public:
    B() { cout << "B "; }
    ~B() { cout << "~B "; } };

class C {
public:
    C() { cout << "C "; }
    ~C() { cout << "~C "; } };

class D : public B {
    C data_;
public:
    D() { cout << "D " << endl; }
    ~D() { cout << "~D "; }
};

int main() {
    D d;

    return 0;
}
```

Inheritance Exercise: What is the output?

```
class B {
public:
    B() { cout << "B "; }
    ~B() { cout << "~B "; } };

class C {
public:
    C() { cout << "C "; }
    ~C() { cout << "~C "; } };

class D : public B {
    C data_;
public:
    D() { cout << "D " << endl; }
    ~D() { cout << "~D "; }
};

int main() {
    D d;

    return 0;
}
```

Output:

```
B C D
~D ~C ~B
```

private Inheritance

- private Inheritance
  - Definition

    ```
    class Base;
    class Derived: private Base;
    ```
  - Use keyword private after class name
  - Name of the Base class follow the keyword
  - private inheritance does not mean generalization / specialization

• Private inheritance means nothing during software design, only during software implementation

• Private inheritance means is-implemented-in-terms of. It's usually inferior to composition, but it makes sense when a derived class needs access to protected base class members or needs to redefine inherited virtual functions

– Scott Meyers in Item 32, Effective C++ (3rd. Edition)

private Inheritance

public Inheritance

```
class Person {...};

class Student:
    public Person {...};

// anyone can eat
void eat(const Person& p);

// only students study
void study(const Student& s);

Person p;  // p is a Person

Student s; // s is a Student

eat(p);    // fine, p is a Person

eat(s);    // fine, s is a Student,
           // and a Student is-a Person

study(s);  // fine

study(p);  // error! p isn't a Student
```

Compilers converts a derived class object (Student) into a base class object (Person) if the inheritance relationship is public

private Inheritance

```
class Person { ... };

class Student: // inheritance is now private
    private Person { ... };

// anyone can eat
void eat(const Person& p);

// only students study
void study(const Student& s);

Person p;  // p is a Person

Student s; // s is a Student

eat(p);    // fine, p is a Person

eat(s);    // error! a Student isn't a Person
```

Compilers will not convert a derived class object (Student) into a base class object (Person) if the inheritance relationship is private

protected Inheritance

- protected Inheritance
  - Definition

    ```
    class Base;
    class Derived: protected Base;
    ```
  - Use keyword protected after class name
  - Name of the Base class follow the keyword
  - protected inheritance does not mean generalization / specialization

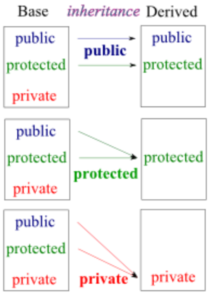
• Private inheritance means something entirely different (from public inheritance), and protected inheritance is something whose meaning eludes me to this day

– Scott Meyers in Item 32, Effective C++ (3rd. Edition)

Visibility across Access and Inheritance

- Visibility Matrix

		Inheritance		
		public	protected	private
Visibility	public	public	protected	private
	protected	protected	protected	private
	private	private	private	private



Inheritance Exercise: What is the output?

```
class B {
protected:
    B() { cout << "B "; }
    ~B() { cout << "~B "; }
};
class C : public B {
protected:
    C() { cout << "C "; }
    ~C() { cout << "~C "; }
};
class D : private C {
    C data_;
public:
    D() { cout << "D " << endl; }
    ~D() { cout << "~D "; }
};

int main() {
    D d;

    return 0;
}
```

Inheritance Exercise: What is the output?

```
class B {
protected:
    B() { cout << "B "; }
    ~B() { cout << "~B "; }
};
class C : public B {
protected:
    C() { cout << "C "; }
    ~C() { cout << "~C "; }
};
class D : private C {
    C data_;
public:
    D() { cout << "D " << endl; }
    ~D() { cout << "~D "; }
};

int main() {
    D d;

    return 0;
}
```

Output:

```
B C B C D
~D ~C ~B ~C ~B
```

Inheritance Exercise: Access Rights

Inaccessible Members

```
class A {
private: int x;
protected: int y;
public: int z;
};
class B : public A {
private: int u;
protected: int v;
public: int w; void f() { x; }
};
class C: protected A {
private: int u;
protected: int v;
public: int w; void f() { x; }
};
class D: private A {
private: int u;
protected: int v;
public: int w; void f() { x; }
};
class E : public B {
public: void f() { x; u; }
};
class F : public C {
public: void f() { x; u; }
};
class G : public D {
public: void f() { x; y; z; u; }
};
```

Accessible Members

```
void f(A& a,
       B& b, C& c, D& d,
       E& e, F& f, G& g) {
    a.z;

    b.z;
    b.w;

    c.w;

    d.w;

    e.z;
    e.w;

    f.w;

    g.w;
}
```

Car HAS–A Engine: Composition OR `private` Inheritance?

Simple Composition

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

class Engine {
public:
    Engine(int numCylinders) { }
    // Starts this Engine
    void start() { }
};

class Car {
public:
    // Initializes this Car with 8 cylinders
    Car() : e_(8) { }

    // Start this Car by starting its Engine
    void start() { e_.start(); }
private:
    Engine e_; // Car has-a Engine
};

int main() {
    Car c;

    c.start();

    return 0;
}
```

`private` **Inheritance**

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

class Engine {
public:
    Engine(int numCylinders) { }
    // Starts this Engine
    void start() { }
};

class Car : private Engine { // Car has-a Engine
public:
    // Initializes this Car with 8 cylinders
    Car() : Engine(8) { }

    // Start this Car by starting its Engine
    using Engine::start;


};

int main() {
    Car c;

    c.start();

    return 0;
}
```

private Inheritance

- Use composition when you can, private inheritance when you have to

• Private inheritance means nothing during software design, only during software implementation

• Private inheritance means is-implemented-in-terms of. It's usually inferior to composition, but it makes sense when a derived class needs access to protected base class members or needs to redefine inherited virtual functions

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Module Summary

- Introduced restricted forms of inheritance and `protected` specifier
- Discussed how `private` inheritance is used for *Implemented-As* Semantics