Object-oriented software development (OOSD)

- In the past, the problems faced by software development were relatively simple, from task analysis to programming, and then to the debugging of the program, if its not too big it can be done by one person or a group.
- With the rapid increase of software scale, software personnel faces the problem that is very complicated, and there are many factors that need to be considered.
- The errors generated and hidden errors may reach an astonishing degree, this is not something that can be solved in the programming stage.
- Need to standardize the entire software development process and clarify the software
- The tasks of each stage in the development process, while ensuring the correctness of the work of the previous stage, proceed to the next stage work.
- This is the problem that software engineering needs to study and solve. Object-oriented software development and engineering include the following parts:

1.Object oriented analysis (OOA)

- The first step of Object-oriented software development is Object-Oriented Analysis (OOA)
- In the system analysis stage of software engineering, system analysts must integrate with users to make precise Accurate analysis and clear description, summarize what the system should do (not how) from a macro perspective.
- Face right the analysis of the image should be based on object-oriented concepts and methods.
- In the analysis of the task, from the objective existence of things and the relationship between the related objects (including the attributes and behaviors of the objects) and the relationship between the objects are summarized.
- The Objects with the same attributes and behaviors are represented by a class.
- Establish a need to reflect the real work situation model. The model formed at this stage is relatively rough (rather than fine).

2.Object oriented design (OOD)

- The second step of Object-oriented software development is Object-Oriented Design (OOD).
- According to the demand model formed in the object-oriented analysis stage, each part is specifically designed.
- The design of the line class may contain multiple levels (using inheritance).
- Then these classes put forward the ideas and methods of program design, including the design of algorithms.
- In the design stage no specific plan is involved, but a more general description tool (such as pseudo code or flowchart)is used to describe.

3.Object-oriented programming (OOP)

- The third step of Object-oriented software development is Object-oriented Programming (OOP).
- According to the results of object-oriented design, to write it into a program in a computer language, it is obvious that object-oriented Computer language (e.g. C++) needs to be used.
- Otherwise the requirements of object-oriented design cannot be achieved.

OOPS(Object Oriented Programming Language)

- OOPS is not a syntax.
- It is a process / programming methodology which is used to solve real world problems.
- It is a programming methodology to organize complex program in to simple program in terms of classes and object such methodology is called oops.
- It is a programming methodology to organized complex program into simple program by using concept of abstraction , encapsulation , polymorphism and inheritance.
- Languages which support abstraction , encapsulation polymorphism and inheritance are called oop language.

Major pillars of oops

- **Abstraction**
  - getting only essential things and hiding unnecessary details is called as abstraction.
  - Abstraction always describe outer behavior of object.
  - In console application when we give call to function in to the main function , it represents the abstraction
- **Encapsulation**
  - binding of data and code together is called as encapsulation.
  - Implementation of abstraction is called encapsulation.
  - Encapsulation always describe inner behavior of object
  - Function call is abstraction
  - Function definition is encapsulation.
  - Information hiding
    - Data : unprocessed raw material is called as data.
    - Process data is called as information.
    - Hiding information from user is called information hiding.
    - In c++ we used access Specifier to provide information hiding.
- **Modularity**
  - Dividing programs into small modules for the purpose of simplicity is called modularity.
- **Hierarchy (Inheritance [is-a] , Composition [has-a] , Aggregation[has-a], Dependancy)**
  - Hierarchy is ranking or ordering of abstractions.
  - Main purpose of hierarchy is to achieve re-usability.

Minor pillars of oops

- **Polymorphism (Typing)**
  - One interface having multiple forms is called as polymorphism.
  - Polymorphism have two types
    1. **Compile time polymorphism**

       when the call to the function resolved at compile time it is called as compile time polymorphism. And it is achieved by using function overloading and operator overloading
    2. **Runtime polymorphism.**

       when the call to the function resolved at run time it is called as run time polymorphism. And it is achieved by using function overriding.
  - Compile time / Static polymorphism / Static binding / Early binding / Weak typing / False Polymorphism
  - Run time / Dynamic polymorphism / Dynamic binding / Late binding / Strong typing / True polymorphism
- Concurrency
  - The concurrency problem arises when multiple threads simultaneously access same object.
  - You need to take care of object synchronization when concurrency is introduced in the system.
- Persistence
  - It is property by which object maintains its state across time and space.
  - It talks about concept of serialization and also about transferring object across network.

Limitations of C Programming

- C is said to be process oriented, structured programming language.
- When program becomes complex, understating and maintaining such programs is very difficult.
- Language don’t provide security for data.
- Using functions we can achieve code reusability, but reusability is limited. The programs are not extendible.

Classification of high level Languages

- Procedure Oriented Programming language(POP)
    - ALGOL, FORTRAN, PASCAL, BASIC, C etc.
    - "FORTRAN" is considered as first high level POP language.
    - All POP languages follows "TOP Down" approach

- Object oriented programming languages(OOP)
    - Simula, Smalltalk, C++, Java, C#, Python, Go
    - "Simula" is considered as first high level OOP language.
    - more than 2000 lang. are OO.
    - All OOP languages follows "Bottom UP" approach

Few Real Time Applications of C++

- Games
- GUI Based Application (Adobe)
- Database Software (MySQL Server)
- OS (Apple OS)
- Browser(Mozilla)
- Google Applications(Google File System and Chrome browser)
- Banking Applications
- Compilers
- Embedded Systems(smart watches, MP3 players, GPS systems)

Characteristics of Language

1. It has own syntax
2. It has its own rule(semantics)
3. It contain tokens:
   - Identifier
   - Keyword
   - Constant/literal
   - Operator
   - Seperator / punctuators
4. It contains built in features.
5. We use language to develop application(CUI, GUI, Library)

History of C++

- Inventor of C++ is Bjarne Stroustrup.
- C++ is derived from C and simula.
- Its initial name was "C With Classes".
- At is developed in "AT&T Bell Lab" in 1979.
- It is developed on Unix Operating System.
- In 1983 ANSI renamed "C With Classes" to C++.
- C++ is objet oriented programming language

C++ Specifications

- In 1985, the first edition of The C++ Programming Language was released.
- In 1989, C++ 2.0 was released. New features in 2.0 included multiple inheritance, abstract classes, static member functions, const member functions, and protected members.Later feature additions included templates, exceptions, namespaces, new casts, and a Boolean type.
- In 1998, C++98 was released, standardizing the language, and a minor update (C++03) was released in 2003.
- After C++98, C++ evolved relatively slowly until, in 2011, the C++11 standard was released, adding numerous new features,enlarging the standard library further, and providing more facilities to C++ programmers.
- A minor C++14 update was released in December 2014.
- A major revision where various new additions were introduced in C++17.

Main Function

- main should be entry point function of C/C++
- Calling/invoking main function is responsibility of operating system.
- Hence it is also called as Callback function

Execution Flow

- Execution of a C/C++ program involves four stages using different compiling/execution tools
  - Preprocessor
  - Compiler
  - Linker
  - Loader

These tools make the program running.

1) Preprocessor

This is the first stage of any C/C++ program execution process, in this stage Preprocessor processes the program before compilation. Preprocessor include header files, expand the Macros.

2) Complier

This is the second stage of any C/C++ program execution process, in this stage generated output file after preprocessing (with source code) will be passed to the compiler for compilation. Complier will compile the program, checks the errors and generates the object file (this object file contains assembly code).

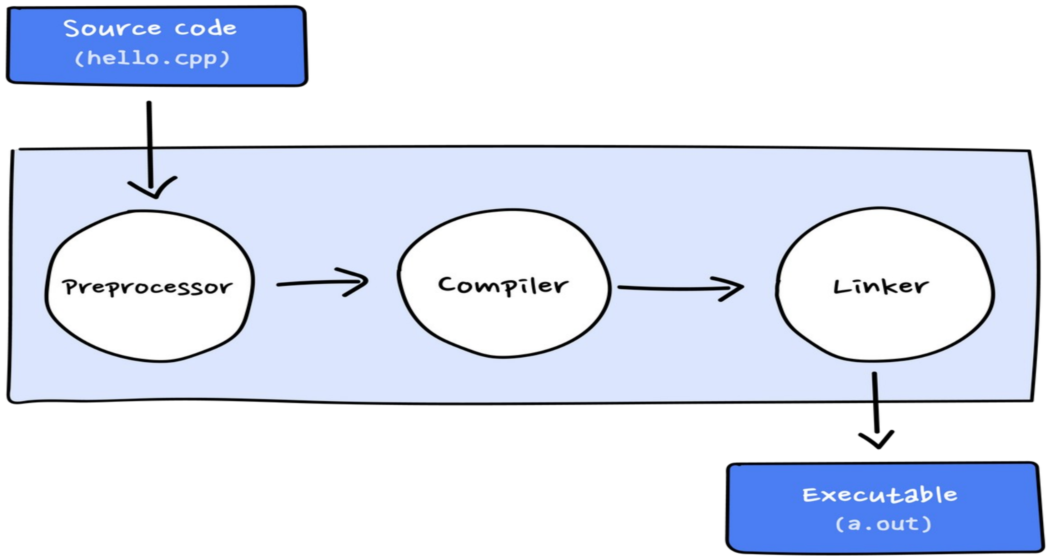
Oops (Object Oriented Programming Concepts) with C++

3) Linker

This is the third stage of any C/C++ program execution process, in this stage Linker links the more than one object files or libraries and generates the executable file.

4) Loader

This is the fourth or final stage of any C/C++ program execution process, in this stage Loader loads the executable file into the main/primary memory. And program run.



Data Types in C++

- It describes 3 things about variable / object

1. Memory : How much memory is required to store the data.
2. Nature : Which type of data memory can store
3. Operation : Which operations are allowed to perform on data stored inside memory.

- Fundamental Data Types
  - (void, int,char,float,double)
- Derived Data Types
  - (Array, Function, Pointer, Union ,Structure)

Two more additional data types that c++ supports are

1. ***bool*** **:-** it can take *true* or *false* value. It takes one byte in memory.
2. **wchar_t :-** it can store 16 bit character. It takes 2 bytes in memory.

Bool and wchar_t

- **e.g: bool val=true;**
- **wchar_t**: Wide Character. This should be avoided because its size is implementation defined and not reliable.
- Wide char is similar to char data type, except that wide char take up twice the space and can take on much larger values as a result. char can take 256 values which corresponds to entries in the ASCII table. On the other hand, wide char can take on 65536 values which corresponds to UNICODE values which is a recent international standard which allows for the encoding of characters for virtually all languages and commonly used symbols.

- The type for character constants is char, the type for wide character is wchar_t.
- This data type occupies 2 or 4 bytes depending on the compiler being used.
- Mostly the wchar_t datatype is used when international languages like Japanese are used.
- This data type occupies 2 or 4 bytes depending on the compiler being used.
- L is the prefix for wide character literals and wide-character string literals which tells the compiler that that the char or string is of type wide-char.
- w is prefixed in operations like scanning (**wcin)** or printing (**wcout)** while operating wide-char type.

Type modifiers

- C++ allows the char, int, and double data types to have modifiers preceding them. A modifier is used to alter the meaning of the base type so that it more precisely fits the needs of various situations.
- The data type modifiers are listed here −
  - signed
  - unsigned
  - long
  - short
- The modifiers signed, unsigned, long, and short can be applied to integer base types. In addition, signed and unsigned can be applied to char, and long can be applied to double.
- The modifiers signed and unsigned can also be used as prefix to long or short modifiers. For example, unsigned long int.

- **Type qualifiers**
  - The type qualifiers provide additional information about the variables they precede.
  - const and volatile are two qualifiers

Structure

- Structure is a collection of similar or dissimilar data. It is used to bind logically related data into a single unit.
- This data can be modified b any function to which the structure is passed.
- Thus there is no security provided for the data within a structure.
- This concept is modified by C++ to bind data as well as functions.

Access Specifier

- By default all members in structure are accessible everywhere in the program by dot(.) or arrow(→) operators.
- But such access can be restricted by applying access specifiers
  - private: Accessible only within the struct
  - public: Accessible within & outside struct

Structure in C & C++

struct in c	struct in c ++
we can include only variables into the structure.	we can include the variables as well as the functions in structure.
We need to pass a structure variable by value or by address to the functions.	We don't pass the structure variable to the functions to accept it / display it.The functions inside the struct are called with the variable and DOT operator.
By default all the variables of structure are accessible outside the structure. (using structure variable name)	By default all the members are accessible outside the structure, but we can restrict their access by applying the keywords private /public/ protected.
struct Time t1;	struct Time t1;
AcceptTime(struct Time &t1);	t1.AcceptTime(); //function call

Structure in C & C++

```
struct time {
   int hr, min, sec;
};
void display( struct time *p) {
   printf(“%d:%d:%d”, p→hr,
   p→min, p→sec);
}
struct time t;
display(&t);
```

```
struct time {
   int hr, min, sec;
void display(){
   printf(“%d:%d:%d”,
this→hr, this→min, this→sec);
}
};
time t;
t.display();
```

OOP and POP

OOP (Object Oriented Programming)	**POP (**Procedural Oriented Programming**)**
Emphasis on data of the program	Emphasis on steps or algorithm
OOP follows bottom up approach.	OOP follows top down approach.
A program is divided to objects and their interactions. Programs are divide into small data units i.e. classes	A program is divided into funtions and they interacts. Programs are divided into small code units i.e. functions
Objects communicates with each other by passing messeges.	Functions communicate with each other by passing parameters.
Inheritance is supported.	Inheritance is not supported.
Access control is supported via access modifiers. (private/ public/ protected)	No access modifiers are supported.
Encapsulation is used to hide data.	No data hiding present. Data is globally accessible.
C++, Java	C , Pascal
It overloads functions, constructors, and operators.	Neither it overload functions nor operators
Classes or function can become a friend of another class with the keyword "friend". Note: "**friend**" keyword is used only in c++	No concept of friend function.
Concept of virtual function appear during inheritance.	No concept of virtual classes .

Namespace

- To prevent name conflicts/ collision / ambiguity in large projects
- to group/orgaize functionally equivalent / related types toghther.
- If we want to access value of global variable then we should use scope resolution operator (::)
- We can not instantiate namespace.
- It is designed to avoid name ambiguity and grouping related types.
- If we want to define namespace then we should use **namespace** keyword.
- We can not define namespace inside function/class.
- If name of the namespaces are same then name of members must be different.
- We can not define main function inside namespace.
- Namespace can contain:
  1. Variable
  2. Function
  3. Types[structure/union/class]
  4. Enum
  5. Nested Namespace

Note :
- If we define member without namespace then it is considered as member of global namespace.
- If we want to access members of namespace frequently then we should use using directive.

Scope Resolution Operator (: :)

- :: operator is used to bind a member with some class or namespace.
- It can be used to define members outside class.
- Also used to resolve ambiguity.
- It can also be used to access global members.
  - Example :- ::a =10; access global var.
- Scope resolution Operator is used to :
  - to call global functions
  - to define member functions of class outside the class
  - to access members of namespaces

cin and cout

- C++ provides an easier way for input and output.
- Console Output : Monitor
  - iostream is the standard header file of C++ for using cin and cout.
  - cout is external object of ostream class.
  - cout is member of std namespace and std namespace is declared in iostream header file.
  - cout uses insertion operator(<<)
- Console Input : Keyborad
  - cin is an external object of istream class.
  - cin is a member of std namespace and std namespace is declared in header file.
  - cin uses Extraction operator(>>)
- The output:
  - cout << “Hello C++”;
- The input:
  - cin >> var;

Functions / User Defined Functions

- It is a set of instructions written to gather as a block to complete specific functionality.
- Function can be reused.
- It is a subprogram written to reduce complexity of source code
- Function may or may not return value.
- Function may or may not take argument
- Function can return only one value at time
- Function is building block of good top-down, structured code function as a "black box“
- **Writing function helps to**
    - improve readability of source code
    - helps to reuse code
    - reduces complexity
- **Types of Functions**
    - Library Functions
    - User Defined Functions

User Defined Functions

- **Function declaration / Prototype / Function Signature**

  <return type> <functionName> ([<arg type>...]);

- **Function Definition**

```
<return type> < functionName > ([<arg type> <identifier>...])
  {
              //function body
  }
```

- **Function Call**

  <location> = < functionName >(<arg value/address>);

Inline Function

- C++ provides a keyword *inline* that makes the function as inline function.
- Inline functions get replaced by compiler at its call statement. It ensures faster execution of function just like macros.
- Advantage of inline functions over macros: inline functions are type-safe.
- Inline is a request made to compiler.
- If a function is inline, the compiler places a copy of the code of that function at each point where the function is called at compile time.

When to use Inline function?

- We can use Inline function as per our needs.

- We can use the inline function when performance is needed.

- We can use the inline function over macros.

- We prefer to use the inline keyword outside the class with the function definition to hide implementation details of the function.

Function Overloading

- Functions with same name and different signature are called as overloaded functions.
- Return type is not considered for function overloading.
- Function call is resolved according to types of arguments passed.
- Function overloading is possible due to name mangling done by the C++ compiler (Name mangling process , mangled name)
- Differ in number of input arguments
- Differ in data type of input arguments
- Differ at least in the sequence of the input arguments
- Example :
  - int sum(int a, int b) { return a+b; }
  - float sum(float a, float b) { return a+b; }
  - int sum(int a, int b, int c) { return a+b+c;;

Name Mangling

- C++ supports function overloading, i.e., there can be more than one function with the same name but, different parameters.
- the C++ compiler distinguish between different functions by changing names by adding information about arguments.
- This technique of adding additional information to function names is called Name Mangling.
- C++ standard doesn’t specify any particular technique for name mangling, so different compilers may append different information to function names.

Default Arguments

- In C++, functions may have arguments with the default values. Passing these arguments while calling a function is optional.
- A default argument is a default value provided for a function parameter/argument.
- If the user does not supply an explicit argument for a parameter with a default argument, the default value will be used.
- If such argument is not passed, then its default value is considered. Otherwise arguments are treated as normal arguments.
- Default arguments should be given in right to left order.
- int sum (int a, int b, int c=0, int d=0) {

  ```
          return a + b + c + d;
  }
  ```
- The above function may be called as
  - Res=sum(10,20);
  - Res=sum(10,20,40);
  - Res=sum(10,30,40,50);

Class

- Building block that binds together data & code.
- Program is divided into different classes
- Class is collection of data member and member function.
- Class represents set/group of such objects which is having common structure and common behavior.
- Class is logical entity.
- Class has
  - Variables (data members)
  - Functions (member functions or methods)
- By default class members are private(not accessible outside class scope)
- Classes are stand-alone components & can be distributed in form of libraries
- Class is blue-print of an object

Data Members and Member Functions

Data Members

- Data members of the class are generally made as private to provide the data security.
- The private members cannot be accessed outside the class.
- So these members are always accessed by the member functions.

Member Functions

- Member functions are generally declared as public members of class.
- Constructor : Initialize Object
- Destructor : De-initialize Object
- Mutators : Modifies state of the object
- Inspectors : Don’t Modify state of object
- Facilitator : Provide facility like IO

Object

- Object is an instance of class.
- Entity that has physical existence, can store data, send and receive message to communicate with other objects.
- An entity, which get space inside memory is called object.
- Object is used to access data members and member function of the class
- Process of creating object from a class is called instantiation

- **Object has**
  - Data members (***state*** of object)
    - Value stored inside object is called state of the object.
    - Value of data member represent state of the object.

  - Member function (***behavior*** of object)
    - Set of operation that we perform on object is called behaviour of an object.
    - Member function of class represent behaviour of the object.
    - is how object acts & reacts, when its state is changed & operations are done
    - Operations performed are also known as messages

  - Unique address(***identity*** of object)
    - Value of any data member, which is used to identify object uniquly is called its identity.
    - If state of object is same the its address can be considered as its identity.

Few Points to note

- Member function do not get space inside object.
- If we create object of the class then only data members get space inside object. Hence size of object is depends on size of all the data members declared inside class.
- Data members get space once per object according to the order of data member declaration.
- Structure of the object is depends on data members declared inside class.
- Member function do not get space per object rather it gets space on code segment and all the objects of same class share single copy of it.
- Member function's of the class defines behaviour of the object.

Access Specifier

- If we want to control visibility of members of structure/class then we should use access Specifier.
- Defines the accessibility of data member and member functions

- **Access specifiers in C++**
  1. private(-)
  2. protected(#)
  3. public(+)

- 1. Private - Can access inside the same struct/class in which it is declared Generally data members should declared as private. (data security)
- 2. Public - Can access inside the same struct/class in which it is declared as well as inside outside function(like main()). Generally member functions should declared as public.
- 3. Protected - Can access inside the same class in which it is declared as well as inside Derived class.

this pointer

- To process state of the object we should call member function on object. Hence we must define member function inside class.
- If we call member function on object then compiler implicitly pass address of that object as a argument to the function implicitly.
- To store address of object compiler implicitly declare one pointer as a parameter inside member function. Such parameter is called this pointer.
- this is a keyword. "this" pointer is a constant pointer.
- this is used to store address of current object or calling object.
- The invoking object is passed as implicit argument to the function.
- *this* pointer points to current object i.e. object invoking the member function.
- Thus every member function receives *this* pointer.
- Following functions do not get this pointer:
    1. Global Function
    2. Static Member function
    3. Friend Function.

Constructor

- It is a member function of a class which is used to initialize object.
- Constructor has same name as that of class and don’t have any return type.
- Constructor get automatically called when object is created i.e. memory is allocated to object.
- If we don’t write any constructor, compiler provides a default constructor.
- Due to following reasons, constructor is considered as special function of the class:
    1. Its name is same as class name.
    2. It doesn't have any return type.
    3. It is designed to call implicitly.
    4. In the life time of the object , it gets called only once per object and according to order of its declaration.

Types of Constructor

- Parameterless constructor
  - also called zero argument constructor or user defined default constructor
  - If we create object without passing argument then parameterless constructor gets called
  - Constructor do not take any parameter
- Parameterized constructor
  - If constructor take parameter then it is called parameterized constructor
  - If we create object, by passing argument then paramterized constructor gets called
- Default constructor
  - If we do not define constructor inside class then compiler generates default constructor for the class.
  - Compiler generated default constructor is parameterless.

Facts About Constructor

- We can not call constructor on object, pointer or reference explicitly. It is designed to call implicitly.
- We can not declare constructor static, constant, volatile or virtual. We can declare constructor only inline.
- Constructor overloading means inside a class more than one constructor is defined.
- We can have constructors with
  - No argument : initialize data member to default values
  - One or more arguments : initialize data member to values passed to it
  - Argument of type of object : initialize object by using the values of the data members of the passed object. It is called as copy constructor.

Constructor's member initializer list

- If we want to initialize data members according to users requirement then we should use constructor body.

```
class Test
{
private:
            int num1;
            int num2;
            int num3;
public:
            Test( void )
            {
            this->num1 = 10;
            this->num2 = 20;
            this->num3 = num2;
            }
};
```

- If we want to initialize data member according to order of data member declaration then we can use constructors member initializer list.

```
class Test
{
private:
            int num1;
            int num2;
            int num3;
public:
            Test( void ) : num1( 10 ), num2( 20 ),
num3( num2)
            { }
};
```

Except array we can initialize any member inside constructors member initializer list.

Copy Constructor

- Copy constructor is a single parameter constructor hence it is considered as parameterized constructor
- Example:
    - **Complex sum(const Complex &c2)**

Destructor

- It is a member function of a class which is used to release the resources.
- It is considered as special function of the class
  - Its name is same as class name and always preceds with tild operator(~)
  - It doesnt have return type or doesn't take parameter.
  - It is designed to call implicitly.
- Destructor calling sequence is exactly opposite of constructor calling sequence.
- Destructor is designed to call implicitly.
- If we do not define destructor inside class then compiler generates default destructor for the class.
- Default destructor do not de allocate resources allocated by the programmer. If we want to de allocate it then we should define destructor inside class.

Other Member functions of class Setter & Getter

- **Mutator/setter :**
  - If we want to modify state of object i.e value of a private data member of the class outside the class using object then we should write a mutator.
  - It is recommended to start the mutator function name with set followed by data member name which will accept a single argument to change the respective single data member value.

- **Inspector/getter :**
  - If we want to read the state of object i.e value of a private data member of the class outside the class using object then we should write a Inspector
  - It is recommended to start the inspector function name with get followed by data member name which will return the respective single data member value.

- **Facilitator**
  - Any member function of a class that deals with all the data members of class and which are used to perform business logic operations are called as facilitators

Constant in C++

- We can declare a constant variable that cannot be modified in the app.
- If we do not want to modify value of the variable then const keyword is used.
- constant variable is also called as read only variable.
- The value of such variable should be known at compile time.
- In C++ , Initializing constant variable is mandatory
- const int i=3; //VALID
- Const int val; //Not ok in c++
- Generally const keyword is used with the argument of function to ensure that the variable cannot be modified within that function.

Constant data member

- Once initialized, if we do not want to modify state of the data member inside any member function of the class including constructor body then we should declare data member constant.
- If we declare data member constant then it is mandatory to initialize it using constructors member initializer list.

```
class Test
{
private:
		const int num1;
public:
		Test( void ) :
num1( 10 ) //OK
		{
		//this->num1 = 10; //Not
OK
		}
};
```

Const member function

- The member function can declared as const. In that case object invoking the function cannot be modified within that member function.
- We can not declare global function constant but we can declare member function constant.
- If we do not want to modify state of current object inside member function then we should declare member function as constant.
- void display() const;
- Even though normal members cannot be modified in const function, but *mutable* data members are allowed to modify.
- In constant member function, if we want to modify state of non constant data member then we should use **mutable keyword.**
- We can not declare following function constant:
    1. Global Function
    2. Static Member Function
    3. Constructor
    4. Destructor

Const object

- If we dont want to modify state of the object then instead of declaring data member constant, we should declare object constant.
- On non constant object, we can call constant as well as non constant member function.
- On Constant object, we can call only constant member functions
- It is C language feature which is used to create alias for existing data type.
- Using typedef, we can not define new data type rather we can give short name / meaningful name to the existing data type.

Modular Approach

- "/usr/include" directory is called standard directory for header files.
- It contains all the standard header files of C/C++
- If we include header file in angular bracket (e.g #include<filename.h>) then preprocessor try to locate and load header file from standard directory only(/usr/include).
- If we include header file in double quotes (e.g #include“filename.h") then preprocessor try to locate and load header file first from current project directory if not found then it try to locate and load from standard directory.

Header Guard

```
#ifndef HEADER_FILE_NAME_H_
#define HEADER_FILE_NAME_H_
//TODO : Type declaration here
#endif
```

Reference

- Reference is derived data type.
- It alias or another name given to the exisiting memory location / object.
    - Example : int a=10;   int &r = a;
    - In above example a is referent variable and r is reference variable.
    - It is mandatory to initialize reference.
- Reference is alias to a variable and cannot be reinitialized to other variable
- When ‘&’ operator is used with reference, it gives address of variable to which it refers.
- Reference can be used as data member of any class
- **Using typedef we can create alias for class whereas using reference we can create alias for object.**

Reference

- We can not create reference to constant value.
  - int &num2 = 10; //can not create reference to constant value
- Reference is internally considered as constant pointer hence referent of reference must be variable/object.

```
int main( void )
{
        int num1 = 10;
        int &num2 = num1;
        //int *const num2 = &num1;
        cout<<"Num2 : "<<num2<<endl;
        //cout<<"Num2 : "<<*num2<<endl;
        return 0;
}
```

pass arguments to function, by value, by address or by reference.

- **In C++, we can pass argument to the function using 3 ways:**

1. By Value
2. By Address
3. By Reference

- If variable is passed by reference, then any change made in variable within function is reflected in caller function.
- Reference can be argument or return type of any function

Static Variable

- All the static and global variables get space only once during program loading / before starting execution of main function
- Static variable is also called as shared variable.
- Unintialized static and global variable get space on BSS segment.
- Intialized static and global variable get space on Data segment.
- Default value of static and global variable is zero.
- Static variables are same as global variables but it is having limited scope.

Static Member Functions

- Except main function, we can declare global function as well as member function static.
- To access non static members of the class, we should declare member function non static and to access
- static members of the class we should declare member function static.
- Member function of a class which is designed to call on object is called instance method. In short non static member function is also called as instance method.
- To access instance method either we should use object, pointer or reference to object.
- static member function is also called as class level method.
- To access class level method we should use classname and ::(scope resolution) operator.

Dynamic Memory Allocation

- If we want to allocate memory dynamically then we should use new operator and to deallocate that memory we should use delete operator.
- If pointer contains, address of deallocated memory then such pointer is called dangling pointer.
- When we allocate space in memory, and if we loose pointer to reach to that memory then such wastage of memory is called memory leakage.

- Example :

```
int main()
{
   int *ptr = new int;          //int *ptr = ( int* )::operator new( sizeof( int ) * 1 );
   *ptr = 125;        //Dereferencing
   cout<<"Value      :          "<<*ptr<<endl; //Dereferencing
   delete ptr;        //::operator delete( ptr );
   ptr = NULL;
   return 0;
}
```

Reference to array:

```
int main( void )
{
        int arr[ 3 ] = { 10, 20, 30 };
        int i;
        int (&arr2)[ 3 ] = arr;
        for(i = 0; i < 3; ++ i)
            cout<<arr2[ i ]<<endl;
        return 0;
}
```

Association

- If has-a relationship exist between two types then we should use association.
- Example : Car has-a engine (OR engine is part-of car)
- If object is part-of / component of another object then it is called association.
- If we declare object of a class as a data member inside another class then it represents association.
- Example Association:

```
class Engine
{ };
class Car{
private:
   Engine e;   //Association
};
int main( void ){
   Car car;
   return 0;
}
```

Dependant Object : Car Object

Dependancy Object : Engine Object

Composition – First Form of Association

Composition

- If dependency object do not exist without Dependant object then it represents composition.
- Composition represents tight coupling.

Example: Human has-a heart.

```
class Heart
{ };
class Human{
   Heart hrt;
};
int main( void ){
   Human h;
   return 0;
}
```

- Dependant Object : Human Object
- Dependancy Object : Heart Object

Aggregation – Second Form of Association

Aggregation

- If dependency object exist without Dependant object then it represents Aggregation.
- Aggregation represents loose coupling.

Example: Department has-a facullty.

```
class Faculty
{ };
class Department
{
   Faculty f; //Association->Aggregation
};
int main( void )
{
   Department d;
   return 0;
}
```

- Dependant Object : Department Object
- Dependancy Object : Faculty Object

Inheritance

- If "is-a" relationship exist between two types then we should use inheritance.
- Inheritance is also called as "Generalization".
- Example: Book is-a product
- 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.
- Size of object = sum of size of non static data members declared in base class and derived class.
- 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.
- Default mode of inheritance is private.
  - Example: class Employee : person //is treated as class Employee : private Person
- Example:
  - class Employee : public Person
- 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:
  - Either we should use member function(getter/setter).
  - or we should declare derived class as a friend inside base class.

Syntax of inheritance in C++

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

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

In C++ Parent class is called as Base class and child class is called as derived class. To create derived class we should use colon(:) operator. As shown in this code, public is mode of inheritance.

```
class Person //Parent class
{
char name[ 30 ];
int age;
};
class Employee : public Person //Child class
{
int empid;
float salary;
};
```

```
int main( void )
{
Person p;
cout<<sizeof( p )<<endl;

Employee emp;
cout<<sizeof( emp )<<endl;

return 0;
}
```

If we create object of derived class, then all the non- static data member declared in base class & derived class get space inside it i.e. non-static static data members of base class inherit into the derived class.

Syntax of inheritance in C++

- Using derived class name, we can access static data member declared in base class i.e. static data member of base class inherit into derived class.

```
class Base{
protected:
static int number;
};
int Base::number = 10;
class Derived : public
   Base{
public:
static void print( void ){
cout<<Base::number<
   <endl;
}
};
```

```
int
main( void )
{
Derived::print(
);
return 0;
}
```

```
class Derived : public
   Base
{
int num3;
static int num4;
public:
void setNum3( int num3 )
   {
 this->num3 = num3;
 }
static void setNum4( int
   num4 )
   {  Derived::num4 =
   num4;
} };
int Derived::num4;
```

```
int main( void )
{
Derived d;
d.setNum1(10);
d.setNum3(30);
Derived::setNum2(20);
Derived::setNum4(40);
return 0;
}
```

Except following functions, including nested class, all the members of base class, inherit into the derived class

- Constructor
- Destructor
- Copy constructor
- Assignment operator
- Friend function.

Mode of inheritance

- If we use private, protected and public keyword to manage visibility of the members of class then it is
- called as access specifier.
- But if we use these keywords to extends the class then it is called as mode of inheritance.
- C++ supports private, protected and public mode of inheritance. If we do not specify any mode, then default mode of inheritance is private.

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

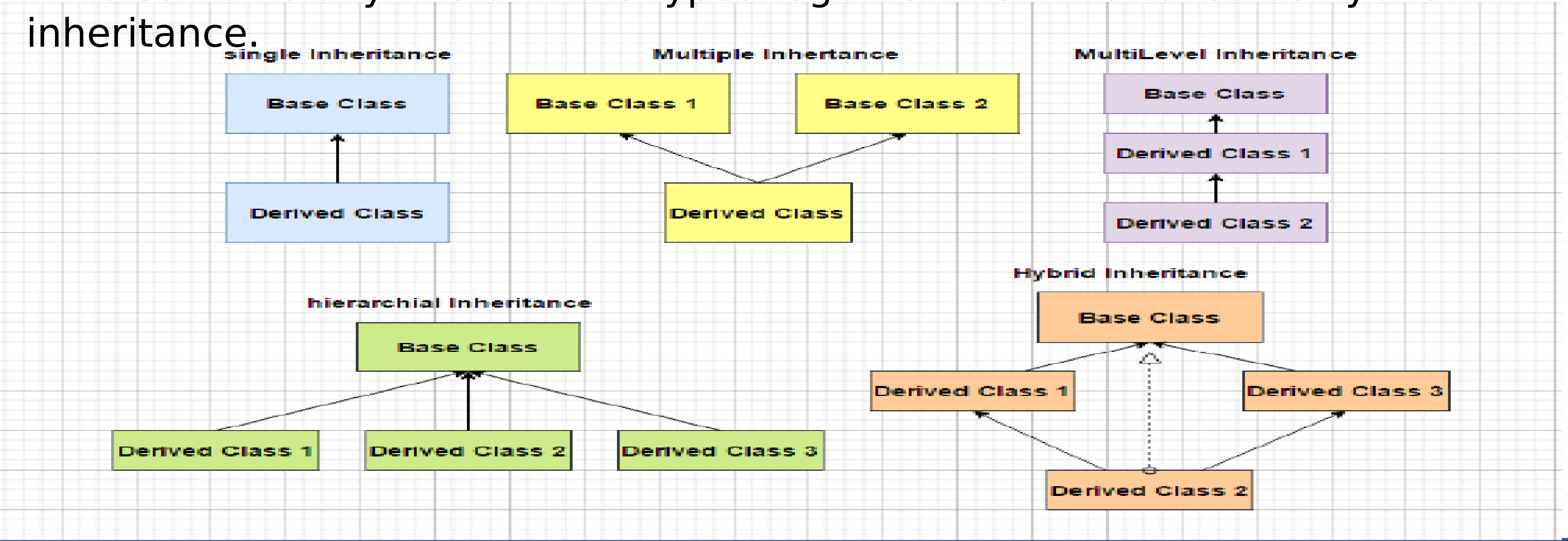
Private Mode of Inheritance		
Access Specifiers from Base class	**Derived Class**	**Indirect Derived Class**
private	NA	NA
protected	A	NA
public	A	NA

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

Types of Inheritance

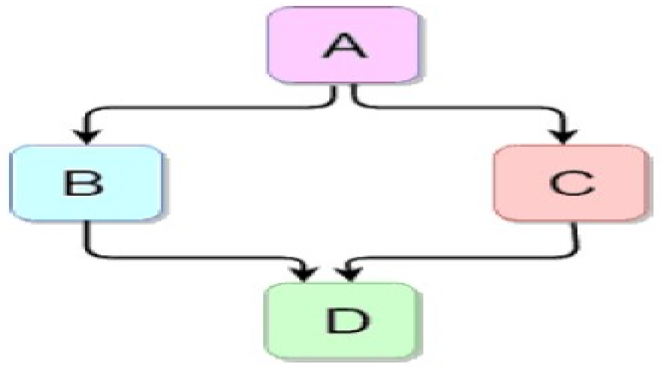
- Single inheritance
- Multiple inheritance
- Hierarchical inheritance
- Multilevel inheritance

If we combine any two or more types together then it is called as hybrid inheritance.



Diamond Problem

- As shown in diagram it is hybrid inheritance. Its shape is like diamond hence it is also called as diamond inheritance.
- 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.



Solution to Diamond Problem– Virtual Base Class

- 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
{ };
```

Upcasting , Downcasting & Object Slicing

- If we put the derived class object into base class pointer or reference then it is called as **Upcasting**
- If you want to access the members of derived class then you can convert the base class pointer/reference into derived class pointer/reference, this is called as **Downcasting**.
- At the time of downcasting explicit typecasting is mandatory.
- When upcasting is done then you can only call the base class members using the base class pointer or reference.
- you cannot access the derived class members using the base class pointer or reference.
- This is because of **Object Slicing**.

Virtual Keyword

- Virtual functions allow us to create a list of base class pointers and call methods of any of the derived classes without even knowing kind of derived class object.
- **Early Binding**
- When we use Base class's pointer to hold Derived class's object, base class pointer or reference will always call the base version of the function.
- **Late Binding**
- **Using Virtual Keyword in C++**
- We can make base class's methods virtual by using **virtual** keyword while declaring them. Virtual keyword will lead to Late Binding of that method.
- On using Virtual keyword with Base class's function, Late Binding takes place and the derived version of function will be called, because base class pointer pointes to Derived class object.
- **Points to note**
  - **Only the Base class Method's declaration needs the Virtual Keyword, not the definition.**
  - If a function is declared as **virtual** in the base class, it will be virtual in all its derived classes.
  - The address of the virtual Function is placed in the **VTABLE** and the compiler uses **VPTR**(vpointer) to point to the Virtual Function

Program Demo

Early Binding

create a class Base and Derived (void show() in both classes)

create base *bptr;

bptr=&d;

bptr->show()

Late Binding

create a class Base and Derived (void show() in both classes one as virtual in base class)

create base *bptr;

bptr=&d;

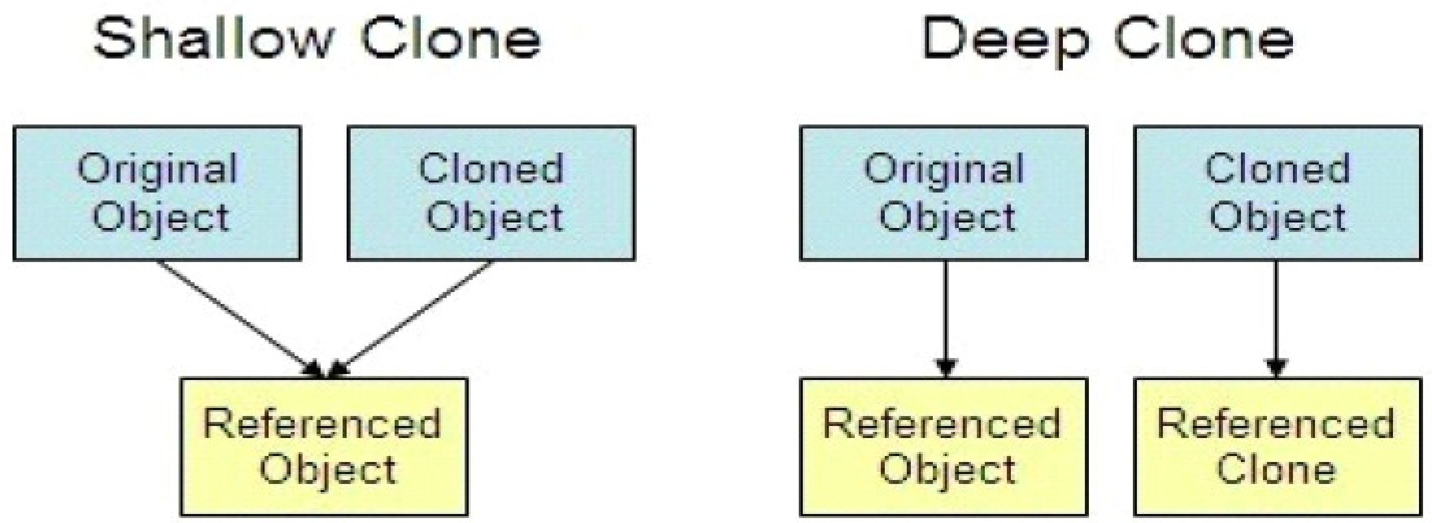
bptr->show()

Abstract Class

- Sometimes implementation of all function cannot be provided in a base class because we don’t know the implementation.
- In such cases we can declare a function but cannot define it.
- Such functions are then made as pure virtual functions which must be implemented by the Derived class.
- Such a class where pure virtual function exists is called abstract class.
- We cannot create an object, but we can create pointer or reference of abstract class.

Object Copying

- In object-oriented programming, “object copying” is a process of creating a copy of an existing object.
- The resulting object is called an object copy or simply copy of the original object.
- Methods of copying:
  - Shallow copy
  - Deep copy



Types of Copy

- **Shallow Copy**
  - The process of copying state of object into another object.
  - It is also called as bit-wise copy.
  - When we assign one object to another object at that time copying all the contents from source object to destination object as it is. Such type of copy is called as shallow copy.
  - Compiler by default create a shallow copy. Default copy constructor always create shallow copy.
- **Deep Copy**
  - Deep copy is the process of copying state of the object by modifying some state.
  - It is also called as member-wise copy.
  - When class contains at least one data member of pointer type, when class contains user defined destructor and when we assign one object to another object at that time instead of copy base address allocate a new memory for each and every object and then copy contain from memory of source object into memory of destination object. Such type of copy is called as deep copy.

Shallow Copy

- Process of copying state of object into another object as it is, is called shallow copy.
- It is also called as bit-wise copy / bit by bit copy.
- Following are the cases when shallow copy taken place:
    1. If we pass variable / object as a argument to the function by value.
    2. If we return object from function by value.
    3. If we initialize object: Complex c2=c1
    4. If we assign the object , c2=c1;
    5. If we catch object by value.
- <u>Examples of shallow copy</u>

  Example 1: (Initialization)

  int num1=50;

  int num2=num1;

  Example 2: (Assignment)

  Complex c1(40,50);

  c2=c1;

Deep Copy

- It is also called as member-wise copy. By modifying some state, if we create copy of the object then it is called deep copy.
    - Conditions to create deep copy
        - Class must contain at least one pointer type data member.

```
class Array
{
private:
int size;
int *arr;
//Case - I
public:
Array( int size )
{
this->size = size;
this->arr = new int[ this->size ];
}
};
```

- Steps to create deep copy
    - 1. Copy the required size from source object into destination object.
    - 2. Allocate new resource for the destination object.
    - 3. Copy the contents from resource of source object into destination object.

Friend function & class

- If we want to access private members inside derived class
    - Either we should use member function(getter/setter).
    - Or we should declare a facilitator function as a friend function.
    - Or we should declare derived class as a friend inside base class.
- Friend function is non-member function of the class, that can access/modify the private members of the class.
- It can be a global function.
- Or member function of another class.
- Friend functions are mostly used in operator overloading.
- If class C1 is declared as friend of class C2, all members of class C1 can access private members of C2.
- Friend classes are mostly used to implement data struct like linked lists.

Operator Overloading

- operator is token in C/C++.
- It is used to generate expression.
- operator is keyword in C++.
- Types of operator:
  - Unary operator (++,--,&,!,~,sizeof())
  - Binary Operator (Arithmetic, relational, logical , bitwise, assignment)
  - Ternary operator (conditional)
- In C++, also we can not use operator with objects of user defined type directly.
- If we want to use operator with objects of user defined type then we should overload operator.
- To overload operator, we should define **operator function.**
- **We can define operator function using 2 ways:**
  - **Using member function**
  - **Using non member function**

Program Demo without operator overloading

- Create a class point, having two fileld, x, y.
  - Point(void)
  - Point(int x, int y)

```
int main( void )
{
Point pt1(10,20);
Point pt2(30,40);
Point pt3;
pt3 = pt1 + pt2; //Not OK( implicitly)
return 0;
}
```

Need Of Operator Overloading

- we extend the meaning of the operator.
- If we want to use operator with the object of use defined type, then we need to overload operator.
- To overload operator, we need to define operator function.
- In C++, operator is a keyword
  - Suppose we want to use plus(+) operator with objects then we need to define operator+( ) function.

We define operator function either inside class (as a member function) or outside class (as a non-member function).	Point pt1(10,20), pt2(30,40), pt3;
	
	pt3 = pt1 + pt2; //pt3 = pt1.operator+(pt2); //using member function
	OR
	pt3 = pt1 + pt2; //pt3 = operator+(pt1, pt2); //using non member function

Operator Overloading

using member function

- operator function must be member function
- If we want to overload, binary operator using member function then operator function should take only one parameter.
- Example : c3 = c1 + c2; //will be called as
  - c3 = c1.operator+(c2)

- Example :

```
Point operator+( Point &other ) //Member Function
	{
	Point temp;
	temp.xPos = this->xPos + other.xPos;
	temp.yPos = this->yPos + other.yPos;
	return temp;
	}
```

using non member function

- Operator function must be global function
- If we want to overload binary operator using non member function then operator function should take two parameters.
- Example : c3 = c1 + c2; //will be called as
  - c3 = operator+(c1,c2);

- Example:

```
Point operator+( Point &pt1, Point &pt2 ) //Non Member Function
{
Point temp;
temp.xPos = pt1.xPos + pt2.xPos;
temp.yPos = pt1.yPos + pt2.yPos;
return temp;
}
```

We can not overload following operator using member as well as non member function

1. dot/member selection operator(.)
2. Pointer to member selection operator(.*)
3. Scope resolution operator(::)
4. Ternary/conditional operator(? :)
5. sizeof() operator
6. typeid() operator
7. static_cast operator
8. dynamic_cast operator
9. const_cast operator
10. reinterpret_cast operator

We can not overload following operators using non member function:

- Assignment operator(=)
- Subscript / Index operator([])
- Function Call operator[()]
- Arrow / Dereferencing operator(->)

Exception Handling

- If we give wrong input to the application then it generates runtime error/exception.
- Exception is an object, which is used to send notification to the end user of the system if any exceptional situation occurs in the program.
- To handle exception then we should use 3 keywords:
- 1**. try**
  - try is keyword in C++.
  - If we want to inspect exception then we should put statements inside try block/handler.
  - Try block may have multiple catch block but it must have at least one catch block.
- **2. catch**
  - If we want to handle exception then we should use catch block/handler.
  - Single try block may have multiple catch block.
  - Catch block can handle exception thrown from try block only.
  - A catch block, which can handle any type of exception is called generic catch block / catch-all handler.
  - For each type of exception, we can write specific catch block or we can write single catch block which can handle all types of exception. A catch block which can handle all type of exception is called generic catch block.
- **3. throw**
  - throw is keyword in C++.
  - If we want to generate exception explicitly then we should use throw keyword.
  - "throw statement" is a jump statement.
  - To generate new exception, we should use throw keyword. Throw statement is jump statement.

Note : For thrown exception, if we do not provide matching catch block then C++ runtime gives call to the std::terminate() function which implicitly gives call to the std::abort() function.

Consider the following code

- In C++, try, catch and throw keyword is used to handle exception.

```
int num1;
accept_record( num1 );
int num2;
accept_record( num1 );
try {
  if( num2 == 0 )
  throw "/ by zero  exception";
  int result = num1 / num2;
  print_record( result )
}
catch( const char *ex ){
  cout<<ex<<endl;
}
catch(...)
{
cout<<"Genenric catch  handler"<<endl;
}
```

Consider the following code

In this code, int type exception is thrown but matching catch block is not available. Even generic catch block is also not available. Hence program will terminate. Because, if we throw exception from try block then catch block can handle it. But with the help of function we can throw exception from outside of the try block.

```
int main( void ){
    int num1;
    accept_record(num1);
    int num2;
    accept_record(num2);
try {
    If( num2 == 0 )
                    throw 0;
    int result = num1 / num2;
    print_record(result);
}
catch( const char *ex ){
    cout<<ex<<endl;  }
    return 0;
}
```

Consider the following code

If we are throwing exception from function, then implementer of function should specify “exception specification list”. The exception specification list is used to specify type of exception function may throw.

If type of thrown exception is not available in exception specification list and if exception is raised then C++ do execute catch block rather it invokes std::unexpected() function.

```
int calculate(int num1,int num2) throw(const char* ){
    if( num2 == 0 )
                throw "/ by zero  exception";
    return num1 / num2;
}
int main( void ){
    int num1;
    accept_record(num1);
    int num2;
    accept_record(num2);
try{
   int result = calculate(num1, num2 );
    print_record(result);
}
catch( const char *ex ){
cout<<ex<<endl; }
return 0;  }
```

Template

- If we want to write generic program in C++, then we should use template.
- This feature is mainly designed for implementing generic data structure and algorithm.
- If we want to write generic program, then we should pass data type as a argument. And to catch that type we should define template.
- Using template we can not reduce code size or execution time but we can reduce developers effort.

Template

int num1 = 10, num2 = 20;
swap_object<**int>(num1, num2);**
string str1="Pune", str2="Karad";
swap_object<string>(str1, str2);
	In this code, <int> and <string> is
	considered as type argument.

template<typename T> //or
template<class T> //T : Type Parameter
void swap(b obj1, **T** obj2 **)**
{
T temp = obj1;
obj1 = obj2;
obj2 = temp;
}
	template and typename is keyword in
	C++. By passing datatype as argument
	we can write generic code hence
	parameterized type is called template

- **Types of Template**
  - Function Template
  - Class Template

Example of Function Template

```
//template<typename T>//T : Type Parameter
template<class T> //T : Type Parameter
void swap_number( T &o1, T &o2 )
{   T temp = o1;
    o1 = o2;
    o2 = temp;
}
 int main( void )
{
    int num1 = 10;
    int num2 = 20;
    swap_number<int>( num1, num2 );     //Here int is type argument
    cout<<"Num1 : "<<num1<<endl;
    cout<<"Num2 : "<<num2<<endl;
    return 0;
}
```

Example of Class Template

```
template<class T>
class Array // Parameterized type
{
private:
   int size;
   T *arr;
   public:
   Array( void ) : size( 0 ), arr( NULL )
   {
   }
   Array( int size )
   {
   this->size = size;
   this->arr = new T[ this->size ];
   }
   void acceptRecord( void ){}
   void printRecord( void ){ }
   ~Array( void ){ }
};
```

```
int main(void)
{
Array<char> a1( 3 );
a1.acceptRecord();
a1.printRecord();
return 0;
}
```

Casting Operators

- dynamic_cast Used for conversion of polymorphic types.
  - dynamic_cast < type-id > (expression)
  - dynamic cast returns NULL if the cast to a pointer type fails
  - The **bad_cast** exception is thrown by the **dynamic_cast** operator as the result of a failed cast to a reference type.
- static_cast Used for conversion of nonpolymorphic types.
  - Risky conversion not be used, should only be used in performance-critical code when you are certain it will work correctly
  - The **static_cast** operator can be used for operations such as converting a pointer to a base class to a pointer to a derived class. Such conversions are not always safe.
- const_cast Used to remove the **const**, **volatile**, and **__unaligned** attributes.
  - const_cast<class *> (this)->membername = value;
- reinterpret_cast Used for simple reinterpretation of bits.
  - Allows any pointer to be converted into any other pointer type.
  - The **reinterpret_cast** operator can be used for conversions such as **char*** to **int***, or One_class* to Unrelated_class*, which are inherently unsafe.

Run-Time Type Information

- Run-time type information (RTTI) is a mechanism that allows the type of an object to be determined during program execution.
- There are three main C++ language elements to run-time type information:
- The dynamic_cast operator.
  - Used for conversion of polymorphic types.
- The typeid operator.
  - Used for identifying the exact type of an object.
  - typeid(Base *).name();
  - If Base ptr holds null then type_id throws bad_typeid exception
- The type_info class.
  - Used to hold the type information returned by the **typeid** operator.

STL

- The Standard Template Library (STL) is a set of C++ template classes to provide common programming data structures and functions such as lists, stacks, arrays, etc.
- It is a library of container classes, algorithms, and iterators.
- It is a generalized library and so, its components are parameterized.
- Working knowledge of template classes is a prerequisite for working with STL.

- STL has 4 components:
  - Algorithms
  - Containers
  - Functions
  - Iterators

Components of STL

1. **Algorithm**

They act on containers and provide means for various operations for the contents of the containers.

- Sorting
- Searching

2. **containers**

- Containers or container classes store objects and data.

3. **Functions**

- The STL includes classes that overload the function call operator.
- Instances of such classes are called function objects or functors.
- Functors allow the working of the associated function to be customized with the help of parameters to be passed.

4. **Iterators**

- As the name suggests, iterators are used for working upon a sequence of values. They are the major feature that allows generality in STL.
- Iterators are used to point at the memory addresses of STL containers.
- They are primarily used in sequences of numbers, characters etc.
- They reduce the complexity and execution time of the program.

vector

- Vectors are the same as dynamic arrays with the ability to resize itself automatically when an element is inserted or deleted, with their storage being handled automatically by the container.
- Vector elements are placed in contiguous storage so that they can be accessed and traversed using iterators.
- In vectors, data is inserted at the end. Inserting at the end takes differential time, as sometimes the array may need to be extended. Removing the last element takes only constant time because no resizing happens.
- Inserting and erasing at the beginning or in the middle is linear in time.
- begin() – Returns an iterator pointing to the first element in the vector
- end() – Returns an iterator pointing to the theoretical element that follows the last element in the vector
- size() – Returns the number of elements in the vector.
- empty() – Returns whether the container is empty.
- front() – Returns a reference to the first element in the vector
- back() – Returns a reference to the last element in the vector
- assign() – It assigns new value to the vector elements by replacing old ones
- push_back() – It push the elements into a vector from the back
- pop_back() – It is used to pop or remove elements from a vector from the back.
- insert() – It inserts new elements before the element at the specified position
- erase() – It is used to remove elements from a container from the specified position or range.