# Agenda

- Inheritance
- Type of Inheritance
- Diamond problem
- Virtual base class
- Mode of Inheritance
- Runtime Polymorphism
- Virtual Functions
- vptr and vtable
- ~~RTTI~~

# Inheritance

- If "is-a" relationship exist between two types then we should use inheritance.
- Inheritance is also called as "Generalization".
- Consider example:
    1. Employee is-a Person
    2. Book is-a product
    3. Car is-a Vehicle
    4. Rectangle is-a Shape
    5. Loan Account is-a Account

```
//Parent class
class Person//Base class
{
};

//Child class
class Employee:public Person//Derived class
{
};
```

- During inheritance, members of base class inherit into derived class.
- If we create object of derived class then non static data members declared in base class get space inside it. In other words non static data members of base class inherit into derived class.
- Using derived class name, we can access static data member( if public ) of base class. In other words, static data member inherit into derived class.
- All the data members( private/protected/public, static/non static) of base class inherit into derived class but only non static data members get space inside object.
- Size of object = sum of size of non static data members declared in base class and derived class.
- We can call non static member function of base class on object of derived class. In other words, using derived class object we can call non static member function of base class. It means that, non static member function inherit into derived class.
- We can call static member function of base class on derived class. In other words, using derived class name, we can access static member function of base class. It means that, static member function inherit

into derived class.
- Following function's do not inherit into derived class:
    1. Constructor
    2. Destructor
    3. Copy constructor
    4. Assignment operator function
    5. Friend Function
- Except above five function's, all the member's of base cass( data member, member function and nested type ) inherit into derived class.
- If we create object of derived class then first base class and then derived class constructor gets called.
- Destructor calling sequence is exactly opposite.
- From derived class constructor, by default, base class's parameterless constructor gets called.
- Using constructors base initializer list, we can call any constructor of base class from constructor of derived class.
- In C++, we can not call constructor on object, pointer or reference explicitly. But constructor's base initializer list represent explict call to the constructor.
- We can read following statement using 2 ways:
    - `class Employee : public Person`
    1. Class Person is inherited into class Employee.
    2. Class Employee is derived from class Person(Recommended).
- Process of acquiring/getting/accessing properties( data members ) and behavior ( member function ) of base class inside derived class is called is called inheritance.
- Every base class is abstraction for the derived class.

## Types of inheritance

### 1. Single Inheritance

- class B is derived from class A
- If single base class is having single derived class then it is called single inheritance.

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

### 2. Multiple Inheritance

- class D is derived from class A, B and C
- If multiple base classes are having single derived class then it is called multiple inheritance

```
class A{
};
class B{
};
class C{
```

```
};
class D : public A, public B, public C{ };
```

### 3. Hierarchical Inheritance

- class B, C and D are derived from class A
- If single base class is having multiple derived classes then such inheritance is called hierarchical inheritance.

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

### 4. Multilevel Inheritance

- class B is derived from class A, class C is derived from class B and class D is derived from class C.
- If single inheritance is having multiple levels then it is called multilevel inheritance.

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

## Hybrid Inheritance

- Combination of any two or more than two types of inheritance is called hybrid inheritance.

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

- According to client's requirement, if implementation of existing class is logically incomplete / partially complete then we should extend the class i.e we should use inheritance.
- In other words, without changing implementation of exsiting class, if we want to extend meaning of that class then we should use inheritance.
- According client's requirement, if implementation of base class member function is logically incomplete then we should redefine function in derived class.
- If name of members of base class and derived class are same then derived class members hides implementation of base class members. Hence preference is given to the derived class members.
- This process is called shadowing.
- If we want to access members of base class inside member function of derived class then we should use classname and scope resolution operator.

## Diamond Problem

- It is hybrid inheritance. Its shape is like diamond hence it is also called as diamond inheritance.

```
class A{
};
class B : public A{
};
class C : public A{
};
class D : public B, public C{
};
```

- Data members of indirect base class inherit into the indirect derived class multiple times.
- Hence it effects on size of object of indirect derived class.
- Member functions of indirect base class inherit into indirect derived class multiple times.
- If we try to call member function of indirect base class on object of indirect derived class, then compiler generates ambiguity error.
- If we create object of indirect derived class, then constructor and destructor of indirect base class gets called multiple times.
- All above problems generated by hybrid inheritance is called diamond problem.
- If we want to overcome diamond problem, then we should declare base class virtual i.e. we should derive class B & C from class A virtually. It is called virtual inheritance. In this case, members of class A will be inherited into B & C but it will not be inherited from B & C into class D.

```
class A{
};
class B : virtual public A{
};
class C : virtual public A{
};
class D : public B, public C{
};
```

# Mode of inheritance

- If we use private/protected/public keyword to control visibility of members of class then it is called access specifier.
- If we use private/protected/public keyword to extend the class then it is called mode of inheritance.
- In below statement, mode of inheritance is public if we dont mention then the default mode of inheritance is private.

```
class Employee : public Person

class Employee : Person
//is equivalent to
class Employee : private Person
```

- In private mode of inheritance, the visibility of base class members that inherit inside the derived class is made as private inside the derived class
- In protected mode of inheritance except private members, the visibility of base class members that inherit inside the derived class is made as protected inside the derived class
- In public mode of inheritance, the visibility of base class members that inherit inside the derived class does not change inside the derived class
- In all types of mode, private members inherit into derived class but we can not access it inside member function of derived class.
- If we want to access private members inside derived class then
    1. Either we should use member function(getter/setter).
    2. or we should declare derived class as a friend inside base class.
- If we want to create object of derived class then constructor of base class and derived must be public

## Mode Of inheritance – Private, Protected & Public

| Irrespective of Mode of Inheritance | | | |
|---|---|---|---|
| Access Specifiers | Same Class | Friend Function | Non Member Function |
| private | A | A | NA |
| protected | A | A | NA |
| public | A | A | A |

| Public Mode of Inheritance | | |
|---|---|---|
| Access Specifiers from Base class | Derived Class | Indirect Derived Class |
| private | NA | NA |
| protected | A | A |
| public | A | A |

| Private Mode of Inheritance | | |
|---|---|---|
| Access Specifiers from Base class | Derived Class | Indirect Derived Class |
| private | NA | NA |
| protected | A | NA |
| public | A | NA |

| Protected Mode of Inheritance | | |
|---|---|---|
| Access Specifiers from Base class | Derived Class | Indirect Derived Class |
| private | NA | NA |
| protected | A | A |
| public | A | A |

# RunTime Polymorphism

- During inheritance, members of base class inherit into derived class hence using derived class object, we can access members of base class as well as derived class.
- Members of derived class do not inherit into the base class hence using base class object we can access members of base class only.
- Members of base class inherit into derived class hence derived class object can be considered as base class object.
- Example : Employee object is-a Person object.
- Since Derived class object can be considered as Base class object, we can use it in place of Base class object.

```
Base b1;
Base b2 = b1;//OK
Derived d1;
b1 = d1;//OK
```

```
Base *ptr = NULL;
ptr = new Base(); // OK
ptr = new Derived(); // OK
```

- If we assign derived class object to the base class object then compiler copies state of base class portion from derived class object into base class object. It is called `Object slicing.`
- During Object slicing, mode of inheritance must be public.

```
class Base{
    public:
    int n1,n2;
    void printBase(){
        cout<<num1<<","<<num2<<endl;
    }
}
class Derived:public Base(){
    public:
    int n3;
    Derived(int n1,int n2,int n3){
        this->n1=n1;
        this->n2=n2;
        this->n3=n3;
    }
}
int main( void )
{
Base base;
Derived derived( 500,600,700);
base = derived; //OK : Object Slicing
base.printRecord(); //Base::printRecord() : 500,600
return 0;
}
```

- Members of derived class do not inherit into base class. Hence base class object, can not be considered as derived class object.
- Since base class object, can not be considered as derived class object, we can not use it in place of derived class object.

```
Derived *ptr = NULL;
ptr = new Derived();//Ok

ptr = new Base();//Not Ok
```

- Process of converting, pointer of derived class into pointer of base class is called upcasting.
- Upcasting represents object slicing.
- In case of upcasting, explicit type casting is optional.
- Main purpose of upcasting is to reduce object dependancy in the code.
- Process of converting pointer of base class into pointer of derived class is called downcasting.
- In Case of downcasting, explicit typecasting is mandatory.
- Note: Only in case of upcasting, we can do downcasting. Otherwise downcasting will fail.

```
int main( void )
{
    Base *ptrBase = new Derived( ); //Upcasting
    ptrBase->printRecord(); //Base::printRecord()

    Derived *ptrDerived = ( Derived*)ptrBase;//Downcasting
    ptrDerived->printRecord();

    return 0;
}
```

## Virtual Function

- In case of upcasting, if we want to call function, depending on type of object rather than type of pointer then we should declare function in base class virtual.
- If class contains, at least one virtual function then such class is called polymorphic class.
- If signature of base class and derived class member function is same and if function in base class is virtual then derived class member function is by default considered as virtual.
- If base class is polymorphic then derived class is also considered as polymorphic.
- Process of redefining, virtual function of base class, inside derived class, with same signature, is called function overriding.
- Rules for function overriding
    1. Function must be exist inside base class and derived class(different scope)
    2. Signature of base class and derived class member function must be same( including return type).
    3. At least, Function in base class must be virtual.
- Virtual function, redefined in derived class is called overriden function.

- Definition 1: In case of upcasting, a member function, which gets called depending on type of object rather than type of pointer, is called virtual function.
- Definition 2: In case of upcasting, a member function of derived class which is designed to call using pointer of base class is called virtual function.
- We can call virtual function on object but it is designed to call on Base class pointer or reference.

## Early Binding And Late Binding

- If Call to the function gets resolved at compile time then it is called early binding.
- If Call to the function gets resolved at run time then it is called late binding.
- If we call any virtual/non virtual function on object then it is considered as early binding.
- If we call any non virtual function on pointer/reference then it is considered as early binding.
- If we call any virtual function on pointer/reference then it is considered as late binding.

## v-ptr and v-table

- Size of object = size of all the non static data members declare in base class and derived class + 2/4/8 bytes( if Base/Derived class contains at least one virtual function ).
- If we declare member function virtual then to store its address compiler implicitly create one table(array/structure). It is called virtual function table/vf-table/v-table.
- In other words, virtual function table is array of virtual function pointers.
- Compiler generates V-Table per class.
- To store address of virtual function table, compiler implicitly declare one pointer as a data member inside class. It is called virtual function pointer / vf-ptr / v-ptr.
- v-ptr get space once per object.
- ANSI has not defined any specification/rule on position of v-ptr hence compiler vendors are free to decide its position in object. But generally it gets space at the start of the object.
- The vptr is managed by the compiler and is automatically set up during object construction. It is not something that you need to initialize or manage explicitly in your code. It's a mechanism provided by the compiler to enable polymorphic behavior and dynamic dispatch of virtual function calls.
- V-Table and V-Ptr inherit into derived class.
- Process of calling member function of derived class using pointer/reference of base class is called Runtime Polymorphism.
- According to client's requirement, if implementation of Base class member function is logically 100% complete then we should declare Base class member function non virtual.
- According to client's requirement, if implementation of Base class member function is logically incomplete / partially complete then we should declare Base class member function virtual.
- According to client's requirement, if implementation of Base class member function is logically 100% incomplete then we should declare Base class member function pure virtual.

## Pure Virtual Function:

- If we equate, virtual function to zero then such virtual function is called pure virtual function.
- We can not provide body to the pure virtual function.
- If class contains at least one pure virtual function then such class is called abstract class.
- If class contains all pure virtual functions then such class is called pure abstract class/interface.

```
//Pure Abstract class or Interface
class A
{
    public:
    virtual void f1( void ) = 0;
    virtual void f2( void ) = 0;
};

//Pure abstract class / Interface
class B : public A
    //Interface Inheritance
    {
    public:
    virtual void f3( void ) = 0;
};
```

- We can instantiate concrete class but we can not instantiate abstract class and interface.
- We can not instantiate abstract class but we can create pointer/reference of it.
- If we extend abstract class then it is mandatory to override pure virtual function in derived class otherwise derived class can be considered as abstract.
- Abstract class can contain, constructor as well as destructor.
- An ability of different types of object to use same interface to perfrom different operation is called Runtime Polymorphism.