25.11 — Printing inherited classes using operator<<

▲ ALEX ● SEPTEMBER 11, 2023

Consider the following program that makes use of a virtual function:

```
#include <iostream>

class Base
{
public:
    virtual void print() const { std::cout << "Base"; }
};

class Derived : public Base
{
    public:
        void print() const override { std::cout << "Derived"; }
};

int main()
{
    Derived d{};
    Base& b{ d };
    b.print(); // will call Derived::print()
    return 0;
}</pre>
```

By now, you should be comfortable with the fact that b.print() will call Derived::print() (because b is pointing to a Derived class object, Base::print() is a virtual function, and Derived::print() is an override).

While calling member functions like this to do output is okay, this style of function doesn't mix well with std::cout:

```
#include <iostream>
int main()
{
    Derived d{};
    Base& b{ d };

std::cout << "b is a ";
    b.print(); // messy, we have to break our print statement to call this function
    std::cout << '\n';
    return 0;
}</pre>
```

In this lesson, we'll look at how to override operator<< for classes using inheritance, so that we can use operator<< as expected, like this:

```
std::cout << "b is a " << b << '\n'; // much better
```

The challenges with operator<<

Let's start by overloading operator<< in the typical way:

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```
#include <iostream>
class Base
public:
    virtual void print() const { std::cout << "Base"; }</pre>
    friend std::ostream& operator<<(std::ostream& out, const Base& b)</pre>
        out << "Base";
        return out;
class Derived : public Base
public:
    void print() const override { std::cout << "Derived"; }</pre>
    friend std::ostream& operator<<(std::ostream& out, const Derived& d)
        out << "Derived";</pre>
        return out;
};
int main()
    Base b{};
    std::cout << b << '\n';
    Derived d{};
    std::cout << d << '\n';
    return 0;
```

Because there is no need for virtual function resolution here, this program works as we'd expect, and prints:

```
Base
Derived
```

Now, consider the following main() function instead:

```
int main()
{
    Derived d{};
    Base& bref{ d };
    std::cout << bref << '\n';
    return 0;
}</pre>
```

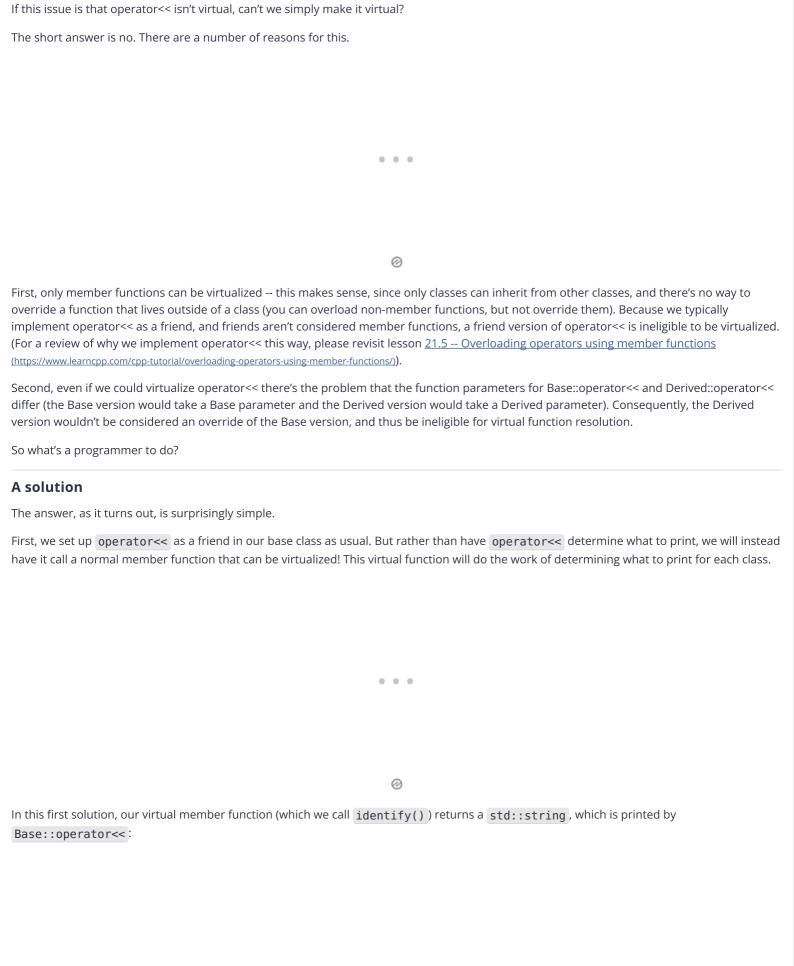
This program prints:

```
Base
```

That's probably not what we were expecting. This happens because our version of operator<< that handles Base objects isn't virtual, so std::cout << breed that handles Base objects rather than Derived objects.

Therein lies the challenge.

Can we make operator<< virtual?



```
#include <iostream>
class Base
public:
    // Here's our overloaded operator<<
   friend std::ostream& operator<<(std::ostream& out, const Base& b)</pre>
        // Call virtual function identify() to get the string to be printed
        out << b.identify();</pre>
        return out;
    }
    // We'll rely on member function identify() to return the string to be printed
   // Because identify() is a normal member function, it can be virtualized
    virtual std::string identify() const
        return "Base";
};
class Derived : public Base
public:
    // Here's our override identify() function to handle the Derived case
    std::string identify() const override
        return "Derived";
int main()
    Base b{};
    std::cout << b << '\n';
    Derived d{};
    std::cout << d << '\n'; // note that this works even with no operator<< that explicitly handles Derived objects
    Base& bref{ d }:
    std::cout << bref << '\n';</pre>
    return 0;
```

This prints the expected result:

```
Base
Derived
Derived
```

Let's examine how this works in more detail.

In the case of Base b, operator<< is called with parameter b referencing the Base object. Virtual function call b.identify() thus resolves to Base::identify(), which returns "Base" to be printed. Nothing too special here.

In the case of <code>Derived d</code>, the compiler first looks to see if there's an <code>operator<<</code> that takes a Derived object. There isn't one, because we didn't define one. Next the compiler looks to see if there's an <code>operator<<</code> that takes a Base object. There is, so the compiler does an implicit upcast of our Derived object to a Base& and calls the function (we could have done this upcast ourselves, but the compiler is helpful in this regard). Because parameter <code>b</code> is referencing a Derived object, virtual function call <code>b.identify()</code> resolves to <code>Derived::identify()</code>, which returns "Derived" to be printed.

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objects and any class derived from Base!

The third case proceeds as a mix of the first two. First, the compiler matches variable bref with operator<< that takes a Base reference.

Because parameter b is referencing a Derived object, b.identify() resolves to Derived::identify(), which returns "Derived".

Problem solved.

A more flexible solution

The above solution works great, but has two potential shortcomings:

- 1. It makes the assumption that the desired output can be represented as a single std::string.
- 2. Our identify() member function does not have access to the stream object.

The latter is problematic in cases where we need a stream object, such as when we want to print the value of a member variable that has an overloaded operator<<.

Fortunately, it's straightforward to modify the above example to resolve both of these issues. In the previous version, virtual function identify() returned a string to be printed by Base::operator<</pre>. In this version, we'll instead define virtual member function print()
and delegate responsibility for printing directly to that function.

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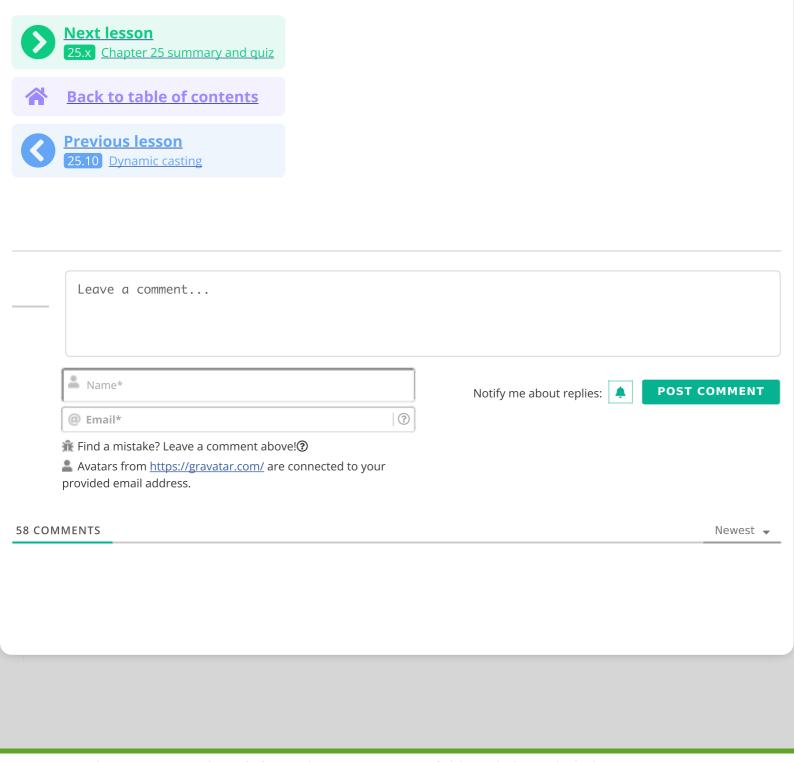
Here's an example that illustrates the idea:

```
#include <iostream>
class Base
public:
    // Here's our overloaded operator<<
    friend std::ostream& operator<<(std::ostream& out, const Base& b)</pre>
        // Delegate printing responsibility for printing to virtual member function print()
        return b.print(out);
    }
    // We'll rely on member function print() to do the actual printing
    // Because print() is a normal member function, it can be virtualized
    virtual std::ostream& print(std::ostream& out) const
        out << "Base";
        return out;
};
// Some class or struct with an overloaded operator<<
struct Employee
    std::string name{};
    int id{};
    friend std::ostream& operator<<(std::ostream& out, const Employee& e)
        out << "Employee(" << e.name << ", " << e.id << ")";
        return out;
};
class Derived : public Base
private:
    Employee m_e{}; // Derived now has an Employee member
    Derived(const Employee& e)
       : m_e{ e }
    // Here's our override print() function to handle the Derived case
    std::ostream& print(std::ostream& out) const override
        out << "Derived: ";</pre>
        \ensuremath{//} Print the Employee member using the stream object
        out << m_e;
        return out;
    }
};
int main()
    std::cout << b << '\n';
    Derived d{ Employee{"Jim", 4}};
    sta::cout << d << '\n'; // note that this works even with no operator << that explicitly handles Derived objects
    Base& bref{ d };
    std::cout << bref << '\n';</pre>
    return 0;
```

This outputs:

```
Base
Derived: Employee(Jim, 4)
Derived: Employee(Jim, 4)
```

In this version, <code>Base::operator<<</code> doesn't do any printing itself. Instead, it just calls virtual member function <code>print()</code> and passes it the stream object. The <code>print()</code> function then uses this stream object to do its own printing. <code>Base::print()</code> uses the stream object to print "Base". More interestingly, <code>Derived::print()</code> uses the stream object to print both "Derived:" and to call <code>Employee::operator<<</code> to print the value of member <code>m_e</code>. The latter would have been more challenging to do in the prior example!



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