Inheritance in C++

The capability of a class to derive properties and characteristics from another class is called **Inheritance**. Inheritance is one of the most important feature of Object Oriented Programming.

Sub Class: The class that inherits properties from another class is called Sub class or Derived Class.

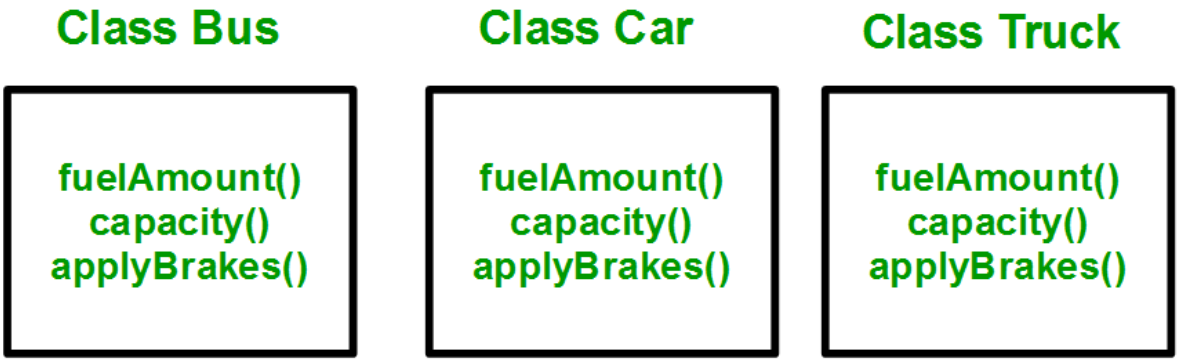
Super Class: The class whose properties are inherited by sub class is called Base Class or Super class.

The article is divided into following subtopics:

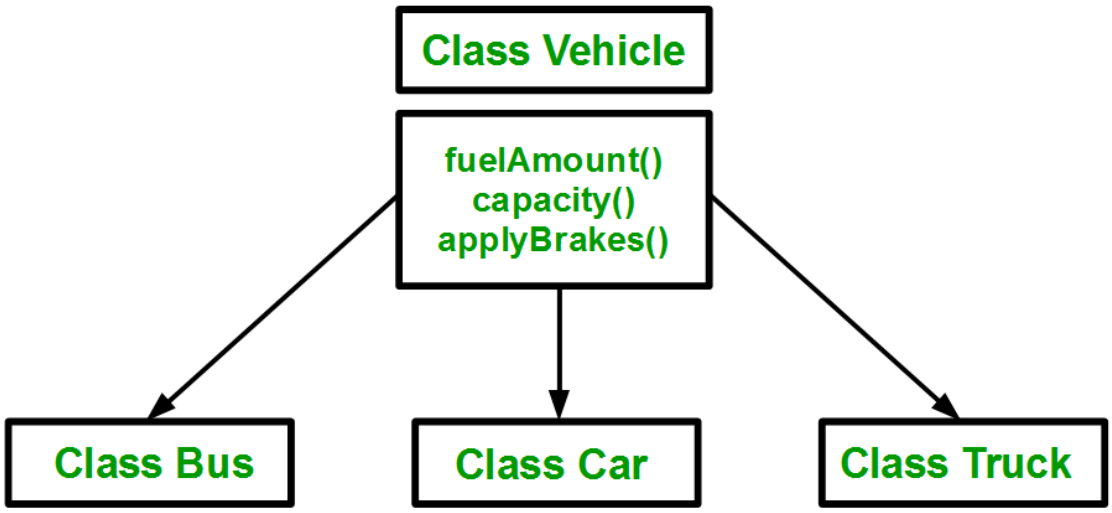
1. Why and when to use inheritance?
2. Modes of Inheritance
3. Types of Inheritance

Why and when to use inheritance?

Consider a group of vehicles. You need to create classes for Bus, Car and Truck. The methods fuelAmount(), capacity(), applyBrakes() will be same for all of the three classes. If we create these classes avoiding inheritance then we have to write all of these functions in each of the three classes as shown in below figure:



You can clearly see that above process results in duplication of same code 3 times. This increases the chances of error and data redundancy. To avoid this type of situation, inheritance is used. If we create a class Vehicle and write these three functions in it and inherit the rest of the classes from the vehicle class, then we can simply avoid the duplication of data and increase re-usability. Look at the below diagram in which the three classes are inherited from vehicle class:



Using inheritance, we have to write the functions only one time instead of three times as we have inherited rest of the three classes from base class(Vehicle).
Implementing inheritance in C++: For creating a sub-class which is inherited from the base class we have to follow the below syntax.
Syntax:

```
class subclass_name : access_mode base_class_name
{
  //body of subclass
};
```

Here, **subclass_name** is the name of the sub class, **access_mode** is the mode in which you want to inherit this sub class for example: public, private etc. and **base_class_name** is the name of the base class from which you want to inherit the sub class.

Note: A derived class doesn't inherit ***access*** to private data members. However, it does inherit a full parent object, which contains any private members which that class declares.

```
// C++ program to demonstrate implementation
// of Inheritance

#include <bits/stdc++.h>
using namespace std;

//Base class
class Parent
{
   public:
     int id_p;
};

// Sub class inheriting from Base Class(Parent)
class Child : public Parent
{
   public:
     int id_c;
```

```
};

//main function
int main()
  {

      Child obj1;

      // An object of class child has all data members
      // and member functions of class parent
      obj1.id_c = 7;
      obj1.id_p = 91;
      cout << "Child id is " <<  obj1.id_c << endl;
      cout << "Parent id is " <<  obj1.id_p << endl;

      return 0;
  }
```

Output:

```
Child id is 7

Parent id is 91
```

In the above program the 'Child' class is publicly inherited from the 'Parent' class so the public data members of the class 'Parent' will also be inherited by the class 'Child'.

Modes of Inheritance

1. **Public mode**: If we derive a sub class from a public base class. Then the public member of the base class will become public in the derived class and protected members of the base class will become protected in derived class.
2. **Protected mode**: If we derive a sub class from a Protected base class. Then both public member and protected members of the base class will become protected in derived class.
3. **Private mode**: If we derive a sub class from a Private base class. Then both public member and protected members of the base class will become Private in derived class.

Note : The private members in the base class cannot be directly accessed in the derived class, while protected members can be directly accessed. For example, Classes B, C and D all contain the variables x, y and z in below example. It is just question of access.

```
// C++ Implementation to show that a derived class
// doesn't inherit access to private data members.
// However, it does inherit a full parent object
class A
{
public:
   int x;
protected:
   int y;
private:
   int z;
};
```

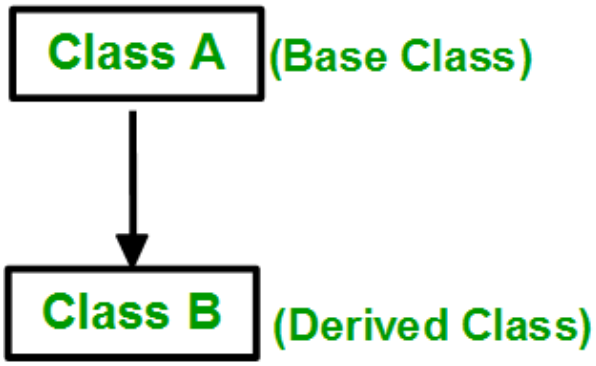
```
class B : public A
{
   // x is public
   // y is protected
   // z is not accessible from B
};

class C : protected A
{
   // x is protected
   // y is protected
   // z is not accessible from C
};

class D : private A    // 'private' is default for classes
{
   // x is private
   // y is private
   // z is not accessible from D
};
```

The below table summarizes the above three modes and shows the access specifier of the members of base class in the sub class when derived in public, protected and private modes:

Base class member access specifier	Type of Inheritence		
	Public	Protected	Private
Public	Public	Protected	Private
Protected	Protected	Protected	Private
Private	Not accessible (Hidden)	Not accessible (Hidden)	Not accessible (Hidden)

Types of Inheritance in C++

1. **Single Inheritance**: In single inheritance, a class is allowed to inherit from only one class. i.e. one sub class is inherited by one base class only.



Syntax:

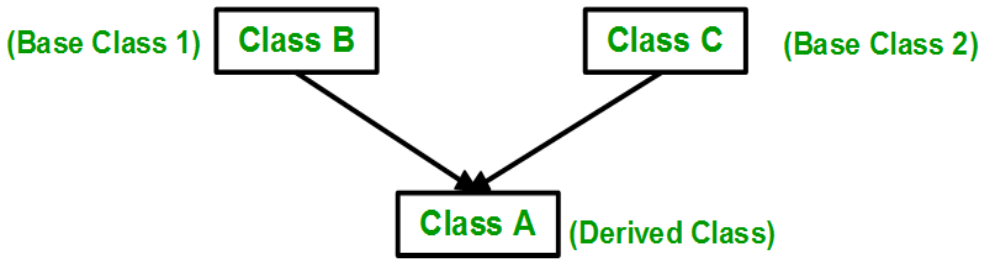
```
class subclass_name : access_mode base_class

{

//body of subclass

};
```

```
// C++ program to explain
// Single inheritance
#include <iostream>
using namespace std;

// base class
class Vehicle {
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};

// sub class derived from two base classes
class Car: public Vehicle{

};

// main function
int main()
{
    // creating object of sub class will
    // invoke the constructor of base classes
    Car obj;
    return 0;
}
```

Output:

```
This is a vehicle
```

2. **Multiple Inheritance:** Multiple Inheritance is a feature of C++ where a class can inherit from more than one classes. i.e one **sub class** is inherited from more than one **base class**



Syntax:

```
class subclass_name : access_mode base_class1, access_mode base_class2, ....
{
  //body of subclass
};
```

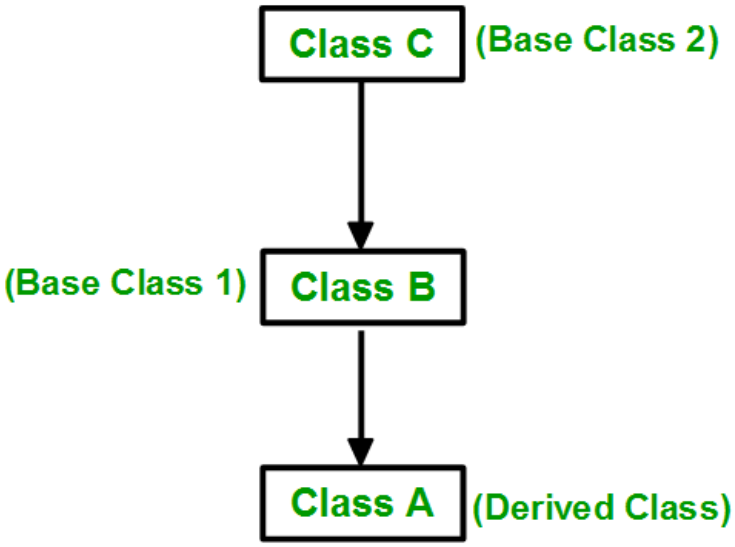
Here, the number of base classes will be separated by a comma (‘, ‘) and access mode for every base class must be specified.

```
// C++ program to explain
// multiple inheritance
#include <iostream>
using namespace std;

// first base class
class Vehicle {
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};

// second base class
class FourWheeler {
  public:
    FourWheeler()
    {
      cout << "This is a 4 wheeler Vehicle" << endl;
    }
};

// sub class derived from two base classes
class Car: public Vehicle, public FourWheeler {

};

// main function
int main()
{
    // creating object of sub class will
    // invoke the constructor of base classes
    Car obj;
    return 0;
}
```

Output:

```
This is a Vehicle
This is a 4 wheeler Vehicle
```

3. **Multilevel Inheritance**: In this type of inheritance, a derived class is created from another derived class.



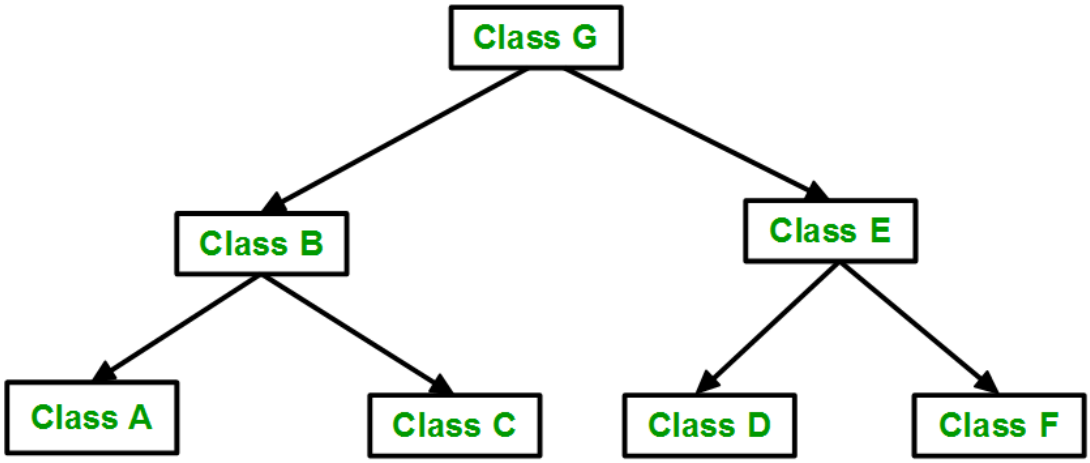

```
// C++ program to implement
// Multilevel Inheritance
#include <iostream>
using namespace std;

// base class
class Vehicle
{
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};
class fourWheeler: public Vehicle
{  public:
    fourWheeler()
    {
      cout<<"Objects with 4 wheels are vehicles"<<endl;
    }
};
// sub class derived from two base classes
class Car: public fourWheeler{
   public:
     car()
     {
       cout<<"Car has 4 Wheels"<<endl;
     }
```

```
};

// main function
int main()
{
   //creating object of sub class will
   //invoke the constructor of base classes
   Car obj;
   return 0;
}
```

output:

```
This is a Vehicle

Objects with 4 wheels are vehicles

Car has 4 Wheels
```

4. **Hierarchical Inheritance**: In this type of inheritance, more than one sub class is inherited from a single base class. i.e. more than one derived class is created from a single base class.




```
// C++ program to implement
// Hierarchical Inheritance
#include <iostream>
using namespace std;

// base class
class Vehicle
{
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};


// first sub class
```

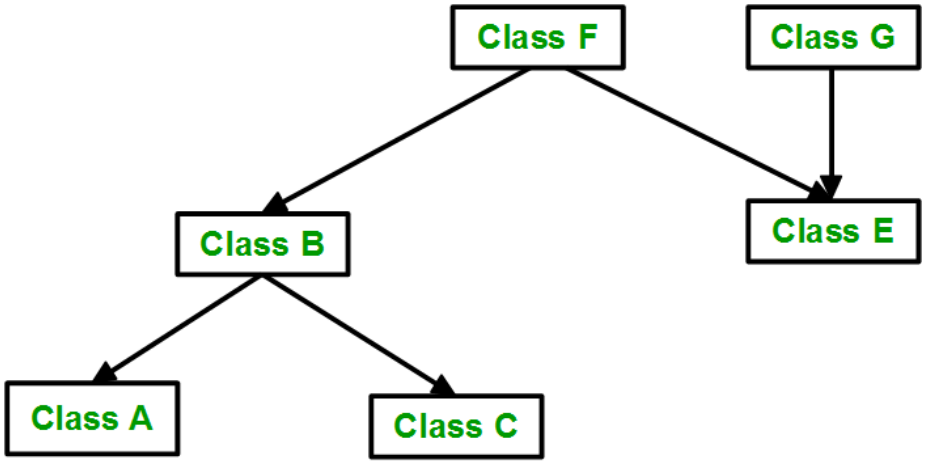
```
class Car: public Vehicle
{

};

// second sub class
class Bus: public Vehicle
{

};

// main function
int main()
{
    // creating object of sub class will
    // invoke the constructor of base class
    Car obj1;
    Bus obj2;
    return 0;
}
```

Output:

```
This is a Vehicle

This is a Vehicle
```

5. **Hybrid (Virtual) Inheritance**: Hybrid Inheritance is implemented by combining more than one type of inheritance. For example: Combining Hierarchical inheritance and Multiple Inheritance.

Below image shows the combination of hierarchical and multiple inheritance:



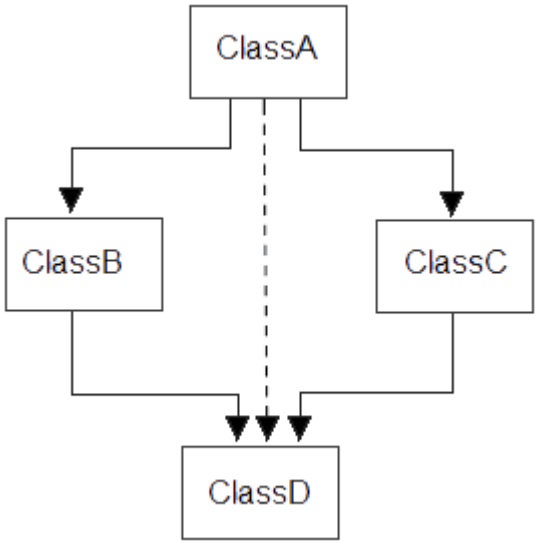

```
// C++ program for Hybrid Inheritance

#include <iostream>
using namespace std;

// base class
class Vehicle
{
```

```
  public:
    Vehicle()
    {
      cout << "This is a Vehicle" << endl;
    }
};

//base class
class Fare
{
    public:
    Fare()
    {
        cout<<"Fare of Vehicle\n";
    }
};

// first sub class
class Car: public Vehicle
{

};

// second sub class
class Bus: public Vehicle, public Fare
{

};

// main function
int main()
{
    // creating object of sub class will
    // invoke the constructor of base class
    Bus obj2;
    return 0;
}
```

Output:

```
This is a Vehicle

Fare of Vehicle
```

A special case of hybrid inheritance : Multipath inheritance:
A derived class with two base classes and these two base classes have one common base class is called multipath inheritance. An ambiguity can arrise in this type of inheritance.



Consider the following program:

```
// C++ program demonstrating ambiguity in Multipath Inheritance

#include<iostream.h>
#include<conio.h>
class ClassA
    {
        public:
        int a;
    };

    class ClassB : public ClassA
    {
        public:
        int b;
    };
    class ClassC : public ClassA
    {
        public:
        int c;
    };

    class ClassD : public ClassB, public ClassC
    {
        public:
        int d;
    };

    void main()
    {

        ClassD obj;

        //obj.a = 10;               //Statement 1, Error
        //obj.a = 100;              //Statement 2, Error
```

```
        obj.ClassB::a = 10;       //Statement 3
        obj.ClassC::a = 100;      //Statement 4

        obj.b = 20;
        obj.c = 30;
        obj.d = 40;

        cout<< "\n A from ClassB  : "<< obj.ClassB::a;
        cout<< "\n A from ClassC  : "<< obj.ClassC::a;

        cout<< "\n B : "<< obj.b;
        cout<< "\n C : "<< obj.c;
        cout<< "\n D : "<< obj.d;

    }
```

Output:

```
A from ClassB  : 10
A from ClassC  : 100
B : 20
C : 30
D : 40
```

In the above example, both ClassB & ClassC inherit ClassA, they both have single copy of ClassA. However ClassD inherit both ClassB & ClassC, therefore ClassD have two copies of ClassA, one from ClassB and another from ClassC.
If we need to access the data member a of ClassA through the object of ClassD, we must specify the path from which a will be accessed, whether it is from ClassB or ClassC, bco'z compiler can't differentiate between two copies of ClassA in ClassD.

There are 2 ways to avoid this ambiguity:

1. **Use scope resolution operator**
2. **Use virtual base class**

Avoiding ambiguity using scope resolution operator:
Using scope resolution operator we can manually specify the path from which data member a will be accessed, as shown in statement 3 and 4, in the above example.
filter_none
edit
play_arrow
brightness_4

```
obj.ClassB::a = 10;       //Statement 3
obj.ClassC::a = 100;      //Statement 4
```

Note : Still, there are two copies of ClassA in ClassD.

Avoiding ambiguity using virtual base class:

```
include<iostream.h>
    #include<conio.h>

    class ClassA
    {
        public:
        int a;
    };

    class ClassB : virtual public ClassA
    {
        public:
        int b;
    };
    class ClassC : virtual public ClassA
    {
        public:
        int c;
    };

    class ClassD : public ClassB, public ClassC
    {
        public:
        int d;
    };

    void main()
    {

        ClassD obj;

        obj.a = 10;       //Statement 3
        obj.a = 100;      //Statement 4

        obj.b = 20;
        obj.c = 30;
        obj.d = 40;

        cout<< "\n A : "<< obj.a;
        cout<< "\n B : "<< obj.b;
        cout<< "\n C : "<< obj.c;
        cout<< "\n D : "<< obj.d;

    }
```

Output:

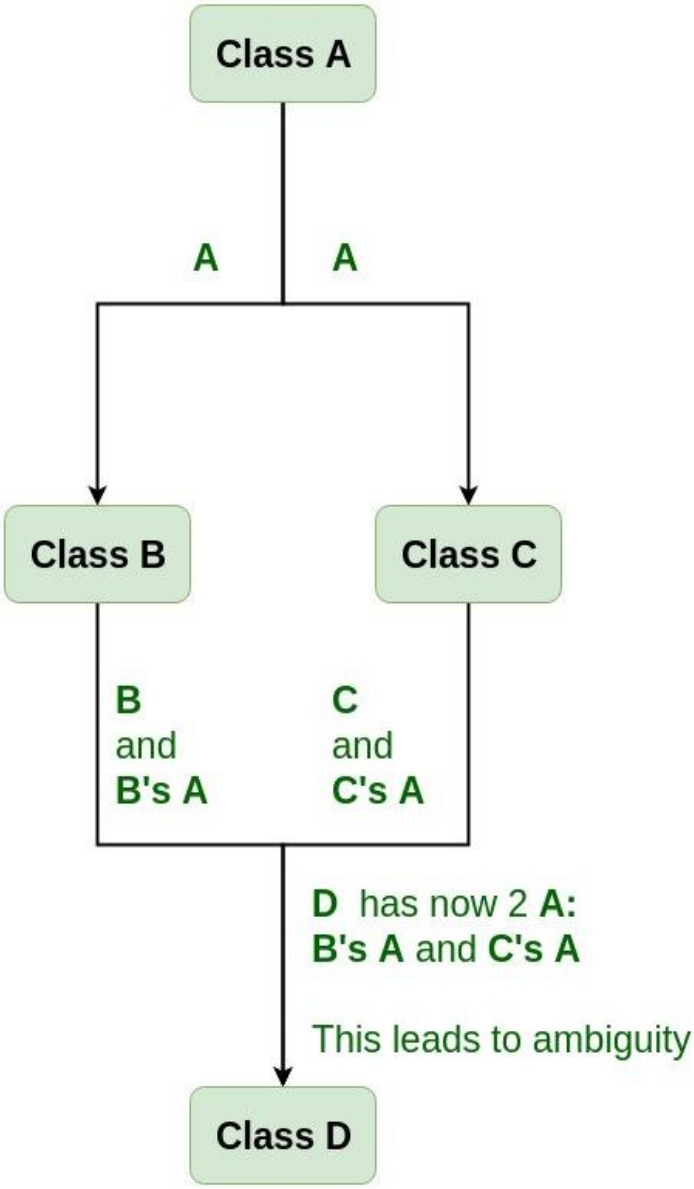
```
A : 100
B : 20
C : 30
D : 40
```

According to the above example, ClassD has only one copy of ClassA, therefore, statement 4 will overwrite the value of a, given at statement 3.

Virtual base class in C++

Virtual base classes are used in virtual inheritance in a way of preventing multiple "instances" of a given class appearing in an inheritance hierarchy when using multiple inheritances.

Need for Virtual Base Classes:
Consider the situation where we have one class **A** .This class is **A** is inherited by two other classes **B** and **C**. Both these class are inherited into another in a new class **D** as shown in figure below.



As we can see from the figure that data members/function of class **A** are inherited twice to class **D**. One through class **B** and second through class **C**. When any data / function member of class **A** is accessed by an object of class **D**, ambiguity arises as to which data/function

member would be called? One inherited through **B** or the other inherited through **C**. This confuses compiler and it displays error.

Example: To show the need of Virtual Base Class in C++

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

class A {
public:
   void show()
   {
      cout << "Hello form A \n";
   }
};

class B : public A {
};

class C : public A {
};

class D : public B, public C {
};

int main()
{
   D object;
   object.show();
}
```

Compile Errors:

```
prog.cpp: In function 'int main()':
prog.cpp:29:9: error: request for member 'show' is ambiguous
  object.show();
         ^
prog.cpp:8:8: note: candidates are: void A::show()
   void show()
        ^
prog.cpp:8:8: note:                 void A::show()
```

How to resolve this issue?

To resolve this ambiguity when class **A** is inherited in both class **B** and class **C**, it is declared as **virtual base class** by placing a keyword **virtual** as :

Syntax for Virtual Base Classes:

Syntax 1:

```
class B : virtual public A
```

```
{
};
```

Syntax 2:

```
class C : public virtual A
{
};
```

Note: virtual can be written before or after the **public**. Now only one copy of data/function member will be copied to class **C** and class **B** and class **A** becomes the virtual base class. Virtual base classes offer a way to save space and avoid ambiguities in class hierarchies that use multiple inheritances. When a base class is specified as a virtual base, it can act as an indirect base more than once without duplication of its data members. A single copy of its data members is shared by all the base classes that use virtual base.

Example 1

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

class A {
public:
   int a;
   A() // constructor
   {
      a = 10;
   }
};

class B : public virtual A {
};

class C : public virtual A {
};

class D : public B, public C {
};

int main()
{
   D object; // object creation of class d
   cout << "a = " << object.a << endl;

   return 0;
}
```

Output:

```
a = 10
```

Explanation : The class **A** has just one data member **a** which is **public**. This class is virtually inherited in class **B** and class **C**. Now class **B** and class **C** becomes virtual base class and no duplication of data member **a** is done.

Example 2:

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

```
class A {
public:
   void show()
   {
      cout << "Hello from A \n";
   }
};

class B : public virtual A {
};

class C : public virtual A {
};

class D : public B, public C {
};

int main()
{
   D object;
   object.show();
}
```

Output:

```
Hello from A
```