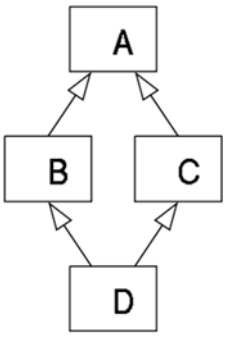
Solving the Diamond Problem with Virtual Inheritance

Multiple inheritance in C++ is a powerful, but tricky tool, that often leads to problems if not used carefully. This article will teach you how to use virtual inheritance to solve a common problem programmers run into, the diamond problem.

The diamond problem



The "diamond problem" is an ambiguity that arises when two classes B and C inherit from A, and class D inherits from both B and C. If there is a method in A that B and C have overridden, and D does not override it, then which version of the method does D inherit: that of B, or that of C?

A classical illustration of this is given by Bjarne Stroustrup (the creator of C++) in the following example:

Sample code

```
class storable //this is the our base class inherited by transmitter and receiver classes
{
        public:
        storable(const char*);
        virtual void read();
        virtual void write();
        virtual ~storable();
        private:
        ....
}

class transmitter: public storable
{
        public:
        void write();
        ...
}

class receiver: public storable
{
        public:
        void read();
        ...
}

class radio: public transmitter, public receiver
{
        public:
        void read();
        ....
}
```

Problem

1. Since both **transmitter** and **receiver** classes are using the method **write()** from the base class, when calling the method **write()** from a **radio** object the call is ambiguous.
2. The compiler can't know which implementation of **write()** to use, the one from the **transmitter** class or the one from the **receiver** class.

What happened?

1. In memory, inheritance simply puts the implementation of two objects one after another.
2. But **radio** is both a **transmitter** and a **receiver**, so the **storable** class gets duplicated inside the radio object.
3. Compile error: 'request for member "**write**" is ambiguous', because it can't figure out whether to call the method **write()** from **receiver** or from **transmitter**.

Solution: Virtual Inheritance

In order to prevent the compiler from giving an error we use the keyword **virtual** when we inherit from the base class **storable** in both derived

classes:

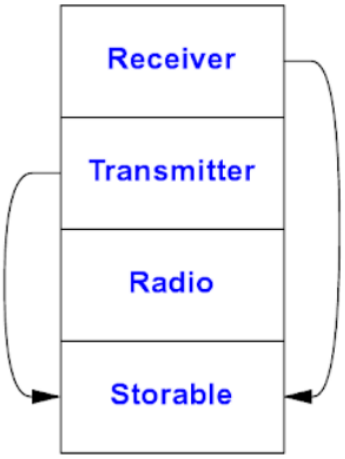
```
class transmitter: public virtual storable
{
        public:
        void read();
        ...
}

class receiver: public virtual storable
{
        public:
        void read();
        ...
}
```

1. When we use virtual inheritance, we are guaranteed to get only a single instance of the common base class.
2. In other words, the **radio** class will have only a single instance of the **storable** class, shared by both the **transmitter** and **receiver** classes

Memory Layout in Virtual Inheritance

When a **radio** object is constructed, it creates one **storable** instance, a **transmitter** instance and a **receiver** instance:



Constructors behind Virtual Inheritance

1. Because there is only a single instance of a virtual base class that is shared by multiple classes that inherit from it, the constructor for a virtual base class

is not called by the class that inherits from it (which is how constructors are called, when each class has its own copy of its parent class)
    - Otherwise, that would mean the constructor would run multiple times.
2. Instead, the constructor is called by the constructor of the concrete class. In the example above, the class **radio** directly calls the constructor for **storable**.
    - If you need to pass any arguments to the **storable** constructor, you would do so using an initialization list, as usual:

```
radio::radio ()
    : storable( 10 ) // some value that storable needs
    , transmitter()
    , receiver()
{}
```

3. One thing to be aware of is that if either **transmitter** or **receiver** attempted to invoke the **storable** constructor in their initialization lists, that call will be completely skipped when constructing a radio object!
    - Be careful, as this could cause a subtle bug!

Some more detailed rules for the constructor calls:

1. (**Constructors**) The constructors for virtual base classes are always called before the constructors for non-virtual base classes.
    - This ensures that a class inheriting from a virtual base class can be sure the virtual base class is safe to use inside the inheriting class's constructor.
2. (**Destructors**) The destructor order in a class hierarchy with a virtual base class follows the same rules as the rest of C++: the destructors run in the opposite order of the constructors.
    - In other words, the virtual base class will be the last object destroyed, because it is the first object that is fully constructed.

References:

1. https://www.cprogramming.com/tutorial/virtual_inheritance.html (by Andrei Milea)
2. The C++ Programming Language, 4th Edition (by Bjarne Stroustrup)
    - Section 21.3.4
    - Section 21.3.5