Programming with C++
UNIT 3

Friend Function

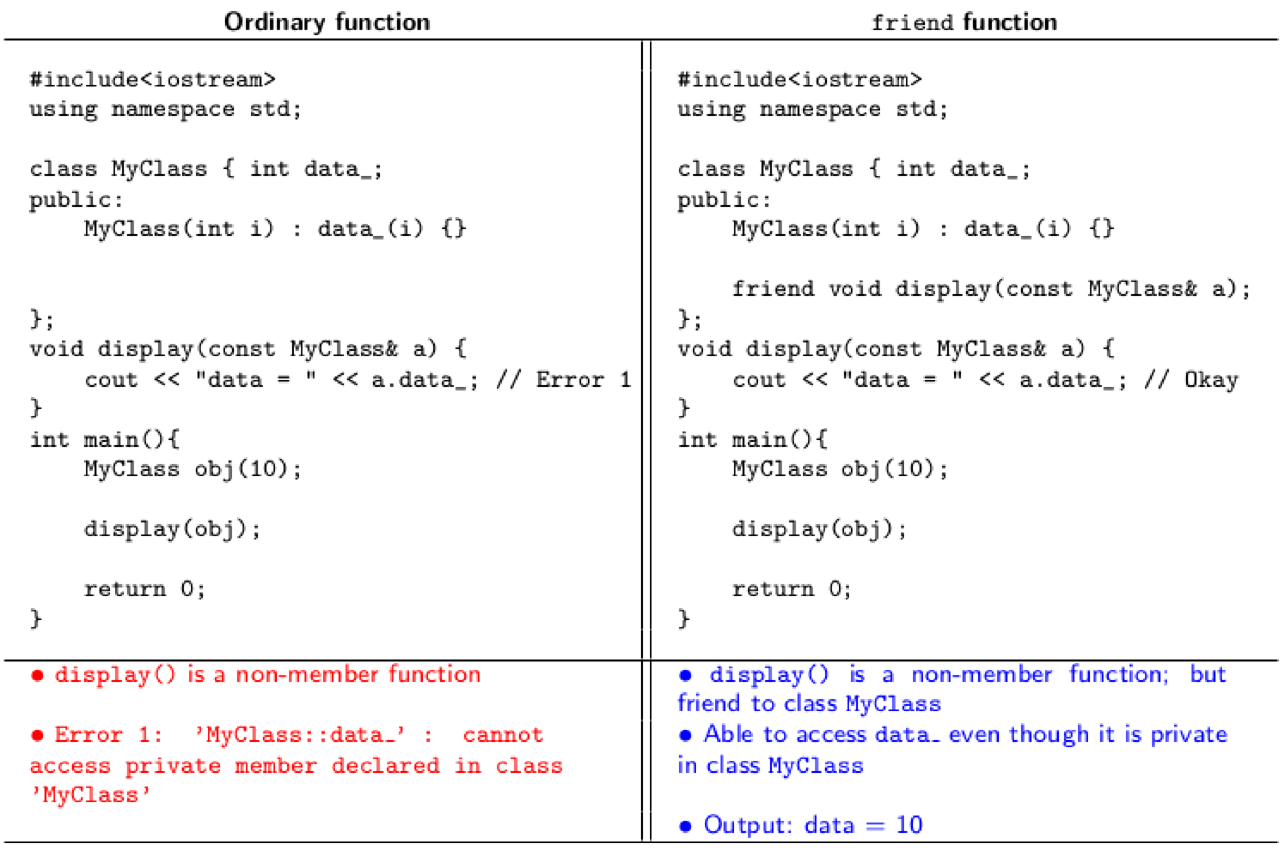
A friend function of a class

- has access to the private and protected members of the class
- must have its prototype included within the scope of the class prefixed with the keyword friend
- does not have its name qualified with the class scope (because not a member function)
- is not called with an invoking object of the class (because not a member function)
- can be declared friend in more then one classes

A friend function of a class can be a

- global function
- a member function of a another class
- a function template

Friend Function (Basic Notion)



Ordinary function

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

class MyClass { int data_;
public:
    MyClass(int i) : data_(i) {}


};
void display(const MyClass& a) {
    cout << "data = " << a.data_; // Error 1
}
int main(){
    MyClass obj(10);

    display(obj);

    return 0;
}
```

- display() is a non-member function
- Error 1: 'MyClass::data_' : cannot access private member declared in class 'MyClass'

friend function

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

class MyClass { int data_;
public:
    MyClass(int i) : data_(i) {}

    friend void display(const MyClass& a);
};
void display(const MyClass& a) {
    cout << "data = " << a.data_; // Okay
}
int main(){
    MyClass obj(10);

    display(obj);

    return 0;
}
```

- display() is a non-member function; but friend to class MyClass
- Able to access data_ even though it is private in class MyClass

- Output: data = 10

//friendFn_Basic.cpp

```
//Non member function print is able to access private data, because it is a friend to the class
#include<iostream>
using namespace std;

class MyFriend
{
        int m_a;
 public:
```

```
	MyFriend(int a):m_a(a){}
	friend void print(MyFriend);
};

void print(MyFriend o){cout<<"a="<<o.m_a<<endl;}
int main()
{
	MyFriend obj1(10);
	print(obj1);
	return 0;
}
/*Output:
a=10
*/
```

Multiply a Matrix with a Vector

```
//FriendFn_VecMat.cpp
//A function which multiplies a vector to a matrix needs access to internals of
//both vector and matrix class
//So make prodVectorMatrix a global function and a friend to both the classes
//prodVectorMatrix should be defined after both the classes are defined

#include<iostream>
using namespace std;

class Matrix;		//Forward Declaration

class Vector
{
	int v[3];
	int m_n;
  public:
	Vector(int n):m_n(n)
	{
		for(int i=0;i<m_n;i++)
			v[i]=i;
	}

	void clear()
	{
		for(int i=0;i<m_n;i++)
			v[i]=0;
	}

	void showVector()
	{
		for(int i=0;i<m_n;i++)
			cout<<v[i]<<endl;
	}

	friend Vector prodVectorMatrix(Matrix*,Vector*);
};
```

```
class Matrix
{
        int m[3][3];
        int m_r,m_c;
  public:
        Matrix(int r,int c):m_r(r),m_c(c)
        {
                for(int i=0;i<m_r;i++)
                        for(int j=0;j<m_c;j++)
                                m[i][j]=i+j;
        }

        void showMatrix()
        {
                for(int i=0;i<m_r;i++)
                {
                        for(int j=0;j<m_c;j++)
                        {
                                cout<<m[i][j]<<" ";
                        }
                        cout<<endl;
                }
        }
        friend Vector prodVectorMatrix(Matrix*,Vector*);
};

Vector prodVectorMatrix(Matrix* pM,Vector* pV)
{
        Vector res(pM->m_r);
        res.clear();

        for(int i=0;i<pM->m_r;i++)
                for(int j=0;j<pV->m_n;j++)
                        res.v[i]=res.v[i]+pM->m[i][j]*pV->v[j];

        return res;
}

int main()
{
        Matrix m(2,3);
        Vector v(3);
        Vector prod=prodVectorMatrix(&m,&v);
        cout<<"Matrix"<<endl;
        m.showMatrix();
        cout<<"Vector"<<endl;
        v.showVector();
        cout<<"Result"<<endl;
        prod.showVector();
        return 0;
}
```

```
/*Output:
Matrix
0 1 2
1 2 3
Vector
0
1
2
Result
5
8
*/
```

Linked List

```
//friendFn_LinkedList.cpp
//List class which is built on Node class needs to access internals of node
//So make the required functions of List class as a friend to Node class
//In this type of pgms, it’s better to make the class itself as a friend(see FriendClass_LinkedList.cpp)
#include <iostream>
using namespace std;

class Node;                         // Forward declaration

class List
{
        Node *head;                 // Head of the list
        Node *tail;                  // Tail of the list
  public:
        List():head(NULL),tail(NULL) {}
        void display();
        void append(Node *p);
};

class Node {
        int info;                   // Data of the node
        Node *next;                 // Ptr to next node
  public:
        Node(int i): info(i), next(NULL) { }
        friend void List::display();
        friend void List::append(Node *);
};

void List::display()
{
        Node *ptr = head;
        while (ptr)
        {
                cout << ptr->info << " ";
                ptr = ptr->next;
        }
        cout<<endl;
}
```

```
void List::append(Node *p)
{
        if (!head)
                head = tail = p;
        else
        {
                tail->next = p;
                tail = tail->next;
        }
}
int main()
{
        List l;                         // Init null list
        Node n1(1), n2(2), n3(3);       // Few nodes
        l.append(&n1);                  // Add nodes to list
        l.append(&n2);
        l.append(&n3);
        l.display();                    // Show list
        return 0;
}
/*Output:
1 2 3
*/
```

Friend Class

A friend class of a class

- has access to the private and protected members of the class
- does not have its name qualified with the class scope (not a nested class)
- can be declared friend in more than one class
- A friend class can be a
    - class
    - class template

Linked List : friend class

//FriendClass_LinkedList.cpp

//List class is now a friend of Node class. Hence it has full visibility into the internals of Node
//When multiple member functions need to be friends, it is better to use friend class

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

class Node;                     // Forward declaration

class List
{
        Node *head;             // Head of the list
        Node *tail;             // Tail of the list
  public:
        List():head(NULL),tail(NULL) {}
        void display();
        void append(Node *p);
};
```

```
class Node {
        int info;       // Data of the node
        Node *next;     // Ptr to next node
  public:
        Node(int i): info(i), next(NULL) { }
//      friend void List::display();
//      friend void List::append(Node *);
        friend class List;              //List class is made friend to Node class
};

void List::display()
{
        Node *ptr = head;
        while (ptr)
        {
                cout << ptr->info << " ";
                ptr = ptr->next;
        }
        cout<<endl;
}

void List::append(Node *p)
{
        if (!head)
                head = tail = p;
        else
        {
                tail->next = p;
                tail = tail->next;
        }
}

int main()
{
        List l;                         // Init null list
        Node n1(1), n2(2), n3(3);       // Few nodes
        l.append(&n1);                          // Add nodes to list
        l.append(&n2);
        l.append(&n3);
        l.display();                    // Show list
        return 0;
}

/*Output:
1 2 3
*/
```

Note:

- friend-ship is neither commutative nor transitive
- A is a friend of B does not imply that B is a friend of A
- A is a friend of B and B is a friend of C does not imply that A is afriend of C

- Visibility and Encapsulation
  - public: a declaration that is accessible to all
  - protected: a declaration that is accessible only to the class itself and its subclasses
  - private: a declaration that is accessible only to the class itself
  - friend: a declaration that is accessible only to friend's of a class.
  - friend's tend to break data hiding and should be used judiciously.
    Like:
    - A function needs to access the internals of two (or more) independent classes (Eg: Matrix-Vector Multiplication)
    - A class is built on top of another (Eg: List-Node Access, List Iterator)
    - Certain situations of operator overloading (like streaming operators)

Operator Functions

Operator overloading lets us define the meaning of an operator when applied to operand(s) of a class type. Judicious use of operator overloading can make our programs easier to write and easier to read.

Why Overload Operators?

The reasons vary for the different operators, but the general guiding principle is to make your classes behave like built-in types.

- The closer your classes are to built-in types, the easier they will be for clients to use. For example, if you want to write a class to represent fractions, it's quite helpful to have the ability to define what + , - , * , and / mean when applied to objects of that class.
- The second reason to overload operators is to gain greater control over the behavior in your program. For example, you can overload memory allocation and deallocation routines for your classes to specify exactly how memory should be distributed and reclaimed for each new object.

It's important to emphasize that operator overloading doesn't necessarily make things easier for you as the class developer; its main purpose is to make things easier for clients of the class.

Choices in Operator Overloading

When you overload an operator, you write a function or method with the name operatorX , where X is the symbol for some operator, and with optional whitespace between operator and X .

The overloaded operator function you write may be Method or Global Function. First, you must decide whether your operator should be a method of your class or a global function (usually a friend of the class). How do you choose? First, you need to understand the difference between these two choices. When the operator is a method of a class, the left-hand side of the operator expression must always be an object of that class. If you write a global function, the left- hand side can be an object of a different type.

There are three different types of operators:

- Operators that must be methods: The C++ language requires some operators to be methods of a class because they don't make sense outside of a class. For example, operator= is tied so closely to the class that it can't exist anywhere else. Most operators do not impose this requirement.
- Operators that must be global functions: Whenever you need to allow the left-hand side of the operator to be a variable of a different type than your class, you must make the operator a global function. This rule applies specifically to operator<< and operator>> , where the left-

hand side is the iostream object, not an object of your class. Additionally, commutative operators like binary + and – should allow variables that are not objects of your class on the left-hand side.

- Operators that can be either methods or global functions: There is some disagreement in the C++ community on whether it's better to write methods or global functions to overload operators. However, following rule may be followed: Make every operator a method unless you must make it a global function, as described previously. One major advantage to this rule is that methods can be virtual , but friend functions cannot. Therefore, when you plan to write overloaded operators in an inheritance tree, you should make them methods if possible.

Good practice: When you write an overloaded operator as a method, you should mark it const if it doesn't change the object. That way, it can be called on const objects.

Choosing Argument Types
You are somewhat limited in your choice of argument types because as stated earlier for most operators you cannot change the number of arguments. For example, operator/ (binary operator) must always have two arguments if it is a global function; one argument if it's a method. The compiler issues an error if it differs from this standard. In this sense, the operator functions are different from normal functions, which you can overload with any number of parameters.
The real choice arises when you try to determine whether to take parameters by value or by reference, and whether or not to make them const .

- The choice of value vs. reference is easy: you should take every non-primitive parameter type by reference.
- The const decision is also trivial: mark every parameter const unless you actually modify it.

Choosing Return Types

C++ doesn't determine overload resolution based on return type. Thus, you can specify any return type you want when you write overloaded operators. However, just because you can do something doesn't mean you should do it. This flexibility implies that you could write confusing code in which comparison operators return pointers, and arithmetic operators return bools. However, you shouldn't do that.
Instead, you should write your overloaded operators such that they return the same types as the operators do for the built-in types. If you write a comparison operator, return a bool . If you write an arithmetic operator, return an object representing the result of the arithmetic.
Sometimes the return type is not obvious at first. For example, operator=, insertion(<<) , extraction operator(>>) should return a reference to the object on which it's called in order to support nested(chained) assignments.

Choosing Behavior
You can provide whichever implementation you want in an overloaded operator. For example, you could write an operator+ that launches a game of Scrabble. However, you should generally constrain your implementations to provide behaviors that clients expect. Write operator+ so that it performs addition, or something like addition, such as string concatenation. operator+ in a Set class should compute union and NOT intersection.
Here we discuss how you should implement your overloaded operators. In exceptional circumstances, you might want to differ from these recommendations; but, in general, you should follow the standard patterns.

Overloaded operators are functions with special names: the keyword operator followed by the symbol for the operator being defined. Like any other function, an overloaded operator has a return type, a parameter list, and a body.

An operator function has the same number of parameters as the operator has operands. A unary operator has one parameter; a binary operator has two. In a binary operator, the left-hand operand is passed to the first parameter and the right-hand operand to the second. Except for the overloaded function-call operator, operator(), an overloaded operator may not have default arguments.

If an operator function is a member function, the first (left-hand) operand is bound to the implicit this pointer. Because the first operand is implicitly bound to this, a member operator function has one less (explicit) parameter than the operator has operands.

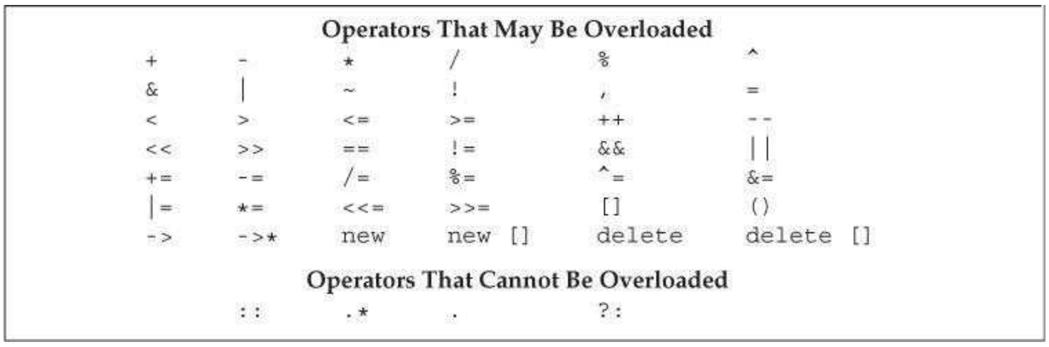
An operator function must either be a member of a class or have at least one parameter of class type:

```
// error: cannot redefine the built-in operator for ints
int operator+(int, int);
```

This restriction means that we cannot change the meaning of an operator when applied to operands of built-in type.

We can overload most, but not all, of the operators. Table 1 shows whether or not an operator may be overloaded.

Table 1: Operators



Operators That May Be Overloaded

+	-	*	/	%	^
&	|	~	!	,	=
<	>	<=	>=	++	--
<<	>>	==	!=	&&	||
+=	-=	/=	%=	^=	&=
|=	*=	<<=	>>=	[]	()
->	->*	new	new []	delete	delete []

Operators That Cannot Be Overloaded

::	.*	.	?:

- We can overload only existing operators and cannot invent new operator symbols. For example, we cannot define operator** to provide exponentiation.
- Four symbols (+, -, *, and &) serve as both unary and binary operators. Either or both of these operators can be overloaded. The number of parameters determines which operator is being defined.
- An overloaded operator has the same precedence and associativity as the corresponding built-in operator. Regardless of the operand types.

  x == y + z; is always equivalent to x == (y + z).

Operator Overloading – Summary of Rules:

- No new operator such as **, <>, or &| can be defined for overloading.
- Intrinsic properties of the overloaded operator cannot be change
  - Preserves arity
  - Preserves precedence
  - Preserves associativity

- These operators can be overloaded:
  [] + - * / % & | ~ ! = += -= *= /= %= = &= |= << >> >>= <<= == != < > <= >= && || ++ -- , ->* -> ( ) [ ]
- The operators :: (scope resolution), . (member access), .* (member access through pointer to member), sizeof, and ?: (ternary conditional) cannot be overloaded.
- The overloads of operators &&, ||, and , (comma) lose their special properties: short-circuit evaluation and sequencing
- The overload of operator-> must either return a raw pointer or return an object (by reference or by value), for which operator-> is in turn overloaded.
- For a member operator function, invoking object is passed implicitly as the left operand but the right operand is passed explicitly
- For a non-member operator function (Global/friend) operands are always passed explicitly.

Guidelines for Operator Overloading

- Use global function when encapsulation is not a concern. For example, using struct String { char* str; } to wrap a C-string and overload operator+ to concatenate strings and build a String algebra
- Use member function when the left operand is necessarily a class where the operator function is a member and multiple types of operands are not involved
- Use friend function, otherwise
- While overloading an operator, try to preserve its natural semantics for built-in types as much as possible. For example, operator+ in a Set class should compute union and NOT intersection
- Usually stick to the parameter passing conventions (built-in types by value and UDT's by constant reference)
- Decide on the return type based on the natural semantics for built-in types. For example, as in pre-increment and post-increment operators
- Consider the effect of casting on operands
- Only overload the operators that you may need (minimal design)

Overloading Binary Operators

Complex no program to demonstrate overloading of plus operator which allows complex+complex complex+integer, integer+complex. If operator+ is a member function of the complex type, then only complex+integer would compile, and not integer+complex. So make it a friend.

```
//ovrldPlsFrn.cpp
//Operator Plus, is commutative, to allow having a non object on LHS of operator
//it is implemented as a friend function
//You may overload other arithmetic operators in the same manner
#include<iostream>
using namespace std;
class Complex
{
        double re;
        double im;
  public:Complex(double r=0,double i=0){re=r;im=i;}
```

```
	void display(){cout<<re<<"+"<<im<<"i"<<endl;}
	friend Complex operator+(const Complex&,const Complex&);
};
Complex operator+(const Complex& c1,const Complex& c2)
{
	Complex sum;
	sum.re=c1.re+c2.re;
	sum.im=c1.im+c2.im;
	return sum;
}

int main()
{
	Complex c1(2,3);
	Complex c2(4,5);
	cout<<"1st Complex Number:";
	c1.display();
	cout<<"2nd Complex Number:";
	c2.display();

	cout<<"sum of c1 and c2:";
	Complex cSum1=c1+c2;			//calls operator+
	cSum1.display();

//Complex cSum2=6.5+c is an Error, if operator+ is implemented as a member function
//here works fine, because operator+ is implemented as friend fn
	Complex cSum2=6.5+c1;			//calls operator+
	cout<<"6.5 added to c1, sum:";
	cSum2.display();

//Complex(0,6.5) is an anonymous object
	Complex cSum3=c1+Complex(0,6.5);	//calls operator+
	cout<<"6.5i added to c1, sum:";
	cSum3.display();

	return 0;
}
/*
Output:
1st Complex Number:2+3i
2nd Complex Number:4+5i
sum of c1 and c2:6+8i
6.5 added to c1, sum:8.5+3i
6.5i added to c1, sum:2+9.5i
*/
```

```
//ovrldPlsFrn.cpp
/*Operator Plus, is commutative, to allow having a non object on LHS of operator, it is
implemented as a friend function. Similarly are overloaded binary minus and multiplication
operator below*/
#include<iostream>
using namespace std;

class Complex
{
	double re;
	double im;

  public:Complex(double r=0,double i=0){re=r;im=i;}
	void display(){cout<<re<<"+"<<im<<"i"<<endl;}
	friend Complex operator+(const Complex&,const Complex&);
	friend Complex operator-(const Complex&,const Complex&);
	friend Complex operator*(const Complex&,const Complex&);
};

Complex operator+(const Complex& c1,const Complex& c2)
{
	Complex sum;
	sum.re=c1.re+c2.re;
	sum.im=c1.im+c2.im;
	return sum;
}

Complex operator-(const Complex& c1,const Complex& c2)
{
	Complex diff;
	diff.re=c1.re-c2.re;
	diff.im=c1.im-c2.im;
	return diff;
}

Complex operator*(const Complex& c1,const Complex& c2)
{
	Complex prod;
	prod.re=(c1.re*c2.re)-(c1.im*c2.im);
	prod.im=(c1.re*c2.im)+(c1.im*c2.re);
	return prod;
}
```

```
int main()
{
	Complex c1(2,3);
	Complex c2(4,5);
	cout<<"1st Complex Number:";
	c1.display();
	cout<<"2nd Complex Number:";
	c2.display();

	cout<<"sum of c1 and c2:";
	Complex cSum1=c1+c2;			//calls operator+
	cSum1.display();

//Complex cSum2=6.5+c is an Error, if operator+ is implemented as a member function
//works fine, because operator+ is implemented as friend fn
	Complex cSum2=6.5+c1;			//calls operator+
	cout<<"6.5 added to c1, sum:";
	cSum2.display();

//Complex(0,6.5) is an anonymous object
	Complex cSum3=c1+Complex(0,6.5);	//calls operator+
	cout<<"6.5i added to c1, sum:";
	cSum3.display();

	cout<<"Difference of c1 and c2:";
	Complex cDiff1=c1-c2;			//calls operator-
	cDiff1.display();

	cout<<"Product of c1 and c2:";
	Complex cProd1=c1*c2;			//calls operator*
	cProd1.display();

	return 0;
}
/*
Output:
1st Complex Number:2+3i
2nd Complex Number:4+5i
sum of c1 and c2:6+8i
6.5 added to c1, sum:8.5+3i
6.5i added to c1, sum:2+9.5i
Difference of c1 and c2:-2+-2i
Product of c1 and c2:-7+22i
*/
```

```
//equality_relOpr.cpp
//You may overload other relational opeators in the same manner
#include<iostream>
using namespace std;

class Complex
{
	double re;
	double im;

public:
	Complex(double r=0,double i=0)
	{
		re=r;
		im=i;
	}

	friend bool operator ==(const Complex& c1,const Complex& c2)
	{
		if(c1.re==c2.re && c1.im==c2.im)
			return true;
		return false;
	}

	friend bool operator !=(const Complex& c1,const Complex& c2)
	{
		return !(c1==c2);
	}

	friend bool operator<(const Complex& c1,const Complex& c2)
	{
		if(c1.re<c2.re)
			return true;

		if(c1.re==c2.re && c1.im<c2.im)
			return true;

		return false;
	}

	void display()
	{
		cout<<re<<"+"<<im<<"i"<<endl;
	}

};
```

```
int main()
{
	Complex c1(2,3);
	Complex c2(2,3);

	cout<<"c1=";
	c1.display();

	cout<<"c2=";
	c2.display();

	cout<<"Zero indicates false, one indicates true"<<endl;
	cout<<"c1 equals c2:"<<(c1==c2)<<endl;
	cout<<"c1 not equals c2:"<<(c1!=c2)<<endl;
	cout<<"c1 less than c2:"<<(c1!=c2)<<endl;

	return 0;
}
/*
Output:
c1=2+3i
c2=2+3i
Zero indicates false, one indicates true
c1 equals c2:1
c1 not equals c2:0
c1 less than c2:0
*/
```

Overloading Unary Operators

- The pre-operator should first perform the operation (increment / decrement / other) and then return the object. Hence its return type should be **MyClass&** and it should **return *this;**
- The post-operator should perform the operation (increment / decrement / other) after it returns the original value. Hence it should copy the original object in a **temporary** **MyClass t;** and then **return t;**. Its return type should be **MyClass**.

Differentiating Prefix and Postfix Operators

There is one problem with defining both the prefix and postfix operators: Normal overloading cannot distinguish between these operators. The prefix and postfix versions use the same symbol, meaning that the overloaded versions of these operators have the same name. They also have the same number and type of operands.

To solve this problem, the postfix versions take an extra (unused) parameter of type int. When we use a postfix operator, the compiler supplies 0 as the argument for this parameter. Although the postfix function can use this extra parameter, it usually should not. That parameter is not needed for the work normally performed by a postfix operator. Its sole purpose is to distinguish a postfix function from the prefix .version.

```
//unaryOpr.cpp
//Vector can be represented using rectangular coordinates(x,y)
//Vector can be represented using polar coordinates(m,theta)
//In this pgm, only rectangular coordinate is considered
//unary operator functions are overloaded as methods of the class here
//unary operators take only one parameter: When implemented as method, the
//parameter is passed as an implicit this ptr
#include<iostream>
using namespace std;

class Vector
{
	double x;
	double y;
public:
	Vector(double x1=0,double y1=0);		//ctor taking default parameters
	void display();				//displays vector
	Vector& operator-();			//unary minus
	Vector& operator++();			//pre increment
	Vector operator++(int);			//post increment
};

Vector::Vector(double x1,double y1)
{
	x=x1;
	y=y1;
}

void Vector::display()
{
	cout<<"("<<x<<","<<y<<")"<<endl;
}

Vector& Vector::operator-()
{
	x=-x;
	y=-y;
	return *this;
}

Vector& Vector::operator++()
{
	x++;
	y++;
	return *this;
}
```

```
Vector Vector:: operator++(int)
{
        Vector temp=*this;
        x++;
        y++;
        return temp;
}

int main()
{
        Vector v1(2,3);
        Vector v2(4,5);
        Vector v3(6,7);

        cout<<"Vector1: ";
        v1.display();
        Vector res1=++v1;                    //calls operator++()
        cout<<"res1:pre incrementing vector1 ";
        res1.display();
        cout<<"vector1 after pre incrementing vector1 ";
        v1.display();

        cout<<endl;
        cout<<"Vector2: ";
        v2.display();
        Vector res2=v2++;                    //calls operator++(int)
        cout<<"res2:post incrementing vector2 ";
        res2.display();
        cout<<"vector2 after post incrementing vector2 ";
        v2.display();

        cout<<endl;
        cout<<"Vector3: ";
        v3.display();
        Vector res3=-v3;                     //calls operator-()
        cout<<"res3:applying unary minus on vector3 ";
        res3.display();
        cout<<"vector3 after applying unary minus ";
        v3.display();

        return 0;
}
/*
Output:
Vector1: (2,3)
res1:pre incrementing vector1 (3,4)
```

```
vector1 after pre incrementing vector1 (3,4)

Vector2: (4,5)
res2:post incrementing vector2 (4,5)
vector2 after post incrementing vector2 (5,6)

Vector3: (6,7)
res3:applying unary minus on vector3 (-6,-7)
vector3 after applying unary minus (-6,-7)
*/
```

Overloading Index Operator

Classes that represent containers from which elements can be retrieved by position often define the subscript operator, operator[].

To be compatible with the ordinary meaning of subscript, the subscript operator usually returns a reference to the element that is fetched. By returning a reference, subscript can be used on either side of an assignment. Consequently, it is also usually a good idea to define both const and nonconst versions of this operator. When applied to a const object, subscript should return a reference to const so that it is not possible to assign to the returned object.

```
//indexOpr.cpp
#include<iostream>
using namespace std;

class IntList
{
private:
        int m_list[10];

public:
        IntList()                                   //ctor
        {
                for(int i=0;i<10;i++)
                        m_list[i]=0;
        }

        int& operator[] (int index);                //overload []
};
 int& IntList::operator[] (int index)              //Fn defn for overload[]
{
        static int iErr = -1;
        if(index>0 && index <10)
                return m_list[index];
        cout<<"Index out of bound"<<endl;
        return iErr;
}
```

```
int main()
{
	IntList list;
	list[2] = 3;				// set a value, calls operator[]
	cout <<"list[2]="<<list[2]<<endl;	// get a value, calls operator[]
	cout<<"list[9]="<<list[9]<<endl;	// get a value, calls operator[]

	return 0;
}
/*
Output:
list[2]=3
list[9]=0
*/
```

Conversion Function

Nonexplicit constructor that can be called with one argument defines an implicit conversion. Such constructors convert an object from the argument's type to the class type.

We can also define conversions from the class type. We define a conversion from a class type by defining a conversion operator. Converting constructors and conversion operators define **class-type conversions**. Such conversions are also referred to as **user-defined conversions**.

A conversion operator is a special kind of member function that converts a value of a class type to a value of some other type. A conversion function typically has the general form

operator type() const;

where type represents a type.

Conversion operators can be defined for any type (other than void) that can be a function return type. Conversions to an array or a function type are not permitted. Conversions to pointer types—both data and function pointers—and to reference types are allowed.

Conversion operators have **no explicitly stated return type** and **no parameters** and must have an **empty parameter list**, and they must be defined as **member functions**. Conversion operations ordinarily should not change the object they are converting. As a result, conversion operators usually should be defined as **const** members.

```
//conversionOpr.cpp
#include <iostream>
using namespace std;

class Fraction
{
	int num, den;
public:
	Fraction(int n, int d)		//ctor
	{
		num = n;
		den = d;
```

```
        }
        // conversion operator: return float value of fraction
        operator float() const {
                return float(num) / float(den);
        }
};

int main()
{
        Fraction f(2, 5);
        float val = f;                          //calls operator float()
        cout << val<<endl;

        return 0;
}

/*
Output:
0.4
*/
```

Overloading Insertion (Output) and Extraction (Input) Operators

The object on the left of an extraction or insertion operator is the istream or ostream (such as cin or cout), not an object of userdefined class. Because you can't add a method to the istream or ostream classes, you must write the extraction and insertion operators as global **friend function** of the required class.

IO Operators Must Be Nonmember Functions

Input and output operators that conform to the conventions of the iostream library must be ordinary nonmember functions. These operators cannot be members of our own class. If they were, then the left-hand operand would have to be an object of our class type:

```
Complex c1;
c1<< cout;              // if operator<< is a member of Complex
```

If these operators are members of any class, they would have to be members of istream or ostream. However, those classes are part of the standard library, and we cannot add members to a class in the library.

Overloading the Output Operator <<

Ordinarily, the first parameter of an output operator is a **reference to a nonconst ostream object**. The ostream is nonconst because writing to the stream changes its state. The parameter is a reference because we cannot copy an ostream object.

The second parameter ordinarily should be a **reference to const of the class type** we want to print. The parameter is a reference to avoid copying the argument. It can be const because (ordinarily) printing an object does not change that object.

To be consistent with other output operators(i.e., to support chaining), operator<< normally **returns its ostream parameter**.

Overloading the Input Operator >>

Ordinarily the first parameter of an input operator is a **reference to the stream** from which it is to read, and the second parameter is a **reference to the (nonconst) object** into which to read. The operator usually **returns a reference to its given stream**. The second parameter must be nonconst because the purpose of an input operator is to read data into this object.

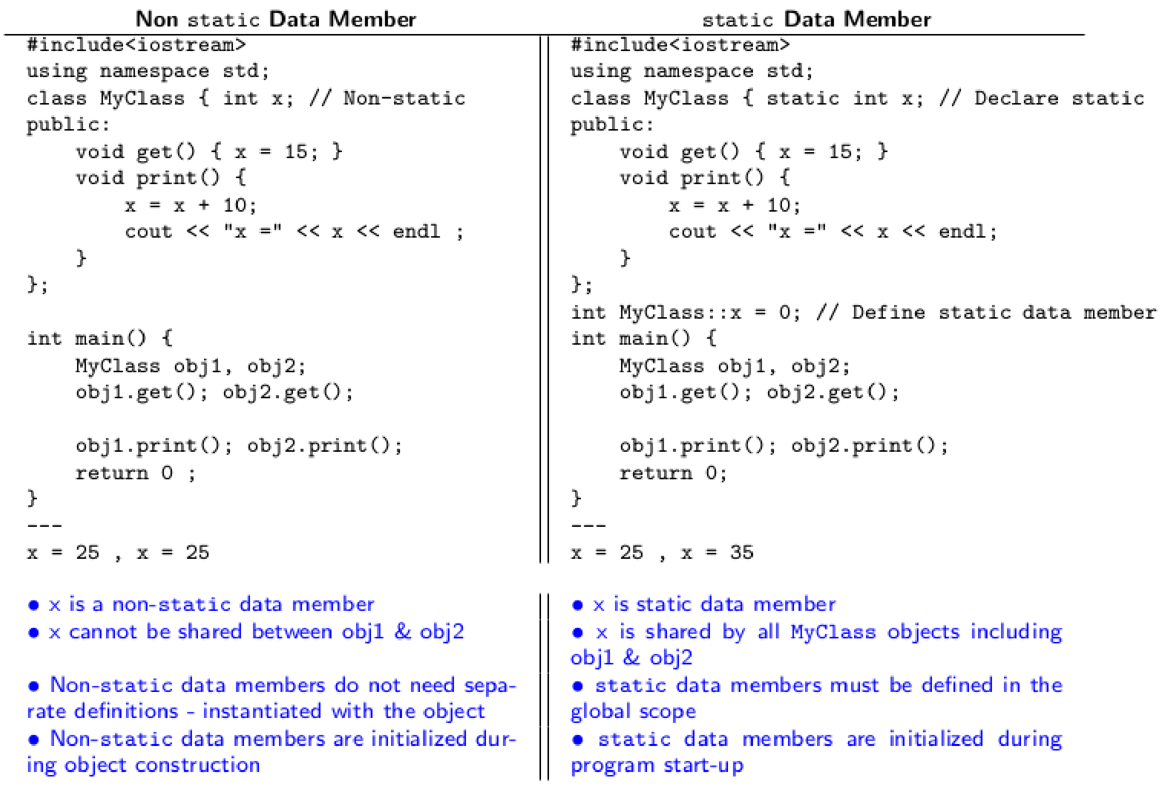
```
//ioOprOverld.cpp
#include<iostream>
using namespace std;

class Complex
{
        double re;
        double im;

public:
        Complex()               //default or zero arg ctor
        {
                re=0;
                im=0;
        }
friend ostream& operator<<(ostream&,const Complex&);
friend istream& operator>>(istream&,Complex&);
};

ostream& operator<<(ostream &os,const Complex &c)
{
        os<<c.re<<"+"<<c.im<<"i"<<endl;
        return os;
}
istream& operator>>(istream &is,Complex &c)
{
        is>>c.re>>c.im;
        return is;
}
int main()
{
        Complex obj1,obj2;

        cout<<"Enter 2 complex no's"<<endl;
        cin>>obj1>>obj2;                        //calls operator>>

        cout<<"Complex no's are:"<<endl;
        cout<<obj1<<obj2;                       //calls operator<<

        return 0;
}
```

```
/*
Output:
Enter 2 complex no's
2 3
4 5
Complex no's are:
2+3i
4+5i
*/
```

Static Members

Static Data Member

- is associated with **class** not with **object**
- is shared by all the objects of a class
- needs to be defined outside the class scope (in addition to the declaration within the class scope) to avoid linker error (Before C++17)
- From C++17 onwards, may be declared as an **inline** static data member.
- must be initialized in a source file
- is constructed before main() starts and destructed after main() ends
- can be private / public type
  - can be accessed with the class-name followed by the scope resolution operator (::)
  - as a member of any object of the class



Non static Data Member

```
#include<iostream>
using namespace std;
class MyClass { int x; // Non-static
public:
    void get() { x = 15; }
    void print() {
        x = x + 10;
        cout << "x =" << x << endl ;
    }
};

int main() {
    MyClass obj1, obj2;
    obj1.get(); obj2.get();

    obj1.print(); obj2.print();
    return 0 ;
}
---
x = 25 , x = 25
```

- x is a non-static data member
- x cannot be shared between obj1 & obj2

- Non-static data members do not need separate definitions - instantiated with the object
- Non-static data members are initialized during object construction

static Data Member

```
#include<iostream>
using namespace std;
class MyClass { static int x; // Declare static
public:
    void get() { x = 15; }
    void print() {
        x = x + 10;
        cout << "x =" << x << endl;
    }
};
int MyClass::x = 0; // Define static data member
int main() {
    MyClass obj1, obj2;
    obj1.get(); obj2.get();

    obj1.print(); obj2.print();
    return 0;
}
---
x = 25 , x = 35
```

- x is static data member
- x is shared by all MyClass objects including obj1 & obj2
- static data members must be defined in the global scope
- static data members are initialized during program start-up

static Member Function

A static member function

- does not have this pointer – not associated with any object
- cannot access non-static data members
- cannot invoke non-static member functions
- can be accessed
  - with the class-name followed by the scope resolution operator (::)
  - as a member of any object of the class
- is needed to read / write static data members
- Again, for encapsulation static data members should be private get()-set() idiom is built for access (static member functions in public)
- may initialize static data members even before any object creation
- cannot co-exist with a non-static version of the same function
- cannot be declared as const

```
//staticDataMember.cpp
//static data members are declared inside class and defined outside the class.
//non static member functions can access both static and non static data

#include<iostream>
using namespace std;

class staticDemo
{
        private: static int a;          //Declaration
        //inline static int a=10;       //Definition, from C++17

        public: static int b;           //Declaration
//inline variables, valid from C++17 onwards
        //inline static int b=20;       //Definition(default initialized to zero)
                int getA(){return a;}
};
int staticDemo::a=10;           //Definition (Before C++17)
int staticDemo::b=20;           // Definition (Before C++17)
int main()
{
  cout<<"static b="<<staticDemo::b<<endl;          //Okay, because b is public

  //Below line is an error, because a is private
  //    cout<<"Static a="<<staticDemo::a<<endl;

  staticDemo obj1,obj2;
  cout<<"static a="<<obj1.getA()<<endl;   //Okay, because private a accessed via member fn
  cout<<"static a="<<obj2.getA()<<endl;   //Okay, because private a accessed via member fn

//But static data can be accessed without object creation, therefore use static member function
//to access static data as shown in staticMemberFn.cpp program
        return 0;
}
/*Output:
static b=0
static a=10
static a=10
*/
//staticMemberFn.cpp
//static data members are declared(with keyword static) inside class
//and should be defined(without keyword static) outside the class.
//static member functions can access only static data
//non static member functions can access both static and non static data
#include<iostream>
using namespace std;
class staticDemo
{
        private: static int a;              //Declaration
                 static int b;              //Declaration

        public:
                 static int getA(){return a;}
                 static int getB(){return b;}
                 static void changeData(){a++;b++;}
};
int staticDemo::a=0;                        //Definition
int staticDemo::b=0;                        //Definition
int main()
{
  cout<<"static a="<<staticDemo::getA()<<endl; //Okay, because private a accessed via member fn
  cout<<"static b="<<staticDemo::getB()<<endl; //Okay, because private a accessed via member fn

  staticDemo obj1,obj2;
  staticDemo::changeData();
  cout<<"static a="<<staticDemo::getA()<<endl; //static fn accessed by class name followed by ::
  cout<<"static b="<<staticDemo::getB()<<endl; //accessed by class name followed by ::
  obj1.changeData();                              //static fn accessed by object
  cout<<"static a="<<obj1.getA()<<endl;           //static fn accessed by object
  cout<<"static b="<<obj1.getB()<<endl;           //static fn accessed by object
  cout<<"static a="<<obj2.getA()<<endl;           //static fn accessed by object
  cout<<"static b="<<obj2.getB()<<endl;
  return 0;
}
/*Above program also demonstrates, static member fn may be accessed by classname or object*/
/*Output:
static a=0
static b=0
static a=1
static b=1
static a=2
static b=2
static a=2
static b=2
*/


//stud.cpp
```

```
//static Data Member belongs to class, not to object
//Only one copy of it is maintained, which may be accessed by classname followed by::
//or by any object
#include<iostream>
using namespace std;

class Student
{
	int m_id;
	string m_name;

  public:
	 static int noOfStud;			//public static data member
	 Student(int id,string name)		//ctor
	{
		m_id=id;
		m_name=name;
		noOfStud++;
	}
	void disp()
	{
		cout<<"id="<<m_id<<" name="<<m_name<<endl;
	}
};
int Student:: noOfStud=0;

int main()
{
	Student s1(1,"abc");
	Student s2(2,"def");

	//static Data Member accessed by classname followed by ::
	cout<<"Number of Students="<<Student::noOfStud<<endl;

	//static Data Member accessed by object
	cout<<"Number of Students="<<s1.noOfStud<<endl;
	cout<<"Number of Students="<<s2.noOfStud<<endl;

	cout<<"Student 1:";
	s1.disp();
	cout<<"Student 2:";
	s2.disp();
	return 0;
}
/*Output:
Number of Students=2
Number of Students=2
Number of Students=2
Student 1:id=1 name=abc
Student 2:id=2 name=def
*/
```

One more example program to demonstrate static data member and static member functions

```
//printJobs.cpp
//when defining static member function outside the class do not use static again
#include<iostream>
using namespace std;

class PrintJobs {
        int m_pages;                    // # of pages in current job
        static int m_trayPages;         // # of pages remaining in the tray
        static int m_nJobs;             // # of print jobs executing

  public:
        PrintJobs(int pages)            //ctor
        {
                m_pages=pages;
                m_nJobs++;
                m_trayPages-=pages;
                cout<<"Printing "<<m_pages<<" pages ..."<<endl;
        }
        ~PrintJobs()    {m_nJobs--; }

        static int getJobs()                            //defining static member fn inside class
        {
                return m_nJobs;
        }

        static int getTrayPages();                      //declaring static member fn inside class

        static void loadPages(int pages)                //defining static member fn inside class
        {
                m_trayPages+=pages;
        }

};
int PrintJobs::m_trayPages=500;                 //Printer has 500 pages loaded
int PrintJobs::m_nJobs=0;               //Initially, no jobs

int PrintJobs::getTrayPages()           //defining static member fn outside class
{
        return m_trayPages;
}

int main()
{
        cout<<"Jobs="<<PrintJobs::getJobs()<<endl;
        cout<<"Pages in tray="<<PrintJobs::getTrayPages()<<endl<<endl;
        {
                PrintJobs j1(100);
                cout<<"Jobs="<<PrintJobs::getJobs()<<endl;
                cout<<"Job1 completed"<<endl<<endl;
        }
        cout<<"Pages in tray="<<PrintJobs::getTrayPages()<<endl;
        cout<<"Jobs="<<PrintJobs::getJobs()<<endl;
        cout<<"Loading 50 pages..."<<endl;
        PrintJobs::loadPages(50);
        cout<<"After loading, Pages in tray="<<PrintJobs::getTrayPages()<<endl;
        return 0;
}
/*Output:
Jobs=0
Pages in tray=500

Printing 100 pages ...
Jobs=1
Job1 completed

Pages in tray=400
Jobs=0
Loading 50 pages...
After loading, Pages in tray=450
*/
```